# A High Resolution Seismic Survey to Assist in Mine Planning

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## ABSTRACT

*A high quality, high resolution 2-D seismic survey was acquired on a coal mining lease in central Queensland, Australia in order to assist in mine planning and future horizontal drilling for coal-seam methane extraction. Careful analysis of the seismic data revealed detailed structural information including the location, nature and throw of faults, definition of fracture zones, and the identification of seam splitting. Instantaneous amplitudes were shown to correspond to measured gas desorption rates. Overlaying of interpreted faults and instantaneous attribute sections reveals compartments of adsorbed gas along with sealing faults. Further analysis demonstrated that the seam thickness could also be predicted with a high degree of accuracy. This has vast implications for increasing the economic viability of extracting coal-seam methane and hazard prediction ahead of mining.*

## INTRODUCTION

The seismic technique offers a great deal of information that is vital to optimising the extraction of coal. The most fundamental geological information provided is structural, such as regional dip and the location of faults. Recent advances in technology have led to major improvements in the acquisition, processing and interpretation of seismic data to the point that the results are now being used to predict areas of roof instability, areas of low sulfur coal and fracture zones (Henson and Sexton, 1991). Mine planners are also interested in being able to predict the location of gas pockets within the coal seam in order to vent the gas either for commercial sale or to prevent life-threatening accidents. This paper presents a case study of a two-dimensional seismic survey acquired on a coal mining lease in central Queensland in which the location of faults, fracture zones, areas of seam splitting, compartments of adsorbed gas and the seam thickness are predicted.

## SEISMIC DATA

A conventional 2-km seismic reflection line was recorded in 1992 across a site at Kianga, to determine if seismic methods could assist mine planning. The explosive-source seismic line had receiver stations at a 3-m interval and a shot interval of 12 m, with a nominal fold of 15. A conventional 30-Hz geophone receiver line was used. The Kianga area is close to the Moura mining area where Broken Hill Proprietary Company (BHP) is currently operating a gas extraction plant producing 35 TJ of gas per week. The region is known for the high level of methane adsorbed in the coal seams; the methane content is proportionately higher at increased depths of seam burial. While the area is being prepared for underground mining, close attention is being paid to the extraction of coal-seam methane (CSM) from the seams, both for mining safety purposes and to establish the viability of CSM as an energy source.

The seismic field data were of very good quality and initially processed to produce the time section of Figure 1, in which the seams are indicated as A, B, BL and DU. The depth section was then produced by tying the data with boreholes, drilled 250 m apart, and a full interpretation was performed, as shown in Figure 2.

## DATA ANALYSIS

A total of 25 seam discontinuities were interpreted on the section using pre- and post-stack analysis, as shown in Figure 2. Pseudo 3-D time slices, seismic attribute analysis (instantaneous phase, frequency and amplitude) and horizon flattening were used in order to interpret very small throw faults and fractures (Urosevic *et al.*, 1992). The only fault that would be considered a problem for mining the B-seam is located between boreholes 2002 and 2004 and has a throw of greater than 4 m.

An obvious splitting of the B-seam can be seen in Figure 2, approximately 235 m west of borehole 2007.

The instantaneous amplitude section alone indicated that there were strong amplitude anomalies in the data, as shown in Figure 3. After reviewing gas desorption tests on cores taken from three boreholes intersecting the B seam, there appeared to be a correlation between reflection strength and gas desorption rates. The values of gas desorption were 9, 5 and 1 m$^3$/tonne, and the high value of 9 m$^3$/tonne coincided with strong amplitudes in the seismic data. The changes in seam reflectivity due to increased gas content were evident at the near offsets, as opposed to the customary far offsets required for gas-developed amplitude anomaly analyses considered in sand/shale sequences.

In “Proceedings of Exploration 97: Fourth Decennial International Conference on Mineral Exploration” *edited by* A.G. Gubins, 1997, p. 473–476

