The Mariánské Lázně granite: petrology and geochemistry, western Bohemia

Mariánskolázeňský monzogranit: petrologie a geochemie (Czech summary)

(7 text-figs.)

EDVÍN PIVEC - JIŘÍ K. NOVÁK

Geologický ústav Akademie věd ČR, Rozvojová 135, 165 00 Praha 6, Czech Republic

The porphyritic, coarse- to medium-grained granitoids of the Mariánské Lázně body vary in composition from monzogranite to to quartz monzonite. New data on the chemistry of the main minerals, similar modal compositions and whole-rock analyses show correspondence to the Bor monzogranite. Both granitoids studied are medium fractionated with low to medium K/Rb (118-197 and 183-252, respectively), high Rb/Sr (1.16-1.36 and 0.87-1.85, respectively), and an increased Zr content. The proportion of TiO_2 and other „femic suite" constituents in Haberland's dioritic facies (Haberlandt 1929) indicate some stage of assimilation of adjacent rocks rather than a fractionation trend. Considering these data, we suggest that the Mariánské Lázně granitoid body is not a part of the surrounding Karlovy Vary Pluton (Hejtman 1984), but a northern elongation of the Bor Massif.

Key words: plutonic rocks, „diorite" facies, petrochemical comparison

Introduction

The Mariánské Lázně body, composed mainly of medium - to coarse-grained porphyritic monzogranite to quartz monzonite, has not been studied by geologists in the past decade. This intrusive rock was previously described by Haberlandt (1929) from abandoned small quarries within the area of the Mariánské Lázně Spa. Besides a main monzogranite intrusive phase, the dark dioritic schlieren at endocontact was characterized by chemical and modal analyses. This small body (Fig. 1) has been usually considered as a part of the Karlovy Vary-Eibenstock Massif (Hejtman 1984). However, the geological occurrence, petrography and chemistry of the granitoids show some similarity with porphyritic biotite granitoids of the Bor Massif. The chemical composition of the granitoids pre-determines the hydrochemistry of some thermal waters in the Mariánské Lázně Spa (Kolářová - Myslil 1979). On tectonic zones near the contact of the Bor Massif, the hydrothermal-metasomatic and vein mineralization of uranium at Vítkov and Bor near Tachov (Romanidis 1980, Fiala 1980) as well as sulfide-uraninite veins at the village of Svatá Anna near Planá (Marešová 1972), were mined. The aims of this paper are to provide the results of a more comprehensive study in order to supplement the monzogranite description by Haberlandt (1929) and to relate data and observations to the Bor monzogranite, which represents the nearest and most similar rock type (Fig. 1). Two-mica Kynžvart granite (Fiala 1968), located north of the Mariánské Lázně granite, is structurally and geochemically different, and its affiliation to the Krušné hory Mts. batholith is unquestioned.

