

Provenance of Cambrian–Ordovician Siliciclastic Rocks of Southwestern Iberia: Insights into the Evolution of the North Gondwana Margin

A. R. Solá, M. Chichorro, M. F. Pereira, M. Hofmann,
U. Linnemann, A. Gerdes, J. Medina, L. Lopes and J. B. Silva

Abstract This study makes a comparison between the populations of detrital zircons of the Cambrian sandstones from the Ossa–Morena Zone (OMZ) and the Ordovician quartzites from the southern domains of the Central Iberian Zone (S-CIZ) to identify the sediment sources during the development of North Gondwana basins (southwestern Iberia). The U–Pb results obtained for the lower Cambrian sandstones of the OMZ show a remarkable similarity to the detrital zircon ages of greywackes from the underlying OMZ Ediacaran basement (the Série Negra succession). However, there is a greater proportion of Cryogenian grains in the Cambrian rocks, whose main sources are: (1) the late Cadomian magmatic arcs (Ediacaran, ca. 635–545 Ma) which also contributed to filling the late Ediacaran

A. R. Solá (✉)

Unidade de Geologia, Hidrogeologia e Geologia Costeira, LNEG, Lisbon, Portugal
e-mail: rita.sola@lneg.pt

M. Chichorro

CICEGe, Departamento de Ciências da Terra, Faculdade de Ciências e Tecnologia,
Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
e-mail: ma.chichorro@fct.unl.pt

M. F. Pereira

IDL, Departamento de Geociências, ECT, Universidade de Évora, Évora, Portugal

M. Hofmann · U. Linnemann

Senckenberg Naturhistorische Sammlungen Dresden, Dresden, Germany

A. Gerdes

Institut für Geowissenschaften Mineralogie, Frankfurt am Main, Germany

J. Medina

Departamento de Geociências, Universidade de Aveiro, Aveiro, Portugal

L. Lopes

CGE, Departamento de Geociências, Universidade de Évora, Évora, Portugal

J. B. Silva

Departamento de Geologia, Faculdade de Ciências, Universidade de Lisboa, Lisbon,
Portugal

basins of the OMZ; and (2) the early Cadomian arcs (Cryogenian, ca. 700–635 Ma). In the Lower Ordovician quartzites of the S-CIZ (the Armorican and Sarnelha formations), the age distribution of detrital zircons overlaps the population of detrital zircons of the underlying S-CIZ Ediacaran basement (the Beiras Group). However, there are some differences in the Sarnelhas quartzites, which have a population of detrital zircons similar to those of the Ediacaran greywackes and Cambrian sandstones of the OMZ. The Cambrian grains found in the Lower Ordovician quartzites fit the ages of magmatism representing the onset of rifting in North Gondwana that is registered in the OMZ but absent from the S-CIZ. The early Ordovician zircon grains are probably related to the magmatic event that preceded the passive margin stage of the Rheic Ocean, and are found in both the CIZ and OMZ.

Keywords Southwestern Iberia · Cambrian–Ordovician · Rifting · Zircon · Provenance

In southwestern Iberia, two main sedimentary unconformities can be recognized in the lower Palaeozoic stratigraphy: (1) The lower Cambrian unconformity, with a regional character in the Ossa Morena Zone (OMZ) and expressed locally in the Central Iberian Zone (CIZ), and which was developed during the transition from a late Cadomian active margin to the initial stages of Cambrian intracontinental rifting (Silva and Pereira 2004 and references therein); and (2) the Lower Ordovician unconformity, which was formed during a new period of emersion followed by transgression and significant subsidence in the passive margin of the Rheic Ocean (Silva and Pereira 2004 and references therein).

In the OMZ, the lower Cambrian stratigraphy comprises basal conglomerates, arkosic sandstones, shales, and limestones with associated volcanic–sedimentary complexes dated at ca. 530–526 Ma (e.g., Pereira et al. 2011 and references therein). The lower Cambrian formations unconformably overlie the Série Negra succession (the OMZ Ediacaran basement, Liñán and Quesada 1990).

In the southern domain of the CIZ (S-CIZ) the upper Cambrian–Lower Ordovician formations unconformably overlie the Beiras Group (S-CIZ Ediacaran basement; Sousa 1984). The upper Cambrian–Lower Ordovician stratigraphy consists of: (1) a lower unit with arkosic quartzites and slates with intercalations of conglomerates (the Sarnelhas Formation; Delgado 1908); and (2) an upper unit with massive beds of quartzites and thin layers of metapelites (the Armorican Quartzite Formation; e.g., Oliveira et al. 1992). In the CIZ–OMZ transition zone, the Lower Ordovician stratigraphy, which rests on the Cambrian and Ediacaran strata of the OMZ, includes at the base a ca. 490–480 Ma felsic volcanic–sedimentary complex (the Urrea Formation; Solá et al. 2008); this passes gradually upwards to arkosic sandstones, conglomerates (containing pebbles of black cherts derived from the Série Negra succession), and quartzites of the Armorican Quartzite Formation (e.g., Linnemann et al. 2008).

