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The effects of rapid and catastrophic sedimentation in tectonically active areas

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Abstract Tectonic activity can have a marked direct and indirect control upon region-wide geomorphology and human activity. A seismic driving model for sediment movement is discussed and key examples are given from two regions in New Zealand. In South Westland, regional episodes of coastal progradation and dune formation have quickly followed all known Alpine fault earthquakes since at least *c*. 1220 AD. On the other side of the Southern Alps the rapid transfer of sand to the coast following the same fault ruptures again caused coastal dune formation. While dune system development occurs soon after tectonic activity, other geomorphological changes such as river channel avulsion and spit/barrier formation can be delayed by many years. The interaction between fine and coarse sediment delivery systems causes significant and often rapid changes to coastal geomorphology and ecosystems that have serious implications for human populations living at or near the coast.

Key words tectonics; dunes; aggradation; geomorphology; coastal change; human settlements

INTRODUCTION

In mountainous regions, earthquake-induced landsliding causes pulses of sediment to be delivered from upper catchments to river flood plains and out to the ocean. Given the right conditions, these sediment pulses can be deposited as new dune ridges at the coast. A seismic staircase model for this process-form link on a catchment-wide basis was proposed for New Zealand by Goff & McFadgen (2002). They linked near-contemporaneous events such as forest disturbance, landslides, increased fluvial sediment transport and aggradation, and rapid coastal dune building (Moseley *et al*., 1991) as a sequence of geomorphological responses to a large earthquake (Fig. 1).

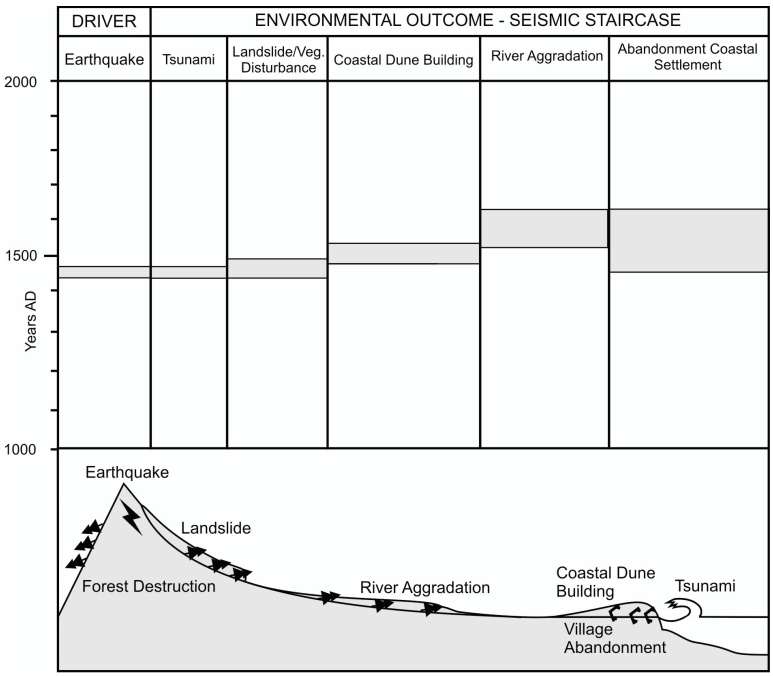

Fig. 1 Example of hypothetical linkages between an earthquake driver and environmental outcomes (Seismic Staircase). Grey shaded boxes are indicative age ranges (modified after Goff & McFadgen, 2002).

SOUTH ISLAND – WEST COAST

In South Westland, between the Haast and Awarua River catchments (Fig. 2), episodes of regional dune development and progradation have followed large Alpine fault earthquakes over the past 800 years, reflecting the coastal storage of huge post-seismic sediment pulses (Fig. 3). No dunes have formed at other times (Wells & Goff, 2007). The dominance of earthquakes as a driver of coastal dune building and progradation is striking. Lasting storm-induced dune ridge building has been insignificant in the region over the past 800 years, despite the occurrence of violent storms and prolonged El Niño events. However, such events are relatively common in the region, and it is suggested that under these normal background conditions the sediment transport system operates in a balanced fashion, i.e. the quantity of material delivered by the rivers is similar to the quantity of sediment removed by longshore drift and other marine processes. Shoreline deposition will presumably occur whenever the volume and rate of sediment discharge are sufficient to override normal marine processes.

As stated, on the West Coast such surges of "abnormal" regional sediment release have only occurred following large earthquakes. In total, six regional dune building episodes can be ascribed to earthquakes on the Alpine fault in 1826 AD, 1717 AD, *c.* 1615 AD, *c.* 1490 AD, *c.* 1420 AD, and *c.* 1220 AD (Wells & Goff, 2007).

