



Mineral Chemistry of Ultramafic nodules from Lavas of the Fogo Island 2014 Eruption (Cape Verde). Preliminary results.

Química Mineral de Encraves Ultramáficas nas Lavas da Erupção de 2014 na Ilha do Fogo (Cabo Verde). Resultados Preliminares.

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Abstract

During the 2014 eruption at Fogo Island some samples of ultramafic enclaves from the extruded lavas were collected. Preliminary petrographic and mineral chemistry analysis show that they correspond to olivine amphibole clinopyroxenites of cumulate origin and that they must have crystallized from the same magma of the host rock. Geothermobarometric calculations performed with compositional data from pyroxenes and amphiboles indicate primary crystallization at magma chambers localized at depths around 22 km.

Keywords: Fogo Island, 2014 Eruption, Clinopyroxenites, Petrography, Mineral Chemistry.

Resumo

Durante a erupção de 2014 na ilha do Fogo, Cabo Verde, foram recolhidas algumas amostras de encraves ultramáficas incluídos em rochas resultantes de lavas então emitidas. Estudos preliminares petrográficos e de química mineral indicam que os nódulos correspondem a clinopiroxenitos olivínicos e anfibólicos, de origem cumulada, que resultaram da cristalização dos mesmos magmas que originaram as rochas hospedeiras. Os cálculos geotermobarométricos realizados com dados analíticos obtidos para as piroxenas e anfíbolos apontam para cristalização primária em câmaras magmáticas situadas cerca de 22 km de profundidade.

Palavras-chave: Ilha do Fogo, Erupção 2014, Clinopiroxenitos, Petrografia, Química mineral



Introduction

Ultramafic nodules are common in rocks from the Cape Verde Islands and have been often reported, namely from Sal, Santiago, São Nicolau, Santo Antão and Fogo (see Mendes et al., 2004; Bonadiman, 2005, Shaw et al., 2006; Hildner et al. 2012 and references therein). Most of these ultramafic nodules have been ascribed either to mantle residues, or to crystalline segregations and cumulative processes inside the magmatic chamber(s). Their study provided valuable information about the mantle nature and the pre-eruptive processes.

Silva et al (1997) and Munhá et al (1997) concluded that nodules in the tephritic and basanitic lavas resultant from the 1995 volcanic event in Fogo Island are wehrlites and pyroxenites representing cumulates from the same magmas related to the volcanic activity. During the 2014 eruption at Fogo Island a few samples of ultramafic enclaves were collected from the lavas extruded until the 5th of December. Here, they are described and the preliminary results on their mineral chemistry are presented and compared with the results from nodules formed inside the magma chambers that fed the 1995 eruption.

Petrography

The studied nodules are small (1 – 2.5 cm in size) and have rounded to angular shapes. They are macroscopically distinguished from the host rock mainly by their granular texture.

Following the IUGS recommendations (Le Bas et al., 1986) they can be classified as olivine amphibole pyroxenites.

They are composed of an early crystallization phase olivine, in subhedral crystals devoid of kink-bands or in rounded crystals enclosed in clinopyroxene oikocrysts. Clinopyroxene occurs in subhedral to anhedral zoned crystals, sometimes partially patchy replaced by late igneous amphibole which also occurs as primary crystals as well as

in some xenocrysts. In both cases they frequently show reaction rims with transformation in rhonite, probably resulting from decompression or in situ melting, in the last case possibly caused by reaction with the host magma. The same kind of feature was described for amphibole phenocrysts in lavas from the 1995 eruption.

Oxide minerals are present as a minor component occurring in sub-euhedral to anhedral crystals as inclusions in olivine and clinopyroxene or interstitially between silicate minerals.

Mineral Chemistry

Mineral analyses were obtained using an automated JEOL 8500 F electron microprobe housed at LNEG (S. Mamede de Infesta) operating at 15 kV accelerating potential and 10 nA probe current. Used standards were of natural or synthetic homogeneous minerals. Precision as indicated by replicate determinations is better than 2% for major elements.

