

# **TOWARDS HIGH PRODUCTIVITY UNDER A CLAYSTONE ROOF**

**BY PJ HAYES**

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# **TOWARDS HIGH PRODUCTIVITY UNDER A “CLAYSTONE” ROOF: GREAT NORTHERN SEAM SUPPORT MANAGEMENT EXPERIENCES AT CHAIN VALLEY, MOONEE AND WALLARAH COLLIERIES**

**Peter J. Hayes**

General Manager Wallarah Coal Joint Venture  
Coal Operations Australia Limited  
Catherine Hill Bay Australia

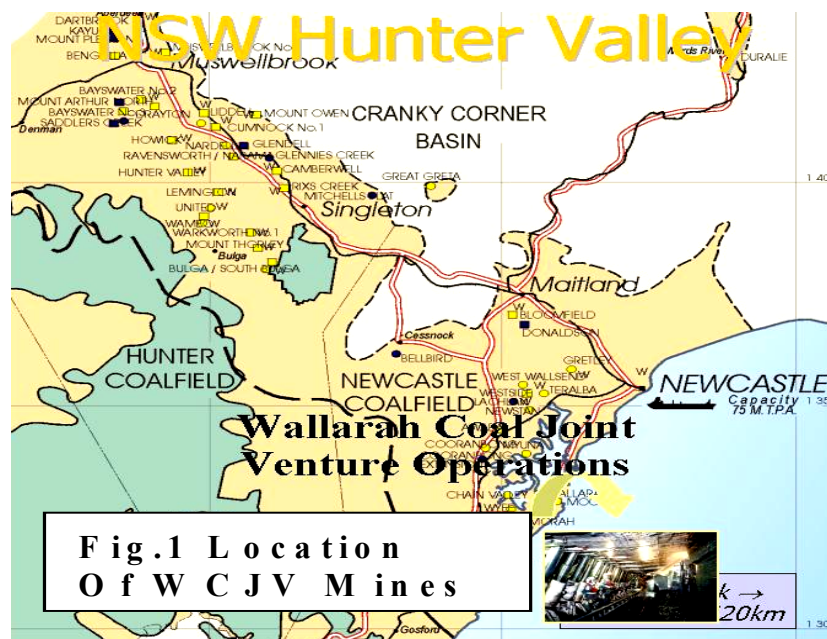
**ABSTRACT:** Coal Operations Australia Limited Operates the Chain Valley, Wallarah and Moonee Collieries which are located in the Newcastle Coal Fields of New South Wales in the Catherine Hill Bay area approximately 100km north of Sydney. Operations are in the Great Northern seam, which until recent years were all conducted under an immediate roof of a strong conglomerate. Large areas of the current reserves at all operations are in areas of a “claystone” immediate roof. All three mines have attempted at various stages of their history to find an economic mining method under these claystone roof conditions, with varying degrees of success at each operation. Moonee currently operates a longwall under claystone roof while Chain Valley and Wallarah are place-changing operations which have operated under claystone with some success. The nature of the “claystone” roof horizons in the three mines is often seen as different at each operation but in practice all of the claystones exhibit similar properties – low strength layers particularly at the coal-claystone interface. Strata control in conditions where the immediate roof above the coal seam is claystone appears to be most sensitive to coal beam thickness left as roof coal, roof bolting pattern and anchorage strength, drivage standards, horizontal stress direction, frequency and type of structures present, exposure time before bolting and possibly depth of cover. Coal beam thickness should be maximised wherever possible to achieve an optimum support density. Place-change mining using deep cuts up to 15m has been successfully carried out under claystone and can be a productive mining method in this environment. There may be potential at Moonee Colliery to introduce place-changing as a method of remnant area mining or even as a gateroad development method. The most critical roof support issues in achieving high productivity under a claystone roof are the setting and maintenance of very high support installation standards and the development of a robust support management plan responsive to changes in strata conditions. This paper sets out to describe and discuss the various attempts to achieve economic success at each of the operations in a claystone roof environment.

## **INTRODUCTION**

Coal Operations Australia Limited Operates the Chain Valley, Wallarah and Moonee Collieries which are located in the Newcastle Coal Fields of New South Wales in the Catherine Hill Bay area approximately 100km north of Sydney (See Fig. 1).

The mines are currently operated as part of the Wallarah Coal Joint Venture which is a joint venture between Billiton Coal Australia Limited and the Japanese company Nissho Iwai. Chain Valley Colliery commenced production in 1962 as a supplier of domestic fuel to the Vales Point Power Station. It initially mined the Wallarah seam up until the early 1990's, when it recommenced operations in the Great Northern Seam. Wallarah Colliery began mining from “E” Shaft pit at Catherine Hill Bay in 1890. Upon exhaustion of the Wallarah Seam reserves it commenced mining in the Great Northern Seam in the 1960's. Both Chain Valley and Wallarah have always been Bord and Pillar operations using continuous miners and pillar extraction methods. Moonee Colliery commenced shortly after World War II, mining the Wallarah Seam, initially for domestic markets and later for export. It was initially a Bord and Pillar operation and when the reserves of the Wallarah Seam were exhausted, the mine moved into the underlying Great Northern Seam. This proved un-economic prior to the introduction of the longwall in late 1997, principally due to the claystone, which forms the immediate roof below the massive conglomerate strata.

Moonee operates a 90m wide DBT longwall face. The depth of cover in operation is around about 200m to the Great Northern Seam at Chain Valley and Wallarah and varies between 60 -160m at Moonee Colliery.



**Fig.1 Location  
Of W C J V Mines**

Nearly all of the workings in the Great Northern Seam up until recent years were conducted under an immediate roof of conglomerate. This is an extremely strong but quite variable roof, which exhibits roof rolls but requires very little roof support, with the normal roof support pattern being around two 1.8 metre bolts per 3 metre of roadway drive.

Large areas of the current reserves at all operations are within areas that have what is called a “claystone” immediate roof above the coal seam. These are in fact a series of Volcanoclastic rocks, which are actually tuffs but are locally referred to as claystone. (Seedsman, 1992).

These types of claystones are wide spread and occur in the roof and the floor of the Great Northern Seam and tend to cause both roof and floor instability problems where they are present. The claystone, where present generally exhibits very low shear strength and may soften, fret and fall simply due to its reaction with atmospheric humidity or under the influence of the major principle horizontal stress. Normally a layer of coal between 0.5 – 1m thick is left in the immediate roof as a support. Unless sufficiently thick, this roof coal may not have sufficient strength to withstand the downward pressure from the claystone if it expands.

