



# Coal pillar extraction experiences in New South Wales

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## Synopsis

New South Wales has a successful history of pillar extraction stretching back more than 60 years. Various methods of pillar extraction ranging from the rib pillar methods (such as the Wongawilli system) to the more recent pillar stripping techniques (similar to those used in the USA) are discussed in this paper. These discussions are based on the experiences of the author stemming from a recent research tour of seven underground pillar extraction operations in New South Wales as part of the Coaltech 2020 collaborative research initiative. Some operational issues of each site visited are presented before some general comments pertaining to the overall success of pillar extraction in New South Wales are discussed. Generally pillar extraction in New South Wales is on the decline in favour of longwalling. However, the pillar extraction that is conducted is done so along specific guidelines to ensure their success, and these are also discussed.

## Introduction

Pillar extraction offers the possibility of a high degree of recovery of reserves and is practiced globally with varying degrees of success. This mining method is not practiced widely in European collieries however, partly because the coal seams are situated at comparatively greater depths (when compared to South Africa and Australia), at 300 metres or more below surface. At these depths the other high extraction mining technique (longwalling) is widely used, as it is inherently safer than pillar extraction<sup>1</sup>. The use of longwalling as a high extraction mining technique in the USA and Australia was initially stifled as a result of competent overburden creating roof control difficulties with the earlier types of longwall supports. In addition to this factor in South Africa, problems with maintenance, mine planning and scheduling, and the presence of high strength dolerite dykes intersecting nearly all the major coal deposits, also contributed to the delay in employing longwalls in South Africa. These dolerite dykes severely limited the number of locations where longwalls could be deployed. Also, from a financial perspective, South Africa

traditionally has a high ratio of cost of equipment to cost of labour which further delayed the implementation of longwall systems. In recent years longwalling has become the predominant mining method in underground mining in Australia, contributing over 80 per cent of the total underground production output in 2000, while in the USA this mining method contributed half of the total underground output in 2000. The remainder of the underground production in these countries comes from bord-and-pillar operations. The longwalling technique has still only found limited success in South Africa for the reasons mentioned previously, contributing approximately 5 per cent of the total coal production in 2000<sup>2</sup>, with bord-and-pillar mining forming the bulk of underground coal production.

Pillar extraction, as an alternative high extraction system to longwalling, is practiced successfully in Australia (New South Wales) and the USA, but only to a limited extent in South Africa. The resultant pillar creation in South Africa and their subsequent extraction is the focus of Task 2.5.2 (the safe and economic extraction of pillars and associated reserves in the Witbank and Highveld coalfields) of the Coaltech 2020 collaborative research initiative. Owing to the geological similarities of the coalfields of New South Wales and South Africa, a research tour of seven pillar extraction operations in New South Wales was conducted in the first half of 2001 to investigate current advancements in pillar extraction that may benefit future pillar extraction in South Africa. Four of the operations visited conducted full pillar extraction while the remaining three conducted partial pillar extraction. This paper will present past and current pillar extraction methods used in New South Wales and will

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discuss from a South African perspective novel and/or unique factors affecting these operations.

## History of pillar extraction in New South Wales

Australia has a long history of pillar extraction dating back more than 60 years. The associated development of new technologies is shown in Table I.

Three highly successful and productive pillar extraction systems were developed and refined by Australia, viz. Wongawilli, Munmorah and Old Ben. Although these methods are predominantly rib pillar extraction methods, they were the focus of research and the development of a similar successful mining method at Sigma Colliery in South Africa<sup>4</sup>. It is worth briefly discussing these three methods to track important changes to the pillar extraction mining practice in New South Wales.

## The Wongawilli pillar extraction system

The Wongawilli system was developed at Wongawilli Colliery in the southern coalfield of New South Wales in the early 1960s. Generally with the Wongawilli system, a panel is created by a secondary development consisting of three to five roads and leaving a continuous pillar of coal between the development and the previously caved area. The pillar is normally between 50 m and 150 m wide and is extracted by

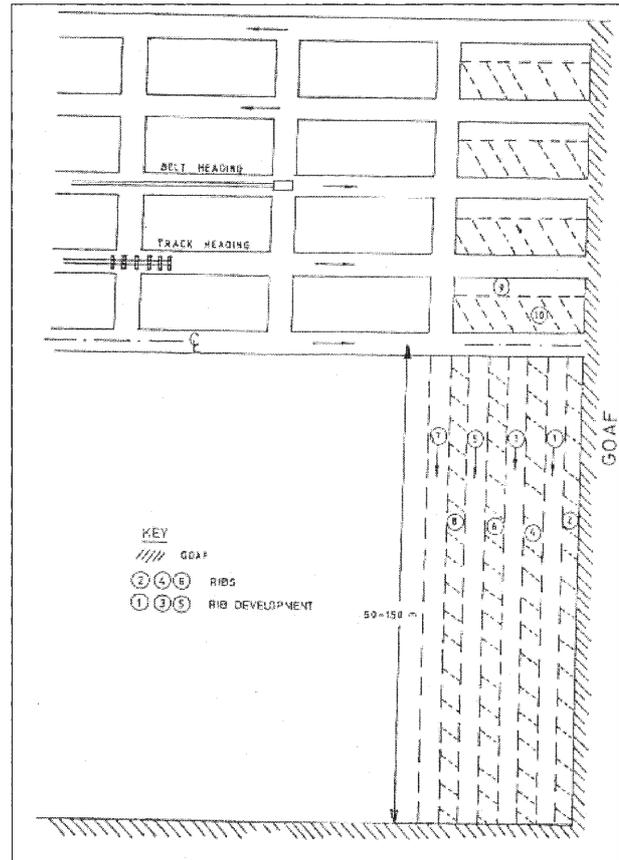


Figure 1—Typical plan view of the Wongawilli system<sup>4</sup>

developing and extracting 7 m wide ribs in a modified split and lift system. The pillars formed by the development are extracted as the rib extraction retreats. As a result of the length of the rib pillars, this method resembles a shortwall face. A typical layout of this extraction system is shown in Figure 1. This method was developed to provide a single working place to extract coal in a stress-relieved area and to utilize the coal seam as support during extraction. An overall extraction of 90 per cent was achieved by this system.

