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Impact of Vertical Stress on Roadway Conditions at Dartbrook Mine

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ABSTRACT

A program of stress change and roadway deformation monitoring was undertaken to measure the forward abutment load distribution about a retreating longwall panel at Dartbrook Mine. The results of this monitoring allow roadway conditions observed at various stages of mining to be ranked according to the estimated vertical stress they have experienced. This ranking also provides a means to predict and visualise future roadway conditions at various stages of mining. This paper presents the results of the monitoring and describes the approach developed to predict future roadway conditions.

The monitoring results show the vertical stress distribution associated with the front abutment from a longwall goaf decreases exponentially away from the goaf edge. The vertical stress distribution peaks at the goaf edge at 5 to 6 MPa stress increase and decreases to 1 MPa within 50 m becoming imperceptible beyond 100 m. By scaling this measured distribution to reflect the loading environment, the vertical stress can be estimated for different overburden depths and different stages of mining. Photographs of roadway conditions at particular vertical stress levels provide a way to visualise roadway conditions at various stages of mining in the future.

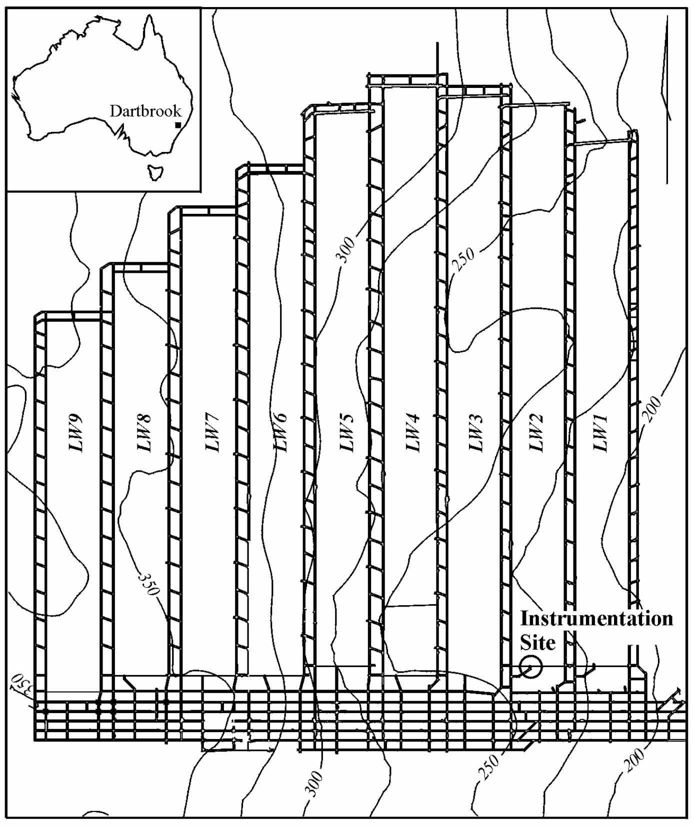


Figure 1(a) **Plan of Dartbrook Mine showing location of instrumentation site and overburden contours.**

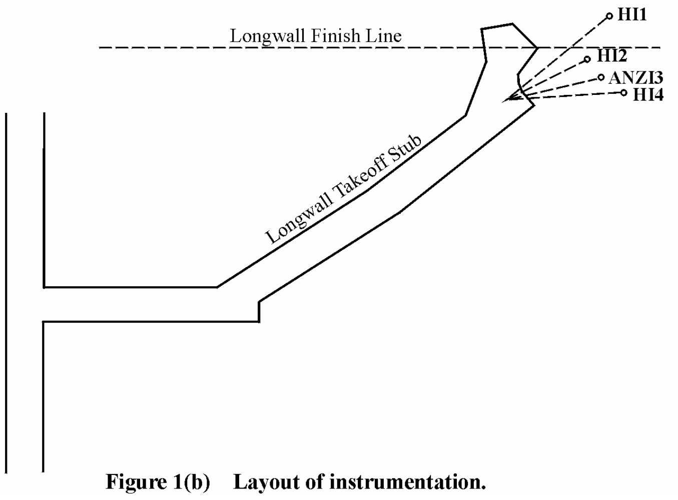


Figure 1(b) **Layout of instrumentation.**

INTRODUCTION

Figure 1 shows a plan of Dartbrook Mine. The mine is currently working a 4m section near the bottom of the 25m thick combined Wynn / Bayswater / Broonie Seam. Longwall panels 200m wide are extracted from north to south. The overburden depth generally increases toward the west ranging from 200 m in Longwall 1 to over 400 m by Longwall 9.

