Bringing the Frontier of Geological Modelling to Earthquake Ground Motion Simulation of the Basin Effect

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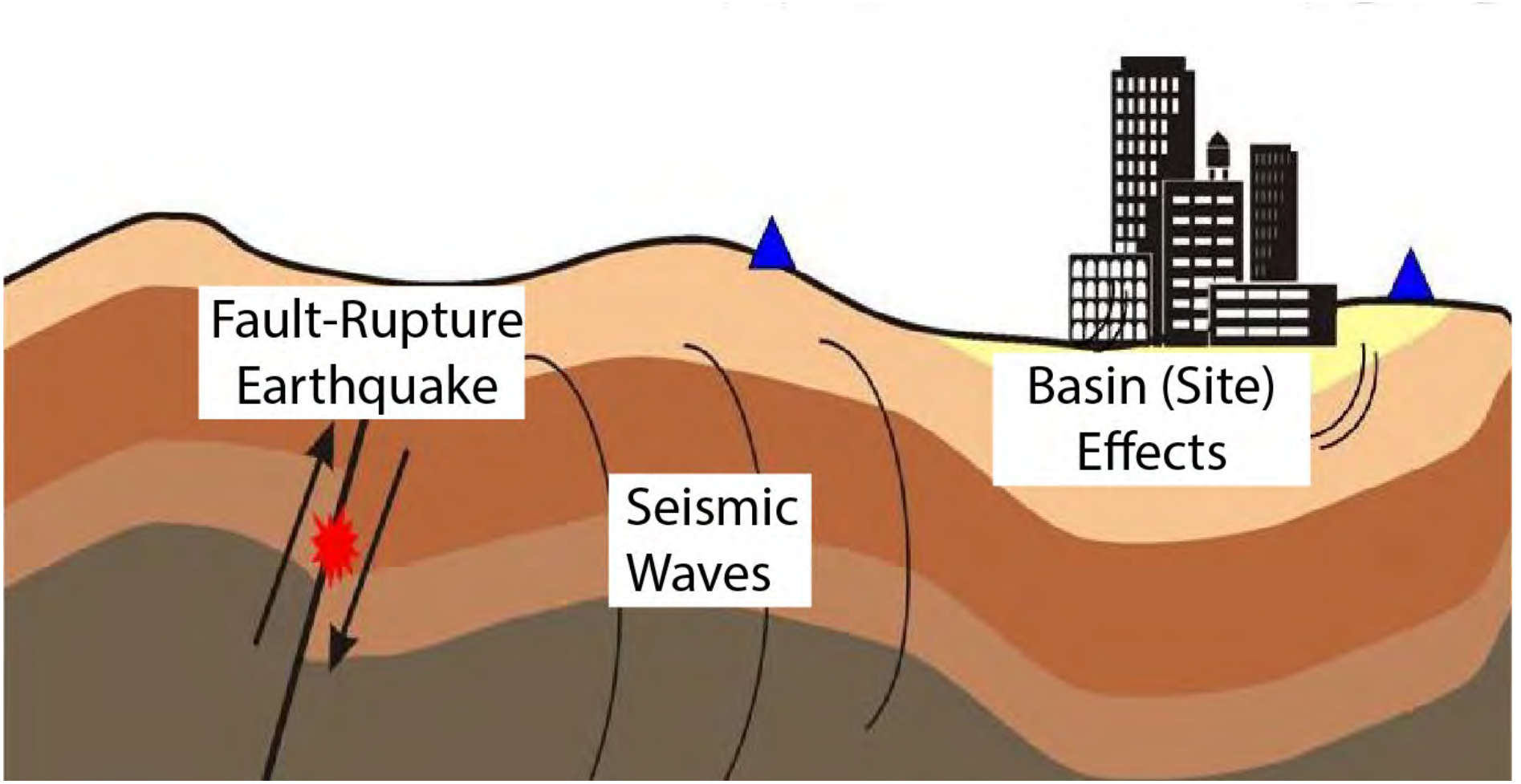
Presentation Outline

1) The Basin Effect
2) Seismic Hazard in New Zealand
3) Research Questions & Goals
4) Frontiers of Geological Modelling
5) Hamilton Basin
6) Dataset & Workflow
7) Early Progress

The Basin Effect



Modified from Bormann, 2002

The Basin Effect

Mexico City 1985

Nepal 2015

Canterbury 2010/2011

Kaikoura 2016

Seismic Hazard in New Zealand

GNS – 2022 New Zealand Seismic Hazard Model

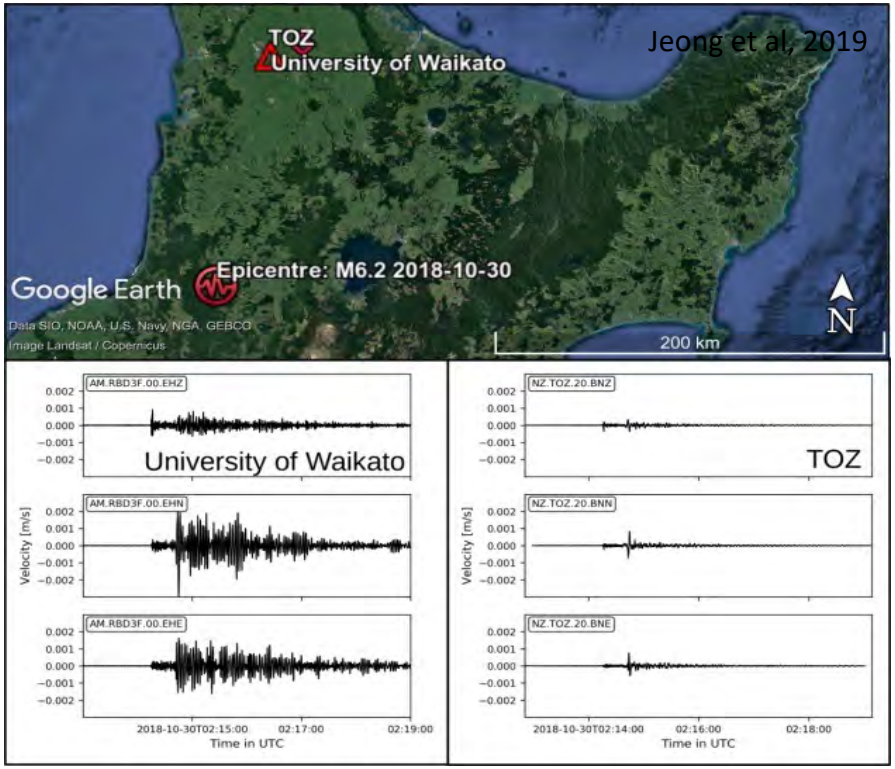
2022 NZSHM is most recent and complex hazard model

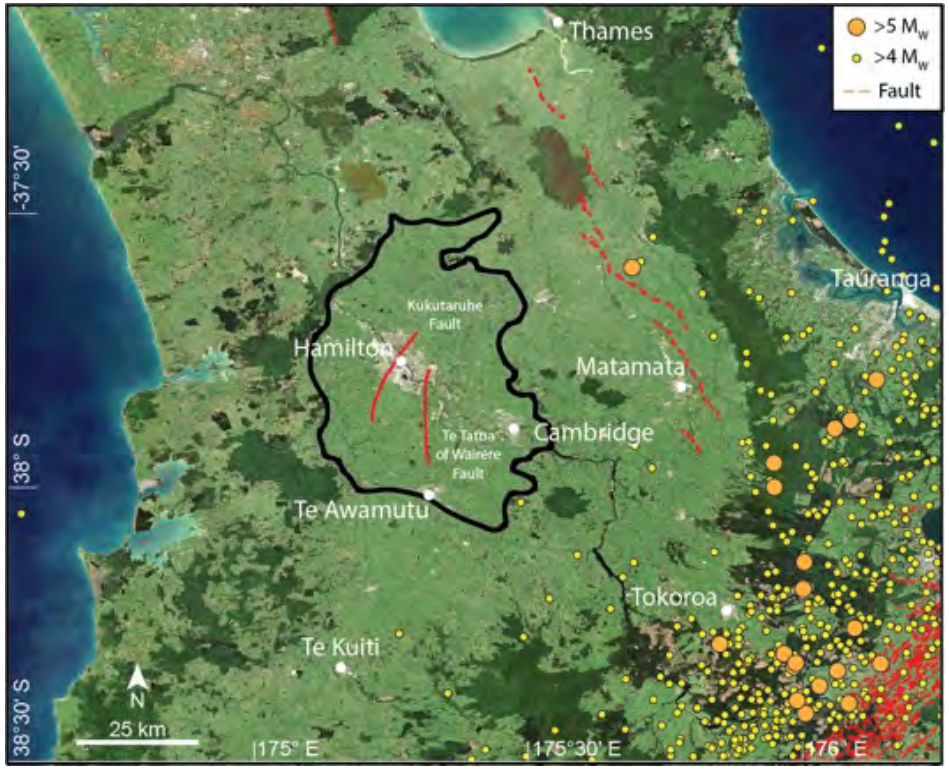
Probabilistic forecast of earthquake ground motion

