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The role of U-Pb ages of detrital zircons in sedimentology—An alarming case study for the impact of sampling for provenance interpretation

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ABSTRACT

U-Pb ages on detrital zircons are often utilised for stratigraphic and paleogeographic interpretations and correlation. Sampling is carried out in such a way that the samples are representative for a formation, and then used for provenance identification and/or defining a maximum time limit for deposition. Is it possible that sedimentological factors and sampling would influence the results? This is perhaps an obvious consideration for sedimentologists, but is in many studies treated as a secondary concern or even not mentioned.

U-Pb LA-ICP-MS analysis on detrital zircons from two samples of Cambrian age (Herrería Formation, Cantabrian Mountains, Spain) revealed very different provenance signatures at the base and top of the formation. Both successions have been deposited in a shallow marine environment, are lithologically comparable (arenites, feldspathic arenites, siltstone, shales intercalated with marls and dolomite) and differ only slightly in age. Nearly 80% of all detrital zircons ($n = 152$; discordance ≤ 10) at the base of the formation are younger than 650 Ma. Detrital zircons older than 1.0 Ga amount to only 10% ($n = 16$) of the entire population. In contrast, only around 32% of all detrital zircons from the top of the formation ($n = 123$; discordance ≤ 10) are younger than 650 Ma while more than 16% are Archean and nearly 50% Paleoproterozoic. This implies a fundamental change in provenance, with a shift from Neoproterozoic to Paleoproterozoic (1.9–2.2 Ga) aged sediment sources. Consequently, changes of sediment transport systems have had an extremely profound impact on the provenance of the formation. Therefore, when correlating sedimentary rocks, interpreting source rocks and modelling paleogeography from U-Pb ages of detrital zircons, sedimentological parameters are possibly paramount and these need to be at least discussed before any interpretation is made.

1. Introduction

U-Pb ages of detrital zircons from sedimentary or metasedimentary rocks are widely used for different purposes, such as deciphering the maximum sedimentation age or revealing the major source rock regions and their ages. In some cases, these minerals are the only tools to determine a maximum age limit for deposition if fossils are not available and volcanic rocks are absent, which is often the case especially in the Precambrian record (Amelin et al., 2000; Schneiderhan et al., 2011; Corcoran et al., 2013), and in Phanerozoic sandstone successions (e.g., Fourie et al., 2011; Naidoo et al., 2013). Time constraints on deposition from detrital zircon are however never very robust since there is no necessary connection between zircon-forming processes and subsequent erosion and deposition of sediment (e.g., Andersen, 2005). In numerous studies, isotope ages of detrital minerals are used to identify the geological evolution of a cratonic or continental block, which is sometimes successful (Bahlburg et al., 2009) and sometimes not (Fourie et al., 2011), depending on the tectonic setting of the sediment (e.g., Cawood et al., 2012) or other criteria, such as the exhumation history of the source area (e.g., Krippner and Bahlburg, 2013) or paleogeographic constraints (e.g., Naidoo et al., 2013). The U-Pb ages of the detrital zircons are also used to identify a specific origin, to interpret the observed detrital zircon age distribution pattern as being typical for a given continent (e.g., Rapela et al., 2007; see Andersen (2014, for a review of some of the problems involved in this approach), and for correlation purposes (e.g., Basei et al., 2008). All these studies need to fulfil minimum criteria in terms of dating a sufficient number of detrital zircons—generally around 100 grains and doing so in an unbiased way when picking the grains to be measured (Vermeesch, 2004; Andersen, 2005; Malusà et al., 2013) when interpreting the absence of certain age or size fractions. In addition to problems arising from sampling statistics, sedimentological processes may affect, and often even entirely control, the detrital information. Most important are (i) sorting effects in reworked sandstones leading to different heavy mineral composition in different grain size fractions, (ii) accumulation of specific heavy

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minerals in placers in general and depending on the type of placer and (iii) sedimentary facies that control the abundance of heavy minerals, such as in point-bars where the provenance of the detritus differs from sand bars in river system (Garzanti et al., 2010, 2011). When studying highly metamorphosed sedimentary successions, these effects cannot easily be estimated, if at all. Sampling for the above-mentioned purposes (which are the most common applications) can be executed by using one single block of rock interpreted to be representative for an entire formation, or by collecting smaller samples throughout one or several exposures or merging a number of sedimentary rock types that sometimes cover different lithofacies, as being representative for one formation or a specific time-span of deposition.

