Mini-SOSIE - Successful shallow 3D seismic data acquisition in an environmentally sensitive area.

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SUMMARY

Environmental and cultural restrictions are increasingly impacting exploration efforts for mineral and energy resources. It is almost impossible to gather seismic data without being constrained by these factors. 3D land seismic data acquisition requires intense source and receiver sampling particularly for high resolution work where shot and receiver line intervals can be as little as 45 metres. Consequently, the acquisition method chosen is extremely important, as it will govern the degree of environmental impact imposed by the survey.

In the case of the Onley 3D survey, traditional sources such as dynamite and vibrator were deemed to be unacceptable, on environmental grounds. Mini-SOSIE, which utilises a light, portable surface compactor (Rammer) as a source was an acceptable alternative. After comparing the results from the 'Rammer' source with dynamite and vibrator sources, the Mini-SOSIE system proved to have the penetration and resolution needed to acquire useful 3D data. However, as could be expected, the signal bandwidth of the Mini-SOSIE (and vibrator) data was not as high as that of the dynamite data.

After extensive software and hardware development aimed primarily at increasing recording channels and receiver line numbers, a pilot 3D seismic survey was recorded. The aim of this survey was to delineate small faults and other geological features, to assist in mine planning. The Mini-SOSIE 3D data were of high quality. From the interpreted data volume it was possible to resolve a seam split as well as a likely small fault - critical information for mine planning.

The environmental impact imposed by the survey was minimal, with no negative feedback from relevant landholders.

INTRODUCTION

The Wyong Areas Coal Joint Venture is exploring a combined area of approximately 250 sq kms consisting of Authorisation 405, EL 4911, and EL 4912. These leases cover areas near and under the town of Wyong, approximately 100 kilometres north of Sydney. The Joint Venture is investigating the feasibility of mining, by longwall method, coal seams that are some 350 metres below the surface. The seams of interest are the Great Northern Seam and the Wallarah Seam. These seams occasionally coalesce, the coalesced seams being referred to as the Wallarah Great Northern Seam. The Joint Venture has undertaken an extensive drilling program (500 metre centres) to determine coal quality, together with the extent and depth of the resource. Drilling at such intervals will not determine faulting, which can cause major interruptions to production and affect the economic viability of the mine. The Joint Venture decided to use the surface reflection seismic method as a tool to map small faults and other geological features. In this particular setting, faults as small as 2 metres could cause significant interruptions to longwall production, so it was hoped that the 3D Mini-SOSIE technique would provide the required resolution to enable definition of this magnitude.

Discussion on environmental issues

The area of investigation exhibits a number of environmental constraints around which the survey needed to be designed. The area is occupied by small acreage subdivisions ranging in size from several hectares to 40 hectares. These blocks comprise residential properties, unoccupied land, cattle grazing and horse agistments etc. Topographically, the survey area includes low-lying damp gullies, dams, a high tension power line agistment, thickly grassed undulations and medium density forest.

Generally speaking, the local community has little knowledge of, or contact with, the coal industry. As a result, their acceptance of exploration activities was greatly influenced by the potential effect on their daily lives, both during the survey operation and also, after completion of the survey (should there be any lasting effects).

The actual survey area comprised a total of 10 separate landholdings. Property access agreements were reached with all landowner except one. This resulted in a large, narrow exclusion zone in the central southern portion of the survey area. Unfortunately, another landowner adjacent to the exclusion zone imposed severe time constraints on access to his property, an issue that demanded strict scheduling of the survey activities. This curtailed some planned undershooting of the exclusion zone, resulting in data through this zone being of very low fold.

Earlier Seismic trials had tested dynamite and vibrator energy sources, and the Mini-SOSIE 'Rammer' source. Because of the abovementioned conditions relating to the survey area, it was felt that a Mini-SOSIE survey would be least environmentally disturbing, unobtrusive and acceptable to the local community. It was necessary to carry out minimal clearing through the medium density forest in the eastern portion of the area, however tree feeling was kept to an absolute minimum (only small trees were removed). Small vehicles and all-terrain quad bikes were able to access much of the survey area but it was necessary to hand-carry equipment through isolated sections. Existing, well-defined tracks proved useful for general access to the grid and enabled the recording truck to set up in strategic locations. All felled trees were chipped and the chips were left in place.

