Geotechnical issues for multi-seam longwall panels

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Abstract

The design of longwall panel layout for multi-seam mining is a very important issue for mining districts where economic seams are in close proximity. Layout options for longwall panels relate to variations of vertical superposition maintaining a constant chain pillar location or offsetting the panels and undermining overlying chain pillars. A design process to assess the various layout options is discussed, together with the relevant issues related to chain pillar strength, subsidence and induced permeability within the overburden. The design process has utilised computer modelling of the caving process together with international experience to assess the various layouts.

The paper will discuss these issues with regard to a site study undertaken in the Hunter Valley under ACARP funding.

INTRODUCTION

Multi-seam longwall mining of seams in close proximity has not been widely practiced in Australia. There are mines at which multiple seams have been mined, however such sites commonly relate to a combination of bord and pillar mining, and later longwall mining. Examples of this are Kemira and Wyee. At these sites the pillars left in the bord and pillar mining in the upper seams had a significant impact on the gateroads in the lower seams during longwall extraction. The effect on the longwall face was less severe in most instances.

Longwall interaction was experienced at Pacific and Stockton Borehole collieries, where the mining of different seams in close proximity caused interaction and significant deformation of gateroads in the lower seam, due to dynamic stress redistributions caused by longwall extraction. In all these examples, the interburden was less than approximately 40 m.

The interaction of seams in close proximity is known in Australia, however there has been insufficient experience to generate layout guidelines. Overseas experience, typically that of the UK, is often used for conceptual planning of multiple seam longwall panels.

In general, the layout options are:

- vertical stacking; gateroad under gateroad
- indented stacking; lower gateroad offset under the overlying goaf
- offset panels; gateroads located under goaf well away from overlying gateroads.

These layouts are presented in Figure 1 (over).

Layouts i and ii either fix the future panel widths to be the same or less for successive seams mined.

Experience in the UK suggests that vertical stacking is often unsuccessful and that indented panels are more successful. In fact, indented panels have varied experience and the success of such layouts is often reliant on competent roof and floor strata which can accommodate the stress redistributions in this location.

The typical concept of multi-seam layout is to vertically indent; the amount of indentation is dependent on the geology and strength characteristics of the strata surrounding the seam.

The use of indentation has significant consequences for multiple seams (e.g. four) whereby the panel widths of the lower two seams may be rendered uneconomic. Another issue is the application of this to multiple roadway panels as practiced in Australia and the US. UK experience relates mostly to single entry mining and as such the application to twin entry panels requires either cut-throughs to be located under the overlying pillars or two sets of roadways indented. This is presented in Figure 2.

Review of experience in the UK indicates that offset panels have been commonly used and have been largely successful. Experience has been obtained for panels mined under and above previously mined seams. The advantage of this layout is that multiple roadway panels can be used and successive panels are not restricted in width. The economics of such layouts appears to be significantly better than those of the stacked and indented layouts. The disadvantage is that pillar interaction occurs on the longwall face.

In overview, the strength properties of the strata, the stress redistributions, the interburden thickness, subsidence and mine economics all have a significant impact on the layout options utilised.

The background experience obtained provided a general framework in which to undertake a design overview, but did not provide sufficient comfort to allow its sole use for feasibility study. Computer modelling of a number of layout options was undertaken to provide another layer of information to assist in the design feasibility. Modelling has progressed to the point where realistic simulation of caving and fracture within the strata can be obtained.

