Applications of LiDAR Data Analysis for Geomorphic Study

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Abstract—**The analysis of elevation data obtained with LiDAR techniques is particularly suitable for geomorphologic studies and fault investigations as it allows for a preliminary study of large areas with desktop-based observations and measurements.**
We present various examples of utilization and interpretation of LiDAR-derived elevation data and their GIS derivatives from a geomorphic study: the Kern Canyon fault characterization in the southern Sierra Nevada, which is an active seismic source.
The analysis of LiDAR data has been very helpful for generating first-order landscape analyses and for identification of key sites, which have been further investigated and in most cases confirmed with field observations. Specifically, in characterizing the Kern Canyon fault, analysis of elevation data helped produce accurate maps of key geomorphic expressions of the fault which would have otherwise been easily disregarded and provided estimates of the amount of vertical displacement along much of the 140-km-long fault.

Introduction

In recent years elevation data acquired through Light Detection And Ranging (LiDAR) techniques has become an increasingly available tool for geologists as it can provide a wealth of information, especially for geomorphic mapping. These types of data analysis are important for providing accurate quantitative and qualitative information over large study areas, even when these are not easily accessible and covered with vegetation, conditions that make field investigations and traditional aerial photography interpretation more problematic. The examples of elevation data analysis presented here are from a geomorphic study focusing on seismic hazards: the characterization of the Kern Canyon fault (KCF). This study, completed in 2010 for the U.S. Army Corps of Engineers, was aimed at assessing the seismic stability of Isabella Lake dams in Kern County, California.

Kern Canyon Fault Case Study

Our Kern Canyon fault assessment was aimed at completing detailed mapping of the fault with the final goal of determining whether it is a Quaternary-active fault.
The use and interpretation of high-resolution LiDAR-derived elevation data facilitated the initial phases of this study due to the fact that the area is very large (about 140 km long) and most of it lies in very remote locations. Therefore, these digital data provided preliminary estimates of the location of active surface faulting in a time- and cost-efficient way. In addition, most of the study area is characterized by rugged terrain covered by vegetation, which would be difficult to interpret by inspection of aerial photography alone.
LiDAR data were collected in 2008 and 2009 and processed to create several tiles representing a Digital Elevation Model (DEM) of the bare-earth topography, as they have been compiled by filtering out non-ground returns from the raw laser returns, using methods proprietary to the vendor.
The result is a representation of the ground surface that does not show any buildings, vegetation or any other extraneous structures. We have created shaded reliefs with different illumination angles and slope maps from 0.6-meter cell size DEMs, which have both been very useful for creating geomorphologic maps and for identifying the location of fault-related lineaments. Furthermore, we used the DEMs to generate detailed fault-normal scarp profiles to estimate the characteristics of fault ruptures along the entire length of the fault and to understand the geomorphic expression within different geologic units.
We made extensive use of shaded reliefs derived from the DEMs but also used slope maps and a combination of DEMs symbolized with color ramps and superimposed on shaded reliefs to support interpretation of aerial photography, topographic maps, and existing geologic maps. By analyzing these types of elevation data and their derivatives, we were able to compile generalized and detailed mapping of fault lineaments and joints, which represented the basis for field reconnaissance and which could not have been easily identified with other methods (Figure 1).

In addition to providing aid for localization and interpretation of geomorphic features, the elevation data collected with LiDAR techniques have allowed us to conduct quantitative analysis through the generation of topographic profiles. By extracting points in ArcGIS along fault-normal lines with distance and elevation values and by plotting these in Microsoft Excel, we were able to create over 100 topographic profiles along the length of the fault, and by displaying these along with the location of the fault we were able to represent the expression of the fault-related scarps and to estimate the amount of vertical separation (Figure 2). For specific locations, these values have been confirmed by detailed field investigations, such as trenching.

