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
Since 2015

• 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
Waikato River seismic reflection survey

Potential fault zones

- 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
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
These lines are available as high-resolution tiff images of original data.
They are not high-quality processed files.
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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
• 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
• 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
• 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
Line 16

- 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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Hill morphology

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

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

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

- Displacement of river bed at 2 locations associated with “scour” holes
- Associated with possible fault trace across Hinuera surface in LiDAR
Osborne Rd located on upthrown side of fault
3D resistivity

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

- Multiple faults evident within river bed near Hammond Park
- Abandoned river channel on left bank
• Have CPT and resistivity data from Inland Port.
• CPT traces correlate with resistivity
3D resistivity

- 3D reconstruction shows fault within Hinuera sediments
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?
Volcanic field

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Tephra seismites

• Seismites were identified in old cores from peat lakes.

• Some lakes have been recored and cores scanned by CT and micro-CT

Spatial pattern of tephra seismites and ages

- Mamaku tephra after 8.0 cal ka
- Waiohau tephra after 14.0 cal ka
- Rotorua tephra after 15.6 cal ka
Tephra seismites

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

Images courtesy N. Ross

Images courtesy R. Johnston
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 $\geq 9$

<table>
<thead>
<tr>
<th>Intensity</th>
<th>CAP Severity</th>
<th>Modified Mercalli Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>unnoticeable</td>
<td>Minor</td>
<td>MM 1 - imperceptible</td>
<td>Barely sensed only by a very few people.</td>
</tr>
<tr>
<td>weak</td>
<td>MM 2 - scarcely felt</td>
<td>MM 3 - weak</td>
<td>Fell only by a few people at rest in houses or on upper floors. Fell indoors as a light vibration. Hanging objects may swing slightly.</td>
</tr>
<tr>
<td>slight</td>
<td>MM 4 - light</td>
<td>MM 5 - moderate</td>
<td>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.</td>
</tr>
<tr>
<td>moderate</td>
<td>MM 6 - strong</td>
<td></td>
<td>Generally felt outside and by almost everyone indoors. Most sleepers are awakened and a few people startled. 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.</td>
</tr>
<tr>
<td>severe</td>
<td>MM 7 - damaging</td>
<td></td>
<td>General alarm. People experience difficulty standing. 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.</td>
</tr>
<tr>
<td>extreme</td>
<td>MM 8 - totally damaging</td>
<td>MM 9 - extremely damaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM 10 - very destructive</td>
<td>MM 11 - devastating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MM 12 - completely devastating</td>
<td></td>
<td></td>
</tr>
</tbody>
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Symbols = estimated MM in Hamilton for Keripehi Fault events.
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

Waikato Expressway – Kay Rd cutting
Acknowledgements

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  • EQC
  • Waikato Regional Council
  • University of Waikato