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STRONTIUM ISOTOPE MODEL OF FORMATION OF BLATNÁ GRANODIORITE

(4 Figs., 2 Tabs.)

Abstract: The Blatná granodiorite is the second most abundant rock type of Central Bohemian pluton. It belongs to the tonalite group. Rb-Sr isochrone was constructed from granodiorite and mixed aplopegmatite-granodiorite whole rock samples.
The age of final Sr isotopic homogenisation results in 331 ± 9 Ma and initial ratio is 0.7072 ± 0.0015.
Solidification temperature of the granodiorite (Whitney — Stormer, 1977) is 550 ± 50 °C and that of the applopegmatite is 460 ± ± 50 °C respectively.
Average Sr concentration in granodiorite is 331 ppm, that of Rb is 186. The ratios are 170 for K/Rb and 14 for Sr. 10^3/Ca. REE patterns reveal crustal component overprint.
Mass balance calculations based on Sr isotopes, its concentration and on the overall geochemistry of the pluton and of the country rock show that magma might have been generated as a mixture of about 30—50 % of mantle and of 50—70 % upper crust materials respectively.
Certain part of mantle component had been brought to the region at the form of volcanics.
The precursors of crustal component might have been represented by recycled former volcanosedimentary material with complex crustal history.

Резюме: Блатенский гранодиорит является вторым наиболее распространенным типом пород Среднечешского плутона. Методом Rb-Sr изохроны валовой пробы породы было установлено, что завершение изотопической гомогенизации Sr в пробах гранодиорита и гранодиорит-аплопегматита произошло 331 ± 9 миллионов лет тому назад ($\lambda = 1{,}42 \cdot 10^{-11} \cdot$ год$^{-1}$). Первичное отношение $(^{87}Sr/^{86}Sr)_0$ было определено равным 0,7072 ± 0,0015. Температура кристаллизации гранодиорита по данным Уитни и Стормера (Whitney — Stormer, 1977) находилась в пределах 550 ± 50 °C (0,2 GPa) или 600 ± 50 °C (0,66 GPa), температура аплопегматита 460 ± 50 °C. Блатенский гранодиорит не образовался непосредственно из магмы, возникшей из земной мантии, или, в результате ее дифференциации. Его образование не связано ни с простым переплавлением и дифференциацией верхнекорового материала. На основе массового баланса изотопов Sr, геохимии плутона и вмещающих метаморфических пород Молданубикума сделан вывод, что магма блатенского гранодиорита состояла из смеси около 30—50 % материала, происходящего из земной мантии и 50—70 % материала верхнекорового происхождения. Часть материала из земной мантии находилась в данной области еще до интрузии в виде вулканитов. Метаморфические породы Молданубикума, которые вошли в состав блатенского гранодиогита, представляют вулканоосадочные породы корового происхождения после рециклования.

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Introduction

Age and genesis of magmatic bodies can be studied by Rb-Sr method. This aproach can reveal new knowledge as deduced from Sr isotope data. Due to this method some geological hypotheses can be confirmed while the other ones ruled out.

Physical chemical principle of Rb-Sr method is time defined spontaneous decay of parent ^{87}Rb to daughter ^{87}Sr. The method utilizes different geochemical behaviors of Rb and Sr during geological and geochemical processes.

Practical application of the method in a Czechoslovak laboratory has been restrained by extreme experimental difficulties and required expansive instrumentation as solid ion source mass spectrometer is.

Crucial and the most difficult parts of Rb-Sr geochronological method is avoiding contamination of the system during the period of the time since sampling to final mass spectrometer runs.

Blatná granodiorite was chosen as an example for Rb-Sr study of magmatic bodies. It forms an important part of Central Bohemian pluton. Blatná granodiorite was studied from geochronological point of view by Van Breemen et al. (1982) recently.

Geological and petrological description

Blatná granodiorite is the second most abundant rock type of Central Bohemian pluton (Kodym — Suk, 1960). The Fig. 1 shows schematically the pluton that intruded in the region of Central Bohemian deep fault. Blatná granodiorite is marked in Fig. 1.

On its NW margin the pluton brought up thermal contact metamorphism that resulted in the appearance of spotted shales and hornfels.

On its SE margin banded migmatites and flaser-gneisses originated in the country rocks of Moldanubicum.

