J. S. Afr. Inst. Min. Metall., vol. 85, no. 5.
May 1985. pp. 151 – 155.

The mechanization of pillar extraction at The Durban Navigation Collieries (Pty) Ltd

by A. SMITH*

SYNOPSIS

After the introduction of mechanized bord-and-pillar development at Durnacol in 1958, pillars were being developed at a much faster rate than they could be extracted by handloading methods. Efforts were therefore made to increase the rate of pillar extraction by mechanization.

Following two partially successful mechanized stooping trials in 1964 and 1971, it was decided that mechanized pillar extraction with 1 m^3 cable-reel front-end loaders should be introduced.

The first section to employ the new equipment started production in May 1979, and the mine now has four mechanized pillar-extraction sections in operation.

Considerable improvements in production, productivity, safety, and percentage extraction have been achieved.

SAMEVATTING

Die instelling van meganiese kamer- en pilaarontsluiting by Durnacol in 1958 het tot gevolg gehad dat ontsluiting vinniger geskied het as wat pilare met handlaai metodes herwin kon word. Pogings is as gevolg daarvan aangewend om die tempo van pilaarherwinning met meganisasie te verhoog.

Na twee gedeeltelik suksesvolle proefnemings, in 1964 en weer in 1971, is besluit om meganiese pilaarherwinning toe te pas met kabelkatrol-vooremmerlaaiers met 'n kapasiteit van 1 m^3.

Produksie met die nuwe meganiese toerusting het in Mei 1979 in een seksie 'n aanvang geneem, en die myn het nou vier meganiese pilaarherwinning seksies in gebruik.

'n Aansienlike verbetering in produksie, produktiwiteit, veiligheid en herwinning is bereik.

Introduction

The Durban Navigation Collieries (Durnacol) is situated in the Dannhauser Magisterial District of Natal, and supplies coking coal to Iscor. The Colliery produces 225 kt of run-of-mine (ROM) coal per month by conventional methods and longwalling. Both handgot and mechanized methods are used to extract pillars in developed bord-and-pillar sections.

Owing to the relative scarcity of reserves of good-quality coking coal in South Africa, Iscor's policy is to maximize the extraction of reserves at Durnacol, and the mechanization of pillar extraction has been successfully implemented at the mine in accordance with this policy.

Pillar-extraction mining, in the context of this paper, is the recovery of pillars that have been developed with conventional bord-and-pillar equipment. Although termed a *total extraction* method, some coal is inevitably left in the goaf. The term *stooping* as used in this paper is synonymous with the term *pillar extraction.*

Geology

The Colliery is located on the Klip River coalfield, and two thin seams, known as the Top Seam and the Bottom Seam, are exploited. Typical sections through the mining horizon containing the coal seams are given in Fig. 1.

The Top Seam has a thickness of 0,75 to 1,10 m, and the Bottom Seam a thickness of 0,75 to 1,35 m, the two seams being separated by a midstone parting, consisting of sandstone, shale, and a minor coal seam of variable thickness. The seams, together with the intervening parting, are generally contained in a 3,5 m section, but this can increase to more than 5,0 m when the parting becomes thicker.

* Manager, Mining, The Durban Navigation Collieries (Pty) Ltd, P.O. Durnacol, 3082 Natal.

SA ISSN 0038-223 X/$3.00 + 0.00. Paper received 28th Aug., 1984.

The coal seams are gently undulating at an average depth of 220 m, and the depth of working varies from 170 to 270 m. The overlying strata are of alternating sandstone and shale into which dolerite sills have intruded. A typical section through the overlying strata is shown in Fig. 2.

Numerous dolerite dykes traverse the coalfield and have a strong influence on the layout of the mine. The shape and size of the stooping panels are normally dictated by the presence of such intrusions.

Situation before Mechanization of Pillar Extraction

In the late 1950s Durnacol embarked on a programme to improve the underground productivity. The sole min-

