Composition of Gabbroic Xenoliths in Flores Island (Azores, Portugal)

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INTRODUCTION.

The western group of the Azores Archipielago includes the Flores and Corvo islands. Both are aligned north-south within the North American Plate. This alignment is parallel to the M.A.R. (Middle Atlantic Ridge) and nearly perpendicular to the general alignment of the other Azores islands (Fig. 1).

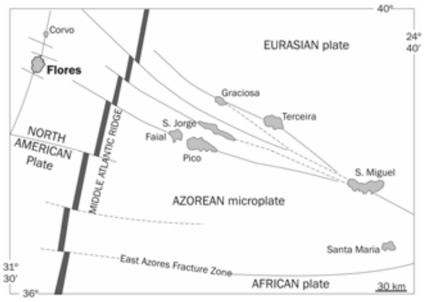

fig 1. *Location of Flores Island within the Azores Archipielago (Azevedo et al., 2006).*

The Flores Island is formed by volcanic basic rocks (basalts and hawaiites) whereas evolved rocks are minoritary. Azevedo et al. (1986) group the volcanic lavas and deposits into two major volcanic complexes:

- Basal Volcanic Complex (BVC): includes products and structures from both submarine and subarerial volcanism. This complex is formed by pyroclastic deposits and interbedded flows of alkali basalts (Azevedo, 1999).
- Upper Volcanic Complex (UVC): represents the main subaerial activity of the island. Includes three main volcanostratigraphic units. Basaltic to trachytic lava flows with interbedded pyroclastic deposits form the first two units. The most recent products are exclusively pyroclastic.

The main structural elements of the island are N30 – 40ºW strike-slip and N20 – 30ºE trending normal faults. These structures are likely related to the M.A.R. and associated transform faults.

In this work we present the first compositional data on the basic xenoliths included within the basalts of UVC.

PETROLOGY OF XENOLITHS.

Xenoliths were sampled from the base of the second unit of the UVC (Fig. 2). Six representative xenoliths were selected from a group of 21, for electron microprobe analysis. The analyses were carried out with a JEOL JXA-8900M electronic microprobe of the UCM. Mineral formulae were calculated according to the IMA recommendations. The Fe^{3+} contents of anhydrous minerals were estimated applying the Droop (1987) algorithm.

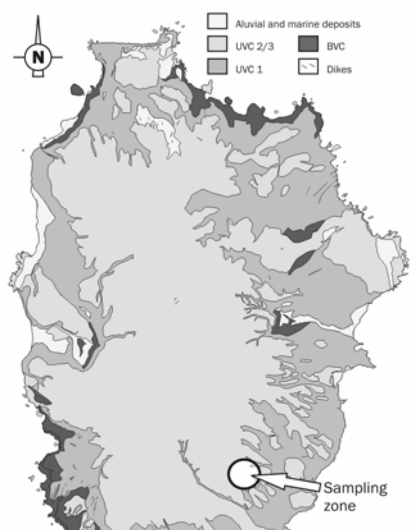

fig 2. *Geological map of Flores Island and location of sampling zone (modified from Azevedo et al., 2006).*

The xenoliths have rounded shapes and sharp contacts. Lava permeations within the xenoliths were observed in some of them.

According to their petrological and mineralogical composition, two groups of basic xenoliths can be defined:

- Olivine bearing gabbros.
- Olivine bearing gabbronorites.

Olivine bearing gabbros.

These xenoliths are fine to medium-grained phaneritic rocks and show a hypidiomorphic granular and seriate texture. Their mineral assemblage consists of olivine (7-25%), clinopyroxene (35-60%), plagioclase (20-30%) and Fe-Ti oxides (~1%) and indicates a composition of olivine-bearing gabbros. Some samples have alkaline amphibole (~7%) and accesory apatite. Different types of discontinuous mineral zoning are recognized in the crystals.

Olivine usually is altered to opaque minerals and iddingsite. When unaltered, displays a wide fractionation range (Fo_{88} - Fo_{69}) and low MnO (0.2–0,55 %) and CaO (0.2–0.45 %) contents. The more magnesian compositions have up to 0.3 % of NiO.

Pyroxene is titanian diopside and ranges from Fs_5 to Fs_{13} (mg#: 0.9–0.7). Their TiO_2 content rises until 2.3% in the ferrosilite-rich terms. TiO_2, Al_2O_3, FeO and MgO show an oscillatory zoning. The Ti, Ca and Na (per formula unit – p.f.u.) content of these clinopyroxenes is typical from alkaline magmatic assemblages (Fig. 3).

