

# Faulting within the Hamilton Basin: Recent Progress



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# Introduction

2015 – 5 known & potential fault zones

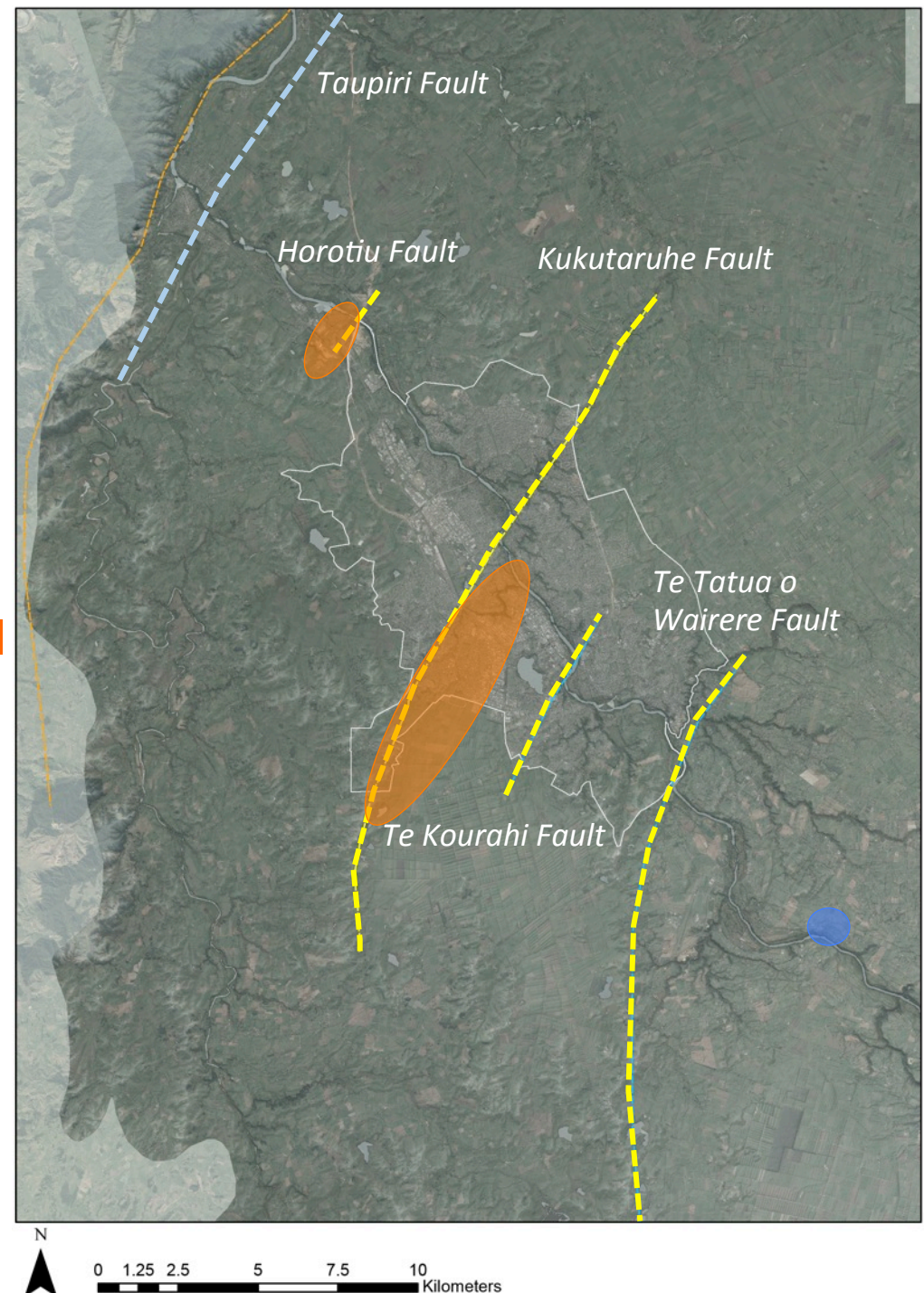
1. Taupiri Fault
2. Horotiu Fault
3. Kukutaruhe Fault
4. Te Kourahi Fault
5. Te Tatua O Wairere Fault



- Geothermal systems
- Basement outcrop

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# Since 2015



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- Continued reviewing existing data
  - Gravity, seismic & drill surveys for oil, gas & coal
- Undertook CHIRP seismic reflection survey & mapped geology along Waikato River
- Excavations for Waikato Expressway have exposed more faults for measurement & analysis
- Started electrical resistivity surveys to locate sites for trenching
- Undertook coring of peat lakes with CT scanning of recover cores
- This presentation is an overview of the results of this work

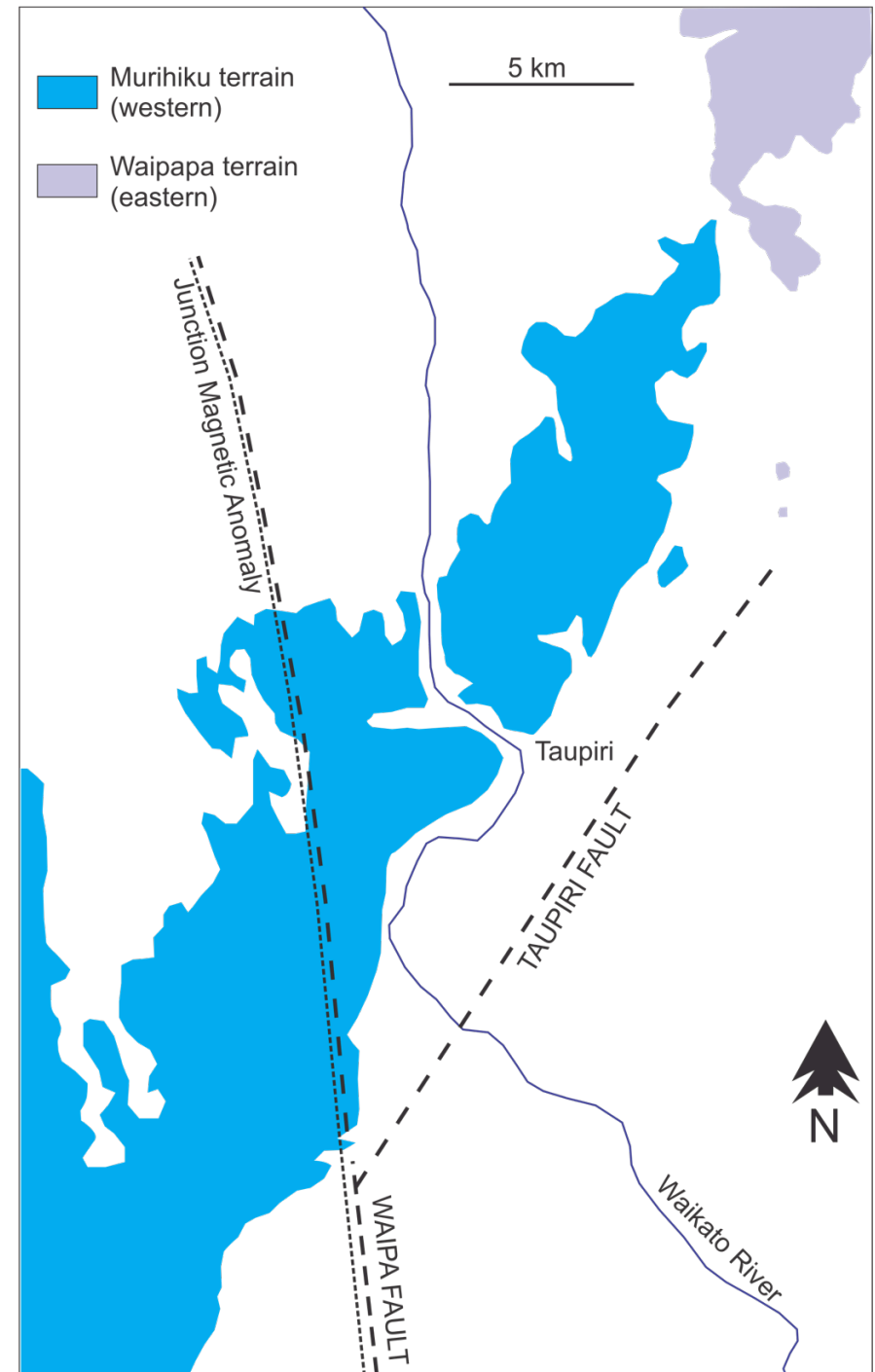
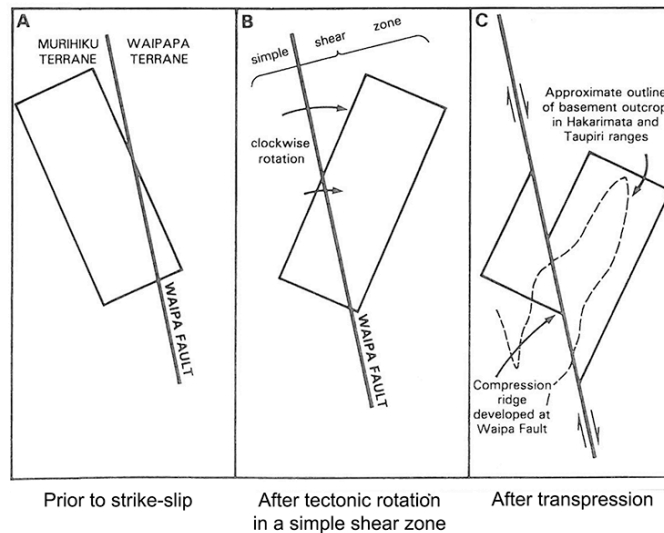




# Basin structure

- Junction Magnetic Anomaly (JMA)
  - Parallels suture between basement terranes
  - Waipa Fault lies along JMA
  - Long history of movement
  - Major north-south trending discontinuity following key structure of North Island
- Hakarimata-Taupiri block on “wrong” side of anomaly
  - Displaced eastward or rotated?
  - Southern margin of Hakarimata Ranges marked by inferred Taupiri Fault
    - Forms northern margin of basin
  - Linked to faulting pattern in basin

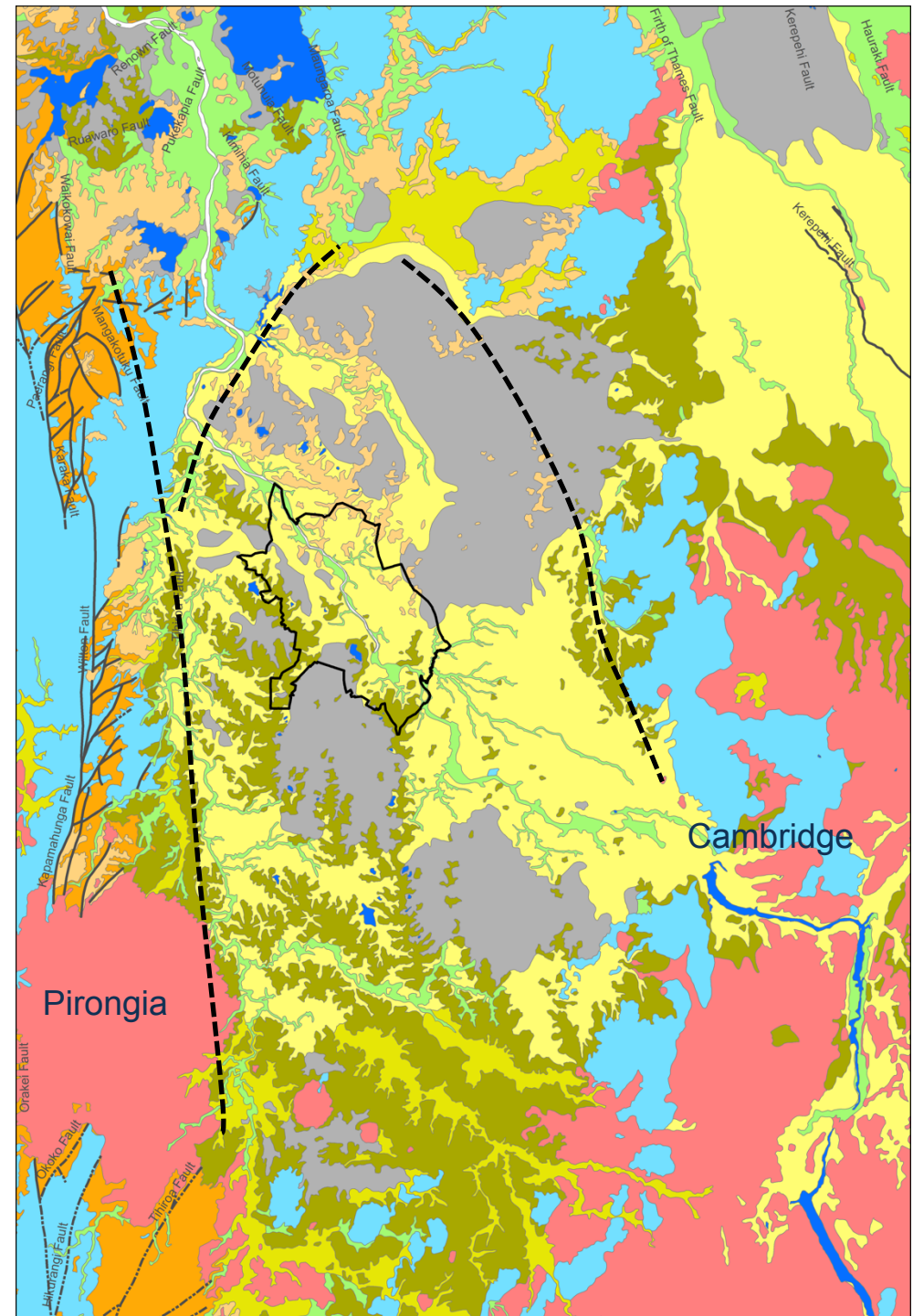
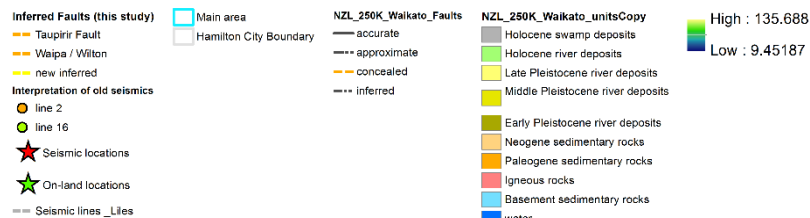
Kirk (1991)





# Defining structures

- Geology includes:
  - Basement (blue) to west, north & east
  - Young sediments (yellows) infilling basin
    - Alluvial fan surrounding older sediments
    - Older Pliocene sediments on eastern side
  - Volcanics to southwest, south & east (red)
- Structures:
  - N-S faults along west and north margins
  - Multiple W-E faults in Tertiary rocks (Te Kuiti Group) on margins of basin
  - Northern faults may extend down eastern margin of basin.
- 3 margins (N-E-W) of basin associated with deep faults providing release surfaces
- Southern margin more uncertain





# Gravity anomaly

- Significant negative gravity anomaly underlying northern basin
- Implies thick infill of low density rocks / sediments

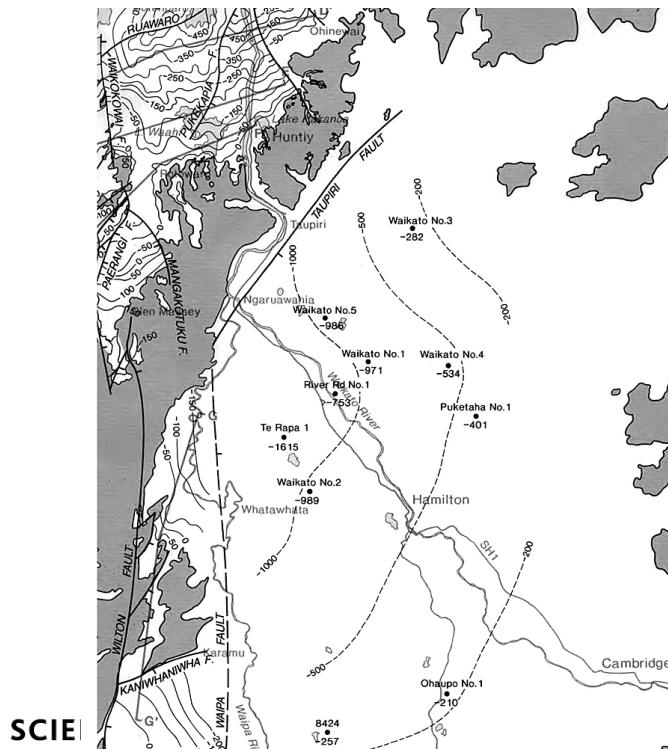
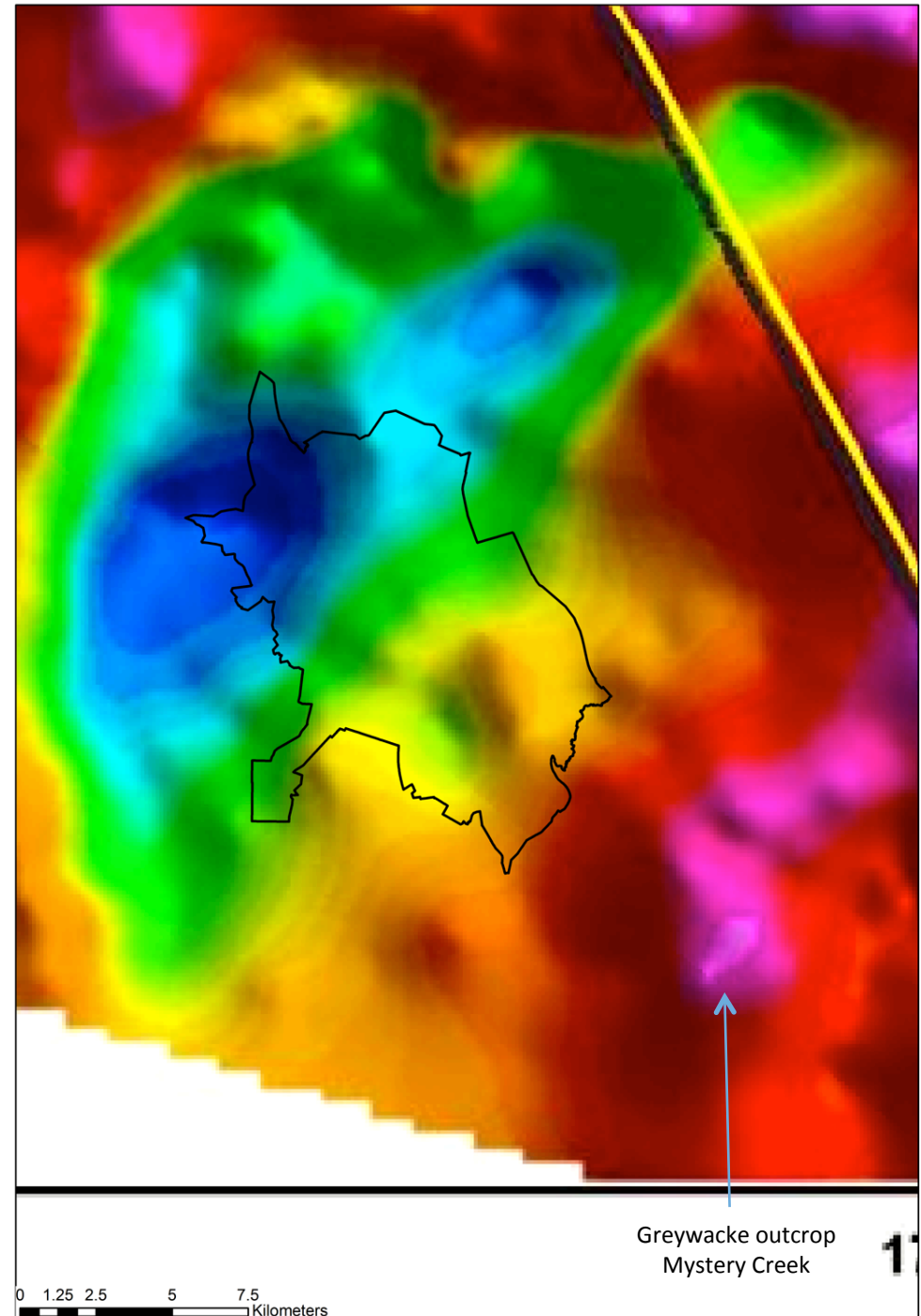


Figure 6.1. Northern Hamilton Basin with bordering basement hills (shaded), major faults and the locations of petroleum exploration wells. Approximate structure contours on basement (metres below sea level) show westward deepening towards Waipā and Taupiri faults.





