The Kaplice dyke swarm of biotite granodiorite porphyry and its relationship to the Freistadt granodiorite, Moldanubian Batholith

Biotitické granodioritové porfyry v kaplickém zlomovém pásmu a jejich vztah ke granodioritu typu Freistadt

(9 figs, 3 tabs)

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A possible link of the Kaplice dyke swarm with Freistadt granodiorite was studied. The swarm of biotite granodiorite porphyry dykes is associated with the Kaplice fault zone – a prominent late Variscan discontinuity in the Moldanubian Zone of the Bohemian Massif, featuring sinistral displacement of ca. 17 km. The dykes have a strongly porphyritic structure in which plagioclase, biotite ± quartz phenocrysts combined represent about 50 vol. % of the rock. The microgranular and spherulitic textures of groundmass in the dykes indicate probable devitrification of the originally present glass, resulting from quenching of the melt carrying phenocrysts. This points to an intrusion of the dykes into relatively cold country rocks and thus to rather shallow emplacement level. The composition of biotite granodiorite porphyry dykes is characterized by analyses of major and trace elements in fourteen samples. The rocks are weakly peraluminous with A/CNK = 1.04 to 1.22, have a relatively low to moderate *mg* number and low Cr and Ni contents. K_2O/Na_2O varies in the range 0.47–0.83. The spread of abundances for major elements in Harker's plot and chondrite-normalized REE patterns are similar to published data for the central and marginal facies of the Freistadt biotite granodiorite. The porphyries have rather unradiogenic initial (age-corrected for 305 Ma) $^{87}Sr/^{86}Sr$ values for seven samples in the range of 0.7043–0.7067. Such isotopic composition would be compatible with an origin from a reservoir with fairly low time-integrated Rb/Sr ratio, probably remelted lower crustal (?metabasic) rocks, with or without contribution from the mantle-derived melts. Given the similarities in petrology and whole-rock geochemistry, the published monazite age of ca. 300 Ma for Freistadt granodiorite is likely to be a best age estimate for the biotite granodiorite porphyry dykes. Two dykes of hornblende quartz diorite porphyries are metaluminous, with A/CNK = 0.90 and K_2O/Na_2O is 0.36 and 0.42. The new ^{40}Ar-^{39}Ar datum of 303±5 Ma for the hornblende in one sample of quartz diorite dyke suggests intrusion of the dyke as within the error co-eval with emplacement of the Freistadt granodiorite and the Kaplice swarm of biotite granodiorite porphyry dykes. It is suggested that the regional distribution of granodiorite porphyry dykes between the major area of the Freistadt pluton near Freistadt and the northernmost outlier near Trhové Sviny approximates the regional extent of the hidden parts of the Freistadt pluton.

Key words: biotite granodiorite porphyry; strontium isotopes; Freistadt biotite granodiorite; Moldanubian batholith; Kaplice-Rödl fault zone; Bohemian Massif; Variscides

Introduction

The Moldanubian batholith represents the largest Variscan granitoid complex in the Bohemian Massif. It is composed of a number of plutons with variable proportions of crustal and mantle components (Liew et al. 1989, Vellmer and Wedepohl, 1994, Holub et al. 1995, Finger et al. 1997, Gerdes 1997, Matějka – Janoušek 1998). Among the late members of the batholith, represented mainly in the southern part of the Bohemian Massif, the Freistadt granodiorite (Klob 1971, Gerdes 1997) (Fig. 1) takes a prominent place. Its recent dating indicates an age near 300 Ma (Friedl et al. 1997, Gerdes et al. 2002).

The Moldanubian batholith is deeply eroded and the erosional level becomes progressively deeper towards its southern parts in Lower Austria. This is due to a significant late regional tilt, indicated by younging of muscovite Ar–Ar ages towards the South (Scharbert et al. 1997). Given this, any dyke intrusions representing magma batches related to individual granitic plutons would have been largely removed by erosion. Relatively abundant granitoid dykes, exposed at the present surface, are represented dominantly by leucogranites and pegmatites, considered usually as residual melts.

Biotite granodiorite porphyry dykes in proximity of the Kaplice–Rödl fault zone are known for some time (Čech 1956). Numerous occurrences of porphyry were recorded in 1960s, during 1 : 25 000 scale mapping by geologists of the Czech Geological Survey (CGS), and the localities are shown in maps published later by the CGS. However, correlation with plutonic rocks of the wider area was impossible due to the absence of sufficient whole-rock geochemical data.

In the current paper will be discussed a possible link of the Kaplice dyke swarm with Freistadt granodiorite. The detailed study of the dyke swarm provides potentially an important information on structural control during intrusion of the granodiorite pluton. It permits drawing a much more advanced picture of the Freistadt intrusion, featuring pivotal dyke intrusions in its roof of metamorphic units and Variscan granite plutons.

Geological setting

The Kaplice–Rödl fault zone is a prominent late Variscan discontinuity in the Moldanubian Zone of the Bohemian Massif, featuring sinistral displacement of ca. 17 km (Fig. 2). Evidence from Austria indicates longevity of the

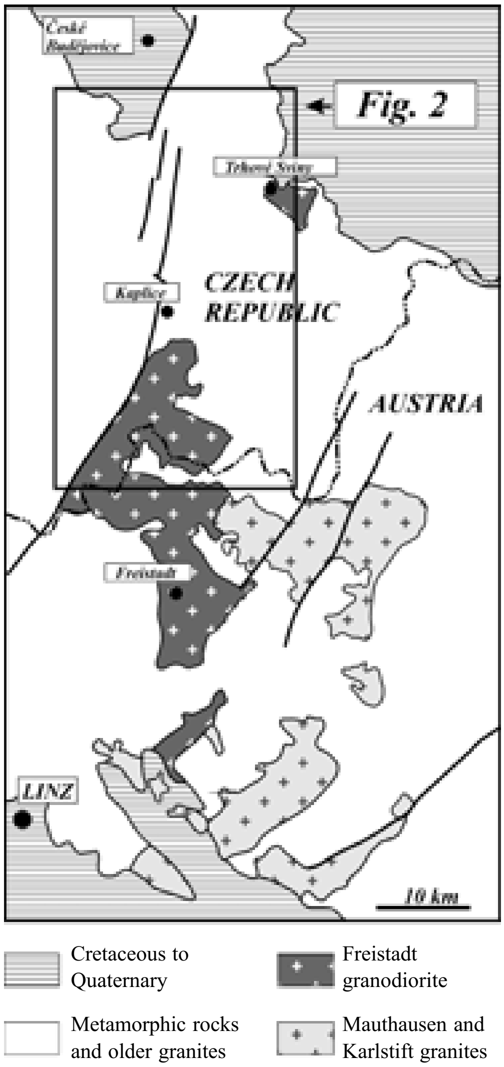

Fig. 1. The southern part of the Bohemian Massif between České Budějovice (Czech Republic) and Linz (Austria), showing the Freistadt granodiorite pluton. Geology of the Austrian part is simplified from 1 : 200 000 map (Schnabel 2002). Frame indicates the position of Fig. 2.

