Tonalites from the Hospitais Massif (Ossa-Morena Zone, SW Iberian Massif, Portugal) I: Geological setting and petrography

Tonalitas del Macizo de Hospitais (Zona de Ossa Morena, SO Macizo Ibérico, Portugal). I: Encuadre geológico y petrografía

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ABSTRACT

The Hospitais Massif is an elliptical-shaped plutonic body, with a WNW-ESE long axis, located in the western Ossa-Morena Zone domains in Portugal. This massif, composed essentially of tonalites, is part of an igneous association, ranging from gabbros to granites, intrusive in a gneissic-migmatitic complex, as part of the Évora High-grade Metamorphic Terrains. The tonalites present magmatic fabrics associated with a moderately developed foliation, recording syntectonic crystallization and cooling, co-planar to steep foliations observed within the surrounding sheared gneisses and migmatites. From field and petrographic studies, it is possible to suggest that the deformation of the tonalites and associated basic rocks was synchronous with Variscan progressive shearing of the gneisses and migmatites envelope.

Key words: *tonalites, gabbros, dioritic enclaves, Variscan orogeny, Ossa-Morena Zone*

RESUMEN

El Macizo de Hospitais corresponde a un plutón elíptico de orientación ONO-ESE localizado en los domínios occidentales de la Zona de Ossa Morena, en Portugal. Este macizo, constituido por una asociación ígnea que incluye desde gabros hasta granitos y en la que son dominantes las tonalitas, está intruida en un complejo de gneises y migmatitas perteneciente a los Terrenos de Alto-grado Metamórfico de Évora. Las tonalitas muestran fabricas magmáticas asociadas a una foliación moderadamente desarrollada durante la cristalización y enfriamiento, paralelas a la foliación subvertical observada en los gneises y migmatitas del encajante. Las evidencias de campo y los estudios petrográficos permiten sugerir que la deformación de las tonalitas y rocas básicas asociadas que afloran cerca de Montemor-o-Novo, fue contemporánea con el progresivo cizallamiento Varisco observado en los gneises y migmatitas del encajante.

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Introduction

Geologically, south-central Portugal is part of SW Iberian Massif where is located the Ossa-Morena Zone (OMZ), one of the major geotectonic divisions of the western European Variscan Chain (Julivert *et al*., 1972). One important characteristic of the OMZ is the presence of distinguishable structural, paleogeographic and magmatic-metamorphic domains, as recognized by Chacón *et al*. (1983), Apalategui *et al.* (1990) and Oliveira *et al*., (1991). In the western Ossa-Morena Zone exists a large area covering approximately 75 km^2 (the Évora Massif; e.g. Carvalhosa, 1983; Quesada and Munhá, 1990) where the magmatism and high-grade metamorphism related with the Variscan orogeny is well exposed. Recently, with the purpose of clarifying the complex internal structure of the Évora Massif, Pereira *et al*. (2003) defined the Évora High-Grade Metamorphic Terrains (EHMT) as a major tectonic unit composed by a complex assemblage of migmatites and gneisses, intruded by syn-orogenic basic to acid plutonic rocks and late-orogenic porphyritic granites. The same authors interpret these high-grade metamorphic rocks as the result of Variscan HT-LP metamorphism developed over Neoproterozoic (Serie Negra) and Lower Palaeozoic rocks.

The Hospitais Massif (Carvalhosa and Zbyszweski, 1994) occupies the northwest end of the EHMT, close to the town of Montemor-o-Novo, and it corresponds to a tonalitic body with an elliptical shape (15km long x 6km width) oriented sub-parallel to the regional Variscan foliation (WNW-ESE striking deformation fabrics) in the region. The tonalitic pluton intrudes mainly gneisses and migmatites, except in its northern boundary, where it contacts a prominent amphibolitic layer. To the west, Tertiary sediments cover both tonalites and country rocks.

