Determining Gas Hydrate Distribution at Porangahau Ridge, Southern Hikurangi Subduction Margin Using Seismic and Controlled Source Electromagnetic Data

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ABSTRACT

Porangahau Ridge is a prominent thrust ridge inferred to contain large concentrations of gas hydrate, located within the accretionary wedge of the southern Hikurangi Subduction Margin. A high-resolution velocity model developed using conventional and horizon based velocity analysis has been used to derive a preliminary migrated seismic section. This preliminary section reveals complex near-surface faulting not previously resolved, and more clearly defines a band of high-amplitude reflections above the regional bottom simulating reflections (BSRs). Interpretation of the depth-converted migrated seismic section provides new insight into the nature of faulting and its relationship to fluid flow and gas hydrate formation on the margin.

Controlled source electromagnetic (CSEM) surveying is sensitive to highly-resistive gas hydrate and free gas in water-saturated conductive sub-seafloor sediments to depths of a few hundred metres below the seafloor. CSEM data acquired along a transect across Porangahau Ridge (coincident with 05CM-38 seismic profile) show anomalously high apparent resistivities above the high-amplitude reflection bands we observe, and close to a near surface, small high amplitude reflection.

INTRODUCTION

A bottom-simulating reflection (BSR) with a negative impedance contrast is a useful tool for identifying locations where gas hydrate is overlying free gas at the base of gas hydrate stability (BGHS). However, seismic data provides little information about the distribution of gas hydrate *within* the gas hydrate stability zone.

Controlled Source Electromagnetic Methods (CSEM) detect variations in the resistivity structure of sediments within the top few hundred metres of seafloor sediments. Hydrocarbons are strongly resistive in comparison with seawater, so produce a strong positive resistivity anomaly. Here we show that joint analysis of resistivity inversions and seismic data provides constraint on the distribution of gas hydrate within the gas hydrate stability zone.

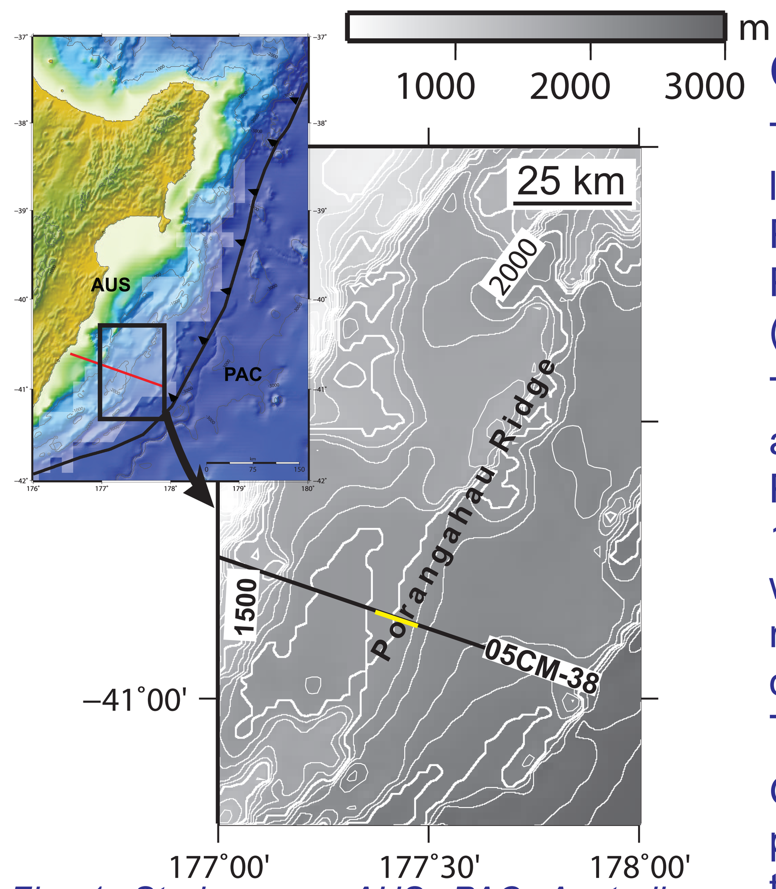


Fig. 1: Study area. AUS, PAC: Australian, Pacific Plates. White shaded region depicts the region of known gas hydrate (after Henrys et al. submitted). Red line = seismic line 05CM-38 shown in Fig. 2, Yellow line marks location of CSEM profile, and section of 05CM-38 in Fig. 3.