The main disadvantages of the Wongawilli system are<sup>4</sup>:

- Excessive floor lift when splitting successive headings in a large panel
- Difficulties when removing snooks on the return run out of each heading
- Difficulties with ventilating rib pillar panels when the roof caves completely, thus filling voids in the goaf area and choking the ventilation flow.

## The Munmorah pillar extraction system

The Munmorah system, developed at Munmorah Colliery in the Lake Macquarie district of New South Wales in Australia, was originally practiced at an average depth of 180 m below the surface. The coal seam was on average between 1.8 m and 3.0 m thick and hard, which made it difficult to cut with a continuous miner. The floor was composed of soft shales and floor heave often occurred due to pillars being forced into the soft floor. The rib pillar panels were usually 1 200 m long and 183 m wide and were developed on either side of

Dates	Mining method changes
1938	Loading machines first used in pillar extraction, but withdrawn in early 1942
Pre-1942	'Open-ended lifting' carried out working multiple (10) places with diamond-shaped pillars.
1949	Modified Old Ben system tried at Bellbird Colliery (Cessnock).
1954	Coal cutters permitted in 'Open-ended lifting'.
1955	Joy continuous miners first introduced.
1957	First shuttle car introduced at Wongawilli Colliery and at Kerima Colliery. The first use of long (100 m) splits on 25 m centres working a diamond-shaped layout without shuttle cars.
1958	Modified Old Ben system used in State mines south of Lake Macquarie.
1957-1961	Initial attempts at Wongawilli and Nebo Collieries to work a long fender system (precursor to the Wongawilli system) and 'split and lift' with continuous miners and shuttle cars were unsatisfactory.
1961	First successful Wongawilli system panels worked at Wongawilli and Nebo Collieries.
Post-1961	Continued improvement of the Wongawilli system especially with regard to split centre dimensions.
Late-1980s	Modified Wongawilli systems developed by driving splits on each side of the panel headings and lifting left and right from the splits.
Mid-1990s	Successful use of pillar stripping at Endeavour and Cooranbong Collieries for partial extraction.
Early-2000s	Successful application of pillar stripping at Clarence, Munmorah and Cooranbong Collieries for partial extraction and at United Colliery for full and partial extraction.

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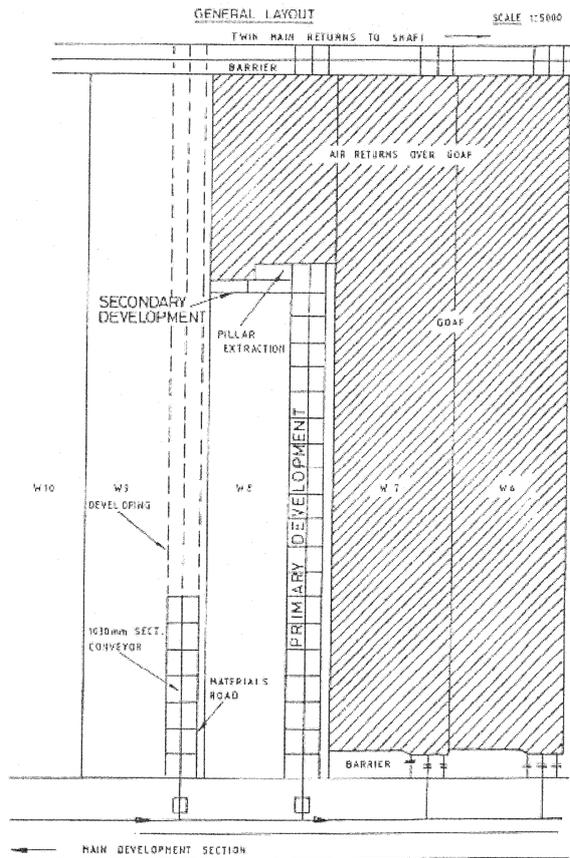


Figure 2—Typical plan view of the Munmorah system<sup>4</sup>

the main development. The primary development consisted of three roads, with the bord width being 5.5 m and the pillar sizes approximately 26 m x 30 m centres. Again, these rib pillars were extracted using a retreat split and lift system. Figure 2 shows a typical extraction sequence and layout of this mining system.

## The Old Ben pillar extraction system

This method is very similar to the Munmorah method and was developed after a very serious accident occurred at Munmorah Colliery in which the very thick, competent conglomerate overlying the coal seam caused sudden, unplanned roof falls. It was based on USA experiences and past practices. Here, the secondary development consisted of three roads, leaving reserves for pillar extraction on either side. The total panel width was greater than 200 m. Tertiary development, consisting of three roads, was done towards the end of the panel to increase overall extraction. From this development, short fenders were then developed and extracted. A typical layout of this method is shown in Figure 3.

These three systems enabled the safe and economic extraction of pillars (over a 40-year period) and the Wongawilli system is still employed at two operations in New South Wales (see below). Although the practice of pillar extraction in New South Wales is dwindling, these early successes with this mining method have ensured that pillar extraction is still successfully conducted today.

