Early Paleozoic rifting in the Ossa Morena Complex (SW Iberian Massif): geochemistry and geochronology of a pre-Variscan event in the Sierra Albarrana Domain and La Cardenchosa Pluton.

Rift Paleozoico temprano en el Complejo de Ossa Morena (SO del Macizo Ibérico): geoquímica y geocronología de un evento pre-Varisco en el Dominio de Sierra Albarrana y el Plutón de La Cardenchosa.

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Abstract: *Recognition of preorogenic geological features in the internal zones of polyorogenic areas, like the Sierra Albarrana Domain and La Cardenchosa Pluton, is difficult. New SHRIMP ages indicate that the main tectonomagmatic event recorded in these areas occurred between Late Cambrian (granite emplacement; 481±2 Ma) and Lower Ordovician (migmatization; 478±2 Ma). These ages also suggest that the intrusion of the igneous body is closely related with the low-pressure partial melting and the deformation of the structurally lower detrital formations. Geochemical data show that the granite from La Cardenchosa Pluton is peraluminous with a slight tendency towards an alkaline geochemical character, and a within-plate setting for the magmatism. Sr-Nd isotope data indicate an igneous origin with a strong upper crustal component, compatible with an extensional environment in the middle-upper crustal levels that marked the early stages of a continental rift development. These data are in agreement with the magmatism reported in other zones from the Iberian Peninsula, and are compatible with the latest magmatic event of the Early Paleozoic rifting. Our results, together with the main regional fabrics, suggest that the granitic magmatism and the migmatization are part of a single event, only slightly modified by Variscan reworking.*

Keywords: *Pre-Variscan event, Paleozoic rifting, Ossa-Morena Complex.*

Resumen: Reconocer los rasgos geológicos preorogénicos en las zonas internas de áreas poliorogénicas, como el Dominio de Sierra Albarrana y el Plutón de la Cardenchosa, es complejo. Nuevas edades U-Pb confirman que el principal evento tectonomagmático registrado en esta zona ocurrió entre el Cámbrico tardío (emplazamiento del granito; 481±2 Ma) y el Ordovícico inferior (migmatización; 478±2 Ma). También sugieren que existe relación entre la intrusión del cuerpo ígneo, la fusión parcial y la deformación a baja presión de las migmatitas de las formaciones detríticas estructuralmente inferiores. El granito de La Cardenchosa es peralumínico con tendencia alcalina y afinidad de intraplaca. Los datos isotópicos Sr-Nd indican un origen ígneo con una fuerte componente de la corteza superior, en un ambiente geodinámico compatible con un entorno extensional en los niveles corticales medios y superiores, que marcaron los momentos iniciales del desarrollo de un rift continental. Estos datos coinciden con el magmatismo descrito en otras zonas de la Península Ibérica y son compatibles con el último evento magmático del rifting Paleozoico. Nuestros resultados, junto con las principales fábricas regionales, sugieren que el magmatismo granítico y la migmatización son parte de un único evento, solo ligeramente modificado por la orogenia Varisca.

Palabras claves: Evento pre-Varisco, rift Paleozoico, Complejo de Ossa-Morena.

INTRODUCTION

Metamorphism, magmatism and the intense deformation that characterise the internal zones of collisional orogens produce important transformations in the rocks, hindering the recognition of the pre-orogenic history. Specific zones of the Ossa-Morena Complex (OMC; Iberian Massif; e.g. Díez Fernández et al., 2016) preserved many pre-Variscan igneous intrusions revealing a complex magmatic evolution, marked by the so called Early Paleozoic rifting (535–460 Ma), which includes a late Cambrian-Early Ordovician magmatic event (490-460 Ma; e.g. Sánchez-García et al., 2019; and references therein).

In this study, we use geochemical and isotopic data of migmatitic and granitic rocks, field relationships and new U-Pb SHRIMP ages to expand the existing information (Azor et al., 2012; 2016) and bear out that the Sierra Albarrana Domain is a polyorogenic terrane.