This methodology has proven to be very efficient and in most cases to produce results that have been confirmed by field inspection. However, some limitations have surfaced in those areas where the density of collected point elevation data, after filtering to exclude non-bare earth signals, was low and therefore the DEM of the topography has been obtained by "over-interpolating" the source data and thus resulted in an elevation model that was not very accurate. By observing the distribution of the source point data, these areas can be easily identified and analyzed with different methods, such as aerial photography interpretation or analysis of elevation data from a different source. Another limitation we have faced has been the absence of a valuable tool in ESRI ArcGIS (our main GIS platform) to accurately represent topographic profiles. An ideal tool would display the profile in a geospatial environment and would allow the user to control most of the settings, such as the scalability of the axes. We resolved to use the plotting capabilities of Microsoft Excel or other software with charting capabilities.

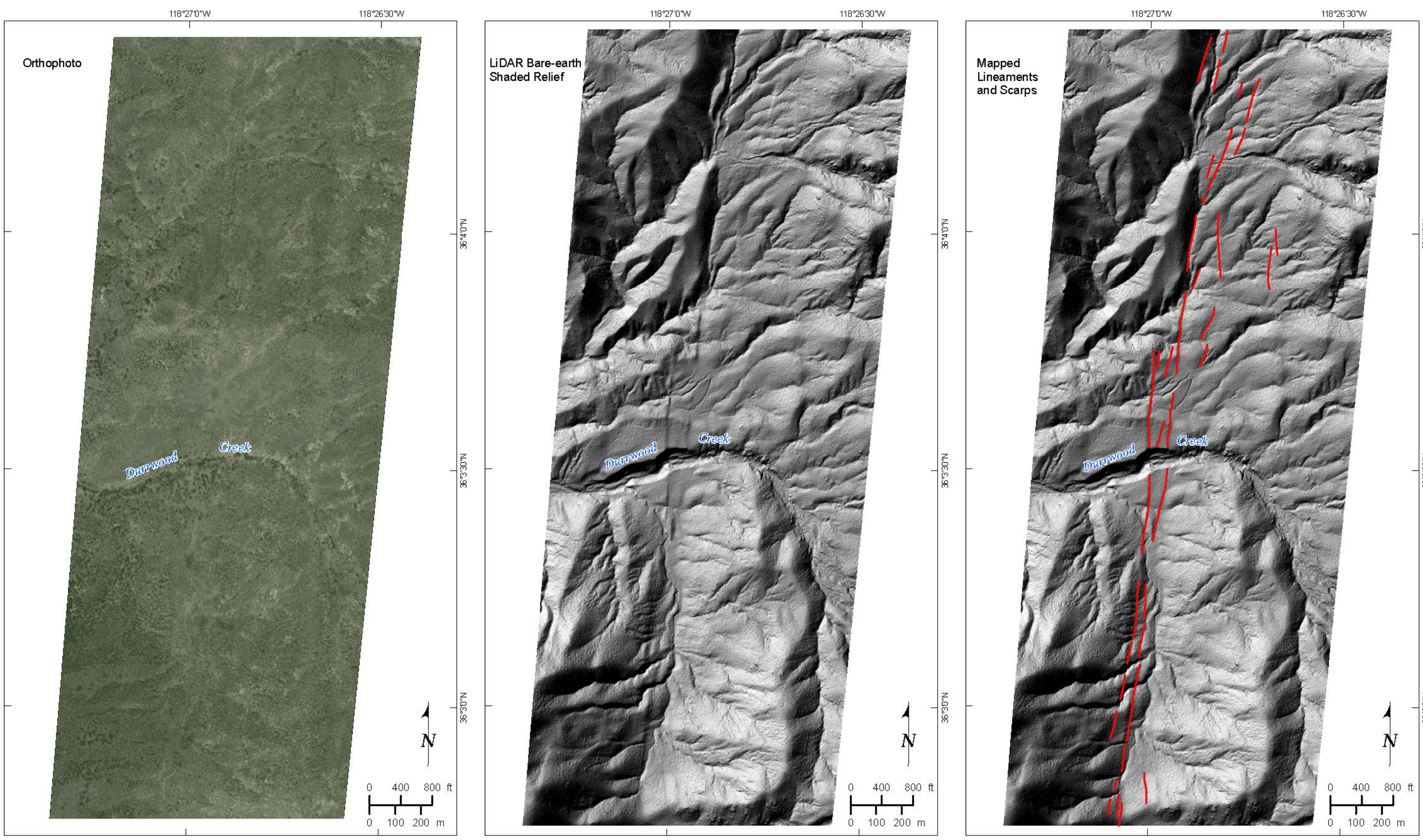


Figure 1. Comparison of aerial photo and shaded relief for the same area (Durrwood Creek): most of the KCF lineaments, shown as red lines in the tile on the right, are not identifiable in the aerial photo but are easily recognizable observing the shaded relief generated from LiDAR data (center and right tiles).

