ASEG-PESA 2013
'THE EUREKA MOMENT'
11-14 AUGUST 2013 • MELBOURNE, AUSTRALIA

Impact of survey design and acquisition technology on 3D Marine Mega-survey success, a recent example from Southern Australia

Ted Manning *BP* *Jakarta*
Eric Green *BP* *Jakarta*
Gary Nicol *BP* *Perth*
Christian Strand *PGS* *Singapore*
Anthony van der Wal *PGS* *Singapore*
Averrouz Mostavan *PGS* *Singapore*
edward.manning@bp.com, eric.green@bp.com, gary.nicol1@bp.com, christian.strand@pgs.com, anthony.van.der.wal@pgs.com, averrouz.mostavan@pgs.com

SUMMARY

This paper describes how a large, 12,030km^2, exploration 3D seismic survey in the Great Australian Bight was designed in order to maximize the efficiency of the survey. The entire survey area was completed within a single acquisition weather window of 7 months with low infill rates.

Challenges for this particular survey included deep targets, very large swells, stormy weather patterns, variable ocean currents and remoteness of the survey area itself.

The acquisition geometry was carefully designed to optimize the efficiency of the survey given the challenging operational constraints. The design of the acquisition parameters helped the acquisition to continue in severe swell conditions without introducing detrimental noise in the data.

Unnecessary infill lines were reduced through combining active infill management with Fanned, steerable streamer coverage. The required coverage was analysed using real data in the survey design stage and the achieved coverage was actively monitored during the survey.

Key words: Infill, Fan, Marine, Acquisition

INTRODUCTION

In January 2011, four deep-water concessions were awarded to BP in the Great Australian Bight, South Australia (Figure 1). This paper describes how a technology driven collaborative planning effort by client and vendor enabled a 12,030km^2 3D seismic survey to be successfully acquired within a single Southern Ocean acquisition weather season, from Nov 2011 to May 2012.

A very large and persistent south-westerly ocean swell, stormy weather patterns and variable currents meant the metocean conditions in this remote and harsh environment both strongly influenced the survey design and posed the biggest challenge to delivering a consistent high quality seismic dataset. The acquisition season was further constrained environmentally by Southern Right Whale calving season, setting an end May deadline.

Existing seismic datasets and modern technologies were used to design the survey as efficiently as possible, without degrading the quality of the seismic image. One pre-requisite for success of this very large area was to secure a very large receiver spread of modern equipment, able to endure harsh conditions over a long acquisition period with very low technical downtime. The impact of variable currents and high seas was expected to result in increased infill and survey time, but was mitigated through combining active infill management with Fanned steerable streamer coverage. The acquisition geometry was also carefully designed to optimize the efficiency of the survey given these challenging operational constraints (the swell size and permit block outline – Table 1). The methods used are discussed in this paper.

Figure 1 Map of 12,030km^2 Survey Area, more than 300km offshore, with NW-SE shooting

BACKGROUND

As Antarctica and Australia separated, a huge Cretaceous basin and delta developed in the Great Australian Bight. The basin has the potential to be a significant new hydrocarbon province.

This exploration 3D survey is located in sensitive and deep water. Depths range from 1 to 3km. The survey overlies the environmentally sensitive GAB marine park, crosses the GAB Benthic Protection Zone, and is south of a Blue Whale foraging zone, Southern Right Whale breeding area, and internationally protected areas around the coast. This area is also important to Southern Blue Fin and other fishing grounds. Although outside the purpose of this paper, it's worth noting that early and high quality engagement with Regulators and a broad range of Stakeholders was vital in the planning stage, and the survey adhered to all the government EPBC Act manner specified decisions, including for example deploying sound logging equipment in the ocean to calibrate modelled source levels from the seismic survey.

Legacy long cable 2D datasets and a 1000km^2 3D survey existed in the area and were used extensively for acquisition design and testing processing parameters.

DESIGN OF SURVEY PARAMETERS

Larger streamer spread widths will lead to fewer sail lines being required to cover the survey area but require larger vessels. For deeper targets it is also necessary to deploy longer cables, further increasing the demand on channel count. The final design was for a huge receiver array patch of twelve 8.1km streamers. Analysis of the existing 3D dataset and subsurface dips in the area demonstrated that the streamers could be towed further apart than the standard 100m separation without impacting the subsurface image needed for exploration. A seismic vessel was required to quietly tow this large cable and channel count at 120m streamer separation yielding an array width of 1320m at the front end of the spread. As described below, a test was carried out at the start of the survey to fan these streamers out to a survey average of 140m separation at the far end, resulting in a receiver spread width of 1540m at the tail; this equates to a moving receiver array footprint of greater than 11.5km2 per shot.

