

# Landslides Research at Omokoroa

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THE UNIVERSITY OF  
**WAIKATO**  
*Te Whare Wānanga o Waikato*



Image courtesy Peter Clark, Western Bay of Plenty District Council

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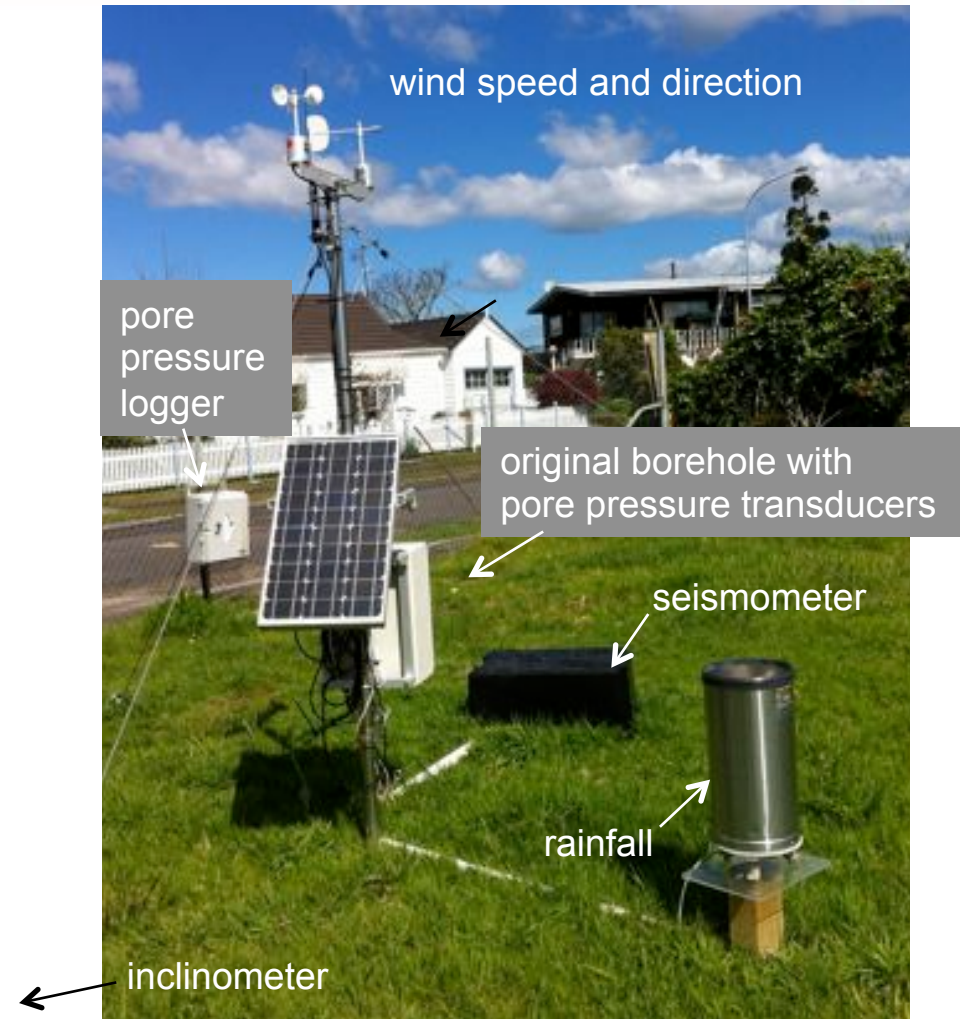
# Introduction

- Landslides well known at Omokoroa; cyclones in April highlighted the continuing susceptibility of the area.
- Two types:
  - translational
    - relatively small amount of material
    - only slice away a few metres from face
  - flow slides
    - long runout of soggy debris
    - deep excursion into face
    - associated with sensitive soils
- We are concentrating on the sensitive soil failures as these regress back into slope and cause the greatest damage.



# Bramley Drive

- We have been working on these issues for some years (earliest thesis in 2009).
- Mostly concentrated on Bramley Drive at the site of the 1979 failure.
- We have been monitoring this site since 2013 after the 2011 and 2012 reactivations.



