Intra-crustal recycling and crustal-mantle interactions revealed by zircon oxygen isotopic composition of SW Iberia rocks

Processos de reciclagem crustal e interação crusta-manto inferidos através da composição isotópica de oxigénio em zircão de rochas do Sudoeste da Iberia

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Abstract

The $\delta^{18}O_{zrn}$ composition of previous dated Neoproterozoic to Paleozoic rocks of the Ossa-Morena Zone and its transition with the Central Iberian Zone shows that: i) Archean zircons show $\delta^{18}O_{zrn}$ comparable with the values from the Archean zircons elsewhere; ii) Paleoproterozoic zircons (ca. 2.1-2.0Ga) show the increase of the involvement of metasediment assimilation; at ca. 1.9-1.8 Ga the mantle-like values document an episodically crustal growth event. iii) Ediacaran show variable and higher $\delta^{18}O_{zrn}$ values (~4-11‰), indicating diversity/mixing of sources (intra-crustal recycling and crust–mantle interactions); values close to mantle derived zircon suggests interaction with juvenile melts probably related with the delamination of the arc; iv) Cambrian times (ca. 536-488 Ma) are associated with a low variety of magmas sources, mainly intermediate to basic igneous sources. In the ca. 536–520 Ma interval, the $\delta^{18}O_{zrn}$ is higher (7.0‰) than in the ca. 520–488 interval (6.2‰), suggesting gradual opening of the system to mantle-derived magmas; v) higher $\delta^{18}O_{zrn}$ >7.5 ‰ at ca. 490–470Ma on rocks of the OMZ-CIZ transition marks a pronounced increase in crustal recycling and different proportions of metaigneous and metasedimentary derived magmas; vi) Carboniferous granitoids show $\delta^{18}O_{zrn}$= 6.7-12‰, consistent with the igneous-metasedimentary derived magmas with a limited mantle-derivation.

Keywords: Ossa-Morena Zone, pre-Mesozoic rocks, Oxygen isotope, Zircon, North-Gondwana

Resumo

A composição isotópica de O em zircões ($\delta^{18}O_{zrn}$) de rochas previamente datadas do SW Iberia, revela que: i) no Arcaico os valores de $\delta^{18}O_{zrn}$ são comparáveis com os descritos para a generalidade dos cratões; ii) No Paleoproterozóico (ca.2.1-2.0Ga) constata-se o envolvimento de processos de assimilação de metasedimentos; aos ca. 1.9-1.8 Ga, surgem valores próximos do manto documentando crescimento crustal. iii) o Ediacárico mostra maior variância e valores elevados (4-11‰), indicando reciclagem intra-crustal e interação crusta-manto; valores similares ao manto, sugerem a incursão de fundidos juvenis provavelmente relacionados com a delaminação do arco; iv) o Câmbrico está associado a menor variedade de fontes, nomeadamente magmas derivados de rochas intermédias-básicas; no intervalo ca. 536–520 Ma o valor médio (7.0‰) é maior do que no intervalo ca. 520–488 Ma (6.2‰), sugerindo a interacção gradual com fontes ígneas derivadas do manto; iv) o limite Câmbrico - Ordovícico (ca. 490–470 Ma) em rochas da transição ZOM-ZCI apresenta valores elevados de $\delta^{18}O_{zrn}$ >7.5 ‰, sugerindo aumento de reciclagem crustal e influência, em proporções variadas, de magmas derivados de rochas ígneas e sedimentares; v) o Carbónico (ca. 340-300 Ma) apresenta valores de $\delta^{18}O_{zrn}$ variando entre 6.7 e 12‰, consistente com magmas derivados de fusão de crusta ígnea-metasedimentar e participação limitada do manto.