movements on the fault zone (Wallbrecher et al. 1992) till rather late stages (hydrothermal muscovite-sericite in mylonites with ^{40}Ar-^{39}Ar ages to 180–170 Ma, indicating post-Variscan reactivation, Brandmayr et al. 1995). The Kaplice dyke swarm is a convenience term for two linear zones of biotite granodiorite porphyry dykes. It includes the Kaplice dyke swarm itself, i.e. belt of dyke occurrences 35 km long, trending NNE-SSW, that is closely tied to the Kaplice (or Kaplice–Rödl) fault zone. Another group of dykes, in a belt 20 km long, occurs south of Trhové Sviny (Fig. 2). In addition to biotite granodiorite porphyry dykes, two small dykes of hornblende quartz diorite porphyry have been found in the area (samples KC10 and KC4 in Fig. 2). This type of hornblende porphyry was designated as "Nadelporphyrit" in the adjacent areas of Upper Austria (Graber 1932).

The dykes intruded a variety of Moldanubian metamorphic and granitoid rock-types: migmatitic biotite paragneiss of the Monotonous unit, muscovite-biotite paragneiss of the Kaplice unit, Weinsberg porphyritic biotite granite, Eisgarn muscovite-biotite granite and biotite granodiorite of the Freistadt type. The field observations (Table 1) thus provide an important evidence on relative age of the Kaplice dyke swarm. Moreover, one biotite granodiorite porphyry dyke (1 km northwest of sample location BO84, Fig. 2) is intruded parallel to the foliation of the mylonite (phyllonite) country-rock and small porphyry apophyses penetrated across the mylonitic foliation (Čech 1956, Vrána et al. 1989). This shows that early stages of deformation connected to the Kaplice-Rödl fault zone pre-dated intrusion of the biotite porphyries.

Samples and analytical methods

The major element composition was analysed using wet methods (Chemical Laboratory of the Czech Geological Survey, chief chemist M. Huka). Minor and trace element abundaces were determined by XRF (most of the ele-

Table 1. Sample location.

Sample No.	Location	Outcrop	Country rock
RO 202	Railway section 1.5 km SW of Rybník village	dyke ca. 10 m wide	Freistadt Bt granodiorite
BE 86	100 m N of Valtéřov village	blocks up to 0.7 m	Eisgarn Ms-Bt granite
BE 85	N margin of Lužnice village	blocks up to 1.2 m	migrnatitic Bt paragneiss with Sil±Crd
TS 72	0.7 km W of Kondrač village	blocks up to 1.2 m	Eisgarn Ms-Bt granite
BO 82	disused quarry S of Vidov village	poorly exposed dyke several m wide; less altered type	migrnatitic Sil-Bt paragneiss
BO 83	disused quarry S of Vidov village	more altered type with minor carbonate veinlets	
BO 84	Confluence or Zborov brook with Malše river	dyke 12 to 15 m wide	Ms-Bt paragneiss, Kaplice unit
KU 1	Disused quarry at Plav village	dyke several m wide	migmatitic Sil-Bt paragneiss
KU 2	Disused quarry at Plav village		migmatitic Sil-Bt paragneiss
TS 100	Near Mezilesí village, 50 m W of elevation point 584 m	blocks up to 3 m	Eisgarn Ms-Bt granite
BE 222	Near Valtéřov village, 100 m S of elevation point 662 m	blocks up to 0.5 m	Eisgarn Ms-Bt granite
BE 223	Near Třebíčko village, 150 m E of bridge across Černá river	blocks up to 1.0 m	migrnatitic Bt paragneiss with Sil±Crd
VE 1	1.5 km NE of Velešín	blocks up to 0.6 m	Ms-Bt paragneiss, Kaplice unit
KC	20 Disused quarry near Malše river, Nažidla campsite	dyke several m wide	migrnatitic Bt paragneiss with Sil±Crd
KC 10	N margin of Kaplice, construction site of appartment houses	dyke 70 cm wide	Weinsberg type Bt granite
KC 4	loose blocks 1.2 km SE of the vil1age Rožmitál na Šumavě	blocks up to 0.7 m	Ms-Bt paragneiss, Kaplice unit