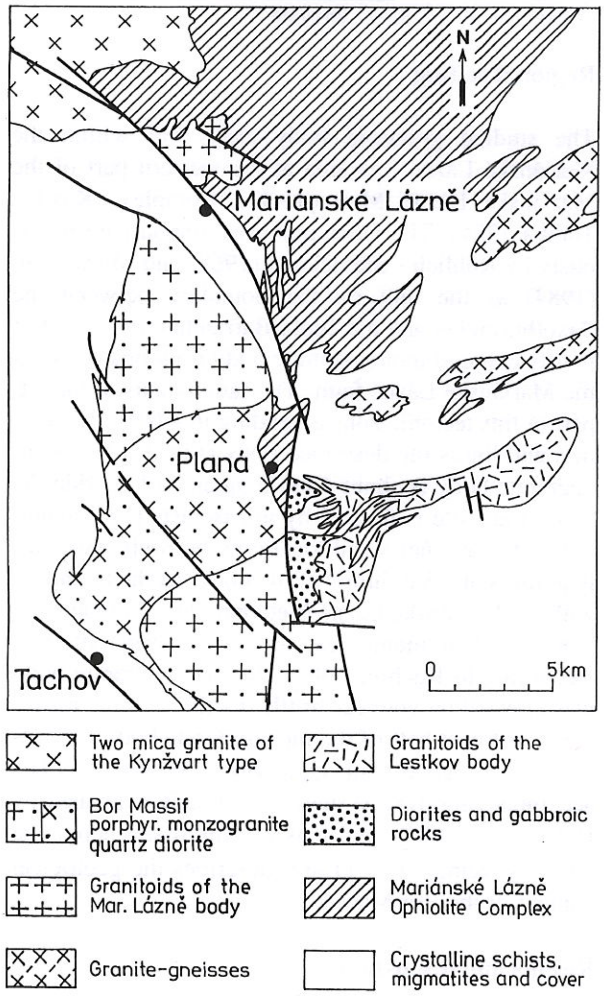

Fig. 1. Distribution of the granitoids in the Mariánské Lázně area

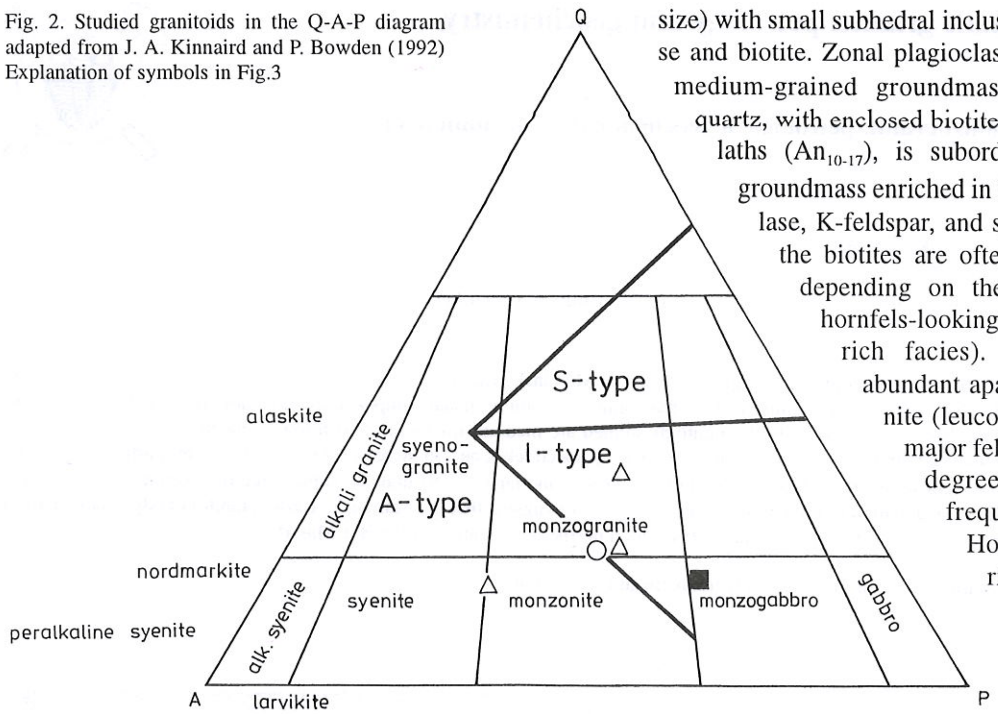

Fig. 2. Studied granitoids in the Q-A-P diagram adapted from J. A. Kinnaird and P. Bowden (1992) Explanation of symbols in Fig.3

Regional setting

The studied granitoid body crops out within the Mariánské Lázně Spa area at the western part of the Mariánské Lázně Metaophiolite Complex (Kastl - Tonika 1984). The latter unit was emphasized previously by Röhlich - Šťovíčková (1968) and Mísař et al. (1984) as the unit on the boundary between the Saxothuringian and the Teplá-Barrandian regions. The poorly exposed monzogranitic body is elongated along the Mariánské Lázně fault. The fault occurs at the NE part of this tectonic zone extending in a NW-SE direction and limits the described body (Fig. 1). The monzogranite body is about 4 km long and 2 km wide. Its contact aureole is formed by micaschists to sillimanite-biotite paragneiss and locally by hornfels, especially at the S and SW limits of the body. At the boundary with the Mariánské Lázně Metaophiolite Complex, the contact phenomena are as yet poorly studied. According to Kachlík (1993), the monzogranite body was affected by younger brittle-ductile tectonic movements. Almost half of the monzogranite body is covered by Neogene and Quaternary sediments. The accompanying dyke system was already evaluated by Haberlandt (1929), and it is not discussed here. The work by Vejnar et al. (1969) describes the geological context of the Bor Massif.

Results and discussion

Petrology

The porphyritic monzogranite to quartz-monzonite is a light-grey, coarse-grained rock which contains euhedral, white megacrysts of microcline-perthite (2-4 cm in size) with small subhedral inclusions of sodic oligoclase and biotite. Zonal plagioclase (An_{24-27}) occurs in a medium-grained groundmass. Slightly undulose quartz, with enclosed biotite flakes and plagioclase laths (An_{10-17}), is subordinate. Less abundant groundmass enriched in biotite contains oligoclase, K-feldspar, and sparse quartz. Some of the biotites are often deformed, probably depending on the content of gneissic hornfels-looking „schlieren" (xenolith-rich facies). Among accessories, abundant apatite, zircon, and ilmenite (leucoxene) are present. The major feldspars show a variable degree of alteration, most frequently kaolinization. However, biotite is chloritized only locally.

The hornfels-looking rock is composed of equigranular oligoclase (An_{15-20}), biotite, quartz and accessory cordierite. The dark facies sometimes designated as diorite, represent the rest of recrystallized and assimilated metamorphic rock. Modal analyses (Table 1), plotted in the Streckeisen's diagram modified by Kinnaird - Bowden (1992), show that the main porphyritic phase lies in the field of monzogranite to quartz-monzonite, and the dark contamined facies corresponds to monzodiorite (Fig. 2).

Chemical characteristics

Chemical composition of minerals

The chemical compositions of K-feldspar, plagioclase, and biotite, were studied on the JEOL XA-50A type microprobe with EDAX (analysts M. Kozumplíková

Table 1. Modal composition of the Mariánské Lázně and Bor granite

sample No.	1	2	3	4	5
quartz	13.23	20.1	25.54	20.53	11.20
K-feldspar	46.15	31.1	23.10	38.30	17.83
plagioclase An_{15-30}	23.74	38.2	29.50	19.89	34.47
biotite	8.30	10.4	8.02	11.27	28.11
secondary minerals:					
kaolinite	7.50		11.17	8.56	3.23
carbonate			0.10		
accessory apatite	0.10	tr.	0.10	0.20	0.23
zircon	0.02	tr.	0.04	tr.	0.06
hematite	0.04		0.01		
ilmenite	tr.		0.37	0.24	
total (volume %)	100.00	99.8	99.99	99.99	99.99
number of points	5 200		7 580	5 320	4 800

1 - coarse-grained, porphyritic quartz-monzonite, Mariánské Lázně Spa, near Koliba; 2 - monzogranite (from Haberlandt 1929); 3 - dtto, slightly kaolinized; 4 - coarse-grained, porphyritic monzogranite, Planá, the Bor Massif; 5 - medium-grained biotite hornfels („dioritic" schlieren in monzogranite), Mariánské Lázně Spa, near Koliba

Table 2. Representative analyses of rock- forming minerals from granitoids the Mariánské Lázně and Bor granite

