Gravity Modelling of Rangitoto Subsurface

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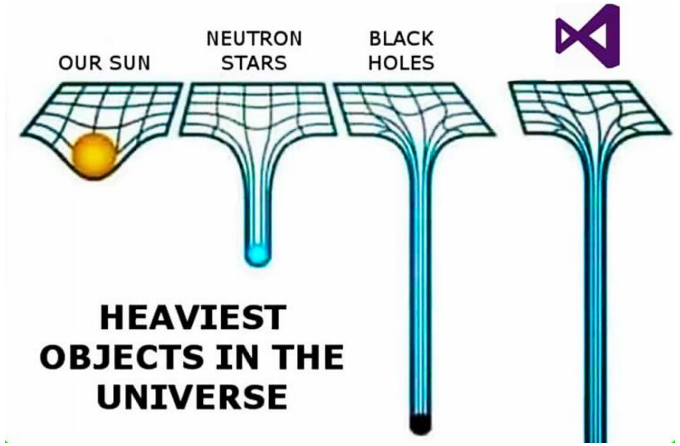
- Born: South Tangerang City, 2 October 1993
- Education:
    - 2nd South Tangerang City SHS
    - Universitas Gadjah Mada (B.Sc. With Honours)
    - Kyushu University (M.Sc.)
    - The University of Auckland (Ph.D. Candidate)
- Focus:
    - Vulcanology,
    - Geophysics,
    - Geology,
    - Mapmaking.

Introduction

The Concepts of Gravity

- First proposed by Isaac Newton in the 17th century.
- A consequence of mass bending the space-time.
- Density = mass per volume
- Denser mass = more space-time bending = more gravity.



What Influences Gravity

- Latitude (gravity @ equator < @ pole)
- Elevation (-0.3086 mGal per m)
- Water bodies
- Instrumental displacement (if you do measurement on ship, airplane, etc.)
- Instrumental drift
- Topographic mass and relief
- Sun and moon position on the sky
- Geological, hydrological, and weather phenomena

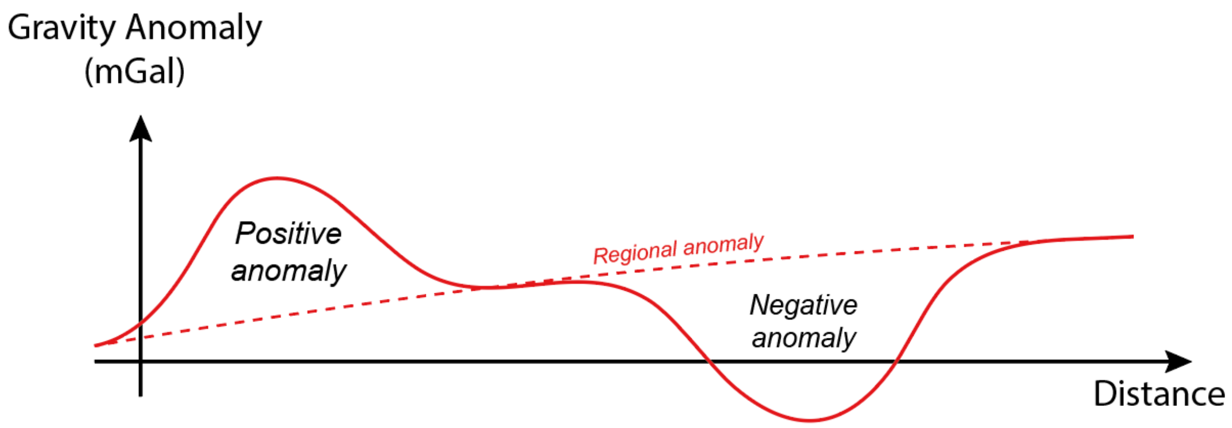
Signal vs Noise

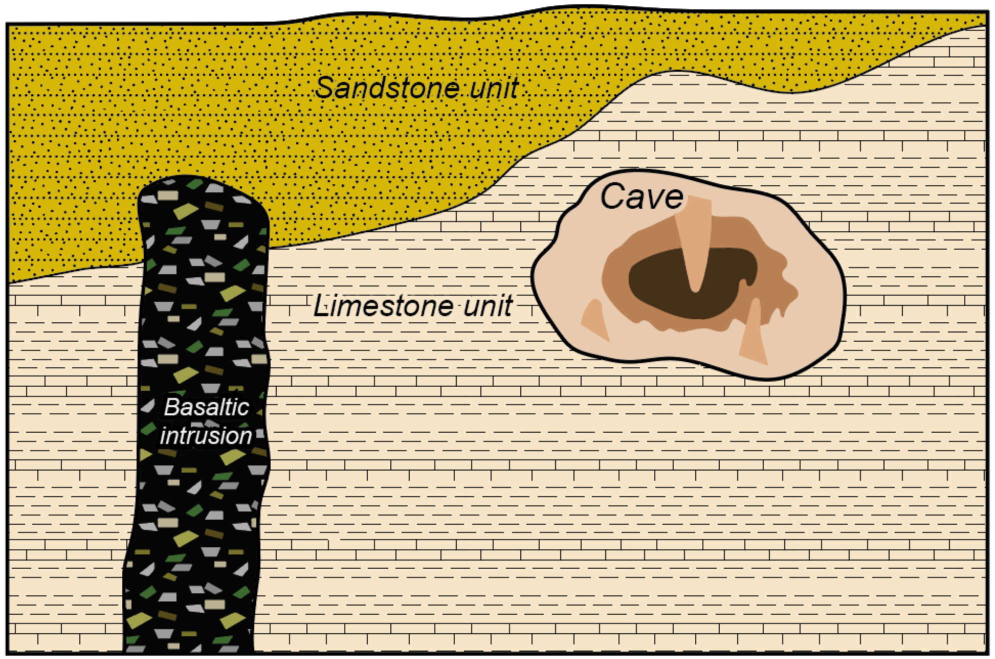
- The aim of my study: geological phenomena
- Non-geological influence on gravity = noise
- Bouguer anomaly = geological effects on gravity
- Bouguer anomaly calculation:

Observed data – (latitude effect + elevation effect + instrumental drift + topography and water bodies effect + sun and moon effect)

Gravity for Geology

- Geological phenomena produces mass anomalies
- Knowledge of various rock density
- Mass deficits: sediments, pyroclastic, cavities, salt domes, mantle upwelling, etc.
- Mass excesses: intrusions, basement highs, mantle downwelling, etc.