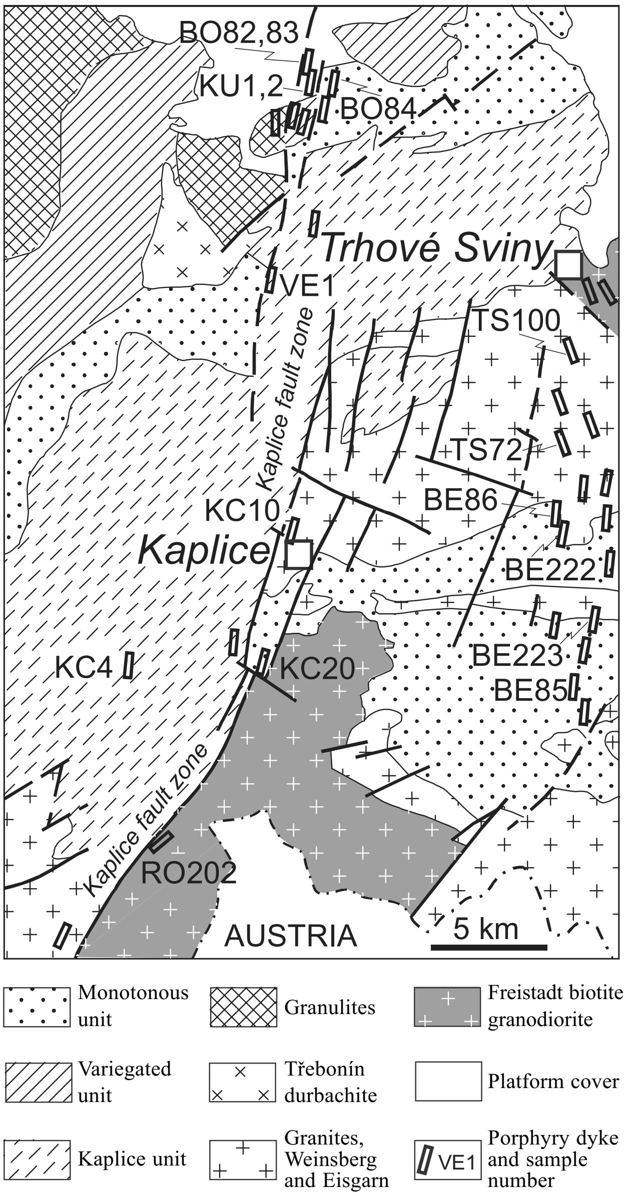

Fig. 2. Biotite granodiorite porphyry dykes of the Kaplice swarm with reference to sample locations. Geology (simplified) is based on published 1 : 25 000 maps.

ments) and INAA (REE and Y) in Geoindustria, Černošice, in 1984; (Moučka, analyst). Th and U abundances were determined by gamma spectrometry on ground samples more than 1 kg in weight in the laboratory of Geofyzika, Brno, analyst M. Škovierová. Standard deviations are 0.5 to 1.0 ppm for Th and 0.2 to 0.5 ppm for U measurements. Isotopic analyses of Sr were performed on whole-rock samples (7 to 15 kg) by one of the authors (J. B.) in 1992 in the Czech Geological Survey, Prague. Aliquot part of powder was dissolved in a mixture of HF and HNO_3. Sr was isolated on quartz ion-exchange columns containing Bio-Rad cation resin. Samples were analysed by Finnigan MAT 262 thermal ionization mass spectrometer in static mode using a double Re filament assembly. Strontium was loaded using H_3PO_4. Measured $^{87}Sr/^{86}Sr$ ratios were normalised to the value 0.1194 for $^{86}Sr/^{88}Sr$. The NBS SRM 987 standard repeatedly yielded $^{87}Sr/^{86}Sr$ of 0.71025 ±(4) (2 sigma errors) at 100 scans. The Rb/Sr ratio was determined by XRF using Philips PW 1450 spectrometer (Gematest Ltd.) following Verdumen (1979) and Harvey and Atkin (1981). The $^{40}Ar/^{39}Ar$ age determination on one sample of primary hornblende separated from quartz diorite porphyry was performed in the Geochronology Laboratory at the Geological Institute, Vienna University, in 1999. Hornblende was separated by crushing, sieving and hand picking of a clean fraction 0.2–0.3 mm under a binocular microscope. After irradiation and cooling, the $^{40}Ar/^{39}Ar$ ratios were measured by stepwise heating on a VG5400 gas mass spectrometer.

Petrography

Biotite granodiorite porphyry shows rather limited variation in petrography of individual dykes. It has a strongly porphyritic structure in which plagioclase, biotite and quartz phenocrysts combined represent about 50 vol. % of the rock. Euhedral plagioclase crystals 0.3–4 mm long have a notable, normal compositional zoning and small-scale oscillatory zoning (Fig. 3a, b). A typical content of plagioclase phenocrysts is 25–30 vol. %, though the total range is 15–35 vol. %. Several samples (BE 86, TS 72, VE 1) are nearly fresh but most show at least a moderately advanced alteration of plagioclase to a very fine-grained aggregate of clinozoisite, sericite and altered feldspar.

Biotite phenocrysts 0.3–2.5 mm (up to 10 mm) across occur as pseudo-hexagonal tablets or shortly prismatic crystals. Biotite is usually altered to chlorite and locally replaced by epidote, carbonate and titanite. The sample VE 1 contains partly preserved strongly pleochroic biotite: X – beige, Y, Z – moderate bright brown. The typical content of phenocrystic biotite is near 8–10 vol. %. Quartz phenocrysts 0.3–4 mm in size (Fig. 3a) make usually 8–10 vol. % but several samples lack them completely (RO 202, BE 85, BE 86, BE 223).

The groundmass is very fine-grained, 0.01–0.05 mm, granular or spherulitic (Figs 3a, b). Spherulites show a radiating structure of feldspar and quartz aggregates and are usually 0.3–0.5 mm in diameter. Fine-grained sericite and chloritized biotite are present in the groundmass, each in quantities near 3–8 vol. %. Structural features of the groundmass indicate devitrification of an original glassy material.

Hornblende quartz diorite porphyry sampled at two localities (KC 10, Kaplice and KC 4 – Fig. 2) contains prominent phenocrysts of prismatic hornblende 0.5–8 mm long (Fig. 3c). The hornblende is khaki light brown along Z and makes 15–25 vol. % of the rock. Small phenocrysts of plagioclase 1–3 mm long, accounting for 5 % by volume, are subhedral and stronly altered to a very fine-grained mosaic of clinozoisite + sericite + chlorite and feld-