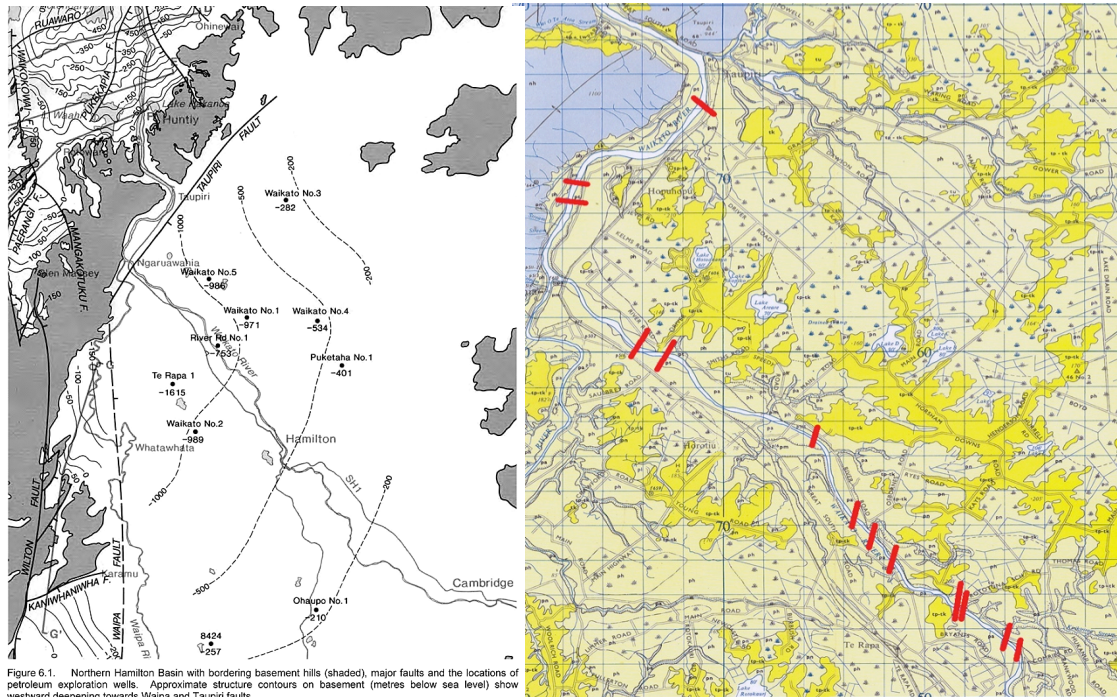


Figure 6.1. Northern Hamilton Basin with bordering basement hills (shaded), major faults and the locations of petroleum exploration wells. Approximate structure contours on basement (metres below sea level) show westward deepening towards Waipa and Taupiri faults.

- CHIRP seismic reflection profile along Waikato River identified ~26 targets as faults or fault zones
- These data were combined with MBES, sidescan sonar & LiDAR to assess if the seismic interpretation was valid

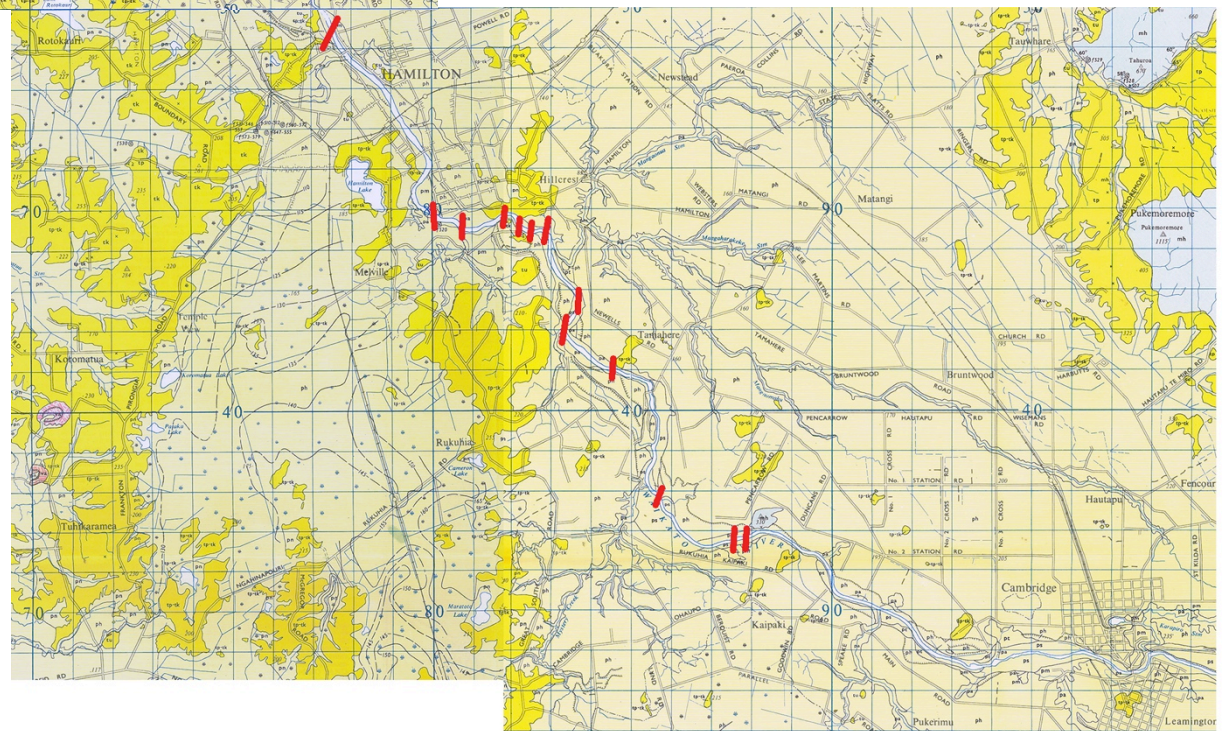
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## Waikato River seismic reflection survey

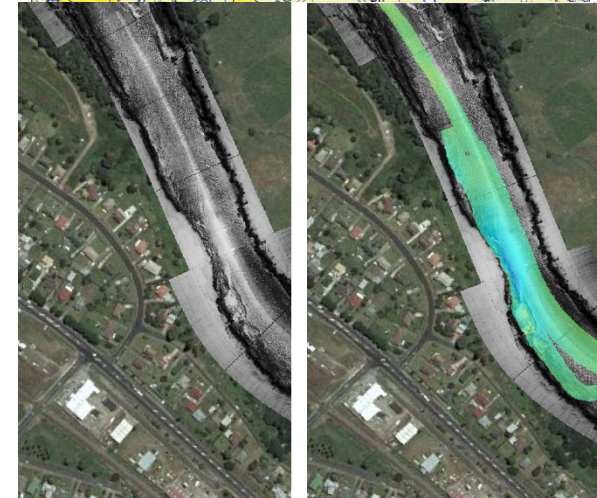
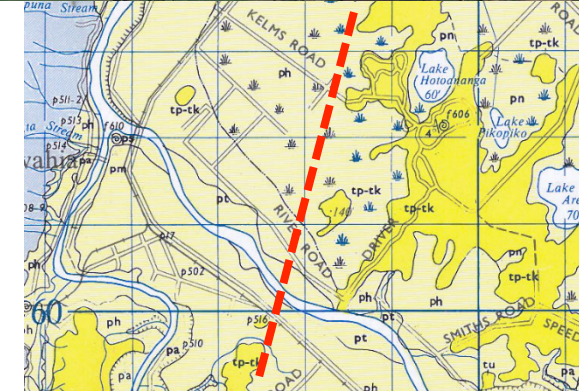
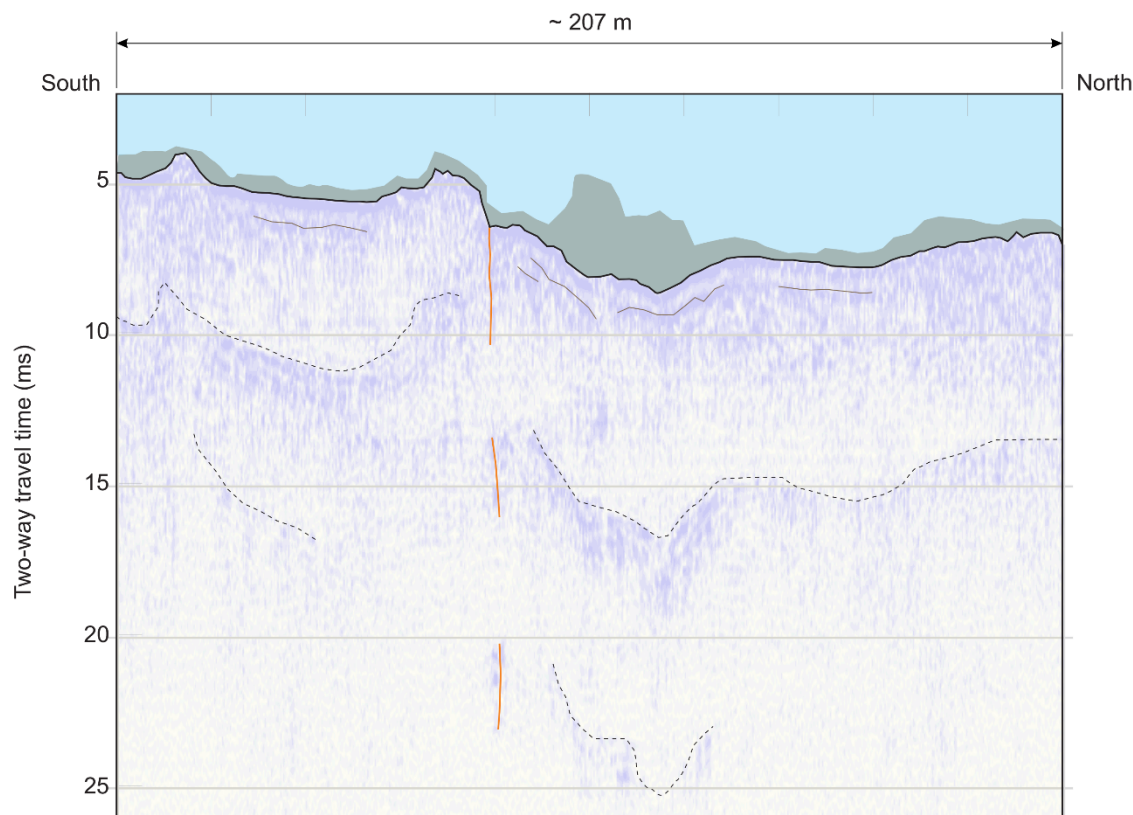
### Potential fault zones





# Taupiri Fault

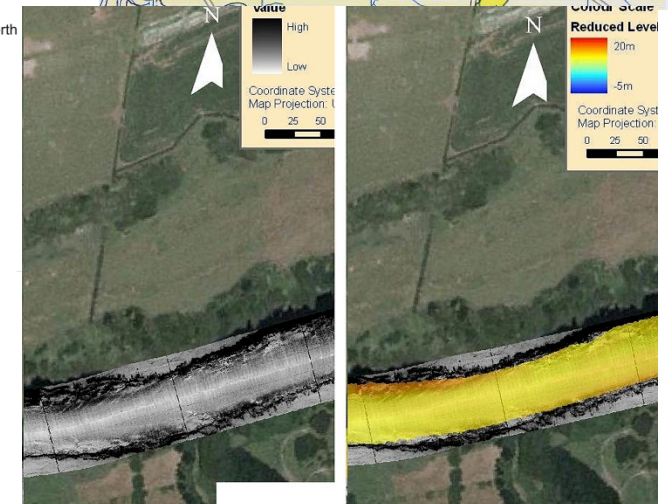
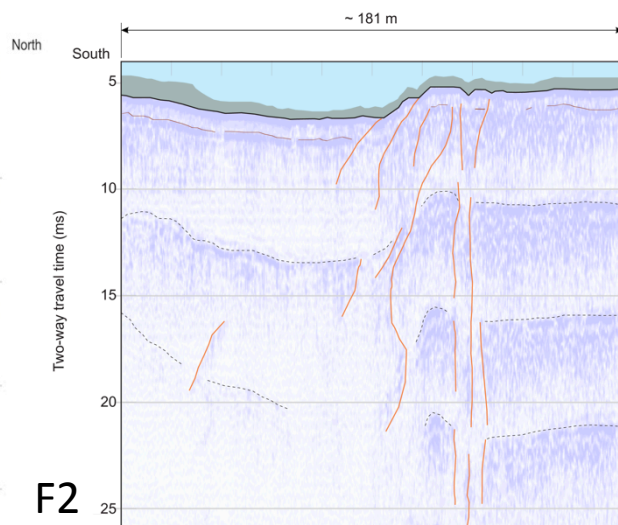
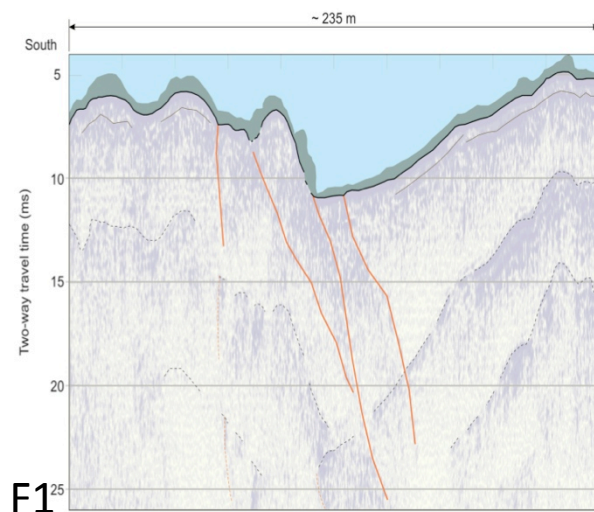
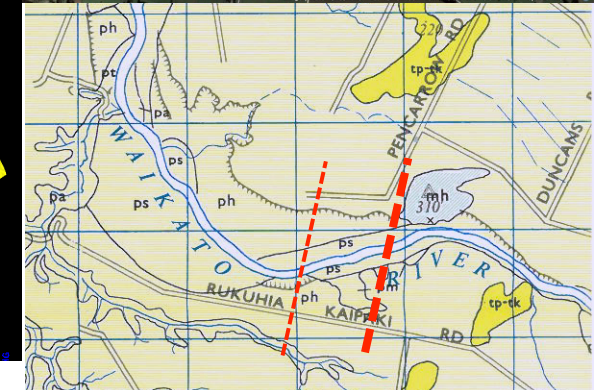
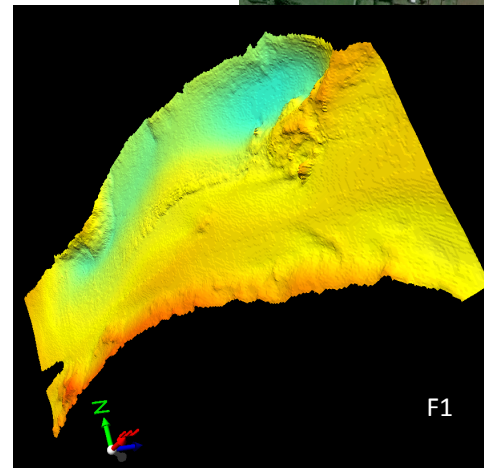
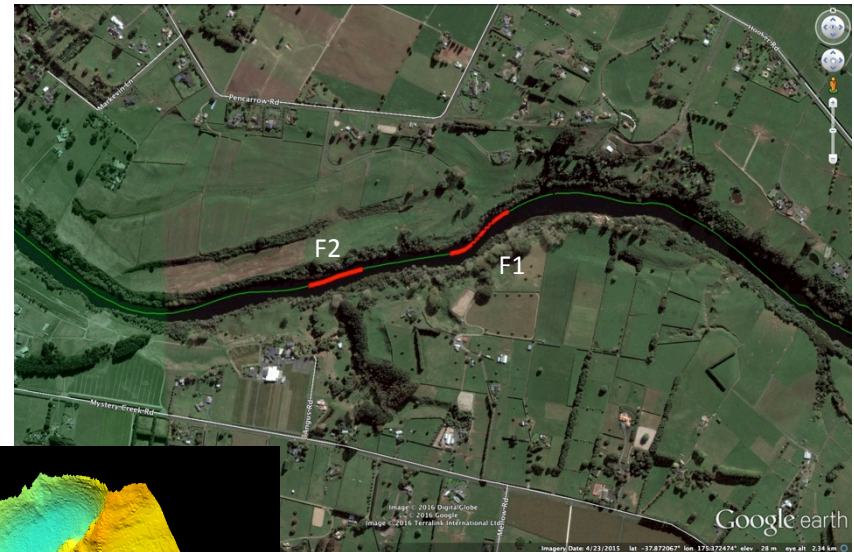
- Known major boundary fault zone flanking Hakirimata Ranges
- We hoped to find a fault at this location if CHIRP methodology worked





