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PETROGENESIS OF APLITES OF THE BOR PLUTON

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Abstract. Aplites of the Bor pluton originated in at least two chronologically separated stages through injection of the aplitic (monzogranitic) magma into the cooled monzogranites of the main phase of the Bor pluton. They are low-fractionated and contain a low proportion of Fe, Mg, Zr, Th and Rb. Their composition can be derived from the main phase of the older magmatic complex of Variscan plutonism of the western part of the Bohemia Massif. Their origin is related to extensional collapse on the Moldanubicum–Bohemicum boundary between the Carboniferous and Permian.

Keywords: aplite, petrography, geochemistry, Bor pluton

1. Introduction

In relation to the ultra-deep KTB borehole drilled in the western part of the Bohemian Massif during the past few years, great attention has been paid to geologic structure of this portion of the central European Variscan terrane. According to the original project, the borehole should verify the course of an inferred suture between the Saxothuringicum and Moldanubicum. Nevertheless, the borehole itself and comprehensive studies in this area have proved the structural evolution of western margin of the Bohemian Massif to be controlled above all by a conspicuous N–S trending transcurrent zone stretching from Magdeburg to northern margin of the Alpine orogen (Behr et al., 1992). This zone experienced upper-crust thickening caused by the thrusts derived from extensional collapse of the Bohemicum block in relation to the Moldanubian block. The Bor pluton lies on eastern margin of this transcurrent zone and its evolution is closely linked with that of this zone. After the cooling of the main magmatic phase (biotite monzogranites), N–S trending extensional structures arose to be gradually infilled by vein granites, aplites, lamprophyres and by hydrothermal mineralization. Comprehensive geologic exploration for economic uranium deposits in the Bor pluton area conducted in the 1970's and 1980's has established above all a chronological sequence of the individual dyke rocks and the ensuing uranium hydrothermal mineralization.

Activities focused on the absolute age determinations of the single granite intrusions in the granitoids of the Oberpfalz area, in the Rozvadov and Bor plutons enable to distinguish separate evolutional phases of the extensional structures on the Moldanubicum–Bohemicum boundary, including the dyke–rock infilled structures (Siebel et al., 1996; Wendt, 1993; Zulauf, 1994).

Objective of this work is to describe aplite petrogenesis of the Bor pluton. Until now, little attention has been paid to the aplite dykes, which are an important element of the Variscan granitoid magmatism of the western part of the Bor massif, although these dykes were discovered both in the KTB borehole and in most of the studied granitoid massifs of the Oberpfalz.

2. Geological Setting

The Bor pluton forms a conspicuous straight-line oriented (N–S) magmatic body exposed between Mariánské Lázně in the north and the Dehetná village in the south. The pluton fills the Cheb – Domažlice graben. Eastern boundary against the Bohemicum is emphasized by the Mariánské Lázně fault. The occurrence of thick shear zones characterizes the western margin of the Bor pluton. The NW–SE striking younger structures cut the Bor pluton into three partial blocks. Based on the abundant country – rocks relics formed by the Moldanubian metamorphics in the central block area, the central block can be considered as the least eroded tectonic block of the Bor pluton. Magmatic and post-magmatic evolution of the Bor pluton is controlled by the development north – south trending shear structures. North – south trending structures with an eastward dip of up to 50° occur within the whole pluton.

The occurrence of uranium mineralization associated particularly with the western exocontact and endocontact of the Bor pluton is above all controlled by favorable structural – lithological factors (Doležel et al., 1975; René, 1992).

The character of relationship of the particular magmatic phases of the Bor pluton are fairly well-known, owing to the large number of boreholes and mining workings done in the course of exploration for uranium ore occurrences and deposits. Geology and petrography of the Bor pluton have been summarized in the papers (Vejnar, Neužilová and Syka, 1969; Hejtman, 1984) and in a number of unpublished reports deposited in the archives Uranium Industry Co. (now DIAMO). The synopsis of the geological exploratory activities related to exploration for uranium ores is given in the paper (Holovka and Hnízdo, 1992).