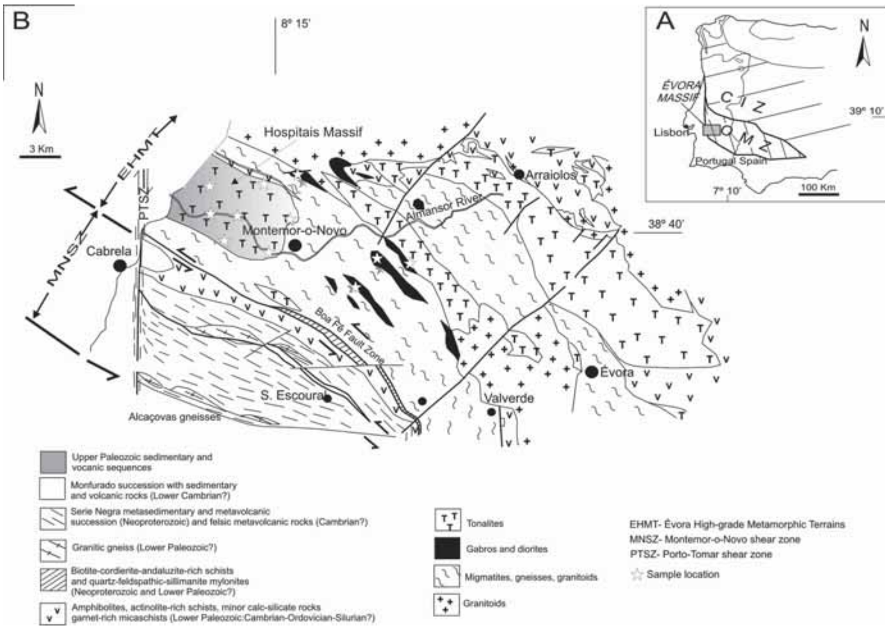

Fig. 1.- a) Geological sketch map of the Évora Massif located at the westernmost domains of the Ossa-Morena Zone (OMZ). b) Simplified geological map of the Évora Massif with the subdivision in two major tectonic units: the Évora high-grade Metamorphic Terrains (EHMT) and the Montemor-o-Novo Shear Zone (MNSZ), with location of tonalites from the Hospitais massif; After Pereira et al., 2003 (élocation of samples that were studied for geochemistry analysis by Moita et al., this volume)

Fig. 1.- a) Esquema geológico con la localización del Macizo de Évora en los domínios occidentales de la Zona de Ossa-Morena (OMZ). b) Mapa geológico simplificado del Macizo de Évora con la subdivisión en los Terrenos Metamórficos de Alto-grado de Évora (EHMT) y la Zona de Cizalla de Montemor-o-Novo (MNSZ), con la localización de las tonalitas del Macizo de Hospitais; Modificado de Pereira et al., 2003 (localización de las muestras analizadas en el estudio geoquímico por Moita et al., en este volumen).

Gabbroic rocks occur within the EHMT, as several WNW-ESE elongated bodies (Fig.1), intrusive in the gneissic-migmatitic complex. Their lengths usually fall between several hundred meters and few kilometres.

Field relations and Petrography

This work is focused on the following rock types: (1) tonalite, constituting the main lithology of the Hospitais Massif (HM); (2) leucotonalitic layers, locally intercalated in the former lithology; (3) microgranular dioritic enclaves hosted by the tonalite; (4) gabbros, forming small intrusions in the EHMT, but outside the Hospitais Massif.

Main tonalite

The dominant tonalite in the Hospitais Massif is monotonous, with small petrographic variation. Texturally, it is hypidiomorphic granular and shows medium to coarse grain size. A WNW-ESE foliation, defined by the alignment of mafic minerals (biotite and amphibole), is often observed (Fig.2). Concerning the mineralogy, the dominant phases in the tonalite are plagioclase (40-50%) and quartz (20-30%), whereas the ferromagnesian silicates do not exceed 20 to 30% of rock volume. The relative proportions of amphibole and biotite are quite variable from sample to sample: either one or the other may be the most important mafic phase. The most common accessory minerals are apatite, oxides, zircon and allanite.

Plagioclase has composition of andesine and forms subhedral grains (length: 2-4 mm) that commonly display either continuous or discontinuous complex zoning (Fig. 3A). Sometimes, these grains contain inclusions of sub-millimetric corroded plagioclase crystals. Another essential felsic mineral is quartz, whose grains are always anhedral with contours adapting to the forms of plagioclase, biotite and amphibole. Wavy extinction and/or subgranulation reveal that quartz was submitted to recovery processes.

Two types of amphibole - hornblende and cummingtonite, typically in close association (Fig. 3B)- may be found in the tonalite. Hornblende is systematically present and is one of the most important mafic phases, whilst cummingtonite occurs in a highly variable proportion between samples, from almost absent to 20-30% of total amphibole. Typically, amphibole grains are 2-4 mm long and have subhedral forms. When the two amphiboles are present, they associate to each other, with the hornblende rimming the cummingtonite. Occasionally, the biggest crystals of amphibole develop a poikilitic texture, including small euhedral and subhedral crystals of plagioclase, oxides and apatite. The other major mafic mineral – biotite - forms subhedral crystals, whose maximum length sometimes achieves 6 mm, and commonly envelops opaques and apatite.

