PETROLOGY AND GEOCHEMISTRY OF LAMPROPHYRIC DYKES IN THE VITOSHA PLUTON

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Introduction

The Vitosha pluton is composed of abyssal gabbros and anorthosites, hypoabyssal monzonites, syenites and late veins of granosyenitic composition. The plutonic body is intruded in Late Cretaceous volcanic rocks and cross cut by post-plutonic dykes (L. Dimitrov, 1893; V.G. Arnaudov, 1932; Str. Dimitrov, 1942; I. Velinov, 1964, 1966; V. Zhelev, 1982).

The objects of this study are two dykes cropping out in the area of Goli (Zelen) Vruh at 1812 m altitude. We confirm the observation of L. Dimitrov (1893), that these dykes cut the gabbro-anorthositic complex in the area of "Petrov grob". According to the petrological classifications these rocks are lamprophyres: rocks for which an independent petrogenetic taxonomy system exists. Therefore, this is the first discovery of lamprophyre dykes in the plutonic rocks of Vitosha, whilst the earlier finds of lamprophyres (Kostov et al., 1964) in the southern stripe of Vitosha mountain are located in the Upper Cretaceous volcanic complex.

Geological background

The Vitosha pluton crops out in the western part of the Srednogorie tectonic zone. According to Dabovski et al. (1991) this zone developed as an island-arc system in Late Cretaceous. The Srednogorie island-arc system is characterized by a mafic-felsic rocks association (volcanic, plutonic and dyke rocks) of ultrabasic, basic, intermediate, acid and ultraacid composition. The rocks belong to the normal, subalkaline and alkaline series.

The lamprophyric dykes crop out at "Goli vruh" lift station. They are intruded in gabbroic rocks in the "Petrov grob" area. The dykes are subvertical and with a NW-SE direction (243°-250°) and dip steeply (81°-90°) to the SW. The first dyke (St 27/01) is 0.6 m thick and the second one (St 28/01) is 0.20 m. They differ from the host gabbro in colour, structure and texture.

Rock-forming mineralogy

The primary rock forming minerals are plagioclase, amphibole, magnetite, ilmenite and titanite. The texture is a hyatal porphyritic or serial porphyritic and the structure is fluidal.

Plagioclase: Three generations of plagioclase (Pl) can be distinguished - Pl_1, Pl_2, Pl_3, presented by single grains or zonal twin complexes. Two types of borders are observed in the zonal crystals: (1) borders related to resorption and/or delustring, change in paragenesis, and small range of the anorthite content; (2) optical indication but without phase borders at parallel nicols. The plagioclases are observed in the groundmass, as well as single phenocrysts with albite, karlsbad, or pericline twinning. The variation in the size of the plagioclase crystals from the three generations predetermines the development of porphyritic textures. They are evidence that the ascent of the magma took place in the range of the hypsometric transition between three facies (abyssal-hypoabyssal-subvolcanic).

Pl_1 builds the cores of the porphyry grains. The composition of the cores is $An_{69.0}$, $An_{63.6}$ and they are enclosed with acid labradorite ($An_{58.6}$ up to $An_{55.5}$). Pl_2 forms the outer zones of the porphyry grains and some single subporphyries and its composition is $An_{60,1}$, $An_{59,9}$, $An_{51,0}$, $An_{50,3}$. Pl_3 ($An_{60,2}$, $An_{55,4}$, $An_{51,0}$) is presented in the groundmass. The Or content is small and varies from 0.0 to 1.2.

Amphibole: This is the main mafic mineral in the lamprophyre dykes and it is observed in the groundmass and as porphyry grains. The pleochroic colors are greenish to brownish. All of the analyzed amphiboles are disposing in the field of actinolite and actinolite - Hbl according to the classification of Leake et al. (1997). No amphibole-pyroxene peritectic complexes have been observed in the lamprophyric rocks in contrast with the hosting gabbros. This is probably due to the origin of the mantle magma that was enriched in fluids with high chemistry potential of water (μH_20) and sodium oxide (μNa_20). The #Mg varies in narrow limits: from 58 to 63 and from 50 to 58 for the "Petrov grob" gabbros. The low value of Al in amphiboles is a consequence from the low alkalinity of the fluidised magma. The total alkali content $(Na+K)_A$ is low: from 0.05 to 0.08. This is another indication that the alkaline content of the partial lamprophyric magma remained low during the whole process of crystallization.

Magnetite: There are two generations of magnetite: Mt_1 forms xenomorphous grains, often as sideronitic cover. Mt_2 forms from the disintegration of Mt_1 and usually occurs as ash like aggregates in the groundmass.

Ilmenite: It is observed as an exsolution product in Mt_1 grains. All grains contain hematite and one - pyrophanite.

Titanite: It is the main accessory mineral in the lamprophyric rocks and is presented by single porphyry crystals with similar chemical composition. The most probable paragenetic minerals of titanite are the magnetite of the first generation and ilmenite.

