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High frequency enhancement of sparker sub bottom profiles with multichannel reflection processing

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SUMMARY

The Petrel Sub-basin Marine Survey was undertaken in May 2012 by Geoscience Australia and the Australian Institute of Marine Science to support assessment of CO_2 storage potential in the Bonaparte Basin. The aim of sub bottom profiling was high resolution data to investigate regional seal breaches and potential fluid pathways.

The sub bottom profiler data were acquired aboard the AIMS RV Solander, a total of 51 lines and 654 line km. Acquisition employed a Squid 2000 sparker and a 24 channel GeoEel streamer. Group interval of 3.125 m and shot interval of 6.25 m resulted in 6 fold stacked data. Record length was 500 ms, sampled every 0.25 ms. Rough sea conditions during the trade winds resulted in obvious relative motion between source and streamer.

Multichannel seismic reflection processing compensated for most of the limitations of sparker acquisition. Front end mute and band pass filter removed low frequency noise. Non surface consistent trim statics corrected for the relative motion of sparker and streamer, aligning reflections pre stack and improving signal to noise. Post stack minimum entropy deconvolution both suppressed ghosting and enhanced high frequencies (>1000 Hz). Vertical resolution of better than 1 m allowed delineation of multiple episodes of channelling in the top 100 m of sediment. Imaging of small channels was improved by collapsing diffractions with finite difference migration.

Key words: sub bottom profiles, sparker, multichannel reflection processing, marine statics, Petrel Sub-basin.

INTRODUCTION

The Petrel Sub-basin Marine Survey (GA0335/SOL5463) was carried out in May 2012 by Geoscience Australia and the Australian Institute of Marine Science (AIMS) to support assessment of CO_2 storage potential in the Bonaparte Basin under the National Low Emissions Coal Initiative (NLECI) Program. Geophysical data acquired aboard the AIMS RV Solander over two grids (Figure 1) comprised multibeam sonar bathymetry and multichannel sub bottom profiles (Carroll *et al.*, 2012). The aim of sub bottom profiling was investigation of possible regional seal breaches and potential fluid pathways by providing high resolution images connecting the multibeam sea floor map to regional seismic reflection data acquired concurrently in the basin (Figure 1).

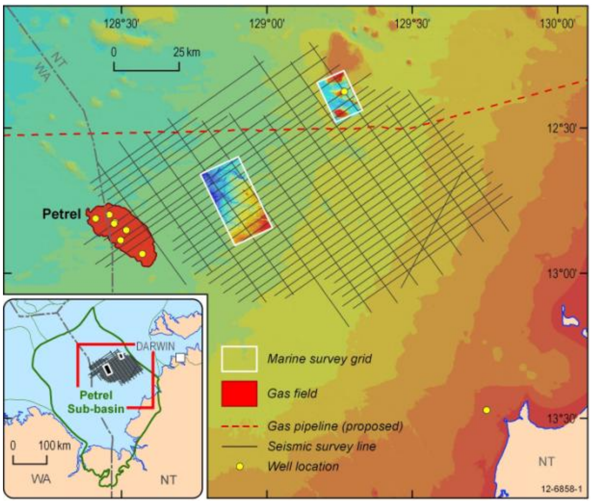

Figure 1. Petrel Sub-basin CO_2 storage assessment study area (A. Fleming, pers. comm.). The marine survey grids are shown by white outlines around the multi-beam images (Spinoccia, 2012). The seismic survey lines indicate the location of Survey GA0336, conducted by the MV Duke.

Limitations in sparker data acquisition must be addressed during processing in order to extract high frequencies for high resolution. Sea conditions were far from smooth; obvious motion of the source and along the streamer led to the idea of using non surface consistent trim statics prior to stack. The combination of source signature and sea surface reflections caused a strong ghost, which varied from shot to shot, but was much more consistent after stack. In this paper, I demonstrate that multichannel seismic reflection processing, designed to enhance high frequencies by use of trim statics and post stack minimum entropy deconvolution, can significantly improve signal to noise and resolution of sparker sub bottom profiles.

DATA ACQUISITION

Details of the sub bottom profiler data acquisition are summarised in Table 1. Acquisition took place mostly at night, with an average of ~100 line km per night. There was no way of controlling streamer depth, except for vessel speed relative to the sea (a nominal 5 to 6 knots). Depths were monitored with a Star Oddi pressure sensor and were quite variable in the sea conditions during the trade wind season. In fact, the sparker data set itself probably provides the best quantitative measure of sea conditions (Figure 2(a)).

