Crustal structures in the Coromandel Volcanic Zone (CVZ) and Hauraki Goldfield, New Zealand: Insight from Qualitative and Quantitative Potential Field Analysis

Engdawork A. Bahiru[1], Julie V. Rowland[1], Jennifer D. Eccles[1], Richard L. Kellett[2]

[1]School of Environment, University of Auckland, Private Bag 92019 Auckland, New Zealand. [2]GNS Science, P. O. Box 30368, Fairway Drive, Lower Hutt 5040, Wellington, New Zealand

1. Introduction and aim

- The North Island of New Zealand has a rich record of protracted and varied deformational history that began with the accretion of Mesozoic Metasedimentary terranes onto the margin of Gondwana and continued under a continental extensional regime (Sporli, 1987). More recently oroclinal bending and oblique convergence occured in response to the initiation and evolution of the modern plate boundary associated with the lateral migration of the arc with assocaited back-arc and intra-arc extension (Mortimer, 2014).
- The Coromandel Volcanic Zone (CVZ), which hosts the Hauraki Goldfield, is New Zealand's premier region for Epithermal Ag-Ag deposits (Christie et al., 2007). Despite the past research on epithermal Au-Ag mineralisation,little is known about regional scale structures and the nature of basement structures underneath this volcanic region. Thus, the aim is to interpret crustal structures that have controlled mineralisation.