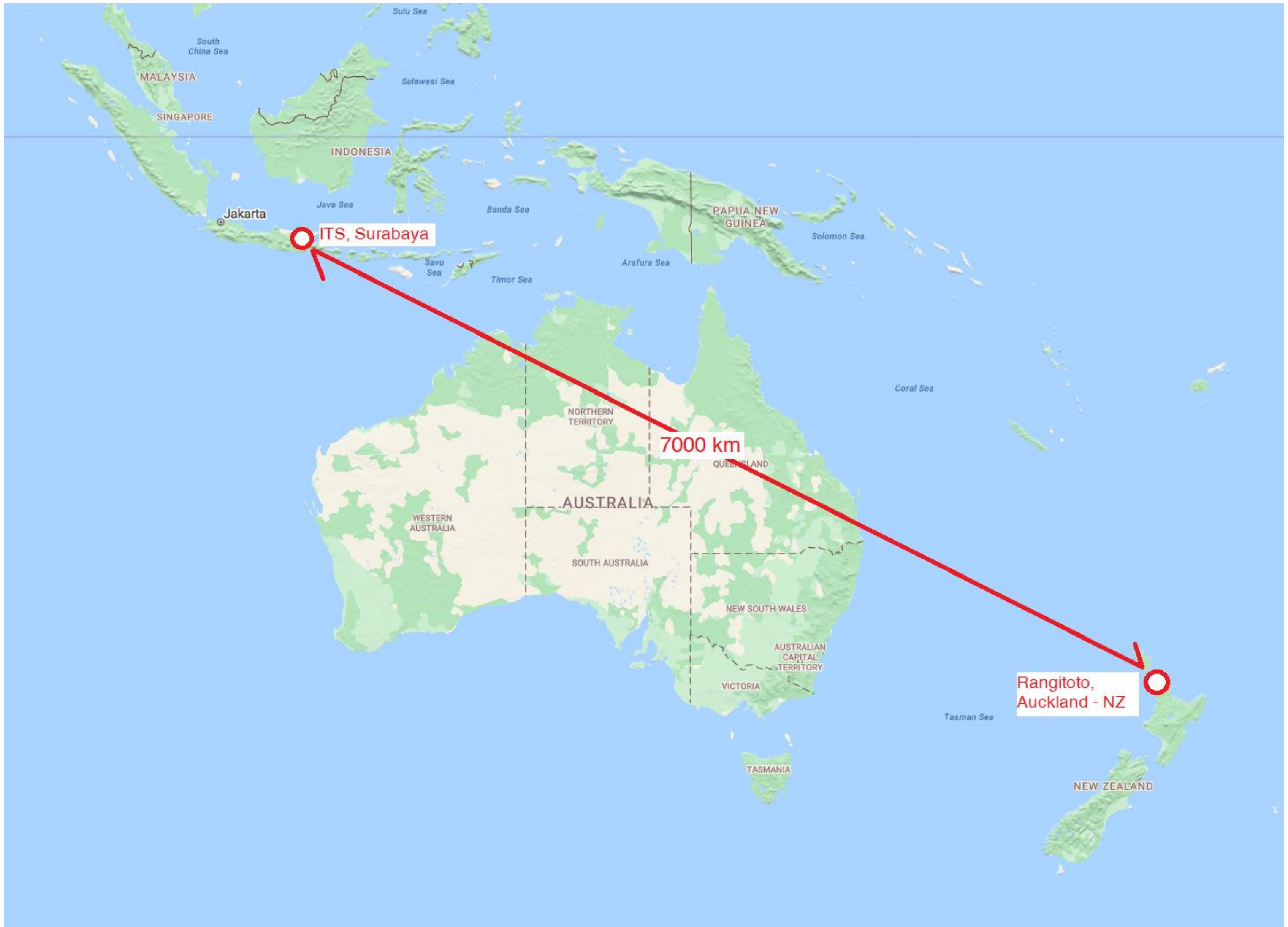


Fieldwork Payloads

- Gravimeter: LaCoste-Romberg, Scintrex, etc.
- Geodetic GPS (we need accurate elevation data at <10 cm accuracy).
- Handheld GPS or mobile phone for wayfinding.
- Handheld GPS can be used for emergency purposes.
- Notebook and waterproof pen.
- Snacks and water.
- First-aid kit.