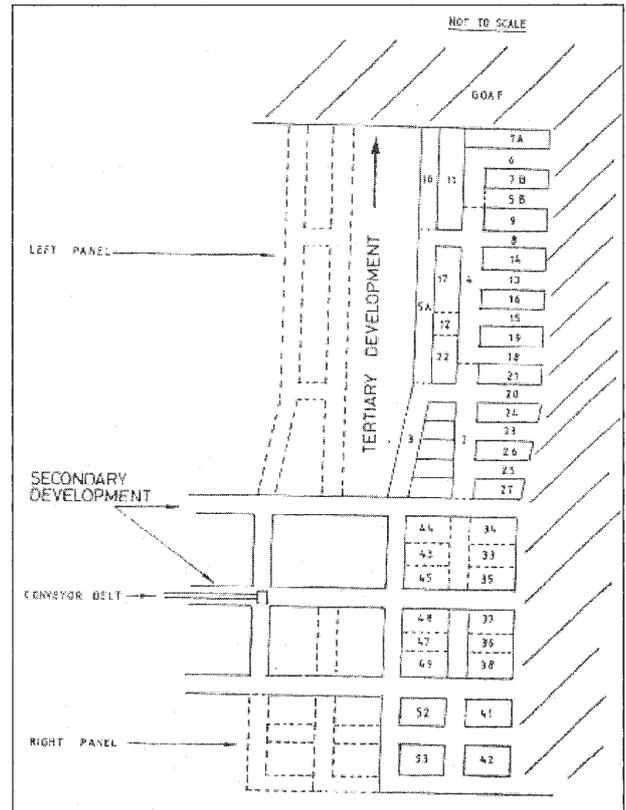


Figure 3—Typical plan view of the Old Ben system<sup>4</sup>

## Current full pillar extraction in New South Wales

As mentioned, four full pillar extraction operations in New South Wales were visited. One operation was in the Southern Coalfield (Colliery A), two operations in the Western Coalfield (Colliery B and Colliery C) and one in the Hunter Coalfield (Colliery D). Figure 4 shows the locations of these coalfields. The observations made at each of these operations are now detailed here and include factors such as mining method, mining equipment and other unique features of the operations.

### Colliery A

Colliery A operated under unique circumstances in that chain pillars that previously acted as barrier pillars and main travelling ways between two longwall goafs were extracted. Colliery A is predominantly a longwalling operation but it was decided to extract these chain pillars to sustain cash flow while new longwall panels were being developed. A modified Wongawilli method was the most suited under the given circumstances and a typical panel layout used at Colliery A is shown in Figure 5, with the pillars extracted on the retreat using double sided lifting as shown in Figure 6.

In terms of the interaction of the adjacent goafs coupled with the depth of the operation (approximately 420 metres), the focus in the extraction design combined the successful creation of a goaf while creating snooks and fenders large enough to maintain a safe working environment. The extraction panels were both long and narrow (2,500 m long and 195 m wide) resulting in a panel width to depth below

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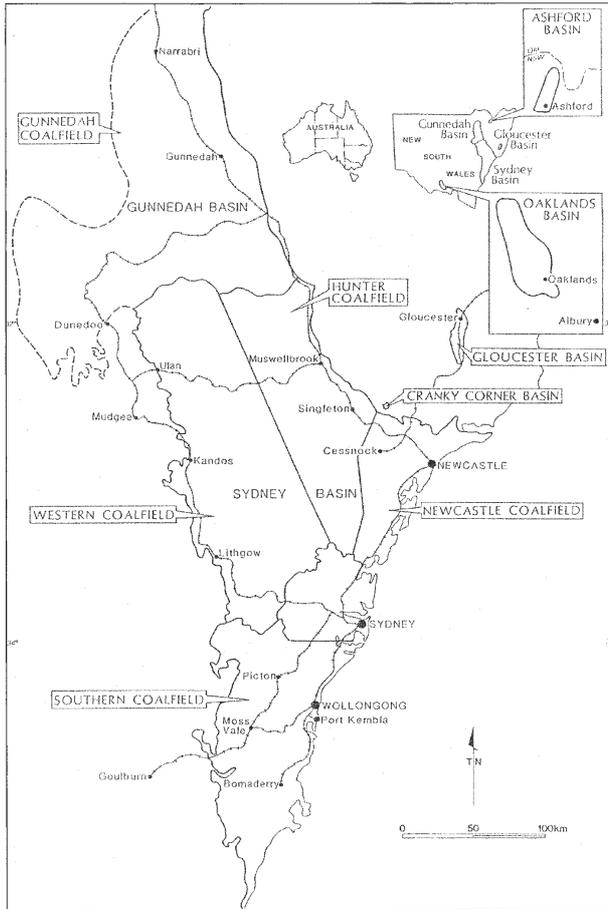


Figure 4—Locations of the coalfields of New South Wales

surface (W:D) of 0.46. This type of panel geometry (when designed in virgin ground) would generally limit full caving and limit abutment stresses in New South Wales. The immediate roof strata consisted of sandstone with interbedded shales and the floor consisted mostly of shales. The coal seam extracted was approximately 2.7 m thick, nearly horizontal and intruded by stone rolls and stringers which caused inherent weaknesses to the pillars which required ribsides support with straps. Effectively, these six-year old panels acted as a pivot separating previous goaves and extracting them merely encouraged caving to consolidate the adjacent goaves. As a result, early caving closely followed the line of extraction. The surface subsidence resulting from the operation was also an extension of the subsidence already caused by the previous longwall operations (which was expected to be approximately 1 metre).

