EQC University Post-graduate Grant
***Structure and Activity of the Hauraki Rift (*14/U693)**

Principal Investigator: Jennifer Eccles, University of Auckland
Associate Investigators: Sigrun Hreinsdottir, GNS Science and Julie Rowland, University of Auckland
PhD Candidate Supported: Robert Pickle, University of Auckland

Key words

Hauraki Rift; Geodesy; Tectonics; Extension; Seismicity; Faults

Summary

Relatively little had been previously known about the nature or origin of tectonic activity throughout north-western New Zealand, beyond that it is a low strain rate environment (~1 mm/yr) and home to the Hauraki Rift. The Hauraki Rift is an N-S trending, 250+ km long and 25 km wide on-shore/off-shore continental rift 40 km east of Auckland City and oblique to the Hikurangi subduction margin. A three-year 40+ station campaign GNSS geodetic survey was done incorporating previously unused historical data to constrain the crustal motion throughout the north-western North Island and the Hauraki Rift. A screw dislocation rift model incorporating this data derived estimates for the far-field widening rate and mechanical thickness of the Hauraki Rift to be ~0.9 mm/yr and ~17 km respectively. Relative to a fixed Australian Plate reference frame, the results generally showed S-SE velocities east of the Hauraki Rift and W-SW velocities west of the rift with increasing magnitudes to the south towards the plate boundary. Analysis of land and satellite-based gravity anomalies in conjunction with the observation of geodetic velocity discrepancies were used to infer the location and motion of several faults not currently considered active, including N-S trending faults parallel to the west coast of Auckland. North of Auckland (~37°S) sites maintained consistent W-SW velocity magnitudes throughout indicating that northernmost New Zealand may not be ‘stable’ relative to the Australian Plate; the observation of similar cGNSS geodetic velocities on both Norfolk Island and New Caledonia may be evidence that the eastern portion of the Australian tectonic plate (east of Lord Howe Island) is mechanically separated from continental Australia. An Oligocene-Miocene tectonic model detailing the westward collision of the Loyalty-Three Kings arc and subsequent opening of the Norfolk Basin is presented. This model proposes that the relative motion between the Australian and "East Australian" sub-plate may be accommodated by a continuous ~2000 km lineament of weakened crust marked by low Bouguer Anomalies, and concentrated volcanism. This feature may extend from New Caledonia along the western Norfolk Ridge through the Reinga Basin and along the western coast of the North Island of New Zealand.

Introduction

The Canterbury Earthquakes Royal Commission (CERC) recommended in 2012 that “Research continues into the location of active faults near Christchurch and other population centres in New Zealand, to build as complete a picture as possible for cities and major towns”. Forty percent of New Zealand’s population live, and 40% of GDP generation occurs, within 50 km of the Hauraki Rift (which stretches from Matamata to Whangarei). Hauraki Rift faults are currently understood to be capable of producing ~M7 earthquakes (e.g. Hull et al., 1995; Persaud et al., 2016). Urban intensification and expansion, particularly in Auckland and surrounds, means improved hazard data is

essential to inform regional planning. Historical earthquakes have occurred in the region e.g. the 1891 Waikato Heads Earthquake and recent seismicity east of Northland (1st and 3rd January 2019; GeoNet). Offset terrace surfaces within the Hauraki Plains resolve tectonic events recurring at 5000-10000 year intervals (Persaud et al., 2016) on individual segments of the Kerepehi Fault. Offset horizons within on a study within the Kopoutai Bog, Elstow section of the Kerepehi Fault, may point to somewhat shorter earthquake recurrence (de Lange and Lowe, 1990).

Objectives

This project proposed to constrain the structure and activity of the active but poorly understood/studied Hauraki Rift using geodesy, seismicity and gravity to identify tectonic structures and their level of activity. During PhD research the geographic scope of the study increased and objectives were revised to geodetically survey much of the northern North Island, occupying marks which had last been surveyed in 1995 and/or 2013 as well as establishing data at many new sites. This also allowed study of structures outside of the 'Hauraki Rift'. Parallel to this, seismic analysis involving relocation of historic catalogued earthquakes in the area was to be done, data from new/constructed seismic sites incorporated, and custom detection algorithms and filters designed to better resolve the region's microseismicity.

Resolution of the small, and small variations in, velocity vectors of the region required careful consideration of the reference frame used and this opened up questions about the context of northern New Zealand in the Australia Plate and a review of gravity and magnetic data throughout the greater north-east Zealandia was undertaken to assess the crustal structure of greater north-east Zealandia and well as the northern North Island/Hauraki Rift region.