GEOLOGICAL SETTING

The Porangahau Ridge is located offshore Wairarapa landward of the Hikurangi Trench. Here, the Pacific Plate is subducting obliquely beneath the Australian Plate (at 50° to the boundary) at a rate of ~41 mm/yr (DeMets et al., 1990).

Trench-fill turbidites with 25-38% pore water are accreting to the margin at 12 ± 3mm/yr (Lewis and Pettinga, 1993; Barnes and Mercier de Lepinay, 1997). Compaction and deformation of accretionary wedge sediments and dewatering of underlying crust results in the expulsion of fluids at > 20 m3, per metre of strike each year (Sibson and Rowland, 2003; Townend, 1997)

Gas hydrates are abundant within the accretionary prism. Intepretation of BSRs in seismic data indicate that the gas hydrate zone extends from water depths of 600 m out to the Hikurangi Trench, with the greatest concentrations located at sites closely linked to fluid expulsion (Pecher and Henrys, 2003; Henrys et al., submitted)

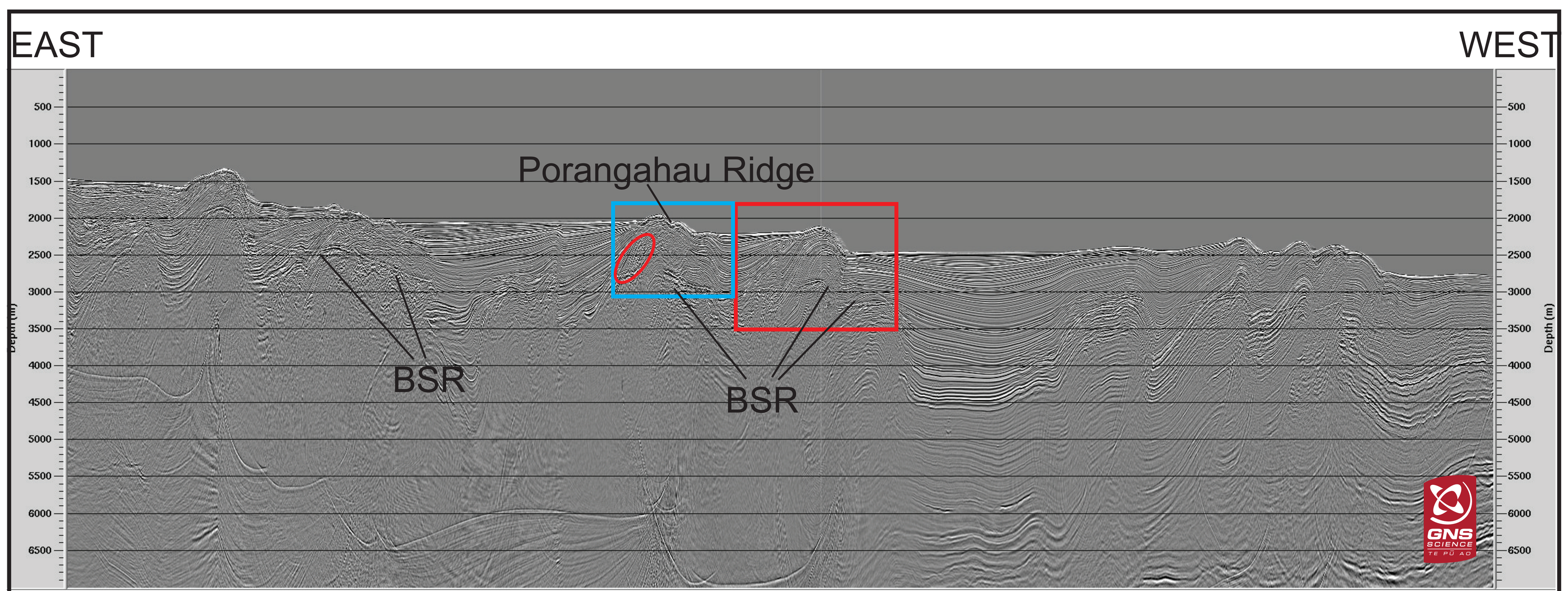
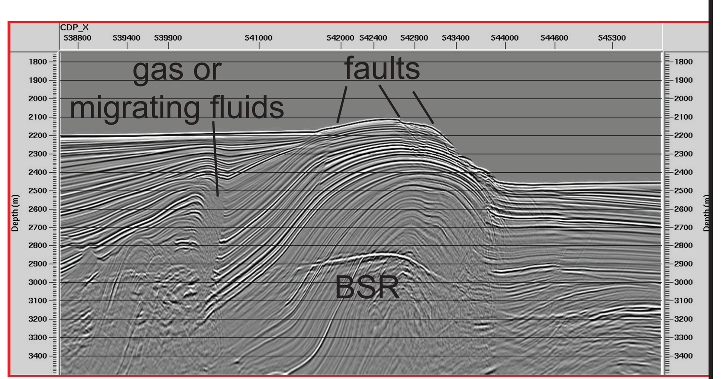