# Mystery Creek

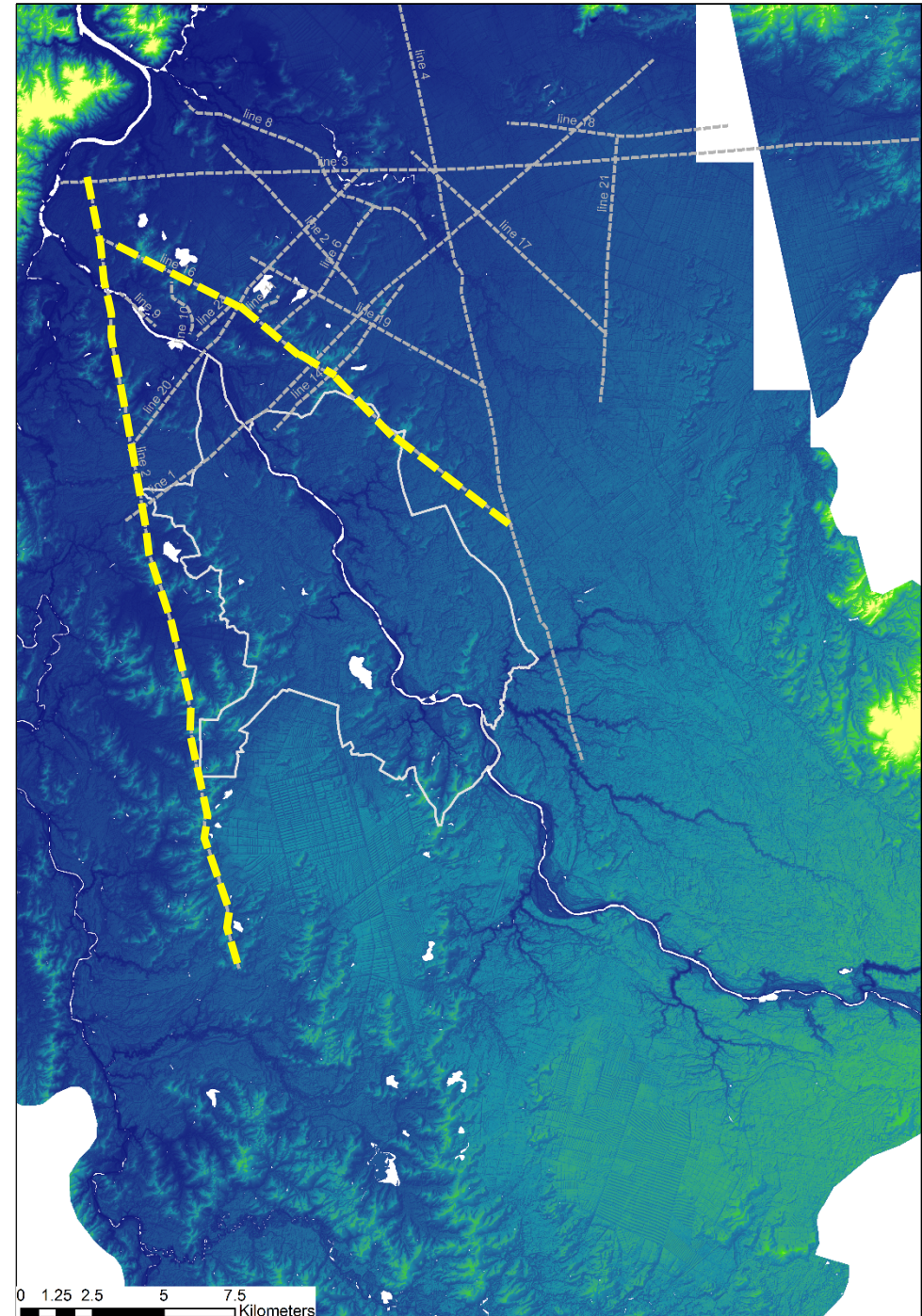
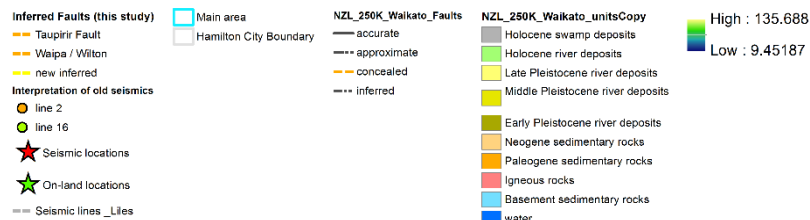
- Outcrop of basement greywacke suggested possible faulting
- CHIRP located 2 faults downstream of greywacke
- MBES data revealed “Scour hole” & rock outcrop in river bed





# Existing seismic data

- Old seismic lines run in 1960s and 1970s for oil & gas exploration
- Some test wells drilled
- We have focused on Lines 2 and 16 that tend to flank Waikato River

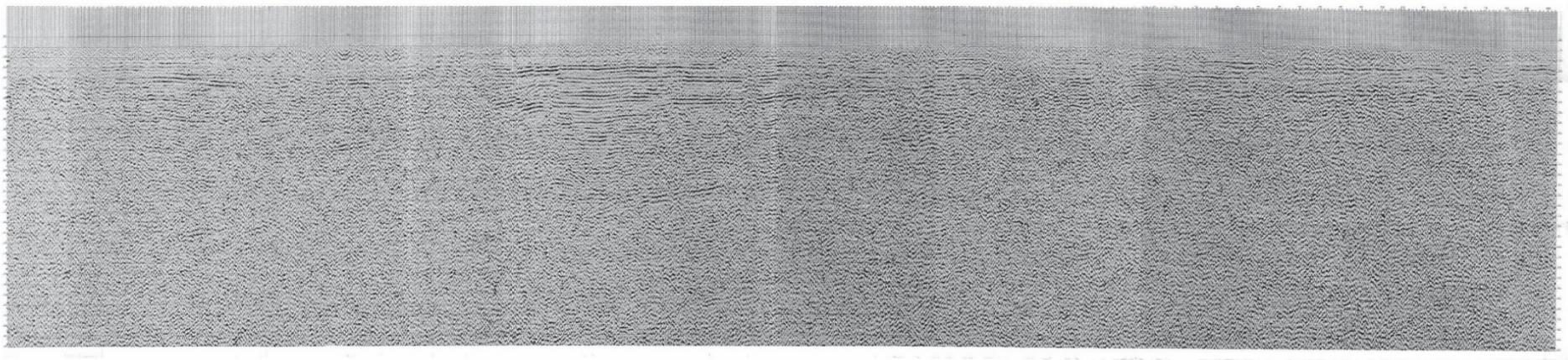


## Line 2 - original



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- These lines are available as high-resolution tiff images of original data.
- They are not high-quality processed files.



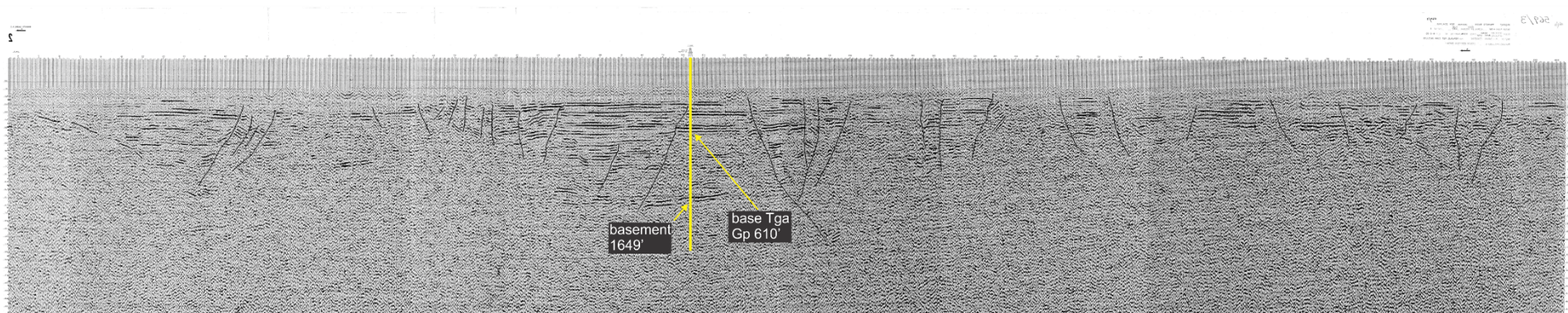


# Line 2 - interpreted



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- These lines are available as high-resolution tiff images of original data.
- They are not give high-quality processed files.
- However, if you stare at them long enough can interpret structure.
- Have a borehole that allows calibration of two key levels:
  - bottom of Tauranga Group sediments
  - top of basement greywacke



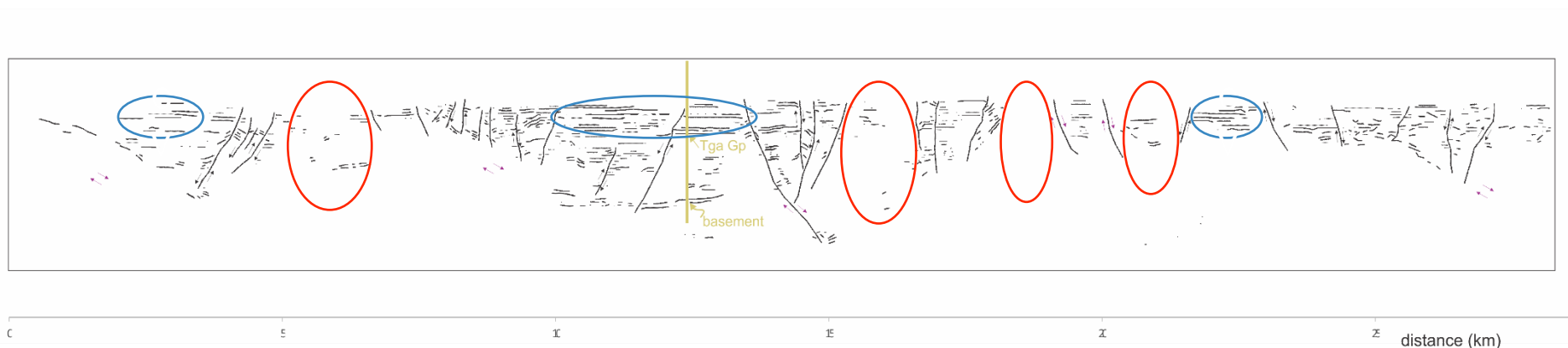


# Line 2 - interpreted



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- The Tauranga Group shows as flat-lying basin infill in many areas, but is horribly distorted in others.
- There are big chunks where cannot see much as traces unreadable.
- Can see:
  - numerous steeply-dipping normal faults
  - two different orientations



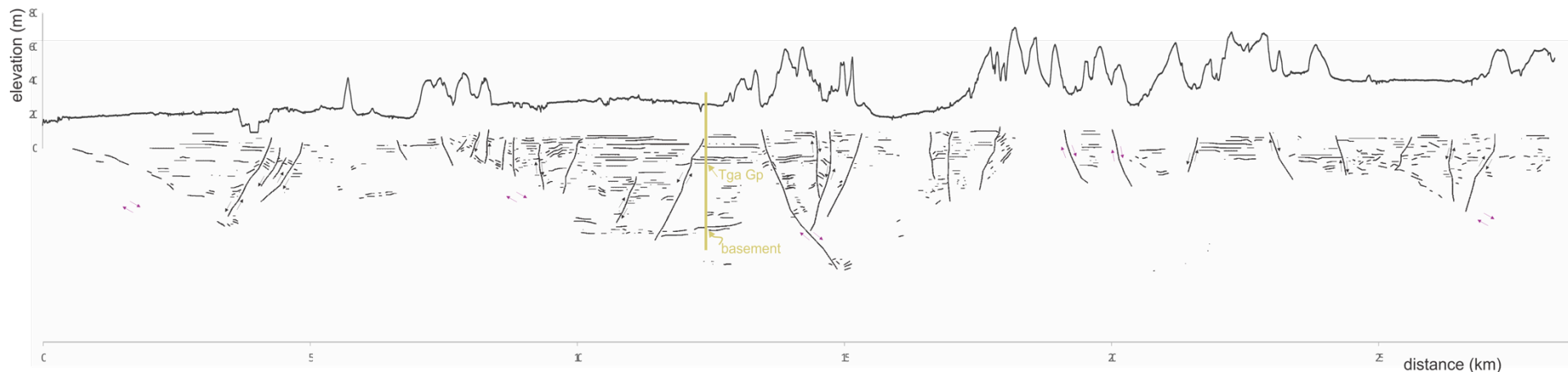


# Line 2 - interpreted



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- Ground surface profile aligned on top:
  - note considerably greater vertical exaggeration
- See considerable agreement between faults and surface geomorphology:
  - faults coincide with hills
  - river nestles against faulted zone
  - even many small lumps and bumps in surface reflect underlying faults



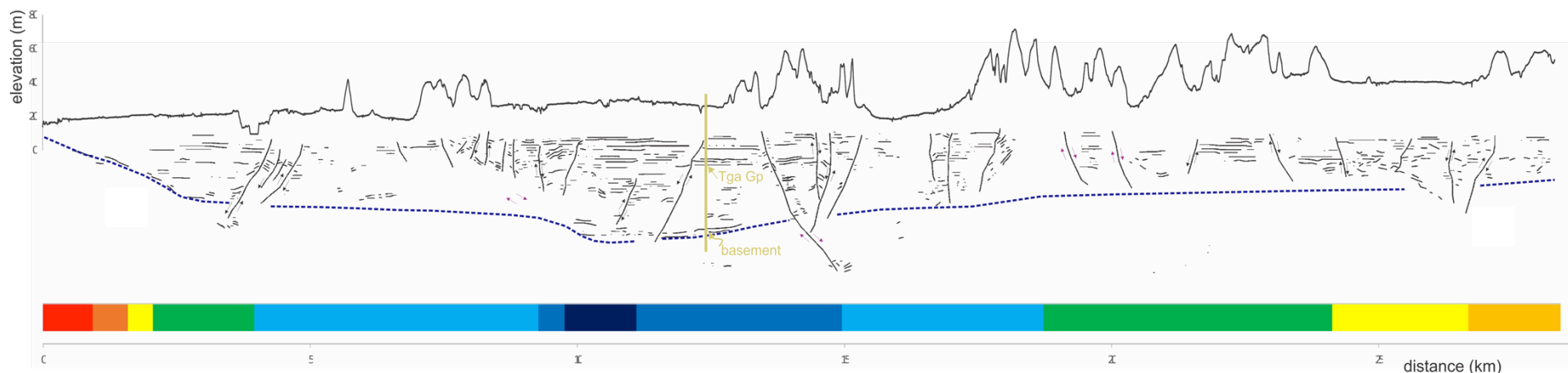


# Line 2 - interpreted



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- Adding in gravity (colour band) allows rough basement profile to be extended from identifiable points.
  - basement dips down from north to deepest point below north Hamilton
  - rises steadily towards south (about  $3^\circ$ ) slope
  - thin or non-existent Tertiary rocks to south

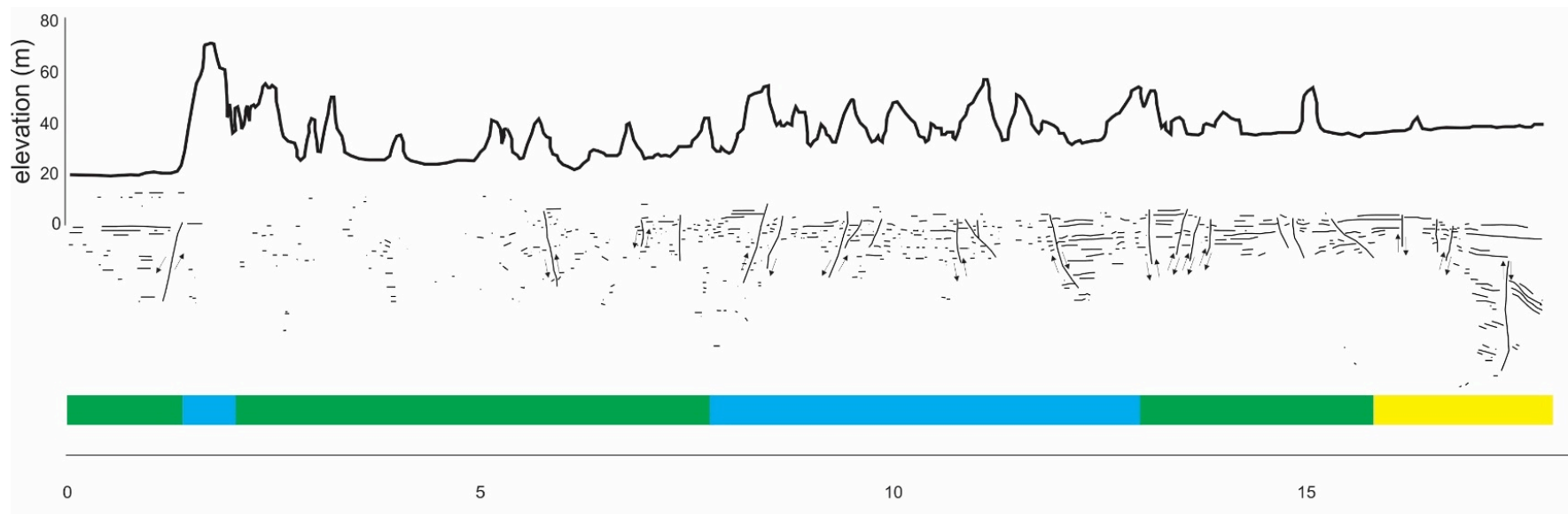


# Line 16



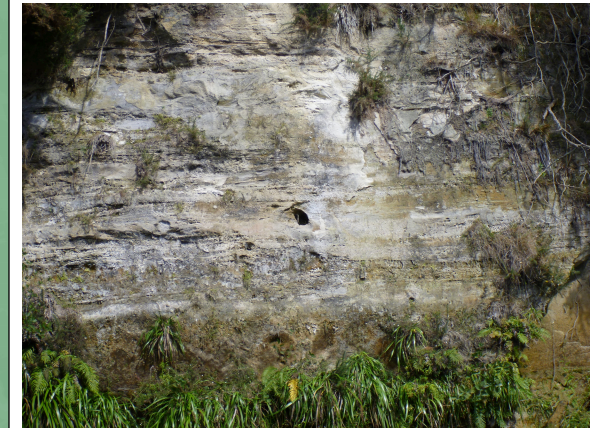
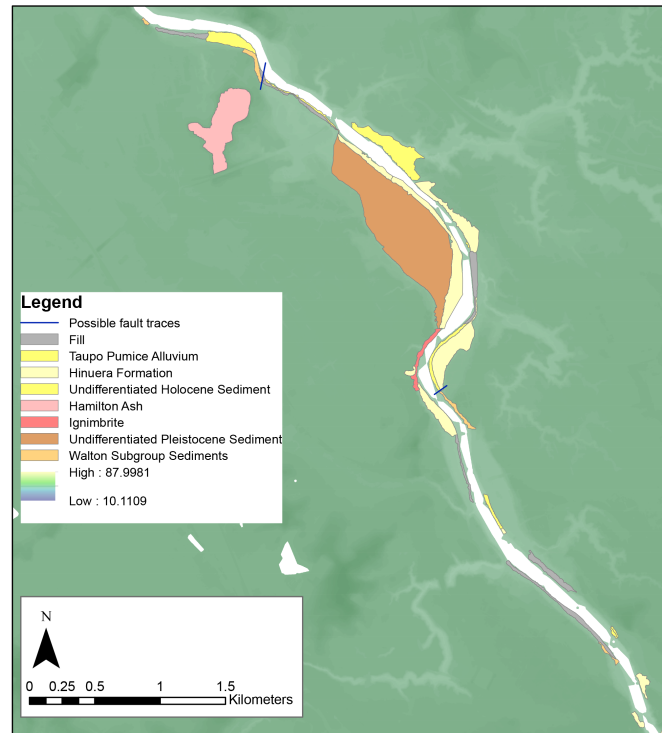
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- Line of poorer quality – zones unreadable
- See similar series of faults, also closely related to geomorphology
- More suggest reverse fault (compressional) movement.