The extraction at Colliery A was an opportunistic decision to maximize the recovery of reserves to extend the life of the mine. The use of remote controlled continuous miners and three Mobile Breaker Line Supports (MBLS) ensured its general success. One of the most important design features of this extraction method was the leaving of large snooks around intersections. Once a sufficient area around the snook has been extracted, it will fail under the deadweight load of being 420 m below surface with the ancillary support from the timber props and the MBLS not only having significantly lower carrying capacities than the

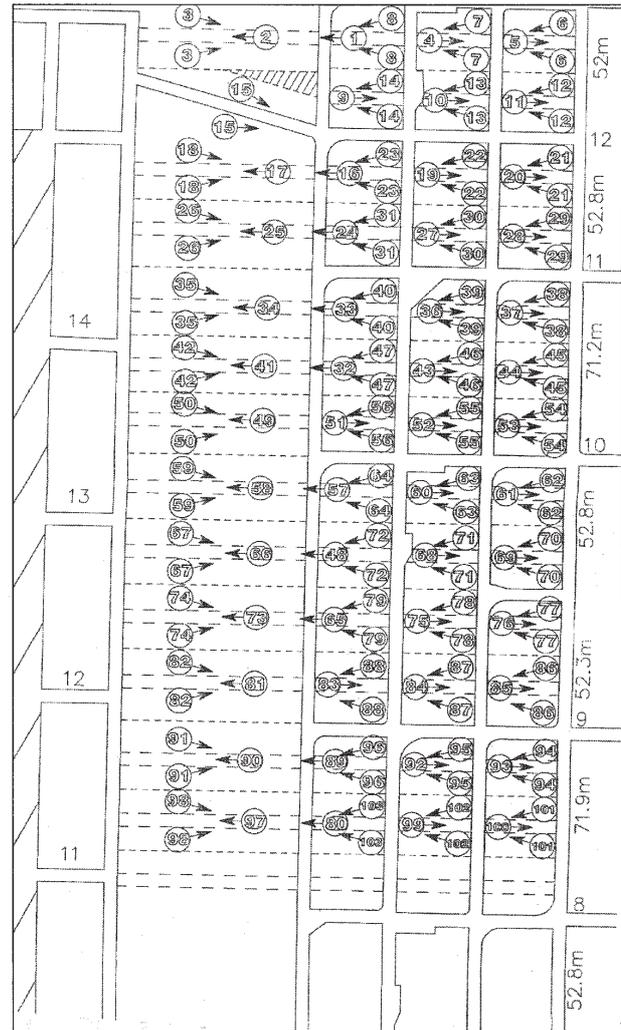


Figure 5—Modified Wongawilli extraction at Colliery A

snooks, but they provide an additional safety zone under which the continuous miner operator can work, and also control the overlying strata and break the goaf in a controlled fashion. The overall extraction of these gate road extractions was approximately 90 per cent.

## Colliery B

Colliery B also operated in unique conditions in terms of its depth below surface being variable at all times (as a result of the mountainous overburden), leading to a continuous and dynamic stress regime which is dependent on the underground location. The depth below surface of the panel visited varied from 30 m at its most outbye position, to 190 m at the centre and to 150 m at its most inbye position.

The modified Wongawilli extraction technique (similar to that used at Colliery A shown in Figure 5) required that the solid side of the panel be developed regularly with all splits and run outs (those roadways which hole into the previously goafed panel) fully driven before the retreat extraction begins, as opposed to the goaf side of the panel where the splits and run outs are created and supported only once the

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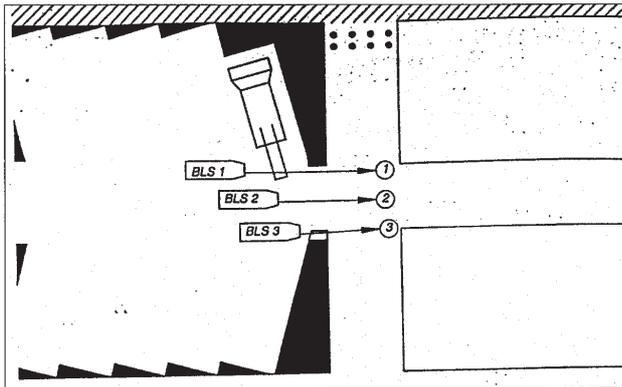


Figure 6—Double-sided pillar extraction using MBLS

panel has started retreating. Beyond the 60 m cover line, only partial extraction is allowed and usual bord-and-pillar type extraction is conducted up to the 30 m cover line, beyond which no extraction is allowed to take place (i.e. from 60 m and deeper high extraction takes place, between 60 m and 30 m only bord-and-pillar mining can take place and from 0 m to 30 m no extraction is allowed). Effectively the panel is thus only half developed before the retreat operation commences, in typical Wongawilli extraction fashion. The Wongawilli extraction method is used at Colliery B to limit the creation of 4-way intersections which had in previous instances required expensive cable truss roof supports as a result of poor geological conditions over the entire mining lease area. The practice of creating pillars at the last possible moment thus also limited the interaction of the stresses associated with the previous goaf and minimized the effects of time on the pillars, as the average age before extraction of these pillars created nearest the previous goaved panel was one week. Snooks were left in every pillar (similar to that shown in Figure 6) with larger snooks left to control return ventilation which are designed to be virtually indestructible on the solid side of the panel, thus ensuring that the bleeder roads which they support remain open once the area has goafed. Each panel creates a new goaf and the nature of the weak roof ensures that goafing closely follows the extraction line. The immediate roof consists of mudstone, claystone and sandstone. Two clay bands exist in the coal seam (which is on average 2.7 m thick and roughly horizontal throughout the mining lease area) which expand when wet but these bands do not however negatively affect the mining operation. The nature of the dynamic roof loading conditions, together with the dynamic panel creation and extraction, make it difficult to quantify the exact nature of the operation, suffice to say that the extraction operation under these conditions was very successful. Again, the use of a remote controlled continuous miner and three remote controlled MBLS ensured a safe working environment. Thirteen panels have been successfully extracted using this method, with the overall extraction at Colliery B being approximately 90–95 per cent.

