BIMODAL VOLCANIC FORMATION OF THE WIBORG BATHOLITH ON THE ISLAND OF HOGLAND (SUURSAARI), RUSSIA

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The island of Hogland is situated in the eastern part of the Gulf of Finland near the southern margin of the Wiborg rapakivi granite batholith. Granitoids, basites, supracrustal rocks of Svecofennian age and anorogenic volcanic bimodal rocks are exposed on the island. Subhorizontal, up to 110-m-thick volcanic strata overlie the Svecofennian rocks. The lower part of the volcanic formation comprises a 20-m-thick sequence at porphyritic basalts (with occasional pillow structures) and quartz-rich conglomerate. Layers of silica-rich sheets occur somewhere among basalt lava flows. These rocks are over-covered by a thick unit of granite porphyries and quartz porphyries.

U-Pb dating of zircons from the granite porphyries of the volcanic succession gave upper intercept age 1638±4 Ma. This age is close to that of rapakivi granites and diabase dykes of Wiborg and Suomenniemi batholiths. Granite porphyries of Hogland have an initial ε_{Nd} value of —1 which is also typical for rocks of Wiborg batholith.

The granite porphyries of Hogland are similar to the ovoid-bearing amphibole rapakivi granites of Wiborg batholith in terms of their overall chemical composition. They show, however, higher K_2O contents (6-8.3%) and lower Na_2O contents (0.2-1*%),* and their K_2O-Na_2O ratio varies from 6 to 20, whereas rapakivi granites usually have K_2O -Na_2O ratios close to 2.

Comparison of petrochemical and geochemical data indicate that the porphyritic basalts are similar to the gabbroids of the Wiborg and Suomenniemi batholiths, exept for their alkalic contents. The basalts of Hogland show higher K_2O contents at lower Na_2O contents. K_2O -Na_2O ratios for these rocks are very variable from 1 to 20.

REE patterns of granite porphyries of Hogland are close to those of the fayalite-and pyroxene-bearing amphibole granites of Wiborg and Suomenniemi batholiths. REE patterns of basaltic porphyrites and gabbroids of Wiborg and Suomenniemi batholiths are also similar.

New chemical, geochronological and isotope geochemical data show that granite porphyries and basalt porphyrites of Hogland belong to the bimodal gabbro-anorthosite-rapakivi granite formation of the Wiborg batholith. Differences among volcanic and plutonic rocks allow us to expect more complicated, probably multistage evolution of granite porphyries, featuring abnormal evolution of alkaline components.

The research described in this abstract was made possible in part by ISF Grant No. R1E000 and RFFI Grants No. 94-05-17033 and 95-05-15305.

AGE AND ORIGIN OF MAFIC XENOLITHS FROM RAPAKIVI GRANITES OF THE BERDIAUSH MASSIF (S. URALS, RUSSIA)

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1.35 Ga Berdiaush massif is located at the eastern margin of the East European Platform near its boundary with the Urals Paleozoic fold belt. Rapakivi granites and quartz syenites of the massif host mafic xenoliths (1-3 meters in diameter) represented in their core zones by meta-gabbronorites. Relics of gabbro-ophitic texture were observed only in core zones of the xenoliths. The outer altered zones of the xenoliths are represented by quartz syenites bearing megacrysts of ovoid-like alkali feldspar and ocelli quartz. These rocks are morphologically similar to the well-known mafic hybrid enclaves which have been reported as products of magma mixing (Eklund et al., 1993).

However, an alternative interpretation involving metasomatic origin of the megacryst-bearing hybrid zone of the enclaves has been also advocated (Belyaev et al., 1994).

U-Pb single-grain dating of six zircon samples, separated from three different zones of two mafic enclaves (including one extracted from an alkali-feldspar megacryst at the outer zone) yields upper intercept age of 1380.4 ± 2.2 (2σ) Ma. The age of 1382.1 ± 3.0 Ma was calculated for the three most concordant points. One zircon extracted from an alkali feldspar ovoid of rapakivi granite gave ~30 Ma younger concordant U-Pb age of 1353.2 ± 5.3 Ma, which is close to the previously reported U-Pb age of the massif at 1354 ± 20 Ma (Krasnobaev et al., 1984).

Estimates based on the parameters of Amph-Bt mutual mineral equilibrium and Amph-Pl (Qtz) thermobarometry show that the earliest hornblende-bearing mineral assemblages within the mafic enclaves have been equilibrated under T 1=780-820°C, P1 =5.5-7.5 kbar. These parameters seem to correspond to the beginning of alteration processes of the deep-seated mafic enclaves and are interpreted as minimum limits of the P-T conditions of their formation. The same values of P and T were obtained for relic mineral assemblages encapsulated within core zones of feldspar ovoids in the rapakivi granites. Thermobarometric data for magmatic assemblages show that rapakivi granites themselves have been emplaced at T2=780°C, P2 = 1.5-2 kbar.