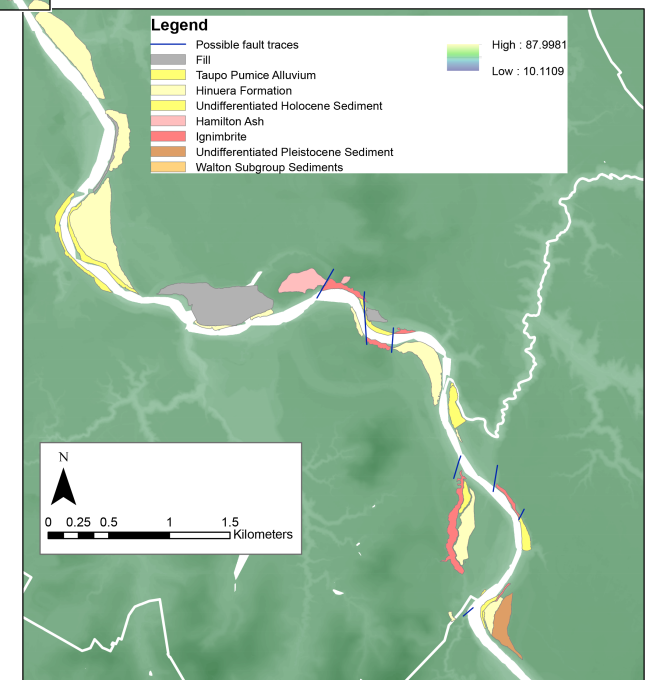




# Riverbank mapping

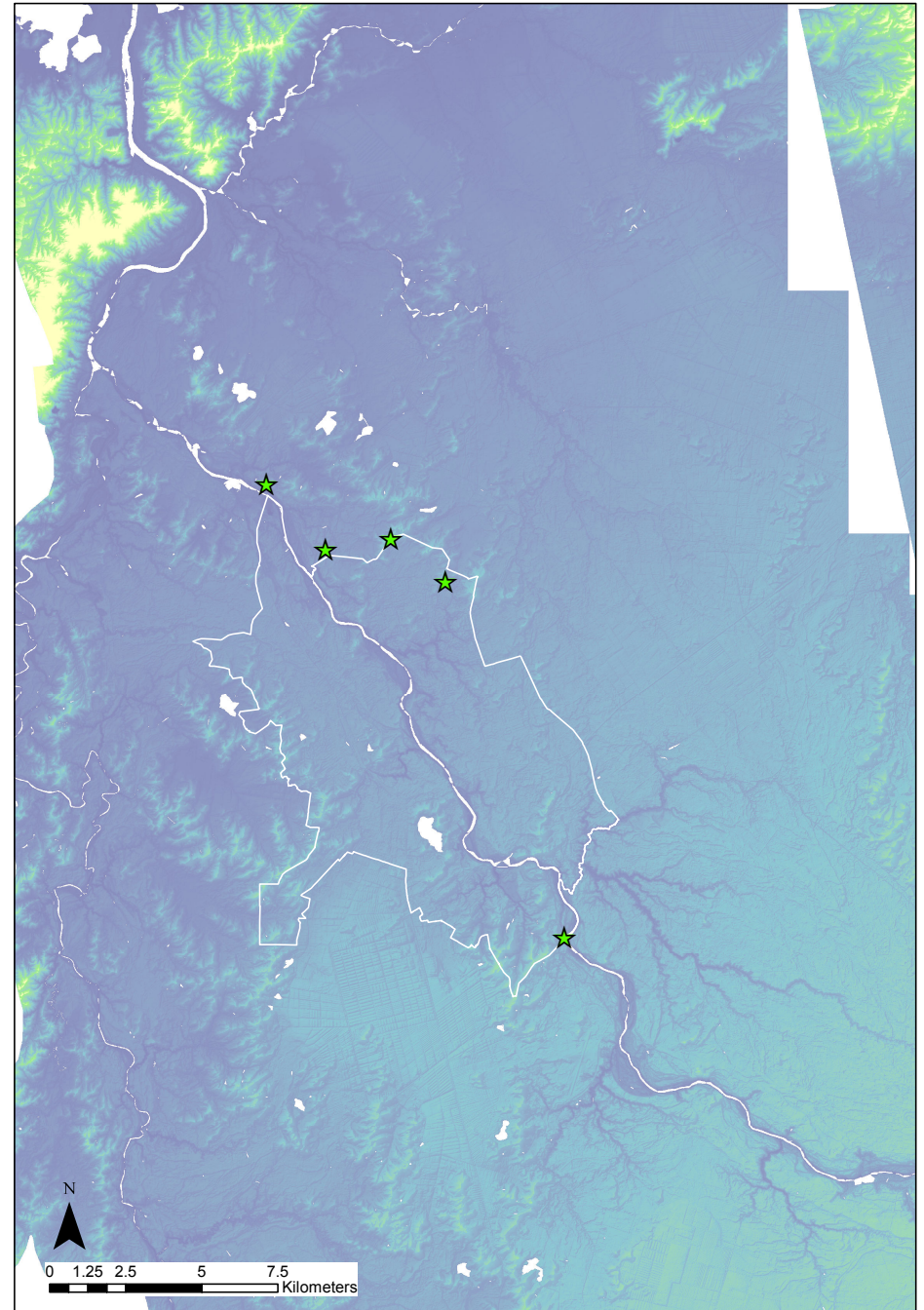
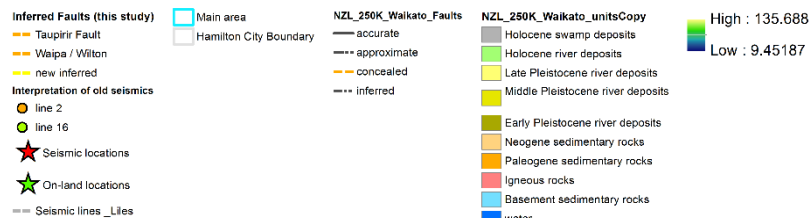


- Geological mapping along riverbanks from Narrows to Horotiu.
- Surprisingly difficult. Still work in progress - Francesca making thin sections to confirm identifications.
- One definite fault identified (Stubbs Road).
- Others inferred from geology.



# Overall faults

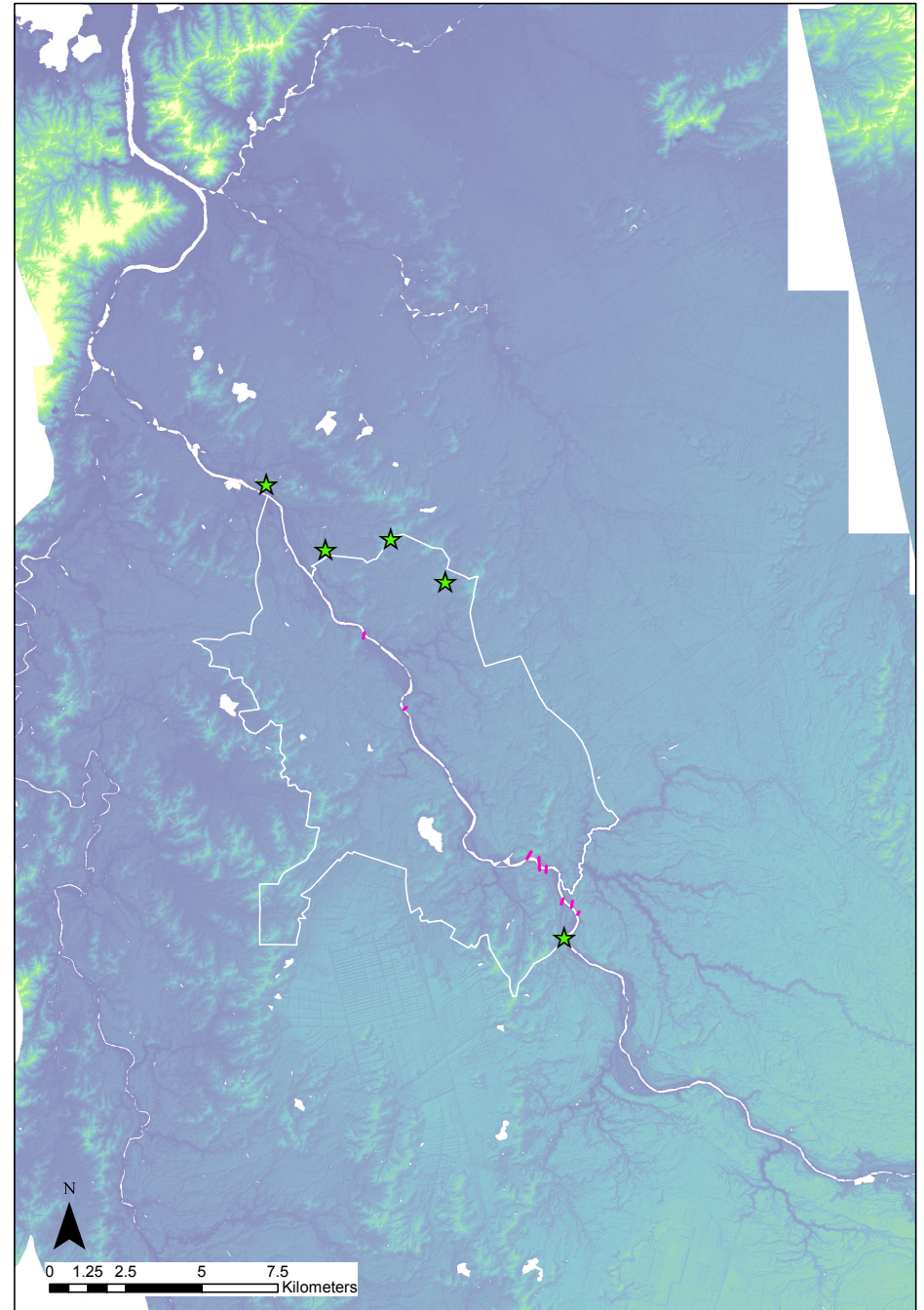
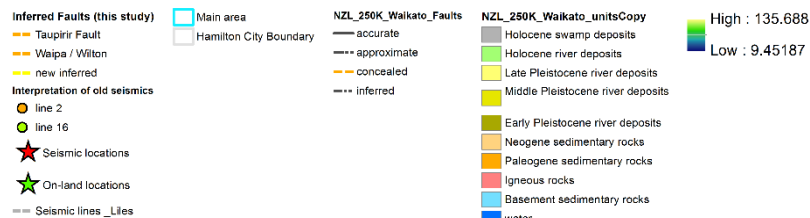
- Building up different lines of evidence allows idea of fault patterns.
- Have shortened to where data actually is, though fully expect many (most) to run right across.
- Colours indicate confidence (yellow highest).





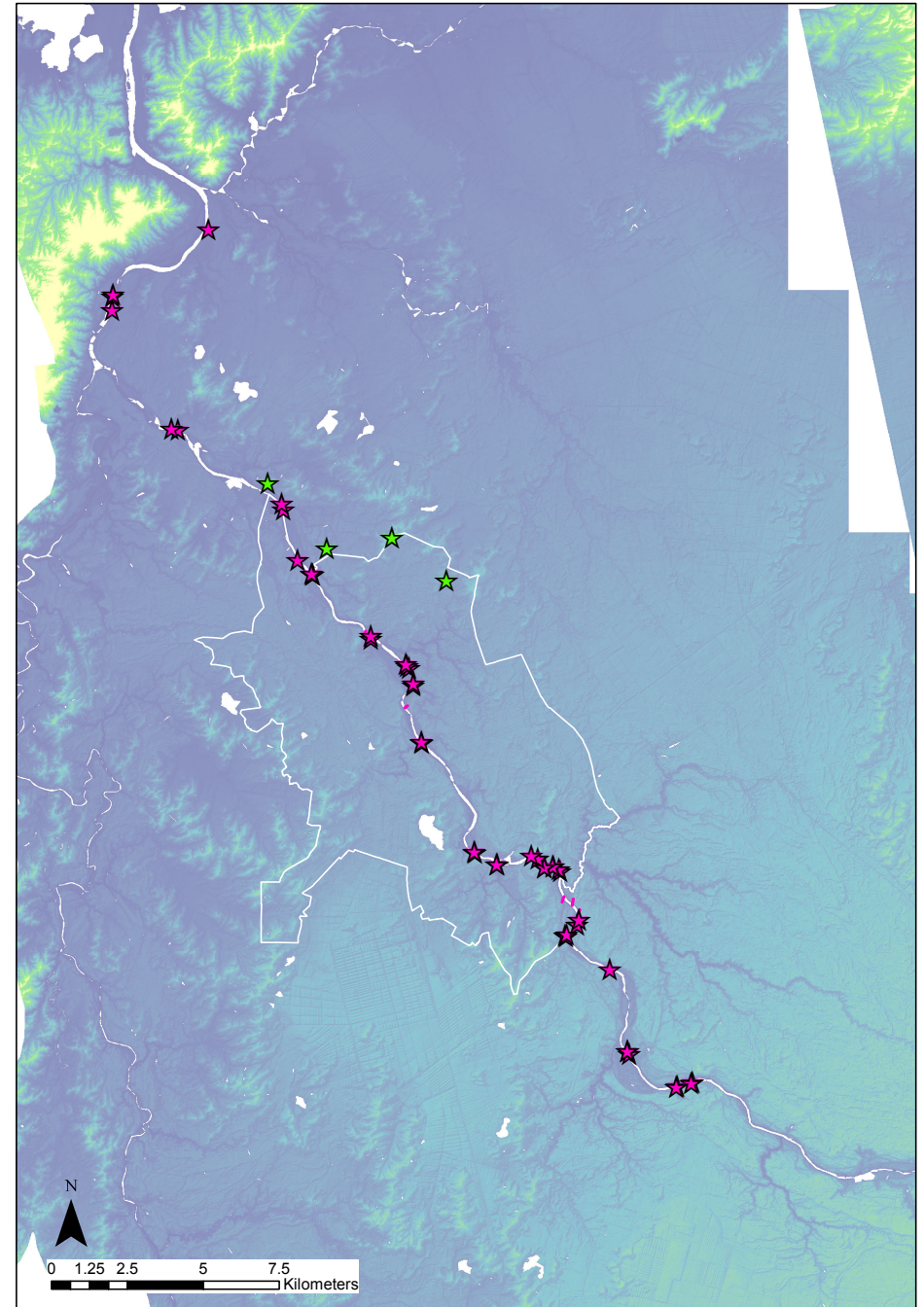
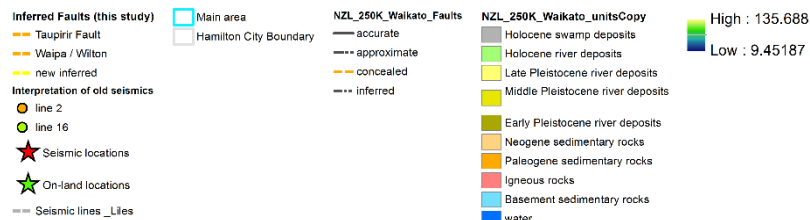
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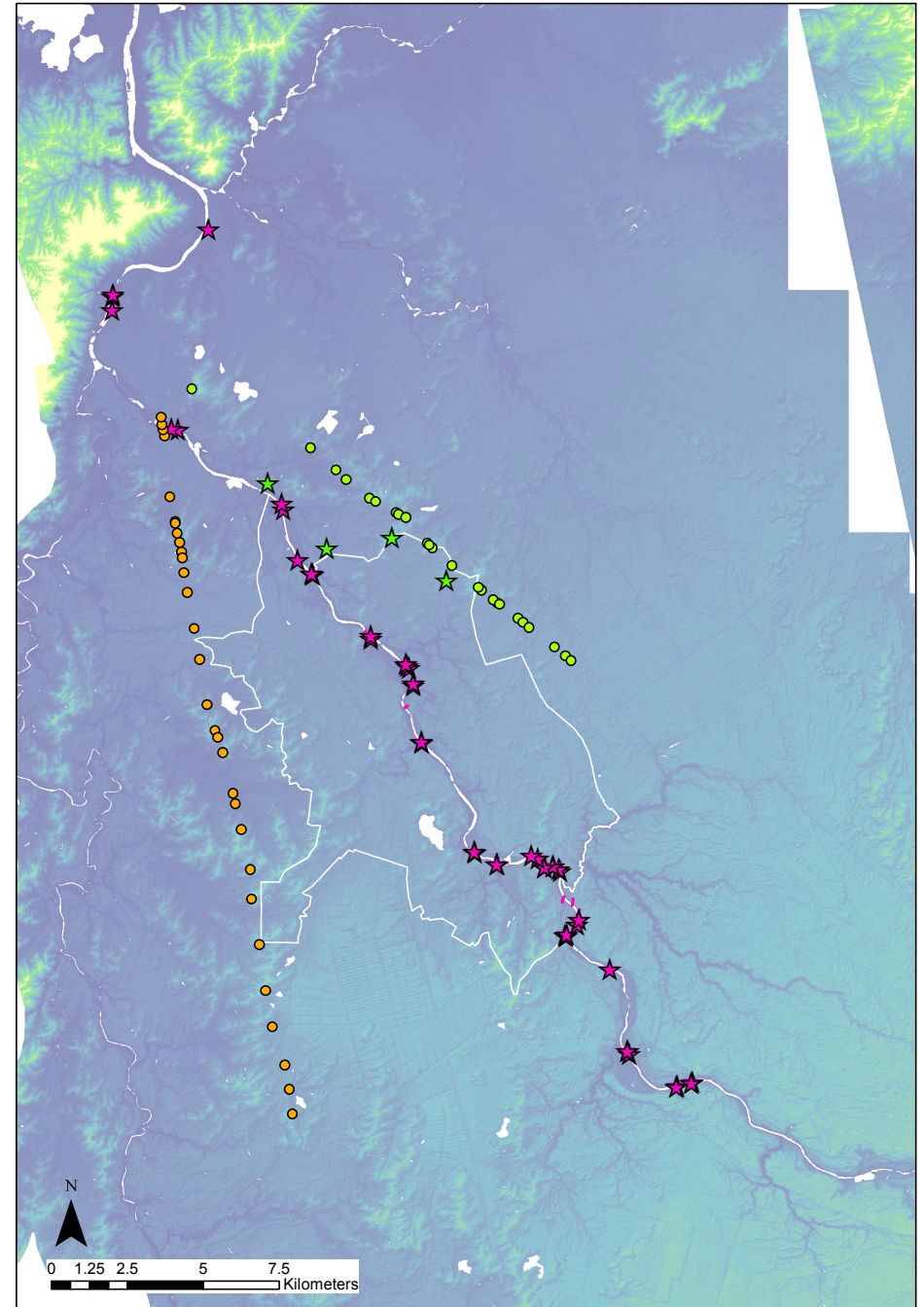
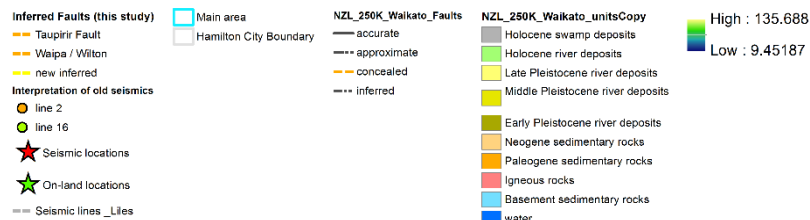
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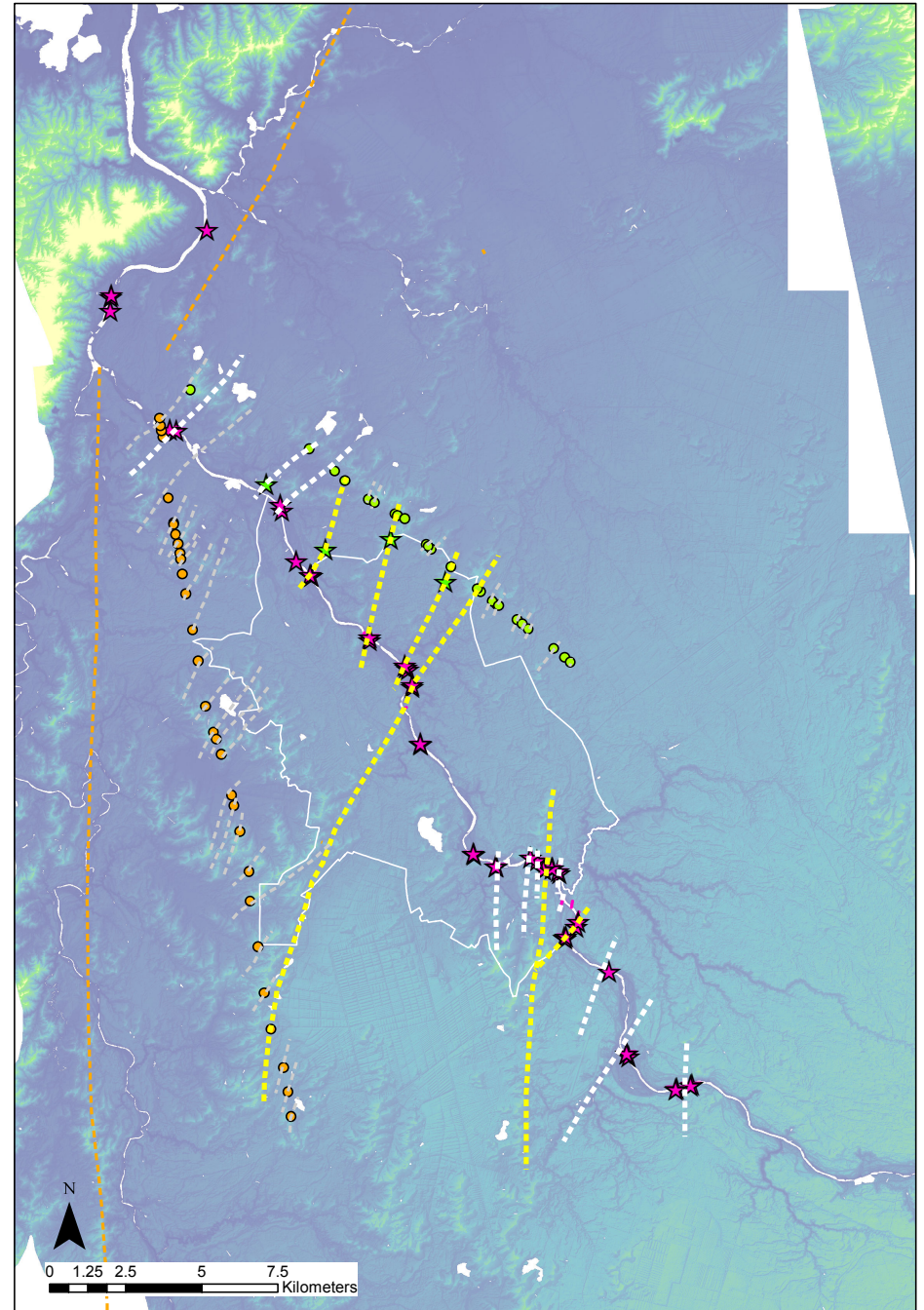
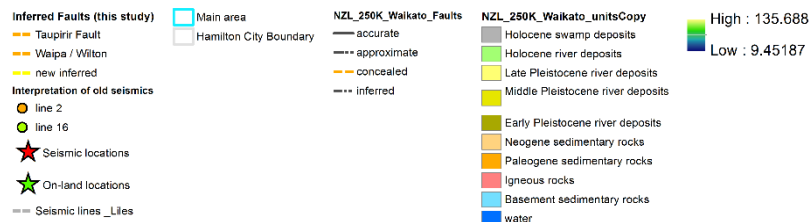
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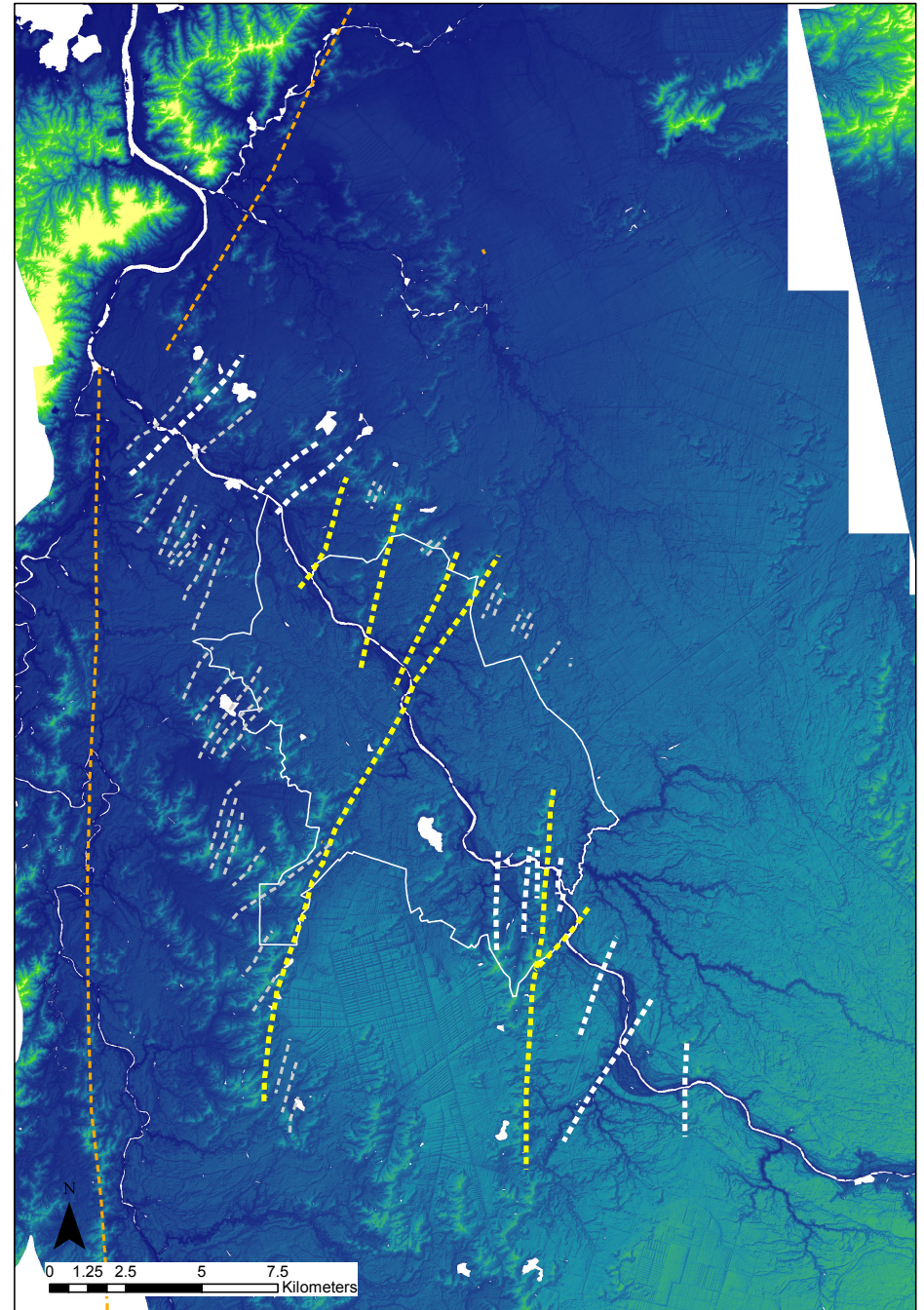
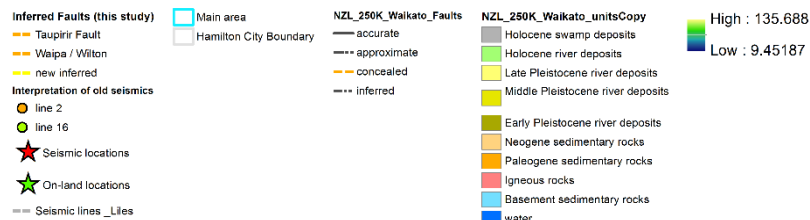
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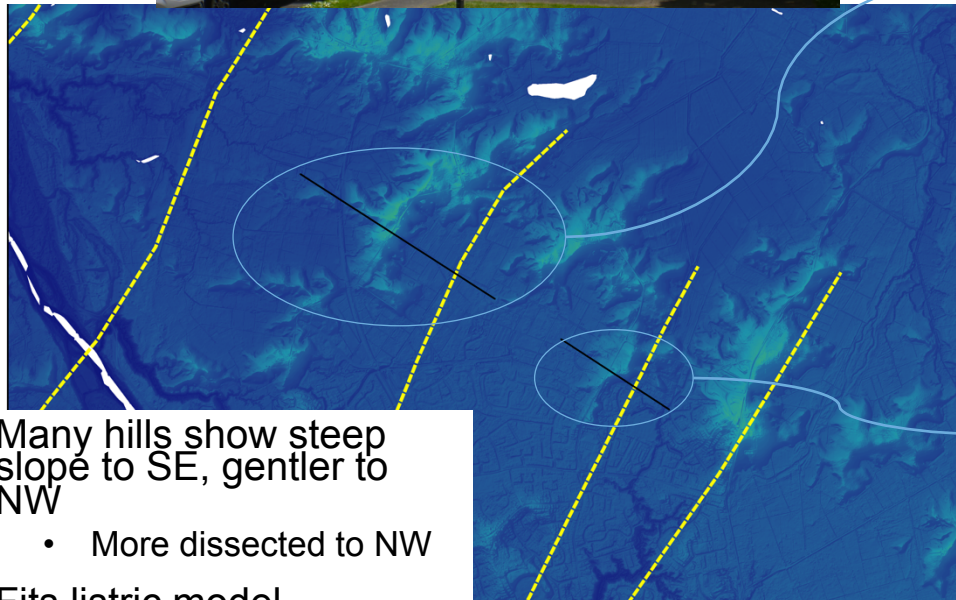


