

# STRATA MANAGEMENT IN WEAK ROOF CONDITIONS AT CRINUM MINE

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*ABSTRACT:* Crinum Mine is located in the Bowen Basin and is operated by BM Alliance Pty Ltd. Longwall extraction commenced in 1997 in the 3.4m thick Lilyvale Seam and seven panels have been mined to date in the current block. The roof strata are variable and include some of the weakest longwall mining conditions in Australia.

The immediate roof is predominantly a 15 to 25 MPa thinly bedded sandstone but includes weaker siltstone layers, typically 1m to 2m thick, with an average strength of 10 MPa. In some parts of the mining area the whole of the immediate roof appears to change laterally to a laminated siltstone with a strength as low as 2.5 MPa.

As the presence of these weaker horizons can influence the effectiveness of the primary and secondary support, as well as the roof stability on the longwall face, delineation of roof conditions forms a significant part of the strata management process. Strata are interpreted into geomechanical units from the sonic velocity logs to enable zones of similar conditions to be identified. More detailed interpretations are made along section lines for maingate development and panel hazard plans.

Roof support and longwall management strategies are based on the delineated roof conditions. Roof performance is monitored by means of dual height telltales, mechanical, and three and four point electronic telltales, GEL extensometers. A substantial base of mining experience has been accrued, enabling support requirements to be matched with confidence to the predicted roof conditions.

## INTRODUCTION

Crinum Mine is located in the Bowen Basin and is operated by BM Alliance Pty Ltd. Longwall extraction commenced in 1997 mining the Lilyvale Seam and seven panels have been mined to date in the current block. The Lilyvale Seam, which is the lateral equivalent of the German Creek Seam, has a consistent thickness averaging 3.4m.

The geological setting is that of a shallow plunging syncline with an axis down the middle of the block. Dip values vary between 2.5° and 3.5°. The depth of cover ranges from a minimum of around 95m to a maximum of 200m. Longwall panels are dip oriented and mined to the rise; face length is 270m and the full seam thickness is extracted. Fig. 1 shows the layout of the current workings.

Gateroad development is two heading at 35m centres with cut throughs at 130m centres. Roadways are 4.8m wide and nominally 3.3m high, cutting 100mm roof and leaving a minimum 200mm of coal in the floor as the stone floor is too weak to withstand trafficking. Drivage is conventional cut and bolt using Joy 12CM30 continuous miners with four onboard Hydramatic roof bolters which bolt within 2m of the cut face.

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## ROOF CONDITIONS

The lower roof section from the Lilyvale Seam to the Corvus Seam has been interpreted in terms of four major geomechanical units that can be correlated across the panels with a fair degree of confidence. Identification of these units is based largely on interpretation of the sonic velocity logs. Fig. 2 illustrates the sequence of roof units.

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The major component in the lower roof, Unit 2, is a moderately strong thinly bedded medium sandstone with numerous siltstone laminae and interbedded thin weaker siltstone layers. It has a thickness usually between 10m and 15m but can range up to a maximum of 20m in places. The estimated average strength of this unit tends to be consistently between 15 and 25 MPa.

Sometimes there is a weak to moderately weak siltstone, Unit 1, directly overlying the seam. It has a patchy development over most of the block, with a thickness typically less than 0.5m, but is more persistent to the north and south, where the thickness is from 0.5m to 1.4m. The estimated average strength of Unit 1 is typically between 7 and 10 MPa but drops to as low as 3MPa in some areas.

The interbedding in the main sandstone is highly variable with no distinct correlation of individual layers between boreholes. However, two thicker, more persistent siltstone horizons have been identified within Unit 2 and have been designated as Units 2A and 2B, as indicated in Figure 2. For the most part these two geomechanical units correspond to correlatable geological horizons but in some cases they appear to die out laterally and reappear at a different horizon and thus may not necessarily be geologically continuous. The estimated average strength of these weaker horizons varies from 7 to 15 MPa, with an average of around 10 MPa.

Unit 2A refers to horizons occurring directly on top of Unit 1 or directly on top of the seam where Unit 1 is absent. These are usually from 1m to 2m thick but have been interpreted as up to 6.3m thick in the southern part of the block. The presence of Unit 2A material usually means a reduction in strength at the primary bolting horizon. Unit 2B refers to weaker horizons at higher levels from 2m to 10m above the seam roof. These are also typically 1m to 2m thick and their presence can influence the strength of cable anchorage horizons.

Overlying the main roof sandstone is a very much weaker thickly laminated siltstone, Unit 3, with a thickness usually between 2m and 7m, and an estimated average strength typically between 5 and 10 MPa. Normally this unit and the remainder of the strata, Unit 4, are too high in the sequence to impact on roof support design.

However in some places the weak Unit 3, as a geomechanical unit, increases in thickness at the expense of the more competent main sandstone, reaching a maximum thickness of up to 9m in places. It is believed in these instances that Unit 2 grades laterally into Unit 3, not as a geological variation but as a geomechanical change, as the sandstone matrix appears to soften and become clayey causing a significant strength reduction. Estimated strengths as low as 2.4 MPa have been interpreted from the sonic logs.