Zircon: This mineral has not been observed in thin sections. For the U-Pb isotope studies it was separated from a heavy concentrate.

Geochemical characteristic

The composition of the studied lamprophyric dykes plot on the (Na_2O+K_2O) vs. SiO_2 diagram in the field of interme-

diate rocks.

On Harker diagrams the variations of the main petrogenetic component show relatively well developed correlation with the SiO_2 content. The binary diagrams show positive correlation for K_2O-SiO_2, CaO-SiO_2, MnO-SiO_2. There is a negative correlation of MgO-SiO_2, Al_2O_3-SiO_2, TiO_2-SiO_2 and Na_2O-SiO_2.

The negative correlation of Ti with Zr, the FeO_{tot}/MgO ratio, the low concentration of TiO_2 and the relatively high content of Al_2O_3 are typical features of island-arc magmatism and hence a subduction scenario should be typical for the Vitosha lamprophyres.

On the FeO_t - $K_2O + N_2O$ – MgO discrimination diagrams of Irvine & Baragar, (1971) the studied rocks plot near the margin between the tholeiitic and calc-alkaline series.

Chondrite-normalized REE distribution patterns of the lamprophyres show the same characteristics as the host gabbros, i.e. an enriched mantle source, probably contaminated with crustal material. The initial Sr ratio in Cretaceous time is 0.70445 (St 28/01) and 0.70426 (St 27/01). All samples show a fractionation of light rare earth elements (LREE) in comparison with heavy rare earth elements (HREE). Another characteristic feature of the rocks is the lack of Eu anomaly. This can be due to the weak fractionation of the crystallized plagioclase or more probably, to the presence of equilibrium conditions between the magma and the plagioclase-containing mantle source. This is possible at shallow mantle levels and is consistent with the obtained thermobarometry data. The general conclusion include that the characteristics of the lamprophyric rocks correspond to an island-arc setting with an input of previously enriched by subduction mantle material.

The N-MORB normalized spidergram shows a distinct negative Nb and Ta and Zr anomaly, which is a typical feature for calc-alkaline arc magmas. The high LILE/HFSE ratio is another evidence for the subduction origin of the rocks. According to Rollinson (1993) the LILE concentration may be a function of the behavior of a fluid phase, whilst the HFSE concentration are controlled by the chemistry of the source and the crystal/melt processes which have taken place during the evolution of the rock.

Mineral norms

Mineral norms calculated according to the CIPW petrochemical system are quartz, orthoclase, albite, anorthite, hypersthene, magnetite, ilmenite and apatite. The differentiation index vary between 33 and 34. According to the petrochemical parameters of Stefanova (1980) the lamprophyres from Vitosha deviate from the eutectic compositions of basic tholeiitic magmas.

Thermobarometry

Following the method of Schmidt (1992) the calculated pressure for the lamprophyres is c.1.5 Kb. This value rocks suggests that the rocks were intruded at about 4 km depth below the Upper Cretaceous surface. The plutonic intrusion (K_2-Q), tectonic processes and the erosion since the Late Cretaceous removed the apical part of Vitosha pluton and its volcano-sedimentary cover and nowadays the rock crop out at the surface. The applied geothermometer of Blandy and Holland (1990) gives temperatures between 609°C and 682°C for the cores of the plagioclase crystals and between 601°C and 672°C for the rims. The two group's of termobarometric values mark the hypsometry of the hypoabyssal and hypoabyssal-subvolcanic facies as well as a distinct perisolidus position with ability of subsolidus re-equilibrium. Normal temperature zoning is observed in only one plagioclase-amphibole pair. In most pairs there is a reverse temperature zoning. This relationship between temperature and pressure is probably a result of mixing processes between an evolved intermediate partial magma and incoming intra-telluric fluids. The inverse temperature zoning is probably due to the fact that during crystallization the magmatic system was open and the magmatic mixing processes were active.

Isotopic and geochemical data

Single zircon crystals from sample St 27/01 were dated using U-Pb single zircon method. Important information about the magmatic source of the lamprophyres is obtained using the Rb-Sr method. From the field relationship we know that the lamprophyric dyke cross cut the gabbro, which was dated at 81.58 ± 0.23 Ma (U-Pb single zircons). The U-Pb data of single zircon grains of the lamprophyric dyke plot on a discordia with an upper intercept at around 600 Ma. It points probably to an age of the protolithic rocks, which were assimilated by the magma of the lamprophyric dykes. The lower intercept shows Pb loss at Variscan time. The lamprophyric dyke does not contain newly formed zircons of Upper-Cretaceous age, as we expected from the field relationship.

A predominantly mantle source for the lamprophyres ($^{87}Sr/^{86}Sr$- 0.070426-0.70445) is shown by the Rb-Sr whole-rock isotope data.

Conclusions

The studied lamprophyres are intermediate, low-K calc-alkaline island arc rocks. They formed as a result of multi-stage processes of mantle magma generation, primitive fluidisation, two- or three-stage fractionation and mixing of melts in intermediate chambers.

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