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Field Trip 2

Hamilton Basin Faults

28th November 2019

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HAMILTON BASIN FAULTS

Itinerary and route

8.30 am – Depart university

8.35–9.00 am – **STOP 1**: Edinburgh Road

9.20–9.45 am – **STOP 2**: Rototuna

9.55–10.45 am – **STOP 3:** Day's Park (includes toilet stop, Swarbrick Landing)

11.00–11.30 am – **STOP 4:** Osborne Road

11.45 am–12.30 pm – **STOP 5:** Kay Road

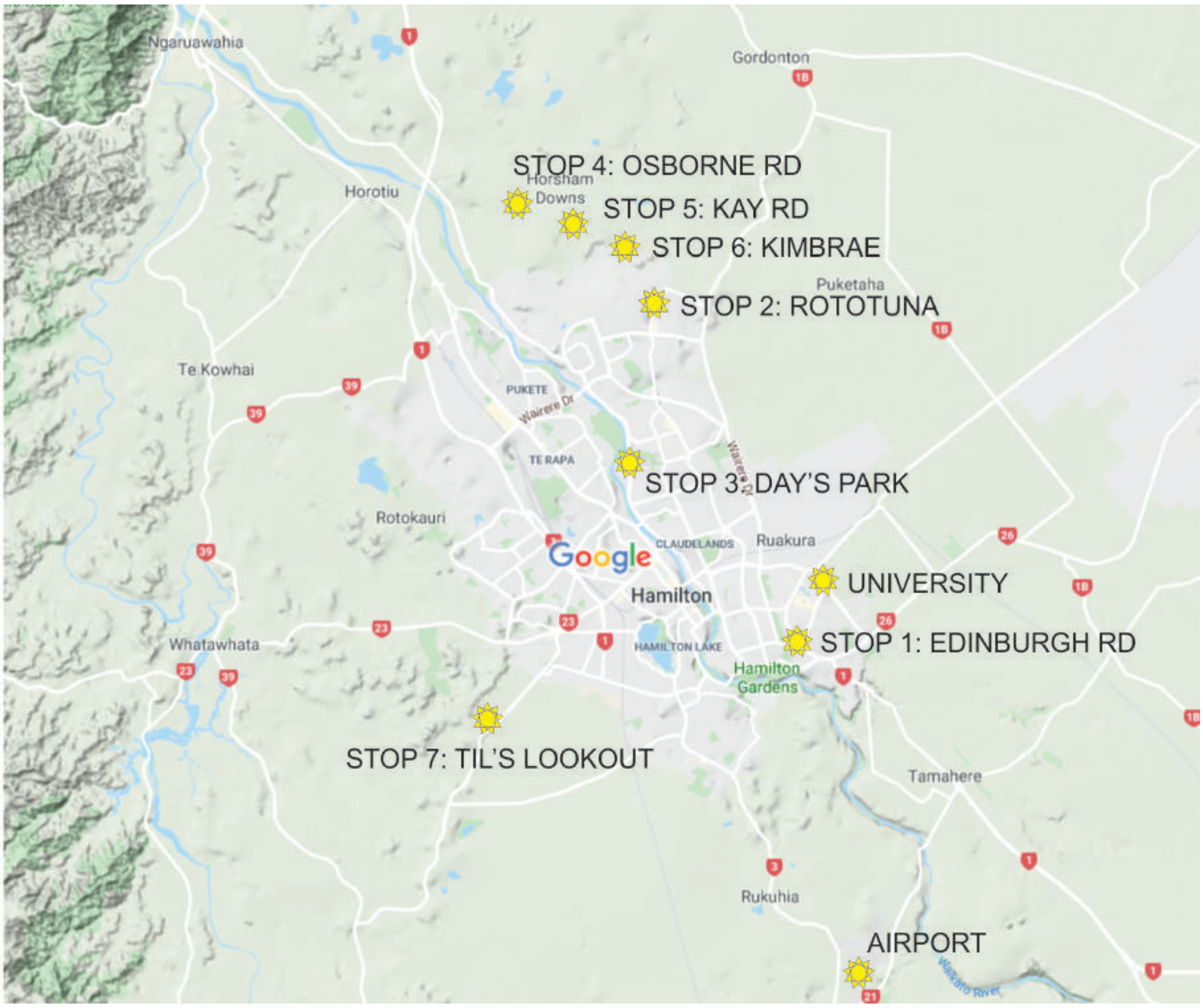
12.45–1.15 pm – **LUNCH:** Rototuna shops/Grosvenor Park (toilets available)

1.30–2.00 pm – **STOP 6:** Kimbrae

2.30–3.00 pm – **STOP 7**: Til's Lookout

3.30 – Hamilton Airport

4.00 pm – Return to university



Introduction

Prior to 2015, our conventional wisdom said that there were no exposed faults within the Hamilton Basin, the assumption being that any faults were covered by the extensive Pleistocene–Holocene sedimentary basin infill materials. A local consultant phoned in April 2015 and said “I think we’ve found a fault”. We visited and logged the site and tried every explanation for it to not be a fault (this was changing our paradigm for the relatively recent development of the basin) but, by elimination, we eventually decided that faulting was the best explanation.

Having identified a fault exposure, we “looked up” (examined the LiDAR), and could see a distinct ridge running southwest-northeast through central/north Hamilton City that was so blindingly obvious it was hard to credit that we had not seen it before. This feature, when linked with (1) a known geothermal system, and (2) a dog-leg offset in the Waikato River, made us pretty confident that we were looking at a fault trace. Since then we have mapped the river floor and walls using shallow seismics and geological mapping, pored over the LiDAR to look for geomorphic signals of faulting, reinterpreted oil prospecting seismic data from the 1970s, undertaken a few electrical resistivity soundings, and, most importantly, mapped and analysed several stunning cuttings prepared as part of the Hamilton Bypass section of the Waikato Expressway development. We are now confident that a complex network of faults occurs throughout the basin.

During this trip we will visit some of our key sites and outline where we are at in terms of understanding the nature and pattern of faulting in the basin, and where we are not confident in terms of the timing of the movements. We will also highlight some of the difficulties of working in an area smothered in young sediments and tephra deposits, both from the point of view of exposure, and the effects of the deposits on fault development and expression, together with the difficulties of working in an urban environment. Unfortunately, relying on development sites means that cuttings are open for short periods then quickly topsoiled and planted. We will therefore end up visiting a number of grassy slopes.

STOP 1: EDINBURGH RD

This is a current development site just down the road from the university. We are pretty certain that there is a fault in the site, but are still in the process of collecting as much data as we can. Interpretation will come later.