The pluton with its area of 3200 square km is petrologically very diverse body. Textural, structural and material inhomogeneities, foliation structures as well as abundant schliers and inclusions are its typical features. The main rock types are represented by hornblende biotite granodiorites and tonalites. Among other rock types pyroxene gabbros, diorites, quartz diorites, granites, syenites and monzodiorites can be found. Gabbros and diorites are confined to small bodies. Those small bodies are metasomatically changed and recrystallized volcanic rocks (Hanuš — Palivcová, 1968, 1969) or older differentiation products of the pluton according to other authors. In the frame of the pluton Blatná granodiorite is relatively homogeneous.

Blatná granodiorite is equigranular biotite granodiorite with subsidiary hornblende. Plagioclase is zoned with andesine cores and oligoclase rims. Zircon, titanite, magnetite, pyrite, pyrrhotite, epidote and orthite occure as accessories.

Inclusions are formed by biotite hornblende quartz diorites and granodiorites with basic andesine in the cores and acid andesine at the rims. Furthermore fragments of biotite paragneisses to migmatites are present as inclusions.

Aplite to pegmatite veins are frequently encountered. Their thickness varies from 1 to 50 cm. They constitute 2 % of granodiorite profile in the Blatná dis-

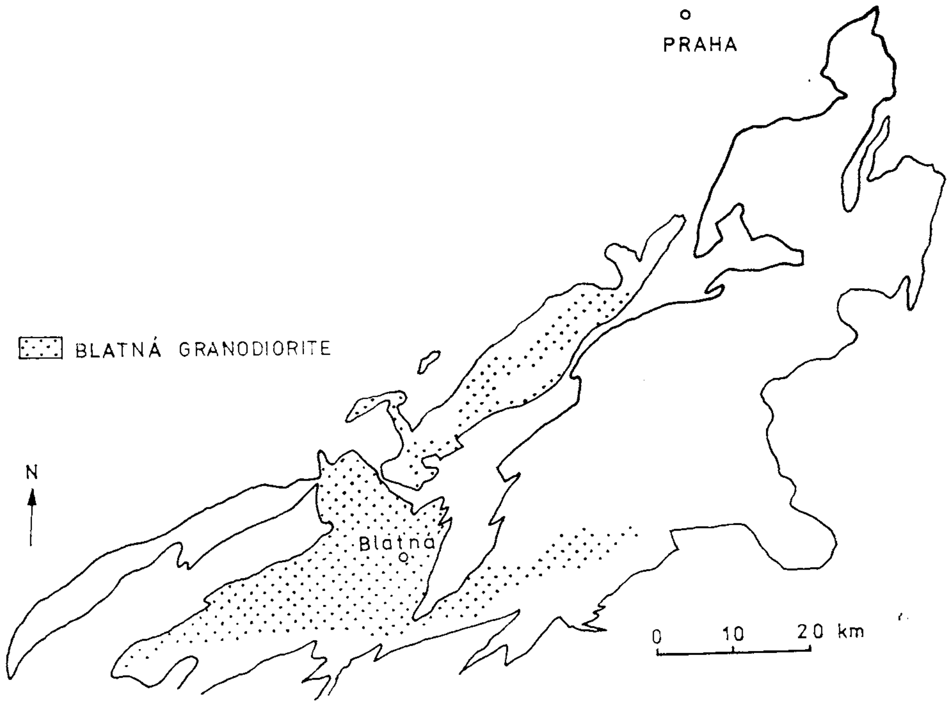

Fig. 1. Occurrence of the Blatná granodiorite in frame of the Central Bohemian pluton.

trict. Porphyry, porphyrite and lamprophyre veins exhibit greater thickness constituing 2 % of the profile too. Regular fracturing bears witness to solidification under calm circumstances (D u d e k — F e d i u k, 1960).

Sampling and crushing techniques

Samples were taken from Řečice quarry 2 km W of Blatná. Weights of six compact isometric rock samples ranges between 25 to 30 kg. Small rock fragments for thin sections were cut off from marginal parts of the big blocks. Samples were cleaned and closed tightly. For breaking the samples specially cleaned devices were employed. During this procedure great care was taken to keep the system closed in respect to Rb and Sr. Crushing and homogenisation were also performed under the conditions of closed system. Final aliquotes of rock debris weighted about 2.5 kg. Grinding of this amount was done gradually per parts in steel-tungsten vibrating mortar. Powders were weighted repeatedly and weights evaluated with wetness taken into account. Powders were stored in hermetically sealed envelopes.