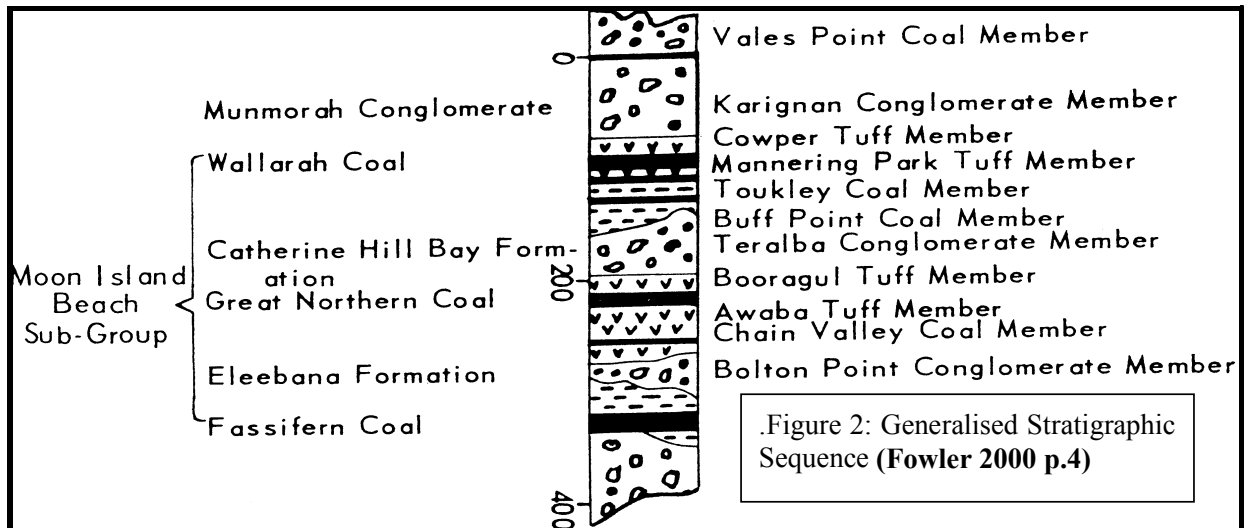
All three mining operations - Chain Valley, Wallarah and Moonee have attempted at various stages of their history to find an economic mining method under these claystone roof conditions, with varying degrees of success at each operation. This paper sets out to describe and discuss the various roof support management systems devised to attempt and to achieve economic success at each of the operations.

### GEOLOGICAL SETTING OF “CLAYSTONE” ROOF AREAS

A generalised stratigraphic sequence of the uppermost subgroup of the Newcastle Coal Measures, the Moon Island Beach Sub-Group, together with the immediately overlying Munmorah Conglomerate Formation of the Narrabeen group is given in Fig. 2. Constituent components include coal, conglomerate, sandstone, shale and rocks of pyroclastic origin which are of variable grain size up to coarse and are termed ‘tuff’. Moon island Beach Sub-Group includes 3 major Coal Members – the Fassifern, Great Northern and Wallarah seams all of which are currently worked at various mines throughout the locality. The Great Northern Seam worked at Chain Valley, Wallarah and Moonee Collieries is a high volatile low sulfur medium ash thermal coal, which is used for power generation. The seam is up to 4m thick but is generally worked at a height of 2.7 – 3 m due to quality, and roof and floor control reasons. Overlying the Great Northern Seam coal is the Catherine Hill Bay formation. This ranges in thickness from zero, where the Great Northern Coal and Wallarah Coal merge, to over 60 m. The immediate roof over much of the seam is the Teralba conglomerate, which is up to 40 m in thickness and exhibits compressive

strength of around 45 MPa. In other areas the Booragul Tuff member forms the immediate roof of the working seam termed the "claystone" roof, the subject of this paper.

The position and extent of the "transition zone" between the tuffaceous claystone roof and the conglomerate roof is controlled by the boundary of the original river stream channels, which completely eroded the original claystone roof and deposited the thick series of conglomerates which form the roof of much of the Great Northern Seam (Edwards, 2000). The accurate mapping of this transition zone is extremely difficult from even closely spaced boreholes, as it not only weaves and moves non-linearly but also the width of the transition zone from full conglomerate roof to claystone roof greater than 2 m thick can occur over many hundreds of metres. In addition the thickness of claystone can vary from zero to several metres across the width of a bord and be accompanied by the notorious "rolls" in the conglomerate roof.



### MINING HISTORY UNDER CLAYSTONE TO 1995

The first mine to be worked in the Catherine Hill Bay area was the new Wallsend Colliery, which commenced in 1873 from the outcropping Great Northern Seam in the south-end of Catherine Hill Bay. The original entries to this mine are still visible although sealed now. This mine worked the Great Northern Seam under a clay stone roof. A journalist from the Sydney Mail Newspaper visited the mine in July 1875 and described the engine room which had been excavated to the full seam height and to the bottom of the conglomerate. He wrote that "the coal rose an unbroken mass to a height of 14 feet [4.3m] with an almost imperceptible scale of slate in two places, then a layer of pipeclay varying from 6 to 14 inches [15-35cm] surmounted by a seam of splint coal." This is a reasonable description of the Great Northern Seam in that area and describes the claystone roof above the top of the seam.

In 1874 in two separate instances two men were killed from falls of top coal. In the investigation of the first fatality of James Hall on the 1<sup>st</sup> June, the inquest as reported in the Miners' Advocate newspaper on the 13<sup>th</sup> June 1874, referred to a statement by the Government Inspector of Collieries who visited the scene after the accident. The inspector commented that the bord was about 22 ft [6.7m] wide and the working height of the coal was nearly 8 ft [2.4m]. The roof was very jointy and open and there were three rows of props set in the bord within 5 ft [1.5m] of the working place. The fall of top coal that occurred had fallen back almost to the first row of props and between two very smooth parallel facings. The mine grew to be a difficult operation due to the undercapitalisation of the mine, the very hard nature of the coal seam and the loading of the coal being subject to the ability of the ships to load at the open sea jetty at Catherine Hill Bay. For the next 80 odd years, little or no attempt was made to mine the Great Northern Seam under claystone roof. This was due to both the discovery of the Wallarah seam and its better roof conditions and the subsequent working of the Great Northern Seam under conglomerate roof conditions.

Chain Valley Colliery was opened in 1962 and it drove the initial headings to connect the pit bottom to the upcast shaft within a claystone roof environment. Poor roof conditions created great difficulties in reinforcing the roof with the support methods used at the time, which consisted mainly of props and cross timbers. In the first attempt all of the coal was mined and the claystone was the immediate roof. The roadways were heavily timbered and the claystone is now considerably broken. Many areas have falls up to a height of 2-3m and roadways are up to 7m wide and 3m high, showing evidence of poor horizon and width control of the bords. Inbye this area the mining