The aplite dykes originates after the cooling of the vein biotite and biotite-muscovite granite dykes. Mining activities in the central block of the Bor pluton at Vítkov II uranium deposit enabled to determine the spatial position of the aplite dykes and their relation within the overall postmagmatic evolution of the Bor pluton. Geological data in the described area suggest that most of the aplite dykes make up infillings of N–S trending structures that dip at 10 – 50° eastwards. Most dykes dip moderately at 10 – 30°. Steep dykes are rare, they dip at 80 –85° westwards and strike N–S. Steep aplite dykes crosscut the more flat-lying ones. The youngest dyke rocks are lamprophyres filling the steep N–S structures dipping at 45 – 80° westwards (Fig. 1). Thickness of the flat aplite dykes is 5 – 15 m and their length ranges from several hundreds of meter to 5 km. Thickness of the steep ones is less than a few tens of centimeters. Shear structures, mostly trending N–S and filled by uranium mineralization were developed or rejuvenated only after the genesis of lamprophyre dykes. The alignment of some aplites indicate the existence of shear movements along the aplite–infilled extensional structures. It can therefore be assumed that aplite injection and the subsequent development of uranium mineralization took place in a tensional field controlled by displacements along N–S trending structures. Moreover, study of the development of uranium mineralization at Vítkov II deposit has proved the concentration of uranium minerals to be to a certain extent controlled by the development of aplite dykes that at places acted as barriers favouring local concentration of the mineralization.

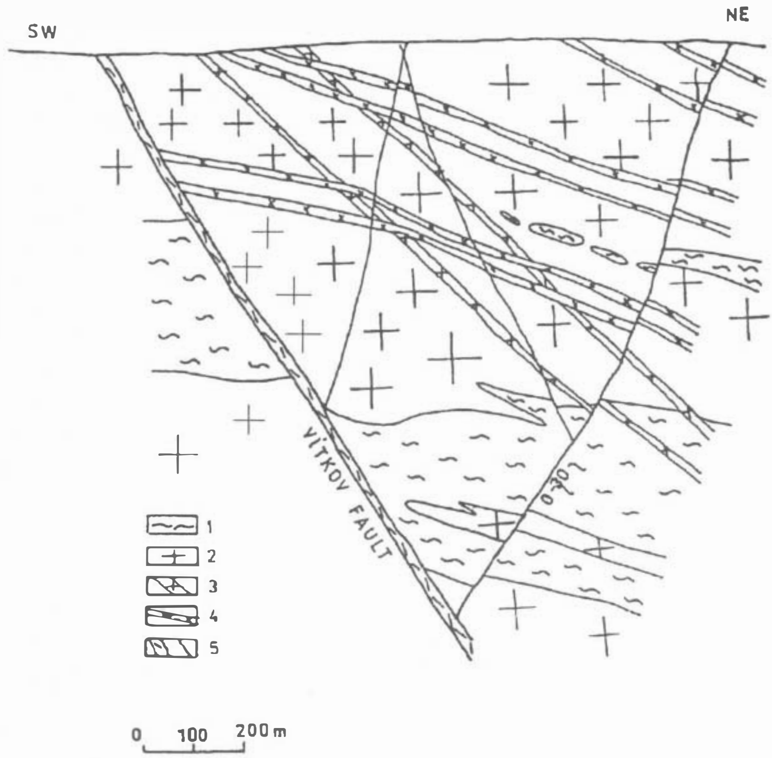

FIG. 1. Cross section of the uranium deposit Vítkov II (1 – metamorphic rocks of the Moldanubian, 2 – Biotite monzogranite of Bor pluton, 3 – Sill–granite, 4 – Aplite, 5 – Faults, mylonite zone)

The age of Bor pluton has been newly determined by (Siebel et al., 1996). The age of the main phase of the Bor pluton made up of biotite monzogranites, often porphyritic, corresponds to 337 Ma. Standard K–Ar analyses of biotite monzogranites and the younger vein granites give an age of 320 – 314 Ma, which represents the cooling stage of the pluton at 500 – 450 °C. Owing to the usually high hydrothermal alteration of lamprophyres of the Bor pluton, age determination of lamprophyres from the KTB borehole has been applied in considering the age of these dykes.

