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Using detrital zircon ages and Hf isotopes to identify 1.48–1.45 Ga sedimentary basins and fingerprint sources of exotic 1.6–1.5 Ga grains in southwestern Laurentia

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ABSTRACT

Globally rare 1.6–1.5 Ga zircons provide an underutilized correlation tool for Precambrian supercontinent reconstructions. Detrital 1.6–1.5 Ga zircons, long known from the Belt Supergroup, have recently been discovered in multiple metasedimentary successions in southwestern North America. Few igneous or metamorphic sources in this age range are known in Laurentia, implying non-Laurentian provenance. Combined U-Pb and Hf isotopic data offer a robust test of their provenance. New U-Pb detrital zircon ages from quartzite exposed in the Defiance uplift in northeastern Arizona indicate a maximum depositional age of ca. 1476 Ma and a predominance of locally derived ca. 1655 Ma and older detritus. The quartzite contains populations at 1570, 1554, and 1519 Ma that do not have known Laurentian sources and are similar to our new and recently published data from the ca. 1474–1436 Ma Blackjack Formation in south-central Arizona. Based on similarities between age spectra and depositional age constraints, we suggest a correlation between the two stratigraphic sections and postulate that a previously unrecognized, and now largely eroded, 1475–1450 Ma sedimentary basin or set of basins may have extended across much of southwestern Laurentia. We refer to this basin as the Yankee Joe-Defiance basin. Hf isotopic analysis of ca. 1.6–1.5 Ga detrital zircons from both localities yields positive epsilon-Hf (ε_{Hf}) values of +0.2 to +12 indicating a near-juvenile Hf fingerprint with a mean of ~ +7. This range overlaps with, but is more juvenile than, ε_{Hf} values of +3 to +7.5 from the Belt basin. In terms of possible non-Laurentian source regions, Hf data from both the North and South Australia cratons overlap with, but are also generally less juvenile than, ε_{Hf} values of Laurentian zircons. Only the North Australia craton contains the full range of ages and Hf isotope values recognized in the 1.6–1.5 Ga Yankee Joe-Defiance populations. This finding supports plate reconstructions involving Australia as a source for exotic detritus in western Laurentia ca. 1480–1450 Ma.

1. Introduction

Laurentia is a central craton in nearly all reconstructions of Rodinia (~ 1.0 Ga) and Columbia (~ 1.8 Ga, using Columbia per Meert (2012)) supercontinents (e.g., Dalziel, 1997; Li et al., 2008; Gibson et al., 2012). However, reconstructions of Rodinia assembly and breakup during the interval ca. 1200–750 Ma variably show East Antarctica (Moores, 1991; Goodge et al., 2008), Australia (Burrett and Berry, 2000; Karlstrom et al., 1999; Evans and Mitchell, 2011), Siberia (Sears and Price, 2000, 2003; Sears, 2007), South China (Li et al., 2008), or West Africa (Evans, 2009) adjacent to western Laurentia. Columbia configurations suggest connections may have existed between East Antarctica, Australia, and western Laurentia as early as 1740 Ma (Blewett et al., 1998; Ross and Villeneuve, 2003; Zhao et al., 2002, 2004; Goodge et al., 2008; Payne et al., 2009; Stewart et al., 2010; Betts et al., 2011; Gibson et al., 2012; Doe et al., 2012). Additional constraints are needed for supercontinent reconstructions for the period between assembly of Columbia at ~1800 Ma and breakup of Rodinia beginning at ~750 Ma.

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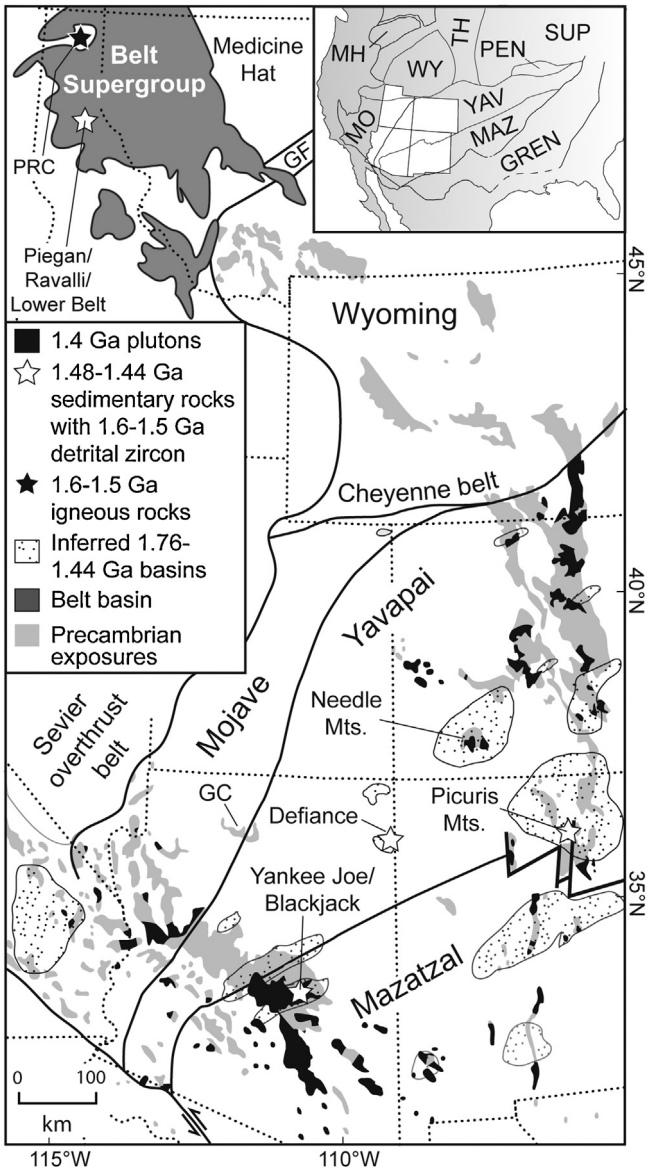

Fig. 1. Precambrian provinces and exposures in the western United States. Outlined areas show inferred extent of Paleoproterozoic and Mesoproterozoic sedimentary basins, and stars highlight localities discussed in the text. PRC––Priest River Complex; GF––Great Falls tectonic zone. Inset shows: MH––Medicine Hat block; MO––Mojave; WY––Wyoming; TH––Trans-Hudson; PEN––Penokean; SUP––Superior; YAV––Yavapai; MAZ––Mazatzal; GREN––Grenville.