Figure 1 Sections of stacked and offset layouts

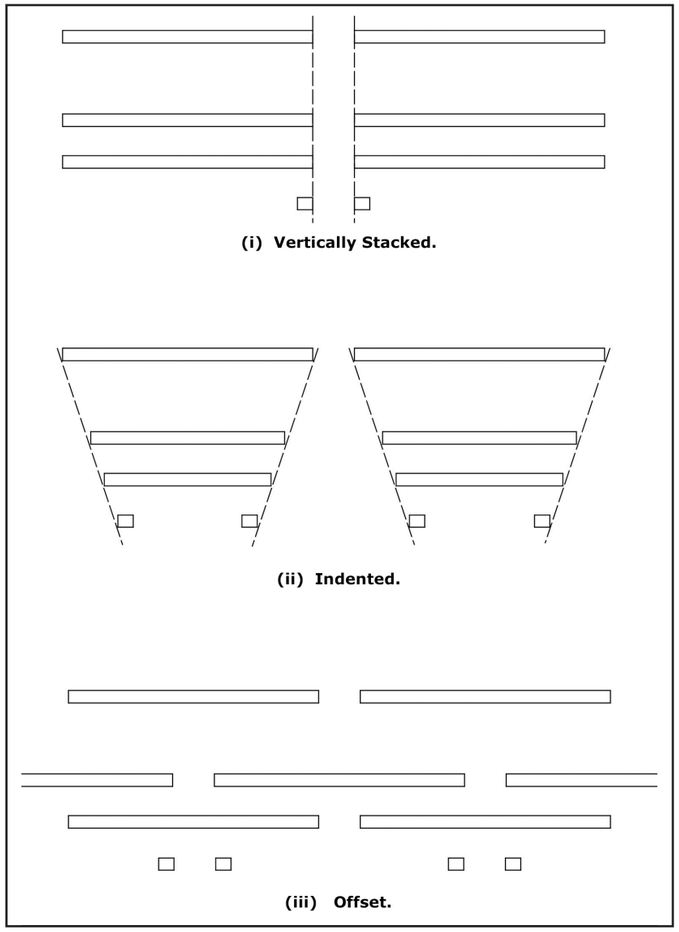
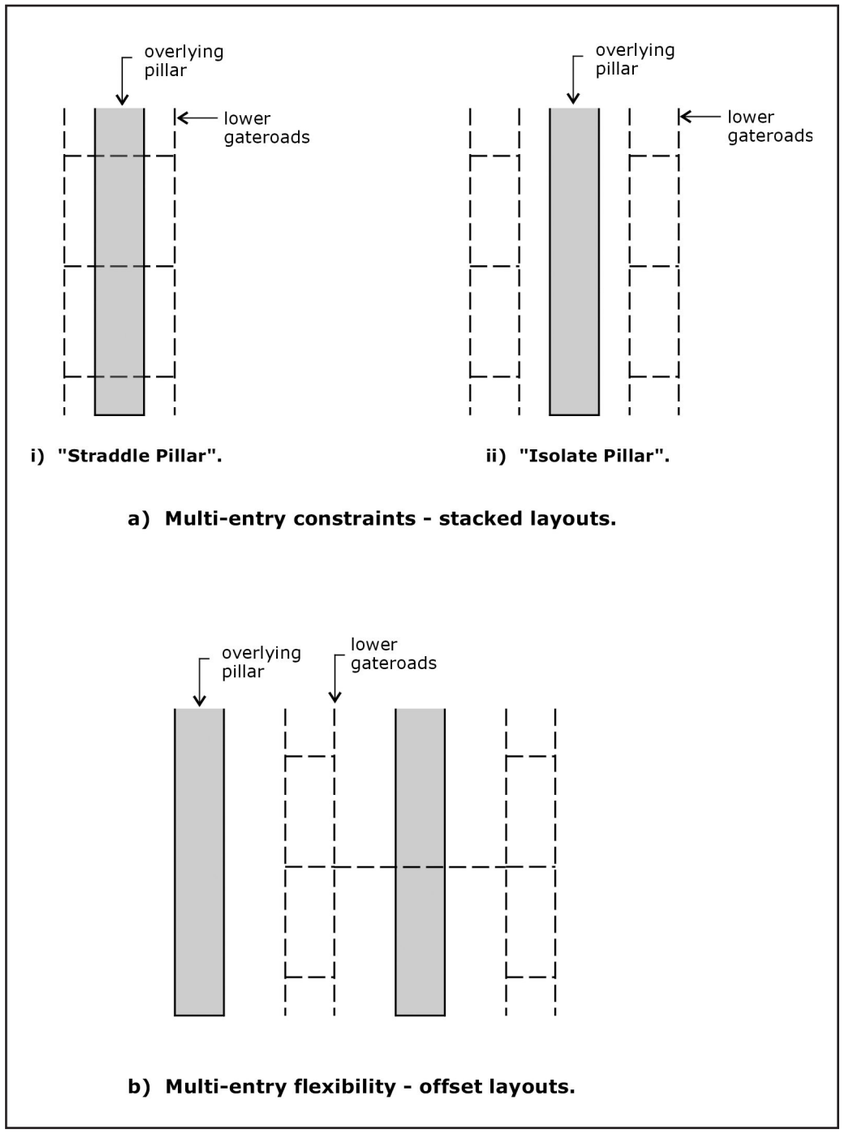


Figure 2 Implications of layouts on multi-entry panels



Past ACARP projects have demonstrated the validity of this method when appropriately used.

The application of computer modelling to the Beltana site in the Hunter Valley was done as a field site within an ACARP project and is discussed below.

MODELLING OF MULTIPLE SEAM LAYOUTS

The modelling has utilised two-dimensional sections using FLAC code. The rock failure process and goaf reconsolidation are controlled routines developed by SCT Operations and found to simulate rock behaviour. Comparison of actual behaviour and modelled prediction has been conducted on many sites and the results found to provide a realistic simulation of the actual ground response on various scales from roadways to multiple longwall panels. Water pressure and fluid flow is coupled into the models.

