Optimisation of Strata Reinforcement at Kenmare Colliery

N. Gordon

South Blackwater Coal Ltd
P.M. Box, South Blackwater, Queensland 4717
Australia

Abstract: Kenmare Colliery is currently longwalling in the 3.6m thick Aries Seam of the Rangal Coal Measures, in the Southern Central part of the Bowen Basin. Underground drivage at Kenmare began in November 1994, and the first Aries Seam longwall (block 1A) was extracted between November 1996 and April 1997. Kenmare is currently mining block 2, which is due to be completed by June 1998.

The increase in strata strength with depth of cover has presented opportunities for optimising the roadway support patterns at Kenmare. Support design is further complicated by the significant number of faults in the South Blackwater lease area. Current gateroad support patterns (in non-faulted areas), range from 6 bolts per metre (with mesh) in shallower areas (<100m), to 4 bolts per 1.5 metre (no mesh) in deeper areas.

Various data sources have been used in the design of support patterns, but in particular detailed strata characterisation, based on the geophysical logging of exploration boreholes, has proved invaluable. Subsequent underground strata monitoring of different support systems in different ground conditions has validated the preliminary support design. This has allowed confidence in applying the above technique, in conjunction with other methods, for designing roadway support systems in future areas of the mine.

Key Words: longwall gateroad support design, strata characterisation, strata monitoring.

Introduction

The mining leases of South Blackwater Coal Ltd are located 42 kilometres due south of the township of Blackwater and 200km west of the major regional city of Rockhampton, Central Queensland, Australia. The product coal is railed 330 kilometres to the port of Gladstone for export (Figure 1).

The seams mined are part of the Late Permian, Rangal Coal Measures located in the Southern Central part of the Bowen Basin. The total resources at South Blackwater are in excess of 2.1 billion tonnes, of these more than 1.8 billion tonnes are underground resources.

Production at South Blackwater consists of three distinct mining operations (Figure 2):
- **Kenmare** - an underground longwall mine with capacity >3 million ROM tonnes per year.

- **Laleham** - an underground bord and pillar mine, utilising place changing and 'conventional' development methods of mining, with capacity of 1 million ROM tonnes per year.

- **Open Cut** - an open cut utilising truck and shovel prestrip and dragline overburden removal for an annual capacity >2 million ROM tonnes.

South Blackwater mine has a 28 year history, evolving from a small bord and pillar mine in 1969, through an expansion in open cut mining to draglines in the late 1970s', to a major investment in the Kenmare longwall mine. Construction at Kenmare began in June 1994 and the first longwall (block 1A) was extracted between November 1996 and April 1997. Block 1B was mined between June 1997 and December 1997. Kenmare is currently extracting Block 2. Introduction of the Kenmare longwall mine has doubled the output of the operation. Production and productivity of all three operations continues to increase.

1 Geotechnical Engineer, South Blackwater Coal Ltd

![Figure 1. Location Plan.](image-url)
Figure 2. Current Mining Areas, South Blackwater.

Geology and Mining Conditions

As shown in Figure 3, the stratigraphic sequence at South Blackwater consists of Tertiary sands and clays overlying interbedded siltstones/sandstones of the Triassic Rewan Formation. Below the Rewan Formation are the Permian Coal Measures which at South Blackwater contain four economic seams. Both underground operations have mined the Aries and Pollux seams. These seams are typically 3.4-3.8m thick and are separated by 30-35m of interbedded siltstone/mudstone/sandstones. The Castor and Orion (where it coalesces with the Pollux seam) seams are also mined by the open cut operation.
Figure 3. Geological Sequence.

Lalcham has mined the Pollux seam by pillar extraction, and is now currently place changing in the overlying Aries seam. Kenmare is currently extracting longwalls in the Aries seam, with longwall extraction in the Pollux seam scheduled for the year 2000.