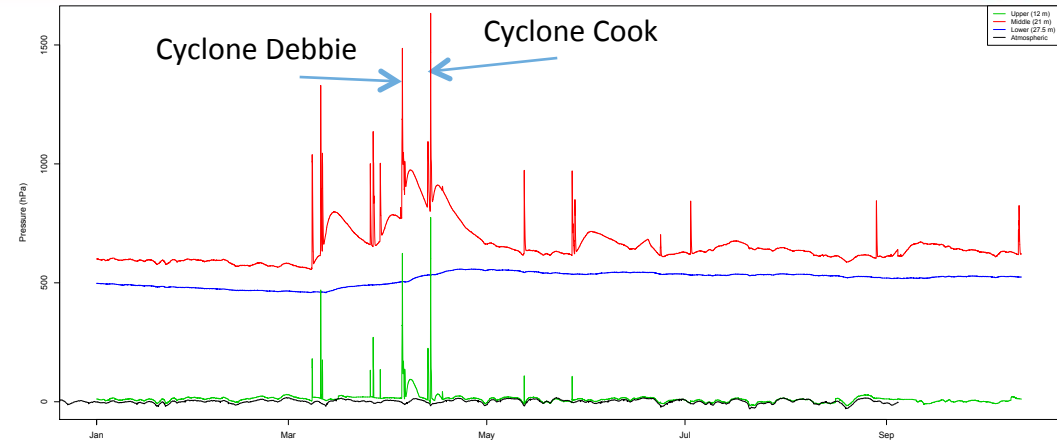
# Intrinsic & triggering factors

- For landslides we can identify two groups of factors that lead to failure:
  - “intrinsic” components of the slope that predispose slope to landslides:
    - soil
    - slope angle
  - “triggers” that actually set a landslide off:
    - rainfall and pore water pressure
    - earthquakes
    - other Earth movements
- We have been working on both aspects.
- Will present the triggers first, then come back to the soils.



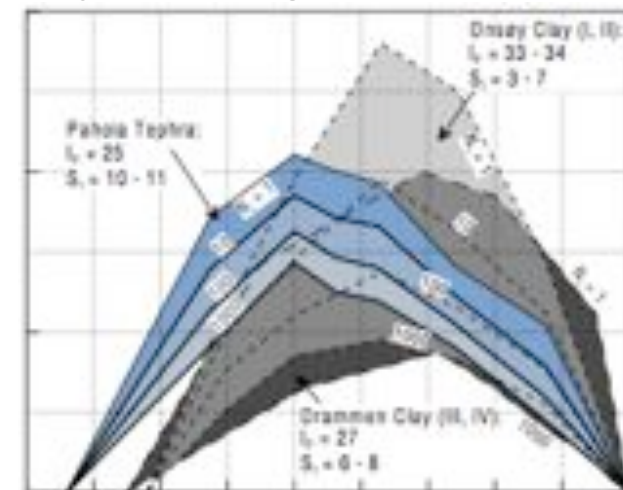
# Triggering processes

- We measured and modelled potential triggering processes at Bramley Drive, including:
  - microseisms
  - atmospheric tidal waves
  - ocean tidal loading
  - thermal expansion & contraction
  - groundwater loading
  - Earth tides
  - pore water pressure
- Heavy rainfall events cause pressure spikes superimposed on slower rises and falls. Slope failures follow some, but not all, pressure spikes.
  - Drainage and managing storm water is clearly a key factor in managing slope stability
- Cyclic loading increases likelihood of failure of Pahoia Tephra but not as much as for northern hemisphere sensitive soils.



