GEOTECHNICAL ENGINEERING AT GERMAN CREEK – A HISTORICAL AND SOMETIMES HYSTERICAL REVIEW

BY MITCH JAKEMAN

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ABSTRACT: The initial drilling exploration started in what we now know as the Bowen Basin coal region in the 1950's, to open up and delineate the coal seams for the whole region. After Utah grabbed the easiest and more favorable large sandpits in the early stages, other companies started to understand the opportunities for the future.

In 1979, German Creek started construction and operations at the end of the boom and bought four draglines. This paper presents the geotechnical experiences at German Creek over 21 years of operations. Today, the operation sustains one dragline, two underground longwall operations and another underground in the project phase. Life long learning experiences and the need to understand what is happening has sharpened our focus about our mines and operational business risks. The task of digging out a longwall, whilst good for experience and character building, should only be ever done once or twice.

INTRODUCTION

The exploration drilling in the 1950's was in the order of 2 holes per km^2. By the late 1970's when German Creek went from feasibility to project status the spacing became 8 holes per km^2. Today it may go as low as 16 holes per km^2 dependant on the project risk. Current borehole densities in mining areas are 1 hole per 150m for structure and 300m for coal quality. Over the last 35 years the role of geotechnical engineering has become more important to understand the deposits we mine. The advances in bringing techniques from concept to maturity have gone from decades to years aided by such diverse areas as the space program and military applications.

The changes to legislation, the increasing requirements for more stringent corporate governance and shareholders expecting companies to manage all facets of their business has focussed our attentions on risk mitigation.

This paper looks at the use of geotechnical engineering in the operations of German Creek. There have been major advances in the technology from the planning predictive tools, the monitoring and modelling of what happens and some of the practical aspects of controlling. There is still room for improvements as at best we can at best only get it 70% correct for an underground operation, looking at the annual failure rates in our industry.

Geotechnical engineering impacts on all areas of mining. It affects ventilation, gas drainage, mine layout, mining methods, strata control, production and costs.

GEOLOGY

Stratigraphy

The German Creek Mine operations are based on coal reserves in the German Creek Formation and the Rangal Coal Measures. The former contain economic coal in the Pleiades, Aquila, Tieri, Corvus and German Creek seams (Fig. 1). In the latter, only the Middlemount seam is of economic significance.

