

# **Coal Seam Modelling and Mine Planning Using Results of a 3D Seismic Reflection Survey – An Example from Huntly Coalfield, New Zealand**

**D A Fergusson<sup>1</sup>**

## **ABSTRACT**

Geological hazards such as faulting, basement ridges, and zones of “thin” (< 6m) coal have a major impact on mining economics of underground operations at Huntly Coalfield. Experience has shown that drillhole-based investigations do not yield sufficiently detailed models of the coal seam to allow management of the planning risks associated with these hazards. Consequently, operational performance is affected by unplanned costs associated with lower productivity, loss of coal reserves, and expensive strata control remedies in problematic ground conditions. Huntly Coalfield is a challenging environment for acquisition of good quality seismic reflection data due to the very thick (10-85m) weathering layer. Since 1994, successful acquisition of 2D and 3D data has been achieved through a combination of careful testing of technical parameters and experimental trials prior to committing to production recording. High resolution seismic reflection (HRSR) is proving to be an investigations technique which results in accurate and reliable models of the coal seam and associated structures such as normal faults and paleo-topography of the surface on which the coal seam rests. The HRSR technique has been applied and developed in the Okowhao Sector where Huntly East Mine is developing and extracting coal reserves. Results of a recent 3D survey demonstrate that this technique is capable of revolutionising risk management in mine planning for underground mines in structurally complicated coal deposits.

## **INTRODUCTION**

In the 1980's high resolution seismic reflection was utilised as an investigation technique in the Waikato coalfields (Gumbley 1988). The results from the Huntly Coalfield were disappointing, largely because the acquisition was undertaken without “tuning-in” of technical parameters (Fergusson 1997). Evidence from the petroleum industry generally, and some Australian and US coal mining companies indicates that seismic reflection delivers major benefits for geological interpretation and hazard mapping (Davies 1992; Gochioco 1990, 1991; Harman 1981; Lamb, Saunders and Sweeney 1992; Lambourne, Evans and Hatherly 1989; Lambourne, Hatherly and Evans 1991; Nestvold 1992; Palmer 1987; Tilbury and Bush 1991; Urosevic, Evans and Hatherly 1992). This technique is especially relevant to the Huntly Coalfield where the thick Kupakupa coal seam is affected by numerous, large-scale geological hazards which defy definition by drilling. Undetected, these hazards have unplanned economic impacts on the operation related to productivity, development efficiency, reserves recovery and safety.

In January 1994 Solid Energy began research and development of 2D high resolution seismic reflection (HRSR) techniques at Huntly East Mine with the acquisition of a 900m experimental 2D line. The purpose of this work was to determine whether HRSR could reliably detect geological hazards for mine planning purposes. The results were very encouraging. A few months later, an additional 5 km of 2D data were acquired. The limitations of 2D seismic for hazard definition were soon realised after development of South 4 Panel. A 3D HRSR survey was undertaken over the Ralph Block in 1996-97 (Fig. 1). The implications for mine planning using the 2D and 3D seismic data are discussed using recent examples from Huntly East Mine

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Solid Energy North, Huntly, New Zealand

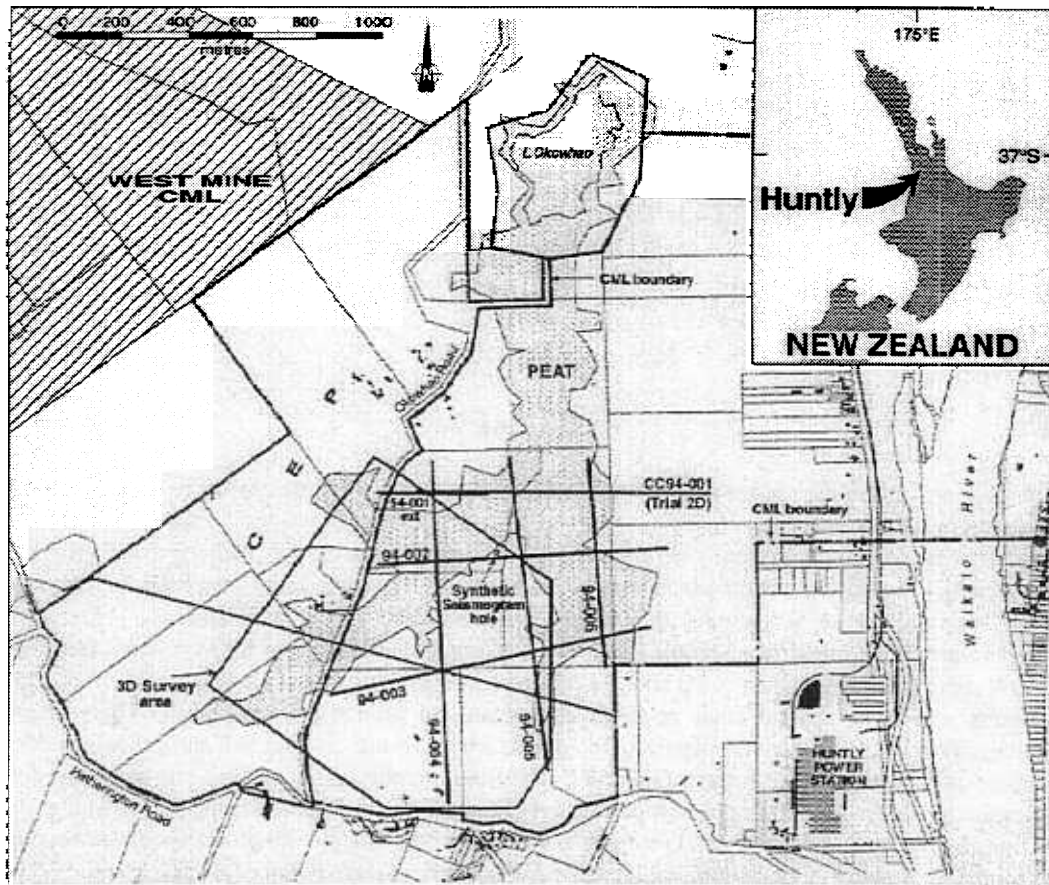


Fig. 1 Location of the 2D seismic lines and 3D survey area in the Eastern sector huntly east mine

### Huntly Coalfield

Coal resources in Huntly Coalfield occur in two economic seams near the base of the Waikato Coal Measures in the Te Kuiti Group (Eocene-Oligocene). The seams rest close to or directly on Mesozoic greywacke ("basement"). West of the Waikato River, in the Okowhao Sector of Huntly Coalfield, the Renown and Kupakupa coal seams merge to a single seam with an average thickness of 16 metres (Fergusson 1994a). Geological controls on seam geometry include a combination of structural and depositional factors such as seam splitting and merging, deposition over an undulating basement surface, wash-outs from an adjacent paleo-fluvial system, and structural thinning along normal faults.