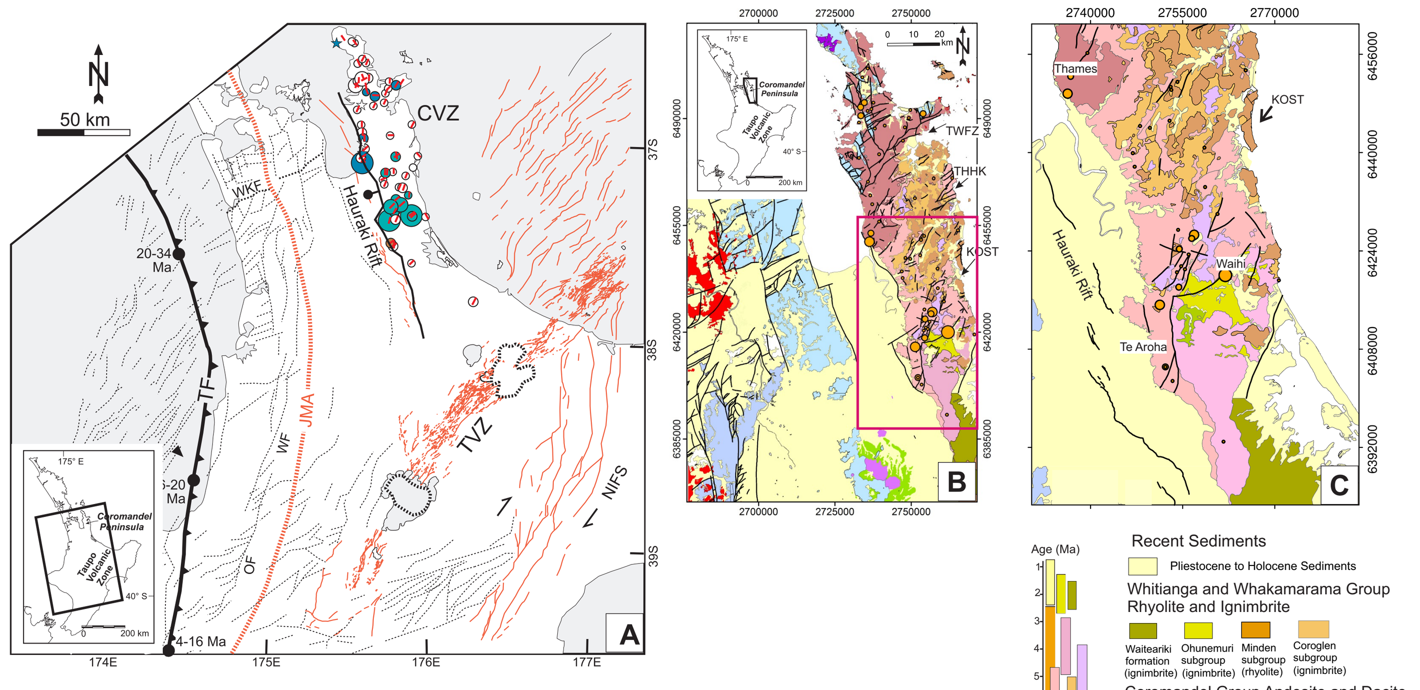


Figure 1: **(A)** The structural architecture of the North Island of New Zealand showing different fault patterns.Taranaki Fault (thich barbed line annotated with position of northern limit of activity through time (Stagpool and Nicole, 2008). The Junction Magentic Anomaly (thick red dashed line), caldera structures (thick black dashed polygons). Green circles are epithermal deposits. OF= Ohura Fault, WF= Waipa Fault, CVZ= Coromandel Volcanic Zone, TVZ= Taupo Volcanic Zone, NIFS= North Island Fault System.
(B) The regional geology of CVZ (Edbrooke, 2001) and the area in a red rectangular box is the southern CVZ. **(C)** the study area: the southern CVZ. **(D)** Simplified stratigraphy of the southern CVZ (after Brathwaite and Christie, 1996)

2. Method

Qualitative Analysis

- Anomaly gradients are enhanced from spectrally filtered Bouguer Gravity and Total Magnetic Intensity reduced to pole (RTP) maps. We use the tilt angle of the horizontal derivative (TAHG; Ferreira et al 2013) technique. Then gradient lineaments are extraced manually. This provides the lateral continuity of lineaments.
- The multiscale edge detection technique (worming; Holden et al 2000) is used to extract worms in the data. This allows detection of edges at different crustal depths.

Modelling approach

- Integrated 2D forward models are constructed across three profiles that transecting the major anomalies and gradients in the Bouguer anomaly and magnetic data as well as major geological and structural fabric.
- Key questions to answer and hypothesis to test in this modelling are:
  (1). What is the depth and lateral continuity of hydrothermal alteration beneath the post-mineralisation volcanic cover?
  (2). Why are Bouguer gravity anomalies and magneitc anomalies spatially uncorrelated over large part of the CVZ?
  (3). How does the Mesozoic greywacke basement configuration change from north to south within the CVZ? Does it agree with the overall regional inferrence of volcanic thickening towards south?
  (4). How do the overall crustal structure (faults) look like underneath the volcanic cover?

