Crustal xenoliths from the Calatrava Volcanic Field: a petrofabric and geochronological study

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INTRODUCTION

Granulite-facies aluminous and anorthositic xenoliths occur, together with mantle-derived peridotite ones, sparsely distributed within volcanic rocks of the Calatrava Volcanic Field (Ciudad Real province, Spain; see also in this volume Sarrionandia et al.). The latter xenoliths were studied by Puelles et al. (2016 and references therein) providing relevant information on the deformation mechanisms, ambient conditions and seismic properties of the Central Iberian subcontinental mantle. The crustal granulite-facies xenoliths are less abundant and are by far less well known. Here we present new data on the petrofabric and age of constituent minerals for two types of crustal xenoliths from the La Encomienda volcano, obtained by means of electron backscatter difraction (EBSD) and laser ablation-ICP-MS methods, respectively, that may contribute to a better knowledge of the lower crust underlying the Calatrava area. Using IUGS criteria, the two types of xenoliths studied are felsic granulites as they carry less than 30 vol % mafic minerals. However, one type corresponds to aluminous granulite-facies rocks composed of K-feldspar, antiperthitic plagioclase, quartz, sillmanite, garnet, rutile, biotite and zircon as primary phases (Fig. 1), and another type corresponds to granulite-facies anorthosites composed of > 90 % plagioclase (labradorite), hypersthene, ilmenite, apatite and zircon. (Fig. 2).

Lattice Preferred Orientations (LPOs) of crustal xenoliths

The aluminous xenoliths bear a planolinear fabric. Plagioclase LPO (with a J texture index of 3.5) is characterized by point concentrations of {010} poles and [001] axes around the Z and X structural directions, respectively. This pattern concurs with activation of the [001](010) slip system, typical of amphibolite and granulite facies conditions. Similar patterns have been found for K-feldspar (J=6), indicating also slip on (010) planes along the c-axis direction. Quartz LPO shows a low texture index of 1.3, suggestive of a weak fabric. However, the obtained pattern displays an orientation distribution where multiple c-axis submaxima occur around the lineation, indicating activation of the m<c> intracrystalline slip system, described for rocks deformed under the granulite facies. Sillimanite (J= 1.7) also shows a distinct LPO (Fig. 1) with (100) and (010) poles close to the Z structural direction and [001] axes around the lineation. Since the intensity of the (010} pole maximum is the strongest, a plastic deformation by activation of the [001](100) slip system is suggested. This system has been detected in experimentally deformed sillimanite at temperatures between 500 and 900 ºC.

In the anorthositic xenoliths some grains show a weak shape-preferred orientation that permits the recognition of a faint foliation and lineation in the rock. Most of the grains are monocrystals with no evidence of internal deformation features. However, distinct LPO patterns have been registered in the main phases. Plagioclase (J= 5.6) presents a fair texture with {010} planes forming a wide girdle perpendicular to the lineation, [100] and [001] axes presenting several submaxima with a distinct point concentration close to the X structural direction. This might be in accord with dislocation glide on [001](010), accompanied by [100] (010) slip, typical of naturally deformed high-grade rocks. LPO patterns for hypersthene (J= 7.5) draw an incomplete girdle for the [010] axes along the YZ structural plane with a point concentration at a low angle to Z and a clear [001] axis maximum around the lineation. Though the typical LPOs in orthopyroxene indicate deformation on the [001](100) slip system, the current fabric suggests a dominant slip on the (010) plane along the [001] direction. This change in the active gliding plane from (100) to (010) has been explained due to the incorporation of aluminum into the crystallographic structure. This explanation is coherent with the high Al-content (> 6 wt % Al_2O_3) measured on this phase**.**