Our results show that hybrid mafic enclaves from the Berdiaush rapakivi granites are ~ 30 Ma older than host granites, and therefore can not be products of mixing between basic and rapakivi granite magmas. Instead, these xenoliths represent relatively old, deep-seated igneous basic rocks, which have been partially transformed into quartz syenites as a result of high-temperature fluid alteration. We suggest that the xenoliths have been transported by the rapakivi granite magma from depths of the middle crust - lower crust boundary.

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GAS COMPOSITION OF FLUID INCLUSIONS IN QUARTZ XENOCRYSTS AS AN INDICATOR OF INTERACTION PROCESSES BETWEEN MAFIC AND RAPAKIVI GRANITE MAGMAS

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The diabase dyke comprising numerous quartz grains and alkali feldspar ovoid xenocrysts cuts ovoid-bearing rapakivi granites of Salmi massif (Karelia, Russia). Our previous study displays that the xenocrysts have become trapped in the basic melt during intrusion through crystal-rich residual rapakivi granite magma (Belyaev et al., 1994). Then the xenocryst-bearing hybrid basaltic magma was emplaced among rapakivi granites of a higher magma chamber level. The comparative study of fluid inclusion compositions was carried out for the phenocryst-like quartz grains in the ovoid-bearing granites and for the quartz xenocrysts enclosed within the diabase dyke. The gas compositions of fluid inclusions (CO_2, H_2O, CH_4 etc.) encapsulated within quartz were determined using mass-spectrometric thermal analyze during heating and decrepitation of the inclusions. The maximum temperature peaks of decrepitation are in consistence with the homogenization temperatures of the inclusions. The presence of two temperature peaks of decrepitation is typical for quartz from rapakivi granites. The first maximum at T_1=525°C corresponds to the decrepitation of primary inclusions. The temperatures of their homogenization are 490°C-540°C. Decrepitation of secondary chain-like inclusions took place at T_2=420°C. Such inclusions show homogenization temperatures between 210°C and 380°C. The primary inclusions encapsulated in quartz from rapakivi granites have the following main component ratios (mol %): H_2O/CO_2=7.6-9.5,

CO_2/CH_4=47.5-58.0. Temperatures of decrepitation varying from 570°C to 750 °C with maximum T_0=650°C were obtained for fluid inclusions encapsulated within quartz xenocrysts of the diabase dyke. Decrepitation peaks at the temperatures typical for the quartz from the rapakivi granite were also marked for some samples but usually they are absent. H_2O-CO_2 ratios at T_0 and T_1, determined for quartz xenocrysts enclosed within the diabase dyke (1.3-4.5 and 1.9-4.7, respectively), are essentially lower than those for quartz in the rapakivi granites. CH_4 is either absent or uncommon at high temperature decrepitation range close to T_0. Data presented above indicate that the quartz xenocrysts were overheated by the basic melt. As a result of the heat influx, either complete or partial natural decrepitation of the primary inclusions within quartz took place. Secondary high-temperature inclusions were formed during the cooling of the diabase dyke. Compared to the primary inclusions, the secondary high-temperature inclusions display losses of more volatile components at higher temperatures. Gas composition of fluid inclusions may be suggested as a useful indicative feature for the interaction processes between basic and felsic magmas.

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AGE, SOURCE, AND CONDITIONS OF FORMATION OF PHENOCRYST-LIKE QUARTZ AND OVOID-LIKE ALKALI FELDSPAR MEGACRYSTS IN AN ALTERED HORNFELS AT THE CONTACT AUREOL OF THE SALMI RAPA-KTVI GRANITE BATHOLITH, RUSSIAN KARELIA

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Roundish phenocryst-like quartz (0.5-2.0 cm in diameter) and ovoid-like megacrysts of alkali feldspar (1-6 cm across) occasionally mantled by a plagioclase rim occur within altered quartz-biotite-plagioclase homfels in the exocontact zone of the Salmi batholith. This homfels replaces the surrounding country rocks (PR2ld). Feldspar and quartz oikocrysts disappear further away from the contact between rapakivi granite and country rocks. Isotopic, geochemical and mineralogical studies of the different zones of the megacrysts within homfels, their plagioclase rims and matrix minerals of the altered homfels were made with the aim to determine the age and origin of these megacrysts.

Alkali feldspar megacrysts in the homfels and the outer rim zones of the alkali feldspar ovoids within the biotite-hornblende rapakivi granite have similar K, Na, Li, Rb and Ba contents. Gas - liquid proportions and homogenization temperatures of primary fluid inclusions enclosed within both quartz grains from the rapakivi granite and quartz grains extracted from the altered homfels are equal. Taken into account the formation pressure, the estimated formation temperatures of these types of quartz are between 490°C and 640°C.