At time of writing (31 October 2019), the slope was still open with the sequence well exposed. However, topsoiling has now been completed. The sequence consists of disturbed soils at the top, overlying Hamilton Ash beds that have a distinctive grey/white layer (bed H1) at their base. This layer is the Rangitawa Tephra, aged ~ 340,000 years (Pillans et al. 1996; Lowe et al. 2001) and is a key marker bed for our work. The Hamilton Ash beds comprise weathered, clayey tephra deposits >c. 50,000 years old (on the basis of overlying c. 50-ka Rotoehu Ash) and ≤c. 340,000 years (e.g. Lowe 2019 and references therein).

Below the Rangitawa Tephra is the Walton Subgroup (Kear and Schofield 1978) that consists of:

1. a sequence of older and weathered, clay-rich tephras, the Kauroa Ash beds, which have a very strongly developed paleosol on top aged >c. 0.78 Ma on the basis of its reversed magnetic polarity (Horrocks 2000; Lowe et al. 2001); elsewhere in western Waikato the the Kauroa Ash beds date back to 2.3 Ma (Briggs et al. 1989);
2. sequence of volcanogenic alluvial sediments, often stained red or pink, sometimes pumiceous, and often containing layers of very slippery white/cream clays;
3. ignimbrite – various ignimbrites are identified within the basin including Ongatiti (c. 1.23 Ma), Kidnappers (c. 1.01 Ma), and Rocky Hill (c. 1.0 Ma) ignimbrites; the distribution of ignimbrites in the basin is complex, and there are clearly locally reworked pyroclastic materials interbedded with them and other deposits.

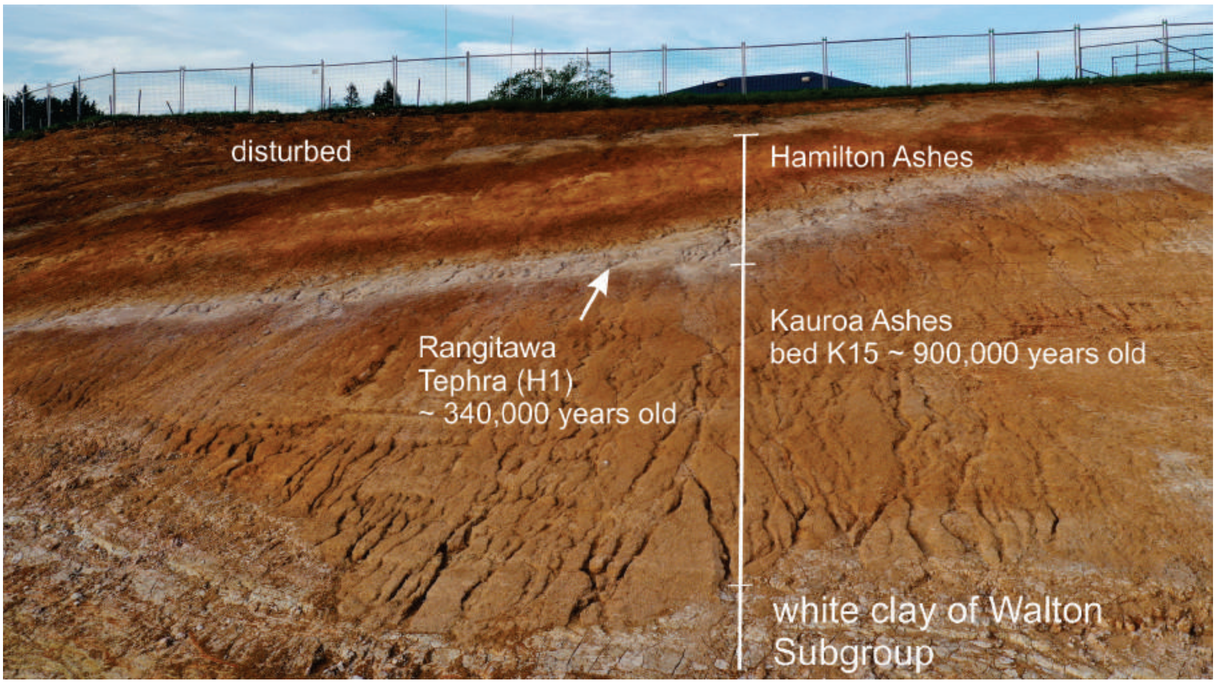


Figure 1: Drone image of the slope behind Edinburgh Road. The base of the Hamilton Ash sequence is marked by a very distinctive pale grey layer, the Rangitawa Tephra (c. 0.34 Ma). This is an important chronostratigraphic marker bed for our work.

STOP 2: ROTOTUNA

This is where we began following a phone call in 2015: an unassuming small cutting in a new subdivision.

The zone is approximately 4 m wide, comprises four main strands of a fault trace, with several smaller strands linking between them, and has a measurable vertical offset across the zone of approximately 0.5 m. Unfortunately, the top layers of the sequence were removed before the vertical exposure was cut and hence limited stratigraphic information is available to date the movement of this fault. The white layers at the top of the cutting, which are clearly displaced by the fault movement, are tentatively identified as beds K12/K13 of the Kauroa Ash sequence (correlated with Ongatiti Ignimbrite: Horrocks 2000; Lowe et al. 2001) and aged c. 1.23 Ma. Soil infilling down the fault traces is identified as part of the upper (younger) Hamilton Ash sequence because of the soil's dark reddish brown colouration; the lower, older Hamilton Ash beds are pale (yellowish-brown) coloured (Lowe 2019). This relationship suggests that the fault movement is <250,000 years, but is not definitive.

From the exposure, a component of normal (extensional) movement can be identified based on the vertical offset. The four apparent main strands have an average dip direction of 089° (strike 359°), while the two measurable minor strands have a dip direction of 351° (strike 081°). All measured strands have steep dips ranging from 51° to 84°. Stereonet analysis indicates dominantly strike-slip movement. Note that splintering, splitting, and spreading are expected as faults develop through weak cover deposits (and we have virtually nothing "strong" exposed in the basin).

This site does not lie immediately along the line of the ridge of the main fault system, but suggests some form of splinter from the main lineament.