(Kreuzer et al., 1993) have dated biotite in the lamprophyre to c. 295 Ma, which corresponds well to an age of 297 Ma (Rb–Sr) for albite granite from a smaller stock at Křížový kámen in the Rozvadov pluton area (Siebel et al., 1996). These analyses suggest that the aplite genesis can be dated within a range of 315 – 295 Ma, i.e. near the Upper Carboniferous – Lower Permian boundary.

3. Petrographic Characteristic

The aplites are whitish, whitish grey to slightly yellowish, usually fine– to medium–grained rocks. They are slightly foliated at places, which suggests the dykes having developed in tensional field of the shear structures. The texture is panxenomorphic granular, transitional to hypidiomophic texture. The aplites contain K–feldspar (30–40 %), quartz (25–35 %), plagioclase (15–30 %), micas (0–3 %) and accessory minerals. The accessories are represented by apatite, tourmaline, garnet and zircon. Gridiron twinned microcline and frequent perthitic exsolution are characteristic for K–feldspars. Their grain size is 0.5–1 mm, exceptionally 1.5 mm. K–feldspar contains at places quartz and plagioclase inclusions. Quartz is anhedral with grains up to 1 mm in size and it sometimes shows a slight wavy extinction. The plagioclase is sodium feldspar (An_{10-15}), with anhedral to subhedral grains. It is usually 0.2–0.8 mm in size, less frequently its grains reach up to 1.4 mm in size. It is polysynthetically twinned. Biotite laths show a marked brown pleochroism. Muscovite is usually anhedral, and at places interstitial. It forms intergrowths with quartz and biotite. Aplites correspond in their mineral composition to monzogranites, which distinguishes them markedly from meta–aplites of the Rozvadov pluton, whose mineral composition corresponds to alkali–feldspar granites.

4. Geochemistry

Standard analyses of major components and selected trace elements were carried out to assess the geochemical specialization of aplites of the Bor pluton. Analyses of the major components and of most of the trace elements were performed using XRF spectral analysis, optical emission spectral analysis was used to determine Sn and gamma spectrometry was used to determine uranium and thorium (Table 1).

Analysis of the major components has shown that aplites of the Bor pluton are slightly peraluminous rocks trending to transition between I– and S–type granites. This trend is particularly obvious from the A–C–F diagram (Fig 2). Low content of Fe, Mg, Zr and Th, relatively low content of the alkalies and a large scatter in uranium content are characteristic for the aplites. Low fractionation of aplites of the Bor pluton is indicated by low scatter in the Rb/Sr ratio values and overall low rubidium proportion (Fig. 3). Based on the distribution of Rb versus the Y and Nb distribution, aplites of the Bor pluton can be assigned to the boundary of the syncollisional and the volcanic–arc granites in the sense of (Pearce et al., 1984).

5. Discussion

Study of geological position of aplites in the Bor pluton has proved the aplites to be produced under an extensional regime after the cooling of main phase of the Bor