Unit:	Mariánské Lázně body								Bor Massif			
Rock Type:	monzogranite monzonite				hornfels („ diorite“)				monzogranite			
Mineral:	K-frs	biot	plg	ilm	plg	biot	K-frs	ilm	K-frs	biot	plg	ilm
SiO_2	64.85	35.12	61.97	0.00	64.22	35.01	65.48	0.25	65.38	36.44	63.82	-
TiO_2	-	4.60	-	55.40	0.05	4.08	0.10	51.02	0.04	4.16	0.03	53.38
Al_2O_3	18.64	14.89	24.12	0.13	22.68	14.83	18.31	0.10	18.15	15.94	22.17	0.77
Cr_2O_3	-	-	-	-	0.02	0.00	-	0.00	-	-	-	0.01
Fe_2O_3	-	7.76	-	-	-	7.44	-	-	-	-	-	-
FeO	-	15.61	0.02	36.28	0.04	14.51	0.05	36.53	0.03	20.69	0.01	28.25
NiO	-	-	-	-	0.00	-	-	0.00	-	0.01	-	0.01
MnO	-	0.31	-	7.62	0.02	0.31	0.02	8.82	0.04	0.37	0.04	17.14
MgO	-	8.06	-	0.00	0.25	8.55	0.11	0.06	-	9.01	-	0.17
BaO	0.20	-	-	-	-	-	-	-	-	-	-	-
CaO	-	0.60	5.59	0.07	4.32	0.61	-	0.08	0.04	-	5.28	0.25
Li_2O	-	-	-	-	-	-	-	-	-	-	-	-
Na_2O	1.01	0.17	8.26	-	9.41	0.20	0.53	-	0.83	0.09	8.83	-
K_2O	15.76	8.00	0.14	-	0.19	8.02	15.28	-	15.51	9.53	0.27	-
P_2O_5	-	0.57	-	-	-	0.49	-	-	-	-	-	-
H_2O^+	-	2.87	-	-	-	4.49	-	-	-	(3.93)	-	-
F	-	0.41	-	-	-	0.34	-	-	-	-	-	-
H_2O	-	1.06	-	-	-	1.47	-	-	-	-	-	-
Total	100.46	100.03	100.10	99.50	101.20	100.35	99.88	96.38	99.98	100.16	100.45	99.98
O = 2F		-0.17				-0.14						
		99.86				100.21						

Structural formulae on basis:	32 (O)	24 (O,OH,F)	32 (O)	3 (O)	32 (O)	24 (O,OH,F)	32 (O)	3 (O)	32 (O)	24 (O,OH)	32 (O)	3 (O)
Si	11.943	5.385	10.975	-	11.236	5.429	12.045	-	12.047	5.547	11.026	-
Al^{IV}	4.046	2.615	5.035	-	4.674	2.571	3.970	-	3.942	2.453	4.612	-
Ti	-	-	-	-	0.006	-	0.014	-	0.006	-	0.004	
	15.988	8.000	16.010	-	15.916	8.000	16.028	-	15.994	8.000	15.879	-
Al^{VI}	-	0.076	-	0.004	-	0.139	-	0.002	-	0.406	-	0.022
Ti	-	0.530	-	1.060	-	0.476	0.008	1.002	-	0.476	-	1.010
Cr^{3+}	-	-	-	-	0.002	-	-	-	-	-	-	-
Fe^{3+}	-	0.895	-	-	0.006	0.868	-	-	-	-	-	-
Fe^{2+}	-	2.002	-	0.772	-	1.882	0.008	0.797	0.005	2.634	0.001	0.594
Mn	-	0.040	0.003	0.164	0.003	0.041	0.003	0.195	0.006	0.048	0.006	0.365
Ni	-	-	-	-	-	-	-	-	-	-	-	-
Mg	-	1.842	-	-	0.063	1.976	0.030	0.002	-	2.045	-	0.006
		5.383	-	-	-	5.382	-	-	-	5.609	-	0.006
Ba	0.014					-	-	-	-	-	-	-
Ca	-	0.099	1.061	0.002	0.810	0.101	-	0.002	-	-	0.998	-
Na	0.361	0.051	2.836	-	3.19	0.060	0.189	-	0.297	0.027	3.022	-
K	3.703	1.565	0.032	-	0.043	1.587	3.586	-	3.646	1.851	0.061	-
	4.078	1.714	3.932	-	4.044	1.748	3.816	-	3.953	1.878	4.088	-
O	32.000	20.000	32.000	-	32.000	20.000	32.000	-	32.000	20.000	32.000	-
OH		3.801				3.833						

and Ing. A. Langrová). Feldspars were also examined by use of an X-ray powder method on the Guinier de Wolf camera with an internal standard. The results were evaluated by the three peak method after Wright (1967). The representative chemical analyses of minerals are given in Table 2.

Perthitic feldspar from the Mariánské Lázně monzogranite corresponds to intermediate microcline-perthite, whereas the megacrysts from the Bor monzogranite (Planá, near Svatá Anna church) are determined to be orthoclase-perthites based on the results of X-ray and optical methods. The structural state of the sodium phase of the perthite lies between intermediate and low albite. The chemical composition of the K-phase of perthite from Mariánské Lázně monzogranite is represented by a higher amount of Or-component ($Or_{93\text{-}90}Ab_{00\text{-}07}$) as well as by orthoclase-perthite of the Bor monzogranite ($Or_{93\text{-}92}Ab_{02\text{-}07}$). The content of Ba is 0.27 wt. percent, and 115 ppm Pb in microcline-perthite. It is comparable with the content of 0.22 wt. percent Ba, and 105 ppm Pb in orthoclase-perthite in the Bor monzogranite. Both samples exhibit rare Carlsbad twins. A higher sodium content of microcline-perthite can be seen in Table 2 and corresponds to the amount of microscopic albite admixtures. A coarse vein perthite, younger than twinning in microcline,

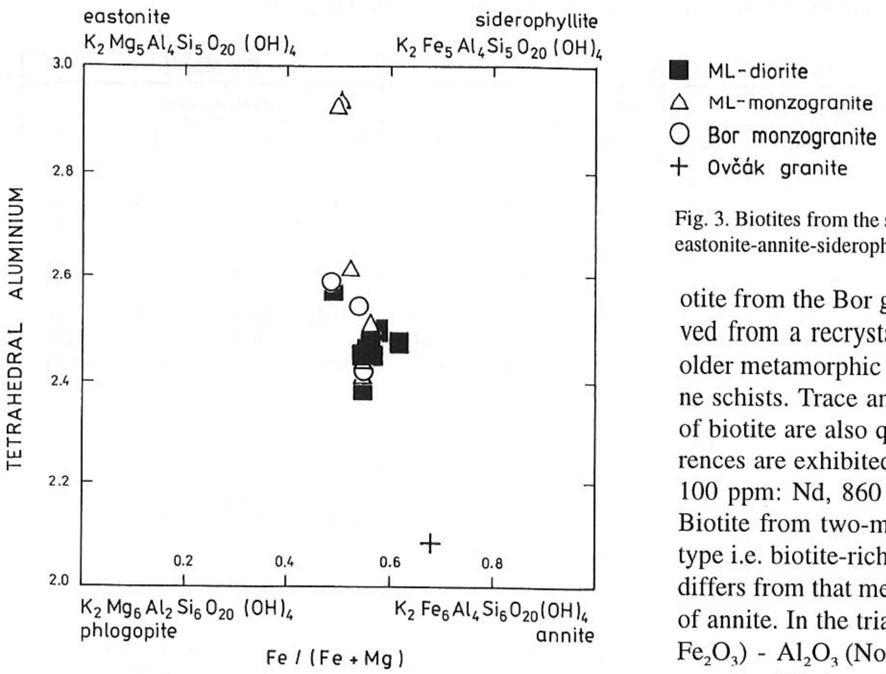

Fig. 3. Biotites from the studied rocks projected onto the phlogopite-eastonite-annite-siderophyllite quadrilateral