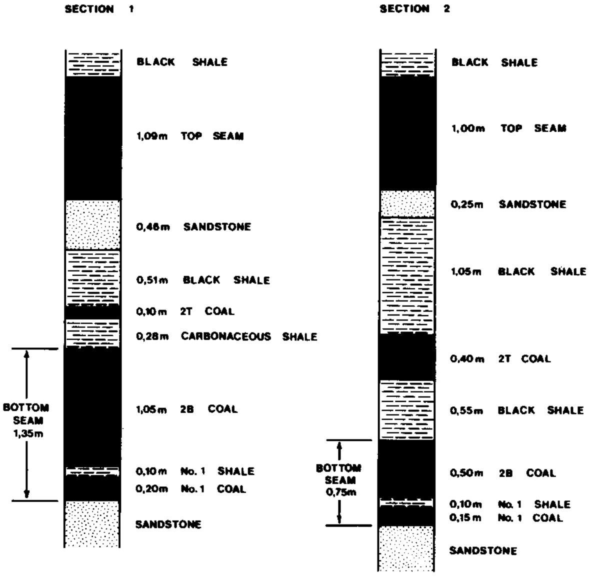

Fig. 1—Typical sections through the coal seams at Durnacol

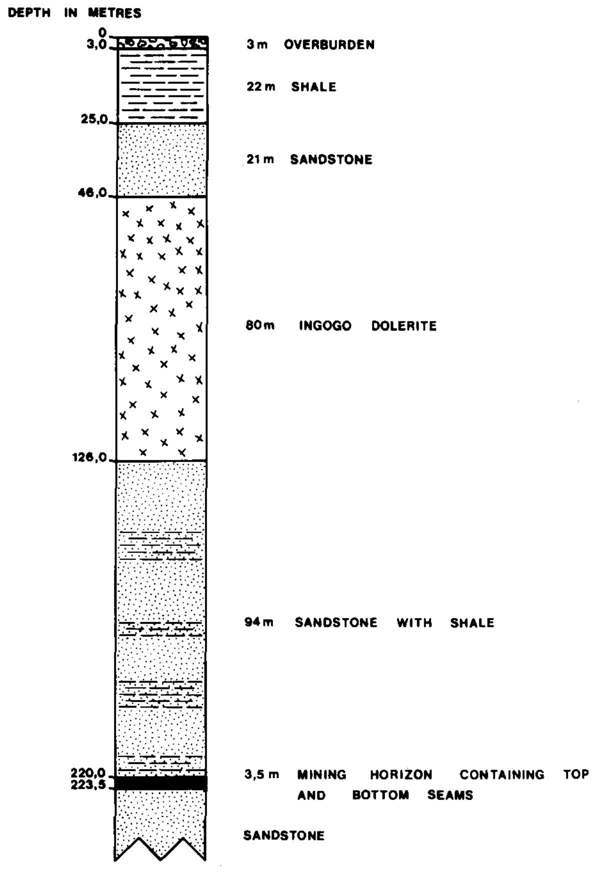

Fig. 2—General stratigraphic section through the overlying strata at Durnacol

ing method in use up to that time had been the well-established practice of bord-and-pillar development and subsequent pillar extraction by handloading.

In the handloading method, which is still employed at Durnacol, the broken material at the face is loaded manually into 0,8 t mine tubs. The tubs are trammed by hand from the working face to the section haulage station, and are transported by endless-rope haulages to tippler stations at an incline shaft. Handloading at present accounts for 18 per cent of the sales tonnage, and is used in the older parts of the Colliery, where the dimensions of the main access roadways prohibit the economic use of mechanized equipment.

A large handloading section can produce only 4 to 4,5 kt of ROM coal per month on a single shift with a labour complement of 40 to 45 section workers under the supervision of one miner. As handgot mining and endless-rope haulages are labour-intensive, it became obvious that rising labour costs would make handloading uncompetitive with mechanized methods in the future. Another aspect that had to be considered was that the manual loading of coal was becoming unattractive to the workforce, and an alternative to manual loading had therefore to be found. Further areas of concern were the comparatively high accident rates with the handloading method, and the desire to improve the percentage extraction in stooping operations.

The management therefore initiated a mechanization programme with a view to improving production, productivity, safety, and percentage extraction.

The first major change in mining practice came with the introduction of mechanized bord-and-pillar equipment in December 1958. Mechanized development sections produce 10 kt of ROM coal per shift per month, at a production rate that is 2,5 times greater than that of a large handloading development section.

However, with the new equipment, pillars were being developed at a far faster rate than they could be extracted by handloading methods. At one stage pillars were being developed 13 times faster than they were being stooped. As the shales in the parting between the seams are subject to weathering and spalling, this resulted in the need to continually clean up developed roadways. Efforts were therefore made to increase the rate of pillar extraction by mechanization.

Early Attempts at Mechanized Pillar Extraction

Two attempts were made to mechanize the pillar extraction, in 1964 and again in 1971, by the use of mechanized development equipment that was available on the mine. Both attempts were partially successful, but problems were encountered because the machinery was too large for the system. In the first stooping operation, gathering-arm loaders, battery-powered shuttle cars, roofbolters, and coalcutters were used. In the second trial, diesel-powered dumpers replaced the shuttle cars.

