THE EFFECTS OF MINING ON THE GEOLOGICAL EQUILIBRIUM
AT LEICHHARDT COLLIERY, BLACKWATER, QUEENSLAND

By
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ABSTRACT

The paper describes the geology, structure, stress, gas and strata geomechanical properties for Leichhardt Colliery and their reactions to mining.

INTRODUCTION

The geological history of a depositional basin defines the current structural and stress environments of its coal seams. Subsequent to their complex histories over geological time, the coal seams have achieved a state of relative equilibrium within their environments. An understanding of the regional and local geological environments is required to provide a basis for understanding the mechanism of the reactions of the strata to disturbance of their equilibrium by mining. With an understanding of the geological environment and the reactions of the environment to mining, safe and efficient mining systems can be designed to enable economic exploitation of a coal deposit (Fig. 1).

Leichhardt Colliery at Blackwater, Queensland was closed in 1982 because of severe mining strain and a difficult economic climate. Geological investigations were conducted to varying intensities from the mid 1960's to the time of closure.

Pre-mining exploration at Leichhardt Colliery was conducted using a phased approach (Johnson, 1977 and Johnson et al, 1986). Consisting of the drilling of boroholes and conducting of high resolution seismic surveys. These investigations yielded information on the coal seams, their structure and geomechanical properties of the seams and their surrounding strata.

When it became obvious that mining was to be subject to violent and disruptive mining strain, investigations were instigated to better define the local geological and geotechnical environment.

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LEICHHARDT COLLIERY

GEOLICAL SETTING

Leichhardt Colliery is located in the Bowen Basin on the 3° dipping eastern limb of the Comer Ridge and western limb of the Mimosa Syncline. Fifty kilometres to the east is the well defined folded zone (Hawthorn, 1973) which trends approximately 150° (Dickens and Malone, 1973). The mine workings are in the Gemini seam which averages 6 m in thickness over the colliery workings at 350 - 410 m depth. The coal has a vitrinite reflectance averaging 1.25%.

STRUCTURE

The colliery area is structurally complex with numerous faults of less than 1 m throw striking predominantly north-west. Three faults of significant throw were intersected in the colliery workings (Fig. 2).

Shallow dipping slickenide planes striking approximately north west are common over the western side of the mine. Cleating is common and prominent. The high frequency face cleat has members with strike length greater than 1 m (many in excess of 5 m) occurring at an average spacing of less than 2 m. Non systematic "butt" cleats are confined to bright coal bands and although their mean strike is perpendicular to the face cleats, their range is as high as 180° (Hanes and Shepherd, 1981). They are invariably filled with a pink mineralization of kaolinite, montmorillonite and dickite. Jointing is essentially absent from the roof strata.

The average maximum palaeostress interpreted from well formed tensile cleats, slickenide faces and faults is horizontal and orientated at approximately 060°. However, variations in the orientation are obvious locally and are probably effected by the proximity of the major sandstone channel to the west of the mine.
Fig. 1 Logical and necessary steps for mine evaluation and design

**STRESS**

In situ stress measured in the stone roof of the Gemini seam by overcoring has the following configuration.

- Horizontal - maximum principal stress = 30 MPa
- Intermediate principal stress = 20 MPa
- Vertical - minimum principal stress = 10 MPa

**STRATA PROPERTIES**

The roof strata of the Gemini seam consist mainly of lithic sandstone with local shale and siltstone laminations. The sandstone was deposited from a palaeochannel located over the western side of the colliery where the sandstone is coarsest and thickest. The floor strata are mainly shales and siltstones.

Unconfined compressive strengths for the strata average 70 MPa for sandstone, 45 - 60 MPa for shale and siltstone, and 8 - 23 MPa for coal.

**GAS**

The Gemini seam contains up to 16 cubic metres of methane per tonne of coal. Seam gas is dominantly methane with up to 15% carbon dioxide in places. Maximum gas pressure is 3.8 MPa which approximates hydrostatic pressure.
John Hanes

Fig. 2 Leichhardt Collery structures and stresses

(Wood and Hanes, 1982).

The apparent permeability of the coal to gas and water is very low. Gas flows during drilling of bores were generally not detected even when drilling with air circulation. Very high gas pressure gradients were measured in the mine (Fig. 3).

MINING

Mining was commenced in the Gemini seam in 1970 by contract miners. In 1973 BHP (Queensland Coal Mining Co.) commenced mining using Joy 10CM continuous miners cutting nominal 6 m wide x 3 m high roadways. Pillar silica commenced at 36 x 36 m centres but were varied throughout the history of the mine. Mining practice and opening dimensions varied with time. Initial support, during the contract mining phase, consisted of timber props and crows plus 2.1 m expansion shell bolts through steel 'u' straps. The 3 m parting, centrally located in the seam, formed the working roof. Initial BHP work was also to the 3 m parting with timber support at the face and outbye bolting using expansion shell bolts.

Following the occurrence of outbursts and associated roof problems in early 1974, timber and 'u' strap supports were erected close to the face. Different horizons in the seam were mined in an attempt to reduce the hazard of bursting. The 4 m parting, the 5 m parting and the seam roof were tried as working roofs. No major changes in burst proneness were experienced as a direct result of mining to the 4 m parting but there was a reduction of outbursts from the roof when the working roof was raised to the 5 m parting and to the sandstone roof of the seam.

