Comparison between detrital zircon populations from the Ordovician rocks of the Pyrenees and from other Perigondwanan terrains: paleogeographic implications

Comparación entre poblaciones de circones detríticos de rocas ordovícicas del Pirineo y de otros terrenos perigondwánicos: implicaciones paleogeográficas

A. Margalef[1], J.M. Casas[2], P. Castiñeiras[3], M. Navidad[3] and M. Liesa[4]

1 Centre d'Estudis de la Neu i de la Muntanya d'Andorra, Institut d'Estudis Andorrans, Av. Rocafort 21-23, 3ª planta, AD-600 Sant Julià de Lòria (Andorra). amargalef.cenma@iea.ad.
2 Departament de Geodinàmica i Geofísica-Institut de Recerca Geomodels, Universitat de Barcelona, c/Martí Franquès s/n 08028 Barcelona. casas@ub.edu.
3 Departamento de Petrología y Geoquímica, Universidad Complutense de Madrid. 28040 Madrid. castigar@ucm.es, navidad@geo.ucm.es.
4 Departament de Geoquímica, Petrologia i Prospecció Geològica, Universitat de Barcelona, c/Martí Franquès s/n 08028 Barcelona. mliesa@ub.edu.

Abstract: The first LA-ICP-MS U-Pb detrital zircon ages from quartzites located in the Ordovician rocks from the Central Pyrenees (the Rabassa Dome, Andorra) were investigated. The four studied samples present very similar U-Pb age patterns. The main age populations correspond to Neoproterozoic (Ediacarian–Cryogenian, ca. 550–750 Ma), Grenvillian (Tonian–Stenian, ca. 850–1100 Ma), Paleoproterozoic (Orosirian, ca. 1900–2100 Ma) and Neoarchean (ca. 2500–2650 Ma). The results presented here enable us to discuss the lower Paleozoic paleoposition of the Pyrenean basement rocks. We have compared our samples with that from other Perigondwanan terrains such as Sardinia, Sicily and the Iberian Massif. The similarity with the Sardinian age distribution suggests that these two terranes could share the same source area and that they were paleogeographically close in Ordovician times in front of the Arabian-Nubian Shield. Comparisons with previous proposed reconstructions allow us to obtain a more complete view of the paleogeography of the Northern Gondwana margin during the Cambro-Ordovician.

Key words: Detrital zircon, Ordovician rocks, Pyrenees, North Gondwana margin.

Resumen: *Se han estudiado los primeros datos de edades de LA-ICP-MS U-Pb en circones detríticos correspondientes a rocas ordovícicas del Pirineo central (Domo de la Rabassa, Andorra). Las cuatro muestras estudiadas presentan unos patrones de edades U-Pb muy similares. Las principales poblaciones corresponden al Neoproterozoico (Ediacárico – Criogénico, ca. 550-750 Ma), Grenvilliense (Tónico – Esténico, ca. 580-1100 Ma), Paleoproterozoico (Orosírico, ca. 1900-2100 Ma) y Neoarcaico (ca. 2500-2650 Ma). Los resultados presentados nos permiten discutir sobre la paleoposición de las rocas del basamento pirenaico durante el Paleozoico inferior. Se han comparado nuestras muestras con las de otros terrenos perigondwánicos tales como Cerdeña, Sicilia y el Macizo Ibérico. Las similitudes con la distribución de edades de las muestras de Cerdeña sugieren que estos dos terrenos podrían compartir las mismas áreas fuente y que se podrían encontrar en posiciones cercanas durante el Ordovícico, en frente del escudo de Arabia y Nubia. Las comparaciones con algunas reconstrucciones propuestas previamente nos han permitido obtener una visión más completa de la paleogeografía del margen norte de Gondwana durante el Cambro-Ordovícico.*

Palabras clave: *Circones detríticos, rocas Ordovícicas, Pirineos, margen norte de Gondwana.*

INTRODUCTION

We report the first U-Pb detrital zircon ages from the pre-Variscan basement rocks at the Rabassa Dome in the Central Pyrenees, where a thick unfossiliferous metasedimentary sequence largely outcrops (Fig. 1a). This sequence is covered by the Upper Ordovician unconformity and is known as "pre-Upper Ordovician" sequence. The used machine is a Thermo-Scientific Element 2 XR sector field ICP-MS coupled to a New Wave UP-193 Excimer Laser System located at the Museum fur Mineralogie und Geologie (Dresden).

