Interburden mapping using 3D seismic attributes at an underground coal mine, Bowen Basin, Queensland

Henk van Paridon	**Fabian Brandimarte**
Geosolve	*Queensland University of Technology*
Brisbane, Australia	*Brisbane, Australia*
henk@geosolve.com.au	*f.brandimarte@qut.edu.au*

SUMMARY

Six high resolution 3D seismic surveys comprising approximately 31 km^2 were recorded for an underground coal mine in the Permian aged Bowen Basin Central Queensland. The colliery had previously interpreted the data with view to identifying hazards at the mined seam level.

The seismic data and an extensive set of borehole data were made available for a Masters Project at the Queensland University of technology with the focus being to study the geology of the interburden.

This paper discusses the background to the seismic surveys and the work flow used for the interburden mapping. Conclusions and recommendations are drawn

Key words: 3D Seismic, Coal, Interpretation, Case Study, Attributes.

INTRODUCTION

3D Seismic is being used extensively for underground coal mining. It has proven to be an accurate and cost effective method of accelerating mine planning. Currently in the coal mining industry, the primary use of 3D seismic data is the structural geology of the mining seam of interest. However, the coal industry generally has seismic data of very high resolution which is also rich in stratigraphic information within the interburden. This data can be interpreted using the concepts of depositional environments and facies models to identify variation in roof facies, distribution of lithologies and channel complexes that may further influence mine planning and safety.

Detailed interpretation of seismic attributes along pseudo horizon slices or stratal slices can reveal changes in depositional patterns and seismic geomorphology that can be interpreted as discrete depositional elements. In this study, seismic attributes have been used to identify and define these features that have previously been postulated in boreholes. This study is also applicable to petroleum explorationists who wish to better understand the basin but do not have access to such high resolution seismic data.

SURVEY DESCRIPTION

Seismic surveying commenced at the colliery in 2001 when a small 1 km^2 survey was recorded prior to the installation of a shaft. A follow up survey in 2004 convinced the mine that a broader use of 3D seismic was justified. It was not practical to acquire all the minable area in a single pass as it was logistically onerous and several years of budget were required. A further 4 surveys were recorded up to 2011 to bring the net coverage to 31 km^2 .

All surveys were recorded using dynamite and a bin spacing of 7.5m by 7.5m. Charges were loaded to just below the base of weathering. For the 4 larger surveys shot line spacing was adjusted to maintain a planned fold of 15-20 at the target seam.

Individual survey geometries were designed with a view to minimising time in the field and subsequent cost. However it was always recognised that some features of interest would occur near the margins and the surveys were designed with sufficient overlap so that they could be pre-stack merged. Individual surveys were processed and interpreted when acquired.

All the surveys have been merged into two large volumes that were used for this study. It was possible to re-use some of the previous processing such as first breaks and velocities. The two volumes underwent a very similar processing sequence although they were produced some 4 years apart. Data was depth converted so that it could be used in mine-planning software. There were over 200 boreholes within the seismic area so that depth conversion was straightforward and reliable.

Some artefacts were produced as binning of neighbouring surveys was imperfect but generally speaking the merged volumes provide excellent data.

INTERPRETATION METHOD

3D seismic attribute volumes were created from the depth converted dataset. The advantage of depth converted data is that borehole data ties without the need for time depth curves. The disadvantage is that the attribute software required TWT data so that some shuffling between the time and depth domains was required. Slices were constructed through interburden intervals by mapping coal horizons of interest, then smoothing and flattening them. In addition to the slices, volume attributes were also calculated for entire interburden intervals. Any feature seen in the attribute map was checked against the section views to confirm that it was not an interpretation or processing artefact. Interpretations of attribute maps were also coupled with wire line log interpretation. Typically in the coal mining environment there are a large number of boreholes.

RESULTS

Among many other features two major features of interest have been identified using seismic attributes.

- A 400m wide, SW-NE trending channel has been imaged in the Southern Merge on multiple attribute maps over an interval of approximately 110m.

- A sill with a maximum thickness of about 10m was identified in the Northern merge.

An Instantaneous Phase (Figure 4) slice taken through the channel and sill enhance these features, allowing the geometries to be accurately mapped through the interburden as this attribute emphasizes the continuity of events. The benefit of instantaneous phase is that it is independent of amplitude; therefore even weak events can be imaged .Phase displays are effective in showing discontinuities, faults, pinchouts, angularities, and events with different dip attitudes which interfere with each other .This is especially useful in a multiple coal seam environment where mining hazards may be difficult to image deeper in the section as reflectors become weak due to the loss of energy from overlying coals.