Source type	Sparker
Source model	Applied Acoustics Squid 2000
Source power	2000 J
SP interval	6.5 m
Source depth	0.5 m (approximate)
Source layback	20 m
Source offset	10 m perpendicular
Cable model	Geometrics GeoEel
No. active channels	24
Group interval	3.125 m
Cable depth	2.5 m (approximate)
Cable layback	40 m
Fold	6
Record length	500 ms @ 0.25 ms
Data format	SEGY (Rev 0) on disk

Table 1: Acquisition parameters for the Petrel Sub-basin sub bottom profiling

DATA PROCESSING

Multichannel seismic reflection processing using Paradigm Geophysical's Focus software is summarised in Table 2. Jones (2013) presents details of the modules and parameters used.

- Dummy line geometry (CDP interval 1.5625 m)
- SEG-Y to Disco/Focus internal format
- Front end mute of leaked timing pulse and direct wave
- Band pass filter 160/24 to 1500/72 (Hz/dB per octave)
- Whole trace amplitude balance
- SRME surface related multiple elimination
- Calculation of true source-receiver offsets
- Common mid-point sort
- NMO using velocity calculated below water bottom
- 10% stretch mute
- Non surface consistent trim statics using water bottom
- AGC (50 ms gate length)
- Common mid point stack
- Minimum entropy deconvolution
- Finite difference migration with 100% velocity
- Band pass filter 160/24 to 1500/72 (Hz/dB per octave)
- Tailored water bottom front end mute
- Statics to MSL for source and receiver depth and tides
- Trace amplitude scaling and SEG-Y (Rev 1) output

Table 2: Multichannel seismic reflection processing stream for the Petrel Sub-basin sub bottom profiling.

Muting and band pass filtering removed low frequency noise, with the result shown in Figure 2(a). Minor coherent noise from the MV Duke (not shown) disappeared after stacking. The greatest improvement in the data resulted from pre stack non surface consistent trim statics and post stack minimum entropy deconvolution, followed by migration.

Trim statics were calculated by cross correlating each NMO corrected seismic trace in a CDP gather with a pilot trace created by stacking the traces, then smashing with adjacent gathers after correcting for dip (smash values from 15 to 51). The cross correlation was carried out on a 20 ms wide gate, starting 5 ms above the water bottom time, which was determined by digitising its reflection on a preliminary stack. Maximum allowable static shifts were usually specified as +/- 1 ms. Figure 2(b) shows the alignment of the water bottom and deeper reflections after static corrections. The marked improvement in the stack is illustrated by comparison of Figure 3(a) and 3(b).

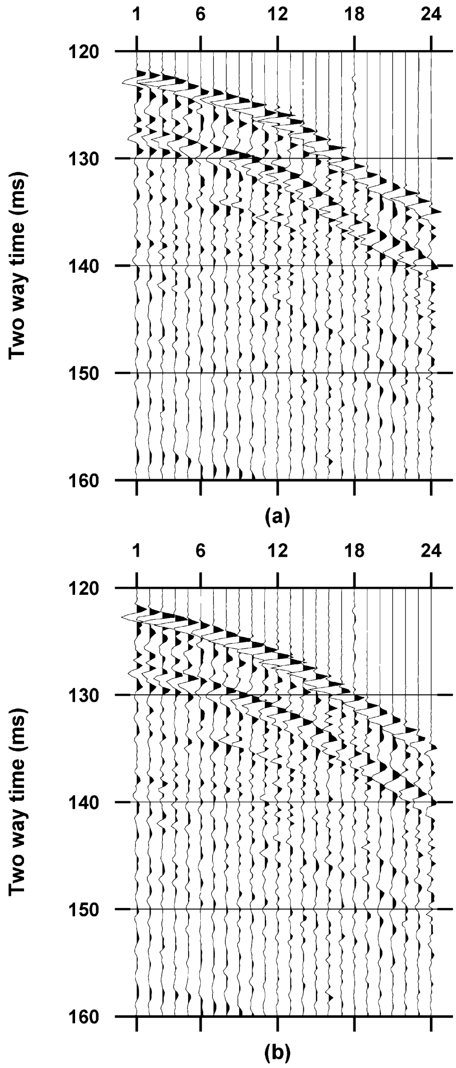

Figure 2. (a) Part of a filtered shot record (FFID 7434) for line GA0335_040 showing effect of wave motion on arrival times of the water bottom reflection. (b) Same shot record after application of trim statics calculated in the CDP domain. Statics range from -0.6 to +0.5 ms in this case. Shot is located at ~CDP 1800 in Figure 3.