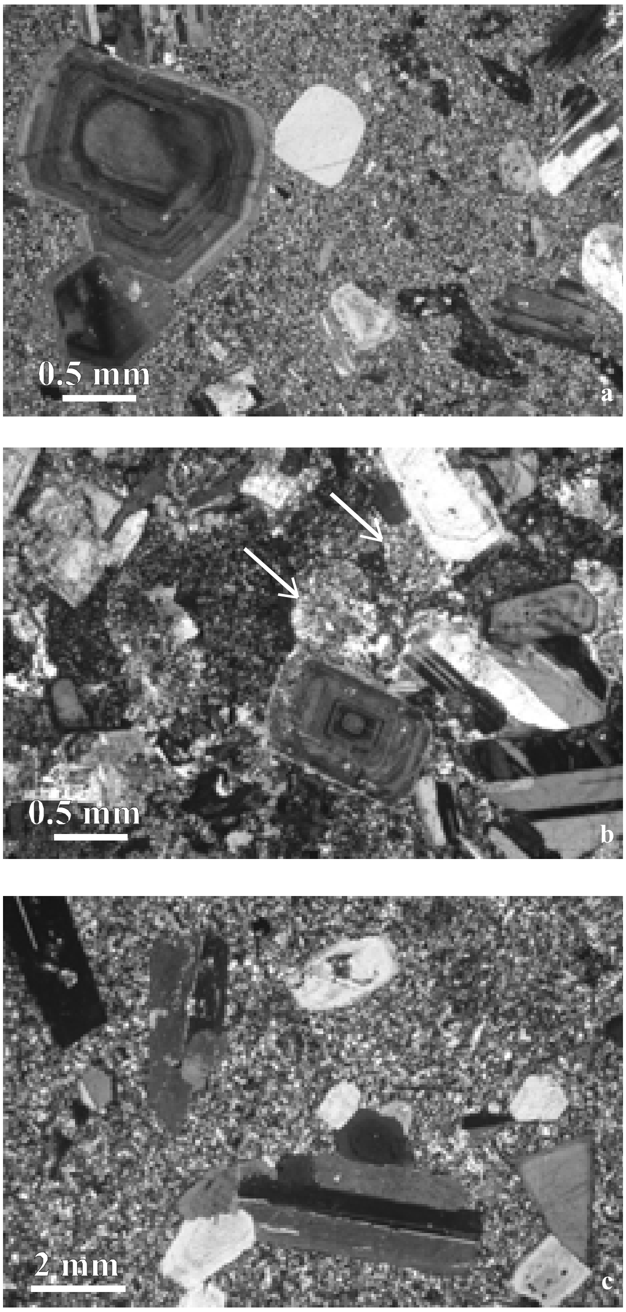

Fig. 3. a – Plagioclase phenocrysts with oscillatory compositional zoning and quartz phenocryst (above centre) in fine-grained granular groundmass of biotite granodiorite porphyry. Sample TS 100; b – Plagioclase phenocrysts in a granular and spherulitic groundmass of biotite granodiorite porphyry. Some spherulites are indicated by arrow. Sample BE 86; c – Hornblende phenocrysts in quartz diorite porphyry. Sample KC 100. Photomicrographs with crossed polarizers.

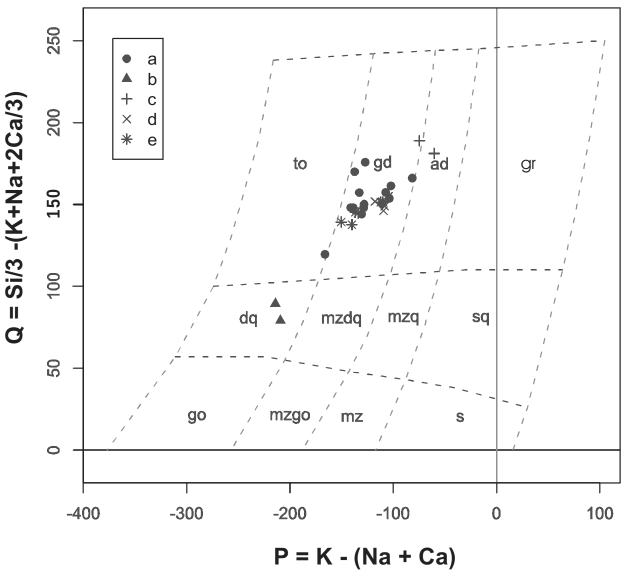

Fig. 4. Multicationic plot plot of Debon and La Fort (1983) showing projection of biotite granodiorite porphyry (a) and hornblende quartz diorite porphyry (b) samples, compared with the three major facies of Freistadt granodiorite: two-mica facies (c), central facies (d) and marginal facies (e). Data for Freistadt type granodiorite are from Gerdes (1997). Explanation: to – tonalite; gd – granodiorite; ad – adamellite; gr – granite; dq – quartz diorite; mzdq – quartz monzodiorite; mzq – quartz monzonite; sq – quartz syenite; go – gabbro; mzgo – monzogabbro; mz – monzonite; s – syenite.

spar. Fine-grained groundmass, 0.03–0.5 mm, is composed dominantly of subhedral plagioclase and several vol. % of fine-grained biotite completely altered to chlorite.

Whole-rock geochemistry

Petrochemical data, in particular H_2O^+ and CO_2 contents in Table 2, indicate that late-magmatic/post-magmatic alteration did not cause significant changes in whole-rock composition. Three samples with the highest carbonation contain 0.67–1.01 wt.% CO_2. The chemical composition is characterized by analyses of major and trace elements in fourteen samples of biotite granodiorite porphyry and two samples of hornblende quartz diorite porphyry (Figs 4–7). Their compositions are compared with data for the three main varieties of Freistadt granodiorite from the adjacent region of Lower Austria (Gerdes 1997). The GCDkit software (Janoušek et al. 2003) was used for comparison of chemical data and their presentation in diagrams. The multicationic plot of Debon – Le Fort (1983) in Fig. 4 shows that nearly all samples of the main porphyry group plot in the granodiorite field, with a small overlap to the adjacent tonalite and adamellite fields. The more mafic hornblende porphyries (samples KC 10 and KC 4) plot in the quartz diorite field (Fig. 4)

Biotite granodiorite porphyries contain 62.24–70.40 wt.% SiO_2, 15.29–18.29 Al_2O_3, 0.75–2.52 MgO, 1.26–4.89 CaO, 2.02–3.38 K_2O and 3.46–4.69 Na_2O. The rocks are weakly peraluminous with A/CNK = 1.04 to 1.22 (one sample slightly lower than 1.0), have a relatively low to moderate *mg* number and low Cr and Ni contents (Table 2). K_2O/Na_2O varies in the range 0.47–0.83. The spread of abundances for major elements in Harker's plot (Fig. 5) is similar to those for the Freistadt biotite granodiorite, though four samples of biotite porphyry feature somewhat higher MgO and *mg* values. Hornblende porphyries are metaluminous, with A/CNK = 0.90 and K_2O/Na_2O is 0.36 and 0.42. The chondrite-normalized (Boynton 1984) REE patterns for biotite granodiorite porphy-

Table 2. Whole-rock chemical composition of biotite granodiorite and quartz diorite porphyry.