The sea state was expected to be rough, with strong swell noise and more difficult streamer handling. For this and other reasons, the sail lines were oriented perpendicular to the expected swell direction and the streamers towed relatively deep, at 9m. For deep targets the receiver notch was not a concern but the quieter acquisition environment would yield better S/N on the low frequencies needed for deep imaging and also reduce bad weather downtime. This design in the end allowed seismic production to continue in wave heights up to 6m without impacting final data quality (Figure 6).

INFILL MANAGEMENT

The on-board navigator steers the seismic vessel for coverage to minimise the amount of infill. However, due to variable currents, there will always be gaps between saillines. Infill acquisition is needed to fill in large gaps and can be a large component of the time and cost of a marine seismic survey. With proper infill management, unnecessary infill lines may be reduced or avoided.

Infill management starts by defining the proper coverage requirements. Day and Rekdal (2005) described how coverage specifications can be defined based on the effect that coverage holes have on the data quality. Following their methodology, the analysis showed that holes up to 180m could be tolerated at the far offsets (6km – 8.1km) in this case.

Decimation tests were performed on the legacy 3D data to validate the results of the modelling. Coverage holes were introduced in the data volume by removing complete offset ranges along selected inlines, and these data were then processed through pre stack time migration with regularisation. Figure 2 shows an example from one decimation test. In this case, a hole of 180m has been introduced in the far-mid offset range. After processing, there is no discernible effect on the data quality when compared to the same data with no holes in the coverage confirming the model.

The coverage achieved during the survey was constantly monitored to decide if additional infill lines were needed. Acceptability maps, as described by Strand et al. (2010) were used as a tool in this analysis. Figure 3 shows an example produced during acquisition where a coverage gap on the far offsets requires an additional infill line. These maps were provided continuously to allow decisions to be made for infill in a racetrack by racetrack manner and avoid long sail times back to acquire infill and also for full 3D processing to continue race track by race track.

STREAMER FANNING

Recorded far offsets contain reflections that are dominated by low frequencies having travelled further through an attenuating earth compared to near offsets. The crossline sampling at the far offsets can thus be relaxed without spatial aliasing allowing streamers to be steered to have a larger separation at the end than at the front, a process known as fan mode acquisition (Capelle and Matthews, 2009). Since the movement of streamers due to currents is largest at the end of the streamers, fan mode acquisition may reduce the infill rate and allow the navigator to steer for near offset coverage.

To confirm that active steering and fanning of the streamers does not introduce noise into the data, the first line was acquired with different modes of steering. Figure 4 shows the corresponding receiver depth and receiver RMS noise plot. The switch between the steering modes is highlighted with the arrows. The digi-fin steering can be seen to affect depth for a short period as the steering mode changes and they work hard to position the streamers, but the noise levels are unaffected.

The relative impact on the infill rate of fan shooting and the use of carefully designed coverage requirements were analysed post survey by removing the fanning from the streamers (in the computer) and re-binning the data. This analysis showed that the largest influence on the low infill rate for this survey (13.9%) was the relaxed coverage requirements, justified as in Figure 2 and verified in as in Figure 3. The fanning facilitated steering the vessel for near offset coverage in the presence of up to +/-15degrees of feather, so rather than having large coverage holes at the sail-line seams, smaller coverage holes were spread throughout the volume. These coverage holes are easier to handle in data processing (Figure 5). However, had stricter coverage requirements been necessary, streamer fanning would have a larger effect on the infill rate.

DISCUSSION AND CONCLUSIONS

The wide and long receiver spread deployed in this project led to several vendor production records. These included production records for one day at 143.6km^2, one week at 919 km^2, and one month at 3,056km^2, while still delivering very high quality seismic data, even in the coarser 30m sampled dip line section (Figure 6).

The design of this seismic survey allowed acquisition to continue in severe swell conditions without introducing detrimental noise to the data. This was also helped by real time, flexible, on-board seismic processing to confirm when swell noise could or could not be removed from the data.