The overburden graphic section is presented in Figure 3 and the UCS section as modelled is presented in Figure 4.

The approach was to mine each seam in descending order and assess the impacts for various stacking and offset layouts.

The rock fracture distribution for a stacked and offset layout is presented in Figure 5. The vertical stresses are presented in Figure 6. The shear stresses under the same geometry is presented in Figure 7.

The style of subsidence created by the geometry is presented in Figure 8.

The results indicate a number of issues to be assessed in the overall design process. These are:

1. It is possible to have strata failure above and below chain pillars. This is not unexpected as past work has indicated this and results of microseismic monitoring commonly indicate rock failure above and below chain pillars; the overburden above chain pillars is therefore not an intact column of rock, but a potentially fractured zone of rock depending on the strata strength properties.
2. Surface strain and tilts appear to be greater for the stacked arrays, particularly the vertical stacking array.
3. Pillar loads and goaf loading appear to re-establish close to that of the initial formation after undermining in the offset array system.
4. The subsidence for multiple panels is additive and influenced by the strata and interburden thickness. Subsidence in addition to that calculated from single seams may occur for multiple seams that are due to pillar and goaf readjustments during undermining.

The stress redistributions below the mining panels have a significant impact on the performance of roadways driven for the lower panels. The performance of a multiseam layout will be significantly influenced by the stability and utility of the gateroads.

The results indicate that shear stresses developed about extraction areas play a significant role in the performance of roadways. The shear stress acts on bedding planes and pre-existing fractures and can significantly destabilise a roadway. The effect can be seen in Figure 7, and in more detail in Figure 9, which shows the shear stress lobes extending under the goaf and pillars. The effect of mining is to add a shear stress component to bedding. An example of the impact is presented in Figure 10, which shows the shear strength of typical strata in comparison with the shear stresses noted. The results indicate that weak to moderate strength bedding planes would be affected depending on the location of the roadway.

One cannot necessarily isolate the effect of one stress component alone in such complex geometries. It was found most useful to model the roadway behaviour under a range of stressfields typical of various locations under panels. The seam chosen was the Glen Munro seam at 300 m depth. The panel interburden was approximately 30 m.

