Tectonic controls on Source to Sink Systems and the interplay with sea level change: Examples from northeastern New Zealand

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M-13

Introduction

Tectonic processes have a fundamental influence on the behaviour of source to sink (S2S) systems on tectonically active margins, acting as both: (i) a driver, creating topography, which results in erosion, transport gradients, and accommodation space (**Fig. 1**), and (ii) a perturbation, causing widespread ground shaking which can result in landsliding (**Fig. 2**), and ultimately sediment delivery to river channels.

The role of tectonics as a driver in S2S systems such as the Waipaoa (**Fig. 1**), NE New Zealand (NZ), is relatively well understood (Berryman et al., 2000, 2009; Gerber et al., 2010), but work on the role of earthquakes has only recently begun (Litchfield et al., 2009).

We present these preliminary results and examine the interplay between tectonics and post-glacial sea level (SL) rise.

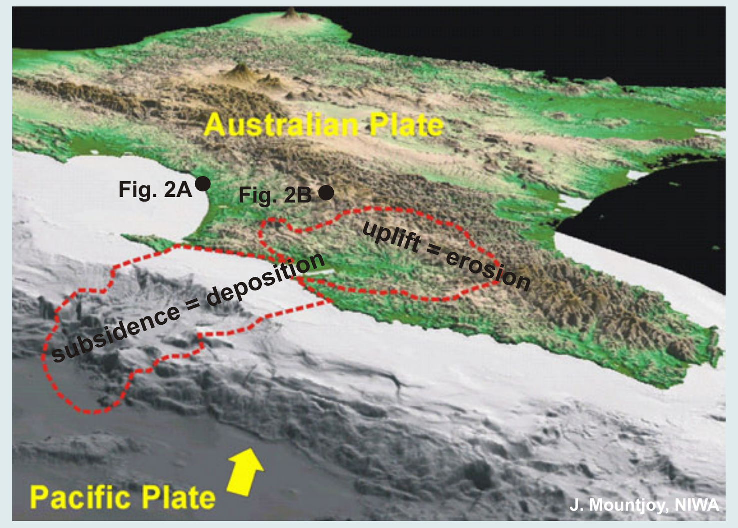
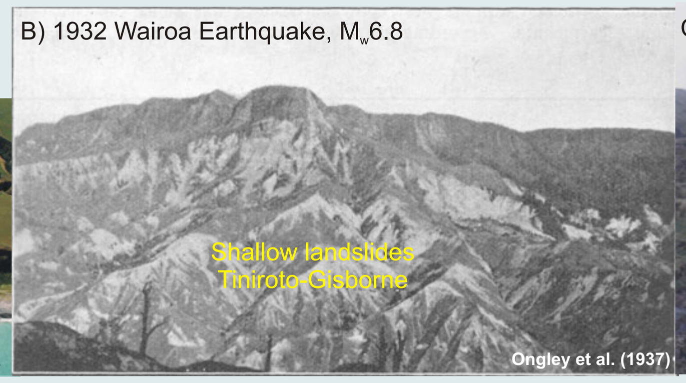
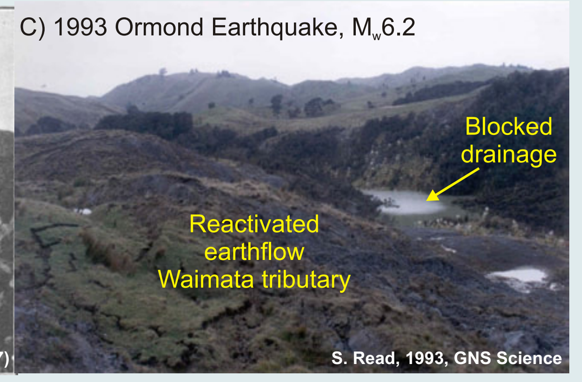


Fig. 1 Tectonic setting of the Waipaoa S2S System, view to the W.