Sample	BE 222	BO 84	KC 20	BE 223	KU 1	BE 86	BE 85	KU 2	TS 100	TS 72	VE 1	BO 82	BO 83	RO 202	KC 4	KC 10
SiO_2	70.40	69.23	68.96	66.57	66.54	66.44	66.33	65.98	65.03	64.34	63.92	63.81	63.67	62.24	55.91	54.46
TiO_2	0.29	0.32	0.42	0.49	0.46	0.41	0.43	0.51	0.53	0.53	0.62	0.50	0.53	0.61	0.87	0.89
Al_2O_3	15.95	15.29	16.34	16.31	16.09	16.45	16.49	16.16	16.48	16.55	17.17	16.19	16.22	17.25	18.01	18.29
Fe_2O_3	0.66	1.37	0.31	1.25	0.73	0.78	0.60	1.04	0.98	1.16	1.08	1.09	0.78	1.59	1.83	2.16
FeO	1.28	1.27	2.41	1.94	2.32	2.43	2.46	2.20	2.79	2.44	2.87	2.52	2.94	2.72	4.40	3.61
MnO	0.044	0.049	0.420	0.051	0.052	0.064	0.057	0.069	0.084	0.068	0.081	0.068	0.074	0.070	0.091	0.088
MgO	0.75	0.98	0.92	1.57	1.49	1.18	1.26	1.56	1.76	1.87	1.99	1.96	2.08	2.52	3.77	5.06
CaO	1.86	1.26	2.53	3.31	2.22	3.22	2.84	3.01	4.14	3.87	3.45	3.75	3.46	4.89	7.40	7.46
Li_2O	0.006	0.006	0.004	0.005	0.007	0.010	0.006	0.007	0.011	0.012	0.006	0.008	0.009	0.008	0.004	0.005
Na_2O	4.69	4.06	4.01	3.82	3.78	3.61	3.62	3.51	3.54	3.54	3.80	3.46	3.54	3.82	3.33	3.26
K_2O	2.22	3.38	2.23	2.33	2.80	2.98	3.00	2.81	2.32	2.48	2.02	2.35	2.25	2.09	1.19	1.37
P_2O_5	0.10	0.18	0.19	0.14	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.14	0.15	0.19	0.20	0.26
CO_2	0.04	0.04	0.02	0.03	0.67	0.09	0.14	0.17	0.01	0.33	0.06	1.01	0.76	0.40	0.41	0.04
C	0.02	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03
F	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.06	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.05
S	0.02	0.04	0.03	0.02	0.04	0.04	0.03	0.03	0.02	0.06	0.03	0.04	0.35	0.17	0.11	0.08
H_2O^+	1.30	1.52	1.38	1.58	2.12	1.32	1.71	1.76	1.45	1.66	1.94	2.28	2.63	1.64	2.08	2.06
H_2O^-	0.25	0.25	0.15	0.20	0.23	0.20	0.13	0.25	0.12	0.19	0.22	0.26	0.28	0.10	0.17	0.16
Total	99.89	99.27	100.34	99.65	99.76	99.45	99.32	99.29	99.48	99.28	99.47	99.48	99.69	100.31	99.79	99.29
Minor and trace elements (ppm)																
Sc	4.74	6.19	6.63	9.19	9.37	8.82	8.62	9.33	10.50	11.50	11.80	12.30	12.70	11.80	19.10	18.40
Cr	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	7	<5	<5	5	23	16
Co	3.13	4.26	3.98	3.13	6.00	6.20	5.14	6.36	7.38	7.63	8.64	7.22	8.09	12.40	15.10	19.20
Ni	<2	5	<2	<2	3	6	2	4	4	6	8	3	6	8	10	17
Zn	2	10	n.d.	2	45	5	11	24	82	16	39	21	30	19	30	30
Rb	47.30	93.00	93.40	47.30	88.70	85.90	82.80	77.20	104.00	82.00	74.20	61.20	65.80	81.70	48.50	63.00
Sr	427	259	n.d.	427	463	382	409	484	487	476	566	662	527	656	841	968
Y	14	16	n.d.	14	20	27	27	18	25	23	20	20	19	18	19	19
Zr	142	109	n.d.	142	161	173	180	164	153	150	165	149	145	167	172	184
Hf	3.82	3.17	4.48	3.82	4.81	5.69	5.54	5.74	5.39	4.35	4.50	4.44	2.90	5.38	3.74	4.55
Nb	7	10	n.d.	7	10	10	10	9	9	7	9	8	9	7	8	7
Ba	554	830	n.d.	554	955	837	806	924	694	664	767	810	753	823	443	546
Pb	23	24	n.d.	22	13	16	29	15	17	9	28	17	17	15	4	3
Cs	2.96	2.29	2.02	1.18	1.32	2.46	3.90	1.56	6.78	5.26	6.14	3.48	5.87	2.27	1.63	2.81
Th	4.70	5.00	n.d.	5.20	5.90	6.60	7.20	6.70	5.20	5.40	3.00	2.80	4.30	3.50	4.70	4.10
U	0.80	2.00	n.d.	3.60	0.90	1.10	1.20	0.60	3.60	5.90	2.60	9.00	2.10	0.20	0.40	2.00
La	24.80	29.30	32.60	28.10	35.20	33.30	38.50	35.60	33.00	32.80	35.10	21.70	25.20	24.80	33.30	31.80
Ce	46.60	50.70	65.00	57.50	64.90	71.60	70.00	71.70	64.20	65.00	64.10	53.10	50.70	60.20	71.60	66.90
Sm	3.62	3.73	5.15	4.68	5.24	5.56	5.72	5.54	5.18	5.10	4.94	4.39	4.33	5.16	4.59	5.84
Eu	0.84	0.96	1.02	1.20	1.32	1.36	1.35	1.39	1.25	1.31	1.37	1.18	1.09	1.25	1.27	1.70
Yb	<1	1.51	1.46	1.55	1.27	2.03	1.81	1.43	1.55	1.44	1.30	1.99	1.20	<1	1.61	1.84
Lu	0.13	0.15	0.21	0.31	0.29	0.38	0.30	0.26	0.34	0.31	0.23	0.25	0.20	0.30	0.38	0.30