Palavras-chave: Zona de Ossa-Morena, Rochas pré-Mesozóicas, Isótopos de Oxigénio, Zircão, Margem Norte de Gondwana

Introduction

Oxygen isotope ratios of magmas reflect the $\delta^{18}O$ of magmatic source rocks and their contaminants. Analyses of *in situ* $\delta^{18}O_{zrn}$ used together with *in situ* U- Pb zircon dating can be critical for: i) tracing the nature and evolution of magmas and their sources (for igneous rocks); and ii) dechiphering sedimentary provenance (e.g. Hawkesworth and Kemp, 2006). Considering that igneous zircon in high temperature equilibrium with mantle, have an average $\delta^{18}O_{zrn}$ = 5.3±0.3 ‰ (1 SD, Valley et al., 2005), significant deviations of this value are the direct or indirect result of intra-crustal recycling, i.e., magma interaction with supracrustal materials. In order to contribute to understanding the crustal growth and recycling processes on SW Iberia in the context of the geodynamic evolution of North-Gondwana marginwe have perfomed analyses on previously dated zircons (detrital/ inherited and melt precipitated). These selected zircons were extracted from Neoproterozoic to Paleozoic rocks of the Ossa-Morena Zone (OMZ) including its transition with the Central Iberian Zone (CIZ). The obtained $\delta^{18}O_{zrn}$ results indicate a great heterogeneity of the source areas (juvenile, evolved or mixed) and variations through time.

Geological setting

The OMZ (SW Iberia) represents a segment of the North-Gondwana margin with a protacted geodynamic evolution, characterized by the superposition of Cadomian and Variscan accretion events separated by a major Cambrian- -Ordovician extensional stages (Sánchez-Garcia et al., 2010). Different groups of pre-Mesozoic rocks from SW Iberia were selected for this study: i) deformed and metamorphosed Ediacaran to Cambrian igneous-sedimentary sequences from a Northern sector (Coimbra- -Córdoba Shear Zone and its boundary; Pereira et al., 2010) and from a Southern Sector (Évora - Aracena metamorphic Belt; Chichorro et al., 2008; Pereira et al., 2009); ii) Upper Cambrian-Lower Ordovician volcaniclastic rocks and coeval granites of the Ossa-Morena - Central Iberian transition zone (Solá et al., 2008); and, iii) Nisa and Arraiolos granitoids including their inherited zircon component (Solá et al., 2009; Pereira et al., 2008, 2009).

In-situ zircon O isotope analyses

Zircon oxygen isotopic analyses were carried out at the Research School of Earth Sciences (Australian National University, Canberra). Oxygen isotopic compositions of 213 zircon grains were measured by SHRIMP II on the same areas previously dated after recasting the mount and polishing it lightly to remove the oxygen implanted during the U–Th–Pb dating (for details see Solá et al., 2009). The sample was complemented by another 38 previously published $\delta^{18}O_{zrn}$ data from Variscan Carboniferous granitoids (Solá et al., 2009), totalizing 251 analysis. The compositions were measured relative to zircon standard Temora ($\delta^{18}O$=8.2‰ VSMOW) using15 kV Cs+ primary ions and multiple collection.

Discussion of Results

Archean zircons from the OMZ Neoproterozoic to Carboniferous igneous/sedimentary show little isotopic variation with most of $\delta^{18}O_{zrn}$ values lying between 4.7 and 7.5‰, (average of 6.20‰,) comparable with the most common $\delta^{18}O_{zrn}$ values of the zircons from the Archean rocks elsewhere (e.g., Valley et al., 2005). The obtained U-Pb ages on these zircons overlap the Leonian and Liberian zircon-forming events characteristic of the West African craton (WAC); they represent detrital or inherited grains resulting of several cycles of crustal growth and recycling. Paleoproterozoic grains are represented by a wide range of $\delta^{18}O_{zrn}$ values in the ca. 2.1 to 2.0 Ga age interval (Eburnian orogenic cycle)

