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A review of U-Pb detrital zircon systematics from Cambrian-Lower Devonian rocks of the Moroccan Meseta

La Meseta Marroquí del Cámbrico al Devónico Inferior: síntesis de edades U/Pb en circones detríticos

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ABSTRACT

U-Pb geochronological analysis of detrital zircon grains is a powerful tool to decipher the pre-Mesozoic paleogeography. In this work, we present a sediment provenance study based on a compilation of 41 Cambrian-Early Devonian siliciclastic samples from the Moroccan Meseta. All of them are characterized by late Tonian-Ediacaran (c. 600 Ma, c. 50% of the data), Rhyacian-Orosirian (c. 2100 Ma, c. 20% of the data), and Neoarchean (c. 2500 Ma, c. 4% of the data) detrital zircon age populations indicating a strong West African Craton affinity. Minor populations are: (i) Cambrian-Ordovician (c. 500 Ma), particularly relevant in Lower Ordovician samples, which were probably sourced by local volcanic centers formed during an aborted rift; (ii) Stenian-early Tonian (c. 1000 Ma); and (iii) Orosirian-Statherian (c. 1800 Ma). These two latter populations were probably fed by paleocurrents from NE-African regions (e.g., Sahara Metacraton and Arabian-Nubian Shield) that reached only intermittently the studied area. Finally, the spatial and chronological distribution of the detrital zircon age populations suggests that the tectonic boundaries normally used to separate internal subdomains in northern Morocco did not imply far-travelled terranes during early-middle Paleozoic times.

Key-words: *NW African Variscides, West African Craton, Northern Gondwana margin, Sediment provenance.*

RESUMEN

El análisis geocronológico mediante el método U-Pb de circones detríticos es una herramienta valiosa para establecer la paleogeografía pre-Mesozoica. En este trabajo presentamos una compilación de 41 muestras siliciclásticas del Cámbrico-Devónico inferior en la Meseta Marroquí. Todas están caracterizadas por poblaciones del Tónico superior-Ediacárico (c. 600 Ma, c. 50% de los datos), Riácico-Orosírico (c. 2100 Ma, c. 20% de los datos) y Neoarcaico (c. 2500 Ma, c. 4% de los datos), que indican una fuerte afinidad de estas rocas con el Cratón de África Occidental. Otras poblaciones menores son del: (i) Cámbrico-Ordovícico (c. 500 Ma), muy comunes en las muestras del Ordovícico inferior y con probable origen en centros volcánicos locales que se formaron durante una fase de rifting abortado; (ii) Esténico-Tónico inferior (c. 1000 Ma) y (iii) Orosírico-Estatérico (c. 1800 Ma), ambas tuvieron su fuente probable en paleocorrientes desde el NE de África (e.g., Metacratón del Sahara y Escudo Arábigo-Núbico) que alcanzaron de forma intermitente el área estudiada. Finalmente, la distribución espacial y temporal de las poblaciones sugiere que los contactos tectónicos que se suelen usar para distinguir diferentes dominios en el N de Marruecos no implicaron a terrenos exóticos durante el Paleozoico inferior-medio.

Palabras clave: *Varíscides del NO de África, Cratón de África Occidental, margen septentrional de Gondwana, proveniencia de sedimentos.*

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Introduction

The understanding of the paleo-geographic framework of ancient orogens, such as the Late Paleozoic Caledonian/ Appalachian/Variscan belts, is a difficult task that must be investigated by multiple approaches. Sediment provenance studies based on the U-Pb geochronology of detrital zircon grains help to recognize different terranes involved in orogenic events. In the European part of the Variscan belt, a large database has already permitted great advances in the paleogeographic reconstruction of the region (*e.g.*, Braid et al., 2011; Eckelmann et al., 2014; Fernández-Suárez et al., 2014; Franke and Dulce, 2017; Gutiérrez-Alonso et al., 2015; Linnemann et al., 2004; Pereira et al., 2017; Pérez-Cáceres et al., 2017; Shaw et al., 2014). In the Northern Moroccan Variscides, this technique has been less applied.

This paper reviews the knowledge of the sedimentary sources and paleogeographic evolution of the Paleozoic northern Gondwanan passive margin prior to its involvement in the Variscan orogeny. To do so, we compile and discuss the available U-Pb detrital zircon age data of 41 sandstone upper Cambrian-Lower Devonian samples from the Moroccan Meseta (Fig. 1; Accotto et al., 2019, 2021, 2022; Ghienne et al., 2018; Letsch et al., 2018).

Geological setting

After the Pan-African and Cadomian orogenies, which affected North Gondwana (*c.* 750-545 Ma), the Cambrian-Ordovician opening of the Rheic ocean created a passive margin that lasted until the Devonian, and was followed by the late Paleozoic Appalachian/Variscan orogeny.