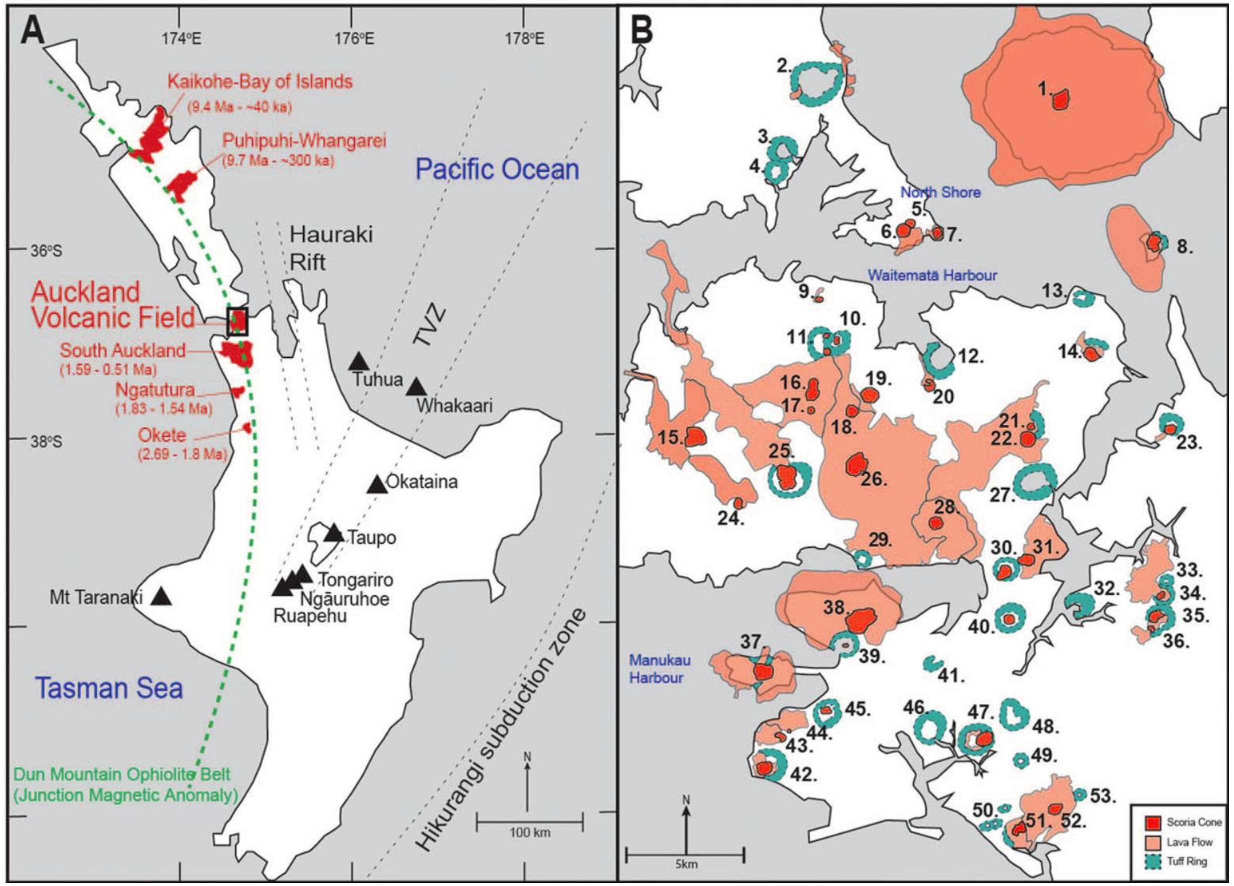
Rangitoto Case Study

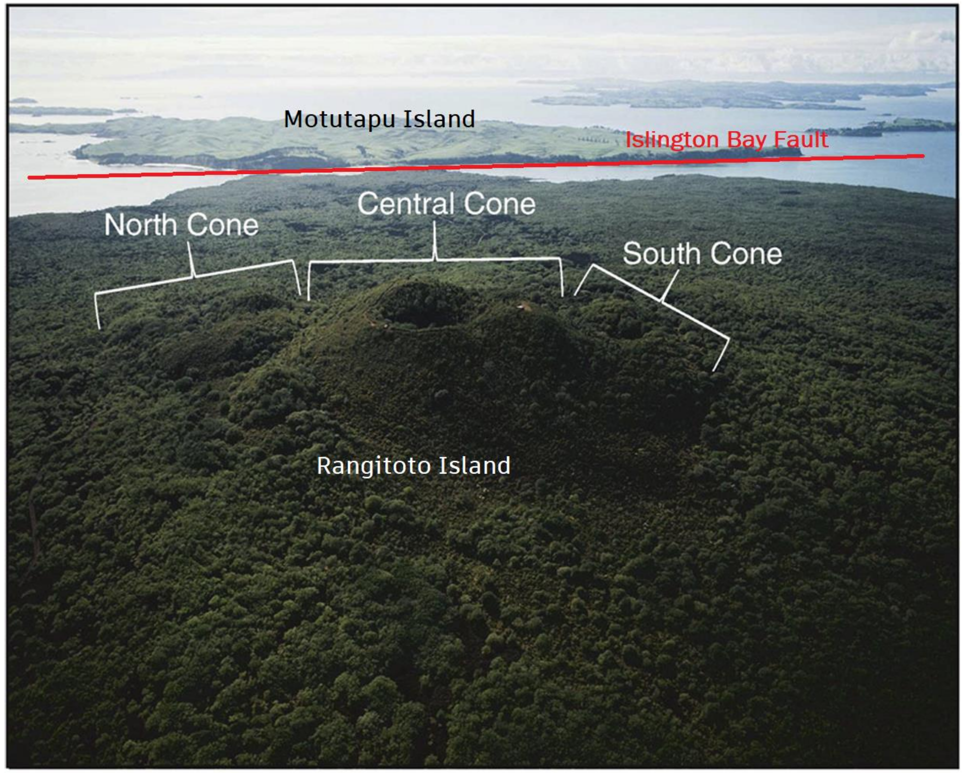
Where Is Rangitoto



Rangitoto Volcano

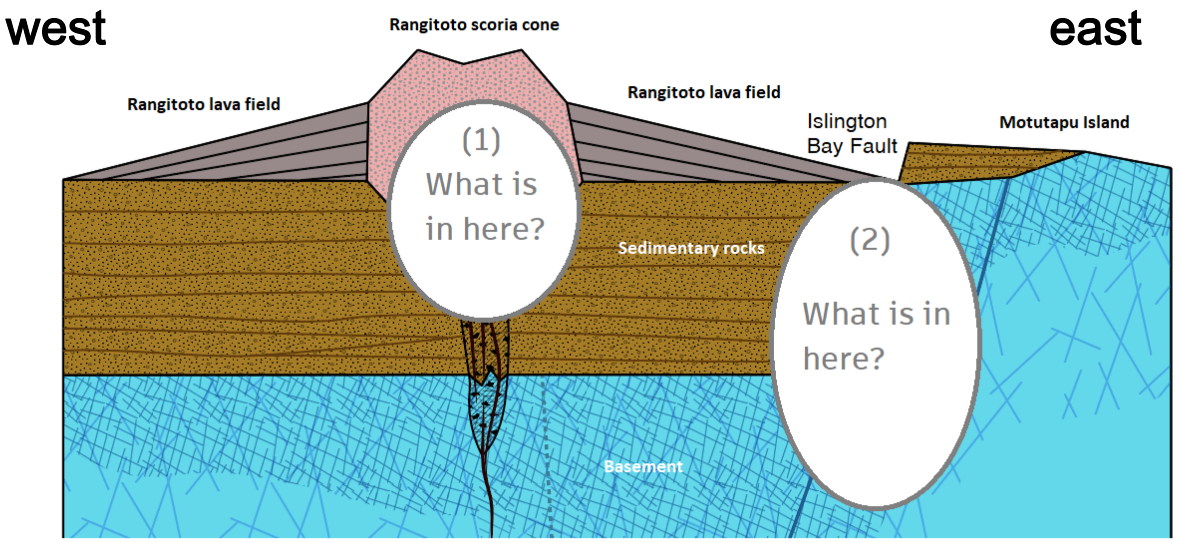
- Rangitoto means “bloody-red sky”
- Erupted at least two times: 1397 AD and 1446 AD.





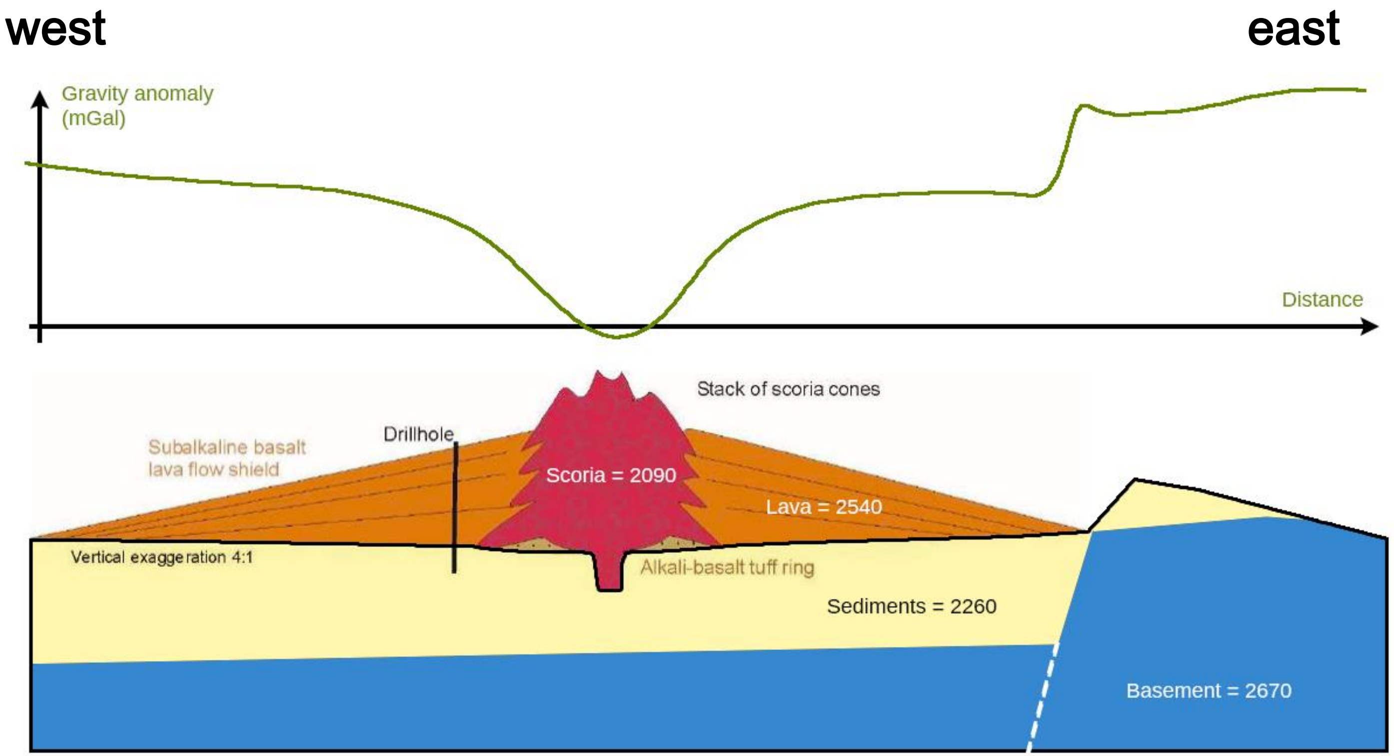
Research Questions

1. How is the internal structure of Rangitoto?
2. How Islington Bay Fault relates to Rangitoto?



Hypothesis

1. If Hayward’s (2017) model of Rangitoto is correct, gravity anomaly will show a negative anomaly over Rangitoto.
2. Over Islington Bay Fault, gravity anomaly will show a steep change.



Rangitoto subsurface structure according to Hayward (2017)

Islington Bay Fault
according to Kenny et al. (2012)