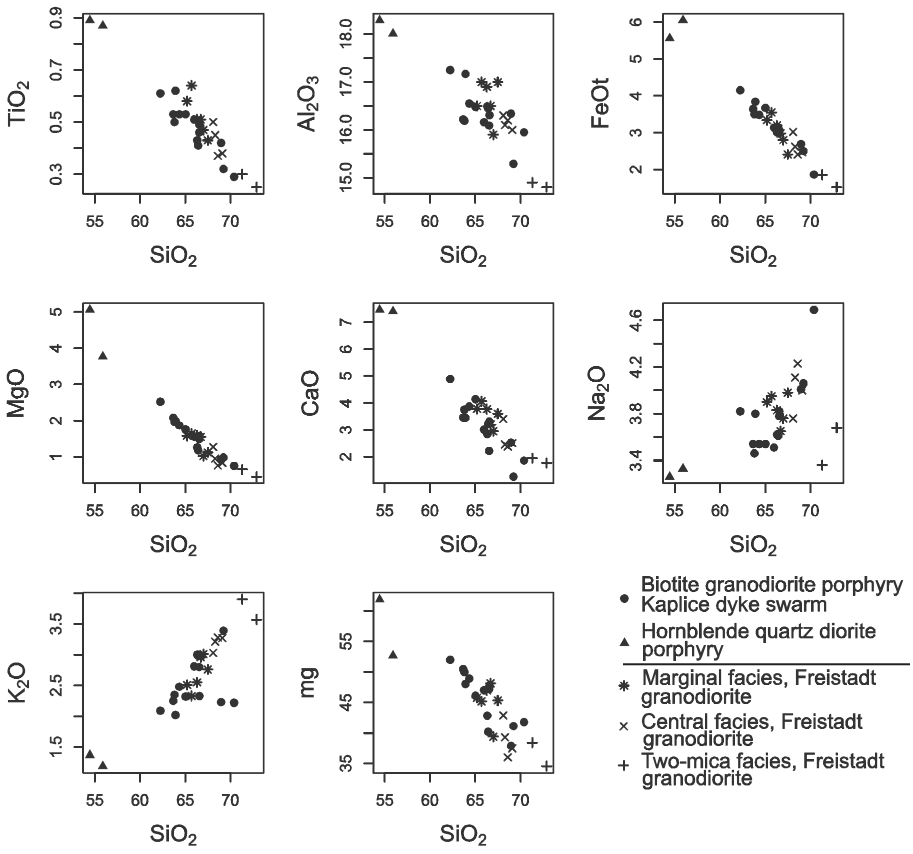

Fig. 5. Harker's plot of major element oxides and *mg* values for samples from the Kaplice dyke swarm, compared with the three major facies of Freistadt granodiorite. Data for Freistadt granodiorite are from Gerdes (1997).

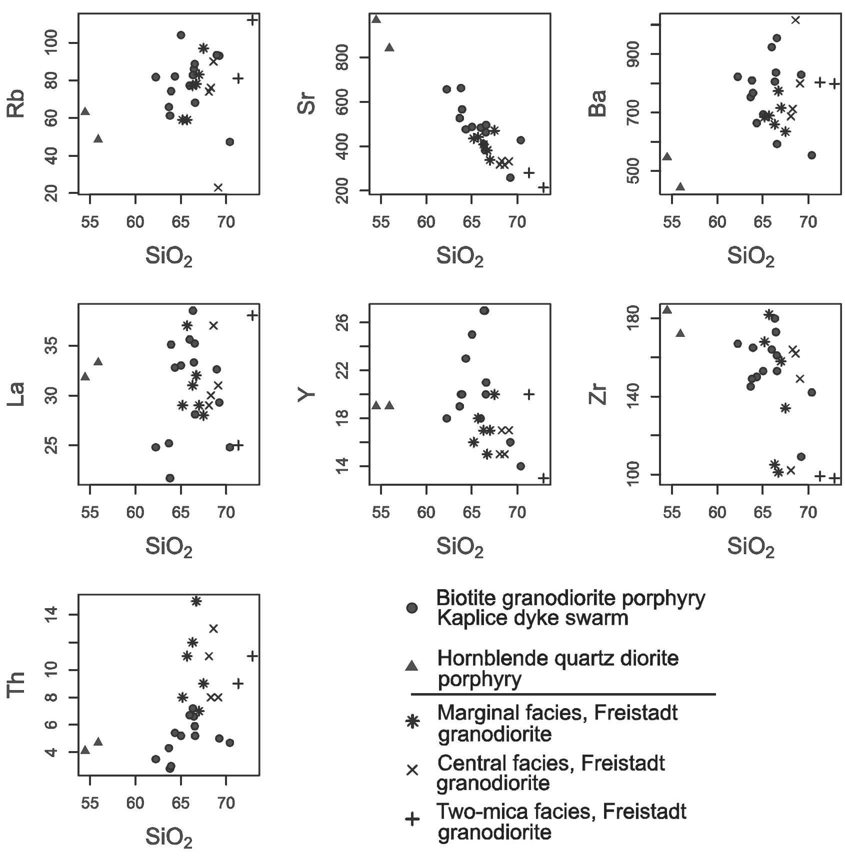

Fig. 6. Trace element vs. SiO_2 plots for samples from the Kaplice dyke swarm, compared with the three major facies of Freistadt granodiorite (Gerdes 1997).

