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PETROGENESIS OF GRANITOIDS IN THE BLATNÁ AREA

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ABSTRACT. The Blatná–type monzogranites and granodiorites are a part of a composite magmatic complex of Variscan age emplaced in a ductile shear zone on the boundary of the Bohemicum and the Moldanubian terranes. In their mineral and chemical composition they are closest to the hybrid granites (H–granites). Their origin is associated with the processes of mixing of the differentiated, high–potassium, mantle–derived magmas with metavolcanics and metasediments of the upper crust and with subsequent extensive homogenization of the granitic melt.

KEYWORDS: granite, petrology, geochemistry, Central Bohemian Pluton

1. INTRODUCTION

Granitoids in the Blatná area are composed of monzogranites to granodiorites of the Blatná type. This type belongs to the fundamental rock types of the Central Bohemian Pluton. This pluton is a large composite magmatic body that occupies an extensive area (3200 km^2) between Prague and Klatovy. The Central Bohemian Pluton represents in its composition petrographically the most differentiated magmatic body of Variscan age on territory of the Bohemian Massif (Fig. 1). The most widespread petrographical types are hornblende–biotite granodiorites, complemented by granites on one hand and by tonalites and melagranites along with melasyenites (durbachites) on the other. Gabbros, along with a wide suite of dyke rocks of predominantly intermediate to mafic character (microgabbros, microdiorites, lamprophyres) emphasize the diversity of the Central Bohemian Pluton. The important petrographic types are the monzogranites to granodiorites of the Blatná type, which are along with the granodiorites of the Červená and Klatovy types and probably also the marginal–type granites a member of a large suite of high–potassium granitoids. Rocks of this group can be assigned to the high–potassium calc–alkaline to shoshonitic series. This assignment is based on the classification of petrochemical types of the Central Bohemian Pluton according to Holub et al. (1995, 1997).

Monzogranites to granodiorites of the Blatná type were for the first time distinguished as an independent petrographic type by Orlov (1932) and their areal extent was thought to be about 300 km^2. Later, similar granodiorites from the environs of Zvíkov (the Zvíkov type of Urban, 1930), the granodiorites from the environs of

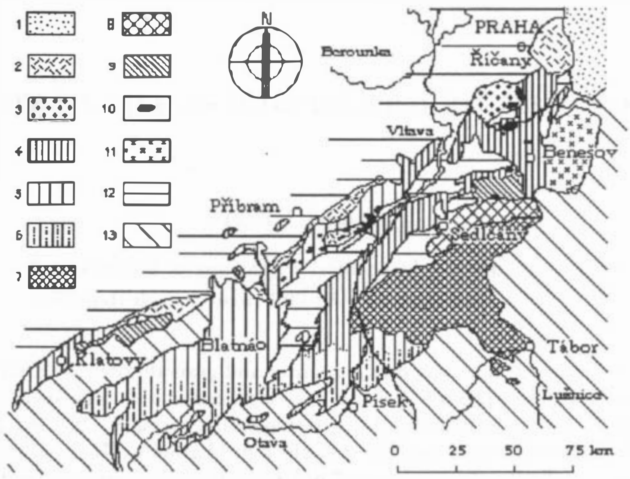

FIG. 1. Geological outline of the Central Bohemian Pluton (after Mísař et al., 1983)
1 – Permo–Carboniferous sediments, 2 – Říčany and marginal type, 3 – Požáry type, 4 – Sázava type, 5 – Blatná and Klatovy type, 6 – Červená type, 7 – Tábor and Čertovo břemeno type (durbachites), 8 – Sedlčany, 9 – Kozlovice and Maršovice type, 10 – Gabbroic rocks, 11 – Benešov type, 12 – Proterozoic and Paleozoic sediments (Bohemicum), 13 – Moldanubian Zone