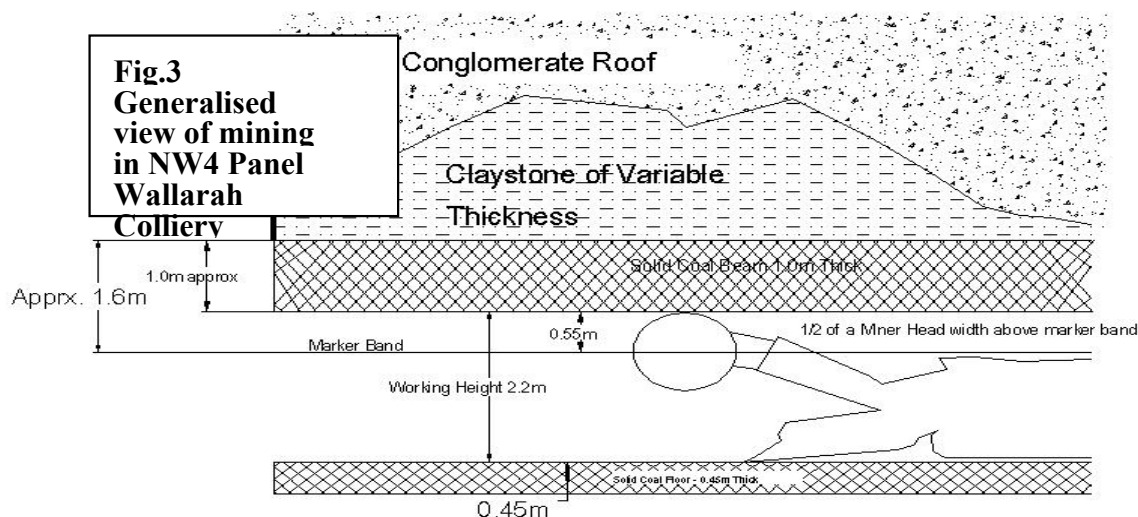
horizon was altered leaving a coal beam of approximately 1m supported with half round bars and the roadway width was reduced to approximately 4.8m. Roof bolts were then introduced and 2 bolts (mechanical anchor point type) were installed approximately every 2m. These changes resulted in greatly improved roof stability and some of those drivages are still intact today, although many have also failed and are on the ground. There were some directional problems and conditions in the headings (driven in a N-S direction) were much better than the cut-throughs with some evidence that cut-through angle drivage had been altered with some success.

In the early 1990's as the Wallarah seam reserves were diminishing Chain Valley decided to recommence work in the Great Northern Seam. To access coal under the conglomerate roof on the other side of the lake, mining under claystone was required. In this area of Chain Valley, workings under claystone consisted of around about 1.4m of coal tops overlaid by in excess of 10m of claystone. Standards of drivage were poor in the early stages and roof horizons and mining widths were inconsistent. Later in the panel as the claystone thinned a decision was made to cut up to the conglomerate.

Both Wallarah and Moonee Collieries in the early 1990's attempted to drive headings and extract coal in the claystone roof areas of the mines with little economic success using similar methods as in the Chain Valley experience described above. Wallarah's NW3 panel was driven in 1992 with minimum support rules for this panel under coal tops being 2 bolts (1.2m minimum) every 2m with 6 bolts in the intersections attempting to leave around 700mm coal tops. The approach at the time was unsystematic and standards not consistently observed. Several intersections failed without apparent warning<sup>1</sup> and the panel was abandoned. Similar occurrences were experienced at Moonee when the Great Northern seam was first worked in the early 1990's.

### WALLARAH COLLIERY EXPERIENCE 1999

Dwindling reserves under conglomerate roof in the Great Northern Seam prompted the attempted development of the seam under a claystone roof. The area in which the panel under claystone was attempted lies at an average depth of 130m and was called NW4 Panel, and located in the northern area of the mine. The coal seam in this area is approximately 3.4m thick and is immediately overlaid by a variable thickness of claystone up to around 4 m thick. Overlying this is the sequence of massive conglomerate and sandstone up to 50m thick. A previous empirical trial in an adjacent area of the mine where a limited length of headings were driven under claystone concluded that around 1.0m thick coal beam in normal conditions was sufficient to maintain a stable roof horizon in a road way around 5.5m wide. This trial was done using an unsupported roadway that was left for several months and no roof deformation occurred. In the same area where 0.5m thick coal beam was left unsupported in a 10 m wide break-away the roof fell within 24 hours of the cut being formed.



NW4 Panel was driven within the transition zone from conglomerate roof to full thickness claystone roof in the Wallarah northern area (Fig.3). Old pillar workings from the Wallarah seam (35m interburden) also overlie this area. This transition zone was unfortunately very extensive and the conditions encountered including extreme roof rolls in the claystone/conglomerate interface did not result in high productivity. In order to leave a minimum of

<sup>1</sup> No monitoring such as tell-tales was carried out in this panel.

800mm of roof coal the working height had to be reduced to around 2.1 – 2.2 m. This proved to be difficult and resulted in the thinning of the floor coal to the extent that the trafficability conditions were extremely poor. This coupled with the roof rolls that occurred together with the claystone roof resulted in an unproductive panel. However the roof support put in place at the time of the driving the panel, resulted in an extremely stable environment and no roof falls or deterioration in conditions have occurred in the 12 months since this section was developed. While this panel averaged only 9m/shift advance rate in what was effectively a three heading panel (see Fig.4), it did result in a proven roof support pattern for the conditions encountered at Wallarah. It also indicated that place-changing under a claystone roof could be productive if the floor horizon could be maintained in a trafficable state. In an adjacent area some years previously NE7 panel had been driven where the claystone was up to 1m thick. NE7 panel was driven to very poor standards (wide roads and inconsistent support pattern and little or no coal top left) which allowed the claystone to fret and consequent rib and roof falls occurred (see Photos 1 & 2). The contrast of these two panels demonstrates the impact that good design and standards can have on roof control.