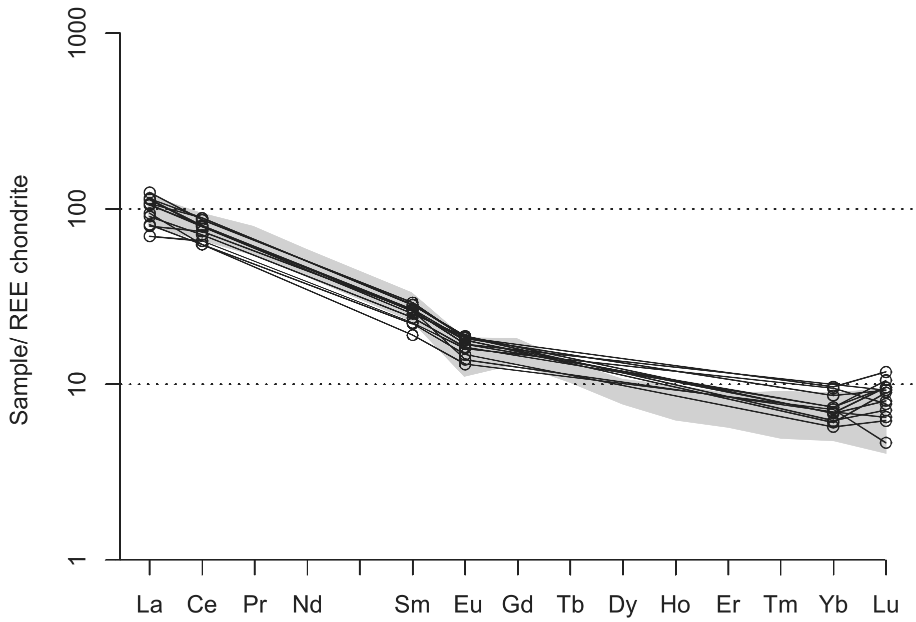

Fig. 7. Chondrite-normalized REE values (Boyton 1984) for biotite granodiorite porphyry samples, compared with data for the central and marginal facies of Freistadt granodiorite (grey field) (Gerdes 1997).

ry samples are closely comparable to data for the central and marginal facies of Freistadt granodiorite (Fig. 7). The Sr concentrations in biotite porphyries range from 259 to 662 ppm and correlate with mg indicator (Fig. 6). Rb abundances ranging from 47 to 104 ppm show a moderate variation with SiO_2 (Fig. 6).

Sr isotope geochemistry

The porphyries have rather unradiogenic initial (age-corrected for 305 Ma) $^{87}Sr/^{86}Sr$ values in the range of 0.7043–0.7067 (Table 3). Such isotopic composition would be compatible with an origin from a reservoir with fairly low time-integrated Rb/Sr ratio. The most appropriate scenario seems to be remelting of lower crustal (?metabasic) rocks, with or without contribution from the mantle-derived melts.

Geochronology

Age determination on hornblende from quartz diorite porphyry was obtained on the sample KC 10 from Kaplice (Fig. 2). The first steps indicate somewhat inhomogeneous age distribution (Fig. 8). Hornblende disintegration and maximal Ar release took place at 1070 °C. The total gas age of 303±5 Ma is interpreted as the cooling age, assuming a blocking temperature around 450–500 °C, and close to the time of intrusion of the dyke, which is only 0.7 m wide.

Discussion and conclusions

A comparison of major element abundances in porphyry with the main varieties (facies) of Freistadt granodiorite (Gerdes 1997) shows a close correspondence, except the fact that the two-mica variety of Freistadt granodiorite shows a more felsic (adamellitic) composition, not represented in the population of biotite granodiorite porphyries.

A comparison of some trace element abundances (Fig. 6) shows a fair correspondence, with several exceptions. Elevated Sr abundances in several biotite porphyry samples largely correlate with the increased MgO contents. Four samples with intermediate SiO_2 and MgO contain higher Y (>20 ppm) than Freistadt granodiorite. Thorium abundances in biotite porphyries are systematically lower than Th contents in the Freistadt granodiorite. It is possible that different methods in Th analyses may be at least

Table 3. Sr isotope data for biotite granodiorite porphyry, Kaplice dyke swarm.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	2 sigma/M/	$^{87}Sr/^{86}Sr_i$	1/Sr (ppm)
BO 87	93.0	259	1.0392	0.710331	0.000012	0.70582	0.003861
BE 222	47.3	427	0.3205	0.706767	0.000010	0.70538	0.002342
BE 223	47.3	427	0.3205	0.706989	0.000009	0.70560	0.002342
RO 202	81.7	656	0.3603	0.705886	0.000011	0.70432	0.001524
TS 100	104.0	487	0.6179	0.707748	0.000010	0.70507	0.002053
BE 85	82.8	409	0.5858	0.709255	0.000009	0.70671	0.002445
BO 82	61.2	662	0.2675	0.707002	0.000010	0.70584	0.001511

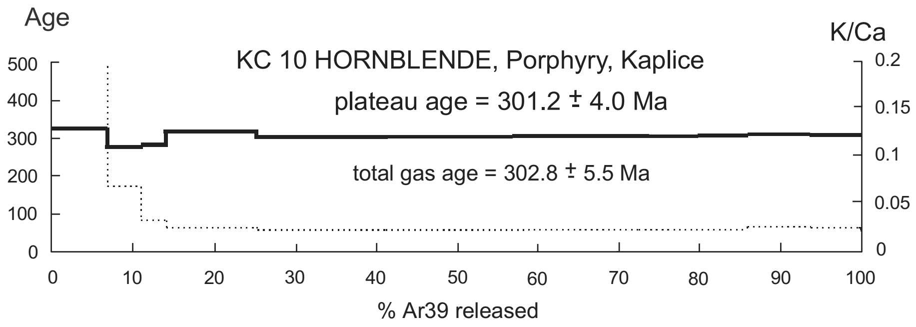

Fig. 8. ^{39}Ar release diagram for hornblende from sample KC 10.

partly responsible for the notable difference, but without additional work the problem remains open. A check of the range of values for trace elements in the whole sample set of biotite porphyry shows that uranium exhibits an exceptionally wide spread of 0.6 to 9.0 ppm. This suggests a possible re-distribution of U due to autohydrothermal (and/or hydrothermal ?) alterations in the porphyry dykes.

