Earth and Planetary Science Letters 308 (2011) 350–358

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

journal homepage: www.elsevier.com/locate/epsl

# Tracing the provenance and recrystallization processes of the Earth's oldest detritus at Mt. Narryer and Jack Hills, Western Australia: An in situ Sm–Nd isotopic study of monazite

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ARTICLE INFO

*Article history:*
Received 15 April 2011
Received in revised form 4 June 2011
Accepted 6 June 2011
Available online 28 June 2011

Editor: R.W. Carlson

*Keywords:*
Nd isotopes
monazite
Hadean
LA-MC-ICPMS
Jack Hills
Mt. Narryer

ABSTRACT

Mount Narryer and Jack Hills metasedimentary rocks in the Narryer Gneiss Complex of the Yilgarn Craton, Western Australia, contain zircons with ages up to 4.4 Ga, the oldest known crustal materials on Earth, and monazites up to 3.6 Ga. In this study, we have investigated $^{147}Sm$–$^{143}Nd$ systematics of detrital and metamorphic monazites from these metasedimentary rocks using laser ablation-multicollector-inductively coupled plasma mass spectrometry (LA-MC-ICPMS). All detrital monazites have negative initial εNd(t) values, indicating that their parental magmas formed by remelting of older crustal materials. A comparison between the initial εNd(t) values of the detrital monazites and granitoids in the Narryer Gneiss Complex indicates that the Mt. Narryer and Jack Hills sediments were partly derived from the most isotopically enriched surrounding granitoids with ages of ca. 3.6 and 3.3 Ga. The metamorphic monazites generally have lower initial εNd(t) values when compared to the detrital monazites. However, the detrital and metamorphic monazites show similar distributions of εNd(t) at the ages of sediment deposition (3.28 Ga for Mt. Narryer and 3.05 Ga for Jack Hills). In addition, multiple analyses on single monazite grains having core-rim structures reveal that the cores and the recrystallized rims had identical Nd isotopic compositions at the time of recrystallization. These findings indicate that older monazites are source of light rare earth elements for younger metamorphic monazite formation and, therefore, that monazite can inherit its primary Sm–Nd isotopic signature during the recrystallization processes. We calculated the Nd model ages for all analyzed monazites to estimate crustal residence time of their source materials. We find that no igneous monazites older than 4.0 Ga were recrystallized to form the monazites. This implies that the lack of Hadean monazites is not due to recrystallization of ancient monazites during later metamorphism, but due to high-Ca compositions of the parental magmas of Hadean detritus, which prevent growth of magmatic monazite.


## 1. Introduction

The oldest exposures of terrestrial crust are 4.03–3.94 Ga granitoid gneisses in the Acasta Gneiss Complex of the Slave Craton (Bowring and Williams, 1999; Iizuka et al., 2007; Stern and Bleeker, 1998) and amphibolites older than 3.8 Ga, possibly up to 4.28 Ga, in the Nuvvuagittuq greenstone belt of the Superior Craton (O'Neil et al., 2008); no crustal rocks have been found from the first 300–500 Ma of Earth's history. Mount Narryer and Jack Hills metasedimentary rocks in the Narryer Gneiss Complex (NGC) of the Yilgarn Craton, Western Australia (Fig. 1a) are of particular importance because they yield Hadean (>4.03 Ga) detrital zircons as old as ~4.4 Ga (Compston and Pidgeon, 1986; Froude et al., 1983; Wilde et al., 2001). The chemical compositions of these ancient zircons have been used to gain insights into the nature and origin of Hadean crust from which they were derived (e.g., Cavosie et al., 2005; Coogan and Hinton, 2006; Nemchin et al., 2006; Trail et al., 2007a; Ushikubo et al., 2008; Watson and Harrison, 2005). Despite the geological significance of the Hadean crustal fragments, other detrital mineral phases in the metasedimentary rocks are only just beginning to receive some attention (Iizuka et al., 2010a; Rasmussen et al., 2010; Valley et al., 2005a) and little is yet known of their nature or significance. Characterization of different detrital phases is crucial for robust provenance analysis.

Monazite, a light rare earth element (LREE) phosphate mineral, is common as an igneous accessory phase in low-Ca felsic rocks and as a secondary accessory phase in a wide range of metamorphic rocks (e.g., Bea, 1996; Kelts et al., 2008; Overstreet, 1967; Spear and Pyle, 2002). Because monazite has high U and Th and low common Pb contents, it can be precisely dated by the U–Th–Pb system (e.g.,

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0012-821X/$ – see front matter 
doi:10.1016/j.epsl.2011.06.006