# Overall faults

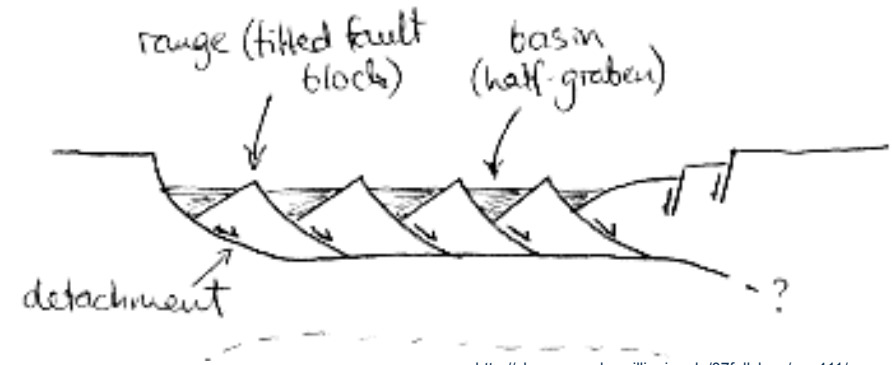
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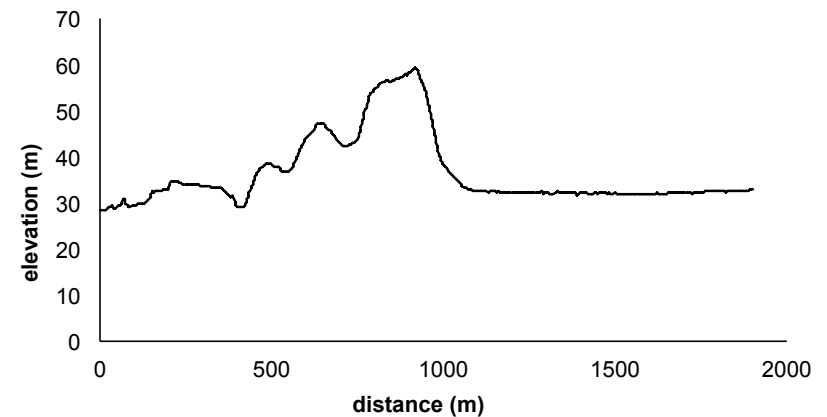
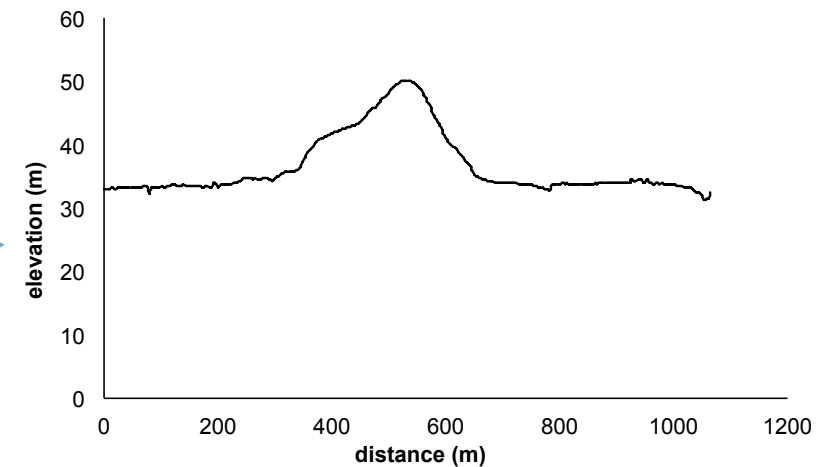
# Hill morphology



- Many hills show steep slope to SE, gentler to NW
  - More dissected to NW
- Fits listric model



[http://classes.geology.illinois.edu/07fallclass/geo411/Tectonics/tectonics\\_files/image001.png](http://classes.geology.illinois.edu/07fallclass/geo411/Tectonics/tectonics_files/image001.png)



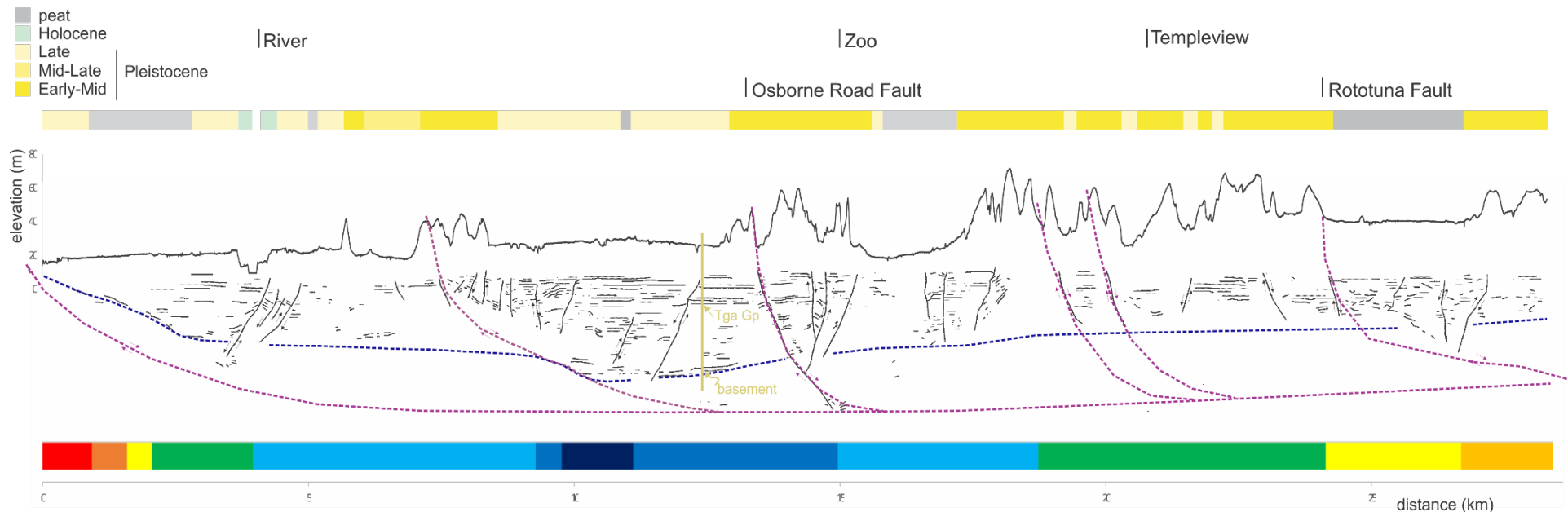


# Line 2 - interpreted



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- Infer a series of listric normal faults dipping south
- Numerous smaller faults in half-grabens between listric faults:
  - both synthetic and antithetic faults
  - form small horst and graben structures

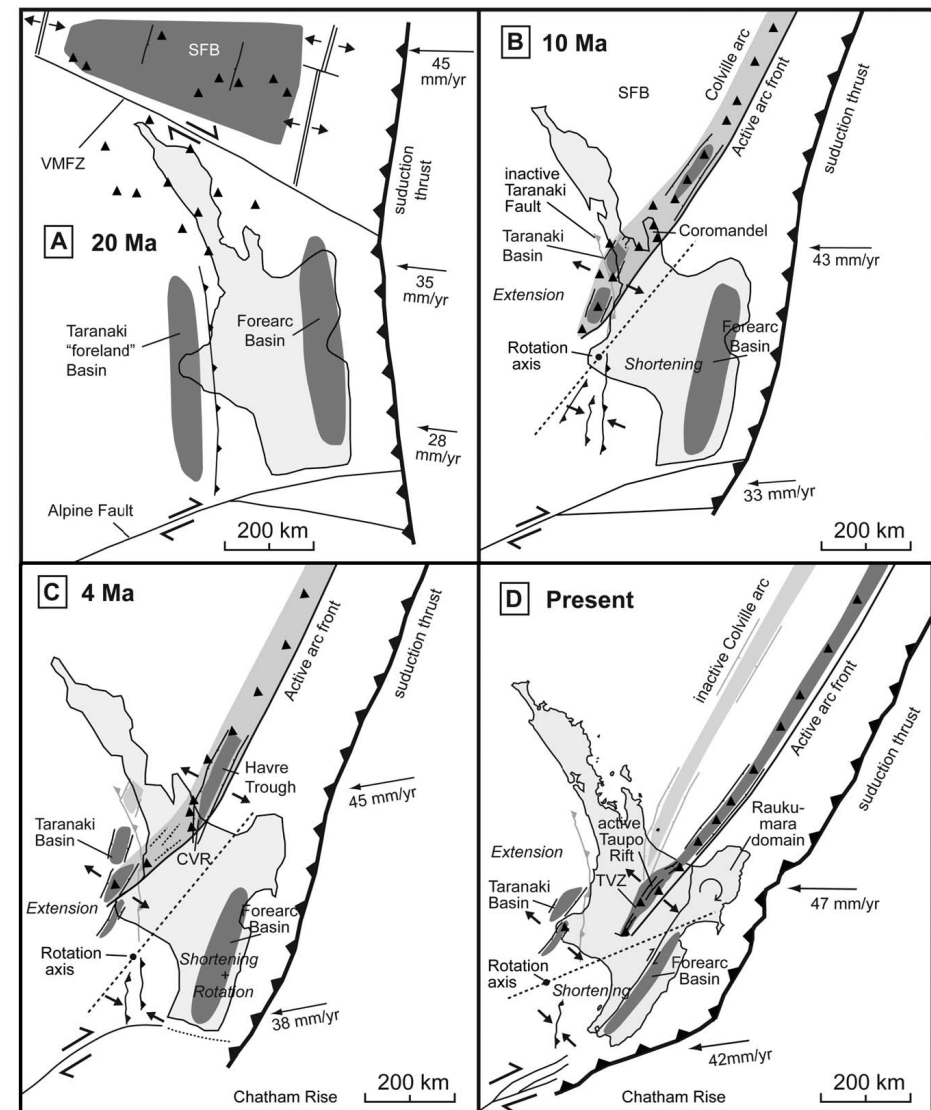


# Tectonics

- Strike-slip Waipa Fault to west, though seems to have dip-slip motion through Waikato
- Hakarimata Range displaced to north
- Eastern boundary ?, but have opening of Hauraki Graben further east
- Accommodation zone between different movements?
- Largely extensional, though more reverse faults in east, hence compression against basement ridge?
- Faulting more intense in northern basin over basement low.
- Southern margin difficult ...