Figure 3 Geological Log

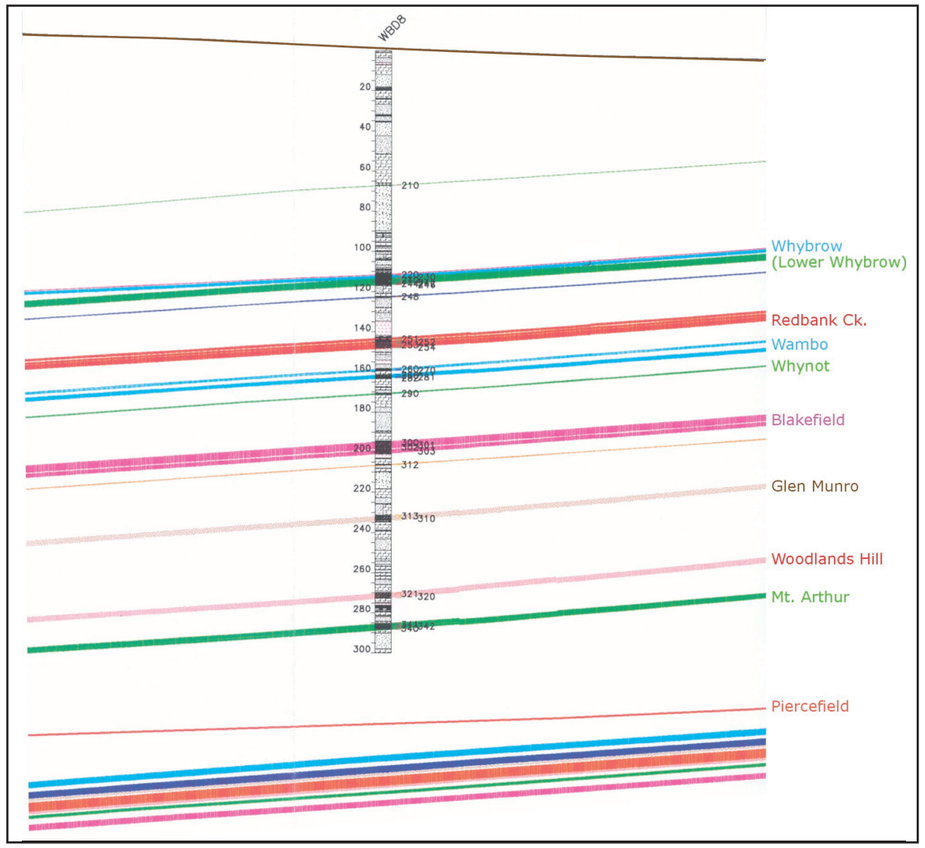


Figure 4 UCS of strata section modelled

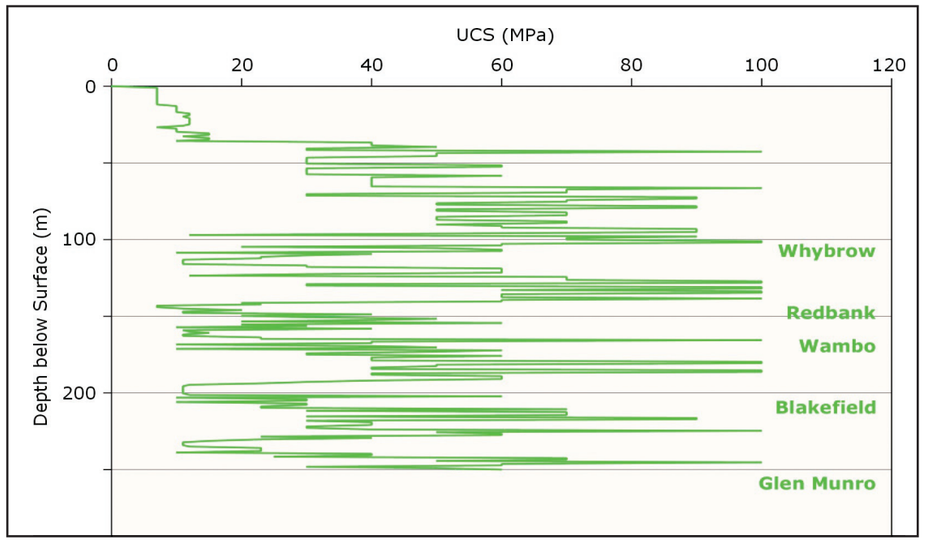
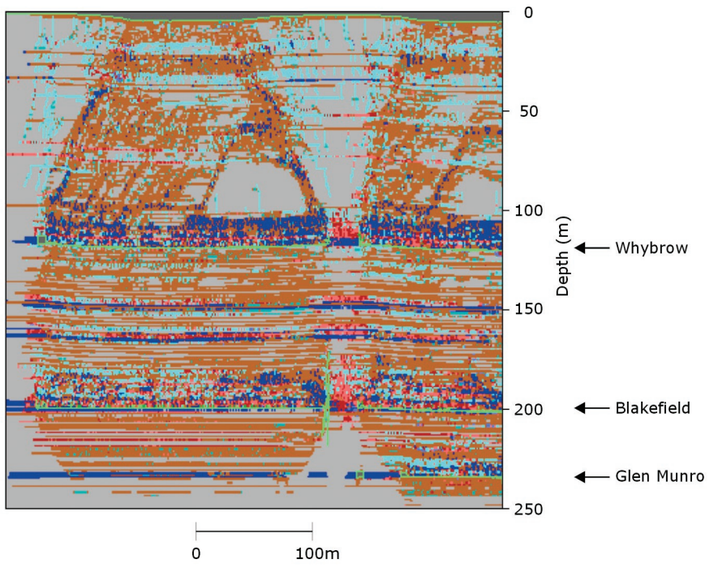
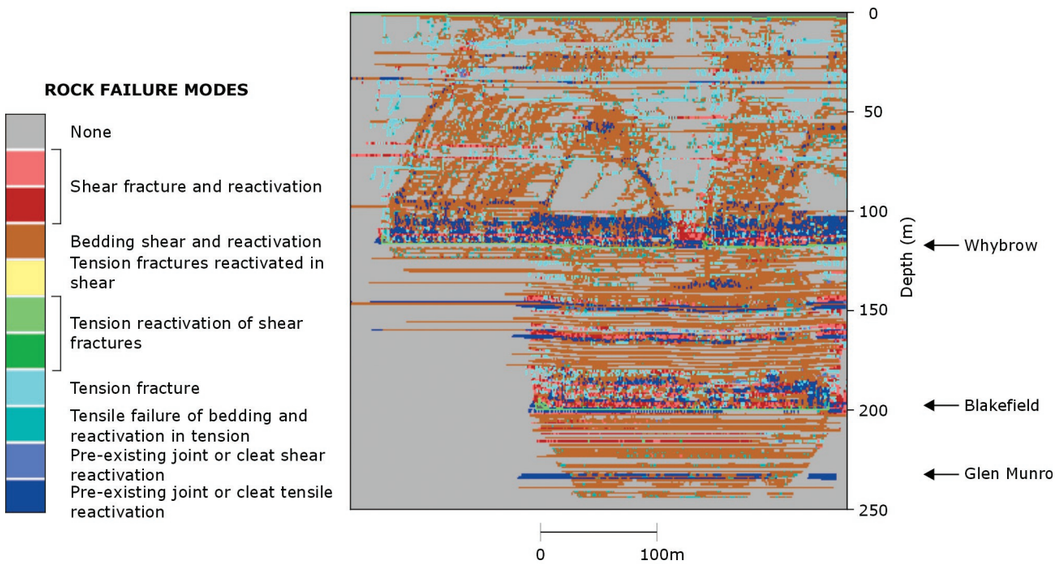


