Application of Computer Modelling in the Understanding of Subsidence Movements

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SUMMARY

Computer modelling is being used to simulate rock fracture, caving and stress redistribution about longwall panels with increasing confidence. The models are being assessed against field monitoring and have significantly increased the understanding of caving mechanics within the overburden.

The modelling supports the concept that the ground subsides from the seam and progresses upwards and as such subsidence is the end point in a failure pathway within the overburden. The nature of the strata, in situ stresses and the mining geometry will influence the subsidence. The nature of the fractures created and the enhanced permeability will influence the interaction of mining with aquifers and surface water.

The results from various models indicates that:

i. the fracture geometry in the overburden is variable on the basis of the rock properties;
ii. rock failure may occur outside the panel boundary as a result of the stress redistribution about the panel;
iii. bedding planes may shear well outside (100m +) the panel boundaries and allow significant horizontal movement to occur within the overburden,
iv. rock fracture may occur above and below chain pillars which may locally modify the subsidence characteristics.

1. INTRODUCTION

Computer modelling is being used to simulate rock fracture, caving and stress redistribution about longwall panels with increasing confidence. The models are being assessed against field monitoring and have significantly increased the understanding of caving mechanics within the overburden.

In general, the models have been intended to assess longwall caving issues, however their application extends to ground subsidence, overburden permeability and water inflow.

The aim of this paper is to discuss the modelling approach and some examples of its application to subsidence and environmental issues.

2. COMPUTER MODELLING APPROACH

SCT Operations has been developing the capability to undertake computer simulations of strata caving and the interaction of longwall supports within a site-specific geological setting. This capability has been developed from inhouse

R&D and from collaboration with CSIRO within three interrelated ACARP Projects researching longwall geomechanics.

The model is two-dimensional and represents a longitudinal slice along the central zone of the longwall panel. Three dimensional effects about the gate ends are not represented in this model, however field monitoring indicates that the central section of the longwall panel is represented very well, particularly for panels which are significantly wider than deep (e.g. supercritical width panels). The code used in the model is FLAC and uses a coupled rock failure and fluid flow system to simulate the behaviour of the strata and fluid pressure/flow effects. The rock failure and permeability routines have been developed and more realistically represent the rock fracture mechanics than is available in the standard codes. Rock failure is based on Mohr-Coulomb criteria relevant to the confining conditions within the ground. Permeability in the horizontal and vertical planes is determined on the basis of the confining stress normal to the flow plane. The permeability of the intact coal increases with confining pressure on the basis of testing conducted by CSIRO. The permeability of fractured coal has been defined on the basis of confining stress and the fractured state.

Computer models are developed on the basis of detailed geotechnical testing of strata properties. Detailed models of the geology are necessary to obtain a satisfactory simulation of the rock failure mechanics. Definition of the rock intact and post failure strengths, stiffness, in situ stresses, permeability and bedding plane characteristics are key factors to be quantified.

The model simulates rock fracture and stores the orientation of the fractures. Shear fracture, tension fracture of the rock, bedding plane shear and tension fracture of bedding is determined in the simulation. The stability of pre existing jointing, faults or cleat is also addressed in the simulations where appropriate.

Longwall supports are simulated with a hydraulic set and yield function. The support pressure is transferred into the strata via a canopy and base structure, as is the actual case. The support pressure and the canopy distance to the face can be varied to assess these and other effects as required.

The model simulates the mining process by progressively excavating approximately 1m shears, allowing caving and then excavating the next shear and advancing the face supports. Ground movement, rock fracture zones, water pressure, longwall support load/convergence and abutment stress distributions are determined and recorded for each "shear" as the longwall retreats. A movie of each mining shear is recorded to show the progressive rock fracture, stresses and support behaviour.

Ground displacements, rock fracture and stress redistributions can be assessed within various rock units and geometries about the extraction panel.