Implicitly models basin effects using $V_{s30} - Z_1$ or $Z_{2.5}$

Suggests NW North Island has relatively low seismic hazard

Waikato Region Seismic Hazard



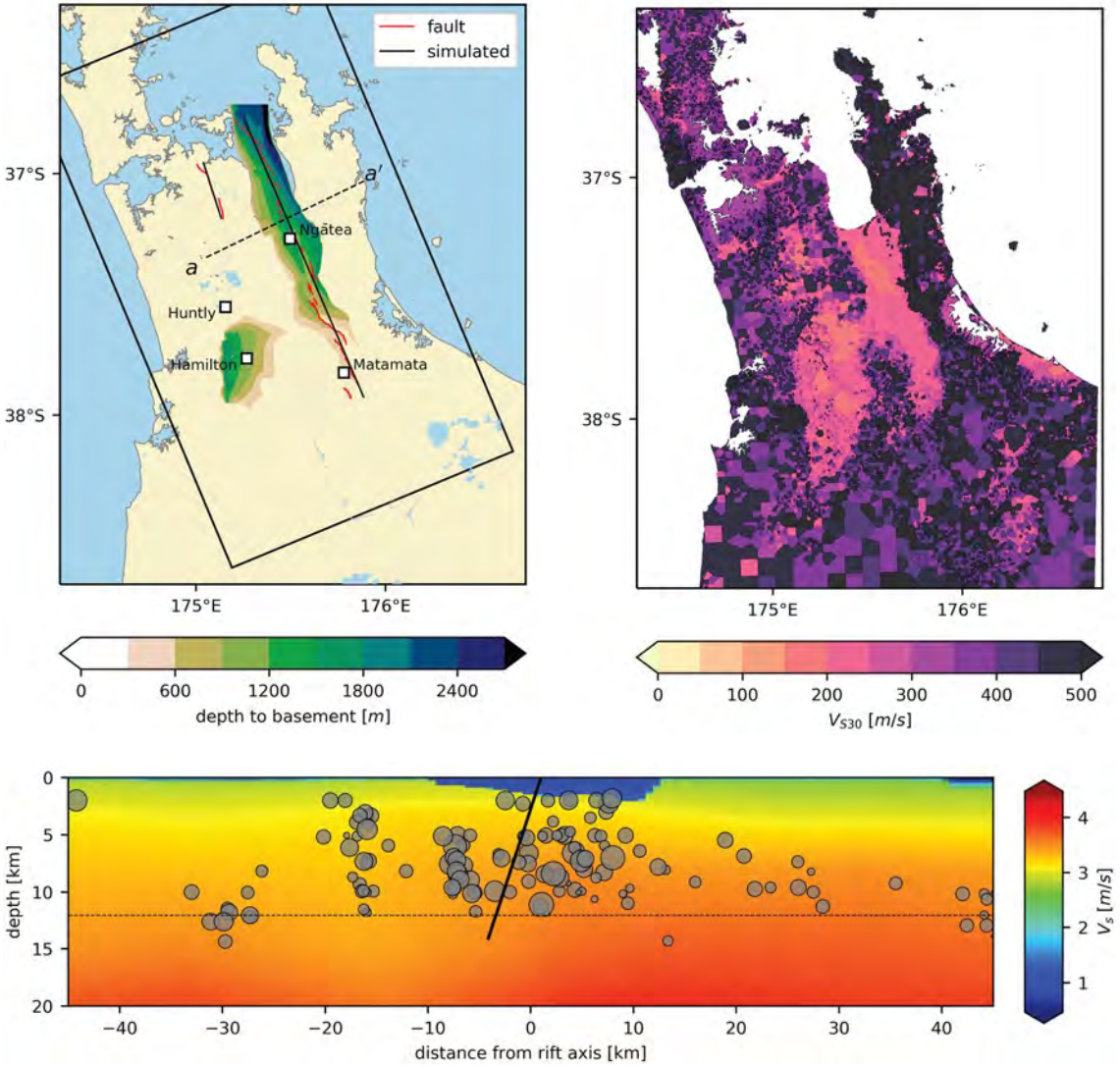


2018 M_W 6.2 Taumarunui earthquake displayed large amplification

Newly discovered faults in the region

Large population centre, including critical infrastructure

Waikato Region Seismic Hazard



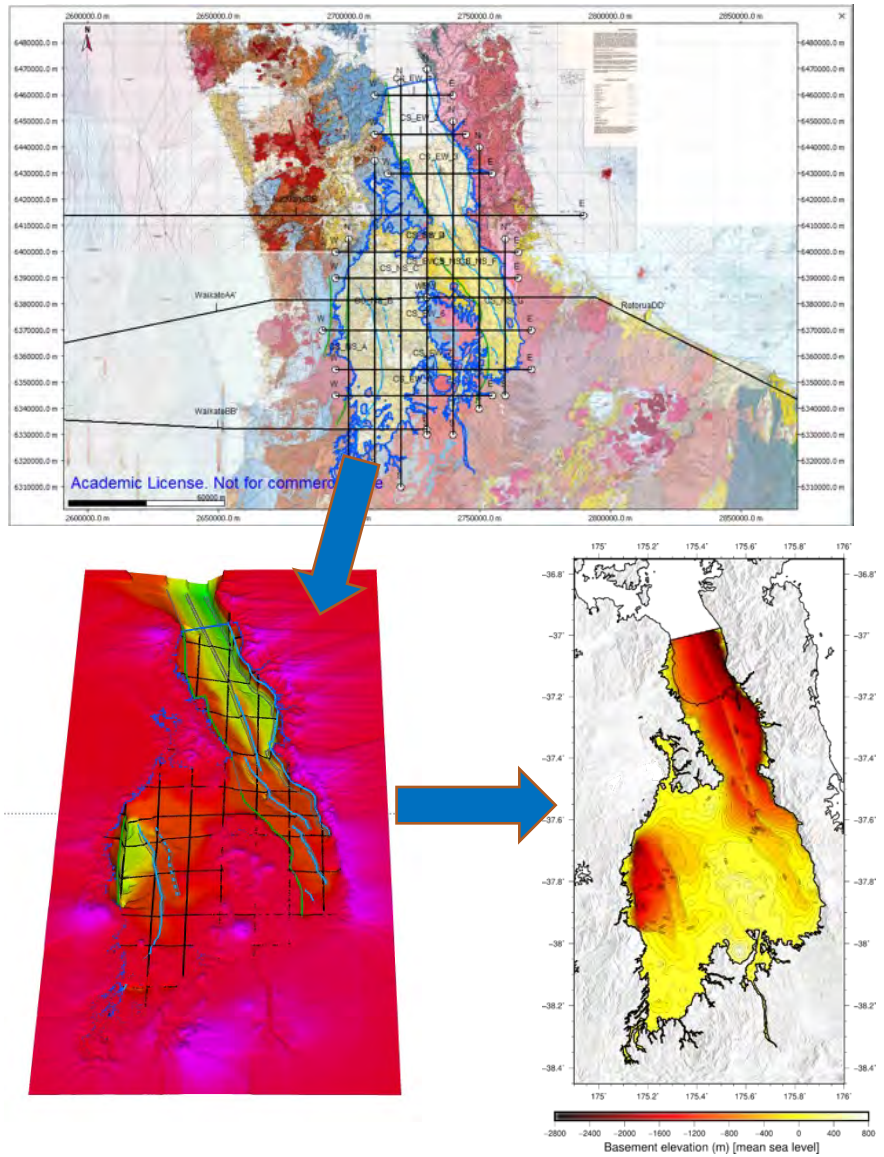
Dempsey et al., 2020

Focus has been on Hauraki region not Hamilton Basin

Type 1 or 2 models

Need for more sophisticated basin analysis