TABLE 1. Analyses of the aplites from the Bor pluton

Sample No.	Re 522	Re 524	Re 666	Re 684	Re 772
SiO_2	78.32	75.98	74.52	73.18	72.47
TiO_2	0.05	0.14	0.06	0.10	0.11
Al_2O_3	12.84	12.91	13.72	13.94	15.49
Fe_2O_3	0.14	0.34	1.21	0.15	0.08
FeO	0.50	0.84	0.54	0.80	0.77
MnO	0.026	0.037	0.02	0.039	0.038
MgO	0.13	0.17	0.16	0.25	0.60
CaO	3.62	1.35	1.23	0.68	0.63
Na_2O	3.39	3.70	3.00	4.40	4.25
K_2O	0.55	4.14	4.60	4.27	3.91
H_2O^+	0.26	0.27	0.77	0.63	
H_2O^-	0.09	0.09	0.04	0.09	0.09
P_2O_5	0.04	0.005	0.21	0.375	0.329
CO_2	0.10	0.041	0.36		0.06
Rb ppm	20	175	161	202	222
Sr ppm	207	66	50	54	7
Zr ppm			24	54	527
Y ppm			19	20	24
Nb ppm			7	12	17
U ppm	21.8	17.8	5.3	7.0	13.3
Th ppm	2.8	14.5	2.5	4.0	1.9

Re-522 uranium mine Vítkov II, 11.level, Re-524 Planá, Sv.Anna, small abandoned mine, Re-666 borehole Chv 16, 252.80 m, Re-684 borehole H1-19, 189 m, Re-772 borehole Chv 54, 155 m

Major elements were analysed by MEGA Stráž under Ralsko, Rb, Sr, Zr, Y, Nb were analysed by Geological exploration enterprise Ostrava, U and Th were analysed by enterprise Geophysics Brno

pluton. Under this extensional regime controlled by the course of a transcurrent shear zone in the sense of (Behr et al., 1992) or by zone of extensional collapse as stipulated by (Zulauf, 1994), a repeated injection of aplitic melt into the extensional shear structures took place. The oldest aplite dykes were generated in a tensional field, which is reflected by the alignment of some of the aplite dykes. After cooling of the aplite dykes, whose genesis can be based on the absolute age determinations of older monzogranites of the Bor pluton and younger lamprophyre dykes, delimited by the interval of 315-295 Ma, new displacements along several shear structures and the injection of the lamprophyre magma took place. Some of the shear structures were regenerated after cooling of the lamprophyre dykes and these structures

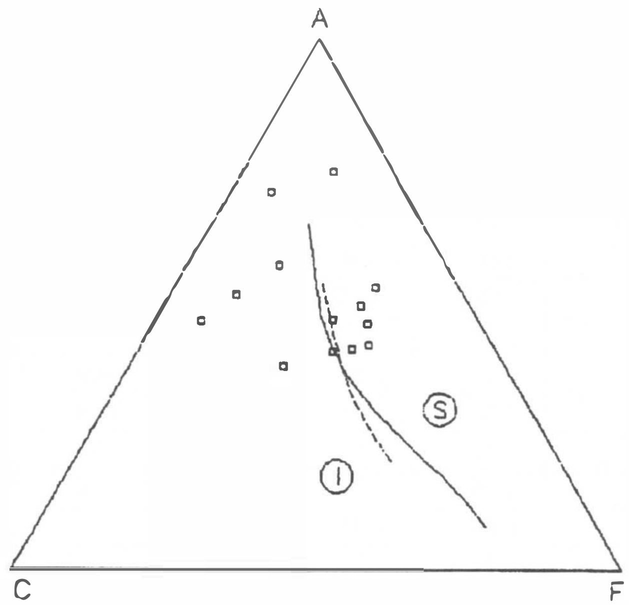

Fig. 2. Diagram A–C–F for aplites of Bor pluton

acted as places of gradual deposition of hydrothermal uranium mineralization. The genesis of uranium mineralization was accompanied by intensive hydrothermal alterations of the surrounding rocks, including the aplite dykes. Deposition maxima for the uranium minerals are documented by two groups of absolute age datings which suggest both Permian (262–259 Ma) and Cimmerian (185 Ma) ages for the uranium mineralization (Ordynec et al., 1987).