3. Datasets

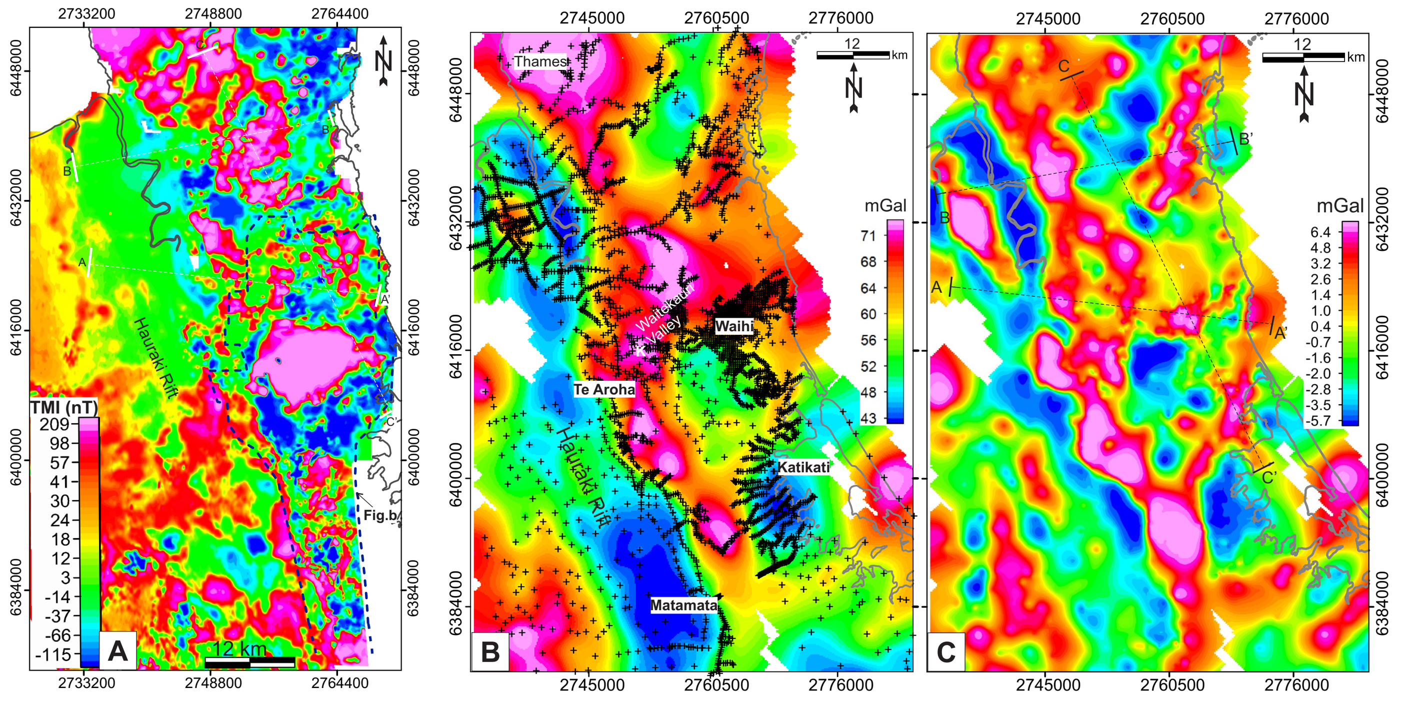


Figure 3: **(A)** Total magnetic intensity reduced-to-pole (RTP) map of the southern CVZ. **(B)** the high resolution aeromagnetic map for the area inside the broken line shown in (A). **(C)** Observed Bouguer gravity map, based on ground data (black cross-marks) gridded at 1 km cell size. **(D)** Residual Bouguer gravity map. These maps depict anomalies that can be related to upper-crustal geological features.

4. Anomaly gradients and crustal lineament analysis

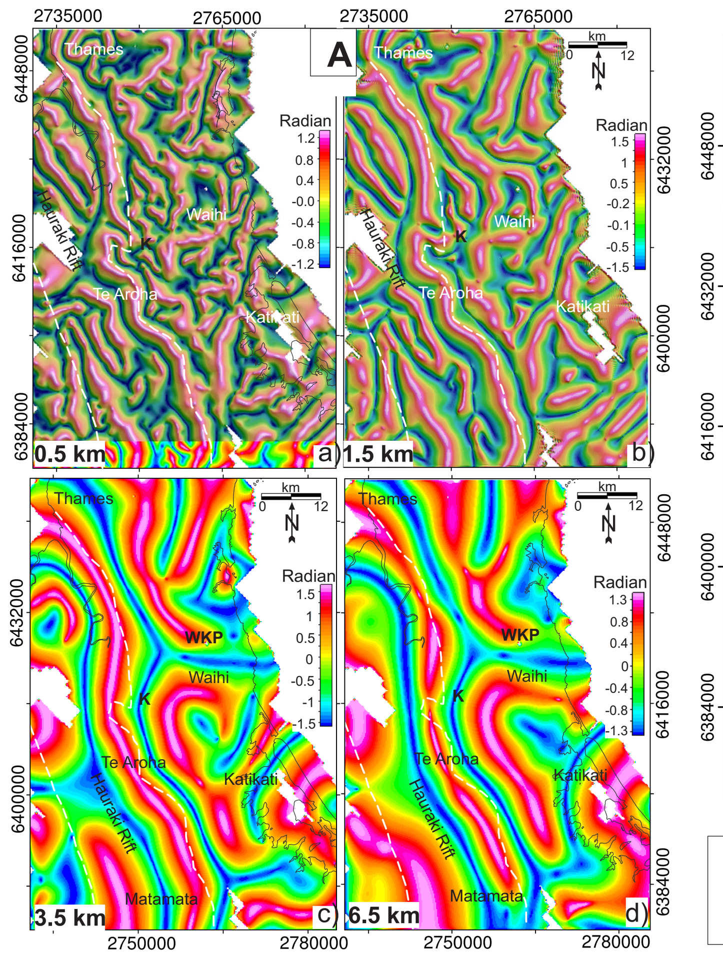


Figure 4: Bouguer gravity gradient of short-wavelength anomalies at apparent depth less than 0.5 km (a), intermediate wavelength at apparent depth less than 1.5 (b) and 3.5 km (c), and long wavelength anomalies at depth greater than 6.5 km (d).