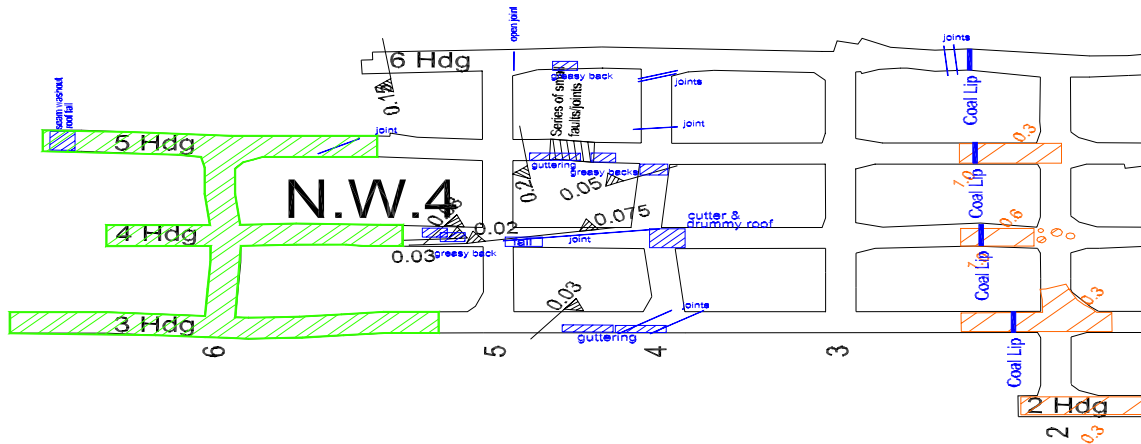
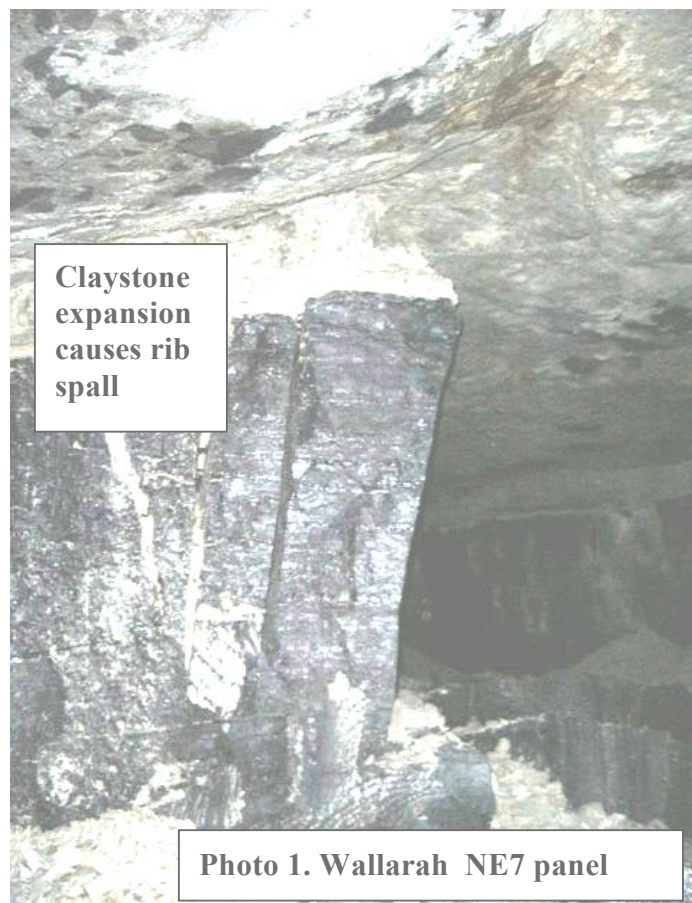
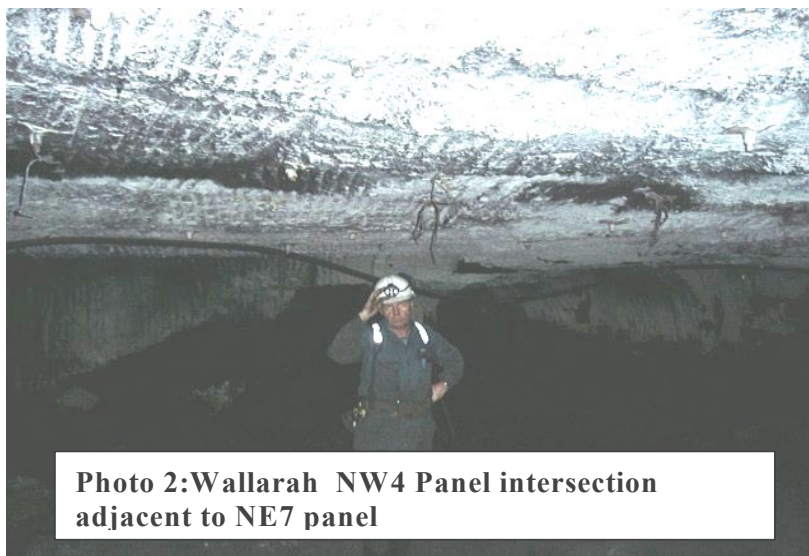


Fig.4 NW4 PANEL WALLARAH COLLIERY

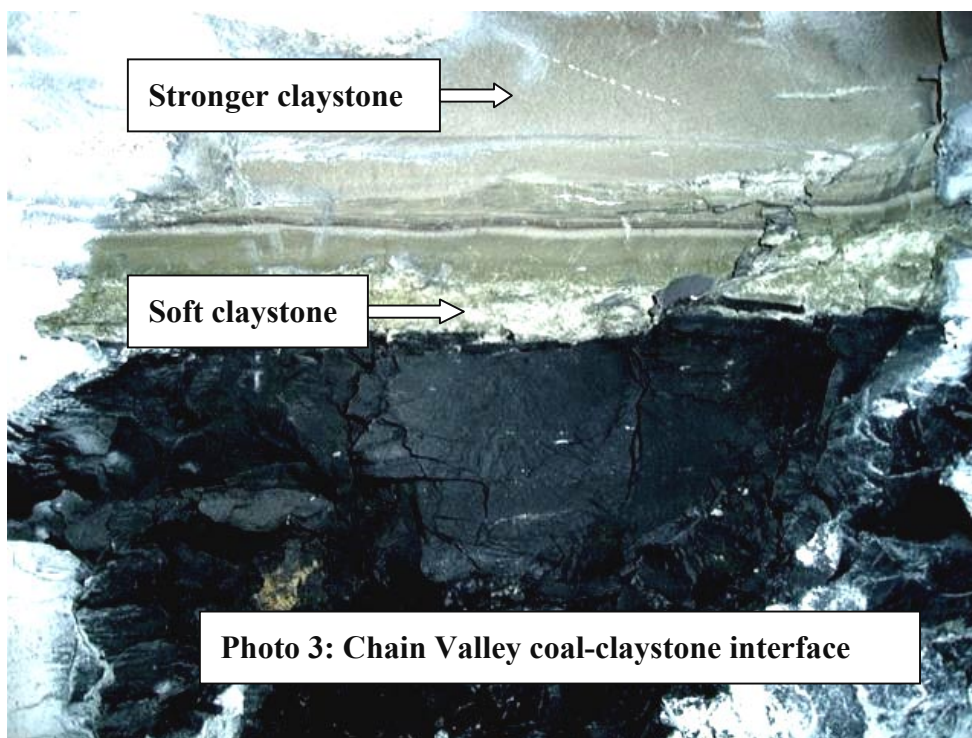




**CHAIN VALLEY COLLIERY EXPERIENCE 1999-2000**

**One North West Panel**

In late 1997 a panel was driven towards the upcast shaft through the “transition” zone and into an area of full claystone. The claystone thickness increased within a cut-through from 50mm to the point where it was too thick to mine and a decision was made to leave a thickness of coal roof underneath the claystone. The places were generally driven too wide and the quality of the roof horizon control was poor, and enforcement of standards was insufficient. The mine was down-sized shortly afterwards and the unit finished with only about 100 metres of drivage completed under claystone, with disappointing results.



