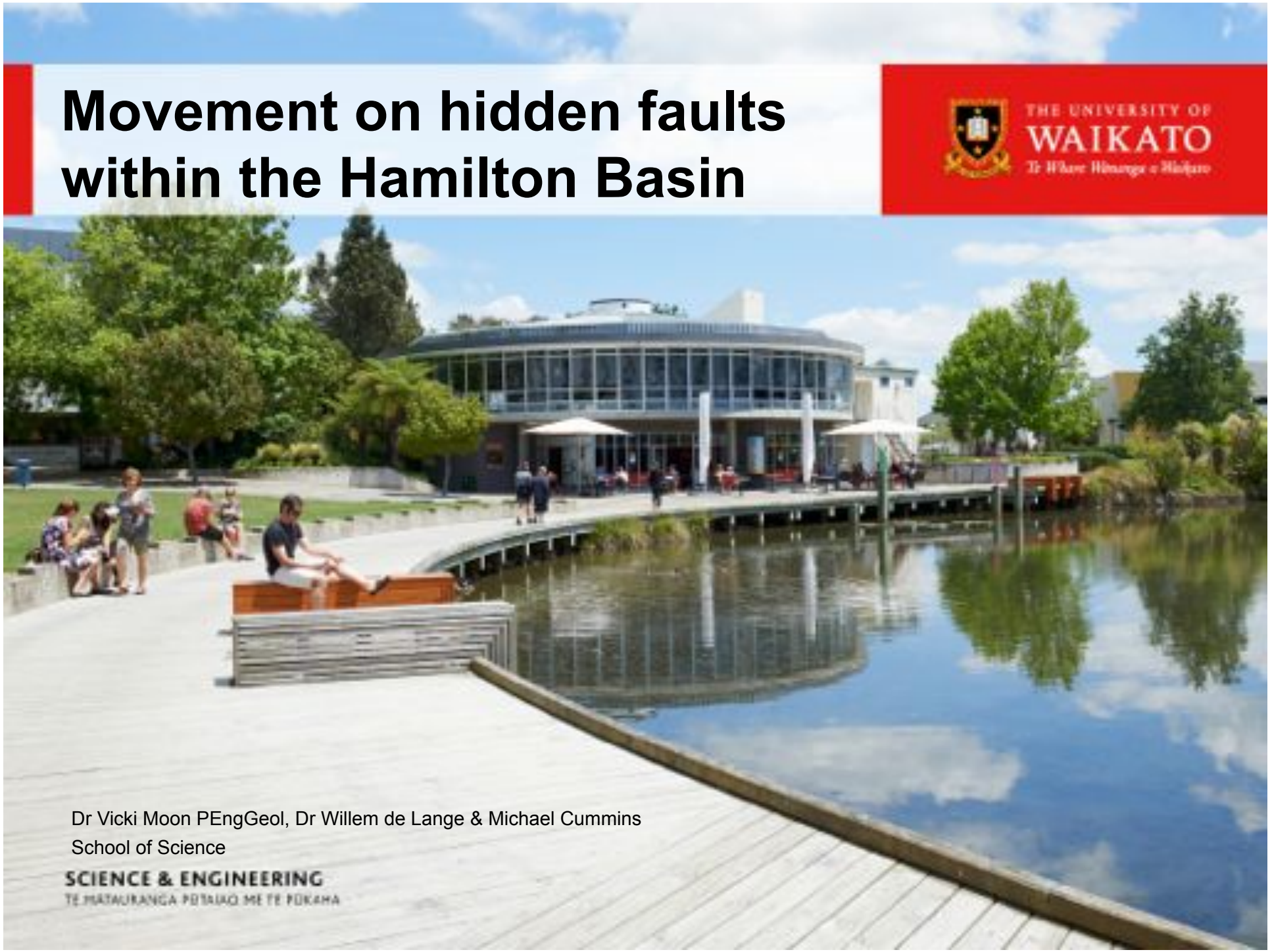
# Movement on hidden faults within the Hamilton Basin



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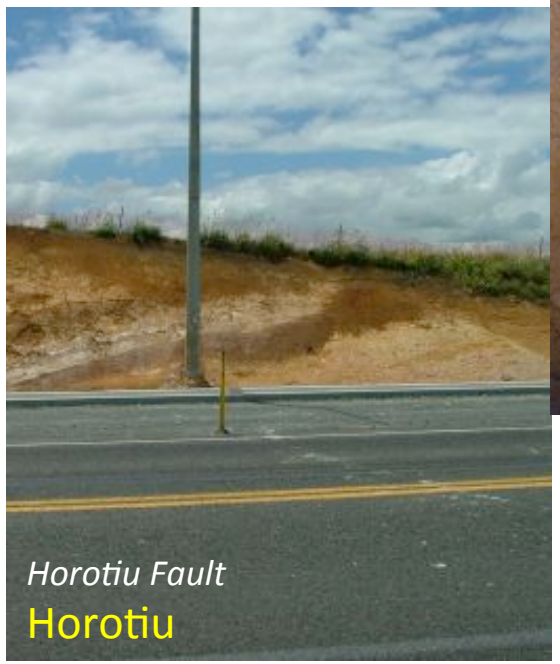
# Introduction

- In May 2015 we presented evidence suggesting
  - 3 fault zones within Hamilton City
  - 1 fault zone at Horotiu
- We had limited data to determine frequency or magnitude
- Suggested next step was seismic survey along Waikato River
- So where are we now?

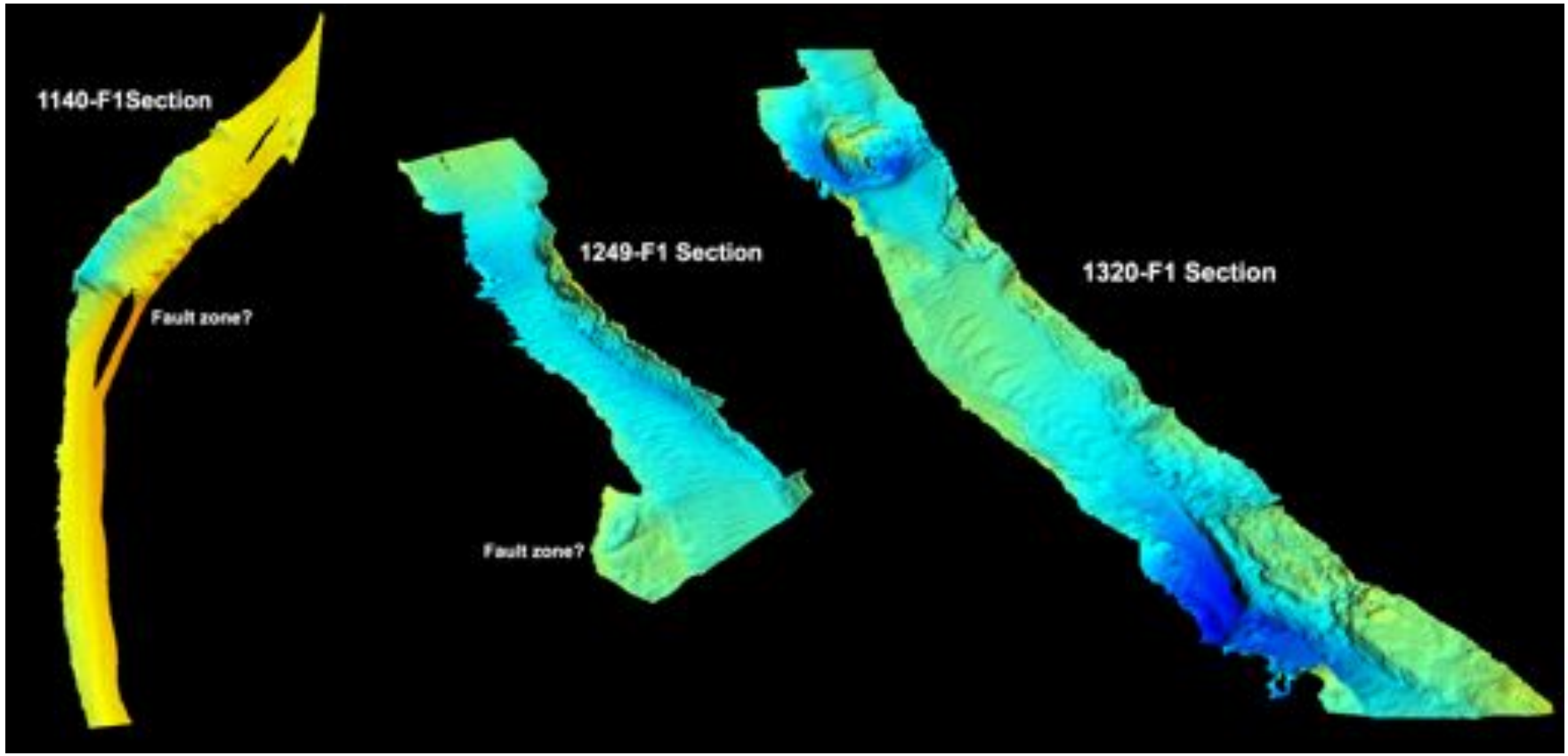





Variable expression of surface faults within Hamilton Basin

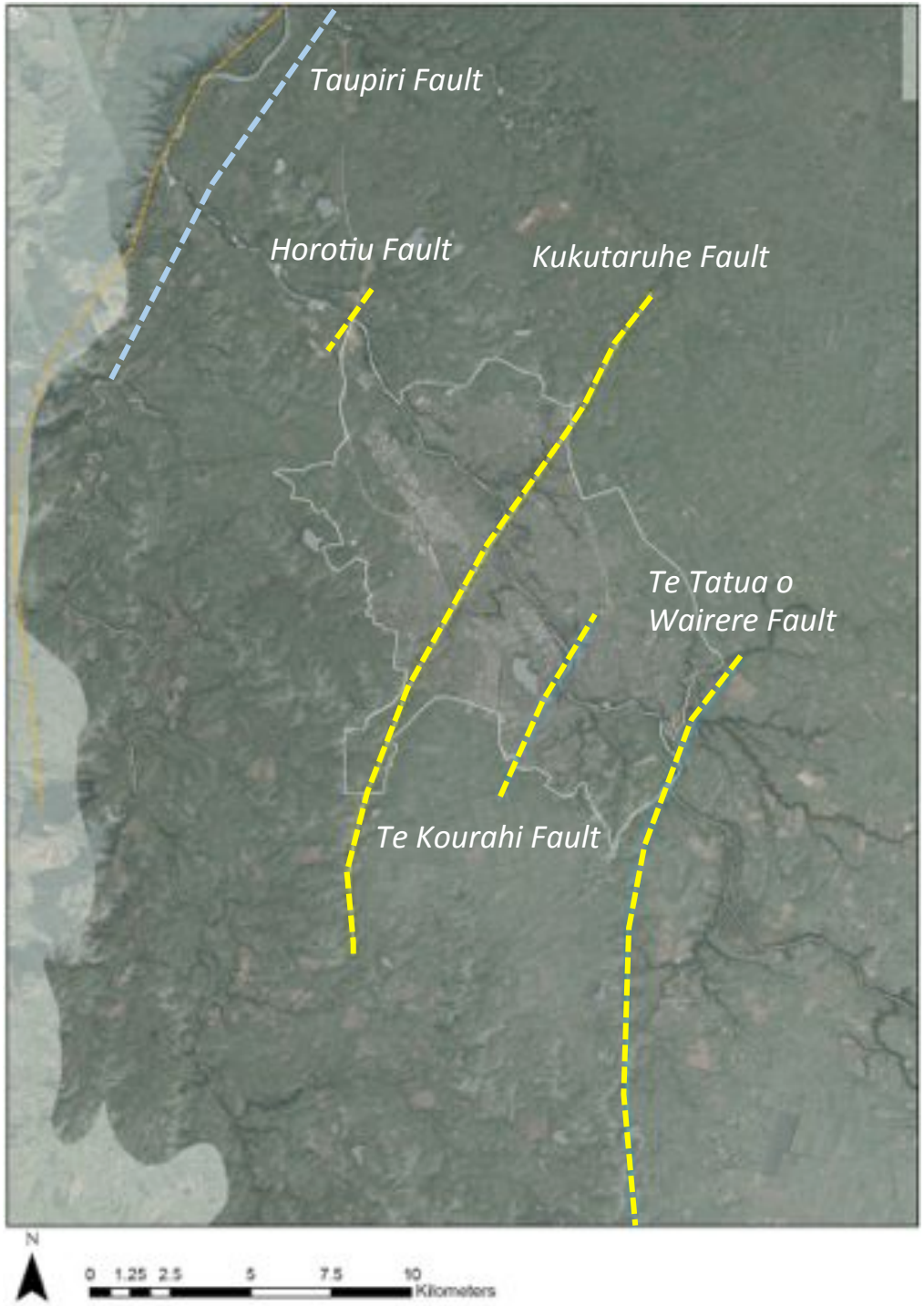
# Multibeam & sidescan survey

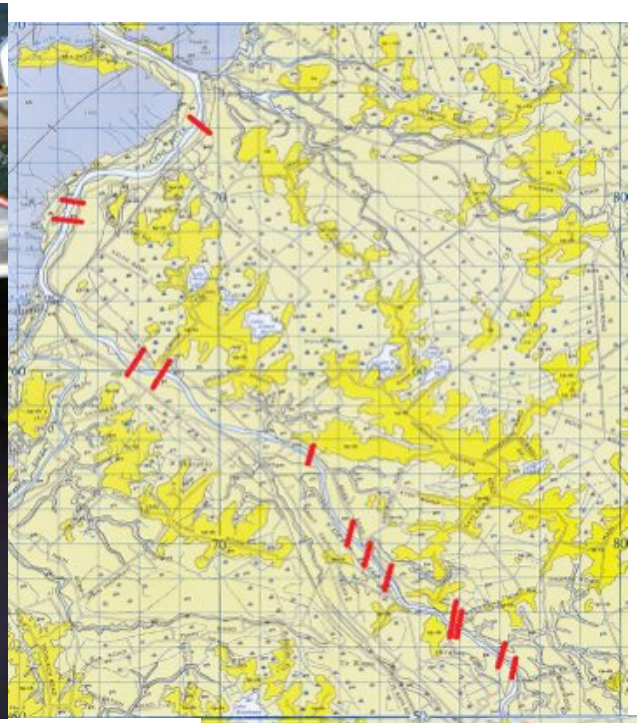
- Data acquired in 2005 indicated “scour holes” consistent with faulted resistant strata, suggesting shallow seismic survey could detect fault zones.



# Waikato River seismic survey

- 4 potential fault zones thought to cross river
  1. Templeview to Rototuna
  2. Hamilton CBD
  3. Between airport (Rukahia) & University
  4. Horotiu
- Known boundary fault along margin of Hakarimata Ranges
  - *Taupiri Fault*
- Undertook seismic survey from Cambridge to Taupiri





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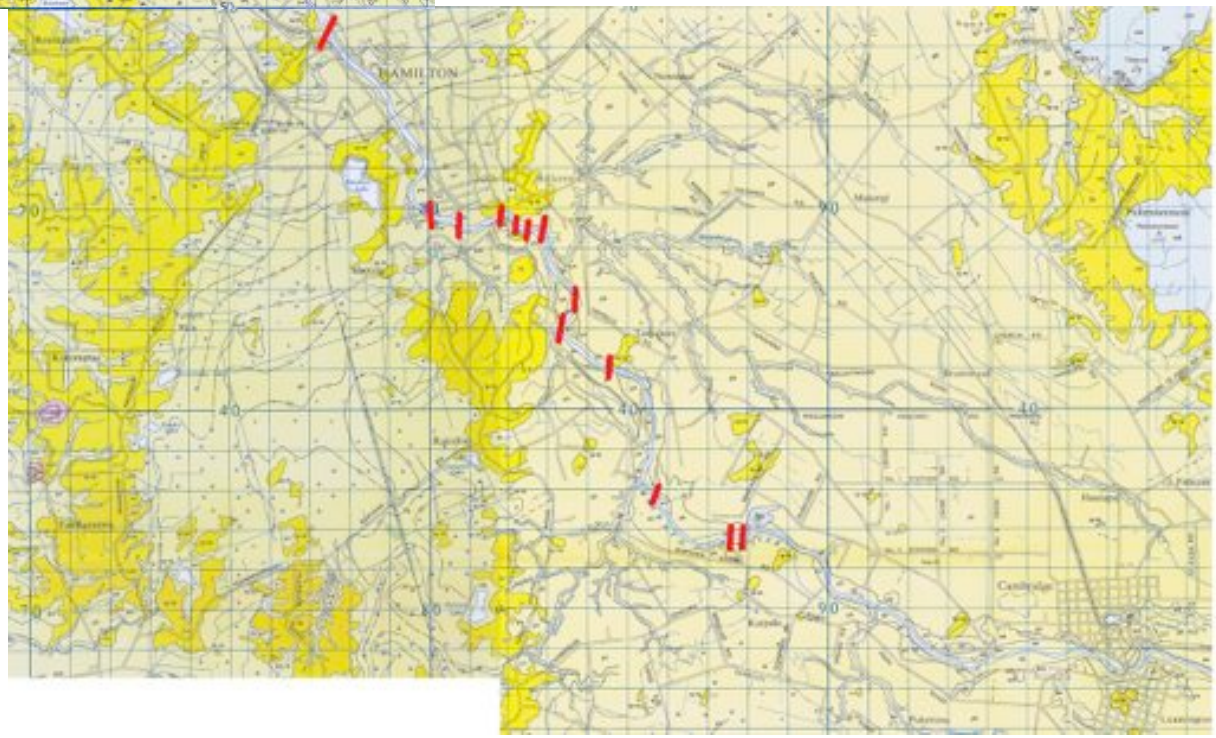
# Potential fault zones after seismic survey

- Seismic survey identified many potential faults along Waikato River
- Those indicated on map are zones that correlate with other indicators of faulting