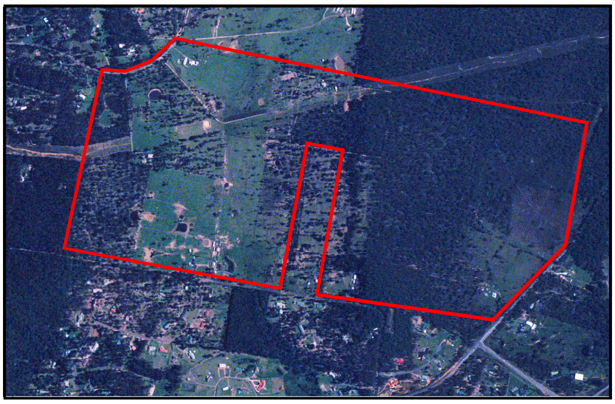

Figure 1: Areal photograph showing survey boundary

2D Seismic trial

A 2D seismic trial took place in November 1997. This consisted of a single dynamite shot/receiver line and two swath lines. The Mini-SOSIE system and electromagnetic mini-vibrators were also utilised to re-record a section of the dynamite shot/receiver line. Velseis Pty Ltd using the same recording instruments and geophones undertook all recording.

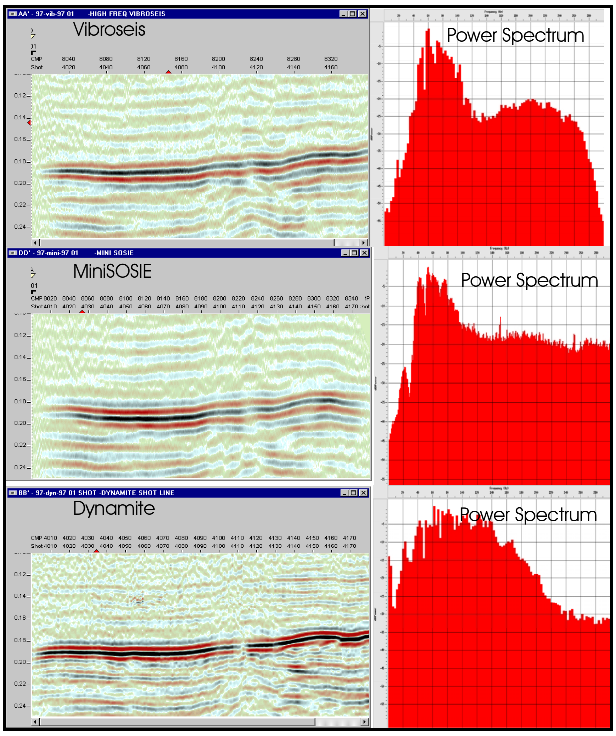

Figure 2: Stack comparison of different sources

Inspection of figure 2 shows all sources produced sections of good data quality. However, it is obvious that the dynamite data have superior bandwidth and resolution. A fault clearly seen on the dynamite data, and estimated to be 3 metres in throw, cannot be seen on the Vibroseis and Mini-SOSIE data. Unfortunately, this fault is intersected at the very end of the Mini-SOSIE and Vibroseis sections; both of which are low fold at the points of intersection.

Although the dynamite data did prove to be superior in resolution, it was not practical to apply this method, given the environmental and cultural restrictions in the Onley Survey area. The less intrusive and environmentally more acceptable Mini-SOSIE system was chosen by the project management.

Mini-SOSIE

The Mini-SOSIE high resolution seismic method was developed by “Societies Nationale Elf Aquitaine” and in its original 24 channel form, was widely used for acquiring shallow, high resolution seismic data. In practice, a 65 kilogram earth compactor or ‘Rammer’ is used as an energy source. Wacker of Germany manufactures one of the most suitable units. A sensor unit mounted on the rammer’s base plate records each base plate impact and these are transmitted to the recording instrument as time breaks. Signal is correlated in real time using a stacking process, resulting in a similar signal strength to that of a single, impulsive energy source. However, the signal-to-noise ratio of the Mini-SOSIE data is usually much higher than that of a single, impulse source.

Figure 3: Picture of an operating Wacker ‘Rammer’

The Wacker ‘Rammer’ source is light and portable, allowing operations in rugged terrain. Cultural hazards such as dams, houses, swimming pools, areas of soft ground and densely wooded forest are easily negotiated. Such versatility allows evenly spaced source locations and fewer off-set ‘recovery’ shots, so often required when using other energy sources. It also offers greater consistency of CDP bin fold and shot-receiver azimuth.

The original Mini-SOSIE recording system was a model DHR 1632 manufactured by Input/Output and was limited to 24 recording channels. Realising the limitations of 24 channel recording, Velseis developed software and hardware to allow 240 channel, one millisecond sample rate Mini-SOSIE data to be recorded with their 348 Hybrid telemetric system. This development provided enough channels for closer spatial sampling and for swath line recording. Further software development was required before multi-line recording, necessary for 3D data acquisition, could be achieved.

