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Geomorphology 67 (2005) 423–435

GEOMORPHOLOGY

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Cosmogenic ^{3}He exposure ages of Pleistocene debris flows and desert pavements in Capitol Reef National Park, Utah

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Received 14 June 2004; received in revised form 1 November 2004; accepted 4 November 2004
Available online 10 December 2004

Abstract

The Quaternary history of the Capitol Reef area, Utah, is closely linked to the basaltic-andesite boulder deposits that cover much of the landscape. Understanding the age and mode of emplacement of these deposits is crucial to deciphering the Quaternary evolution of this part of the Colorado Plateau. Using cosmogenic ^{3}He exposure age dating, we obtained apparent exposure ages for several key deposits in the Capitol Reef area. Coarse boulder diamicts capping the Johnson Mesa and Carcass Creek Terraces are not associated with the Bull Lake glaciation as previously thought, but were deposited 180±15 to 205±17 ka (minimum age) and are the result of debris flow deposition. Desert pavements on the Johnson Mesa surface give exposure ranging from 97±8 to 159±14 ka and are 34–96 kyears younger than the boulder exposure ages. The offset between the boulder and pavement exposure ages appears to be related to a delay in pavement formation until the penultimate glacial/interglacial transition or periodic burial and exposure of pavement clasts since debris flow deposition. Incision rates for the Capitol Reef reach of the Fremont River calculated from the boulder exposure ages range from 0.40 to 0.43 m kyear^{-1} (maximum rates) and are some of the highest on the Colorado Plateau.

Keywords: Cosmogenic isotopes; ^{3}He; Colorado plateau; Utah; Desert pavement

1. Introduction

Quaternary deposits in the Capitol Reef area are predominantly comprised of basaltic-andesite boulder diamicts derived from the summits of Boulder and Thousand Lake Mountains (Fig. 1). The coarse black boulder deposits contrast markedly with the red and orange Mesozoic strata of the region. Geologists since the time of G.K. Gilbert have been struck by this contrast and have attempted to understand the genesis and age of these deposits (Gilbert, 1877; Dutton, 1890).

Most early research on these deposits was strongly glacial in outlook (Gould, 1939; Flint and Denny, 1958). This was particularly true of the deposits around the flanks of Boulder Mountain, which was clearly glaciated during the late Pleistocene (Osborn and Bevis, 2001; Marchetti, 2002). Deposits interpreted as moraines, till, and outwash were assigned

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0169-555X/$ - see front matter
doi:10.1016/j.geomorph.2004.11.004

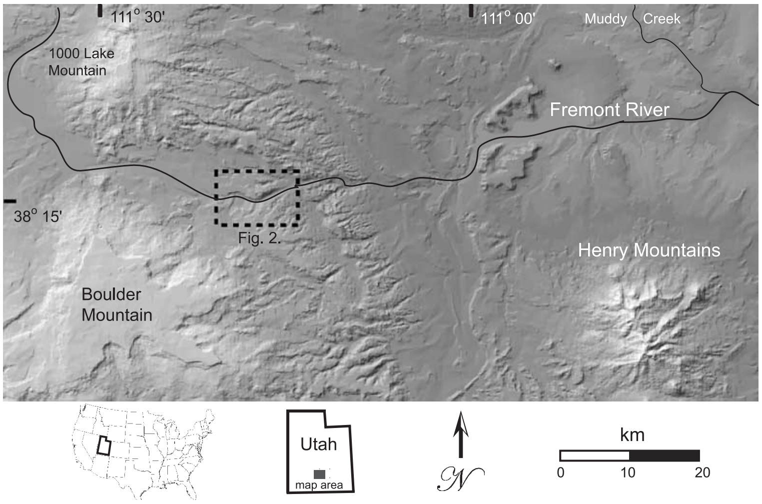

Fig. 1. Shaded relief map of the study area. The Fremont River flows west to east across the mapped area.

relative ages based on stratigraphic relationships, soil development, and amount of weathering and were correlated with other known glacial chronologies from the Rocky Mountain region (e.g., Pinedale and Bull Lake of the Wind River Range, Wyoming, USA) (Flint and Denny, 1958). More recent studies have questioned some of this early work and many of the deposits derived from Boulder Mountain have been re-interpreted as resulting from land sliding and debris flow (Williams, 1984; Waitt, 1997). Quantitative estimates of the ages of these deposits are needed to determine if they are temporally related to periods of glacial advances. Additionally, ages on several of these deposits would allow estimations of local fluvial incision and provide a better understanding of the Quaternary evolution of this landscape.

Cosmogenic exposure age dating can provide quantitative estimates of surface exposure ages and erosion rates in the Quaternary (Bierman, 1994; Cerling and Craig, 1994b; Gosse and Phillips, 2001). This information can then be used to better understand a variety of geomorphic processes and rates (Gosse et al., 1995; Wells et al., 1995; Phillips et al., 1998; Cerling et al., 1999). The basaltic-andesite boulder deposits in the Capitol Reef area are ideal for ^{3}He exposure age dating because they contain abundant pyroxene phenocrysts. Pyroxene has been shown to quantitatively retain ^{3}He over million-year timescales (Schäfer et al., 1999), and ^{3}He has the highest production rate of all the routinely measured cosmogenic nuclides (Gosse and Phillips, 2001).

In this study, we used cosmogenic ^{3}He exposure age dating to date two debris flow fill terraces of the Fremont River and associated desert pavements forming on one of the terrace treads. We used completely shielded clasts from within one of the debris flow deposits to correct for possible non-cosmogenic ^{3}He in our samples. Using equations governing the production of nucleogenic ^{3}He, we determined the source of noncosmogenic ^{3}He in our shielded samples and developed a simple correction for our exposure ages. The resulting exposure ages are used to determine the timing of debris flow deposition, the rate of Fremont River incision, and the timing of desert pavement formation and its relation to Pleistocene climate change.

2. Study area

The study area is located in south central Utah, along the Fremont River and partly within Capitol Reef National Park (Figs. 1 and 2). The clasts that mantle the surfaces we sampled are derived from Boulder Mountain. Boulder Mountain is a large (180 km^{2}) flat plateau at an elevation of ~3400 m that is capped with a series of basaltic-andesite flows ~140 m thick. The basaltic-andesites capping Boulder Mountain have been dated