Research Stages

Administrative

•Collecting geological data and writing a proposal

•Getting permission from native land holders

•Lab inductions

•Finding field mates

•Submitting field plan for insurance purposes

Fieldwork

Gravimeter and GPS checks

Establishing local gravity base station

Data collections along planned points

Interpretation

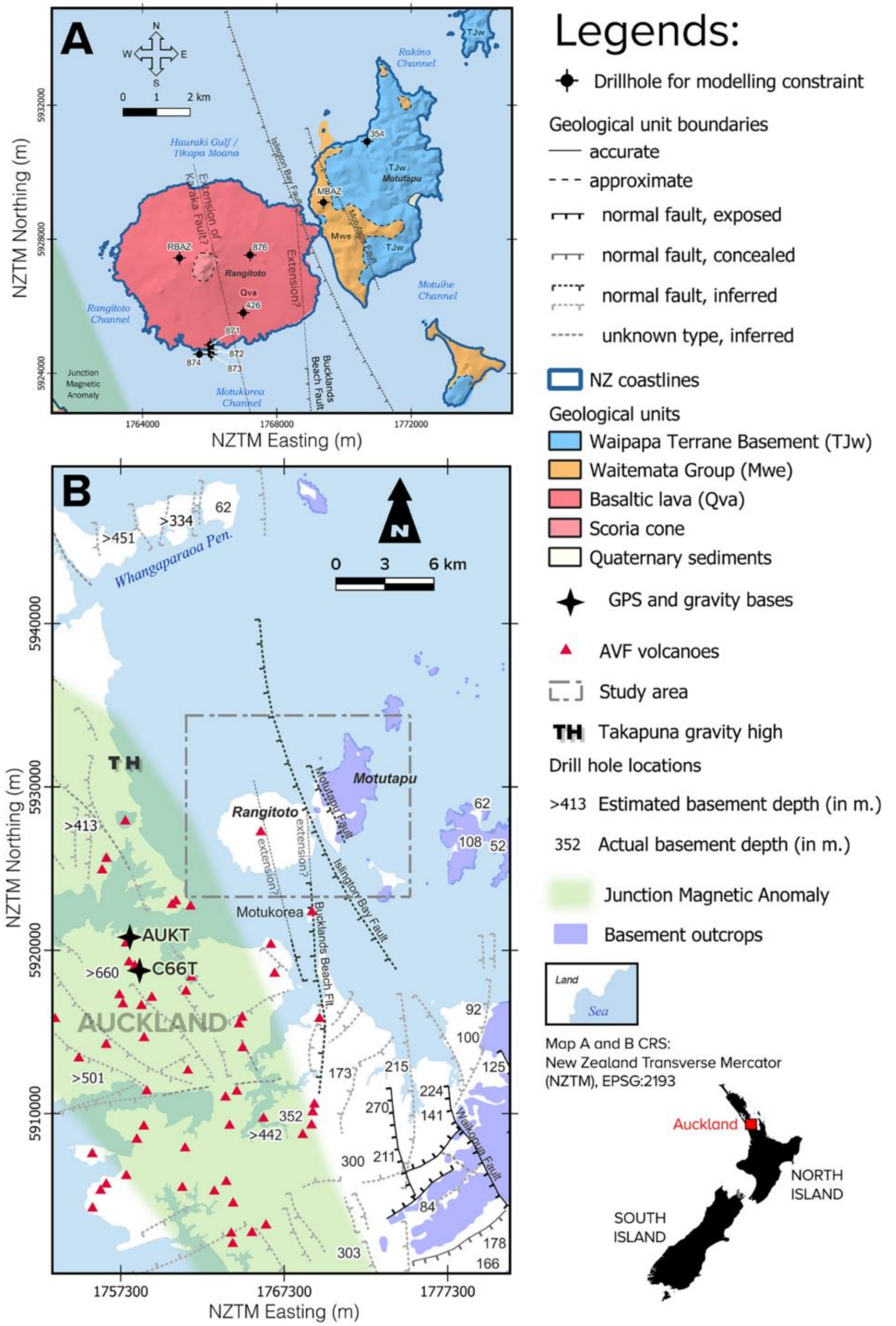
•Data processing to Bouguer Anomaly

•Regional-residual separation

•Modelling

Collecting Geological Data

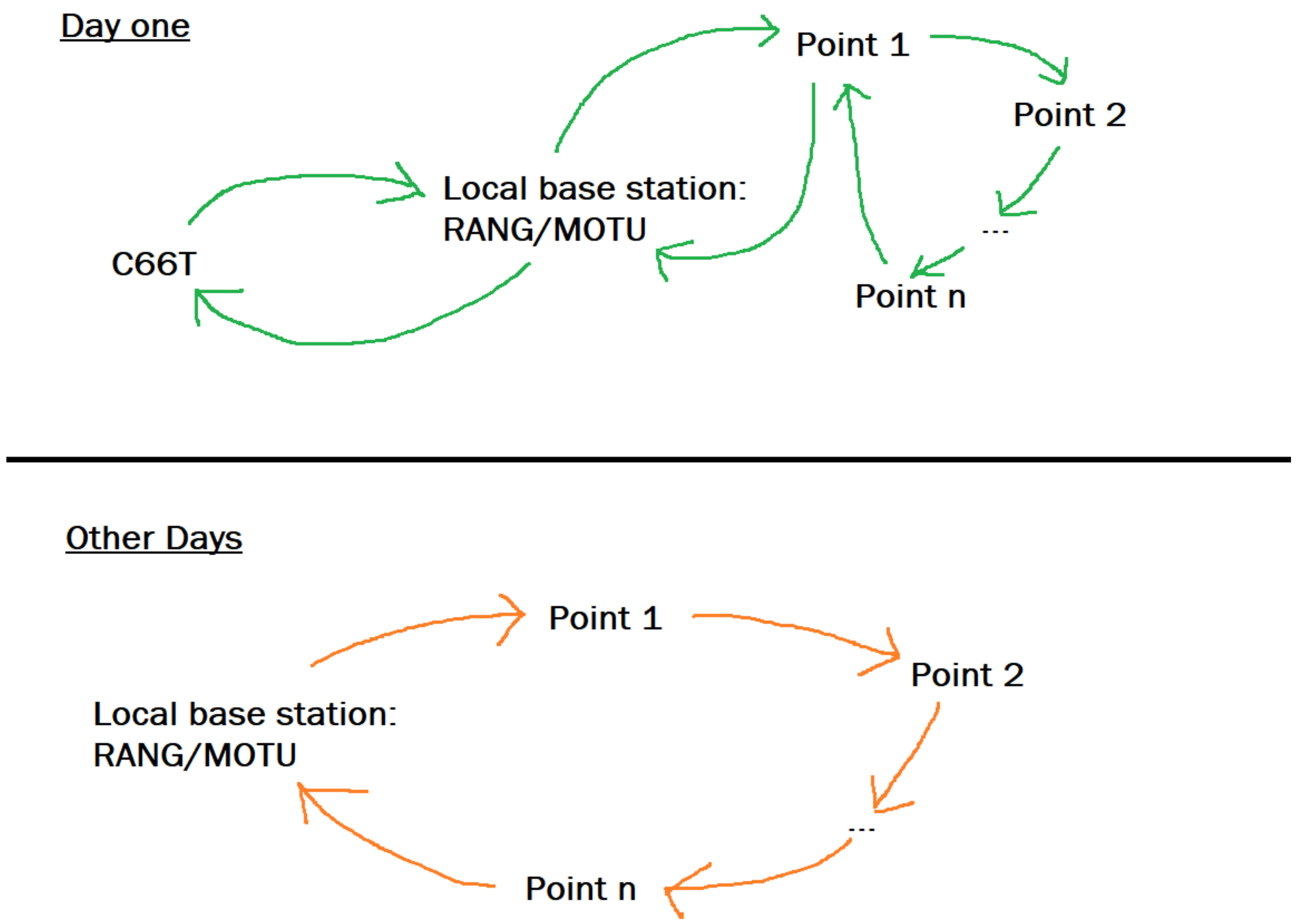
- GNS Science's Qmap
- Drill hole logs in NZGD and PETLAB
- Pre-existing geophysical data (unpublished)
- Recent studies on Rangitoto and Auckland in general.



Gravity Base Stations

- One on Rangitoto and one on Motutapu.
- Located near ferry terminal, easily re-occupied at the start and end of the survey.
- Tied to NZ national gravity network at point C66T near my university.

Fieldwork Operation

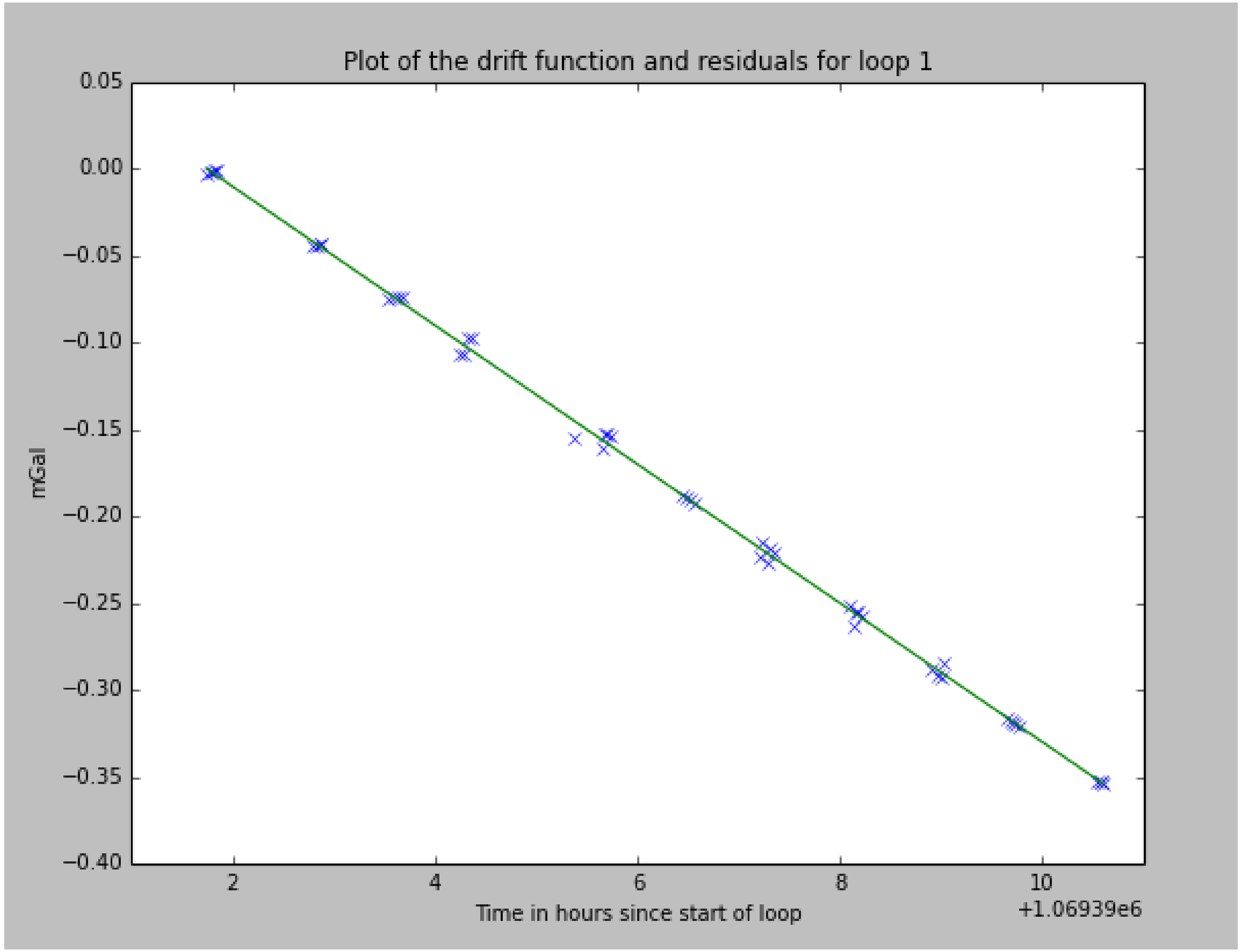


Gravity Measurement

- Take at minimum 3 nearly or similar values.
- Set the GPS first before the gravimeter and turn the GPS off after the gravimeter.
- Keep quiet and motionless during the measurement. Use it for dhikr if you can.

