Lithos 111 (2009) 156–167

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

U–Th–Pb SHRIMP ages and oxygen isotope composition of zircon from two contrasting late Variscan granitoids, Nisa-Albuquerque batholith, SW Iberian Massif: Petrologic and regional implications

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ARTICLE INFO

Article history:
Received 29 February 2008
Accepted 27 March 2009
Available online 14 April 2009

Keywords:
SHRIMP
Zircon
Oxygen isotopes
Granite magma genesis
Iberian Massif
Variscan

ABSTRACT

The late Variscan Nisa-Albuquerque batholith in the SW Iberian Massif, consists of a dominant very coarse-grained porphyritic S-type monzogranite to syenogranite (Nisa monzogranite) surrounding a discontinuous central core that includes contrasting very fine-grained I-type tonalite–granodiorite (Aldeia da Mata tonalite). The batholith is located at the boundary between the Central Iberian and Ossa-Morena Zones, a complex segment of crust that was subject to both Cadomian and Variscan tectonism. Variscan zircons in the Nisa monzogranite can be broadly classified into three texturally and chemically distinct types with mutually indistinguishable SHRIMP $^{206}Pb/^{238}U$ ages: 1) high-U, low-Th/U (<0.1) outermost overgrowths (307.4 ± 4.0 Ma); 2) moderate U and Th/U zircon with concentric zoning occurring both as inner overgrowths and whole grains (305.4 ± 6.2 Ma)";; and 3) texturally discordant cores (309.0 ± 4.6 Ma). Many other cores have ages in the ranges 2.56–1.85 and 0.66–0.51 Ga. The overgrowths and Variscan cores with low Th/U have uniformly high $\delta^{18}O$ (9.5 ± 0.2‰). Variscan cores with moderate Th/U have a wide range of $\delta^{18}O$ (6.7–10.9‰). Cores older than 500 Ma have an even wider range of composition (4.4–10.0‰). Zircon from the central Aldeia da Mata tonalite, in contrast, contains no inherited cores, has moderate to high Th/U (0.5–1.8), and is uniform in $^{206}Pb/^{238}U$ age (306.2 ± 3.0 Ma) and $\delta^{18}O$ (7.4 ± 0.3‰). The zircon in the Nisa monzogranite records a history of magma genesis involving mixing between 1) a metaluminous magma progressively contaminated by a small sedimentary component, and 2) a more voluminous peraluminous magma originating from a largely metasedimentary source. The inherited zircon age pattern closely matches the age pattern of detrital zircon in early Paleozoic sediments from North Africa. The zircon in the Aldeia da Mata tonalite records nothing of the age of the magma's source rocks, but the moderately high $\delta^{18}O$ does preclude derivation of the magma directly from the mantle. Both the chemical and isotopic compositions of the tonalite zircon make it highly unlikely that the tonalite magma was a component in the monzogranite magma mixture.

1. Introduction

Precise dating of granites associated with orogenic processes, and studies of their petrogenesis, are essential to understanding the overall evolution of continents. The Iberian Massif represents a large segment of the European Variscan Belt (e.g., Ribeiro et al., 1990), interpreted to have formed during Early Devonian to Carboniferous oblique continental collision (e.g., Matte, 1986, 1991). One of the important features of the Iberian Massif is the huge volume of granitic rocks, particularly in the innermost domains (Central Iberian Zone, Fig. 1A). Most of the Central Iberian Zone granitoids are related to the post-collisional stage (D_3) of the Variscan deformation (e.g., Ferreira et al., 1987). Several granitoids have been dated isotopically by means of Rb–Sr, K–Ar and/or ID-TIMS U–Pb (e.g., Pinto et al., 1987; Dias et al., 1998; Neiva and Gomes, 2001; Valle Aguado et al., 2005). According to their emplacement ages and relationships to late deformation, the granitoids have been classified as syn-D_3, late-D_3, late- to post-D_3 and post-D_3 (Ferreira et al., 1987; Dias et al., 1998), or syntectonic to late-tectonic (c. 336–304 Ma) and post-tectonic (c. 300–280 Ma) granites (Neiva and Gomes, 2001) respectively. Sometimes this classification conflicts with other geological evidence, however (Dias et al., 1998; Zeck et al., 2007). This, as well as the known limitations of Rb–Sr and K–Ar isotopic systems (e.g. low closure temperatures) and also ID-TIMS zircon U–Pb dating (e.g. susceptibility to inheritance and radiogenic Pb loss) (Zeck et al., 2007 and references therein) has prompted us to measure the ages of granitoids from a late-tectonic