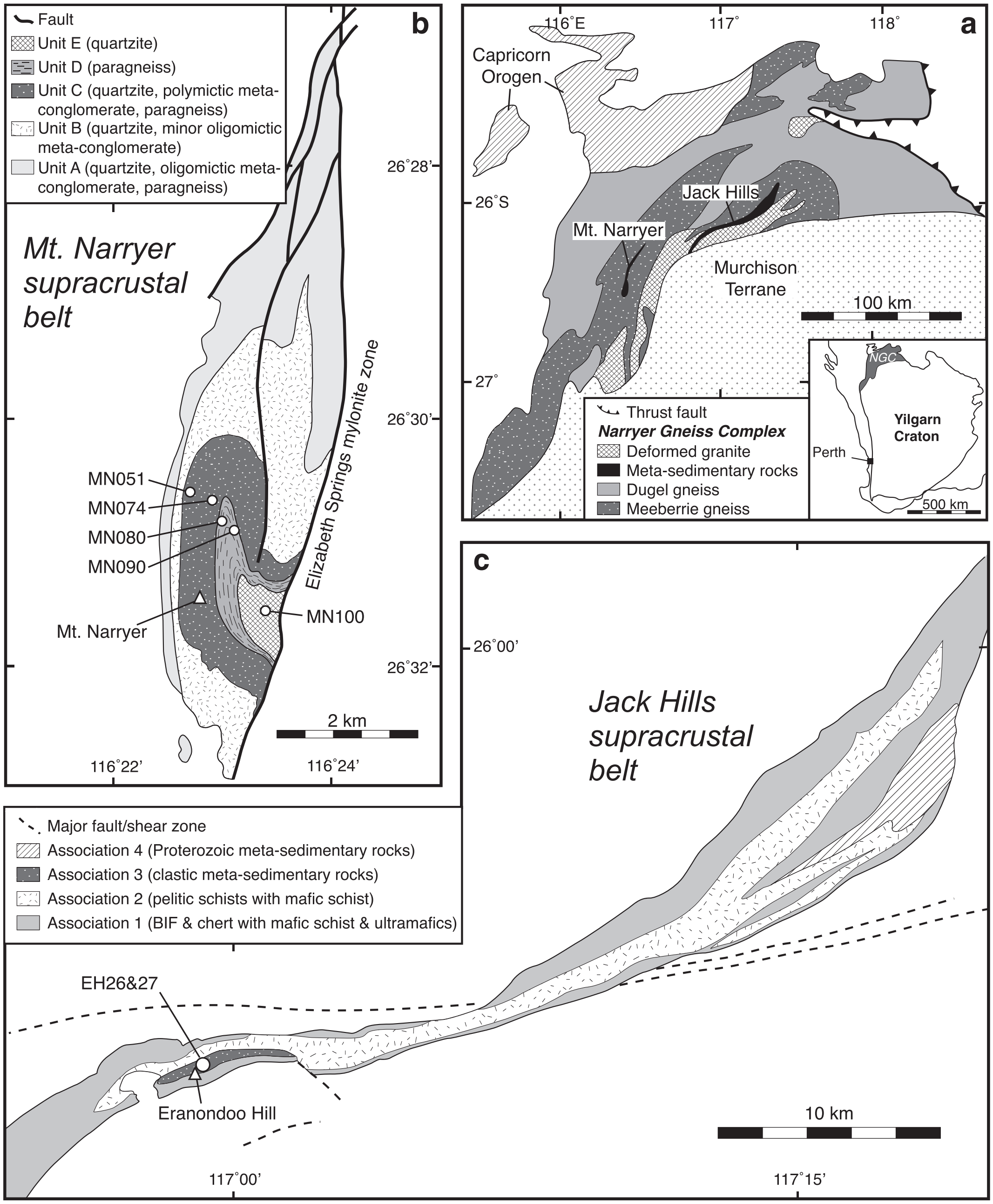


**Fig. 1.** (a) Simplified geological map of the Narryer Gneiss Complex (NGC) after Myers (1988). The inset shows the position of NGC in the Yilgarn Craton of Western Australia. (b) and (c) Geological sketch maps of the Mt. Narryer (after Williams and Myers, 1987) and Jack Hills (after Spaggiari, 2007) supracrustal belts, respectively. Locations of studied samples are shown.

Parrish, 1990). Detrital monazite is generally unstable in regional metamorphic terranes, because it reacts to form other REE-rich minerals such as allanite and apatite in the early stages of prograde metamorphism (Ferry, 2000; Finger et al., 1998; Rasmuseen and Muhling, 2009; Wing et al., 2003). However, relict detrital monazites are commonly observed, especially in low-Ca metasedimentary rocks, which prevent replacement by metamorphic allanite (Wing et al., 2003). In fact, recent monazite geochronological studies of the Mt. Narryer and Jack Hills metasedimentary rocks (Iizuka et al., 2010a; Rasmussen et al., 2010) demonstrated the occurrence of detrital monazites with ages up to 3.6 Ga, and multiple periods of metamorphic monazite growth at ca. 3.2 and 2.7–2.6 Ga at Mt. Narryer and at ca. 3.1, 2.7–2.6 and 1.8 Ga at the Jack Hills. Importantly, monazite is excellent not only for U–Th–Pb dating but also for Sm–Nd isotopic analysis due to high concentrations of Nd and Sm (Evans and Zalasiewicz, 1996; Gregory et al., 2009; Tomascack et al., 1998).

Previous whole-rock Sm–Nd isotopic studies (Fletcher et al., 1992; Maas and McCulloch, 1991) indicated that most Mt. Narryer and Jack Hills metasedimentary rocks provide Nd isotopic model ages of 3.8–3.3 Ga. However, because the Nd isotopic model ages only reflect the mean mantle-extraction ages of the crustal materials contributing to sedimentary rocks, whole-rock studies alone give no clue about either the magmatic ages of the crustal provinces or their source characteristics (i.e., juvenile versus reworked). Furthermore, some of the Mt. Narryer and Jack Hills metasedimentary rocks yield model ages older than the age of the Earth or younger than the deposition ages (Fletcher et al., 1992; Maas and McCulloch, 1991), indicating that their whole-rock Sm–Nd isotope systems were disturbed during later