25+ million years of landscape evolution within New Zealand's Marlborough Fault System

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The Marlborough Fault System (MFS) South Island, New Zealand

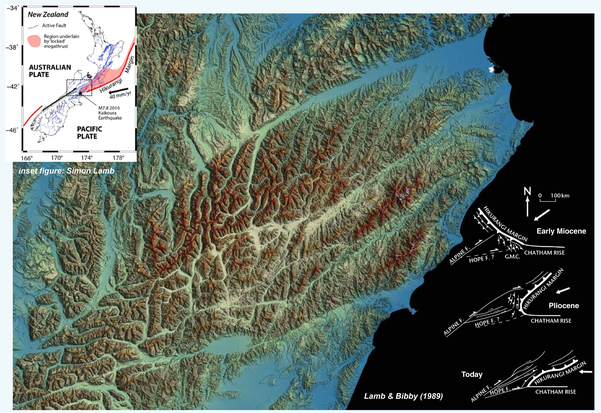
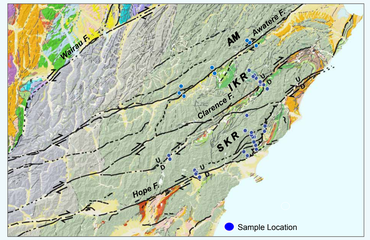


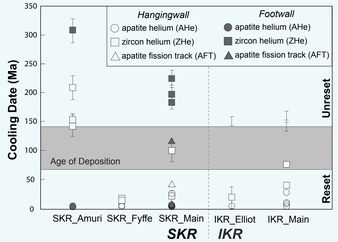
FIGURE 1 - Shaded relief map of the northeastern end of the South Island, New Zealand. (a) Upper left Inset (figure from Simon Lamb preventionweb.net) shows the New Zealand plate boundary. (b) Lower right Inset shows the changing plate boundary convergence vector through the 25 million years of Kaikoura Orogeny from Lamb and Bibby (1989). Note that it has become more oblique toward the present time.

*** How has the landscape evolved in this * complex, long-lived tectonically active setting?**

1. When did the mountains rise, when did the faults form?
2. How have the rivers evolved at this changing plate boundary?
3. Do erosion rates reflect river and hillslopes patterns? And what happens during big earthquakes such as the 2016 M7.8?

① Low-Temperature Thermochronology





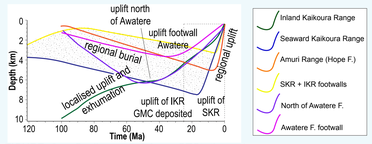


FIGURE 2 - Cooling paths from QTQt thermal models of low-temperature thermochron dates. **Upton et al. (*in prep*)**

FIGURE 3 - Plot of thermochronology cooling dates along each elevation transect site. Gray shaded region covers the range in depositional age of sampled rocks. Note that all AHe dates are reset, whereas only ZHe in hangingwall rocks are reset.

Two Stage History:

- **Miocene exhumation limited to hanging walls indicates early thrust faulting and uplift, first in the Inland then in the Seaward Kaikōura Range**
- **Exhumation is rapid and widespread across the Marlborough Fault System after Pliocene onset of dextral faulting**

Collett et al. (2019)

② Planform River Patterns

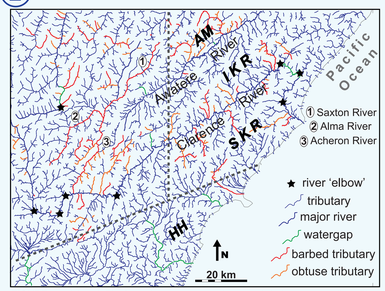
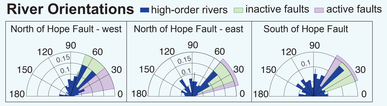


FIGURE 4 - (above) Planform river patterns and mapped drainage anomalies. River elbow = channel bends ~90; obtuse trib. = trib meets river at 90 or greater; barbed trib. = obtuse w/ deflection; water gap = river flows across divide. (below) Polar histograms of River orientations (Strahler orders >1). Anaylsis from network segment routines [c/o Philippe Steer] and Topotoolbox [Schwangart and Scherler, 2014]. Plots from CircStat [Berens, 2009]. Figs. from Duvall et al. [2020]

River Orientations high-order rivers inactive faults active faults



→ Rivers oriented w/ inactive faults

→ Rivers oriented w/ inactive, active faults

Duvall et al. (2020)