Figure 5 Rock failure geometry for a stacked and offset layout

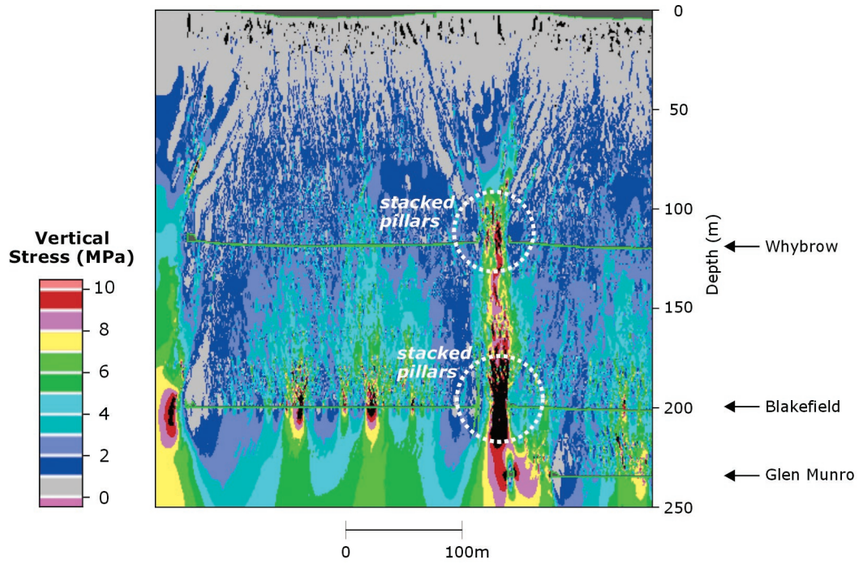


a) Stacked Blakefield and indented Glen Munro geometry.

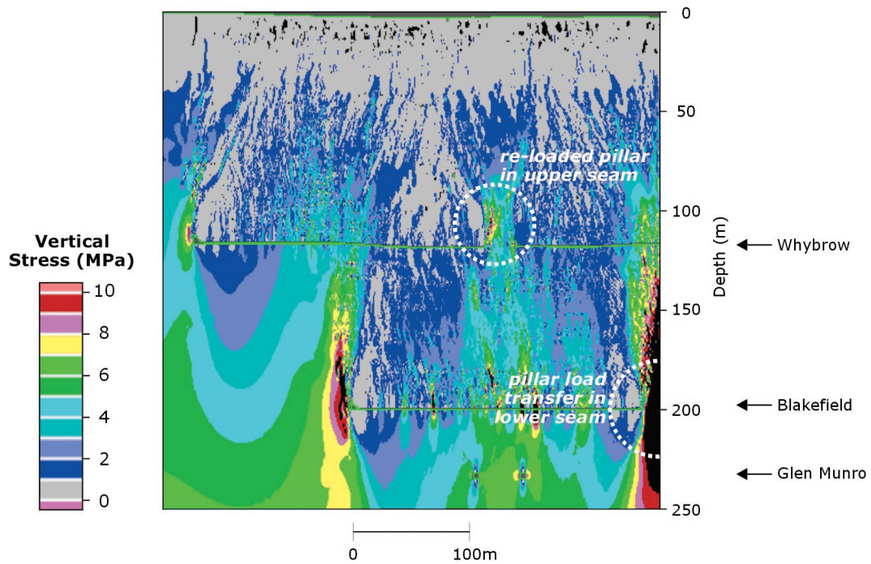


b) Offset geometry.