Considering the accessory phases, their most significant features are the following: opaque minerals are commonly spatially related to the main mafic minerals, showing euhedral and subhedral shapes; apatite forms small (tenths of mm) euhedral prismatic crystals; zircon was almost always observed as euhedral grains with hundredths or tenths of mm; allanite was found only sporadically, as anhedral to subhedral grains hosted by amphibole or biotite.

Although primary minerals are usually well preserved in the collected samples, plagioclase may contain sericite, whereas biotite is occasionally replaced by chlorite plus epidote.

Leucotonalitic Layers

Locally, it is possible to observe some centimetric layers impoverished in mafic phases (Leucotonalitic Layers – LTL, Fig. 2B) that are commonly parallel or slightly oblique to the foliation, although they also can be seen, rarely, cutting that structure. Within these discordant layers, it is possible to identify an internal fabric defined by the alignment of undeformed grains of mafic minerals and feldspars.

At the two existing quarries in the Hospitais Massif, there is a vertical magmatic layering characterized by the alternation of (1) bands of particularly quartz-rich and mafic-poor tonalite, and (2) levels with modal composition similar to that of the main tonalite.

Mafic enclaves

Dark-coloured enclaves, displaying well-rounded outlines, ovoid forms and sharp limits, occur sparingly within the main tonalite. They show variable dimensions, from 2 to 40 cm long and from 0.5 to 6 cm wide, and represent, when present, a small percentage of the outcrop area: 1-2% and sometimes less. Mineralogically, all the studied enclaves show dominance of amphibole. Two petrographic groups based on the type of the amphibole, relative volume of ferromagnesian minerals and granularity were defined: *hornblendic enclaves* (HbE) and *cummingtonitic-hornblendic enclaves* (Cm-HbE).

The HbE enclaves are medium-grained (2mm) and have a hypidiomorphic granular texture. Modally, they may be classified as