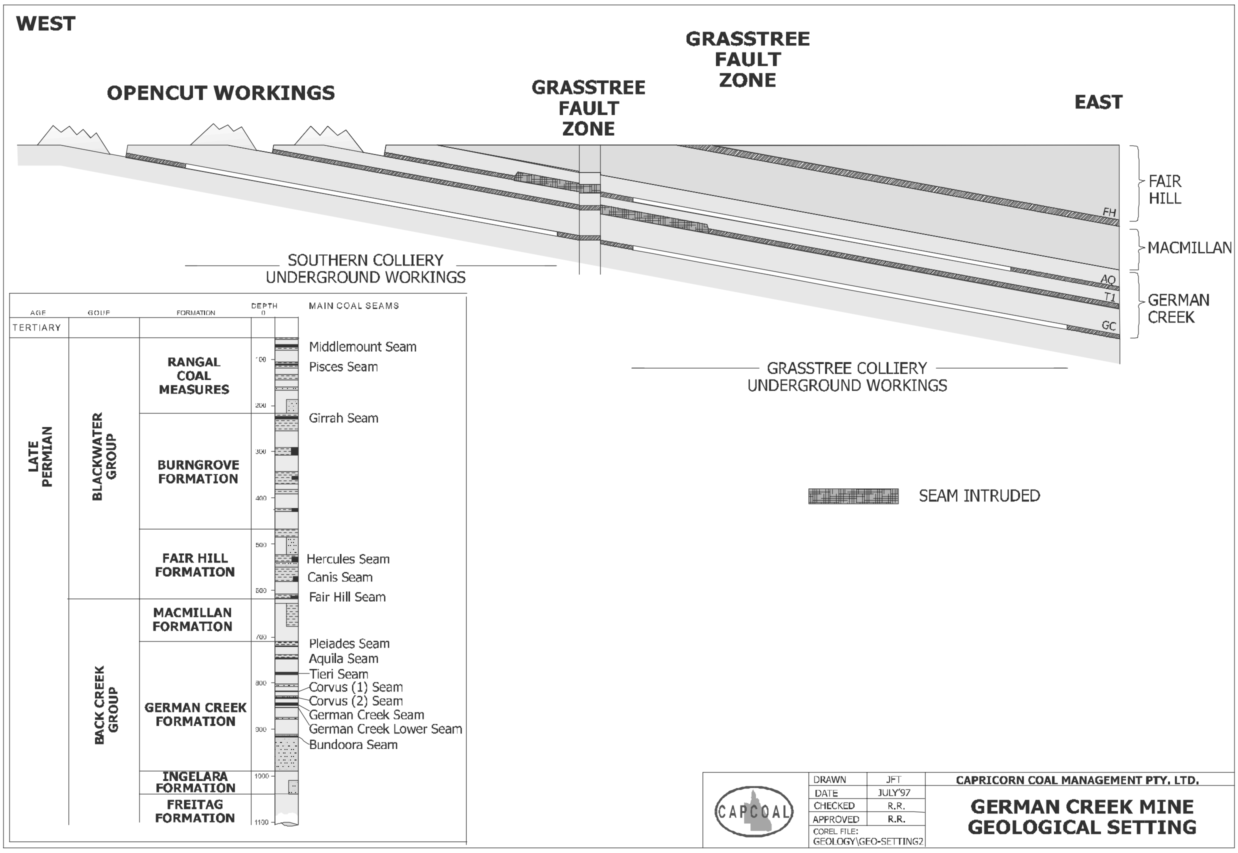

Fig. 1 German Creek Mine Geological Setting

The mine is situated in the centre of the Bowen Basin and the operation is worked over a 12km-strike length. Seams dip to the east at an average grade of 5º. The strata containing the German Creek Group of seams are hard to very hard, well lithified, interbedded claystones, siltstones and sandstones with some massive sandstone beds overlying the German Creek, Tieri and Aquila seams. The sediments are well jointed with the primary joint set trending northeast and a well-defined secondary set trending southeast. In the mine area, the sediments were deposited in a fluvio-deltaic/paralic environment. The massive sandstone units found in the area have been attributed to beach bar deposition. Coal seams worked range in thickness from 0.5m to 4.0m.

The Middlemount Seam subcrops 8km to the east beneath a thin blanket of Tertiary clay and sand. This seam is mined by open cut strip mining in Pits T and U. The sediments overlying the Middlemount Seam are weaker than those of the German Creek Formation but overburden blasting is still required. Jointing is well-developed but less regular and pervasive than in the German Creek Formation.

Igneous Activity

Igneous activities in the form of sills and dykes have had a significant influence on mine design for both open cut and underground pits. Sills in the open cut have coked what otherwise would have been economic reserves in the Aquila, Tieri, and German Creek seams.

Early in the life of the open cut several dykes, ranging in thickness from 0.1m to 14m, were uncovered. Although having limited affect on the open cut operations, these dolerite dykes have had a significant impact on the underground operations (Fig. 2).