Around Huntly, Te Kuiti Group has a regional dip of 5-10° N-NW. Locally, coal seam dips may be as high as 40° adjacent to faults and above basement ridges (Fowke 1987, Fergusson 1994a). Exposures in underground mine developments have revealed a fault system consisting of persistent NNW trending faults with throws of 10-50m, and NE trending faults with throws of 5-25m. In the broader setting, the southern end of Huntly Coalfield is situated between the tips of two opposed-dipping N-S fault systems, the Maungaroa-Kimihia and Waipa-Wilton/Karaka faults (Fig. 2). These faults are separated by a 10-15 km NE-SW step in the Huntly area. This step is marked by the Hakirimata Range in the Taupiri-Huntly region. Faulting close to this step is thought to be more intense and complex than faulting further north and south (A Nicol pers. comm.).

### Underground mining

Present-day coal mining in Huntly Coalfield occurs at the up-dip southern and southeastern end where the coal seams are less than 350 m deep (Fig. 2). Two underground mines produce coal, Huntly East Mine (450,000 tonnes per annum) and Huntly West Mine (20,000 tonnes per annum). Since 1992, coal investigations have been concentrated in the "Western

Sector” of the Huntly East Coal Mining Licence (CML) area. The Western Sector constitutes the CML west of the Waikato River, and is within the Okowhao Sector of Huntly Coalfield (Fig. 1).

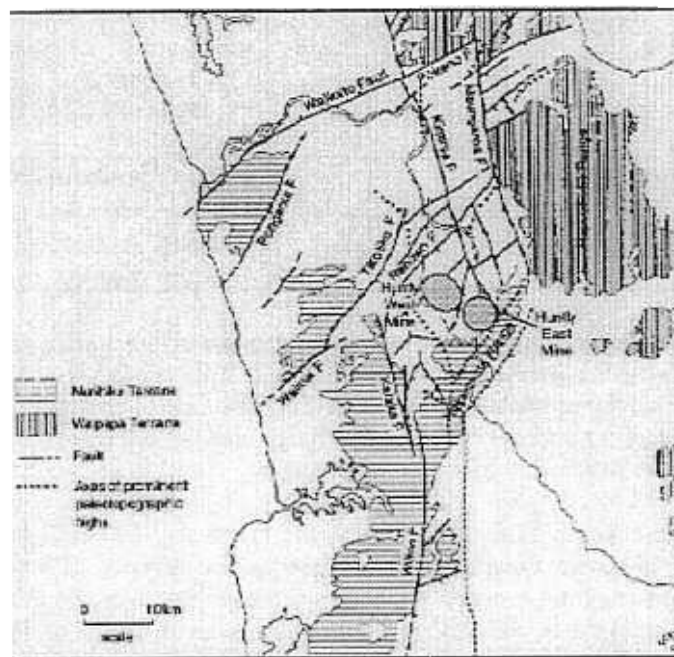
Huntly East Mine is a thick seam mining operation. The coal seam attains a maximum thickness of 24 metres and is a very weak to weak rock (UCS = 5-15 Mppg), yet it is stronger and more durable than the enclosing mudrocks (“fireclays”) of the Waikato Coal Measures (Mills 1986, Tan and St George 1989). Development tunnels are planned with two to three metres of roof coal to help ensure roof stability. The minimum practical workable coal seam thickness for underground extraction is six metres (i.e. 2-3 metres roof coal; 2-3 metres tunnel height; 1 metre floor coal). Coal is currently won by bord and pillar and bottom-coal extraction using continuous miners.

### Geological hazards and mining risk

Reliable seam geometry and structural models are essential for effective mine planning if mining risk is to be managed. At Huntly Coalfield, mine economic performance is more related to geological hazards than to any other factor. Areas where the coal seam is thinner than 6m pose the greatest risk for mine planning. There are several types of geological hazard which cause adverse mining conditions and therefore impact on the productivity, efficiency, recovery and safety of the mining operation (Table 1).

### Limitations of drilling for mine planning

Historically, coal seams in Huntly Coalfield have been investigated using surface drilling methods. Outcrop and natural exposures of Te Kuiti Group are very rare because the coal-bearing strata are concealed below a very thick (up to 85 m) sequence of Quaternary sediments and volcanic ash deposits. Drilling programmes have been undertaken periodically since the early 1900’s, consequently, a mixture of wash-drilled to fully cored holes exist in the drillhole database, with touch-cored holes being the most common type. Wash-drilled and touch-cored holes yield very little structural data.



**Fig.2 – Regional geological setting of Huntly Coalfield showing basement distribution and major structural features (modified from Edbrooke, Sykes and Pocknall 1994)**

Geological modeling of drillhole data with spacings as low as 100 m, such as in the Huntly East Mine east of the Waikato River (Huntly East Sector), was not able to resolve the seam structure (Fergusson 1988). Although the mine was planned for longwall mining, extraction using this method would have been extremely difficult and almost certainly unproductive,

due to the frequency, size and number of sets of faults. The longwall was not installed and the longwall panels were extracted using a Wongawilli type of mining system during 1987-1991.