3. EXAMPLES OF SIMULATIONS AND VALIDATION

The approach is to develop a model of the strata and then excavate the panel progressively. An example showing the geology and the resultant fracture mode within the overburden for one excavation geometry is presented in Figure 1 and 2. The results from various models indicates that:

i. the fracture geometry is variable on the basis of the rock properties ;

ii. rock failure may occur outside the panel boundary as a result of the stress redistribution about the panel;

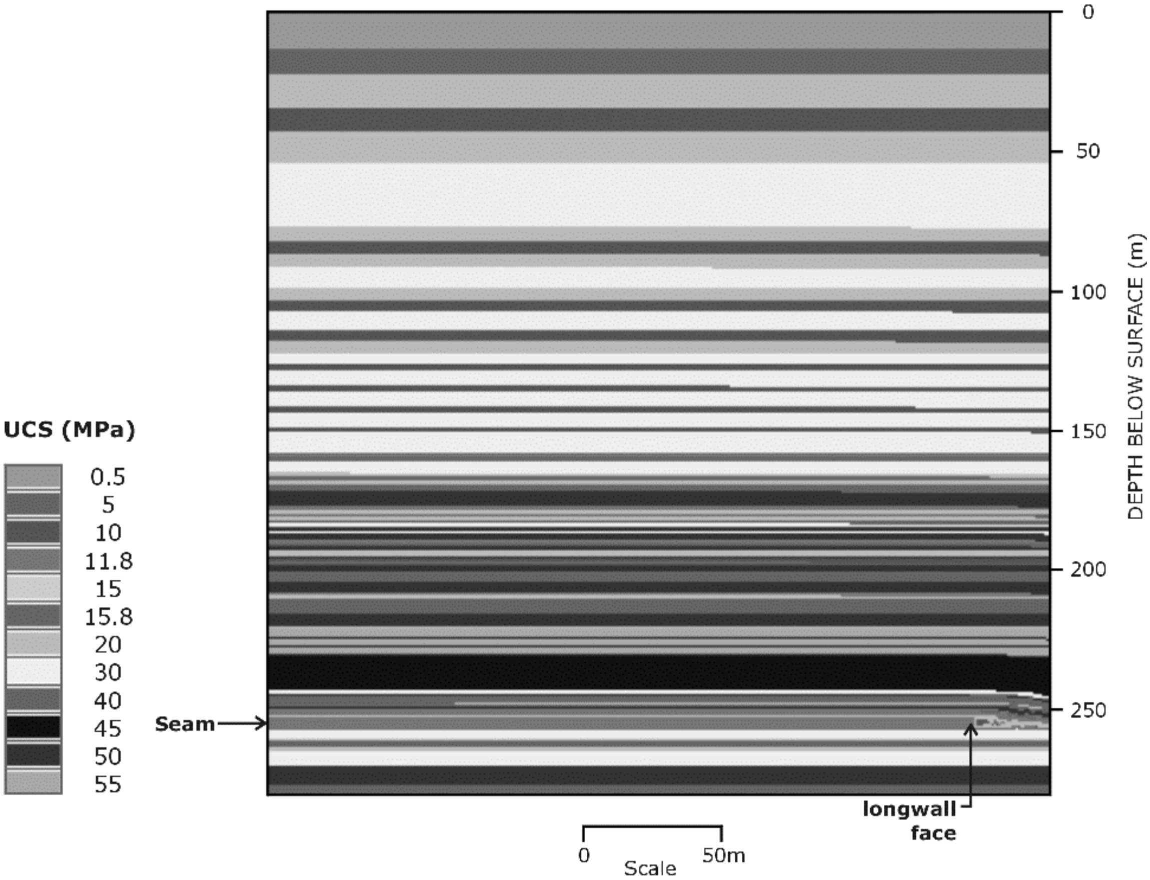


Figure 1 Geological section based on UCS of the strata.