All available sonic velocity logs are examined and interpreted in terms of the geomechanical roof units described above, and the results compiled into a borehole database. This geomechanical database is used to provide the basic framework for the main gate roof sections described below.

## ROOF SUPPORT

Roof support design has to cater for what is relatively weak conditions with low strength laminated rock. Current roof support patterns have been evolved through experience, trial and monitoring and are as follows:

### 1. Primary Support

Moderate roof: 6 x 2.1m bolts at 1.0m centres, with mesh mats. Bolts are anchored with two stage resin and are pre-tensioned to nominally 10t. Although this has been the normal support pattern used at Crinum, a decreasing trend in average roof strengths has reduced the usage of this pattern to 50% of development drive in gateroads and 0% in the Mains.

Poor roof: 8 x 2.1m bolts at 1.0m centres, with mesh mats, bolts in a 6 + 2 pattern. This pattern is used where the bolting horizon strength is less than about 10-12 MPa; which, as previously stated, is about 50% of development drive in the gateroads and 100% in the Mains.

### 2. Secondary Support

Groutable Megabolts are currently the long tendon support employed and are installed as follows:

- in response to roof movement i.e. trigger response

- in widened sections e.g. installation roads, drivehead areas
- in critical areas e.g. face take-off headings and intersections
- in longwall belt road areas where geologic interpretation suggests weak roof and some deterioration has become visible.

The length of megabolts employed (6m, 8m or 10m) depends on the lowest horizon at which reasonable roof strength exists as determined by the sonic velocity logs using both roof strength horizon contours and roof unit sections described below. The support density is designed to work in cooperation with the primary support pattern and the geometry of the opening, and match the degree of deterioration already experienced and the service required whether longwall abutment, roadway widening, or mine life requirement.

Megabolts are point anchored with resin which sometimes results in heavy loads being experienced at the roof line. 300mm plates are required at Crinum due to the weak roof and the tendency for 200mm plates to exceed the bearing capacity and punch into the roof. When very high loading is observed on 300mm plates the Megabolts® in the area are grouted with Ordinary Portland Cement (OPC) eliminating the potential for full loss of support if the cable breaks at the bearing plate. Grouting has been a very effective form of tertiary support. In critical areas such as faceroads and takeoff intersections where rates of movement are too high to safely inject OPC, PUR has been injected into the Megabolts. This technique fully encapsulates the Megabolts as well as injecting PUR into the roof strata without the requirement for additional drilling which would entail time, expense and further deterioration of the roof due to water injection. It is estimated that only 5% to 10% of Megabolts installed at Crinum are grouted.

### GEOTECHNICAL INPUT INTO THE STRATA MANAGEMENT PLAN

Geotechnical information is used at three levels in the strata management process.

In the first instance, a contour of the bolted horizon roof strength for the mine is prepared from the sonic velocity logs of surface boreholes. Figure 3 shows the interpreted bolting horizon strength over the current longwall block from which the contour plots are generated. The contour plot has been back analysed for accuracy in predicting roof control problems, telltale results and long tendon support requirements and found to be extremely representative. The updated contour is then used to budget primary support patterns involving costs and development rates and secondary support requirements utilising costs and material requirements and even assist in mine planning longwall setup and takeoff points.

In the second instance, the roof UCS contour is detailed over individual development panels. The 2m roof strength contour assists in the decision to implement different primary support patterns which are designed such that longer bolts using two pass drilling is not required at the face. Sufficient roof stability is achieved by the primary pattern so as to allow completion of the development sequence before secondary support is required which ensures there are no production delays. This is achievable 99% of the time.

As well as the 2m roof strength, 2-4m, 4-6m, 6-8m and 8-10m roof strength contours are prepared over the development panel prior to the commencement of mining. The upper horizon contours allow proper assessment of the minimum required length of long tendon support, saving both time and money. Fig. 4 shows an example of sequential roof strength horizons.

In addition, and also prior to development, a 12m roof section is prepared showing the variation in roof conditions. Borehole spacing is a minimum of 200m along the gateroads but additional infill drilling is frequently carried out to reduce the spacing to 100m, depending on the whether conditions are considered as critical. These sections are based on the roof units in the geomechanical database but are taken to the next level of detail, that is, sub units or local variations are included, together with any other features such as low strength or sheared horizons as indicated on individual borehole logs. Average roof strengths for the units are also included.

Fig. 5 shows an example of a maingate roof section. This plan is used to show the anchorage horizons, indicate where the roof unit contacts and discontinuities are, show how much immediate roof is weak and assist in the assessment of primary and secondary support patterns.

It is a requirement of the Strata Management Plan that the roof strength contours and the roof section diagrams are included in the panel folders and posted on the crib room bulletin boards for each development section. These plans, as well as many other geologic and roof support issues, are reviewed with the crews prior to the commencement of a new gateroad.