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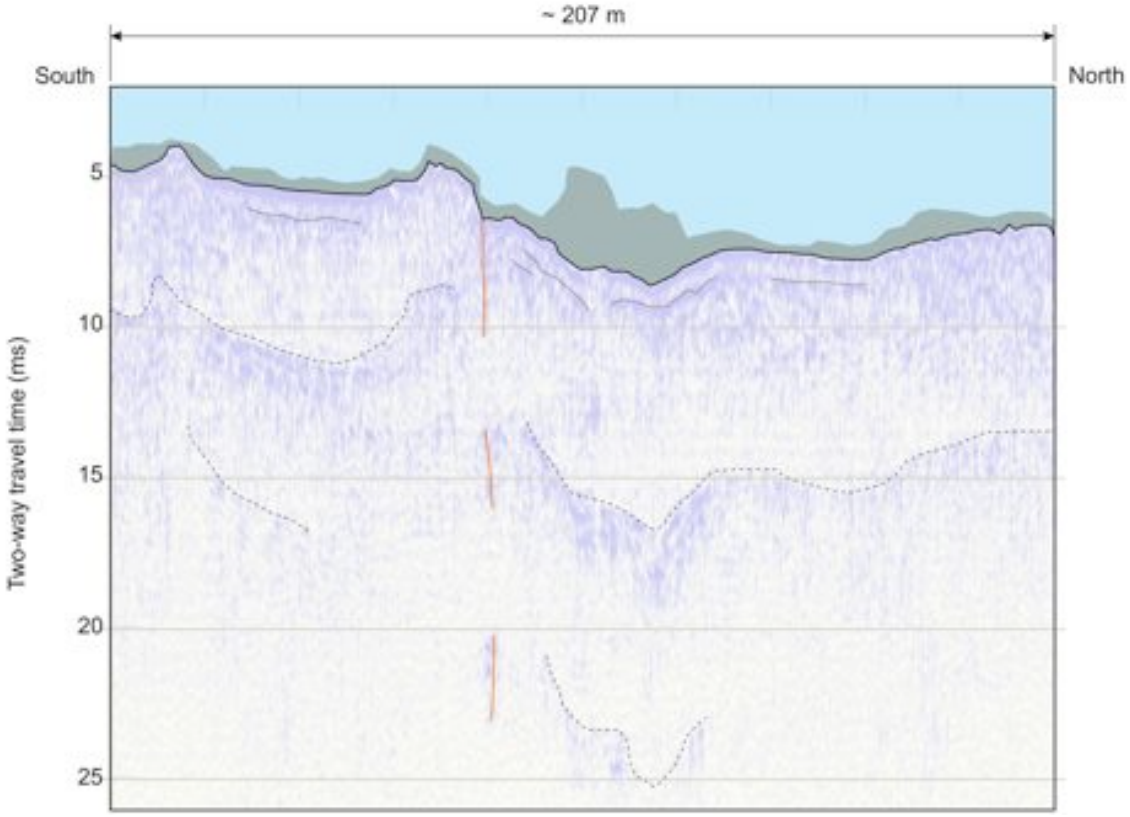
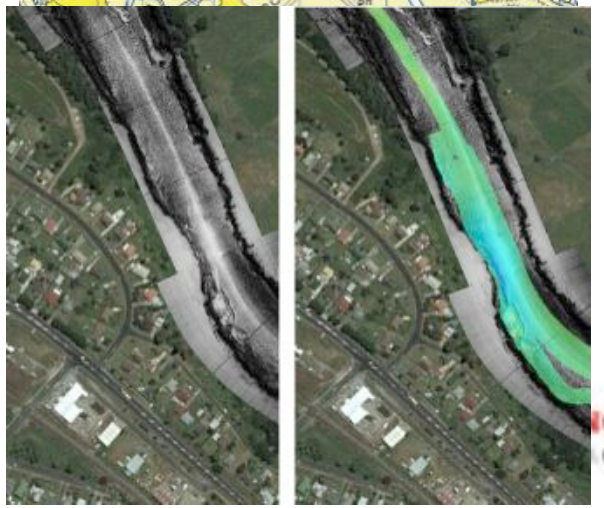
# Taupiri Fault

- Known major boundary fault zone flanking Hakirimata Ranges

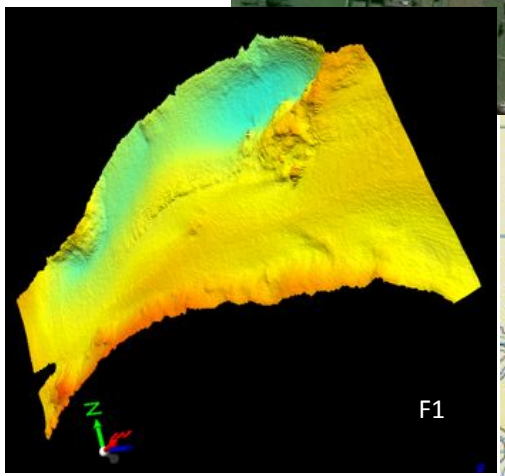





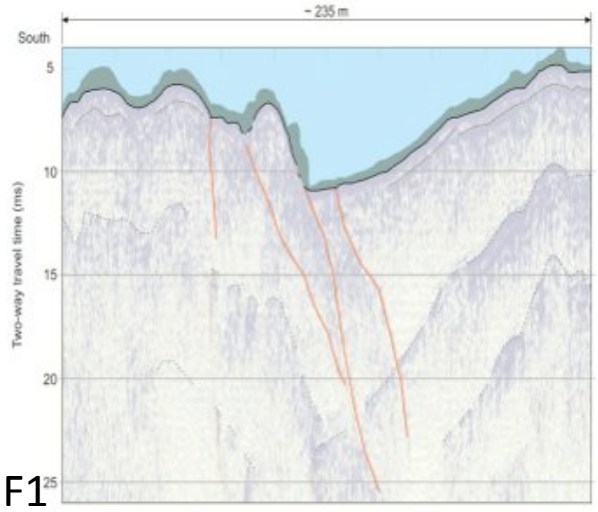


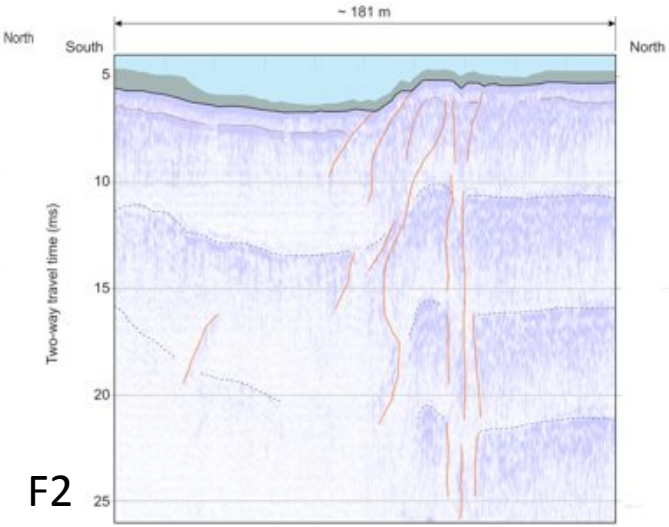
# Mystery Creek

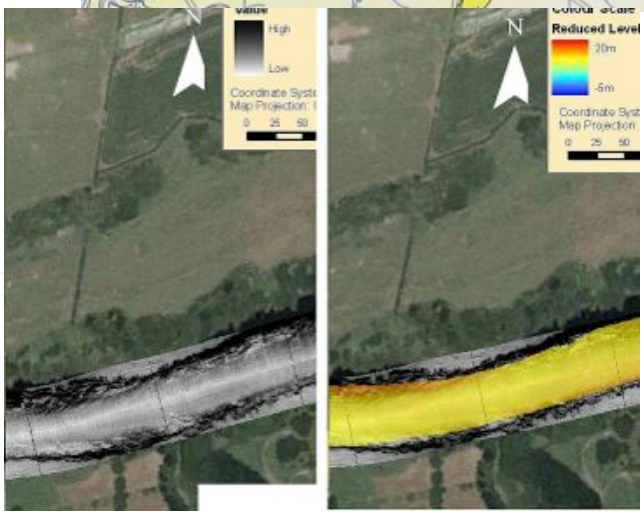
- Outcrop of basement greywacke
- Inconsistent terraces flanking river
- “Scour hole” & outcrop in river bed





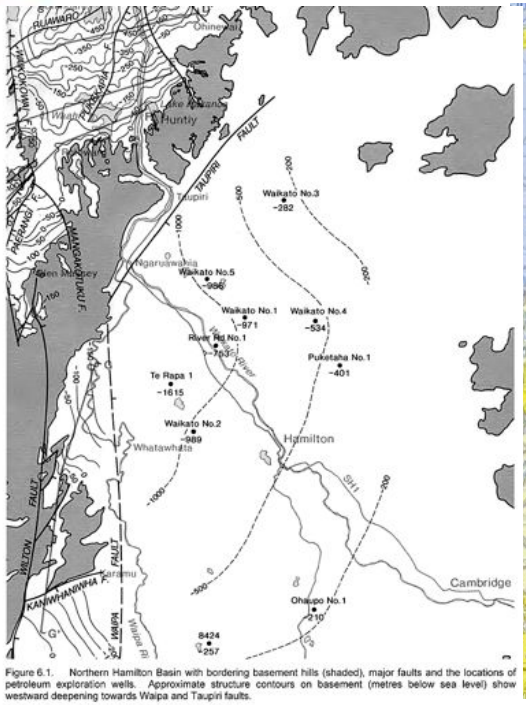
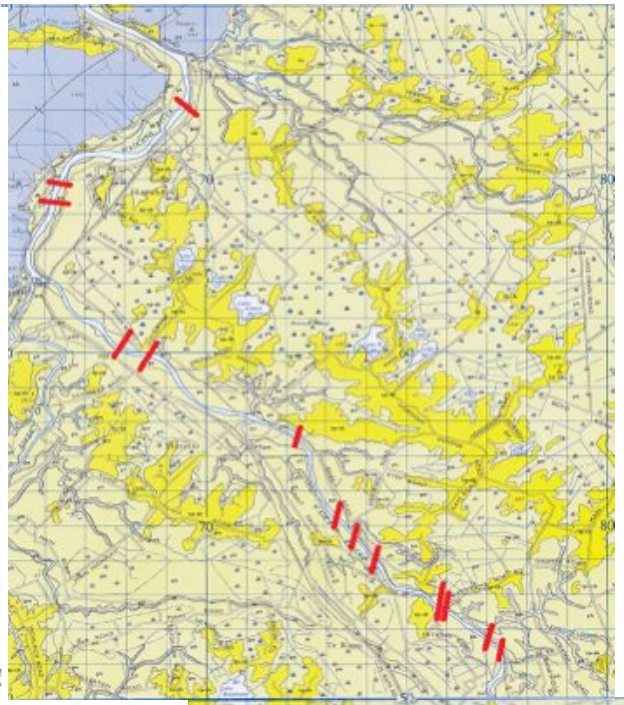



Figure 6.1. Northern Hamilton Basin with bordering basement hills (shaded), major faults and the locations of petroleum exploration wells. Approximate structure contours on basement (metres below sea level) show westward deepening towards Waipa and Taupiri faults.



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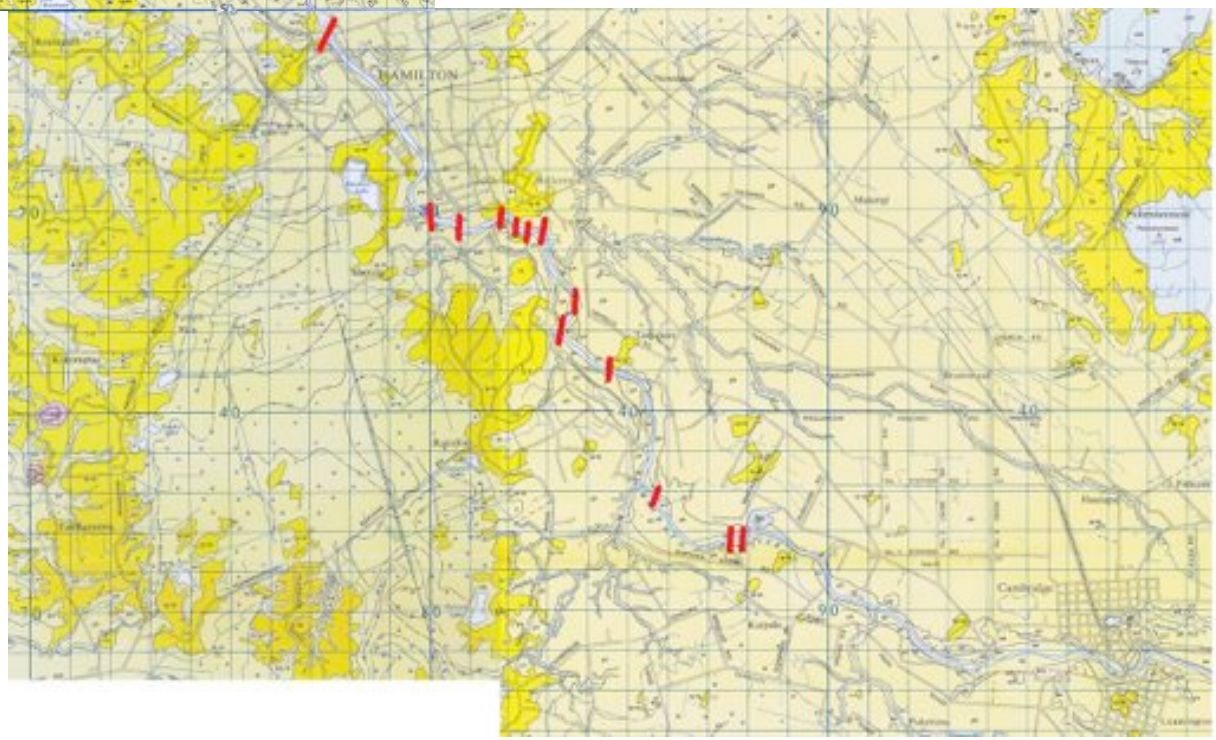
# What controls surface fault locations?

- Do the potential faults identified by shallow seismic reflection data along the Waikato River correlate with deeper structures identified by earlier studies?

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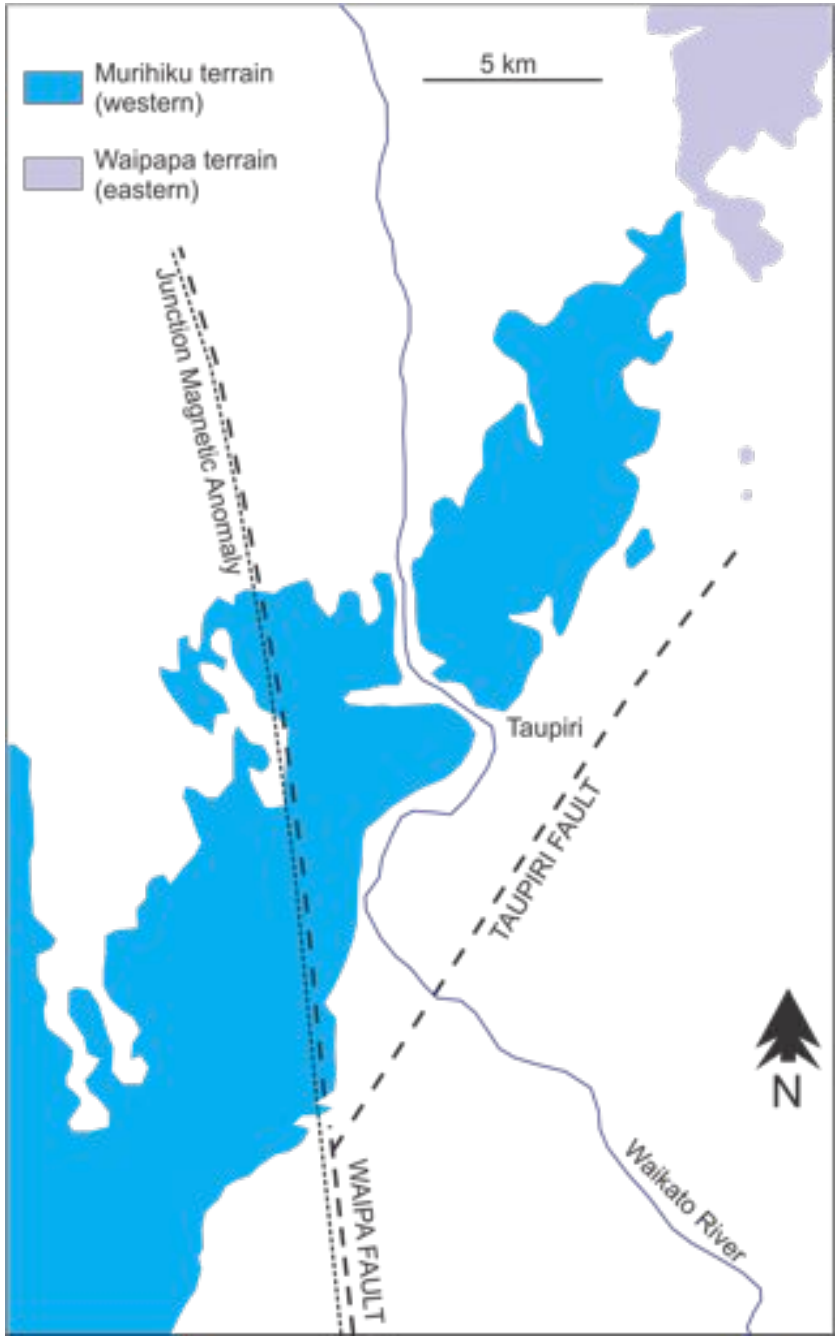
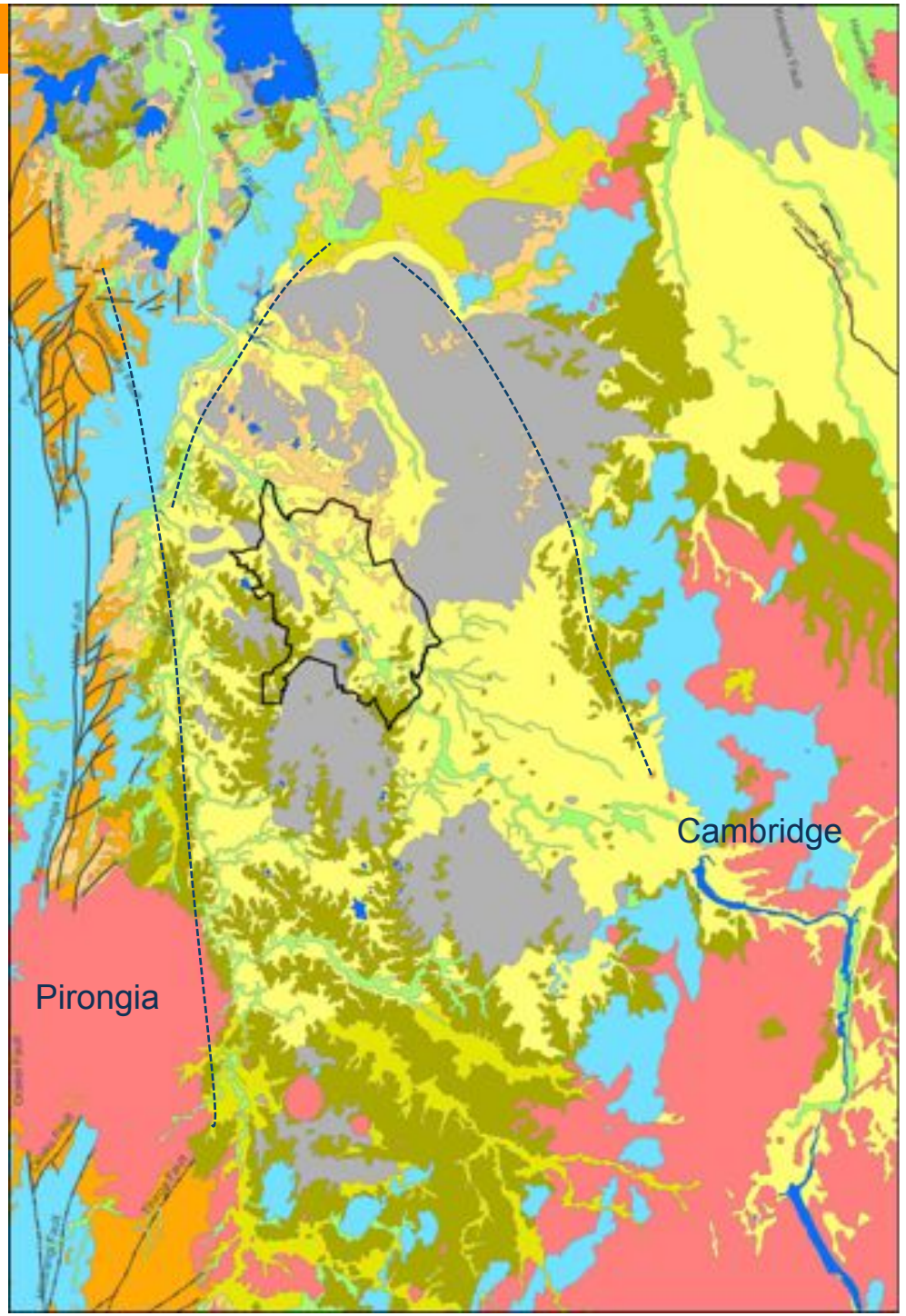
# Basin structure