We selected three samples of quartzites from just below the Upper Ordovician unconformity and one sample of quartzite from above it. Samples RB-10-01, RB-10-02 and RB-10-03 correspond to quartzites from the uppermost part of the Júnols Group collected near the village of La Moixella on the northern slope of the Rabassa Dome (Andorra), below the Upper Ordovician unconformity. Sample RB-10-04 corresponds to the Upper Ordovician Bar quartzite and is a medium-grained, almost pure quartzite with some undeformed chlorite-mica blasts (Fig. 1b).

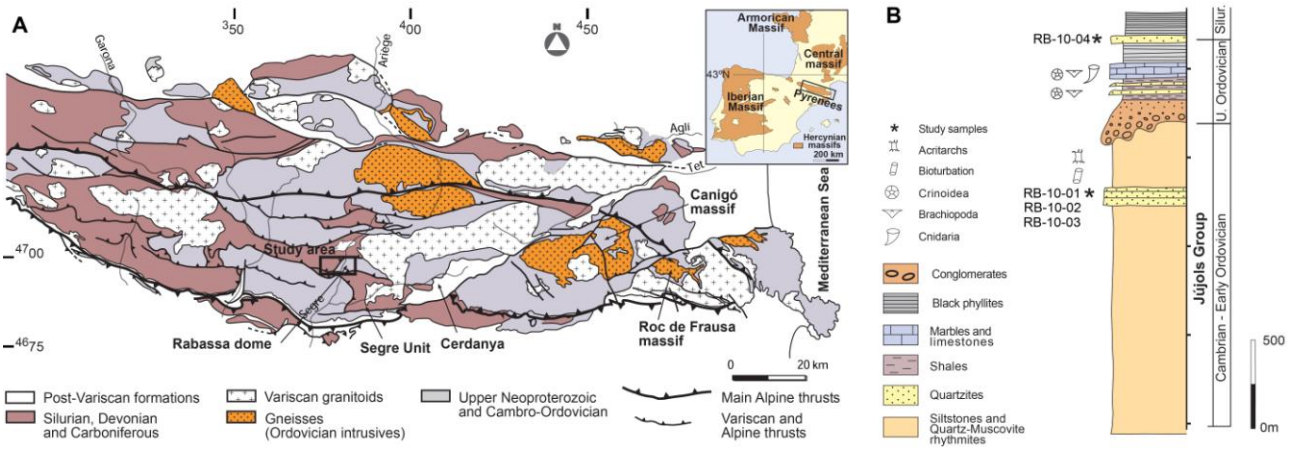

FIGURE 1. A) *Simplified geological map of the Central and Eastern Pyrenees showing the location of the study area. B) Synthetic stratigraphic column of the pre-Silurian rocks of the Rabassa dome with the location of the study samples.*

RESULTS

The results of the U-Pb dating of the detrital zircon are represented as relative probability plots (Fig. 2).

