Peralkaline and alkaline magmatism of the Ossa-Morena zone (SW Iberia): Age, source, and implications for the Paleozoic evolution of Gondwanan lithosphere

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ABSTRACT

The Ossa-Morena zone in SW Iberia represents a section of the northern margin of West Gondwana that formed part of a Cordilleran-type orogenic system during the Neoproterozoic (Cadomian orogeny). The crustal section in this zone preserves the record of rifting that led to the opening of the Rheic Ocean in the early Paleozoic and the collision of Gondwana and Laurussia in the late Paleozoic (Variscan orogeny). We present U-Pb zircon data from three alkaline to peralkaline syenites that intruded Neoproterozoic and Cambrian strata and give crystallization ages ranging between ca. 490 Ma and 470 Ma. Lu/Hf isotopic data from these zircons give positive initial ε_{Hf} values ($0 \leq \varepsilon_{Hf(t)} \leq +11.5$) that approach the model values for the depleted mantle at the time of crystallization. This suggests that a significant proportion of the magma was derived from the mantle, with limited mixing/assimilation with crustal-derived melts. Alkaline/peralkaline magmatic suites of similar age and chemical composition intruded other sections of the northern margin of West Gondwana and along the boundaries of the continental blocks that today make up Iberia. These blocks are further characterized by the presence of high-pressure metamorphic belts that formed during accretion and subsequent collision of peri-Gondwanan domains against Laurussia during the Devonian and Carboniferous (Variscan orogeny). Our U-Pb and Lu-Hf data set indicates that during the Cambrian–Ordovician transition, lithosphere extension reached a stage of narrow intracontinental rifting, where deeply sourced magmas, probably coming from the lower crust and/or the upper mantle, intruded continental upper crust across various sections of previously stretched crust. We propose that necking of the Gondwana lithosphere into several continental microblocks with fertile mantle beneath them compartmentalized extension (multiblock model), which favored the onset of early Paleozoic peralkaline and alkaline magmas. The boundaries of microblocks represent zones of inherited crustal weakness that were later reactivated during the late Paleozoic as major accretionary faults related to the amalgamation of Pangea during the Variscan orogeny. Our dynamic model provides an explanation for the unusual spatial relationship between peralkaline and alkaline igneous provinces (usually shallow in the crust) and the occurrence of high-pressure rocks. Our observations suggest that Cordilleran-type orogens subjected to extension after long-lived subduction can develop wide continental platforms that feature multiple continental blocks. In addition, the formation of sequenced high-pressure belts in collisional orogens can be explained as the ultimate consequence of multiple necking events within continental lithosphere during previous collapse of a Cordilleran-type orogen.

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INTRODUCTION

Peralkaline and alkaline magmatism is most commonly associated with lithospheric extension (Fitton and Upton, 1987, and references therein), although it does occur less commonly in some intraplate settings (Clague, 1987; Fitton, 1987; MacDonald et al., 1987) and along some convergent plate margins where partial melting occurs in the deeper parts of subduction zones (Barker, 1987). Peralkaline and alkaline magmatism also occurs in a variety of other tectonic settings, including: continental rifts (e.g., the East African Rift—Peccerillo et al., 2007), hotspots (e.g., Canary Islands—Sumner and Wolff, 2003), island arcs (e.g., Miyakejima volcano in Japan—Macdonald, 2012; Mayor Island in New Zealand—Houghton et al., 1992; New Guinea—Zirakparvar et al., 2013), and collisional orogens that undergo postcollisional delamination, which may produce within-plate alkaline magmatism (Bonin, 2004).

Furthermore, it is relatively common for active plate margins to switch from subduction-related calc-alkaline magmatism to extensional alkaline magmatism. Tectonic mode switching occurs either after the cessation of subduction or during slab rollback, and it results in extension in the upper plate (James and Henry, 1991; Collins, 2002; Touil et al., 2008; Rey and Müller, 2010).

Despite the numerous petrogenetic models that have been used to explain the anomalous composition of peralkaline rocks and their relationship with basaltic magmas, there is a general agreement that deeply sourced fluids play a significant role in the formation of peralkaline silicic rocks (Collins et al., 1982; Whalen et al., 1987; Eby, 1992; Bonin, 2007). Most models fall between two end-member hypotheses. The first suggests derivation from continuous fractional crystallization from basaltic magmas, possibly with crustal contamination (Barberi et al., 1975; Civetta et al., 1998; Peccerillo et al., 2003), whereas the second proposes a mantle origin for the basaltic liquid and a crustal source for the silicic rocks (i.e., old crust or underplated mafic crust; Davies and MacDonald, 1987; Black et al., 1997; Trua et al., 1999). Peralkaline granitoids, particularly syenites, are very rare at lower-crustal depths, and most of their occurrences are located at the subvolcanic level (Macdonald, 2012). They are commonly associated with normal faults and typically form ring complexes beneath calderas (Anderson, 1936;

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