An average Instantaneous Frequency Envelope Weighted attribute map was also calculated for the interburden between the Pleiades and Aquila seams, enhancing the channel within the interburden. The channel fill responds with a higher frequency content to that of surrounding lithologies. A marked difference in the performance of these two attributes can be noted in this case, as Instantaneous Phase allows the channel to be mapped across the entire survey whereas the Instantaneous Frequency Envelope Weighted loses clarity in the south-western most area.

In this case, instantaneous attributes have proven to be more useful in defining these features than the geometric and wavelet attributes. The Similarity depth slice enhances the channel in part but is less effective in imaging the sill. Within the Southern merge volume the northern channel margin is clearly imaged in contrast to the southern accretionary bank.

The channel has a sinuosity of 1.1, therefore it is not considered to be meandering. Furthermore, no point bar scrolls or lateral accretion surfaces are visible in section view or on attribute maps to suggest lateral migration. The channel fill is interpreted to be vertically stacked sandstone units based on wireline logging. The occurrence of the channel over this interval could be explained by differential compaction of underlying peat and mudstone relative to the channel fill. This is similar to observations by Esterle et al (2000) in the laterally equivalent Moranbah Coal Measures to the north. The underlying peats and mudstones may compact more beneath the channel relative to adjacent lithologies, creating accommodation for younger channels to occupy.

These features were also confirmed from borehole drilling. An isopach map of the Pleiades-Aquila interburden indicates a thicker package where the channel is interpreted. It can also be interpreted from an isopach between the Pleiades and German Creek seams. Additionally, a distinct change in seismic character in section view can also be observed. The presence of the sill is also confirmed in wireline logs.

CONCLUSIONS

3D seismic has useful stratigraphic information that can be added to mine planning which can reduce drilling costs and improve hazard management. A different workflow to structural mapping is appropriate with greater use of attributes. If the seam of interest is poorly imaged some information may be extrapolated from the overburden. Other workers (Hatherly et al) are attempting to extract more quantitative information about roof strengths from the seismic data. Although it does incur a price penalty, pre-stack merging at the time of processing the latest data set leads to larger seamless seismic volumes that (1) avoid edge effects and (2) enable clearer imaging of features whose dimensions are ill defined on smaller surveys. Surveys should be designed around the known geology not the mine plan as mine plans change over time. No single attribute reveals all the features and a combination of wavelet, instantaneous and geometric attributes is required. Petroleum geologists who wish to understand the geometry of reservoir sands within coal measures can develop models from coal mine borehole and seismic data.

ACKNOWLEDGMENTS

The authors would like to acknowledge the advice and support of the Queensland University of Technology. We would also like to thank Anglo American Metallurgical Coal for making the data available.

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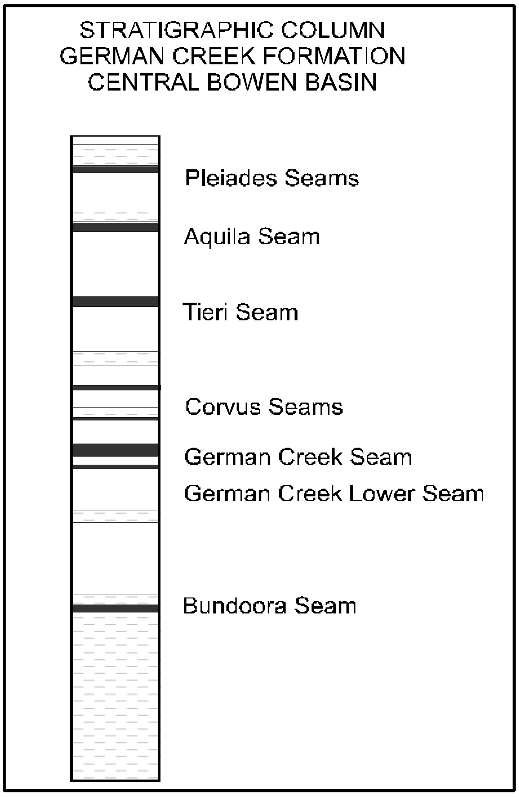