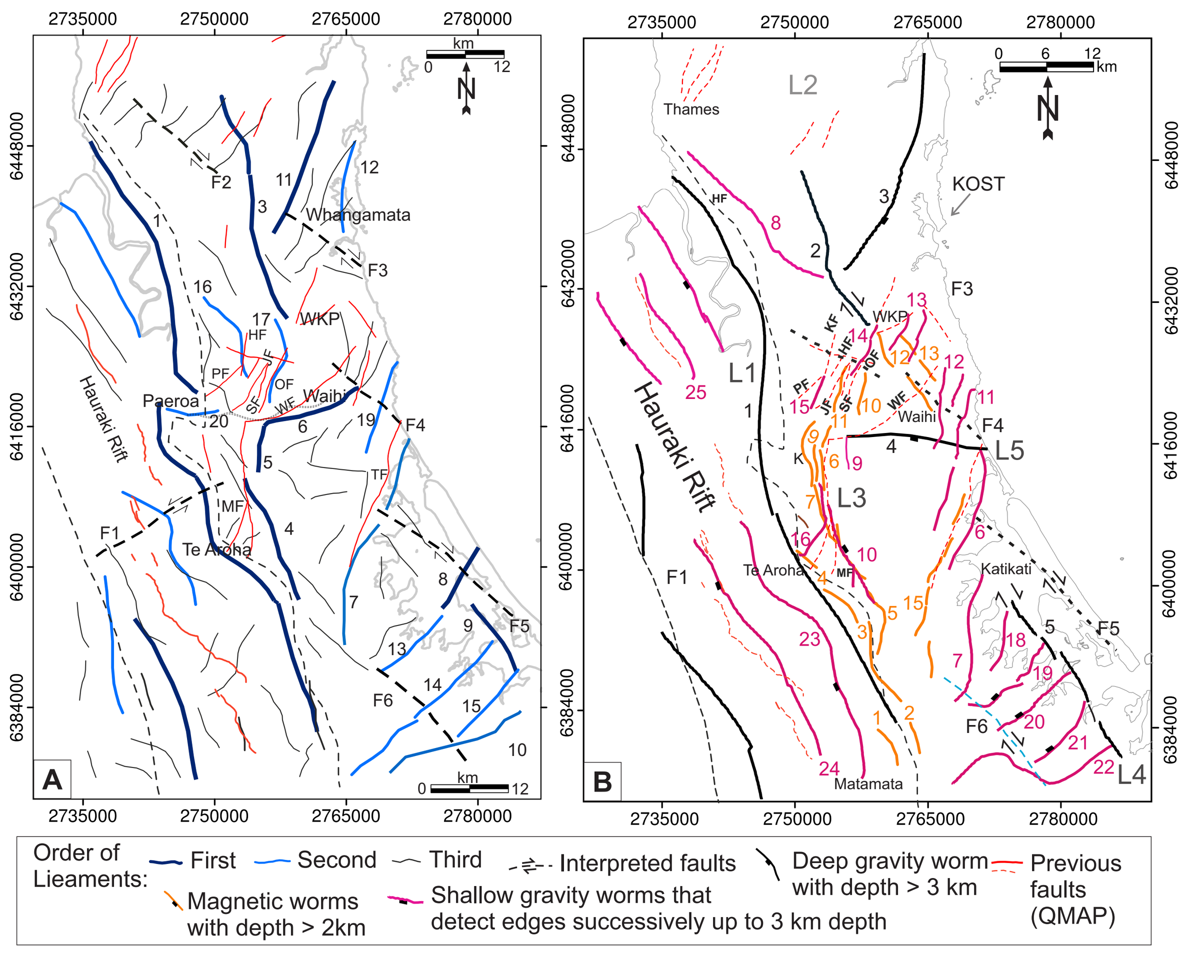


Figure 5: Lineament analysis: (**A**) gravity lineaments. First-order lineaments with length > 15 km occur at different depths and interpreted to show a regional significance. Second-order lineaments have length > 10 km. Third-order lineaments do not show depth continuity and are < 10 km in length. (**B**) crustal worms.