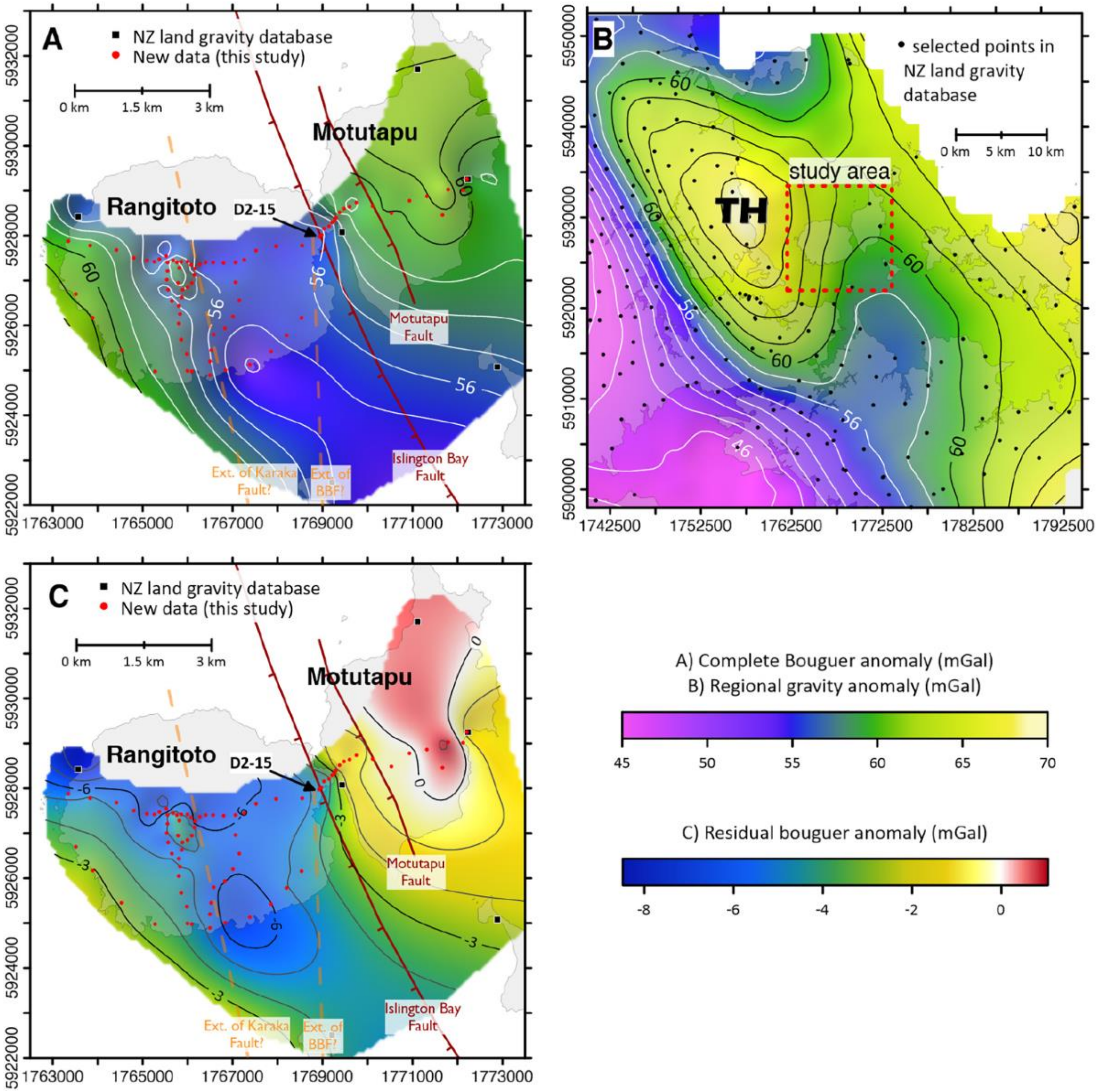
Changing Instrumental Value to mGal

- Uses GSolve by McCubbine et al. (2018).
- Drift is normally 0.02 mGal/hour.
- Also removes effects from sun-moon position.



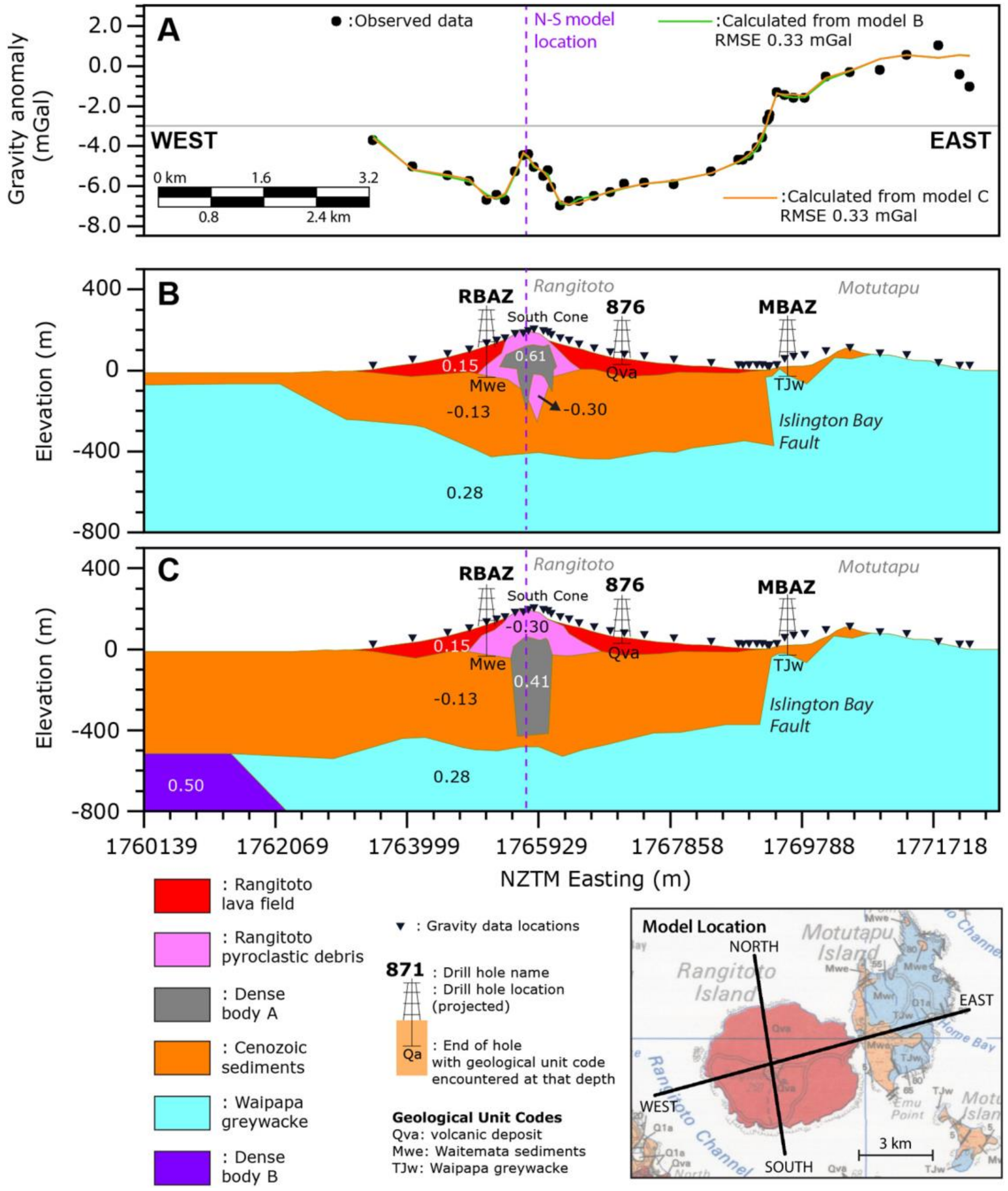
Calculation of Bouguer Anomaly

- Uses a variety of software
- Python for latitude, elevation, simple Bouguer plate and atmospheric effects
- Oasis Montaj for terrain variation effects
- Golden Software Surfer to produce regional gravity grid