**Table 1- Geological hazards in the Huntly Coalfield**

<i>Geological Feature</i>	<i>Nature of Hazard</i>	<i>Impact on Operation</i>
Normal faults	<ul style="list-style-type: none"> <li>• localised poor coal mass conditions</li> <li>• water seeps</li> <li>• steep grades due to drag folding</li> <li>• very weak</li> <li>• low durability coal measures exposed</li> </ul>	<ul style="list-style-type: none"> <li>• closer supervision required to negotiate fault</li> <li>• unplanned stone drivage</li> <li>• on-going tunnel instability and maintenance</li> <li>• higher reinforcement and/or support costs (cable bolts, steel sets)</li> <li>• pumping to handle water make</li> <li>• loss of reserves and/or lower productivity</li> </ul>
Thin coal (less than 6 metres)	<ul style="list-style-type: none"> <li>• insufficient roof or floor coal</li> <li>• greater vulnerability to effects of faulting</li> </ul>	<ul style="list-style-type: none"> <li>• roof bolts ineffective if anchored in fireclay</li> <li>• on-going tunnel instability and maintenance</li> <li>• higher reinforcement and support costs</li> <li>• lower productivity and/or loss of reserves</li> </ul>
Basement ridges	<ul style="list-style-type: none"> <li>• thin disturbed coal - flexural shears and tension fractures</li> <li>• stress concentration</li> <li>• steep grades</li> </ul>	<ul style="list-style-type: none"> <li>• lower productivity and/or loss of reserves</li> <li>• higher reinforcement or support costs</li> <li>• on-going tunnel instability and maintenance</li> <li>• unplanned stone drivage through seam floor</li> </ul>
Fault troughs	<ul style="list-style-type: none"> <li>• poor quality coal mass</li> <li>• intensified minor faulting and shearing</li> </ul>	<ul style="list-style-type: none"> <li>• lower productivity</li> <li>• increased reinforcement and support costs</li> <li>• lower recovery</li> </ul>

In 1992-93, a drilling programme consisting of 39 touch-cored drillholes was undertaken, reducing the drillhole spacing from 250 m to 175 m over the consented part of the Western Sector (Fergusson 1994a). 25% of these holes intercepted faults, with approximately half having estimated throws exceeding 5m. All of the drillholes were geotechnically and geophysically logged (with dipmeter) to improve the structural interpretation, but the data were generally insufficient to reliably and accurately map the fault pattern and basement ridge extents.

The drillhole spacing in the adjacent Huntly West CML (Figs. 1 and 2) averages 200 m in the developed part of the mine. This drilling was not sufficient to model and predict the frequency and severity of basement relief and faulting as encountered in the pit bottom area resulting in major unplanned development costs (Fowke 1987). Over the remaining part of the Huntly Coalfield, north of the two CMLs, drillhole spacings are in excess of 300 m implying that additional geological investigations will be needed prior to mine development.

Modeling and interpretation of these drillhole datasets indicates that spacings of around 200-300 m are adequate to measure coal quantities and to provide indicative quality data (Fergusson 1994a). However, the data are insufficient to accurately define geological hazards for mine planning. The limitations of surface drillhole data for seam geometry modeling relate primarily to the low number of seam intersections i.e. point sample (Lambourne *et al* 1991), the inherent limitations of using (often disturbed) drill core for interpreting several types of geological structures, and the relatively

small scale of many structural features. The drillhole spacing required for high reliability structure mapping is probably in the order of 50-100 m (Fergusson 1994b), and therefore cost-prohibitive.

### High resolution seismic reflection data acquisition in Huntly Coalfield

Huntly Coalfield is a challenging geological setting for HRSR data acquisition. The main reason for this is the thick weathering layer - the Tauranga Group (Quaternary). Seismic energy is readily absorbed and attenuated by a combination of surface peat deposits in the valleys, thick unconsolidated sediments, pumice-rich gravel layers, hard ignimbrite lenses, and buried organic-rich muds. In addition, the soft, unconsolidated nature of these materials, especially the peat, encourages the formation of guided waves (ground roll), which obscure first arrivals during recording.

A combination of modern acquisition techniques and recording equipment, together with close attention to experiments and trials before finalising the technical design of acquisition and processing methods, greatly increases the likelihood of successfully acquiring usable HRSR data (e.g. Lamb *et al* 1992). The technical strategy at Huntly East Mine involved the following:

- field experiments to “tune in” charge size, depth and spacing; receiver type, configuration, and spacing;
- placing geophones below the surface peat layer;
- drilling very deep shot holes to ensure the signal to noise ratio was sufficient over the thickest Tauranga Group;
- quality assurance procedures during all project stages (surveying, drilling of source and receiver holes, loading, acquisition, and processing);
- acquisition of experimental data before committing to production recording; and
- emphasis on data quality not quantity

## 2D HIGH RESOLUTION SEISMIC REFLECTION PROGRAMME

### 2D trial

In February 1994 an experimental programme began to determine acquisition parameters for a trial 2D line (Table 2). This entailed recording upholes and a refraction line, testing charge size, and geophone design. Once these parameters were tuned-in, a 900m trial line was recorded ahead of the West Headings face position and above the Men and Materials tunnel alignment (Figs. 1 and 4). The line position was chosen to cover a representative range of surface/access and weathering layer conditions, and, if successful, would provide information about seam structure in the direction of mine development.

Table 2 - 2D HRSR Technical Parameters

Parameter	Experimental Line	Production Lines
Charge type and weight	Anzomex A boosters - 260 gms	A and K boosters - 260 gms
Max. source hole depth	40m or base weathering layer	50m or 3m below weathering layer
Source hole interval	20m; between receiver stations	18m; on station
Receiver interval	5m	3m
Receiver pattern	Hills: 6 at point Peat: 1 downhole	Hills: 6 perp. to line; 3x3 split Peat: 3 downhole in casing
Nominal Fold	12	12

Fig. 3a illustrates that good quality HRSR image resulted from this trial and that the problems associated with the Tauranga Group weathering layer could be overcome by some relatively straight-forward field testing. The benefits of



using downhole geophones in peat swamp areas is also evident as data quality is consistent along the entire line. The top of the seam is clearly resolved, as are geological structures. Ralph Fault, Okowhao Fault and Taupiri 1 Fault were previously inferred and modeled using surface drillhole data (Fergusson 1994a, b). The fact that these faults were successfully imaged and the resultant seismic interpretation was consistent with the existing data, was critical for the credibility of the experimental programme. The agreement between the nature and positions of faults determined from the 2D profile and the actual intercept positions, sense of offset and degree of drag folding revealed in the development tunnels has proved to be very good (Fergusson 1997).