5. Forward modelling

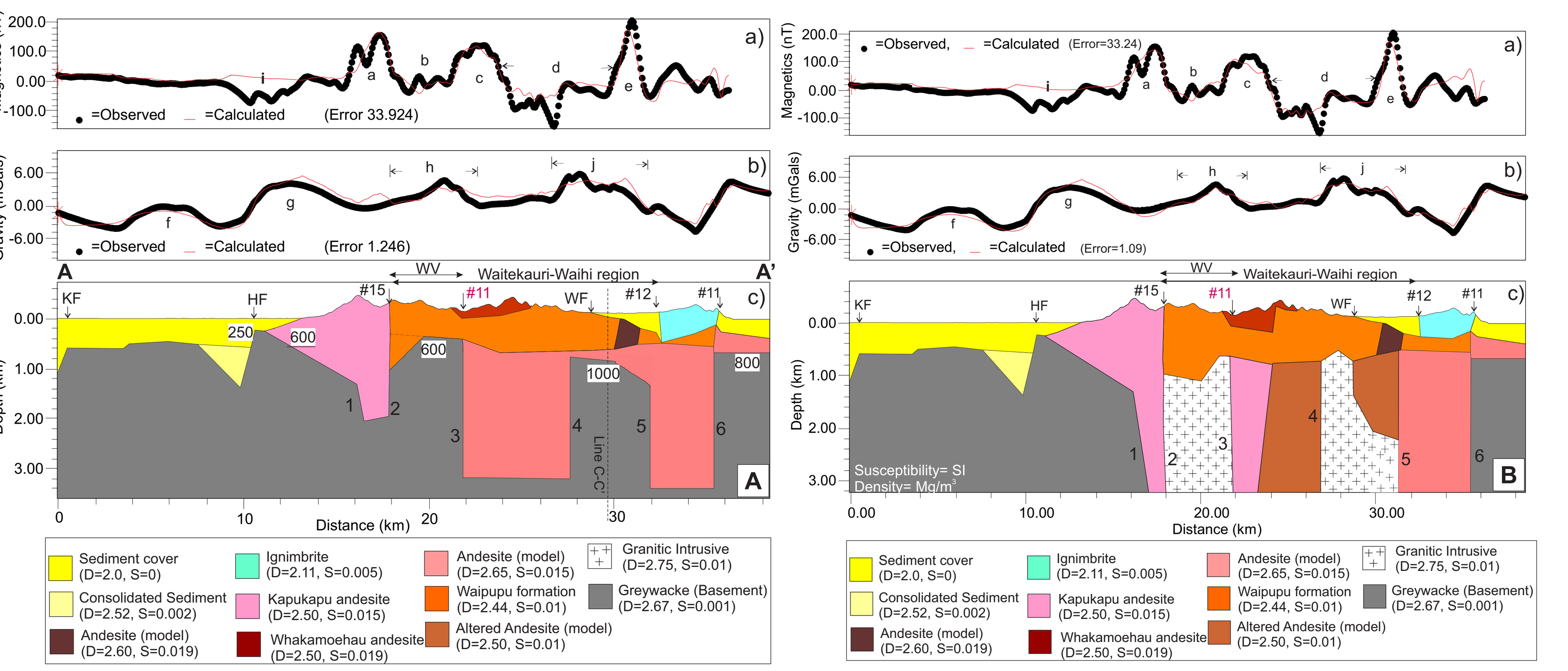