Analytical procedures

Samples were studied by optical microscope and electron microprobe.

Sr chemistry was made in ultraclean laboratory. Acids were purified by subboiling destilation. Sr was separated in quartz columns filled with cation exchange resin.

Strontium was run on MI 1201 mass spectrometer in Geological Survey Prague using Re double filament technique as described in Bendl — Vokurka (1987). Measured $^{87}Sr/^{86}Sr$ ratios were corrected for fractionation by normalisation assuming $^{86}Sr/^{88}Sr$ ratio to be 0.1194.

$^{87}Rb/^{86}Sr$ ratios were determined by XRF technique following the method of Panckhurst — O'Nions (1973). Rb and Sr concentrations were determined by XRF. Measuring and data evaluating approach applied is similar to that of Verdurmen et al. (1979).

Results and discussion

Determined concentrations of Rb and Sr together with isotope ratios $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ are summarised in Tab. 1.

Table 1

Blatná granodiorite and granodiorite — aplopegmatite from Řečice quarry

Sample	Rb ppm	Sr ppm	$^{87}Sr/^{86}Sr$ mol/mol	$^{87}Rb/^{86}Sr$ mol/mol
1	247	79	0.7504 ± 0.0009	9.059 ± 0.061
2	236	146	0.7288 ± 0.0019	4.679 ± 0.041
3	190	352	0.7168 ± 0.0006	1.567 ± 0.023
B 4	218	164	0.7235 ± 0.0010	3.828 ± 0.014
5	185	185	0.7199 ± 0.0008	2.894 ± 0.032
B 7	257	71.5	0.7565 ± 0.0010	10.410 ± 0.100

The isochrone was constructed from the data given in Tab. 1 and is plotted in Fig. 2. Resulting last homogenisation of Sr isotopes in whole rock samples and closure of Rb-Sr systems were found to amount to 331 ± 9 Ma ago. Initial isotope ratio $(^{87}Sr/^{86}Sr)_0$ equals to 0.7072 ± 0.0015. The decay contact λ $^{87}Rb = 1.42.10^{-11}.y^{-1}$ (Steiger — Jager, 1977) was used in the course of age calculation. The $(^{87}Sr/^{86}Sr)_0$ initial ratio of Blatná granodiorite is similar to that of large volume Phanerozoic North American batholithes with their typical Sr isotope initial ratio of 0.707 ± 0.001.

Solidification temperature was estimated based on distribution of albite component between coexisting K-feldspar and plagioclase according to the method of Whitney — Stormer (1977). The temperature was found to be 550 ± 50 °C for assumed pressure of 0.2 GPa or 600 ± 50 °C for 0.65 GPa respectively in the case of Blatná granodiorite. Solidification temperatures of aplopegmatite were estimated to equal to 460 ± 50 °C.

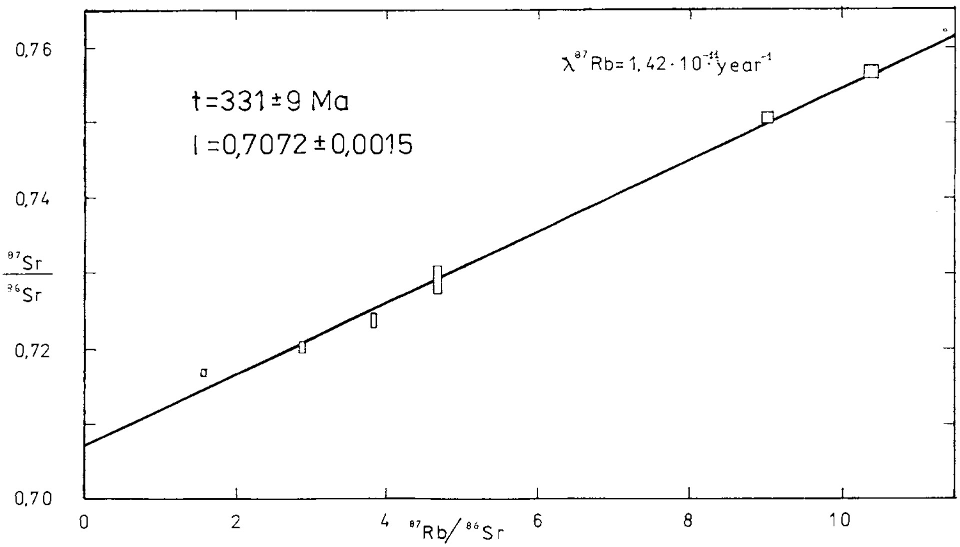

Fig. 2. Rb-Sr whole rock isochrone of Blatná granodiorite.

