Imaging of shallow coal structures using 2D6C Mini-SOSIE

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SUMMARY

At a trial field site in the Bowen Basin previous seismic surveys had difficulty imaging the coal seams near the base of weathering. It was suspected that these may be highly structured which could complicate future open-cut mining.

To improve the understanding of the geology a multicomponent 2D trial was conducted. This used the Mini-SOSIE technique to simultaneously generate P-wave and transverse S-wave energy. This allowed for the processing and interpretation of three separate datasets (P, S, and PS).

In this case, the PS image provided the best structural interpretation. This was achieved using information (e.g. statics and velocities) gained from processing the pure P and S datasets.

Key words: Multicomponent, Mini-SOSIE, S-wave, Converted-wave

INTRODUCTION

When planning an open-cut coal mine it is important to gain as much information as possible about the extent of the resource, and structures that may increase the cost of production. In addition, drilling of sufficiently close spacing to identify these near surface structures may not be completed until very close to production, if at all. Unfortunately, very shallow targets in the vicinity of the base of weathering are often difficult to image using seismic reflection. This is due to low target fold and the presence of noise (both coherent and random).

One approach that may be used to improve the target fold is to increase the source and receiver density. However, this can add significant expense if the survey area is large. Alternatively, non-conventional seismic methods can be employed such as those that utilise S-waves (e.g. Hendrick, 2006) S-waves travel slower than conventional P-waves. This results in S-wave and converted-wave (PS) energy arriving later on seismic sections, thus providing more separation between target events and coherent noise events.

In this paper we present the preliminary results from a multicomponent trial conducted at an exploration site within the Bowen Basin. The area consists of a number of coal packages extending from depth up to the base of weathering. Prior to this trial, a conventional 2D survey had been conducted using a Vibroseis source. This generally showed good data quality. However, there were a number of zones that showed poorer imaging. These tended to be at shallower depths, and in the vicinity of increased structure.

One of the areas of reduced signal quality was selected to investigate whether S-wave techniques can provide a better understanding of the coal structures.

MINI_SOSIE ACQUISITION

The trial was conducted in conjunction with a conventional 2D survey using the Mini-SOSIE source. The Mini-SOSIE method was selected as it has a long history of good images of shallow coal targets (e.g. King, 1979; Driml et al., 2001) with minimal environmental impact. One of the advantages of the Mini-SOSIE technique is that the rammer (Figure 1a) used to generate the impacts tends to produce less operating noise on the seismic records than larger sources (e.g. Vibroseis). This provides potential for increasing the fold of shallow targets.

The Mini-SOSIE technique has previously been used (e.g. Hendrick, 2006) to produce converted-wave (PS) images of shallow open-cut coal targets. This is relatively easy to implement, by replacing conventional single component geophones with 3C geophones. However, the processing of PS data is generally more complicated.

An alternative approach is to use a pure S-wave survey. White et al. (1956) demonstrated that S-waves can be generated by applying a horizontal impact force to coupled mass on the surface. This usually requires a specifically designed source. These are often difficult or slow to use.

Greenhalgh et al. (1986) pointed out that the Mini-SOSIE source has the potential to generate significant lateral shear force with each impact. These impacts can be stacked using the standard Mini-SOSIE method to enhance the S-wave record. For this trial we have taken advantage of this characteristic in order to generate both P and S-waves at the same time. These have been separated in processing.