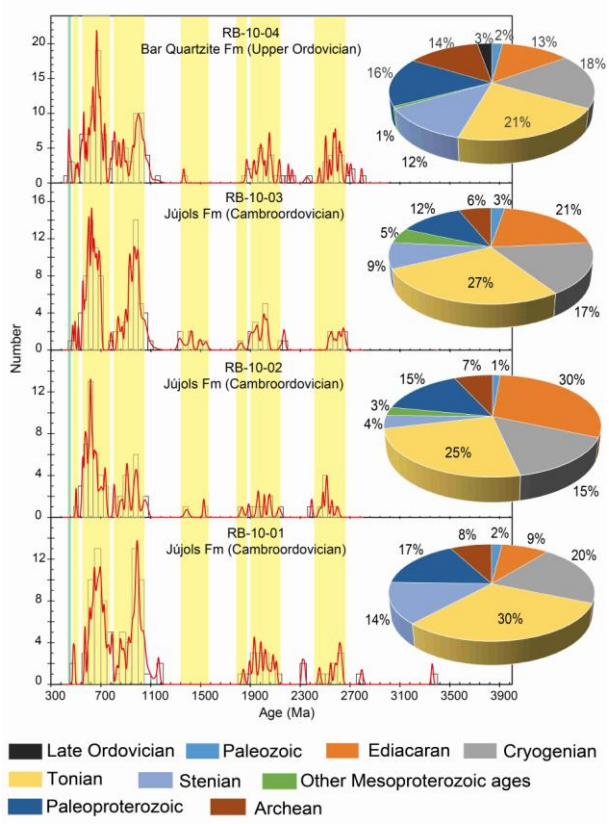

FIGURE 2. *Relative probability plots and age frequency histograms of detrital zircon grains in the range 300–3900 Ma. Yellow bars represent a visual approximation of the main age groups. The green bar represents an Upper Ordovician zircon population peak only present in the sample RB-10-04.*

The Age Pick program (Gehrels, 2012) was used to define statistically robust, mutually comparable age populations that can also be juxtaposed with samples from other peri-Gondwanan regions. In order of abundance, and taking into account jointly the results from the analyses of all four samples, the main age population groups of the samples from Andorra are as follows: (1) The main age population is Neoproterozoic, in the range 770–550 Ma, (2) the second age population is in the range 1100–770 Ma (Tonian–Stenian) which has previously been reported in the literature as a Grenvillian-age population, (3) finally, both Neoarchean (ca. 2650–2500 Ma) and Orosirian (ca. 2075-1900 Ma) populations are present in a similar proportion. The youngest population corresponds to early Cambrian–Early Ordovician zircons (ca. 470–520 Ma) in samples RB-10-01, RB-10-02 and RB-10-03, whereas sample RB-10-04 presents an early Silurian–Late Ordovician age population (ca. 440–455 Ma).

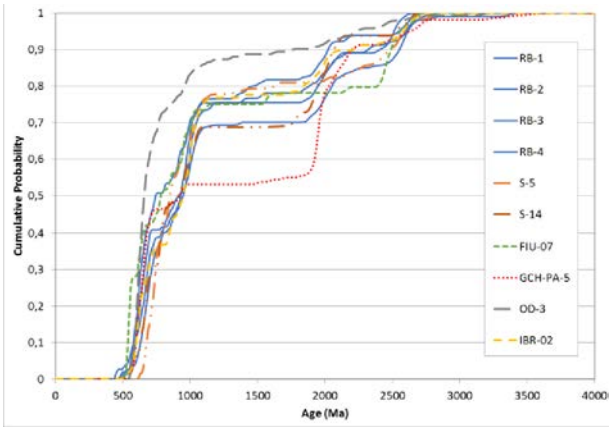

FIGURE 3. *Cumulative probability plot showing the behavior of the Andorran detrital zircon populations (in blue) and each of the samples from other regions: samples S-14 and S-5 from Sardinia (Avigad et al. 2012); sample FIU-07 from Sicily (Williams et al, 2012); and samples GCH-PA-5, OD-3 and IBR-02 from the Iberian Massif (Díez-Fernandez et al. 2012; Fernández–Suárez et al. 2014; Shaw et al. 2014 respectively) See colour graphics in digital version.*

PALEOGEOGRAPHIC IMPLICATIONS

The most accepted paleogeographic reconstructions of the northern Gondwana margin during the late Proterozoic-early Paleozoic, place the terranes either to the west, in front of the West African Craton, if no

Mesoproterozoic ages are found, or to the east, next to the Saharan Metacraton and the Arabian-Nubian Shield, if the Mesoproterozoic signature is maximum (e.g., Meinhold et al. 2013).