**Bramley Drive pore water pressure 2017**

## Cyclic loading failure contours

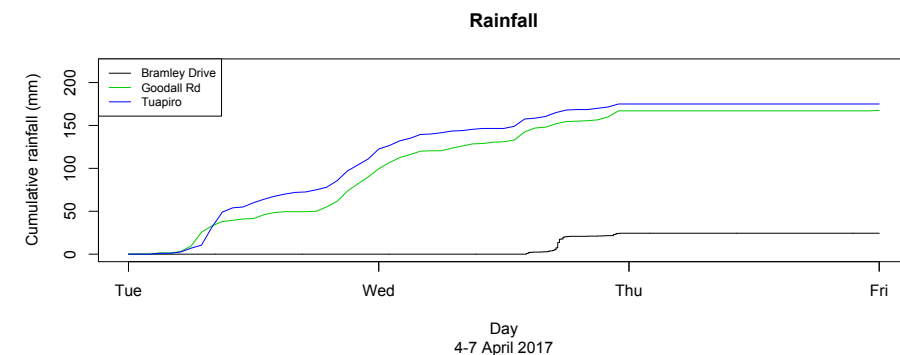
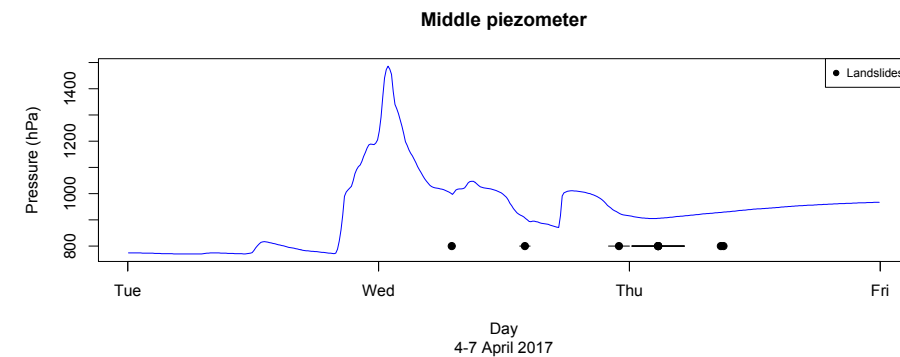
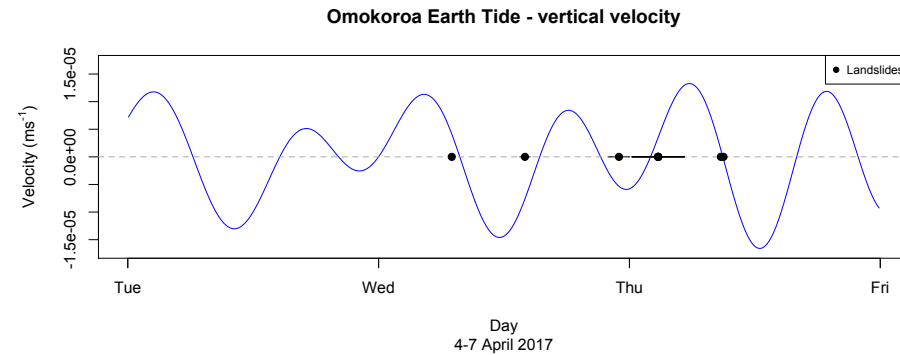


# Earth tide effects

- Timing of failure in April 2007 was mostly controlled by vertical motion due to the Earth tide ( $\pm 15$  cm at the time):
  - landslides occurred when Earth tide vertical velocity was close to zero (maximum displacement), and not when pore water pressures peaked
  - increased pore water pressure is a necessary condition for failure, but was not the final trigger