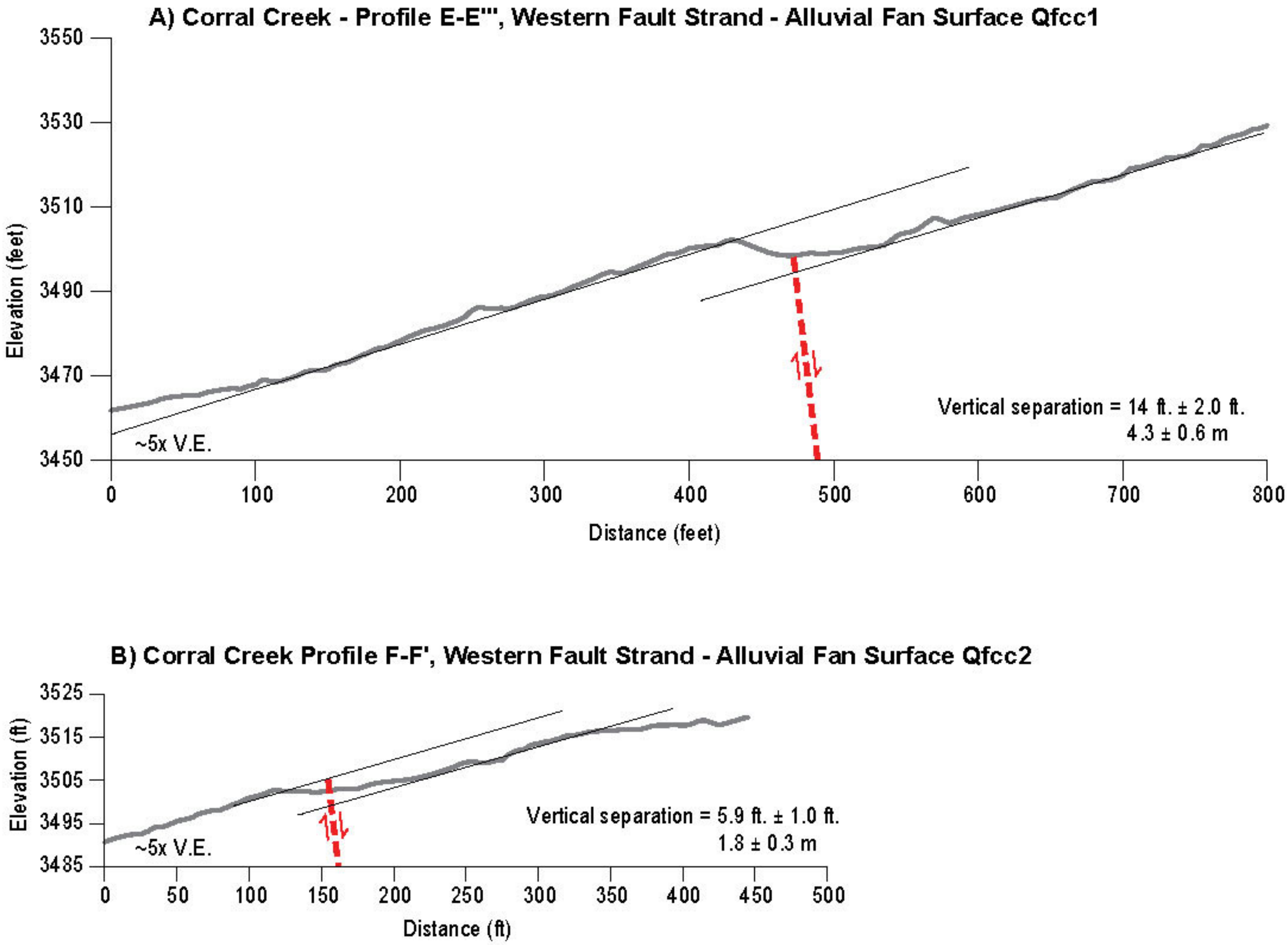
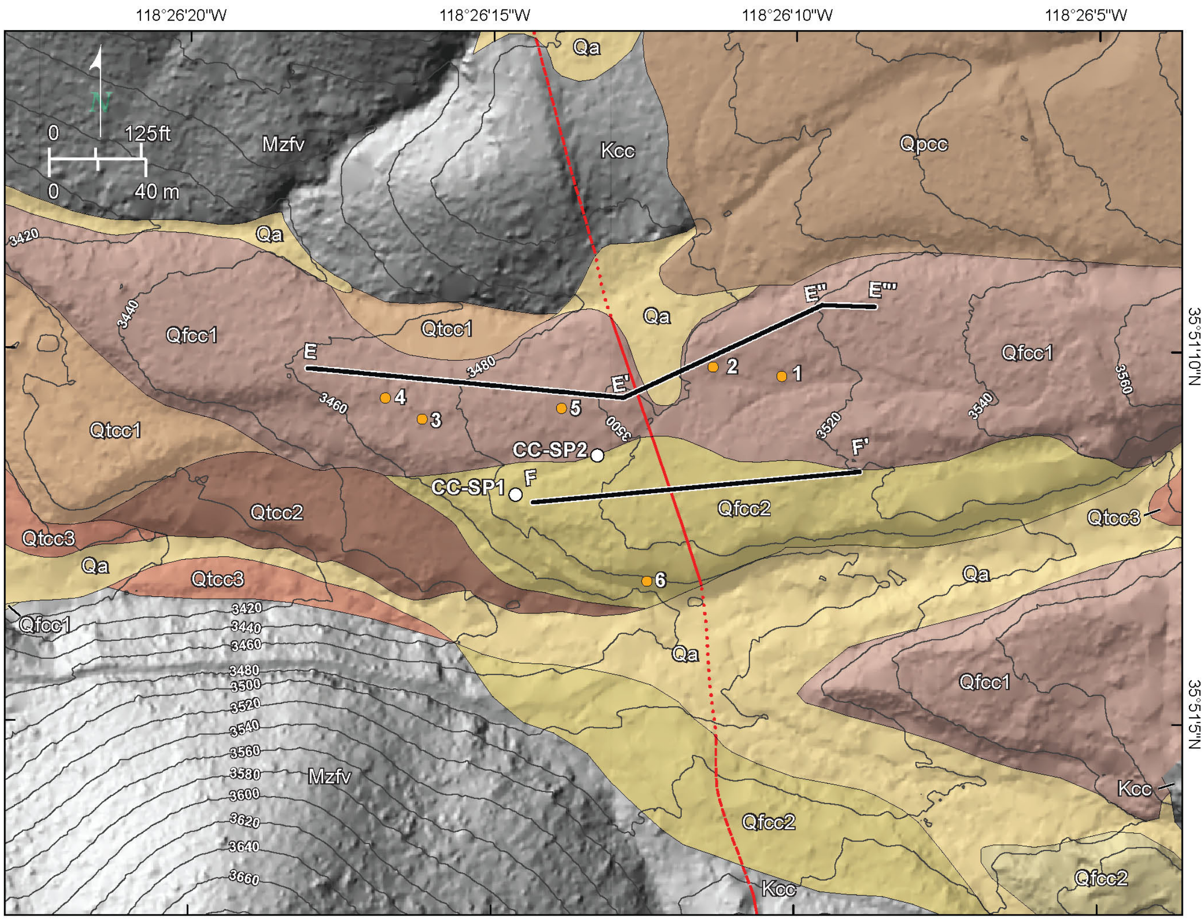


Figure 2. Examples of fault-normal topographic profiles at the Corral Creek site used to estimate vertical separation along the KCF (location of fault plane is shown with dashed red line). Units along the axes are feet for consistency with the source elevation data (1 ft = 0.3048 m). Total profile lengths are: A) 244 m; B) 136 m.



Hillshade and contours derived from 2008 LiDAR provided by Towill, Inc.

Figure 3. Geologic map of the Corral Creek site with location of the two topographic profiles shown in Figure 2.

ACKNOWLEDGMENTS

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