Waikato Region Seismic Hazard



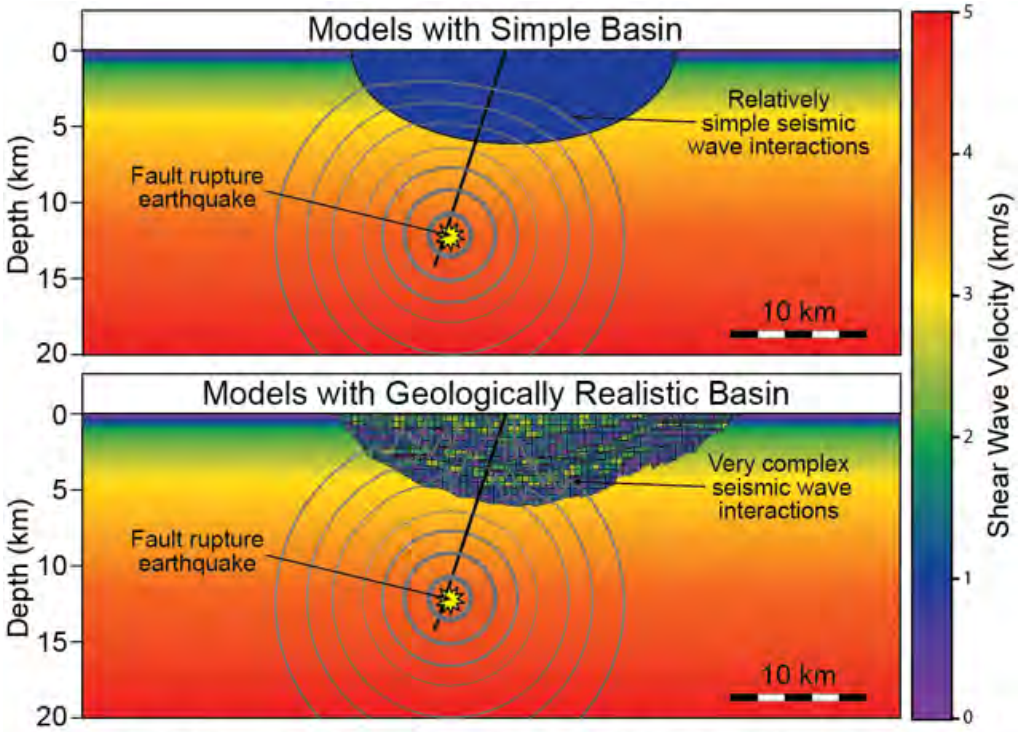
Stolte et al., 2019

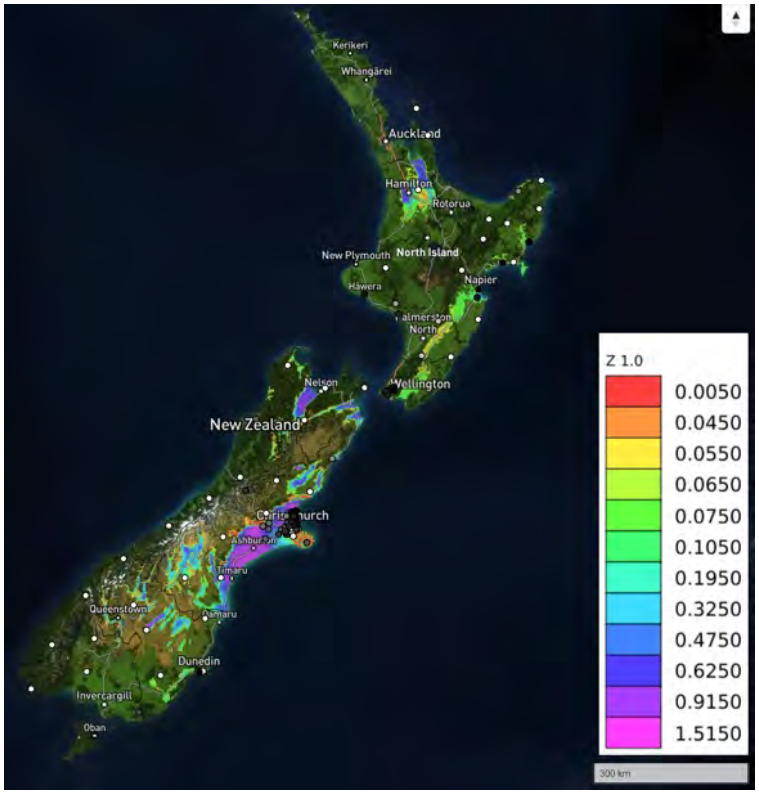
Focus has been on Hauraki region not Hamilton Basin

Type 1 or 2 models

Need for more sophisticated basin analysis

Research Questions



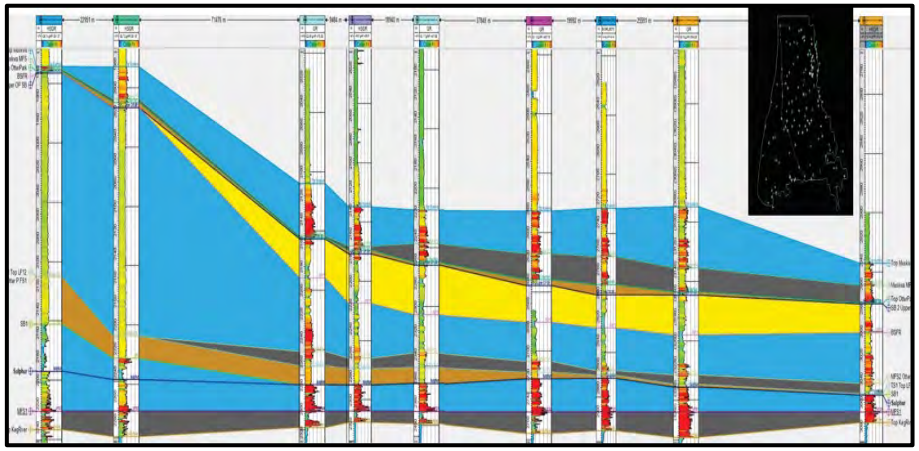


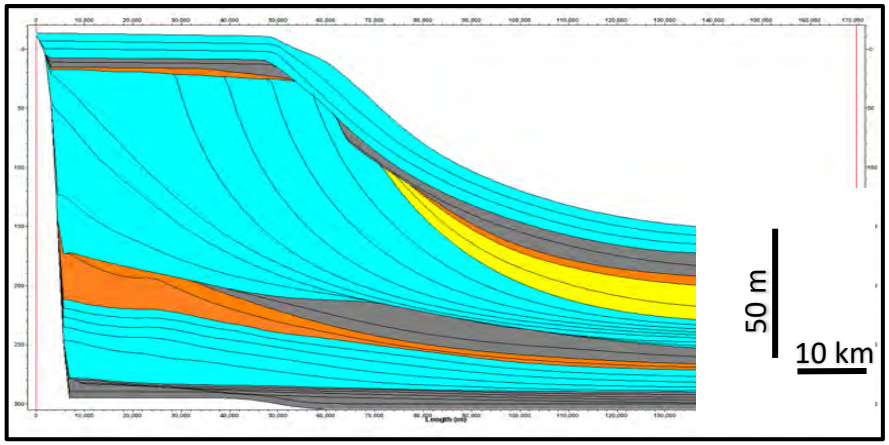
How does geological heterogeneity affect ground motion?

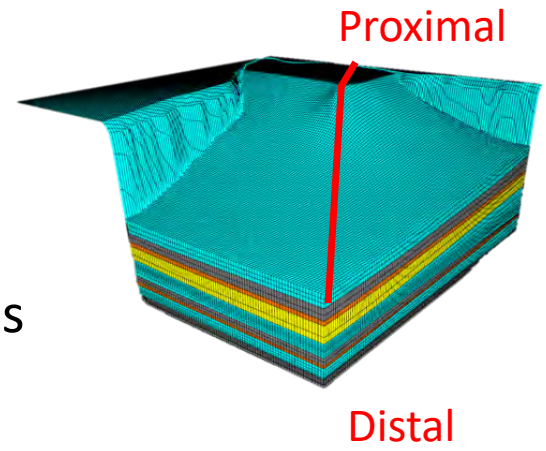
Can earthquake modelling and hazard assessment be improved?

Is there potential to scale-up the work?