Aplites have been described from the other plutons on western margin of the Bohemian Massif and from metamorphic complexes in the Moldanubicum and the Erbendorf–Vohenstrauss zone. These aplites have been divided into three groups based on their geologic position. The oldest are the meta–aplites from the Moldanubicum in the environs of the Rozvadov pluton (Breiter and Siebel, 1995), the younger group is represented by the aplites in the monzogranites of the older magmatic complex of the Oberpfalz and Fichtelgebirge (G1, Leuchtenberg) (Hecht, 1993), the youngest group is made up by the aplites found in rock of the younger intrusive complex (G2, G3 and the Falkenberg, Steinwald and Flossenbürg plutons) (Richter and Stettner, 1987; Tavakkoli, 1984). Aplites of the youngest group are probably comagmatic with lithium pegmatites of the Moldanubicum (Hagendorf) and with lithium albite granites (Křížový kámen, Silbergrube) (Breiter and Siebel, 1995). Aplites of the Bor pluton are in their geologic position and mineral composition related to aplites of the older magmatic complex of the Oberpfalz and Fichtelgebirge. Geochemical pattern of their evolution also corresponds to this group of aplites. Monzogranitic parental magma with low–grade fractionation of incompat-

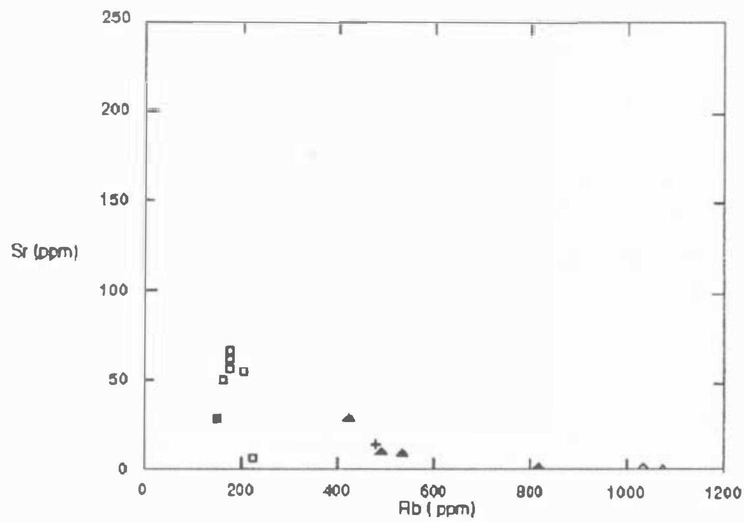

Fig. 3. Scatter diagram for Sr and Rb
open box – aplite of Bor pluton, filled box – aplite of Rozvadov pluton, triangle – aplite of Flossenbürg pluton, cross – aplite of Steinwald pluton, diamond – lithium albite granite (Křížový kámen, Silbergrube)

ible elements is characteristic for this group. The differences in fractionation are particularly reflected by low content of Rb in aplites of Bor pluton in comparison with those of the Steinwald and Flossenbürg plutons, or with the lithium granites of the Silbergrube and Křížový kámen stocks. Higher proportion of the alkalies with moderate predominance of K over Na is characteristic for aplites of the Bor pluton. This ratio decreases in favour of Na towards the younger dyke complexes.

6. Conclusion

Aplites of the Bor pluton were produced under a tectonic regime derived from an extensional collapse on the Moldanubicum–Bohemicum boundary. This collapse was brought about by the existence of an important N–S trending transcurrent zone that in turn controlled the existence and further development of shear zones on western margin of the Bohemian Massif. The aplites infilled the N–S shear zones generated in th Bor pluton. Timing of the aplite dyke systems falls within the range of 315 and 295 Ma. Aplites of the Bor pluton show a certain affinity in composition to monzogranites of the main magma phase of the Bor pluton. They differ from the aplites described from younger granites of the Oberpfalz, particularly in their lower Rb content and partially also in their higher K/Na ratio.

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