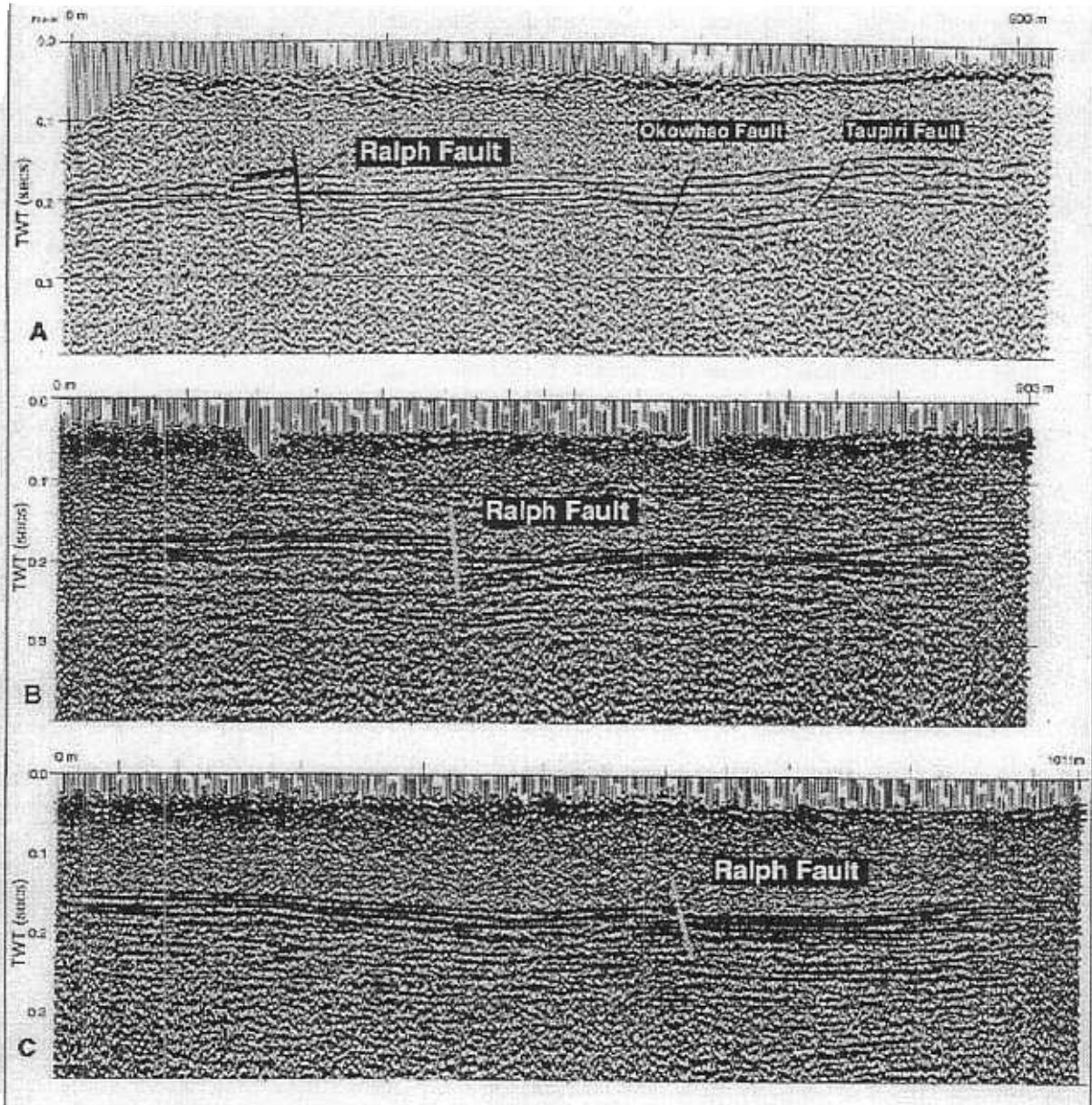


Fig. 3 – E-W 2d seismic profiles acquired in western sector – 12 fold, deep Anzomex energy source data showing the NNW-trending Ralph Fault: (A) experimental line, (B) Production line CC94-002, (C) production line CC94-003

## 2D production survey

The trial demonstrated that with appropriate emphasis on technical parameter selection, high quality data can be recorded, and the position of structural geology hazards accurately mapped in the line of proposed mine development alignments. A 2D production survey consisting of five lines plus an extension of the trial line was conducted in May-June 1994 (Fig. 1). In addition to more pre-survey parameter testing (upholes), the programme included drilling and sonic logging of a drillhole to generate a synthetic seismogram for picking and correlating the target coal seam over the survey area (Fig. 1). Migration of one of the lines resulted in improved image quality and refinement of fault positions. Unfortunately, not all lines could be migrated due to budget limitations, however unmigrated fault positions were constrained to  $\pm 10\text{m}$ , which was considered to be acceptable for planning of mine developments. The source hole and receiver spacing were reduced to improve processed image quality (Table 2).

The resultant profiles were of very good quality (Fig. 3b and 3c). The top of the coal seam is clearly imaged, as are normal faults and the crest of "drape" folds marking basement ridges (Fergusson 1994c). Unfortunately, the base of the seam was not consistently resolved by processing. The three E-W seismic lines (Fig. 1) allowed better definition of the Ralph Fault, a major geological hazard and planning obstacle, along strike to the south. They showed that total offset on Ralph Fault reduces southwards, and the proportion of offset represented by normal drag folding increases (Fig. 3). This has been borne out by development and extraction in South 4 Panel on the eastern (downthrown) side (Fig. 4). The three N-S lines indicated a 150-200m wide fault zone made up of several, discontinuous faults with less than half seam thickness offsets. These faults stepped the seam down to the north. The zone represents another major planning obstacle. Basement ridges are also evident south of this fault zone, indicating localised seam thinning is likely.

Despite the success of this programme in imaging the seam "in line", several limitations with the resultant data were obvious from a structural interpretation and mine management point of view (Fergusson 1994c). The strike of the NE trending faults were inferred because the 2D lines were too widely spaced for correlation purposes. The definition of seam base was poor compared with the top of seam, such that the extent and severity of basement ridges could only be inferred. In short, the chief limitations of 2D seismic reflection had been realised, a fact amply illustrated in the South 4 Panel where a fault striking  $015^\circ$  was intercepted, instead of the more typical  $045^\circ$ , and significantly impacted upon the extraction plan (Fig. 4).