Infill management and fanning of the streamers contributed to an overall low rate of infill. Analysing coverage requirements during the survey design stage with seismic data, gave confidence to accept holes up to 180m in the coverage on the far offsets, as predicted by the infill modelling.

Post survey analysis of the navigation data showed that accepting larger coverage gaps was the main driver for reducing infill for this survey. Fanning the streamers facilitated steering for optimal near offset coverage, with a more even distribution of the coverage overall (Figure 5). Instead of large holes at the sail line seams, smaller coverage holes were distributed more evenly.

The combined strategies employed in the planning of this survey ensured a successful large scale exploration survey was acquired in one season in an operationally challenging area.

In addition to the well understood benefits of deeper tow and shooting direction, seismic acquisition efficiency can benefit from newer acquisition technologies like fan shooting and infill monitoring in areas of moderate feather.

ACKNOWLEDGMENTS

The authors would like to thank BP and PGS for permission to publish the results, the crew onboard the Ramform Sterling and support vessels for a safe and efficient survey.

REFERENCES

Capelle, P. and Matthews, P. 2009, Intelligent infill for cost effective 3D marine acquisitions. 71st annual EAGE meeting, expanded abstracts

Day, A and Rekdal, T. 2005, Determining infill specifications based on geophysical criteria. 75th annual SEG meeting expanded abstracts, 80-83.

Strand, C. Campbell, S. and Dhelie, P. 2010, Reducing infill – Real time application of geophysically based coverage specifications. 72nd annual EAGE meeting, expanded abstract

Design Options	Strike, 100m	Strike, 120m (chosen)	Dip, 100m	Dip, 120m
Survey duration (days)	184	153	225	187
Number of lines	176	147	361	302

Table 1 Comparison of survey efficiency using 100m and 120m streamer separations and acquiring the survey in dip direction, with shorter line lengths.

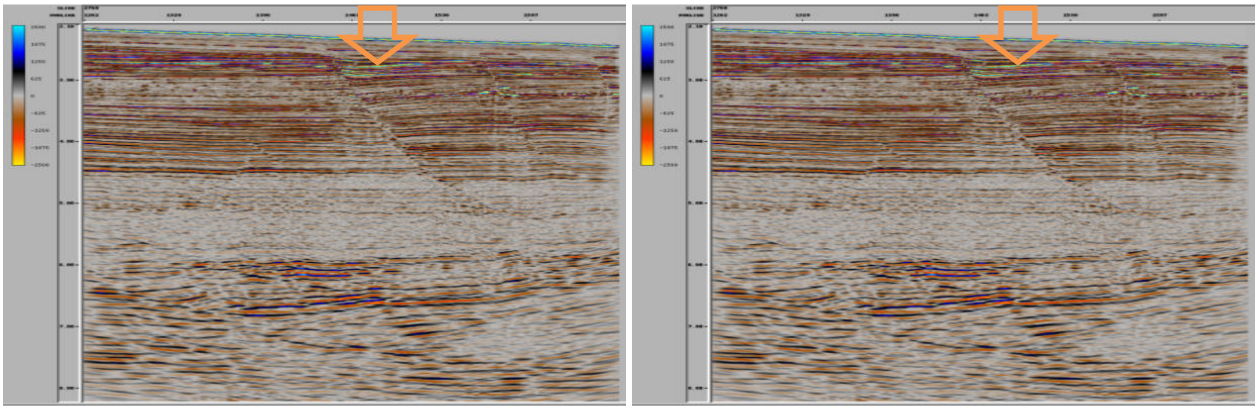

Figure 2 Example from the decimation tests performed on legacy 3D data. The section to the left shows a crossline stack with no holes in the coverage. In the right section, a coverage hole of 180m has been introduced at the far-mid offset range.