### Colliery C

The full extraction operation at Colliery C was a good example of maximizing extraction of a reserve by extracting

existing pillars created by drill and blast methods almost a century ago. Originally, the pillars were formed to a height of 1.5 m using drill and blast methods. The height of the bords was increased to the full seam height of 2.7 m by means of brushing the top coal with a continuous miner before extracting the pillars. The original design parameters of the area being extracted created pillars of width-to-height ratio equal to 10, and the subsequent brushing of the roadways to the full seam height reduced this ratio to 5.6 before extraction commenced. The overall panel width-to-depth below surface ratio of 6 indicates that full caving will develop and that surface subsidence will occur (in terms of New South Wales conditions).

As only single-sided lifting is conducted here, the approach of leaving snooks is also different from the double-sided lifting operations. Generally at Colliery C, snooks are left only where there are geological anomalies (stringers, faults, etc.) or where the direction of mining changes. Rather, a thin fender (approximately 1 m wide) is left at the rear of the pillar being extracted as an additional support in place of regular snooks. As it is a thin fender fails readily under the weight of the roof, thus ensuring that the goaf line closely follows the extraction operation. Severe rib crush in an area of the panel (resulting from high stresses on the reduced pillar size) resulted in a small area having to be abandoned (marked A on Figure 7). This was a result of the panel being mined out of sequence to extract an irregular shaped area which resulted in the pillars at the edge of the panel being surrounded by goaf on three sides and creating unusual stress regimes in this area. A further consequence of this area being abandoned is that full caving of adjacent areas was retarded and resulted in further abutment stress problems for subsequent extraction, particularly at the point of extraction. In general the extraction operated under stress as was observed by rib spall of up to one-half of the pillar height around the pillars adjacent to those being extracted. It is inferred that the age of the pillars are a contributing factor to this, but other factors such as depth below surface (approximately 60 metres), extraction method, etc. would also have contributed to this. Madden's<sup>5</sup> explanation of how rib spall is more severe in areas created by drill and blast methods is however a more satisfactory explanation for this rib spall.

Although only single-sided lifting was conducted at

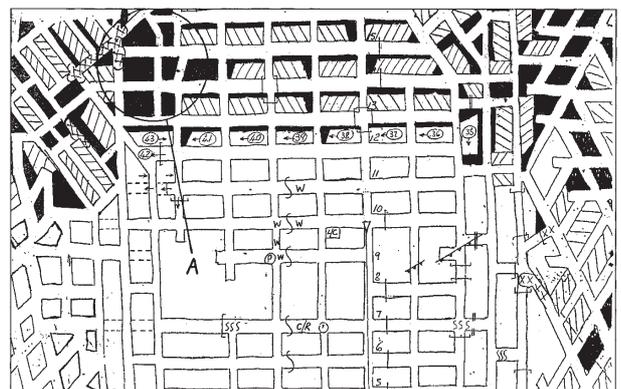


Figure 7—Full pillar extraction sequence at Colliery C

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Colliery C, three remote controlled MBLs were still used with timber as secondary temporary supports for the sandstone and mudstone roof. The overall recovery at Colliery C was approximately 80 per cent.

## Colliery D

Colliery D has conducted six full pillar extraction panels by means of using both continuous miners and a continuous haulage. The use of the continuous haulage unit obtained variable results with component failure being the major reason for it being discontinued in early 2000, although the added problem of the weight of the 5 unit continuous haulage creating damage to the floor (which consisted of mostly mudstones with some laminations) also contributing to this decision. The coal seam extracted is the deepest in the Hunter Coalfield and it dips in a north-east to south-west direction which is roughly normal to a number of equidistant and parallel minor fault zones which intersect the entire lease area. The coal seam thickness ranges from 3.2–3.6 m although the average mining height in the panel visited was 3.2 m. The layouts for the extraction panels lie at approximately 45° to the fault planes which is the common mining practice in New South Wales when encountering geological anomalies such as fault zones. However, the added problem of the seam dip has resulted in the panel layouts dipping down from right to left when a cross-section of the panel is viewed. In the initial, shallower panels this was not significant. However, in the later, deeper panels it required leaving the centre pillars of the extraction panels so as to reduce the overall span of the panel and in so doing combat severe rib spall and pillar crush which was more dominant on the pillars on the left-hand side (down dip side) of the panel by bridging the roof cantilever. Figure 8 indicates that a greater proportion of pillars are extracted on the right-hand side of the panel, whereas the pillars on the left-hand side were only partially extracted in an attempt to reduce the effects of the high stresses encountered there. The panel extracted (when visited) also lies between two previously extracted panels which has resulted in further high abutment stresses affecting pillar loading in the extraction panel. It was not uncommon for the pillars to be only partially extracted in an effort to combat the negative stress regimes (as well as the risk of a roof fall or rib fall incident), but this practice then leads to the panel consisting

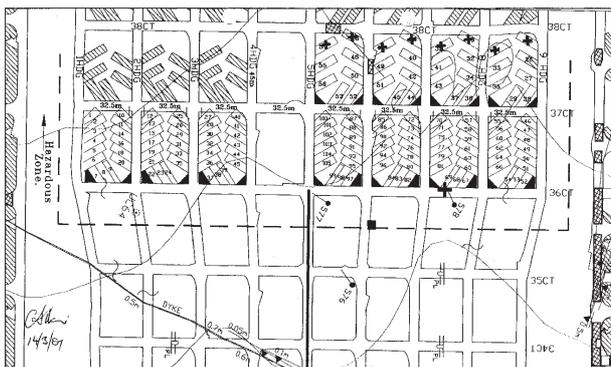


Figure 8—Full pillar extraction sequence at Colliery D

of a combination of full and partial extraction which is generally not considered good pillar extraction practice.