In early 1975 it was decided that to reduce the potential of outbursts from the roof, the working roof should be raised to the sandstone roof of the seam. At this stage, chemically point anchored 2.1 m roof bolts were introduced and installed with hydraulic bolters.

Between 1976 and 1979 two changes in the basic mining section were introduced. The first of these was the introduction of an Alpine miner to cut an arched profile 5 m high by less than 6.8 m wide, supported by curved 'u' straps with 5 chemically point anchored 2.1 m bolts installed at 90° to the strap. Although this section had its peculiar pattern of mining induced cleavage and some spalling of
coal from the ribs, the drives remained relatively stable. Some outbursts occurred from the arched roadway drives which exceeded 500 m total length.

The second major change was the narrowing of the continuous miner drives from an initial 7 m actual (6 m nominal) to 5.5 m width. The support included 4.7 m long crowns on props with intermediate 4.3 m long, 5 hole 'W' straps. Roof bolts were 2.1 m long, chemically point anchored bolts installed vertically with the outside bolts spaced 0.9 m apart.

Pre-boring of faces with degassing/destressig holes accompanied the narrowing of drives. Some drives in the north were eventually driven using the above pattern of support but excluding the use of timber crowns.

After a major fatal outburst on the 1st December 1978, drive was conducted by shotfiring (Moore and Hanes, 1980).

Mining conditions were highly variable over the life of the mine.

MINING STRAIN

Outbursts

In excess of 200 outbursts of coal and gas occurred at Leichhardt Colliery between April 1975 and late 1981. They ranged in size from less than 1 tonne to 500 tonnes (Moore and Hanes 1980, Hanes and Shepherd 1981 and Hanes, Lams and Shepherd 1981).

Mining induced cleavage

Mining induced cleavage occurred in the Gemini seam and stone roof as en-echelon surfaces which curved on-mass around the opening producing a fracture envelope (Hanes and Shepherd 1981). Cleavage was most prominent in headings driven by a continuous miner where frequencies of 100 to 1,000 per metre were noted, especially in the very dull coal at the top of the seam. Conjunction of numerous cleavage planes produced large curvilinear slabs of coal which fell readily into the opening. Intense cleavage was recorded for 3 m ahead of many continuous miner drives. Where induced cleavage was absent from the upper dull coal plies, outbursts did not occur.

In places, occasional shallow dipping, irregular mining induced shears striking approximately parallel to a heading were recorded in the coal roof. These appeared to represent an overtrust of the coal roof due to high lateral stresses approximately perpendicular to the heading direction.

Where headings were driven to the 5 m parting (i.e. with approximately 1 m of coal between the working roof and the roof of the seam) roof deformation was reduced. The coal roof did not exhibit the mining induced cleavage characteristics peculiar to the sandstone roof.

The sections driven with an Alpine miner displayed a cleavage pattern around the opening but the cleavage was less intense and closely paralleled the arched opening.

Mining induced cleavage occurred in the stone roof of continuous miner driven roadways especially in those drives near perpendicular to maximum principal stress direction. It was best developed in the fine grained solid rocks of the eastern workings. The cleavages occurred in two broad sets. One set appeared to mainly affect the immediate 0.3 m of roof and the second set extended for several metres into the roof. The former set was similar in strike and dip patterns to the closely spaced cleavages noted in the coal ribs and faces. Although dips in the basal 0.1 m of roof material varied from 30° to around 80°, the dip decreased to nearly horizontal at about 0.3 m from the seam roof with the cleavages apparently coalescing with bedding planes.

These cleavage planes were formed concurrently with mining and caused up to 0.3 m of roof material to fall irregularly before it could be supported. In a few cases rock flour and very fine slickenside striations were noted on these cleavages. The second set extended high into the roof. The cleavage planes were clean breaks with strikes parallel to the opening and dips towards the coal ribs thus defining a high arch into the stone roof over the opening. Many of these cleavage planes extended several metres.

Rib failure

At Leichhardt Colliery three types of general rib strain were noted: rib spall, rib crush and "hard" ribs.

Rib spall, typically found in many cottesons, occurred as the gradual sloughing of the ribs with time from fractures induced parallel to the rib. It is believed that these fractures were produced by vertical load as the roof strata relaxed and the rib was released from the constraining influence of lateral stress. It was the only rib strain noticed in obviously distressed/degassed drives.

Rib crush at the face with continuous mining at Leichhardt Colliery was considered a safety indicator. In general when the ribs at the face crushed on mining, outbursts did not occur. Rib crush typically occurred in those drives near parallel to maximum stress. In these cases it was mainly the lower half of the...
section which crushed with the upper half
remaining hard and retaining pick marks.

Hard ribs which stood solidly and showed
pick marks for the full height associated with
face coal which also showed pick marks for the
full height were considered as a danger sign
for continuous miner faces. Outbursts commonly
followed the hardening of a coal face. In
numerous cases, hard ribs were found to
alternate with intensely cleaved ribs over
zones about 1 m wide. Hard coal ribs with the
formation of pick marks have also been noted by
the author to be associated with outburst
related phenomena in other Australian mines and
at least two coal mines in the United States of
America.