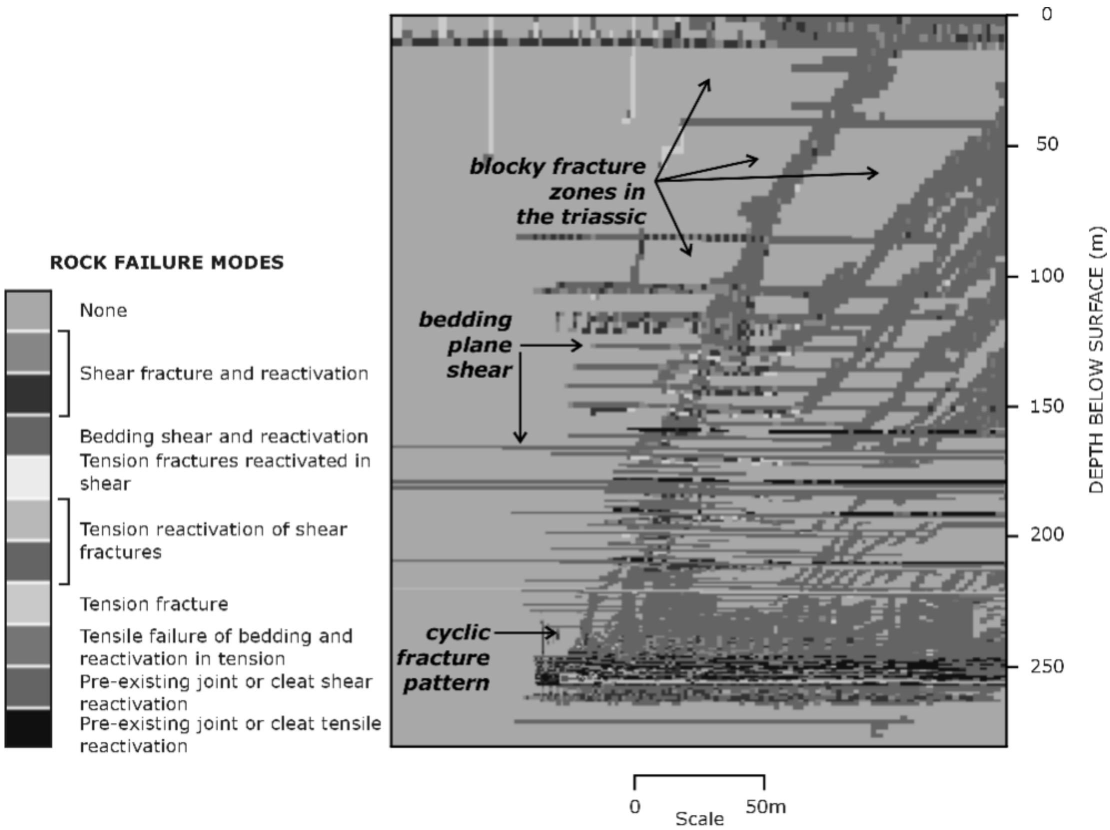


Figure 2 Rock fracture distribution about the face of a panel.

iii. bedding planes may shear well outside (100m +) the panel boundaries and allow significant horizontal movement to occur within the overburden,

iv. rock fracture may occur above and below chain pillars which may locally modify the subsidence characteristics.

The geometry of the fractures and the permeability of the strata can be evaluated within each stratigraphic model.

A general relationship of the height of significant connected cracking relative to panel width, obtained from various models, is presented in Figure 3. Local variations to this relationship occur as a result of local geology, however in general it appears to compare with measured data.

Computer simulations have been undertaken at a wide variety of mine sites and found to display a good correlation to field measurements and visual observations of longwall behaviour. Examples of the method have been published (Gale, 1998), (Sandford, 1998) and ACARP results have been published by Kelly et al, 1998.

Computer modelling results should be compared with monitoring data to evaluate their accuracy and application. A range of examples is presented below to provide an overview of the applications found to be useful.

Vertical Stress Redistribution About a Longwall Panel

The vertical stress redistribution measured by stress cells adjacent to a longwall panel compared to the modelled results is presented in Figure 4. This presents the results of two measurement sites over two longwall panels. The results indicate that the stress redistribution characteristics over the adjacent pillar are well represented in the modelling process.

