GEOLOGICAL CONDITIONS AND
APPLIED GEOMECHANICS AT TOWER COLLIERY

By
Rod Doyle1, John Boi2 and Scott Lowe3

ABSTRACT

BHP's newest colliery on the Southern Coalfield is Tower Colliery. It is situated near Wilton some 60 km south west from Sydney. It commenced its operations in 1978 and since that time has experienced considerable roof problems. In its eight years of operations, production has been 935,687 tonnes to December 1985. To a certain extent this is a reflection of the ground control problems present in the colliery.

The paper outlines the significant geological features that are known to exist in the colliery and their influence on roadway development. Faulting has hindered the mine’s development and an igneous intrusion has had a detrimental effect on the roof rock. The prevailing roof rock has also had an impact on the roadway conditions.

The paper will look at intersection deformation in present workings. Extensometers have been installed in these areas and provide measurements to verify visual observations. The results show a significant increase in roof movement as the roadway is developed from a single heading, to a T-intersection and then onto a four-way intersection.

INTRODUCTION

Tower Colliery is located some 30 km north west of Wollongong (Figure 1). During 1986 the Colliery will extract its one millionth tonne of coal. Its total production has come from development only – no goaf has been formed.

Figure 1. Location plan of Tower Colliery

Shepherd and Gale, (1982) have asserted that "the stress field and lithology are the most important natural factors that affect mine roof stability". At Tower Colliery high stresses have affected mining conditions throughout the underground workings. Directional mining has been successful in reducing the effect of the high stresses on roadways. However, when these stresses become concentrated on intersections, poor conditions are generally the result. Measurements of these stresses have been made.

Various methods are being reviewed in an effort to overcome the ground control problems that are presently being experienced. They include narrower drivages, smaller intersections and smaller pillar sizes.

1. Geologist, BHP Steel International Illawarra Collieries, N.S.W.
2. Mining Technician, BHP Steel International Illawarra Collieries, N.S.W.
3. Mining Engineer, BHP Steel International Illawarra Collieries, N.S.W.

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986
STRATIGRAPHY AND GENERAL GEOLOGY

A generalized stratigraphic section of the lithology present in the Tower Colliery area is shown in Figure 2. The section shows the formations and members which are also typical for the Southern Sydney Basin.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FORMATION AND MEMBER</th>
<th>AVERAGE THICK. (M)</th>
<th>GRAPHIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIANAMATTA GROUP</td>
<td>HAWKESBURY SANDSTONE</td>
<td>175 (135-197)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Newport Formation</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Garie Formation</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bald Hill Claystone</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Woombarra Sandstone</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>NARRABEEN GROUP</td>
<td>Stanwell Park Claystone</td>
<td>0 - 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scarborough Sandstone</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Woombarra Claystone</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coalcliff Sandstone</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wingecarri Sandstone</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bellowie Coal Member</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lawrence Sandstone</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cape Horn Coal Member</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unnamed Member</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wondawill Coal</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Stratigraphic Column of lithology at Tower Colliery

The Wianamatta Group outcrops over most of the surface area of the colliery. The group consists predominantly of shales interbedded with minor sandstones, it is recognised as being the last known stage of deposition in the Sydney Basin. The Catarract and Nepean Rivers have incised deep gorges into the Wianamatta shales, exposing steep cliffs of Hawkesbury Sandstone. The Hawkesbury Sandstone consists essentially of sandstone with minor shale. Cross bedding is a distinctive feature of the formation. No other sedimentary rocks are found in outcrop in this area.

The Narrabeen Group consists of a series of shales and alternating shale and sandstones. These reach a thickness in excess of 320 m in the Tower Colliery area. The units are relatively constant throughout the Southern Coalfield, with the exception of the Stanwell Park Claystone which varies considerably in thickness over the Appin-Wilton Area. In several boreholes the Stanwell Park Claystone has been recorded as being absent. Recent work involving geophysical logs and fully cored holes shows a discrepancy between the core as logged by the geologist and the hole as logged by geophysical means. The latter showing a typical shale response where the naked eye observes what appears to be fine-grained sandstone (G.R. Poole, 1986 pers. comm.). Further work needs to be carried out to elucidate this discrepancy.

