Numerical Simulations of Dispersed Waveforms from Wadati-Benioff Zone Seismicity

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1. INTRODUCTION

Guided wave dispersion is observed in the fore-arc of several subduction zones, and has been attributed to a low velocity crustal layer that acts as a waveguide. Here we show observations of guided wave dispersion from well below the slab surface that cannot, therefore be described by a single simple low velocity layer. Numerical simulations show that low velocity dipping normal faults act as waveguide causing the observed dispersion. Synthetic waveforms are directly compared to the observed waveforms to constrain the low velocity fault structure. Analysis of the extended P-wave coda associated with these events shows that the oceanic mantle is highly hydrated by these low velocity normal faults imaged at depth.

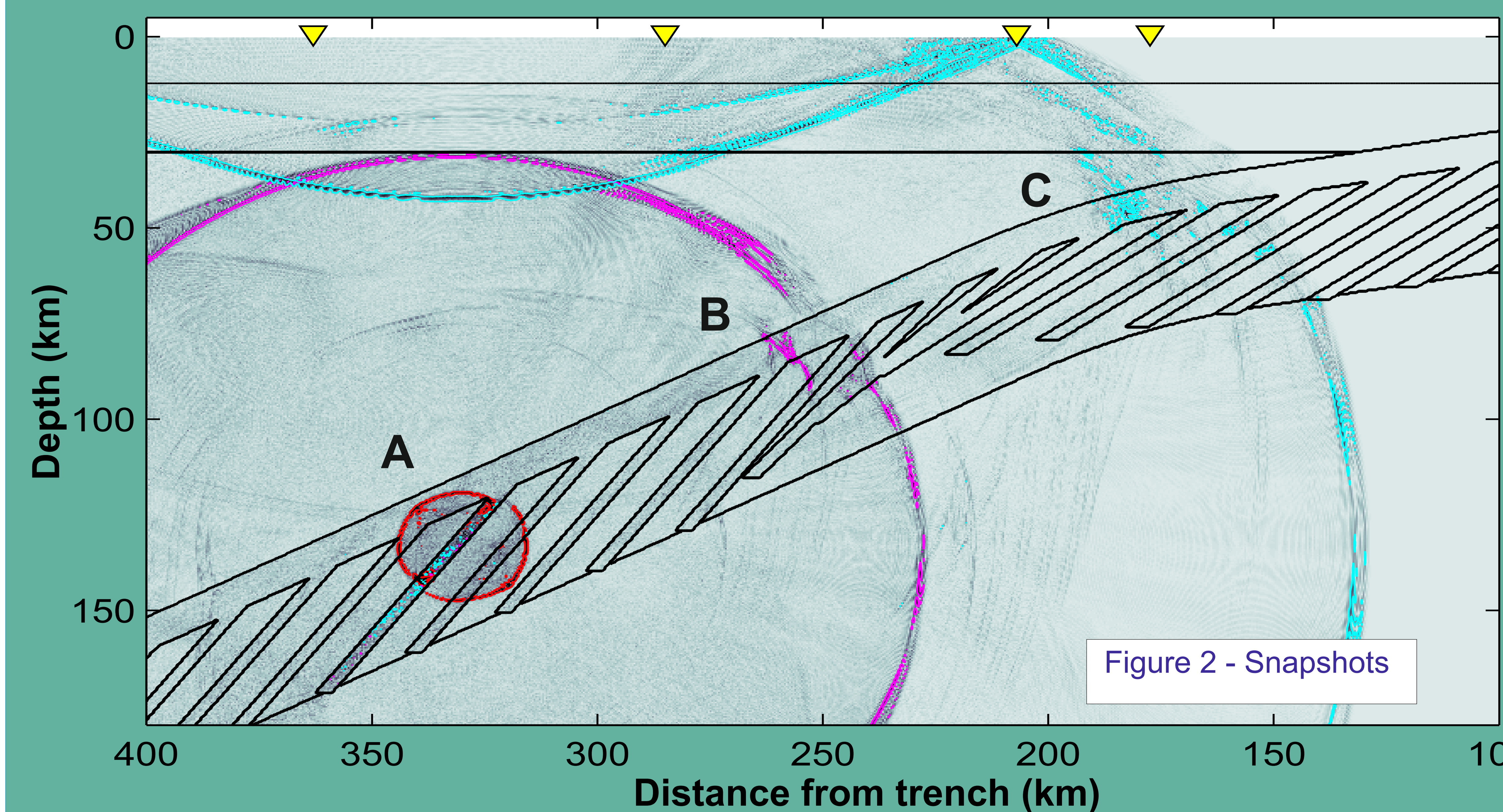


Figure 2 - Snapshots

2. OBSERVATIONS

- Arrivals are noted at the GSN and F-net stations (shown in yellow figure 1a) in Northern Japan.
- Dispersion of 1-2 seconds is seen for events 5-35 km below the surface of the slab (figure 1b).
- Slab shape is based on the JMA seismic catalogue and the slab1.0 model (Hayes et al. 2012).
- High resolution bathymetry data shows a surface expression of outer rise faulting (figure 1a).

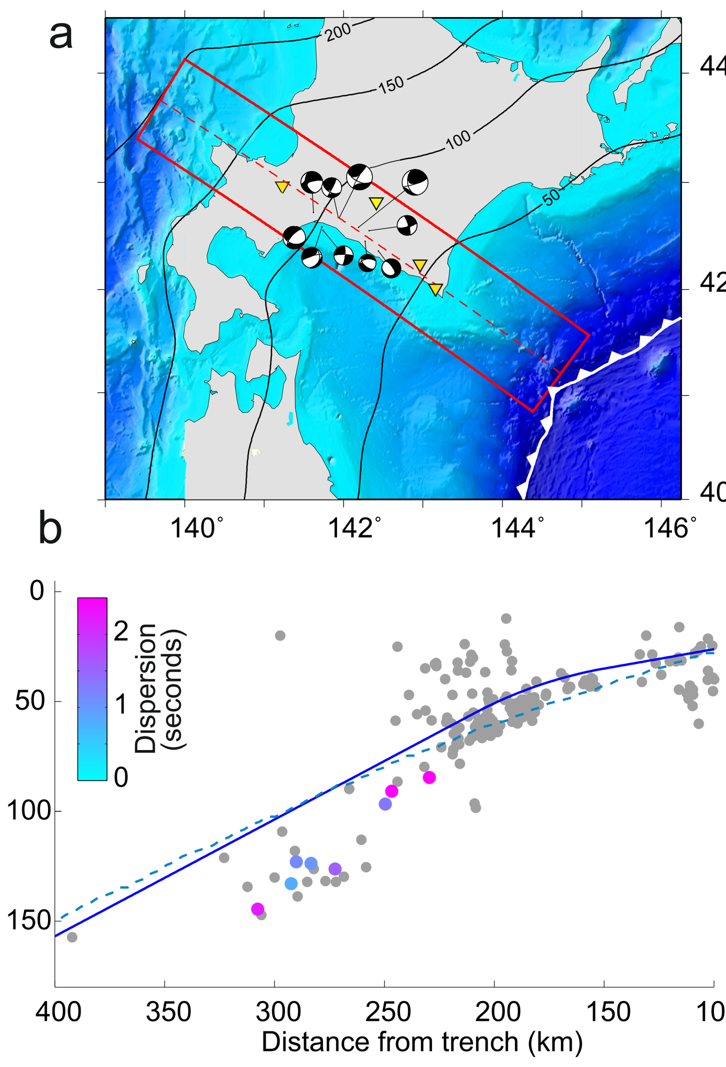


Figure 1 - location map & profile

3. WAVEFORM MODELLING

Figure 2 (above) shows snapshots of the waveform model as the energy from an event occurring on a low velocity normal fault propagates up dip