Forward Geological Modelling







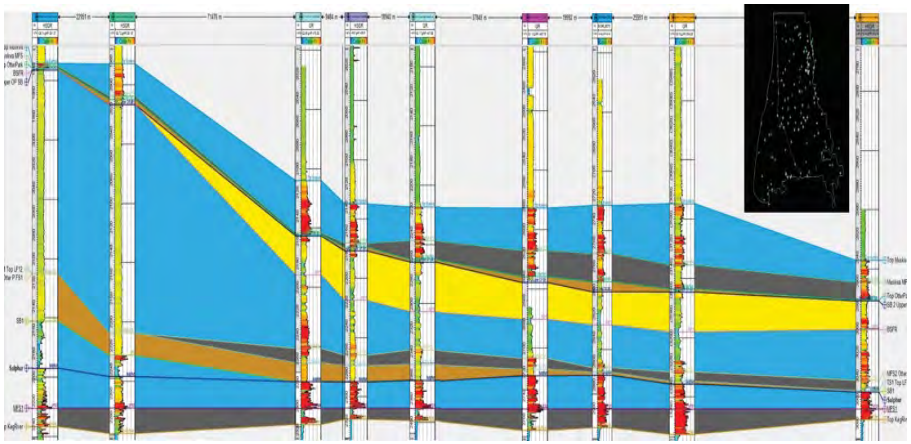
Forward stratigraphic and seismic methods

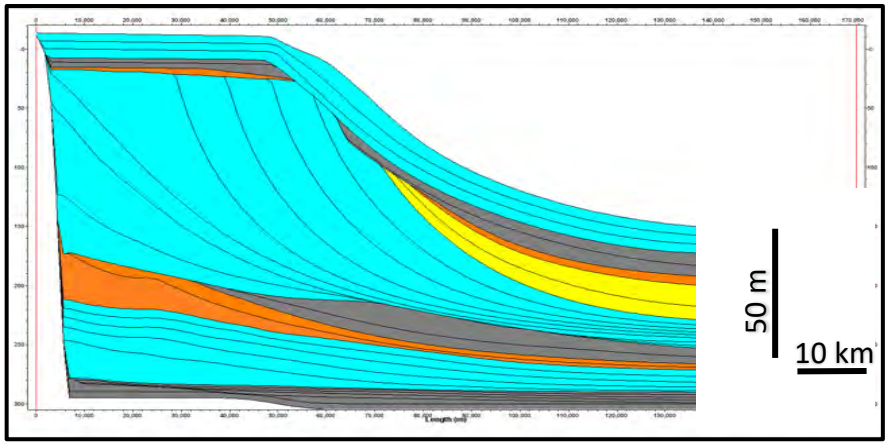
4D simulation of sedimentation, erosion, and bypass

Mixture of diffusion and hydraulic modelling

At present, only used to de-risk energy exploration

Forward Geological Modelling

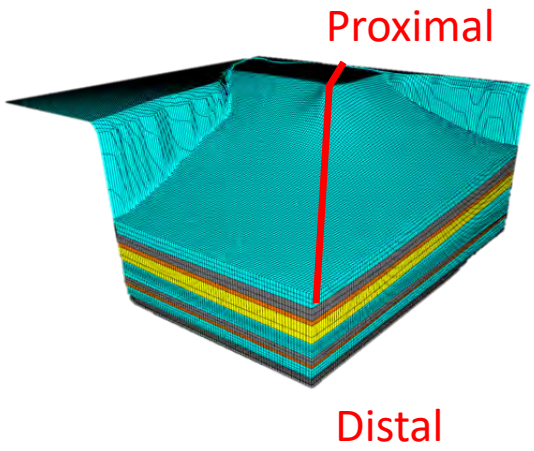




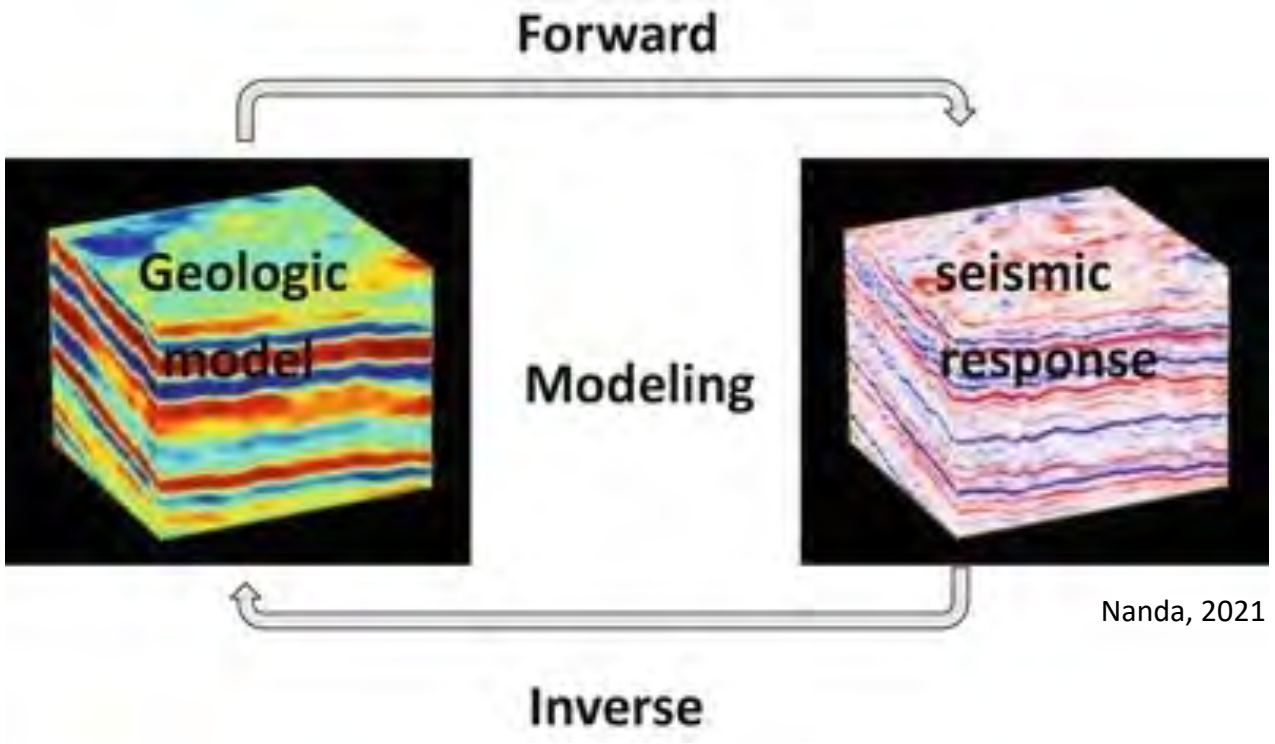
Quantify geological control parameters and basin evolution