Historical earthquake-triggered landslides

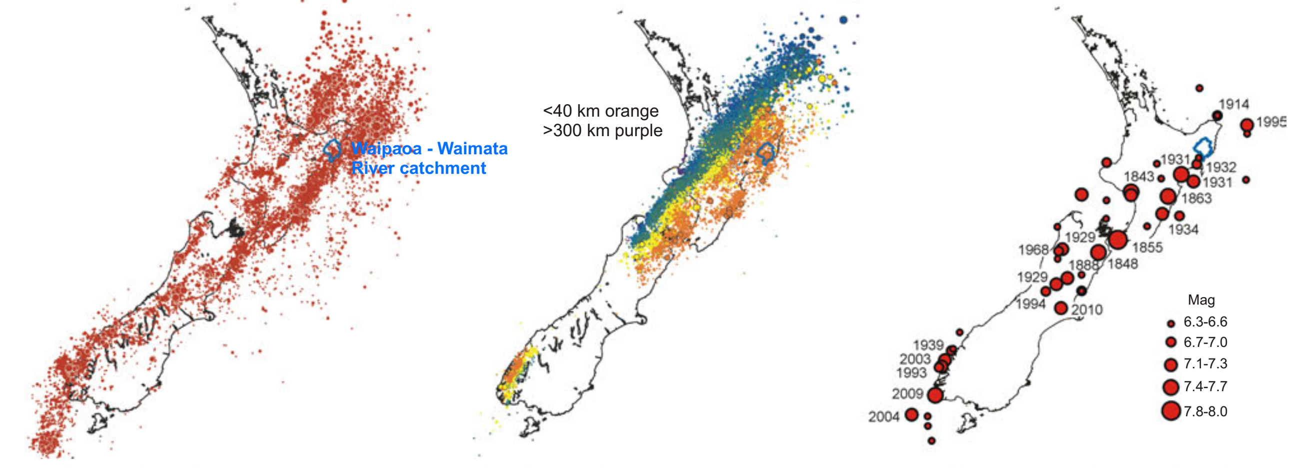
Fig. 2 Historical (post 1840AD) earthquake-triggered landslides from NE NZ. Located in **Fig. 1** and **6**. Refer to Hancox et al. (2002) for further details.





Waipaoa River catchment earthquake sources

Fig. 3 Historical New Zealand earthquakes (http://www.geonet.org.nz)

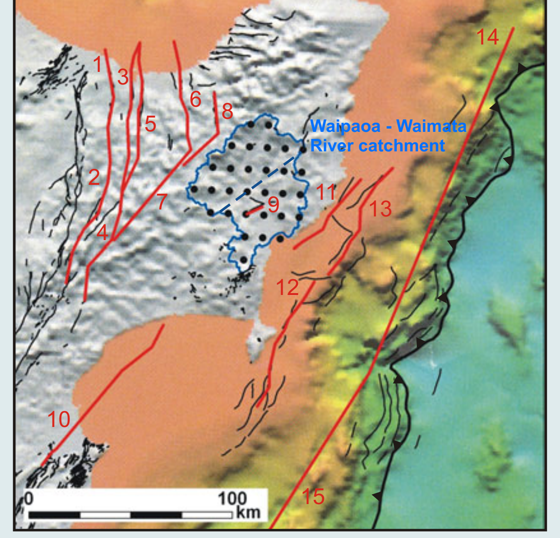


A) 10 yrs of shallow (≤40 km) earthquakes

B) 10 yrs of deep (≥40 km) earthquakes

C) Large shallow (≤40 km) earthquakes since 1840 AD

Fig. 4 Active fault earthquake sources. Litchfield et al. (2009).



Earthquake sources were compiled from instrumental seismicity (**Fig. 3A,B**) and active faults (**Fig. 4**). For the faults, moment magnitude (M_w) was calculated from fault length.

