Mud Volcano Imaging Using Ambient Seismic Noise

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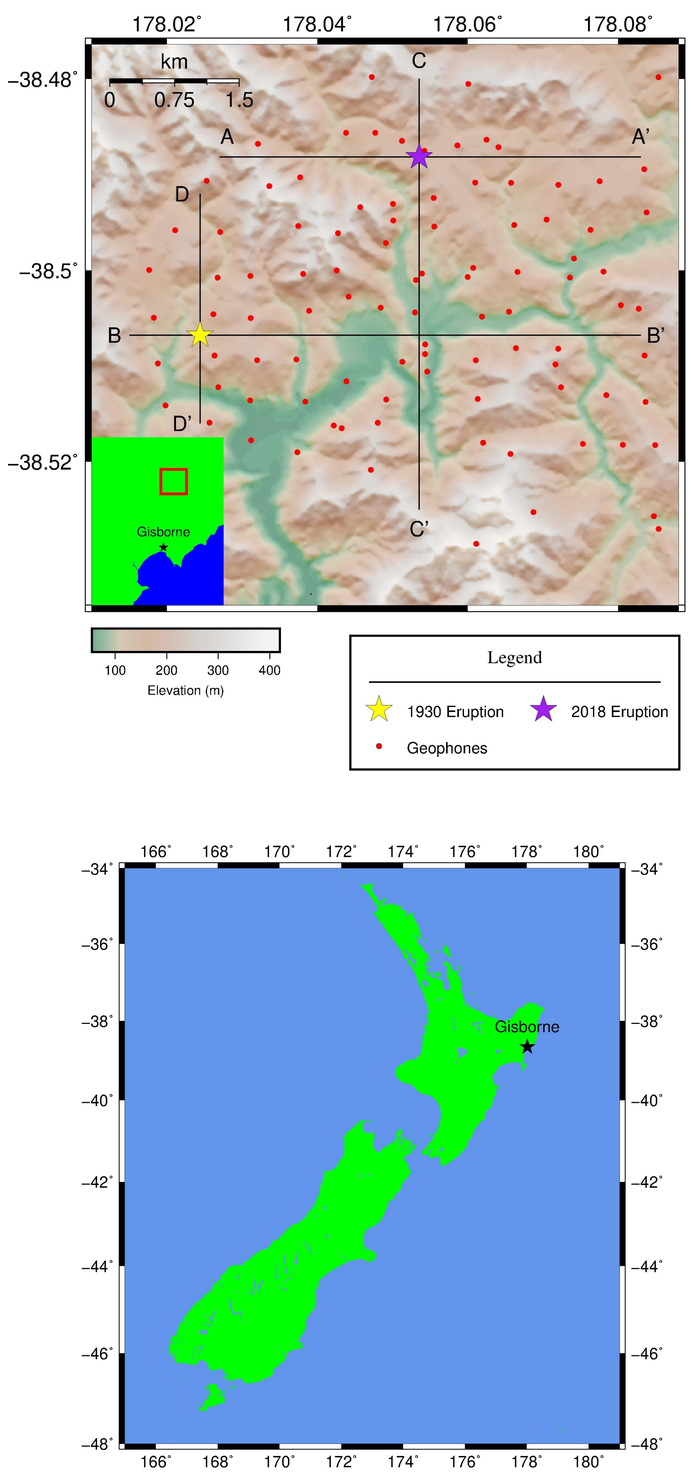
1. Introduction

Mud volcano's are loosely defined as an eruption of mud at the Earth's surface, and are generally associated with subduction zones. Mud volcano eruptions represent a serious risk to human life, health, and property, as demonstrated by the ongoing eruption of the LUSI mud volcano in Indonesia that has claimed several lives and displaced tens of thousands of people (Richards, 2011). Mud volcano research is essential to mitigate the impacts of such events.

Ambient Noise Tomography (ANT) involves the use of background noise recorded by seismic stations to create a 3D model of the subsurface.

In this experiment, an array of 97 short period seismic instruments was deployed in the Waimata Valley near the city of Gisborne, New Zealand. The deployment lasted from December 2017 to February 2018. The purpose of this deployment was to image the subsurface structure of a mud volcano in the Waimata Valley.

The study area is represented in the figure below. Elevation data from Columbus et al., 2011 was used. Black lines represent cross sections used to show the 3D model in panel 5.

