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Late Quaternary alluvial fans at the eastern end of the San Bernardino Mountains, Southern California

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ABSTRACT

Alluvial fans at the eastern end of the San Bernardino Mountains in Southern California provide a record of climate modulated sediment transfer and erosion, and are deformed and displaced in places by active faults. Alluvial fans within two study areas, the Mission Creek and the Whitewater River drainages, were examined using geomorphic, sedimentological, and ^{10}Be terrestrial cosmogenic nuclide (TCN) surface exposure methods to define the timing of alluvial fan formation and erosion, and to examine the role of climatic, tectonic and autocyclic processes. These alluvial fan complexes were studied because they are amongst the best-preserved successions of alluvial fans in southern California and they are located at the mouths of two of the largest drainages, Whitewater River and Mission Creek, in the San Bernardino Mountains and traverse major faults, the Mission Creek and Banning. The alluvial fans comprise bouldery debris deposits that represent deposition dominated by flash flood and debris flow events. TCN surface exposure dating indicates that abandonment/incision of alluvial fan surfaces date to early in the Last Glacial or more likely the penultimate glacial cycle, to marine isotope stage (MIS) 4, and to the Holocene. The lack of alluvial fan ages during the latter part of the Last Glacial (MIS 2 and 3) suggests that there has been little alluvial fan lobe deposition/incision during that time. This is similar to findings for many other alluvial fans throughout the American Southwest, and supports the view that there is a strong climatic control on alluvial fan formation throughout this region. Furthermore, the oldest alluvial fan surfaces in the Mission Creek region are beheaded by the Whitewater River drainage, showing that the oldest alluvial fans in the Mission Creek region underwent significant capture by the Whitewater River drainage. This shows the autocyclic controls are also important on alluvial fan evolution in this region; but the importance of these processes to alluvial fan development in other regions of the American Southwest needs to be more fully assessed. The alluvial fans in the Mission Creek area traverse the Mission Creek fault, but are not deformed by it, which suggests that there may have been little if any movement along this fault since at least MIS 4. In contrast, alluvial fans in the Whitewater River study are displaced by active faults highlighting the influence of tectonism on alluvial fan development in this region. In addition to illustrating the importance of climatic controls on the development of alluvial fans in the American Southwest, a classic region for alluvial fan studies, this study illustrates the complex mixture of autocyclic and allocyclic factors that force alluvial fan development in tectonically active settings.

1. Introduction

Alluvial fans are one of the most common landforms in mountain front areas in arid and semi-arid regions (Bull, 1977; Beaty, 1990; Reheis et al., 1996). Many researchers have suggested that alluvial fans are highly sensitive to environmental change and that they provide an important archive for environmental conditions, notably climate and hydrology, and tectonics (Lustig, 1965; Beaty, 1970; Rockwell et al., 1985; Harvey, 1990, 1997; Lecce, 1990; Bull, 1991; Ritter et al., 1995; Harvey et al., 1999a,b, 2003; Owen et al., 1997, 2006; McDonald et al., 2003; Quigley et al., 2007; Stokes et al., 2007; Frankel et al., 2007a,b; Arboleya et al., 2008; Spelz et al., 2008; Miller et al., 2010; Hedrick et al., 2013). However, deciphering the potentially strong environmental and tectonic record preserved by alluvial fans has been severely restricted by a lack of adequate chronological control. This is mainly because of the absence of preserved organic matter within arid and semi-arid environments that is needed for the standard method of