Conclusions and key findings

The geodetic velocities produced by this work (shown in Figure 1) were modelled to estimate that the far-field rate of widening at the Hauraki Rift was 0.9 mm/yr, and that its mechanical thickness was about 17 km. Variations in magnitude and direction of the new velocities determined also provided evidence that several faults within the greater Auckland region could be active, including a N-S trending feature near the Waitakere Ranges by the west coast west of Auckland and a possible northward extension of the Wairoa North Fault through Waiheke Island. The seismic work highlighted the value in additional seismic stations provided they are far removed from Auckland City, and also showed that a narrow waveform filter of 3-11 Hz explicitly targeting the region's microseismicity was able to uncover many more events than typical default values (e.g. 2-20 Hz). The elevated south-west geodetic velocities observed throughout Northland confirm that the region is not stable relative to the Australian Plate and the similarity of vectors also observed on Norfolk Island and New Caledonia may mean that the eastern Australian Plate (including New Zealand as a whole) is mechanically distinct.

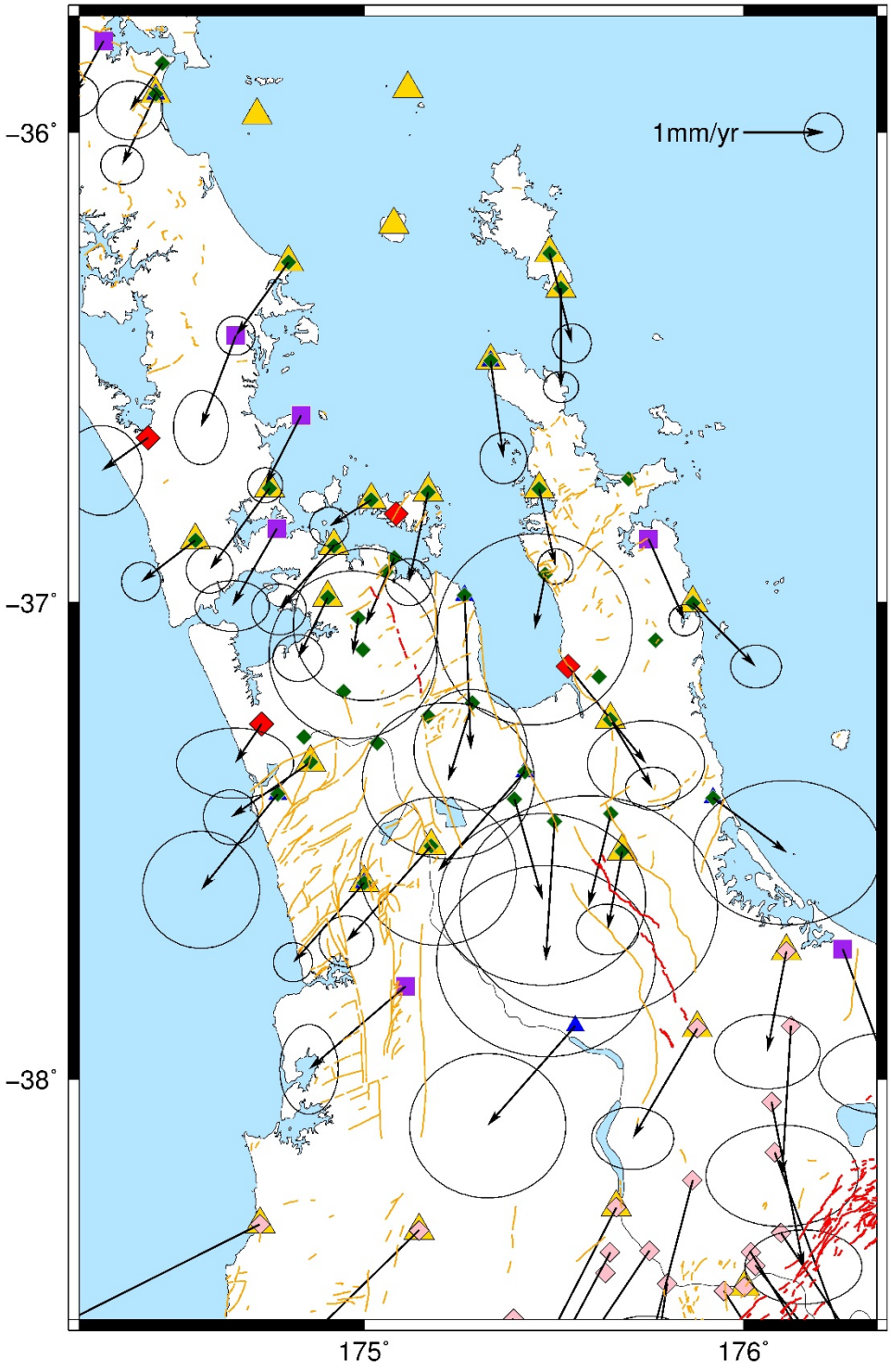

Figure 1: Map of velocity vectors (arrows) within the Hauraki Rift region (Pickle, 2019) at sites represented by coloured symbols. Error ellipses are shown in black. Active faults are mapped in red and faults deemed inactive in yellow.