M_w was converted to strong ground shaking (Modified Mercalli Intensity, MMI, scale I-XII) (**Fig. 5**), using attenuation functions (Smith, 2002; Dowrick and Rhoades, 2005).

Return periods (**Table 1**) were calculated for grid cells (**Fig. 4**) using a Monte Carlo procedure.

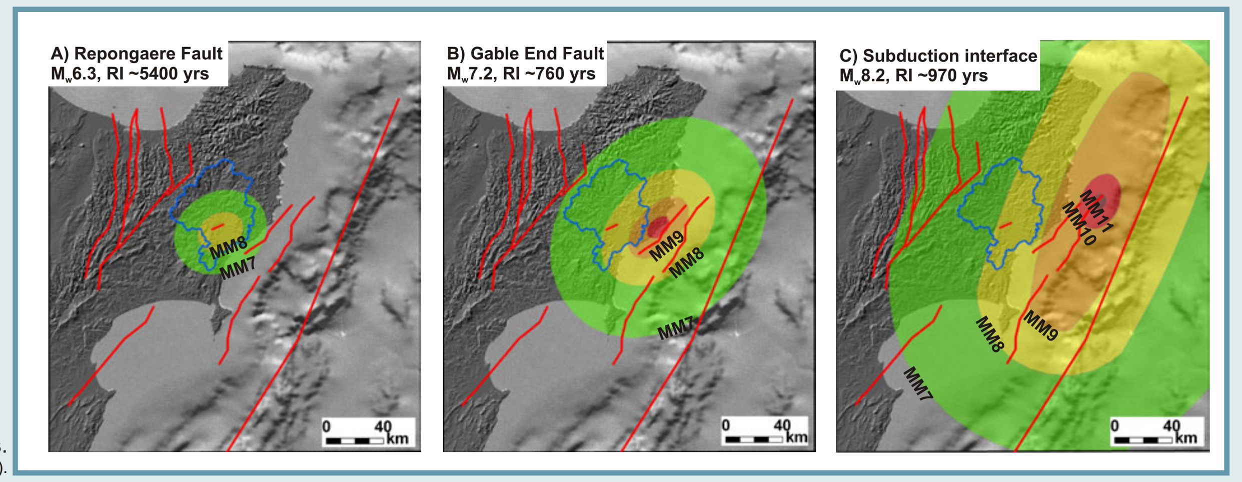


Fig. 5 Example mean calculated MMI maps from active fault sources. Litchfield et al. (2009).

How often does strong ground shaking occur?

Calculated mean return periods range from ~26 to ~10,000 yrs (**Table 1**), with ~620 yrs considered the most likely for triggering widespread landsliding.

Detailed examination of contributions show:

- MM7 is mainly from distributed small-moderate size earthquakes (**Fig. 3A,B**)
- MM8-9 is from the Gable End Fault and the subduction interface (11 and 14 in **Fig.**

Differences for each half (divided by the dashed line in **Fig. 4**) reflect the contribution of the North Is Dextral Fault Belt faults in the NW and offshore faults (11-15 in **Fig. 4**) in the SE.

These results can be combined with maps of landslide susceptibility to assess sediment delivery.

Area of impact (km^2)	MM7	MM8	MM9
90	26	96	420
750	130	**620**	10,000
90 (NW half)	34	150	790
90 (SE half)	37	150	630
750 (NW half)	260	2100	-
750 (SE half)	350	1600	-

Table 1 Mean calculated ground shaking return periods (years) over parts of the 2500 km^2 Waipaoa-Waimata catchment. Litchfield et al. (2009).