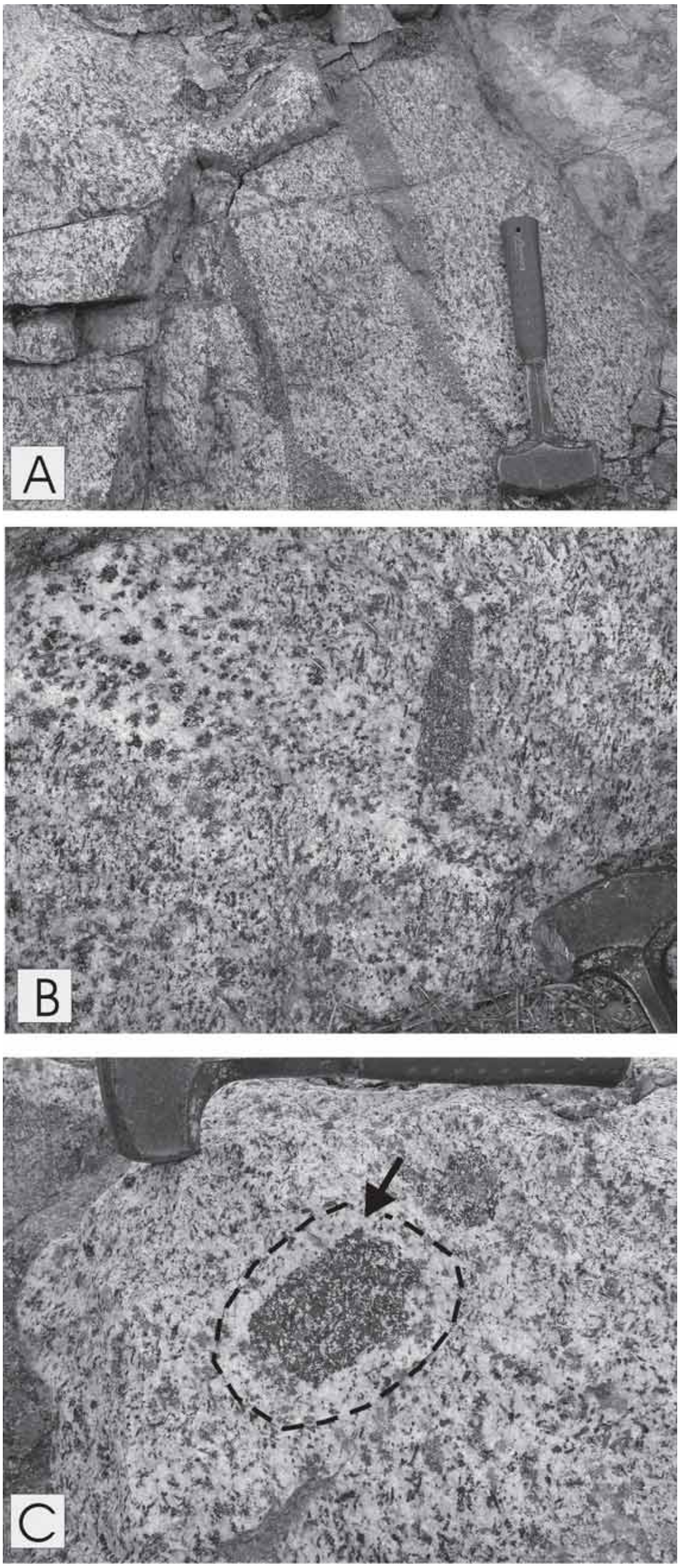

Fig. 2.- Field relations within Hospitais Massif: A) Elliptic flattened enclaves parallel with the main tonalitic foliation, B) Development of LTL, cutting the tonalitc foliation, C) Development of a LTH around the microgranular mafic enclave

Fig. 2.- Relaciones de campo en el Macizo de Hospitais: A) Enclaves elípticos y aplastados paralelos con la foliación principal de la tonalita, B) Desarrollo de LTL cortando la foliación de la tonalita, C) Desarrollo de LTH en el borde de un enclave diorítico contenido en las tonalitas.

diorites: hornblende is the most important mineral (40-50%), followed by plagioclase (30-50%) and quartz (5%). Cummingtonite is characteristically absent, but, sometimes, hornblende shows mimetic features (specially "ghosts" of a previous fine twinning) after the ferromagnesian amphibole. Hornblende occurs as euhedral/subhedral crystals (~ 2mm) occasionally containing plagioclase, apatite and opaque inclusions. When in contact with plagioclase, amphibole grains tend to adapt to the feldspar contours. Crystals of plagioclase (andesine-labradorite) typically exhibit subhedral forms and display complex continuous zoning. The oxide minerals have subhedral habit and, in some samples, reach 4-5% of the mode. In these enclaves, biotite occurs in small amounts, but it may show a poikilitic development. Quartz is anhedral with lamellar subgranulation.

The Cm-HbE enclaves are distinguished from the previous type mainly by (1) the significant amounts of both amphiboles (hornblende and cummingtonite), (2) the seriate texture with dominance of relatively small grains (<2mm) and (3) the systematic presence, as an accessory phase, of biotite. These enclaves have modal compositions typical of diorites or microdiorites, since plagioclase (50-60%) and amphibole (30-35%) are largely dominant. Quartz (~5%) and biotite (1-2%) are other significant phases, whilst opaques and apatite only occur in very small amounts. Plagioclase (labradorite) grains are anhedral and their dimensions vary from 0.5 to 1-2mm (rarely 4mm). The biggest crystals have concentric zoning - sometimes of complex nature - and diffuse twinning, in contrast with the sub-millimetric grains, which show well-defined twinning and minor zoning. In several cases, well developed plagioclase preserve cores that seem to have been reworked. Amphiboles are usually present in aggregates of small (usually, less than 250ìm in length) and irregularly shaped grains. In those sets of crystals, both hornblende and cummingtonite are present, in a proportion of approximately 60:40, and the ferromagnesian amphibole is confined to a central position. Biotite is a subordinate phase occurring as small and elongated grains; it is occasionally replaced by chlorite and epidote. The crystals of apatite, characteristically euhedral and elongated (axial ratios 3:1 - 5:1 and some acicular), are usually associated with the felsic minerals. Quartz is anhedral with lamellar subgranulation and opaques are manly associated with the felsic minerals.

Leucotonalitic halos

Surrounding the mafic enclaves it is sometimes possible to observe 1-3cm thick leucotonalitic halos (LTH) (Fig.2C). The grain size of the halo is similar to that of the *host* tonalite. The felsic minerals (plagioclase and quartz) strongly predominate, whereas the mafic phases (hornblende ± cummingtonite ± biotite) represent only 5% of the modal composition. Zircon occurs as an important accessory phase. Plagioclase shows complex and discontinuous zoning, as well as some deformation features like wedge twinning. The quartz is more abundant in the halos than in the surrounding tonalite and shows lamellar subgranulation.