Surface Extensometer to Validate Caving Characteristics

The caving characteristics of a massive sandstone unit was modelled and measured by subsequent extensometer measurements at South Bulga Mine. The results of the computer simulation in predicting the ground movement and the actual movements is presented in Figure 5. The comparison is very good and indicates that the model has the capability to simulate the caving displacements and the fracture geometry created within the overburden.

Surface Subsidence Examples

An example of surface subsidence measured from various locations within a mine and compared with a model of the typical overburden and depth range is presented in Figure 6. The subsidence characteristics appear to be well represented in general. The subsidence is the end point in the caving process, and as such it is a useful check on the modelling process, rather than being intended to simulate the subsidence specifically. However, in general the models appear to simulate subsidence in a realistic manner as the end point of the rock fracture and caving process.

Water Pressure Example

The computer models with coupled water pressure and ground movement provide an understanding of the effect of rock fracture and caving on the pore pressure distribution. This requires suitable information of the porosity and permeability of the strata as part of the exploration data.

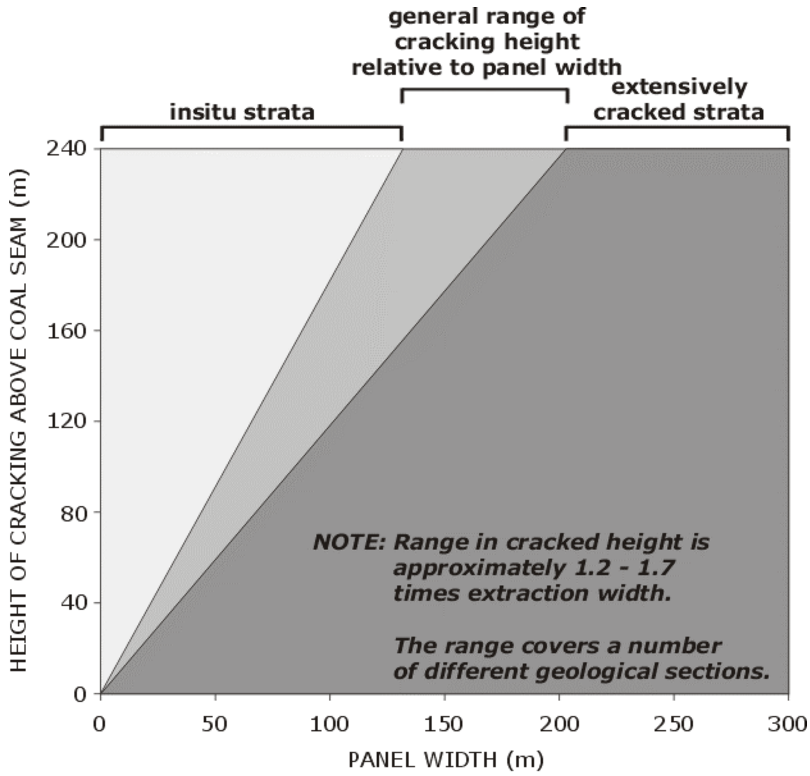


Figure 3 General relationship of the height of cracking versus panel width.