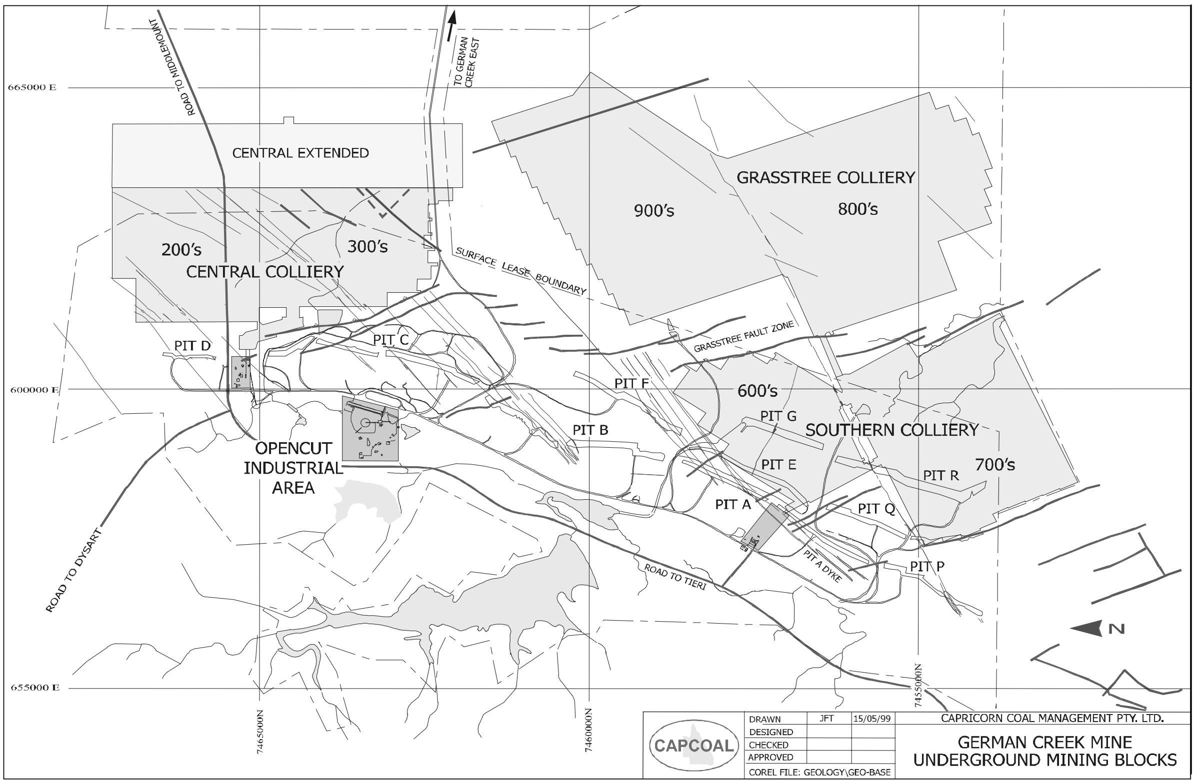

Fig. 2 German Creek Mine Mine Underground Mining Blocks

Central Colliery has encountered several dykes of variable thickness and hardness, which have hampered the mining operations. However, the layout of Southern Colliery was specifically designed to minimise the impact of dykes and in particular to avoid a 4m thick dyke encountered in open cut Pit A and the 14m thick Grasstree Dyke.

Structure

The German Creek Formation is characterised by a series of north to north-north-west trending normal faults. Faulting is more frequent in the area of the subcrop. The Grasstree-Central Colliery Fault system divides the mine into eastern and western development areas (Fig. 2). The structural features of the mine have been described by Whitby (1985).

Seam Gas

The deeper reserves in the mine area are characterised by moderate to high levels of seam gas, which is composed almost entirely of methane. Methane is encountered at depths from about 70m and at 250m gas content is approximately $8m^3/t$. Seam gas content of $14m^3/t$ has been measured at 420m depth of cover in the German Creek Seam.

In those reserves containing a seam gas content of $7m^3/t$ or higher, methane drainage of the coal and strata is required to enable efficient and safe production. At Central Colliery methane drainage practice has been successfully applied to lower gas emission during development and longwall extraction. The process involves two stages:

- Pre-drainage – gas drainage ahead of development by in-seam drilling.
- Post-drainage – gas drainage of the goaf after extraction by surface boreholes.

Significant quantities of hydrogen sulphide gas were encountered in the early development of Southern Colliery. More detail will be discussed later in the paper.

UNDERGROUND GEOTECHNICAL AND HYDROLOGICAL INVESTIGATIONS

Central Colliery

Detailed geotechnical investigations were conducted over the Central Colliery mine area prior to commitment to longwall mining. Detailed geological mapping, surface geophysics, diamond and rotary drilling, downhole geophysics, permeability testing, laboratory testing of core samples and the determination of *insitu* stress conditions were undertaken. Technical data on roof, floor and coal seam conditions, groundwater regime and inflow rates were provided for the selection of appropriate mining equipment for maximum production and a safe working environment.

Main heading pillars were designed on a conservative 50m x 50m basis. Chain pillars were designed using Wilson's yield pillar design modified for Australian conditions and Commonwealth Scientific Industrial Research Organisation's (CSIRO) Minlay numerical modelling programme. The design was validated by undertaking extensive in-pit geotechnical monitoring. Irad stress cells were installed in pillars, as were wire extensometers and rib extensometers. Sonic extensometers were used to determine roof and floor behaviour.

Chock shield design was based on a physical model constructed and caved at the Australian Coal Industry Research Laboratory at Wollongong. Chocks rated at 640t were initially recommended but following consideration of the geotechnical characteristics of the overlying strata, 800t chock shield supports were ultimately chosen.

Roof support in the development headings and gateroads was established by using beam theory. Bolt lengths were chosen to ensure adequate bond length in competent strata and to provide a stable bolted roof beam.

Southern Colliery

The experience gained from the development at Central Colliery was drawn upon to assist with the design of Southern Colliery roadways and chocks. Chain pillars were designed using the Minlay programme, as at Central Colliery. However, main heading pillars were designed using Bieniawski's rigid pillar design for optimal pillar dimension to reduce development drivage. Final pillar dimension was 100m x 30m. Sonically derived uniaxial compressive strengths (UCS) were used to design roof bolting patterns under Southern Colliery's massive and bedded sandstone roof.

The 800t capacity chocks used at Central were selected at Southern Colliery following detailed geotechnical study and finite element analysis.

Water Management

Both collieries have subsided strata under known aquifers. The principal aquifers are semi-confined igneous sills, which lie within the critical tensile strain zone above the German Creek Seam. The water contained is highly saline.