The ratio of the width of the panel to its depth below surface of 1.32 indicates that in terms of New South Wales average strata behaviour, full caving should not occur as this ratio is below 1.4 (the current workings are approximately 220 m below surface). These values being so close to one another however creates a situation whereby caving either may or may not occur. In general, no regular sizes of snooks or fenders have been left (the section miner uses his discretion in terms of observing stress conditions) as conditions are dynamic and change from location to location as a result of the seam dip.

Burial of the remote controlled continuous miners and MBLs equipment has also occurred regularly as a consequence of the stresses. The roof consisted of a 30 cm band of coal overlain by a 3 m band of shales and mudstones and then by a layer of competent sandstone which is approximately 2.5 m thick. The overall recovery of the pillar extraction at Colliery D was between 60–65 per cent.

## Current partial pillar extraction in New South Wales

In addition to the four full pillar extraction operations visited, three partial pillar extraction operations in New South Wales were visited. One operation was in the Western Coalfield (Colliery E) and the other two operations were in the Newcastle Coalfield (Colliery F and Colliery G). Figure 4 shows the locations of these coalfields. Again, the observations made at each of these operations are detailed here including factors such as mining method, mining equipment and other unique features of the operations.

## Colliery E

The partial extraction technique developed at Colliery E required an increase in the overall extraction without creating caving so as to limit the influx of water associated with two overlying aquifers and the problems (such as windblasts) associated with goafing of the overlying massive Triassic sandstones. Previous full pillar extraction methods broke these two aquifers and the mine as a result pumps between 14–18 megalitres of water per day. The initial panel design of the width of the panel to the depth below surface of 0.84 indicates that the overall extraction will not induce caving or have surface effects if full extraction is to be considered. The seam mined is 3.7 m thick, but only the top 2.7 m is extracted. Since only partial extraction is used at Colliery E, this ratio becomes less important than when considered with full extraction operations. The partial extraction method used here (shown in Figure 9) effectively creates two smaller panels within the original panel, separated from one another by the two unmined centre pillars.

Once partially extracted, the resulting pillars of 24.5 m by 13.5m are large enough to aid the massive sandstone roof to span the resultant 16.5 m bord widths. These pillars have load-bearing capacities of 550,000 tonnes and are considered to be substantial permanent supports. The two lines of centre pillars that are left unmined take the most

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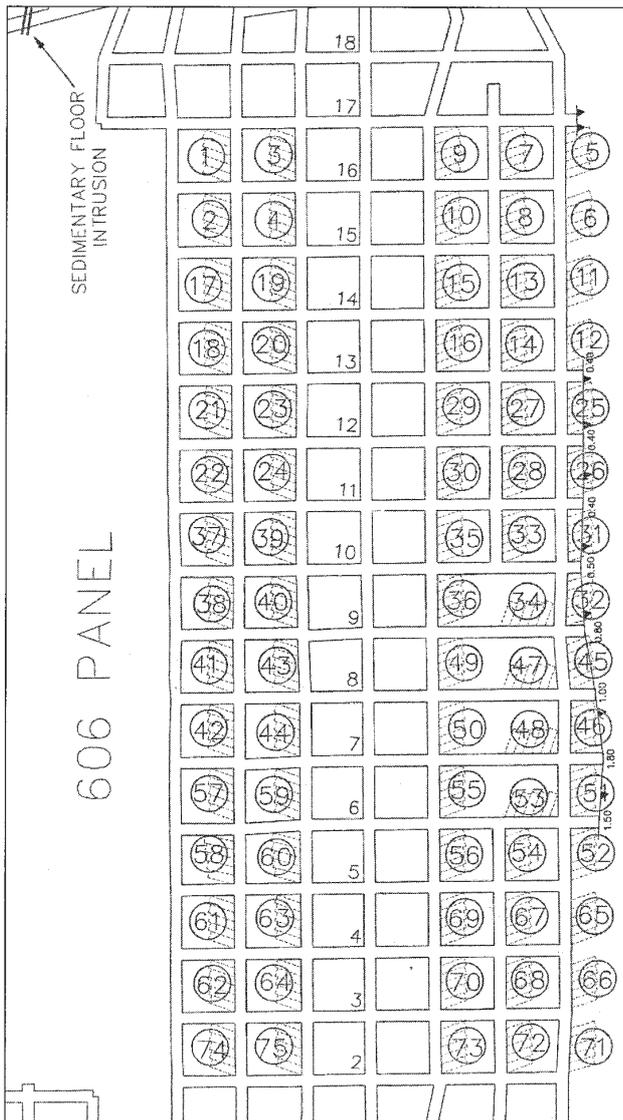


Figure 9—Partial pillar extraction sequence at Colliery E

pressure as a result of being larger than the smaller, partially extracted pillars in the panel. The success of this method has been hampered only by the low rates of extraction achieved and future modifications to this method will include leaving only one line of centre pillars to further increase recovery. MBLS are not used at Colliery E, although a large amount of timber was used in the form of breaker lines. This method has increased the overall extraction by 10 per cent to 45 per cent.