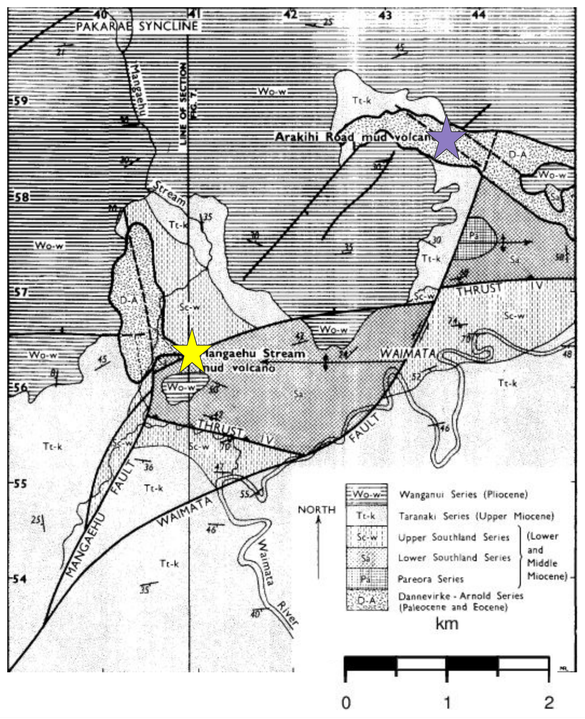


3. Method

Cross-correlation functions between each of the seismic stations were calculated using the NoisePy code (https://github.com/mdenolle/NoisePy). The Automatic Frequency Time Analysis (AFTAN) (Bensen et al., 2007) method was then used to extract the dispersive relations (dispersion curves) between phase velocity and period from the cross-correlation functions. The dispersion curves were then used to invert for a 3D shear wave velocity model, using the DSurfTomo code (https://github.com/HongjianFang/DSurfTomo). The final model was chosen as a model that had low values of roughness and data misfit.

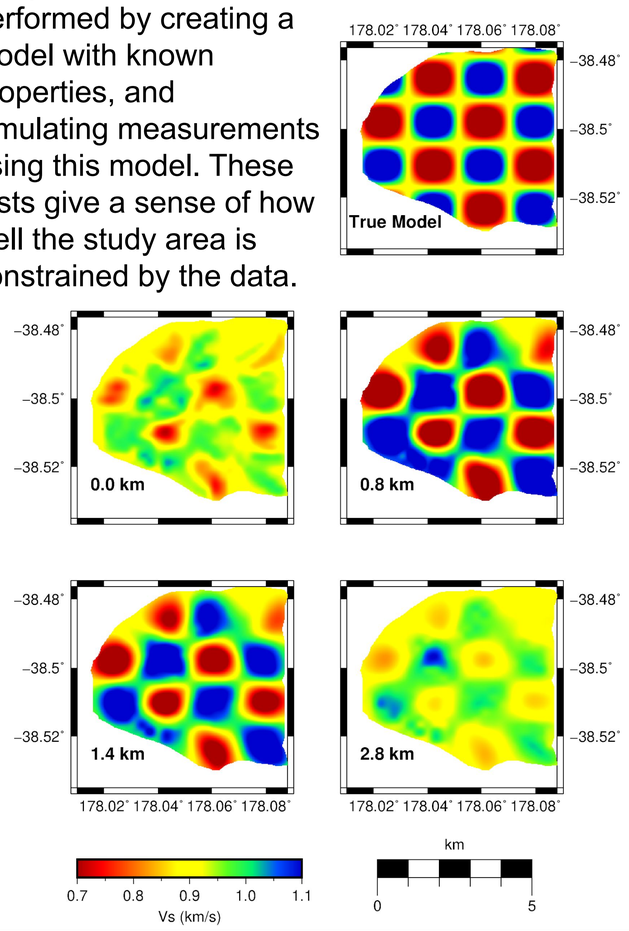
2. Geologic Setting

The Waimata Valley is located on the North Island of New Zealand, near the city of Gisborne. This is located along the Hikurangi margin. where the Pacific Plate is subducting beneath the Australian Plate. There are two sites of known mud volcanism within the study area. One site had previously erupted in 1901, 1907, 1908, and 1930 (Ridd, 1970). In the second location there was an eruption in December 2018 (Bell, 2018), soon after the geophone array was dismantled. The following figure depicts the geology of the Waimata Valley, and was adapted from Ridd, 1970.



4. Synthetic Tests

Synthetic tests are performed by creating a model with known properties, and simulating measurements using this model. These tests give a sense of how well the study area is constrained by the data.