The Variscan domains in Northern Morocco include the Caledonian Sehoul Block, the Moroccan Mesetas, the Southern Zone, and the Anti-Atlas foreland (Fig. 1A; Michard et al., 2010). These domains have been classically considered as separated by fault zones, whose paleotectonic significance is unclear (Hoepffner et al., 2006; Michard et al., 2010; Simancas et al., 2009).

During the passive margin time span, a sedimentary sequence deposited above the Precambrian (Cadomian) basement in the Moroccan Meseta. A Cambrian carbonate platform was soon interrupted and followed, especially in the west, by the infilling of grabens with thick siliciclastic deposits accompanied by local volcanic centers, these latter representing an aborted rift related with the opening

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of the Rheic Ocean (El Attari et al., 2019; Pouclet et al., 2018). Shallow platform conditions characterized the Early-Middle Ordovician with the deposition of shales and sandstones (Michard et al., 2010), followed by Late Ordovician tillites (Le Heron et al., 2009). Silurian sedimentation was mainly pelitic and changed to Lower Devonian siliciclastic turbidites with carbonatic intercalations, particularly frequent in the western domains.

Results

U/Pb zircon analyses with discordance > ±10% were discarded. The Kernel Density Estimators (KDE; Fig. 2) were realized with Density Plotter 8.4 (Vermeesch, 2012) using $^{207}Pb/^{206}Pb$ data for ages older than 1.5 Ga, and $^{206}Pb/^{238}U$ data for younger ages.

Almost all of the samples are characterized by the same common age populations (Fig. 2): Late Tonian-Ediacaran (*c.* 850-540 Ma, 33-59% of the data in each sample), Rhyacian-Orosirian (*c.* 2200-1950 Ma; 9-30% of the data), and Neoarchean (*c.* 2800-2500 Ma; usually 3-9% of the data).

Minor and variably represented age populations are (Fig. 2): Cambrian-Ordovician (*c.* 540-450; this population is frequently absent; when present, it includes 2-4% of the data, although a few Lower Ordovician samples contain 21-68% of the data); Stenian-early Tonian (*c.* 1150-850 Ma; this population is mostly present in Middle Ordovician-Lower Devonian samples; it can include up to 26% of the data); and Orosirian-Statherian (*c.* 1950-1750 Ma; 2-12% of the data).