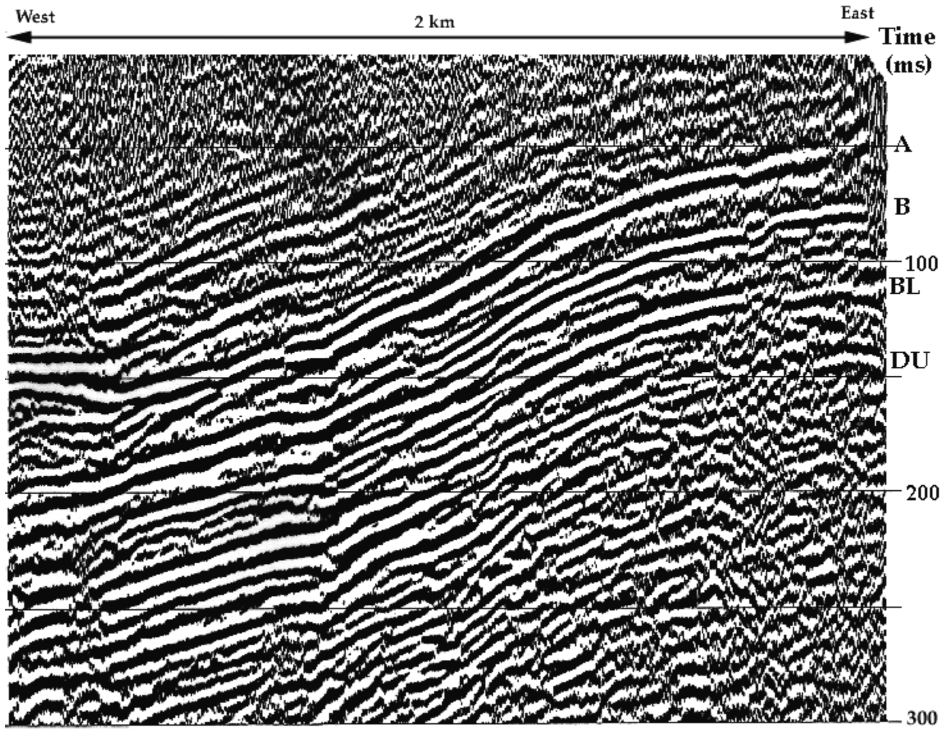


**Figure 1:** *Kianga time section showing four seams (A, B, BL, DU).*

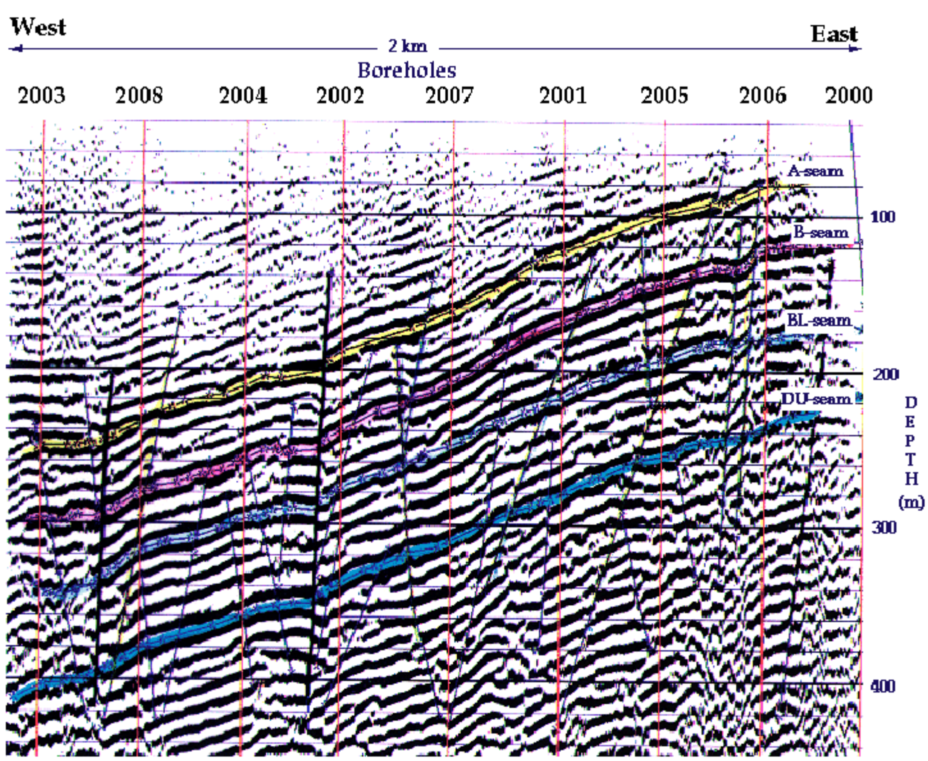


**Figure 2:** *Interpreted depth section with boreholes (vertical lines).