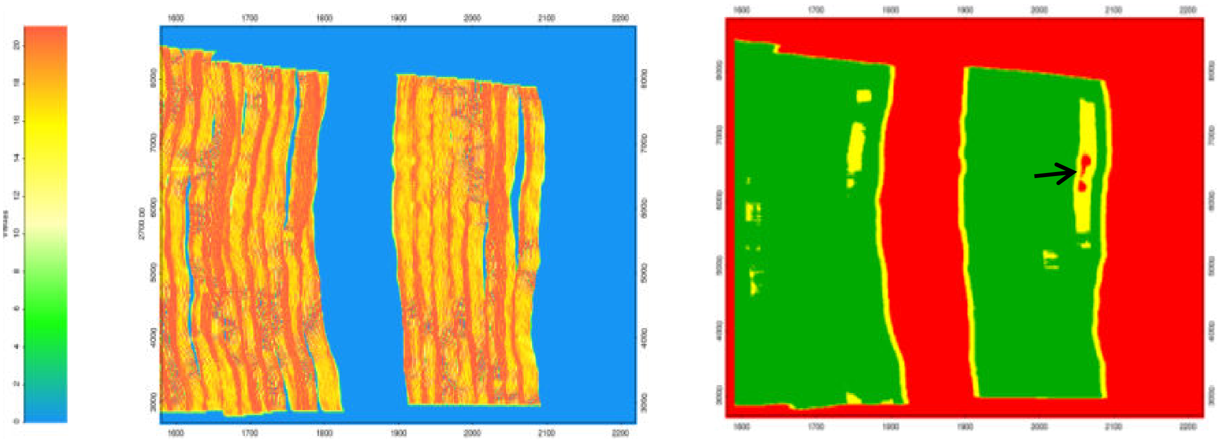

Figure 3 Left: the fold achieved at the far offset interval. Right: the acceptability plot. The red area on the acceptability plot (arrowed) highlights where additional infill is needed to maintain image quality

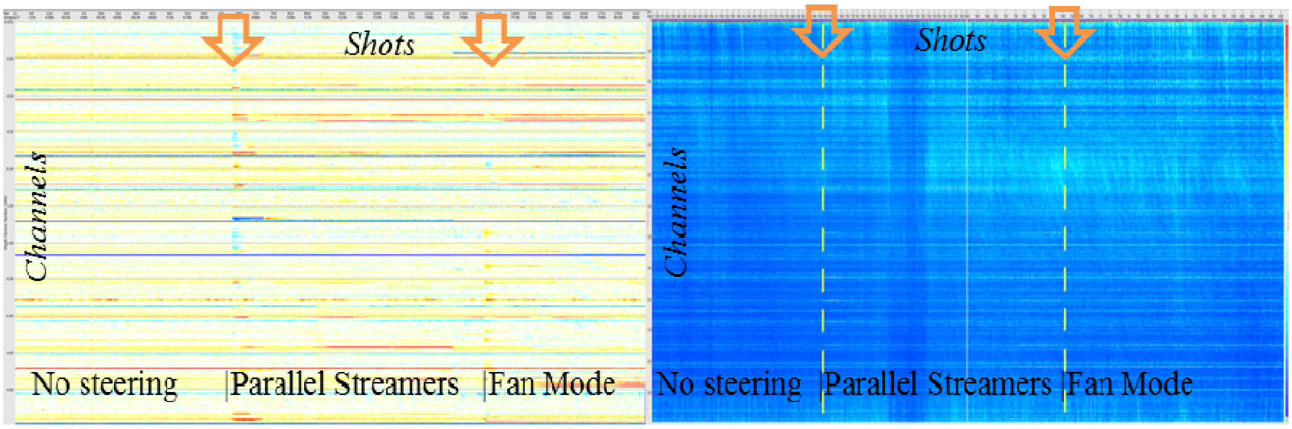

Figure 4 Single Sail-line: Left: streamer depth, Right: RMS noise plot. For each shot (x- axis), the depth or RMS noise is plotted in colour for each receiver (y- axis), arrows mark the shot where the steering mode was changed.