Plagioclase ranges from bytownite to andesine (An_{86}–An_{53}). In detail, three compositional groups of plagioclase are

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recognized. The earlier plagioclase euhedral phenocrysts are minoritary and have a composition of An_{86}. The main group of phenocrysts evidence oscillatory and reverse zoning (An_{77}–An_{83}). The later group is andesine in composition and usually shows normal zoning (An_{72} – An_{60}).

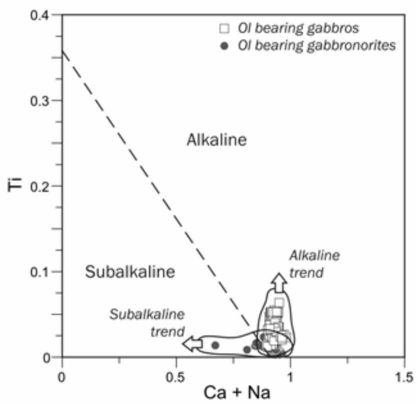

fig 3. Ti vs Ca+Na (u.p.f.) diagram of Cpx from xenoliths. Arrows indicate typical magmatic trends (Leterrier et al., 1987).

All three groups have low K_2O contents, and the evolved terms demonstrate a little increment in the orthose molecule proportion (Or ~1%).

Amphibole occurs only in one of the samples, as intergranular allotriomorphic and non-zoned phenocrysts surrounded of plagioclase and clinopyroxene. It has composition of kaersutite with high TiO_2 content (5.31–5.67%) and very narrow fractionation range (mg#: 0.72–0.67). This fractionation is consistent with the crystallization temperature (1052–1038ºC) estimated with the Ti-in-Amp geothermometer (Otten, 1984).

The opaque minerals are mainly Ti-rich magnetite. F-rich apatite (F: 1.43–2.54%) occurs as accesory microcrystals in one sample.

Olivine-bearing gabbronorites.

The textural features of this group are similar to those of the previous one but the presence of orthopyroxene in its mineral assemblage indicates their different petrological and geochemical composition.

These xenoliths consist of olivine (5-7%), clinopyroxene (20-25%), orthopyroxene (20%), plagioclase (50%), amphibole (~2%) and Fe-Ti oxides (~1%).

Olivine is usually altered to iddingsite and its composition ranges from Fo_{80} in phenocrysts to Fo_{74} in microcrysts. Also includes low contents of trace elements (MnO: 0.31–0.55 %; CaO: 0.24–0.40 % y NiO < 0.23 %).

Clinopyroxene phenocrysts (diopside) have corroded margins. Orthopyroxene exsolution lamellae are a common feature of these crystals as a result of crystallization below the Pgt–Opx inversion temperature (Deer *et al*., 1992). Diopside crystals contain relatively small amounts of TiO_2 (< 0.53 %), according to their subalkaline affinity (Fig. 3).

Orthopyroxene appears as isolated subhedral microphenocrysts and as exsolutions in Cpx. Its composition ranges from Fs_{19} to Fs_{27}.

Plagioclase is bytownite (An_{84}–An_{78}) and occurs as corroded phenocrysts with oscillatory zoning.

Opaque minerals are spinel and have high Fe, Ti and Al contents.

CONSIDERATIONS.

The petrology and mineral chemistry of the studied xenoliths lead us to define two main groups of basic xenoliths probably related to different origins.

The mineral assemblage of olivine-bearing gabbros and the composition of their clinopyroxene support the alkaline affinity of these xenoliths. This affinity suggests a genetic relationship with the alkali basalts that form the subaerial volcanism of the island. This hypothesis of a common origin between gabbroic xenoliths and the alkali basalts has been proposed for the examples studied in the Corvo Island (Lago *et al*., 2007).

The second group of xenoliths (Olivine gabbronorites) has a different origin than the previous one. The occurrence of both orthopyroxene and clinopyroxene indicates a subalkaline affinity as supported by the composition of their clinopyroxene. The occurrence of olivine in the gabbronorites suggest that they crystallized from a sub-saturated tholeiitic melt.

The tholeiitic affinity of the gabbronorite xenoliths contrasts with the alkaline affinity of all the emersed and subaerial volcanism of the Flores Island (Azevedo, 1999). This suggests that they come from a source not related to that of the alkaline volcanic rocks and xenoliths. Probably the gabbronorites were crystallized on deeper volcanic levels or represent part of the oceanic crust.

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