The 1999 Onley 3D Seismic Survey-data acquisition

The Onley 3D seismic survey covered an area of 1.4 Km² and comprised 25 receiver lines and 18 source lines. The source lines totalled 28.62 kilometres, with 1908 source points.

Coal Operations Australia Limited supervised line clearing and was also responsible for permitting. Line clearing consisted of a wheeled tractor/slasher in the more densely wooded areas with a slasher only, in the grassy and lightly wooded areas. More closely settled areas devoted to hobby farming required little or no clearing.

Recording operations commenced on 15/09/99 and were completed on 30/09/99 - a period of 16 days, of which 2 days were lost though permitting problems and rain. Recording was also slowed on some occasions due to strong winds. This dictated a greater source effort and the number of rams per segment (shot point) had to be increased in order to improve the signal-to-noise ratio. The average recording production was 2 kilometres per day and the maximum daily production was 2.7 kilometres (lineally). The recording crew was comprised of 17 people.

Recorded by:		Velseis Pty Ltd
Recording dates:		15 - 30 September, 1999
Energy source:		single Wacker BS62Y 'Rammer' (65kg)
Instruments:		Velcom 368 Telemetric System
Recording channels		240
Geophone type:		Sensor SM-7; natural frequency 30Hz
Data format:		SEG-Y; recording media - 8mm Exabyte
Sample rate:		1 millisecond
Record length:		1,000 milliseconds
Record	Low Cut	40 Hz
filters:	High Cut	375 Hz
	Notch	Out
Source array:		500 rams over 15m (800 rams on windy days)
Receiver array:		6 geophones in 2m diameter circle pattern
Recording template		8 receiver lines; 30 channels per line; symmetrical geometry - salvo centred
Shot line spread:		45m
Rec. line spacing:		90m
Nearest trace offset		10.6m
Farthest trace offset		414.2m
Geophone grp int.		15m - 240 groups per record
Ram seg. (SP int.)		15m
CDP coverage:		2500%
CDP Bin size:		7.5m x 7.5m

Table 1: Recording statistics/parameters

Interpreted Results

Data from the 1999 Onley survey were processed and interpreted at Velseis Processing's facility in Brisbane. ProMAX software loaded on a Sun Workstation was used for processing and the PC based GeoGraphix software 'SeisVision' was used for interpretation and display. The processing sequence was typical of that used on other high resolution 3D surveys and included the following steps:

- Reformat to ProMAX data format
- Geometry assignment and binning to 7.5 metre bins
- 3D static calculation and application
- Deconvolution
- Velocity analysis
- 3D Residual static calculations
- 2nd Pass velocity analysis
- 2nd Residual statics
- Mute
- Trace balance
- Stack
- FX-Deconvolution
- Filter and balance

The processing of this data set proved to be routine, due to a high signal-to-noise ratio and a relatively simple geological setting.

As explained previously, the economic coal seams in this area are the Wallarah and Great Northern seams. When these seams join, the combined seam is referred to as the Wallarah-Great Northern Seam (WGNS). The first process in interpretation was to link geological boundaries such as the top and bottom of the WGNS to reflectors seen on the seismic data. Five exploration boreholes are located in or near the survey area. A synthetic seismogram was generated for hole B850W250.

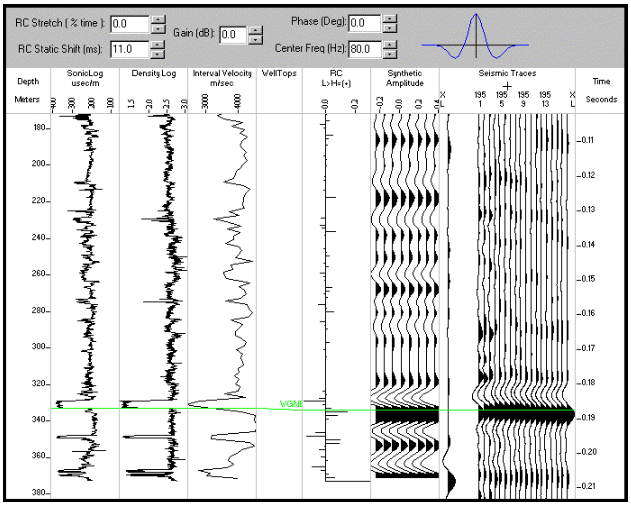

Figure 4: Synthetic Seismogram Well B850250

The synthetic produced with a Ricker wavelet of central frequency 80 Hz matches well at the Wallarah Great Northern Seam with data from the 3D volume. The coal thickness of 6m is below the limit of separability, which is calculated to be wavelength/4 or 7.5 metres using a frequency of 80 Hz and a rock velocity of 2400 m/s. Therefore, the seismic data are not resolving both the top and base of the seam. Changes in seam thickness will result in amplitude changes. Note that the thinner seams below and above the WGNS are resolved on the synthetic seismogram but are not apparent on the seismic traces. However, sections displayed in colour (Figure 5) clearly show continuous, interpretable reflectors above and below the WGNS.