## Colliery F

The partial stripping operation at Colliery F was designed to prevent caving as the mine underlies a residential area near Lake Macquarie (approximately 300 m below surface). Also, the 2.4 m thick coal seam is overlain by a 0.5 m thick continuous layer of mudstone which does not provide a good roof contact. The extraction at Colliery F is different from the other partial extraction operations in that the centre line of pillars (which remain as a permanent support) are specifically designed to be larger than the other pillars that

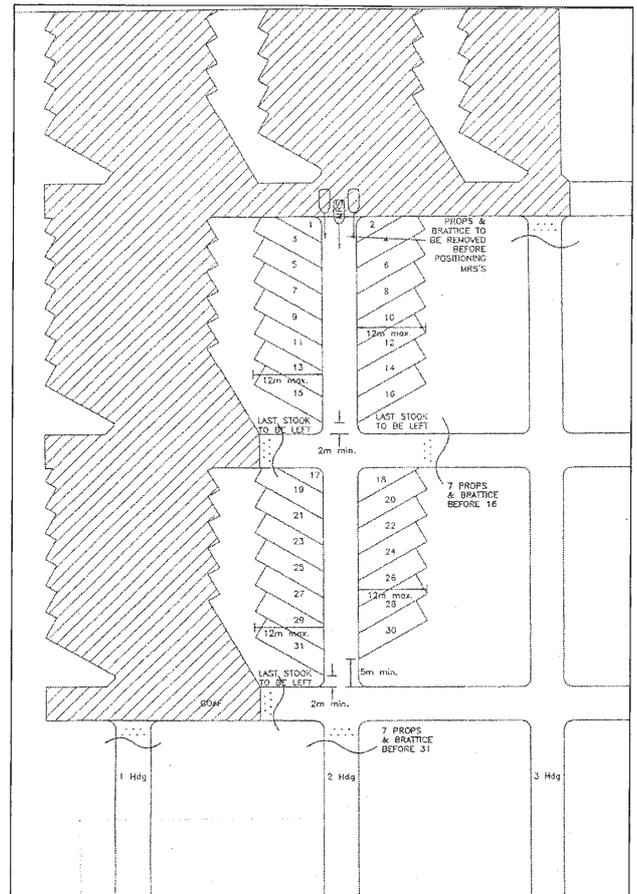


Figure 10—Partial pillar extraction sequence at Colliery F

will be extracted (40 m square pillar as opposed to the 40 m x 30 m sizes of the other pillars). This would imply that these pillars will take more load from the outset as a result of their larger geometries. Thus, when the surrounding pillars are extracted, the shift of load onto these pillars is not as dramatic since they are already loaded. The partial extraction of the two lines of pillars on either side of the centre pillars results in the creation of saw-toothed fenders approximately 40 m long and 6 m wide (shown in Figure 10).

These resultant fenders have a load-bearing potential of approximately 240,000 tonnes. To date there has been no failure of these fenders and they are thus strong enough in aiding the massive conglomerate roof to span the voids created. The floor in this area consists of soft materials<sup>6</sup> and to date no negative effect to this soft Awuba tuff floor has been noticed. The original panel design width-to-depth below surface ratio of 0.61 is well below the 1.4 required for full caving operations, indicating that this design is suitable for partial extraction. Further, the panels are positively flood ventilated (through holing the last through road of each panel into the previously extracted panel) which has successfully ensured that previous problems associated with methane and the subsequent risk of frictional ignitions have been minimized. The partial extraction method has also limited the occurrences of windblasts as the massive conglomerate roof is not broken or caved. It has also increased the overall recovery from 25 per cent to over 80

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per cent by successfully using a remote controlled continuous miner and three remote controlled MBLs.

## Colliery G

The geology at Colliery G is similar to that experienced at Colliery F with the same soft floor and massive conglomerate roof conditions. The partial extraction technique (mining at a height of 2.5 m) reduces the 40 m by 30 m pillars to 20 m by 30 m, thus ensuring that these provide an adequate permanent support of almost 1 million tonnes each (shown in Figure 11).

The maximum void of 25.5 metres created by this method is adequately spanned by the massive conglomerate roof. The effects of time have, however, resulted in the pillars punching into the soft floor and creating floor heave although this does not affect the current mining method, the current mining areas or results in surface subsidence. The original panel ratio of width to depth below surface of 4.37 would indicate that full caving and surface subsidence would occur if full extraction were conducted. The depth below surface ranges from 50–85 m. However, the partial extraction technique creates substantial fenders that are designed not to fail and this extraction thus does not create any surface subsidence. This mining method has increased the overall extraction from 25 per cent to approximately 75 per cent again by successfully utilizing a remote controlled continuous miner and three remote controlled MBLs.