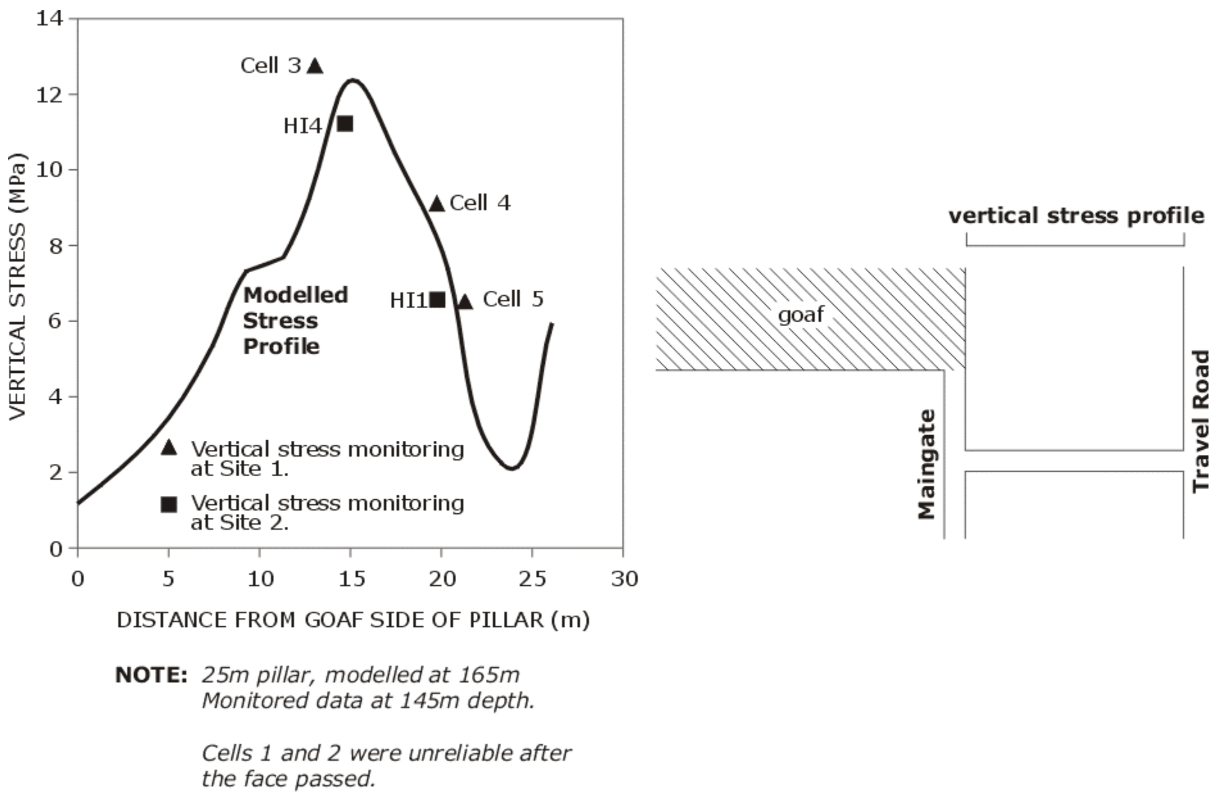
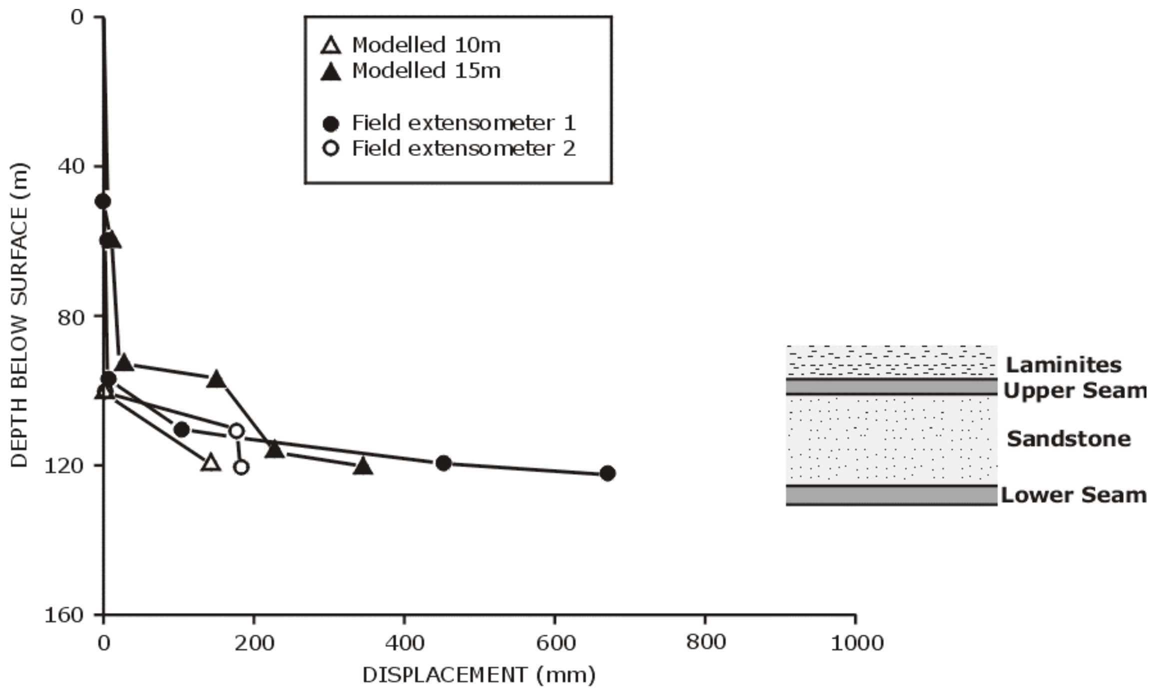