*

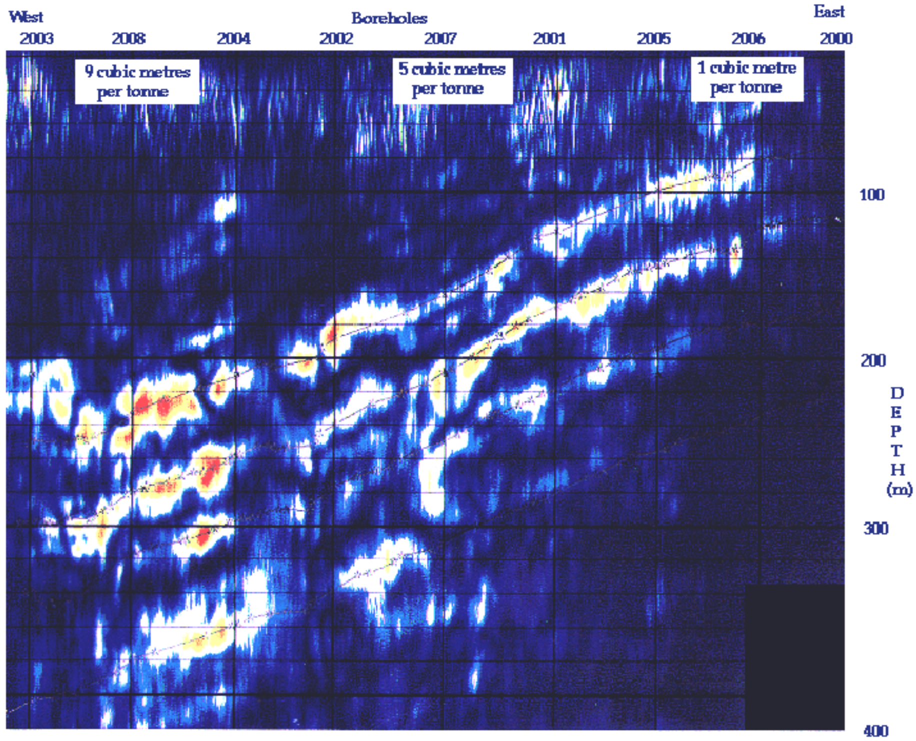


**Figure 3:** *Reflection strength section indicating areas of adsorbed gas. The three boreholes have desorption rates of 9, 5 and 1* $m^3$*/tonne in the B seam.*