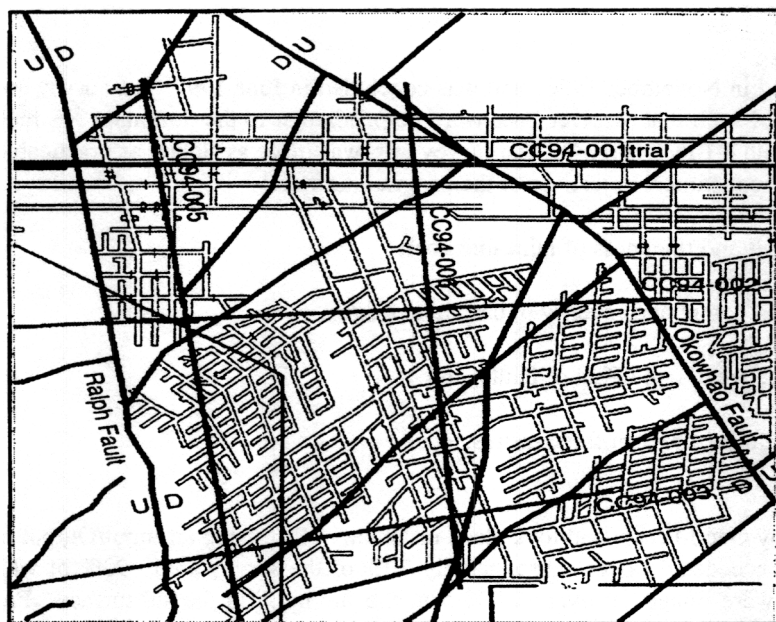


Fig. 4 – South 4 panel, Huntly east mine showing mapped faults and mine workings

## RALPH 3D SEISMIC PROJECT

In May-June 1996 work began justifying a 3D survey over the Ralph Block and part of the adjoining Coal Exploration Permit area (Fig. 1). The cost benefits were estimated using the performance of South 4 Panel in terms of unplanned support, maintenance and production costs and inaccessible reserves. An internal rate of return of 14% was determined from discounted cash flow analysis (Fig. 4).

### 3D experimental programme

Results of field experiments involving upholes, source holes and an experimental geophone spread conducted in May-June 1996 were consistent with the 2D uphole results. The results confirmed that a weathering layer *per se* is not readily definable in the Tauranga Group sediments due to an absence of strong velocity interfaces below the peat layer (Bjoroy 1996). Signal to noise levels of shots degrade from 40-45m depth upwards. The drop in signal to noise ratio, signal continuity and frequency content was found to be sudden rather than gradual. It was concluded that the interval between 5-50 m can be treated as a single horizon geophysically (Bjoroy 1996).

In light of this, source hole depths in the Tauranga Group could not be based on lithological criteria. Three target depth criteria were formulated for source hole drilling:

- a minimum depth of 25 m where Te Kuiti Group was intercepted at shallow depths
- an intermediate depth criterion of drilling three metres into Te Kuiti strata where Tauranga Group was 25-47 m thick
- a maximum depth of 50 m where Tauranga Group was more than 50 m thick

To complement the field experimentation, a series of processing trials was conducted on one of the 2D lines to determine the optimum processing sequence and the effects of data interpolation (Hawkes 1996).

### Ralph 3D survey

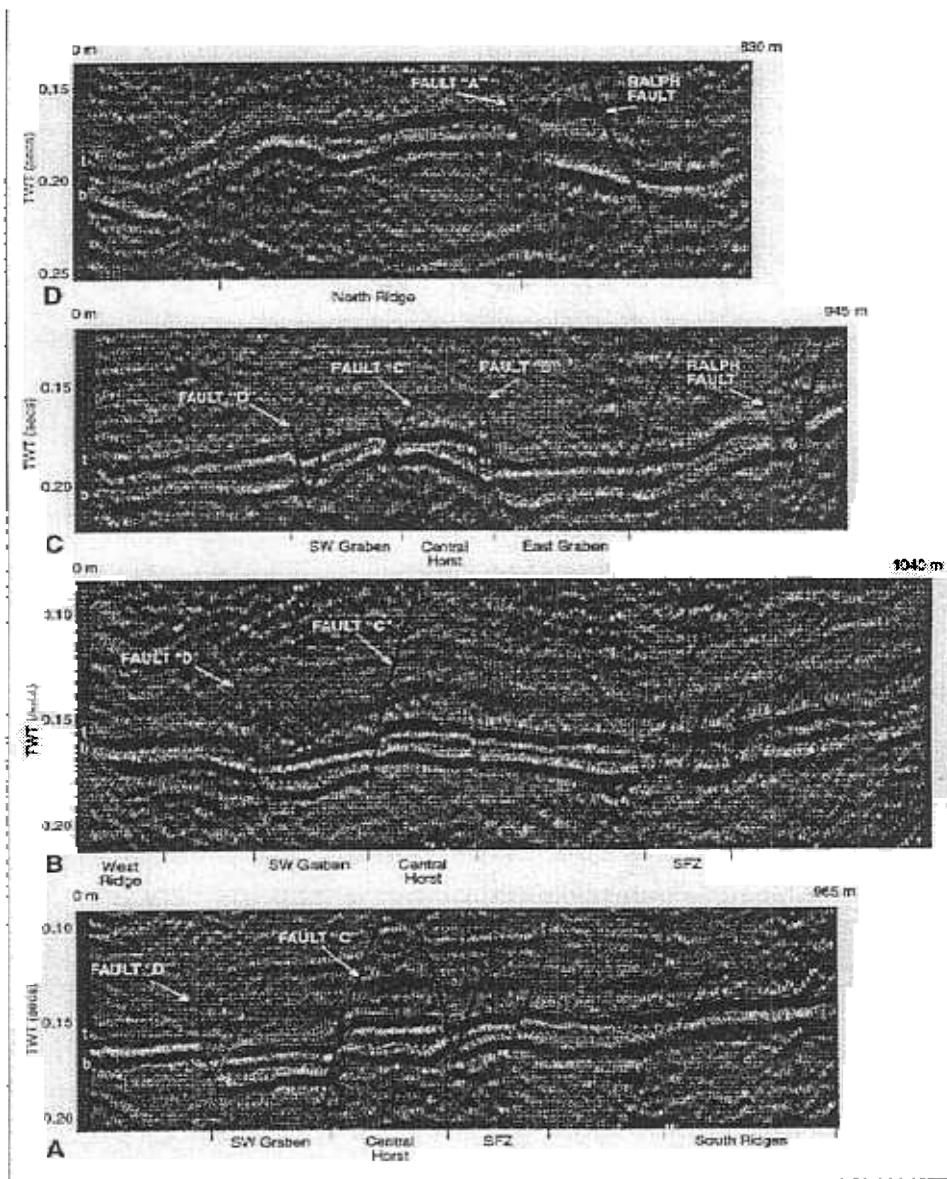
The Ralph 3D project started in November 1996, and was concluded in June 1997. The survey area was 0.82 km<sup>2</sup> (Fig. 1). The survey area was oriented such that receiver lines were perpendicular to the dominant NE fault trend determined from mapping in the adjacent South 4 Block (Fig. 4). The survey area was made as square as practicable to minimise the area of low fold peripheral data. The technical objectives of the programme were:

- Determine the extent and thickness of mineable coal;
- Define the location, extent and severity of basement ridges;
- Define the location, trend and offset of faults; and
- Vertical resolution in the order of three metres.