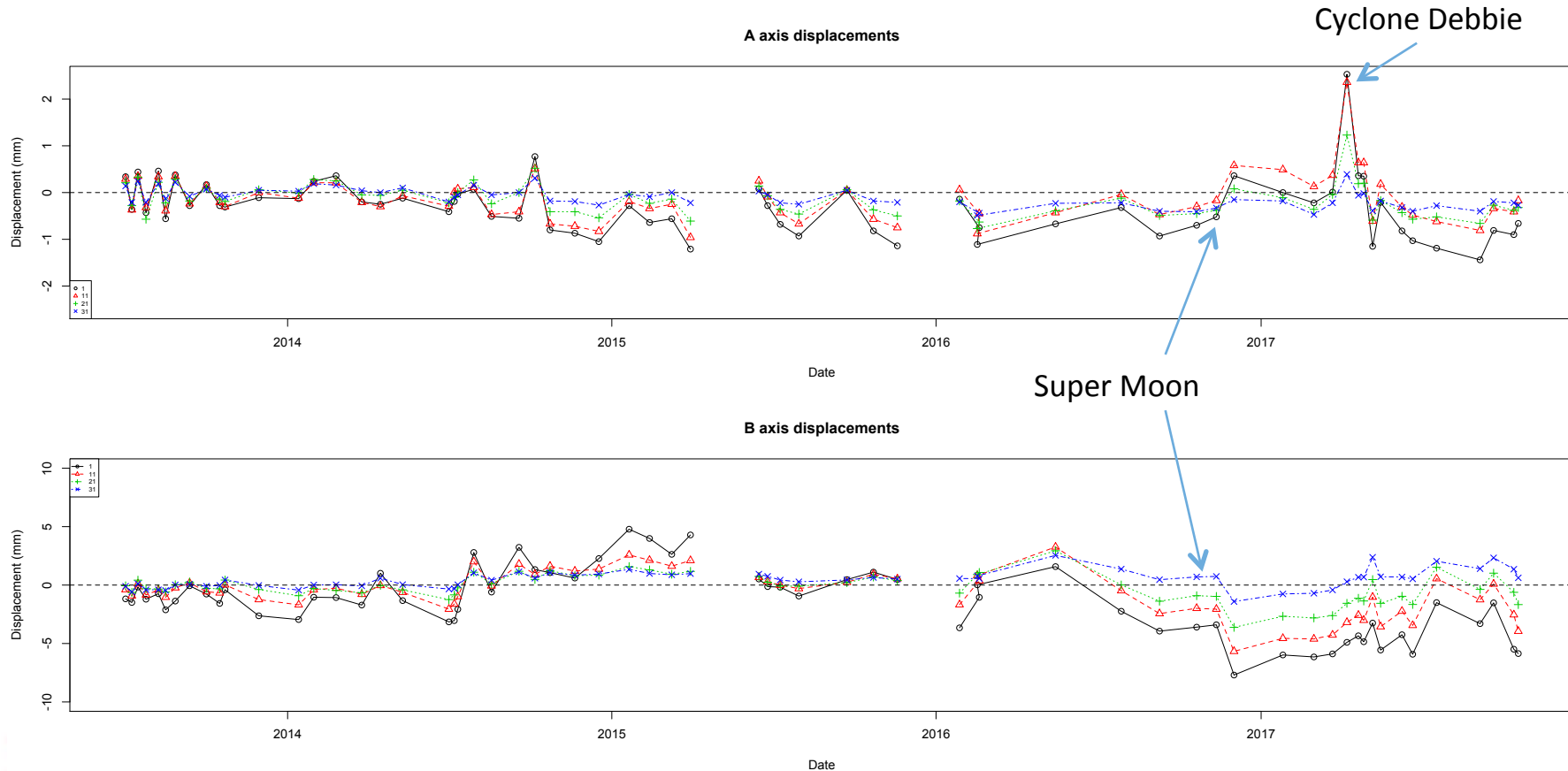
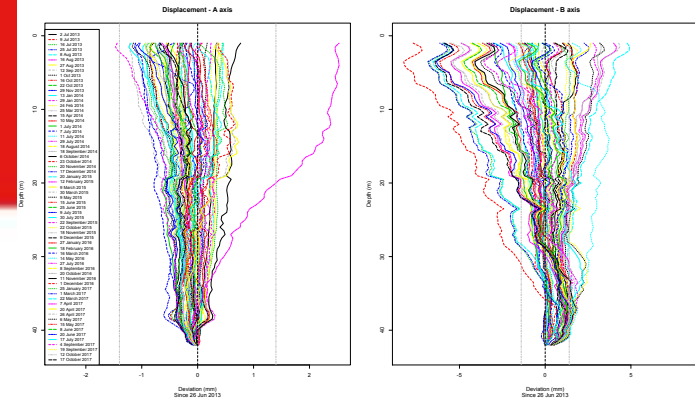
Data plotted are for the period during and immediately after Cyclone Debbie. The Bramley Drive rain gauge malfunctioned during the Cyclone and didn't start recording reliably until the afternoon of Wednesday 5th April.