Roof falls

Throughout the history of Leichhardt
Colliery numerous small falls of roof material
occurred at the face from induced cleavage as
described above. Most of these falls were
initiated by high lateral stresses but they
progressed as gravitational failures as
vertical loads exceeded support capacity.
However, lateral stress effects played a major
role in initiating and propagating major roof
falls. These occurred on mining or within a
short period after mining. Their top sections
were elongated approximately perpendicular
to the maximum principal stress.

g eo\_\text{logy, mining methodology, direction of
mining, principal stress orientations and
}n magnitudes, section of the seam mined, opening
shape and related stress effects, rate of
advance, distance of advance in the virgin
coal, seam fluid pressure and pressure
gradients. Table 1 and Fig. 4 summarise the
mining strain patterns for various mining
directions in virgin development.

**Mining strain in degassed/destrressed coal**

In a few locations at Leichhardt Colliery,
development progressed in partly degassed and
destrressed conditions under much improved
mining conditions. In these drives it was
difficult to differentiate strain between
mining directions. Mining conditions were
good. There was minimal or no mining induced
cleavage typical of outbursting conditions.
Outbursts did not occur. The coal ribs showed
typical gravitational loading with some spall
from fractures oriented parallel to the
heading. The initially flat coal roofs showed
central sag tendencies with time due to the
insufficient tensioning of the chemically point
anchored bolts.

**CONCLUSIONS**

Leichhardt Colliery was the first deep
underground (+300 m) colliery to be sunk in the
central Bowen Basin. The technology applied to

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>MINING STRAIN PATTERNS FOR VIRGIN DEVELOPMENT</th>
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<tbody>
<tr>
<td>Drives near perpendicular to maximum stress</td>
<td>Drives near parallel to maximum stress</td>
</tr>
<tr>
<td><strong>Coal Ribs</strong></td>
<td>Intense mining induced cleavage to 1.5-2 m depth. Ribs hard. Outbursts.</td>
</tr>
<tr>
<td><strong>Coal Roof</strong></td>
<td>Sag and low angle shears, some outbursts. Increased peripheral bolt tension.</td>
</tr>
<tr>
<td><strong>Stone Roof</strong></td>
<td>Cleaved over one or both ribs to 30 cm above coal. Roof sag and failure plus increased bolt tension over one or both ribs. Failure on first ribline to intersect stress trajectories.</td>
</tr>
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</table>

**Mining strain patterns**

Mining strain was most pronounced in
rectangular roadways driven by the Joy 10CH
continuous miners. Generalised patterns of
mining strain for various roadway orientations
were observed but were affected by changes in
material and rock mass properties, structural
mining was initially imported from the Southern
Coalfield of the Sydney Basin. The early
investigations of mining strain phenomena
including outbursting and the attempts to
alleviate strain were based on supposedly
similar occurrences in New South Wales and
overseas. The assumption was that mining
technology should have been readily
transferable.

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By the late 1970's it was recognised and accepted that the Leichhardt conditions were not the same as those prevailing in New South Wales or overseas, although similarities did exist. Investigations were intensified to produce a better understanding of the geological environment and how it reacted to mining so that efficient mining systems could be developed for the area.

The investigations showed that the strata surrounding the Gemini seam were subjected to high magnitude lateral stresses and that the Gemini seam was a structurally complex and geomechanically anisotropic body. The stabilities of mine openings of different orientations were controlled by the directionally anisotropic mass strengths and stresses. The outbursts were a direct result of very high gas pressures at the coal face acting in structurally and geomechanically anisotropic coal. The high gas pressure gradients were caused by very low coal permeability (especially perpendicular to the face cleft) which was decreased by the mining induced stress concentrations at the face. Seam gas drainage offered the highest potential for reduction of outbursts and other mining strain phenomena, but in excess of two months standing time was required for seam drainage holes to achieve peak flows. Selection of mining directions to minimise strain when combined with seam gas drainage offered a high success potential. The structural setting of the colliery with major bounding faults to the north, west and east restricted future development and with the frequency of smaller faults, precluded the use of longwall mining.

Mining under difficult ground conditions in a tough economic climate prevented Leichhardt Colliery from becoming an economic operation and it was closed in 1981. A lesson which can be learned from the experience gained at Leichhardt Colliery is that any colliery potentially has its own peculiar rock mass characteristics and that mining technology cannot necessarily be imported successfully to that colliery unless the geological environments and the effects of disturbance of the geological equilibrium are understood.

REFERENCES


The AustIMM Ilwarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986


a  Drive Perpendicular to $\sigma_1$

b  Drive parallel to $\sigma_1$

Fig. 4 Leichhardt Colliery, Mining Strata patterns for various orientations of virgin drivage.

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c) Drive at angle to $\sigma_1$

d) Drive at angle to $\sigma_1$

Fig. 4 Leichhardt Colliery, Mining Strata patterns for various orientations of virgin driveage.

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