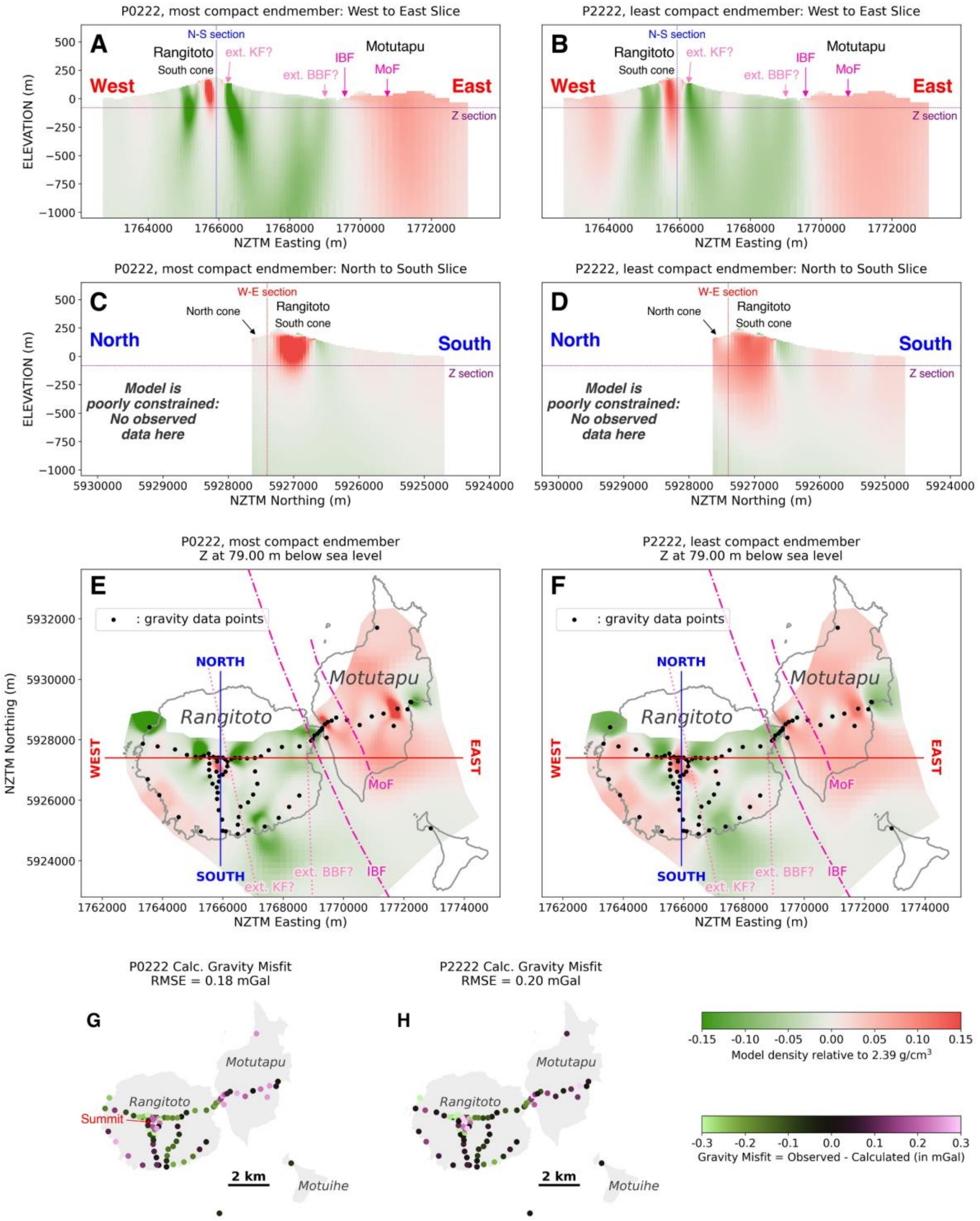
2.5D Modelling

- Explore various possible scenario that produces the anomaly in GM-SYS in Oasis Montaj.
- A dense body under Rangitoto is always needed = disprove Hayward (2017) idea.
- Basement depth ~500 m under Rangitoto.
- Islington Bay Fault can be a normal/reverse fault.



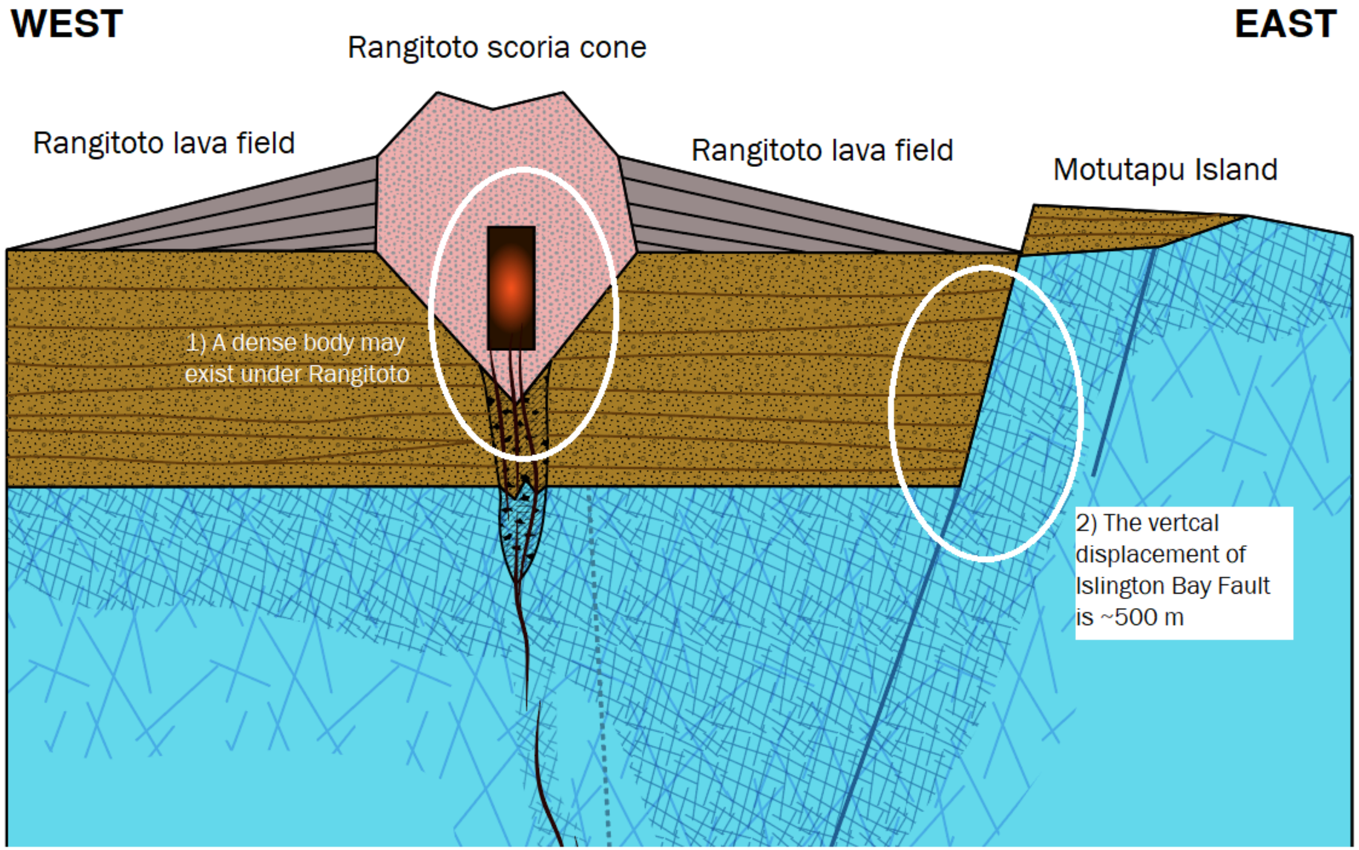
3D Modelling

- Uses SimPEG (free, open-source python module).
- Compact vs smooth endmembers.
- Dense body under Rangitoto.
- Islington Bay Fault is present in the model.