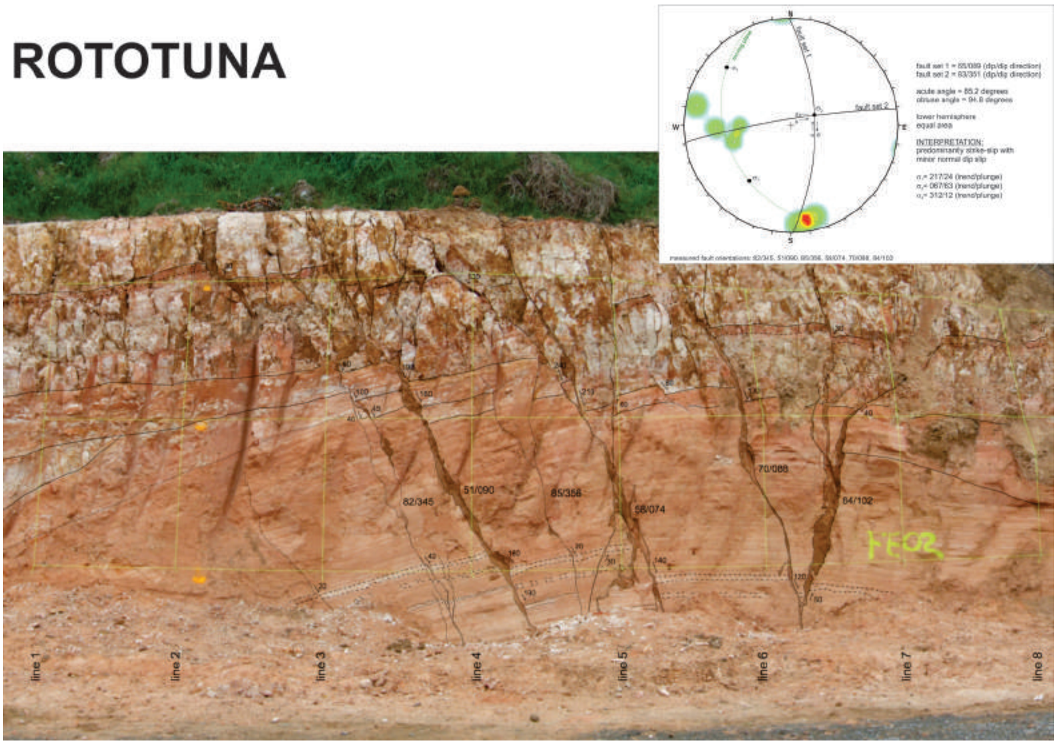


Figure 2: Image and stereonet analysis of initial fault zone identified at Rototuna.

STOP 3: DAY'S PARK

Geomorphic evidence has been critical in extending the known fault positions to lineations that may reflect the main fault traces. The Waikato River and its tributaries in particular provide pathways through many of the young sediments that display a number of interesting geomorphic features such as knickpoints, offsets, and gully beheadment. Unfortunately, none of these lines of evidence give unequivocal support for faulting, as geomorphic features can usually have multiple potential explanations. Putting together as many lines of geomorphic evidence as possible, however, suggests that the river has been affected by fault movement since (or during) entrenchment over the last c. 18,000 calendar (cal.) years.

(A) (B)

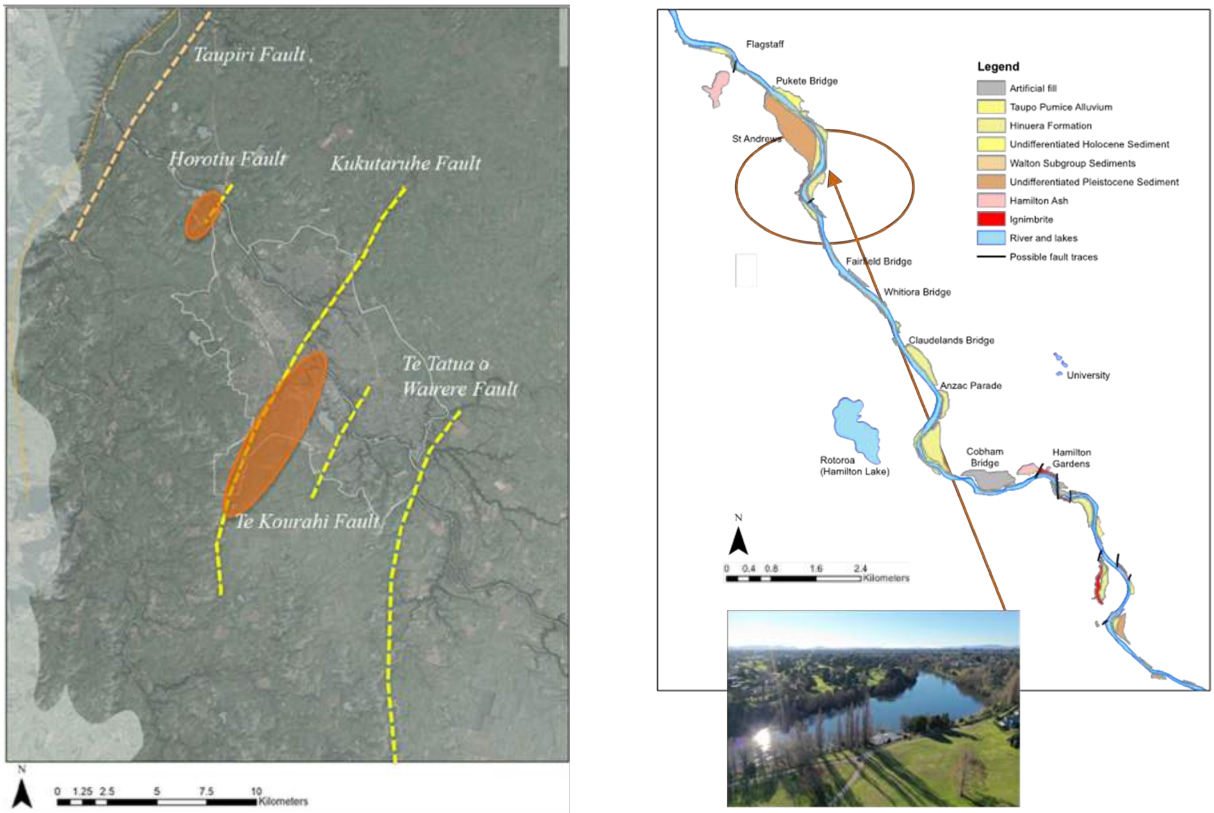


Figure 3: (A) Kukutaruhe Fault zone identified based on LiDAR information. (B) A "dog-leg" in the Waikato River at Day's Park provides geomorphic and geological evidence of this fault trace.

Day's Park provided an "ah-ha" moment at the start when we examined the LiDAR initially. This area is located on a sharp "dog-leg" in the river. The river at this point is quite deeply entrenched into the Hinuera Surface. Day's Park itself lies on volcanogenic sediments of the Hinuera Formation (Hume et al. 1975) aged c. 22,000 to 18,000 cal. years BP (Hogg et al. 1987; Manville and Wilson 2004), which were formerly mined as a gravel source for construction in Hamilton; the immediate geomorphology in the park area is thus highly modified.
On the eastern side of the river (true right bank) immediately south of Day's Park are fluvial

sediments, whilst on the western side (true left bank) is a steep bank of ignimbrite. The river takes two sharp turns at this point – to the east just south of the park, and back towards the west at the northern end. Our interpretation of this dog-leg is not strike-slip offset since the entrenchment of the river (that would be scary), but that the harder ignimbrite has been uplifted along the fault strike in the past, and the river has encountered this as it entrenched into the surface. It has been forced to migrate around the upstanding block of more resistant material.