In the trials, pillars at 31 m centres, with roadways 4,7 m wide, were extracted with an inclined stooping line of 45 degrees.

Roofbolts were the only means of support installed, other than timber breaker lines adjacent to the goaf. Timber side props could not be installed owing to the size of equipment in use, and it was for this reason that the early attempts were discontinued. In addition to providing extra support, timber props give a better warning of bad roof conditions, whereas support using only roofbolts can give a false sense of security in stooping operations. Another advantage of the use of side props is that they offer some protection from falls of ground from the pillar sidewalls, which are dangerous in the high working heights at Durnacol.

However, both attempts proved the viability of mechanized pillar-extraction techniques under the conditions at Durnacol, and valuable experience was gained. In the second trial, which was more extensive, over one hundred pillars were extracted containing more than 400 kt of ROM coal.

Present Method of Mechanized Pillar Extraction

With the experience gained from the earlier trials, it was decided to recommence stooping operations with 1 m^3 cable-reel front-end loaders instead of the loader–shuttle car and loader–dumper combinations used in previous attempts. Small electric front-end loaders were chosen in preference to diesel-powered alternatives in accordance with the mine policy to limit the consumption of diesel fuel. A further important advantage is that the electric machine is quieter than a diesel machine of similar size. Operation with this equipment is therefore safer since it is easier to hear the sound of roof movement.

The first stooping section using front-end loaders started production in May 1979. The use of the equipment proved very suitable, and mechanized pillar extraction is now an integral part of mining operations at Durnacol. At present, the Colliery has four mechanized stooping sections in operation, each producing approximately 15 kt of ROM coal per month on a double-shift basis. The number of stooping sections is to be increased in the future.

Equipment

The potential for the use of front-end loaders in stooping was realized from the good performance of these machines in other operations at the Colliery. Diesel front-end loaders were first introduced into the mine for general cleaning-up duties, and for the loading of dyke material, which gathering-arm loaders in conventional bord-and-pillar sections found difficult to handle. In one case, small front-end loaders were also successfully used for longwall development.

Originally, the roofbolter in use for stooping operations was the type being used for mechanized bord-and-pillar development. However, this machine was the largest piece of equipment in the section, and care had to be exercised during tramming to avoid knocking out timbers. The machine has since been replaced by a smaller roofbolter for easier manoeuvrability.

Each stooping section is equipped as follows:

1 track-mounted coalcutter
1 high-seam roofbolting machine
3 1 m^3 cable-reel front-end loaders.

In addition, the following spare equipment is kept in each section:

1 roofbolting machine
1 cable-reel front-end loader.

The mechanical availability of the equipment is good, being approximately 85 per cent for the front-end loaders and 90 per cent for the roofbolter and coalcutter.

Method of Mining

Panels for stooping are first developed with mechanized bord-and-pillar equipment. When the panel development is complete, pillars are extracted by retreating with an inclined stooping line of 45 degrees, as shown in Fig. 3.

Panels are normally developed with 5 or 6 roadways, but odd-shaped panels are sometimes wider. So far, stooping lines consisting of up to 9 pillars have been mined by mechanized pillar-extraction methods. Panels developed with 6 roadways are considered the optimum size for stooping.

Pillar sizes vary according to the depth of cover, but are normally developed at 30 m centres, with roadway widths of 4,7 m. The sizes of the pillars are determined according to Salamon's empirical formulae, and a safety factor of 1,8 to 2,2 is applied. The working heights are exceptionally high for stooping operations, and vary from 3,0 to 5,2 m.

Two basic methods of mechanized pillar extraction are employed at Durnacol. These are Methods 1 and 2 as shown in Figs. 4 and 5 respectively, but other extraction methods are used if they are thought to be advantageous. This applies especially when irregular-shaped panels or pillars are extracted.

