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# Provenance and paleoweathering reconstruction of the Neoproterozoic Johnnie Formation, southeastern California

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ABSTRACT

Petrologic and geochemical data confirm that mudstones and sandstones of the Johnnie Formation were the initial siliciclastic deposits laid along the Cordilleran Laurentian margin following the Neoproterozoic break-up of Rodinia. Sedimentary rocks of the Johnnie Formation have corrected CIA values between 63 and 83 (or higher), which suggest moderate to intense weathering of crystalline source rocks or recycling. Based on modeling the fresh source rocks likely consisted of 90% granodiorite and 10% high-K granite. This conclusion is based on petrographic observations, major element geochemistry, and investigation of the REE: ($La_{CN}/Sm_{CN} = 4.19 \pm 1.26$, $Gd_{CN}/Yb_{CN} = 1.34 \pm 0.38$, $Eu/Eu^* = 0.63 \pm 0.09$ and $La_{CN}/Yb_{CN} = 9.55 \pm 2.27$). Feldspars are unevenly distributed in the finer grained sedimentary rocks. Observed fluctuations in feldspar content throughout the Johnnie Formation are interpreted as a result of abrasion and hydrodynamic sorting, which concentrated feldspars in the finer grained sediment. None of the mudstone samples, including those collected just below and above the flat-pebble conglomerate in the upper Johnnie Formation, show evidence of true cold weather depositional conditions. Consequently, Johnnie Formation mudstone geochemistry does not record evidence of an extreme paleoclimatic environmental shift in the succession. Textural characteristics of Johnnie Formation sandstones are consistent with quiescent tectonic conditions characterized by low relief, and deposition of Johnnie Formation strata in a passive-margin setting.

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## 1. Introduction

The composition of clastic sedimentary rocks results from the combined effects of many factors active during sediment production, including source rock composition, physical and chemical weathering, transport, deposition and diagenesis (Johnsson, 1993). Chemical weathering progressively modifies the mineralogical composition of crystalline bedrock by turning primary minerals into clays, secondary oxides, and hydroxides (Nesbitt and Young, 1984, 1989). These secondary minerals, in addition to quartz, represent the mineral assemblage developed atop fresh bedrock that is subject to mass wasting, transport, and hydraulic sorting. Therefore, the mineralogical maturity of sediment largely reflects the composition of weathering profiles (Nesbitt et al., 1996, 1997), where the degree of conversion of feldspars to secondary aluminous clays is related to paleoweathering intensity, paleoclimate (cf., Fedo et al., 1996, 1997b; Nesbitt et al., 1997), and tectonism (e.g., Hurowitz and McLennan, 2005).

In western North America, the Neoproterozoic-to-Cambrian continental margin succession preserves evidence related to both paleoclimate and tectonic setting. Several significant events are encompassed by these strata including breakup of the supercontinent Rodinia (Dalziel, 1991, 1997; Moores, 1991; Borg and DePaolo, 1994; Buchan et al., 2001; Karlstrom et al., 2001; Eyles and Januszczak, 2004; Li et al., 2008), and at least two episodes of widespread glaciation that may have extended to equatorial regions (Young, 1995; Hoffman et al., 1998; Williams, et al., 1998; Crowell, 1999; Prave, 1999; Sohl, et al., 1999, Hoffman and Schrag, 2002), including cap carbonates (Kaufman et al., 1992, 1993, 1997; Corsetti and Kaufman, 2003). The distribution and lithologic characteristics of Neoproterozoic and Cambrian age strata suggest that the crust was initially thinned, underwent a complex rifting process (Ferri et al., 1999; Prave, 1999), then was covered by a thick sedimentary sequence typical of stable continental margins (Stewart, 1972; Link et al., 1993; Fedo and Cooper, 2001). This succession includes glaciogenic diamictites of the Kingston Peak Formation (Wright et al., 1976; Miller, 1985, 1986; Prave, 1999) overlain by siliciclastic and subordinate carbonate rocks. Evidence for rifting exists in Kingston Peak diamictites (Wright et al., 1976; Miller, 1985, 1986; Walker et al., 1986), and possibly extends into the post-glaciogenic detrital sequence immediately above (Bond et al., 1985; Link et al., 1993; Summa, 1993; Clapham and Corsetti, 2005). The post-glaciogenic sequence is comprised predominantly of siliciclastic deposits, initiated by the Johnnie Formation, that were deposited above storm wave base in shallow marine and terrestrial settings (Levy and Christie-Blick, 1991; Summa, 1993; Fedo and

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Cooper, 2001). Quartz-to-feldspar ratios in arenites comprising the post-Kingston Peak succession change repeatedly (Link et al., 1993), questioning whether compositional variation can be solely attributed to tectonic causes. Variable feldspar content in post-Kingston Peak arenites could also have been influenced by fluctuating climatic conditions because, by Cambrian time, the region had migrated from high to low latitudes (McKerrow et al., 1992; Dalziel, 1997; Weil et al., 1998; Hodych et al., 2004; Cawood and Pisarevsky, 2006; Li et al., 2008).