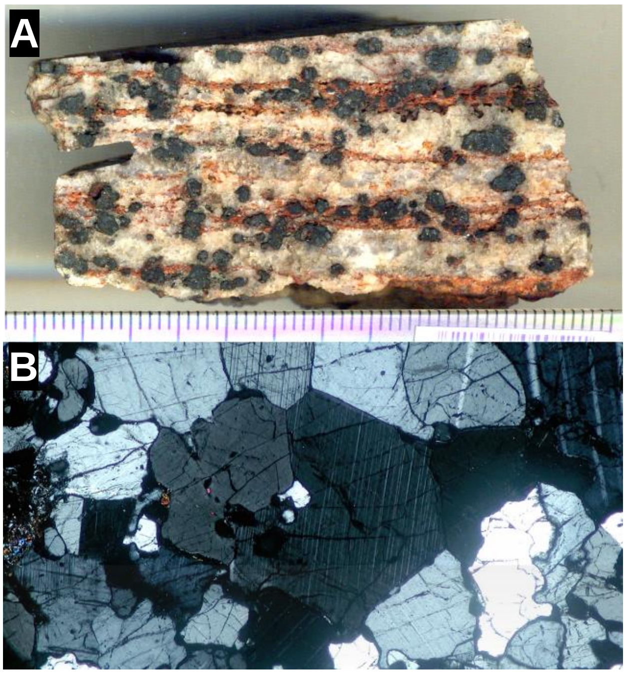

Fig 1. ***A:*** *Aluminous granulite-facies xenolith in hand sample depicting shape preferred orientation of garnet, sillimanite ± biotite ± rutile and feldspars.* ***B:*** *Granulitic anorthosite formed essentially by plagioclase (> 90 %) with triple junctions among labradorite crystals.*

U-Pb age results

Zircon and rutile from the two types of xenoliths have been analysed for U-Pb isotope composition by means of laser ablation-Q-ICP-MS methods. Rare zircons from the anorthositic xenoliths are small (50-100 µm), prismatic, idiomorphic and devoid of inherited cores with just minor zonings under BSE microscopy (Fig. 2A). 28 concordant data provided an age of ca. 309 ± 3 Ma which is interpreted as that of the igneous protolith of the granulitic anorthosite. Zircons are abundant in some aluminous granulitic xenoliths and practically absent in others. When present, they are very small in size (usually < 50 µm), subrounded and generally unzoned or poorly zoned with, in cases, inherited subidiomorphic cores or inner areas (Fig. 2B). The pattern of ages for these zircons is not clear, although most results cluster in the age range of 295-300 Ma which is interpreted as close to that of a regional metamorphic event under granulite-facies conditions. Two less well defined maxima are observed at ca. 575 and 420 Ma that might be related to the age of an igneous component of the protolith and that of a previous tectonothermal event, respectively. Finally, the U-Pb system of abundant rutiles in the aluminous granulite appears to have been completely reset during the volcanic activity since the great majority of age results cluster around 5 Ma, which is comprised within the known ages for the volcanism in the area and might be an indicator of that of the eruption at La Encomienda.

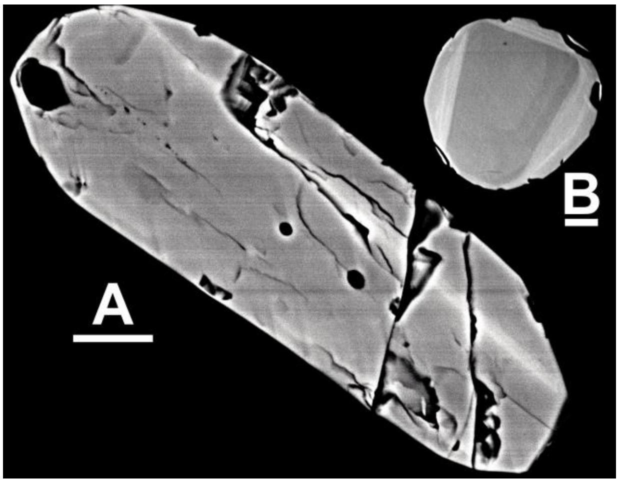

Fig 2. ***A:*** *Poorly zoned, prismatic zircon from granulitic anortholite.* ***B: R****ounded zircon with an inherited subidiomorphic core from aluminous granulite xenolith. La Encomienda volcano. Scale bar: 10 µm.*

CONCLUSIONS

Crustal xenoliths within volcanic rocks of the La Encomienda volcano in the Calatrava Volcanic Field are Variscan metamorphic rocks (aluminous granulites) derived from supracrustal protoliths and deep seated Variscan igneous anorthosites. The LPO patterns of the equilibrium mineral phases from both xenolith types permit us to unravel their operative intracrystalline systems and interpret they are tectonites deformed under the high-T amphibolite and granulite facies conditions (500-900 ºC)**.** The aluminous granulite-facies rocks bear many features in common with known occurrences of metamorphic rocks in high-grade areas elsewhere in the Iberian Massif, in particular with those from the Toledo area. They have been classically regarded as residual-rich rocks related to partial melting of the lower crust (precursors of the Variscan granitoids). The origin of the anorthositic granulite xenoliths is less clear and might attest to the participation of mantle-derived components during those melting processes.

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