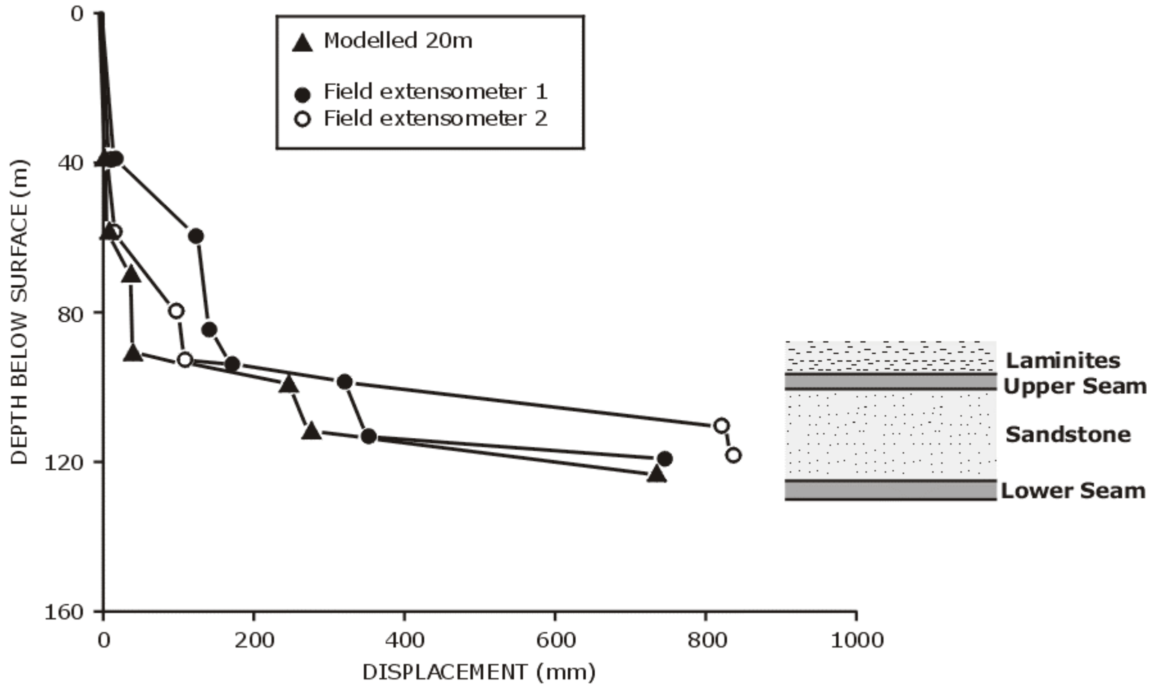