Post-glacial cap carbonates with significant negative $\delta^{13}C$ anomalies that possibly record extreme shifts in paleoclimate occur in the Noonday Dolomite, which rests atop Kingston Peak diamictite, as well as in carbonates within the younger post-glaciogenic siliciclastic succession. The largest excursion ($\delta^{13}C = -11‰$ PDB) is preserved in carbonates interbedded with detrital rocks of the Rainstorm Member of the upper Johnnie Formation, located well above the Kingston Peak Formation, and not associated with any glacial unit (Corsetti and Kaufman, 2003). Associated with these carbonates are incised

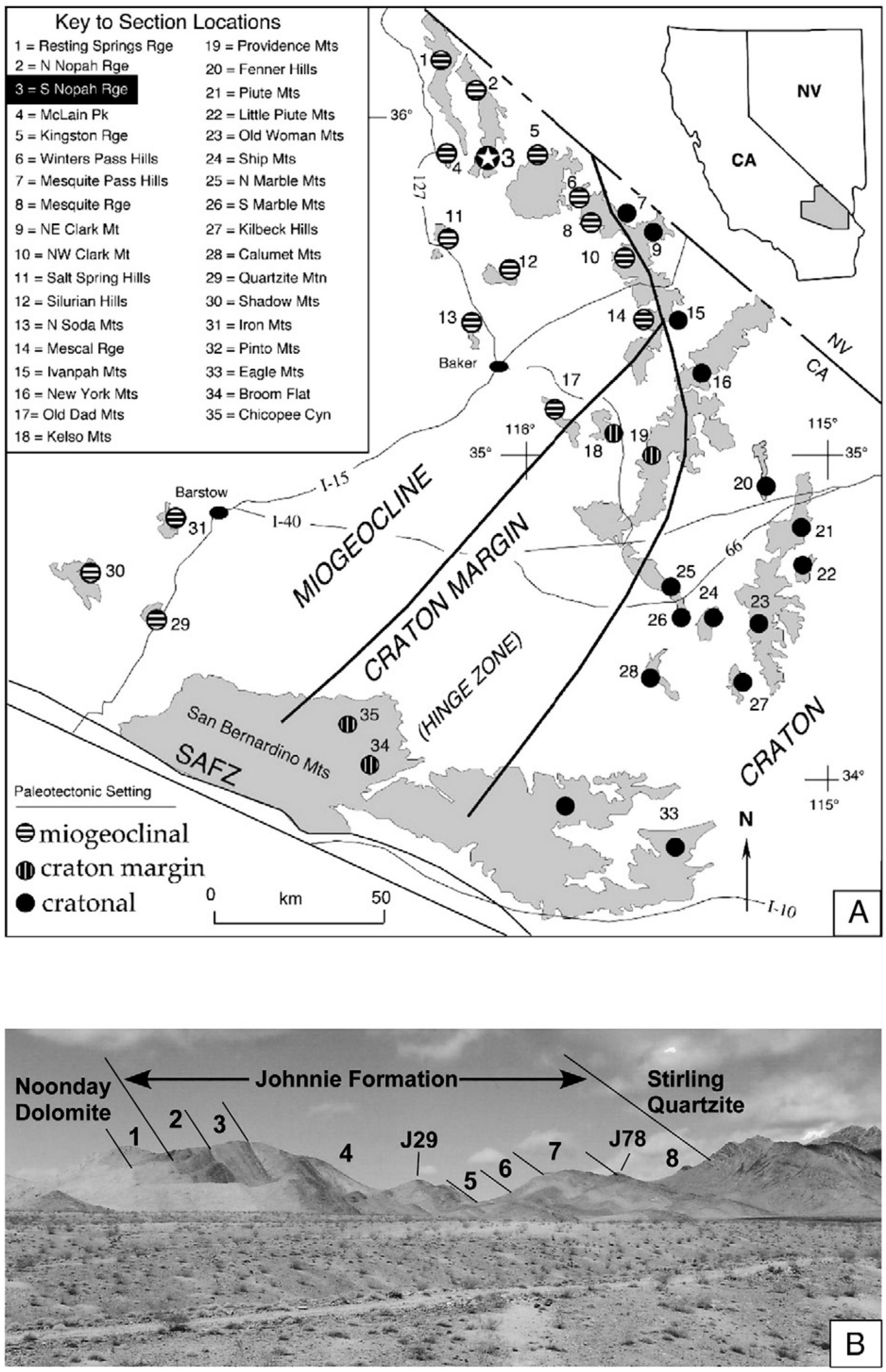


**Fig. 1.** (A) Index map showing location of study area in the Nopah Range (Station 3, black highlight) relative to the Precambrian cratonic margin in southeastern California (after Fedo and Cooper, 2001). (B) Photograph of stratigraphic section looking northwest along the Noonday mine road (location: N35° 48.861′, W116° 06.243′) showing major stratigraphic units (Noonday Dolomite, Johnnie Formation, and Stirling Quartzite) along with subunits of the Johnnie Formation. Sample J78 is located at the base of the incised valley fill (flat-pebble conglomerate).