Is there a sediment transfer record?: Large landslides

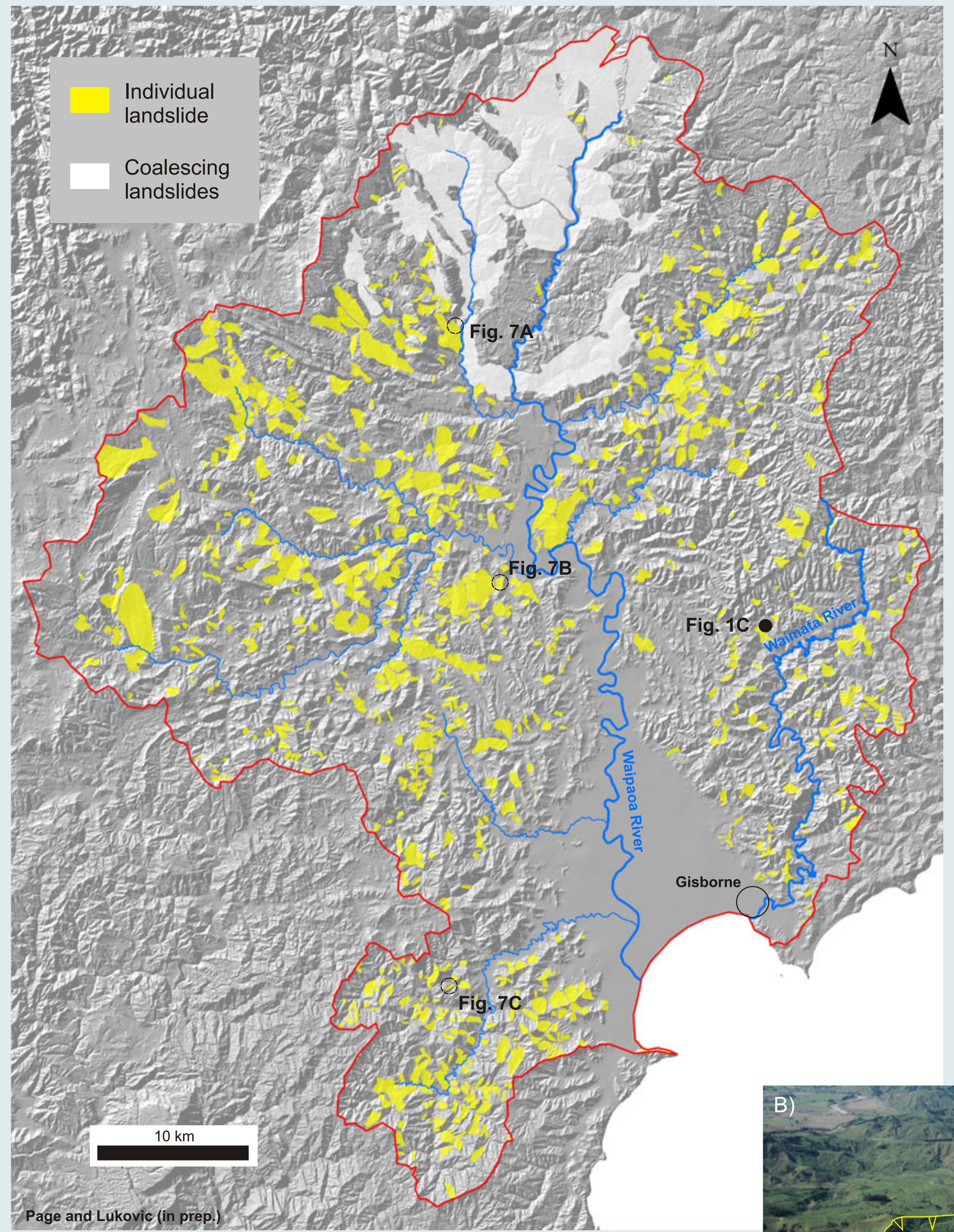


Fig. 6 Large landslides mapped from 1940's aerial photographs

Large (>2 ha, deep-seated, bedrock) landslides were a previously unknown component of the Waipaoa S2S system. Recent mapping (**Fig. 6**) and GIS analysis (Page and Lukovic, in prep.) show:

- 1026 landslides cover 21.4% of hilly terrain
- locations are controlled by: lithology, slope and stream incision
- 83% are connected to streams, but sediment accumulation (blockage) upstream is only evident for 3%
- assuming an average depth of 20 m and SDR of 0.25, large landslides may have contributed ~2.3 km^3 or ~10% of the post-18 ka sediment budget

The sediment budget calculations will be better constrained from results from detailed analyses by Richard Taylor (MSc thesis) and Eric Bilderback (PhD thesis, **Poster M-9**).