Planform Fault Patterns

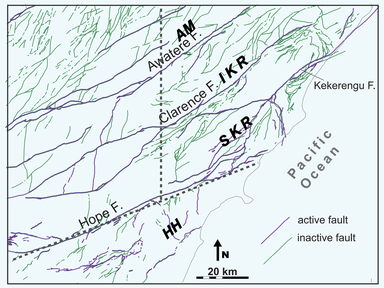
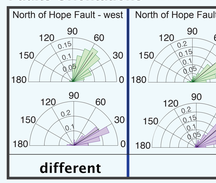


FIGURE 5 - (above) Map of active and inactive faults from GNS database. Inactive and active category. (below) Polar histograms of Fault orientations. Anaylsis from ArcGIS. Plot from CircStat [Berens, 2009]. Figs. from Duvall et al. [2020]

Faults Orientations inactive faults active faults



Synthesis of Landscape Patterns

- **Drainage anomalies indicative of river capture and rearrangement abundant in west (predominantly) & east MFS, with fewer S. of Hope (youngest landscape)**
- **Overlapping river & fault orientations suggest structural control to drainage network. Why do rivers align preferentially with inactive faults rather than active faults in the west?**
- **Zones of high k_{sn} overlap with youngest thermochron ages, likely regions of highest uplift rates**

MFS Landscape through Time

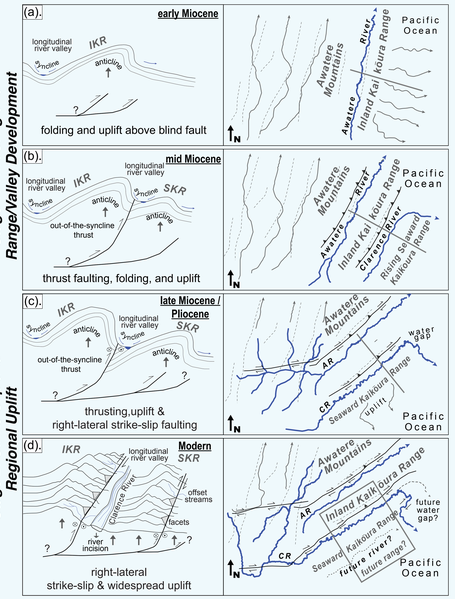
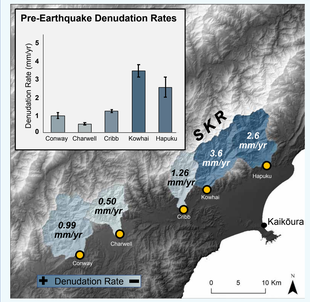


FIGURE 6 -Schematic cartoon of Marlborough Fault System landscape evolution through time. Left panel shows cross-section view of the Kaikōura domain and right panel shows map view of landscape, expanded to include both the Kaikōura and Inland Marlborough domains. Approximate location of left-panel cross section shown with gray line (a,b,c) or box (d) in right panel. Right panel depicts active faults in black and inactive faults in gray and the approximate rotation of the faults and landscape from Randall et al. (2011). IKR - Inland Kaikōura Range, SKR - Seaward Kaikōura Range, AR – Awatere river, CR – Clarence river.

Duvall et al. (2020)

③ Detrital ^{10}Be Cosmogenic Nuclides



- *** Order of magnitude variation in pre-earthquake denudation rate across SKR cathcments**
- *** Rates correlate well with morphology (slope, relief, channel steepness, elevation)**
- *** Rates are higher than apparent exhumation rates from low-temperature thermochronology exhumation rates**

FIGURE 7 - ^{10}Be derived pre-earthquake denudation rates.

What about after the earthquake?

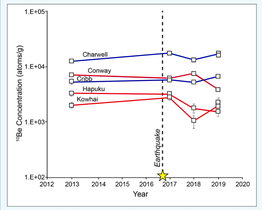


FIGURE 8 - ^{10}Be concentration pre and post earthquake

- **3 of the 5 catchments (in red) show post-earthquake dilution in 10Be concentration**
- **Conway, Kowhai, Hapuku experience ~ factor of 2 dilution, which is delayed after 2017 event**
- **Kowhai headed back to pre-2017 conditions?**

Does dilution relate to coseismic landslide volume?

Example preliminary post-M7.8 earthquake landslide mapping (slide areas in red).

- ^{10}Be dilution correlates well with total landslide volume despite differences between catchments in terms of erosion rate, pre-eq sediment concentration, and catchment hypsometry. Reults suggest that **landslide volume is the dominant control on diluation** and the possibility of a landslide volume threshold for dilution.

Williams et al. (*in prep*)

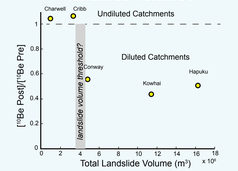


FIGURE 9 - Plot of catchment ^{10}Be dilution and landslide volume.

Acknowledgements and Works Cited

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