Supporting data

At this point we (1) searched existing geophysical data, and (2) undertook CHIRP shallow seismic survey along the river, together with mapping riverbank geology.

From Cambridge to Taupiri, we identified 26 "targets" in our seismic traces that represented some discontinuity in the riverbed sediments that may represent faults. Fortunately, we had pre-existing multibeam and side scan sonar images of the riverbed to help interpret these traces.

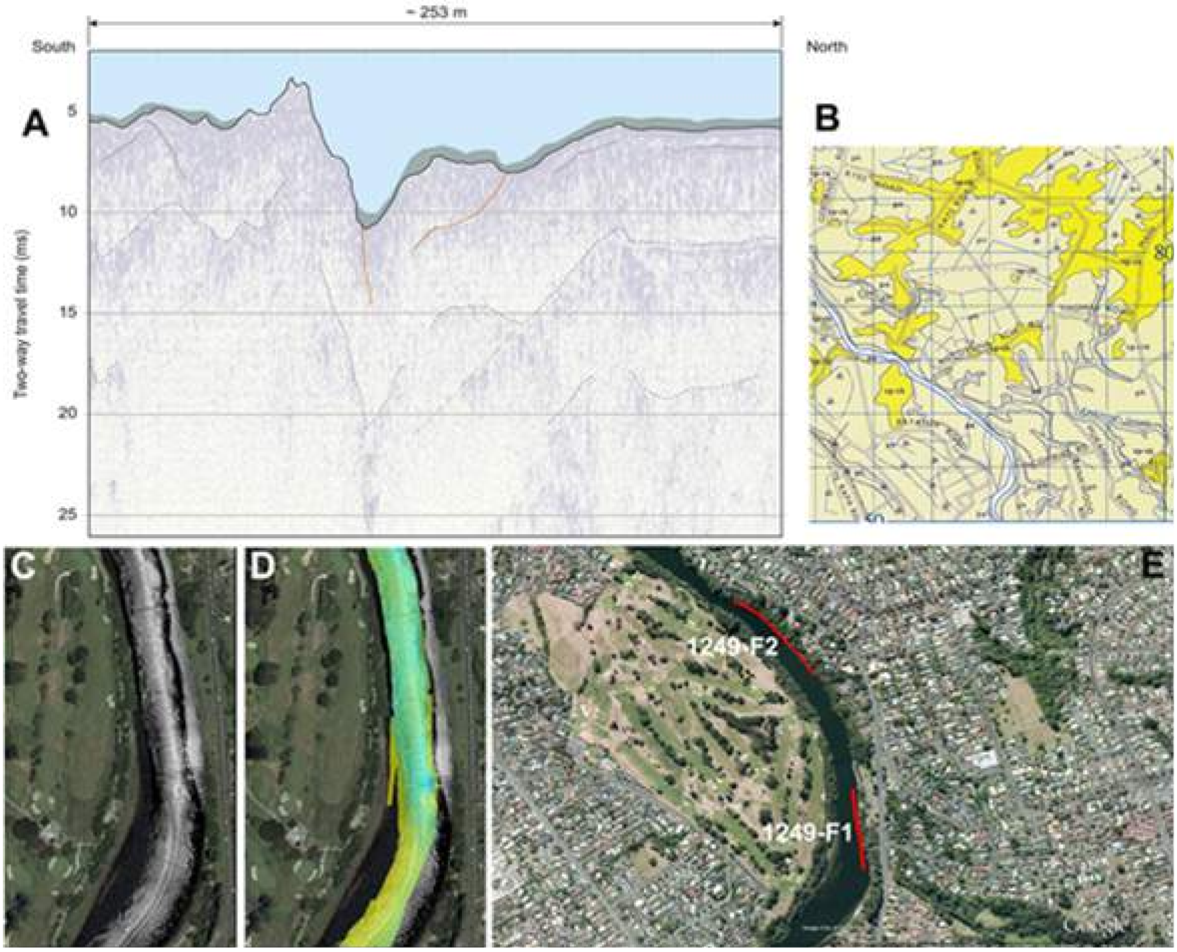


Figure 4: Kukutaruhe fault zone. (A) Seismic section showing multiple discontinuities below the riverbed near Swarbrick Landing in section 1249-F1 – the low-angle trace may reflect the fact that the river is running parallel to the fault for part of this section, (B) N56 surficial geology, (C) sidescan image, (D) multibeam image, and (E) Google Earth locations.

A series of deep seismic surveys was undertaken in the northern part of the basin in the 1970s as part of oil exploration; these surveys were accompanied by two deep boreholes. Unfortunately, only scanned copies of unprocessed traces exist, and so the interpretation of the old seismic data is sketchy at the best, but from looking at the two long traces running roughly north-south we can recognise features underlying all of the hills.

