Sedimentary deposits formed by postseismic sediment flux constrain the rupture length of great earthquakes on the Alpine Fault, New Zealand

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Introduction

The episodic nature of earthquakes makes the determination of accurate rupture lengths difficult, especially for longer segments of the fault, where the seismic hazard is high. The determination of the rupture length is critical for accurate seismic hazard analyses, of conceptual models of fault behaviour, and for paleoseismic studies that resolve the length of fault rupture during successive earthquakes. In the New Zealand context (Fig. 1A), a review of existing paleoseismic data for the South Island’s largest active plate boundary, the Alpine Fault, suggests that different fault lengths rupture during successive earthquakes (Fig. 2). The data suggest the fault does not produce characteristic earthquakes. Here we test this hypothesis by developing a new approach to reconstructing the timing and rupture length of earthquakes using lake sediments. We demonstrate the approach using sediments from two lakes, Mapourika and Paringa, adjacent to the Alpine Fault (Fig. 1B).

Lake deposits & depositional processes

The sedimentary fills of lakes Mapourika and Paringa are comprised of three types of deposits formed by coagulation, postseismic and aseismic processes, which together represent deposition over a seismic cycle (Fig. 4). This pattern of deposition is repeated in deposits from both lakes suggesting that the lake basins record multiple Alpine Fault earthquakes and the landscape response to these events.

Methods

Lake sediments were cored using a 6 m Mackinaw core (Fig. 3). Cores were digitally imaged and analyzed for physical properties using a GROTEK MCSV. TOC and TN were determined using an elemental analyser and the concentration of Cs and 

Postseismic sediment flux was constrained by estimating the mass of clastic sediment deposited in each lake basin during the postseismic landscape response to Alpine Fault earthquakes (cf. Howarth et al.)

Chronostratigraphic modeling using the architectural relationships of Dowrick and Rhoads¹, with the Smith¹ correction for long faults, was used to estimate the shaking intensity required to produce large postseismic sediment fluxes.

Acknowledgments and References


Figure 1: Map of the study locations. A) the Alpine Fault in northern South Island, New Zealand with the location of lakes Mapourika (black star) and Paringa (red star). B) the location of lakes Mapourika and Paringa (bubbles) and the historical sequence of inter-seismic and post-seismic A.D. earthquakes from 1770 to 1980 (modified after Berryman et al.3). The Alpine Fault earthquake of A.D. 1717 is the most recent earthquake to rupture the central segment of the Alpine Fault.

Figure 2: Hypothesized rupture lengths based on published paleoseismic records of Alpine Fault earthquakes (Barckhausen et al., 2008; Page and Langridge, 2008; Howarth et al., 2010).

Compare the earthquake ages for the central segment of the Alpine Fault with the last three earthquake ages previously published by Bernsen et al. (°): for the southern segment suggests earthquakes are temporarily offset between the fault segments. However, the lake records highlight problems with this interpretation. Rupture of the southern fault segment (~1570 A.D.) in Lake Paringa reveals that the lake’s sedimentary record contains no evidence of an earthquake. The absence of a megaturbidite in Lake Paringa suggests an earthquake is unlikely to have ruptured the southern segment at this time. Reinterpretation of the earthquake chronology from the northward on the southern segment suggests the last three events correlate with earthquakes on the central segment. The difference in postseismic sediment flux between the 1717 A.D. and ~1570 A.D. earthquakes provides an opportunity to test the relative seismic hazard at which these deposits formed because the earthquakes ruptured different fault segments.

Postseismic sediment flux, shaking Intensity & rupture length

Lake deposits record the extent of earthquake shaking and the shaking intensity associated with the spatial extent of fault rupture. We conclude that four of the last five earthquakes ruptured the central segment of the Alpine Fault.

Figure 3: Mackinaw core surfacing at Lake Mapourika

Figure 4: Postseismic and aseismic records from lakes Mapourika and Paringa. A) Digital image, graphic log, mean grain sizes and % gravel facies for representative samples of each facies identified in cores from both lakes. B) Map of clastic sediment (MAP) and CN vitrinite in a seismic cycle (1) for a sequence of events (2) and the postseismic fault formation.