- Junction Magnetic Anomaly
- Waipa Fault lies along suture:
  - high hills between here and Raglan
  - long history of movement
- Hakarimata Range on “wrong” side of anomaly
  - displaced eastward
  - southern margin of Hakarimatas marked by inferred Taupiri Fault
- So we have:
  - major north-south trending discontinuity following key structure of North Island
  - Fault forming northern margin of basin



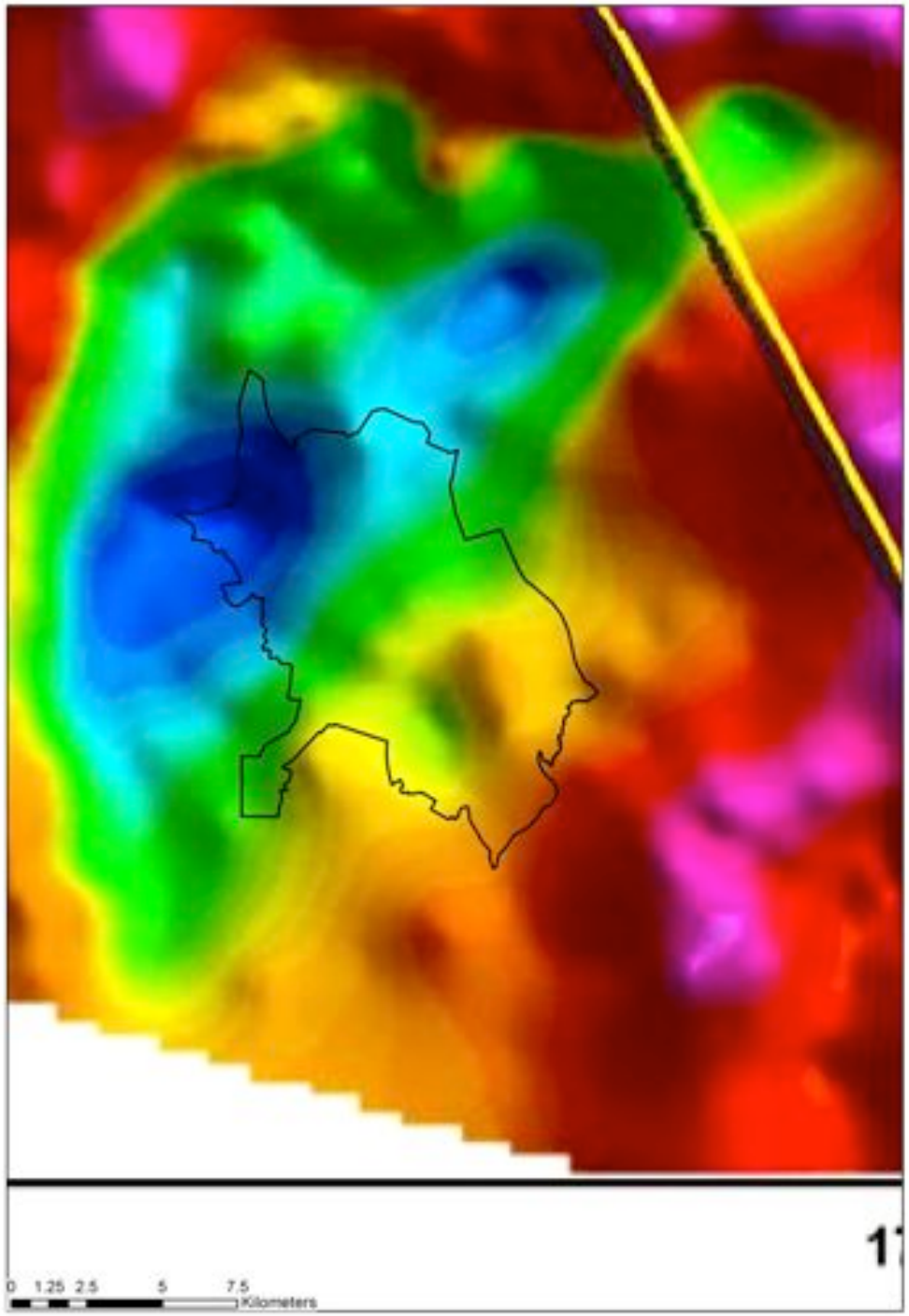
# Defining structures

- Geology includes:
  - basement (blue) to west, north & east
  - young sediments (yellows) infilling basin
    - alluvial fan surrounding older sediments
    - note Pliocene sediments on east side
  - volcanics in red
- Structures:
  - N-S faults along west and north margins
  - bunch of more west – east faults in Tertiary rocks (Te Kuiti Gp) pointing into basin
  - northern faults may extend down eastern margin of basin.
- So 3 margins of basin surrounded by deep faults providing release surfaces.
- Southern margin more challenging



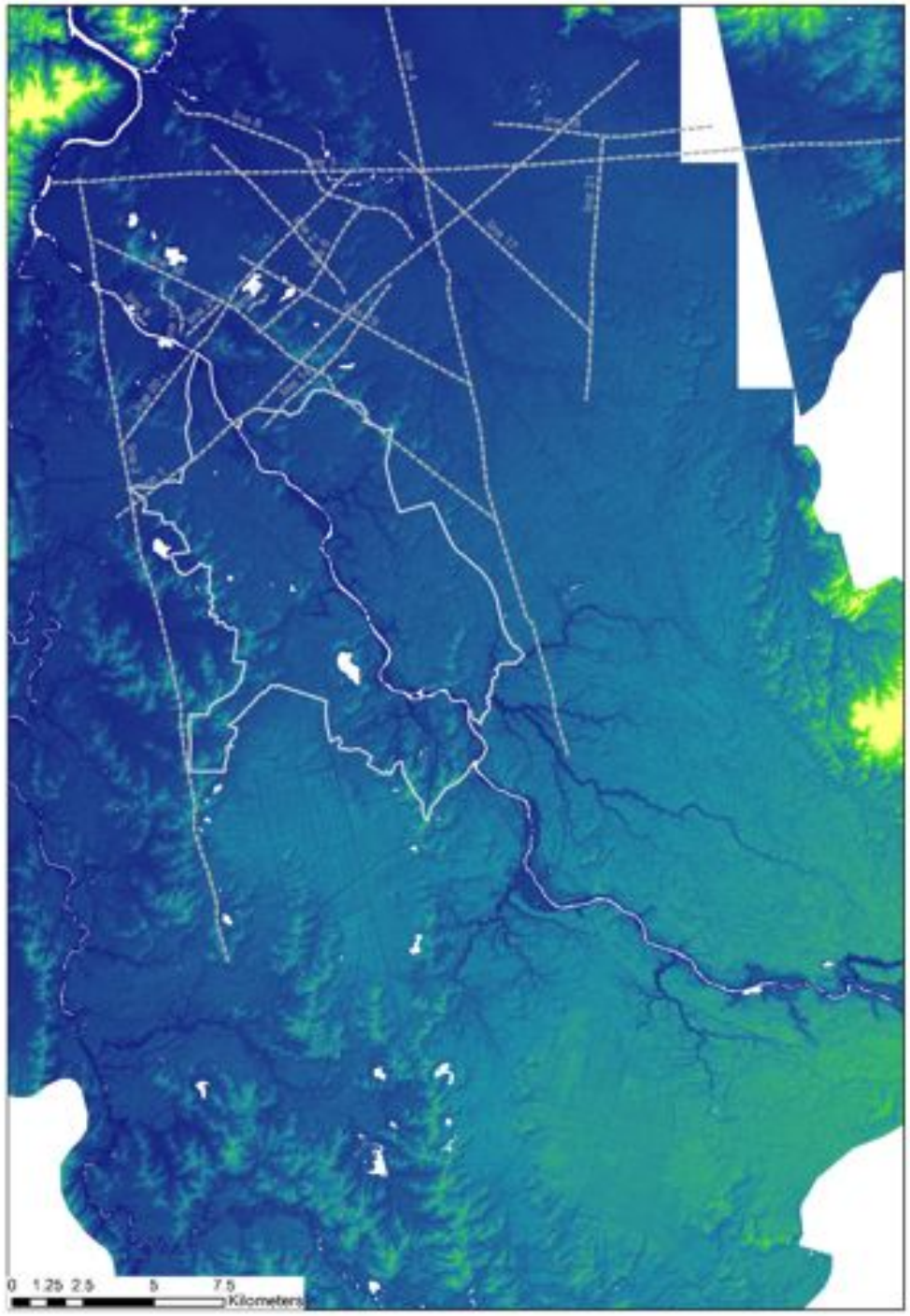
# Gravity anomaly

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



# Existing seismic data

- Old seismic lines run in 1960s and 1970s
- Will focus on Line 2 down western side of basin.

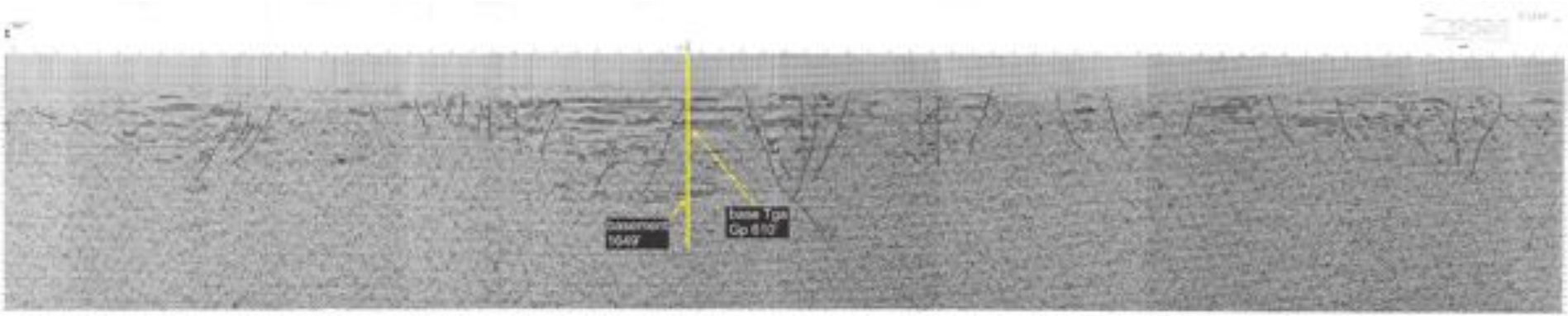


# Line 2 - original

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

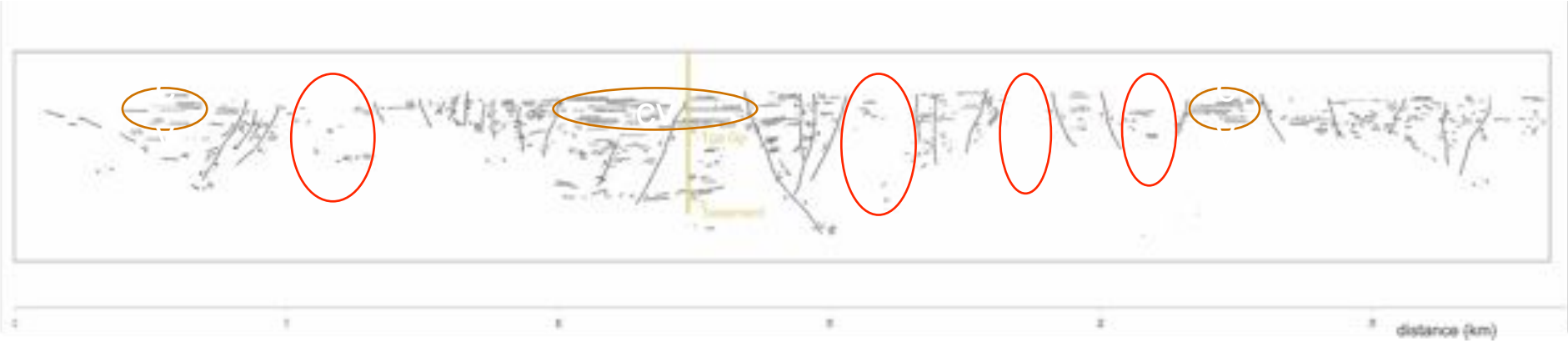
# Line 2 - interpreted

- 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

- 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

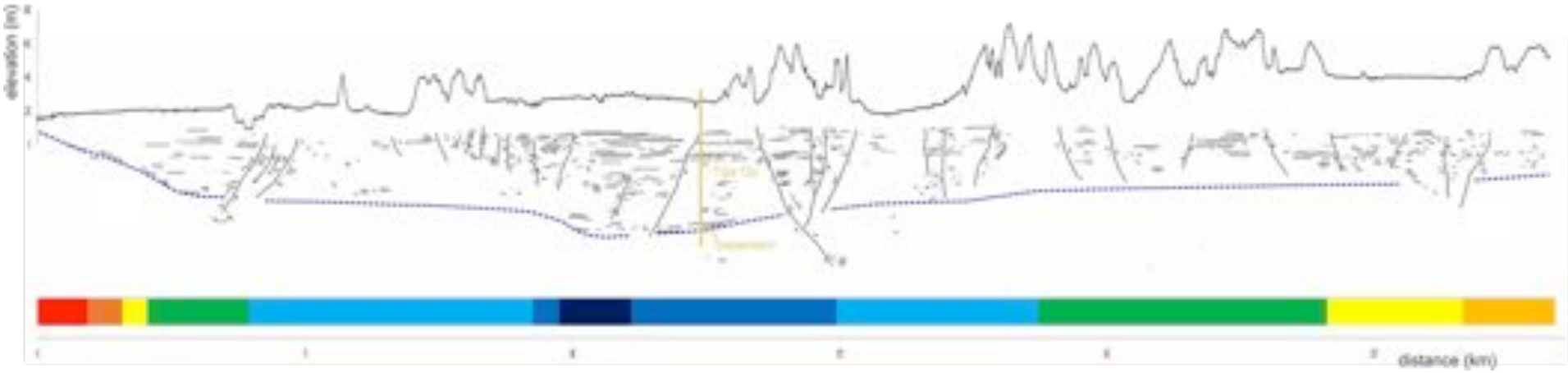


# Line 2 - interpreted

- 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

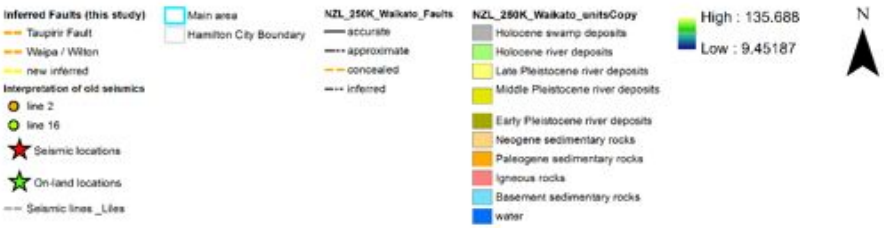
# Line 2 - interpreted

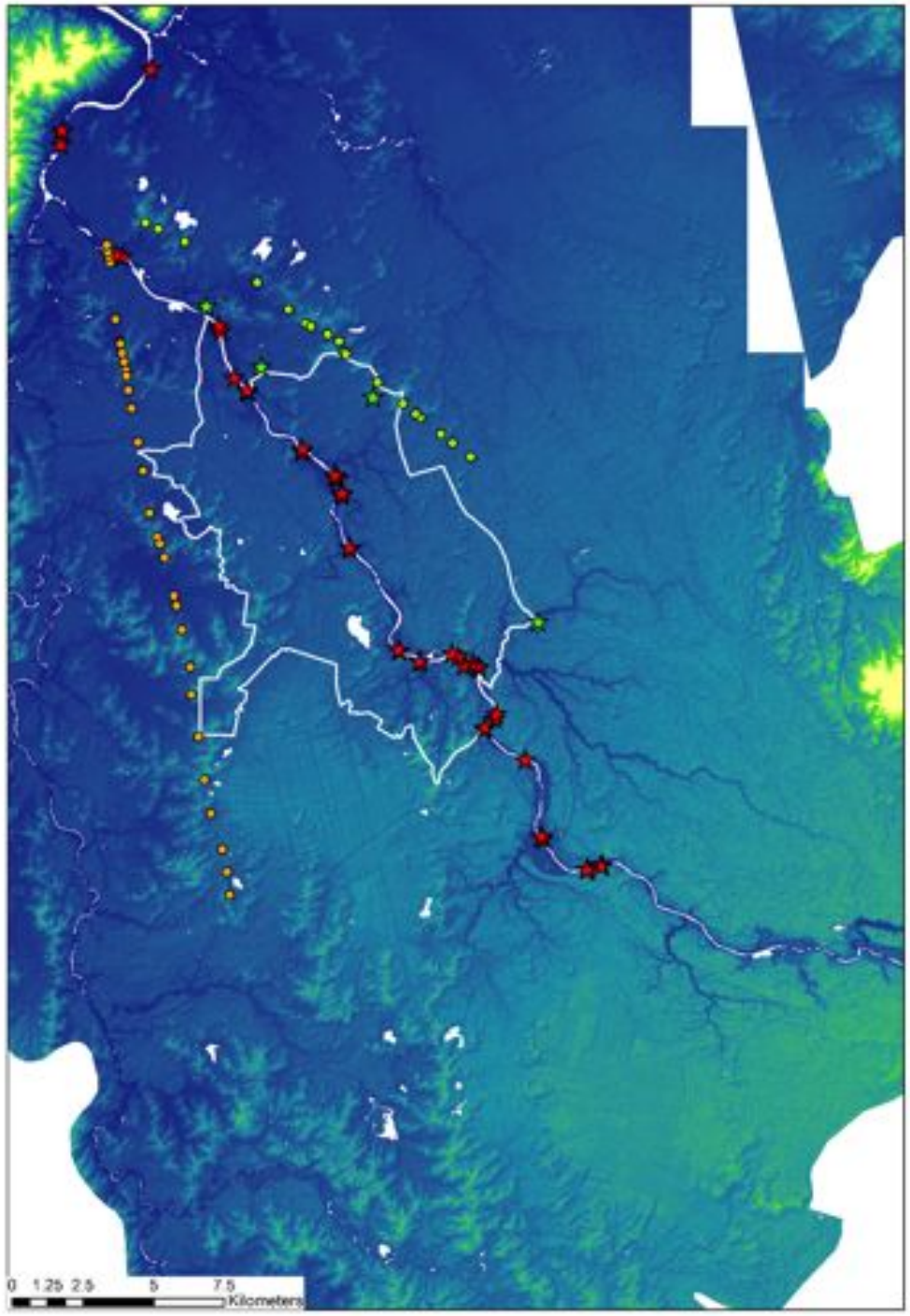
- Adding in gravity (colour band) allows rough basement profile to be extended from identifiable points.
  - basement dips down from north to deepest point below north Hamilton
  - rises steadily towards south (about 3°) slope
  - thin or non-existent Tertiary rocks to south