The same section was recommenced in late 1999 to drive the panel to connect to the up cast shaft. The original headings driven were downdip and had filled with water and there were some concerns that the claystone was saturated and would cause roof support problems. In preparation for this new attempt at mining this area, extensive training and education of the new workforce was carried out. A Jeffrey continuous miner with Hydramatic bolting rigs mined 3 headings with 50m x 30m centres. The concerns with the saturated claystone were realised when the first cut through driven guttered along the middle to about a metre wide. Drivages were supported with four 1.8m AX bolts at 1m centres but this was changed in better roof conditions further inbye, to 1.5m spacings when it was evident that the roof had become competent. The seam was generally flat and the places were driven at less than 5m wide and with approximately 1200mm of coal roof using a working section of 2.2m. Headings and cut-throughs did not appear to be any different in conditions and no problems occurred in this panel with respect to cutters. As an experiment stubs were driven off the main roadways with different beam thickness and seam height, width and cut out configurations and they were left unsupported. These varied from coal beam thickness of 800mm at 4.8m wide to 1200mm at 5.5m wide and over 12 months later these unsupported stubs are still standing and showing no signs of deterioration. After a series of roof bolt tests two-thirds of the way through the panel the roof bolts spacing was increased to 2m and this proved successful. The roof above the coal beam was predominately a sandy claystone and appeared to provide reasonable anchorage for the roof bolts installed. A roof core around No. 5 cut-through was taken and showed a hard fine-grained claystone. The productivity in this 3-heading panel reached 500 t per unit shift, but an average was around 250 t per unit shift (or 15m/shift). As a miner bolter was used the productivity was quite low, but in the same conditions it is believed that place changing would certainly have achieved 1000 t per unit shift plus.

### Sump Headings – 2000 Panel

This panel was formed in an area of the mine that had been blocked out and avoided for many years and was known to be under extensive thick claystone roof conditions. Place changing was used as the mining method in the panel for the first time at Chain Valley Colliery. The panel was being formed as a sump area for a new pumping system for the Wallarah and Great Northern Seams. The area was highly structured with both predominating major and minor cleats and cutters running through the area known as well as some faults projected from the overlying Wallarah seam workings. The Wallarah Seam had been worked over the top of this panel with pillars being formed but not extracted and the inter-burden being around 35m. Places were kept to 4.8m wide in the cut-throughs and 5m in the headings. The depth of cover was around 200m and the pillar size used was 24m centres. The roof support management system specified four degrees of support requirements, determined by the minimum coal beam thickness at the last bolt installed at the face and the structures present. Table 1 shows these requirements; Level 3 support diagram is shown in Fig.5.

**Table 1- Summary of Chain Valley Colliery Roof support in Sump headings under claystone roof**

Coal Beam thickness, mm	Cut depth max, m	No. 1.8m bolts in row	Spacing between Rows, m	Mesh Modules (y/n?)
>1200	15	4	2.0	No
800-1200	15	4	1.5	No
<800	12	4	1.2	No
Broken roof beam	6	4	1.2	Yes

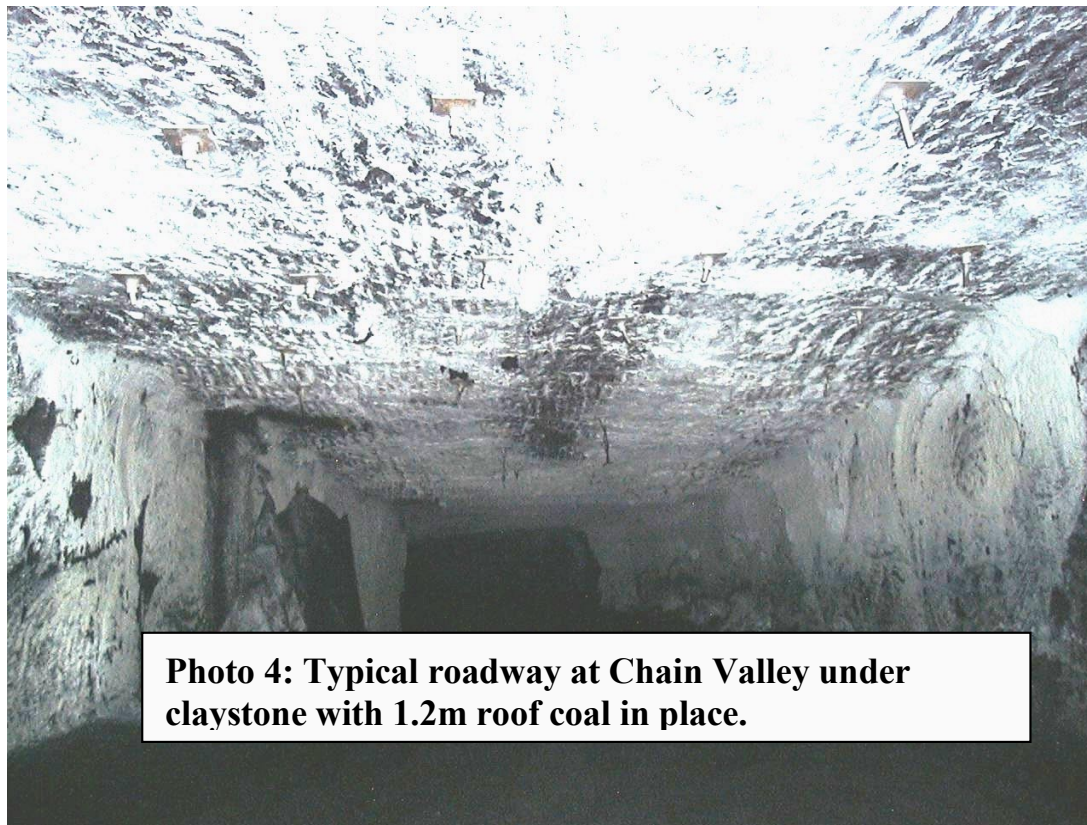
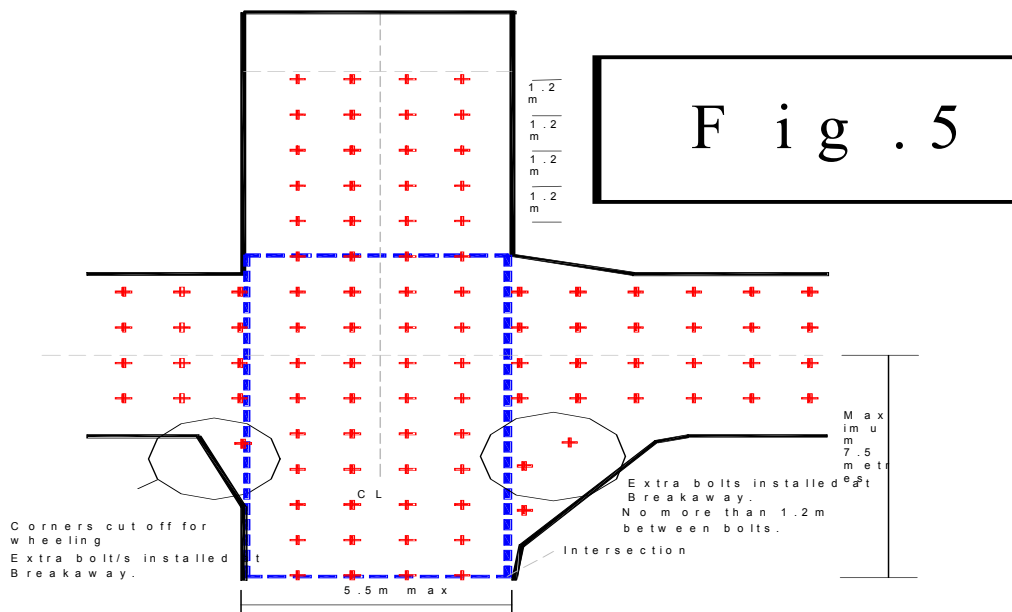