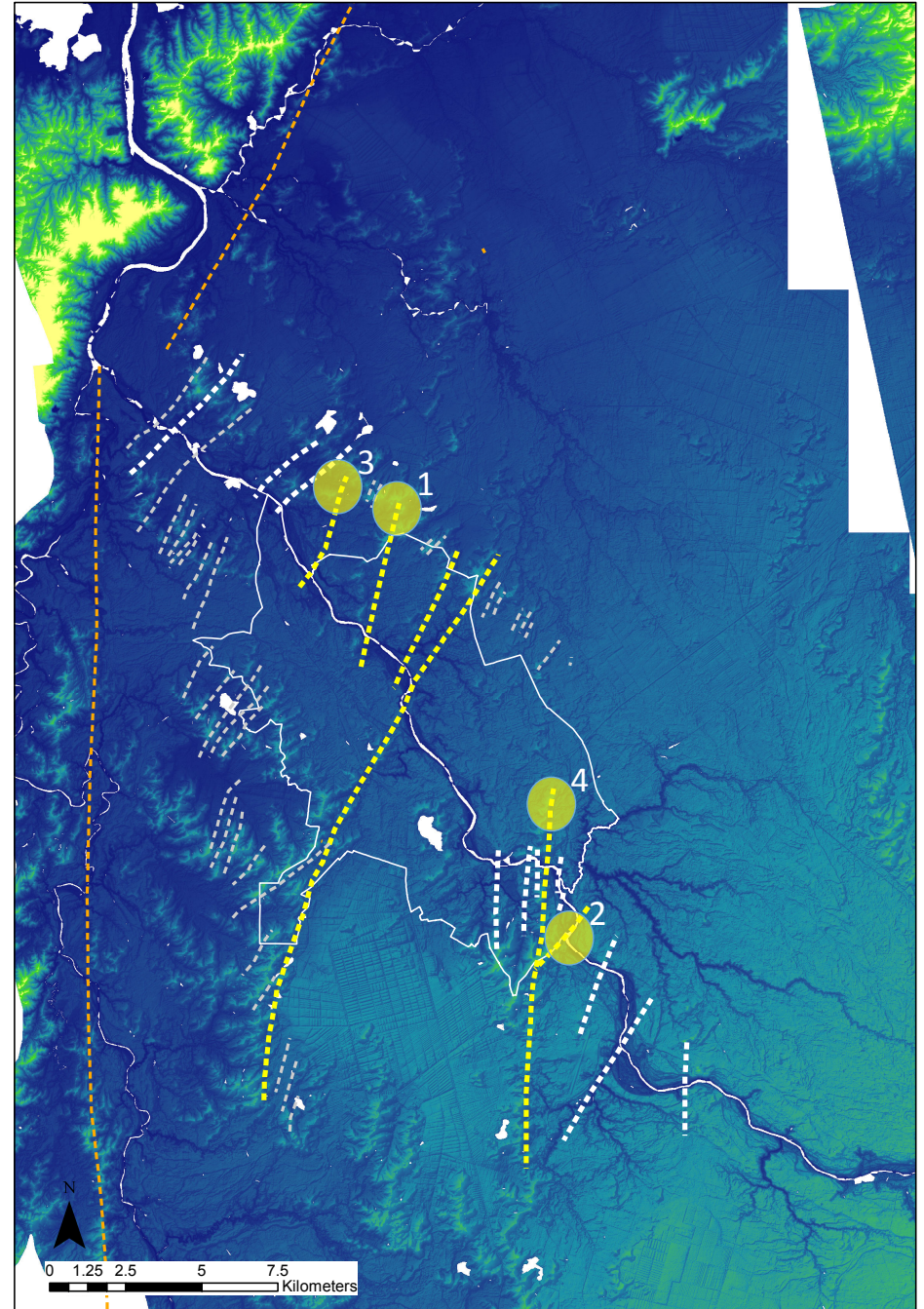
GIBA ET AL.: TARANAKI BASIN EVOLUTION





# Detailed sites

- Examining specific sites gives information on timing.
- We will consider:
  1. Kay Road
  2. Stubbs Road
  3. Osborne Road
  4. University / Ruakura

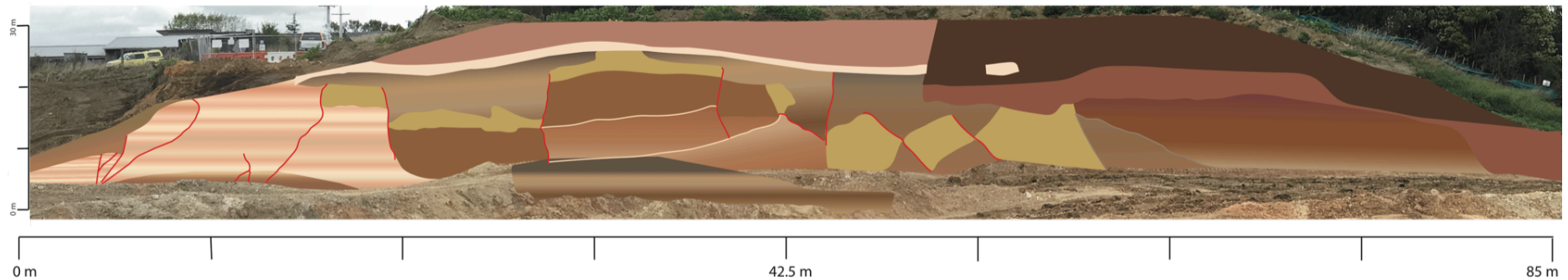


# Kay Road



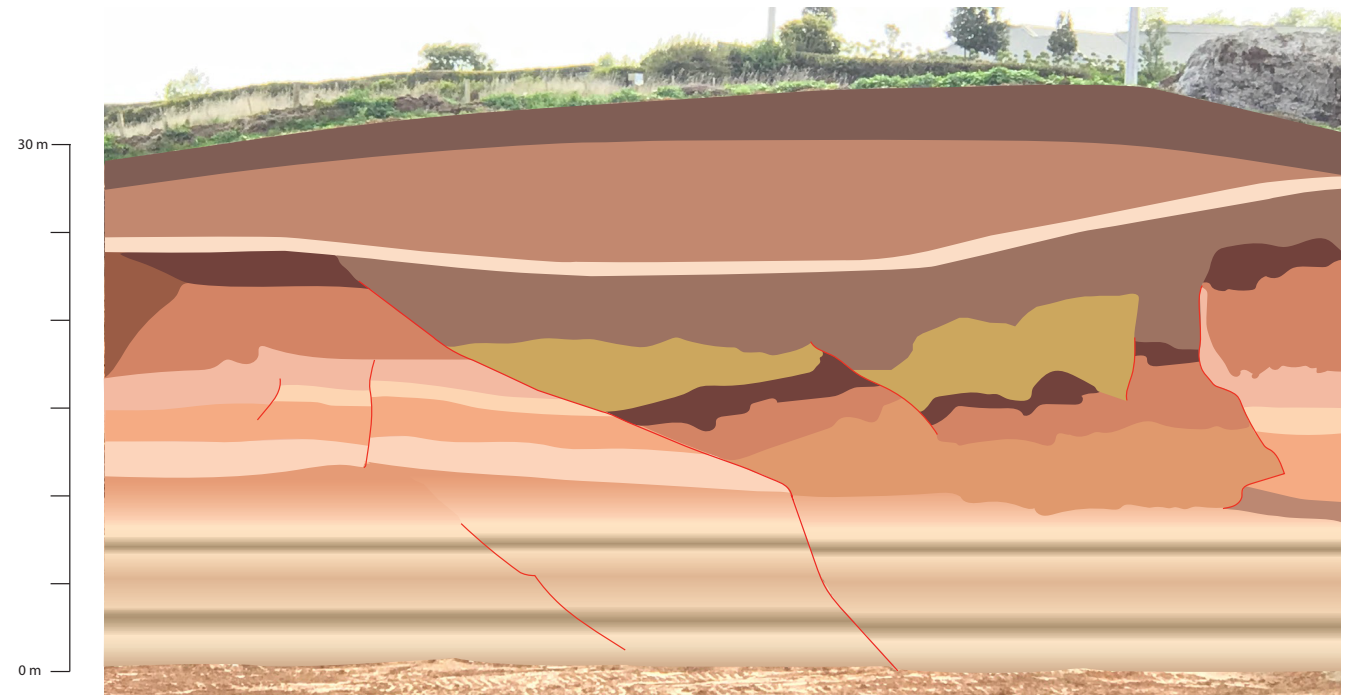
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- Complex fault zone
- Mostly steeply dipping normal faults.
- Some lower angle (thrusts?)
- Greater than 5 m throw on individual faults





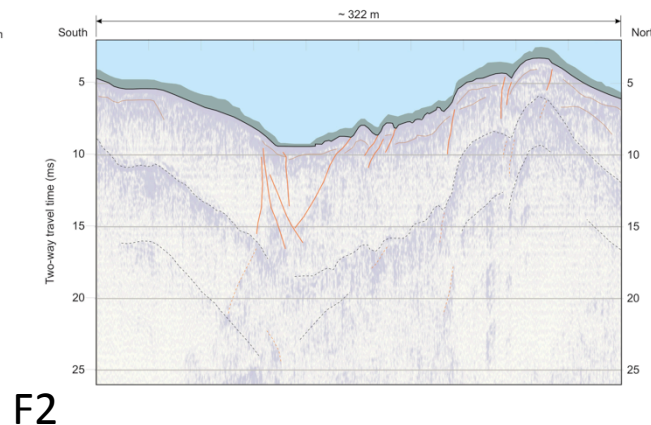
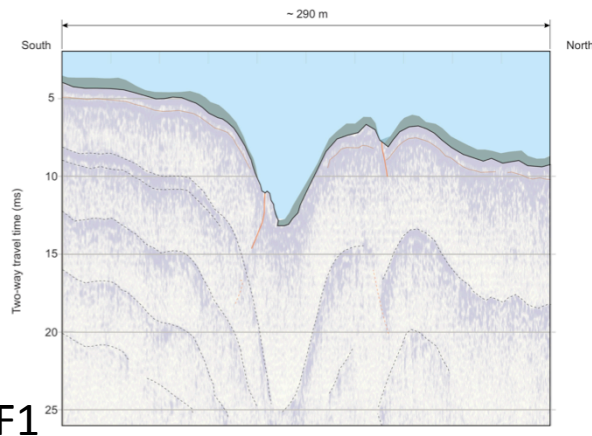
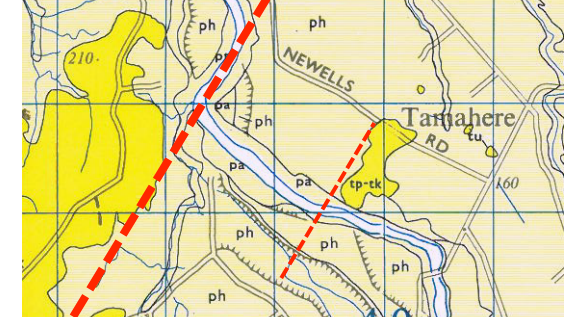
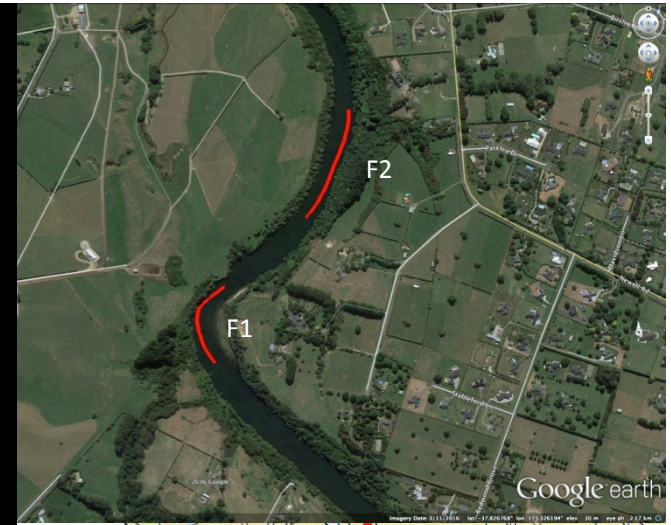
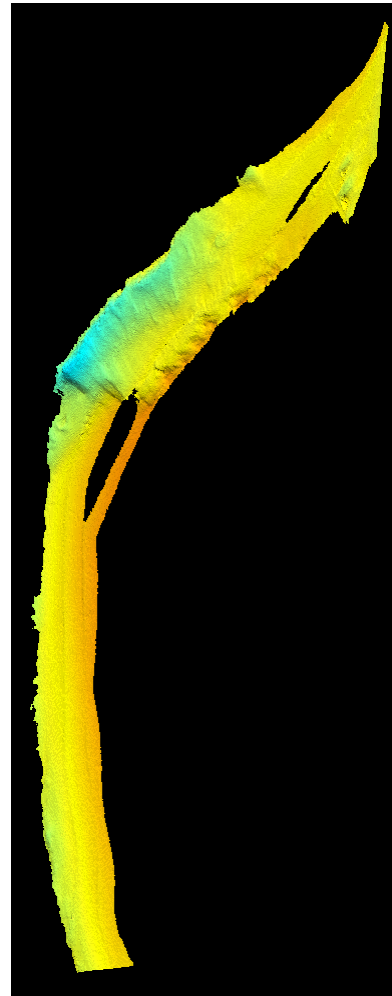
# Kay Road



- Key point is that Rangitawa Tephra (lowest layer of Hamilton Ashes) is **undisturbed**.
- This layer is ~350,000 years, indicating that these faults are inactive in terms of NZ definition.

# Stubbs Rd

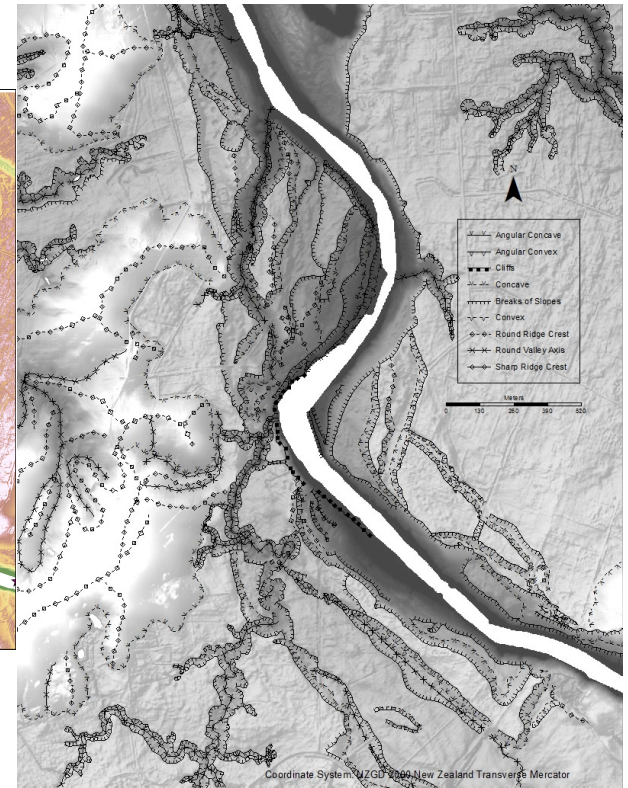
- Scour hole within river with offset scarp
- Multiple traces on sub-bottom profile





# Stubbs Rd

- Inconsistent terraces flanking river
- Abandoned river channel(s) & impoundment?
- LiDAR & resistivity survey of terraces indicate faulting
- Fault identified in riverbank mapping









# Osborne Road



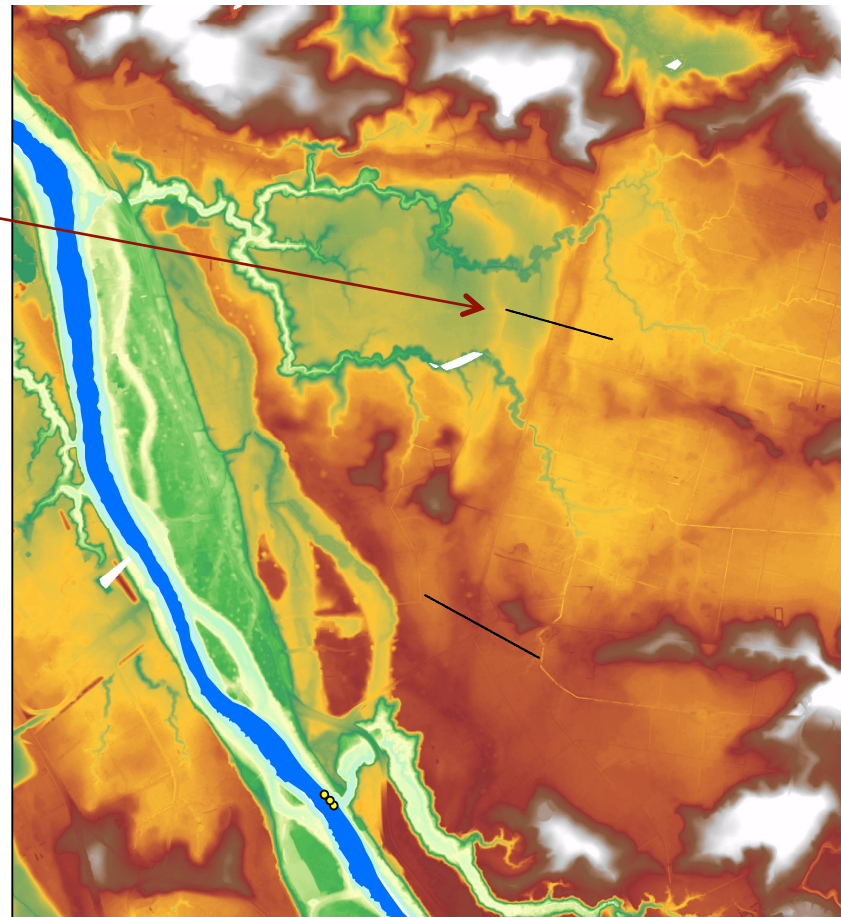
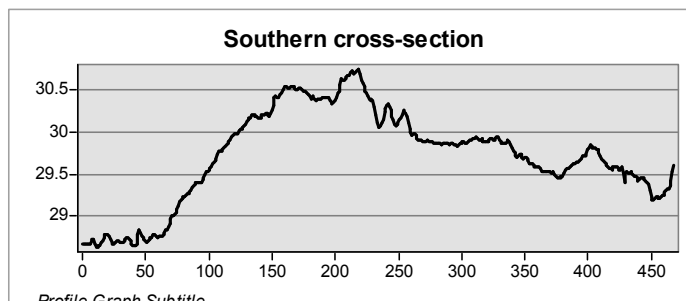
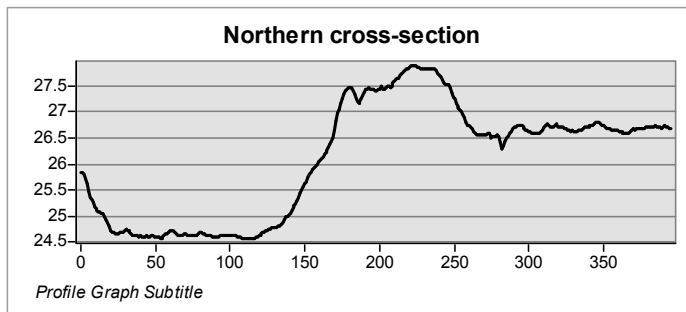
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Osborne Rd located on upthrown side of fault

## Legend

- Fault traces
- High : 64.7908
- Low : 9.12676

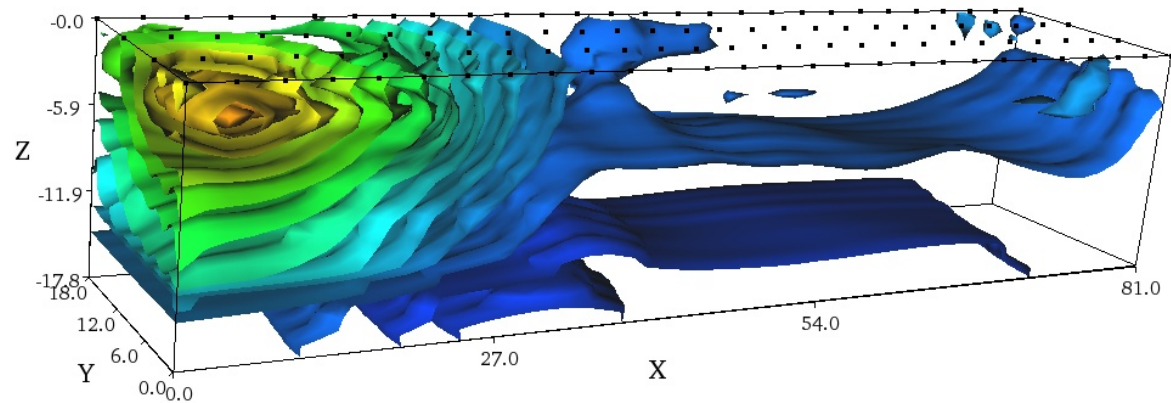


# 3D resistivity

- Appears to be a small fault that displaces 16 ka Hinuera Surface.
- Possible location for trenching.