# Identified locations

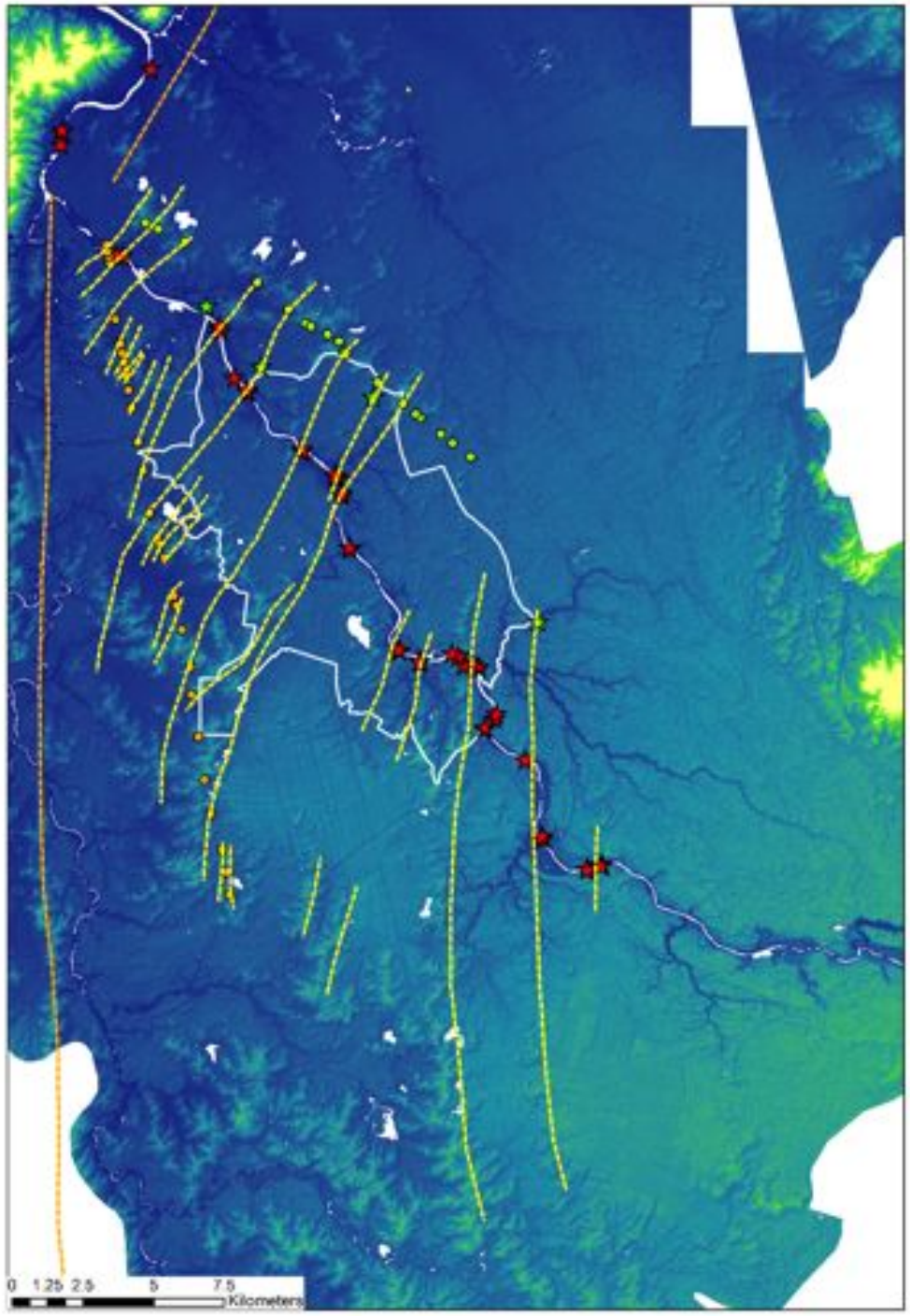
- Have known points representing fault locations from:
  - 4 on-land sites
  - reflection along river
  - old seismic lines



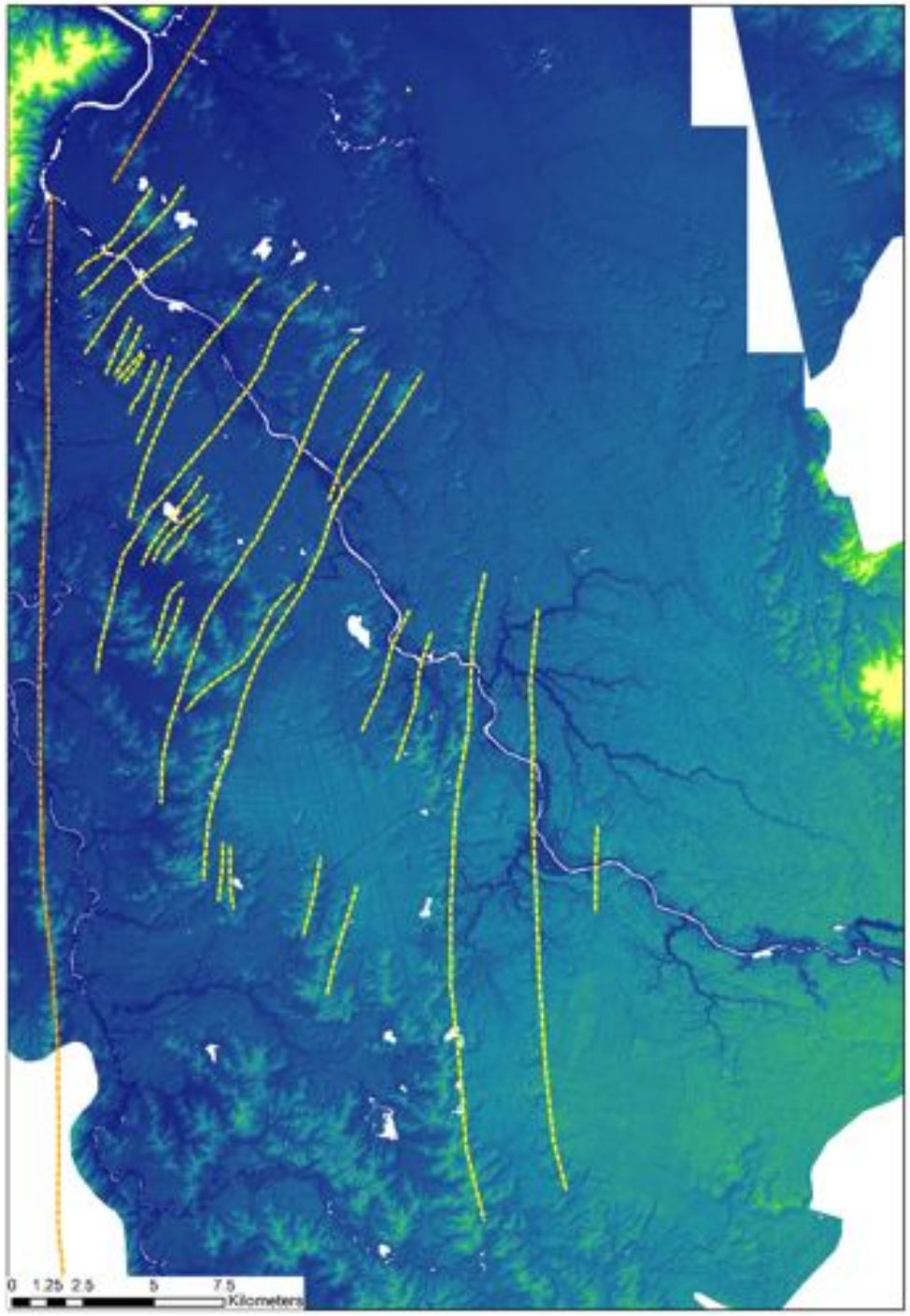
# Inferred faults

- Can start to infer surface fault traces.
- Strongly based on geomorphology.
- Suspect many of the shorter ones indicated actually longer, but have restricted traces to where there is good evidence.



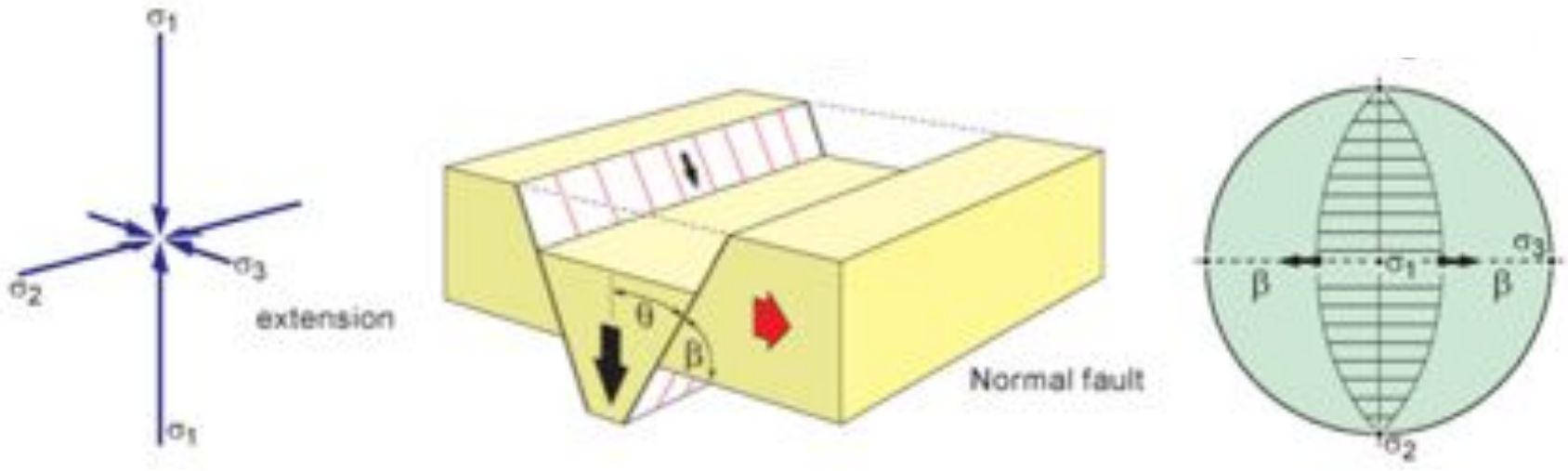
# Inferred faults

- See:
  - faults tend to be curved in plan view
  - some longer faults with likely shorter sections in between



# Andersonian Faults

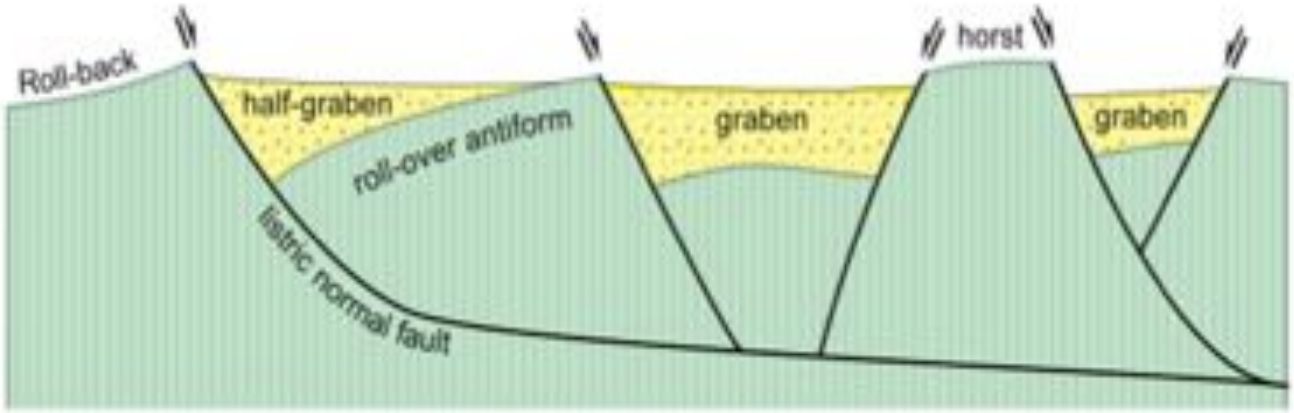
- Angles are correct for classical Andersonian Faulting in an extensional environment.
- Maximum principal stress is vertical (gravity).



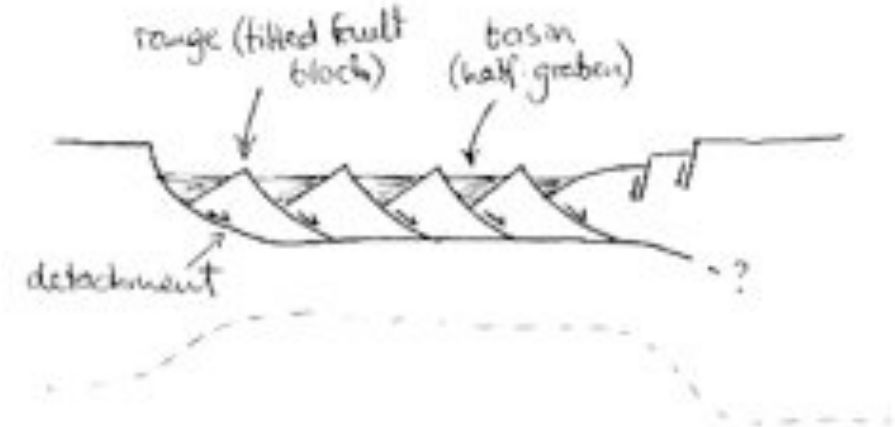

http://www.files.ethz.ch/structuralgeology/JPB/files/English/3faults.pdf

# Listric faults

- Curved, or listric, faults common in extensional systems.




http://www.files.ethz.ch/structuralgeology/JPB/files/English/3faults.pdf

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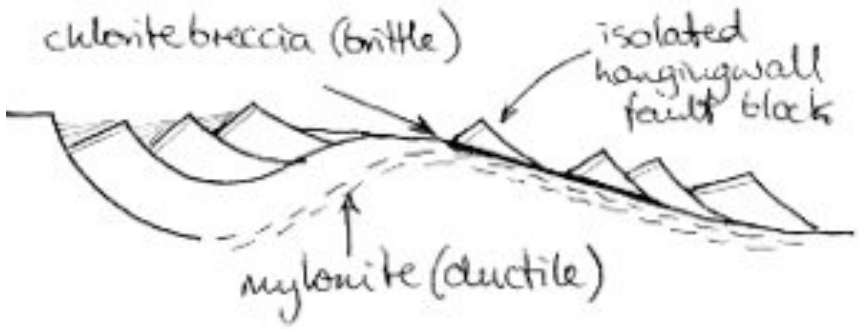


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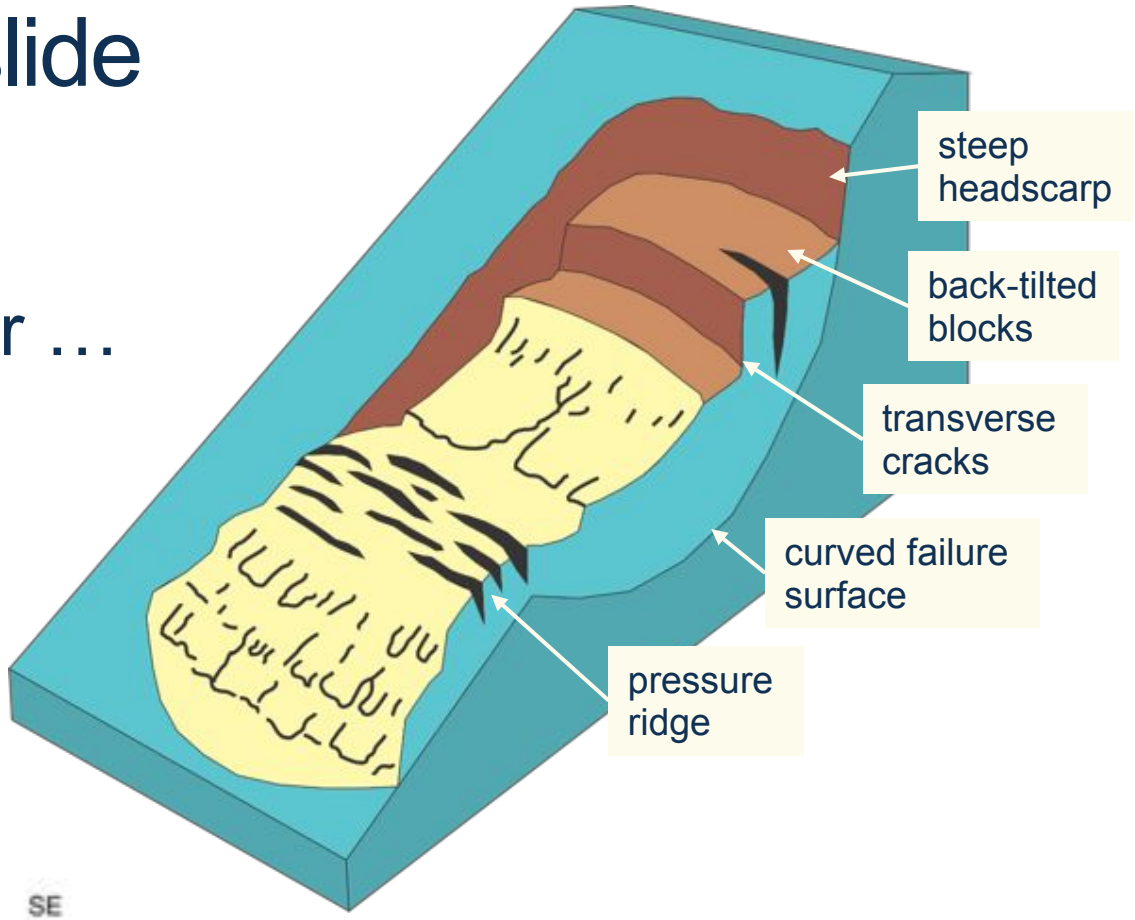
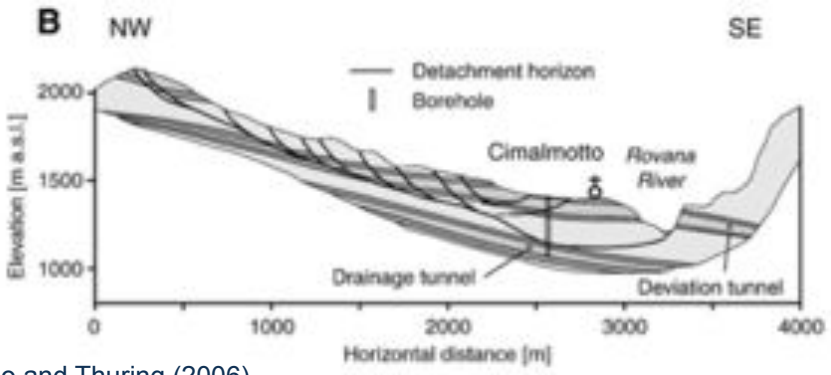
# Line 2 - interpreted