Sr and Rb concentrations in Blatná granodiorite from Řečice quarry (352 ppm and 190 ppm respectively) similars average concentrations of Blatná granodiorite as well as the average of Central Bohemian pluton as a whole. Average Sr contents in Blatná granodiorite is close to the typical value for continental crust. Rb concentrations approach average value of acid rocks. Rb/Sr ratio is 0.56, K/Rb is 170 and Sr.10^3/Ca is 14 in Blatná granodiorite.

Sr isotope model of magma genesis

REE patterns in various locations including that one where the isochrone was constructed show inevitable presence of crustal component in the granodiorite. Never the less presence of Earth's mantle derived component can not be excluded based purely on REE patterns.

An attempt was made to construct the evolution scheme of $^{87}Sr/^{86}Sr$ ratio for Moldanubian crystalline rocks.

Based on literary data (Zoubek et al., 1979; Gorokhov et al., 1979, 1983; Van Breemen et al., 1982; Gebauer — Grünenfelder, 1973; Grauert et al., 1974; Köhler — Müller-Sohnius, 1985) $^{87}Sr/^{86}Sr$ ratio of selected Moldanubian metamorphic rocks was estimated to equal to 0.7167 at the time of 331 Ma ago. $^{87}Rb/^{86}Sr$ ratio was found to be 3.43. Average Rb and Sr concentrations were determined to equal to 146 and 155 ppm respectively.

Sr isotope evolution of Moldanubian metamorphic rocks is not contradiction to Sr isotope initial ratios of most of European metamorphic Variscan rocks as reported by Dornsiepen (1979).

Simple mass balance calculations taking into account Sr concentrations and its isotopic composition were performed. Parental magma of Blatná granodiorite was supposed to have originated as a two component mixture. Crystalline rocks of Moldanubicum were chosen as the first component. Using the evolution scheme (Fig. 3) Sr isotope composition for Moldanubian rocks could have been estimated at the time of 331 Ma ago. Weighted average concentrations of Sr in Moldanubian metamorphic rocks were taken as representative values. Mantle derived basaltic melts were selected as representatives of the second component. Silurian basalt (Loděnice—Bubovice) from Barrandian basin studied for Sr isotopic composition (sample n. 1 in Vokurka — Kober, 1988) was used

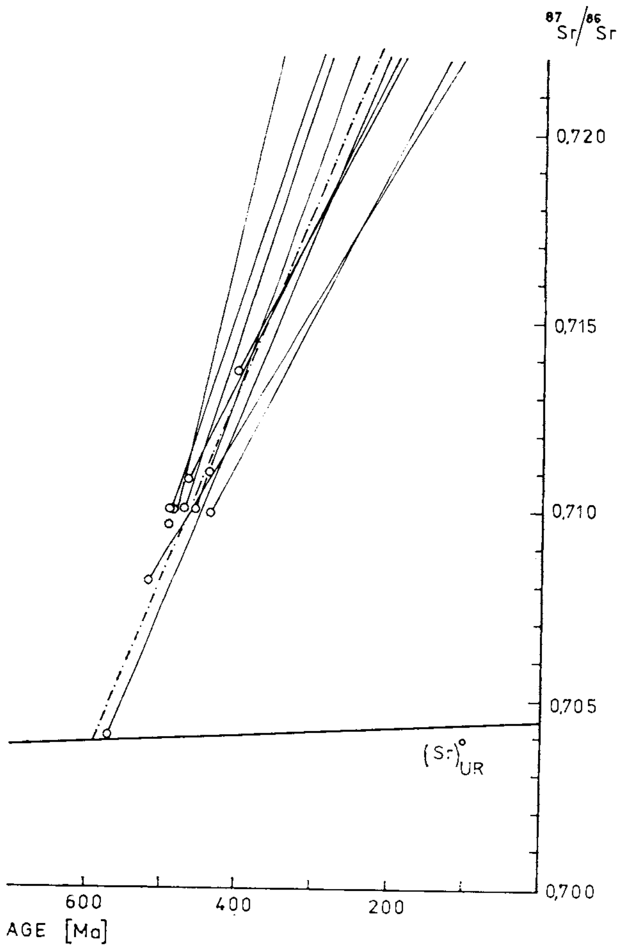

Fig. 3. Sr isotope evaluation of selected Moldanubian crystalline rocks based on literary data. List of literature used is given in the text.

