

## Lidar reveals uniform Alpine fault offsets and bimodal plate boundary rupture behavior, New Zealand

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De Pascale et al. (2014) present a new “bimodal” fault rupture behavior model for the dextral-reverse Alpine fault using evidence from several new, small (<30 m) dextral displacements identified on lidar along a 20 km stretch of the densely forested, central section of the Alpine fault near Whataroa. The proposed model asserts that partial fault ruptures (related to moderate to large earthquakes) occur in addition to full ruptures (related to major or great earthquakes). However, De Pascale et al. do not provide evidence for bimodal rupture behavior. The paper fails to: (1) identify a bimodal displacement pattern in the geologic record, (2) provide geological age control for any measured displacements, (3) adequately address the role of the ca. A.D. 1600 earthquake event, and (4) accommodate the lack of moderate to large earthquakes in the historical record. We briefly address these points here.

De Pascale et al. demonstrate from lidar and field data that similar amounts of dextral offset ( $\sim 7.1 \pm 2.1$  m dextral slip per event) occurred in each of the last three movements recorded on what appears to be the main dextral trace of the Alpine fault, south of Gaunt Creek. They concede that no smaller-sized displacements (<3 m) were identified, and if they are present they would likely be below the resolution of field studies (see their figure 4) or the 3 m lidar model published by Langridge et al. (2014). In addition, the authors neglect to mention the presence and importance of range-front thrust and oblique-slip fault traces and the likelihood that at least some partitioned dextral slip occurs on them, as is known from Gaunt Creek (Cooper and Norris, 1994; Barth et al., 2012).

Preliminary paleoseismic results from Gaunt Creek emphasize the lack of well-dated late Holocene fault displacements along this part of the Alpine fault (De Pascale and Langridge, 2012). In place of independent age constraints on their measured offsets, De Pascale et al. (2014) explore the timing of individual earthquakes by dividing their single-event displacement estimates by the average Late Quaternary slip rate. Although entirely hypothetical, the calculated ages appear broadly consistent with independent dating of past Alpine Fault earthquakes. However, the authors have neglected to properly propagate displacement and slip-rate uncertainties through their calculations. Correct propagation of uncertainty renders the resulting “ages” meaningless—the uncertainties are so great that each inferred displacement increment correlates with more than one dated Alpine fault event. In fact, we have been unable to replicate the values in their table 1 using the data and methods presented.

We do not discount the possibility of “partial” ruptures or of events of  $M_w < 7.0$ , but argue that a bimodal rupture behavior is supported by neither paleoseismic data nor the historical earthquake record. De Pascale et al. fail to evaluate the published paleoseismic data adequately to support their statement that moderate to large earthquakes ( $M_w \geq 6.5$ ) occur on the Alpine fault. They suggest that the ca. A.D. 1600 Alpine fault earthquake was such a moderate-sized earthquake. However, the available data documented from six on-fault trench sites and off-fault landscape impact sites suggest that this event likely ruptured the northern (with overlap onto the central) section of the fault in a  $M_w \sim 7.6$  earthquake with slip over a length of 200–300 km (using the Alpine fault  $M_w$  scaling relationship of Stirling et al. [2012]; Sutherland et al., 2007;

Yetton and Wells, 2010; Howarth et al., 2012). If this published scenario for the ca. A.D. 1600 event is accepted, then there is no paleoseismic evidence to support the De Pascale et al. hypothesis that partial ruptures occur in between full ruptures of the fault, nor is there a mismatch between displacements, timing, and slip rate for the central Alpine fault. Critically, no  $M_w$  6.5–7.0 earthquakes (that a bimodal model would predict) have occurred on the Alpine fault during the New Zealand historical period (since ca. A.D. 1840). Furthermore, recently published recurrence times for earthquakes on the central ( $260 \pm 70$  yr) and southern ( $329 \pm 68$  yr) sections of the Alpine fault derived from long paleoearthquake records support relatively regular recurrence of similar-sized (major) earthquakes at a point (Howarth et al., 2012; Berryman et al., 2012).

In summary, De Pascale et al. have not identified any smaller offsets (as subsets of the  $\sim 7.1$  m increments) caused by moderate to large earthquakes, or reliably dated the strike-slip displacements at their sites caused by major Alpine fault ruptures. Therefore, they present insufficient data to argue for bimodal fault behavior or new earthquake recurrence models that would impact on the current understanding of Alpine fault hazards. Their paper does, however, highlight the need for continued efforts to better locate and precisely date on-fault records of earthquake timing and slip along the fault.

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