## Factors influencing pillar extraction in New South Wales

The full and partial extraction methods as examined in New South Wales were all implemented and designed around specific health and safety, economic and environmental requirements of the individual operations. The choice of a partial versus a full extraction system appeared to be based on the following factors:

- ▶ Surface subsidence
- ▶ Nature of the immediate 20 m roof

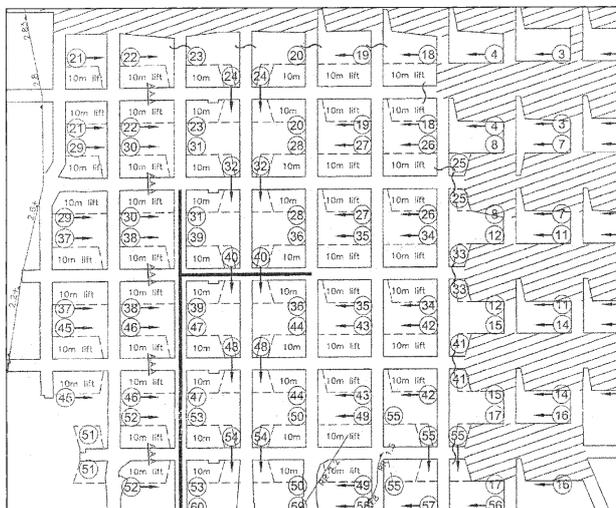


Figure 11—Partial pillar extraction sequence at Colliery G

- ▶ Geological nature of the potential goaf zone.

Where the roof was massive and problems with goafing was anticipated, partial pillar extraction was conducted. Also, if surface subsidence was expected that would negatively affect the usage thereof, partial pillar extraction was conducted. Anderson<sup>7</sup> reports that the nature of the immediate roof strata, ranging from the seam roof to 20 m above the seam, plays a critical role when the goaf is formed and how cantilevering of the goaf strata leads to collapses which is one of the most important design factors in deciding whether to conduct full or partial pillar extraction. Generally for New South Wales conditions, when the W:D ratio (width of the panel to the depth below surface) is greater than 1.4, full caving can be expected and when the ratio is greater than or equal to 2 one can expect surface disturbances and this was used as a guide for designing an extraction method. Where favourable conditions existed, full pillar extraction was conducted whenever possible.

Of the full pillar extraction operations, two utilized modified Wongawilli methods designed to suit their individual conditions. At Colliery A this was the most suitable extraction method given the pre-developed nature of the panel, while at Colliery B the panels were specifically designed to accommodate this type of extraction as a result of the dynamic roof stresses. Of the other two full pillar extraction operations, Colliery C utilized an open ended system and Colliery D utilized an extraction method resembling the pillar stripping method, with the main difference here being that the resultant fenders collapse rather than provide a support to the roof cantilever as occurs with the partial extraction operations. All of the full pillar extraction operations visited had no restriction on the amount of surface subsidence that they created. There was also no sterilization of overlying economic reserves resulting from the full pillar extraction operations.

The three partial pillar extraction mining operations used modifications of the so-called pillar stripping method, designed specifically at Colliery G to maximize extraction without creating surface interferences (similar to those employed in the USA).

All the pillar extraction operations conducted lifting of pillars on retreat and at an angle of 60° and generally in open ended lifts (except for Colliery D where small ribs at times were left between lifts as a result of high stresses in places). Double-sided lifting was practiced at all the collieries visited (except for Colliery C) which was made possible by the introduction of remote controlled continuous miners and remote controlled MBLs (used everywhere except at Colliery E). Maleki and Owens<sup>8</sup> indicate that MBLs influence the overlying strata up to 18 m. In terms of Anderson's<sup>7</sup> inference that the immediate 20 m roof dictates the goafing behaviour, this indicates that MBLs are a successful means of controlling the immediate overlying strata during pillar extraction and ensuring that goafing occurs in a controlled manner. Recent pillar extraction in New South Wales was conducted using pillar stripping (similar to the extraction methods used in the USA) rather than using specialist rib pillar techniques such as the Wongawilli, Munmorah and Old Ben methods discussed previously.

Issues pertaining to safety, cost and production output of

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the operations was of a confidential nature and the information presented here is reported in a generalized manner rather than on an individual basis. In the 1999/2000 financial year, a total of 3 fatalities occurred on mining operations in New South Wales (of which one occurred in a pillar extraction operation) with a lost time injury frequency rate of 43 per million hours worked for underground operations<sup>9</sup>. These figures are also consistent with those reported for the 1998/1999 financial year. As for the cost aspect, the operations attributed the absence (or lower usage) of roof support, lower consumption of continuous miner picks and lower labour (usually 2–3 less than a development bord-and-pillar section) during extraction as factors contributing to operating costs being generally lower during pillar extraction than with a development bord-and-pillar operation. The average extraction per shift ranged from approximately 1,000–1,500 tonnes for the full extraction operations and approximately 1,300 tonnes for the partial extraction operations. These relatively low production rates indicate that pillar extraction operations in New South Wales focus more on safety and continuity in production.

Generally, the trend in New South Wales is to move away from the pillar extraction method of mining in favour of longwall mining. This move is primarily for safety reasons. By the end of 2001, three of these operations (two full and one partial extraction) will for various reasons have ceased conducting pillar extraction.

### Conclusions

The visit to pillar extraction operations in New South Wales in 2001 was aimed primarily at ascertaining whether any new pillar extraction technologies exist which may be of benefit to future pillar extraction operations in South Africa. New South Wales is moving away from the pillar extraction techniques in favour of the safer and more productive longwall method of mining. This paper has shown that although Australia has provided novel mining methods to extract pillars in the past, little in the way of new innovations in terms of mining methods have been introduced more recently. Rather, pillar extraction methods from the USA (Christmas Tree and Outside Lift methods)

which employ either single- or double-sided extraction of pillars have been adopted and adapted for use in New South Wales. However, some important design considerations obtained from New South Wales experiences have been presented here. From these experiences, guidelines can be established to form a uniform base for the safe and economic utilization of coal reserves in South Africa, particularly through pillar extraction endeavours (as envisaged by Coaltech 2020) which is the focus of current research.

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