Landslide event times are based on eyewitness accounts



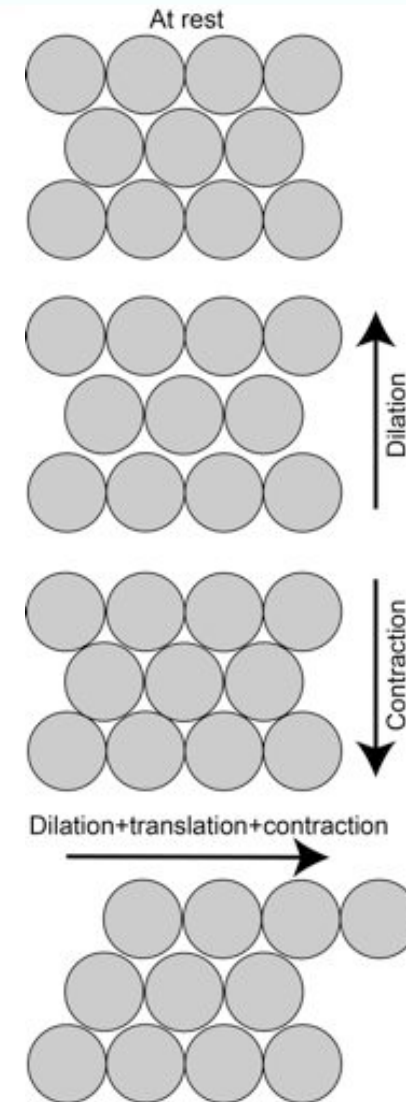
# Inclinometer data

- The response to the Earth tides at Bramley Drive is changing
  - 42 m section of vertical borehole changes shape daily
  - magnitude of the daily changes is increasing
  - mostly the borehole returns to an average shape, including after Cyclone Debbie – elastic deformation
  - periodically the average shape shifts abruptly, such as during the Super Moon event in November 2014



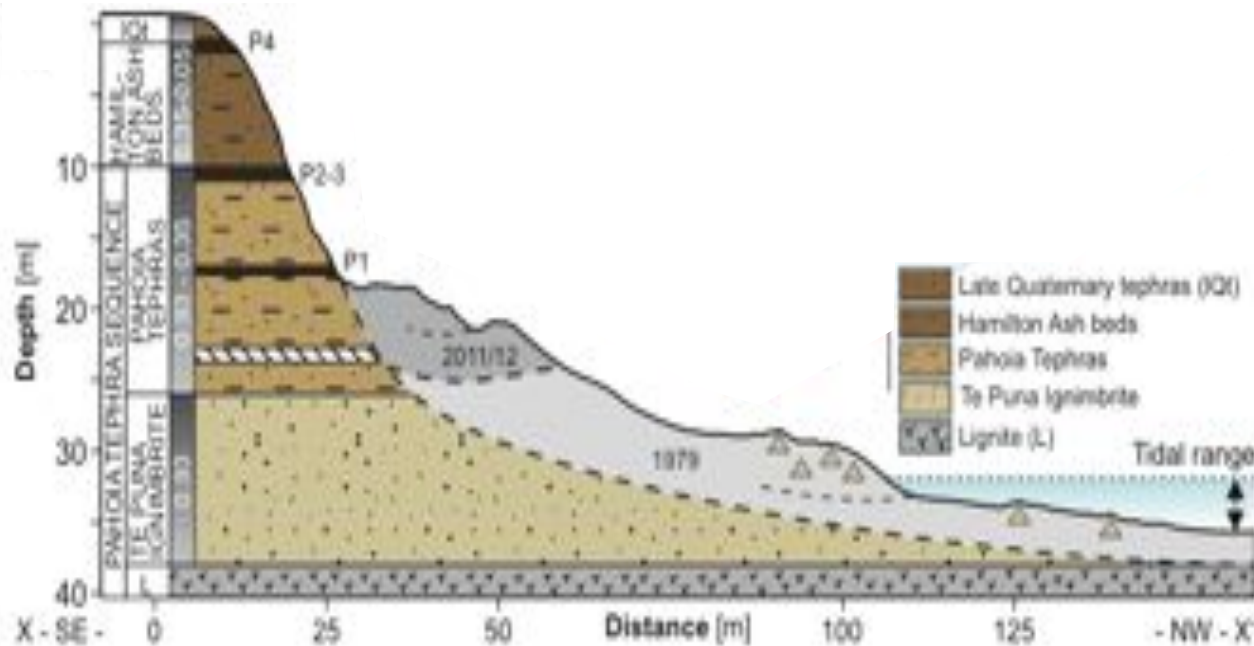
# Soil movement

- For granular materials the Earth tide is causing stress dilatancy that changes pore volumes, and hence pressures:
  - can initiate fracturing and slope failure;
  - depends on pore water pressure when “at rest”;
  - failure at Omokoroa appears to occur when conditions change from dilation to contraction and vice versa;
  - it is not clear what happens when clays are present, or are the predominant material.