The Aries seam main roof (taken as 40 metres above the seam) is made up of a consistent sequence of finely interbedded siltstones, mudstones and sandstones. Bedding plane testing of roof samples indicate high friction angles of about 35°. The immediate Aries Seam roof in the shallower areas (<100m deep) consists of a carbonaceous shale band up to 1 metre thick. This peters out to less than 5cm at greater depths (Figure 4). The Aries Seam immediate floor consists of a clayey siltstone. This floor is prone to break up on wetting and under mine traffic.

The first 5 longwalls in the Aries seam are at depths varying from 100-180 metres (Figure 5).

In the current Kenmare Aries Seam longwall area the seam dip averages 1 in 15 to the east, but localised steepening (up to 1 in 8) and flattening (down to 1 in 50) occurs, usually related to faulting.

The pre-mining head of water above the Aries Seam reached a maximum of 80-90 metres at the start of Longwall 1A. This water was drained during the drivage of the first gateroads. Subsequent gateroad development has been noticeably drier with localised water encountered in faulted areas.
Figure 4. Aries Seam Immediate Roof Shale Thickness.

Figure 5. Aries Seam Depth of Cover.
The South Blackwater area is characterised by intense faulting of both normal and reverse type. The reverse faults strike dominantly north-west due to a regional north-east thrust direction. The normal faults occur in various orientations. The first three longwall blocks have mined through faults ranging in throw from 0.1 to 7m. The face cleat direction is dominant (the butt cleat is poorly developed) and trends north-east. The main roof joints trend either north-north-west or north-north-east. Both cleating and roof jointing are affected by faulting and higher intensities and/or changes in orientation are good indicators of proximity to faulting.

Aries seam gas makes arc low, with borehole core test data indicating <2m³/tonne. These tests are validated by underground measurements. The dominant gas is methane. Stress measurements and underground observations obtained pre-mining and during mining indicate that the initial Aries Seam Kenmare longwall blocks are in a low stress tectonic environment.

**Roof and Floor Strata Strength**

The primary tool used in initial support design in a new mining area at Kenmare is the determination of strata strength. Strength values are derived, from geophysically logged boreholes, using the formula (McNally, 1987):

\[
UCS = 1000e^{-0.035\times\text{Soil Transit Time}} \quad \text{(MPa)}
\]

Back analysis to geotechnical test data has been carried out to validate the accuracy of this formula. The technique is particularly useful in the South Blackwater area, due to the effect of variation in strength with depth.

As shown in **Figure 6**, the Aries Seam main roof average strength increases from <20MPa at 60m to 40-60MPa down to depths >120m. The Aries Seam immediate (1.8m) roof average strength (**Figure 7**) also shows this increase in strength, not only due to depth but also the thickness of shale. In the gateroad drivage this horizon varies from <20MPa to >50MPa. As shown in **Figure 8** the Aries Seam immediate (0.5m) floor varies in strength from 15-25MPa down to <5MPa in shallower areas.
Figure 6. Aries Seam Main (40m) Roof Average Strength (MPa).

Figure 7. Aries Seam Immediate (1.8m) Roof Average Strength (MPa).
Figure 8. Aries Seam Immediate (0.5m) Floor Average Strength (MPa).

Roof and Rib Support Design - Pre Mining

Prior to the start of mining at Kenmare in November 1994, 26 years of mining experience in the Pollux Seam and six months in the Aries Seam at Laleham were available. Furthermore longwall experience at nearby Cook Collicry, although in the Castor seam, provided some insight into longwall mining conditions in the Rangal Coal Measures.

The Aries Seam workings at Laleham were at depths >100m depth. However the initial Kenmare drivage was from an open cut highwall with approximately 45-50m cover and less than 5m of unweathered rock above the seam. Hence the initial 200m of entry drivage from the highwall required specialist type support, initially steel sets and later a shotcreted arched profile. It is not intended to discuss the pit bottom support requirements in this paper, but rather concentrate on gateroad support.

The data used for gateroad support design, prior to mining, was obtained from the following sources:

- Geotechnical logging and testing of 8 cored boreholes.
- 1108 open drill holes for structure definition.
- 25 coal quality holes.
- Detailed lithological logs of all geophysically logged open exploration boreholes using the CLOG software (developed by Wootmac & Associates of Maitland, NSW).
- Detailed strength analysis using the QLOG software (developed by BPB Instruments Ltd).
- Local experience from underground workings at South Blackwater and nearby collieries.
- Geotechnical reports by several consultants.