Figure 4 Comparison of vertical stress measured and modelled.



a) Comparison of modelled and measured extensometer results in the 7-15m range behind the face area.



b) Comparison of modelled and measured extensometer results 20m behind the face area.

Figure 5 Comparison of modelled displacements with surface extensometer.

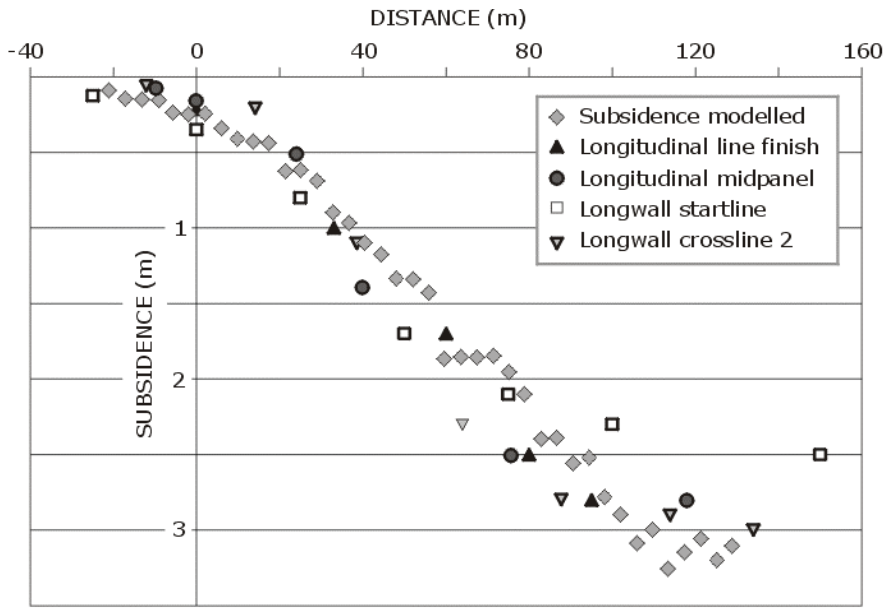


Figure 6 Comparison of surface subsidence and modelled subsidence.

To date, the results appear to match with available measured data on the scale of a roadway and of a narrow longwall panel. The comparative results of modelling and monitoring are presented in Figure 7 for a roadway and in Figure 8 for a narrow extraction panel. The results are encouraging and are being used to improve mine planning with regard to potential groundwater impacts.

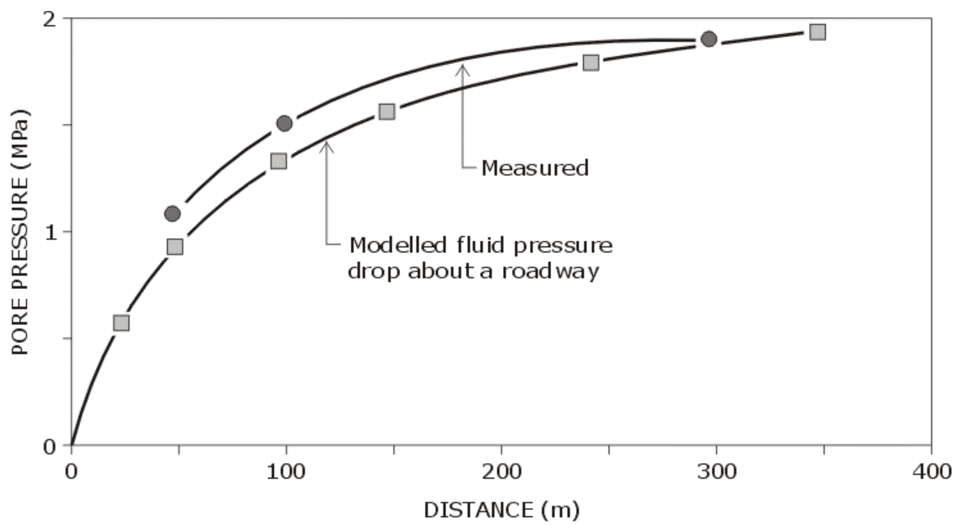


Figure 7 Pore pressure versus distance modelled and measured.