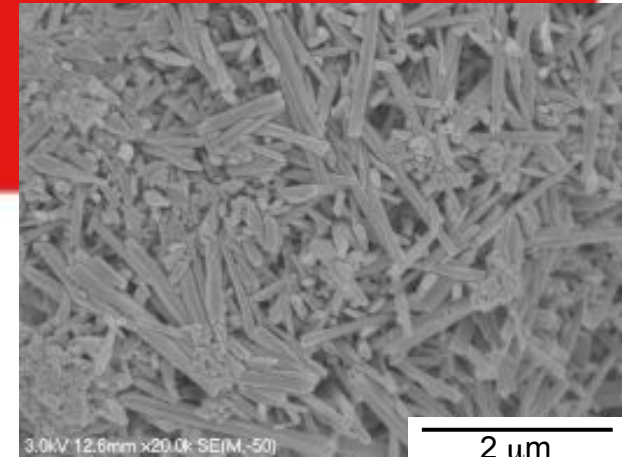
# Intrinsic factors - soils

- Much of our effort has been related to looking (very) closely at the sensitive soils at the base of the landslide:
  - tephra (ashes) about 1 million years old, overlie ignimbrite (soft rock) and below younger tephra.
- We have looked at clay mineralogy, microstructure, failure patterns, strength ... This detailed work that may seem esoteric, but is critical to understanding the system.

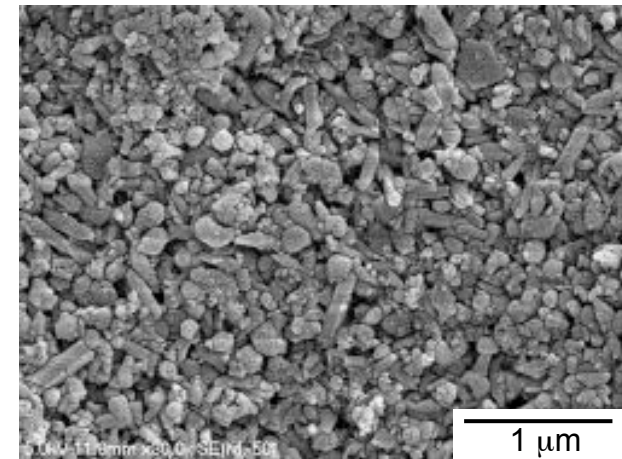


# Halloysite

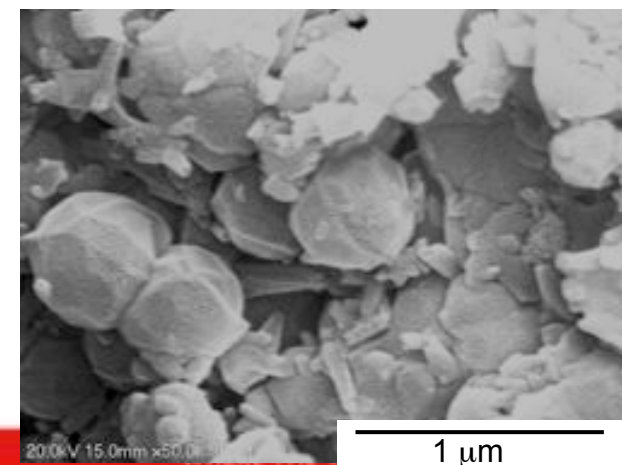
- First finding (reinforces work from 1981) is that the key clay mineral in the soils is halloysite.
- Halloysite forms from silicic volcanic ashes in a poorly drained environment – Tauranga is perfect.
- Halloysite minerals come in many shapes:
  - long and short tubes
  - spheres
  - plates
  - books – brand new
  - mushroom caps – brand new
- Interactions of charges between clay minerals and ions in the pore water controls “sticking together” of different mineral grains.
- Different forms allow for different levels and types of interactions.



