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IDADES U-Pb DOS ZIRCÕES DETRÍTICOS DO GRUPO DAS BEIRAS – IMPLICAÇÕES PARA A EVOLUÇÃO DO SW DA IBÉRIA DURANTE O NEOPROTEROZÓICO

U-PB DETRITAL ZIRCON AGES FROM THE BEIRAS GROUP – IMPLICATIONS FOR THE NEOPROTEROZOIC EVOLUTION OF THE SW IBERIA

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Resumo

Idades U-Pb obtidas em zircão de grauvaques do Grupo das Beiras (SW da Zona Centro-Ibérica - ZCI) indicam uma idade de deposição máxima do final do Ediacariano (c. 560-578 Ma). Os dados mostram duas diferenças significativas nos grauvaques do Grupo das Beiras relativamente aos da Série Negra (de idade contemporânea da Zona de Ossa-Morena - ZOM): i) A presença de zircões com idades Tonianas e Mesoproterozóicas (<8%), que são praticamente inexistentes na ZOM, implica uma fonte adicional de zircões detríticos para além do Cratão Oeste Africano – WAC , e ii) a grande percentagem de idades Criogenianas (~50%) nos grauvaques do Grupo das Beiras (principalmente c. 840-750 Ma e c. 685-660 Ma), contrasta com a predominância de idades Ediacarianas dos grauvaques da Série Negra (ZOM). Os eventos Criogenianos registados nos zircões dominantes das bacias sedimentares do SW da CIZ, estão provavelmente relacionados com a génese de uma crusta Cadomiana juvenil (c. 700-635 Ma) possivelmente relacionada com anterior sutura Pan-Africana (c. 850-700 Ma). Os dados isotópicos de Nd dos metassedimentos do Grupo das Beiras são compatíveis com a adição de uma fonte juvenil na crusta pré-existente. A combinação dos dados geocronológicos com as assinaturas isotópicas de Nd sugere que a ZCI e a ZOM terão tido uma evolução comum ao longo da margem activa do Gondwana, embora representem bacias sedimentares suficientemente afastadas explicando assim as suas diferenças nos conteúdos de zircão detrítico e assinaturas isotópicas.

Palavras chave: Grupo das Beiras, geocronologia do zircão, Neoproterozóico, isótopos de Nd, SW Iberia

Abstract

U-Pb detrital zircon ages from the Beiras Group greywackes (SW Central Iberian Zone - CIZ) indicate a maximum depositional age of late Ediacaran (c. 560-578 Ma). Two salient features distinguish the Beiras Group from the Série Negra greywackes (age equivalent from the Ossa-Morena Zone - OMZ): i) The presence of Tonian and Mesoproterozoic (<8%) age clusters in the Beiras Group greywackes, that are almost absent in the OMZ, imply either a distinct or an additional source of detrital zircons from the West African Craton; and 2) The higher content of Cryogenian zircon ages of the Beiras Group greywackes (mainly at c. 840-750 Ma and c. 685-660 Ma), that contrast with the dominant Ediacaran zircon ages of the Série Negra greywackes (OMZ). The Cryogenian zircon forming events that are dominant in the SW CIZ basins are probably related to a different source with early Cadomian juvenile crust (c. 700-635 Ma) and with a possible contribution of the Pan-African suture (c. 850-700 Ma). The Nd isotopic signatures support the addition of a juvenile source to pre-existent older crust for the Beiras Group metasediments. Although the Beiras Group (SW CIZ) and Serie Negra (OMZ) late Ediacaran basins have evolved together in the active margin of Gondwana, they were sufficiently separated to account for the differences in their detrital zircon content and isotopic signatures.

Keywords: Beiras Group, zircon geochronology, Neoproterozoic, Nd isotopes, SW Iberia

Introduction

SW Iberia includes exposures of late Ediacaran rocks in the Central Iberian Zone-CIZ, and in the Ossa-Morena Zone-OMZ (Fig.1).

The U-Pb detrital zircon geochronology from late Ediacaran sedimentary rocks of the OMZ (Série Negra) document a complex history of zircon forming events that is dominated by late Cryogenian and Ediacaran (late Cadomian arc, c. 640-550 Ma; Pereira et al., 2011 and references therein). This information was never sufficiently explored by comparison with the equivalent age sedimentary rocks of the CIZ.