Explain heterogeneity in stratigraphical/geological context

Predict internal geometry and property distribution



Forward Geological Modelling



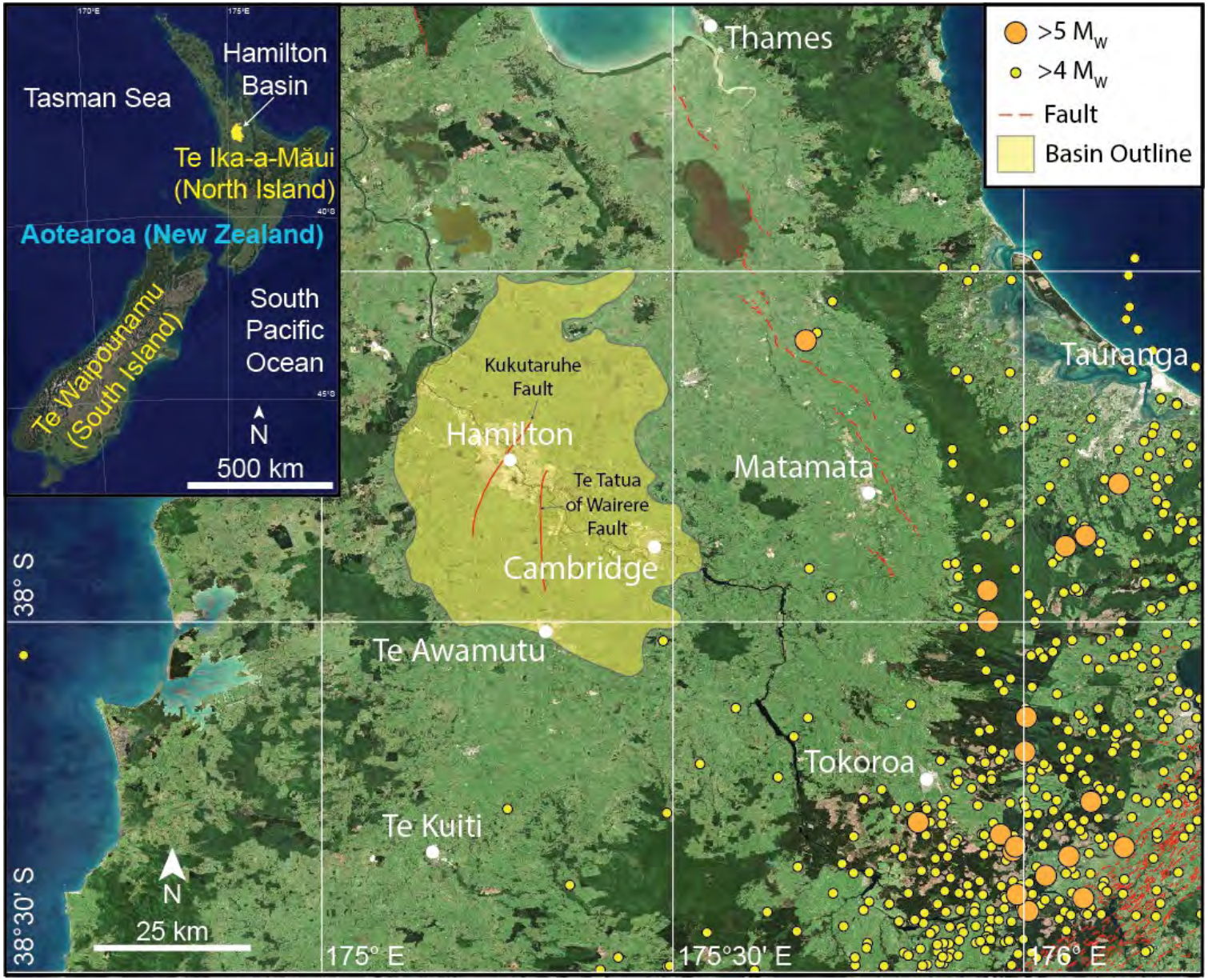
Nanda, 2021

Generation of seismic reflection response based on a geological model

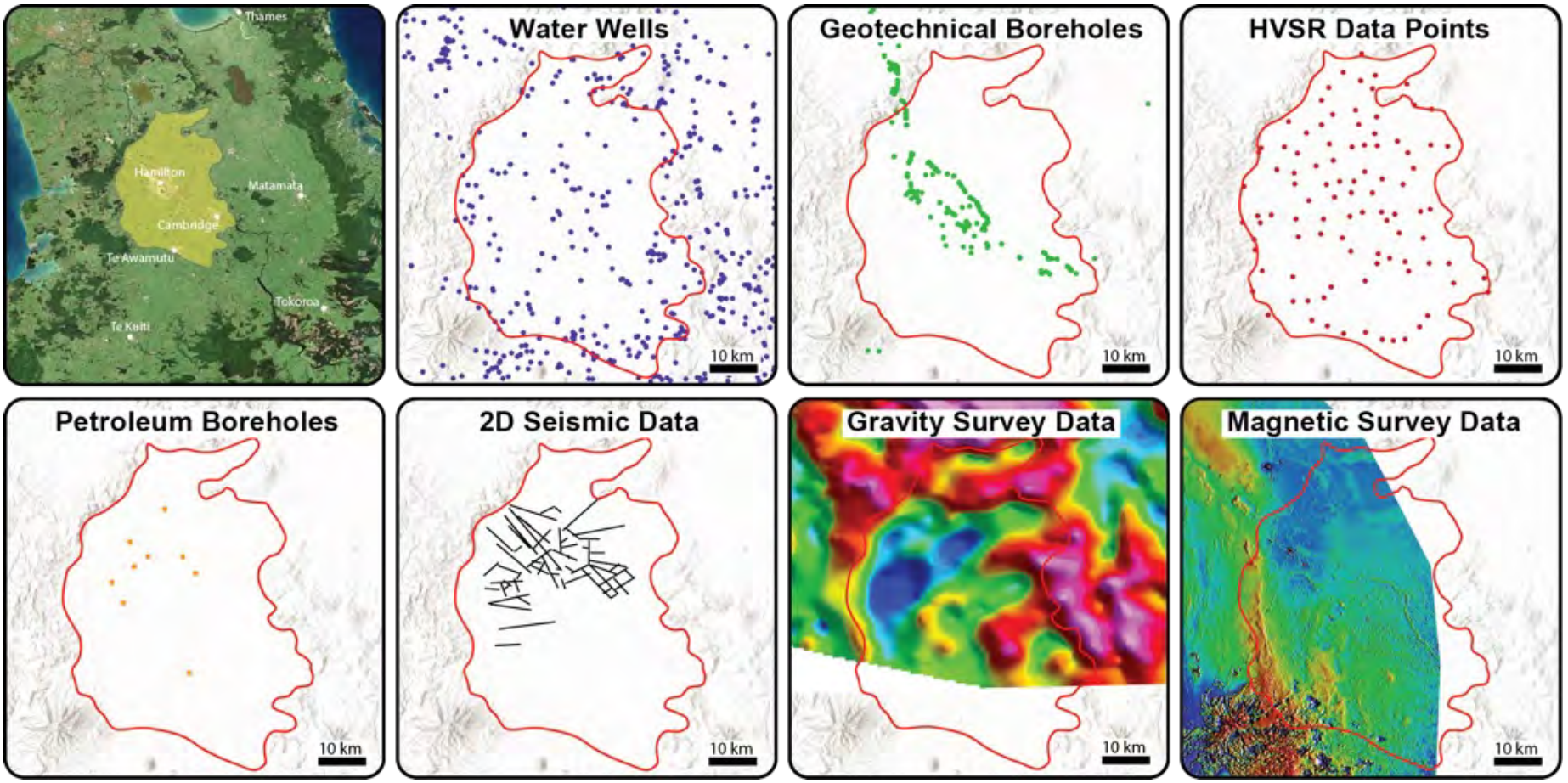
Incorporates impedance and wavelet information