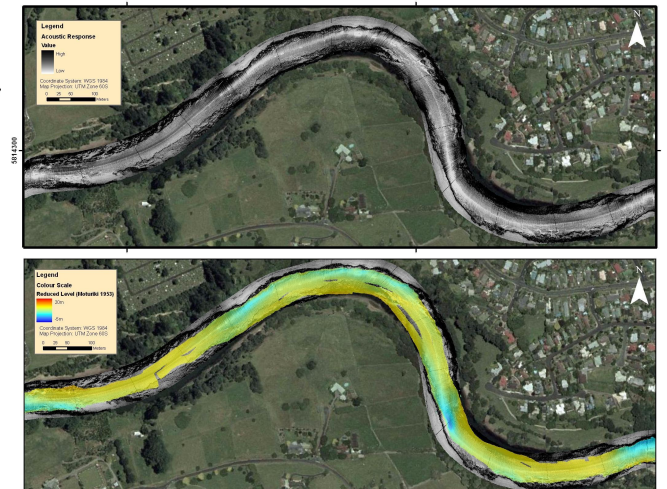
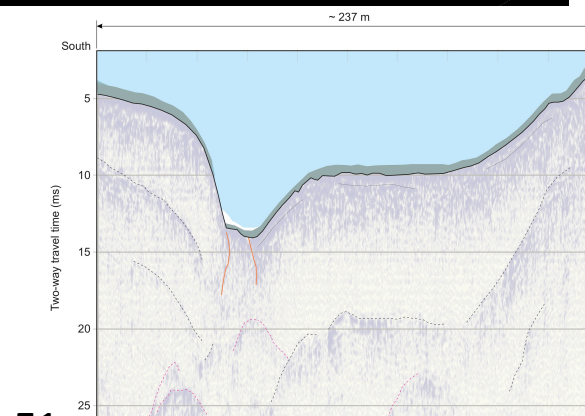
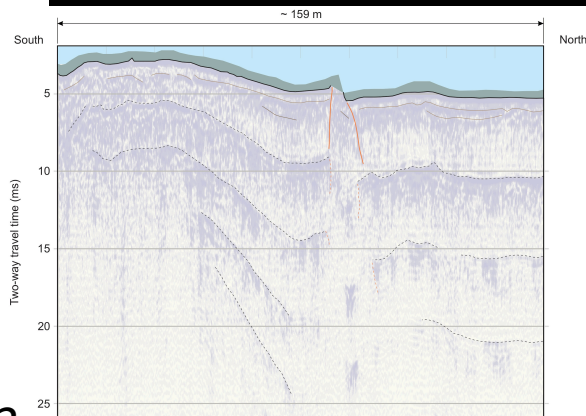
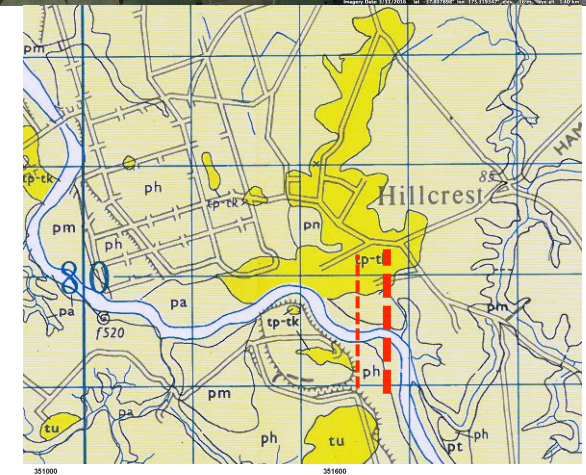
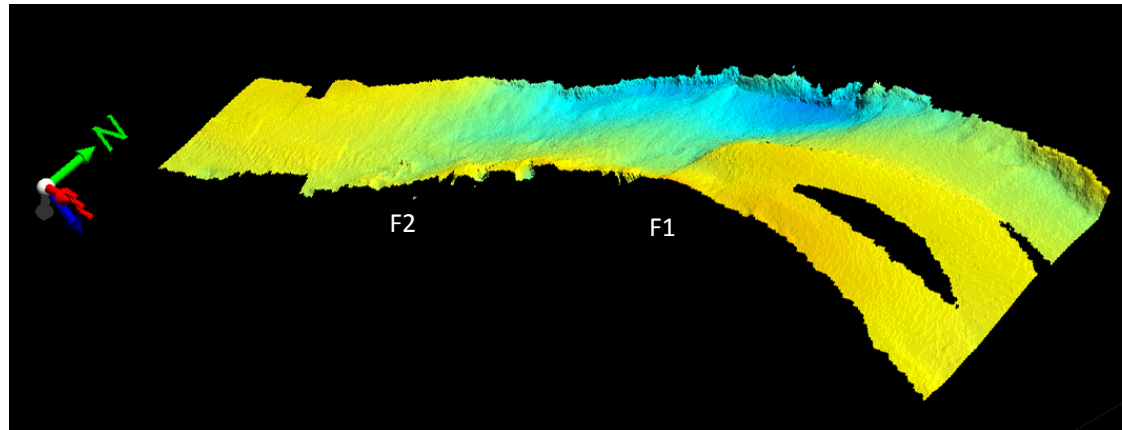
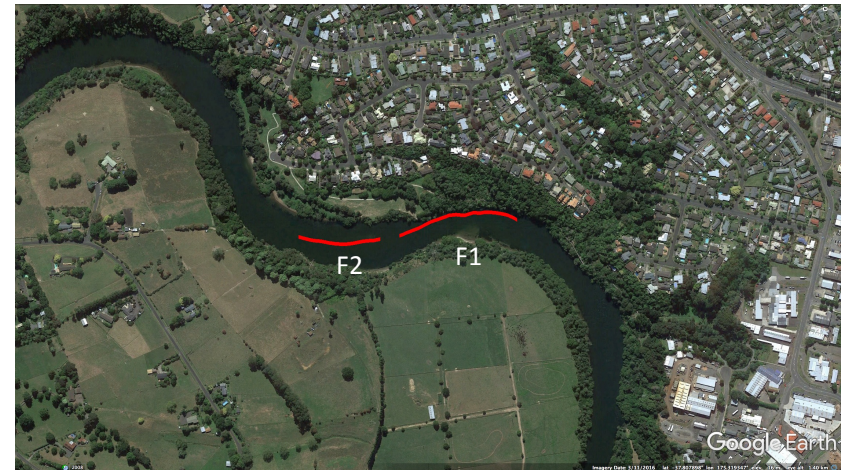
3D Resistivity Contour Plot





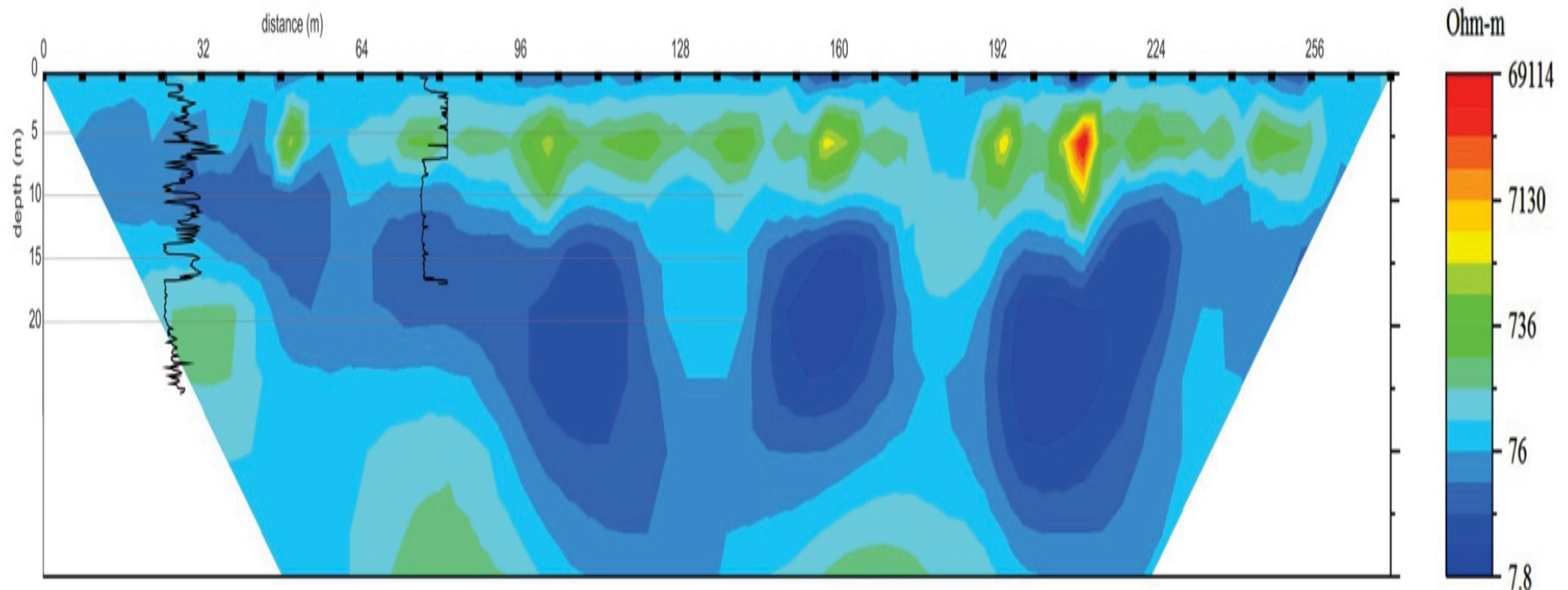
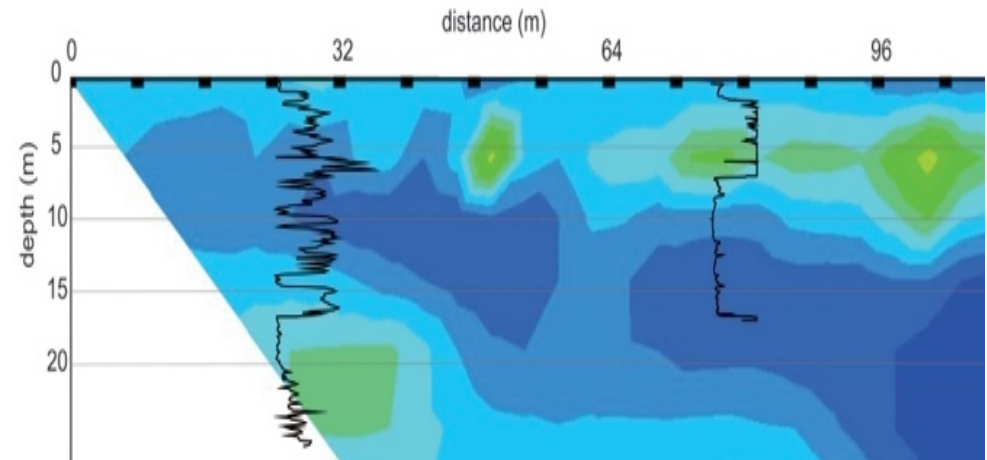
# University / Ruakura

- Multiple faults evident within river bed near Hammond Park
- Abandoned river channel on left bank



# University / Ruakura

- Have CPT and resistivity data from Inland Port.
- CPT traces correlate with resistivity



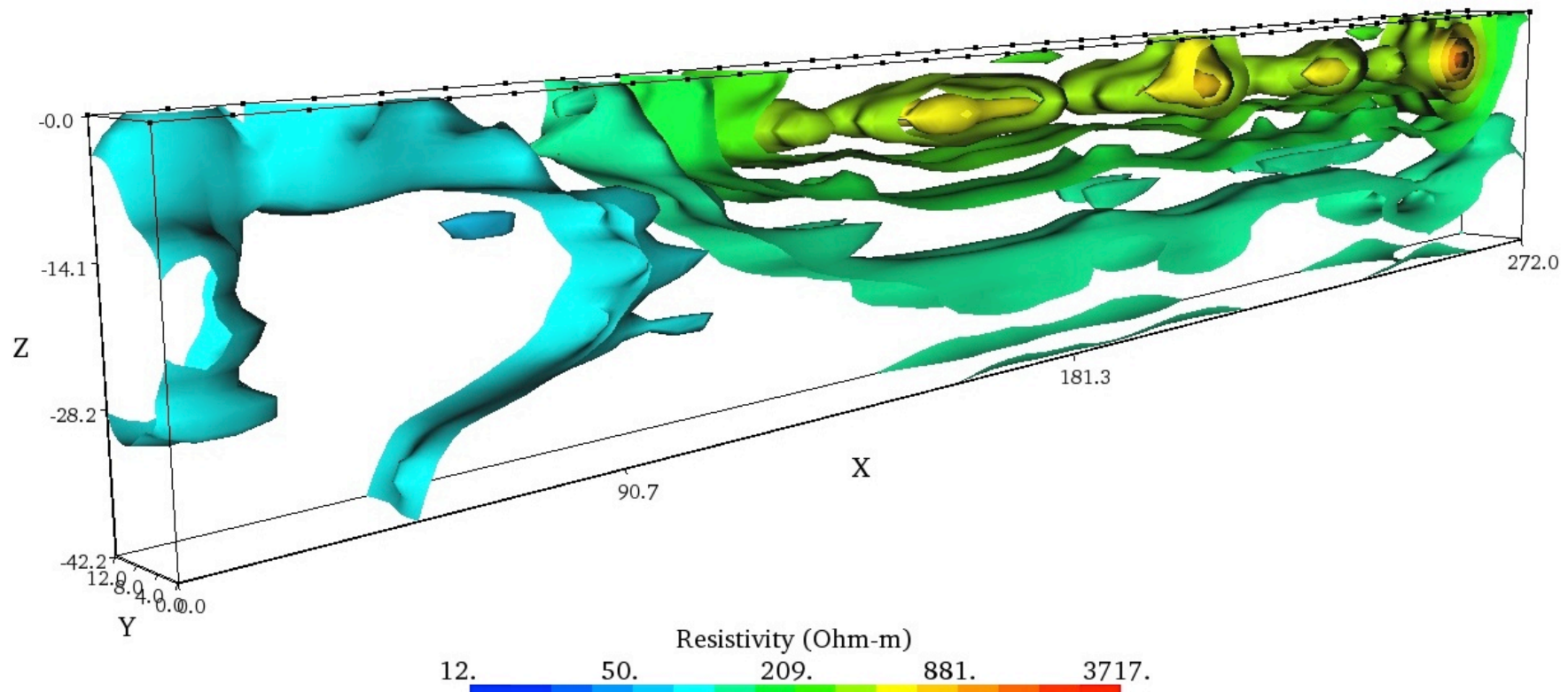


# 3D resistivity



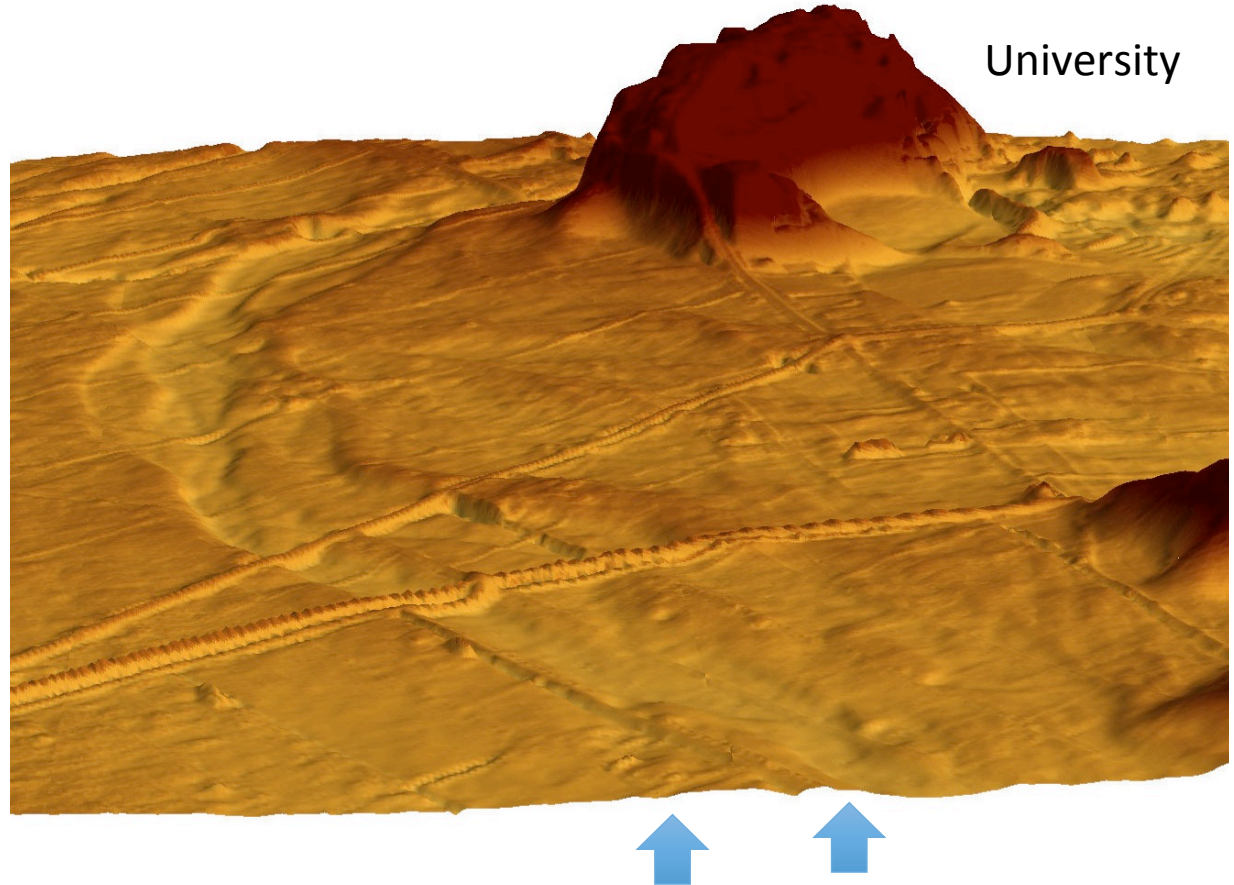
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- 3D reconstruction shows fault within Hinuera sediments



