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THE HORNBLENDE-BIOTITE GRANITE FROM STRZEGOM-SOBÓTKA
MASSIF – PARENTAL MAGMA EVOLUTION

Abstract: Parental melt evolution leading to hornblende-biotite granite formation has been reconstructed. Field evidence argues for assimilation-fractional crystallization (AFC) as a process taking control on melt evolution. Although in the granitic rocks numerous mafic-like enclaves have been found, the composition of granitic parental melt seems not to be much influenced by mafic components. The main process responsible for magma evolution is fractional crystallization (FC). Cumulate composition has been calculated and the degree of FC has been evaluated. The results are consistent with both field observations and geochemical trends.

Keywords: major elements, trace elements, fractional crystallization, mixing, hornblende-biotite granite, Strzegom-Sobótka massif, Sudetes

INTRODUCTION

The Variscan granitoid massif Strzegom-Sobótka (Fore-Sudetic Block, NE Bohemian Massif) consists of many small plutons with different modal compositions: hornblende-biotite granite, biotite granite, two-mica granite and biotite granodiorite. The plutons also display distinct geochemical and isotopic features, which could point to different origin of parental melt as well as different path of the melt evolution. The aim of this paper is to show the model of parental magma evolution of the hornblende-biotite granite from the western part of Strzegom-Sobótka massif.

Field investigations, mineral textures and bulk rock geochemistry give evidence for magma mixing in the hornblende-biotite granite. The granite varieties contain numerous mafic enclaves. Most of them show doubtless hybridization symptoms. Basing on these observations we created mixing model for hornblende-biotite granite evolution (Domańska, Słaby 2003). The model confirmed hybridization of mafic-like magma blobs by granitic melt. It also demonstrated that the mafic and silicate melts interaction was limited, as some of the elements (e.g. potassium) exhibited inconsistency. The evolution of granitic parental melt itself was thus not much influenced by mixing. The aim of the present research work is recognition of

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the main petrogenetic mechanism responsible for granitic parental magma evolution.

GEOCHEMICAL MODELLING

Major elements have been estimated by means of XRF method in twenty one samples of hornblende – biotite granite. Sixteen most representative granitoid samples have been analyzed for trace elements using ICP-MS method.

Liquid line of descent (Richardson 1989; Martin 2002) has been constructed to receive preliminary information on the type of the process, which influenced the melt generation and evolution. Almost all major (e.g. Al₂O₃, Fe₂O₃, CaO, MgO) and trace elements (e.g. Nb, Sr, Y, La) define good linear trends over whole silica range (68,74 – 75,30 wt. %). Potassium, barium and rubidium behave like incompatible elements during magma evolution. The other show well defined decreasing trends. Basing on the contrasted behavior of trace elements during melting and crystallization, the process responsible for granite differentiation trends has been recognized. The more compatible (Ni, Cr) and incompatible (Ba, Rb) elements have been chosen and plotted on Log(compatible element) versus Log(incompatible element) diagram (Fig. 1). The elements show sub-vertical trend indicating fractional crystallization.

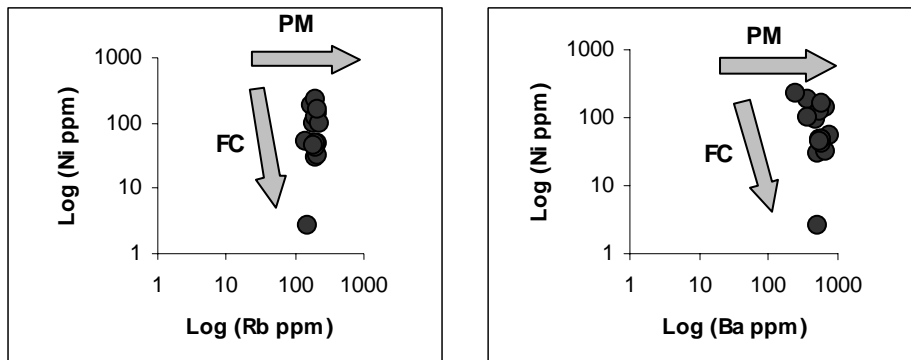


Fig. 1. Recognition of melt differentiation process. FC – fractional crystallization; PM – partial melting.

Using the mass balance calculation for the major elements ($C_o = F \cdot C_1 + (1-F) \cdot C_s$, where C_o is initial liquid; C_1 is differentiated liquid; C_s is cumulate and $1-F$ is the degree of FC) we calculated the model by adjusting the relative proportions of minerals entering the melt to reproduce the composition of expected melt. The most differentiated sample – 067 from Zimnik, has been taken for the composition of the most differentiated liquid C_1 , whereas the less differentiated sample – 066, also from Zimnik, has been chosen for the initial liquid composition C_o . The results are shown in Table 1.

Table 1. Results of geochemical modelling.