The barrier pillars at the southern end of the longwall panels are designed to protect the main headings from the influence of the longwall forward abutment. A successful program of stress change and roadway deformation monitoring was undertaken at the outbye end of Longwall 2 to measure the longwall forward abutment and its influence on adjacent roadways to assist in reducing the width of the barrier pillar.

At Dartbrook, the stress environment and strata conditions are somewhat unusual in terms of coal mining experience on the east coast of Australia. In this thick seam environment, the vertical stress is the major stress and the strata surrounding the roadway is entirely coal material and therefore relatively homogeneous (Enever & Doyle 1996). This in situ stress regime is unusual in Eastern Australia where horizontal stresses tend to be more dominant in terms of roadway behaviour.

At Dartbrook, roadway deterioration is primarily a function of vertical stress overloading the rib coal. Roof deterioration is virtually non-existent. The dominance of vertical stress provides an opportunity to predict roadway conditions using vertical stress alone.

SITE DESCRIPTION

A plan of the monitoring site and the layout of the instrumentation within the takeoff stub at the end of Longwall 2 are shown in the inset of Figure 1. The depth of overburden at the site is 240 m. The average overburden density is 2200 kg/m^3 due to the high proportion of coal, so the initial background vertical stress at the site is approximately 5 MPa.

An array of four stress change monitoring instruments was installed from the takeoff stub into the coal barrier ahead of (and over) the finish line of the face. Three CSIRO HI stresscells (Worotnicki & Walton 1977) and one ANZI stresscell (Mills 1997) were installed. These instruments measured a profile of stress changes in three dimensions ahead of the face.

RESULTS

Figure 2 shows a summary of the vertical component of the stress monitoring results. The results indicate an exponential distribution of vertical abutment stress away from the goaf edge. The vertical stress peaks at about 11 MPa at the goaf edge (6 MPa increase plus 5 MPa background). The vertical stress change is less than 1 MPa at 50 m from the goaf edge and is imperceptible beyond about 100 m from the goaf edge.

The area under the vertical stress curve represents the total abutment load. The vertical stress distribution measured indicates a total load of approximately 140 (120-200) MN/m.

The full side abutment load is estimated from the weight of material contained within the triangle shown in Figure 3. At 240 m depth and an overburden density of 2200 kg/m^3, this total load is approximately 350 MN/m.

In the face area, the overburden weight can be distributed onto the side abutment and onto the solid coal ahead of the face. A balance of the weight distributed in this area gives an estimate of the total load that would be expected on the forward abutment. At the location of the stress monitoring site, the abutment load is estimated to be in the range 135 to 200 MN/m. The measured load fits within this range and gives confidence in the approach used to estimate vertical abutment load from redistribution of overburden weight.