Figure 1. Stratigraphic Column for the German Creek Formation

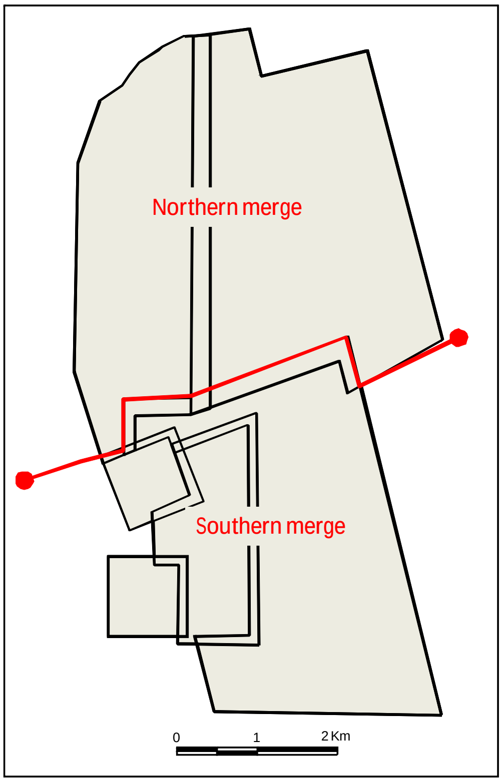

Figure 2. Location Map showing the six individual 3D seismic surveys recorded between 2000 and 2011. There are about 31km^2 of net seismic coverage.

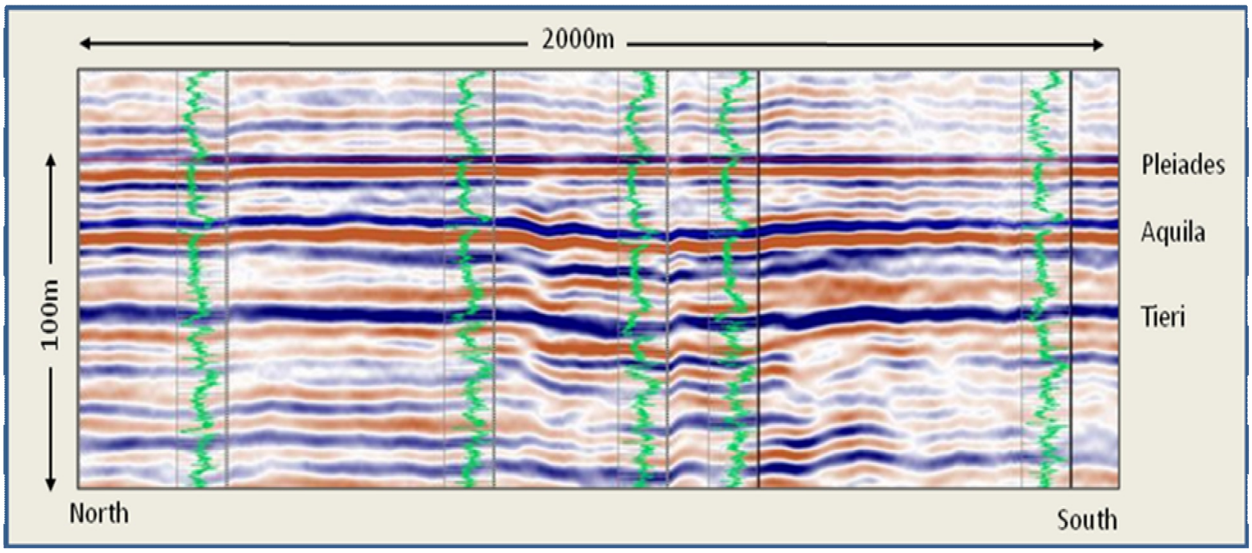

Figure 3. Final Migrated Depth Converted section across the southern channel. Gamma Ray logs are shown. Section is flattened on the Pleiades. Approximate location of section is shown in Figure 4.