shows an interesting veinlet shape and metasomatic origin. The fact that both the Mariánské Lázně and the Bor monzogranite differ little in feldspar composition is apparent from the diagrams. As shown by Neužilová (1971), monoclinic structures of alkali feldspars appear at the eastern margin of the Bor Massif (in a 2 km wide contact zone), and samples with a higher triclinity degree occur in the central and western part.

Plagioclase from phenocrysts of the Mariánské Lázně monzogranite usually has an oligoclase composition varying from $An_{15}Ab_{84}$ to $An_{20}Ab_{79}$. Generally, the same variations in anorthite content were recorded by Haberlandt (l.c.) using optical methods. The core is often more kaolinized. Plagioclase composition of the Bor monzogranite (specimen from Planá) is characterized by a wider range of An-component (from $An_{15}Ab_{82}$ to $An_{30}Ab_{69}$). Optical data indicate that some of the structural features (e.g. interrupted polysynthetic twin-lamellae on the albite law and indistinct zoning between the core and rims) are similar in both types of granitoids. The Or-content lies in the range of 0.7 to 2.6 percent, while in the Mariánské Lázně plagioclase ranges between 0.7 and 0.8 percent. Random rectangular inclusion of biotite are common throughout the host phenocrysts.

Biotite. The chemical data on biotite (Table 2) shows that differences between the Mariánské Lázně body and the Bor massif near Planá are not evident. In the quadrilateral diagram for phlogopite-annite-eastonite-siderophyllite (Fig. 3) at least two generations of biotite are visible. The generation containing higher tetrahedral aluminium has a composition between eastonite and siderophyllite. The second (prevailing) generation corresponds to biotite from the Bor granite. The Al-biotites can be derived from a recrystallization stage of remnants of the older metamorphic biotites from surrounding crystalline schists. Trace and minor elements in the two types of biotite are also quite different. The important differences are exhibited by La and Nd (La, 1100 ppm and 100 ppm: Nd, 860 ppm, and 280 ppm, respectively). Biotite from two-mica granite of the so-called Ovčák type i.e. biotite-rich facies within the Kynžvart granite differs from that mentioned above and falls in the field of annite. In the triangular diagram MgO - (FeO + 0.9 Fe_2O_3) - Al_2O_3 (Nockolds 1947), most of the biotites examined lie in the field where mica is accompanied by other mafic constituents (Fig. 4). However, biotite from the Ovčák granite corresponds to micas associated with muscovite or topaz. Therefore, its affilation to the Krušné hory Mts. granites is shown. Wet chemical analyses ferrous/ferric iron shows a ratio $Fe^{3+}/(Fe^{3+}+Fe^{2+}) = 0.31$ for samples from the Mariánské Lázně body. The ratio $Mg/(Fe^{2}+ Mg)$ varies in the biotites in the range 0.72-0.81, and a similar range is shown by both the biotite of the Bor monzogranite and biotite hornfels schlieren. The biotite coexisting with ilmenite contains up to 4.6 wt. percent TiO_2.

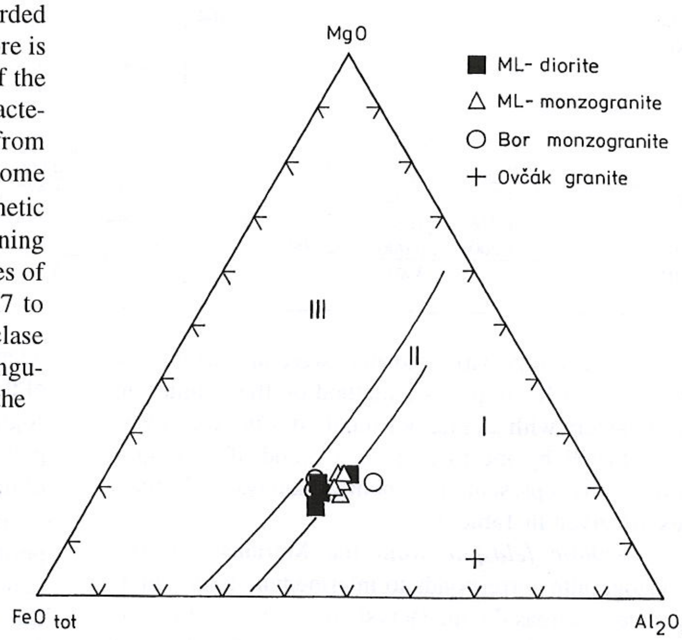

Fig. 4. Biotite composition in triangular diagram MgO - (FeO + 0.9 Fe_2O_3) - Al_2O_3. Field of biotite after S. R. Nockolds (1947), i.e. I - biotite associated with muscovite or topaz, II - unaccompanied by other mafic minerals, III - biotite associated with hornblende, pyroxene or olivine