The Coalcliff Sandstone is the basal member of the Narrabeen Group, unconformably overlying the Bulli seam. It consists of a quartzitic sandstone, commonly containing a shaly facies at its base. The importance of this unit is paramount to the colliery as it forms the immediate roof of the underground workings.

The Bulli Coal is the uppermost unit of the Illawarra Coal Measures. It is also the seam which is exploited at the colliery. The depth of cover over the seam ranges from 450 m to 510 m. The characteristic properties of this prime coking coal vary throughout the colliery. The thickness of the seam itself ranges from 1.7 m in the south-west to 3.40 m in the north-east. Ash yield of the coal also varies along the same trend from 15% in the south-west down to 9% in the north-east.

The interval between the Bulli and Wondawill Coal consists of shales, sandstones and minor uneconomic coals. The Wondawill Coal occurs on average 45 m beneath the floor of the Bulli Coal. It has a thickness approaching 10 m, only the basal section of which reaches an economic standard. Using an economic cut-off of 30% raw ash the thickness of a working section would vary from 1.65 to 2.10 m. At the time of writing, only seven analyses have been returned for the Wondawill coal. Present exploration will greatly expand on this information.

GEOLoGICAL STRucURe AND ITS EFFECT ON MININg

Surface seismic was initially used to determine the structure of the Bulli seam. The results of these were mixed. However, they were responsible not only for delineating the early structure of the mine, but also for positioning the two access shafts. Over 25 boreholes have been drilled to assist in understanding the structure of the lease. The major geological structures affecting the mine are shown in Figure 3.
Faulting

A normal 13 m downthrown inbye fault (the Pit Bottom Fault) was intersected 40 m from the downcast shaft. The fault played a large role in restricting the mine's development to the north-east. The mine was then committed to developing in the north-west and south-west directions.

In association with the Pit Bottom Fault a reverse fault zone occurs ranging from 2.6 m to 0.2 m diminishing in throw to the south-east.

Initially, this caused problems in developing the linking roadways between the two shafts. Heavy roof was experienced and extra roof support, in the form of wooden chocks and steel carriers was used.
North West Entry has suffered some very large roof falls. The mining conditions experienced within this panel have been so poor that they were directly responsible for the cessation of mining. The "Pit Bottom Fault" occurs in close proximity to the panel and it is thought the fault has had a large effect on the overall mining conditions of the panel.

At a distance of 250 m to the south-east of the downcast shaft, the Pit Bottom Fault was re-exposed. Here it diminished in its throw to less than 1 m giving access to the north of the lease without the necessity of drifts.

The North-East Intakes and Returns were developed to the north of the Pit Bottom Fault, experiencing comparatively fair mining conditions. A minor thrust fault of 0.3 m displacement was intersected and this is believed to be associated with differential compaction of the roof. A boundary between shale and sandstone parallels the thrust fault.

Igneous Intrusions

The South West Mains developed slowly with some roof control problems, including intersection failure. The panel encountered a strike-slip fault and a three metre thick dyke. The dyke was relatively fresh and very hard, having a syenitic composition. A total of 12 outbursts were associated with the dyke during development of this panel. The outbursts and poor roof conditions limited the rate of development (Battino and Doyle 1986).

In the South-East Entry the same dyke was also encountered. The character of the dyke changed; it split into three inconsistent features with the thickest section being 1.6 m. This dyke was also located on the surface in an almost vertical position above the underground exposure. The surface dyke was weathered, but was estimated to be 0.8 m thick some 500 m above the 3 m thick section in the South West Mains.

Further to the south of the South West Mains, in-seam drilling has intersected both zones of cinder and further igneous intrusions. It occurs as a complex structure and further work will need to be done to clarify the structure.