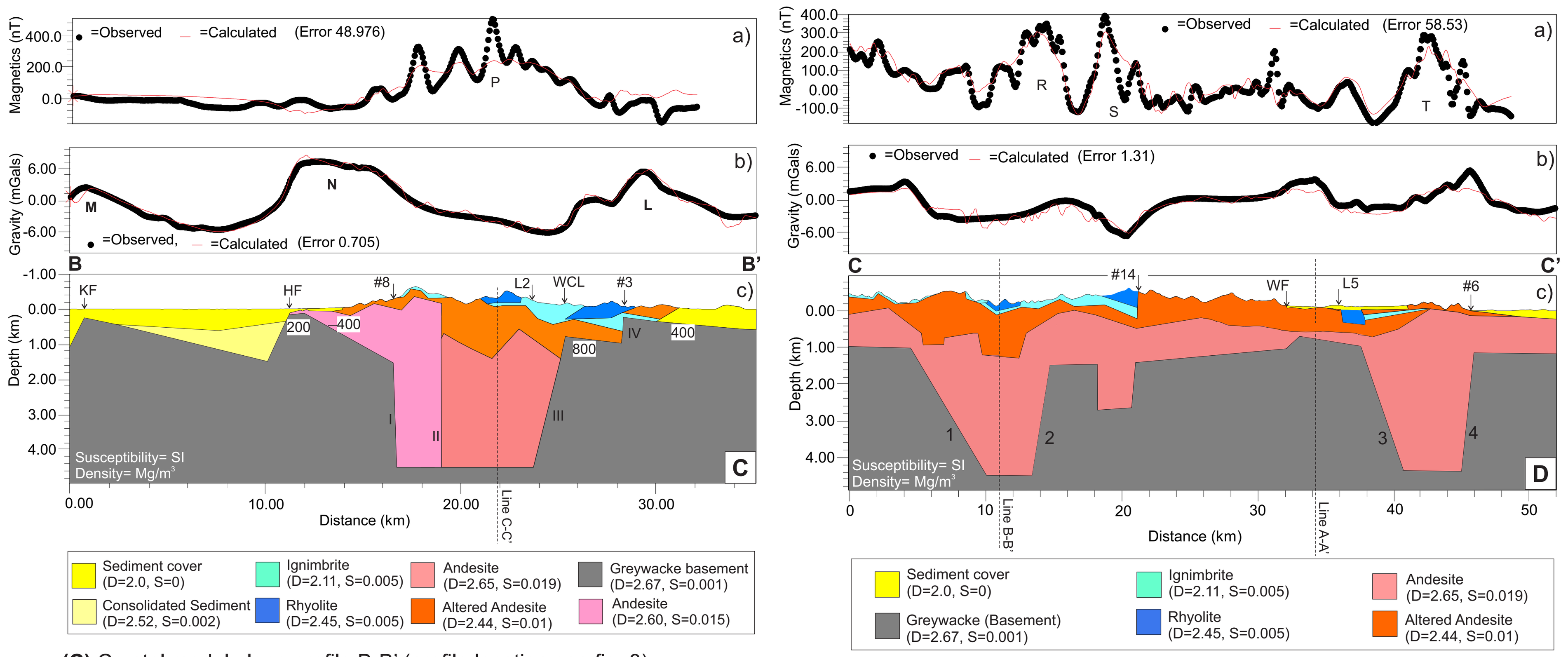