Milín (the Milín type of Vachtl, 1932) and the granodiorites from the environs of Velenovy and Zavlekov (the Zavlekov granodiorite of Vejnar, 1954) were added to this type. Today, the Blatná type is supposed to occupy an area of 630 km^2 (Holub et al., 1995). Granitoids of the Blatná type were subject of a series of particularly petrographically oriented studies related to the extraction of ornamental stone, widespread above all in the environs of the Blatná town (Dudek and Fediuk, 1960). A new incentive for the study of this rock type was provided by the discovery of uranium mineralization near Nahošín and Mečichov and subsequently exploration for uranium ores. The exploration for uranium was carried out between 1977 and 1988 and involved drilling of many boreholes to the depth of 150 – 600 m and caving of the Nahošín prospect pit to the depth of 190 m (Litochleb and Kotlovský, 1988). The exploration also included studies of mineral composition and chemistry of the Blatná and Červená granodiorites (Knotek and Lang, 1985). The results discussed in this paper are also based on the technical and analytical work related to the exploration of uranium.

2. Geological Setting

Monzogranites to granodiorites of the Blatná type form an independent, NE–

SW striking intrusion parallel to the general strike trends of the whole Central Bohemian Pluton. Its southern part at contact with the chemical and structurally related Červená type is sometimes called the Chanovice offshoot. The fundamental structural evolution of the area in which the granites and granodiorites of Blatná and Červená types occur, is controlled by E–W, NW–SE and N–S trending joint systems. The most expressive system of subparallel joints and joint systems strikes E–W and is parallel with the Q–joints of the granite tectonics in this part of the pluton. Joints of this system, which at places form south–dipping fracture zones several tens of meters thick, are often filled by lamprophyre dykes and by other dyke rocks (porphyry, aplite, pegmatite). The length of the dykes reaches for the lamprophyre and aplite dykes 5 km (Tonika et al., 1980 b; Vejnar, 1954). Joints of this direction are also paralleled by the inexpressive preferred orientation of minerals in the Blatná–type granodiorite (Tonika et al., 1980 a). Occurrences of metasomatic and vein–type uranium mineralization (Litochleb and Kotlovský, 1988) are associated with the younger, N–S trending joint systems. These joints are in several cases also infilled by quartz veins. The NW–SE trending joint systems, which are infilled by mylonitized and hydrothermally altered granitoids and locally also by carbonate–sulfide–hosted mineralization, are the youngest. The Blatná–type granitoids have been dated both based on their relation to the surrounding intrusives and radiometrically. From the viewpoint of their relative age the Blatná–type granitoids are older than the Čertovo břemeno–type durbachites and younger than the Sázava–type granodiorites. The granites and granodiorites of Blatná type show gradual transitions into the Červená–type granodiorites, but sharp contacts also occasionally occur (Kodym and Suk, 1958). The Rb–Sr radiometric dating of van Breemen et al. (1982) and Bendl and Vokurka (1989) showed a value of 331 ± 4 million years or 331 ± 9 million years respectively. The more recent, U–Th dating on zircons showed an age of 349 ± 10 million years (Holub et al., 1996). New dating of the main rock types of the Central Bohemian Pluton has shown that the individual intrusions of the Central Bohemian Pluton followed in a fast succession during the Lower Carboniferous and the whole sequence of the geochemically varied magmatic suites was generated within 15 – 20 million years.