This study presents new U-Pb detrital zircon data from the Beiras Group greywackes (included in the Schist-Greywacke Complex of the SW CIZ) together with Sm-Nd isotope data from literature. A comparison is made with available data from the equivalent sedimentary rocks of the Série Negra (OMZ) in order to: i) characterize potential sedimentary provenances and sources involved; ii) contribute to understand the relationship between CIZ and OMZ and therefore, to improve paleogeographic reconstructions for the Neoproterozoic, along the northern Gondwana margin (e.g. Fernández-Suárez et al., 2000; Linnemann et al., 2008; Chichorro et al., accepted; Pereira et al., 2011; Pereira et al., accepted).

Geological background

The Schist-Greywacke Complex that represents the oldest outcrops of the CIZ includes the Beiras and Douro Groups which consists of Neoproterozoic to early Cambrian sedimentary rocks (Medina et al., 1998 and references therein). In SW CIZ, the Beiras Group is overlain by the early Ordovician sedimentary record. The early Ordovician outcrops along NW-SE trending ridges (Variscan kilometer-scale folds on the 1/500 000 and 1/1000 000 scale Geological Maps of Portugal).

The Penacova ridge located in the SE extreme of the Buçaco mountains range is a 130-140º trending syncline with a steeply (70-80º) dipping axial plane (Fig.1-cross section).

The late Ediacaran-early Ordovician stratigraphy in Penacova is characterized by a gap of Cambrian rocks and includes from the base to the top: 1) the Beiras Group with metagreywackes and slates (late Ediacaran; Medina et al., 1998); 2) the Sarnelhas Formation and 3) the Armorican Quartzite Formation (both early Ordovician; Oliveira et al., 1992) (Fig. 1-stratigraphic column).

Two samples of metagreywackes of the Beiras Group (PNC 1 and PNC 2) from the Penacova - Raiva Section (Fig. 1), were collected for geochronology.

U-Pb zircon geochronology

Methods

Zircon grains were extracted, and then mounted in epoxy resin with zircon standards. Zircons from sample PNC-2 were imaged by SEM cathodoluminescence (CL) to document the internal growth zoning of the grains.

Zircon were analyzed for U, Th, and Pb isotopes by LA-ICP-MS (Laser Ablation with Inductively Coupled Plasma Mass Spectrometry) techniques at the Museum für Mineralogie und Geologie (Senckenberg Naturhistorische Sammlungen Dresden, Germany), using a Thermo-Scientific Element 2 XR sector field ICP-MS coupled to a New Wave UP-193 Excimer Laser System.

Concordia diagrams (2□ error ellipses), concordia ages (95% confidence level) and probability plots were produced using Isoplot/Ex 2.49 (Ludwig, 2001). The $^{207}Pb/^{206}Pb$ age was taken for interpretation for all zircons >1.0 Ga, and the $^{206}Pb/^{238}U$ ages for younger grains. For further details on analytical protocol and data processing see Frei and Gerdes (2009).

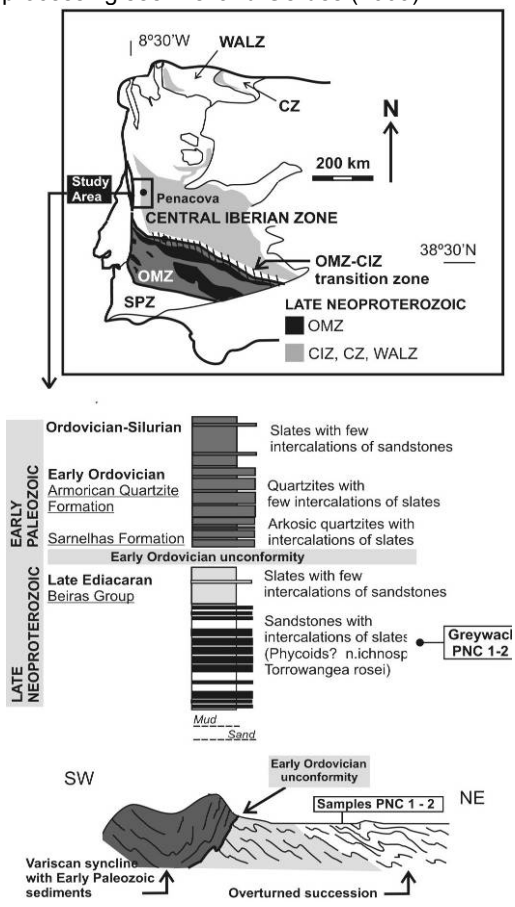

Fig. 1 - Simplified geological map of Iberia showing the location of the late Neoproterozoic rocks. Simplified geological cross section and stratigraphic column of the Penacova syncline with sample location (adapted from Pereira et al., accepted).