Fig. 2: Depth converted migration section of 05CM-38. Red box denotes the location of the enlargement (right), blue box shows the location of the section in Figure 3.



SEISMIC DATA

Here we present a depth converted migrated seismic section which has been processed using a smoothed version of our high resolution velocity model. The seismic section clearly resolves the BSR, a high-amplitude anomaly extending from the BSR towards the apex of Porangahau Ridge (red ellipse), extensional faulting in the upper layers of anticlines due to tension and wipe-out zones due to migrating fluids.

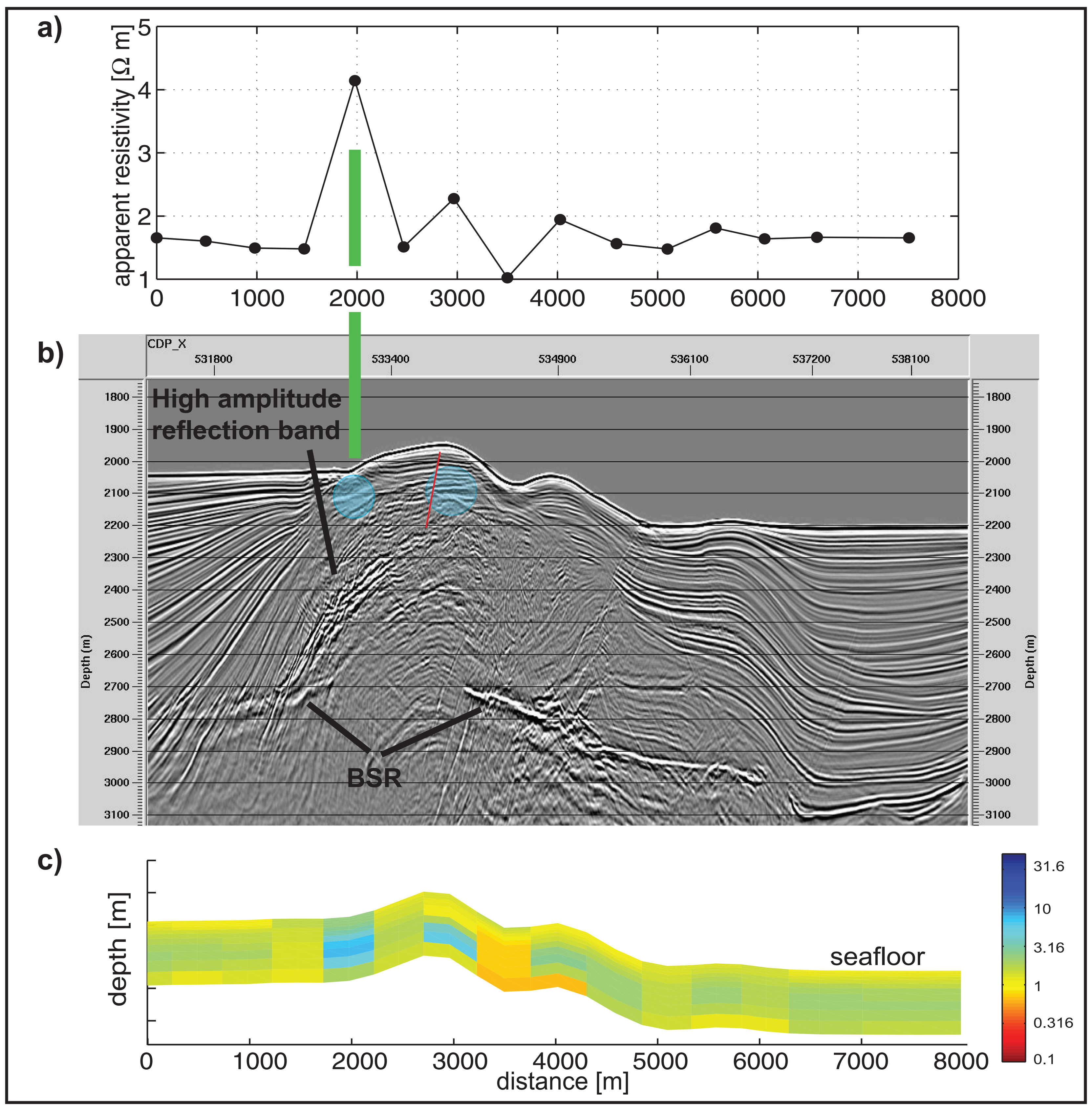


Fig. 3: Resistivity structure and seismic data at Porangahau Ridge. a) Apparent resistivity profile at Porangahau Ridge (after Schwalenberg et al. submitted). b) a short segment of depth converted migrated seismic line 05CM-38. c) 1-D layered resistivity inversions presented as a "stitched model" (after Schwalenberg et al. submitted). The vertical scale on this resistivity section is identical to that on the seismic data

COMPARISON OF CSEM AND SEISMIC DATA

CSEM data across the Porangahau Ridge were acquired during the SO191 voyage in 2007, using a bottom-towed electric dipole-dipole system consisting of a transmitting dipole 126 m long, and two receiving dipoles at offsets of 386 m and 706 m (Bialas et al, 2007). Data presented here are from Schwalenberg et al (submitted). The CSEM profile is coincident with the 05CM-38 seismic line (Figure 1).

The resistivity profile (Fig 3a) shows a strong resistivity peak (~ 4 times the background value) at 2000 m profile distance (Schwalenberg et al. submitted), with a smaller peak at 4000 m.

Comparison of stitched 1D resistivity inversions (Fig 3c) and seismic data (Fig 3b) show:

- High resistivity anomalies occur *above* the high amplitude reflection band
- Highest resistivity of ~ 7 Ωm, at 2000 m profile distance, corresponds, within uncertainty, with a small seismic amplitude anomaly 90 m beneath the seafloor. This likely indicates the presence of a small concentrated pocket of gas hydrate