3. Petrography

Monzogranites to granodiorites of the Blatná type are mostly medium–grained equigranular pale grey or blue–grey rocks when fresh. The major rock–forming minerals are quartz, feldspars and biotite. Besides biotite, also hornblende is represented among the mafic minerals and occurs above all at contacts with the Červená type or at the northern margin of the intrusion near Hudčice. Its content in this area reaches up to 5 – 7 %. The size of individual minerals averages between 2 and 3 mm. Potassium feldspars sometimes form porphyritic phenocrysts. Structurally, the Blatná–type contains even–grained types, porphyritic types and foliated types, which sometimes have a well–developed cataclastic structure (Tonika et al., 1980 b). The most common textural type is the even–grained type with hypidiomorphic texture or with massive texture. At contact with the Moldanubian metamorphic rocks the granodiorites contain often streaks or are foliated and have a larger amount of mafic minerals. Quartz is anhedral and usually has a slight undulatory extinction. The size of its grains is 0.5 – 2 mm. Potassium feldspar is also anhedral with a low grade of triclinity (Neužilová in Tonika et al., 1980 b). Myrmekite is locally developed at contact with plagioclases. In the porphyritic variety of the Blatná–type granodiorite the size of porphyritic K–feldspar phenocrysts reaches 1 – 2 cm. The best evolved felsic mineral is plagioclase with a well developed polysynthetic albite twinning. Plagioclase shows a wide range of An values (An_{14-45}), even within the individual grains, as it has been proved by X–ray microprobe study (Knotek and Lang, 1985). The plagioclase cores are always more mafic than the margins of the grains. The most frequently represented plagioclases are those with An_{23-31} value. Biotite is pleochroic, it is pale yellow–brown parallel to X and dark brown to red–brown parallel to Y and Z. Its gradual transformation into chlorite associated with the hydrothermal alteration of granodiorite in the vicinity of uranium mineralization occurrences has been observed in some samples. Poorly represented amphibole corresponds according to its optical properties to hornblende.. It forms short, hypidiomorphic columns, 0.3 – 1.2 mm in length. Accessory minerals are represented by pyrite, zircon, apatite, allanite and sphene, with varying amount of epidote and scheelite. Their quantitative composition was studied by Kodymová and Vejnar (1974), who also proved a constant presence of uraninite among the opaque accessory minerals. The basic association of accessory minerals formed by apatite, zircon and allanite corresponds to associations typical for metaluminous granitoids (Bea, 1996).

The quantitative composition of the Blatná–type granitoids corresponds, in accordance with the IUGS classification, to hornblende–biotite to biotite monzogranite to granodiorite with some analyses plotting in the quartz monzonite field. Results of 59 point counter analyses in total were takes from the papers of Steinocher (1958, 1959, 1961, 1963), Vejnar (1955, 1973), Dudek and Fediuk (1960), Špaček et al. (1976), Knotek and Lang (1985), Tonika et al., (1980 a,b) and Votřel et al. (1989) (Fig. 2). More mafic variants occur particularly at the boundary with the Červená type or in north area near Příbram (Hudčice, Milín). Among all 59 analyses, amphibole was present only in 31 samples. The quartz content oscillates between 17 and 33 %, content of K–feldspar is 5 – 40 % and plagioclase content is 33 – 49 %. The content of biotite oscillates between 6 and 23 %, averaging 13 %.

4. Geochemistry

In total 46 analyses of major elements were take from published and unpublished papers (Vejnar, 1973; Tonika et al., 1980 a, b; Melín, 1988; Vlašímský, 1985; Machart, 1991) by the author of the presented work. They have been complemented by further 23 newly made analyses (analyst J. Adam, Faculty of Science, Charles University) (Tab. 1). In the diagram by Maniar and Piccoli (1989) dividing granitoids into metaluminous and peraluminous types, the Blatná–type monzogranites and granodiorites plot at the boundary of both these types, with a slight preponderance of analyses plotting in the peraluminous group (Fig. 3). In the di-