Figure 6 Vertical stresses for a stacked and offset layout

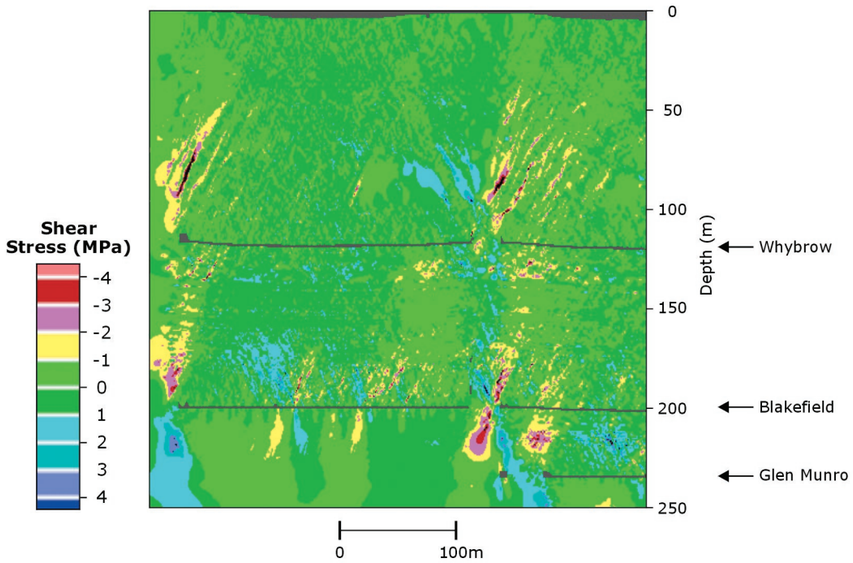


a) Stacked Blakefield and indented Glen Munro geometry.

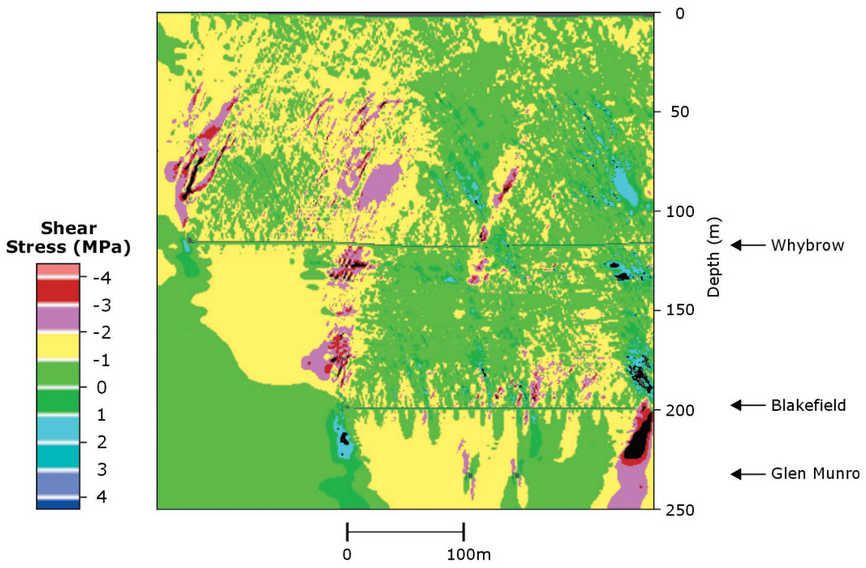


b) Offset geometry.

Figure 7 Sheer stresses for a stacked and offset layout



a) Stacked Blakefield and indented Glen Munro geometry.



b) Offset geometry.

Figure 8 Subsidence for a stacked aray, offset array and indented Glen Munro seam