GEOLOGICAL SETTING

This study focuses in the Sierra Albarrana Domain (SAD) and the intrusive body of La Cardenchosa Pluton (LCP). Both are located in the Ossa-Morena Complex (OMC). The Sierra Albarrana is a mountainous alignment representing an elongated thermal dome with an NW-SE directed anticlinorium; it is dominated by metasediments (Insúa et al., 1990) that can be divided in: (i) Sierra Albarrana Group, made up of platformal metapelites and quartzites, and (ii) the Azuaga Formation, formed by turbidite deposits (López-Guijarro et al., 2008) and whose metamorphic grade decreases rapidly upwards. LCP intrudes the SAD and is an NNW-SSE elongated sigmoidal body of more than 10 Km long following the regional structural trend. It has two main granitic facies: (i) very coarse-grained and porphyritic in the centre and (ii) albitized leucogranite towards the margin of the body. Magmatic crystallization age is 478–480 Ma (Azor et al., 2016).

ANALYTICAL RESULTS

Whole rock geochemistry

Chemical analyses of whole-rock major, minor and trace elements were carried out at ACTLABS Laboratory (Canada).

For the major elements, the coarse-grained granites facies of LCP show high K_2O contents (> 5.0 wt %) and moderate Na_2O (2.16–4.28 wt %). The albitized leucogranite show remarkable lower K_2O content (< 1.0 wt %). Migmatites from the SAD show high K_2O (> 3.0 wt %) and moderate Na_2O (2.69–3.28 wt %) contents. According to the classification diagrams of Frost et al. (2001), the granites are ferroan, alkali-calcic to alkalic (Fig. 1) and peraluminous. The albitized leucogranite is magnesian, calcic and also peraluminous. Migmatites are plotted in the magnesian, alkali-calcic and peraluminous fields. Chemical analyses from Garrote and Sánchez Carretero (1979) and Insúa et al. (1990) have been included in the diagrams to compare with ours results.

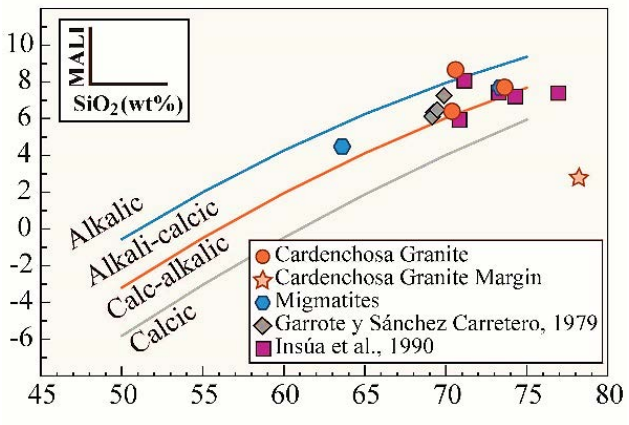

FIGURA 1. MALI vs. SiO_2 wt.% (Frost et al., 2001) *modified alkali-lime index = (Na_2O+K_2O-CaO).*

In the tectonic setting discrimination diagrams for granitic rocks (Pearce et al., 1984) for trace elements, the samples from the central part of LCP are drawn consistently in the Within-Plate Granites field (WPG). However, the samples from the western margin are very close to the boundary between WPG and Syn-Collisional or Volcanic-Arc Granites.

Chondrite-normalized rare earth element (REE) diagrams (McDonough and Sun, 1995; Fig. 2) show an enrichment in LREE and a planar trend for the coarse-grained facies. HREE keeps a decreasing trend from the centre to the border of the pluton, with slightly fractionated patterns [$(La/Lu)_n$]. The fractionation is higher in LREE [$(La/Sm)_n$] than in HREE [$(Gd/Lu)_n$]. Regarding Eu anomalies, two samples of the porphyritic granite show a similar pattern and moderate negative values with a similar Eu/Eu relation (~0.33), suggesting a feldspar fractionation in the source. A sample, taken near the border, has an intriguing negative Eu anomaly with an Eu/Eu* value of 0.23, a little lower than that for samples from the central zone of the pluton. The albitized leucogranite has a marked positive anomaly and a high Eu/Eu* value (8.54). REE contents dramatically decreases from the central zone of the intrusion (ΣREE = 226.35–386.81) to the margin (44.35), the lowest value (5.88) is reached in the border.*

