Revealing the Australian-Pacific Plate Boundary Beneath Macquarie Island with Teleseismic Tomography

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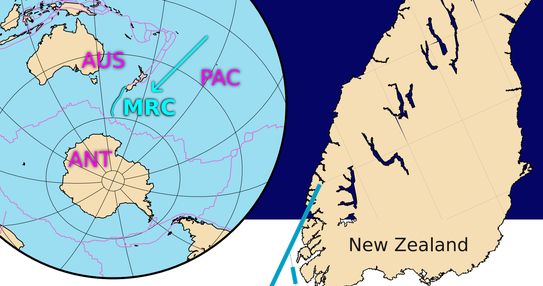

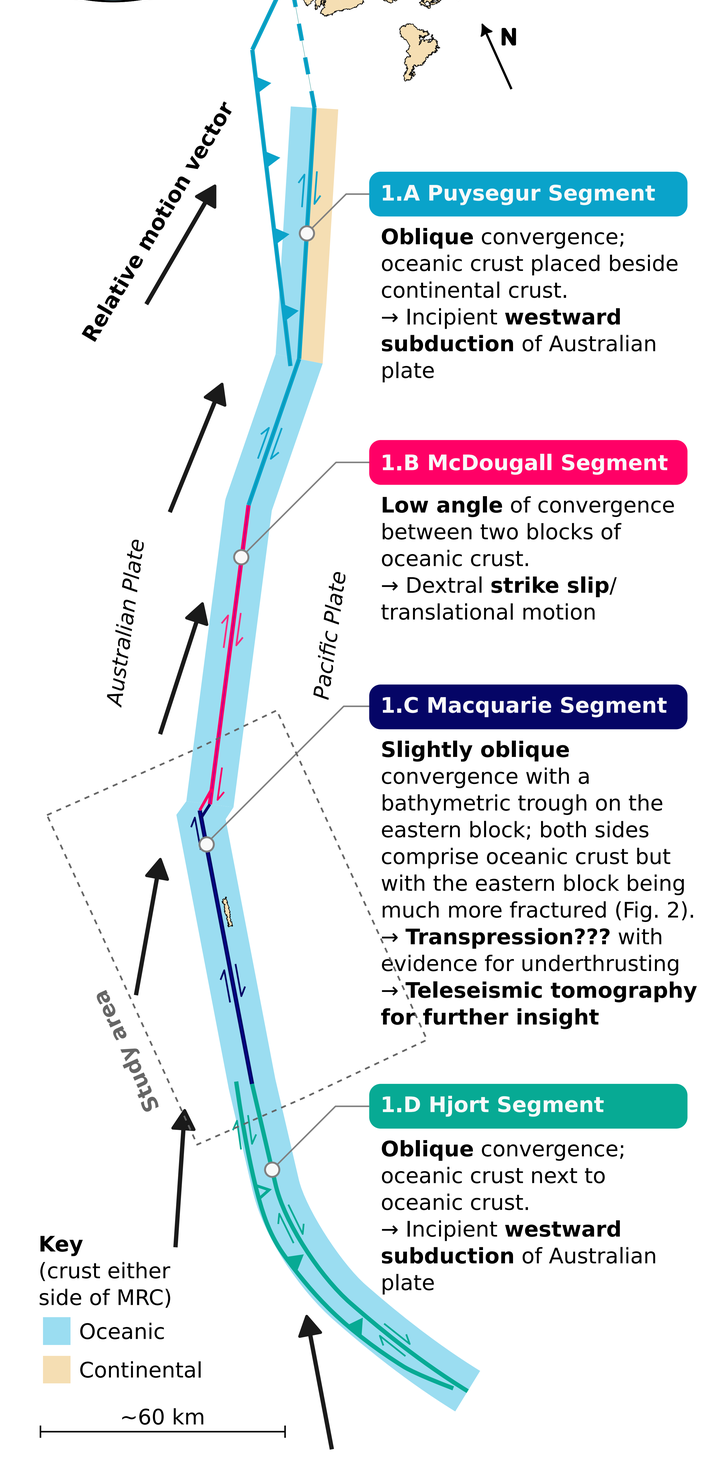

Figure 1 The four segments of the Macquarie Ridge Complex (MRC), each with a different tectonic regime[1,2,3]. A regional-scale map at the top shows the MRC in the context of the Australian (AUS), Pacific (PAC) and Antarctic (ANT) plates. Relative motion vectors[2] not accurately to scale.

1. Introduction

The Macquarie Ridge Complex (MRC) comprises four segments (1.A to 1.D) and marks the plate boundary separating the Australian and Pacific plates south of New Zealand[1]. The MRC hosts diverse tectonic regimes (Fig. 1) controlled principally by the angle between the relative plate motion vector and plate boundary orientation[2,3].

We use teleseismic data from a temporary seismometer network (Fig. 2) to produce a P-wave velocity model of the mantle beneath Macquarie Island via seismic tomography.

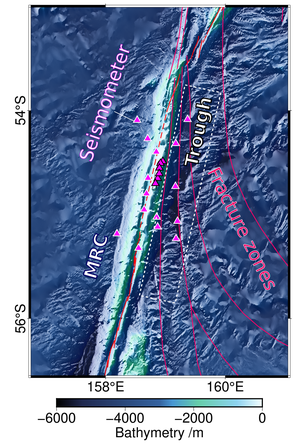

Figure 2 Bathymetric[4,5,6] features and seismometer locations (black outline→land; white→OBS) around the Macquarie segment.