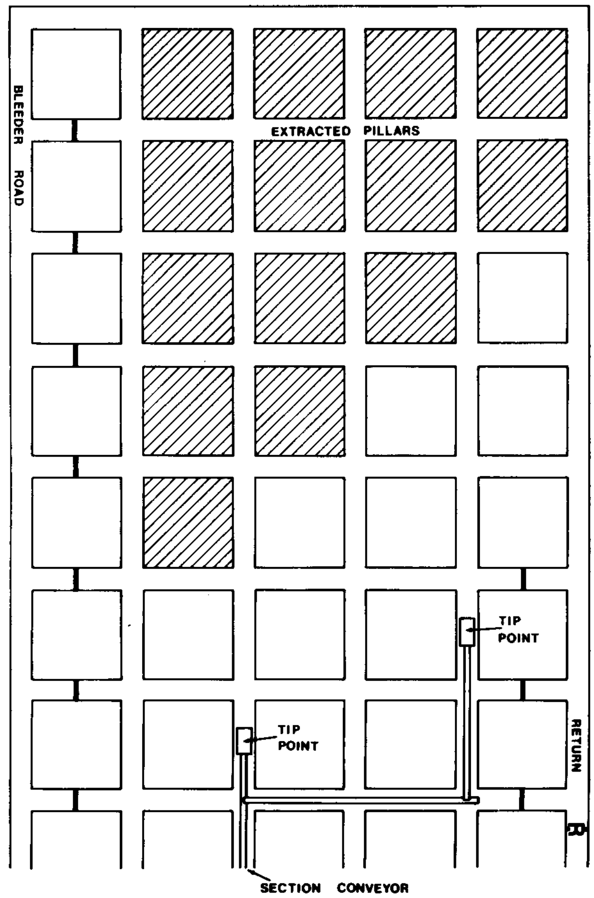

Fig. 3—Panel layout showing inclined stooping line

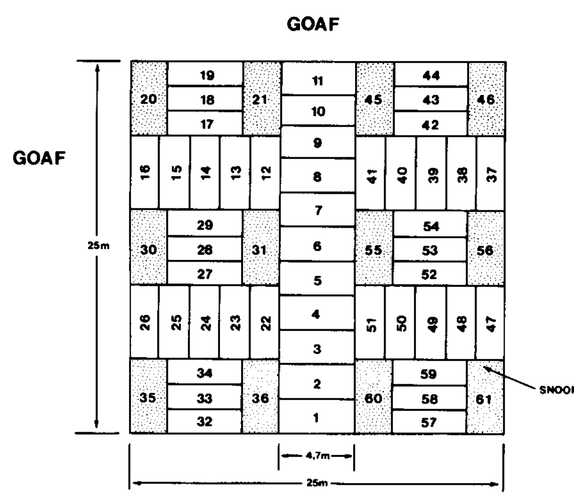

Fig. 4—Sequence of pillar extraction, Method 1

All the miners, shift bosses, and mine overseers are given a sequence plan similar to that shown in Fig. 4. The sequence is strictly adhered to and, if the extraction of one pillar is proceeding faster than others in a stooping line, the mining of that pillar is delayed until the other pillars reach the same stage. The following of a strict sequence allows the uniform retreat of the stooping line and maximizes the percentage extraction.

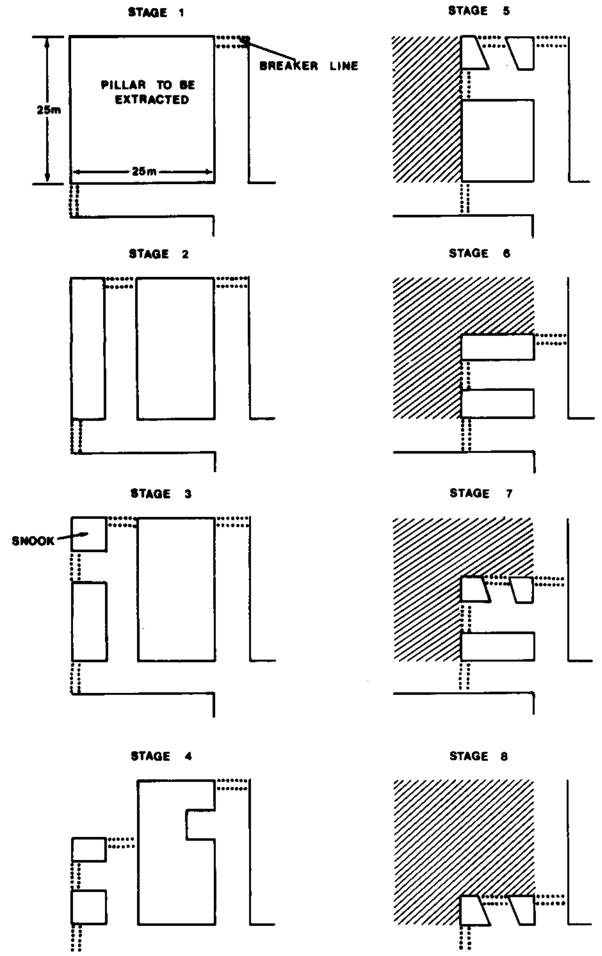

Fig. 5—Sequence of pillar extraction, Method 2

Headings and splits are developed in the pillars to form pillar remnants, or snooks, which are extracted as indicated in the stooping sequence plans. Faces are drilled with hand-held electric rotary machines, the upper half of the face being drilled from trestles. The faces of headings and splits are cut; for safety reasons, snooks are not cut but are removed by open-end blasting. Where possible, all the snook is extracted but, if it is felt that a portion of a snook cannot be recovered, an attempt is made to destroy it so that good roof control can be maintained.

