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Seeing faults through the trees: A case study on using LiDAR in highly vegetated areas to determine fault activity and geomorphology

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The Gore Range is a densely treed, steep-sloped mountain range in north-central Colorado, USA. The range is bounded along its eastern flank by the late Quaternary Gore Range Frontal Fault. Much of the range and the fault are contained within a national wilderness area that has no roads and few trails. This remote, rugged setting creates a situation where undertaking traditional fault investigations and field work are difficult. Much of the past work has utilized aerial photography and many of the geomorphic features associated with the fault were not recognized; the trace of the fault and associated scarps simply could not be detected through the dense tree cover. As a result, surficial geologic mapping is limited and while the fault has been studied for over 30 years, identification of geomorphic features associated with the fault has been immensely difficult. Multiple fault traces and differing rates of activity have been interpreted in past studies.

LiDAR data collected in 2008 for a 620-km2 section of the range front has allowed us to 1) map the surficial geology, including glacial landforms and landslides, and 2) identify lineaments and scarps that could indicate late Quaternary fault surface rupture. The LiDAR survey produced data for all returns, including bare earth, and the average point spacing was 1.57 m, average point density was 0.41/m2, and area/point was 2.47 m2. We used the LiDAR imagery to distinguish multiple glacial depositional systems, to delineate recurrently active landslides, and to estimate qualitative ages for these landforms. We identified at least 9 potential fault scarps that cut glacial deposits within the Gore Range, and these locations were field verified. The LiDAR imagery is extremely useful in differentiating scarps and lineaments that may be the result of tectonics fault rupture from those associated with other geomorphic processes such as mass wasting and fluvial erosion. Fault scarps were identified within multiple Quaternary glacial landforms along the 45-km length of the Gore Range Frontal fault.

One area in particular included a lineament that appears to cut through glacial deposits of two different ages (Pinedale: 12 ka to 35 ka, and Bull Lake: 120 ka to160 ka), and may indicate fault surface rupture since the last major glaciation in the Rocky Mountains (since $\sim$12,000 years). In addition, the scarp profiles measured along the Gore Range Frontal fault can further refine the timing of fault rupture along the range front.