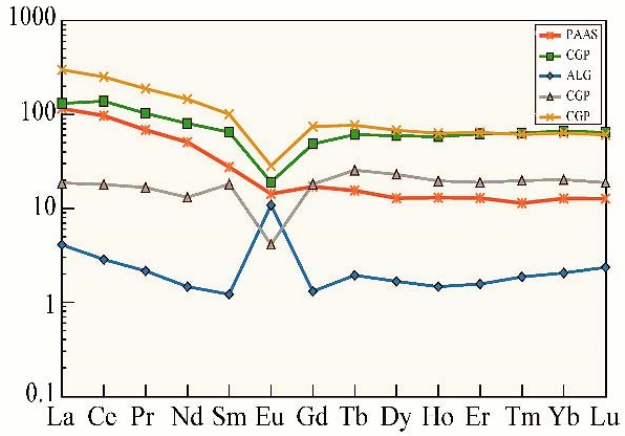

FIGURA 2. Chondrite normalize REE diagram for granites. Normalization values of McDonough and Sun (1995). CGP: coarse-grained porphyritic; ALG: Albitized leucogranite (PAAS=Post Archaen Australian Shale).

Sr-Nd Isotopic Signatures

Sr and Nd isotope analyses were performed at the Geochronology and Isotope Geochemistry Service of the Complutense University of Madrid, using Thermal Ionization Mass Spectrometry (TIMS). The reference age for the calculation of the εNd and $^{87}Sr/^{86}Sr$ values is 487 Ma.

LCP have a similar isotopic composition for $^{87}Sr/^{86}Sr$ and plot in the continent crust field (Fig. 3). Nd isotopic compositions are negative for all samples and range between -2.9 and -6.4. Leucosomes from the SAD have a very similar isotopic composition for $^{87}Sr/^{86}Sr$ and plot in the continent crust field (Fig. 3). Nd isotopic compositions are negative and between -8.5 and -10.3.

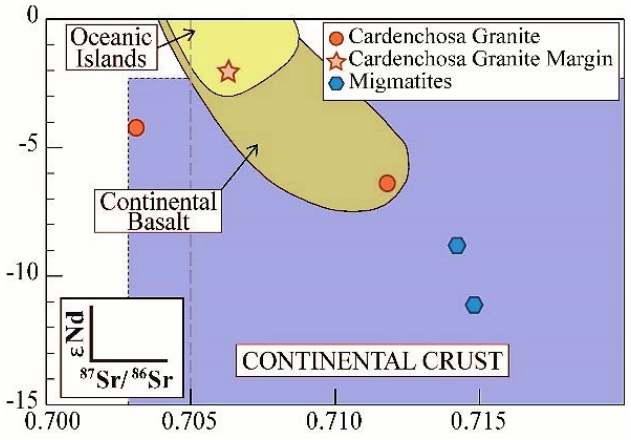

FIGURA 3. εNd vs. $^{87}Sr/^{86}Sr$ diagrama.

U-Pb Geochronology

The analyses were performed at the IBERSIMS Laboratory (University of Granada), equipped with a sensitive high-resolution ion microprobe (SHRIMP). Each selected spot is rastered with the primary beam for 120 s prior to the analysis, and then analysed 6 scans. The primary beam, composed of $^{16}O^{16}O^-$, is set to an intensity of about 5 nA, with a 120 microns Kohler aperture, which generates 17 x 20 µm elliptical spots on the target. The secondary beam exit slit was fixed at 80 microns.

Fourteen zircons from LCP (60-170 µm) are idiomorphic crystals with characteristic textures of magmatic zircons from acid igneous rocks. They provide concordant analyses yielding a robust age of 481 ± 2 Ma (MSWD = 0.59), interpreted as the age of magmatic crystallization. Zircon crystals from the migmatitic leucosomes (Cabril-Peña Grajera Sequence) have frequent homogeneous overgrowths (< 30 µm) with low Th/U ratios (0.00 to 0.07), suggesting metamorphic recrystallization. Ten concordant analyses gave an age of 478 ± 2 Ma (MSWD = 0.15), that is interpreted as the age of migmatization.