When more than 5 pillars were being mined in a stooping line, it was found that the rate of extraction was too slow. This resulted in a lower percentage extraction because snooks were being lost as a result of roof pressure. Therefore, in stooping lines of more than 5 pillars per row, half the number of pillars in the row are extracted completely before the remaining pillars in the same row are mined.

During the initial panel development, the roadways are supported by rows of three or four 2,1 m roofbolts installed at 1,5 m centres. Extra support is provided at intersections by 3,0 m bolts installed at the same spacing. Before the start of stooping operations, timber props with headboards are installed 1,8 m on either side of roadway centre lines, and are set 1,5 m apart along the length of the roadway. Back-timbering proceeds as the stooping line is retreated. As headings and splits are developed in pillars in the stooping operations, the side props and 2,1 m roofbolts are extended in the same pattern. Breaker lines consisting of a double row of timber props with headboards spaced 1,0 m apart are installed at the goaf edges. It is estimated that some 50 per cent of the timber installed is recovered during drawing from the goaf.

Headings are ventilated with fans and flexible ducting but, once the headings have holed through to the goaf, the fans are switched off. This is done as a safety precaution so that any sound due to roof movement can be heard.

The bleeder system of ventilation is used, and air is drawn from the workings, over and through the goaf, to bleeder road return. Therefore, dust and fumes are drawn away from the working area, and methane is not allowed to build up in the goaf. The ventilation arrangement for a typical stooping section is shown in Fig. 6.

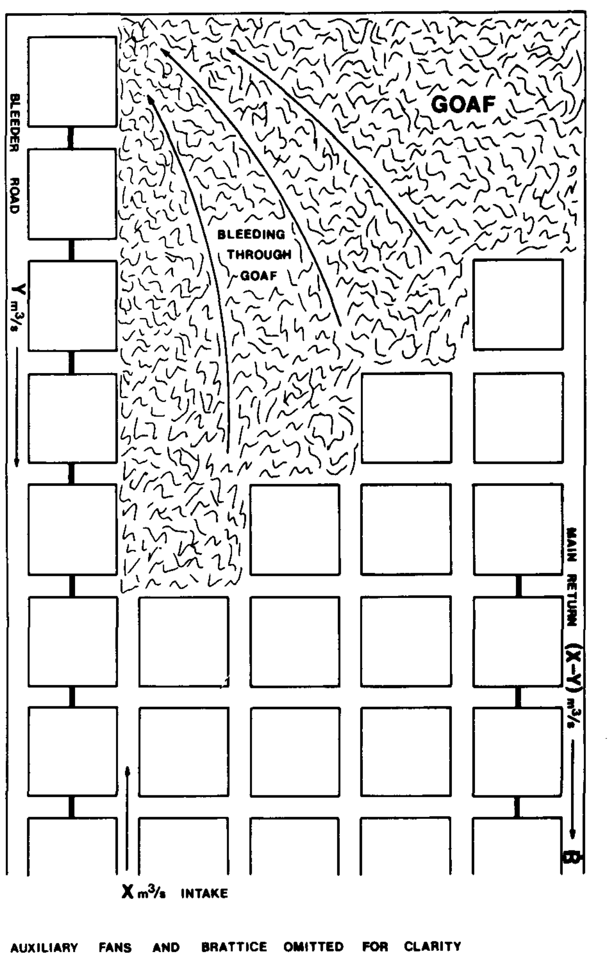

Fig. 6—Typical ventilation arrangement

Since the introduction of mechanized pillar extraction, the ratio of pillars developed to pillars stooped has improved to one pillar developed for every 2,7 stooped. More pillars are being stooped at present because a backlog of developed pillars had built up in the past.

Percentage Extraction

Depending on pillar sizes, between 30 and 40 per cent of the mineable reserves within the barrier pillars of a panel are extracted in the initial development.