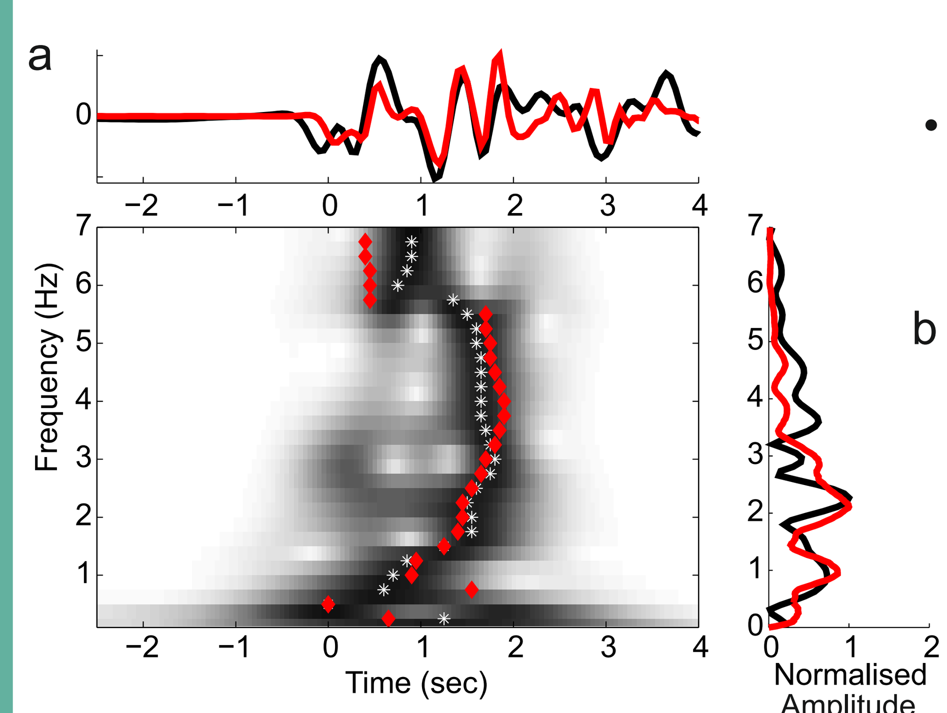
[A] 1 SECOND – **The high frequency energy is retained by the low velocity fault structure**

[B] 12 SECONDS – **The energy is transferred to the low velocity oceanic crust**

[C] 24 SECONDS – **Retained energy decouples from the waveguide due to the bend of the slab**

4. WAVEFORM FITTING

- A 2D FD model is used to produce the synthetic waveforms (Bohlen, 2002).
- A spectrogram (Abers, 2005) is used to identify the characteristic guided wave dispersion in the observed and synthetic waveforms (figure 3a, bottom left).
- Comparing the waveforms as a spectrogram gives a constraint on the relative arrival time of different frequency bands.
- Comparing the waveforms in the frequency domain (figure 3a, bottom right) give an indication of the relative amplitudes of different frequency of arrival.
- Constraining the waveform in these two ways means that the whole waveform is constrained and the low pass filtered (at 2.5 Hz) waveforms can be compared (figure 3a, top).