- 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

# Rotational landslide

- This shape seems remarkably familiar …

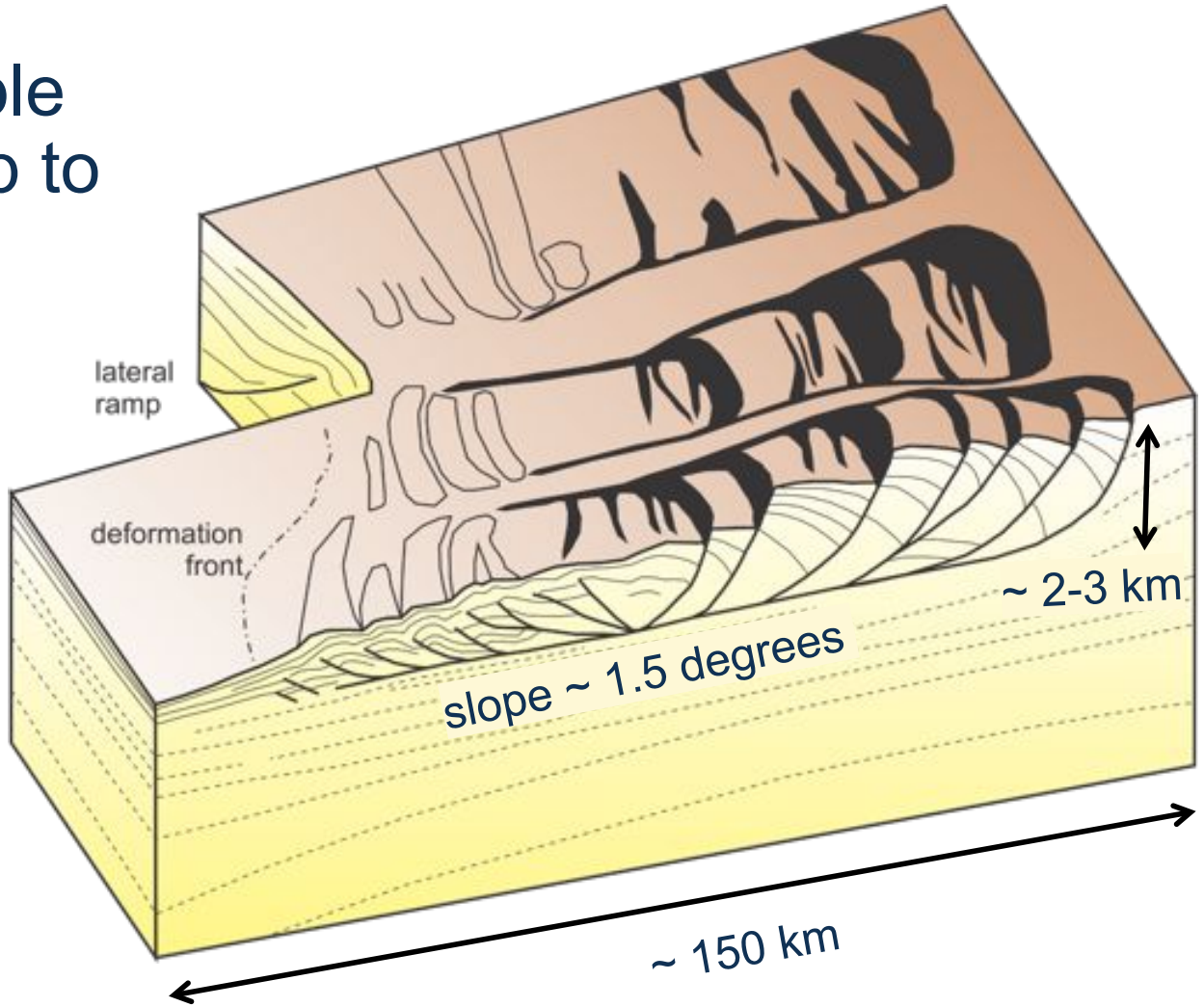



Seno and Thuring (2006)

# Mass movement

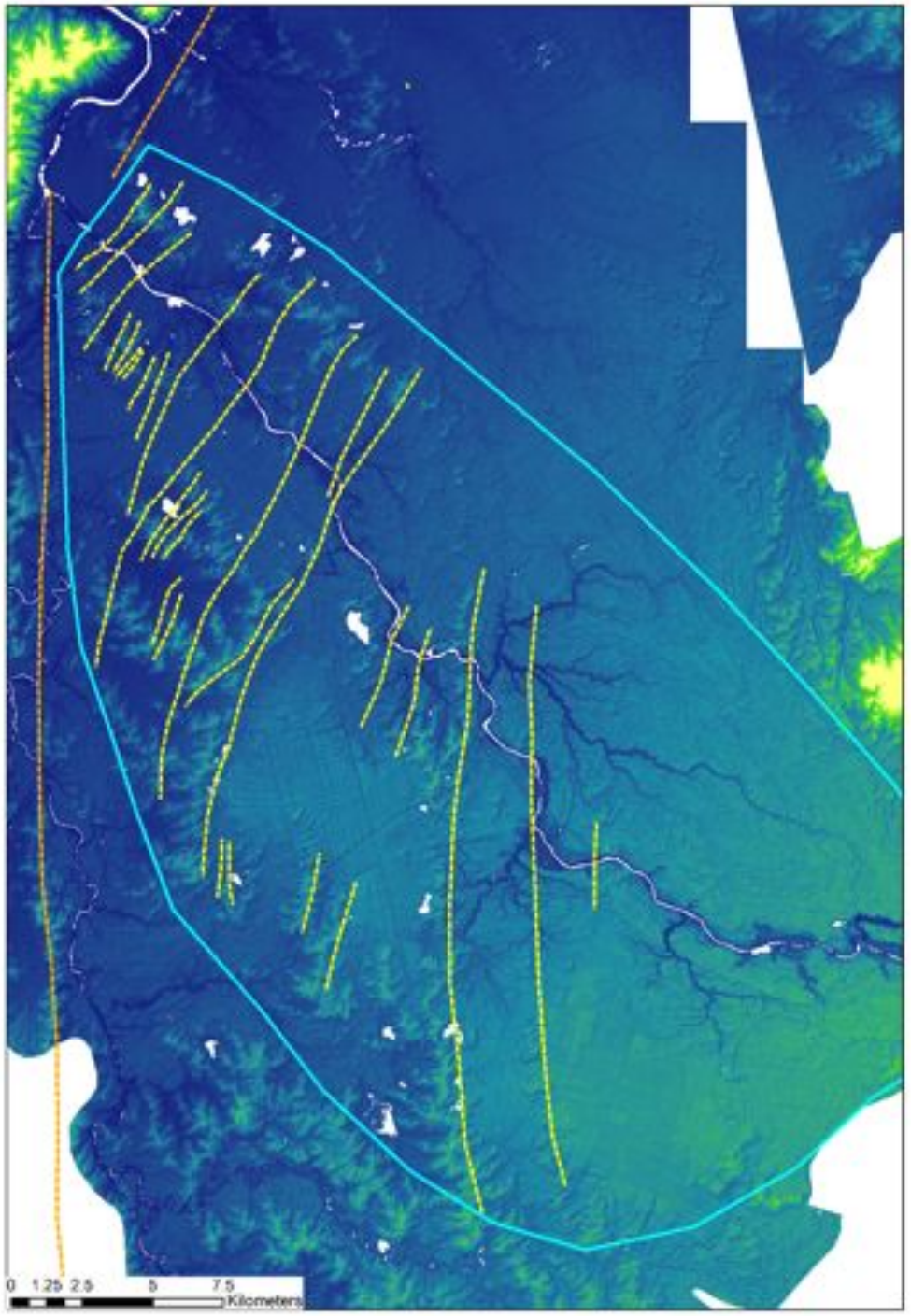
- Still recognisable when scaled up to fault scale.
- Example is Orange Basin, offshore Namibia.
- Lateral ramps separate discrete parts of failure.




de Vera, J., Granado, P. and McClay, K., 2010

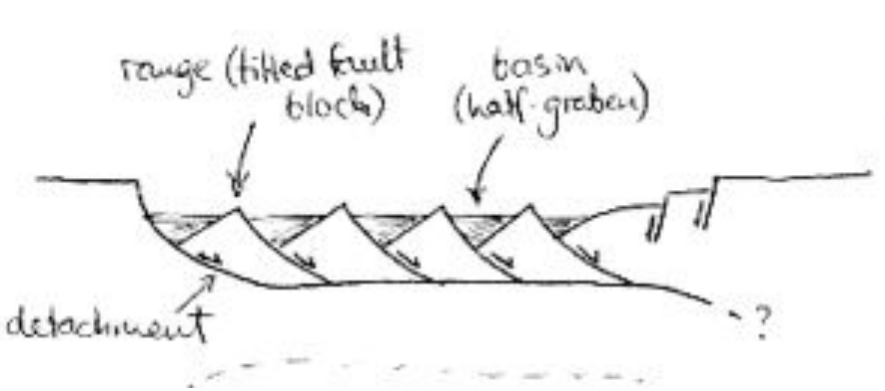
# Final model

- Gravity-driven collapse:
  - about 20 x 40 km
  - suspect extends into basement, depth…?
- Appears to stop at ridge in gravity anomaly.
- NE corner obscured by peat; likely also part of structure.



# Hill morphology

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

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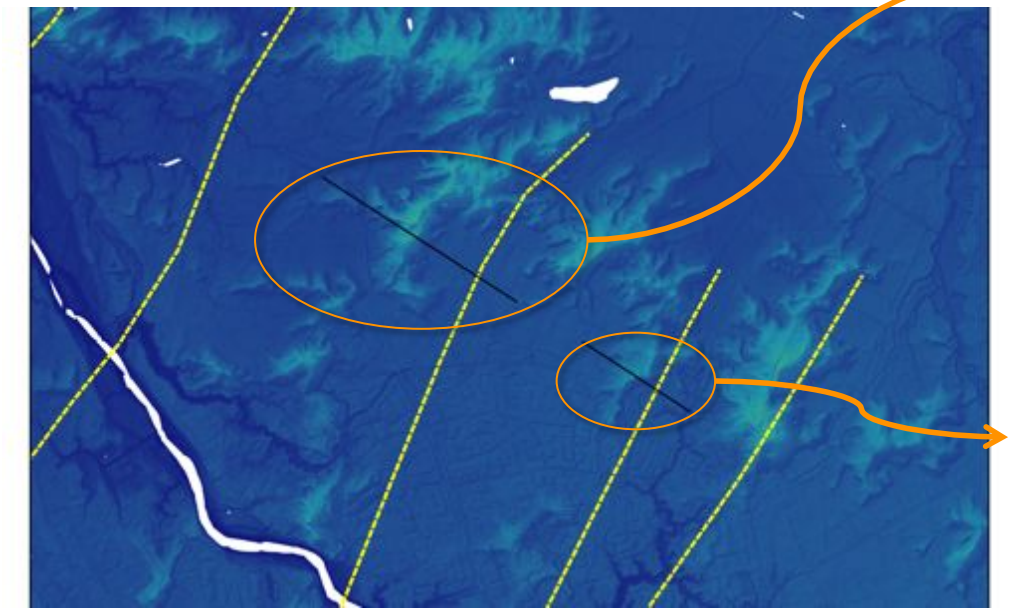
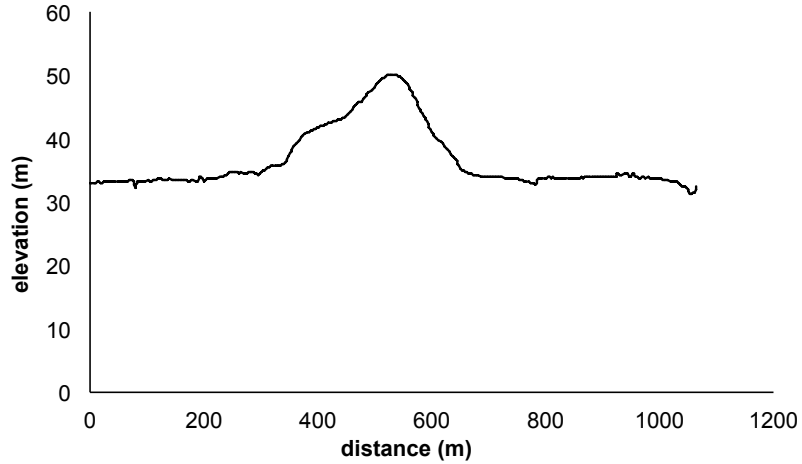
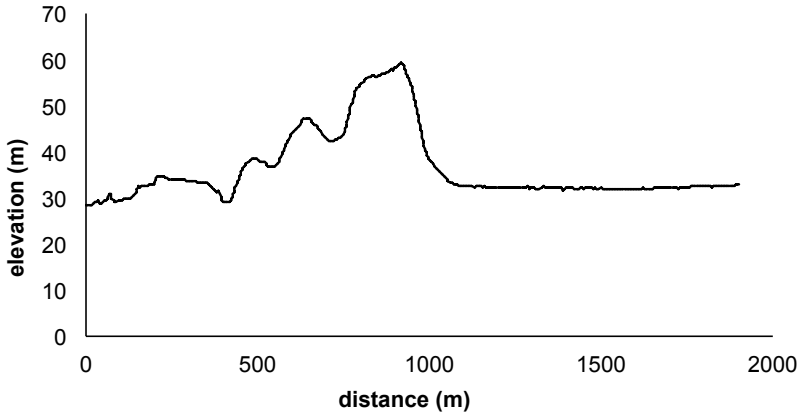
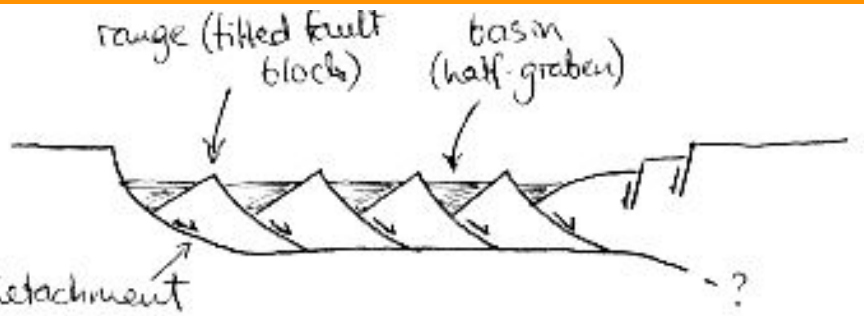




# Hill morphology

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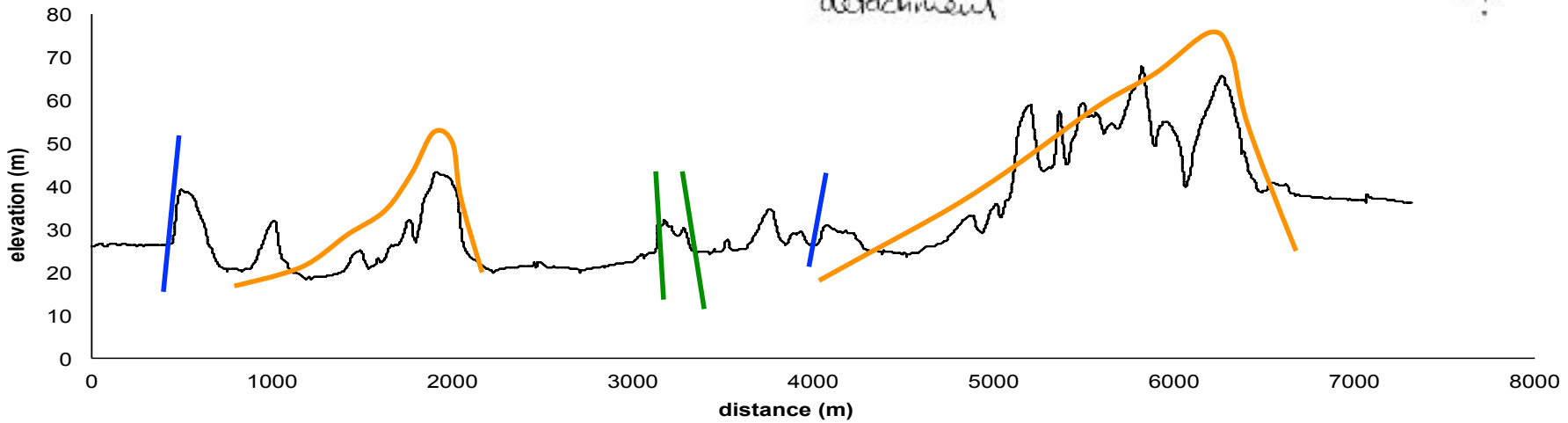
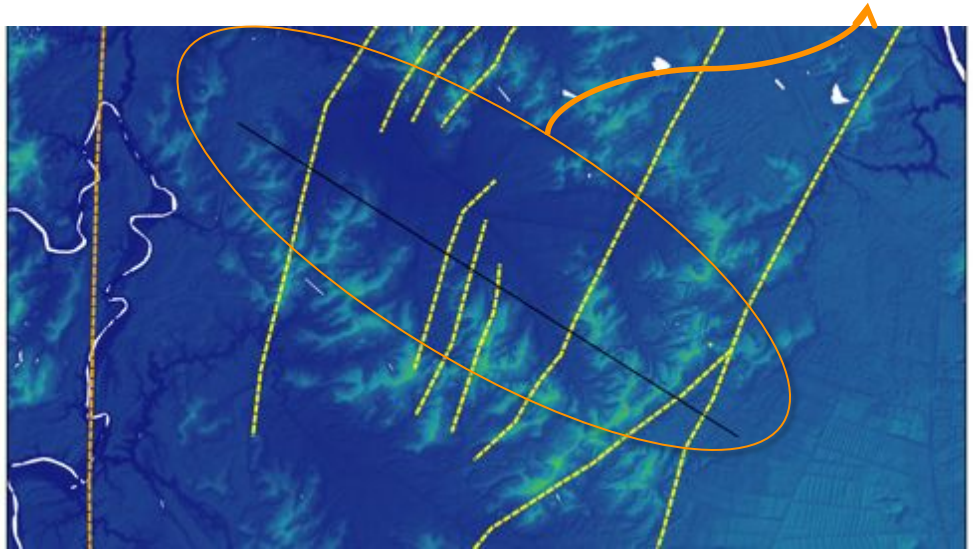
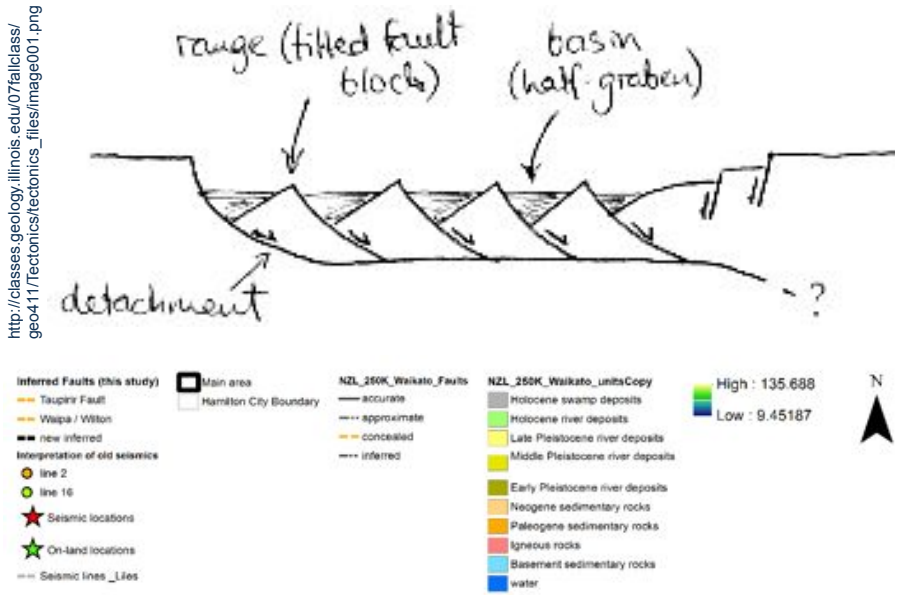


- Multiple listric faults.
- Small horsts and grabens.
- Antithetic faults also reflected in geomorphology.