A full hazard plan is prepared for each longwall prior to extraction. In addition to the 2m roof strength contour and the 12m roof section along the panel, other geological information is also added as follows:

- a seam to surface section along the panel showing the change in depth of cover, the location of overlying seams and the position of strong or water bearing strata horizons
- a 0.5m roof strength contour to help assess the tendency for immediate roof flaking or slabbing
- all geological mapping information, contours of any any strong beds, and all telltale results.

It is a requirement of the Strata Management Plan that the hazard plan is included in the panel folders and posted on the crib room bulletin board for each longwall. This plan, as well as many other geological and roof support issues, is reviewed with the crews shortly after the transfer from the previous longwall.

### **STRATA MANAGEMENT PLAN**

The three main elements of the strata management plan are:

- hazard plans / support rules
- responsibilities / monitoring / action response
- support testing / auditing

Hazard plans are developed for both development and longwall panels using the available geological and geotechnical information. This information is used to familiarise miners and deputies with upcoming conditions and design primary and secondary support rules for development. These plans as well as telltale results are referred to when a final maingate inspection/review is done to assess any additional secondary support requirements prior to longwall operations.

All employees of and visitors to the mine have responsibilities under the Strata Management Plan. Deputies (ERZ Controllers) in particular have a high level of responsibility. Dual height telltales are installed in all intersections and any other areas of anomalous roof conditions by the development crews at the face. These are monitored by the deputies daily and the readings taken to the surface for input into the database.

Four levels of alarm can be generated based on roof movement in either horizon (10mm, 20mm, 40mm and fall of ground). In addition, alarms can be generated by other forms of roof or rib deterioration, such as when encountering faults, having abnormal slabbing of the roof ahead of the miner, or guttering, cracking or flaking of the roof or rib outbye the miner during development, and on the longwall by slabbing of the roof, roof movement in the gateroads or significant spall of the face or gate ribs. All alarms are acted on immediately and then reviewed by the Strata Control Group once per week to ensure actions and monitoring has been completed.

As part of the program of monitoring, when alarms have been reached which result in long tendon support installation, a data sheet is attached to the rib which includes the date of telltale installation, dates of reaching the different alarm levels, date of long tendon support installation and the readings at the time, and the most recent readings. This allows on the spot evaluation of roof stability in an area where secondary support has already been installed.

In critical areas such as installation roads, takeoff areas where roof movement has exceeded telltale limits, or areas which have been grouted with OPC, three or four point GEL extensometers (electronic telltales) are installed to a minimum of 10m by a contractor. Readings are taken by deputies and brought to control for input and analysis, but in addition, a sheet of readings is installed on the rib and with a resolution of 0.1mm, stability can be quickly assessed underground.

Deputies are also responsible for first mapping of geological anomalies encountered at the face. Mapping information is recorded on sheets in crib rooms and taken to the surface. This prevents loss of information due to stonedusting and is used when final mapping is done and recorded on the mine plan.

The Underground Mine Manager, Longwall Coordinator, Development Coordinator, Geotechnical Engineer and Shift Coordinators also have responsibilities under the action response plans and make up the Strata Control

Group which reviews all aspects of the Strata Management Plan at the Strata Management meetings, which are held as a minimum on a monthly basis.

An equally important aspect of the strata management plan is roof support testing and auditing. Three complete audits have been developed to audit roof support at Crinum.

A primary support audit is carried out quarterly by the geotechnical engineer usually in conjunction with the roof bolt supplier. This involves a surface materials inspection checking storage, quantities, best before dates, condition and delivery of all materials used for primary support. Then an underground inspection is done at the face auditing the same things as on the surface as well as installations, insertion times, spin times, hold times, hole depths, hole diameters, encapsulation, tail lengths, bolter torques, bolt loads, patterns, and all other aspects involved in the installation of the primary support. Discussions are held with crews if any deficiencies are found or improvements can be made.

A secondary support audit is carried out quarterly by the geotechnical engineer usually in conjunction with the cable bolt supplier or installation contractor. It involves virtually the same audit modified to suit long tendon support installation.

A longwall support audit is carried out quarterly by the geotechnical engineer usually in conjunction with the longwall coordinator or the longwall production coordinator. This involves auditing the gate end conditions, use and status of Gun Set supports, the hydraulic delivery system including pumps in use and operating pressures, the main gate data including leg pressures and status of positive set, the longwall shield gauge readings and leg extensions and the tailgate support and conditions. This information is collated with the continuous monitoring of leg pressure results from the surface and presented to the longwall coordinator and longwall mechanical and electrical engineers.

Actions for improvement are generated from the audits and all audit results are reviewed with the crews.

### CONCLUSIONS

The following conclusions can be drawn from the Crinum experience with regard to mining in weak and variable roof.

3. systematic evaluation of sonic logs can provide a general understanding of the variation in roof strength, can identify areas of concern and can provide the basis for delineation of roof support categories.
4. roof strength plans can enable comparisons to be made of proposed development with previous experience and hence improve predictability of mining conditions ahead of mining and improve planning and budgeting.
5. hazard plans with roof strength sections are an important control element for determining roof support design and monitoring requirements and for making changes on the run during development and extraction.
6. on site ownership of the strata management process is essential to manage roof monitoring and to augment changes based on cumulative experience.

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