Figure 7: **(A)** 2D forward model of TMI and Bouguer gravity along profile A-A' (see fig.3). (a) TMI response, (b) residual gravity response, (c) crustal model interpreted based on magnetic susceptibility and density values and surface geology. Numbers 1-6 refer deep-seated faults and lithology contacts. Nubmers inside boxes are approximate depth-to-basement top values. HF=Hauraki Fault, WF=Waihi Fault, WV=Waitekauri Valley. #11, 12 and 15 refer surface projection of deep-seated gravity and magnetic worms.

(B) An alternative model interpreted along profile A-A'. A granodiorite intrusive is modelled in stead of greywacke basement high. #11, 12 and 15 refer surface projection of deep gravity worms. Numbers 1-6 refer deep-seated lithology contacts.HF=Hauraki Fault, WF= Waihi Fault, WV= Waitekauri Valley



(C) Crustal model along profile B-B' (profile location see fig. 3). Numbers I-to-IV refer modelled deep-seated faults and lithology contacts. Numbers inside white boxes are approximate depth-to-basement top values. #3, #8 and L2 are surface locations of deep gravity worms. HF= Hauraki Fault, WCL=Whangamata-Coromandel Lineament.

(D) Crustal structure modelled along along profile C-C' (profile location see fig.3). Numbers 1-4 are deep faults and lithology contacts. #6, #14 and L5 are surface locations of deep gravity worms. WF= Waihi Fault

6. Key Findings

(1) Our qualitative structural analysis indicate the presence of near-surface NE-to-NNE trending rift basins defined by parallel arrays of faults interpreted within the volcanic cover sequence. These structures appear to have segmented across inherited basement transfer structures that likely reactivated in response to the NW-SE directed extension. This interpretation is consistent with a model in which inherited basement fabrics, particularly those parallel to the New Zealand oroline, appear to have influenced the late Miocene-to-Present tectonic segmentation of the CVZ.

(2) The joint 2D models illustrate the presence of steeply dipping crustal faults with up to ~3 km vertical offset of the greywacke basement. These fauls as well as deep contacts between greywacke and early andesite depost define large scale inherited fabric that control subsurface basin geometry in the CVZ.

(3) The greywacke basement that is shallowest at ~150 m below sea level along the Hauraki Fault across profile B-B'is modelled to gradually deepen toward the southeast. This agree with the overall regional inference that volcanic cover sequence thicken towards the southeast.

(4) Our integrated models show a hydrothermally altered andesite layer that overlies the greywacke basement and unaltered early andesite. This alteration continues to a depth of ~1 km and attains lateral continuity ~15 km and ~48 km in the west-east and north-south direction, respectively.

(5) Modelling provides insight in to the gravity and magnetic pseudo-depths interpreted using spectral analysis technique. The models suggest two dominant depths of an interface with a considerable vertical variation, which are at ~1 km and ~4.5 km below sea level; these correlate to the modelled laterally varying depths of the volcanic overburden-basement interface.

(6) Modelling demonstrate that a greywacke basement high or hydrothermally altered grano-diorite intrusion at a depth of ~1 km below sea level, explain the disparity between gravity and magnetic anomalies over the extensively altered southern CVZ.

(7) The model along profile A-A' shows the presence of NE-to-NNE striking crustal faults that correlate with deep gravity worms beneath the Waitekauri Valley and Waihi regions. These structures have likely controlled the localisation of epithermal mineralisation as well as emplacement of granodiorite intrusion in the alternative model. Similarly, the NNW-striking crustal faults interpreted along profile B-B' appear to coincide with deep-seated gravity and magnetic worms/lineaments that are previously interpreted to localise epithermal deposits and deep hydrothermal alteration.

(8) Overall, modelling provide insight in to the sub-surface basin geometry of the greywacke basement bounded by crustal faults and deep lithology contacts. These faults have likely propagated upward and exert control on patterns of faults within the volcanic cover sequence.

Reference

1) Christie AB, Simpson MP, Brathwaite RL, Mauk JL, Simmons SF 2007. Epithermal Au-Ag and related deposits of the Hauraki Goldfield, Coromandel Volcanic Zone, New Zealand. Economic geology 102 (5): 785-816.

2) Edbrooke SW 2001.Geology of the Auckland area. Institute of the geological and Nuclear sciences: 1:250,000 geological map sheet 68p. Lower Hutt, New Zealand

3) Ferreira FJ, Souza JD, Bongiolo AD, Castro LGD 2013. Enhancement of the total horizontal gradient of magnetic anomalies using the tilt angle: Geophysics 78(3):J33-J44

4) Holden DJ, Archibald NJ, Boschetti F, Jessell MW 2000. Inferring geological structures using wavelet based multiscale edge detection and forward models. Exploration Geophysics 31:617-621

5) Jacobsen BH 1987. A case of upward continuation as a standard separation filter for potential filed maps. Geophysics 52(8): 1138-1148

6) King PR 2000. Tectonic reconstruction of New Zealand. New Zealand Journal of Geology and Geophysics 43: 611-638.

7) Mortimer N 2014. The oroclinal bend in the south Island, New Zealand. Journal of structural geology 64: 32-38.

Acknowledgement

The Ministry of Business, Innovation and Employment (MBIE), New Zealand, has funded the study expenses through the 'Mineral Exploration Models' programme. New Zealand Petroleum and Minerals and OceanaGold at Waihi are acknowledged for providing aeromagnetic and regional gravity datasets.

Contact

Engda A. Bahiru
University of Auckland, School of Environment, New Zealand
E-mail: ebah622@aucklanduni.ac.nz