**LEVEL 3**

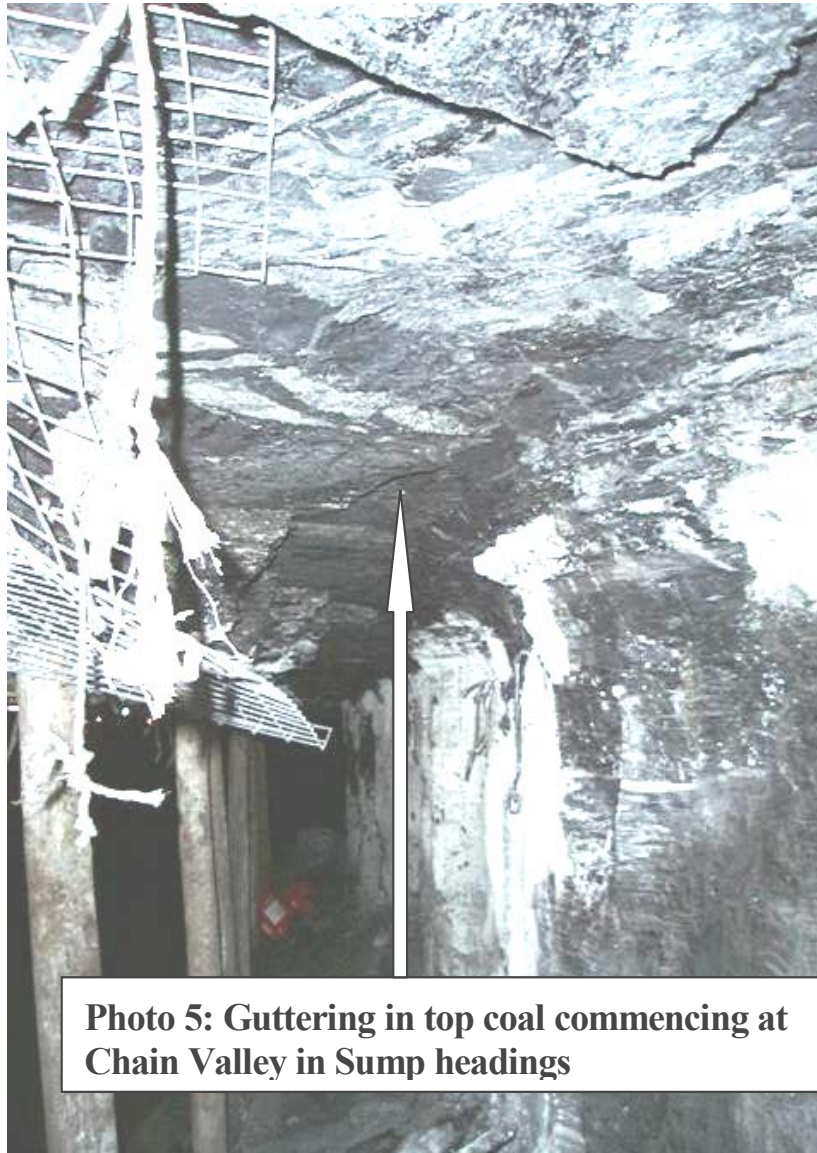
Where Coal Roof Beam is less than 800mm

4 AVH Bolts, 1.8m long @ maximum 1.2m row  
 Maximum cutout = 12 metres. NO PERSON TO GO PAST L,  
 In the Sections - 4 AVH bolts, 1.8m long @ 1.2m row  
 Extra bolts in breakaways as  
 Roof bolts are to be fully encapsulated and to manufacturers  
 Roof bolts are to be installed as near to vertical as  
 Temporary mechanical roof supports shall be placed prior to

**B O L T I N G**



**Photo 4: Typical roadway at Chain Valley under claystone with 1.2m roof coal in place.**



**Photo 5: Guttering in top coal commencing at Chain Valley in Sump headings**

The initial drivages in the panel were very difficult due to the structures and on occasions cut-outs were limited to a few metres. A few pillars inbye the panel was widened to 3 headings and roof support conditions improved enough to accommodate a 15m cut out. In this area the best month achieved averaged 30 m/shift advance rate. The cutters were extensively mapped and it was evident that they were the key criteria relating to poor roof conditions. Some areas exhibited such intense structures that the coal beam even at 1200mm was broken and fell out like broken bricks with no mortar. However, cuts that were going to fall always fell before bolting with the mobile bolter and there were no problems after the cavity had been meshed and bolted i.e. the support issue was one of an immediate problem that had occurred within a short period of time of exposing the cut. No intersections have fallen to date although some signs of guttering in the top coal have occurred. Inbye of this area the coal beam was reduced in thickness from 1200mm to 900mm to increase the sump capacity and a second bolter was brought in to keep up with the bolting required. Fifteen metre cut outs were regularly achieved and did not cause problems. When a cut did fall in it often required 2 – 3 shifts to mesh and bolt it up and this is the reason that the 2<sup>nd</sup> bolter was required. Many shifts of more than 1000 tonnes per shift were achieved the best shift being nearly 1300 tonnes (66m). This is by far the best performance achieved in the Great Northern Seam under claystone roof at any of the COAL operations using continuous miner technology. Photographs 4 & 5 show this area in Chain Valley several months after the completion of the panel. Some incipient guttering has commenced in some areas but no roof falls have occurred in any of the mine roadways and the intersections all appear to be stable.

**MOONEE 1995-2000**

The Great Northern Seam at Moonee is approximately 3.7m thick over the areas proposed to be mined by longwall and the depth of cover 80 m to 160m. The stratigraphy of the immediate roof includes a very weak claystone, a moderately weak claystone and an anchor coal above which is up to 30m of a massive conglomerate with strength between 15 MPa and 50 MPa. The coal of the Great Northern Seam is extremely strong coal with a laboratory strength of 25-30MPa. The stress regime in which Moonee is worked is a maximum horizontal stress of 10 MPa in NE/SW direction. The key design issues for the roof support at Moonee is the thickness of the immediate roof coal left intact and the very weak claystone forming the lower and upper coal-claystone boundaries. The claystone softens considerably soon after contact with air or moisture. When the claystone is cut by a continuous miner it exhibits pick marks for some time before becoming the characteristic pliable clay material well known to Moonee personnel (Strata Control Technology 1994, p.3). Early work by Strata Control Technology showed that the majority of movement in the area between the roof coal and the conglomerate was in the coal claystone boundary area. (Strata Control Technology, p.6).