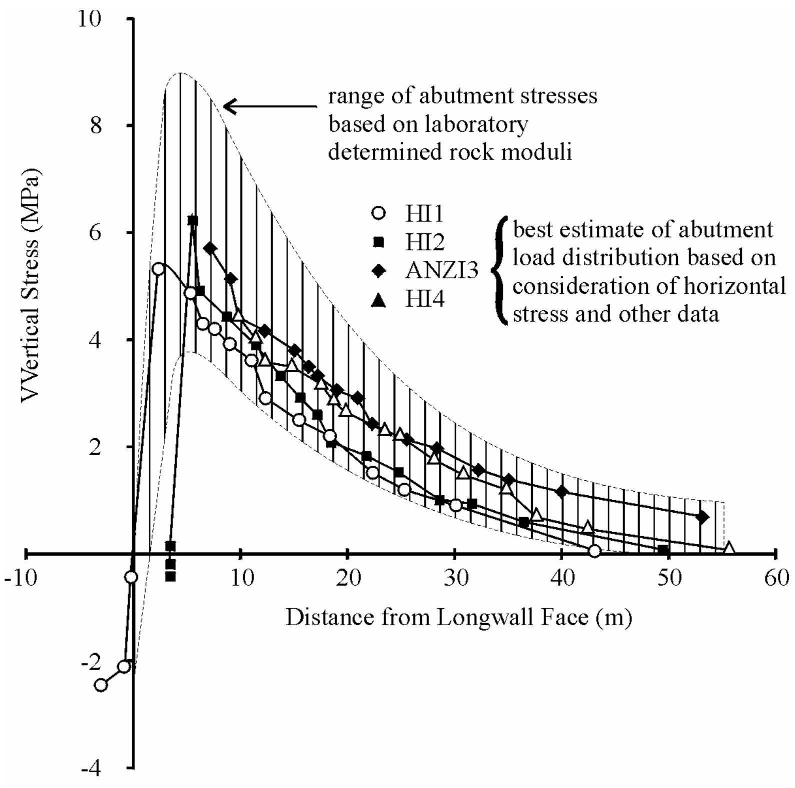


Figure 2 Results of abutment stress monitoring.

Rib deterioration was observed in the roadways adjacent to the end of Longwall 2 when the vertical stress increased by 1 to 2 MPa. This observation indicates that the in situ, unconfined strength of the Wynn seam coal is in the range 6 to 7 MPa. The more general observation that rib deterioration occurs routinely on development when the overburden depth increases beyond about 240 to 280 m is also consistent with in situ coal strength of approximately 6 MPa.

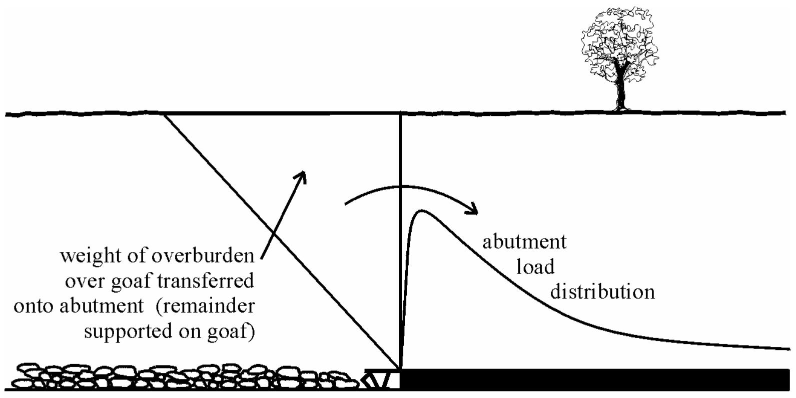


Figure 3 Overburden weight transfer.

ESTIMATION OF VERTICAL STRESS AT VARIOUS STAGES OF MINING

Vertical stress is a function of overburden depth and abutment loads that result from longwall extraction. On development, the vertical stress is primarily a function of overburden depth. The vertical stress increases during the various stages of longwall extraction when overburden weight is redistributed from above the goaf.

During longwall extraction, the various roadways experience different levels of loading depending on their location relative to the longwall. A maingate roadway experiences a peak vertical stress at the corner of the longwall face. At this time, the roadway adjacent to the maingate experiences a smaller vertical stress increase. The stress increases further as the longwall moves on and full side abutment loading conditions develop. During extraction of the next longwall (the roadway becomes a tailgate), the abutment load from this next panel is added to the side abutment load from the previous panel and reaches a peak at the tailgate corner of the longwall face. The loading at the tailgate corner is typically the highest loading experienced by an underground roadway.

Increasing chain pillar size provides a means to distance roadways from the effects of an adjacent goaf and thereby reduce the vertical stress they experience. However, as overburden depth increases, this strategy requires very large chain pillars to be effective. Alternative reinforcement strategies are required.

At Dartbrook, the overburden depth increases with each panel mined and a range of pillar sizes have been utilised. Roadways have therefore experienced a wide range of vertical stress conditions. Their response to this range of stresses has been mapped. This experience provides a basis to predict roadway behaviour and design effective reinforcement strategies in future panels.

Estimates of Vertical Loading

Figure 4 shows the vertical stress experienced by roadways at four stages:

- pre-mining
- maingate corner of longwall face
- side abutment loading for the roadway adjacent to the maingate
- tailgate corner of the longwall face .