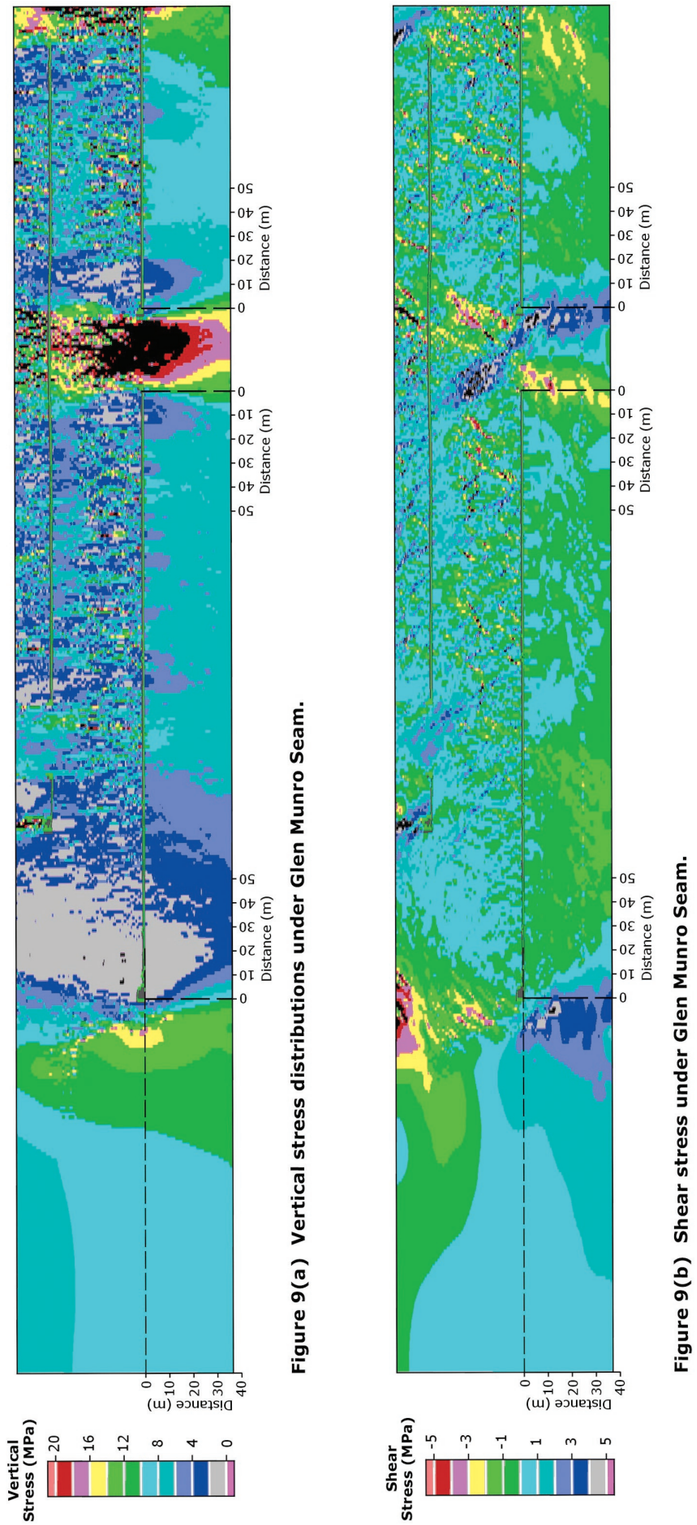
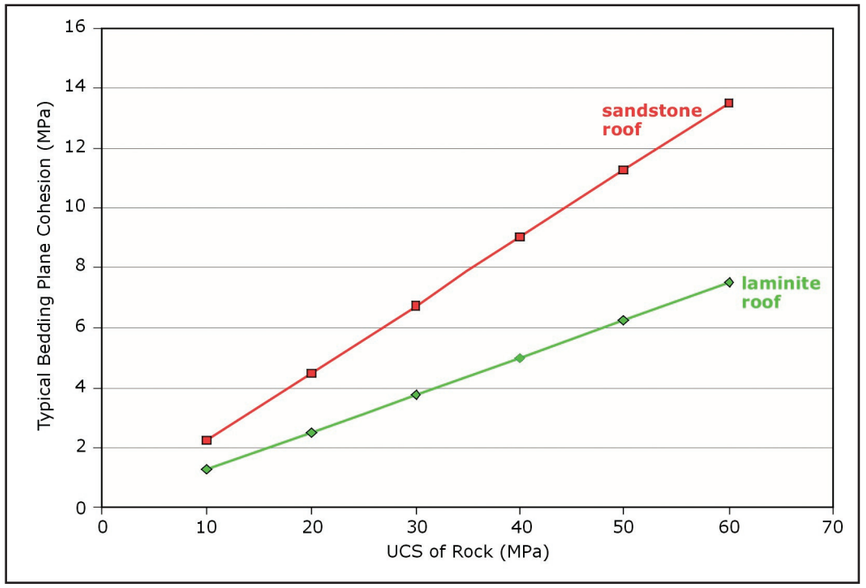


Figure 9 Stress directions under seams to be extracted in closest proximity

Figure 9(a) Vertical stress distributions under Glen Munro Seam.

Figure 9(b) Shear stress under Glen Munro Seam.

Figure 10 Bedding plane cohesion for various rock types



The examples were:

- virgin driveage
- under goaf (offset)
- under pillar edge (vertically stacked)
- indented under goaf edge.

The stress conditions were presented in Table 1 and the results of a number of examples are presented in Figure 11. The results indicate that bedding planes are activated causing floor heave and biased roof failure in the stacked/indented arrays. The offset array having a roadway under goaf was the best location for roadway stability.

