Mineralogy of Gabbroic Xenoliths in the Graciosa Island Vulcão Central Unit (Azores, Portugal)

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INTRODUCTION.

The Graciosa Island belongs to the Central Group of the Azores archipelago. It is located along the Terceira throught, close to the triple junction among the Eurasian, African and American plates (Fig. 1a).

The island is composed of three volcanic complexes (Gaspar, 1996), distributed so that it has a WNW-ESE elongated geometry (*Fig. 1b*). The oldest one is the Serra das Fontes Volcanic Complex (SFVC; 620±120 Ky, Féraud et al. 1980), followed by the Serra Branca Volcanic Complex (SBVC; 350±40 Ky) and the Vitória-Vulcão Central Volcanic Complex (without available radiometric ages). The latter comprises two contemporaneous units: the Vitória basaltic Unit (VU) and the Vulcão Central Unit (VCU).

Nine mafic xenoliths have been studied. They crop out in the southern area of the island, in a basaltic lava flow from the VCU (*Fig. 1b*). The host basalts have an alkaline affinity (Almeida, 2001). They are composed of olivine, Ti-augite, kaersutite, plagioclase, Fe-Ti oxides and accessory apatite.

In this work we have recognized different types of xenoliths according to petrographical observations and mineral compositional data. Most of them have an alkaline affinity, whereas others turn to be transitional or even subalkaline.

XENOLITH EMPLACEMENT.

The xenoliths concentrate in a small area, sized about 75x100 m². Together with some amphibole xenocrysts, they define an alignment which may represent a wide volcanic tube, although its margins could not be recognized.

The xenoliths are gabbros displaying subrounded geometries, sharp contacts with the host basalt and a wide range of sizes (5-30 cm). The smallest ones, if elongated, run parallel to the general enclave alignment.

The emplacement characteristics suggest a deep fracture system, which allowed the quick and turbulent magma rise able to carry the enclaves in a short period of time.

In agreement with this hypothesis, many xenoliths present melt inclusions, up to the 2% in volume. They are composed of isolated plagioclase, clinopyroxene, amphibole and oxide crystals embedded in a glassy matrix. These inclusions may indicate a strong decompression of the magma, caused by its quick ascent; the generated spaces would be filled by the host magma carrying the xenoliths.

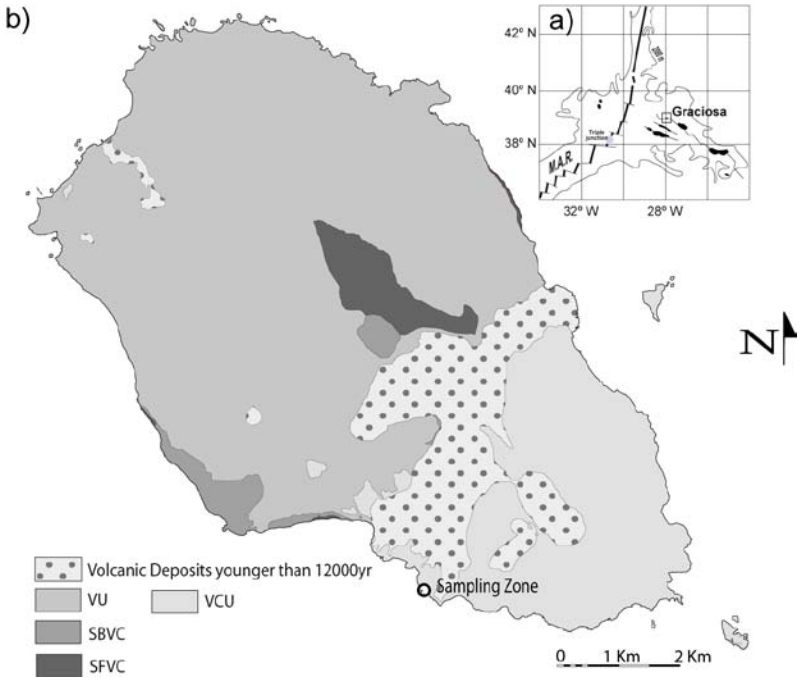

fig 1. *a) Location of Graciosa Island within the Azores Archipelago; modified from França et al. (2006) (M.A.R.: Middle Atlantic Ridge). b) Volcanological map of Graciosa (modified from Gaspar, 1996).*

XENOLITH TYPES.

All the studied xenoliths are gabbros (*Fig. 2*). They display a coarse-grained texture composed of amphibole, plagioclase, opaque minerals and accessory apatite; olivine and clinopyroxene crystals are sometimes present.

According to their modal proportions, 5 types can be distinguished: alkaline leucogabbros (2 samples), amphibolic alkaline gabbros (2 samples), alkaline gabbros bearing clinopyroxene and amphibole (2 samples), transitional gabbros (1 sample) and subalkaline gabbros (1 sample).

palabras clave: Xenolito, Gabro, Graciosa, Azores.

key words: Xenolith, Gabbro, Graciosa, Azores.