Recording was conducted by Geco-Prakla and took place in January 1997 using an Input/Output System 2 data acquisition system. Sub-surface fold exceeded 12 over approximately 70% of the survey area, 90% of which was 14-20 fold data. The top and base of seam were imaged at over 32,000 5 m x 5 m "bins" in the subsurface. Processing was carried-out using Gecoseis software. Time-structure interpretation and depth conversion was carried-out using GeoQuest software (IESX and InDepth).

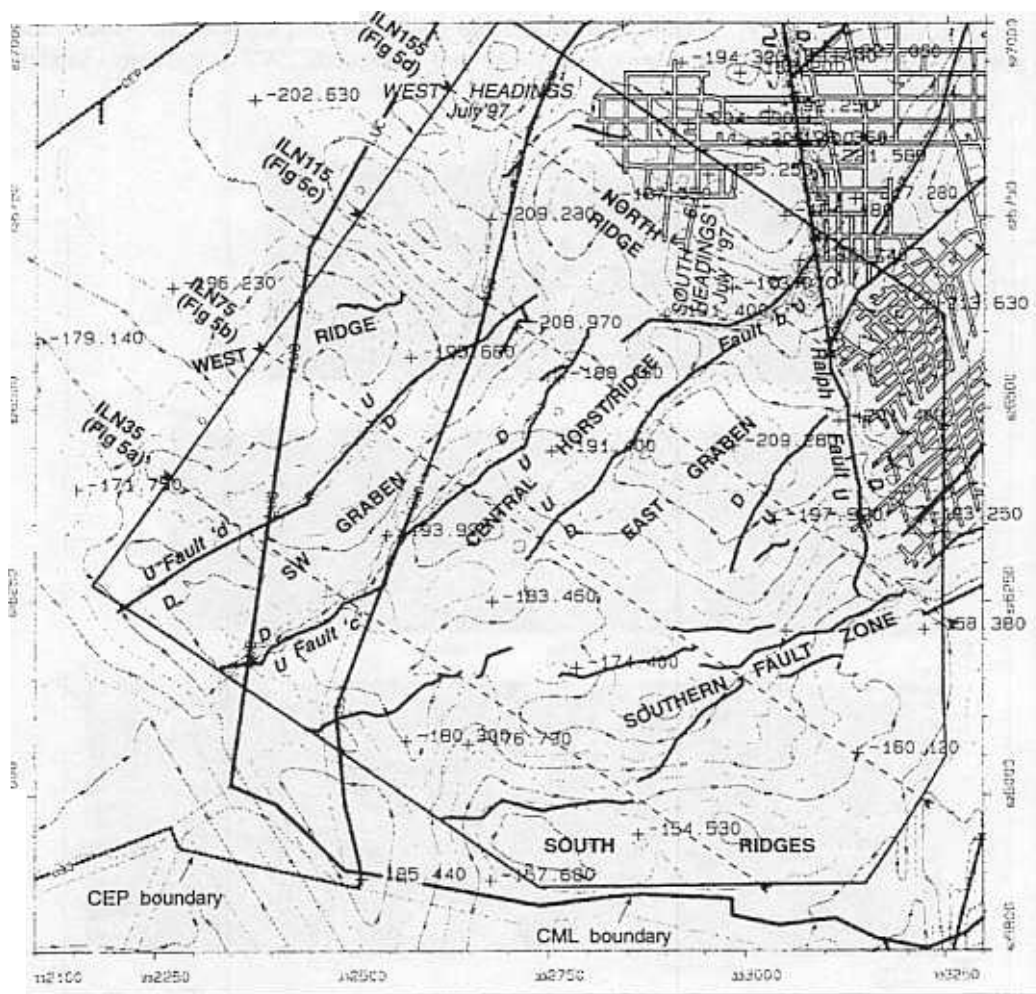


Fig. 5 illustrates the high quality of the processed data volume. Top and base of seam reflectors are very obvious between 0.15 to 0.20 seconds two way time (TWT). Faults were interpreted where they cut the seam boundary reflectors. Some faults were seen cutting a shallower reflector at approximately 0.12 to 0.15 seconds TWT (= Pukemiro Sandstone).



