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Extension rate determination through the analysis of high-resolution LiDAR dataset and cosmogenic dating of the Fish Lake Valley fault zone: Implications for Pacific-North America plate boundary deformation

P.N. Ganev (1), J.F. Dolan (1), K.L. Frankel (2), and R.C. Finkel (3)

(1) Department of Earth Sciences, University of Southern California, Los Angeles, CA, USA, (ganev@usc.edu), (2) School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA, (3) Department of Earth and Planetary Science, University of California Berkeley, Berkeley, CA, USA

The oblique normal-dextral Fish Lake valley fault (FLVF) accommodates much of the Pacific-North America plate boundary deformation in the northern part of the eastern California shear zone (ECSZ). New geologic slip rates from FLVF, near the California/Nevada border, provide constraints on the kinematic relationships among the major faults in this complex part of the Pacific-North America plate boundary. Analysis of light detection and ranging (LiDAR) data (1 m horizontal resolution and a decimeter vertical accuracy), coupled with cosmogenic nuclide ^{10}Be geochronology, provides new insights into the late Pleistocene extension rate of this fault system. Right-lateral shear accommodates most of the deformation on the NW-striking FLVF, but fault segments that strike approximately N exhibit predominantly normal slip. This extension is manifest by east- to southeast- and west- to northwest- dipping normal fault scarps cutting late Pleistocene alluvial fans. LiDAR data are crucial to the recognition and analysis of these fault strands, allowing for a comprehensive study of all normal fault scarps that would be otherwise nearly impossible. The high vertical resolution of the LiDAR-derived digital elevation models, plus the ease of analysis using geographic information systems (GIS) software allow for the precise measurement of cumulative scarp heights across numerous scarps. Using these measurements and cosmogenic ^{10}Be dates of the faulted alluvial fans we present the extension rates on the FLVF at four different locations, from south to north: Furnace Creek, Wildhorse Creek, Perry Aiken Creek, and Indian Creek. The vertical component of oblique slip (measured in ArcGIS 9.2 using LiDAR-derived DEMs) along the FLVF at Furnace Creek = 25 $\pm$ 1.3 m, Wildhorse Creek = 42 $\pm$ 2.1 m, Perry Aiken Creek = 85 $\pm$ 4.3 m, and Indian Creek = 75 $\pm$ 3.8 m. Previous work by Frankel et al. (2007, GRL) reported cosmogenic nuclide ^{10}Be ages from the offset Furance Creek and Indian Creek alluvial fans of $\sim$94 ka and $\sim$71 ka, respectively. New cosmogenic ^{10}Be dates from the offset alluvial deposits at Wildhorse Creek and Perry Aiken Creek yield ages of $\sim$121 ka and $\sim$71 ka, respectively. Combining displacement from LiDAR data and ^{10}Be geochronology yields a vertical component of slip ranging from 0.3 mm/yr at Furnace Creek and Wildhorse Creek, to the south, to 1.2 mm/yr at Perry Aiken Creek, and 1.1 mm/yr at Indian Creek, to the north. These slip rates are generally in agreement with previous estimates based on alluvial fan morphology, soil development, and theodolite surveys. Assuming a 60º dip for the fault planes, we calculate late Pleistocene extension rates for the FLVF of 0.2, 0.2, 0.7 and 0.6 mm/yr, at the four sites, from south to north. Comparison of these rates with geodetic measurements of $\sim$1 mm/yr of extension across the ECSZ north of the Garlock fault indicate that as much as half of the current rate of east-west extension in this part of western North America is accommodated along the FLVF. Our data also imply an increase in late Pleistocene extension rates from south to north, which is opposite the trend of the dextral slip rate along the FLVF. This discrepancy can be explained by an extensional transition zone in northern Fish Lake Valley that transfers slip between FLVF and the Walker Lane Belt to the north and east, and by westward transfer of slip onto the Saline Valley-Hunter Mountain-Panamint Valley fault system to the south and west. Determining the extension rates of the faults parallel or sub-parallel to the FLVF at the same latitude, such as the White Mountain and Sierra Nevada frontal faults, will further improve our understanding of how slip is accommodated and transferred from the ECSZ into the Walker Lane Belt along this important segment of the Pacific-North America plate boundary.