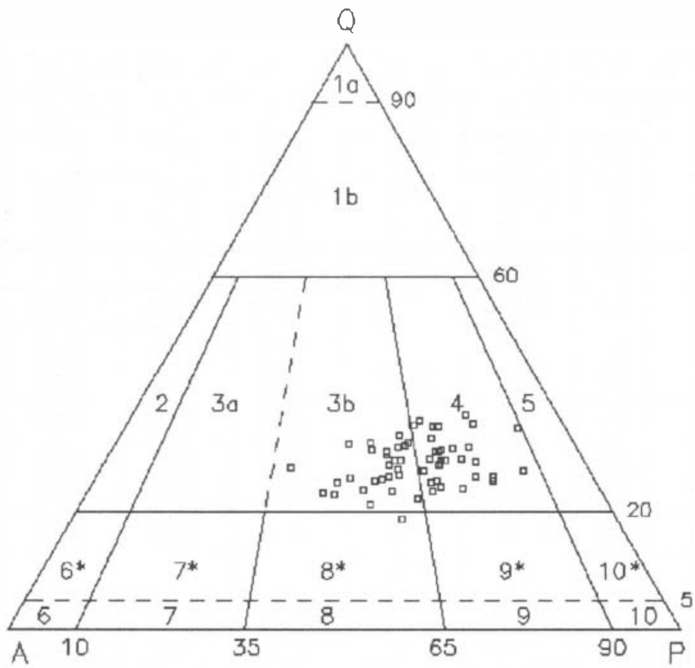

FIG. 2. Modal composition of the Blatná type

agram by Batchelor and Bowden (1985) the granitoids of the Blatná type are at the boundary of pre-plate collision granites and of the post-collision uplift field. In the K_2O vs. SiO_2 diagram the Blatná-type granodiorites are at the boundary of high-potassium calc-alkaline and shoshonitic magmas. The elevated K_2O proportion and the K_2O vs. Na_2O ratio with predominating K_2O (1.26) describe best the Blatná type and assign it rightly to the high-potassium magma suite of the Central Bohemian Pluton. By their average A/CKN value (alumina saturation index, expressed as a molar ratio of $Al_2O_3/(Na_2O + K_2O + CaO)$ of 1.04, the monzogranites and granodiorites of Blatná type belong to I-type granites.

The trace element contents were determined by standard X-ray fluorescence spectrometry (analysed in the Geologický průzkum, Co. Ostrava, Brno laboratories). Besides the analyses of samples collected by the author of this paper, also analyses from the paper of Melín (1988) were used. The U and Th distribution was evaluated based on gamma spectrometric analyses carried out on a multi-channel gamma spectrometer of Geofyzika Brno Co. The Blatná-type monzogranites and granodiorites belong to the poorly differentiated granites in the Rb–Ba–Sr diagram. In the discrimination diagram by Pearce et al. (1984) the granitoids of the Blatná type lie in the volcanic arc granites field near the boundary with the syn-collision granites and the within-plate granites. The Rb–Sr diagram shows a very homogeneous composition of the Blatná-type granodiorites without any conspicuous differentiation. A more marked differentiation is visible on the Zr–TiO_2 diagram (Fig. 4), or on Harker's diagrams of interdependence of the individual components

TABLE 1. Representative analyses of the Blatná type (wt. %)

Sample	Re–704	Re–709	Re–713	Re–799	Re–803	Re–854	Re–866
SiO_2	69.52	68.87	68.96	70.37	68.37	62.90	62.52
TiO_2	0.60	0.58	0.60	0.37	0.42	0.72	0.74
Al_2O_3	15.66	15.63	15.85	14.27	15.01	16.05	16.23
Fe_2O_3	0.01	0.44	0.57	2.57	0.56	0.96	1.29
FeO	2.08	1.80	1.73	1.94	2.17	3.73	3.45
MnO	0.04	0.045	0.045	0.044	0.056	0.073	0.073
MgO	1.27	1.19	1.12	1.06	1.42	2.83	2.65
CaO	1.98	2.36	2.06	2.16	2.40	3.51	3.53
Na_2O	3.26	3.58	3.41	3.26	3.48	3.25	3.34
K_2O	4.20	3.98	3.89	4.42	4.39	4.09	3.92
H_2O^+	0.83	0.81	0.90	0.31	0.48	0.74	0.94
P_2O_5	0.30	0.36	0.29	0.14	0.15	0.26	0.28
CO_2	0.14	0.12	0.15				
Total	99.82	99.765	99.575	100.91	98.906	99.113	98.963
Rb ppm	161	146	166	123	133	107	94
Ba ppm	1165	1144	1044	838	961	1485	1488
Sr ppm	410	453	383	261	279	347	389
Zr ppm	144	141	135	147	158	186	195
U ppm	9.4	8.2	14.3	13.3	14.5	4.6	8.6
Th ppm	17.7	20.1	23.6	23.5	32.7	19.2	10.8