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0024-4937/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.lithos.2009.03.045

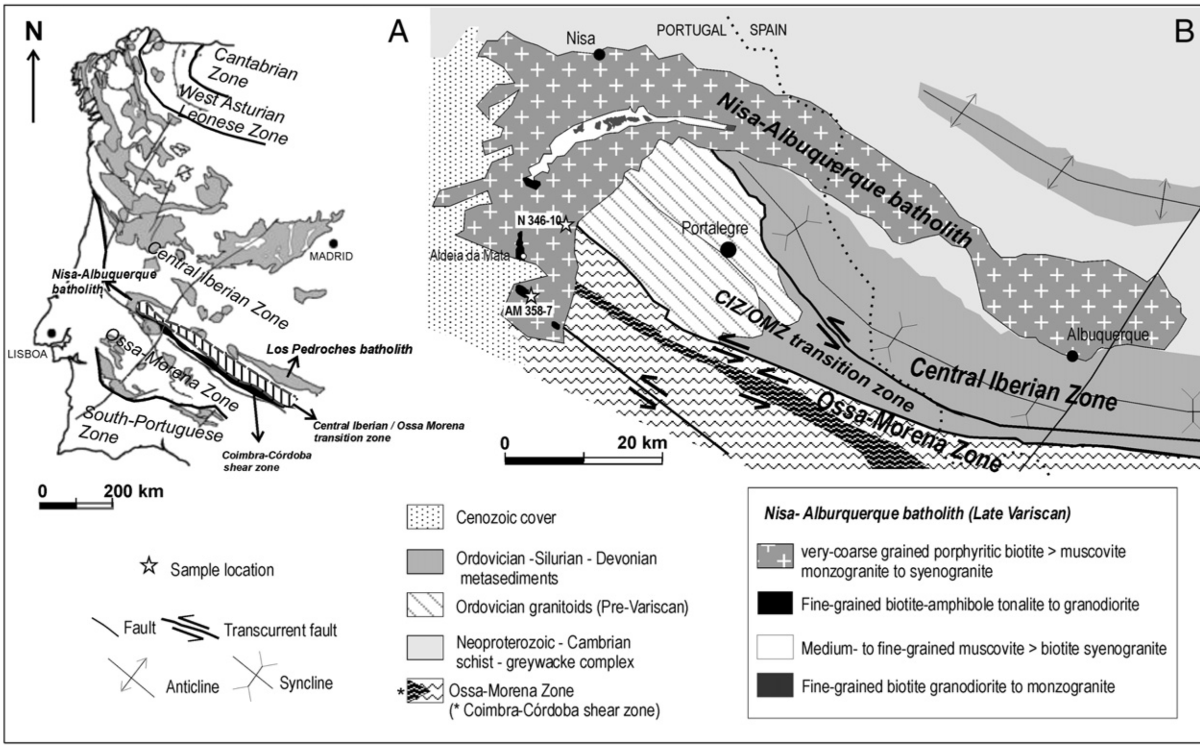

Fig. 1. A. Sketch of the distribution of Variscan granite batholiths in Iberia (modified after Bea et al., 1999) and geological setting of area B located at the boundary between the Central Iberian and Ossa-Morena Zones. B. Simplified geological map of the Nisa-Albuquerque batholith and its host rocks (modified from the Geological map of Portugal, 1992; Moreira, 1994; Pereira and Silva, 2001; Geological map of Spain, 2004).

batholith by sensitive high resolution ion microprobe (SHRIMP) *in situ* zircon U–Th–Pb dating. Moreover, the refractory character of zircon allows us to get information on the possible provenance and nature of the magma sources (from zircon cores) and the ages of post-magmatic events (from late zircon overgrowths). The oxygen isotopic compositions measured on the same spots provide valuable information on the magma genesis.

