Magmatic processes in the oceanic lithosphere: characterization of the ultramafic and mafic materials from the Holocene volcanic centers of Bandama and La Caldera de Pinos de Gáldar (Gran Canaria, Canary Islands)

J. Mangas and F.J. Perez-Torrado

Departamento de Física. Universidad de Las Palmas de Gran Canaria. 35017 Las Palmas de Gran Canaria. Spain

jmangas@dfis.ulpgc.es

Introduction

Mantle and crustal xenoliths carried to the surface by basaltic melts in intraplate oceanic islands represent one very important information source of the deeper parts of the oceanic lithosphere. Thus, our research is based on the study samples of peridotite xenoliths and olivine-pyroxene-amphibol crysts and cumulates from pyroclastic deposits of Bandama and La Caldera de Pinos de Galdar volcanic centers (Gran Canaria, Canary Islands) and samples of lava flows associated to these volcanoes. We have combined data from the volcanological study and the electronic microprobe and microthermomertric analysis of minerals and melt and fluid inclusions, and the bulk-rock analysis of these samples to define some characteristics of magmatism which gave rise to these volcanoes.

Gran Canaria island is at the centre of the Canary Archipielago and this is associated to a mantle plume. Geophysical data indicate the occurrence of an oceanic-type basement underneath the Gran Canaria island modified by massive intrusions with a Moho depth of 13 kms. Magmatic activity of this island began in the Miocene with an episode of submarine volcanism and their subaerial volcanism have been divided over three main episodes: Old cycle (Miocene, 14.5-7 Ma), Roque Nublo cycle (Pliocene, 5.5-3 Ma) and Recent cycle (Plio-Quaternary, 3 Ma-Present). Taking into account the hawaiian formation model for intraplate volcanic islands, the Old cycle of Gran Canaria contains magmatic materials associated to the shield building and alkaline declining stages, and the Roque Nublo and Recent cycles represent the rejuvenation stage. Thus, Bandama and La Caldera de Pinos de Galdar Holocene volcanic centers are one of the latest eruptions associated to the rejuvenation stage of Gran Canaria.

The Holocene volcanic center of Bandama is made up of a volcanic caldera (La Caldera de Bandama) and a strombolian cone (El Pico de Bandama). Bandama eruption began in the area of La Caldera with a strombolian episode which produced deposits of fall and a basanite lava flow. Later, the magma in the counduit mixed periodically with groundwater, producing both phreatomagmatic eruptions with base surge deposits and strombolian eruptions with fall deposits. Although the volcanism episodes were to continue in the area around La Caldera, most of these manifestations were centred around the NW area of the fisure, producing the strombolian cone known as the Pico Bandama, abundant deposits of fall in the surrounding areas and an intracanyon flow. The genesis of La

Caldera is posterior to El Pico and was produced as a result of the last effusive-explosive eruptions and the eventual collapse of the volcanic cone located to the SE of the fissure.

On the other hand, the Holocene eruption of La Caldera de Pinos de Galdar (2,830 years b.p.) is characterized by an strombolian cone, several lava flows of basanite composition and fall pyroclastic deposits. This volcano and other neighbour volcanic cones (Valleseco, Montañón Negro –2,970 years b.p.--, Hondo de Fagagesto –2,210 years b.p.--, Sao and Los Berrazales) are almost contemporaneous and they form a NW-SE structural lineation of 9 km long.

Mineralogical and geochemical characteristics

Lava flows of Bandama show basanite composition (SiO_2 41.8% and sum of the alkalis 3.8%) and porphyritic texture with phenocrysts and microcrysts of olivine, pyroxene and oxide (spinel and ilmenite) with sizes under 2 cm. Microprobe analysis of these minerals reveal olivine Fo_{70-89} (Ni/Ca ratio: 0.3-2.2) and clinopyroxene Wo_{40-52}, En_{27-54} (augite-diopside). Spinel appear as subordinate minerals and as inclusions in phenocrysts and have Cr_2O_3 content between 36.4 and 40.2%. These analysis show variations of composition between the cores and rims of some phenocrysts and reveal different crystal generations. In addition, the lava flows contain some ultramafic and mafic xenolitiths and cumulates

On the other hand, the lava flows of La Caldera de Pinos de Galdar have basanitic composition (SiO_2 43.2% and sum of the alkalis 5%), show porphyric texture and these flows contain olivine (Fo_{81-90}) and augite-diopside (Wo_{44-55}, En_{28-50}) phenocrysts, subordinated spinel ($\#Cr_{35-65}$) and magnetite ($\#Cr_{0.4-3.3}$), and scarce mafic and salic cumulates.