Although we don't know how many of the mapped landslides are earthquake-triggered, many can be morphologically distinguished from the largest landslides triggered by the 1988 Cyclone Bola (**Fig. 7C**).

Landslide initiation ages obtained so far are ≤60 ka, with several in the mid-late Holocene.

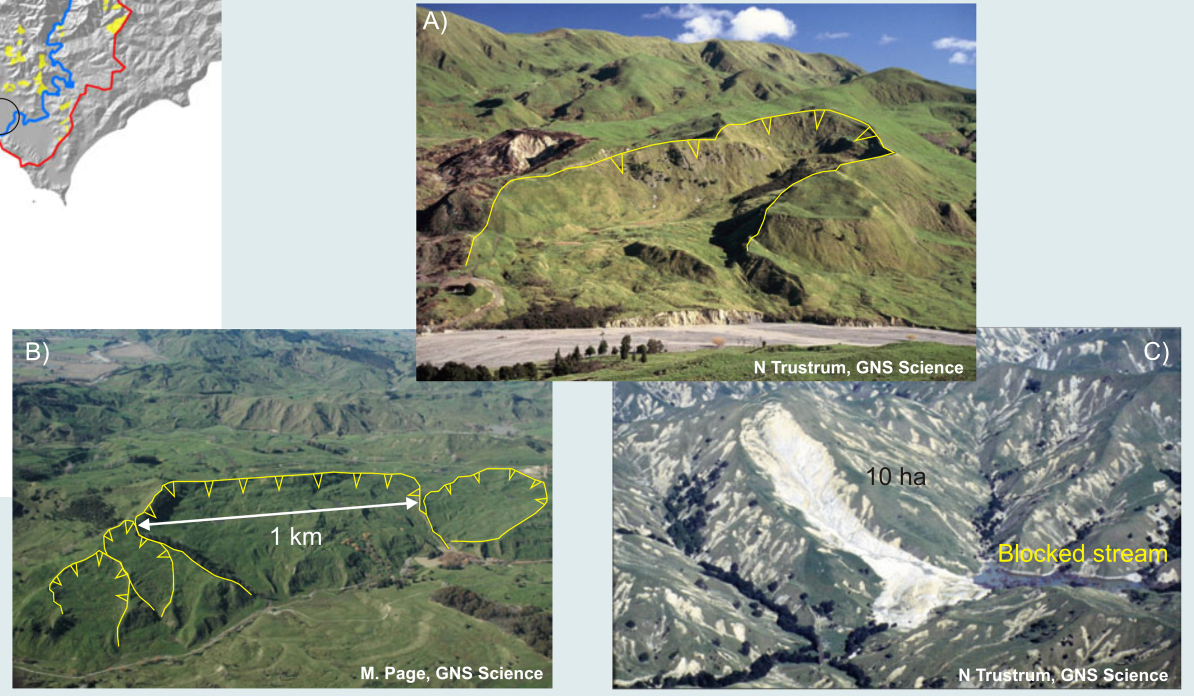


Fig. 7 Examples of large landslides in the Waipaoa River catchment. See Fig. 6 for locations