Re–704 – borehole Na–15, 71.80 m; Re–709 – borehole Na–16, 97.00 m;
Re–713 – borehole Na–18, 59.20 m; Re–799 – borehole Mi–1, 762.00 m;
Re–803 – borehole Mi–1, 964.00 m; Re–854 – Velký Bor, excavation for gas piping;
Re–866 – Zavlekov, natural outcrop in the village.

in relation to silica content. According to the behavior of typical metaluminous granites, the P_2O_5, Zr, and Ba content decrease with the increasing silica content (Fig. 5). The decrease in content of these elements is attributable to the preferential crystallization of apatite, zircon and plagioclases at the outset of cooling of the parental magma. The behavior of Th, whose content increases with increasing silica content and decreases with the increasing Zr content, is significant. Its behavior distinguishes these granitoids from the typical metaluminous granites and may be due to the preferential association of thorium either with allanite or with the accessory uraninite, which probably crystallized at the end of cooling of the melt. The bond of thorium to uraninite is obvious from a marked correlation between the U and Th contents (Fig. 6) and from a positive correlation between the Pb and Th contents. The Pb content does not depend on the Ba and Sr contents, which shows that lead is not associated with plagioclases, but above all with uraninite. A major

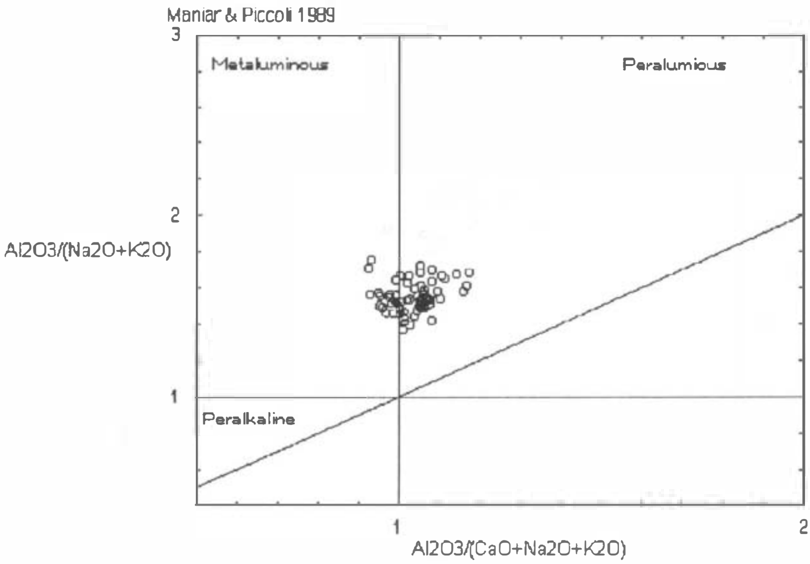

FIG. 3. Diagram of the Shand index for the Blatná type

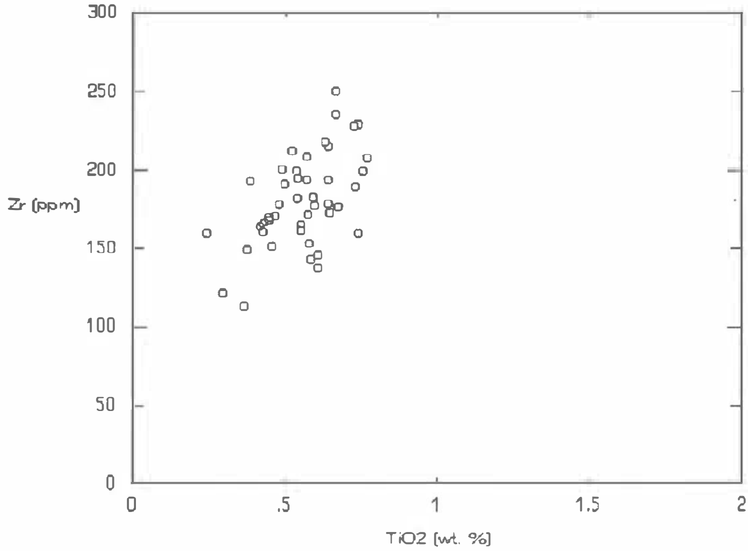

FIG. 4. Variation diagram of TiO_2 and Zr for the Blatná type

role of allanite fractionation during differentiation of the magma that produced the Blatná–type granitoids is also obvious from a positive correlation between La and Th contents.