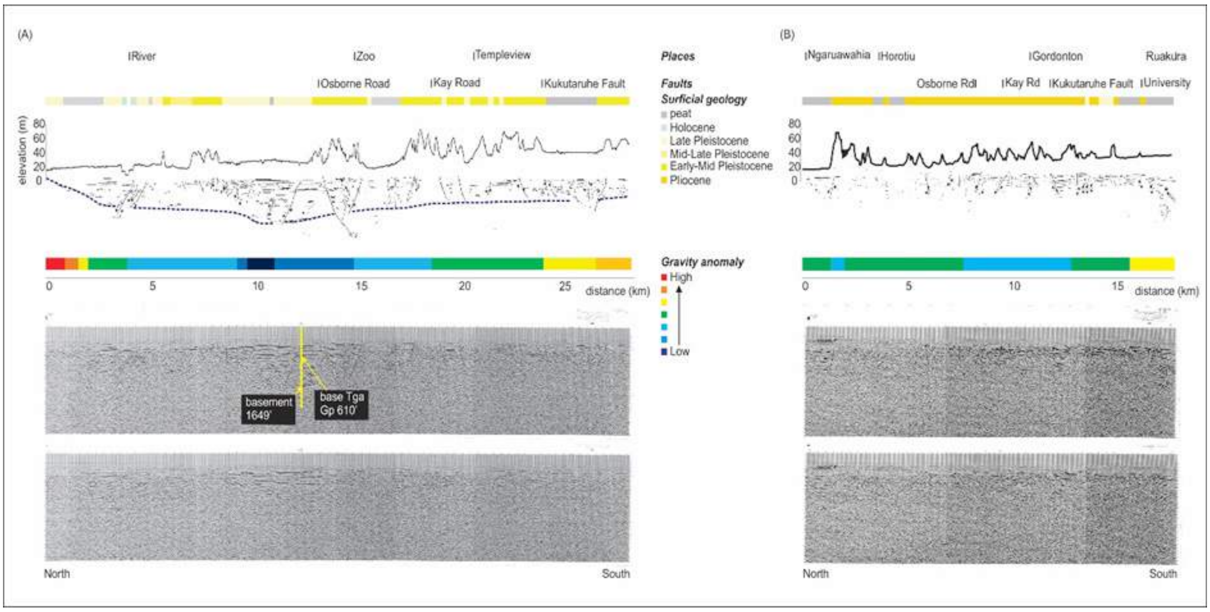


Figure 5: Interpretation seismic reflection lines from PR569 (Liles 1971). (A) Line PR569-2 running along the western margin of Hamilton City (B) Line PR569-16 running to the east of Hamilton City. Original and interpreted images are shown at the base of the diagrams, with key stratigraphic horizons identified from borehole Te Rapa-1 (Liles 1971) marked on (A). Indicative gravity anomaly strips are shown with colours derived from FrOGTech (2011). Interpreted sections, including depth to basement for (A) marked with a dashed blue line are overlain with geomorphology (vertical exaggeration ~ 30x), and surficial geology is marked with a coloured strip. Fault traces identified on land are indicated, and several geographic locations are projected onto the line and marked for reference.

Airborne gravity data (FrOGtech 2011) shows that the depth to basement is deep in the northern portion, shallowing to the south. This gradient in depth is supported by seismic tests recently undertaken by our engineering colleagues. From the LiDAR, distinctive features at the southwest end of the Kukutaruhe Fault zone appear to be volcanic structures (maars). These were originally mapped by Kear and Schofield (1966), but removed from more recent geological maps (Edbrooke 2005). Aeromagnetics suggest that there is magnetic material below them, but our drilling so far has not confirmed a volcanic origin.

(A) (B)

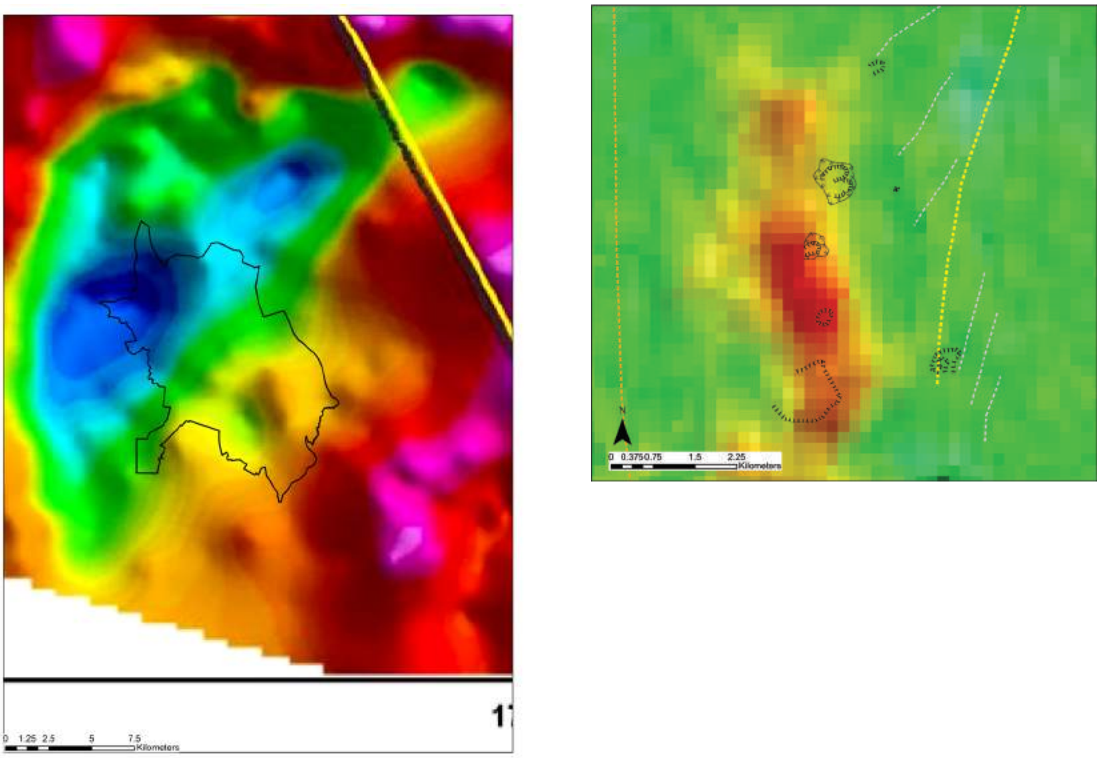


Figure 6: (A) Gravity anomaly for the Hamilton Basin (Hamilton City boundary shown in outline). (B) Georectified aeromagnetics map at Koromatua with the geomorphological map interpretation superimposed.

STOP 4: OSBORNE RD

The cutting at Osborne Road showed two sub-parallel faults that run at very shallow angles to the cutting face. Displaced materials suggest normal displacement; no evidence exists to determine any strike-slip movement.

Between the two faults is a stretch of highly deformed materials (including vertical tilting of large blocks) overlying a distinctive zone of bedded alluvial sediments (red/pink discolouration makes these clay-rich beds stand out very clearly and identify them as Walton Subgroup sediments). Orientation measurements on the bedding surface at the top of the alluvial sediments suggests gentle folding. Our interpretation is of a relay between two developing, almost parallel, faults, with folding and ductile deformation in this transfer zone.

The upper tephra layers are partially removed by the earthworks so it is not immediately clear whether the tephras are displaced by movement along the faults, or whether they are simply mantling a paleotopography. We think they are displaced, but we cannot put an age on them.

