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Chronological link between deep-seated processes in magma chambers and eruptions: Permo-Carboniferous magmatism in the core of Pangaea (Southern Pyrenees)

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ABSTRACT

In the Southern Pyrenees there are Upper Carboniferous–Lower Permian sedimentary basins with a significant volume of volcanic material derived from explosive eruptions (rhyolitic ignimbrites and andesitic flows). These basins are spatially associated with granodiorites and dacitic dykes emplaced in Variscan basement rocks. U–Pb SHRIMP dating of zircons extracted from three granodiorites, an andesitic flow, a dacitic dyke and six ignimbrites, revealed that magmatism occurred over an extended period of thirty eight million years, from ca. 304 Ma to ca. 266 Ma (Upper Carboniferous–Middle Permian). A scattering of zircon ages in each sample shows that the history of melt crystallization was complex, with more than one zircon-forming event in each magma chamber. The prolonged crystallization history was transferred to the product of the eruptions. A chronological link between the deep-seated magma chambers and processes in eruptions was identified on the basis of four overlapping intervals at: ca. 309–307 Ma (Upper Carboniferous), ca. 304–296 Ma (Upper Carboniferous–Lower Permian), ca. 294–282 Ma (Lower Permian), and ca. 276 Ma (Lower Permian). The variation of zircon U/Th ratios exposes a tendency for an increase in mafic sources as crystallization advances in the Permian. Zircons probably crystallized from melt phases related to both a felsic-intermediate metaluminous source from ca. 310–293 Ma (mostly $0.1 < Th/U < 0.6$) to ca. 289–273 Ma (especially in the range $0.6 < Th/U < 1$) and a mafic source (mostly $1.2 < Th/U < 1$) at ca. 266–265 Ma. U–Pb zircon ages from volcanic and plutonic rocks of the Southern Pyrenees are consistent with the ages of the post-Variscan magmatism of Iberia associated with orocline generation and subduction of the Paleotethys Ocean (ca. 304–283 Ma), and in addition reveal a later magmatic event at ca. 276–266 Ma (Lower–Middle Permian). The location of the Iberian orocline in the core of Pangaea and near the western end of the subduction zone of the Paleotethys Ocean leads to the hypothesis that this later magmatic activity of the Southern Pyrenees could provide the missing link between the Variscan and Cimmerian cycles that acted sequentially in Permo-Carboniferous times.

1. Introduction

Caldera-forming eruptions represent the culmination of a long-lasting geological process involving the generation of magma at depth, magma ascent and differentiation, and finally eruption on the earth's surface. Beneath the volcanic successions and the eruptible caps of evolved magmas, geophysical methods have enabled imaging of vertically extensive magmatic systems affecting the whole crust and even extending into the mantle (e.g. Miller and Smith, 1999; Masturyono et al., 2001; Zandt et al., 2003). However, the identification of plutons as fossil subvolcanic magma is not always straightforward. Significant discrepancies between rates of magma replenishment in batholiths and rates of magma production in large ignimbrite flare-ups have been reported (e.g. Glazner et al., 2004; Sparks et al., 2008). However, these comparisons are biased towards the volcanic record, and there is a lack of detailed geochronology studies of magma chambers and eruptions with a view to constructing realistic models for magma dynamics in the continental crust.

The emplacement of silicic magma within the shallow continental crust marks the final stage in magma chamber formation. The way in which magma accumulates in the shallow crust has been a subject of debate during recent decades (Wickham, 1987; Petford et al., 1993, 2000; Petford and Clemens, 2000). The problem is particularly acute where large batholitic volumes (ca. 100 km^3) of magma are considered to have been emplaced in a single episode, often explained as

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