in the course of calculation as the source of Sr isotope composition and Sr concentration data, Sr data for Blatná granodiorite were taken from Tab. 1 and Fig. 1 in this paper.

Proposed system of equations is given in Tab. 2.

Table 2

System of equations describing mass balance of strontium isotopes

$$\left(\frac{^{87}Sr}{^{86}Sr}\right)_b .a. /Sr/_b = \left(\frac{^{87}Sr}{^{86}Sr}\right)_m .a. /Sr/_m.X_m + \tag{1}$$

$$+ \left(\frac{^{87}Sr}{^{86}Sr}\right) .a.X_p . /Sr/$$

$$X_m + X_p = 1 \tag{2}$$

$$/Sr/_b = /Sr/_m . X_m + /Sr/_p . X_p \tag{3}$$

Where X is a mass fraction of a component, b — indicates Blatná granodiorite, m — indicates Moldanubian metamorphic rocks, p — indicates mantle derived material, a — is relative abundance of ^{87}Sr isotope in bulk Sr, /Sr/ is strontium concentration,

$\left(\frac{^{87}Sr}{^{86}Sr}\right)$ is strontium isotopic ratio.

Conclusion

The emplacement of Blatná granodiorite was accomplished 331 ± 9 Ma ago ($\lambda = 1.42.10^{-11}.year^{-1}$). At this time the temperature decreased below the value when whole rock samples became closed systems in respect to Rb and Sr. The initial ratio $(^{87}Sr/^{86}Sr)_0$ was set to 0.7072 ± 0.0015.

Solidification temperatures calculated according to the method of Whitney and Stormer (1977) were found to be 550 ± 50 °C (0.2 GPa) or 600 ± 50 °C (0.65 GPa) respectively. These estimates are based on areal distribution of albite component. According to the discrete points analyses the temperature was shown to range between 400 to 450 °C in the case of granodiorite and 460 ± ± 50 °C in the case of aplopegmatite respectively.

Blatná granodiorite could have originated neither directly nor by the means of differentiation from uncontaminated mantle derived magma. Furthermore its origin can not be explained purely by remelting or differentiation of upper crust material.

The parental magma might have originated as a mixture of 30 to 50 % of Earth's mantle derived material and 50 to 70 % of upper crust material.

At least a part of Earth's mantle component presumably had existed in the form of volcanics in the region prior to the intrusion (Fig. 4).

Metamorphic rocks of Moldanubicum having been incorporated into parental magma of Blatná granodiorite are likely to represent recycled rocks with crustal prehistory.

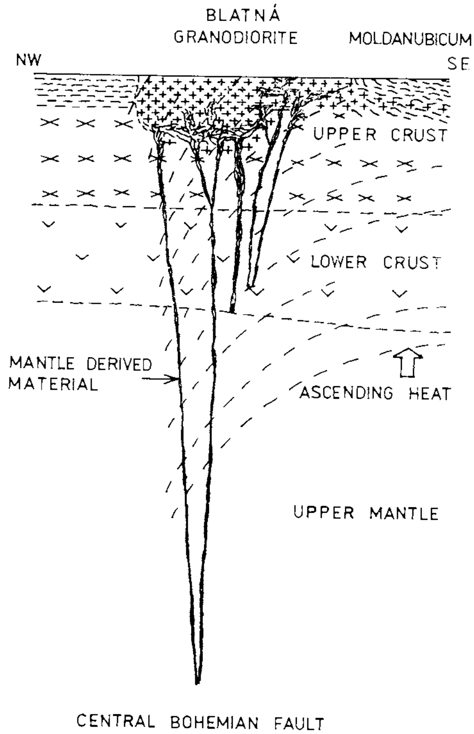

Fig. 4. Model of the origin of Blatná granodiorite.

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