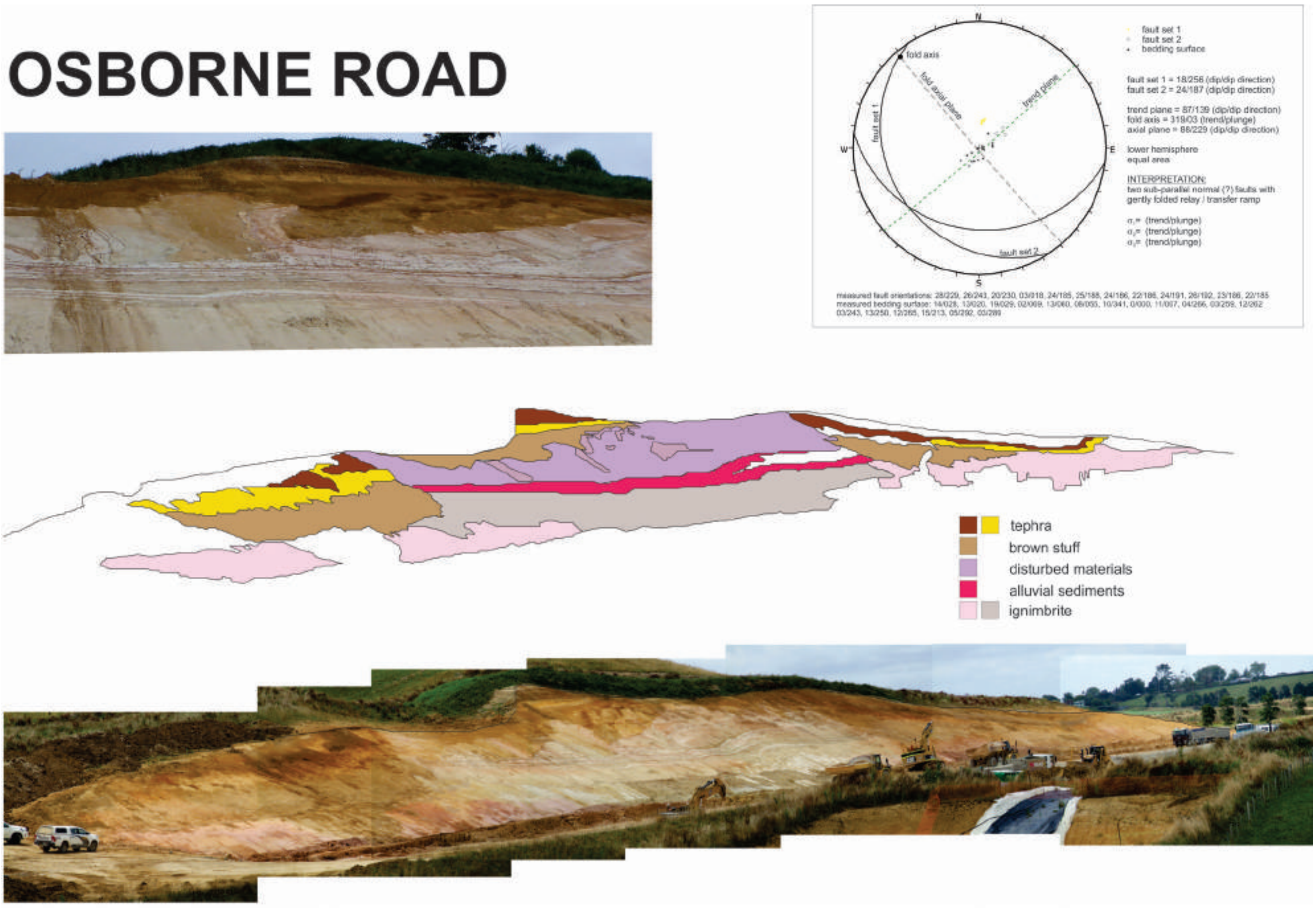


Figure 7: Osborne Road Expressway cutting site.

STOP 5: KAY ROAD

Kay Road overbridge site was the first of the Expressway cuttings available. The site showed a series of normal faults, forming horst and graben structures that extended across the site. Although the overall graben structure appeared quite simple, there was very complex deformation of the materials within the graben.

Faults extended through the full thickness of the Kauroa Ash beds. Within the weathered ash materials the faults were frequent and odd shapes. Many faults could also be recognised deeper into the underlying Walton Subgroup alluvial materials. These faults were more distinct, and their offset was marked by well defined displacement of recognisable sedimentary layers.

When examining this sequence we were unable to identify any offset in the distinctive Rangitawa Tephra (H1) at the base of the Hamilton Ash sequence. This pale grey layer clearly sagged into the graben, but no brittle-type fractures could be identified extending across the Rangitawa Tephra nor into the overlying Hamilton Ash beds.

A clear graben structure on the western face showed conjugate jointing with almost pure normal dip-slip movement; the eastern wall proved more difficult to interpret due to a lack of suitable measurement sites. The western wall suggests a major principal stress from the northeast, steeply dipping, and almost horizontal minor principal stress.