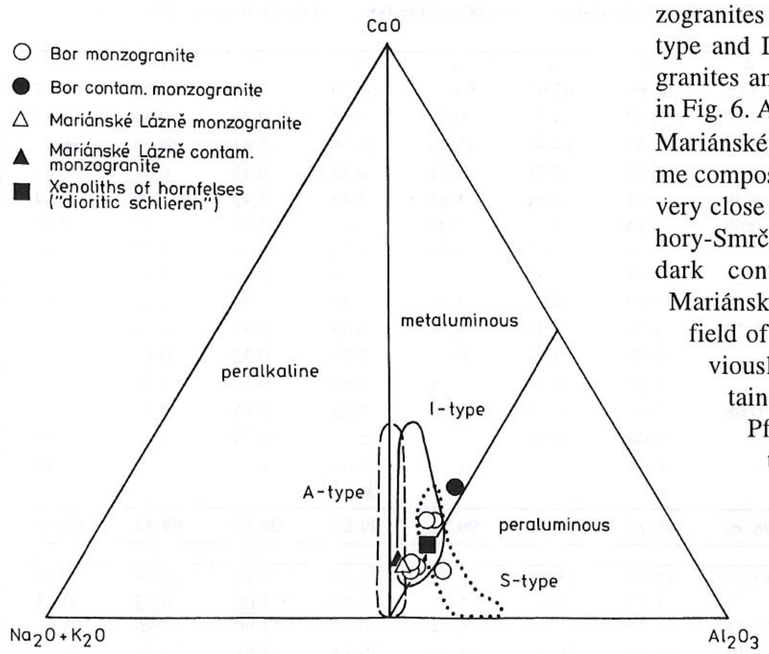

Fig. 5. Studied granitoids in diagram CaO - (Na_2O + K_2O) - Al_2O_3 (Adapted from N. C. Loiselle and D. R. Wones 1979)

Ilmenite was found enclosed in biotite in all studied granites. A higher content of Mn (the pyrophanite end-member, $MnTiO_3$) is a characteristic feature of ilmenite in the Mariánské Lázně monzogranite as well as in the Bor monzogranite.

Chemical composition of rocks

Major elements. The general composition of the monzogranites under study is characterized by lower SiO_2 (67-68 wt. %), higher levels of Al_2O_3, FeO + Fe_2O_3, MgO, CaO, and P in comparison with nearby granites from the Smrčiny Mts. (Fichtelgebirge), due to large feldspar phenocrysts and a groundmass rich in biotite. The K_2O content (5.17, 5.56 wt. %) predominates over Na_2O considerably. It should be noted that no marked difference is observed between the Mariánské Lázně monzogranite to quartz monzonite and the Bor monzogranite (see Table 3). By the low Li and F contents, these monzogranites correspond to granitic rocks of OIC (in the sense of Lange 1972), representing the oldest phase of the Krušné hory Mts. batholith. Bulk composition of monzogranite is plotted to determine their variation in percentage versus the differentation index (D. I.). The molecular ratios of Al_2O_3/ K_2O + Na_2O + CaO (Chappel - White 1974) of monzogranites range from 1.14 to 1.31, and those of dark facies range between 1.12 and 1.29. The ratios show that the granitoids examined correspond mainly to peraluminous monzogranite of S-type near the boundary with I-type (Fig. 5). If diagram ACF by Takahashi at al. (1980) is used as a criterion, where A = molar Al_2O_3 - K_2O - Na_2O, C = molar CaO, and F = molar MgO + FeO, the projection points of both monzogranites fall on the boundary between fields of the S-type and I-type granites. The position of the studied granites among the west Bohemian granites is shown in Fig. 6. According to the ratio of MgO and Al_2O_3, the Mariánské Lázně monzogranite is practically of the same composition as the Bor monzogranite, and both are very close to the oldest intrusive phases of the Krušné hory-Smrčiny granite. In contrast, the projection of the dark contamined monzodiorite from both the Mariánské Lázně body and the Bor Massif lies in the field of the S-type granite. This dioritic facies previously described by Haberlandt (l.c.), often contains normative cordierite (calculated using Pfeiffer's method, Pfeiffer 1962) and undoubtely represents a portion of the monzogranite to quartz-monzonite body contaminated by surrounding gneisses. The chemical analyses of those facies show that the CaO and FeO + Fe_2O_3 + MgO contents are higher, and the SiO_2 content (from 57.45 to 65.9 %) is lower, compared to the main monzogranite. Analysis No. 5, representing pearl gneiss, is added for comparison. Localities see Table 3.

Trace element. There are no significant differences in the trace element concentrations of the Mariánské Lázně and the Bor monzogranites (Table 3). The set of eight samples is characterized by high Ba,

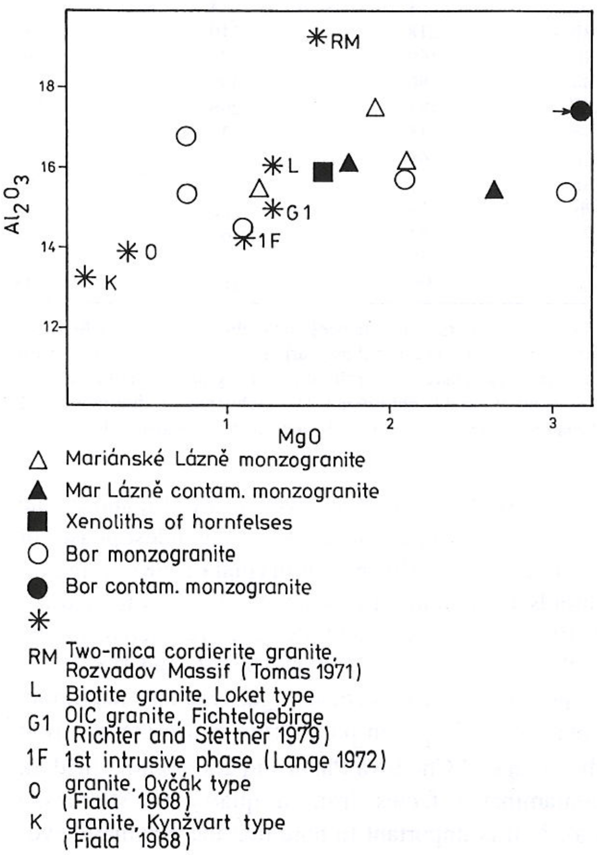

Fig. 6. Position of the studied granites among granitoid bodies of the southwestern part of the Krušné hory Mts. batholith

T a b l e 3. Major element analyses and CIPW norms of the rocks from Mariánské Lázně granite body and northern part of Bor Massif