- A second resistivity peak (at 3000 m profile distance) occurs underneath the apex of the anticline, adjacent to a shallow extensional fault which vertically offsets uppermost stratigraphic layers by 5 – 7 m, but does not have a surface expression. This fault is immediately above the upper termination of the high amplitude reflection band.

The next step in resistivity modelling is to jointly-invert for both receivers (at present inversion is only for near receiver) using depth-converted seismic horizons to better constrain the vertical distribution of resistivity anomalies.

DISCUSSION AND CONCLUSIONS

A combination of good quality seismic data and controlled source electromagnetic data provides constraint on the vertical distribution of gas hydrate within the Gas Hydrate Stability Zone at Porangahau Ridge.

Our results show that a high amplitude seismic reflection close to the seafloor coincides with a strong resistivity anomaly, indicating the presence of hydrocarbon (likely gas hydrate) at 90 mbsf, on the western flank of Porangahau Ridge.

A smaller resistivity anomaly is located immediately beneath the apex of the anticline and adjacent to a fault extending towards a high amplitude reflection band. Crutchley et al (2006) suggests that this high amplitude reflection band (and others on the margin) are connected to the gas hydrate system. Furthermore, Crutchley et al (2006, submitted) and Pecher et al (2006) suggest that the high amplitude reflection band is caused by the presence free gas above BGHS. The second, smaller resisitvity anomaly is therefore intepreted to be caused by free gas, or gas hydrate, formed by gas migrating upwards from the high amplitude reflectivity band and along the intepreted fault. On encountering a low permeability layer the gas is forced laterally into a high permeability bed. If the sediments become methane saturated, gas hydrate will form.

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