In the case of Central Colliery, the mine subsided the Tieri Sill aquifer, which, on initial goafings, caused a minor inrush of 25L/sec of water into the mine. This water was managed underground by pumping the water to the surface through gateroad boreholes and that magnificent technique of running the longwall AFC.

Studies into this event and subsequent field investigations enabled a pre-drainage programme to be designed for the Aquila Sill aquifer which overlies the 600's block at Southern Colliery (Klenowski and Phillips, 1998). Techniques used to define the aquifer included routine airlift pumping in exploration drill holes, downhole geophysical and geological logging and upstage packer testing. Permeability and other hydraulic parameters were calculated from pumpout and pump-in test results to predict inflow rates. It was estimated that initial inflow into Southern Colliery would reduce this to the order of 165L/sec. Pre-drainage would reduce this to the order of 45L/sec.

Four pumphole sites were required and dewatering of 4km^2 of aquifer was achieved before longwall mining began, using downhole electric submersible pumps. The dewatering boreholes continued to pump a total of 600ml over a 4yr period to reduce the inflow rates to less than 5L/sec after initial caving.

Southern Colliery underlies several abandoned open cut pits in which water can collect during storm (cyclone) events. These pits have been shown to have direct connection to the mine on caving and thus provide a potentially dangerous environment. High rainfall events in excess of 10mm/hr can result in water ponding in spoilpiles and open cut pits. This water can percolate into the mine through subsidence cracks at rates of up to 150L/sec, as was experienced during Cyclone Joy in January 1991. Considerable effort has been expended in protecting Southern Colliery from flood event by blanketing the floor of the open cut voids with compacted parting and reject material and by ensuring that all spoilpiles drain externally. In-pit surface pumps are also installed to ensure these pits remain dewatered during high rainfall events and before the area is subsided.

OPERATIONAL EXPERIENCE

1980 – 1984

German Creek was planned at the height of the energy crisis and coal boom of the late 1970's. Everything looked rosy as Utah was scrapping off a bit of dirt and finding coal everywhere. Prices were expected to continue rising and margins were fat.

German Creek had a lease length of about 16kms and four economic seams to mine. With such a great prospect, four draglines were purchased to start production in 1981 to 1984.

During 1984, German Creek started development of Central Colliery and by 1990 we had sold two hardly used draglines.

The promised land was starting to tarnish. We had to contend with three creek diversions, two large silled out areas and a thinning of two seams. Suddenly our 16km of strike length was greatly reduced as our basic geotechnical knowledge was based on too few holes, highly extrapolated assumptions and a poor knowledge base for planning. This was rapidly improved during the feasibility stage for each underground mine before approvals were granted (Fig. 3).