Will verify and expand insights of geological modelling

Hamilton Basin



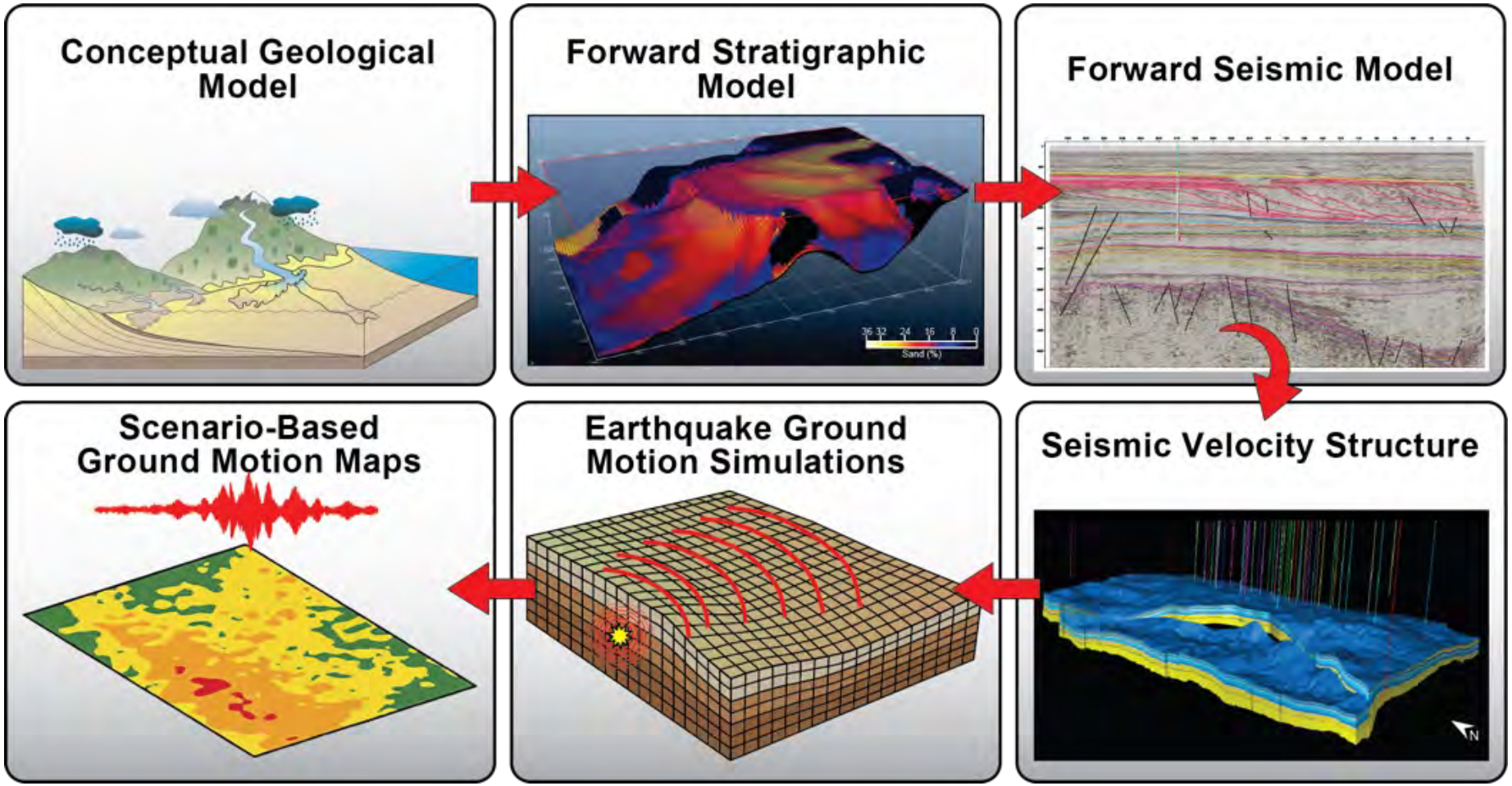
Dataset



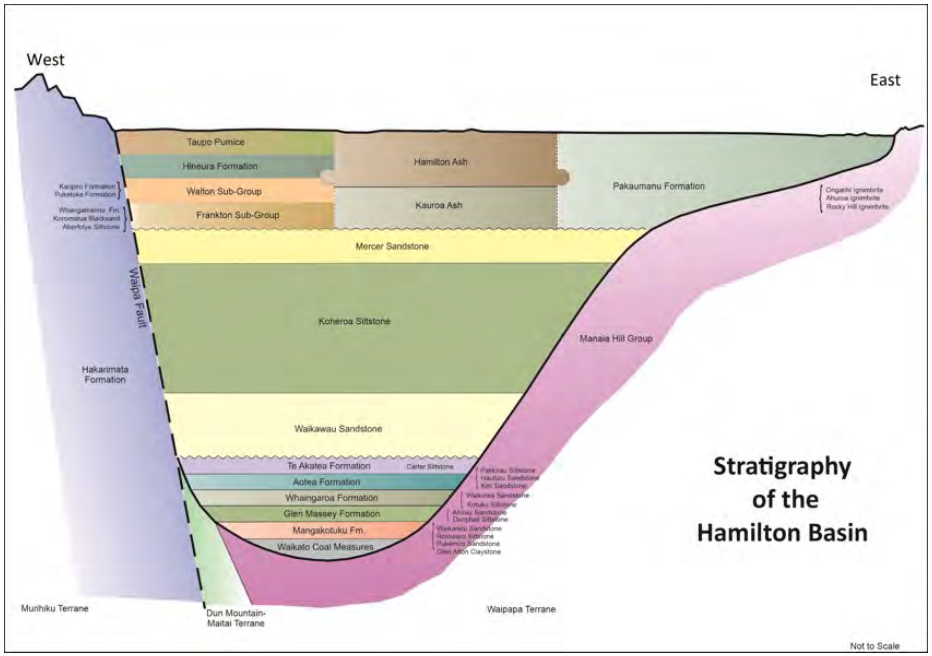
Variety of data types, vintages, and distribution

Challenges of data harmonization and integration

Workflow


Conceptual Geological Model
Forward Stratigraphic Model
Forward Seismic Model
Scenario-Based Ground Motion Maps
Earthquake Ground Motion Simulations
Seismic Velocity Structure