The water bottom reflection in Figure 2 illustrates the complex source wavelet which is long (~8 ms), and very variable from shot to shot and line to line. There are components from reverberation in the collapse of the vapour bubble, plus sea surface reflections above source and receiver. Differential moveout is also evident across the gather. However, after stack, the waveform is much more consistent and amenable to post stack deconvolution. A minimum entropy filter design algorithm was used to iteratively maximise the spikiness of the deconvolved trace using a filter length of 20 ms. Figure 3(c) illustrates the suppression of ghosting and enhancement of latent high frequencies (well above 1000 Hz).

Finite difference migration was necessary to image small channels by collapsing diffractions. Tidal statics of +/- 2 ms were critical at line joins and intersections of the high frequency processed data.

DISCUSSION

There is little in the literature on the use of statics for high resolution multichannel marine seismic surveys, the most comprehensive study being by Gutowski *et al*. (2002), who used trim statics to correct for the bending of a 600 m long streamer in calm seas, due to buoyancy between depth controllers. Their static corrections were consistent from shot to shot and a function of receiver position along the streamer. In contrast, in the present study, statics corrections changed from shot to shot and varied along the streamer in a manner consistent with moving through sea swells (Figure 4).

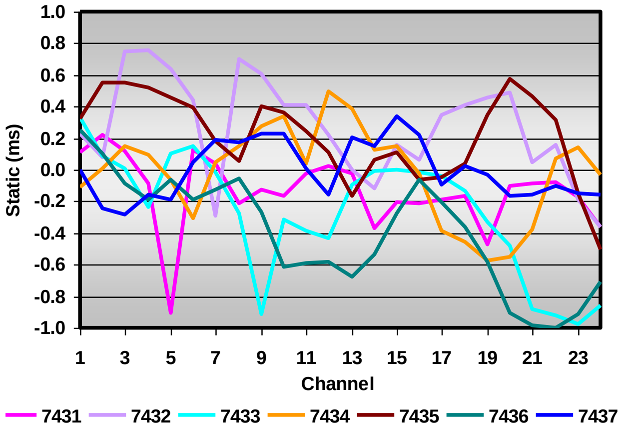

Figure 4. Trim statics for 7 adjacent shot records centred on FFID 7434 (Figure 2) showing DC shift associated with sparker motion and undulation of the streamer with peaks and trough at different positions for each shot.

Trim statics calculated for the part of line GA0336_040 shown in Figure 3 followed a normal distribution with mean ~0 ms and standard deviation of 0.36 ms. The distribution was tighter for lines requiring less correction in calmer sea states. Some lines could not be improved much with statics, possibly because of too much variation in the wavelet and too much movement, resulting in cycle skips. Statics commonly did not work at the very beginning and ends of lines where the ship was turning, the cable out of alignment and offsets unknown.

Duchesne *et al*. (2006) presented strategies for deconvolution of single channel sparker data, while Bellefleur *et al*. (2006) also studied pre stack deconvolution on multichannel data. The rough seas in this study meant that post stack deconvolution was a better option, after averaging some of the variability in the wavelet. The nature of the geology satisfied the assumptions of the minimum entropy deconvolution algorithm regarding a random reflectivity response, where intense channelling, crosscutting and progrades occurred (Figure 3). Lines with uniform stratigraphy did not respond as well to post stack deconvolution. In practice, the usable part of the section for design of the deconvolution filter extended to the first water bottom multiple (even though SRME did attenuate the long period multiples). Hence post stack deconvolution should work better in the deeper water (85 to 95 m) of the larger south western grid, with opportunity to include more reflections in the filter design.

Finally, the nature of the water bottom controls the amount of downward propagating energy. Results were much worse for the smaller north eastern grid, with the dual problems of shallower water and carbonate banks.

CONCLUSIONS

The Petrel Sub-basin Marine Survey collected 654 line km of multichannel sparker sub bottom profiler data along 51 lines during rough sea conditions in the trade wind season. This study demonstrates that multichannel seismic reflection processing can compensate for most of the limitations of sparker acquisition. The key is the combination of (1) non surface consistent trim statics to align reflections pre stack and improve signal to noise, and (2) post stack minimum entropy deconvolution to suppress ghosting and enhance latent high frequencies (>1000 Hz). Vertical resolution of better than 1 m allowed delineation of multiple episodes of channelling in the top 100 m of sediment. This processed data set (Jones, 2012) surpassed the aims of the investigation by providing high resolution images connecting the multibeam sea floor map to regional seismic sections.