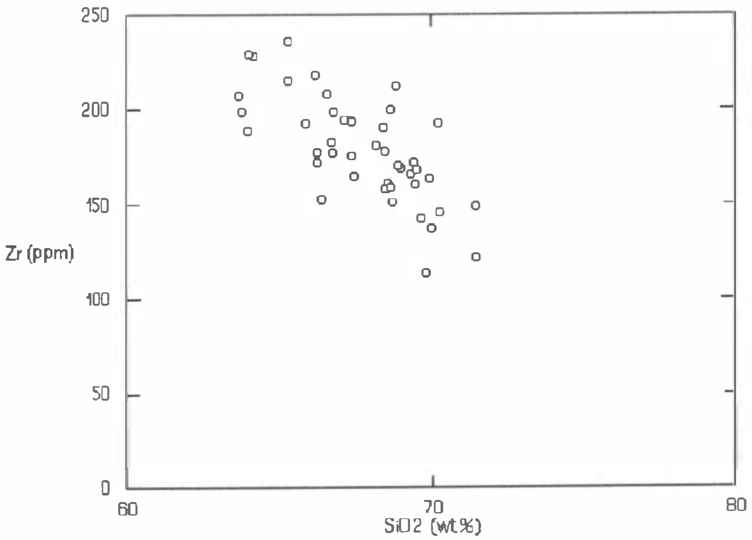

FIG. 5. Harker's diagram of SiO_2 and Zr for the Blatná type

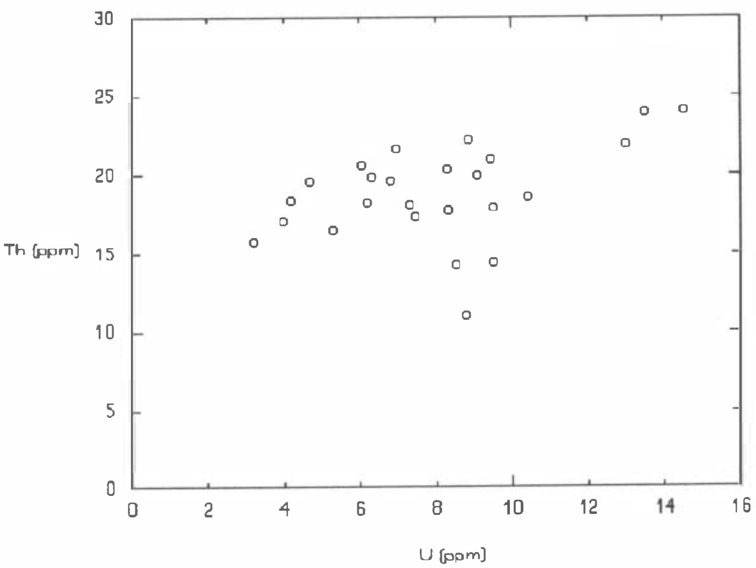

FIG. 6. Variation diagram of U and Th for the Blatná type

5. DISCUSSION

The Blatná–type monzogranites and granodiorites represent an important and independent magma suite of the Central Bohemian Pluton, which in its temporal relation and chemical composition, is situated between the older calc–alkaline Sázava–type granodiorites and the younger ultra–potassium mantle–derived differentiates of the Čertovo břemeno type. These granodiorites are by their alumina saturation index (A/CKN) usually assigned to I–type granites. Geochemical evolution of I–type granites is interpreted on the restite–model basis or on the magma–mixing model basis. Isotopic data based on the discussion of the primary Rb/Sr ratio and on the Nd–isotope evolution studies (Janoušek et al., 1995) show the magma–mixing model being more acceptable for the evolution of the Blatná–type granitoids. According to the granitoid classifications used today, it is more plausible to denominate the Blatná–type monzogranites and granodiorites as hybrid H–granites in the sense of the Castro et al. (1991) classification. These authors subdivide the H–granites into further sub–groups. Their subdivision assigns the Blatná–type granodiorites to the sub–group of H_S–granites to H_{SS}–granites, i.e. quite typical hybrid granites in the sense of the classification proposed by Castro et al. (1991).