# Final model

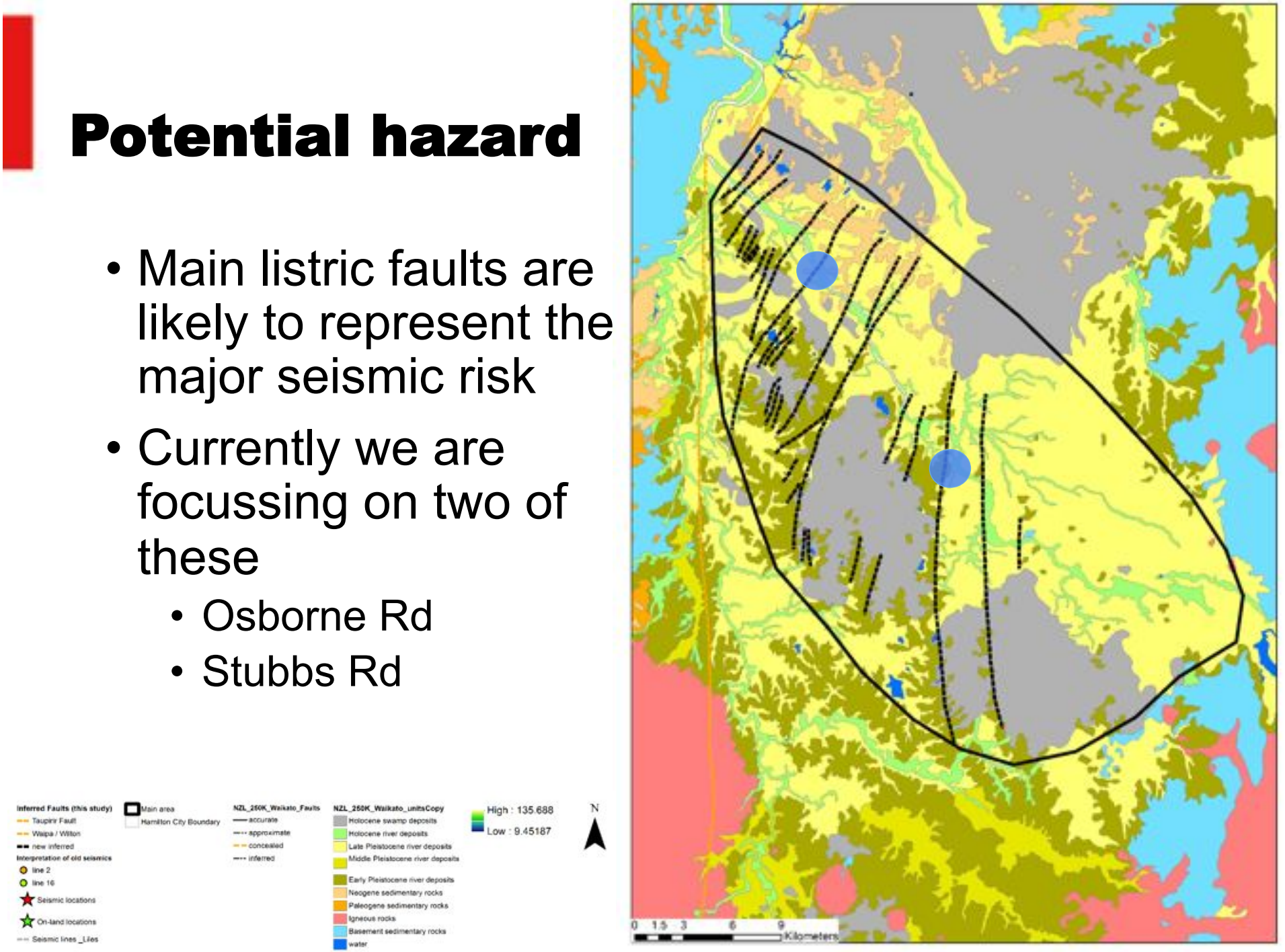
- How does it end?
  - antithetic fault near Cambridge?
  - Tertiary / Pleistocene sequences thin to south
    - thrust?
  - pressure ridges at SW?



http://classes.geology.illinois.edu/07falclass/geo411/Tectonics/tectonics_files/image001.png

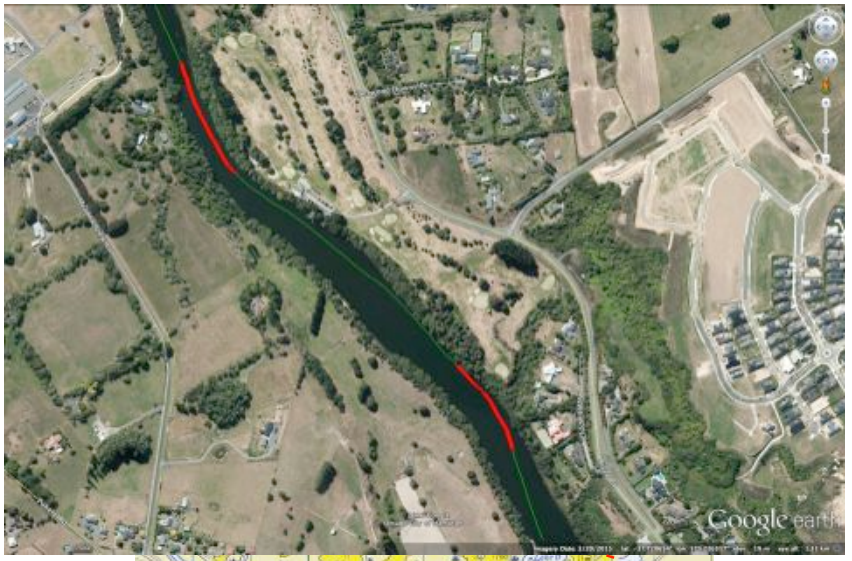
# Potential hazard

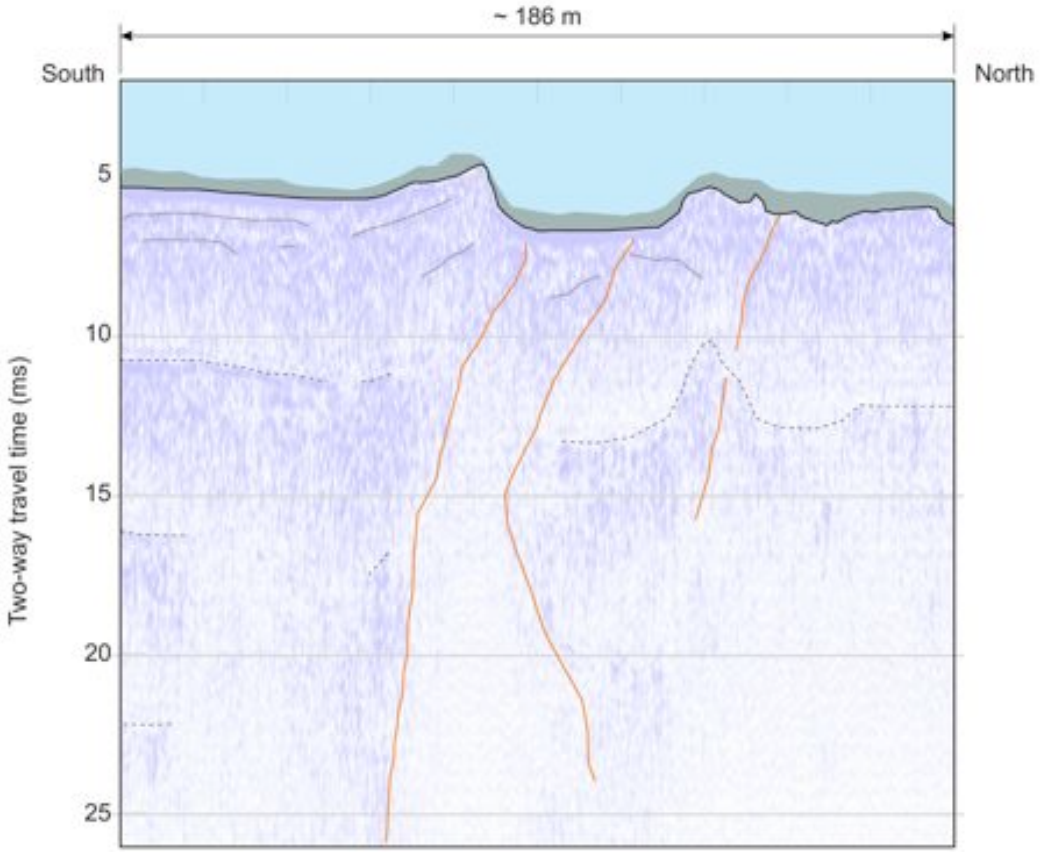
- Main listric faults are likely to represent the major seismic risk
- Currently we are focussing on two of these
  - Osborne Rd
  - Stubbs Rd

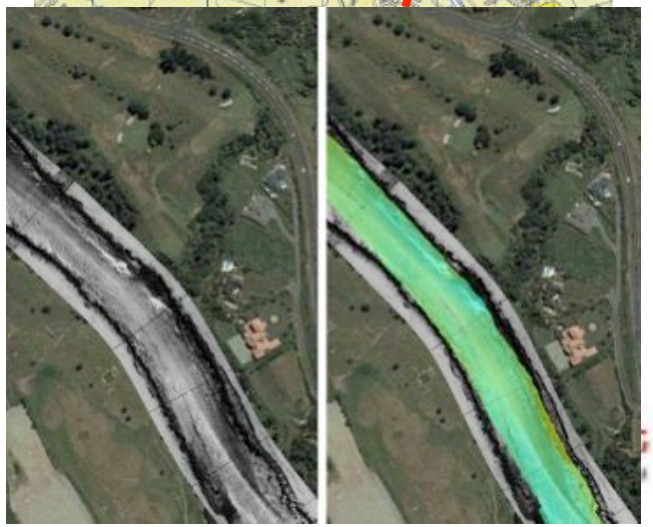


# Osborne & Kay Rds

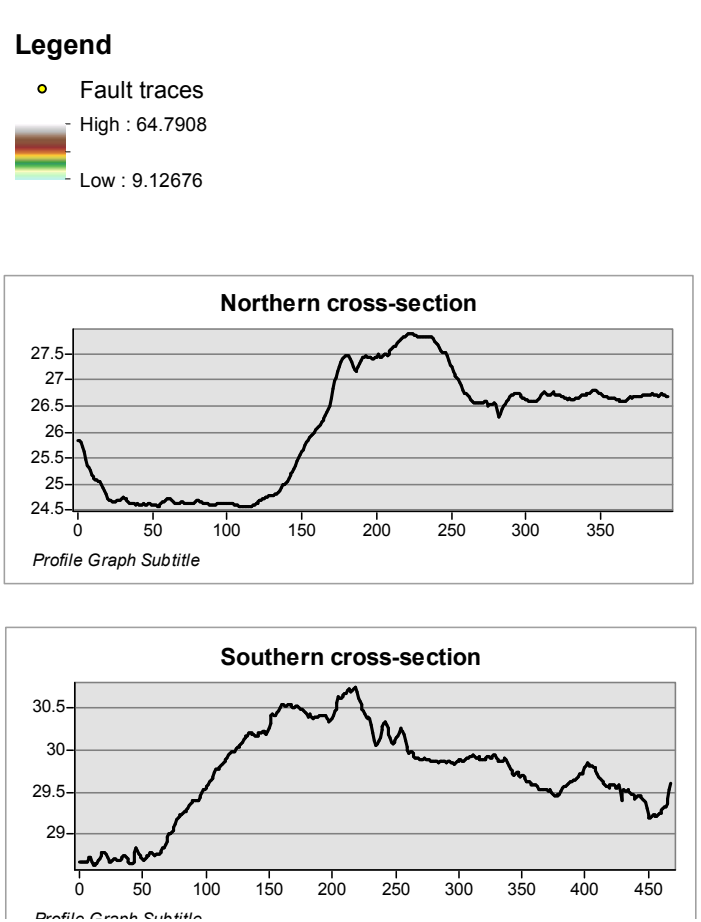
- Outcrops of Puketoka Formation
- Gully formation
- Displacement of Hinuera Surface
- Lateral spreading

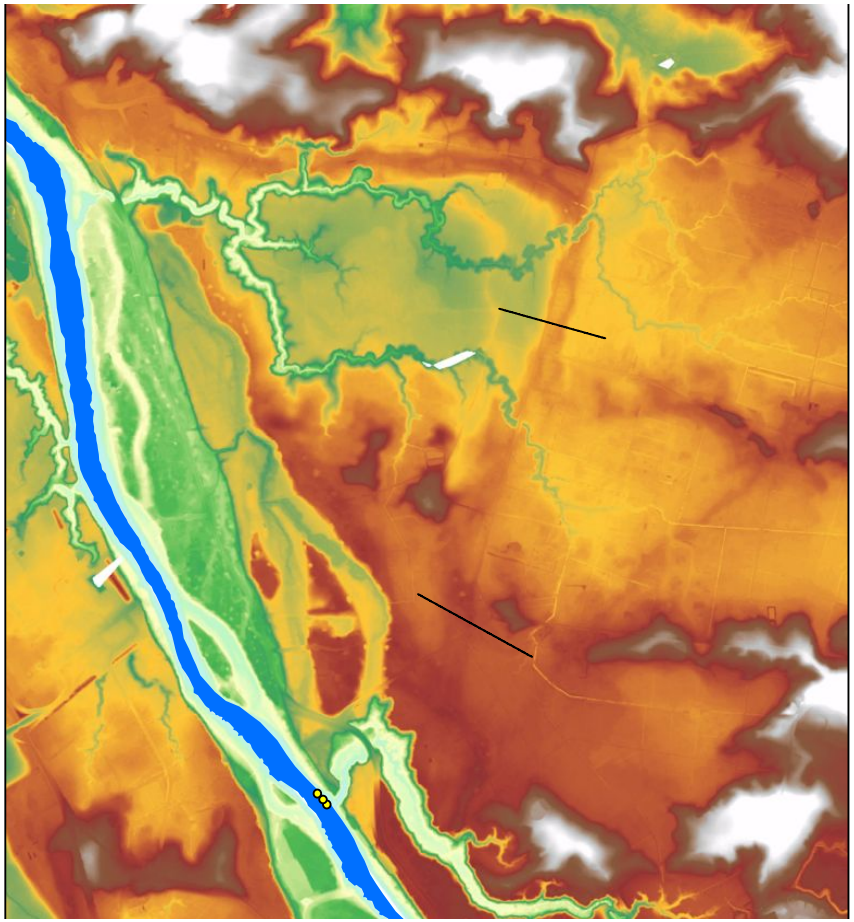


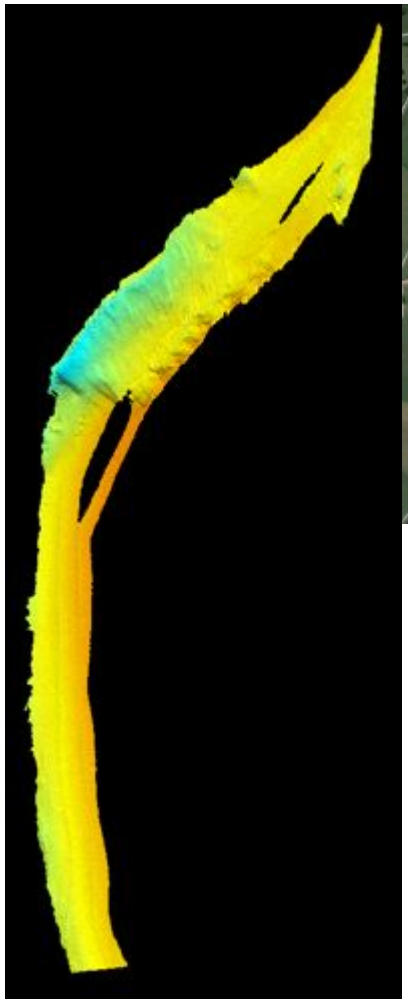
# Osborne & Kay Rds

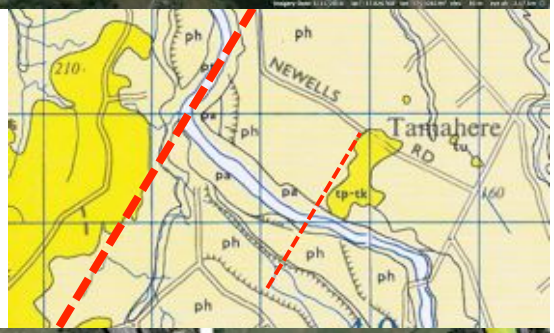


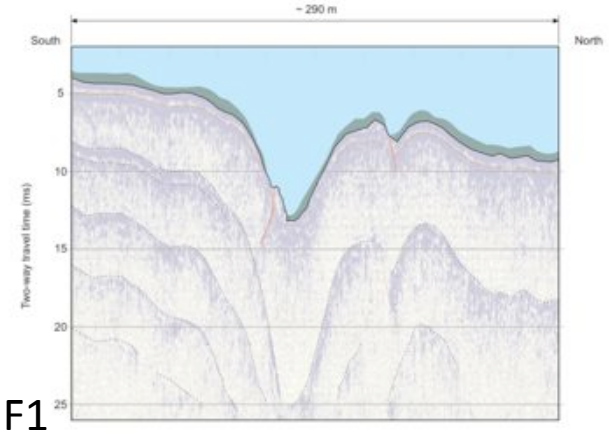



# Stubbs Rd

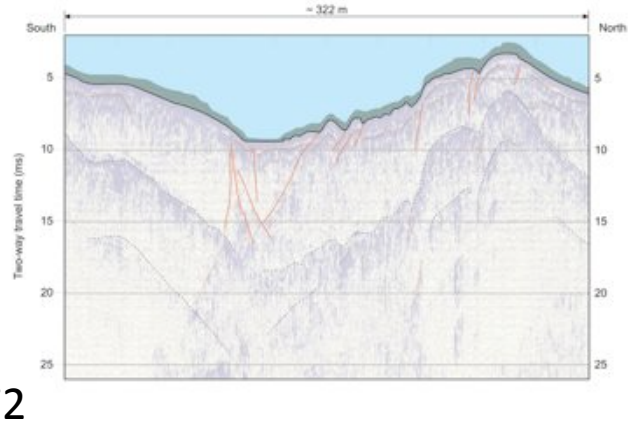
- Inconsistent terraces flanking river
- Abandoned river channel(s) & impoundment?
- Scour hole within river with offset scarp
- LiDAR & resistivity survey of terraces indicate faulting