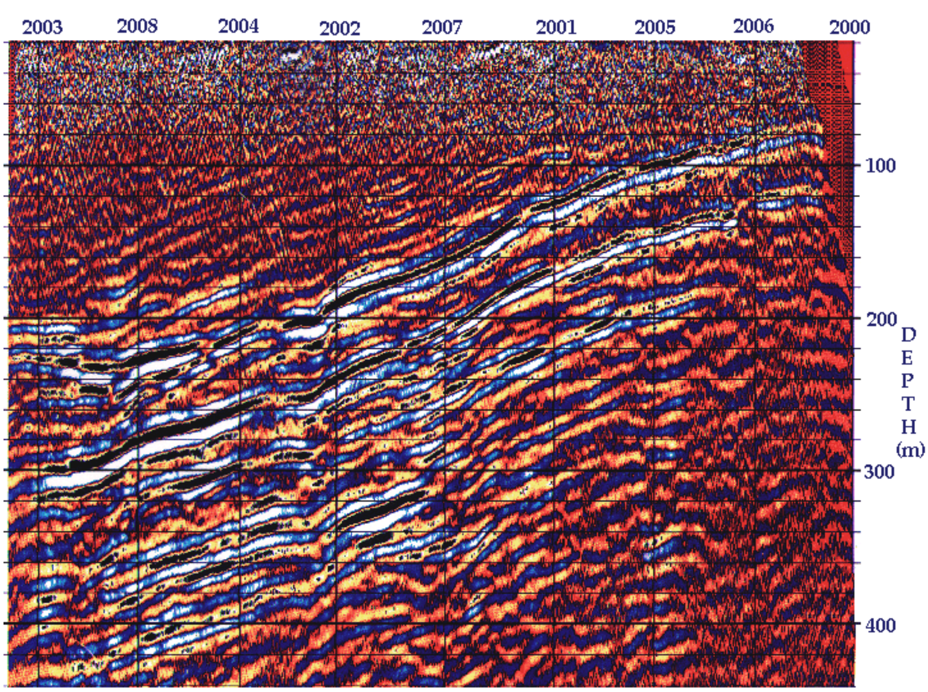


**Figure 4:** *Attribute display showing relative change in seam thickness.*

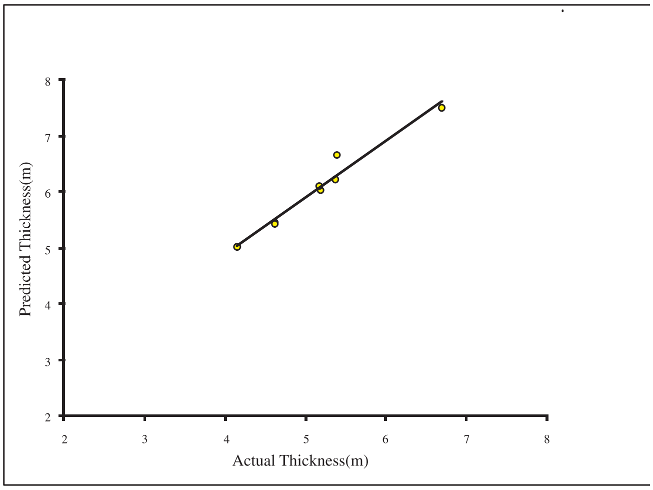


**Figure 5:** *Actual seam thickness versus thickness predicted from instantaneous phase, reflection strength and coal seam velocity.*

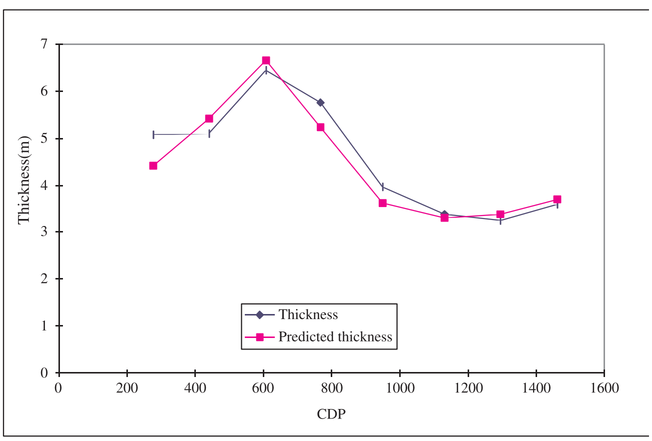


**Figure 6:** *Measured and predicted seam thickness derived from peak-to-trough times and amplitude information.*

A number of accumulations of gas could be considered as trapped within compartments when the fault interpretation is overlayed on the instantaneous amplitude and frequency sections. This suggests the identification of sealing faults where gas accumulations do not straddle the faults.

Economic quantities of adsorbed methane can only be found in seams that have an adequate thickness in the first place. Consequently it was of great interest to develop a method by which the seam thickness could be predicted.

Several approaches for predicting the seam thickness were tried, the two most successful methods using the following seismic attributes:

1. instantaneous phase and velocity of coal; and,
2. amplitudes and peak-to-trough times.

By combining the instantaneous phase attribute of the depth section with reflection strength, an attribute section showing a varying seam thickness was produced. This was calibrated initially at borehole 2008, to produce the display of seam thickness shown in Figure 4. The prediction of changing seam thickness then compared favourably with actual seam thicknesses measured in other boreholes, with the linear relationship shown graphically in Figure 5. In the second method, the seam thickness was derived using the peak-trough times and amplitude information. A comparison of the actual versus predicted seam thicknesses for the B seam is shown in Figure 6. This method also provided a very strong correlation between the predicted and actual thickness values. The usefulness of such a remote detection method for seam thickness has profound implications for methane exploration.

## CONCLUSION

This study shows promising results for remotely detecting coal seam thickness and adsorbed gas prior to mining. The ability to do this has major implications for the coal mining industry. The use of horizontal drilling to extract commercial quantities of gas could be enhanced by the identification of faults and/or fractures that may cause the compartmentalisation of gas reservoirs. Analysis of the faults and the intervening sections with respect to the average reflection strength and instantaneous frequency can suggest whether the fault is sealing or provides a permeability barrier.

## REFERENCES

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Urosevic, M., Evans, B.J. and Hatherly, P.J., 1992, The improvement in seismic resolution by map and trace attribute analysis: Exploration Geophysics, 23, 387-392.