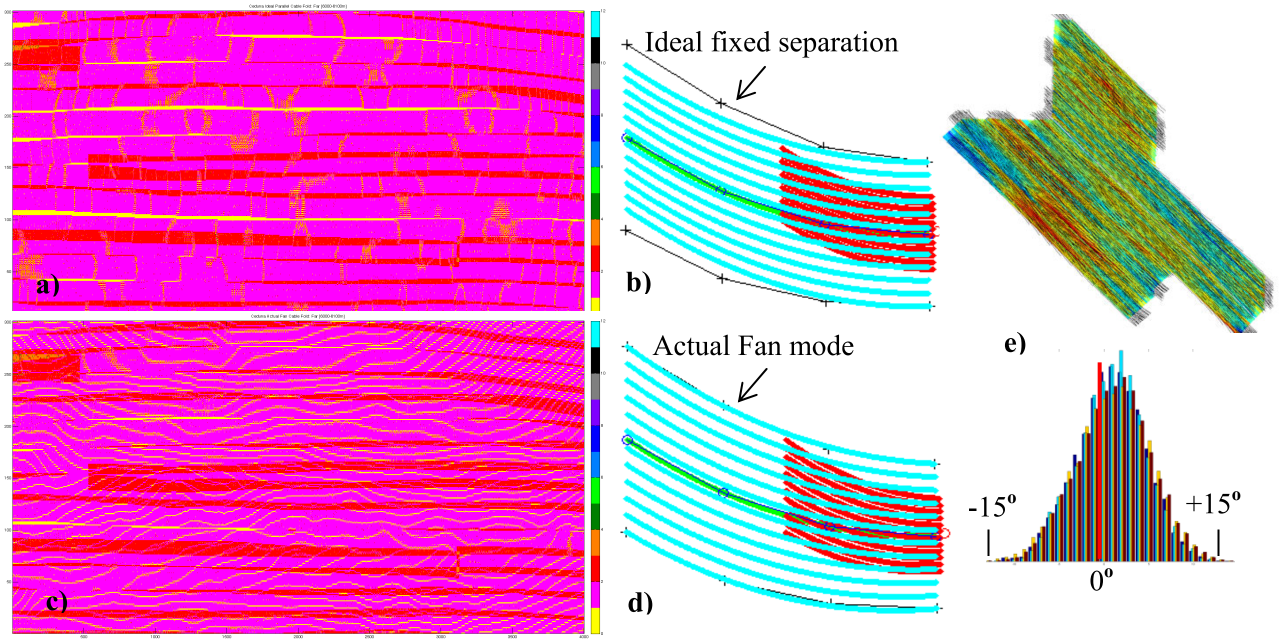

Figure 5 a) single offset fold (8km), yellow = empty cell, cables fixed separation as in b), cyan=receivers, red=midpoints, c) single offset fold (8km), yellow = empty cell, cables fixed separation as in d), same feather, same saillines, same channel count, e) Survey Feather map and histogram 780,000 shots.

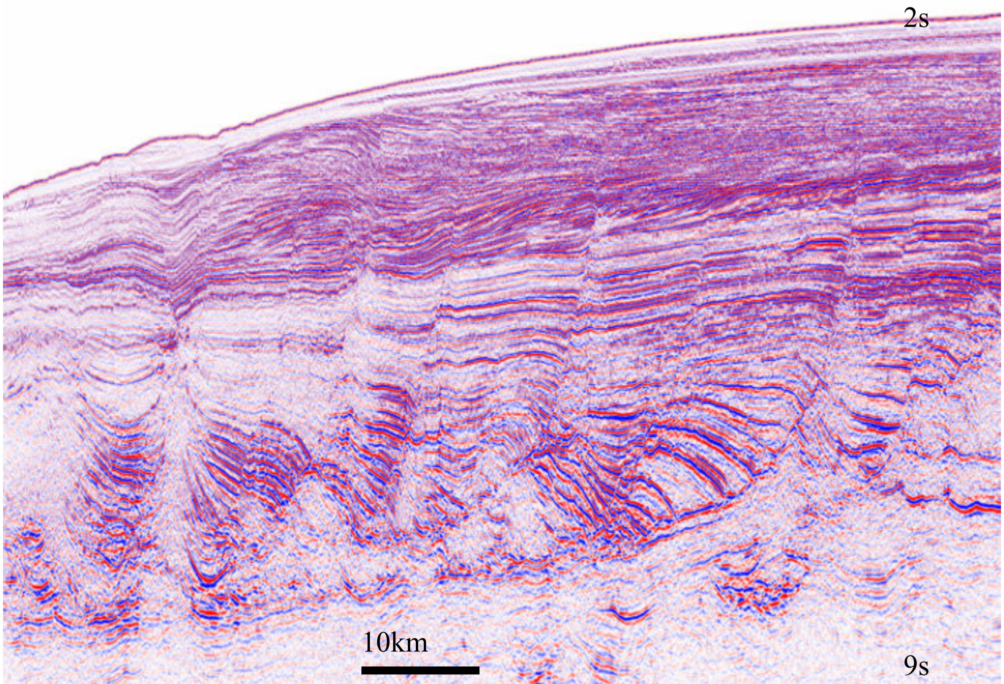

Figure 6 Seismic cross-line image after final Time Migration, down to 9 second twt with 30m cross-line bin size.