In each case, the contour value represents the maximum stress that would be experienced for the particular stage of mining for that particular roadway. For instance, Figure 4b shows the maximum vertical stress experienced at the maingate corner of each longwall face. The contoured values are only relevant to the maingate roadway. Figure 4c shows the maximum vertical stress experienced under side abutment loading conditions and is only relevant to the roadway adjacent to the maingate. Figure 4d shows the vertical stress experienced by the tailgate roadway under loading conditions from two adjacent longwalls.

Figure 4a shows the pre-mining vertical stress increasing with depth toward the west.

Figure 4b shows vertical stress experienced at the maingate corner of Longwall 1 was approximately 10 MPa for the full length of the panel. As overburden depth increases this will increase to 15 MPa by Longwall 9.

Figure 4c shows that roadway adjacent to the maingate experiences a range of vertical stress from 8 MPa in Longwall 1 to greater than 14 MPa by Longwall 9.

Figure 4d shows that the vertical stress experienced at the tailgate corner was 15 MPa for Longwall 2 and will be 24 MPa by Longwall 9. The wider chain pillar between Longwall 4 and 5 has the effect of reducing the vertical stress in the tailgate of Longwall 5 to less than 20 MPa. From Longwall 6 onward, vertical stress at the tailgate end of the longwall face is consistently higher than 22 MPa.

Experience of Roadway Behaviour

The roadway conditions experienced at various stress levels are shown as a series of photographs. Figure 5a shows roadway conditions typically experienced at less than 200m depth of overburden when there is no inclination of the vertical stress. The rib and roof conditions are excellent.

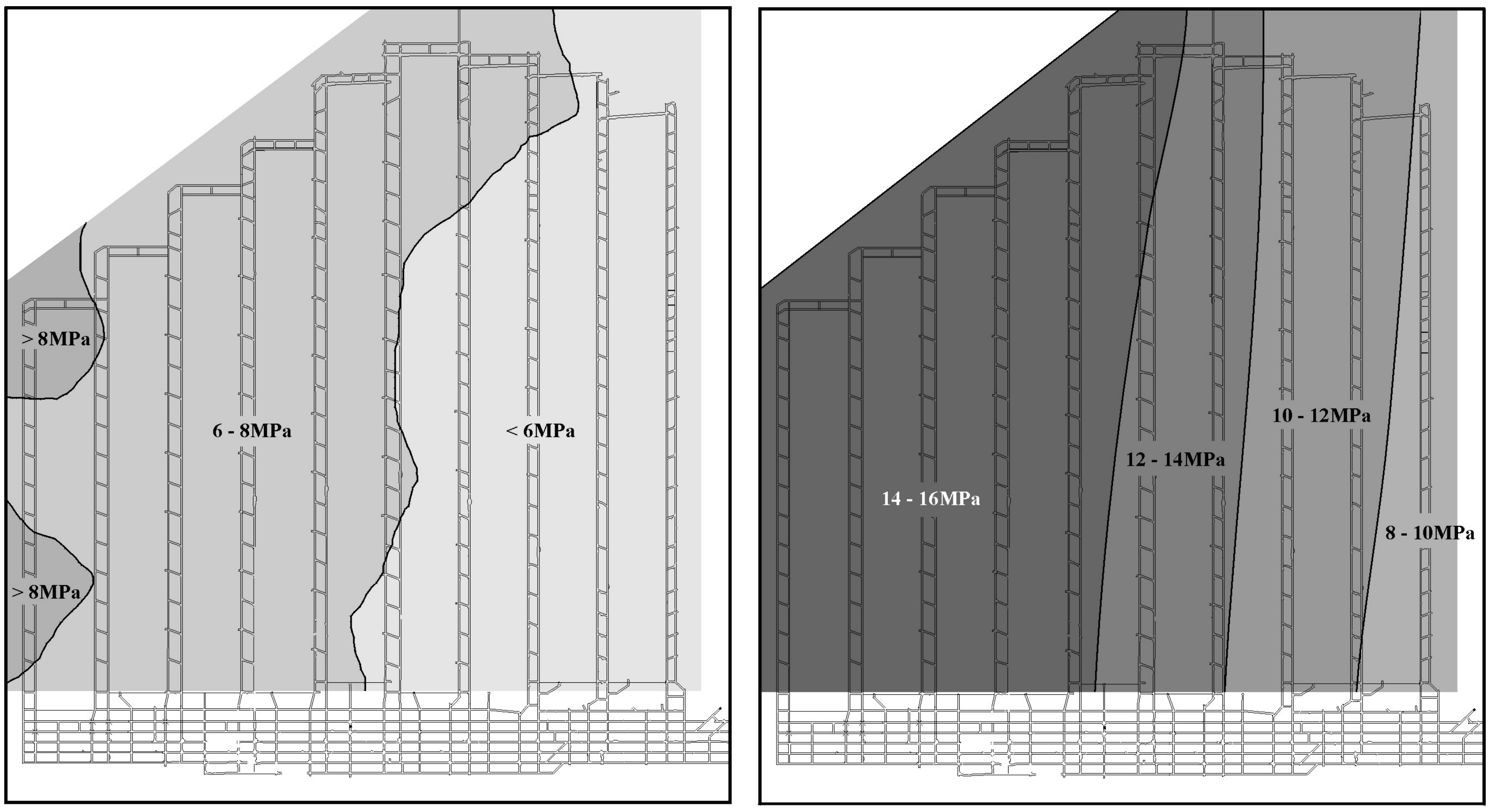
When the vertical stress increases to above 5 MPa, biased rib deterioration (top corner on one side and bottom corner on the other side) begins to become apparent in areas where the vertical stress is inclined slightly from vertical as shown in Figure 5b.

