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Research Paper

The complexity of sediment recycling as revealed by common Pb isotopes in K-feldspar

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ABSTRACT

Detrital zircon U–Pb geochronology has become the gold standard in evaluating source to sink relationships in sedimentary basins. However, the physical and chemical robustness of zircon, which make it such a useful mineral for provenance studies, is also a hindrance as zircon can be recycled through numerous sedimentary basins, thus obscuring the first cycle source to sink relationship. An elegant approach to addressing this potential issue is to compare the Pb isotope composition of detrital K-feldspar, a mineral which is unlikely to survive more than one erosion-transport-deposition cycle, with that of magmatic K-feldspar from potential basement source terranes. Here we present new *in situ* Pb isotope data on detrital K-feldspar from two Proterozoic arkosic sandstones from Western Australia, and magmatic K-feldspar grains from potential igneous source rocks, as inferred by the age and Hf isotope composition of detrital zircon grains. The data indicate that the detrital zircon and K-feldspar grains could not have been liberated from the same source rocks, and that the zircon has most likely been recycled through older sedimentary basins. These results provide a more complete understanding of apparently simple source to sink relationships in this part of Proterozoic Western Australia.

1. Introduction

Comparing the age and chemical or isotopic signature of minerals in sedimentary rocks to those in potential basement hinterlands is a fundamental tool used to fingerprint source to sink relationships. Such source to sink relationships provide many key constraints used to test palaeogeographic models, refine stratigraphy, and potentially understand depositional timeframes. Detrital zircon geochronology has evolved as the choice for provenance studies because zircon grains are ubiquitous in sandstones, highly resistant to both chemical and physical weathering, amenable to U–Pb dating and carry other isotopic and chemical signatures (e.g. Lu–Hf, REE) that may uniquely link a zircon grain to its basement source. However, although the refractory nature of zircon provides the benefit of recording much of the high-temperature history of a geological terrane, its resistance to erosion provides a challenge to provenance reconstruction as it can be recycled a multitude of times. The (U–Th)/He and U–Pb ‘double’ dating of detrital zircons from a number of sedimentary basins (e.g. Rahl et al., 2003; Campbell et al., 2005) has showed that many zircon grains were exposed to the surface environment long before their host sedimentary rocks have been deposited. In many cases, a major source of sediment detritus is uplift, erosion and recycling of pre-existing (meta)-sedimentary basins. The longevity of the sedimentary cycle means that apparent direct source to sink pathways may, in reality, be much more cryptic (Dickinson et al., 2009; Dickinson and Gehrels, 2009; Hadlari et al., 2015; Anderson et al., 2016), particularly in Precambrian (meta)-sedimentary basins which are commonly deformed or metamorphosed and where other indicators of source provenance, such as paleoflow structures are obscured or obliterated.

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One elegant approach to address the primary source to sink relationship is to compare the common Pb isotopic signature of detrital K-feldspar, a mineral unlikely to survive more than one erosion-transport-deposition cycle, with the signature of potential source basement terranes (e.g. Tyrrell et al., 2006, 2007, 2009, 2012; Flowerdew et al., 2012; Zhang et al., 2014, 2016, 2017; Gagnevin et al., 2017; Lancaster et al., 2017; Reat et al., 2017). K-feldspar is a common mineral in many clastic rocks and is a major constituent of arkosic sandstones. It usually has appreciable concentrations of Pb (10–40 ppm) and little to no U or Th, so there is minimal post-crystallization contamination of radiogenic Pb, which can obscure primary ratios. Furthermore, the Pb isotopic signature in detrital feldspar has been shown to be retained despite recrystallization associated with diagenesis (Tyrrell et al., 2006). Lead isotope variations ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$) in igneous and metamorphic crustal rocks define broad spatial patterns that make the Pb signature of detrital K-feldspar grains a useful provenance tool (e.g. Tyrrell et al., 2012; Flowerdew et al., 2013; Lancaster et al., 2017). Regional patterns in Pb isotopic composition can be identified by characterizing a relatively small number of feldspar grains from potential granitic basement sources (Zartmann and Wasserburg, 1969; DeWolf and Mezger, 1994), or by analysing Pb variations in galena (Fletcher and Farquhar, 1982; Dixon et al., 1990).

The Paleo- to Mesoproterozoic Edmund Group in the Capricorn Orogen of Western Australia is dominated by sandstone units containing detrital zircons that are similar in age and isotopic composition to the underlying basement magmatic rocks of the Gascoyne Province (Martin et al., 2008; Cutten et al., 2016). However, abundant, well-developed paleoflow indicators throughout the basin suggest a primary source outside the province (Martin et al., 2008), implying that the zircon detritus has been recycled, presumably through older basins (Cutten et al., 2016). Here we report the common Pb isotopic signature of detrital K-feldspar from two arkosic sandstones in the Edmund Group, and compare the results to the composition of magmatic K-feldspar from various basement granitic rocks in order to address this dichotomy and further elucidate source to sink relationships in this basin.