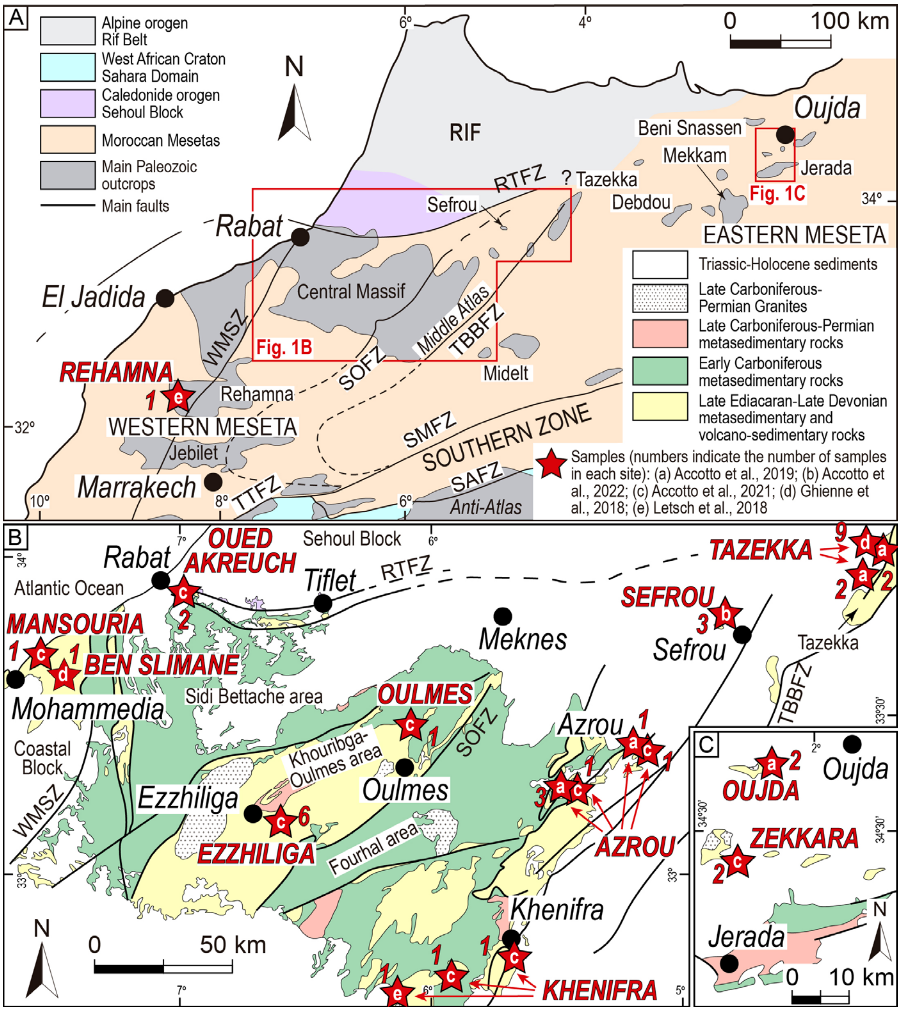

Fig. 1.- (A) Main Variscan domains in North Morocco (modified from Hoepffner et al., 2006; Michard et al., 2010). (B) Sample location in the Western Meseta (modified from Arboleya et al., 2004; Becker and El Hassani, 2020). (C) Sample location in the Eastern Meseta (modified from Muratet, 1995). RTFZ: Rabat-Tiflet Fault Zone; WMSZ: Western Meseta Shear Zone; SOFZ: Smaala-Oulmès Fault Zone; TBBFZ: Tazekka-Bsabis-Bekrit Fault Zone; TTFZ: Tizin'Test Fault Zone; SMFZ: South Meseta Fault Zone; SAFZ: South Atlas Fault Zone. Ver figura en color en la web.

Fig.1.- (A) Principales dominios variscos en Marruecos septentrional (modificado de Hoepffner et al., 2006; Michard et al., 2010b). (B) Situación de muestras en la Meseta Occidental (modificado de Arboleya et al., 2004; Becker and El Hassani, 2020). (C) Situación de muestras en la Meseta Oriental (modificado de Muratet, 1995). RTFZ: Zona de Falla de Rabat-Tiflet; WMSZ: Zona de Cizalla de la Meseta Occidental; SOFZ: Zona de Falla de Smaala-Oulmès; TBBFZ: Zona de Falla de Tazekka-Bsabis-Bekrit; TTFZ: Zona de Falla de Tizin'Test; SMFZ: Zona de Falla de la Meseta meridional; SAFZ: Zona de Falla Sud-Atlásica. See color figure in the web.

Discussion

The consistent presence of Late Tonian-Ediacaran, Rhyacian-Orosirian, and Neoarchean detrital zircon age populations, together with a lack of Mesoproterozoic (c. 1700-1200 Ma) populations, is typical of West African Craton (WAC) sources (e.g., Nance et al., 2008 and references therein), both primary or recycled. These populations are generally related to the Pan-African/Cadomian, Eburnean, and Leonian/Liberian orogenies, respectively.

Among the Late Tonian-Ediacaran population, it is normally difficult to distinguish between Pan-African (*c.* 760-555 Ma; assembly of Northern Gondwanan cratons; Hefferan et al., 2014) and Cadomian (*c.* 590-545 Ma; Andean-type arc along the Northern Gondwana margin; Linnemann et al., 2008) sources, because of their overlap in time and space. Nevertheless, it is perceivable in Fig. 2 (right column) that the Neoproterozoic highest peaks in Lower Ordovician samples are slightly younger (*c.* 590-550 Ma, indicating a predominance of Cadomian sources) than in Middle Ordovician-Lower Devonian samples (*c.* 650-600 Ma, whose main source probably was the Pan-African basement).

The Cambrian-Ordovician population is particularly prevailing in Cambrian-Lower Ordovician samples (Fig. 2). The sources of these detrital zircon grains were probably close to volcanic centers, related to the rifting phase (El Attari et al., 2019; Pouclet et al., 2018), which were rapidly buried by the overlying passive margin sediments.

Sources of Stenian-early Tonian detrital zircon grains are unknown in the WAC, but common in NE African regions, such as the Sahara Metacraton and the Arabian-Nubian Shield (*e.g.*, Bea et al., 2010; Meinhold et al., 2013). The recurrence of this population in the Moroccan Meseta is irregular in space and time (Fig. 2), suggesting intermittent, very distant sediment input from NE Africa. The Orosirian-Statherian detrital zircon population might also be sourced from NE African regions, together with the Stenian-early Tonian grains.

Conclusions

A sediment provenance study based on a compilation of U-Pb geochronological data of 41 Cambrian-Lower Devonian samples from the Moroccan Meseta indicates a strong WAC affinity during all the Northern Gondwana passive margin phase. Secondary sources of sediments might be found in rift-related Cambrian-Ordovician local volcanic centers and NE African regions (*e.g.* Sahara Metacraton and Arabian-Nubian Shield).