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	67.91	67.11	65.93	65.05	62.69	62.97	69.64	68.74	67.51	68.22	57.45
TiO_2	0.49	0.63	0.80	0.77	0.92	0.72	0.52	0.52	0.49	0.61	1.17
Al_2O_3	15.46	16.17	16.15	15.42	17.51	14.46	15.36	15.79	15.41	16.15	16.47
Fe_2O_3	1.21	0.67	1.40	1.03	0.89	0.88	1.02	0.313	0.49	0.68	0.63
FeO	1.64	2.11	2.64	2.48	5.91	4.08	1.83	2.84	2.42	1.69	5.64
MnO	0.05	0.08	0.07	0.08	0.14	0.12	0.04	0.05	0.06	0.05	0.10
MgO	1.20	0.90	1.61	1.77	2.63	1.93	1.09	0.72	0.99	0.72	5.13
CaO	1.70	2.15	2.74	2.23	3.65	3.07	1.72	1.54	2.08	3.12	4.99
Na_2O	3.00	3.76	4.00	4.00	3.79	4.09	3.41	3.33	3.59	3.06	2.88
K_2O	5.17	5.56	3.01	5.32	1.90	4.01	4.34	5.05	5.31	4.54	3.01
P_2O_5	0.20	0.24	0.28	-	0.23	0.33	0.10	0.25	0.22	0.17	0.41
H_2O+	0.63	0.73	0.66	-	1.23	0.35	1.08	0.94	0.72	1.00	1.60
H_2O-	0.14	0.07	0.14	0.08	0.11	0.12	0.08	0.18	0.15	0.07	0.15
CO_2	-	-	-	-	0.08	0.19	-	st	0.04	-	0.10
F	-	-	-	-	0.05	-	-	0.09	-	-	0.06
S	-	-	-	-	st.	-	-	st.	-	-	0.05
Total	99.48	100.27	99.21	98.96	99.72	100.38	99.33	99.65	99.57	99.34	99.86
Q	20.42	15.55	21.78	12.47	17.68	11.33	26.41	23.25	17.86	23.08	8.12
C	1.33	0.70	1.99	-	1.17	2.29	1.42	2.47	1.08	0.22	0.43
or	31.01	33.04	18.15	31.67	11.53	23.78	26.34	30.47	31.80	27.56	18.13
ab	33.55	36.87	36.53	6.19	34.96	36.87	31.45	30.53	32.68	28.23	26.37
an	7.24	9.15	12.00	10.48	17.06	11.92	8.09	6.13	8.75	14.76	22.51
di	-	-	-	0.53	-	-	-	-	-	-	-
hy	3.61	6.22	5.70	6.13	14.49	12.11	3.87	5.41	6.67	4.91	20.87
ap	0.43	-	0.60	0.00	0.50	0.69	-	0.53	0.47	0.37	0.87
pr	-	-	-	-	-	-	-	-	-	-	0.13
Sal	93.56	92.39	90.58	90.81	82.41	86.19	93.71	92.86	92.17	93.85	0.13
Fem	6.44	7.61	9.42	9.19	17.59	13.81	6.29	7.14	7.83	6.15	24.43
D.I.	84.99	82.55	76.59	80.33	64.17	71.98	84.20	82.35	78.86	52.62	76.59
Trace element											
	1		3		5		7	8			
Rb	218		210		38		143	229			
Sr	160		181		265		164	124			
Ba	796		500		530		711	1140			
Zr	187		266		131		174	212			
Nb	15		22		12		13	17			
Cr	68		85		154		118	13			
Ni	11		12		66		11	32			
Pb	39		22		8		30	30			
V	34		60		-		38	-			
Y	27		0.2		-		-	-			
Li	90		117		25		44	22			

Localities: 1 - porphyritic monzogranite abandoned quarry Mariánské Lázně near Koliba, 2 - dtto, 3 - „ dark schlieren" in granite above , 4 - dtto as 3, 5 - dtto designated as pearle gneiss, 6 - dark facies corresponding to monzonite, 7 - porphyritic monzogranite, old abandoned mine sv. Anna, near Planá, 8 - porphyritic monzogranite, small abandoned quarry near Chodová Planá, 9 - porphyritic monzogranite as no. 7, 10 - dtto as no. 9. weakly chloritized, 11 - „schlieren" of diorite within Bory monzogranite. Laboratories: 1-4, 7, 9, 10 Geol. Inst. of the Czech Academy of Sci., 5, 8, 11 Czech. geol. inst., 6 (Haberlandt, 1929).

Cr, Ni, Sr, Zr, and by low levels of Rb, Li, and F. The spectrum is comparable to that of the oldest phases of the Krušné hory Mts. batholith (Fiala 1968). Both granitoids are medium fractionated with a low to medium K/Rb ratio (118-197 and 183-252, respectively) and with a higher Rb/Sr ratio (1.16-1.36 and 0.87-1.85, respectively). Zr content is high, reaching maximum values of 212 ppm in porphyritic monzogranite from the village of Chodová Planá and 266 ppm in the dark contaminated facies from a quarry in Mariánské Lázně. It is important to note that the magmatic evolution of these rocks is controlled by assimilation of adjacent metamorphic rocks and by restite mixing. Elevated contents of Ti and Cr, Ni, Pb, V are probably caused by an irregular distribution of hornfels or gneissic xenoliths.

The REE normalized concentration pattern (Fig. 7) in the Mariánské Lázně body is comparable with the older phases of the Krušné hory granites (Breiter et al. 1991). The relative enrichment of LREE with respect to HREE and moderately pronounced negative Eu-anomaly is most characteristic in comparison with more evolved granites of both the OIC and especially the YIC Table 4).

Table 4. REE concentrations (in ppm)

localities	1	2	3
La	46.9	46.0	52.7
Ce	102.3	103.3	125.0
Nd	39.0	49.0	36.0
Sm	5.95	5.95	6.27
Eu	0.92	0.77	0.91
Gd	<2	<2	8.1
Tb	0.9	0.9	0.9
Ho	3.1	5.1	3.5
Tm	0.6	0.4	1.5
Yb	2.8	3.7	3.2
Lu	0.24	0.42	0.22
Σ REE	202.71	214.54	237.90
La/Yb	16.7	12.4	16.3
La/Sm	7.9	7.7	8.3
Eu/Eur•	0.27	0.25	0.25

sConclusions

The present study is based upon available data of the dominant porphyritic monzogranite from the Mariánské Lázně Spa (abandoned quarries) and the dark contaminated facies compared with data from northern section of the Bor Massif (from two places around Planá). The chemical composition characterizes both granitoids as peraluminous granites with $Al_2O_3/Na_2O + K_2O + CaO$ greater than 1.1 .Both monzogranites are characterized by higher Ba, Sr, Cr, Ni, Zr, and lower Rb, Li, and F. The mutual similarity is also documented by the differentiation index (Mariánské Lázně monzogranite DI = 84.99, Bor monzogranite DI = 84.20). Moreover, the K/Rb ratio represents the me-

