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Detrital zircon geochronology of quartzite clasts, northwest Wyoming: Implications for Cordilleran Neoproterozoic stratigraphy and depositional patterns

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ABSTRACT

U-Pb ages of detrital zircons extracted from quartzite clasts (n = 857), 11 sampling localities in Cretaceous and Tertiary conglomerates in Jackson Hole and the Bighorn Basin in northwest Wyoming, reveal that the source of these clasts is Neoproterozoic in age. We collected multiple clasts at ten of the sampling localities and co-mingled the extracted zircons; we analyzed zircons from a single clast at the eleventh locality. The maximum depositional age of the ten composite samples is 1016 ± 18 Ma. The principal peak ages for the aggregate of these clasts are 1715 and 1791 Ma, and about 50% of all zircon grains yield Yavapai-Mazatzal ages (~1600–1800 Ma). Other age peaks are 1844 and 1918 Ma (various Paleoproterozoic orogenic provinces), 2711 Ma (Wyoming Province), 1444 (Mid-continent Granite-Rhyolite Province), and 1100 Ma (Grenville Province). The detrital zircon age spectra indicate a significant distal provenance in eastern and southern Laurentia for these quartzite clasts. The maximum depositional age for these quartzite clasts is 1016 Ma, which is too young for these quartzite clasts to be correlative to the Belt-Purcell Supergroup (~1390–1470 Ma) to the north. We interpret that the principal source rock for these quartzite is most likely the Neoproterozoic lower Brigham Group of southeastern Idaho. The most likely source was rocks was the upper plate of the Paris thrust sheet. The source was either completely eroded away during the Neogene, and/or was buried by Snake River Plain volcanism. This correlation requires the Brigham Group to occur much more extensively to the north than current mapping indicates.

1. Laurentian Precambrian basement age provinces

Yonkee et al. (2014) provides an excellent summary of Cordilleran Precambrian geology and the detrital zircon provenance of Neoproterozoic quartzites that occur in this region. The basement of the Cordillera orogen is complex, with many different age provinces defined. The Archean Wyoming Province contains largely 2.8–3.0 Ga gneissic rocks that are intruded by 2.5–2.7 granitic plutons and overlain by supracrustal rocks of similar age (Mueller and Frost, 2006; Foster et al., 2006; Whitmeyer and Karlstrom, 2007). The Grouse Creek terrane (NW Utah) contains ~2.5–2.6 Ga granite that intruded metasedimentary rocks (Strickland et al., 2011). The Farmington zone, (Bryant, 1988; Mueller et al., 2011; Nelson et al., 2011; Yonkee et al., 2013), which occurs as a north–south belt between the Wyoming Province and Grouse Greek Block, is comprised of largely gneissic and metasedimentary rocks. Ages of these rocks range from 1.7 to 2.7 Ga, and with peak ages of 2.45 Ga (Yonkee et al., 2013). The Mojave terrane, which occurs in SE Utah, Nevada, California, and Arizona, contains granite and gneiss that range in age from 1.7 to 2.7 Ga (Shufeldt et al., 2010). The Selway Terrane, which comprises the basement of western Montana and northern Idaho has plutonic and metasedimentary rocks that range in age between 1.7 and 1.9 Ga (Mueller et al., 2005; Foster et al., 2006) and intersects with the ~1.9 Ga Great Falls zone (Mueller et al., 2002). The 1.8–2.1 Ga Paleoproterozoic trans-Hudson orogeny is further to the northeast (Gehrels et al., 1995; Gehrels and Pecha, 2014). The Yavapai and Mazatzal terranes contain volcanic and plutonic rocks that range in age from 1.6 to 1.8 Ga (Bickford et al., 2008). Few rocks in the Cordilleran orogen are 1.5–1.6 Ga,

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which is known as the "North American Magmatic Gap" (Ross et al., 1992). Further to the south and east, the mid-continent granite-rhyolite province contains rocks that range in age from 1.3 to 1.5 Ga (Bickford et al., 1986). Further to the south and east, the Llano Province, which is part of the Grenville orogen (Rivers, 1997; McLelland et al., 2013), contains rocks that are 1.0–1.3 Ga, with peak ages being 1.1 Ga.

2. Mesoproterozoic Belt-Purcell Supergroup

Greenschist facies metasedimentary rocks of the intracratonic Mesoproterozoic Belt-Purcell Supergroup occur extensively in northern Idaho and western Montana (Ross et al., 1992; Ross and Villeneuve, 2003; Link et al., 2007; Stewart et al., 2010; Link et al., 2013, 2016, Jones et al., 2015). Most of the 14 km of sediment in these strata, based on cross cutting and interbedded igneous rocks (Anderson and Davis, 1995; Doughty and Chamberlain, 1996; Sears et al., 1998; Evans et al., 2000) accumulated between 1.47 and 1.40 Ga, accumulating in an intracontinental rift system (Winston and Link, 1993).

Four major units comprise the Belt-Purcell Supergroup (Winston and Link, 1993; Jones et al., 2015). These are the Lower Belt, Ravalli, Piegan, and Missoula Groups. The Lower Belt rocks are dark sulfide-rich argillite, siltstone and less commonly sandstone that were deposited in a deep euxinic basin (Cressman, 1989). The Ravalli Group consists of shallow water mudstone, siltstone and sandstone (Winston et al., 1989). The Piegan group consists largely of carbonate rocks. Many of these carbonates are impure, and interbedded with terrigenous strata (Pratt, 2001; Winston, 2007). The Missoula Group is the upper most unit in the succession, and consists of sandstone which is sometimes pebbly and feldspathic. It is interpreted to have formed in terrestrial and shallow marine environments (Winston, 1986).