Workflow – Geological Concept



Courtesy of Dave Gardiner

Stratigraphic framework

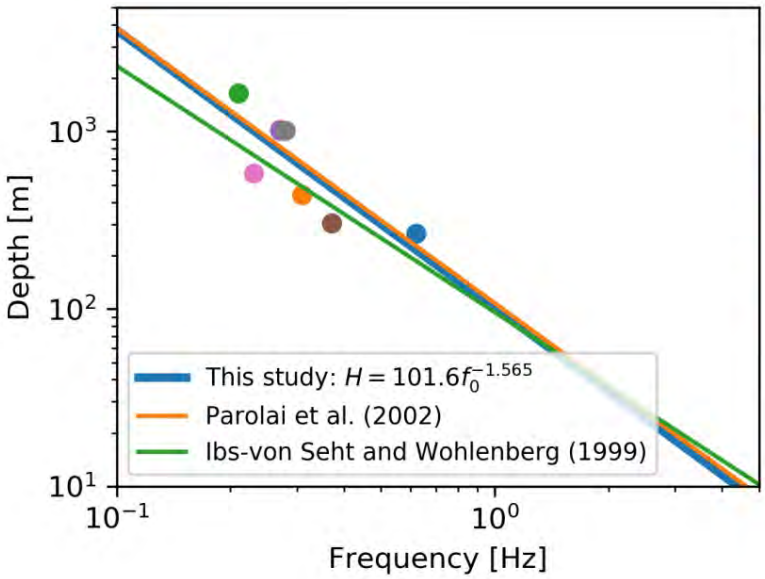
Palaeogeography

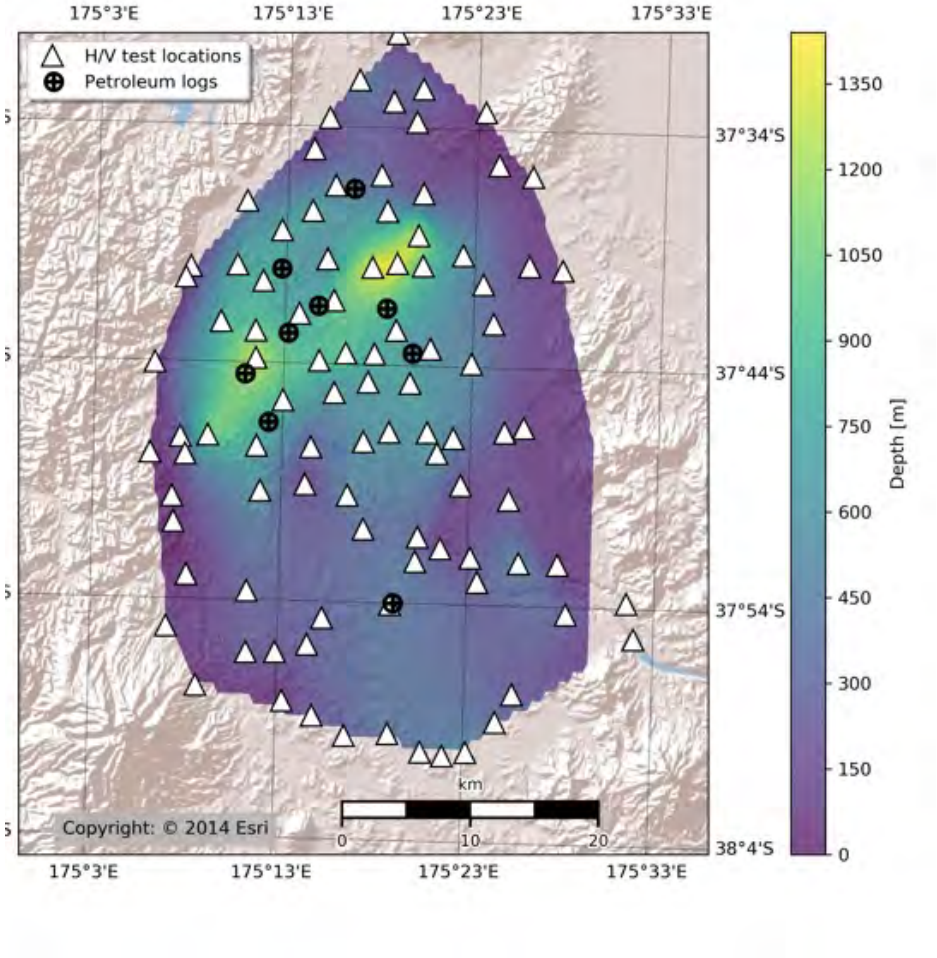
Environments of deposition

Sedimentary processes

Workflow - HVSR

Spectral ratio method to help constrain basin depth and shape



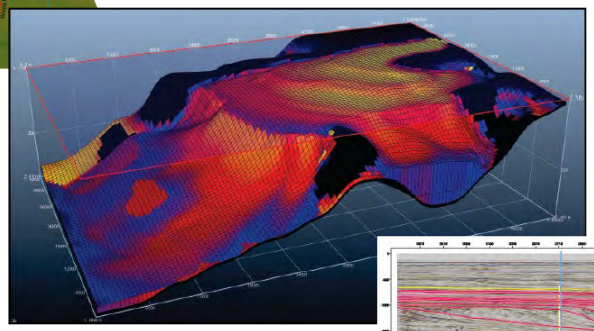


Jeong et al, 2019; Stolte et al., 2019

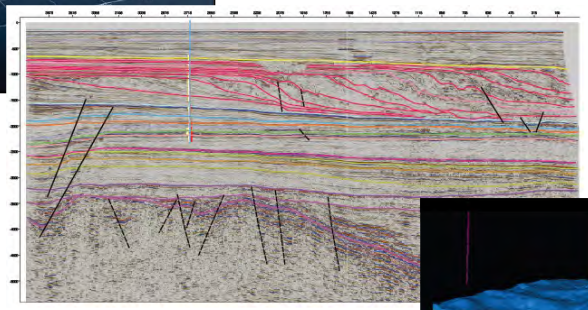
Workflow – Forward Modelling

Concept

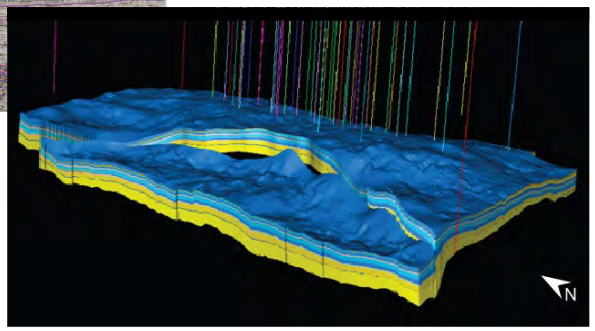
Stratigraphic Model



Seismic Model



Velocity Model



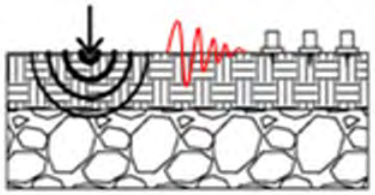
Geological process modelling + 2D/3D forward seismic models

Stochastic to allow scenario testing

Workflow – Surface Wave Testing

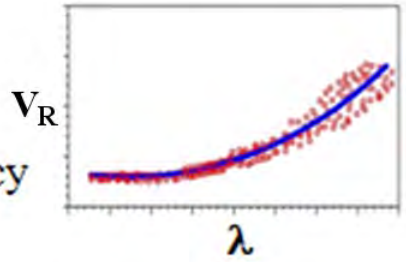
Acquisition

Field Data Collection:
Measurement of stress waves at the ground surface



Processing

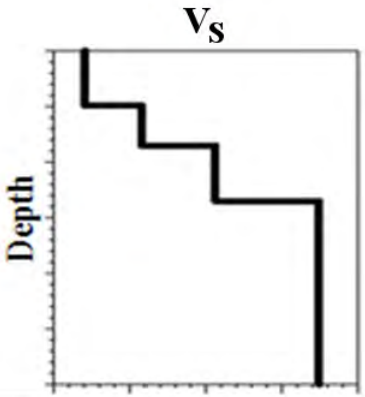
Dispersion Curve:
Rayleigh Wave Phase Velocity vs. Wavelength/Frequency



Inversion

Shear Wave Velocity Profile:
Variation of Small Strain Shear Modulus vs. Depth

$$G_{max} = \rho V_S^2$$



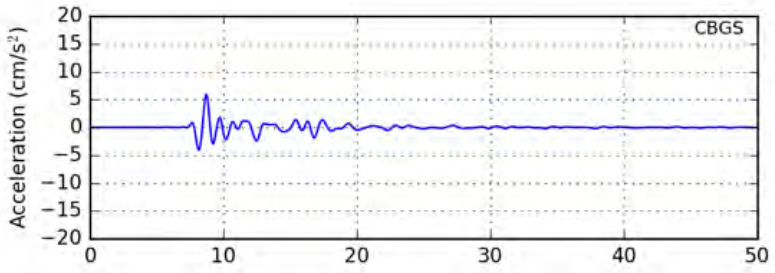
V_s profiles compatible with the observed surface wave dispersion

Compare with and tune forward modelling process

Workflow - Simulation

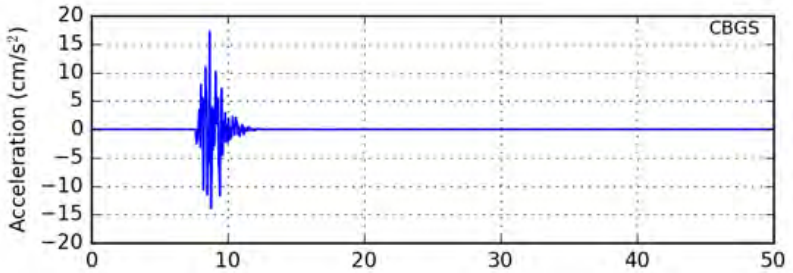
- Graves and Pitarka (GP) hybrid approach

Low-frequency (e.g. f < 1.0 Hz) comprehensive physics-based wave propagation method



+

High-frequency (e.g. f > 1.0 Hz) simplified physics-based method



Merged to produce broadband ground motion

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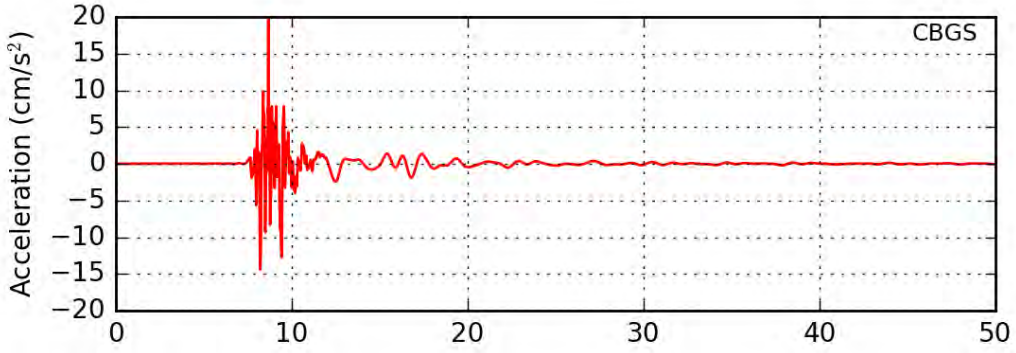
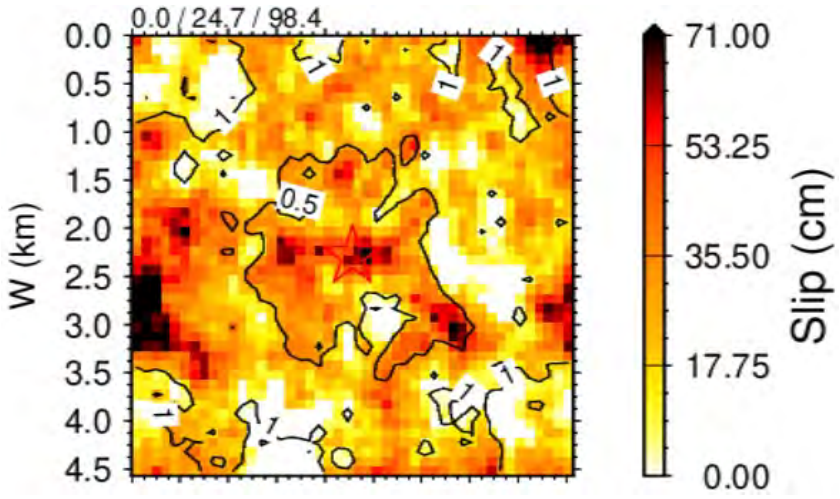
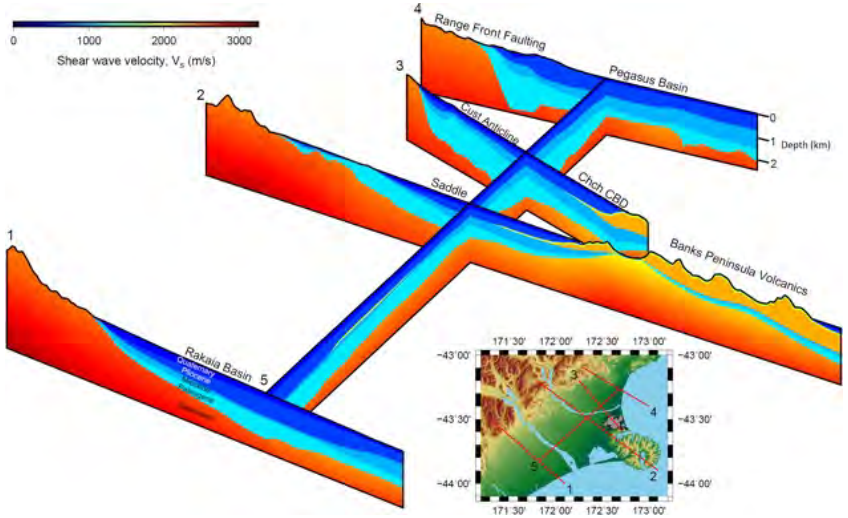