2. Data and Methods

Seismometer network[7] (Oct 2020 to Nov 2021; Fig. 2):
• 15 temporary ocean bottom seismometers (OBSs)
• 5 temporary and 1 permanent land stations

OBS data is very noisy, so ATaCR[8,9] was used to denoise the data (Fig. 3). After denoising, 65 phase arrivals (Fig. 4) could be used for teleseismic tomography.

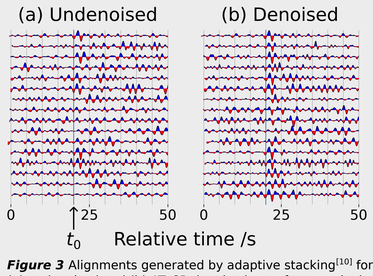

Figure 3 Alignments generated by adaptive stacking[10] for (a) undenoised and (b) ATaCR denoised waveforms. t_0 is the predicted P arrival time for event 2021-01-08T05:01:04.07.

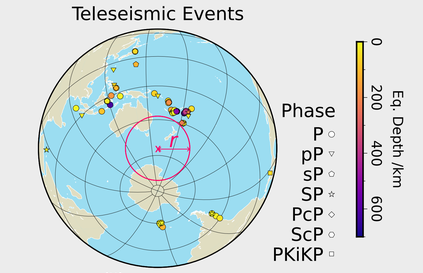

Figure 4 Events[11] used for teleseismic tomography. r is the teleseismic threshold (27°) from the center of the study region.

3. Results

Good checkerboard recovery at lithospheric mantle depths. Velocity model reveals contrast across plate boundary: lithosphere to W is ~0.4 km/s faster.

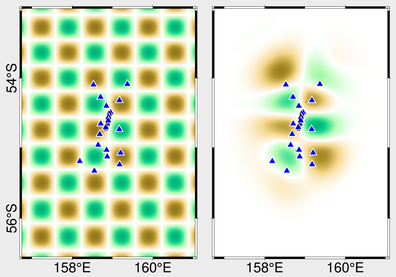

Figure 5 Checkerboard recovery test at 30 km depth. Left: true velocity structure. Right: recovered velocity structure. Stations are plotted as blue triangles.

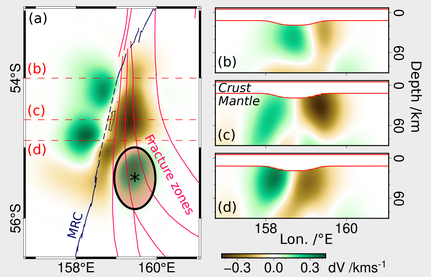

Figure 6 Recovered velocity model at (a) 30 km depth, (b) 54.0°S, (c) 54.6°S and (d) 54.9°S. *Feature constrained by singular station and thus not robust.

4. Interpretations

High density of fracture zones on eastern block provide pathways for deep lithospheric hydration[12], so the velocity contrast likely reflects a difference in fracture density and hydration across the plate boundary (Fig. 7), which tracks this segment's tectonic history as previously being an oblique spreading ridge cut by numerous transform faults[1].

High fracture density leads to mechanical instability in the Pacific plate and a wet lithosphere favours megathrust development[13]. Therefore westward subduction of the Pacific may become possible.

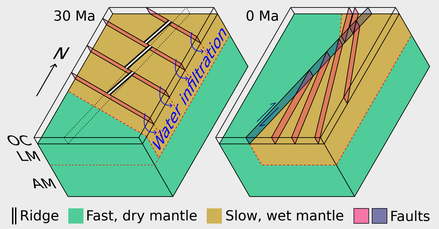

Figure 7 Schematic tectonic history: oceanic transform zone fracturing, then dextral strike slip. OC: oceanic crust; LM: lithospheric mantle; AM: asthenospheric mantle.

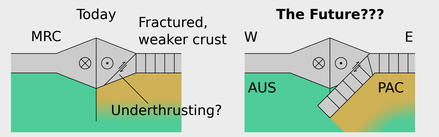

Figure 8 E-W cross sections speculating on the future of Macquarie Island? A wet lithosphere promotes the development of a lithospheric-scale localised shear zone, potentially leading to incipient subduction. AUS: Australian plate; PAC: Pacific plate.

5. Future Work

A local earthquake catalogue with accurate locations and focal mechanisms can provide further insights. Are there any reverse faults arranged along a thrust plane? Or is seismicity principally hosted by strike slip faults along subvertical fault planes?

The nature of local seismicity can determine whether the low convergence angle or the compositional contrast is the primary control of the PAC-AUS boundary along the Macquarie segment.

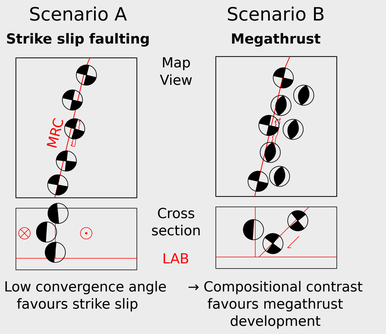

Figure 9 Competing hypotheses for the type and distribution of seismicity beneath the Macquarie segment.

6. Conclusions

A collection of denoised waveforms images the lithospheric velocity structure beneath Macquarie Island.
Low velocity hydrated Pacific lithospheric mantle is placed against unhydrated Australian oceanic lithosphere in a configuration that will not hinder westward subduction. However, the current status of the plate boundary along the Macquarie segment remains uncertain, which we hope to resolve using a local earthquake catalogue.

References

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