Figure 5c shows the roadway conditions when the vertical stress is approximately 10 MPa. There are consistently high levels of rib deterioration, but the roadways remain serviceable provided adequate rib support has been provided. There is no sign of roof deterioration.

Figure 5d shows the roadway conditions when the vertical stress is approximately 15 MPa. The ribs are beginning to fail as large blocks of sufficient size to make the roadway unsuitable for regular travel. There is still no sign of roof deterioration although some of the straps show signs of shortening, by buckling away from the roof.

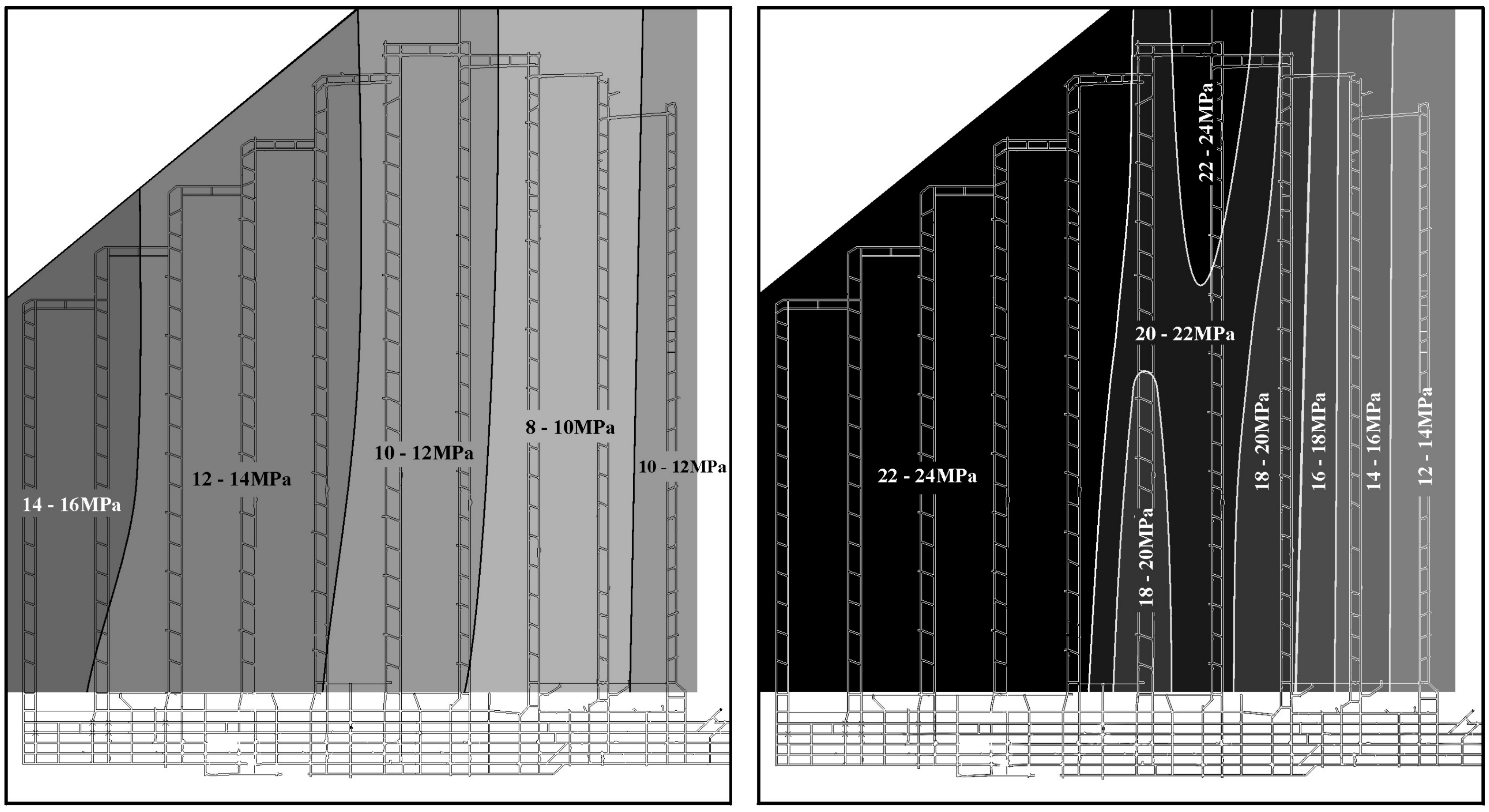
Figure 5e shows the roadway conditions when the vertical stress is approximately 20 MPa. The ribs are broken and rotate in large blocks out into the roadway. Under these conditions, the roadway is barely serviceable and significant secondary support is required.