Results

The zircon ages obtained (Fig. 2) are quite similar in both Beiras Group samples, with slight differences for the percentages of pre-Cryogenian ages.

For sample PNC 1 were analyzed 110 targets (90-110% concordance). The main group of ages is Neoproterozoic (74%, 914-550 Ma). The remaining zircons are older, with the follow distribution: Mesoproterozoic (4%, c. 1.2-1.0 Ga) Paleoproterozoic (14%; c. 2.3-1.7 Ga) and Archean (9%; c. 3.5 - 2.5 Ga).

The Neoproterozoic population of sample PNC 1 is dominated by Cryogenian zircon ages (55%, c. 833 - 632 Ma), followed by Ediacaran (16%, c. 630 - 550 Ma) and few Tonian (3%, c. 914-900 Ma) ages.

The youngest zircon found yields 549.6 ± 4.4 Ma (lattermost Ediacaran; 99.5% concordance), the oldest grain gave c. 3.4 Ga (Paleoarchean). The youngest population average age was estimated using six younger zircon ages, at 560.3 ± 6.6 Ma (late Ediacaran; 2σ, MSWD = 0.87, Probability = 0.35).

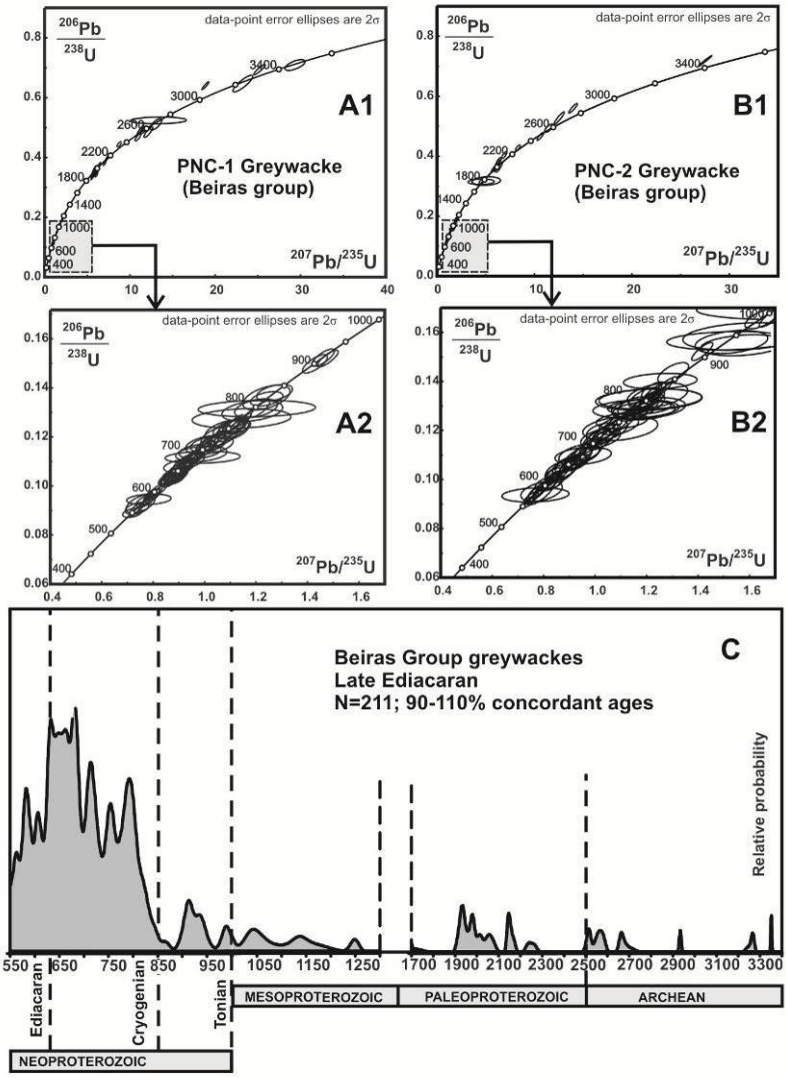

Fig. 2 - A and B: U-Pb Concordia plots of zircon grains from samples PNC 1 and PNC 2 of the Beiras Group (Concordia plots A1 and B1 showing all analyses. Concordia plots A2 and B2 showing the Neoproterozoic analyses. C: Relative age probability plot for samples PNC 1 and PNC 2 (adapted from Pereira et al., accepted).

In sample PNC 2 were analyzed 118 zircon targets and 102 spots have 90-110% concordance. The zircon population shows the following age distribution: Neoproterozoic (77%, 992-563Ma), Mesoproterozoic (8%, c. 1.2-1.0 Ga), Paleoproterozoic (10%, 2.2-1.7 Ga), and Archean (5%, 3.4-2.5 Ga).

Like sample PNC 1, the Neoproterozoic population of sample PNC 2 is dominated by Cryogenian zircon grains (52%, c. 845-631 Ma), followed by Ediacaran (18%, 630-563 Ma) and Tonian (8%, c. 992-865 Ma).

The youngest zircon was dated at 562.5 ± 6.1 Ma (late Ediacaran; 96.6% concordance) and the oldest at c. 3.4 Ga (Paleoarchean). The youngest population was estimated at 578.5 ± 4.7 Ma (late Ediacaran; 2σ, MSWD = 0.85, Probability = 0.36).

Discussion

The age of deposition of the Beiras Group greywackes (CIZ)