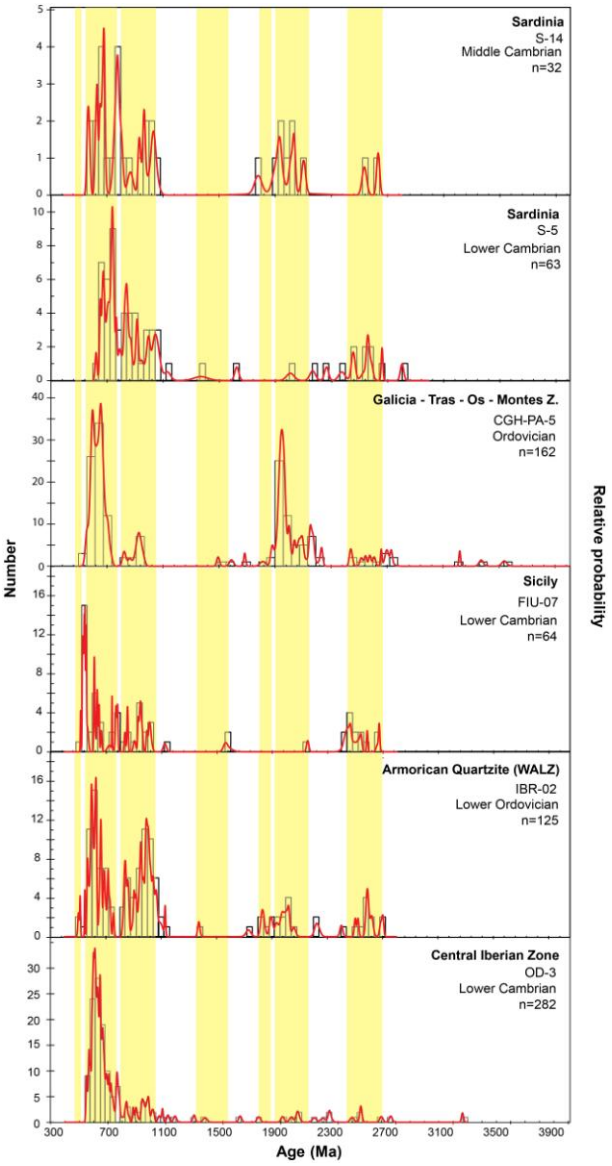

FIGURE 4. *Relative probability plots built up with data from Sardinia (Avigad et al. 2012); Sicily (Williams et al. 2012) and the Armorican Quartzite (Díez-Fernandez et al. 2012; Fernández–Suárez et al. 2014; Shaw et al. 2014). Yellow bars show the main age groups in the Pyrenees and correspond to those in Figure 2.*

Concerning the Pyrenees, the presence of the Grenvillian age population in the Andorran samples suggests that their paleoposition was close to the eastern North Africa domain during the Early Paleozoic. In order to precise this hypothesis, we have compared our data with the available detrital zircon data from the nearest Perigondwanan terranes: Sardinia, Sicily and the Iberian Massif (Fig. 3). The samples chosen were: 1) samples S-5 and S-14 from Sardinia (Avigad et al. 2012); 2) sample FIU-07 from Sicily (Williams et al. 2012) and 3) samples GCH-PA-5, OD-3 and IBR-2 from the Iberian Massif (Díez-Fernandez et al. 2012; Fernández–Suárez et al. 2014; Shaw et al. 2014 respectively). We have overlaid the markers derived from the main age populations from the Pyrenees on the relative probability plots of these samples (Fig. 4), which enabled us to compare the Pyrenean populations with these other Perigondwanan samples.

Sardinian S-5 and S-14 samples are from early–middle Cambrian quartz–arenites and exhibit Neoproterozoic zircon populations in similar proportions to Andorran samples (Fig. 4). It can be noted the Sardinian and the Pyrenean detrital zircon populations are very similar and so, they could share common source areas and they could be located in a close paleoposition during Cambro-Ordovician times.

The Sicilian sample FIU-07 (Upper Ediacaran–Lower Cambrian paragneiss, Williams et al. 2012) shows a population pattern similar to that of the Andorran samples except for the lack of a Paleoproterozoic zircon population.