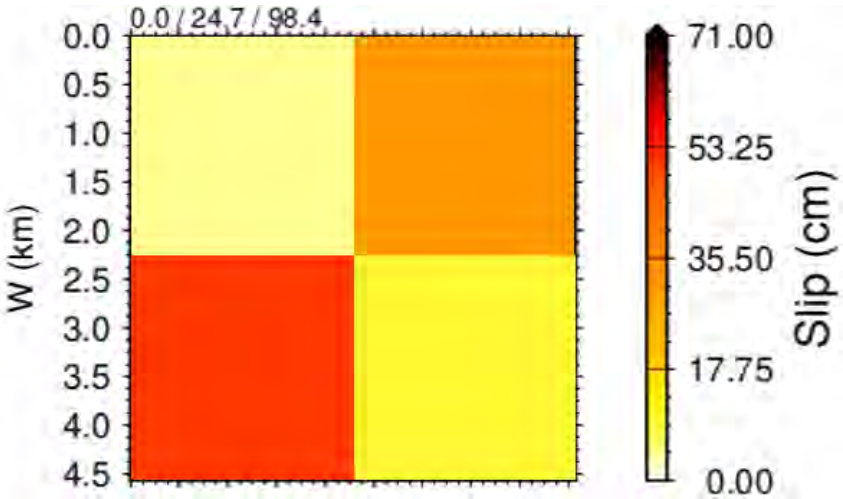
Workflow - Simulation

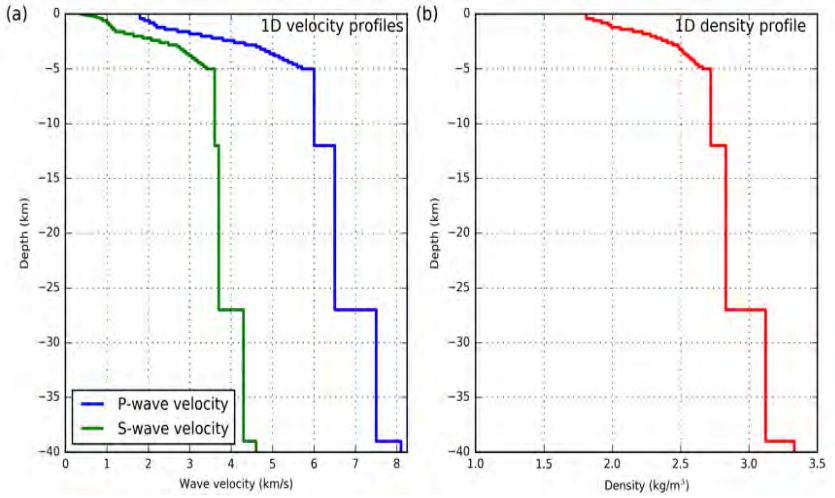
Low-frequency Ingredients





High-frequency Ingredients



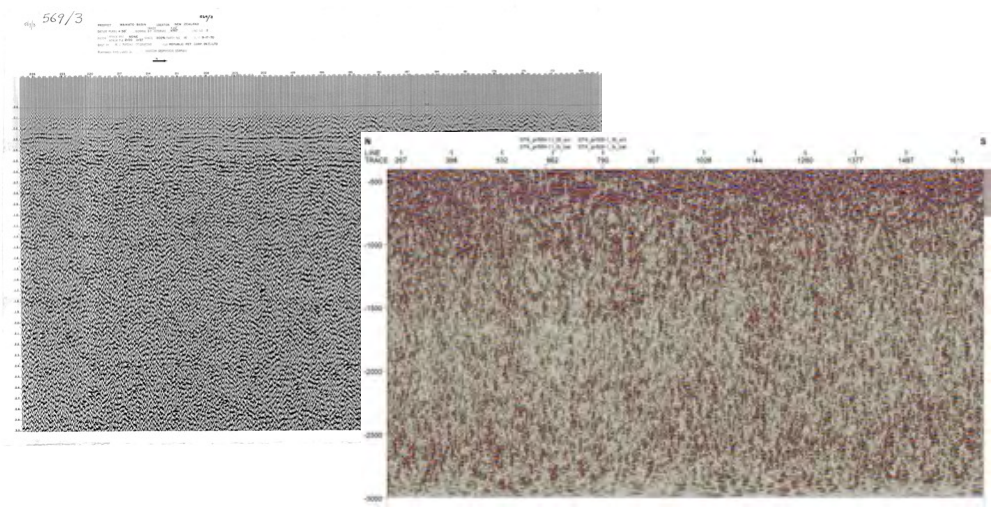


Early Progress

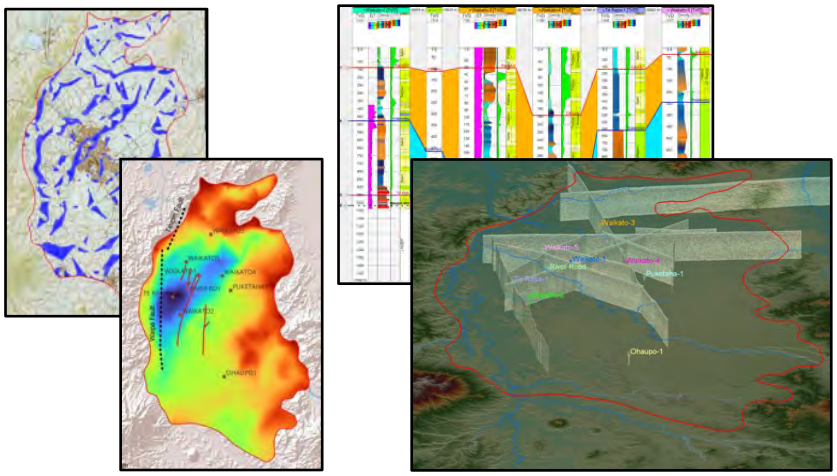
PhD Student Confirmation

Dave Gardiner

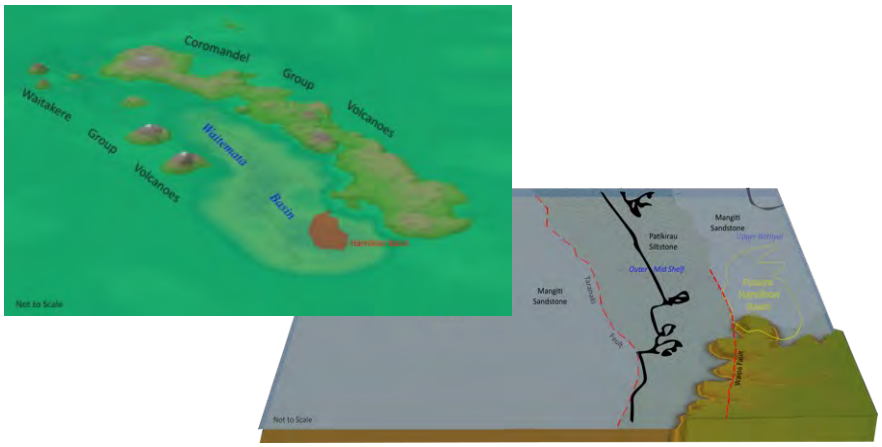
Seismic Data Reprocessing



Data Exploration & Synthesis



Developing Geological Concept




Tēnā Koutou Thank You