Impact

This work could reduce the impact of seismic hazard in greater Auckland by highlighting potential fault activity in a region in which there was no previous evidence for active motion and allowing further research into, and planning for earthquake rupture scenarios involving, these structures. Additionally by deriving the characteristics of the actively widening Hauraki Rift east of Auckland, its potential for large earthquakes can be reassessed and modelled by future workers.

Future work

This project was unable to resolve velocity estimates at several geodetic sites due its short three year duration and residual effect of crustal displacements resulting from the 2016 Kaikoura Earthquake, including many sites near the Hauraki Rift axis. Additional surveying of these sites will provide the data needed to resolve these to a high precision, reduce the ambiguity of our Hauraki Rift model, and possibly determine activity on new faults. Furthermore this project noted that the degree of microseismicity resolved in the northern North Island would be increased dramatically with the addition of ~2-5 new seismic stations, even relatively low-cost short period sensors, and that this lack of stations in this area was the primary bottleneck for future seismic work here. Aside from resolving the seismicity near Auckland and the Hauraki Rift, an array along the west coast of Northland may be able to confirm the presence of active strain immediately offshore in the Tasman Sea hypothesised by this project and may also help to understand the cluster of M4+ earthquakes which occurred in the Hauraki Gulf east of the Whangarei Harbour in early 2019.

Acknowledgements

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Persaud, M., Villamor, P., Berryman, K.R., Ries, W., Cousins, J., Litchfield, N., and Alloway, B.V., 2016, The Kerepehi Fault, Hauraki Rift, North Island, New Zealand: active fault characterisation and hazard, New Zealand Journal of Geology and Geophysics, 59:1: 117-135, DOI: 10.1080/00288306.2015.1127826.

Outputs and Dissemination

Presentation title: New Results From Ongoing Geodetic Surveys of the Hauraki Rift
Authors: Pickle R.C.

Conference: DEVORA Symposium
Date of presentation: November 10 2016

Presentation title: Misaligned Deformation Well Within The Over-Riding Plate, Hikurangi Subduction Zone, New Zealand
Authors: Pickle R.C., Eccles J.D., Hreinsdottir S., Palmer, N., Rowland, J.V..
Conference: New Zealand Geosciences Conference
Date of presentation: November 2016

Presentation title: Misaligned Deformation Well Within The Over-Riding Plate, Hikurangi Subduction Zone, New Zealand
Authors: Pickle R.C., Eccles J.D., Hreinsdottir S., Palmer, N., Rowland, J.V..
Conference: American Geophysical Union
Date of presentation: December 2016

Presentation title: New Results From Ongoing Geodetic Surveys of the Hauraki Rift
Authors: Pickle R.C.
Conference: Geoscience Society NZ
Date of presentation: July 18 2017

Presentation title: Results from the 2015-2017 Northern North Island Geodetic Campaign
Authors: Pickle R.C.
Conference: Devora Forum
Date of presentation: Nov 7 2017

Presentation title: Recent Results from the Hauraki Rift Survey; Could this Activity be Affecting Auckland Volcanism?
Authors: Pickle R.C., Eccles J.D.
Conference: Devora Workshop
Date of presentation: Nov 28 2017

Presentation title: Geodetic Results from the Hauraki Rift: Slow Continental Rifting Oblique to Subduction, North Island
Authors: Pickle R.C., Eccles J.D., Hreinsdottir S., Palmer, N., Rowland, J.V..
Conference: New Zealand Geosciences Conference
Date of presentation: December 2017

Presentation title: Crustal Strain Measurements via Geodesy: Evidence for Episodic Deformation
Authors: Pickle R.C.
Conference: Devora Forum
Date of presentation: November 2018

Presentation title: ACTIVE STRUCTURES IN THE NORTHERN NORTH ISLAND INTERPRETED FROM GNSS GEODESY
Authors: Pickle R.C., Hriensdottir, S., Rowland, J.V. and Palmer, N.
Conference: Geosciences 2018
Date of presentation: November 2018

This work has additional be used in many discussions with stakeholders such as Northland, Auckland, Waikato and Bay of Plenty Councils, Civil Defence, EQC and the insurance industry undertaken during the development of an Endeavour Fund proposal

“Bridging the Gulf between Hauraki Rift Tectonics and Hazard Management” submitted to the Ministry of Business, Innovation and Employment in March 2019.

Links to publications/theses

Thesis Title: NATURE AND POT ENT IAL ORIGINS OF THE LOW-RATE TECTONICS OF THE HAURAKI RIFT AND NORTH-WESTERN NEW ZEALAND: A GEOPHYSICAL INVESTIGATION
Author: Robert Pickle
Submitted March 2019 to the University of Auckland for the award of the PhD degree

List of key end users

Northland Regional Council
Auckland Council
Waikato Regional Council
Hamilton Council
Bay of Plenty Regional Council
EQC
GeoNet
RMS (Hazard models for the insurance industry)