Table 1 Stress changes under overworked areas Glen Munro seam

In situ	Vertical 8.25; Shear 0.0; Horizontal 10 (40GPa)
Goaf edge	Vertical +15%; Shear 2-3; Horizontal +5%
Pillar edge	Vertical +51%; Shear 3.4-4; Horizontal +20%
Under goaf	Vertical -3%; Shear <0.5; Horizontal -10%

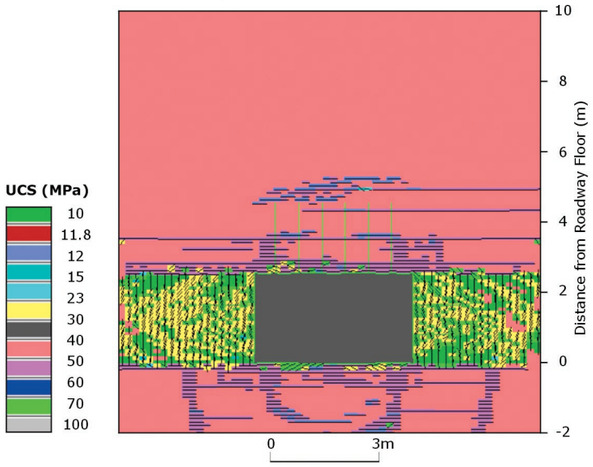
This example explains much of the experience noted in the UK, in particular whereby the success of roadways located close to the goaf edges is significantly dependent on the roof and floor material. UK experience often displayed the following situations for roadway indented below goaf edges:

- Conditions may be acceptable until a change of geology occurs in a roadway.
- Conditions in a roadway were different to expectations, as the decision of how much to indent was taken from a site with a stronger geology.

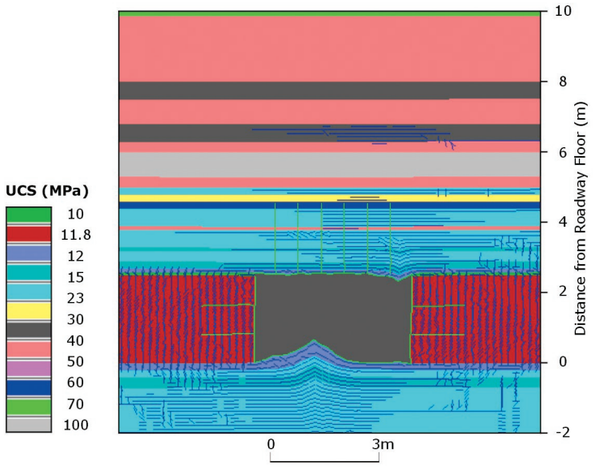
CONCLUSIONS

Additional work was undertaken in the project to assess the effect of overcutting chain pillars to reduce the stress concentrations in lower seams. The results of this work will be discussed in the final report, however the procedure was found to have logistical limitations when applied at a number of sites.

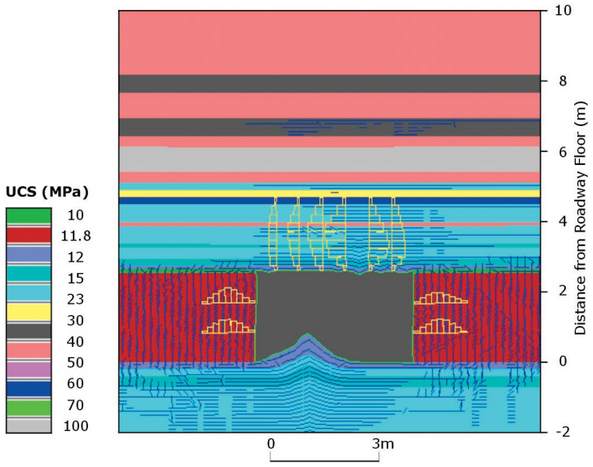
Figure 11 Rock failure zones about roadways driven at various locations



a) Virgin and offset layout.



b) Under pillar.



c) Under goaf edge.

In multi-entry mining as practiced in Australia, the results of this study indicate that roadway stability is optimised for offset panels. The use of indented layouts may provide variable success dependent on local geological factors in the gateroads, however the drivage of cut-throughs directly under overlying pillars is unlikely to provide optimum conditions.

These panels also provide greatest flexibility in longwall panel width for progressive seams and do not provide an economic constraint of seams in close proximity.

The issue to be further investigated is the performance of the longwall face under chain pillars. This is currently being assessed by modelling, however experience overseas and also local experience suggests that conditions are manageable with appropriate longwall equipment and operating methods. It appears preferable to put priority onto gateroad stability rather than longwall loading effects.

This paper aimed to highlight issues for design and to provide an approach which can be applied to assess the design constraints or opportunities within different geological domains.

General guidelines for design will be presented in more detail within the final report.