First Results from the Scarborough Marine EM Survey

Steven Constable, Kerry Key, David Myer
Scripps Institution of Oceanography
http://marineemlab.ucsd.edu
Commercial Marine EM:

Marine MT being used for geological structure in seismic low-productivity areas (salt, sub-basalt, and carbonate)

Marine CSEM being used for pre-drill reservoir appraisal

- Instrumentation and practice little changed from academic precursors
- Many contractors are fighting for a relatively small market
- Processing and interpretation tools are wanting
- Navigation errors probably main limitation of data

The physics is sound - where do we go from here?

Need a high quality academic data set to drive the science.
NW Shelf Australia
May 22 - June 23 2009
50 seafloor E/B receivers
2 deep-towed EM transmitters
2 long-wire receivers
2 3-axis towed receivers
250 m antenna (+ 100m spare)
160 concrete anchors
20 lbs Peet’s coffee
Scarborough gas field: The only academically collected data set since the first Statoil Girasoll survey in 2000. Funded by BHP-Billiton.

Seafloor is mostly flat in 900 m water, with pock-marks over areas of shallow gas.

144 receiver deployments
12 days/300km CSEM tow
New instrument systems
New waveform

Western Australia
Pre-cruise MARE2DCSEM model study based on seismics and well logs shows little sensitivity to reservoir below 1 Hz.

Well logs show overlying resistor (Gearly formation)
Close-up of reservoir

- Depth (km): 1.5, 2, 1
- Position (km): 0 to 20
- Resistance: 25 Ωm
- 50 m (!)

Inset: Geophysical survey data.
Ey, Ez and Bx at 0.1 and 1 Hz inverted with OCCAM1D after adding 1% random noise and omitting data below noise floor:
A new long baseline navigation solution was a critical part of the CSEM data acquisition:
Phase 2 transmitter navigation: estimated 5-10 m accuracy
Phase 1 2D OCCAM MT inversion:

Scarborough Phase 1
TE + TM, Iteration 9, RMS Misfit = 1.1

Normal faulting on basement?
Phase 1 2D OCCAM MT inversion: Looking deeper

Scarborough Phase 1
TE + TM, Iteration 9, RMS Misfit = 1.1

0.5 Ωm conductor!

Can this be real?
Yes! This feature has been seen before:


Rifting of a passive margin and development of a lower-crustal detachment zone: Evidence from marine magnetotellurics

Graham Heinson
Antony White
F. E. M. Lilley

![Diagram of geophysical research showing a map and a resistivity section diagram.](image)

**Scale change**
CSEM $E_y/B_x$ data on/off reservoir:

Frequency: 0.75 Hz

Electric Field

Magnetic Field

Amplitude, $\log_{10}$ V/m, T/Am

Horizontal Range (km), in-tow(+), out-tow(-)
Line 1 anomaly pseudosections (red = x2 referenced to 1 Ωm layer underlain by 2 Ωm)
For 2% error floor, MT helps find the reservoir, but with a 1% error floor, CSEM amplitudes give a similar model.
Agreement with pre-cruise design study is good. Reservoir response is shallow, but perhaps smeared with Gearly, and we have yet to include phase, magnetics, etc.
Data fits for 2% error floor: MT data are being neglected because they are only 8% of the total data, but fits to CSEM amplitudes across more than 1 decade of frequency are excellent.
IN CONCLUSION:

We have collected 144 sites of very high quality CSEM data over a well-documented gas reservoir.

These data will be extremely useful to drive the development of 1D, 2D, and 3D inversion/interpretation.

Data will be publicly released as we publish our work.