6. Conclusions

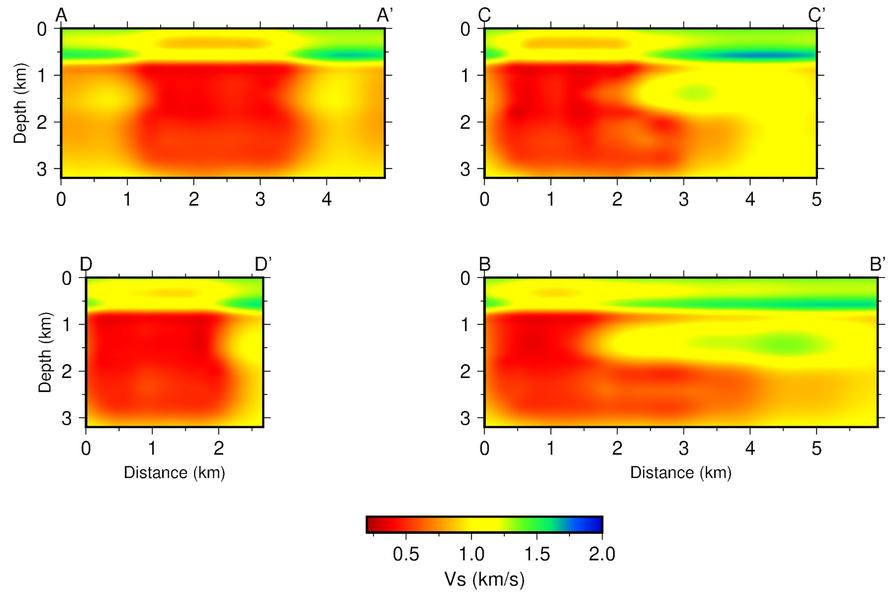
- Both eruption areas correspond to a low velocity zone in the 3D model
- Both mud volcano eruptions share the same reservoir at depth
- The mud volcano reservoir extends to at least 3.2 km in depth

7. Future Work

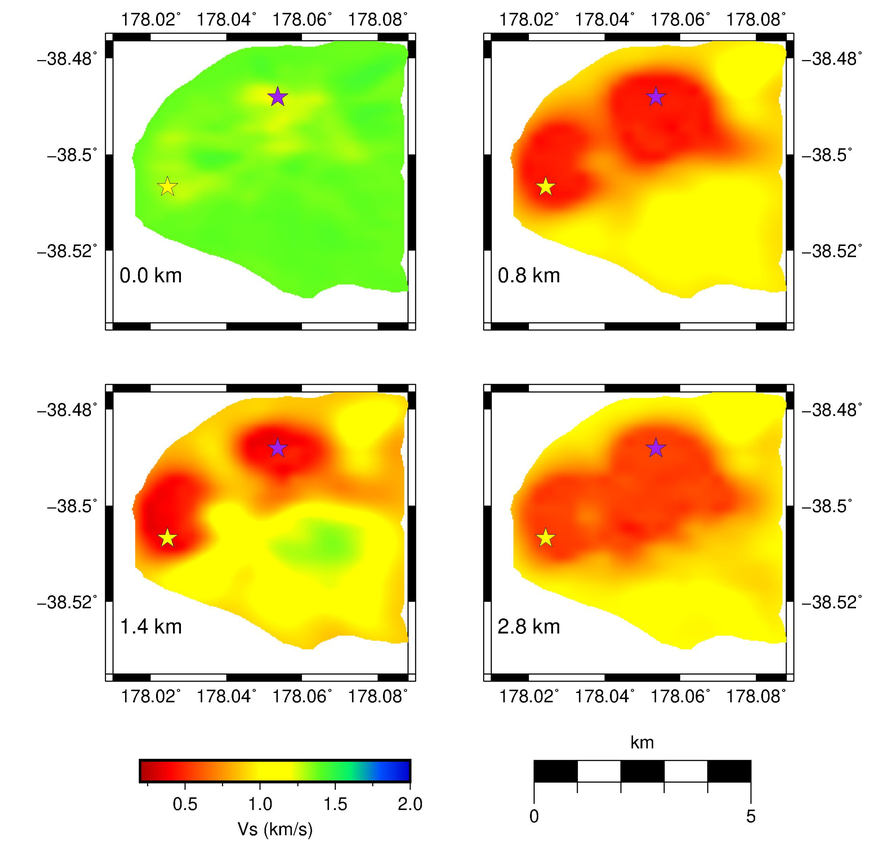
Spatio-temporal monitoring of the mud volcano may be used to look for precursory signals prior to the December 2018 eruption. Seismic anisotropy measurements may provide useful information for interpreting the mud volcano's evolution.

5. 3D model

Vertical Cross-Sections



Horizontal Depth Slices



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