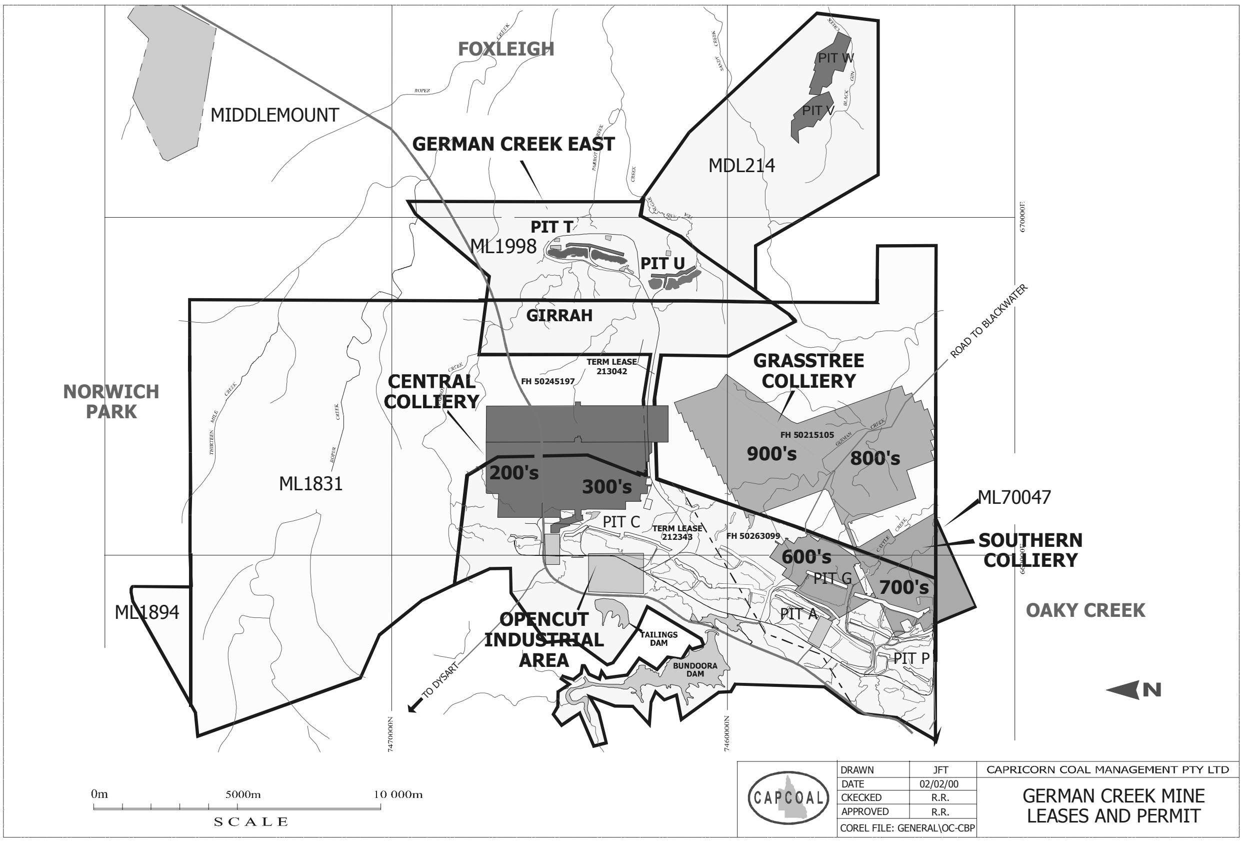

Fig. 3 German Creek Mine Leases

1985 – 1989

This period was a combined operation with four draglines decreasing to two, and the first underground longwall mine in Queensland.

Central was now in full production and soon became one of the top consistent producing mines in Australia until the mid 90's.

Better geotechnical knowledge and planning was necessary to get the Boards approval to start a new underground mine after a relatively short period of time in starting the whole mining operation. German Creek needed the underground resources to supplement the diminishing quantities from the open cut reserves to meet customer specifications and tonnages.

Although we knew the basic geotechnical data for Central in terms of seam thickness of 1.6–2.4m, dip of 5–6 % and coal quality data – there was a certain amount of guess work and good luck. The conditions were good with strong competent roof and floor, no gas except as it got deeper beyond 250m depth of cover, little structure and no major stress problems. In all of this and with the wisdom of hindsight of today – the mine layout was wrong and should have either had the main headings continuing off the main drift access or move the drift access to align with the main heading, instead of mixing the worst features.

After the success of the first few years of Central and the continued demise of the open cut, feasibility plans were started to bring Southern online. In 1988 we sold another dragline and Southerns construction was completed down an old open cut pit haul road to access the highwall (Fig. 4).

Fig. 4 Southern Mine Access

1990 – 1994

The start of the 1990's had seen a complete change in the original intent of German Creek. It had changed within the decade from a large four dragline open cut to an underground operation with some open cut production.

The next five-year plan was based on seeing the end of the open cuts by 1995, Central producing 3Mtpa and Southern producing 3.75Mtpa.

Central did produce well for a very long time in benign conditions and reached 3Mt in 1992. Some of our technical designs on later analysis actually showed that we created bottlenecks in the system when we were correcting other problems. Much of our geotechnical knowledge was now substantially better but our approach to managing or controlling the issues it highlighted were poor or absent. Better exploration and mapping now indicated areas in Central which would be affected by shear zones, dykes or faults in a north east south west direction. The operational response was to mine in the good country only and leave any other areas as too hard. Consequently if you look at the plan of Central, many of our panels on the 300 side of the mine are a lot shorter than the 200's side – but the coal on the 300's side is better quality and thicker.

We also know that as we got deeper, then the stress problems due to depth of cover and increasing quantities of methane would have to be managed. At the start of the 90's both of these issues were thought of at the time would effectively close Central when it reached about 250m depth of cover limit if nothing was done.

The story at Southern was different and many of the early design failings of Central improved. Southern was bounded and restricted by lease boundaries and some major regional faults in the initial layout of the mine. It also suffered from poor selection of personnel creating industrial problems for a long time. During the mining of the 600's, we encountered for the first time in an underground situation, the presence of small pockets of low concentration hydrogen sulphide.

In late 1990 we got approval to start mining another open cut resource in the Rangles measures at German Creek East. This created a new set of operating conditions for low-highwall stability, blasting and box cut angles on set up, as the material had no structure. During this time we started highwall mining using Eltin to trial this in some of our completed pits. This showed some promise but again the geotechnical understanding of pillar design and controlling the direction of cutting caused some problems. From the underground experience at Central and Southern, the geotechnical knowledge of roof and floor conditions was well known. This has been used four times with mixed success by Eltin, MTA and Roche Bros. (Fig. 5).

