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Rift-related volcanism predating the birth of the Rheic Ocean (Ossa-Morena zone, SW Iberia)

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ABSTRACT

Two very different periods of magma emplacement in the crust of the Ossa-Morena zone (early and main events) in SW Iberia have been previously interpreted to record a Cambrian/Early Ordovician rifting event that is thought to have culminated in the opening of the Rheic Ocean during the Early Ordovician. New stratigraphic, petrographic, geochemical and Sm–Nd isotope data from Cambrian volcanic rocks included in six key low-grade sections in both Portugal and Spain considerably improve our understanding of these events. These data: (1) confirm the existence of two rift-related magmatic events in the Cambrian of the Ossa-Morena zone, (2) demonstrate that the early rift-related event was associated with migmatite and core-complex formation in the mid-upper crust and is represented by felsic peraluminous rocks, the parent magmas of which were derived mainly from crustal sources, and (3) show the main rift-related event to be represented by a bimodal association of felsic and mafic rocks with minor amounts of intermediate rocks. Some of the mafic rocks show N-MORB affinity, whereas others have OIB or E-MORB affinities, suggesting different heterogeneous mantle sources (depleted and enriched, asthenospheric and lithospheric, plume-like and non-plume-like). The acid and intermediate rocks appear to represent hybrid mixtures of crust and mantle-derived magmas.
This new data supports the hypothesis that the onset of rifting was associated with a process of oblique ridge-trench collision. We interpret the significant differences between the early and main events as reflecting the evolution from a wide rift stage with passive extension mainly accommodated by lower-crust flow in a high heat-flow setting, to a narrow rift stage with active extension characterized by extension rates that outpaced thermal diffusion rates.

1. Introduction

Two events played crucial roles in the evolution of the Iberian Massif during the Paleozoic. The first of these was a Cambrian/Early Ordovician rifting event, which was largely responsible for the compartmentalization of the Paleozoic Iberian autochthonous margin of Gondwana and consequent paleogeographic and lithotectonic differences between the Cantabrian, West Asturian-Leonese, Central Iberian, and Ossa-Morena zones (Fig. 1) (Liñán and Quesada, 1990; Quesada et al., 1991; Quesada, 1991; Sánchez-García, 2001; Sánchez-García et al., 2003; Quesada, 2006; Quesada et al., 2006; Sánchez-García et al., 2008a). This rifting event is interpreted as having culminated in the sequential opening of the Rheic Ocean by the Early Ordovician (Quesada, 1991; Sánchez-García et al., 2003, 2008a; Fernández et al., 2008). The second event was the Variscan orogeny, which was caused by continental collision following the closure of the Rheic Ocean and is responsible for the deformation of the Paleozoic Iberian margin of Gondwana and the present geometrical arrangement of units (Fig. 1) (Ribeiro et al., 1990; Quesada et al., 1991; Quesada, 1991; Quesada et al., 2006; Quesada, 2006).

Previous to these Paleozoic events, the geodynamic evolution of northern Gondwana was characterized by a period of arc growth and accretion to the continental margin during the Ediacaran (Cadomian orogeny). This process had come to a fairly abrupt halt by the Early Cambrian, when the margin, including parts of the previously accreted Cadomian-Avalonian arc (Quesada, 1991; Nance et al., 2002; Sánchez-García et al., 2003; Murphy et al., 2006; Pereira and Quesada, 2006; Pereira et al., 2006; Sánchez-García et al., 2008a), started to undergo differential uplift and erosion together with a cessation of subduction-related magmatism. This was followed by an onset of extensional deformation, which was responsible for crustal thinning with compartmentalization into subsiding (graben) and more stable (horst) domains (Liñán and Quesada, 1990). At the same time mantle upwelling triggered rift-related igneous activity, which reached its maximum expression in Iberia within the Ossa-Morena zone (Sánchez-García et al., 2003, 2008a). This evolution from subduction/arc growth to continental