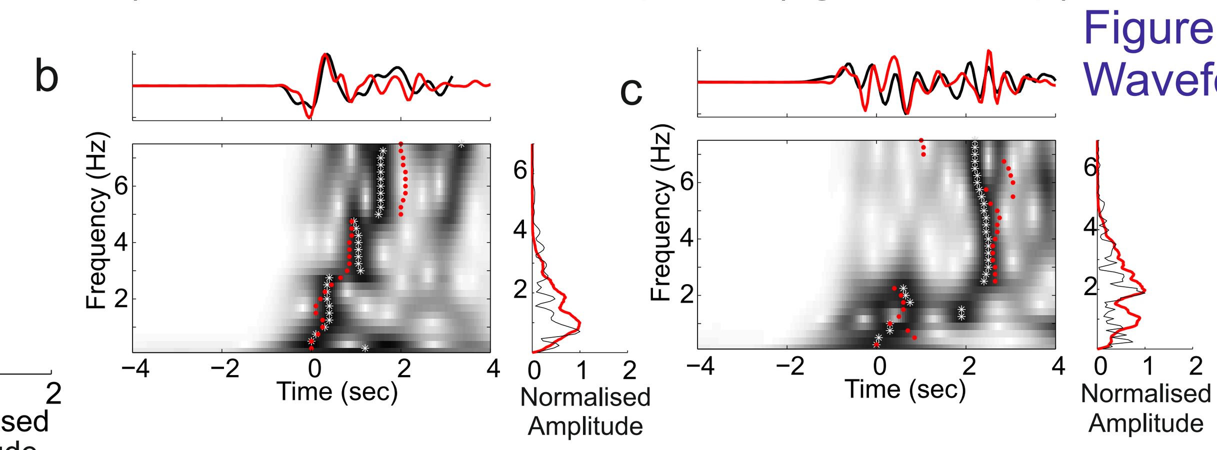


Figure 3 - Waveform fitting

5. SCATTERING ANALYSIS

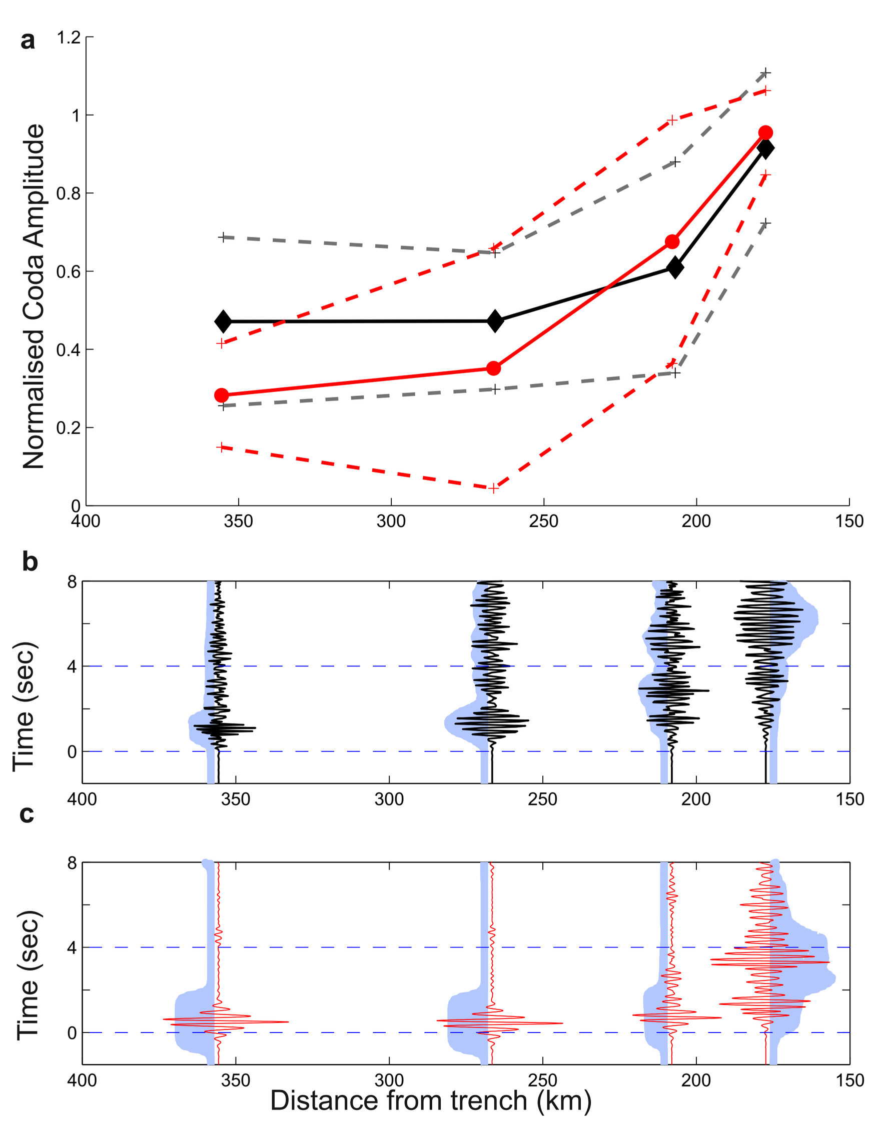


Figure 4 - Scattering observation and modelling

- Events that occur within in the WBZ are associated with an extended P-wave coda, as has previously been noted in Northern Japan for deeper events (e.g. Furumura & Kennett, 2005).
- The amplitude of the high frequency coda (>3 Hz) decays, with respect to the first motions, with distance from the trench (figure 4a & b).
- The amplitude of the coda, with respect to the first motions, is calculated for 7 events in the Japanese slab and averaged (black line, figure 4a).
- We use a von Kármán function to describe the scattering media (following Furumura & Kennett, 2005) and show that dipping low velocity normal fault structure can account the coda (red waveforms bottom left figure) and for this decay in coda amplitude (red line, figure 4a).