Fig. 5 Eltin Highwall Mining

1995 – 1999

During this period we were down to one dragline in German Creek East continuing to supplement the undergrounds and becoming more efficient to survive. Major organisational changes were starting to occur in an industry under pressure to survive.

By 1996 Central had to manage the increasing problems caused by methane. The earlier attempts started in 1993 around 306 longwall were not good enough now. Major delays were starting to occur both in development and from the longwall goaf. It was after Moura in 1995, that a trend to enclose active longwall goafs was adopted in Queensland to minimise the affects of spontaneous combustion. This created a more dangerous situation with a build up of methane in the goaf and the problem was recognised to allow controlled bleeding of goafs.

Considerable efforts were needed to introduce gas drainage into Central for extensive post-drainage of goaf areas. The use of gas drainage and some other enhancements has assisted the continued operation of Central.

More work was started on how to manage the increased stresses due to depth of cover and the dip of the seam. Chris Hansen (German Creek) and Russell Frith started to prepare a comprehensive modelling, measuring and monitoring program to provide practical controls for stopping the three or four roof failures we were getting each year. Extensive panel maps were prepared identifying all the geotechnical data extrapolated and known in section and plan. Overlying these plans we superimposed ventilation, roof and rib support and panel layout plans to identify modifications of controls that may have to be tightened. The use of drilling to verify gas and ground conditions, in seam seismic and use of extensometers to provide better information has allowed a more robust design of strata control devices.

Gate road pillars have been increased by 5m as we have passed the 300m depth of cover. The use of flexibolts, cable bolts and increased tension on the bolts as well as the judicious use of tin cans and wooden cribs have reduced the frequency and damage of falls. Ongoing work is going on with rib support and understanding the effects of directional mining and the minimising of regional stress effects.