This study aims to characterize U–Pb detrital zircon data from the Cambrian sandstones of the OMZ and those from the Lower Ordovician quartzites from the

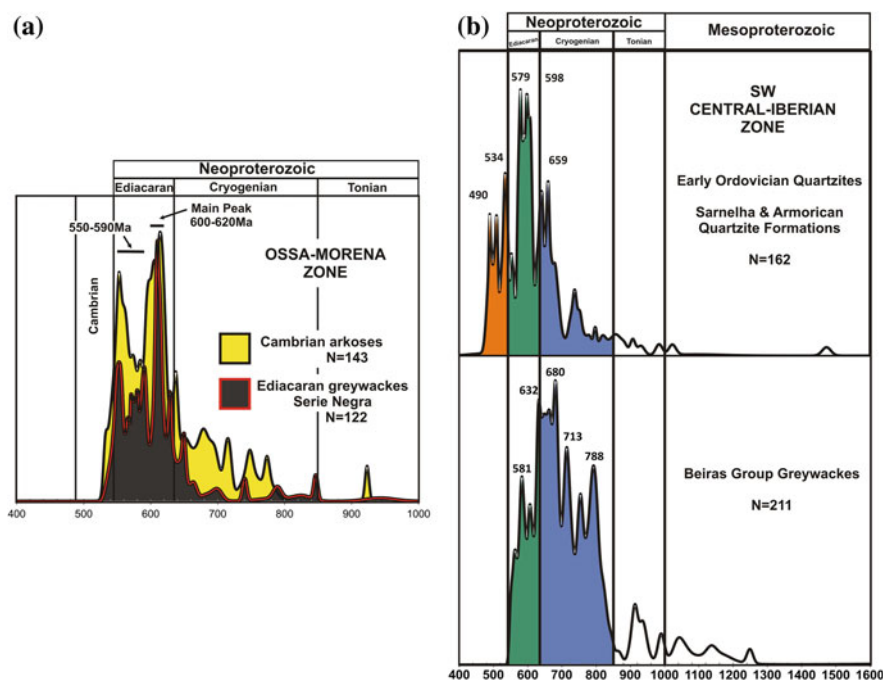


Fig. 1 **a** Probability density distribution plot of detrital zircon grains from lower Cambrian arkoses of the Ossa–Morena Zone compared with their underlying basement (the Série Negra succession); **b** Probability density distribution plots of detrital zircon grains from Lower Ordovician quartzites of the Central Iberian Zone compared with their underlying basement (the Beiras Group)

S-CIZ, in order to: (1) compare their provenances and their possible relationships with the underlying Ediacaran basements (the Série Negra succession in the OMZ and the Beiras Group in the S-CIZ); and (2) to provide additional insights into the evolution of the North Gondwana margin by identifying variations in the sources during the development of the sedimentary basins.

In the OMZ, the lower Cambrian siliciclastic rocks (Linneman et al. 2008; Pereira et al. 2011, 2012a) show a remarkable similarity to the zircon age records found in the underlying Série Negra succession (OMZ Ediacaran basement) (Fig. 1a). There is a strong contribution of Ediacaran grains with main peaks at ca. 620–630 Ma and ca. 590–550 Ma, and rare Tonian and Mesoproterozoic zircons. It is important to highlight the greater proportion of Cryogenian detrital zircons in the Cambrian rocks. This feature shows similarities to the S-CIZ Ediacaran strata, where Cryogenian zircons are well represented (Pereira et al. 2012b; Chichorro et al. this volume). The absence of Cambrian zircons in the sediments suggests that deposition probably occurred far from the volcanic centres and/or that magmatism was mainly hypabyssal.

The U–Pb results show that the sources of the lower Cambrian siliciclastic rocks were most probably the late Cadomian magmatic arcs (ca. 635–545 Ma), which contributed to the infilling of the late Ediacaran basins of the OMZ. In addition, a contribution from early Cadomian arcs (ca. 700–635 Ma), dominant in the S-CIZ basement (the Beiras Group), is also plausible.

In the S-CIZ, the U–Pb data of the Lower Ordovician siliciclastic rocks (the Sarnelhas and Armorican Quartzite formations, Pereira et al. 2012b; Fig. 1b) indicate a predominance of Neoproterozoic grains but with some differences. In the Sarnelhas quartzites (the lower unit), the population of Ediacaran zircons is larger than the Cryogenian, whereas in the Armorican quartzites (the upper unit) the opposite is true. The distribution of detrital zircon ages of the Sarnelhas quartzite resembles those of the Ediacaran and Cambrian siliciclastic rocks of the OMZ (Pereira et al. 2011, 2012a), the Urro Formation (Solá et al. 2008), and the Armorican quartzites from the CIZ–OMZ transition zone (Linnemann et al. 2008). This suggests that the S-CIZ Cadomian basement was not exposed at the time of deposition of the Sarnelha quartzites and, therefore, the main source of detritus was probably the OMZ. In the S-CIZ, the population of detrital zircons from the Armorican quartzites overlaps those of the underlying Sarnelha quartzites and Beiras Group greywackes, which would appear to indicate more than one source. However, we note that these S-CIZ quartzites have a higher percentage of Tonian and Mesoproterozoic grains than do the Armorican quartzites from the CIZ–OMZ transition zone (Linnemann et al. 2008), suggesting lateral variations in the sources. During the Early Ordovician, rifting in southwestern Iberia was most probably characterized by the formation of rift shoulders, tilted blocks, and/or complex systems of horsts and grabens such that the S-CIZ Ediacaran basement was exposed in some places but not in others.