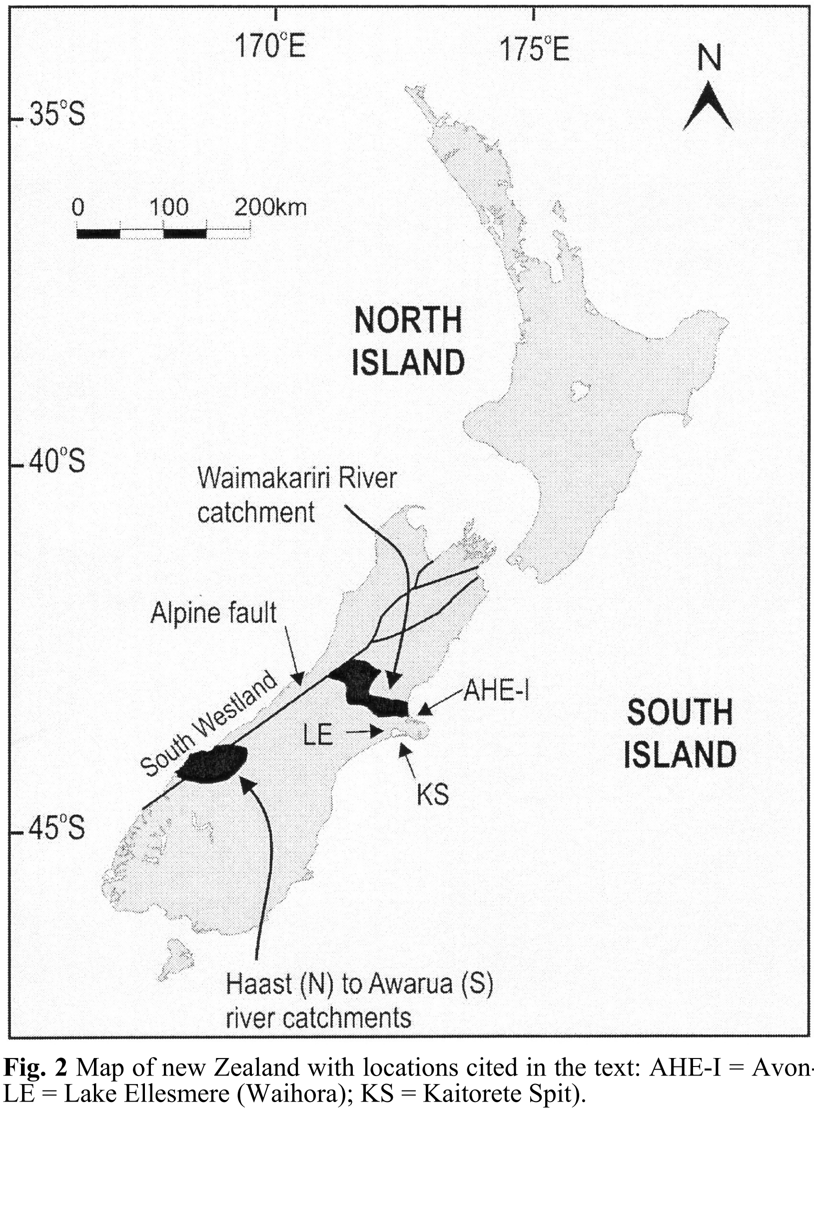

Fig. 2 Map of new Zealand with locations cited in the text: AHE-I = Avon-Heathcore Estuary (Ihutai); LE = Lake Ellesmere (Waihora); KS = Kaitorete Spit).