The obtained U-Pb detrital zircon data from the Beiras Group greywackes contributes to better define the stratigraphy of the CIZ. The results of this study indicate the late Ediacaran as the maximum depositional age for the Beiras Group greywackes (Penacova region), based on the youngest population of zircon ages that was estimated at c. 560 Ma (for sample PNC 1) and c. 578Ma (for sample PNC 2).

The probable maximum depositional age of c. 578-560 Ma for the Beiras Group greywackes matches the interval of deposition of the Serie Negra greywackes in the OMZ (c. 590 - 545 Ma; Pereira et al., 2011 and references therein). The new data suggest that deposition in both CIZ and OMZ Ediacaran basins was coeval.

Potential sedimentary sources

The U-Pb detrital zircon data set for the Beiras Group greywackes indicates predominance of Neoproterozoic (74-77%) and minor Mesoproterozoic (<8%), Paleoproterozoic and Archean age contents (Fig 2C).

The most probable source for the Beiras Group greywackes (SW CIZ) seems to be the West African Craton as is attributed to the Serie Negra (e.g. Linnemann et al., 2008, Pereira et al., 2011). However, a significant feature distinguishes the Beiras Group from the Série Negra - the presence of Mesoproterozoic and Tonian ages - Fig. 2C, that are almost absent in the Serie Negra - OMZ. The presence of Mesoproterozoic and Tonian age clusters in the Beiras Group may reflect either a different source area, or an additional source to the West African Craton.

The Neoproterozoic zircon age content of the Beiras Group greywackes is dominated by Cryogenian zircon ages (52-55%), followed by Ediacaran (16-18%) and Tonian (3-8%) ages (Fig 2C). The predominance of Cryogenian ages (mainly at c. 840-750 Ma and c. 685-660 Ma) over Ediacaran ages, distinguish the Beiras Group greywackes (SW CIZ) from the age-equivalent Série Negra (OMZ) where the main age clusters are concentrated in Ediacaran (Linnemann et al., 2008, Pereira et al., 2011).

The Beiras Group greywackes have a significant content of detrital zircons derived from erosion of igneous rocks probably formed in a long-lived Neoproterozoic magmatism (c. 840-560 Ma, Fig. 2C), located near or at the Gondwana margin (Pan-African/Cadomian magmatic arc; Pereira et al., 2011, accepted).