This data was evaluated and a 6x2.4m AVH bolts per metre pattern, with mesh, was used as the initial gateroad roof support. It was considered that this was a conservative approach, but a prudent one given the lack of site-specific roof behaviour data, particularly regarding Aries roof deformation under transient abutment loads. It is easier to over design the support and reduce at a later stage. The overriding concern was not to have a gateroad failure in the first longwall area. To date no gateroad failure has occurred at Kenmare colliery, even in faulted areas.

**Roof and Rib Support Design - During Mining**

Once gateroad drivage was started the optimisation of the initial support pattern was achieved through detailed geotechnical and geological studies in the form of:

- Installation of 20 anchor roof and rib extensometers (38 installed).
- Installation of dual anchor Telltales (>100 installed).
- Monitoring and comparison of different roof support systems in different ground conditions.
- Geotechnical rock testing.
- Detailed geological mapping of all roadways and longwall faces.
- Updating of the strength and strata characterisation data of new boreholes using both QLOG and CLOG.
- In situ stress field determination using overcoring.
- Roof and pillar stress change measurements.

Two specific examples are discussed below to highlight the optimisation of strata reinforcement in the Kenmare Aries Seam workings. These encompass:

- Gateroad Drivage
- Installation Roads

**Aries Seam Longwall Gateroad Drivage**

All gateroads are driven with Joy 12CM12 continuous miners at 5.2m wide and 3.1m high, leaving approximately 0.5m of coal in the floor. Rib and roof bolting rigs are mounted on both sides of the continuous miners.
As mentioned previously the initial Tailgate 1 and Maingate 1 gateroad drivages were driven using a 6x2.4m AVH bolt per metre with mesh pattern. In the Maingate 1 belt road 1.2m steel rib bolts in a W pattern were installed in the chain pillar side and 1.2m plastic bolts in the block side. The ribs in the belt road spill, when subjected to longwall abutment loading and rib bolting in this roadway is a routine part of the primary support pattern in gateroad development. Elsewhere rib bolts were installed on an as required basis, depending on the condition of the ribs.

Detailed roof strength analysis (derived from the geophysical logs), as shown in Figure 9, facilitated changes (in non faulted areas) to be made to the support patterns in both the Tailgate 1 and Maingate 1 drivages. In addition underground observations and monitoring were used to validate any change in the support pattern.

![Comparison of Roof Strength - Tailgate 1, 1-5CT](image)

**Figure 9. Increasing Immediate Roof Strength with Depth.**

The Tailgate 1 support pattern changed firstly to 5x2.1m bolts per metre with mesh, then to a 5x2.1m bolts per metre without mesh and finally to 4x2.1m bolts per metre without mesh (Herring Bone pattern). The Maingate 1 support changed firstly to 5x2.1m bolts per metre with mesh in the belt road and then to 4x2.1m bolts per metre with mesh in the belt road. The intersections in both gateroad developments, where a 4 bolt per metre pattern was used, were supported with a 6 bolt per metre pattern, 5 metres either side and through the intersection. These changes are highlighted in Figure 10 and include:

- reduction in bolt length from 2.4m to 2.1m,
- reduction in mesh usage,
- reduction in support density.
All these changes are associated with a significant cost saving to development drivage in both materials and increased production rates.

Figure 10. Gateroad Roof Primary Support Patterns.

Mesh was retained in the Maingate 1 belt road primarily as a safety issue, as people are active and concentrated in this area when the longwall is retreating. The likelihood of flaking roof when subjected to abutment loads was unknown initially. Subsequent belt roads driven without mesh have shown no signs of significant flaking, when subjected to longwall abutment loads.