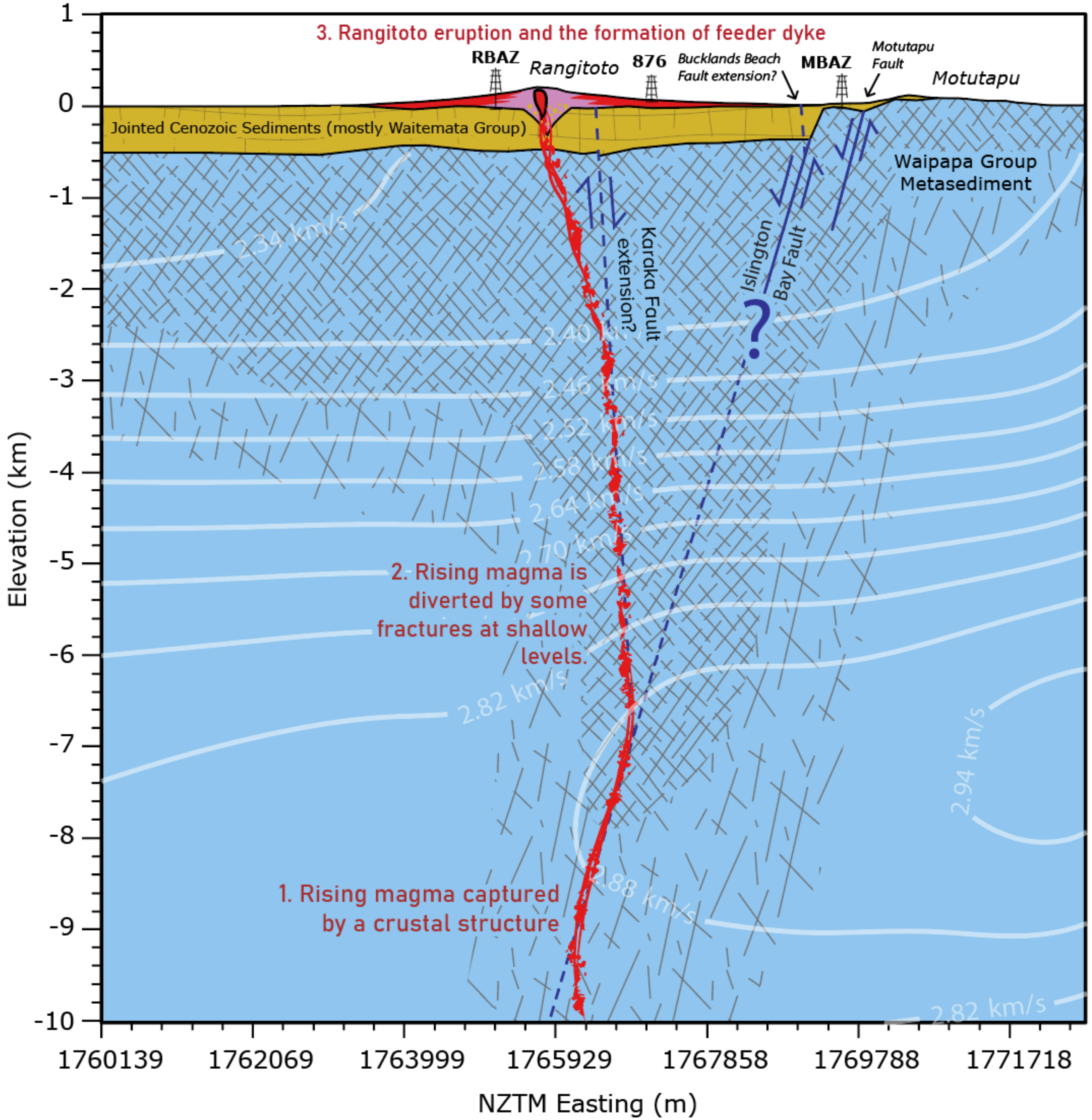
Modelling Takeways

- A dense body is present under Rangitoto volcano,
- Islington Bay Fault exists as a likely normal fault with a ~500 m vertical displacement.
- But how do these two things relate?



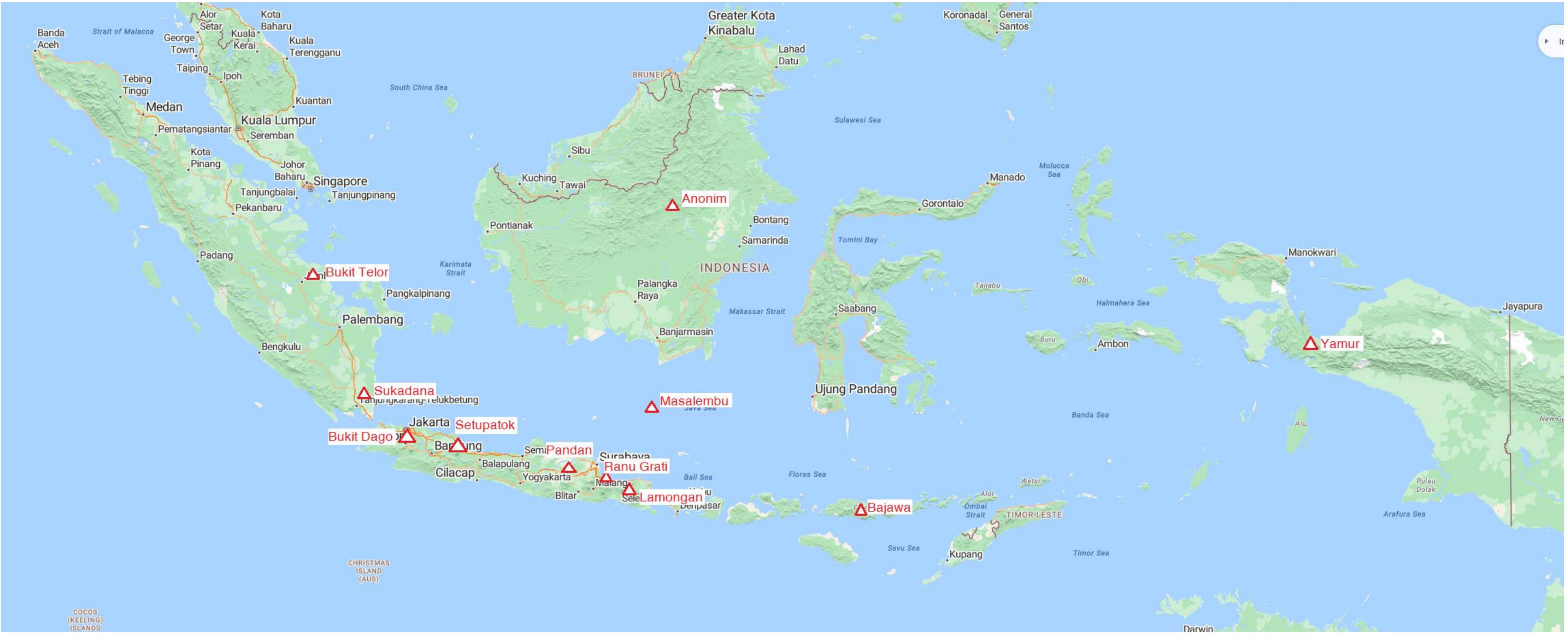
Interpretations

- Dense body: a residual basalt magma
- Islington Bay Fault might provide an easy pathway for the magma to pass through
- Joints and other fractures near the surface divert the magma away from the fault