Fig. 6 Southern Longwall 701

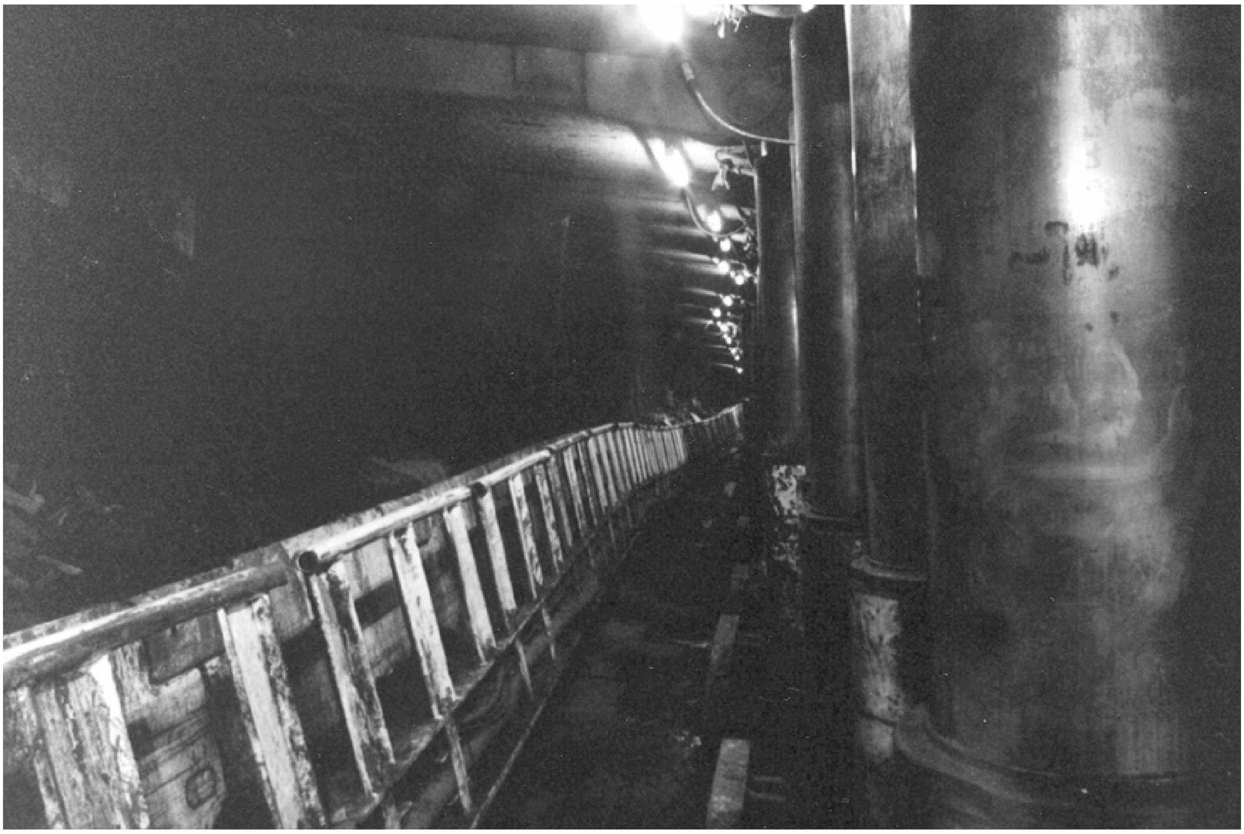

Fig 7 Southern Longwall 701

In late 1995, Southern was forced to relocate its longwall operation to the 700's area, due to a major dyke dividing the lease. This altered the mining panel layout and the new area was bounded by four major geological inferred features. The drivage of the gate roads for 701 encountered a larger extent of H_2S in the first quarter of the panel. Exploration drilling from the surface identified substantial beds of sandstone, which would create heavy weighting events in the last section of the panel.

What we didn't pick was the change in floor condition, even though the continuous miner had some indicative problems during development of the face line and last three pillars. The longwall started production in January 1996, got bogged, the roof fell in and was finally recovered in July/August/September. It had moved about 100 metres in that time and we found out the floor strength was less then 7MPa. After the longwall was moved beyond the H_2S zone and we had repaired the damage to equipment, we tightened our operation procedures and had a good run to the end of the block (Figs. 6 & 7).

702 Longwall started with all chocks retrofitted with base lift rams, very tight operational control and chocks operating at 100% system efficiency. We were faced with three geotechnical mining risks – soft floor, a larger H_2S zone and large area of heavy roof. It would have been a courageous move (or short career) to start at the same place, so we moved the longwall outbye where the floor strength was greater than 10MPa. This worked well and we experienced no problems. We collaborated with the University of Queensland to:

a) try and predict where the H_2S was,
b) it's method of deposition, and
c) how to control it.

There are some excellent research papers on this by Harvey, Gillies and other (2000), but the parameters around the H_2S changed each block. In summary, although we had some success with drainage by trying to put it into a solution, which we pumped into the area, the conditions then changed and became too variable. The best option was excessive ventilation with monitoring to get the H_2S (which is only released whilst cutting) into return airways. The heavy roof cutting procedures developed during 701 longwall worked well for 702 and all later panels.

At the start of 703 longwall after an excellent start up and about 85m from the beginning of the panel, the longwall was suddenly subjected to a severe weighting event. From an operating height of 2.9m, the weighting caused over a 1m leg closure in a 20 minute period. Fortunately due to the position of the shearer and quick thinking by the operators, the shearer was moved to the tailgate. Some back calculations after the event indicted that you would have needed chocks capable of withstanding a 2000t load to support the roof. After looking at the final result, we set a plan in place, which recovered the height over some 45 chocks, in 16 days without any more convergence or weight occurring (Fig. 8).