The age spectra of the Beiras Group greywackes also reveal three major episodes of zircon crystallization that are probably associated with the following sequence of events occurred in SW Iberia: i) c. 850–700 Ma - Pan-African suture (not well represented in OMZ); ii) c. 700-635 Ma - Early Cadomian arc (dominant in the SW CIZ); and iii) c. 635-545 Ma late Cadomian arc (the most salient in OMZ) (Chichorro et al., accepted; Pereira et al., accepted).

Integration of U–Pb data with Nd isotopic data

Sm–Nd data for the Beiras Group (Schist-Greywacke Complex) and for the Série Negra available in the literature are summarized in Table 1, Figs. 3 and 4 and briefly discussed below in light of the detrital zircon ages obtained in this study.

The $\varepsilon Nd_{(t)}$ values from the Beiras Group metasediments (Penacova-Raiva section) were calculated from Tassinari et al., (1996) for 560 Ma (time of deposition from this study). The $\varepsilon Nd_{(t)}$ values are moderate negative in the range of -1.6 to -3.6 and T_{DM} model ages range from 1.32 and 1.24 Ga, providing an estimate of the average age of the source rocks of the Schist-Greywacke Complex in SW CIZ (Table 1, Fig. 4)

Both parameters (T_{DM} and $\varepsilon Nd_{(t)}$) indicate an important contribution of juvenile magmas, younger than 1.2 Ga, to pre-existent older crust (e.g. Beetsma, 1995; Tassinari et al., 1996).

This is consistent with the ages of detrital zircons reported in this study: a significant input of Cryogenian ages (~50%) and older ages (up to 3.4 Ga, Paleoarchean) (Fig 2C). The Cryogenian zircon crystallization ages that are dominant in the SW CIZ basins (and not well represented in the Serie Negra, ZOM) are most likely related to a source with early Cadomian juvenile crust (c. 700-635 Ma) and with a

possible contribution of the Pan-African suture (c. 850-700 Ma).

The Nd isotopic signatures for the Schist-Greywacke Complex (CIZ: -1.6< εNdt <-4.5; 1.2<T_{DM}<1.5 Ga) have a relatively higher εNd(t) and younger T_{DM} model ages than the Série Negra (OMZ: -5.5< εNdt < -11.4; 1.6< T_{DM} <1.9 Ga; (Table1, Figs. 3 and 4). This difference mean that the main source of the OMZ late Ediacaran basins is dominated by the contribution of older basement rocks and with relatively minor input from juvenile sources (Fig. 4).

The small amount of detrital zircon typical of the early Cadomian magmatic arc (c. 700-635 Ma) that characterizes the Serie Negra greywackes (e.g., Linnemann et al., 2008; Pereira et al., 2011 and references therein) seems to agree with this interpretation.

This "change" in the Nd isotopic signature of the OMZ correlative sediments indicates that the contribution of juvenile crust (from "Early Cadomian arc") decreased progressively (Fig. 4). In the light of zircon ages, this is reflected in the presence of older Cryogenian ages (700-635Ma) that locally/sometimes occur in Série Negra. This implies that both Ediacaran sedimentary basins (CIZ and OMZ) evolved together in an active margin of Gondwana but were separated sufficiently to justify the differences in their detrital zircon and isotopic signature.

Table 1 – Range of □Nd(0), □Nd(t) and TDM Nd model ages of Ediacaran metasediments from the CIZ and OMZ.

	$\varepsilon Nd_{(0)}$	Age (Ma)	$\varepsilon Nd_{(t)}$	T_{DM} (Ga)	Author
CIZ-Schist-Greywacke Complex					
Upper unit (S)	-6.7 to -9.2	545	-2.7 to -4.0	1.43 - 1.51	López-Guijarro et al. (2008)
Lower unit (S)	-8.1 to -10.1	550	-2.8 to -4.5	1.35 - 1.53	López-Guijarro et al. (2008)
Beiras Group, Penacova (P)	-7.2 to -9.9	560	-1.6 to -3.6	1.24 - 1.32	Tassinari et al. (1996)
OMZ-Série Negra					
Biscaia-Escoural (P)	-10.8	550	-5.5	1.58	Chichorro et al. (2008)
Assumar - Crato (P)	-19.04	560	-12.49	1.89	Pereira et al. (2006)
Fm. Tentudia (S)	-14.1 to -17.5	560-570	-8.4 to -11.4	1.75 - 1.89	López-Guijarro et al. (2008)
Fm. Montemolin (S)	-13.8 to -17.5	570	-8.0 to -10.9	1.72 - 1.81	López-Guijarro et al. (2008)
Albergaria-a-Velha (P)	-12.3 to -12.9	600	-6.3	1.56 - 1.63	Beetsma (1995)