- A scattering medium with an average velocity of 7.62-7.85 km/s describes the observed coda, and corresponds to a 17-31 % serpenization of the subducting mantle material.

6. SUMMARY

- Waveform modelling shows that low velocity hydrated fault zone structure can account for dispersion observed in the WBZ of Northern Japan.
- This structure can also account for the observed P-wave coda decay.
- This suggests that the slab mantle is 17-31% serpentinized and can carry large amounts of water to the mantle.
- Much of this water is likely to be delivered to the deep mantle, with significant consequences for the rate of convection and melt production at these depths.

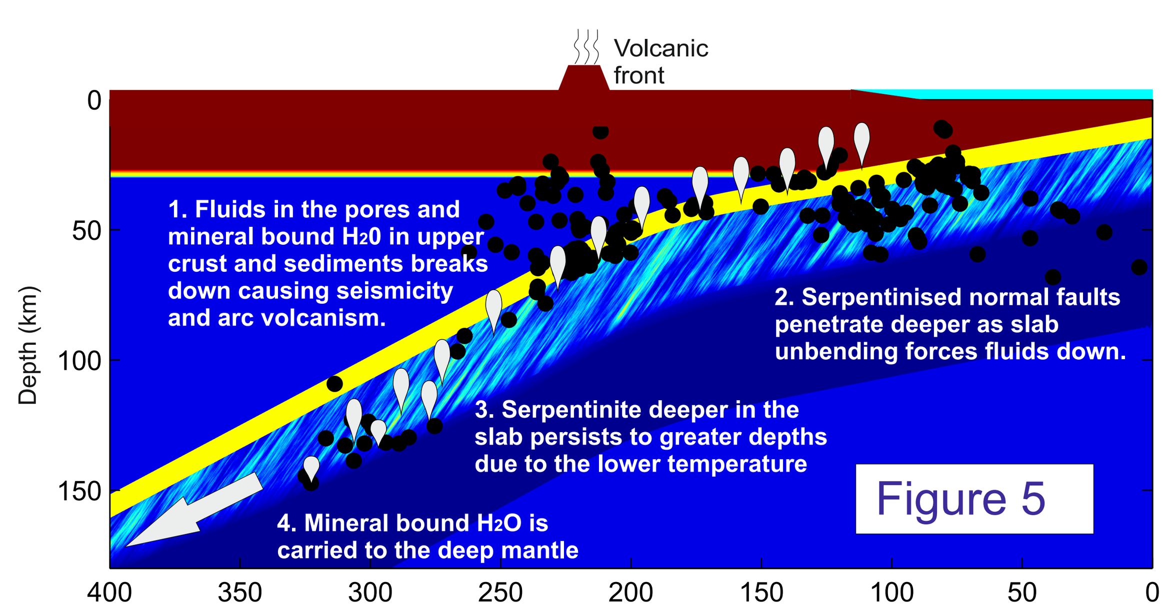


Figure 5

ACKNOWLEDGEMENTS

Data is used from the GSN and F-net seismic networks. Earthquake locations from the JMA catalogue are used. The authors are greatfull that the Finite Difference coda SOFI is made freely available.

REFERENCES

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