Above 20 MPa, the Poisson’s ratio effect of the increase in vertical stress is in the range 5 to 6 MPa. When added to the pre-existing horizontal stress, the total horizontal stress begins to exceed the in situ strength of the coal and roof failure becomes an issue.



a) Pre-mining vertical stress on all roadways.

b) Vertical stress at maingate corner of longwall panel.



c) Vertical stress on the roadway next to the maingate under full side abutment loading.

d) Vertical stress at tailgate corner of longwall panel.

LEGEND

▨	< 6MPa	▨	8 - 10MPa	▨	12 - 14MPa	▨	16 - 18MPa	▨	20 - 22MPa
▨	6 - 8MPa	▨	10 - 12MPa	▨	14 - 16MPa	▨	18 - 20MPa	■	22 - 24MPa

Figure 4 Vertical stress estimated at four stages of mining for specific roadways.

Figure 5(a) Excellent roadway conditions when major stress is vertical and less than 6-7MPa.

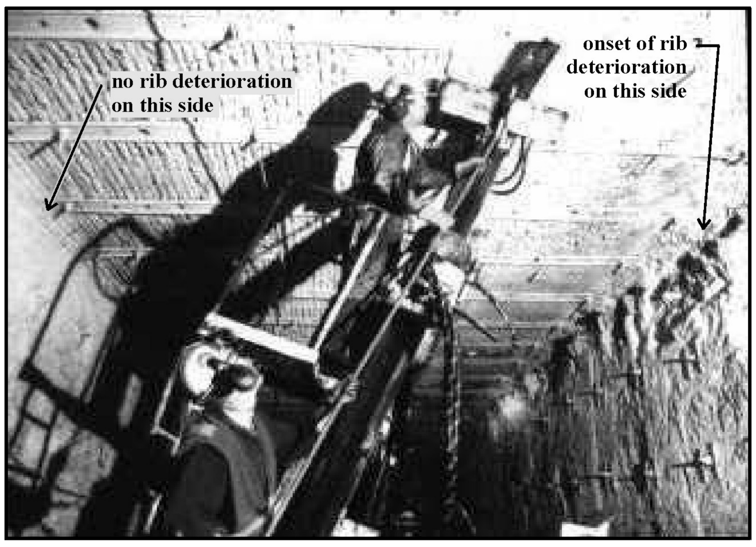


Figure 5(b) Onset of biased rib deterioration above approximately 5MPa vertical stress.