Proterozoic sedimentary basins in western North America provide key constraints on the craton positions and interactions. One notable example is the Mesoproterozoic Belt-Purcell Supergroup, a > 15-km-thick succession of predominately siliciclastic strata exposed in the northwestern United States and southwestern Canada (Fig. 1). The lower three groups of the succession and their equivalents were deposited between ca. 1469 and 1454 Ma (Fig. 2A; Sears et al., 1998; Evans et al., 2000) and contain abundant detrital zircon with ages between 1600 and 1490 Ma (Fig. 2B; Ross et al., 1992; Ross and Villeneuve, 2003; Link et al., 2007). This age range corresponds to a well-documented "magmatic gap" in western Laurentia (Fig. 2F), suggesting that these grains were derived from other continents that were formerly adjacent or proximal. Paleocurrent data from the lower part of the Belt succession indicate a western sediment source across the rifted and fault-segmented Laurentian margin (Winston, 1986; Ross et al., 1992; Ross and Villenueve, 2003), and prominent ca. 1590 Ma detrital zircon age populations match well-documented igneous events in the Gawler region of southern Australia and associated parts of the Mawson continent in East Antarctica (Figs. 2B and D; Creaser and Cooper, 1993; Fanning et al., 1998, 2009; Peucat et al., 2002; Payne et al., 2009). Similarities in zircon ages and Nd isotopic data from the lower part of the Belt succession and multiple provinces in North Queensland (Blewett et al., 1998; Sears and Price, 2003) also support sedimentary connections between western Laurentia and northern Australia ca. 1469–1454 Ma. Circa 1600–1500 Ma detrital zircon are not recognized in the upper part of the Belt succession (Fig. 2B; Ross and Villeneuve, 2003; Link et al., 2007; Stewart et al., 2010), indicating removal of the exotic western source and a shift to predominately Laurentian sources ca. 1450 Ma. However, Stewart et al. (2010) argued that East Antarctica was an important sediment source in the upper Belt succession on the basis of rock characteristics, Nd isotopes, and detrital zircon ages and Hf signatures, raising the possibility that the sedimentary record in the Belt-Purcell basin records the changing positions of formerly adjacent continents over a ca. 100 m.y. period of the Mesoproterozoic.

This paper examines two Mesoproterozoic metasedimentary successions in Arizona that also contain relatively uncommon, presumably non-Laurentian, 1.6–1.5 Ga zircons. We present a combined U-Pb and Hf isotopic study of detrital zircon; this approach is more powerful than using detrital zircon ages alone because a given age of zircon growth can occur on multiple cratons. Hence, the addition of Hf isotope information to the crustal age can potentially provide more unique constraints on possible source regions (Howard et al., 2009). Detrital zircon ages from ca. 1474–1436 Ma quartzite of the Blackjack Formation in southern Arizona were initially reported by Doe et al. (2012). This paper adds additional U-Pb and new Hf data from the Blackjack Formation and also reports the discovery of potentially correlative quartzite in the Defiance uplift of northeastern Arizona. Our first goal is to test possible correlations between these 1474–1436 Ma Mesoproterozoic sedimentary successions within western Laurentia that may provide a record of widespread deposition during the early stages of a still-enigmatic ca. 1.45–1.35 Ga orogenic event (Nyman et al., 1994; Karlstrom and Humphreys, 1998; Williams et al., 1999; Daniel and Pyle, 2006). Our second goal is to evaluate potential source regions that meet the conditions of having a source for 1.6–1.5 Ga zircons, having similar Hf isotopic character, and that could have provided detritus to 1.49–1.45 Ga sedimentary successions in western and southwestern Laurentia. The relative scarcity of 1.6–1.5 Ga zircon sources worldwide (Condie et al., 2009) makes detrital zircon within this age range a particularly useful constraint in ca. 1.50–1.45 Ga reconstructions. This is especially true along the western Laurentian margin, where 1.6–1.5 Ga detrital zircons are now recognized in multiple locations (Fig. 1), and where the positions of formerly adjacent continents throughout the Proterozoic are still widely debated (e.g., Evans and Mitchell, 2011; Gibson et al., 2012).

2. Newly recognized 1.48–1.44 Ga sedimentary basins in Arizona and New Mexico

2.1. Yankee Joe and Blackjack Formations, Arizona

Doe et al. (2012) first reported a Mesoproterozoic depositional age, bracketed between 1488 and 1436 Ma, for the Yankee Joe and Blackjack Formations. These metamorphosed and deformed sedimentary units exposed in central Arizona (Fig. 1) were previously described as part of the Paleoproterozoic Hess Canyon Group (Cuffney, 1977; Trevena, 1979). The Yankee Joe and Blackjack Formations are herein referred to as the Yankee Joe Group (Fig. 2E) to distinguish them from the ca. 1657 Ma White Ledges and Redmond Formations that disconformably underlie them (Fig. 2E; Doe