Tectonics and post-glacial marine inundation

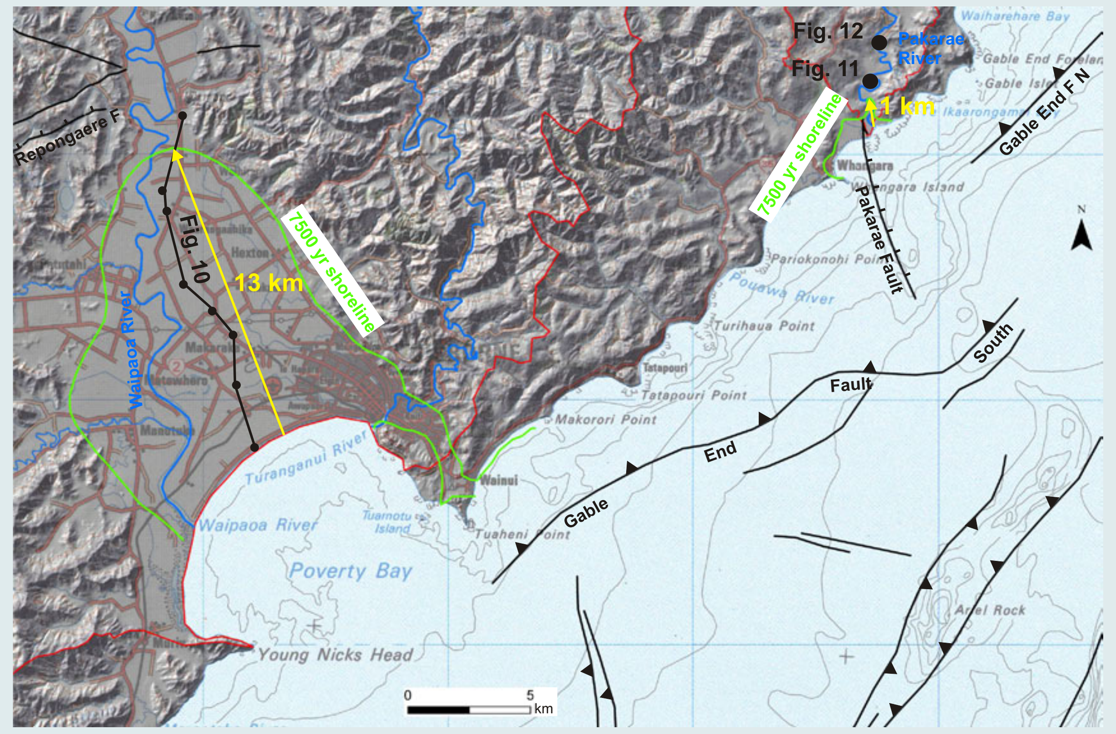


Fig. 9 Maximum post-glacial marine inundation as marked by the 7500 yr shoreline (Brown, 1995; Wilson et al., 2006, 2007; Litchfield et al., 2010). Offshore faults from Mountjoy and Barnes (submitted).

Rapid post-glacial SL rise stabilised in NZ at ~7500 cal. yr BP (Gibb, 1986; Clement et al., 2010) (**Fig. 8**). The interplay between SL rise and tectonics is illustrated by the differences in max. marine inundation distances into the mainly *subsiding* lower Waipaoa and *uplifting* lower Pakarae River valleys (**Fig. 9**).

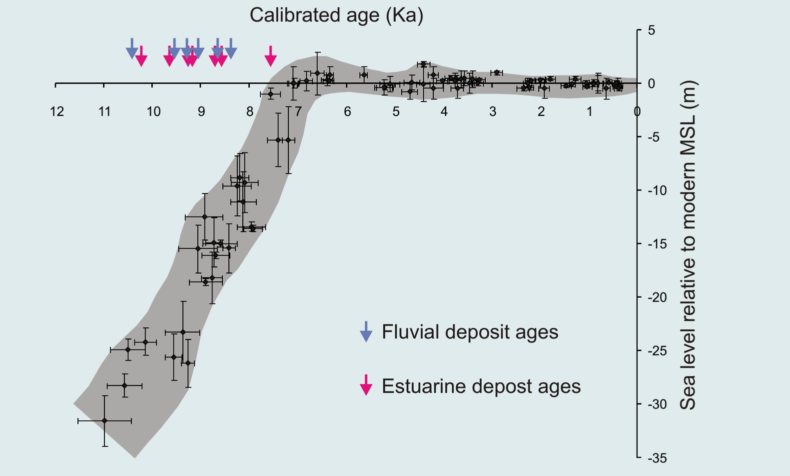


Fig. 8 NZ sea level curve (calibrated from Gibb, 1986) with radiocarbon ages from Pakarae River mouth (Wilson et al., 2007).