Mini-SOSIE has clearly been able to image the WGNS but what fault resolution can we expect to see with this dataset?

Experience in other coal exploration areas has shown that, after validation drilling, and eventual mine development, accurate seismic fault resolution is reliant on the following criteria :

- frequency content of reflectors
- signal to noise ratio
- consistency of lithology
- depth of target

3D seismic data in the Bowen Basin has shown that, with consistent lithology, a high signal to noise ratio, and a dominant frequency of 150 Hz, faults as small as 2 metres can be detected. The Onley data volume also has good signal to noise characteristics and we would expect fault definition (considering a dominant frequency of 80 Hz) to be about half that of the higher frequency Bowen Basin data - somewhere in the order of 4 metres or less. (Fault definition, even of this magnitude, will greatly assist mine planing and will ensure that problem faults will be detected before significant development capital is investment.)

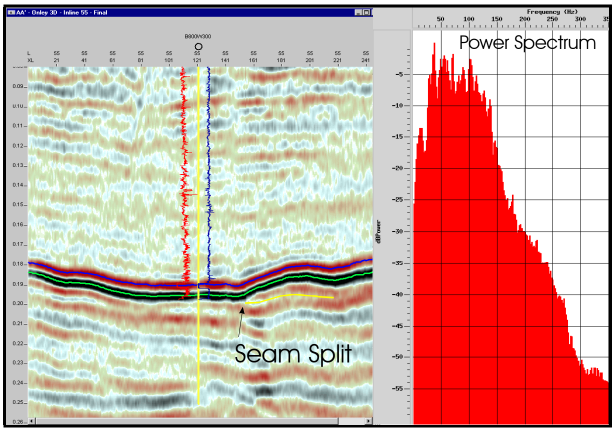

Figure 5: Interpreted in-line cross-section

Figure 5 show that the picks made on the peak and trough of the reflector closely correlate with the base and top of the WGNS. A seam split, which has been seen in borehole data has been interpreted on the seismic data. It is possible that there is a fault associated with this splitting but we cannot see a clean break on the seismic section. The gradient plot (figure 6) clearly shows this feature. This plot also shows another small feature near the western edge of the survey area.

It is interesting to note that the power spectrum demonstrates that the 3D Mini-SOSIE data has a greater bandwidth than the 2D Mini-SOSIE data. The reason for this is not clear at this time and may be the subject of another paper.

The interpreted Mini-SOSIE data have given the mine planner the exact locations of the seam split and a possible fault. Further characterisation of these features could be achieved by either recording a single, high resolution dynamite line or by drilling closely spaced bore holes for structural information.

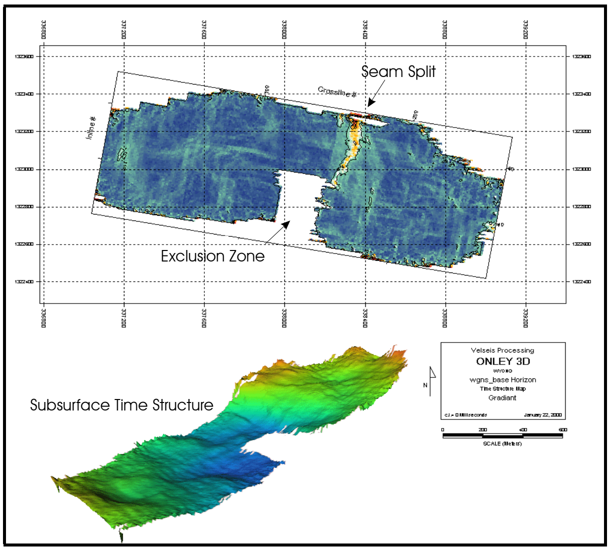

Figure 6: Gradient Plot - Base of WGNS

CONCLUSIONS

The Mini-SOSIE technique has enabled the acquisition of 3D seismic data in an area where other methods such as dynamite and Vibroseis could not be used. While the Mini-SOSIE data did not provide all the answers, important information on faulting and seam splitting was obtained and can by used for mine planning and development.

The survey resulted in minimal environmental impact with no negative feedback from affected landholders

ACKNOWLEDGEMENTS

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