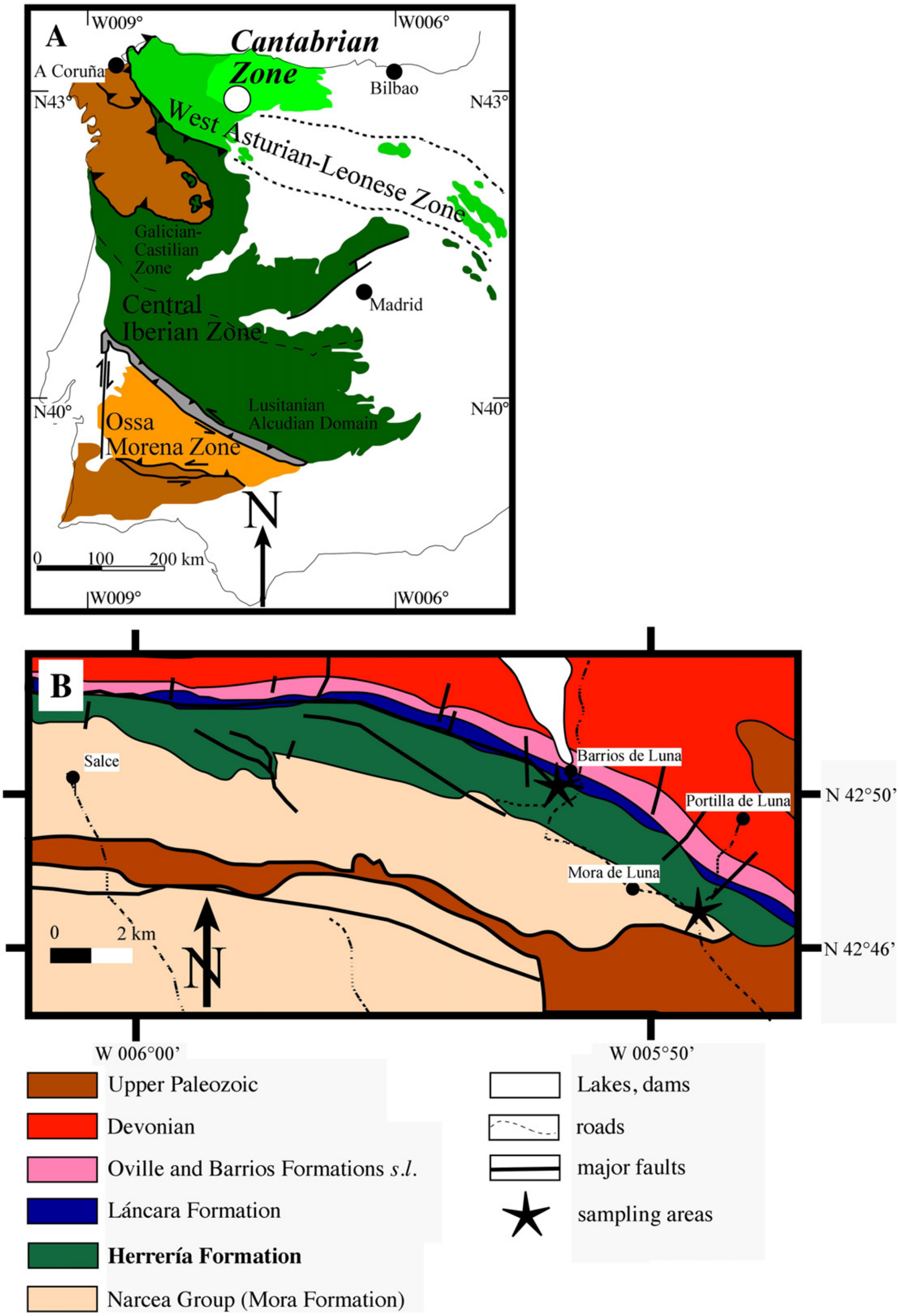

Fig. 1. (A) Subdivision of the Iberian Peninsula and Iberia in several tectonic zones—in brown exotic terranes and in grey the Bardajoz-Córdoba Shear Zone (after López-Guijarro et al., 2008). The white circle in the Cantabrian zone marks the study area. (B) Geological sketch map with the sampling areas (indicated by a star) in northern Spain (modified from Rodríguez Fernández, 1984; Martín Parra, 1989).