Impacts on rivers and sediment transfer

Marine incursion reduces river gradient, which enhances flooding upstream of the river mouth.

In the mainly subsiding, lower Waipaoa River (Poverty Bay Flats) this likely resulted in an increase in aggradation rate, beginning with deposition of the Makauri Gravel (**Fig. 10**). In the uplifting lower Pakarae River, this resulted in a temporary switch from incision to aggradation (**Fig. 11,12**).

As a result, the period ~10,000 - 7500 yr BP was likely a time of increased floodplain sediment trapping.

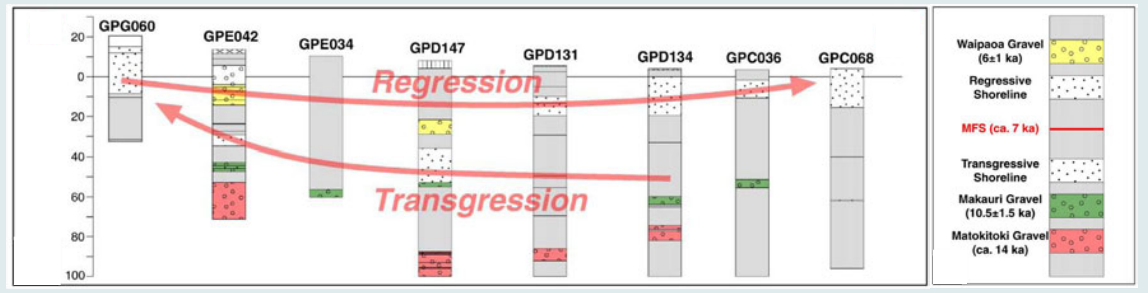


Fig. 10 Stratigraphy beneath the lower Waipaoa River floodplain (Poverty Bay Flats) as recorded by water bores. Located in **Fig. 9**. Adapted from Wolinsky et al. (2010).

Fig. 11 Lower Pakarae River fluvial terraces. Located in **Fig. 9**.

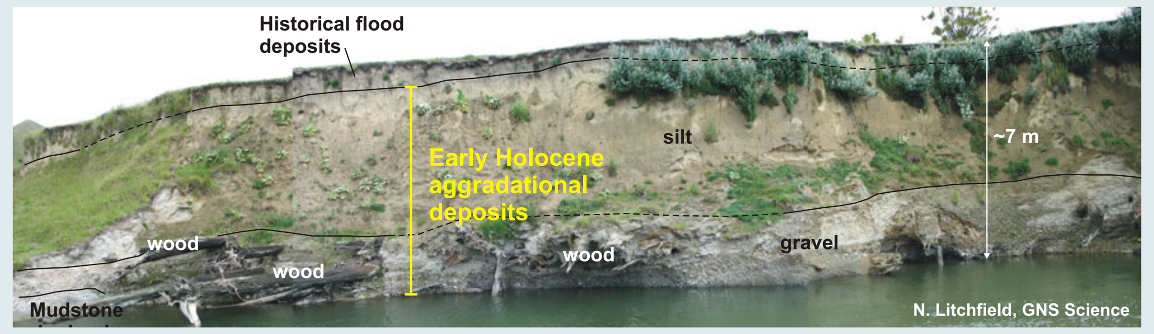


Fig. 12 Aggradation (fill) deposits in the lower Pakarae River. Located in **Fig. 9**. Litchfield et al. (2010).

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