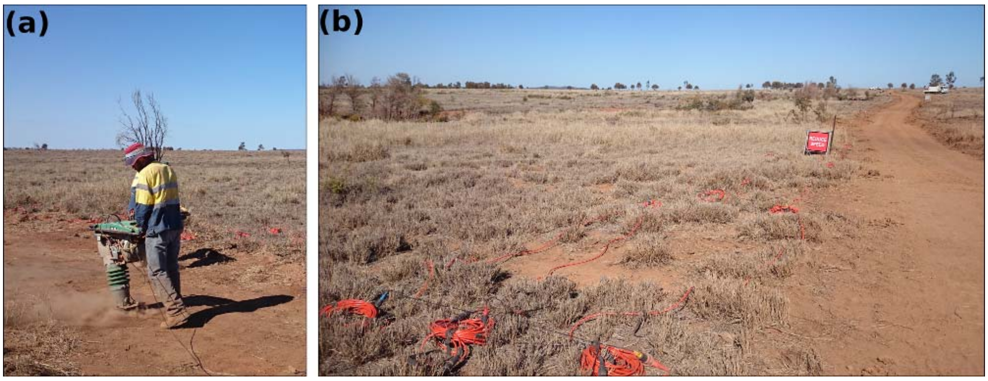

Figure 1: Photos of the seismic acquisition. (a) A Mini-SOSIE rammer source was used to generate P, S and PS data. (b) The multicomponent geophones were used with a conventional Sercel 428 system in a parallel configuration

SELECTED PROCESSING

The following outlines some of the processing steps peculiar to this type of seismic acquisition.

Separation of P and S waves

By operating the rammer in a slightly inclined configuration, and perpendicular to the line we tend to generate horizontally polarised S-waves on the cross-line component. At the same time each impact generates P and PS energy predominantly on the vertical and inline components respectively. Ideally we would like to completely separate the individual waveforms as each acts as coherent noise in the processing of the others.

One technique to achieve such separation has long been used in S-wave reflection surveys (e.g. Layotte, 1983). This exploits the polarity characteristics of P and S waves generated by a surface source. Generally the polarity of a P-wave is independent of the azimuth of application of the force. For S-waves the polarity is dependent on the azimuthal direction of the shearing force. Therefore, if two Mini-SOSIE shots are generated in opposite directions they will have opposite S-wave polarities but the same P-wave polarity. Summing these will enhance the P (and PS) data, while subtraction will enhance the S-wave data.

Figure 2 presents an example of this from our trial survey. At each site so-called Left (Figure 2a) and Right (Figure 2b) records were taken. Due to complexities in the near surface the two records have slight variations in amplitude and timings. These need to be corrected before the records can be combined.

Figure 2c shows the summed record. This has removed some of the horizontally polarised S-wave energy from the vertical and inline components which enhances the P and PS energy. Note there is still some cross-line energy, suggesting that either the process is not perfect, or there are other coherent energy sources contributing.

Figure 2d shows the subtracted record. This has done a very good job of removing the P and PS energy while enhancing the S-wave energy on the cross-line component.