The distribution of the detrital zircon age populations suggests that the tectonic boundaries between the different domains of the Moroccan Meseta had limited effects on the early-middle Paleozoic sedimentation in this region.

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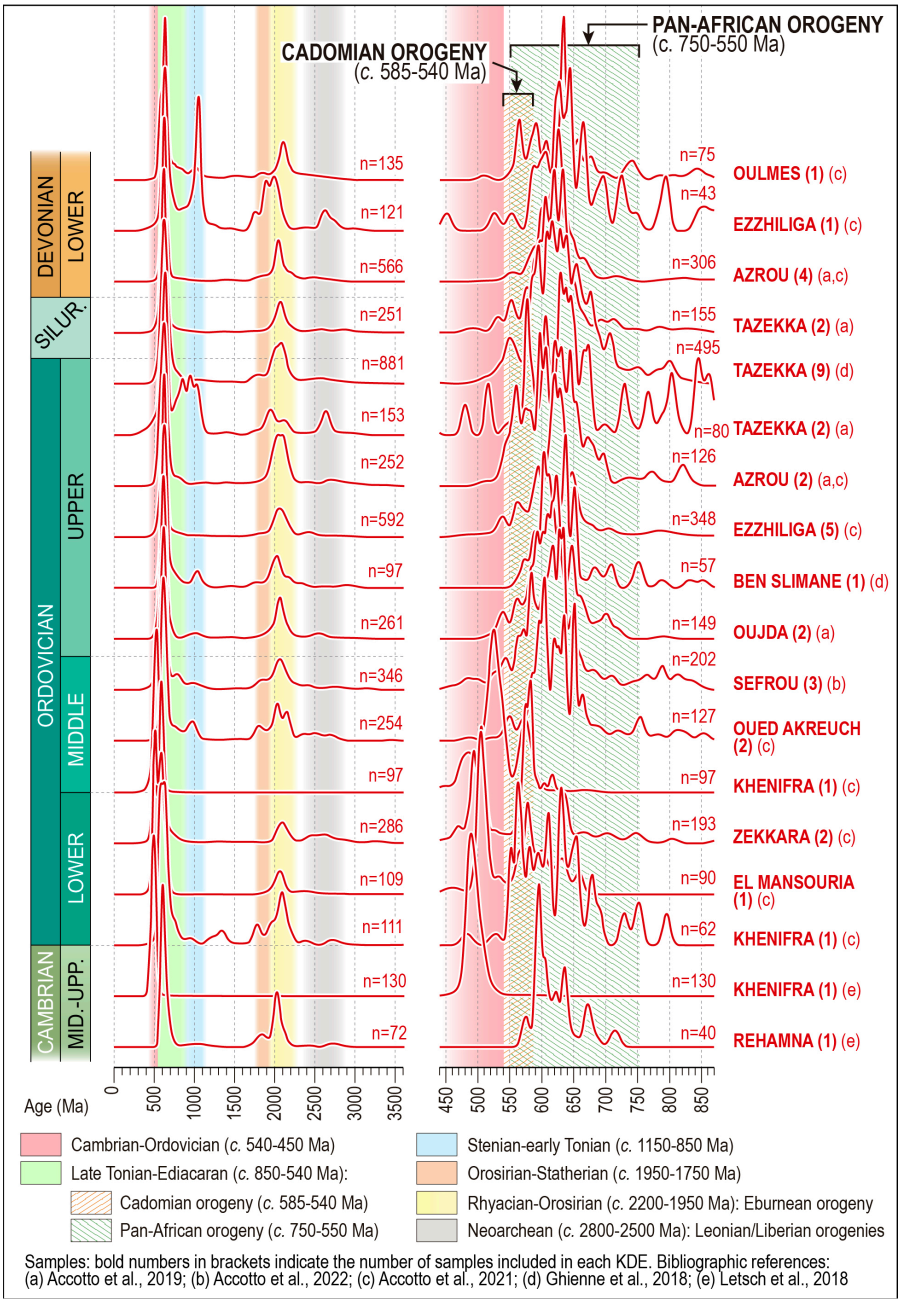

Samples: bold numbers in brackets indicate the number of samples included in each KDE. Bibliographic references: (a) Accotto et al., 2019; (b) Accotto et al., 2022; (c) Accotto et al., 2021; (d) Ghienne et al., 2018; (e) Letsch et al., 2018

Fig. 2.- Comparison of Kernel Density Estimators of the compiled samples. The left column shows total results, while the right column shows the 870-440 Ma interval. Ver figura en color en la web.

Fig.2.- Comparativa entre los Kernel Density Estimators de las muestras estudiadas. La columna de la izquierda muestra todos los datos, mientras que la de la derecha muestra sólo el intervalo 870-440 Ma. See color figure in the web.

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