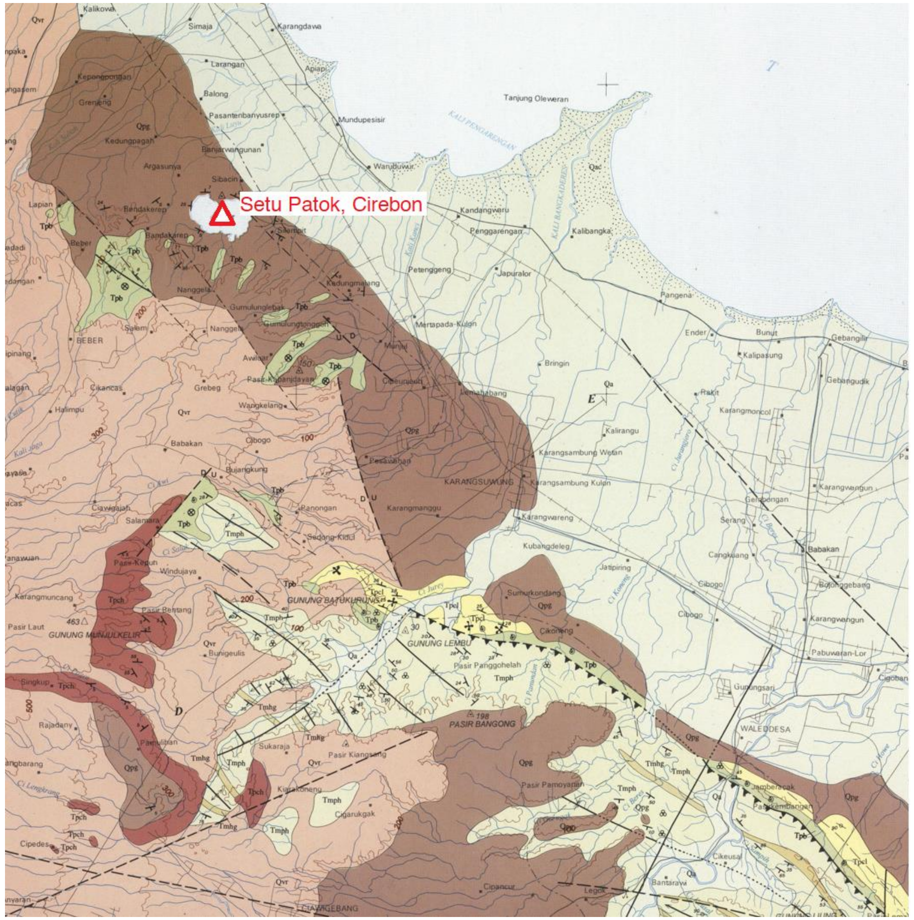


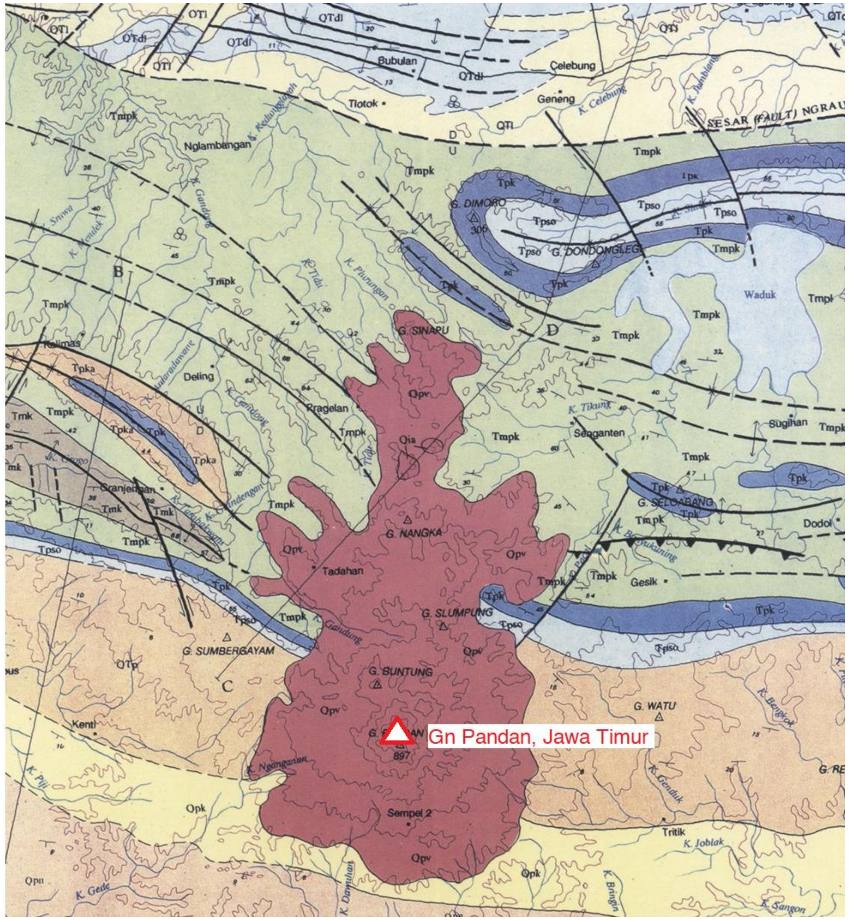
Application for Indonesian Small-Volume Volcanoes?

Small-volume Volcanoes in Indonesia



Structure – Volcano Relationship



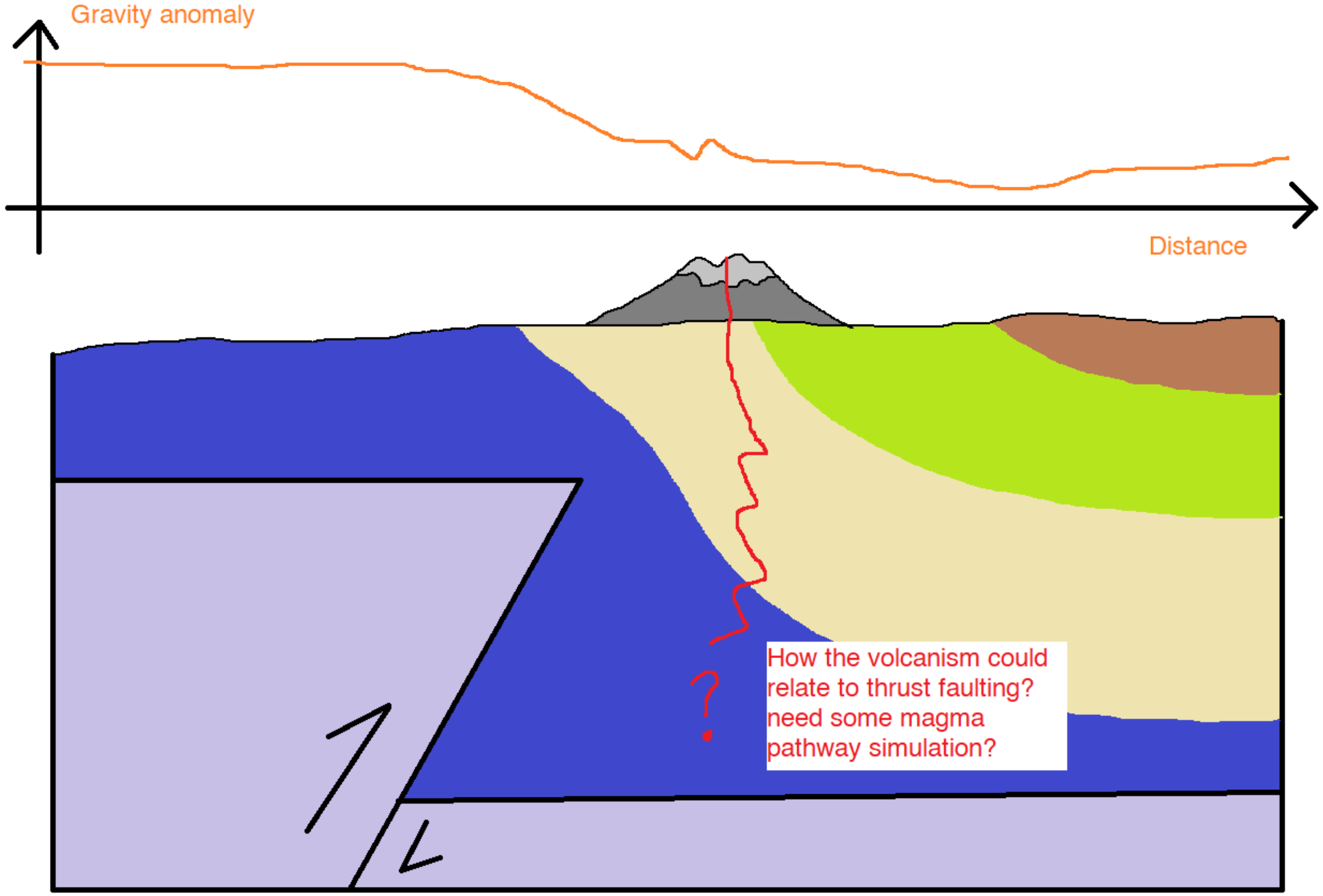


Differences

- **Setu Patok and Gunung Pandan**
  1. Near thrust fault
  2. Back-arc setting
  3. Only one or a few vents during its lifetime

- **Rangitoto**
  1. Near a normal fault
  2. Intraplate setting
  3. Part of a large volcanic field (53 volcanoes)

Possible Use of Gravity Study in Indonesia



Challenge for Indonesian Volcanologist

Dyke propagation through structures in extensional tectonic environment is straightforward: magma opening the crack and flow through it.

However, an active thrust fault cannot be easily opened as the main stress mode is compressive.

In what situations do thrust fault can assist magma ascent processes?

References

- Hopkins et al. (2020)
- Luthfian et al. (2023)
- Needham et al. (2011)
- Hayward (2017)
- Ensing et al. (2022)
- ESDM GeoMap Portal
- SimPEG manual