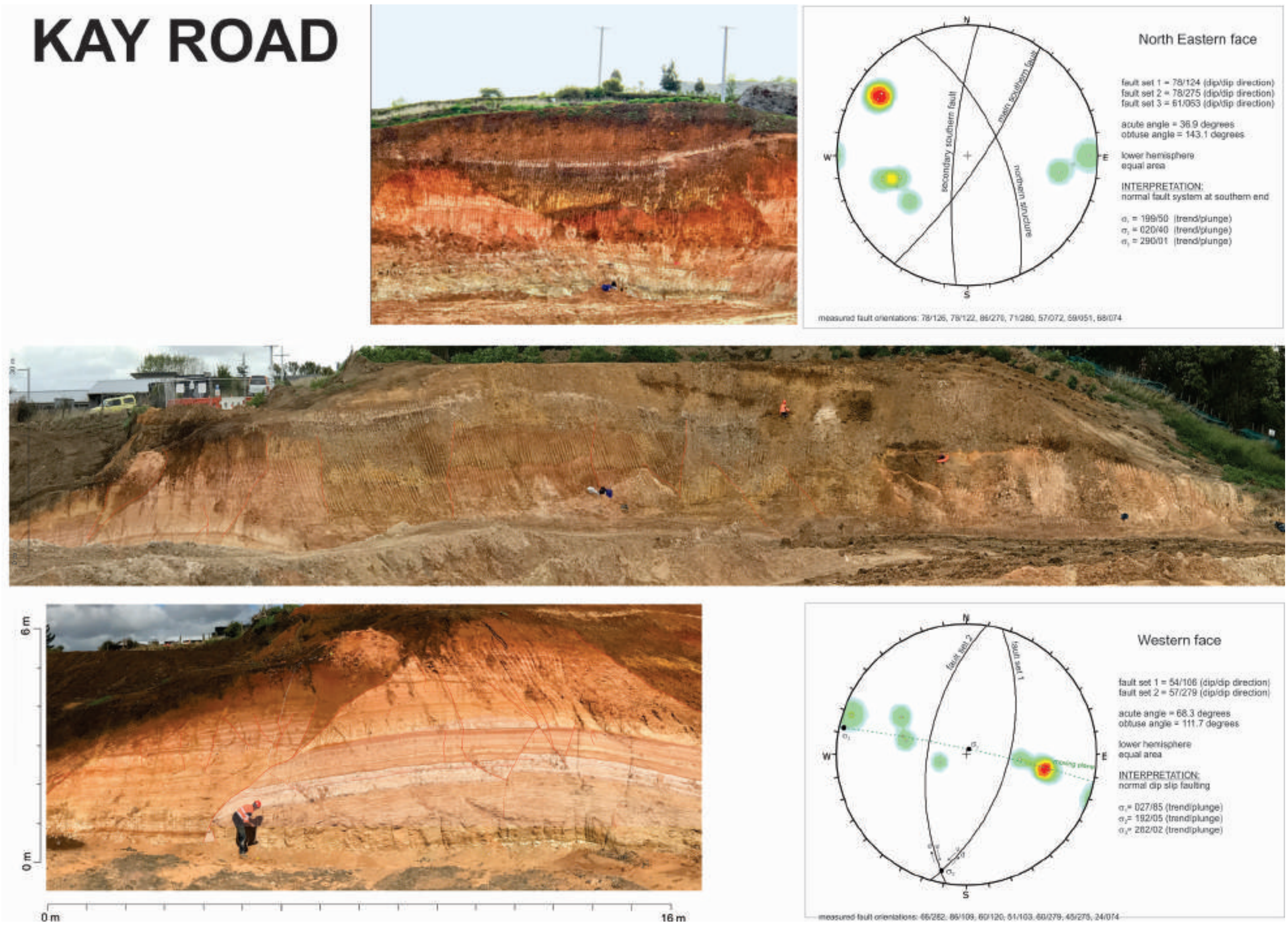


Figure 8: Kay Road Expressway cutting site.

STOP 6: KIMBRAE

Kimbrae is a complex site that will be described when we reach the stop.

STOP 7: TIL'S LANDING - OVERVIEW

What we think we do know now:

We are convinced of a complex network of faults in the basin. They generally run SW–NE, with some curvature. Most of the faults show at least a component of normal displacement in cutting faces. However, we believe that in a number of instances there is evidence of strike-slip movement. It is unclear whether strike-slip is dominant.

Principal stresses generally show σ_1 to be steeply plunging from the NE direction, with σ_3 sub-horizontal. These stresses indicate an extensional environment, but are only measurable for the simplest fault exposures (the ones that show most normal displacement).

Below is our latest map, with indications of confidence of our identifications. Two key systems are clear: one along the ridge we are standing on at Til's Lookout; the other that we can see to the southeast which runs through the Hamilton Gardens and University of Waikato. There are likely a number of splinters associated with them.

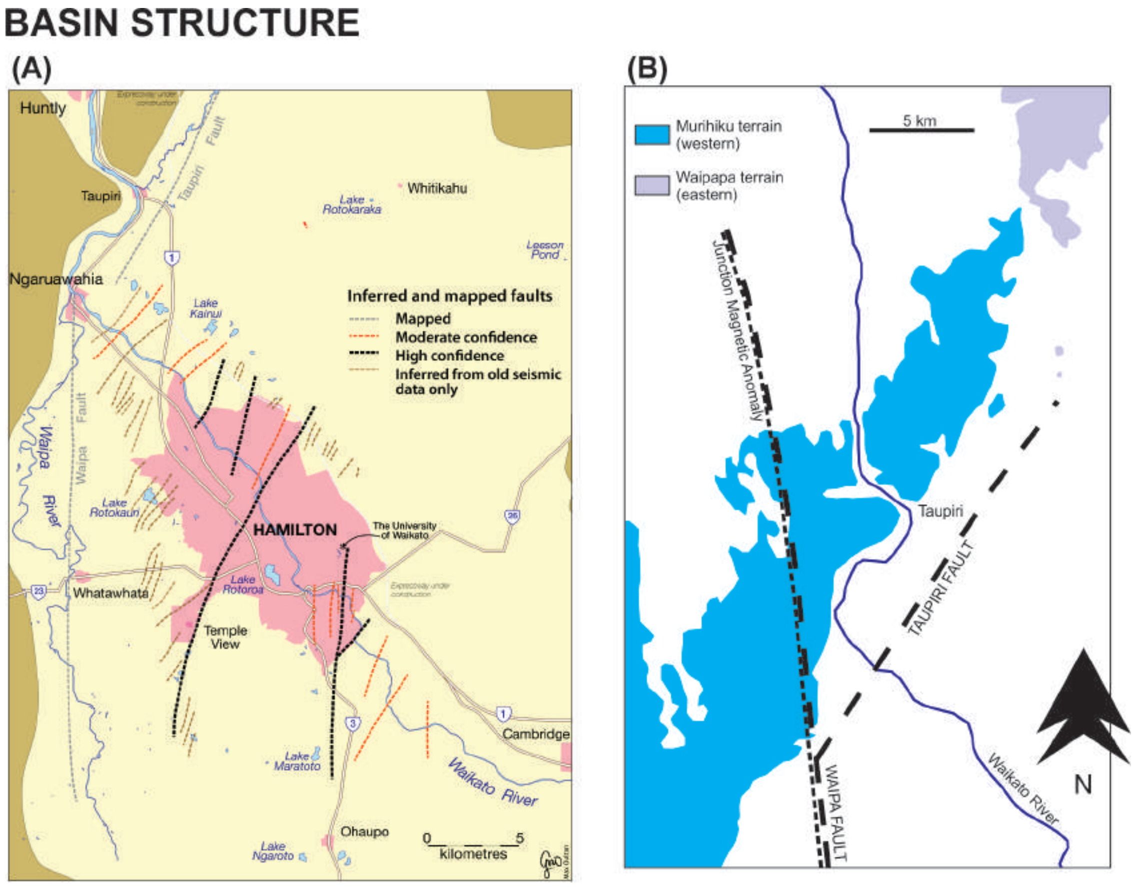


Figure 9: (A) Our most recent map of inferred faults. Reality is almost certainly much more complex. (B) Waipa Fault, Junction Magnetic Anomaly, and basement terranes at the northern boundary of the Hamilton Basin.

What we don't yet know (but we have some new avenues to explore…):

1. We cannot yet put the faults into a model of the overall basin structure.

    a. The Waipa Fault, bounding the western margin of the Hamilton Basin, follows the Junction Magnetic Anomaly (JMA) beneath the eastern rim of Pirongia. To the south there is serpentine recognised along the JMA at PioPio, but there is no, to limited, vertical displacement along the Waipa Fault at this point.

Only in the Hamilton Basin area does the Waipa Fault show significant vertical offset.

b. The Hakarimata Range, which separates the Hamilton Basin from Huntly in the north, is comprised of Murihiku terrane rocks on the “wrong” (eastern) side of the JMA. Kirk (1991) has proposed that these rocks are rotated across the JMA in some way.

c. The Taupiri Fault is postulated along the southern margin of the Hakarimata Range, but little real evidence for it exists.

2. Timing – geomorphic evidence suggests displacement of Hinuera Formation sediments (which also show some evidence of paleoliquefaction: Kleyburg et al. 2016). However, we have not yet found a site we are willing to pour money into for trenching that may give a history of recent movement.