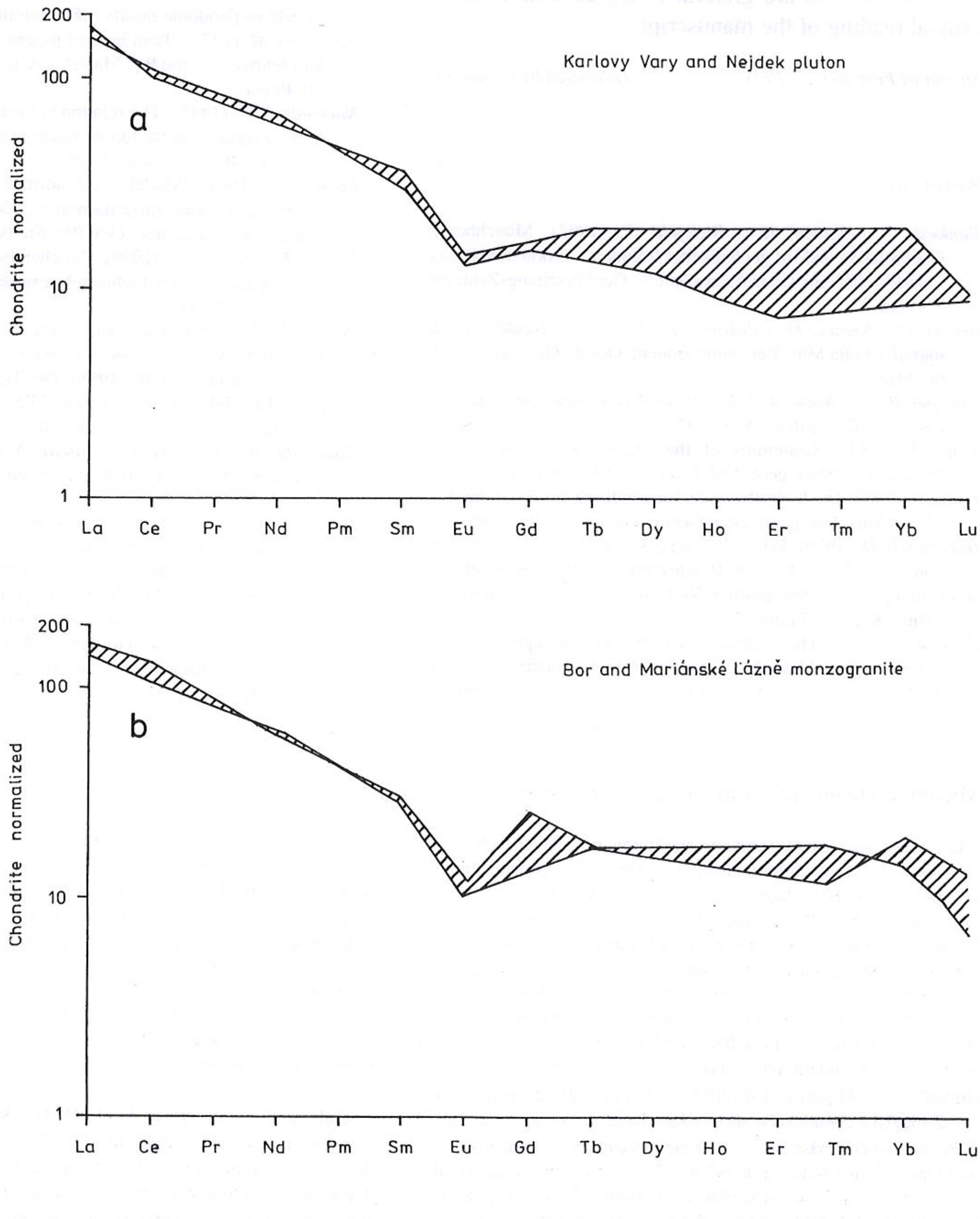

Fig. 7. The chondrite-normalized REE patterns for samples a) of the OIC granites of the Nejdek massiv (Oldříš) and of the Karlovy Vary pluton (Březová) b) of the Bor and Mariánské Lázně monzogranite

dium fractionation effect (K/Rb = 118-197 and 183-252, respectively). Therefore, it is suggested that the Mariánské Lázně body most probably represents northern elongation of the Bor Massif rather than a part of the Krušné hory-Smrčiny batholith.

The main rock-forming minerals (feldspars and biotite) and their chemical compositions provide evidence for the similarity of both studied granitoids. Within the Mariánské Lázně monzogranite, there were found at least two generations of biotite, which differ in composition.The older Al-biotites are probably remnants of the older metamorphic biotites from the surrounding crystalline schists.

Acknowledgements: This work was supported by the Grant Agency of the Czech Republic No. 205/93/0343. We are grateful to Dr. E. Oches for his critical reading of the manuscript.

Submitted February 27, 1995 *Translated by the authors*

References

Bankwitz, P. - Kämpf, H. - Bielefeld, E. (1992): Münchberger Gneissmasse und ihr geologischer Rahmen. - Exkursionsführer. - Gesellschaft für Geowissenschaften, GeoForschungsZentrum, Potsdam.

Breiter, K. - Knotek, M. - Pokorný, L. (1991): The Nejdek granite massif. - Folia Mus. Rer. natur. Bohem. Occid., Geologica 33, 1-60. Plzeň.

Chappel, B. W. - White, A. J. R. (1974): Two contrasting granite types. - Pacific Geology, 8, 173-174.

Fiala, F. (1968): Granitoids of the Slavkovský (Císařský) les Mountains. - Sbor. geol. Věd, Geol., 14, 93-159. Praha.

Fiala, V. (1980): Die hydrothermale Verwandlung des Bor-Granits I. - Folia Mus. Rer. natur. Boh. Occid., Geologica, 16, Plzeň.

Haberlandt, H. (1929): Petrographische Studien am Tiefengesteinen von Marienbad. - Jb. geol. Bundesanst., 79, 257-306. Wien.