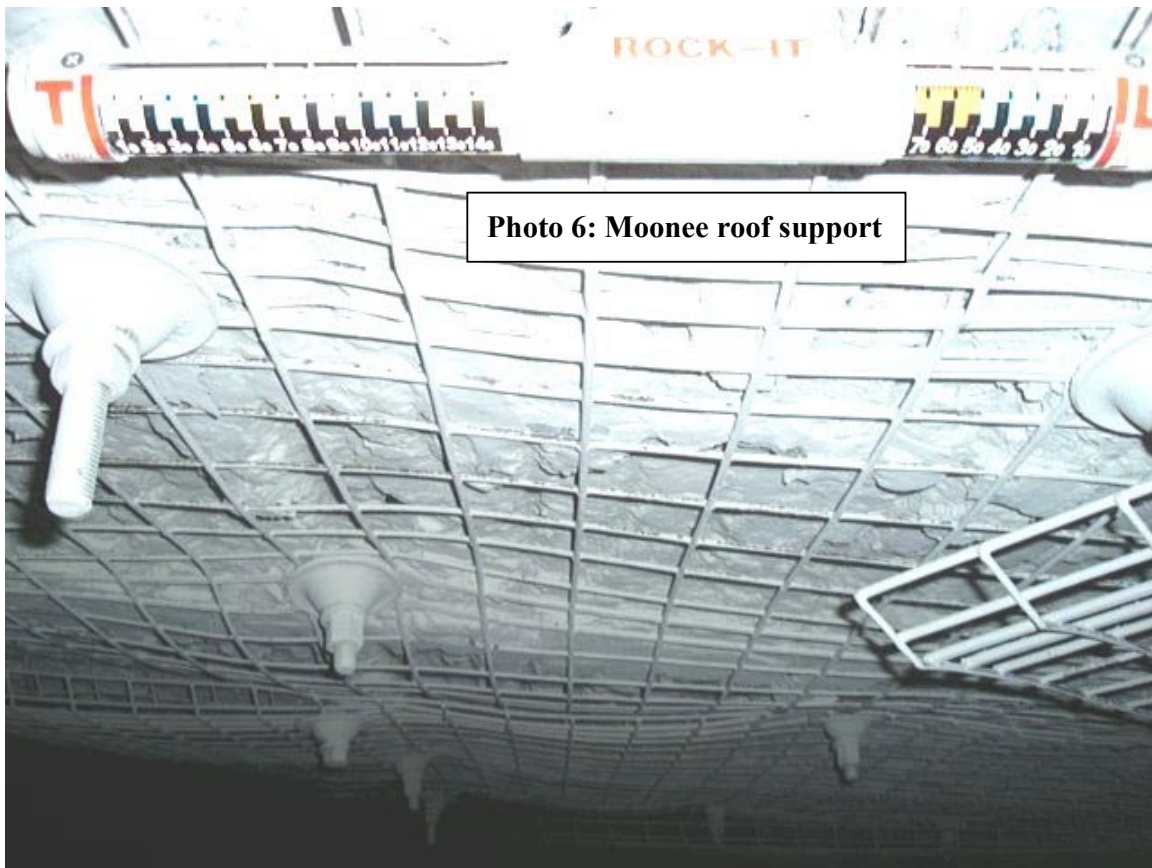
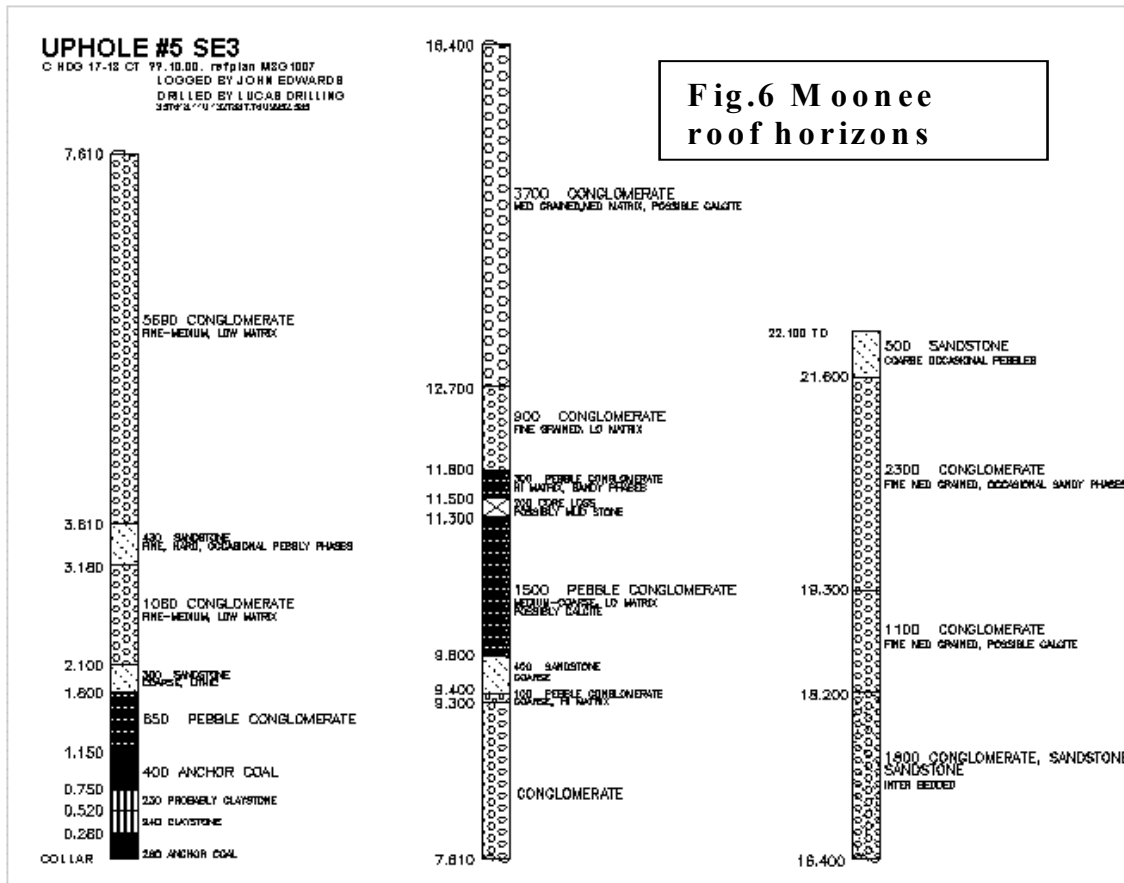


Fig. 6 is a log of an uphole drilled from SE mains panel and shows typical immediate roof lithology used in the initial support design. The maintenance of the roof coal integrity to attempt to resist the pressures imposed by the bulking of the failed claystone, is the most critical issue in roof support design at Moonee, as the vertical stress and the road ways at the maximum depth of 160 m on initial drivage is insufficient to even cause rib softening.

Longwall extraction was however predicted to cause significant rib spall once vertical abutments exceeded the unconfined strength of the coal. At 160 m depth of cover the rib spall in the main gate area within a few metres of the face would be about 2 m and that, moderate to severe guttering, with associated centre-line cracking would occur in this area (Strata Control Technology, p.10). This has not occurred at Moonee and rib spall in the longwall face area has not been experienced. Convergence measurements demonstrated that the additional convergence added by the passing of the longwall on Maingate 2 was around 1mm that the roadways were very stable. (Strata Engineering, 1999, p. 10).