long tubes



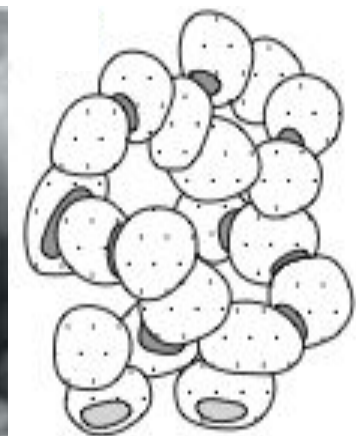
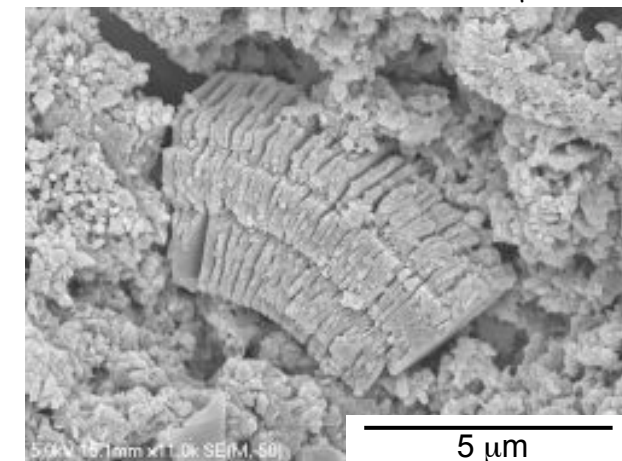
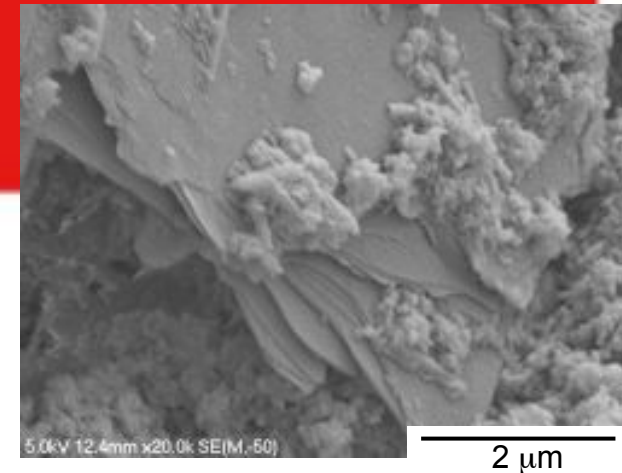
stubby tubes



small spheres

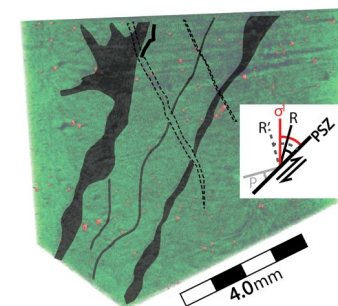
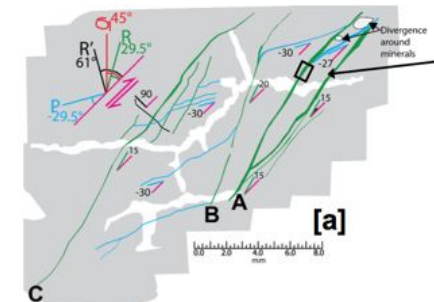
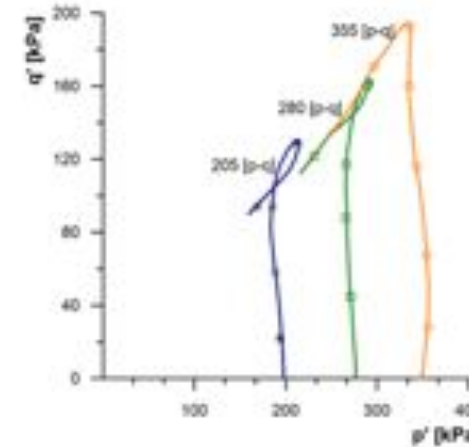
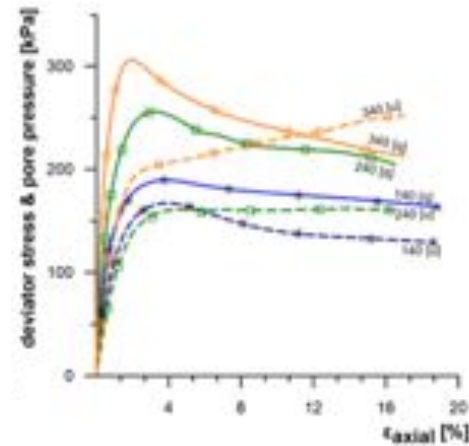
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# Strength and fracture

- In laboratory testing we find:
  - brittle failure at  $\sim 3\%$  strain;
  - reasonable peak strength (high friction);
  - sharply rising pore water pressures that rise that remain high post-failure;
  - contractive failure with considerable strain softening;
  - well developed, complex shear surfaces with densified clay mineral matrix and particle realignment;
  - progressive failure (earth tides).