Hejtman, B. (1984): Petrografie vyvřelých hornin Českého masívu I. - Univ. Karlova, Praha.

Kachlík, V. (1993): The evidence for Late Variscan nappe thrusting of the Mariánské Lázně Complex over the Saxothuringian terrane (West Bohemia). - J. Czech Geol. Soc., 38, 43-58. Praha.

Kastl, E. - Tonika, J. (1984): The Mariánské Lázně Metaophiolite Complex (West Bohemia). - Krystalinikum, 17, 59-76. Praha.

Kinnaird, J. A. - Bowden, P. (1991): Magmatism and mineralization associated with Phanerozoic anorogenic plutonic complexes of the African plate, 410-494. *In: A. B. Kampunzu - R. T. Ubala* (Eds.): Magmatism in extensional structural settings. - Springer Verlag. Berlin, Heidelberg, New York.

Kolářová, M. - Myslil, V. (1979): Minerální vody Západočeského kraje. - Ústř. úst. geol. Praha.

Kwak, T. A. P. - White, A. J. R. (1982): Contrasting W-Mo-Cu and W-Sn-F skarn types and related granitoids. - Min. Geol., 32, 339-351.

Lange, H. - Tischendorf, G. - Pälchen, W. - Klemm, I. - Ossenkopf, W. (1972): Zur Petrographie und Geochemie der Granite des Erzgebirges. - Geologie, 21, 457-493. Berlin.

Loiselle, N. C. - Wones, D. R. (1979): Characteristic and origin of anorogenic granites. - Geol. Soc. Amer., Abstr., 11, 468.

Marešová, Z. (1972): Co-As mineralizace na ložisku Sv. Anna u Plané u Mariánských Lázní. - Sbor. geol. Věd, ložisk. Geol., 15, 53-65. Praha.

Mísař, Z. - Jelínek, E. - Souček, J. - Tonika, J. (1984): The correlation of gabbro-peridotite masifs. - Krystalinikum, 17, 93-113. Praha.

Neužilová, M. (1971): Twin laws of plagioclases and triclinity of alkali feldspars in the Bor Massif. - Acta Univ. Carol., Geol. 1, 1-10. Praha.

Nockolds, S. R. (1947): The relation between chemical composition and paragenesis in the biotite micas of igneous rocks. - Amer. J. Sci., 245, 401-420. New Haven.

Pfeiffer, L. (1962): Modale und normative Mineralbestände als Grundlagen einer quantitativ-mineralogischen Gesteinssystematik. - Bergakademie, 695-700. Freiberg/Sa.

Richter, P. - Stettner, G. (1979): Geochemische und petrographische Untersuchungen der Fichtelgebirgsgranite. - Geologica bavar., 78, 1-133. München.

Romanidis, K. (1980): Uranová ložiska v granitoidech. - Hornická Příbram ve Vědě a Technice, G, 9-65. Příbram.

Röhlich, P. - Šťovíčková, N. (1968): Die Tiefenstörrungstektonik und deren Entwicklung im zentralen Teile der Böhmischen Masse. - Geologie, 17, 6-7, 670-697. Berlin.

Takahashi, M. - Aramaki, S. - Ishihara, S. (1980): Magnetite series /ilmenite series vs. I-type/S-type granitoids. - Min. geol., Spec. Isue, 8, 13-28.

Tomas, J. (1971): Geologie a petrografie rozvadovského masivu v západních Čechách. - Sbor. geol. Věd, Geol., 19, 99-117. Praha.

Vejnar, Z. - Neužilová, M. - Syka, J. (1969): Geologie a petrografie borského masívu. - Věst. Ústř. Úst. geol., 44, 247-256. Praha.

Wright, T. L. (1968): X-ray and optical study of alkali feldspar: II. An X-ray method for determining the composition and structural state from measurement of 2θ values for three reflections. - Amer. Mineralogist, 53, 88-104. Washington.

Mariánskolázeňský monzogranit: petrologie a geochemie

Malé těleso mariánskolázeňského granitoidu, považované většinou za samostatný útvar, je tvořeno porfyrickým, středně až hrubě zrnitým monzogranitem až křemenným monzonitem. Důvodem pro jeho studium byla i okolnost, že jeho poslední petrografický výzkum se uskutečnil před více než 65 lety (Haberlandt 1929). Je to významné také proto, že část proslulých minerálních vod získává svou mineralizaci právě z tohoto horninového prostředí. Popisované těleso (asi 4 km dlouhé a 2 km široké) vystupuje zejména v depresi podél mariánskolázeňského zlomu na jeho sv. straně. Kontaktní aureola nebyla studována, ale „dioritické" uzavřeniny okolních metamorfik, přeměněné na rohovce s cordieritem, svědčí o kontaktním působení tělesa na okolní ruly, případně i na některé metabazity mariánskolázeňského komplexu.

Na základě modálního složení odpovídají horniny z tohoto tělesa monzogranitu až křemennému monzonitu a horniny ze s. okraje borského masívu monzogranitu. Rozdíly obou těles vyznačuje pouze stav K-živců (ortoklas-perthit v borském masivu oproti mikroklin-perthitu v mariánskolázeňském tělese) v důsledku rozdílných podmínek tuhnutí magmatu. Podobné složení biotitu v obou granitoidech je také v souladu s příslušností k jednomu plutonu. Pouze v mariánskolázeňském tělese byly zastiženy biotity nejméně dvou generací, z nichž biotity s vyšším obsahem tetraedrického Al jsou patrně relikty biotitů ze starších okolních metamorfik.

Z hlediska chemického složení lze charakterizovat oba granitoidy jako peraluminiové s poměrem Al_2O_3/ Na_2O + K_2O + CaO větším než 1, 1. Ze stopových prvků jsou významné zvýšené koncentrace Ba, Sr, Cr, Ni, Zr a naopak snížené obsahy Rb, Li a F ve srovnání s krušnohorskými granity. Poměr K/Rb (118-197 a 183-252) vykazuje střední hodnoty frakcionizace, zatímco poměr Rb/Sr je poněkud vyšší.

Z porovnání dat obou studovaných granitoidů a granitů z okolních plutonů je pravděpodobné, že mariánskolázeňské těleso není součástí krušnohorského batolitu, ale je pokračováním borského granitoidního masivu za mariánskolázeňskou tektonickou zónou.