Phreatomagmatic eruptions of Caldera de Bandama form base surge and explosive breccia rich in lithics (such as phonolites, tephrites, alkaline basalts, etc.) deposits with spectacular volcanic-sedimentary structures (imbricated channels, sand waves, bomb impacts, etc.). However, the strombolian volcanism is characterized by the presence of fall deposits, containing peridotite xenoliths and olivine-pyroxene-amphibole megacrysts and magmatic cumulates with sizes under 7 cms. Electronic microprobe analysis of these minerals show:

1) phenoscrysts and megacrysts of olivine Fo77-89 (Ni/Ca: 0.5-2.2 and spinel with Cr2O3: 34-36.3%), clinopyroxene Wo34-52, En33-51 (spinel with Cr2O3: 20.8-23.4%) and kaersutite (destabilized to fassaite --Wo54-57, En31-34--, rhönite, olivine and subsaturated melt).

2) ultramafic cumulates (dunite, werhlite, clinopyroxenite with olivine and clinopyroxenite) with olivine Fo_{80-87} (Ni/Ca: 0.6-2.1 and spinels with Cr_2O_3: 14-31.2%) and clinopyroxene Wo_{39-51}, En_{36-55} (spinels with Cr_2O_3: 10-16.1%).

3) ultramafic xenoliths (dunite and lherzolite) with olivine Fo_{83-89} (Ni/Ca: 1-20 and spinels with Cr_2O_3: 13.2-32.8%), orthopyroxene Fo_{84-85} (spinels with Cr_2O_3: 31.3%) and clinopyroxene Wo_{40-44}, En_{48-50}.

The pyroclastic deposits of La Caldera de Pinos de Galdar display mafic and ultramafic xenoliths and cumulates with sizes below 15 cms and these are characterized by:

1) ultramafic xenoliths: A) dunite (olivine I: Fo_{87-91}, olivine II: $Fo_{89-93;}$ spinel I: $\#Cr_{95}$ and spinel II: $\#Cr_{50-96}$), B) lherzolite (olivine I: Fo_{91}; olivine II: Fo_{91-94}; orthopyroxene: $Fo_{81-96;}$ clinopyroxene: Wo_{41-47}, $En_{50-57;}$ spinel I: $\#Cr_{90-91}$ and spinel II: $\#Cr_{89-96}$) and C) harzburgite (olivine I: Fo_{88-93}; olivine II: Fo_{82-97}; orthopyroxene: Fo_{91-96}; clinopyroxene: Wo_{40-47}, En_{48-58}; spinel I: $\#Cr_{86-87}$ and spinel II: $\#Cr_{67-88}$).

2) mafic and ultramafic cumulates: A) olivine clinopyroxenite (olivine: Fo_{81-83}; augite-diopside: Wo_{47-56}, En_{38-45}; spinel: $\#Cr_{40-57}$), B) clinopyroxenite (olivine: Fo_{81-83}; augite-diopside: Wo_{46-55}, $En_{39-51;}$ spinel: $\#Cr_{13-30}$), C) hornblende clinopyroxenite (olivine: Fo_{77-91}; augite-diopside: Wo_{42-55}, En_{38-56}; spinel: $\#Cr_{15-44}$), D) clinopyroxenite with apatite and Fe-Ti oxides (augite-diopside: Wo_{50-53}, En_{39-44}; magnetite: $\#Cr_{<2.1}$; ilmenite: Ilm_{55-66}, $Geik_{16-34}$, Hem_{10-17}), and E) clinopyroxenite with apatite, titanite and Fe-Ti oxides (augite-diopside: Wo_{50-56}, En_{25-44}; magnetite: $\#Cr_{<1.8}$; ilmenite: Ilm_{52-86}, $Geik_{6-34}$, $Hem_{<19}$; hematite: $Hem_{96-100,}$ $Geik_{<4}$, $Pyroph_{<3;}$ and Fe sulphides). Clinopyroxene megacrysts (Wo_{50-54}, En_{35-42}) containing cristal inclusions of apatite and hematite ($Hem_{98-100,}$ $Geik_{<1}$, $Pyroph_{<1}$).

Melt inclusion study in olivine from fall deposits and lava flows of Bandama volcanic center show SiO_2 content: 35-44%, sum of alkalis: 4.1-7% and high values of S and Cl (<5,500 and <980 ppm, respectively). The melt inclusion compositions are different from the lava whole rock and the intersticial melt. The melting temperatures (Tm) of melt inclusions range between 1,060 and 1,260°C.

Microthermometric study of melt and fluid inclusions in olivine and clynopyroxe of Bandama volcanoes shows pure, or almost pure, CO_2 trapped in the gas bubble. These carbonic fluids reveal a wide range of Th of CO_2 (-39 to 31°C) in liquid, indicating minimum depths of mineral formations (at Tm: 1200°C) between 12-18 Km for olivine-pyroxene-anphibol megacrysts, 4.5-27 Km for olivine-pyroxenes cumulates, 10.5-25 km for ultramafic xenoliths, and 7.5-33 Km for olivine phenocrysts of lava flows. The depth ranges observed indicate magma reservoirs and mineral genesis within the upper mantle and in the lower and upper crust (Fig. 1).