Mafic rocks

Gabbros occur as small isolated outcrops with no direct contact with the HM. They are predominantly medium grained rocks with hypidiomorphic granular textures, but, in some cases, poikilitic textures developed. Brown hornblende (30-40%), clinopyroxene (20-30%) and plagioclase (30-40%) are the essential minerals, whilst opaques and apatite are the accessory phases. The amphibole commonly envelops the other primary minerals, especially plagioclase, and it may constitute oikocrysts (reaching 5mm). Pyroxene is present as isolated corroded nuclei (0.25-0.5mm) inside amphibole or as euhedral crystals (0.25-1mm) when associated with plagioclase. The grains of calco-sodic feldspar (labradorite-bytownite) are usually subhedral and variable in size: crystals inside hornblende are small, from 0.25mm to 0.5mm with round edges, while outside they may be up to 2mm long. Apatite constitutes anhedral grains, although sometimes elongated, reaching 0.5mm. The opaque grains have usually round contours and small dimensions, and are mainly included in amphibole. Comparatively with the others lithologies, the mafic rocks exhibit more often the development of secondary minerals, namely growth of sericite, inside plagioclase, and actinolite, at hornblende and pyroxene expenses.

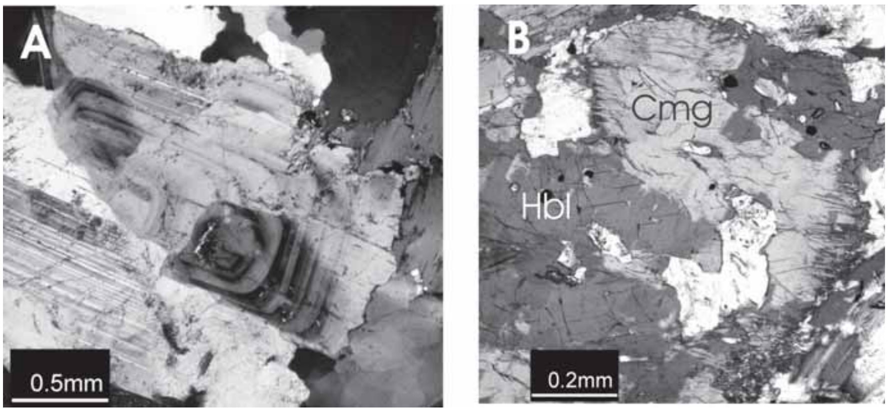

Fig. 3.- Photomicrographs showing some textural aspects of the main tonalite: A) Complex zoning of plagioclase, B) Common association of cummingtonite (Cmg) and hornblende (Hbl).

Fig. 3.- Microfotografías con aspectos texturales de la tonalita: A) Zonado complejo de plagioclasa, B) Asociación común entre cummingtonita (Cmg) y hornblenda (Hbl).

Conclusions

The Hospitais Massif is a Variscan syn-tectonic plutonic body that comprises medium-grained tonalites with leucotonalitic layers and microgranular enclaves. These enclaves have typical igneous compositions and are sometimes surrounded by hololeucocratic halos. Outside this massif, but in the same sector of the Évora High-Grade Metamorphic Terrains, several minor gabbroic syn-tectonic intrusions can be found. This spatial and chronological association suggests that the gabbros, the mafic enclaves and the different tonalitic facies may represent the primitive and intermediate terms of a cogenetic igneous suite, as will be discussed in the companion paper (Moita *et al*., this volume), formed during the Variscan orogeny.

The tonalites present magmatic fabrics associated with a moderately developed foliation, recording syntectonic crystallization and cooling, co-planar to steep foliations observed within the surrounding sheared gneisses and migmatites. Locally, it is possible to observe LTL commonly parallel or slightly oblique to the foliation with internal fabric defined by the alignment of undeformed grains of mafic minerals.

The enclaves display well-rounded outlines, ellipsoidal forms (with maximum axes sub-parallel to the foliation of tonalites) and sharp limits. These structural characteristics suggest that they were formed when the crystallization of the magma was not complete, but then they were affected by strain in a progressive deformation process. In fact, the fabric displayed by tonalites seems to be of magmatic origin and controlled by regional deformation since some microstructures developed on feldspars, biotite and quartz are possible to observe.

In some places, there are discordant LTL with an internal foliation oblique to the foliation of the main tonalite, implying that, at some point during the crystallization of the tonalite, tensional stress-originated fractures immediately replenished with the remaining magma, after which shearing continued to deform both lithologies.

Field relationships reveal that crystallization and cooling of the main tonalites and gabbros are synchronous with progressive shearing of the gneisses and migmatites envelope, with both intrusion and country rock showing steep fabrics sub-parallel to regional Variscan structures.

Acknowledgments

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