Roof Rocks

Diesel, et al (1966) divided the roof rocks of the Bulli Seam throughout the Southern Coalfield into three categories:

1. Mudstone and shale
2. Laminita, and
3. Sandstone and conglomerates.

All of these rock types have been mapped underground at Tower Colliery, with the sandstone being predominant in the workings. Diesel, et al (1966) believes that there is a close genetic relationship between the mudstone, shale and laminita facies and the Bulli seam. They state that, the mudstone/shale, laminita deposits have the appearance of continued coal measure strata. This contrasts strongly with the appearance of the erosional sandstones and conglomerates which form the roof rocks not only at Tower but elsewhere in the Coalfield. This aspect deserves attention not only because of stratigraphy, to determine if the mudstones and shales should be part of the Illawarra Coal Measures – divorcing it from the Coalcliff Sandstone of the Narrabeen Group, but also from the point of view of roof support and the question of changing mining environments.

The mudstone/shale facies is a roof lithology of moderate strength. It is a stillwater deposit forming a flat roof over the seam. From mapping and boreholes it would appear that this facies will become more predominant in the underground workings. Mining induced fracturing is a more common feature than jointing.

The laminita has been encountered only in the South West Mains. Its occurrence is minor and its extent throughout the colliery is uncertain. It also has a moderate strength with U.C.S. values of 40 MPa being measured.

The sandstone is medium to coarse grained with minor conglomeratic phases. It is a moderately strong roof rock with typical U.C.S. values of 80 MPa and Young's Modulus of 12 GPa. It exhibits abundant mining induced fractures but shows few joints or natural fractures. It is a fluviatile deposit occurring both as a flat roof and a highly irregular roof, the latter due to its highly erosive nature.

Geological mapping to determine and predict structural features is an essential part of mine planning, and has been thoroughly undertaken at Tower Colliery. Understanding these features and their effect on underground workings is also necessary. Geological features reflect the mining environment that will be present in any area and indicate the problems that will be encountered underground.
PROBLEMS ENCOUNTERED UNDERGROUND

Williams and Wilson (1976) recognised that roof conditions in Southern Coalfield mines were acknowledged as being the worst of all N.S.W. coalfields. At Tower Colliery, intersection deformation and poor roof conditions have been a problem that has seriously hampered the colliery's development.

It is the question of roof control to which the authors are applying themselves in an effort to firstly, comprehend the phenomena of failure, and secondly, to apply this understanding to reduce the effects of failure. This would culminate in increasing the safety and productivity of the mine. A programme was developed to look at the problem of failure. To focus on several modes. These included conducting tension torque tests, installing multi-anchor wire extensometers and the use of the strain relaxation method. These will be discussed in more detail.

**Torque wrench tests**

Torque wrench tests were introduced to monitor the change in load on the roof via the normally installed roof bolts with a conventional torque wrench. Initial load readings were taken on the bolts at the time of installation (approx. 130 ft/lbs - 0.5 K). The load on the bolts came on very quickly and exceeded the limits of the torque wrench within a 24 hour period. Suggesting high stress, and limiting the usefulness of continuing this work.

**Multiwire extensometers**

To identify and determine the causes of instabilities associated with the working roof at the colliery, it was decided to observe and measure the roof movements by the installation of a series of multi-wire extensometers. The extensometer is an instrument which measures the total amount of roof movement, whilst simultaneously identifying movement between specific points of the extensometer. This establishes the area of greatest separation and points to the area of earliest breakage. Allowing an appraisal to be made of the strata behaviour and the effectiveness of the roof support system.

Earlier similar attempts to identify the causes of instabilities with the use of mechanical extensometers, although unsuccessful, proved valuable for our purposes. The extensometers at this stage were being installed at depths of 2 m. Results were inconsistent and indiscriminate, suggesting that movement was occurring much deeper. This realization led to a series of extensometers being installed at depths of 4 m in roadways and 6 m at intersections; supporting the findings of the shallower extensometers, that the movement was occurring at a greater height above the roadway.