distributed between from 5.42 to 9.23‰ (average of 7.19‰). This result suggests the increase of supracrustal recycling with the involvement of metasediment assimilation, as demonstrated by a significant cluster with $\delta^{18}O_{zrn}$ average of 8.82‰. The mantle-like values ($\delta^{18}O_{zrn}$ <5.43‰) observed at ca. 1.9-1.8 Ga document a later crustal growth event (Birimian event), compatible with average T_{DM} model age ~ 1.8 Ga obtained for the Ediacaran sedimentary rocks and for the Cambro-Ordovician crust-derived magmatism of the OMZ (Cambeses et al, 2014). Zircon-forming events of Stenian-early Tonian ages (ca. 1.1–0.9 Ga), have mildly evolved $\delta^{18}O_{zrn}$ values in the range 5.58-7.05‰. The scarce grains with $\delta^{18}O_{zrn}$ values close to mantle-derived zircon suggests a probable juvenile crustal event for the OMZ (ca. 1.1–0.9 Ga), which was previously documented for the CIZ (ca. 1.0–1.2 Ga) by Villaseca et al., (2011). The most fertile period in terms of magma production is the age interval of ca. 623-574 Ma; this zircon-forming event is characterized by the largest range in $\delta^{18}O_{zrn}$ values (~5.14-11.59‰), reflecting great diversity and mixing of sources evolving intra-crustal recycling. This process was probably attended by root delamination of a magmatic arc and the intrusion of juvenile melts.This stage is related with the development of a late Cadomian magmatic arc (*sensus* Pereira et al., 2012). In the Cambrian, the $\delta^{18}O_{zrn}$ average is higher at ca. 536-520 Ma (~7.0‰) than at ca. 520-488 Ma (~6.2‰) indicating a gradual opening of the system to the mantle-derived magmas. The $\delta^{18}O_{zrn}$ data are consistent with felsic magmatism mostly representing the last residual melts of high-temperature zircon subsaturated mafic magmas progressively more influenced by the underplating of mantle-derived magmas culminating with the tholeiitic N-MORB magmatism.

Cambrian-Ordovician (ca. 490-460 Ma) melt precipitated zircons have higher $\delta^{18}O_{zrn}$ values (> 7.5 ‰), with 49% of the data showing $\delta^{18}O_{zrn}$ > 8.5‰, resultant from crustal-metaigneous to crustal metasedimentary derived magmas (recycling of upper-crust).

The $\delta^{18}O_{zrn}$ values of the Carboniferous melt precipitated zircons range in the interval ~6<$\delta^{18}O_{zrn}$<11‰, suggesting great diversity and mixing of sources and magma hybridization in a system where anatectic felsic melts periodically underwent injection of more mafic magmas at higher temperatures.

Conclusions

The compilation of $\delta^{18}O_{zrn}$ versus zircon U-Pb age for the age interval of ca. 3.4 Ga to ca. 290 Ma revealed directly (by melt-precipitated zircon) and indirectly (inherited/detrital zircon) that SW Iberia crust was evolved in several cycles of continental crustal growth and recycling. The obtained isotopic data shows that the compositional of OMZ crust, was probably greatly influenced by the erosion and recycling of two major Precambrian magmatic arcs: i) in the Paleoproterozoic (Eburnian-Burinian orogenic processes (ca. 2.1-1.8 Ga), and ii) in the Neoproterozoic (Pan-African/Cadomian orogeny) (ca. 700-550 Ma); there are no evidence of Paleoproterozoic rocks in the OMZ but is well known a Cadomian magmatic arc formed by Ediacaran igneous and sedimentary rocks (Eguiluz et al., 2000; Henriques, et al., 2015). The Cambrian (ca. 536-488 Ma) rift-related magmatism of the OMZ was dominated by felsic I-type magmas progressively more influenced by mantle sources.

Magma sources of the Cambrian-Ordovician (ca. 490-460 Ma) volcanic and plutonic rocks from the OMZ-CIZ transition zone are mainly linked with crustal recycling processes (metasedimentary and igneous derived melts).

The $\delta^{18}O_{zrn}$ data of Carboniferous (ca. 340-300 Ma) zircon are consistent with partial melting of older

metasedimentary and metaigneous rocks precluding a mantle-derivation.

Aknowledgements

This paper is a contribution to projects Gondwana - PTDC/CTEGIX/110426/2009 and Gold - PTDC/GEO-GEO/2446/2012 funded by FCT.

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