The Nisa-Albuquerque batholith, the subject of the present study, has several interesting features: 1) it cuts the Central Iberian/Ossa-Morena Transition Zone (Fig. 1) and the Coimbra–Córdoba shear zone, a major high-grade transcurrent structure of the Ossa-Morena Zone (e.g., Burg et al., 1981; Eguiluz et al., 2000; Pereira and Silva, 2001; Silva and Pereira, 2004; Pereira et al., 2008a); 2) it has a concentric zonation: a dominant S-type monzogranite–syenogranite, the Nisa monzogranite, surrounds a contrasting very fine-grained discontinuous central core of I-type tonalite–granodiorite, the Aldeia da Mata tonalite (Fig. 1B); and 3) it is closely associated with uranium mineralization, mainly in the contact metamorphic aureole.

According to previous Rb–Sr and K–Ar age measurements, the Nisa-Albuquerque batholith was emplaced at 312–286 Ma (Mendes, 1967-1968, Penha and Arribas, 1974; Roberts et al., 1991; González Menéndez, 2002). Here we present SHRIMP zircon U–Th–Pb analyses from two intrusions from the batholith that further constrain the ages and petrologic relationships of the I- and S-type granite association, as well as the timing of the Variscan deformation in the SW Iberian Massif. Moreover, the analyses and zircon growth textures are used to assess the processes that were active during crystallization of the magmas, relating zircon growth zoning and chemical characteristics to thermal and chemical changes in the magma during crystallization.

Zircon oxygen isotopic compositions were subsequently measured by SHRIMP on many of the same spots on the same grains analysed for U–Th–Pb. Zircon effectively preserves a record of the oxygen isotopic composition of the magma from which it crystallized (Valley, 2003), providing valuable information about the magma source (metasedimentary, meta-igneous, mantle). The oxygen isotope variations in zircon populations, combined with zircon ages, growth textures and chemical compositions, are a useful tool for tracing the nature and evolution of granite magmas and their sources.

2. Geological setting and previous work

The Nisa-Albuquerque batholith forms part of the regional Nisa-Los Pedroches NW–SE magmatic alignment, located in the southernmost sector of the Central Iberian Zone (Fig. 1A). It is a composite, elongate body exposed over an area of 1000 km^2 in central Portugal and Spain, oriented parallel to, and crossing, the southern boundary of the Central Iberian Zone (Fig. 1). In the north, the batholith intruded metasediments of the Schist–Greywacke complex (Neoproterozoic–Cambrian) and produced a contact metamorphic aureole 800–1200 m wide (Campos and Pereira, 1991) that consists of cordierite schists and pelitic and quartz–pelitic hornfelses. The contact between the batholith and its host rocks is sharp and vertical. Towards the south, the granitoids intruded an Ordovician to Devonian sedimentary sequence of the Castelo de Vide-Albuquerque syncline. Near Nisa (Portugal) the granitoids, which have an arcuate shape, intruded Ordovician granitoids and Ossa-Morena Zone rocks including the Coimbra–Córdoba shear zone. A late-stage fracture system affected the batholith, producing several N–S faults (Campos and Pereira, 1991). Intra-batholithic and peri-batholithic tungsten, phosphorous and mainly uranium mineralization is associated with the batholith (Neiva et al., 1952; Faria and Mesquita, 1962; Pilar, 1966; Neiva, 2003).

The Nisa-Albuquerque batholith consists of a dominant peraluminous coarse-grained porphyritic, two-mica monzogranite to syenogranite (S-type affinity) that occupies over 85% of the outcrop area and shows a marked differentiation from west to east (Solá et al., 1998a; González Menéndez, 2002). In the core, there are three generally finer-grained granitoids that clearly contrast with the host granite, forming a discontinuous alignment with the same arcuate shape as the batholith (Moreira, 1994; Fig. 1B). In order of increasing SiO_2 content they are: 1) a fine-grained biotite–amphibole tonalite to