CONCLUSIONS AND DISCUSSION

LCP is a peraluminous granite with a tendency to an alkaline geochemical character. The tectonic discrimination diagrams point to a within-plate setting for the magmatism. The Sr and Nd data indicate an igneous origin with a strong upper crustal component. The most compatible geodynamic setting is an extensional environment in the middle-upper crustal levels, marking the initial stages of a continental rift development.

Considering a possible correlation between the SAD and the autochthonous Central Iberian Zone (Díez Fernández et al., 2016), the magmatism in both domains has been compared. However, the geochemical characteristics of the subalkaline rift-related rocks of the OMC and the Central Iberian Zone partly overlap in the discrimination diagrams (Fig. 4; Sánchez-García et al., 2019). Hence, it is no possible to discriminate between them and favour a correlation only based on the magmatic geochemical affinities.

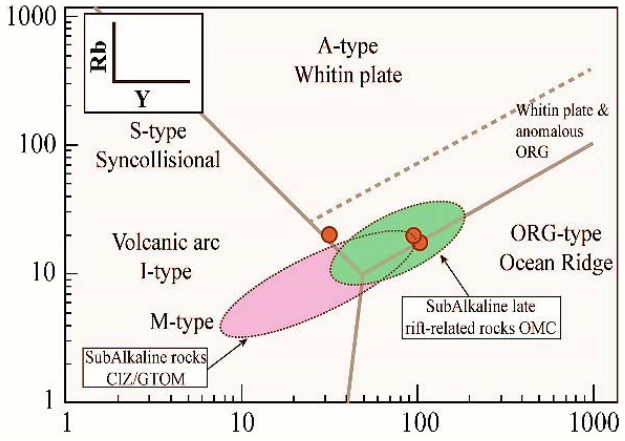

FIGURA 4. Nb vs. Y (Pearce et al. 1984) including a comparison with late rift-related granites in the OMC, Central Iberian Zone (CIZ) and Galicia–Tras-os-Montes (GTOM). (modified from Sánchez-García et al., 2019).

The new U-Pb SHRIMP data presented in this study for LCP emplacement, 481 ± 2 Ma, confirm the previous ages from Azor et al. 2016, and gives a more robust framework for the interpretation of the tectono-metamorphic evolution of the SAD. The metamorphic ages obtained in the migmatitic gneisses of the lower sequences of the SAD are slightly younger than the granite emplacement, although both can be considered similar ages within error (478 ± 2 Ma; Fig. 5), and are in agreement with those obtained by Azor et al. (2012).

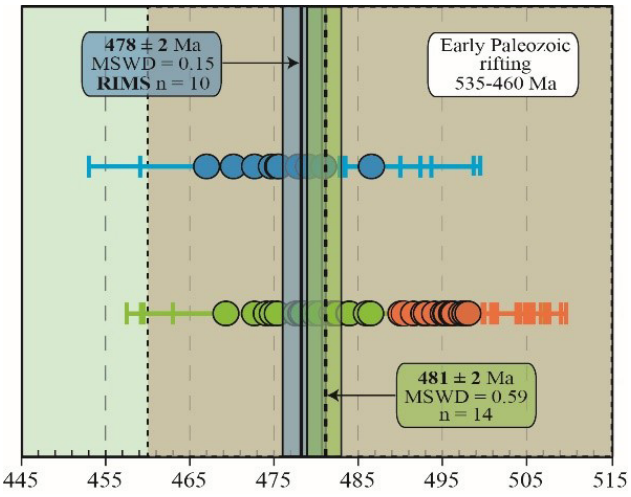

FIGURA 5. Comparison of ages (Ma) in the SAD.

Our interpretations are based on the new data, combined with the following field observations: (i) the preserved contacts of the granite with the wall-rocks indicate cross-cutting relations with the regional metamorphic fabric, (ii) the external contact aureole developed in the west and

south contacts of the pluton produce a recrystallization of the metamorphic minerals that define the regional foliation and (iii) the metamorphic grade decreases dramatically upwards in the sequence, but maintains the structural pattern of the regional foliation suggesting a common origin for the high- and medium- to low-grade regional foliation. We propose that the regional metamorphic fabrics of the SAD are pre-Uppermost Cambrian and, accordingly, the granitic magmatism, the migmatization and the main regional fabrics are part of a single Cambrian-Ordovician event only slightly modified by Variscan reworking.

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