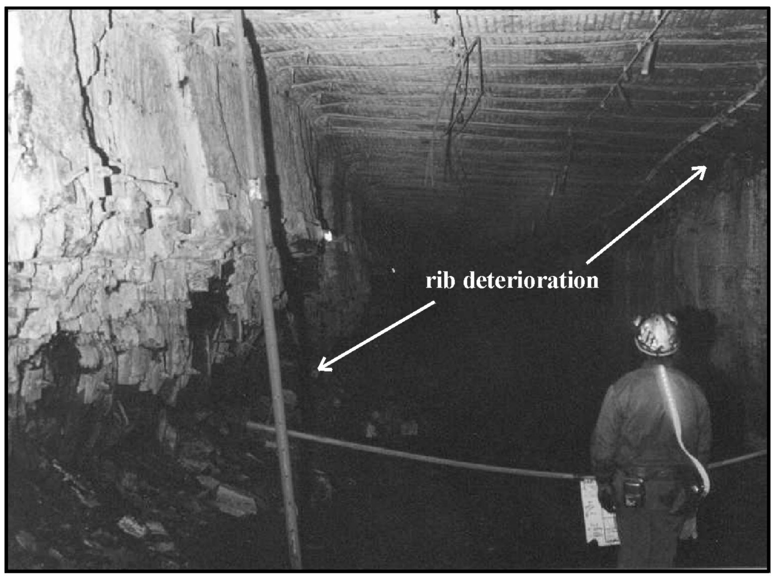


Figure 5(c) Biased rib deterioration worsens at 8-12MPa vertical stress.

CONCLUSIONS

The monitoring results show the vertical stress distribution associated with the front abutment peaks at 5 to 6 MPa stress increase at the goaf edge, and decreases exponentially away from the goaf edge to be barely perceptible beyond 100 m.

Figure 5(d) Rib deterioration threatens serviceability of roadway as a travel road above 15MPa vertical stress.

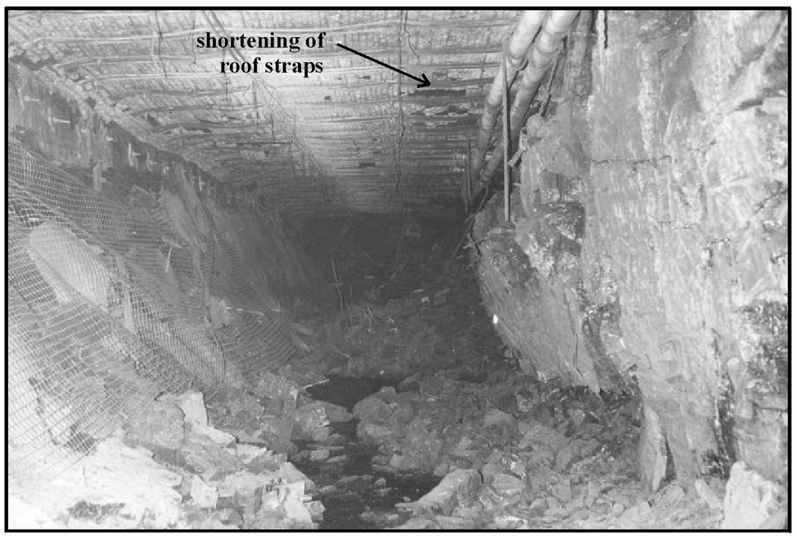


Figure 5(e) Roadway conditions are severe and potential for roof falls becomes an issue above 20MPa vertical stress.

The particular stress conditions at Dartbrook allow roadway conditions to be estimated in future panels on the basis of past experience. The vertical stress is estimated, using the measured distribution, as a function of overburden depth and distance from the goaf edge for each stage of mining. A scale of photographic records of previous roadway behaviour under estimated vertical stress conditions can then be used to visualise likely roadway behaviour in future panels at various stages of mining.

Dartbrook Mine now has available a method that allows an estimation of future roadway conditions on the basis of past experience and the design of appropriate reinforcement strategies to combat the anticipated conditions.

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