**Strain Relaxation**

The strain relaxation method as described by Voight (1968) has been carried out in 4 surface boreholes and in one underground bore. Only the underground core was successfully orientated. The stress magnitudes for the 4 surface boreholes were relatively consistent averaging, 32 MPa for o1, 20 MPa for o2 and 12 MPa for o3, (o3 being the vertical stress). The one underground test displayed stresses of approximately half the magnitude of the surface ones, which may be a result of underground rearrangement of stress due to mining. These results confirm the high level of stress within the mining environment and the possible stress relief, via deformation, within the immediate roof of the seam.

**Intersection size**

Another problem encountered underground is the size of the intersections. Where the roadways were 5.0 m wide, the span of a 4-way intersection approached 10 m due to the continuous miners cutting corners to make cut-throughs. The extensometer results clearly show the excessive amount of roof movement in 4-way intersections. Figure 4 shows the relationship between intersection size and bed separation.

<table>
<thead>
<tr>
<th>Nature of roadway</th>
<th>Roof movement, mm</th>
<th>Time, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Roadway</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>T-Intersection</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>4-way intersection</td>
<td>200</td>
<td>14</td>
</tr>
</tbody>
</table>

Figure 4. Degree of Roof Movement in relation to type of development

**DISCUSSION OF RESULTS**

Figure 5 shows results of measurements taken at extensometer locations. Figure 5a shows very little movement (approximately 10 mm) over the 20 day period. This extensometer was installed in a single roadway. Figure 5b shows a larger increase in total displacement over the 20 day period reaching 80 mm. The extensometer results shown in 5b represent a 3-way intersection. By comparison, Figure 5c shows results from a 4-way intersection and the amount of movement taken place has reached 200 mm after 20 days.
Figure 5. Movement of roof as measured by extensometers

The legends show the depths that extensometers were anchored at.
14 days. The majority of movement occurring in the range from 7.5 to 4.0 m above the roof, well above anchor bar horizons of the roof support system of 2.4 m bolts. Failure of this nature at Tower Colliery is widespread and is why a revision of mining practices and development procedures of intersections is necessary.

Strain relaxation has provided measurements of the large virgin stresses involved in the underground mining environment. It also points to the possible redistribution of these stresses when mining takes place, resulting in poor roof conditions and roadway deformation. This is evidenced by the mining induced fracturing and the results of the extensometers which clearly show the developing failure of the roof - as the amount of activity and the size of the openings develop.

These findings persuaded management that a revision of mining practices would be needed. An emphasis is being placed on reducing the width of roadways and therefore the width of intersection especially 4-way intersections. Initially this will be done by narrowing roadways to 4.6 m and changing drivage sequences, limiting the turns from the centre in only 1 direction and hence limiting the size of the intersection. Pillar dimensions will also be altered, reducing the amount of drivage in the poorer directions.

CONCLUSION

Poor roof conditions have caused delays in the development of Tower Colliery. A programme aimed at quantifying the size of the roof failure was instigated. It involved the use of multi-wire extensometers which highlighted the need for a change in the formation of intersections. The amount of failure is believed to be associated with the high degree of stress present as measured using the strain relaxation method.

Geological mapping and geomechanical processes have been undertaken and are described in this paper with the aim of presenting what has taken place to date at Tower Colliery in an effort to improve on existing ground control methods.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the efforts of colleagues of the Coal Geology Department, Collieries Research, in particular Mr. A. Filopowski and Tower Colliery, both past and present. BHP Company Limited is thanked for permission to prepare and present this paper. The contents of the paper are the opinions of the authors and not necessarily those of the Company.

Dr. W. Gale is thanked for his reading of the paper and for his helpful comments. Mr. J. Archer and Mr. W. Black patiently typed the paper. Our thanks to both.

REFERENCES

BATTINO, S., AND DOYLE, R. (1986)


Colliery Roof Stability and the Role of Geology: A Review. In: The Australian Journal of Coal Mining Technology and Research, Number 1, 47-67


VOIGHT, B. (1968)
Determination of the virgin state of stress in the vicinity of a borehole from measurements of a partial anelastic strain sensor in drill cores. Felsmechanik a Ingenieureng, 6.