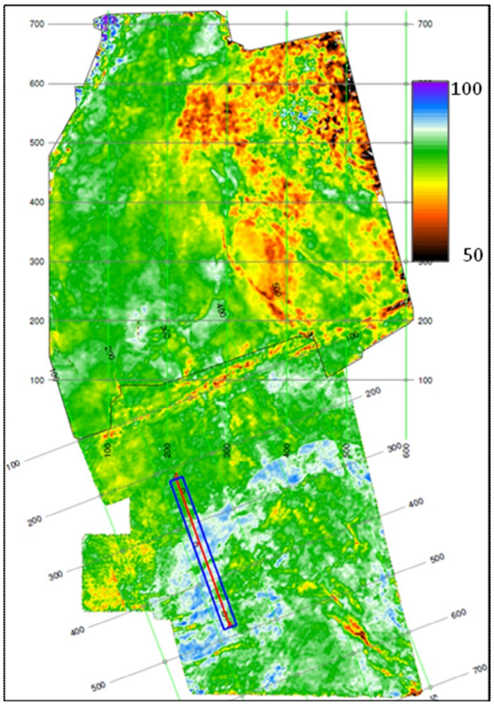

Figure 4. Averaged Instantaneous Frequency Envelope weighted calculated between the Pleiades and Aquila seams. A 400m wide channel in the interburden is seen. The channel fill responds with a higher frequency; however this characteristic diminishes in the SW.

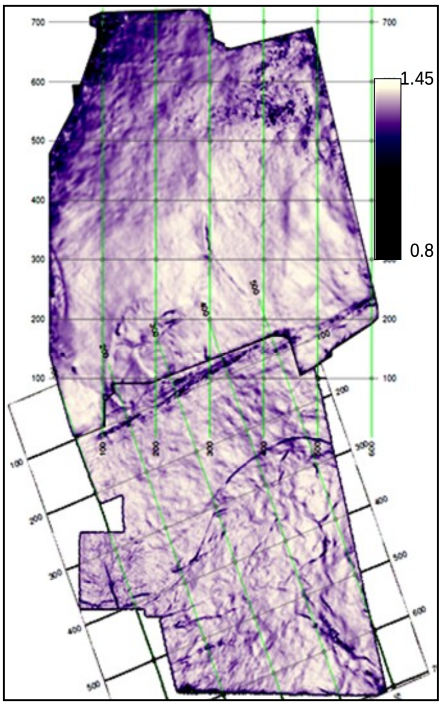

Figure 6. Similarity slice 20m above the Aquila shows the southern channel margin and a fault that is caused by channel.

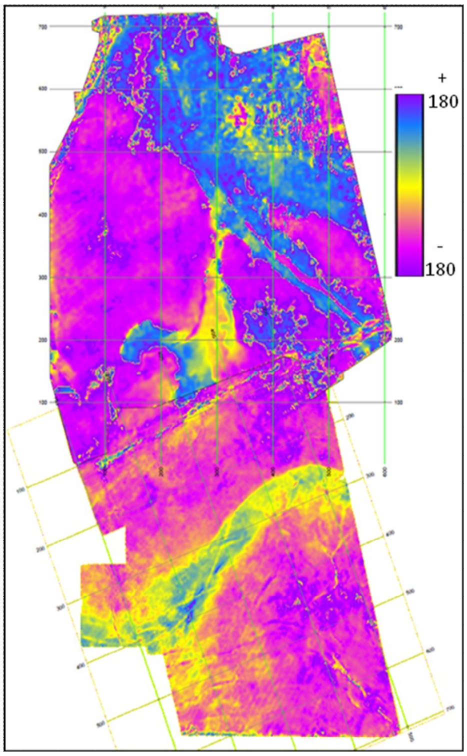

Figure 5. Instantaneous phase depth slice 20m above the Aquila seam. Instantaneous phase enhances the continuity of events, allowing the channel and sill to be confidently mapped

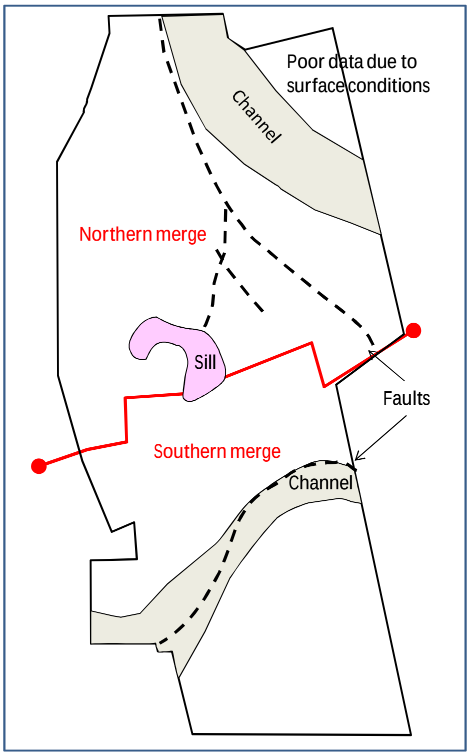

Figure 7 Some of Interpretation features identified within this study.