Olivine shows a regular composition in the different nodules with Fo (= $100\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$) varying from 78 to 80. The low NiO (< 0.15 wt%) and high CaO (0.27 – 0.34 wt%) are consistent with a cumulate origin and incompatible with crystallization at high pressure.

Clinopyroxenes are Ti-augites ($\text{Wo}_{49-51}\text{En}_{42-36}\text{Fs}_{12-10}$) with Mg# = 0.80 – 0.88 [$\text{Mg\#} = \text{Mg}/(\text{Mg}+\text{Fe}^{2+})$], high $\text{TiO}_2 = 1.59 - 3.60$, $\text{Al}_2\text{O}_3 = 5.79 - 8.54$ wt% and $\text{CaO} \approx 22$ wt%. Phenocrysts of the host rock show similar composition. However, the clinopyroxenes from the nodules have $\text{Al}^{\text{VI}}/\text{Al}^{\text{IV}} > 0.25$ while those from the host rock decrease from 0.23 in the core down to 0.10 in rims. These values are often associated with different pressure/depths of crystallization. The application of the Soesoo (1997) geothermometer indicates nodules pyroxene crystallization between 6 and 10 kbar at 1150 to 1200 °C.

Primary amphiboles belong to the group of calcic amphiboles and can be classified as kaersutites. They present a significantly



constant composition having the following average contents: $\text{SiO}_2 = 38.89 \text{ wt}\%$, $\text{Al}_2\text{O}_3 = 13.55 \text{ wt}\%$, $\text{CaO} = 11.98 \text{ wt}\%$, $\text{TiO}_2 = 5.57 \text{ wt}\%$, $\text{MgO} = 12.90 \text{ wt}\%$, $\text{Na}_2\text{O} = 12.16 \text{ wt}\%$; $\text{K}_2\text{O} = 1.51 \text{ wt}\%$. Rhonite ($\text{SiO}_2 = 25.45$, $\text{FeO} = 16.31$, $\text{CaO} = 11.75$, $\text{Al}_2\text{O}_3 = 16.89 \text{ wt}\%$, $\text{TiO}_2 = 11.89 \text{ wt}\%$, $\text{MgO} = 14.13 \text{ wt}\%$, $\text{Na}_2\text{O}_3 = 1.11 \text{ wt}\%$) was identified as resulting from kaersutite in two nodules. Geothermobarometric calculations based on the Al content in amphibole (see Yavuz, F., 2007 and references therein) point to crystallization at pressures around 7 kbar and temperature around 1000 °C.

Until now, no phlogopite was identified in opposition to the reported for the 1995 ultramafic xenoliths (Silva et al., 1997).

Oxide minerals are Ti-magnetites, where Fe^{3+} is the main trivalent cation. They are Al, Mg rich Ti-magnetites ($\text{Al}_2\text{O}_3 \approx 7.14 \text{ wt}\%$, $\text{MgO} \approx 6.97 \text{ wt}\%$) with high TiO_2 (= 13.94 to 19.28 wt %), as typical in magnetite crystallizing from primitive alkaline basaltic magmas.

Conclusions

The typical cumulus textures, and the mineral chemistry already obtained for the ultramafic nodules from the 2014 eruption at Fogo strongly suggest that they have a cumulate origin and are cognate with the host magmas.

Indeed, the similar composition of Ti-augites from the nodules and phenocrysts, the low values of Mg# and Fo, the low TiO_2 and high CaO contents in olivine are explained by crystal segregation from the same magma of the host rock.

Geobarometric data obtained from amphibole core compositions and clinopyroxenes, although not conclusive, point to primary crystallization pressures of 6 – 10 kbar, indicating a magma chamber system located at depths of at least 22 km.

The 2014 nodules, here described, are similar to the 1995 pyroxenite xenoliths except for the different role played by hydrated minerals with amphibole

characterizing the 2014 nodules while the 1995 ones have late phlogopite and also amphibole that, however, is present mainly as xenocrysts.

We plan to perform further sampling of the ultramafic nodules and increase the analytical data in order to better constrain some of the aspects here described.

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