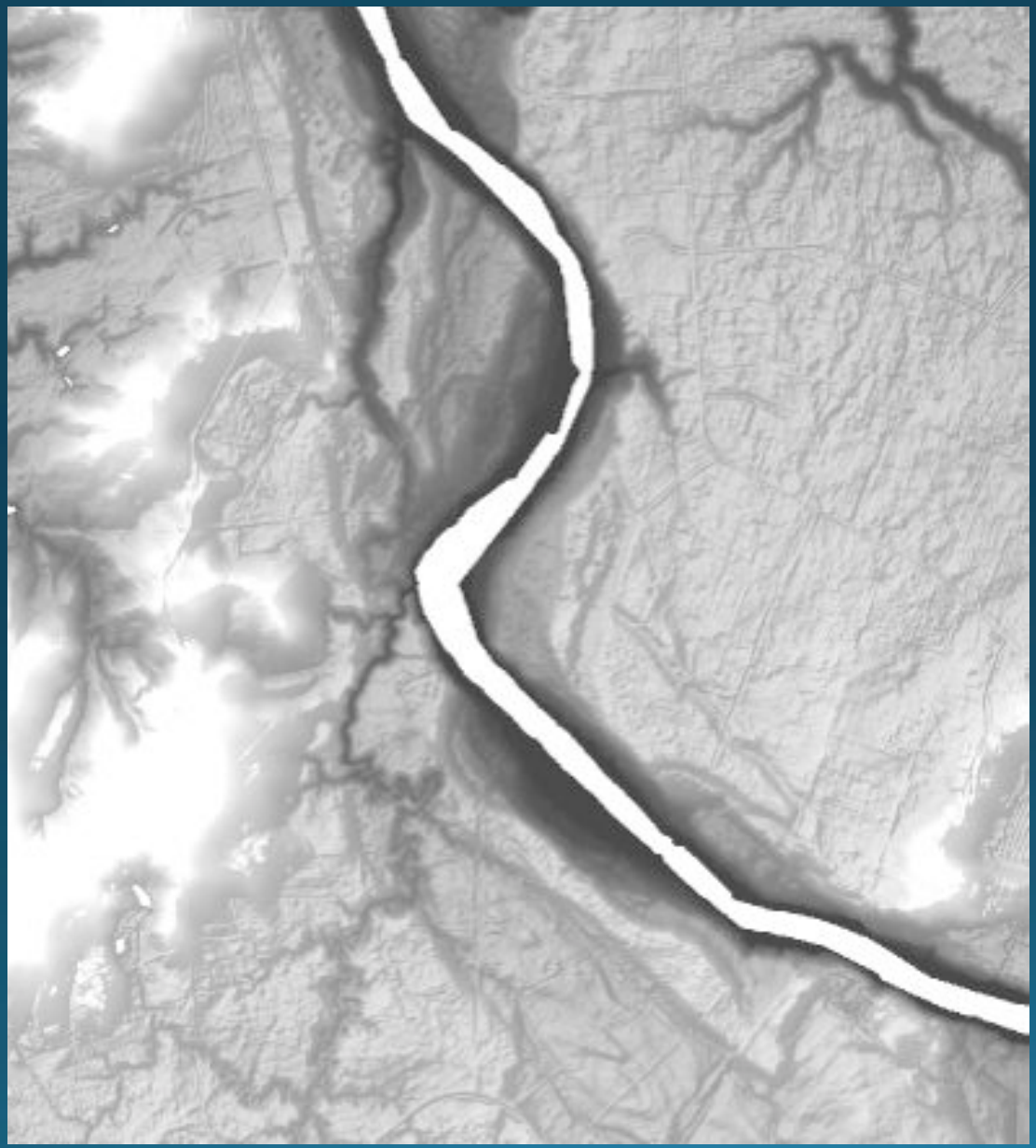




F1

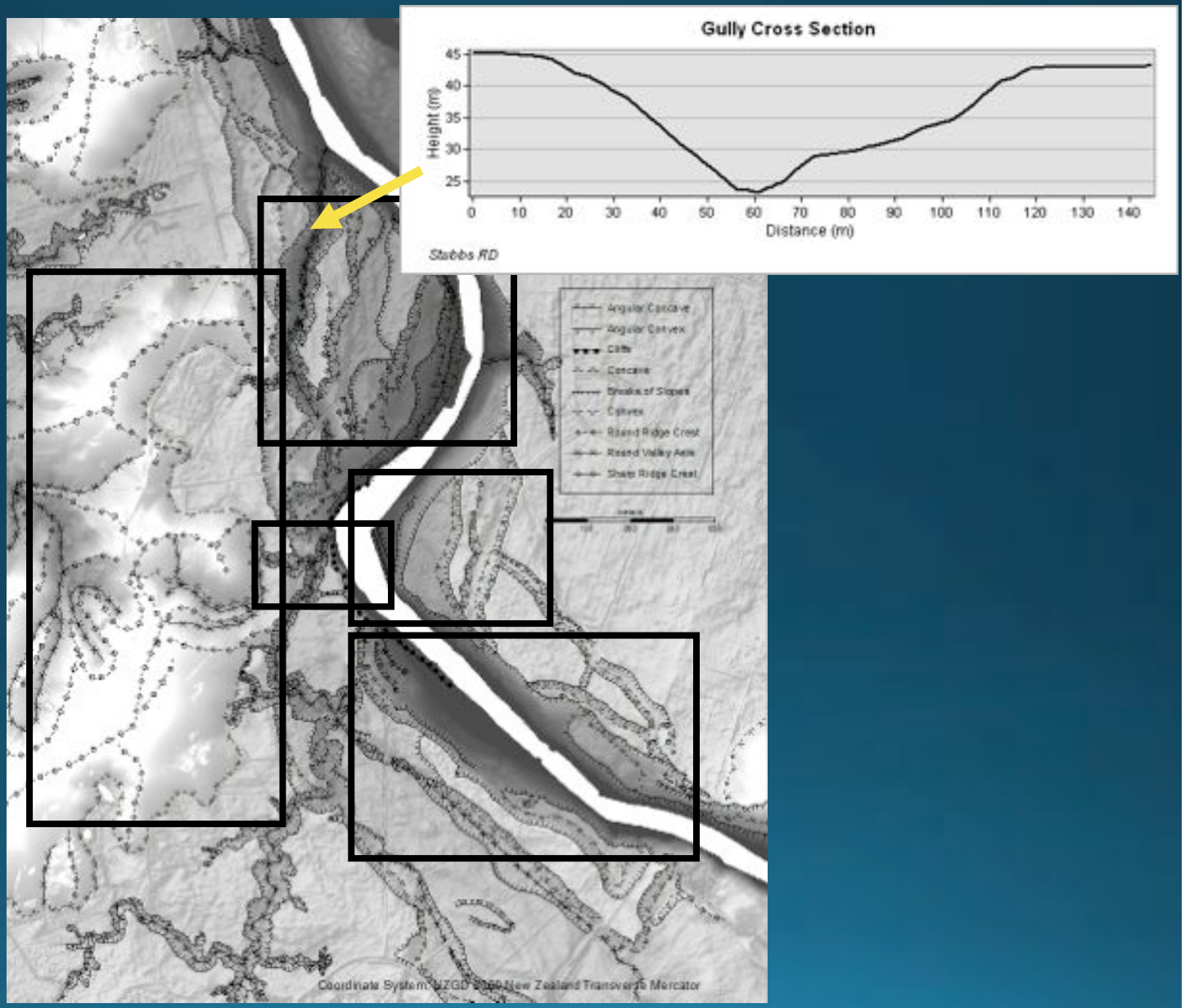



F2

# ***Stubbs Rd***



# Morphology


Gully Cross Section
Height (m)
45
40
35
30
25
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Distance (m)
Stabbs RD
Angular Concave
Angular Convex
Cliffs
Concave
Breaks of Slopes
Convex
Round Ridge Crest
Round Valley Axis
Sharp Ridge Crest
Coordinate System: NZGD 2000 New Zealand Transverse Mercator

# ***Resistivity***

Controls

Electrode

Survey


## ***Survey selection: Survey 1***

# ***Survey selection: Survey 2***

# Survey location

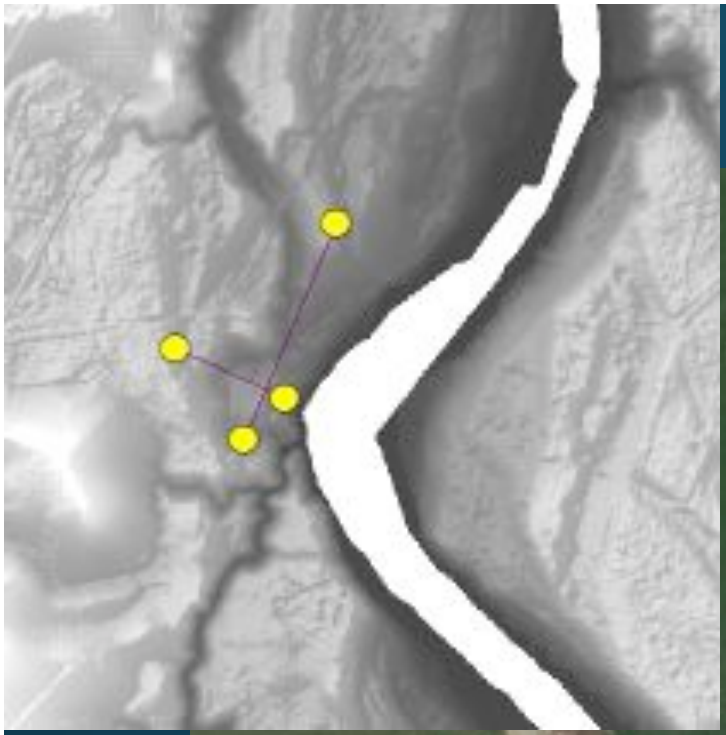
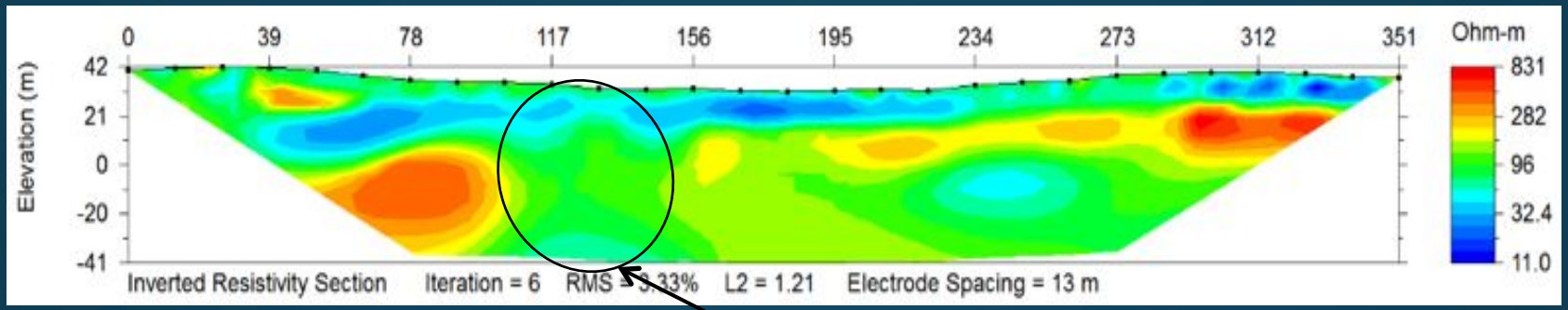




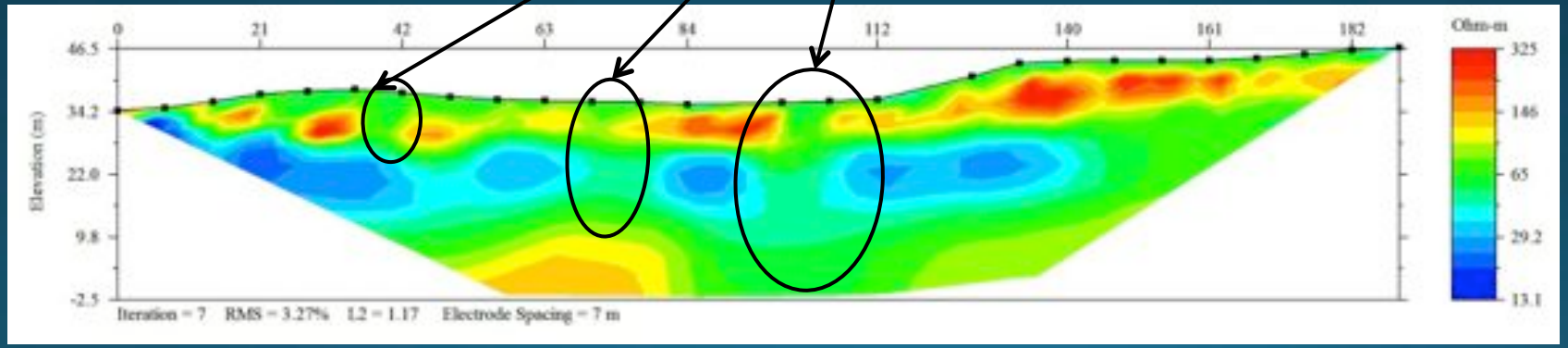

*Image courtesy of C. Morcom*

## Survey 1

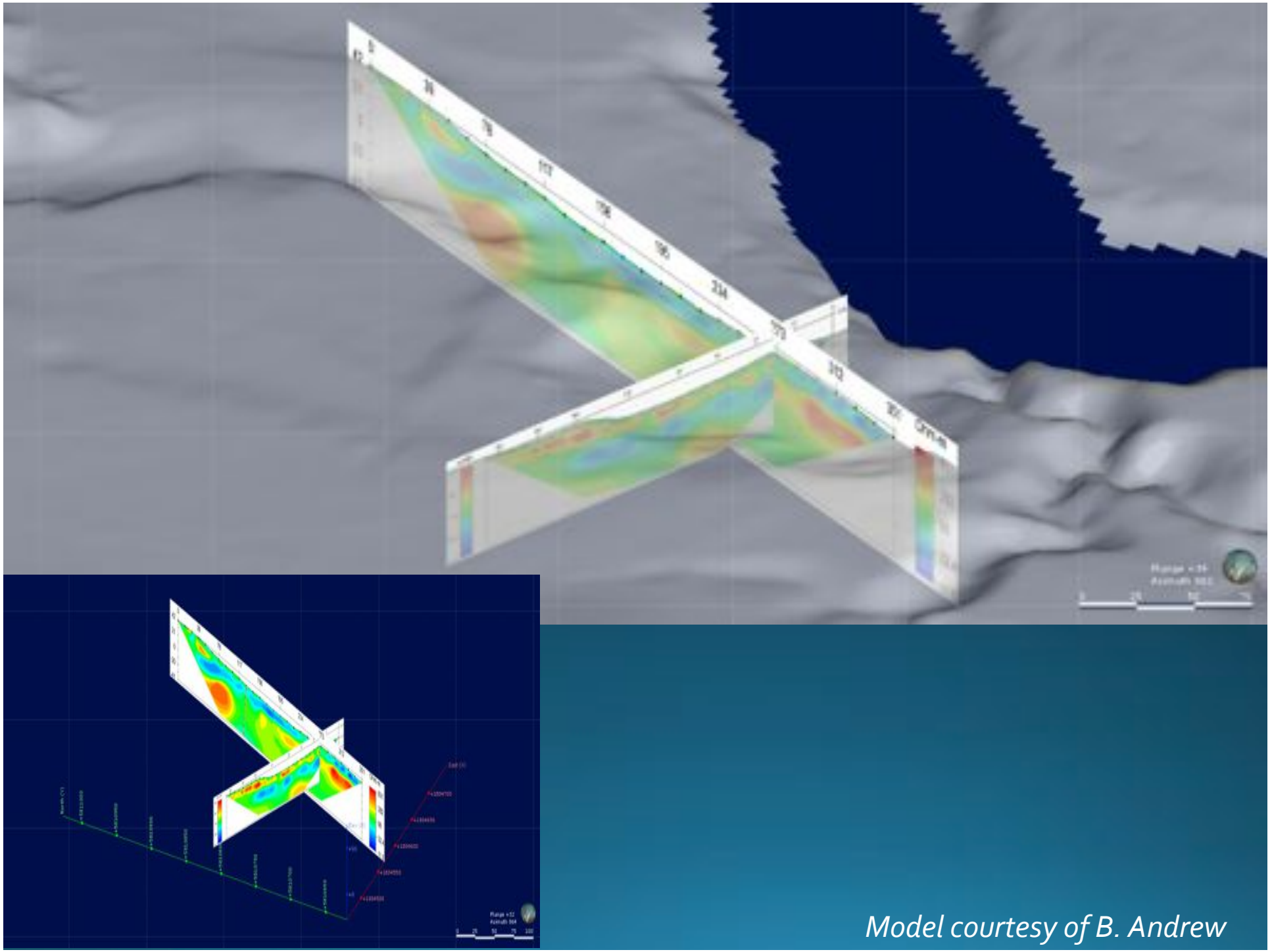



Fracture zones ??