The detrital zircon age populations for the lower three groups (Lower Belt-Purcell, Ravalli, and Piegan Groups) are complex and multimodal. Ross and Villeneuve (2003) report age groupings for these strata of 2.60 and 1.80 Ga for Belt strata in the eastern regions of the basin. Correlative strata in the western part of the basin have detrital zircon ages that range from 1.92 to 1.46 Ga (Ross and Villeneuve, 2003; Link et al., 2007). The detrital zircon age populations for the Missoula Group are distinctly different from the age populations present in the older members of the Supergroup. Detrital zircon age populations in rocks of the upper Missoula Group in Idaho (the Swauger Formation and overlying strata) are unimodal with a major peak at 1.73 Ga. This zircon age peak was likely derived from the "Big White arc" within the Paleoproterozoic Yavapai or Mojave provinces to the south and east (Ross and Villeneuve, 2003; Jones et al., 2015; Link et al., 2016).

3. Neoproterozoic-Cambrian strata

Neoproterozoic quartzites and associated metasedimentary strata are ubiquitous in southeast Idaho, and were deposited along the Rodinian margin, which underwent protracted rifting beginning at about 770 Ma (Yonkee et al., 2014). The first rocks deposited during this interval were ~5 km of siliciclastic strata of the Uinta Mountain Group about 770–740 Ma (Ehlers and Chan, 1999; Dehler et al., 2010). The Uinta Mountain Group consists of mainly of quartz sandstone that is sometimes arkosic, with lesser conglomerate and shale (Hansen, 1965; Kingsbury-Stewart et al., 2013). The arkosic sandstones in this succession contain largely Archean zircons, which were derived locally from the Wyoming craton (Dehler et al., 2010). In contrast, the interbedded quartz sandstones have detrital zircon age peaks that are 1.0–1.5 Ga, which indicates a distal, southerly source area in the Grenville and Midcontinent Granite-Rhyolite provinces.

More than 1 km of the Pocatello Formation was deposited during the earliest phases of rifting from 720 to 660 Ma (Yonkee et al., 2014). These strata include sandstones, mudrocks, carbonates, diamictites and interlayered volcanic rocks (Link, 1982, 1987; Keeley et al., 2013). The Scout Mountain Member of the Pocatello Formation shows variable detrital zircon age patterns, with peaks at 1.7–1.8. 2.45, 2.55, and 2.6–2.8 Ga that reflect both local and distal sources. The upper members of the Pocatello Formation have a higher proportion of Mesoproterozoic grains that were derived from distal, southerly sources. Some of these samples also have notable ~700 Ma detrital zircon populations (Fanning and Link, 2004; Keeley et al., 2013).

The Brigham Group (Papoose Creek, Caddy Canyon, Inkom, Mutual, Camelback Mountain and Gibson Jack formations) was deposited from ~660 to ~530 Ma, and consists of mature siliciclastic rocks that are as much as 4 km in thickness (Crittenden et al., 1971; Stewart, 1972; Link, 1987; Link et al., 1993). These units have similar detrital zircon age spectra, with peak ages that reflect Grenville and Midcontinent Granite-Rhyolite origins (Yonkee et al., 2014). The youngest rocks in the Brigham Group are of Cambrian age. The Mutual Formation has a higher preponderance of Archean and Yavapai-Mazatzal age zircon than the lower units. Cambrian rocks above the Mutual lack Grenvillean age grains, and all zircons are 1.7 Ga or older.

4. Incorporsation into Cretaceous-Tertiary conglomerates

Dorr et al. (1977) was the first to make a regional stratigraphic compilation of all the synorogenic sediments in the area where Sevier-Laramide structures converged in northwest Wyoming. The preponderance of Cretaceous-Eocene quartzite cobble conglomerates in the region is striking, as is the thickness (1–4 km) of some units, and their presence on mountain tops. Most of these conglomerate formations are largely undeformed and are strikingly similar in texture and composition (Figs. 1 and 2).

Lindsey (1972) reported that 75% of the clasts in the Upper Cretaceous to lower Tertiary Harebell and Pinyon conglomerates in northwestern Wyoming consist of well-rounded quartzite cobble and pebbles (Fig. 3). Based on our own observations in the areas that we visited, this proportion of quartzite to other clast lithologies is much higher, perhaps more than 95%. Although the clasts are variable in color, the vast preponderance are clean, mature quartzites. There is also no certain source for any of these quartzites in the Harebell (Lindsey, 1972), Pinyon and Beaverhead (Love, 1973), or Pass Peak formation (Steidtmann, 1971; Antweiler et al., 1977) although paleocurrents all suggest a source from the now-eroded ancestral Targhee uplift to the northwest (Love, 1973; Love et al., 1978). Ryder and Scholten (1973) believed that the Pinyon and Harebell quartzite clasts were derived from Mesoproterozoic Belt-Purcell Supergroup rocks that were exposed during the uplift of the Idaho Batholith. Schmitt and Steidtmann (1990) presented arguments that the source was an interior ramp supported uplift of strata in the Paris plate, above the active Absaroka thrust fault. Janecke et al. (2000) suggested that the major Eocene (and possibly as old as Cretaceous) Lemhi Pass and Hawley Creek paleovalleys were the conduits to transport the voluminous quartzite debris to the Pinyon and Harebell formations 200–350 km away. They further interpreted that these clasts were derived from Belt-Purcell quartzites exposed in north-central Idaho.

The definitive work on the Hominy Peak Formation was done by Love et al. (1978). The Hominy Peak Formation rests unconformably above the Paleocene Pinyon Conglomerate. Above the Hominy Peak unconformably lie the rhyolitic Conant Creek Tuff