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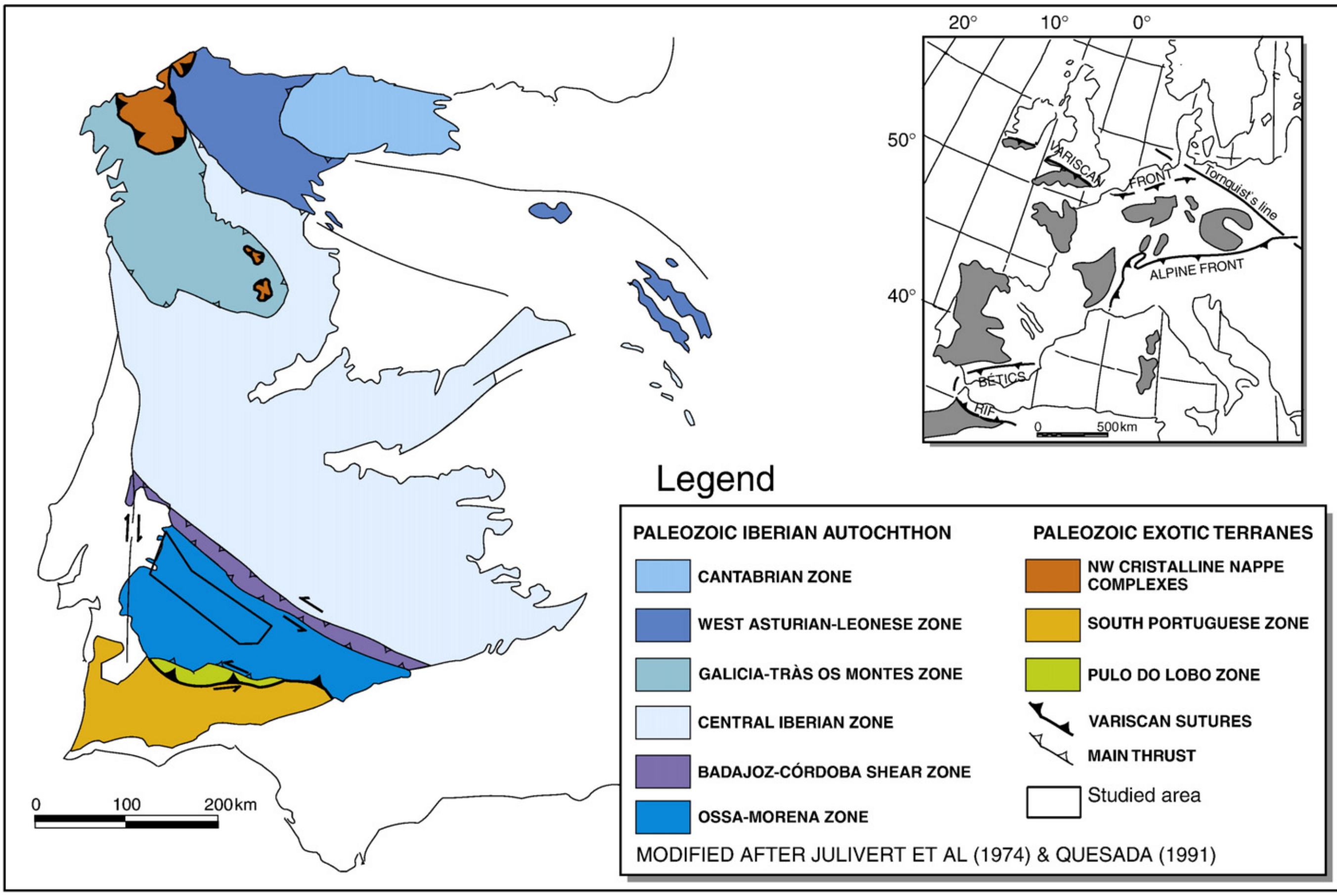

Fig. 1. Zonal division of the Iberian massif, modified according to Julivert et al. (1974) and Quesada (1991).

rifting is believed to have been associated with a process of ridge-trench collision, followed by the development of a slab window, which eventually led to the opening of a brand new oceanic tract (the Rheic Ocean) and drifting of a terrane (Avalonia?) consisting mainly of a part of the previously accreted Ediacaran arc (Nance et al., 2002; Sánchez-García et al., 2003; Pereira et al., 2006; Pereira and Quesada, 2006; Murphy et al., 2006; Sánchez-García et al., 2008a; Nance et al., 2010-this volume). A model similar to the present collision of the East Pacific rise with the Pacific margin of North America, which is leading to the opening of the Gulf of California and the separation of the Baja California peninsula, would be broadly applicable (Sánchez-García et al., 2003; Lizarralde et al., 2007; Sánchez-García et al., 2008a).

Our research group has already published general descriptions of the sedimentary, structural and magmatic expression of the Cambrian/Early Ordovician rifting in the Ossa-Morena zone (Sánchez-García et al., 2003; Quesada, 2006; Pereira et al., 2006; Pereira and Quesada, 2006; Chichorro et al., 2008; Sánchez-García et al., 2008a,b). However, a precise understanding of the various elements has still not been arrived at and this is particularly true of the igneous rocks. The main factors contributing to this gap in our knowledge relate, on the one hand, to the heterogeneity of rock types (plutonic, subvolcanic and volcanic), rock compositions (from acid to basic; calc-alkaline, tholeiitic, alkaline and peralkaline) and apparent magma sources (asthenospheric, lithospheric and crustal) and, on the other hand, to the complex and varied Variscan deformation and metamorphic history of the different fault-bound structural units that currently make up the Ossa-Morena zone. Within this context, making correlations between low-grade and high-grade units (locally migmatitic) becomes particularly difficult.

Outcropping low-grade crustal segments in the Ossa-Morena zone contain both volcanic and shallow plutonic rocks, which, according to their relationship with coeval sedimentary successions, can be assigned to one of two periods of magma emplacement: (1) an early rift-related igneous event comprising felsic peraluminous rocks and associated with migmatite formation during the development of core-complex structures in mid- to upper-crust environments, and (2) a main rift-related igneous event, which produced predominantly basaltic and felsic (rhyolite) rocks and minor amounts of intermediate (trachyte) rocks (Sánchez-García et al., 2003, 2008a). Tholeiites and alkaline rocks predominate in this suite but minor calc-alkaline peraluminous compositions are also present (Sánchez-García et al., 2008a).

We concentrate here on the stratigraphic, petrographic, geochemical and isotopic correlation of the mainly Cambrian volcanic components of the two rift-related igneous sequences that cut through some key structural units in the Ossa-Morena zone in both Portugal and Spain. We chose six low-grade key sections to characterize the Cambrian volcanic record of the northeastern Alentejo and the southern flank of the Olivenza-Monesterio antiform: the Alter do Chão-Elvas, Assumar and Ouguela sections in Portugal, and the Alconchel, Jerez and Segura de León sections in Spain (Figs. 2 and 3).

2. Cambrian volcanic rocks of the Ossa-Morena zone

2.1. Stratigraphy

The Cambrian succession in the various (low-grade) structural units of the Ossa-Morena zone rests unconformably upon a previously deformed Ediacaran basement [mainly the so-called Serie Negra (Alía, 1963)]. It consists of both sedimentary and volcanic rocks, and includes considerable variation in both the facies and their thickness from unit to unit. Despite these variations, the sedimentary successions in most of the structural units are made up of four components, in ascending stratigraphic order (Fig. 3): a lower detrital formation (LDF), a detrital-