The appurtenance to the typical metaluminous granites in the sense of Shand's classification is rather based on the heavy mineral association and not on the alumina saturation index values. According to Bea (1996), the allanite, sphene and apatite association is indeed characteristic for metaluminous granites. On the other hand, significant content of zircon and the presence of uraninite in trace contents argue for peraluminous character. Appurtenance to peraluminous associations is, nevertheless excluded, due to monazite absence.

The discussions about the genesis of the composite magmatic body of the Central Bohemian Pluton are usually based on three models. The original model of Orlov (1937), elaborated on later by Steinocher (1969), was based on classical models of granitoid magma differentiation. Palivcová (1965) revised the original magmatic model according to the classical transformist theories of genesis of the Central Bohemian Pluton through metamorphic mobilization of rocks of the Moldanubian zone. Later, Palivcová-Waldhausrová and Ledvinková (1989) and Vlašímský et al. (1992) put forward a theory of isochemical granitization of older volcanics and metasediments of Paleozoic and Proterozoic ages of the Bohemicum and the Jílové Belt and metamorphic rocks of the Moldanubian Zone. The Blatná–type granodiorites, according to this theory, were thought to be generated by granitization of metamorhic rocks of the Jílové Belt and the Moldanubian Zone. These theories, nevertheless, disregard many important geological observations, such as sharp contacts, presence of various xenoliths, homogeneity of large intrusions, many of distinctive generations of dyke rocks, presence of aureoles of contact metamorphosis in the surrounding rock series, etc. It is the homogeneity of the Blatná–type granodiorites and the occurrence of different textural varieties that argue against the metamorphic mobilization and granitization models.

Another problem related to the genesis of the Central Bohemian Pluton as a whole is the mechanism of its emplacement into the Bohemicum and Moldanubian Zone rock units. Geophysical and structural studies suggest that the granitoids of the Central Bohemian Pluton filled a ductile Central Bohemian NE–SW trending shear zone that represents a first-order tectonic element in the Bohemian Massif (Rajlich, 1988). According to Rossi and Cocherie (1995), this shear zone is a part of the European mega-shear zone that formed the southern margin of the Variscan orogen and influenced the Gondwana paleocontinent after the crustal collision process. Intrusion of the Central Bohemian Pluton was probably associated with a rapid uplift and decompression of the surrounding metamorphic rocks and produced a wide front in which both the mixing and granitization processes could locally take place. E–W trending tensional fractures infilled by younger rock dykes were generated after cooling of the Blatná–type granodiorites due to the altered pressure regime. The hybrid granites model, which is accepted as the most plausible one in the other regions of the Hercynian orogen (Castro et al., 1991), can also be applied to the Blatná–type monzogranites and granodiorites. The hybrid character of rocks of the Central Bohemian Pluton was already postulated by Palivcová (1965).

6. Conclusion

Monzogranites and granodiorites of the Blatná–type represent an independent suite of high–potassium up to shoshonitic magmatites occurring within the Central Bohemian Pluton. By their age they belong to the group of Early Carboniferous Variscan magmatites of the Bohemian Massif. Based on their mineral and chemical composition they can best be assigned to the group of hybrid granites in the sense of Castro et al. (1991). They are characterized by their position on the boundary of metaluminous and peraluminous granites. The most plausible model for their genesis is that of mixing of mantle–derived high–potassium magmas with metavolcanics and metasediments of the upper crust. This concept has been confirmed by the results of isotopic investigation of Janoušek et al. (1995) and by the results of complex studies of Holub et al. (1995, 1997). Based on the evolution in distribution of the individual components, the ideas of genesis of the Blatná–type granitoids and of the Central Bohemian Pluton as a whole, through metamorphic mobilization and in situ granitization must be regarded as less plausible.

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