The strontium isotope analyses gave results (Table 3) indicating a close similarity with data for the Freistadt granodiorite, ranging from 0.70544 to 0.70620 ($^{87}Sr/^{86}Sr_i$ = 305 Ma) (Gerdes 1997). The 1/Sr vs. $87Sr/86Sr_i$ (305 Ma) diagram (Fig. 9) shows the extent of deviation for seven porphyry samples from a simple theoretical model of evolution via fractionation in a closed system. This indicates a role of open system processes that may included mixing with isotopically distinct magmas or assimilation of country rocks, as considered by Gerdes (1997) for Freistadt granodiorite. The emplacement of the Freistadt pluton (and the porphyry dykes) possibly as several melt batches would explain some variation of the Sr isotope system. On the other hand, any disturbance of the Rb-Sr system in the course of an autohydrothermal alteration (i.e. closely post-dating dyke implacement) would not explain relations in Fig. 9.

It is suggested that the regional distribution of biotite granodiorite porphyry dykes (Fig. 2) approximates the regional extent of the Freistadt pluton, in particular its hidden parts. The exposed portions of the pluton are centred near Freistadt and the Austrian/Czech border. The northernmost outlier, about 10 km^2 in size, occurs southeast of Trhové Sviny (Figs 1, 2). Notably, one important granodiorite facies exposed therein features euhedral phenocrystic biotite to 7 mm, quartz phenocrysts to 7 mm and small euhedral plagioclase, resembling the structure in some of the porphyry dykes (Vrána et al. 1984, Matějka 1998). The studied porphyry dyke swarm in the intervening area (Fig. 2) strongly indicates the presence of the Freistadt pluton at a subsurface level, covered by metamorphic rocks and older Variscan granitoids, i.e. Weinsberg and Eisgarn plutons. Two remote and isolated localities of the same type of biotite granodiorite porphyry occur in the Světlík area, ca. 15 km west of Kaplice (Vrána et al. 1994).

The northernmost localities of biotite granodiorite porphyry are those 10 km south of České Budějovice (Figs 1, 2). Further north and along the Kaplice-Blanice graben fault system, between the towns of České Budějovice and Veselí nad Lužnicí, there is a domain of pyroxene microgranodiorite dykes dated as Autunian, 270±2 Ma (Košler et al. 2001).

Age constraints for Freistadt granodiorite are provided by U-Pb monazite dating at 302±2 (Friedl et al. 1997) and ca. 300 Ma (Gerdes et al. 2002). The latter paper presents indication of an older, inherited population of monazite dated at 331 Ma. Given the similarities in petrology and whole-rock geochemistry the age of ca. 300 Ma is also likely to be a best age estimate for the biotite granodiorite porphyry dykes. The new ^{40}Ar-^{39}Ar datum of

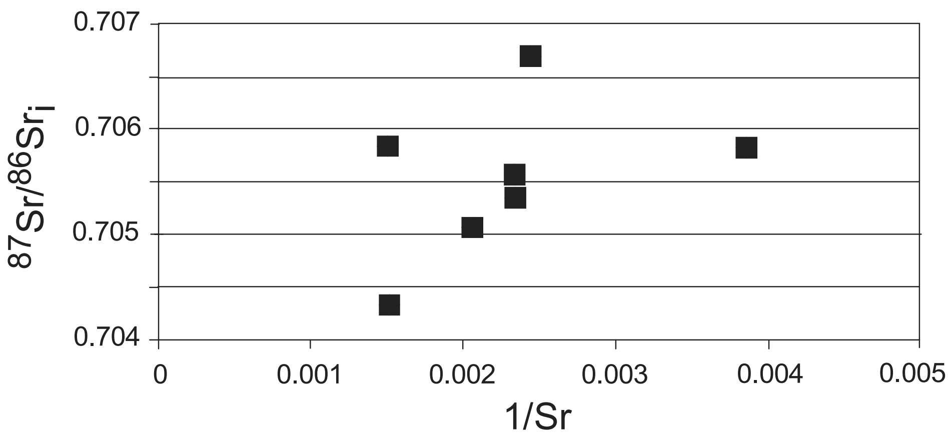

Fig. 9. 1/Sr vs. $^{87}Sr/^{86}Sr_i$ for biotite granodiorite porphyry samples, age corrected to t = 305 Ma.

303±5 Ma for the hornblende in quartz diorite dyke sample KC 10 (Fig. 8) suggests intrusion of the dyke as within the error co-eval with emplacement of the Freistadt granodiorite and the Kaplice swarm of biotite granodiorite porphyry dykes.

The microgranular and spherulitic textures of groundmass in biotite granodiorite porphyry dykes indicate probably a devitrification of the originally present glass, resulting from quenching of the melt carrying ca. 50 vol.% of phenocrysts as glass (Lofgren 1971). This points to an intrusion of the dykes into relatively cold country rocks and thus to rather shallow emplacement level. This is likely to having been a case also for the Freistadt pluton.

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Biotitické granodioritové porfyry v kaplickém zlomovém pásmu a jejich vztah ke granodioritu typu Freistadt

Granodioritové porfyry v kaplickém zlomovém pásmu mají výraznou porfyrickou strukturu, obsahují ca. 50 obj.% vyrostlic plagioklasu, biotitu, příp. křemene. Mikrogranulární a sférolitická struktura základní hmoty indikuje pravděpodobný vznik devitrifikací sklovitě utuhlé taveniny. Složení porfyrů je charakterizované analýzami hlavních a stopových prvků ve 14 vzorcích. Data prokazují úzkou geochemickou příbuznost k horninám centrální a okrajové facie biotitického granodioritu typu Freistadt (Gerdes 1997). Porfyry mají A/CNK = 1,04–1,22, poměrně nízké až střední hodnoty *mg*, nízké obsahy Cr a Ni. Charakteristické jsou poměrně nízké iniciální hodnoty $^{87}Sr/^{86}Sr$ = 0,7043–0,7067 při korekci na stáří 305 mil. let. Vzhledem ke geochemické a petrologické podobnosti lze považovat publikované stáří granodioritu typu Freistadt získané na monazitu (ca. 300 Ma) za nejbližší odhad stáří porfyrových žil. Rozšíření porfyrových žil v území mezi hlavním výskytem granodioritu typu Freistadt v okolí Freistadtu v Dolním Rakousku a nejsevernějším výběžkem u Trhových Svin pravděpodobně vyznačuje podpovrchový rozsah freistadtského plutonu.