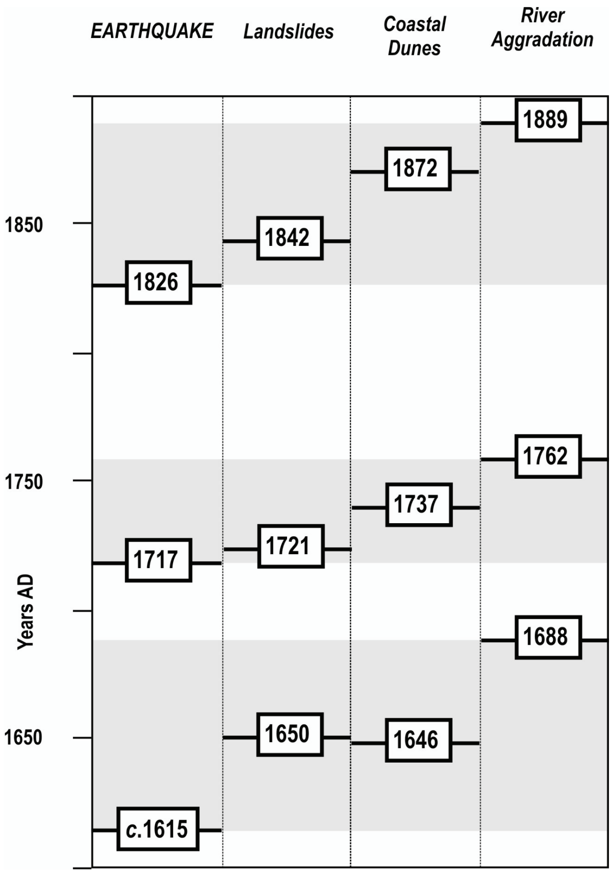

Fig. 3 Diagram of the chronology of the last three Alpine fault earthquakes and three related environmental outcomes (landslides, coast dune building, river aggradation) in southwest New Zealand. All ages are in years AD. Ages for environmental changes give the age of the single oldest tree in all the post-earthquake forest cohorts sampled on the respective landforms following each earthquake (modified after Wells & Goff, 2006).

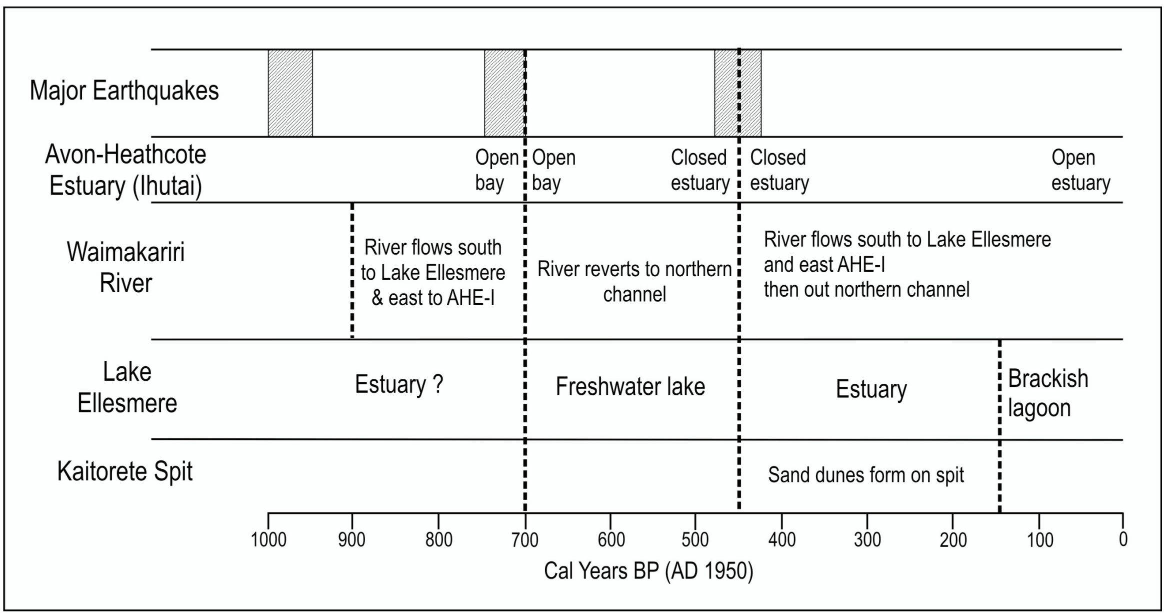

Fig. 4 Geomorphological changes in the Avon-Heathcote Estuary (Ihutai) and Lake Ellesmere (Waihora) compared with major earthquakes and changes in the Waimakariri River (modified after McFadgen & Goff, 2005).

SOUTH ISLAND – EAST COAST

A subsequent study of the Waimakariri River catchment on the eastern side of the South Island (Fig. 2) revealed that the model was also valid for areas at a greater distance from an earthquake epicentre (McFadgen & Goff, 2005). Of particular note was the rapid fluvial transfer of sand to the coast, causing dune formation, and a more delayed pulse of coarser sediment that caused channel avulsion of the Waimakariri River as far south as Lake Ellesmere (Figs 2 and 4). While dune system development seemed to occur soon after tectonic activity, river channel avulsion, spit/barrier formation and ongoing geomorphological changes were often related to periods of tectonic activity that occurred 100–200 years previously. The interaction between these two sediment delivery systems caused significant, and often rapid, changes to coastal geomorphology and ecosystems that had serious implications for human populations living at or near the coast (Fig. 4). There were changes in intertidal shell fish resources, abandonment of settlements, movement to safer locations, and re-occupation of favoured sites that all reflected the direct and indirect impacts of tectonic activity.

The record of prehistoric occupation of the coast ties in closely to geomorphological processes. To understand cultural processes therefore presupposes a thorough understanding of the relevant geomorphological processes. As a more subtle, delayed geomorphological response to tectonic activity, the indirect controls are important to consider for hazard mitigation.

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