2. Geological setting

The Capricorn Orogen is a ~1000 km long, ~500 km wide zone located between the Archean Yilgarn and Pilbara Cratons of Western Australia. The orogen comprises the deformed margins of the two Archean cratons, Proterozoic granitic and metasedimentary rocks of the Gascoyne Province as well as numerous, variably deformed Proterozoic sedimentary basins including the Paleo- to Mesoproterozoic Edmund Basin (Fig. 1; Martin and Thorne, 2004; Martin et al., 2008; Cutten et al., 2016). The orogen formed during the punctuated assembly of the Yilgarn and Pilbara Cratons to form the larger West Australian Craton (e.g. Johnson et al., 2013), and has subsequently been the site of repeated intraplate reworking spanning over one billion years (Sheppard et al., 2005, 2007; Korhonen et al., 2017). The province is dominated by medium- to coarse-grained felsic magmatic rocks of the 1820–1775 Ma Moorarie Supersuite and the 1680–1620 Ma Durlacher Supersuite. Following the emplacement of the Durlacher

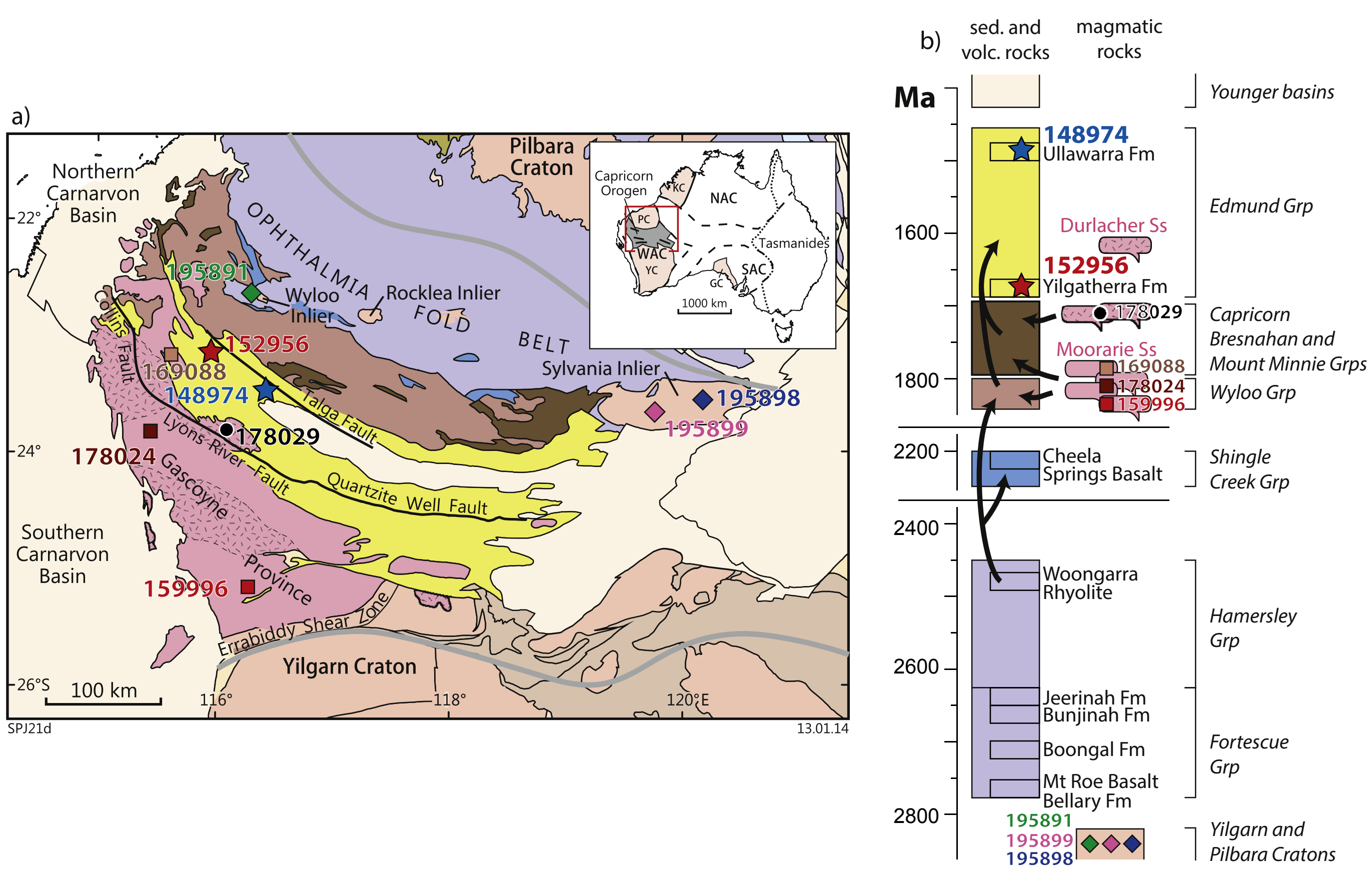

Figure 1. (a) Simplified geological map of the Capricorn Orogen of Western Australia, showing the location of samples studied. The geological legend is provided as a stratigraphic column in (b) which shows possible pathways for recycling of detrital zircons. Inset in (a) is a simplified tectonic map of Australia. Abbreviations: GC–Gawler Craton; KC–Kimberley Craton; NAC–North Australian Craton; PC–Pilbara Craton; SAC–South Australian Craton; WAC–West Australian Craton; YC–Yilgarn Craton.

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