# Norwegian soils

- Sensitive soils in the Northern Hemisphere are composed of different clay types, but have many similarities in behaviour.
- It is known that salt from seawater (NaCl) is important for these soils.
- Recent results of long-term trials (since 1970s) of adding salts to these soils are suggesting considerable improvement in stability.



**Geological Survey of Norway**

<https://www.ngu.no/sites/default/files/styles/fagomradebanner/public/NGUW10576.jpg?itok=FQN0bW33>

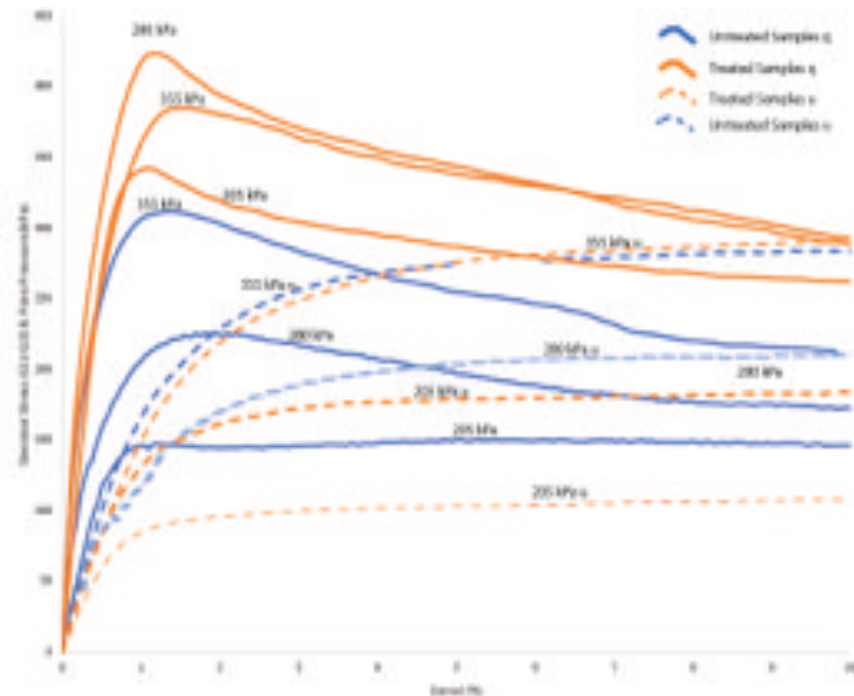
# Remediation

- We have been investigating this possibility for our soils.
- So far:
  - most salts don't work because of the nature of halloysite;
  - indeed adding most salts decreases strength (found out the hard way);
  - but knowing it is halloysite, and knowing the likely nature of the interactions across the mushroom-caps, allows some targeted work.



# Remediation

- Tom has identified  $K_2CO_3$  (potassium carbonate) as a salt likely to improve characteristics of halloysite-rich soils.
- Need to:
  - raise pH (carbonate);
  - use potassium as right sized ion to fit into clay structure
- Initial tests show huge promise with a big uptake of  $K_2CO_3$  by the soil and a near-doubling of peak strength.
- But impacted by not being able to sample since April.



# Next steps

- Tom hopes to carry on to PhD in this topic. We need to:
  - complete a much more rigorous laboratory programme to confirm earlier results over a wider range of stresses;
  - establish minimum concentrations of  $K_2CO_3$  to achieve outcomes;
  - scale up to a small field trial – install soil mixed columns and monitor to see how quickly and over what distance these concentrations can be achieved;
  - consider the environmental and financial implications of using this stuff in the real world.



# Acknowledgements

- Deutsche Forschungsgemeinschaft (DFG) via the Integrated Coastal Zone and Shelf Sea Research Training Group INTERCOAST and the MARUM Center for Marine Environmental Science at the University of Bremen.



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