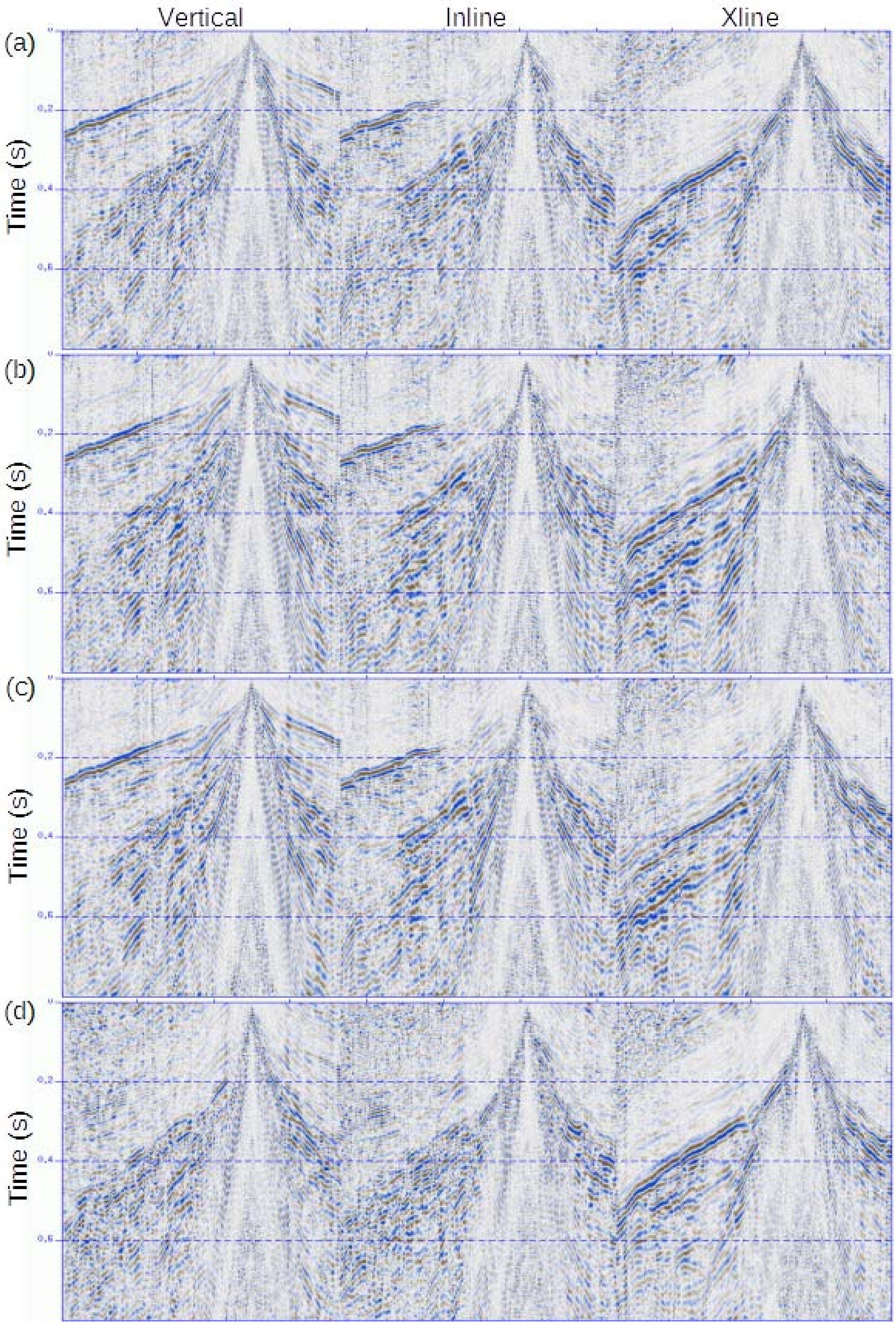

Figure 2: (a) Left record. (b) Right record. (c) Left+Right enhances the P and PS reflections on the vertical and inline components. (d) Left-Right enhances the S reflections on the xline component. Records have been phase and amplitude corrected before combining.

PS processing

The pure P- and S-wave reflection processing were quite straight forward, utilizing standard methods. PS processing is usually more complicated. The PS ray-path is asymmetric and varies with depth and velocity. Also S weathering statics are usually larger and more variable than P-wave statics. These can be quite difficult to determine from PS data. Calculation of statics from PS data requires significantly more user input than equivalent methods applied to conventional data.

However, the advantage of acquiring a survey that includes P, S and PS data is that the statics and velocities derived from the standalone P and S processing can then be used with our PS data. This provides a great improvement in processing time and confidence in the PS data.

Figure 3 shows the P and S weathering statics generated for the trial line. These were generated by analysing the P and S refractions on the separated records. These statics where then applied to the PS data.

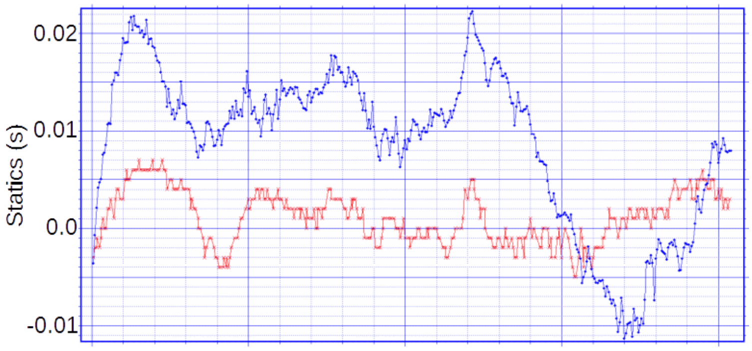

Figure 3: Comparison of the P (red) and S (blue) refraction statics.