The initial and indeed subsequent roof support designs at Moonee relied on full encapsulation along the bolt length (bolted into and above the anchor coal, which is above the claystone) and a minimum 700mm coal left in place in the roof. One of the key findings from the early modelling was the most effective method of maintaining integrity of the lower coal was to increase its' thickness and thus a minimum thickness of 700mm was specified. The role of the bolts is simply to modify the behaviour of the claystone by improving the integrity of the lower coal. The philosophy was based on the fact of the claystone does not easily lend itself to reinforcement. Many of the falls in the early history of Moonee Colliery before the longwall was commenced were in areas where top coal was much less than 700mm thick and typically less than 500mm thick. The coal roof thickness is intended to be the principle means of controlling the behaviour of the roadway and the roofbolts could be installed up to a maximum of 2m from the face with the security that the coal beam provided. The full encapsulation of the bolt particularly at the coal horizons from the collar to the back of the hole was critical to maintaining the load transfer and reducing collar loading. Many of the early falls were attributed to collar loads and bolts pulling through the immediate coal strata. SCT maintained that if the roof coal thickness was reduced to even 500mm, collar failure is highly likely even with good load transfer and full encapsulation (Strata Control Technology 1994, p.13).

Initial roof support design recommendation was using six 2.1m bolts in a W-strap and the straps placed 1.5m apart. Some failures of the coal between the straps occurred in the early part of the Moonee longwall operation which resulted in a further re-evaluation of roof support design. Initially bolting density was increased to 8 bolts per 1.5m and the coal beam thickness reduced to 600mm to facilitate a reduction in bolting length to 1.95m and mesh modules introduced together with domed plates (Strata Engineering 1999, p.7). This pattern was further changed to mesh modules with 6 bolts every 1.5m set in a 4-2 pattern eventually settled upon.

Although the initial design of the roof support system at Moonee relied heavily upon the reinforcement of the coal beam, the focus at the mine level became principally one of ensuring that the coal beam (no matter how thin or thick) was anchored at least 300mm into the conglomerate. The mine has now successfully completed five longwall blocks which have retreated along 20km of gateroads without any falls of ground in either maingate or tailgate or any problems encountered during longwall salvage operations. This is testament to the generally high operational standards of drivage and the probable overdesign of the roof support systems. The accompany photograph shows the shearer holing the maingate on Longwall 4B at a depth of cover of about 130m. Note the ribs are intact and standing vertically even though the shearer has less than 0.5m of coal to hole the gate. The mine is now driving gateroads in an area where the claystone has thickened to such an extent that anchorage in conglomerate is not possible. Fortunately the claystone above the anchor coal appears more competent and is sustaining bolt loads (Tarrant, 2001). In this area the mine is using a pattern of four 2.1m bolts at 0.75m spacing on 1m mesh modules.

## DISCUSSION

The nature of the "claystone" roof horizons in the three mines is often seen as different at each operation. Chain Valley claystone is seen as more competent than Wallarah or Moonee. Moonee is often cited as the weakest claystone. In practice all of the claystones exhibit similar properties – low strength layers particularly at the coal-claystone interface. At Wallarah Colliery in the same area that could not be supported years before and the claystone fretted away to a soft puggy material, a new panel was driven which has not deteriorated at all 12 months afterwards, thus demonstrating the benefits of high standards of drivage and a systematic approach. Chain Valley established that when working under claystone roof using place-changing technology up to 15m cuts could be driven successfully. The mining system productivity in a 6-heading layout was sufficient to be financially viable even in areas with a moderate degree of structure provided that floor trafficability could be maintained.

Strata control in conditions where the immediate roof above the coal seam is claystone appears to be most sensitive to the following, some of which are interdependent:

- Coal beam thickness left as roof coal. In good conditions at Wallarah, Chain Valley (and probably Moonee<sup>2</sup>) a coal beam thickness of 1m resulted in good drivage conditions that enabled a 15m cut.
- Roof bolting pattern & anchorage strength. A lower coal beam thickness was adequately compensated for at all mines by increasing the support density. Conversely a thicker coal beam enabled support density to be reduced successfully at both Wallarah and Chain Valley. The ability of the upper claystone to provide sufficient anchorage for bolting is critical if there is no conglomerate in which to anchor the bolts.

<sup>2</sup> The indications at Moonee are scant because the ability to leave a coal beam thicker than 700mm is constrained by equipment height considerations. However an unsupported stub heading was driven in MG6 which left 1m of coal roof intact inbye of a cut-through which required secondary support and the stub remained stable for many months.

- Drivage standard. The older panels under claystone at both Wallarah and Chain Valley failed at least in part because of poor alignment of drivages and poor width control
- Horizontal stress direction. As would be expected, drivages perpendicular to the major principal horizontal stress tended to fare worst.
- Frequency and type of structures present. Increasing coal beam thickness to even 1.2m did not prevent coal roof falls freshly-driven cuts in highly structured areas of Chain Valley.
- Exposure time before bolting. Face falls even in structured ground are very rare at Moonee which does not expose more than about 2m of roof at one time. Falls of top coal in cuts, where often 10-15m of roof was exposed at one time, occurred at Chain Valley in highly structured areas. However no falls occurred after the cuts were bolted, even though this was a higher stress environment than Moonee because of a greater depth of cover and the superimposition of the Wallarah seam workings above.
- Depth of cover. The conditions in the claystone drivages at Wallarah Colliery at 130m depth show little sign of deterioration after 12 months whereas Chain Valley's drivages (using the same equipment and mining method) appear to be showing some early signs of guttering in some headings. The difference may in part at least be due to depth issues.

At Wallarah, Chain Valley and Moonee, the intersections under claystone appear to be often more stable than the headings. This is particularly evident at Chain Valley where 4-way intersections show no signs of deterioration but headings leading into them show early signs of guttering. At Moonee there are several outbye lightly-supported intersections on the belt road where the cut-throughs have fallen right up to the intersections on both sides and the intersections show no sign of deterioration. It is unclear as to the reasons for this.

### CONCLUSIONS

1. Working the Great Northern Seam under claystone requires good risk management practices.
2. There may be minor differences in the claystones between Chain Valley, Moonee and Wallarah, even indeed within the same mine, but all exhibit low strength properties especially in the contact area with the coal seam. They appear to become more competent the higher up in the strata.
3. Coal beam thickness should be maximised wherever possible to achieve an optimum support density.
4. The influence of structures on the roof support requirements is immense. Structures can ultimately result in the need to "stringbag" the roof in order to maintain stability.
5. Place-change mining using deep cuts up to 15m has been successfully carried out at Chain Valley Colliery under claystone and can be a productive mining method in this environment. Place-changing under claystone at Wallarah Colliery has the potential for similar or even higher productivity levels provided the floor trafficability issue is addressed successfully.
6. Depth of cover may prove to be a limiting factor in achieving high productivity under claystone.
7. There may be potential at Moonee Colliery to introduce place-changing as a method of remnant area mining or even as a gateroad development method.
8. The most critical roof support issues in achieving high productivity under a claystone roof are the setting and maintenance of very high support installation standards and the development of a robust support management plan responsive to changes in strata conditions.

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