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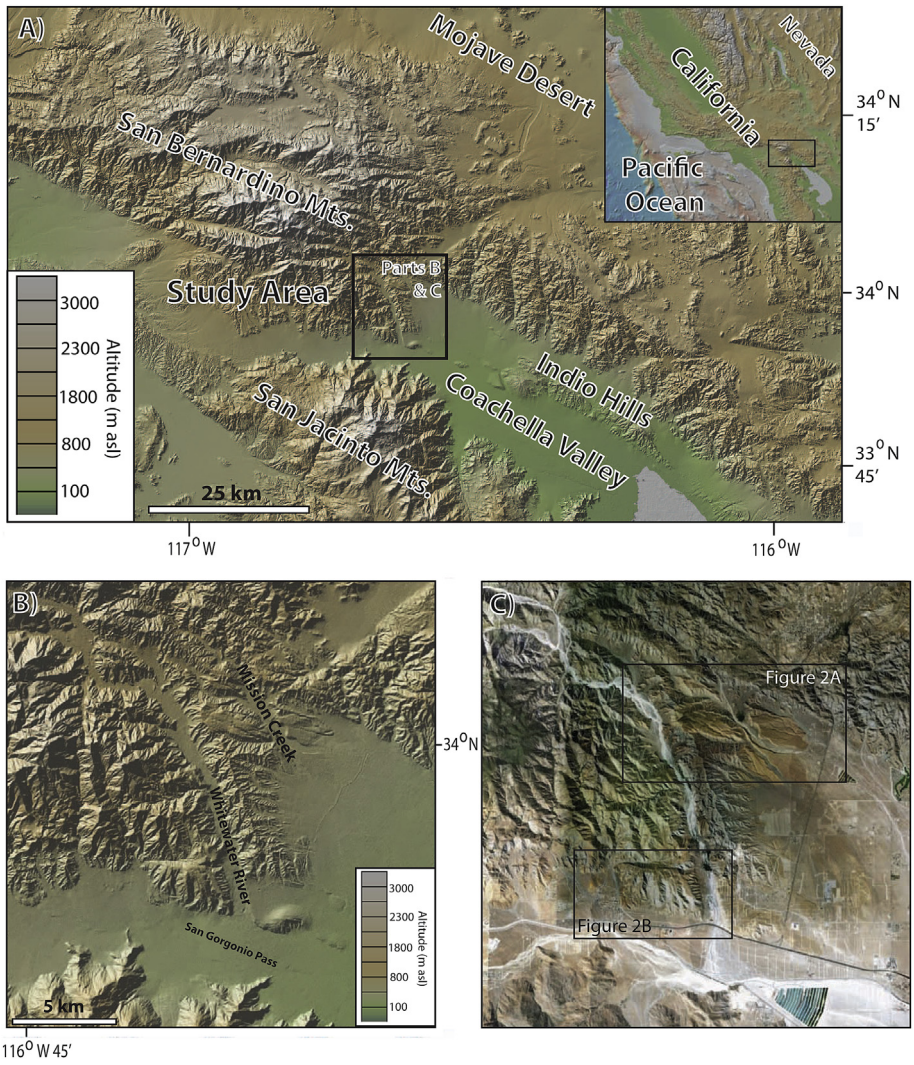

Fig. 1. Digital elevation models for A) regional setting and B) study area produced using GeoMapApp (http://www.geomapapp.org/), and C) Google Earth image of the study area. The inset box on part A) indicates the area shown in parts B) and C).

radiocarbon dating. The development of terrestrial cosmogenic nuclide (TCN) surface exposure, optically stimulated luminescence (OSL) and U-series dating has helped remove this restriction by providing methods to directly determine the timing of alluvial fan formation, erosion and deformation (e.g., Reheis et al., 1996; Zehfuss et al., 2001; Owen et al., 2006, 2011; Frankel et al., 2007a, b; Arboleya et al., 2008; Spelz et al., 2008; Armstrong et al., 2010; Fletcher et al., 2010; Blisniuk et al., 2012). OSL ages provide depositional ages for alluvial fan sediments, whereas TCN ages define the ages of alluvial fan surfaces and therefore represent the timing of abandonment/incision of the surface being dated. U-series dating is usually used to define the ages of carbonate cement formation, which provides minimum ages on landform formation. TCN, OSL, and U-series dating can be used to date alluvial fans beyond the age range for radiocarbon dating (30–50 ka), in some cases to >100 ka.

To examine the nature of alluvial fan development and to help develop a framework for paleoenvironmental and tectonic studies in the American Southwest we examined a succession of alluvial fan surfaces in Whitewater River and Mission Creek drainages at the eastern end of the San Bernardino Mountains along a stretch of the San Andreas Fault system (Fig. 1). We utilize ^{10}Be TCN exposure dating of surface boulders and depth profiles combined with geomorphic and sedimentological analysis to investigate these surfaces.

The Whitewater River and Mission Creek drainages are located at the western end of the Salton Trough in Southern California and they are the primary catchments draining the eastern end of the San Bernardino Mountains within the Transverse Ranges of southern California (Fig. 1). The drainages traverse the Mission Creek and Banning faults, which are two potentially active strands of the San Andreas fault system (Yule et al., 2001; Orozco and Yule, 2003; Orozco, 2004; Yule, 2009; Yule and Spotila, 2010; McGill et al., 2013). Furthermore, the Whitewater River and Mission Creek drainages flow from formerly glaciated source areas within the San Bernardino Mountains and hence alluvial fan development may have been influenced by paraglacial processes (Sharp et al., 1959; Owen et al., 2003). This area, therefore, provides an opportunity to examine the interaction of climate, glaciation, hydrology, tectonics and autocyclic processes on alluvial fan development. We also compare our new alluvial fan record with other quantitative dating studies on alluvial fans in the American Southwest to test whether regional correlations can be made as a framework for future studies.