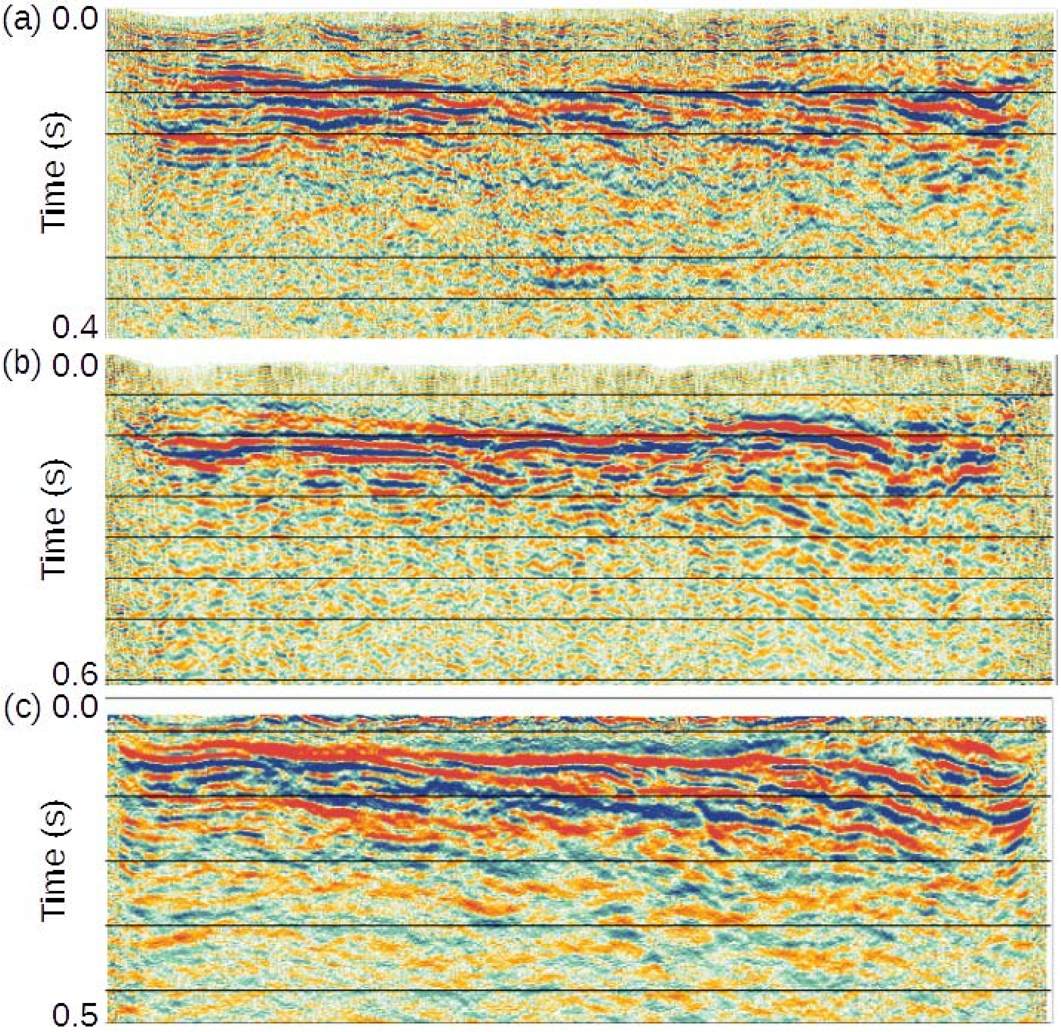

Figure 4: Stacked Section (a) P-wave data. (b) S-wave data. (c) PS data. Sections have been scaled such that they have approximately the same depth extent.

Preliminary Section

Figure 4 compares the preliminary stacked sections from each of the datasets. These are shown with approximately the same depth extent. The P-wave data (Figure 4a) are difficult to interpret and are likely to be contaminated by a significant amount of refraction energy.

The S-wave data (Figure 4b) show reduced complexity and less coherent interference. However, in this case the higher attenuation may make it more difficult to interpret the structures.

The PS data (Figure 4c) is quite noisy, but in this case it tends to provide the most realistic structural interpretation.

CONCLUSION

This trial has demonstrated that the Mini-SOSIE source can be used to simultaneously generate P-wave and transverse S-wave energy. Recording into 3C geophones efficiently yields a so-called 6C dataset. With appropriate processing, P-wave, S-wave and PS-wave images can be extracted.

This type of surveying allows comparison of structural interpretation from the three wavetypes. Structures observed on multiple images will have greater confidence.

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