The bolting pattern is constrained by the use of the mesh modules (1.2x4.8m) which normally require bolts to be installed in line. Discarding the mesh has allowed the development of a 4 bolt herring bone pattern initially at a 0.5m spacing and then 0.75m spacing. This pattern involves staggering the bolts by installing the 2 inside bolts then the 2 outside bolts etc to give effectively a 4 bolts per 1m and 1.5m spacing. This pattern has significantly improved the productivity of the development panels (Figure 11).

The current gateroad primary support pattern consists of a 4x2.1m bolts per metre with mesh at 20-40MPa immediate roof strength and 4x2.1m bolts per 1.5m without mesh at >40MPa. The roof movement plot of various support patterns (without secondary support), subjected to longwall abutment loads, in Figure 12 validates the decrease in support density.
As a precaution the first 300 metres of the Tailgate 1 belt road and both Main Gate 1 roads were secondary supported with 6m flexibolts per 2m (pro-tensioned to 20-25 tonnes) and at 1m spacing through the intersections. This was to supplement the four bolt primary support pattern. Subsequent roof monitoring of several roof extensometers failed to show any significant roof movement. Pre-tensioned flexibolts are now installed only in areas of poor ground, wider than normal intersections, or critical areas such as longwall take off road intersections.

It must be highlighted that the above comments are for non-faulted areas. In faulted areas extensive secondary support including both tensioned and non-tensioned flexibolts, cable bolts, timber cogs and PUR have been used to reinforce the gate roads as the longwall retreats.

![Graph](image1.png)

**Figure 11.** Metres per Cutting Shift vs Primary Support Pattern (Non-faulted areas)

![Graph](image2.png)

**Figure 12.** Gate Road Roof Movement Plots For Various Primary Support Densities (Subjected to Longwall Abutment Loads).
Installation Roads

The first installation road (for Block 1A) at Kenmare was driven in two passes. The first pass driven at 5.2m wide was supported with 4x2.1m bolts per metre with mesh. Before the roadway was widened 6m pre-tensioned flexibolts were installed at a 2m spacing along the face line (offset so as to be centred in the widened face line) and at a 1m spacing through the intersections. The second pass widened the face line to 8.5m with a further 3x2.1m bolts per metre installed. At the Tailgate end of the face line the roadway was 9.5m wide for installation of the Tailgate drive. Extensometers installed on the first pass (at the face) prior to widening have shown no movement (Figure 13).

Based on this extensometry Longwall 1B was driven and supported the same way except the flexibolts on the face line were installed at a 3m spacing. As shown in Figure 13 no movement was recorded 4 months after widening. Similarly the Longwall 2 face line which was supported the same way showed no movement for the 9 months prior to chock installation.

---

**Figure 13. Installation Road Face Line Roof Movement For Different Flexibolt (Pre-Tensioned) Spacings.**

The face lines of Longwalls 3A, 4 and 5 were also driven in 2 passes but supported with 7x2.1m bolts per 1.5m without mesh. The Longwall 3A face line was secondary supported as per the Longwall 2 face line, however the face lines for Longwalls 4 and 5 have been supported with flexibolts at 5m and 2m spacings on the face and intersections respectively. The widened Longwall 5 face line will be required to stand for over a year before the chocks are installed. Figure 13 illustrates the lack of roof movement in the installation roads which has allowed a reduction in the primary and secondary support requirements.
Conclusions

The methodology in the early days of gateroad development and longwall extraction at Kenmare has been to collect as much geotechnical information from Longwalls 1A, B and 2 as possible, to allow optimisation of the support design in future areas of the mine. This has facilitated improved rates of development, such that the next three longwall blocks will have been formed up by the time Longwall 2 is completed.

With ever changing conditions at Kenmare colliery the challenge of optimising roof support will continue. In the near future gateroads in the weaker Kenmare West area are planned. Gateroads will also be driven under existing goafed areas in the Pollux seam.

The main methods which have been successfully used in support design work at Kenmare are detailed strata characterisation followed up by underground strata monitoring. It is envisaged that these methods will continue to be used in future areas of the mine.

References


Acknowledgments

The author wishes to thank South Blackwater Coal Ltd for the opportunity to present this paper. The views expressed are those of the author and not of SBCL.