Wt.%	Mineral compositions of calculated cumulate Cs								
	Co	Cl	Cs	plg An 30	biotite	amphibole	magnetite	ilmenite	apatite
SiO ₂	69.02	75.62	44.10	60.82	36.11	45.56	0.00	0.00	0.09
TiO ₂	0.60	0.14	2.40	0.00	1.80	1.17	0.00	52.70	0.00
Al ₂ O ₃	14.30	13.29	18.20	24.66	17.74	13.98	0.00	0.00	0.00
Fe ₂ O ₃	5.39	1.49	20.19	0.00	23.95	4.43	100.00	44.63	0.23
MnO	0.10	0.04	0.08	0.00	0.34	0.00	0.00	0.61	0.10
MgO	0.63	0.19	2.35	0.00	8.64	20.29	0.00	1.78	0.02
CaO	1.91	1.05	5.18	6.19	0.70	11.95	0.00	0.23	56.15
Na ₂ O	3.87	3.53	5.00	8.08	0.49	2.48	0.00	0.00	0.11
K ₂ O	4.04	4.61	1.82	0.25	10.13	0.13	0.00	0.05	0.00
P ₂ O ₅	0.15	0.04	0.68	0.00	0.10	0.00	0.00	0.00	43.30

Modal compositions of calculated cumulate Cs						
Cs	59.57 %	16.43 %	4.25 %	14.32 %	3.9 %	1.53 %

Degree of fractional crystallization (1-F) = 20.89 %

R² = 0.005

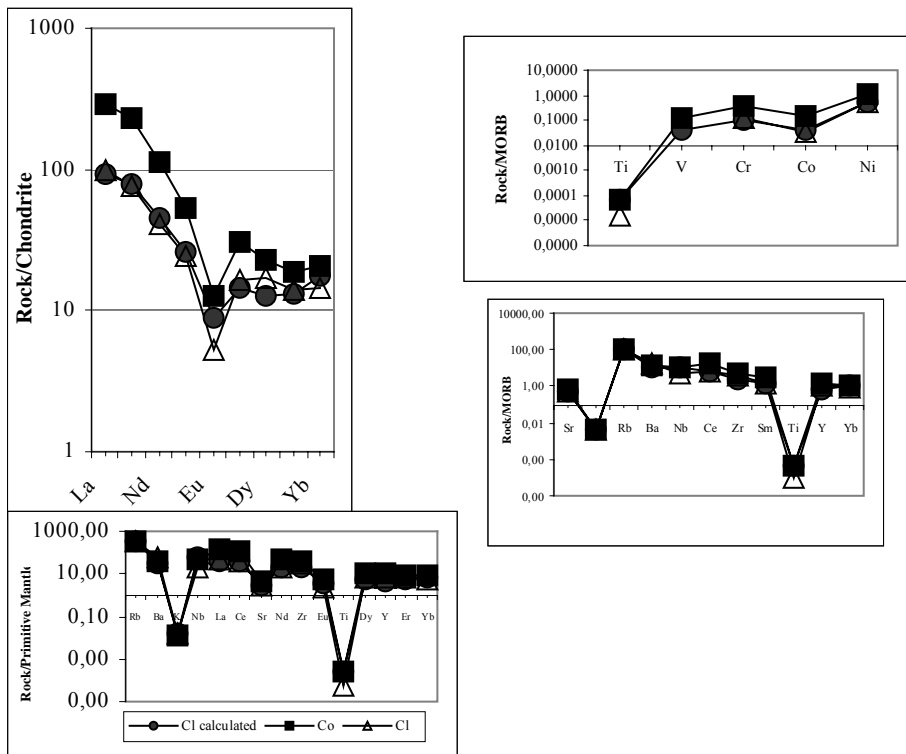


Fig. 2. Results of trace elements geochemical modelling.

Next, using degree of fractional crystallization and cumulate composition estimated from the major element modelling, we calculated the trace elements composition of melt. The partition coefficients $K_D^{\text{min/liq}}$ were taken from references (Martin 1985; Rollinson 1993). The effect of accessory minerals on the melt evolution has been estimated. The best fit was obtained by adding 2% of apatite, 0,02 % of zircon, 0,045 % of monazite and 0,005 % of allanite. The patterns fit excellent except for some HREE (fig. 2).

CONCLUSIONS

The calculated FC model seems to be reliable. The quality of the model is measured using the sum of the squares R^2 of the differences between calculated melt and expected liquid for each element. The model is reliable when $R^2 < 10$, and good if $R^2 < 1$ (Martin 1985). The value obtained in the presented model is 0.005.

The composition of cumulate fractionated from parental melt is: plagioclase (oligoclase), biotite, amphibole, magnetite, ilmenite and apatite, zircon, monazite, allanite. The calculated degree of FC equals 20,89 %. In the cumulate composition alkali feldspars are absent. Indeed, the K-feldspars are not fractionated during melt differentiation. Potassium displays increasing trend on *LLD*.

Using the cumulate composition and analysing the major and trace element behaviour along *LLD* we can conclude, that the model is fully consistent with FC. Fractional crystallization can be considered as the major process accounting for most of the geochemical features of the hornblende-biotite granite. Mixing in granitic parental melt appears to be subordinate, having negligible influence on the melt evolution process.

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