# University / Ruakura

Vertically exaggerated  
LiDAR image looking  
south

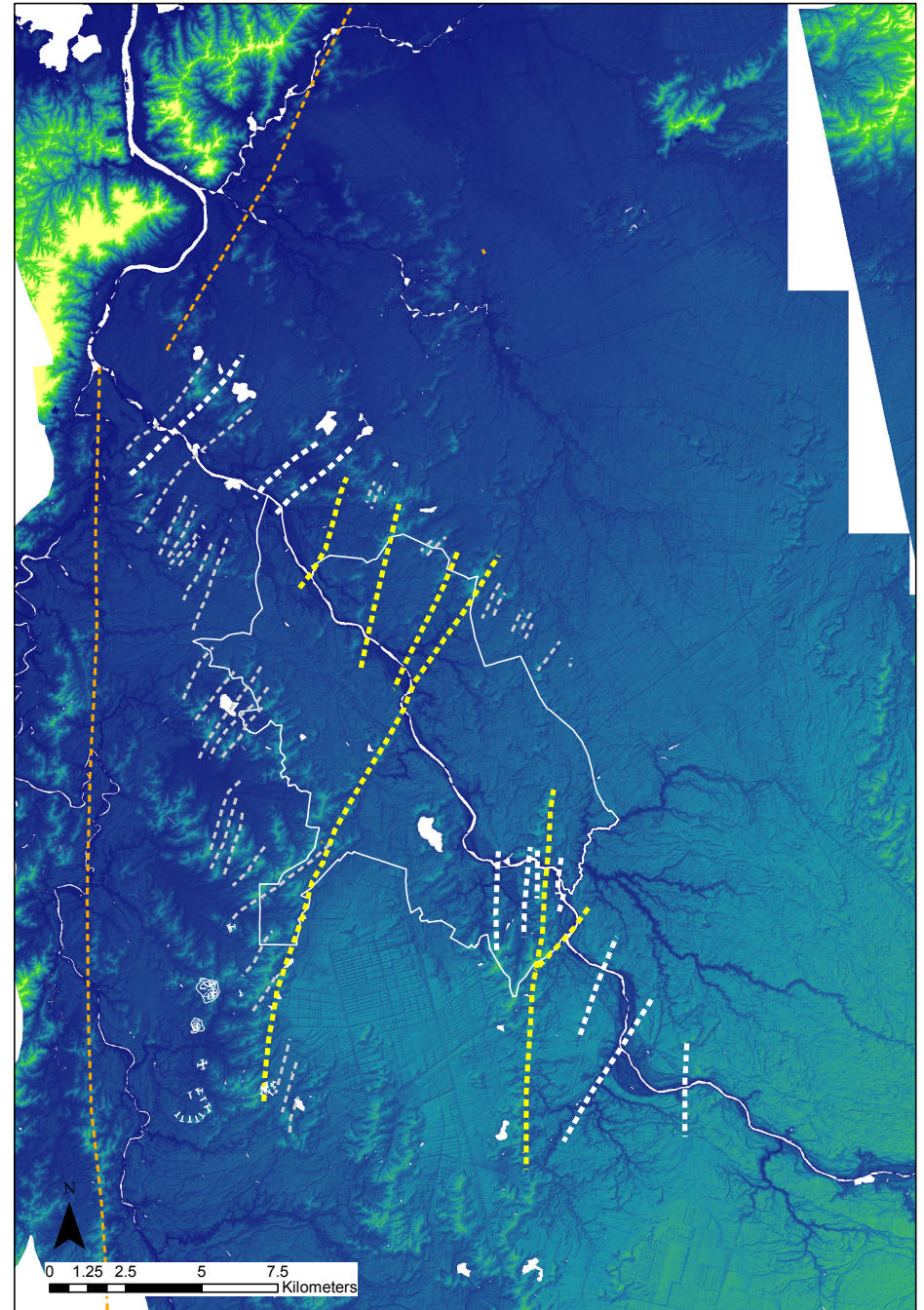
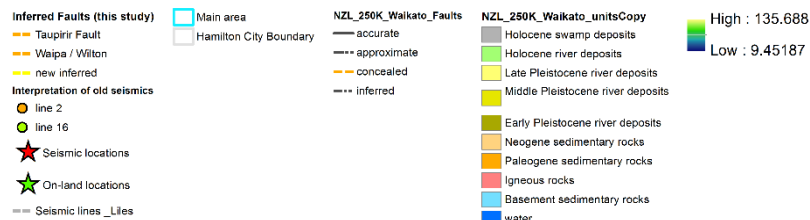


- Can trace a possible fault zone through geomorphology.
- Needs ground truth to be sure.



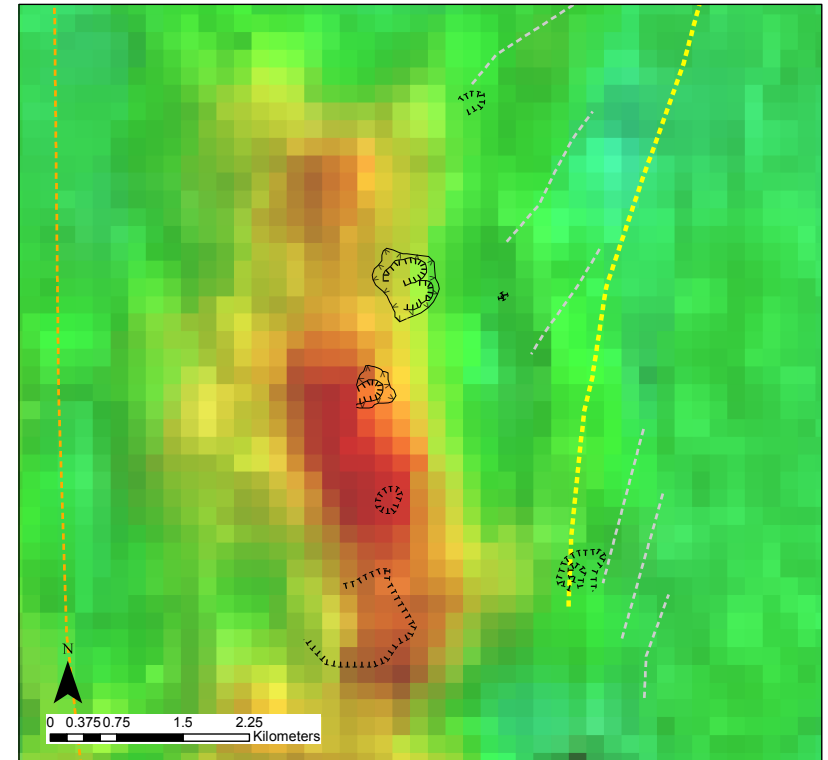
# Volcanic field

- Small volcanic field recognised on maps in 1960s.
- Removed from more recent maps, but present in:
  - Geomorphology
  - Aeromagnetics
- Age?



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100

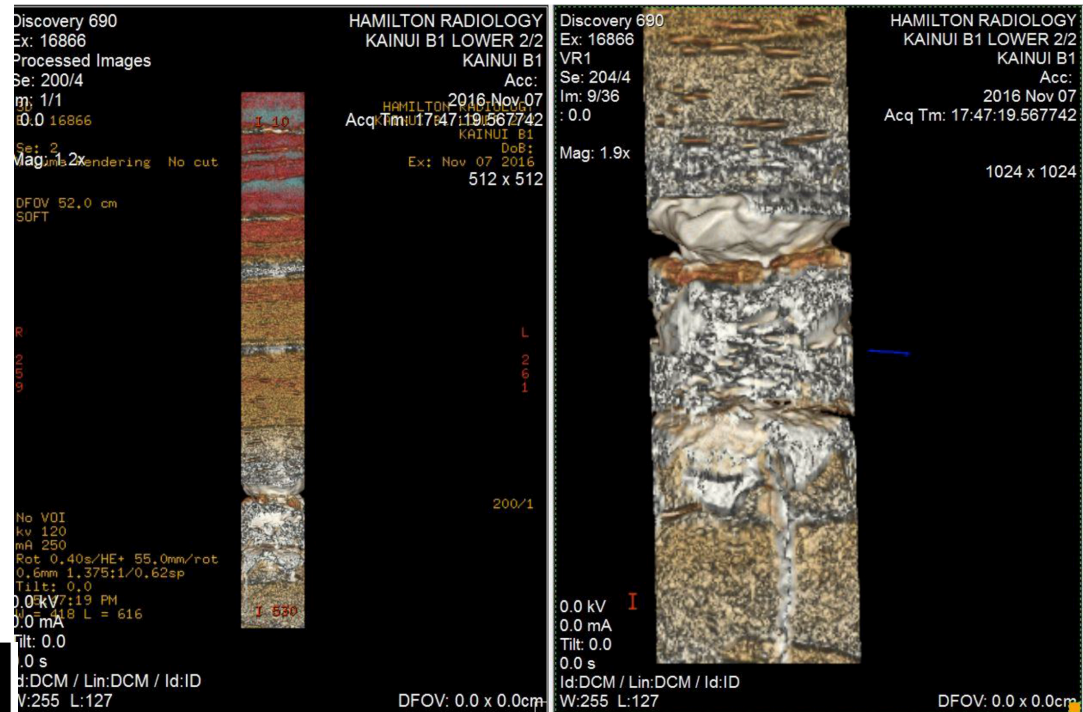
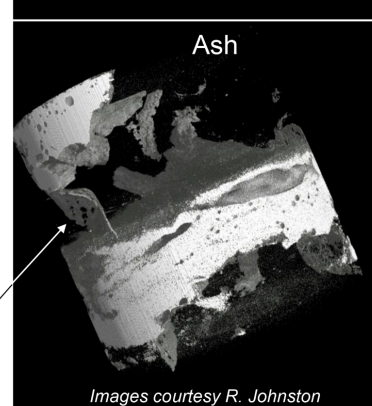
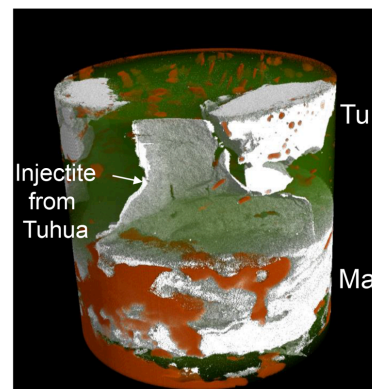
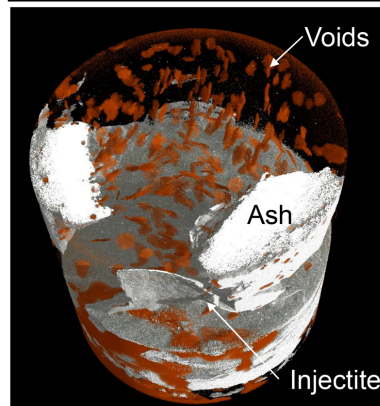
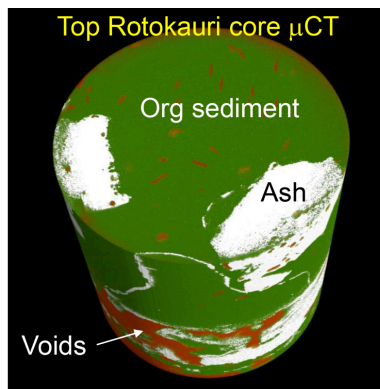


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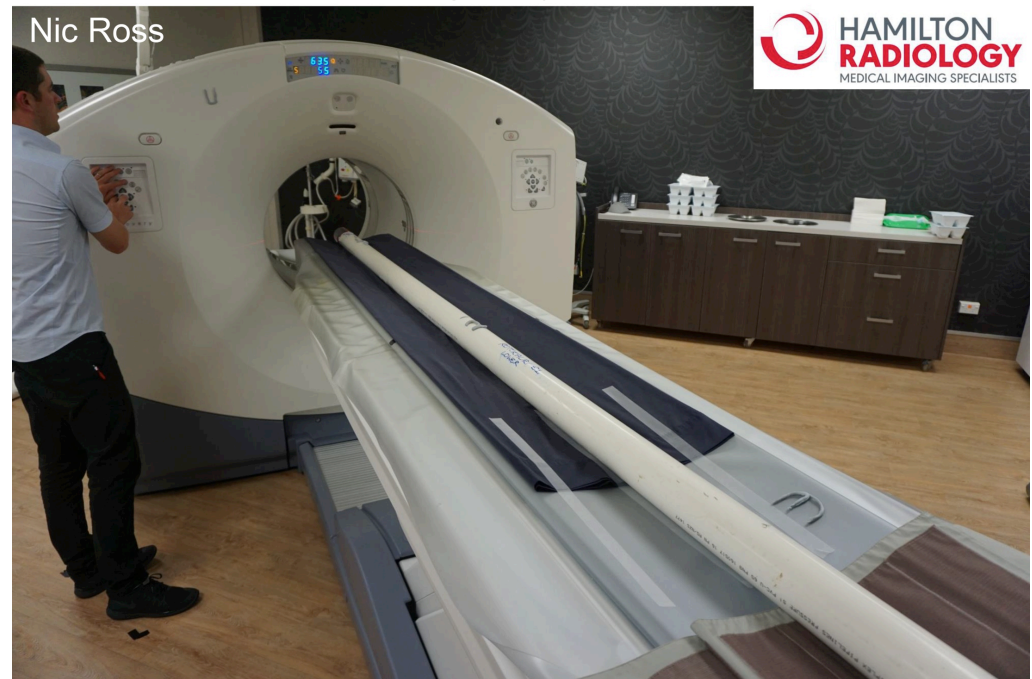
[illegible]

# Tephra seismites

- CT & micro-CT can identify seismites & may provide dates for the events causing liquefaction



Images courtesy N. Ross

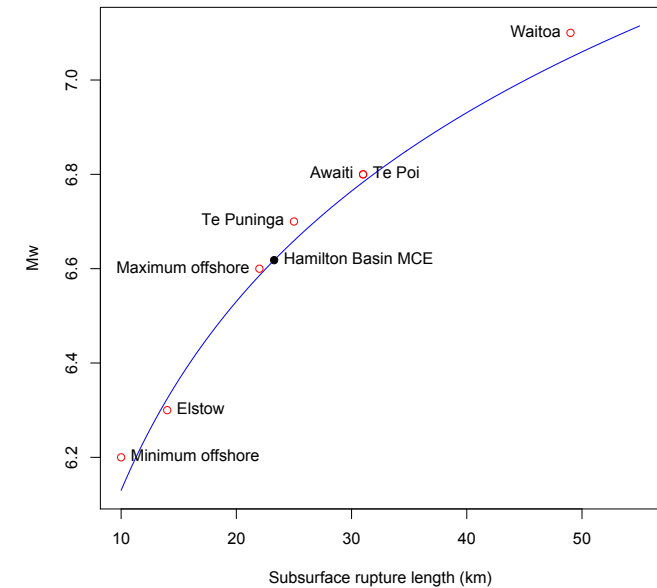




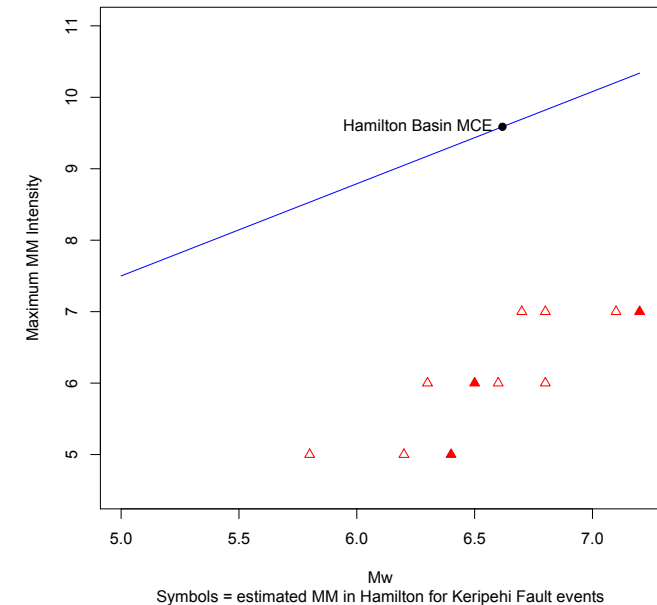
# MCE Mw & MM Intensity

- Following methodology of Persaud *et al* (2016) for Kerepehi Fault, we can estimate maximum earthquake (MCE) magnitude ( $M_w$ ) & Modified Mercalli (MM) shaking intensity
  - MCE  $M_w = 6.6$
  - MCE maximum MM = 9 to 10
    - This is higher than expected MM intensity for Hamilton due to an event on the Kerepehi Fault
    - Current seismic risk for Hamilton Basin gives annual probability of 0.0025% for  $MM \geq 9$

Magnitude versus rupture length - Kerepehi Fault



Modified Mercalli Intensity versus moment magnitude - New Zealand



Symbols = estimated MM in Hamilton for Kerepehi Fault events

Intensity	CAP Severity	Modified Mercalli Level	Description
unnoticeable  weak light moderate	Minor	MM 1 - imperceptible	Barely sensed only by a very few people.
		MM 2 - scarcely felt	Felt only by a few people at rest in houses or on upper floors.
		MM 3 - weak	Felt indoors as a light vibration. Hanging objects may swing slightly.
		MM 4 - light	Generally noticed indoors, but not outside, as a moderate vibration or jolt. Light sleepers may be awakened. Walls may creak, and glassware, crockery, doors or windows rattle.
		MM 5 - moderate	Generally felt outside and by almost everyone indoors. Most sleepers are awakened and a few people alarmed. Small objects are shifted or overturned, and pictures knock against the wall. Some glassware and crockery may break, and loosely secured doors may swing open and shut.
strong	Moderate	MM 6 - strong	Felt by all. People and animals are alarmed, and many run outside. Walking steadily is difficult. Furniture and appliances may move on smooth surfaces, and objects fall from walls and shelves. Glassware and crockery break. Slight non-structural damage to buildings may occur.
severe	Severe	MM 7 - damaging	General alarm. People experience difficulty standing. Furniture and appliances are shifted. Substantial damage to fragile or unsecured objects. A few weak buildings are damaged.
		MM 8 - heavily damaging	Alarm may approach panic. A few buildings are damaged and some weak buildings are destroyed.
	Extreme	MM 9 - destructive	Some buildings are damaged and many weak buildings are destroyed.
		MM 10 - very destructive	Many buildings are damaged and most weak buildings are destroyed.
		MM 11 - devastating	Most buildings are damaged and many buildings are destroyed.
		MM 12 - completely devastating	All buildings are damaged and most buildings are destroyed.

# Summary

- Multiple fault zones located within Hamilton Basin
  - Listric normal faulting
- Hamilton Hills interpreted as back-tilted blocks bounded by faults
- Inferred maximum earthquake
  - $M_w = 6.6$
  - $MM = 9 - 10$
- Ongoing projects to better characterise frequency & magnitude



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Waikato Expressway – Kay Rd cutting



# Acknowledgements



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- Funding support has been provided by:
  - EQC
  - Waikato Regional Council
  - University of Waikato