(P)-Portugal (S)-Spain

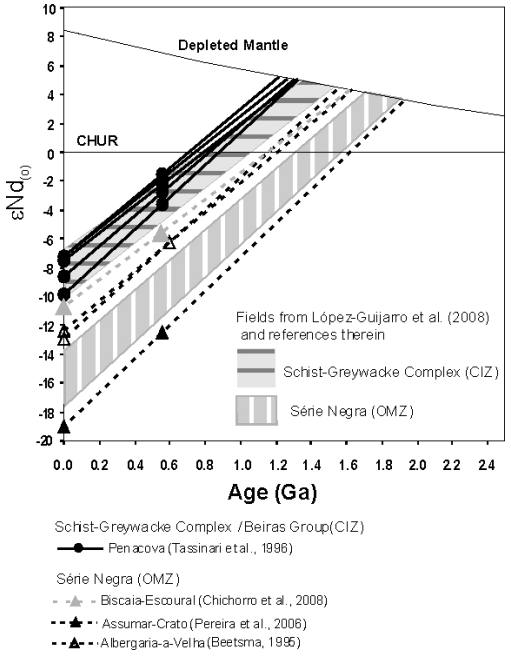

Fig. 3 - εNdt vs. Age diagram for Ediacaran metasediments from the CIZ and OMZ (adapted from López-Guijarro et al., 2008).

Conclusions

The main conclusions of this study are:

i) The maximum age of deposition of the Beiras Group (Penacova region) is late Ediacaran or younger, as the age of the youngest zircon population is estimated at c. 560 Ma, for sample PNC 1.

ii) The predominance of Cryogenian zircon ages over Ediacaran ages, distinguish the Beiras Group greywackes (SW CIZ) from the age-equivalent Série Negra greywackes (OMZ).

These data seems to indicate that the Beiras Group basin was probably located close to the early Cadomian magmatic arc, whereas the Serie Negra basin (where the main age clusters are concentrated in Ediacaran) would be very close to the late Cadomian magmatic arc.

iii) The presence of Tonian and Mesoproterozoic (<7%) ages in the Beiras Group greywackes, which are almost absent in the Serie Negra greywackes, implies either a distinct, or an additional source of detrital zircons from internal regions of the West African Craton.

iv) The Nd isotopic signatures for the Schist-Greywacke Complex (CIZ), have relatively higher εNd(t) and younger T_{DM} model ages than

the Série Negra (OMZ), indicating different sources.

v) Although the Beiras Group (SW CIZ) and Serie Negra (OMZ) basins have evolved together in the active margin of Gondwana, they were sufficiently separated to account for the differences in their detrital zircon content and isotopic signatures.

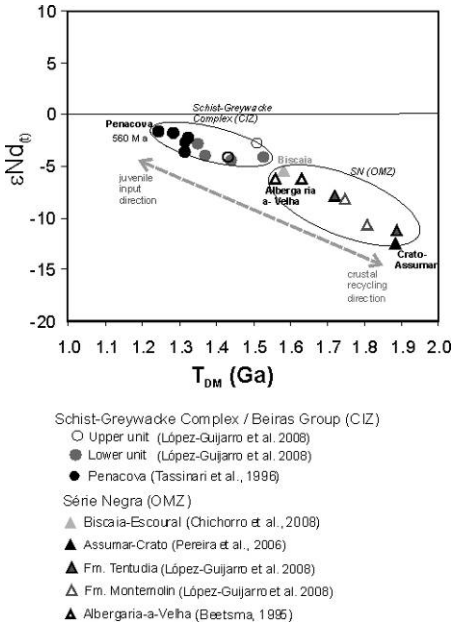

Fig. 4 - T_{DM} *vs.* εNdt diagram for the late Ediacaran metasediments of the CIZ and the OMZ (adapted from López-Guijarro et al., 2008).

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