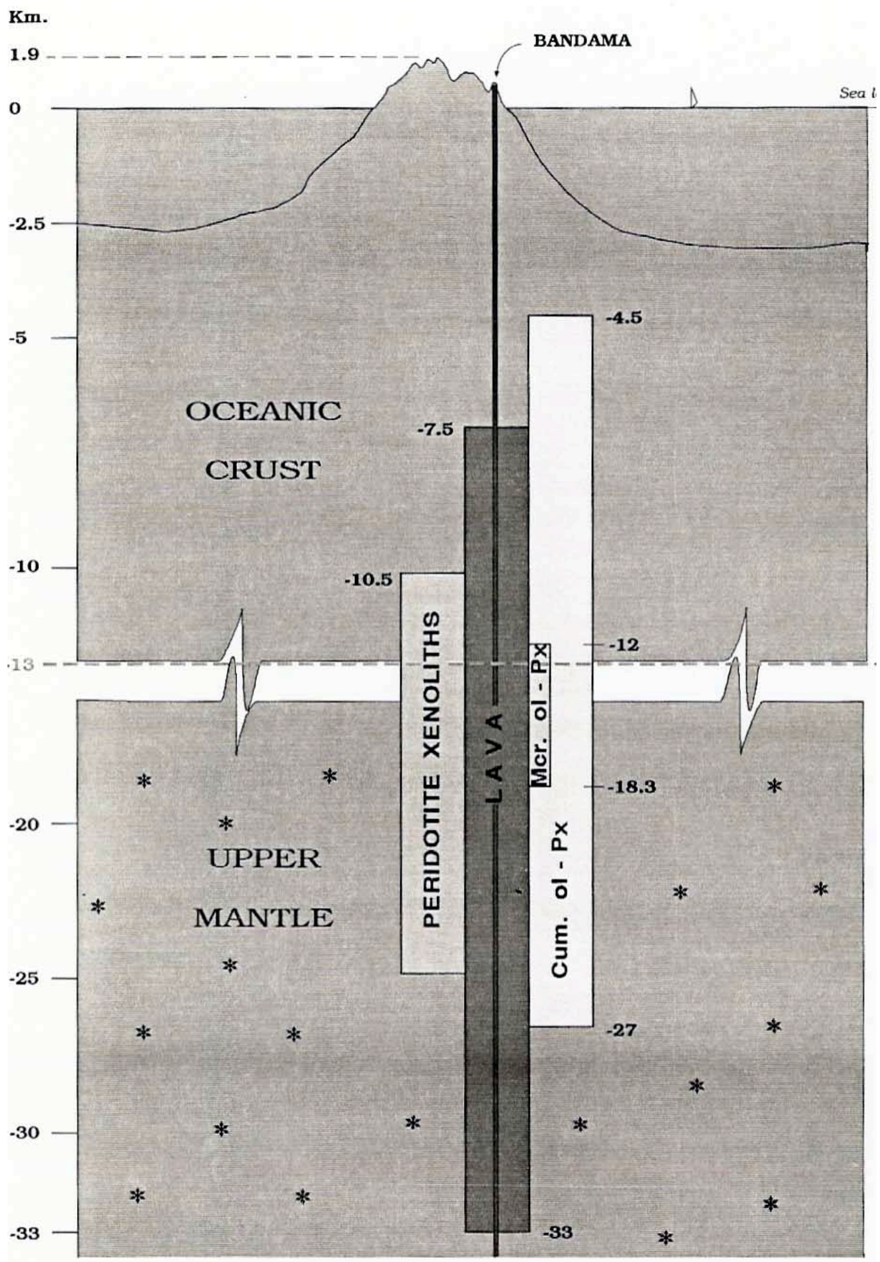

Figure 1. Interpretative scheme of depth calculated by CO2-rich fluid inclusions trapped in olivine and pyroxene from lava flows, xenoliths, cumulates and megacrysts of the Bandama volcanic center (Gran Canaria, Canary Islands).

Discussion

The olivine, clinopyroxene and anphibole which make up the crysts (phenocrysts and megacrysts), cumulates and xenoliths of Bandama and La Caldera de Pinos de Galdar volcanoes display different textural, mineralogical, microthermometric and chemical composition characteristics. Thus, the lava flows have basanite composition (ultramafic, low-evolved magma), cumulates and megacrists were formed in more-evolved magmas (mafic and ultramafic) and the upper mantle xenoliths have variable peridotitic compositions and textures (ultramafic). In addition, numerous studied minerals reveal generally reaction rims with basanite melts, documenting prolonged magma contact (mineral diffusion zones). Therefore, we can conclude that these studied minerals were originated under variable magmatic conditions and chambers.

We propose a model of the multi-stage magma ascent and storage beneath Gran Canaria island (Fig. 1). Therefore, the basanitic magmas which gave rise to Bandama and Pinos de Galdar volcanoes ascended from upper mantle to the surface trapping xenoliths, cumulates and megacrysts of different depths and genesis. The basanite ascending magmas stagnated in several reservoirs en route to the surface between -33 km to 1,5 km, trapping ultramafic xenoliths, mafic and ultramafic cumulates, and olivine-pyroxene-amphibole megacrysts from the upper mantle and the upper oceanic crust (-27 to -4.5 km.).