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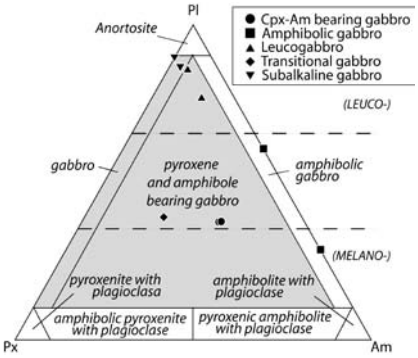

fig 2. *Modal classification of the studied xenoliths in the Strekeisen (1976) Pl-Px-Am diagram.*

All the established types present orthocumulate textures. Cumulus crystals are plagioclase and olivine, when present (Table *1*). Plagioclase develops single or intergrown micrometer- to millimeter- sized subidiomorphic crystals. Olivine displays 200-600 μm subrounded crystals. Clinopyroxene is allotriomorphic and can appear as a cumulus (in Cpx-Am bearing alkaline gabbros and transitional gabbros) and intercumulus (in alkaline leucogabbros and subalkaline gabbros) phase. In alkaline-type and transitional xenoliths it presents centimeter-sized pale-pink crystals with common corroded rims. Zoned crystals and overgrowth rims are frequent. On the contrary, clinopyroxene from subalkaline gabbros has 200-600 μm sizes and a greenish hue. Amphibole is the principal intercumulus phase in all the cases, developing poikilitic crystals. Its size ranges from 200 μm to 1,5 cm. Very often, amphibole crystals show 200 μm-sized reaction coronas composed of 10 μm-sized olivine, clinopyroxene, plagioclase and amphibole crystals.

MINERAL COMPOSITION.

Plagioclase from the alkaline-type gabbros displays a range of compositions between An_{76} and An_{49}. The Or molecule increases towards the andesine terms, indicating the alkaline trend. Plagioclase crystals in the leucogabbros and the Cpx-Am bearing gabbros frequently show oscillatory zoning (e.g. An_{50} -> An_{75} -> An_{58} -> An_{51}), whereas those in the amphibolic gabbros present normal zoning (An_{60} to An_{49}). On the other hand, in the transitional gabbro plagioclase is labradorite without major compositional variations ($An_{69\text{-}65}$). Finally, in the subalkaline gabbros plagioclase single crystals reflect several crystallization stages (An_{61}-An_{30}-An_{16}). When those crystals are in contact with a melt inclusion, they develop an orthoclase overgrowth rim (An_3; Or_{45}).

Olivine in the alkaline-type gabbros crystallizes in two stages: $Fo_{78\text{-}68}$ and $Fo_{57\text{-}53}$. On the contrary, in the transitional and subalkaline gabbros, only the first stage is recognized ($Fo_{73\text{-}71}$ and $Fo_{76\text{-}66}$, respectively).

Studied clinopyroxene crystals are diopside and augite. In alkaline-type xenoliths they cover a wide fractionation range ($Fs_{8\text{-}17}$) and present high TiO_2 values (up to the 2,7%), accordingly with the alkaline affinity of the rock. Cr-rich compositions (Cr_2O_3 up to the 0,6%) have been found in some phenocrysts cores. Diopsides with little fractionation ($Fs_{10\text{-}13}$) and intermediate TiO_2 contents (1,2-2,1%) are present in the transitional-type xenoliths. An only Cr-rich core has been detected (Cr_2O_3: 0,5%). Regarding the subalkaline gabbros, their clinopyroxene is green-coloured, highly fractionated ($Fs_{19\text{-}28}$), Ti-poor (TiO_2: 0,1-0,3%) augite. When those crystals are in contact with a melt inclusion, they develop a 15 μm overgrowth rim with higher TiO_2 contents (1,4%) and small fractionation rates (Fs_{19}).

All xenoliths contain amphibole. It is classified as kaersutite and presents little compositional variations (mg#: 0,7-0,6). The highest and lowest TiO_2 contents correspond to amphibole crystals in the amphibolic gabbros (up to the 6,3%) and the leucogabbros (4,0-5,0%), respectively.

Opaque minerals are Fe-Ti oxides, corresponding to magnetite and ilmenite. Accessory apatite is F-rich; it displays idiomorphic crystals present in all the samples (<1%). However, this mineral is more abundant (3%) in amphibolic alkaline gabbros (type 3).

Type	*Ol*	*Pl*	*Cpx*	*Am*	*Op*	*Ap*
Alkaline leucogabbro	*1-5%*	*67-80%*	*8%*	*5-12%*	*6%*	*0-2%*
Amphibolic alk. gabbro	*–*	*28-57%*	*–*	*37-70%*	*2-3%*	*0-3%*
Cpx-Am alkaline gabbro	*6-30%*	*24-34%*	*15-22%*	*28-35%*	*3-5%*	*<1%*
Transitional gabbro	*4%*	*35%*	*35%*	*20%*	*6%*	*–*
Subalkaline gabbro	*–*	*82-84%*	*10%*	*0-3%*	*4-5%*	*<1%*

Tabla 1. *Modal proportions of the 5 established xenolith types.*

CONSIDERATIONS.

Vulcão Central Unit (VCU) mafic xenoliths are gabbros. Their mineral assemblage includes olivine, augite, kaersutite, plagioclase, Ti-magnetite, ilmenite and F-apatite. Most of them are alkaline, resembling xenoliths from other Azorean islands.

Alkaline-type xenoliths can be arranged in order of increasing fractionation as follows: Cpx-Am bearing gabbros, amphibolic gabbros and leucogabbros. Xenoliths of transitional and subalkaline affinities have been also recognized. They share some characteristics with the alkaline-type gabbros, especially with the least fractionated.

The cumulate textures and the main alkaline affinity suggest that both the xenoliths and their host VCU alkali basalts may have the same origin. The xenoliths may be magma chamber cumulates; the established different types may reflect the chamber zoning.

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