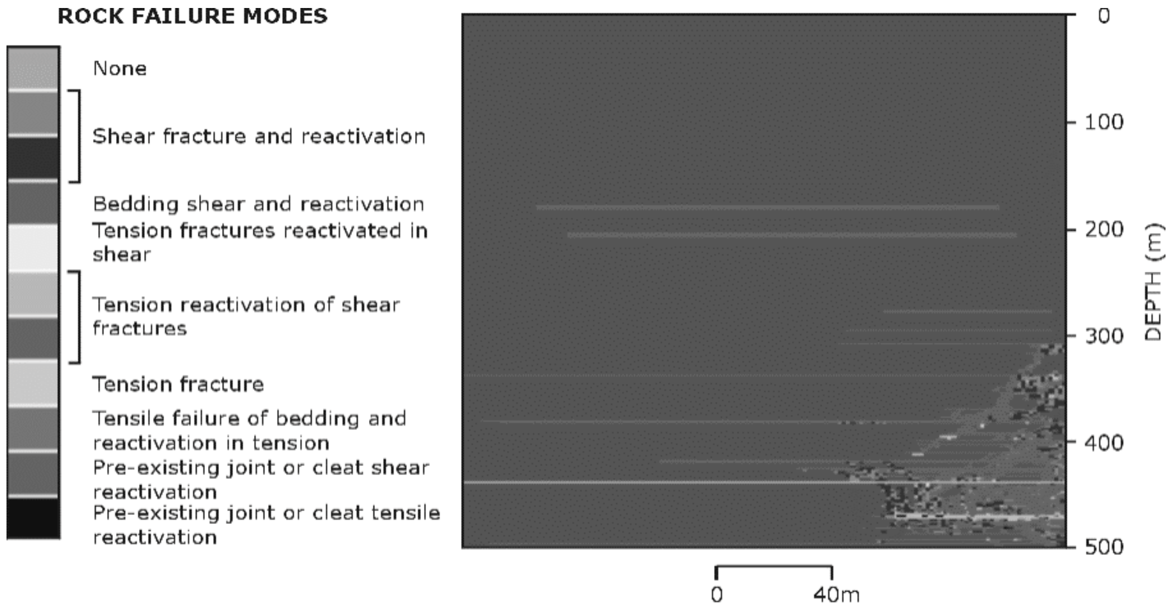


Figure 8(a) Panel fracture geometry.

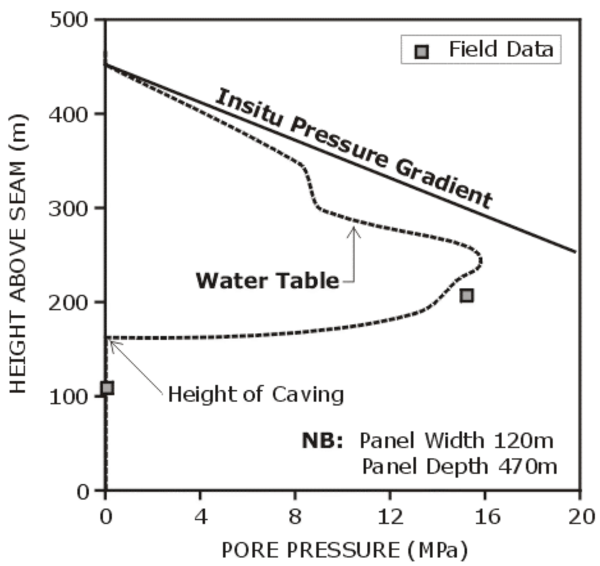


Figure 8(b) Pore pressure into the overburden relative to measured data.

4. DISCUSSION AND CONCLUSIONS

The ground subsides from the seam and progresses upwards and as such subsidence is the end point in a failure pathway within the overburden. The nature of the strata, in situ stresses and the mining geometry will influence the subsidence. The nature of the fractures created and the enhanced permeability will influence the interaction of mining with aquifers and surface water.

The application of computer models is improving our understanding of the caving process and the resultant surface impacts. A particular application of the modelling with regard to subsidence is to evaluate the potential effects of complex mining geometry or multi seam mining effect where the empirical databases may not have sufficient experience to predict the ground response.

Modelling is viewed as an additional tool to be used, however it is recognised that ongoing monitoring and validation is essential.

5. REFERENCES

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