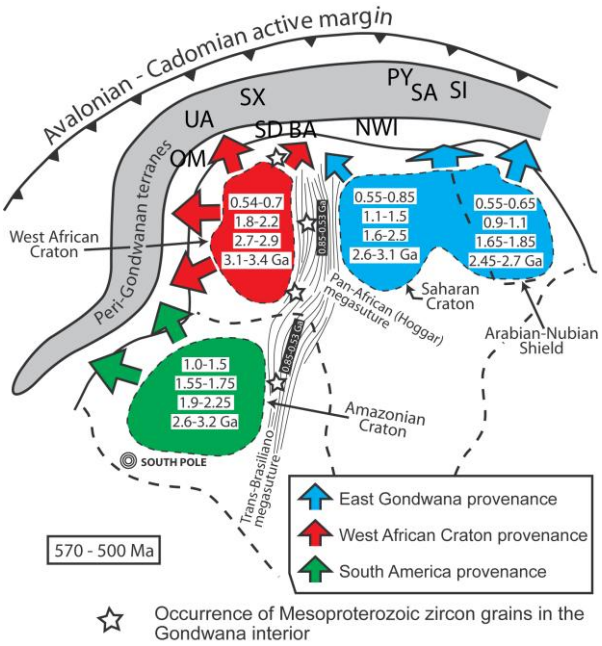

FIGURE 5. Simplified reconstruction of Western Gondwana during the late Neoproterozoic–early Paleozoic, modified after Díez-Fernández et al. (2010). Suggested paleoposition of the uppermost terrane of the allochthonous complexes of NW Iberia (UA), the Basal Units of the allochtonus complexes (BA) and the Schistose Domain (SD) after Díez-Fernández et al (2010); Ossa-Morena Zone (OM), afer Fernández-Suárez et al. (2002) and Linnemann et al. (2008); Saxo-Thuringian Zone (SX) after Linnemann et al. (2008) and Meinhold et al. (2013); Central Iberian, West Asturian and Cantabrian Zones of NW Iberia (NWI) after Fernández-Suárez et al (2014); Sardinia (SA) after Avigad et al. (2012); Sicily (SI) after Williams et al. (2012) and the Pyrenees (PY) this study.

Regarding the Iberian Massif, sample GCH-PA-5 is a quartzite form the Parautochthon or Schistose Domain, (Díez-Fernandez et al. 2012); sample OD-3 is a lower Cambrian sandstone from the Central Iberian Zone (Fernández–Suárez et al. 2014) and sample IBR-

02 belongs to the easternmost outcrops of the Lower Ordovician Armorican Quartzite (Shaw et al. 2014). A qualitative visual approach from cumulative probability plots allows us to propose that the detrital zircon populations from samples GCH-PA-5 and OD-3 differ from Andorran populations (Figs. 3 and 4). On the other hand, Armorican Quartzite sample IBR-02 has a Cambro-Ordovician zircon population that is similar to that observed in samples from Andorra. Neoproterozoic, Tonian–Stenian and Neoarchean populations are also similar to the samples from Andorra. Thus, we suggest that Andorra and the easternmost part of the Iberian Armorican Quartzite may share part of the detrital zircon input and some source areas.

The similarity with the Sardinian age distribution points out that the Andorran samples could have the same source area than the SW of Sardinia at Ordovician times, somewhere between Libya and Algeria in the west, and the mouth of the Arabian–Nubian drainage system in the east, as shown in Figure 5. This assumption could be confirmed by the presence of a Late Ordovician zircon population (sample RB-10-04) that is coincident with the Late Ordovician zircon population of the Kufra basin in Libya (Meinhold et al. 2013, Fig. 3).

CONCLUSIONS

All the study samples analyzed below and above the unconformity show similar U-Pb age patterns. The main age populations correspond to Neoproterozoic (Ediacarian–Cryogenian, ca. 550–750 Ma), Grenvillian (Tonian–Stenian, ca. 850–1100 Ma), Paleoproterozoic (Orosirian, ca.1900–2100 Ma) and Neoarchean (ca. 2500–2650 Ma).

The similarity displayed between our samples and the Sardinian zircon age populations suggests that they could share source areas and therefore they also could be located very close to each other in Ordovician times. Based on a comparison with other parts of the northern Gondwana margin, we propose that the Eastern Pyrenees were located in front of the Saharan Metacraton.

ACKNOWLEDGEMENTS

This work was funded by projects CGL2010-21298 and Consolider-Ingenio 2010, under CSD2006-00041 *Topoiberia*. Funding for A. M. came from Institut d'Estudis Andorrans.

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