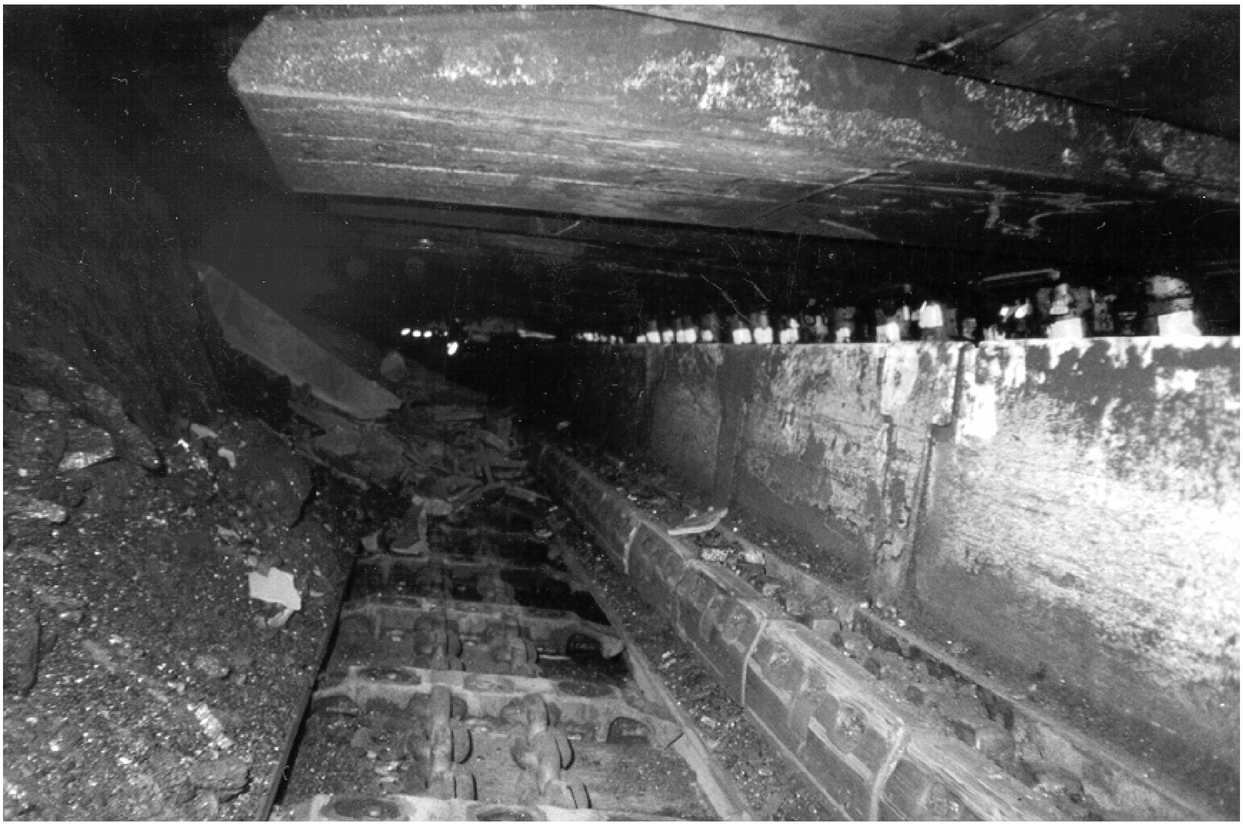

Fig 8 Southern Longwall 703 - Heavy Weighting

The following table shows the range of geotechnical risks and quantifies the impact on production that Southern has experienced. We had two sudden weighting events mid face in different locations resulting in about two weeks of lost production in 702 and 706.

Table	FI	Weighting	Soft Floor	H_2S	Heavy Roof	Parallel
701	-	✓	✓	✓	✓	✓
702	-	-	✓	✓	✓	✓
703	-	✓	✓	✓	✓	✓
704	-	-	-	✓	✓	✓
705	✓	✓	-	✓	✓	-
706	✓	?	-	?	✓	-

The drivage in main headings encountered some increased quantities of CH_4 and change to the roof lithology which lead to two frictional ignition events. Although both events were small in nature and quickly controlled, the Southern bush lawyers and hysteria caused considerable delays and changes to operations.

- Gas drainage was installed to reduce *insitu* methane levels from 5.5 m^3 to less then 2.5 m^3.
- Design and operating parameters were changed on the continuous miner.
- Ventilation performance was improved and controls verified.
- Mine plans depicting the types of roof that had a potential for frictional ignition were developed and distributed together with a Management Plan on the system issues.

SUMMARY

Many of the speakers today that Dr. Alan Hargraves pioneered have been active participants in the quest to understand the medium we try to make a living out of. Some are gaining an expertise in predicting or monitoring what happens. Others like me, try to manage to some small extent the operational aspects and use the geotechnical skills that have evolved over the last four decades.

There are no quick and easy answers in underground mining, and even those that play with the big Tonka toys must try to understand the geological and technical constraints. Boards of Directors and shareholders are becoming less forgiving like Mother Nature.

Geotechnical advances have progressed from simple holes in the ground with a geologist looking at drill cores, cleats and stress directional joint systems to a wide variety of techniques. Geological mapping, surface geophysics, in seam seismics, radio imaging, geophones, drilling, permeability testing, *insitu* stress tests along with technical data on roof, seam and floor conditions are used to fill in the missing pieces for what risks can be encountered in your mine design, equipment selection and mining methods.

Strata controls have gone from the use of timber props and steel as passive supports; to bolts, flexibolts and cable bolts with emphasis on direction of drivage, sequence and width of roadways. The changes in Australia as we get deeper will have to look at roadway shape and whether we do our drivages in or out of seam, for longer term roadway stability.

The challenges for the geotechnical experts and operators for the future, is to look outside the box so we can still get the productivities to keep costs down, but also improve operational safety and reduce business risk.

Note: *The views expressed in this paper are those of the author who has the luxury of using the wisdom of hindsight. It is not intended to be critical of any person(s) involved in any decisions at Capcoal but reflect what was planned and what actually happened as our theoretical and practical knowledge improved.*