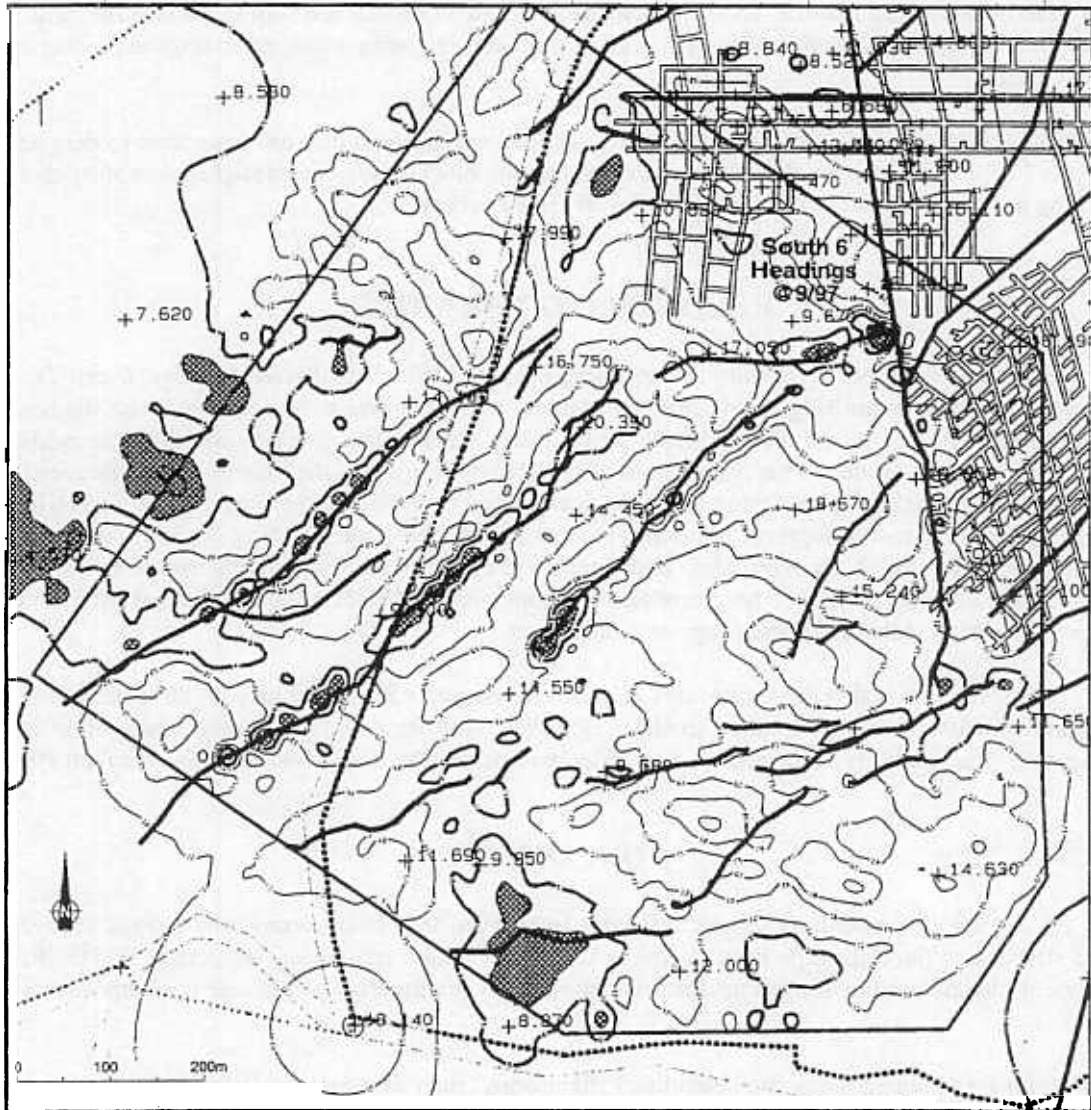
**Fig. 5 – Selected in-line (NW-SE) profiles from the Ralph 3D survey – nominal 14 fold, deep Anzomex energy source data: (A) ILN 35, (B) ILN 75, (C) ILN 155 (vertical exaggeration ~5; section locations shown on Fig. 6)**

Data sets containing the depth converted time-structure points were modeled using Vulcan mine planning software (McGuire 1997). Triangulations were generated of seam roof and base and faulted using the fault trace data from the 3D interpretation (Fig. 6). Seam thickness was derived from “grid arithmetic” using grids of seam floor and roof, thus accounting for thinning across faults and above ridges (Fig. 7).



**Fig. 6 – Base of seam structure of Ralph block and part of adjoining CEP: interpretation after modelling of seam using 3D survey results**

The seam base model revealed a pre-seam basement topography consisting of a complex system of ridges and valleys representing the erosional surface on the pre-coal measure basement surface (Fig. 6). The basement relief indicated by drilling and 2D seismic in the south of Ralph Block has been confirmed in detail by the 3D survey. The North and South ridges are connected by the Central Horst/Ridge, which runs along the western side of the Ralph Block. Consideration of the position of this Central Ridge and the location and throw of the faults has allowed the South 6 Headings to be positioned where the geological hazards will have the minimum impact on mine development. Development tunnels have been designed in three dimensions to negotiate structures with minimal stone drivage and to meet tolerances of mine infrastructure (such as the vertical curvature of conveyor belt structures, and maximum grades for mine vehicles).



**Fig. 7 – Derived combined seam thickness contours of Ralph block and adjoining CEP. Bold contours are 9m isopachs, hatched areas are coal less than 6m thick**

A total of five previously unknown faults with throws ranging between 2 - 25 m, and numerous sub-5 m throw faults were defined (Figs. 5 and 6). The main faults define two fault troughs (SW Graben and East Graben) and an intervening structural high. These areas have been planned as distinct mining blocks with prescribed lower rock mass conditions (Roy 1997), requiring separate development and extraction plans. The Ralph Fault dies-out against the Southern Fault Zone (SFZ). The SFZ continues southwestwards as a series of irregular, discontinuous, minor faults which collectively form a planning obstacle.

The derived seam structure and thickness maps (Fig. 7) are consistent with observations from drillholes and development tunnels. The West Headings were stopped 50-75 m from the CML boundary because the seam started to thin and dip-over steeply. It is now apparent this is due to encountering the NW end of a basement ridge (the North Ridge - Fig. 6). The South 6 Headings have encountered thinning and steep seam grades as they develop southwards into Ralph Block consistent with climbing up the NE flank of the North Ridge.

Once accurately depth-converted, the 3D results can be used to model the distribution of coal quality parameters within a “real” geometrical framework allowing more accurate scheduling of run-of-mine coal quality. At Huntly East Mine, the first iteration of detailed mine planning and scheduling has indicated months where run-of-mine coal quality will be out of

specification, and demonstrated that the ratio of development to extraction was too high to achieve the mine's production targets in the last two quarters of the operating plan. These problems are being corrected to achieve product specifications and planned tonnages.

A combination of basement relief (West Ridge), seam thickness and drillhole data has been used to define the limit of extraction in the CEP (Figs. 6 and 7). Development and extraction blocks have been designed and scheduled for the next three years using the geological model derived from the 3D HRSR survey.

## RECONCILING THE MODEL

Development tunnels in the South 6 Heading are accessing the Ralph Block coal reserves (Figs. 6 and 7). They have successfully negotiated the North Ridge, revealing its position, trend and size to be consistent with the seismic-derived model. The coal seam was less than 6 m thick locally on the North Ridge crest, as opposed to 6-9 m as modelled (Fig. 7). The difference is assumed to be due to the higher level of subjectivity in picking the base of seam reflection, which has a variable reflector due to thickening and thinning of the coal caused by relief on the immediately underlying surface on which the seam rests. Three development tunnels have now intercepted Fault "b" (Fig. 8) and have substantiated the geometry of this fault in terms of location, dip, and decrease in throw and swing in strike toward its western tip. Face drilling data from the developments have been modeled and compared to the seam roof model derived from the 3D time-structure map. The actual seam roof position agrees within  $\pm 2$  m.