## Survey 2




*Figures courtesy of C. Morcom*



*Model courtesy of B. Andrew*

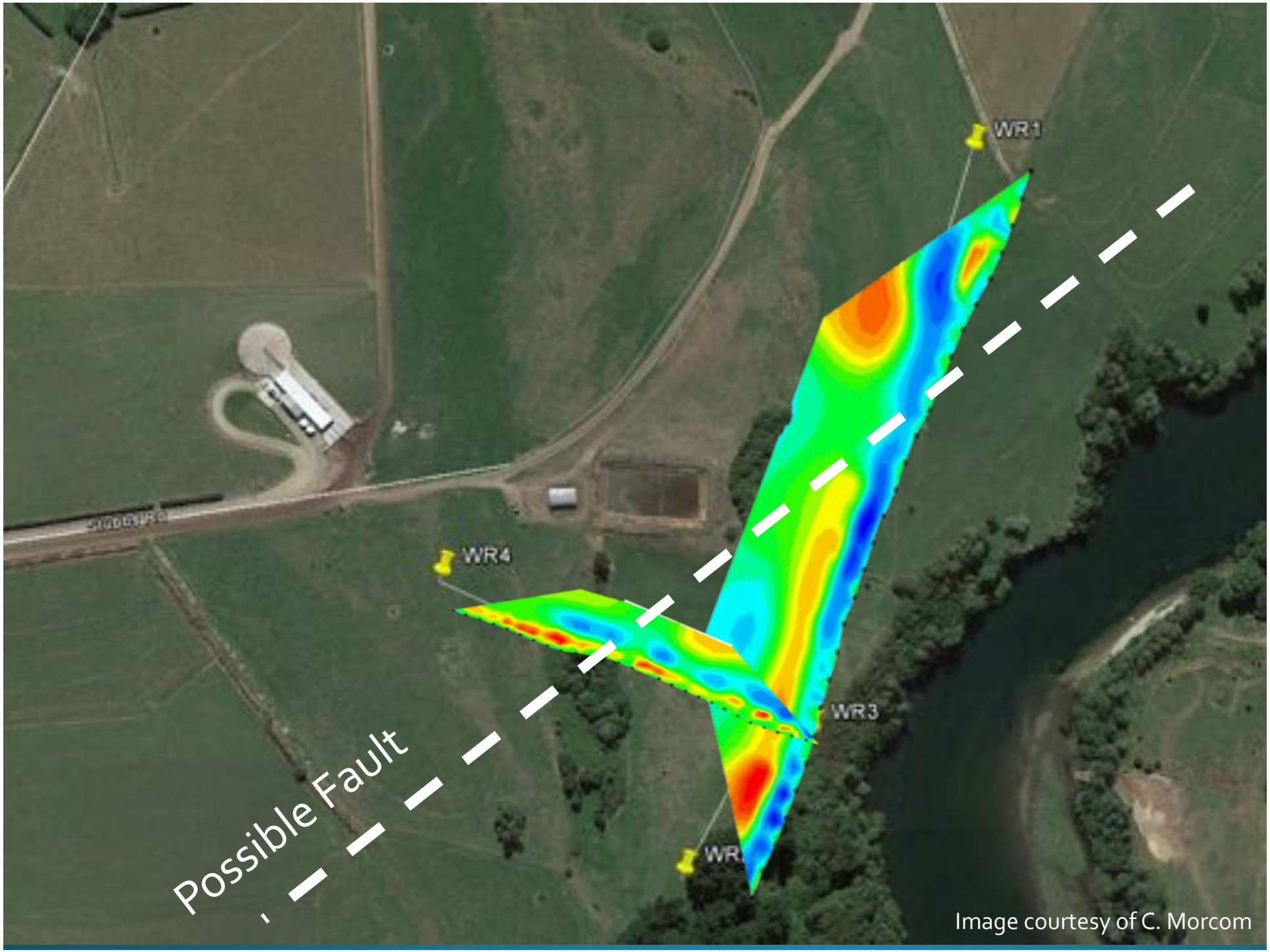
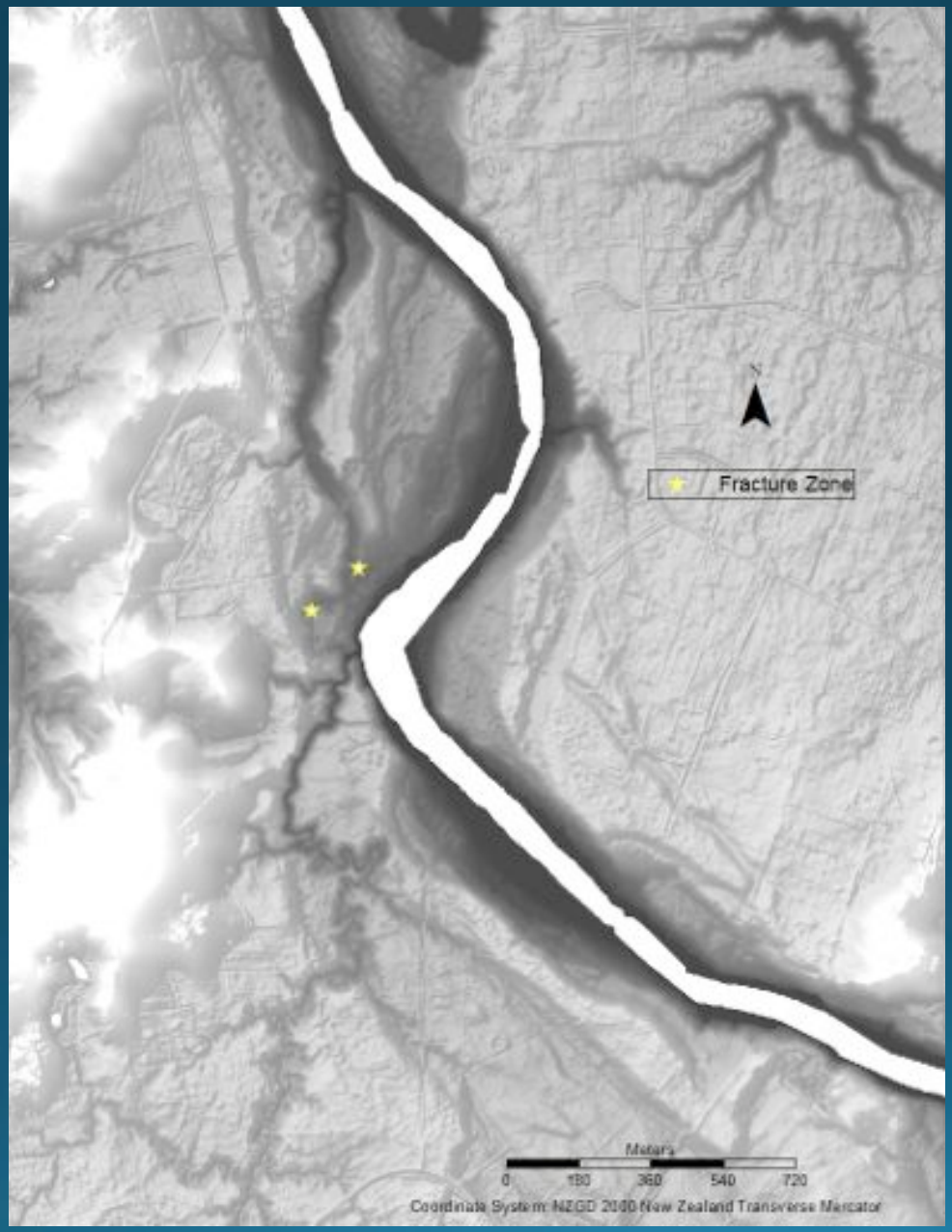



Image courtesy of C. Morcom

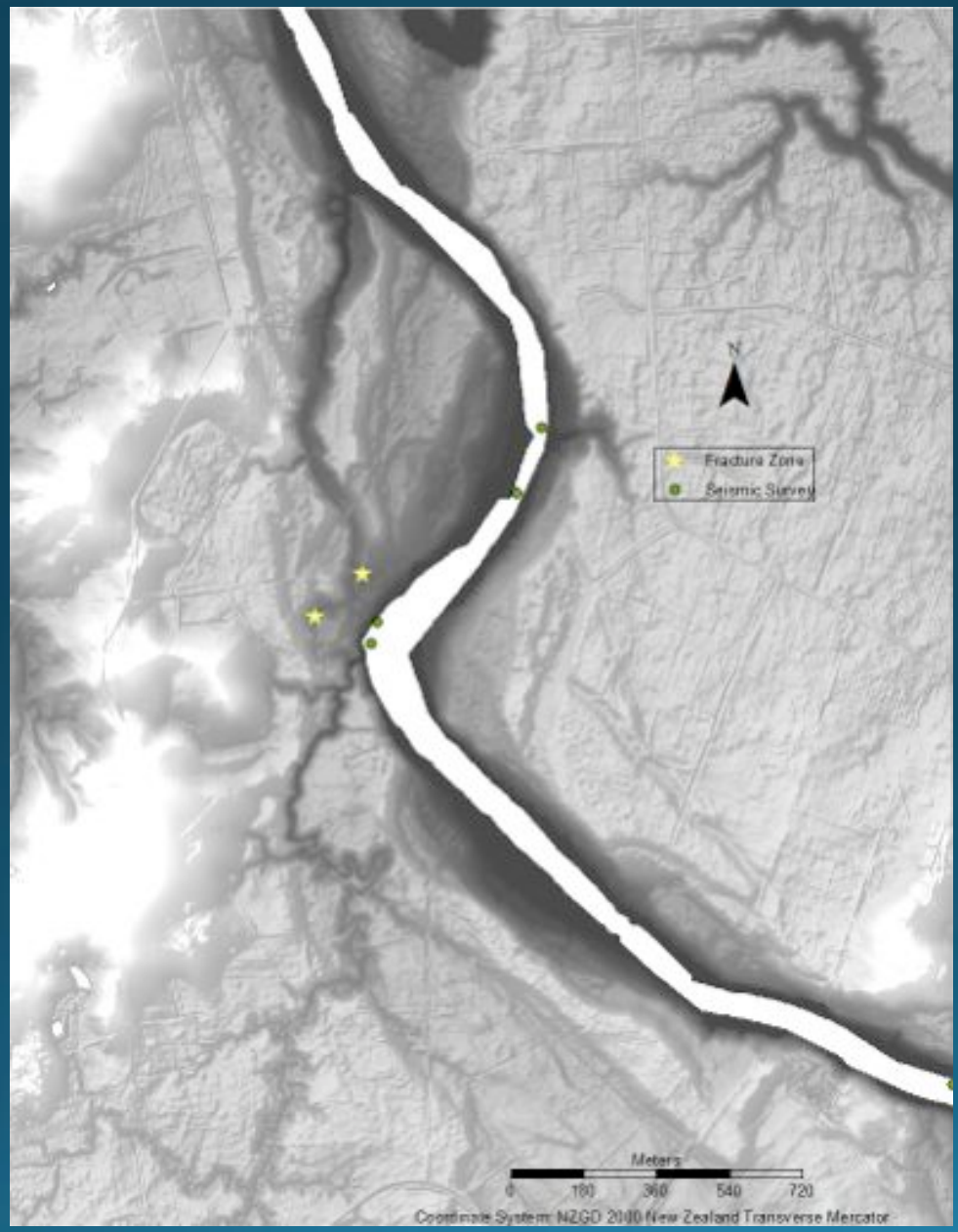
***Where there's fractures there's surface features***

Isolated hills along survey 1 & seepage located at survey 2

# GIS Analysis

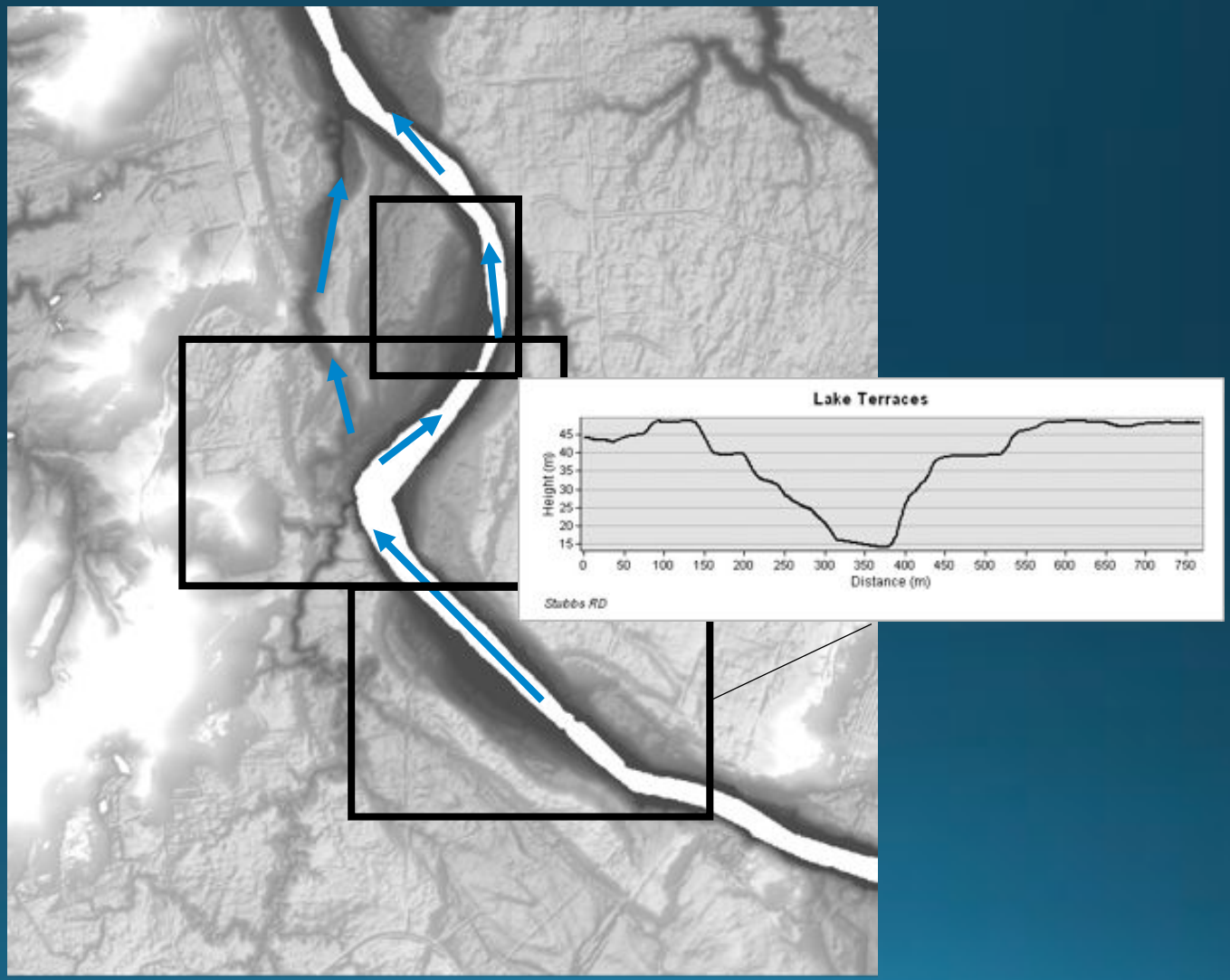


# GIS Analysis

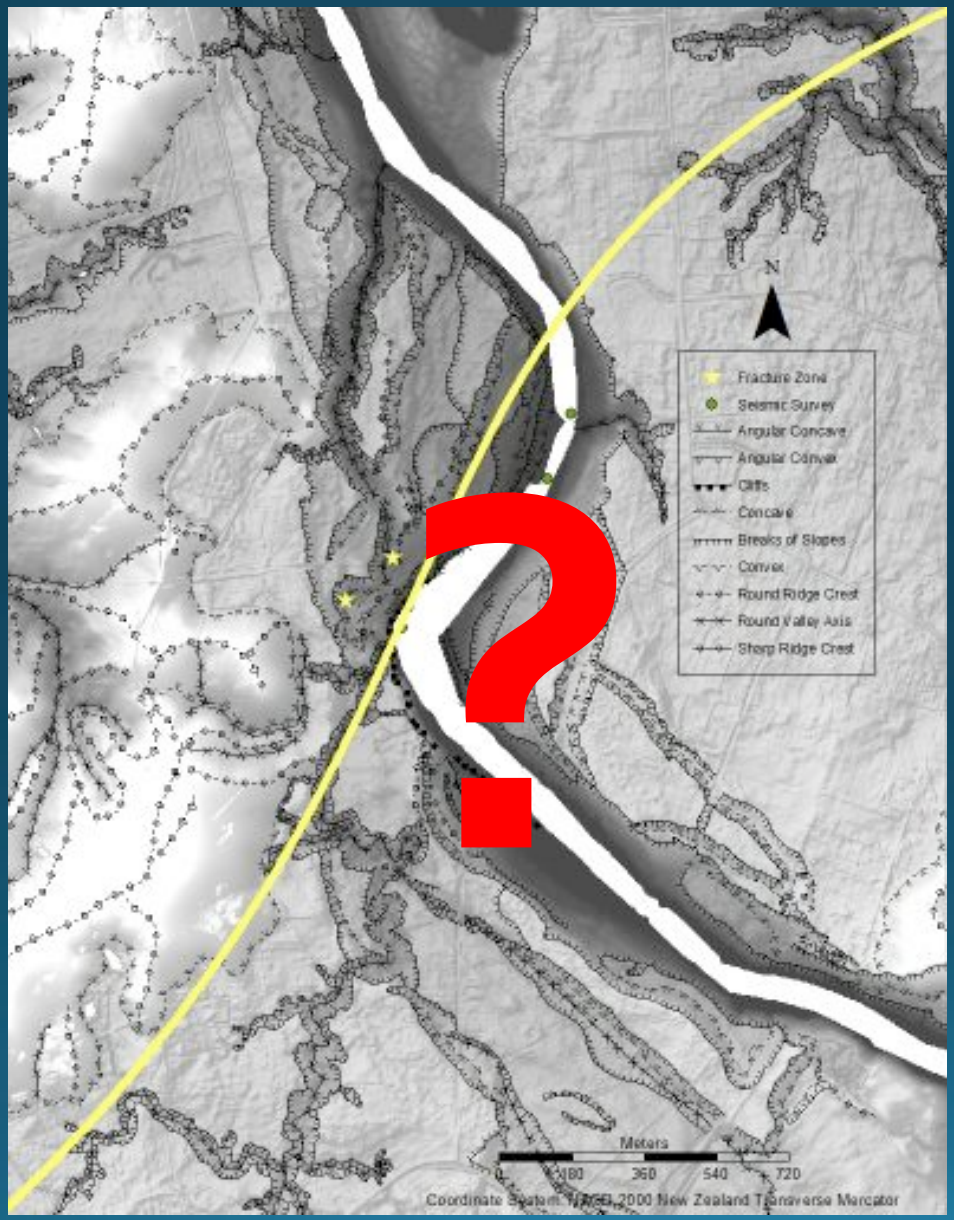


# ***Interpretation***

Post river entrenchment – 16 000 yrs



# ***Interpretation***

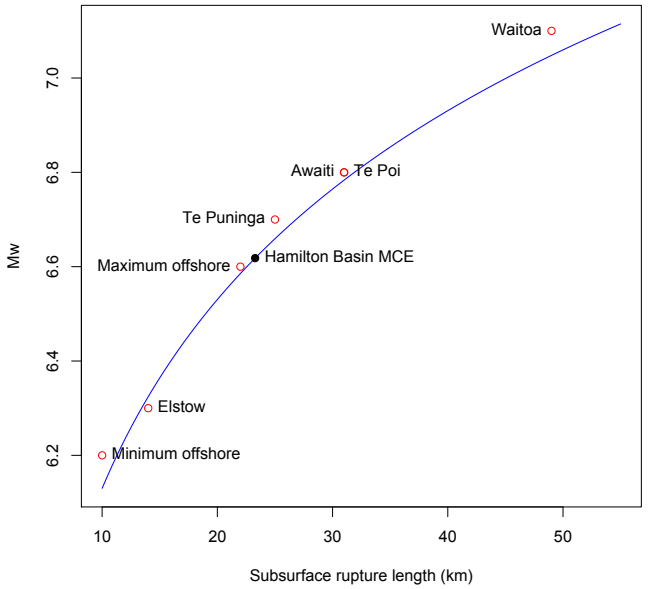


# MCE Mw & MM Intensity

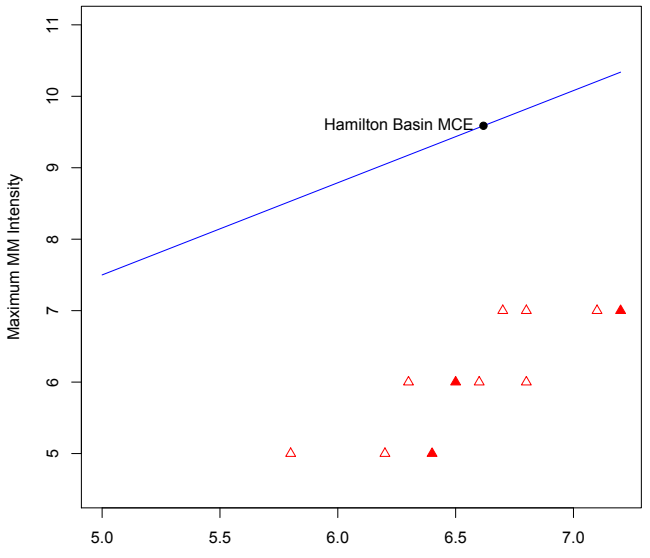
- Following methodology of Persaud *et al* (2016) for Kerepehi Fault, we can estimate maximum Most Credible Earthquake (MCE) magnitude (Mw) & Modified Mercalli (MM) shaking intensity
  - MCE Mw = 6.6
  - MCE maximum MM = 9 to 10
    - This is higher than expected MM intensity due to an event on the Kerepehi Fault
    - Current seismic risk for Hamilton Basin assumes MM ≥ 9 with annual probability of 0.0025%

| Intensity | CAP Severity | Modified Mercalli Level | Description |
|---|---|---|---|
| unnoticeable | 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. |
| weak | | MM 3 - weak | Felt indoors as a light vibration. Hanging objects may swing slightly. |
| light | | 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. |
| moderate | | 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. |
| | Extreme | MM 8 - heavily damaging | Alarm may approach panic. A few buildings are damaged and some weak buildings are destroyed. |
| | | 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. |

**Magnitude versus rupture length - Kerepehi Fault**




**Modified Mercalli Intensity versus moment magnitude - New Zealand**




Symbols = estimated MM in Hamilton for Keripehi Fault events

# Immediate future work

- Students:
  - Francesca Spinardi
    - Geological mapping & LiDAR
  - Ben Campbell
    - Resistivity, GPR & trenching @ Osborne Rd
  - Aleesha McKay
    - Liquefaction assessment

# Acknowledgements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  - EQC
  - Waikato Regional Council
  - University of Waikato