The Cambrian zircons found in the Lower Ordovician quartzites fits the interval of magmatic activity in the OMZ (absent in the S-CIZ), representing the onset of rifting in North Gondwana (Sánchez-García et al. 2010 and references therein). The discovery of Early Ordovician detrital zircons seems to indicate a source related to the widespread magmatic event that occurred in the CIZ (the Urro Formation, Solá et al. 2008; and the Ollo de Sapo Formation, Montero et al. 2007) and which preceded the passive margin stage of the Rheic Ocean (North Gondwana).

Acknowledgments This work is a contribution to research project GONDWANA-PTDC/CTE-GIX/110426/2009. It is a contribution to project PEst-OE/CTE/UI4073/2014.

References

- Delgado, J. F. N. (1908). *Sistema Silúrico de Portugal. Étude de stratigraphie paléontologique. Memórias dos Serviços Geológicos de Portugal* (p. 245).
- Liñán, E., & Quesada, C. (1990). Part V Ossa-Morena Zone: 2. Stratigraphy. In R. D. Dallmeyer & E. Martinez-Garcia (Eds.), *Pre-mesozoic geology of Iberia* (pp. 229–266). Berlin: Springer.

- Linnemann, U., Pereira, M. F., Jeffries, T., Drost, K., & Gerdes, A. (2008). Cadomian orogeny and the opening of the Rheic Ocean: New insights in the diachrony of geotectonic processes constrained by LA–ICP–MS U–Pb zircon dating (Ossa–Morena and Saxo–Thuringian Zones, Iberian and Bohemian Massifs). *Tectonophysics*, 461, 21–43.
- Montero, P., Bea, F., Gonzalez-Lodero, F., Talavera, C. M., & Whitehouse, J. (2007). Zircon ages of the metavolcanic rocks and metagranites of the Ollo de sapo domain in central Spain: Implications for the Neoproterozoic to early Palaeozoic evolution of Iberia. *Geological Magazine*, 144(6), 963–976.
- Oliveira, J. T., Pereira, E., Piçarra, J. M., Young, T., & Romano, M. (1992). O Paleozóico Inferior de Portugal: Síntese da estratigrafia e da evolução paleogeográfica. In J. Saavedra, I. Rábano, & J. G. Gutierrez Marco (Eds.), *Paleozoico inferior de Ibero-América* (pp. 359–375). Spain: Universidad de Extremadura.
- Pereira, M. F., Chichorro, M., Solá, A. R., Silva, J. B., Sánchez-García, T., & Bellido, F. (2011). Tracing the Cadomian magmatism with detrital/inherited zircon ages by in situ U–Pb SHRIMP geochronology (Ossa–Morena Zone, SW Iberian Massif). *Lithos*, 123, 204–217.
- Pereira, M. F., Solá, A. R., Chichorro, M., Lopes, L., Gerdes, A., & Silva, J. B. (2012a). North-Gondwana assembly, break up and paleogeography: U–Pb isotope evidence from detrital and igneous zircons of Ediacaran and Cambrian rocks of SW Iberia (Estremoz Anticline). *Gondwana Research*, 22(3–4), 866–881.
- Pereira, M. F., Linnemann, U., Hofmann, M., Chichorro, M., Solá, A. R., Medina, J., et al. (2012b). The provenance of late Ediacaran and early Ordovician siliciclastic rocks in the Southwest Central Iberian Zone: Constraints from detrital zircon data on northern Gondwana margin evolution during the late Neoproterozoic. *Precambrian Research*, 192–195, 166–189.
- Sánchez-García, T., Bellido, F., Pereira, M. F., Chichorro, M., Quesada, C., Pin, C., et al. (2010). Rift related volcanism predating the birth of the Rheic Ocean (Ossa–Morena Zone, SW Iberia). *Gondwana Research*, 17(2–4), 392–407.
- Solá, A. R., Pereira, M. F., Williams, I. S., Ribeiro, M. L., Neiva, A. M. R., Montero, P., et al. (2008). New insights from U–Pb zircon dating of early Ordovician magmatism on the northern Gondwana margin: The Urro Formation (SW Iberian Massif, Portugal). *Tectonophysics*, 461, 114–129.
- Sousa, M. B. (1984). Considerações sobre a estratigrafia do Complexo Xisto-Grauwauquico (CXG) e sua relação com o Paleozoico Inferior. *Cuadernos de Geología Ibérica*, 9, 9–36.
- Silva, J. B., & Pereira, M. F. (2004). Transcurrent Continental Tectonics model for the Ossa–Morena Zone Neoproterozoic–Paleozoic evolution, SW Iberian Massif, Portugal. *International Journal of Earth Sciences, Geologische Rundschau*, 93, 886–896.