3. However, liquefied tephra layers and ash-grade injectites, projected downwards, occur systematically within undeformed organic sediments in c. 20,000 cal. year-old lakes in the Hamilton Basin (Fig. 10). We suggest that the liquefied tephras reflect (palaeo) liquefaction arising from severe shaking from earthquakes generated on faults proximal to the lakes in which the tephras occur, forming ‘tephra seismites’ (Loam et al. 2018; Lowe et al. 2018). The lakes are found scattered amidst the faults (see Fig. 9A). Our preliminary works shows that the same ash layer is not necessarily liquefied in every lake, suggesting that the effect of an earthquake relies on proximity to a nearby fault. The tephra seismites are unlikely to represent shaking induced by movement on the distant Kerepehi Fault system in the neighbouring Hauraki Basin (Persaud et al. 2016). The University of Waikato has just been granted Endeavour and Marsden funding to work on these liquefied lacustrine tephra layers in the Hamilton Basin over the next three years.

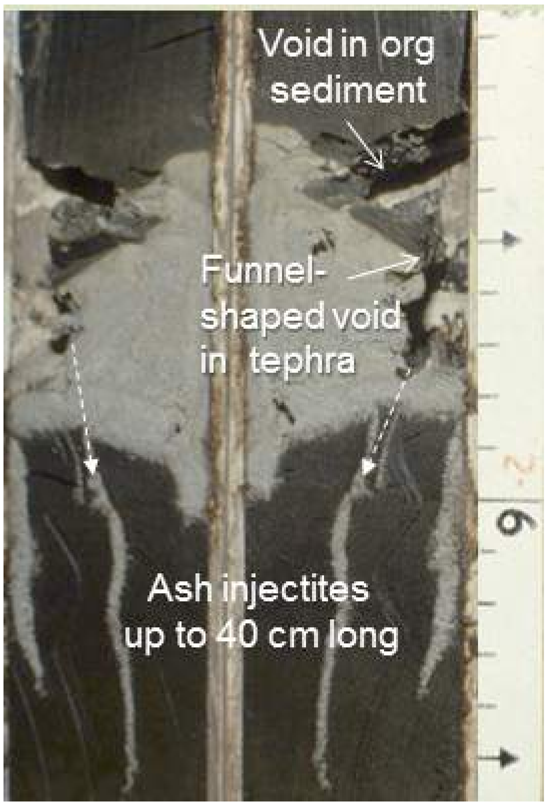


Figure 10 (A)

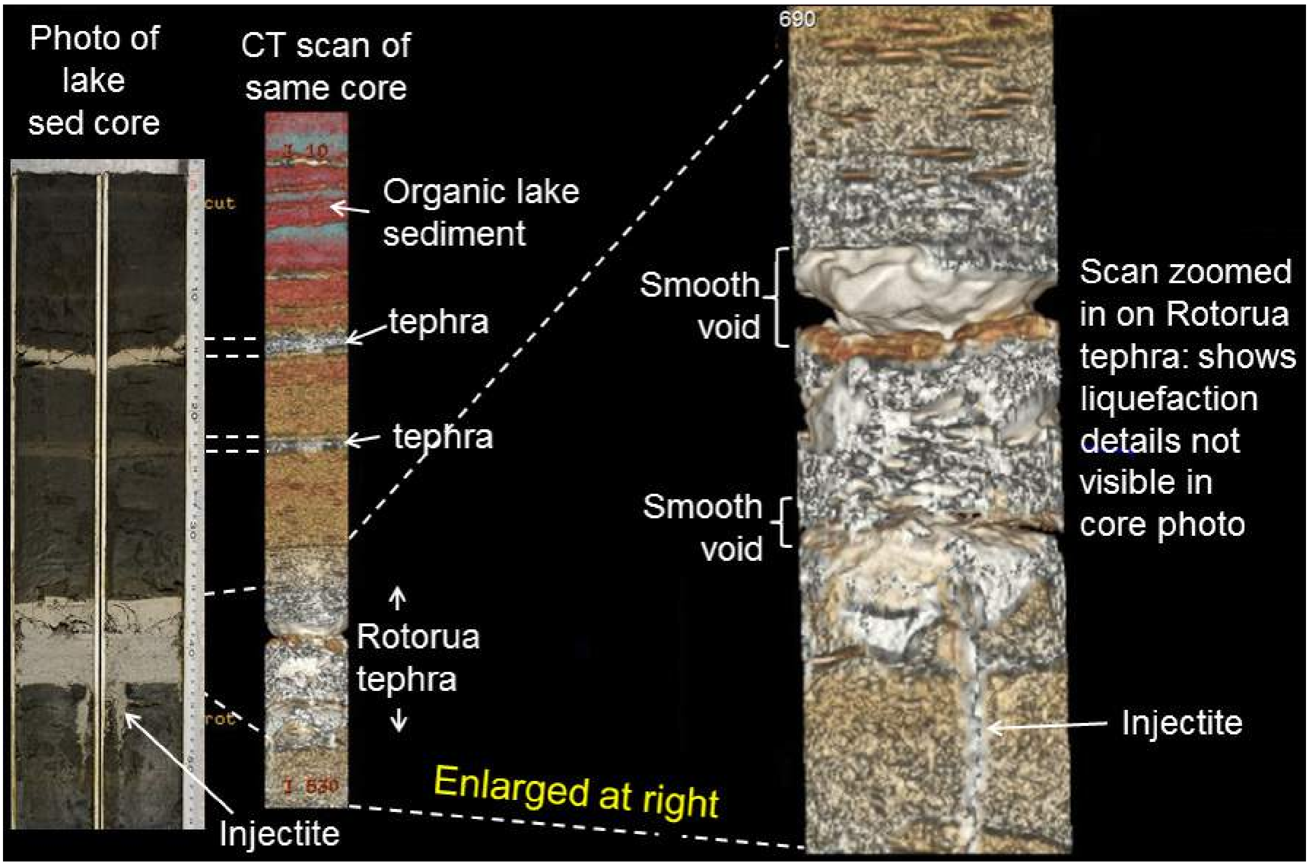


Figure 10: (A) Photo of liquefied Rotorua Tephra (c. 15,600 cal. years old) in a core taken from Lake Kainui in the early 1980s (Lowe 1988, p. 134). The image shows that fine ash has 'flowed' downward from the centre of the 5-cm-thick layer leaving a funnel-shaped void later infilled with organic sediment from above; a downward-propagated injectite underlies the layer. Originally, Lowe (1988) suggested, in the absence of known faults at the time, that these features may have been the result of bioturbation and methane gas pocket formation. (B) These images include (left) a photo of part of a new core (0.6 m long) extracted in 2016 containing Rotorua Tephra near the base. To the right are CT images including a close-up of voids (far right). Photos by David Lowe and CT images by Nic Ross.

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