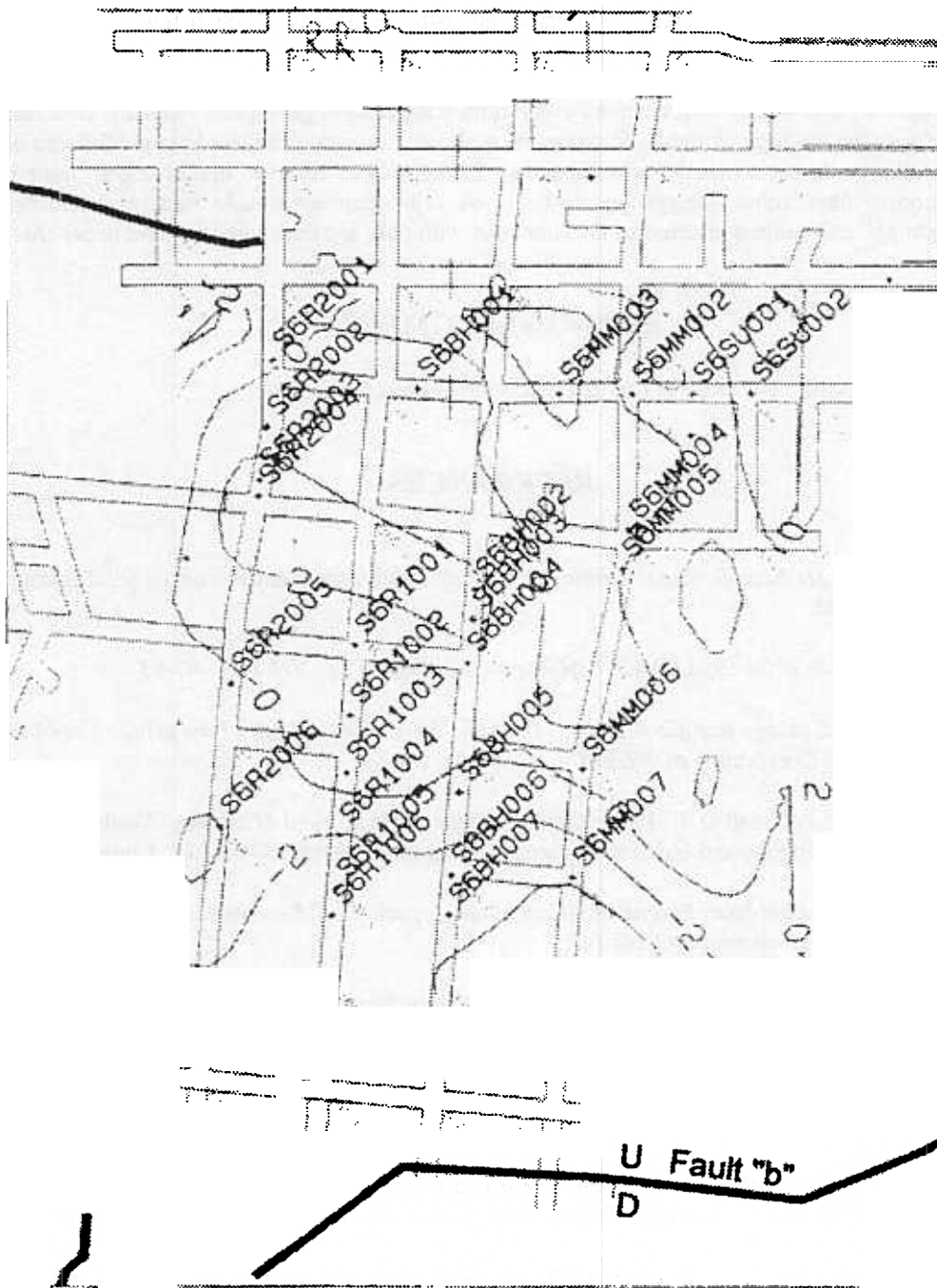
Although development of the Ralph 3D survey area is at an early stage, a reliability level in the order of 90% appears to have been achieved with the seam structure model. However, further development and observation is required to substantiate and quantify the reliability of the model, especially in respect to the base of the seam and the fault system.

## CONCLUSIONS

Since 1994, 2D and 3D high resolution seismic reflection techniques have been successfully applied to investigating the geometry and structure of the Kupakupa seam in Huntly Coalfield. These techniques, especially 3D HRSR, have major advantages over drillhole-based investigations for mine planning in structurally complicated coal deposits such as Huntly Coalfield.

2D HRSR is useful for planning along pre-determined alignments, such as mine development directions, but has some major limitations for defining structural trends and apparently does not fully resolve seam base. 3D HRSR yields detailed geometry models of the seam. The trend, location and nature of faults are very obvious and require minimal "interpretation". Faults have been traced out to the limit of resolvable offset, which is 2-3 metres. Basement ridges are evident on 2D lines as subtle drape folds on top of the seam, whereas in 3D datasets their severity and lateral extent are evident on time-structure maps and can be readily modeled and structure contoured once the time-domain data sets have been depth-converted.

Geological models with high reliability allow management of mining risks such as unplanned development costs, loss of reserves and low productivity. Other benefits, especially for "greenfield" deposits, include extraction method design (especially relevant in thick seams) and definitive land-use management. Reliable models of the seam structure also have potential to improve strata control strategies. For example, fault troughs and basement ridges are known to be poor coal mass and distressed coal situations requiring planned strata control measures to be implemented during development to ensure planned development and extraction rates are achievable, and tunnels are stable in the short-term.



**Fig. 8 – 3D model reconciliation over developed part of Ralph block**

An investigations technique which delivers a seam geometry model with a confidence level in the order of 90% is a major step forward in risk management for planning underground mines in the Huntly Coalfield. The turn-around time from acquisition to mine planning was in the order of 10-12 weeks.

HRSR techniques can be employed independent of the mining operation, well in advance of mine development. This allows mine planning, risk assessment and economic appraisal of new reserve blocks in existing mines, mine extensions and, indeed, new underground prospects prior to committing capital expenditure. Coal quality drilling can be targeted to

sample coal reserves which will be extracted, with improved cost-effectiveness through fewer holes and representative results.

A “stable” mine plan (i.e. one which is not altered every time a significant geological hazard is intercepted) has major potential cost benefits to the mining company. For example it allows coal quality scheduling and forward planning of run-of-mine blending scenarios to meet product specifications. In the area of reserves optimisation, mine plans based on reliable geology models allow mine management to focus on value-generating tasks such as production engineering, rather than “fire-fighting” and endless revision of the mine plan with only apparent improvement in benefits.

## ACKNOWLEDGMENTS

I wish to thank Solid Energy of New Zealand Ltd for permission to present this paper.

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