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Terrestrial cosmogenic surface exposure dating of glacial and associated landforms in the Ruby Mountains-East Humboldt Range of central Nevada and along the northeastern flank of the Sierra Nevada

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ABSTRACT

Deposits near Lamoille in the Ruby Mountains-East Humboldt Range of central Nevada and at Woodfords on the eastern edge of the Sierra Nevada each record two distinct glacial advances. We compare independent assessments of terrestrial cosmogenic nuclide (TCN) surface exposure ages for glacial deposits that we have determined to those obtained by others at the two sites. At each site, TCN ages of boulders on moraines of the younger advance are between 15 and 30 ka and may be associated with marine oxygen isotope stage (MIS) 2. At Woodfords, TCN ages of boulders on the moraine of the older advance are younger than ~60 ka and possibly formed during MIS 4, whereas boulders on the correlative outwash surface show ages approaching 140 ka (~MIS 6). The TCN ages of boulders on older glacial moraine at Woodfords thus appear to severely underestimate the true age of the glacial advance responsible for the deposit. The same is possibly true at Lamoille where clasts sampled from the moraine of the oldest advance have ages ranging between 20 and 40 ka with a single outlier age of ~80 ka. The underestimations are attributed to the degradation and denudation of older moraine crests. Noting that boulder ages on the older advances at each site overlap significantly with MIS 2. We speculate that erosion of the older moraines has been episodic, with a pulse of denudation accompanying the inception of MIS 2 glaciation.

1. Introduction

Terrestrial cosmogenic nuclide (TCN) surface exposure dating of boulders is now frequently employed to estimate the age of glacial deposits and interpret the timing of late Pleistocene glacial advances and recessions (e.g., Owen et al., 2005; Gillespie and Clark, 2011; Jimenez-Sanchez et al., 2013). Application of the method remains challenging though because early stabilization and denudation of glacial landforms, as well as weathering, exhumation, prior exposure, and shielding of the surface that is being dated by snow and/or sediment reduces the concentration of TCNs, resulting in an underestimate of the true age of the landform (Hallet and Putkonen, 1994; Owen and Dortch, 2014). Alternatively, prior exposure of the boulder before deposition may result in an overestimation of the landform's age. Problems associated with the application of TCN methods to date moraines have been discussed in depth in numerous studies (Hallet and Putkonen, 1994; Benn and Owen, 2002; Putkonen and Swanson, 2003; Putkonen and O'Neal, 2006; Seong et al., 2007, 2009; Putkonen et al., 2008; Applegate et al., 2010; Chevalier et al., 2011; Owen and Dortch, 2014).

A number of investigators have used conventional and TCN studies to quantify rates of bare-rock weathering (Summerfield and Hulton, 1994; Brown et al., 1995; Bierman and Steig, 1996; Gosse et al., 1997; Fleming et al., 1999), and these rates are commonly cited and assumed when calculating surface exposure ages (e.g., Balco et al., 2008). Simultaneous measurement of multiple TCNs on boulders also affords a method to assess the exposure and erosion history of a clast (e.g., Klein et al., 1986; Lal, 1991; Nishiizumi et al., 1991). Similarly, models of surface degradation have been invoked to correct for the

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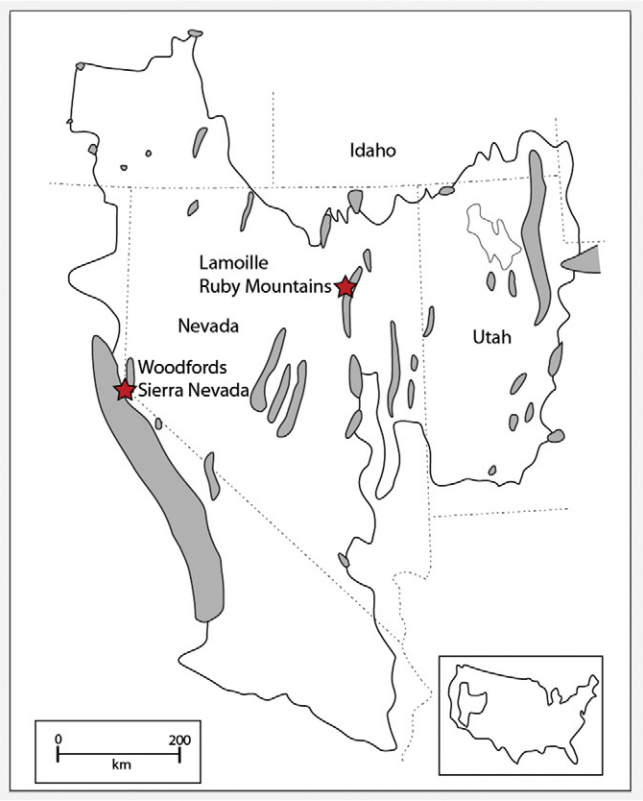

Fig. 1. Location of study areas on schematic map of glaciated ranges (shaded) draining into the Great Basin of the western United States (adapted from Osborn and Bevis (2001).

effect of denudation on TCN ages computed for samples on sloping unconsolidated deposits or, more specifically, glacial moraines (e.g., Putkonen and Swanson, 2003).