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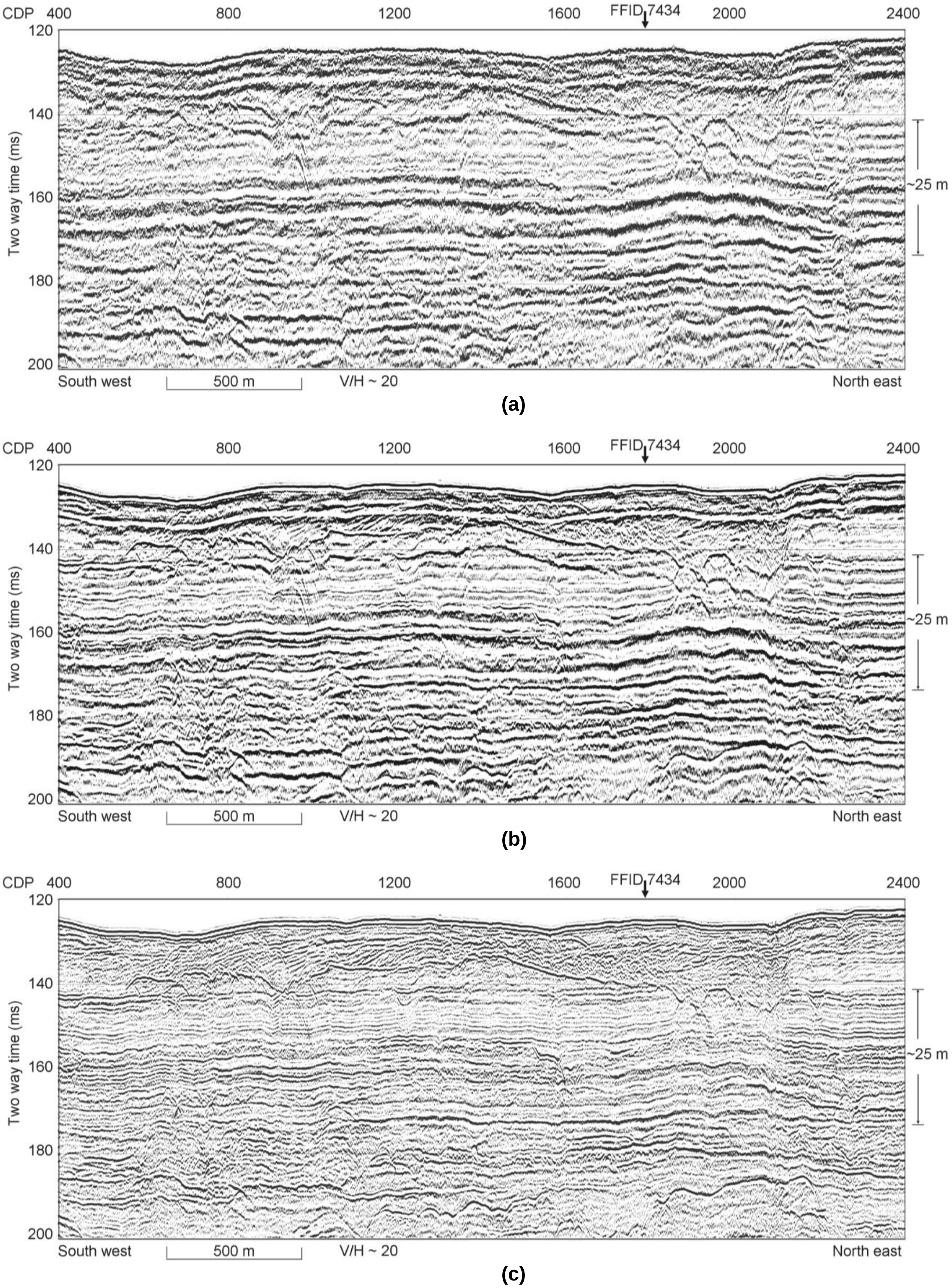

Figure 3. Part of line GA0335_040. Shot in Figure 2 is located at ~CDP 1800. (a) 6 fold CDP stack without statics. (b) 6 fold CDP stack with trim statics. (c) As in (b) followed by minimum entropy deconvolution. ~60 m of sediment are imaged in this view, with a vertical resolution of better than 1 m, showing multiple episodes of channelling. Water depth is ~95 m. Post stack migration does improve the imaging of small channels by collapsing diffraction tails and broadening synforms.