Rb-Sr isotopic data for the rock forming minerals of the altered homfels groundmass gave following results: T = 1515 ± 33 Ma, I_{Sr} = 0.7167 ± 0.0012, MSWD = 6. Whole-rock data for unaltered homfels plots also on this best-fit line. The obtained age of the altered homfels is consistent with the previously reported age of the biotite-hornblende rapakivi granite (Neymark et al., 1994). Rb-Sr isotopic data for core and rim zones of plagioclase-mantled alkali feldspar megacrysts shows that they were formed from a mixed source representing both rapakivi granites and country rocks. We suggest, that both the alkali feldspar and the phenocryst-like quartz megacrysts found within quartz-biotite-plagioclase homfels were formed from a supercritical, potassium- and silica-saturated fluid, which was derived from the rapakivi granite intrusion at late- and post-magmatic stages.

RELIC MATERIAL IN THE RAPAKIVI GRANITES OF THE SALMI BATHOLITH, RUSSIAN KARELIA: NEODYMIUM ISOTOPIC EVIDENCE

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Neodymium isotope study of minerals from biotite-hornblende rapakivi granites was carried out with the aim to date different mineral assemblages and to constrain their origin. On the mineralogical basis, some minerals encapsulated within the core zones of feldspar ovoids were assumed as relics (Shebanov and Belyaev, 1994). Neodymium isotope composition was determined for mafic hydrous minerals and alkali feldspar extracted from the core and peripheral zones of ovoids, plagioclase mantle around them, and mafic hydrous minerals from the rapakivi granite matrix.

Neodymium isotope data obtained for rim zones of alkali feldspar ovoids and matrix minerals are in agreement with the age of rapakivi granite intrusion (ca. 1540 Ma; Suominen, 1991; Neymark et al., 1994). Data on alkali feldspar, amphibole, and biotite from the cores of ovoids yield an age of 1777 ± 22 Ma (ε_{Nd} - 4.5) that clearly exceeds the intrusion age. This age is in agreement with the fact that old zircon has been detected within the ovoids; for example, abraded zircons from the cores of ovoids in the biotite-hornblende rapakivi granite of the batholith show a $^{207}Pb/^{206}Pb$ age of ca. 1.8 Ga (Neymark et al., 1994). The initial ε_{Nd} value of - 4.5 fits the Salmi rapakivi granite evolution trend (see Neymark et al., 1994).

The data allow us to conclude that the relic material encapsulated within the cores of alkali feldspar ovoids represent the crustal protolith of the rapakivi granites. We suggest that the age of the relic mineral assemblages reflect the time of the last thermal influx on the protolith.

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ON THE PETROGENESIS OF ALKALINE SYENITES IN THE BERDIAUSH RAPAKTVI GRANITE, SOUTHERN URALS, RUSSIA

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Dykes of alkali feldspar syenites occur in some anorthosite - rapakivi granite complexes (Berdiaush complex [BM], the Urals Region; Ragunda and Suomenniemi [SM] complexes, Fennoscandian Shield).

Alakali feldspar syenites of SM and BM are similar in their mineral composition and geochemical patterns including REE spectra. It has been established that the alkali feldspar syenites and rapakivi granites of SM have the same source (Ramo, 1991). Preliminary work has shown that alkali syenites and rapakivi granites have been derived from the different sources (Belyaev et al., 1995). Two types of alkali rocks are distinguished in BM. There are undersaturated and saturated with silica rocks which are nepheline-bearing and quartz-bearing, correspondingly. Sometimes, these rocks occur on the same outcrops. Both types of alkali syenites composed of alkali feldspar, albite, Fe-rich hornblende, alkaline amphiboles, aegerine, biotite, and either quartz or nepheline. Accessory minerals comprise apatite, orthite, zircon, titanite and opaque.

Compositions corresponding to silica-saturated and undersaturated alkali syenites are in the different fields of the quartz-nepheline-calsilite ternary system. These compositions are separated by the albite-orthoclase join which is a thermal divide. Consequently, two alkali syenite types distinguished above could not be formed as a result of the common melt fractionation.

However, the fact that the silica-saturated and undersaturated alkali syenites have similar isotope signatures (ε_{Nd} - 1, I_{Sr} 0.710 and ε_{Nd} -1.4, I_{Sr} 0.705, respectively) indicates that these rocks were originated from the same source. Model of silica-saturated syenite formation due to the contamination of silica-unsaturated syenite magma granitic magma seems unrealistic, because rapakivi granites differ in neodymium isotope composition (ε_{Nd} - 6.5). Such of a conclusions is in agreement with recent data on lead isotope composition of feldspars (Belyaev et al., 1995). Our data show the following:

Alkali-feldspar syenites undersaturated and saturated with silica were derived from the same source. However, they do not belong to a common fractionation sequence. These rocks were probably formed as result of different grade of fraction at melting of a common protolith that was homogeneous in isotope composition. Chemical and mineralogical heterogeneity of this protolith probably resulted in compositionally different melts.

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