Supplementary Material

Nicol, A., Begg, J., Saltogianni, V., Mouslopoulou, V., Oncken, O., Howell, A., 2022. Uplift and fault slip during the 2016 Kaikōura Earthquake and Late Quaternary, Kaikōura Peninsula, New Zealand. *New Zealand Journal of Geology & Geophysics: Kaikoura Earthquake Special Issue*

Abstract

The Kaikōura Earthquake uplifted Kaikōura Peninsula by up to ~1 m. Uplift in 2016 mainly resulted from slip on an offshore thrust fault (OSTF), modelled to splay from the plate-interface, and was further influenced by slip on two newly identified faults (Armors Beach Fault, ABF; Te Taumanu Fault, TTF) mapped onshore from differential lidar (D-lidar). Forward dislocation modelling indicates that 2016 uplift on the peninsula can be reproduced by mean slip of ~2.3 m on the OSTF and 0.25-0.5 m on the ABF and TTF. The variable co-seismic uplift recorded during the 2016 earthquake differs from the near-uniform ($1.2 \pm 0.2^\circ$) northwest tilting of MIS5c (96 ± 5 ka) and MIS5e (123 ± 5 ka) marine terraces; these ages are constrained by Optically Stimulated Luminescence (OSL) dating and correlation to sea-level curves. Tilting of Late Quaternary marine terraces can be primarily reproduced by slip rates of ~0.8 to 2.7 mm/yr on the OSTF and 0.3-0.6 mm/yr on the ABF. Slip on the TTF is not required to produce tilting of the marine terraces, suggesting that it may have ruptured less frequently than the OSTF and ABF in the Late Quaternary. The OSTF links 2016 ruptures north and south of Kaikoura, with the earthquake rupturing an interconnected network of faults.

Figure S1. Predicted vertical displacement profiles assuming equal homogeneous slip of 1 m across all fault sources, **(a)** along profile A and **(b)** for the OSTF along profiles B and C. Each curve represents the predicted displacement on the points (open circles) across the peninsula in **(c)**. Yellow shaded areas indicate the extent of the Lidar data along profile A (see c for location of data). **(c)** Map view of the modelled fault traces and profiles shown in **(a)** and **(b)**.

Figure S2. Cross sections (upper panels) and uplift profiles along profile A (lower graph) showing the impact of varying dip on the OSTF and ABF on predicted uplift. To explore the impact of dip we have modelled uniform dip on the OSTF (Scenario 1), listric fault dip on the OSTF (Scenario 2) and bimodal dip on the OSTF (Scenario 3). The geometry of the OSTF was tested for the three different scenarios shown in the upper part. For all scenarios the ABF was fixed at 60° dip, while the geometry of OSTF varied as following; scenario 1: dip angle at 35° , scenario 2: linearly decreasing dip angle from 60° to 30° , scenario 3: dip angle at 60° at depths <15 km and 20° at depths >15 km. In all scenarios fault slip is assumed to be uniform. In the lower graph we compare the observed uplift (black line) and to the predicted uplift for scenarios 1 (red line), scenario 2 (blue line) and scenario 3 (pink line). This comparison shows that changes in the fault dip model do not significantly impact the predicted uplift patterns. Matching the observed uplift profile requires down-dip variations in the magnitude of slip (see text in journal article for further discussion).

Figure S3. Slip models derived from forward modeling for the long-term uplift assuming the listric fault geometry of scenario 2 in Figure S2. Normalized slip models for the OSTF are shown with increasing depth (grey lines, top graph). The optimal best-fit slip model with the minimum residual between data and predicted data is shown in red. Comparison between the observed (black line and dots) and the best-fit predicted (red line and triangles) uplift is also shown in the lower panel. Figure similar to Figure 5a.