Assessing the uncertainties caused by weathering that are attendant to cosmogenic surface exposure age calculations nonetheless remains problematic, particularly for surfaces formed prior to the time period over which radiocarbon dating techniques may be employed to independently corroborate calculations (~40 ka). In this brief note we compare TCN dating of glacial deposits at two locations by different laboratories and investigators. The two locations are located between 38.5°and 40.5°N, along the east flank of the Sierra Nevada near the town of Woodfords in California and the western flank of the Ruby Mountains-East Humboldt Range adjacent to the town of Lamoille in central Nevada (Fig. 1). The results illustrate the significant impediment imposed by weathering processes to the use of TCN in confidently dating older glacial moraines at these two sites.

2. Glacial deposits and sample distributions at Woodfords and Lamoille

2.1. Woodfords, California, Sierra Nevada

Pleistocene moraines and outwash deposits are preserved at the eastern end of Hope Valley along the Carson River as it flows eastward from the Carson Range of the Sierra Nevada (Fig. 2). Similar moraines and associated outwash surfaces have long been recognized and studied along the eastern flank of the Sierra Nevada (Blackwelder, 1931; Birman, 1964; Burke and Birkeland, 1979; Gillespie and Clark, 2011). Other than appearing on the map of Armin and John (1983), a generalized sketch in Ramelli et al. (1999), and interpreted by Clark et al. (1984) in their estimation of California fault slip rates, little attention

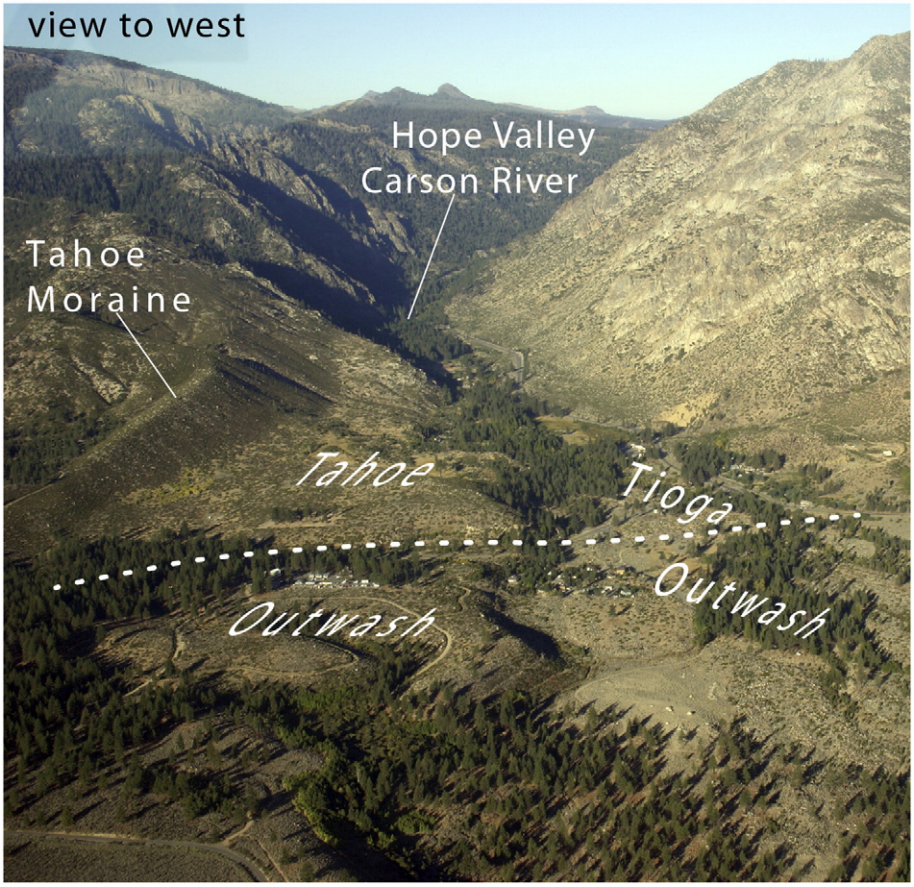

Fig. 2. Pleistocene glacial landforms and deposits preserved along the course of the east-flowing Carson River. Trace of Genoa fault is dashed line.