After the subsequent pillar extraction, between 80 and 90 per cent of the initial reserves are extracted. Coal not recovered is lost in snooks that cannot be mined, and in pillars that remain to protect the bleeder road. It should be noted that, when two or more adjacent stooping panels are mined, the same bleeder road is often used for all the panels. Coal is also lost where it lies against the goaf and breaker lines, and cannot be loaded. A lower percentage recovery is obtained in high sections owing to the earlier failure of snooks.

Environmental Impact

The method of mechanized pillar extraction results in only minor subsidence on the surface, and has little effect on surface drainage patterns. No deterioration in the quality of overlying farmland has resulted from the use of the method. The maximum surface subsidence so far recorded over stooping panels is 0,2 m. Subsidence is minimized by the action of the main overlying dolerite sill, which spans the goaf of the stooping panels.

Labour and Productivity

A breakdown of the mining and engineering labour for a typical mechanized stooping section is given in Table I, which excludes supervisors above the levels of miner and artisan.

TABLE I

LABOUR REQUIREMENTS IN A MECHANIZED STOOPING SECTION

Section supervisors per shift		*Artisans per shift*	
Miner	1	Fitter	1
		Electrician	1
		Sub-total	2
Section workers per shift		*Artisan assistants per shift*	
Team leader	2	Aides	2
Coalcutter operator	2	Helpers	2
Roofbolter operator	2	Sub-total	4
Front-end-loader driver	3		
Electric-drill operator	4		
Timber	8		
Bar and water	1		
Duff	1		
Box attendant	2		
Stonedust and ventilation	1		
Tip-point attendant	2		
Sub-total	28		
Total mining	29	Total engineering	6

Handloading and Mechanized Pillar Extraction

A comparison between the two methods of pillar extraction is given in Table II.

TABLE II

COMPARISON BETWEEN HANDLOADING AND MECHANIZED PILLAR EXTRACTION

Description	Handloading	Mechanized
Labour—Section Supervisors per shift	1	1
Labour—Section Workers per shift	40	28
Labour—Artisans per shift	0,5	2
Labour—Artisan Assistants per shift	1	4
Total labour	42,5	35
Production (ROM coal per month/shift), t	4000	7500
Productivity (ROM coal per manshift), t	4,0	9,1
Percentage extraction (including initial development)	65 to 75	80 to 90

It can be seen that considerable improvements in production, productivity, and percentage extraction have been achieved since the introduction of mechanized pillar mining. The adoption of the mechanized method has also contributed to a declining number of accidents.

The cost of mechanized stooping is lower per ROM ton, and will become increasingly competitive in the future as labour costs rise.

A major disadvantage of the handloading method is the lower percentage extraction. This is because pillars are mined at a far slower rate than with the mechanized method, and more snooks are lost in the goaf.

Conclusion

Mechanized pillar extraction is now firmly established at Durnacol Colliery and is replacing the handgot methods previously used. Handloading has several disadvantages and is now restricted to the older areas of the mine, where it cannot be replaced by mechanized methods.

Improvements have been achieved in production, productivity, safety, cost per ton, and percentage extraction of reserves. The increase in the percentage extraction of reserves will result in an extension of the life of the mine.

Further advantages are the reduction in the total mine workforce, with the improved control and supervision that this allows.

Acknowledgements

The contributions of the staff of Durnacol to the compilation of this paper, and the permission granted by Mr B.C. Alberts, Senior General Manager (Mining), and Mr C.O. Esterhuysen, Manager, Mining Operations (Underground Coal Mines), of Iscor Limited, are gratefully acknowledged.

Computer applications

The Pennsylvania State University will host the Nineteenth International Symposium on Computer Applications in the Mineral Industries (APCOM) from 14th to 18th April, 1986, at the Pennsylvania State University, University Park, Pennsylvania, U.S.A. The Pennsylvania State University is a permanent member of the International Council for APCOM. Other permanent members are University of Arizona, Colorado School of Mines, and the Society of Mining Engineers of AIME.

The Symposium is designed to bring together those interested in the application of computers, mathematics, statistics, geostatistics, and operations research to the mineral industries. It will be an opportunity for the discussion of new and potential developments in the use of mathematical methods and computers for the planning and design of mineral projects, particularly in the areas of exploration, exploitation, beneficiation, financing, management, and control.

The Symposium will be of particular interest to planning, research, and operations personnel in the mineral industries, and to managers, engineers, and computer and operations research scientists engaged in exploration, mine planning and development, marketing, and valuation of mineral projects. It will offer an opportunity for software and hardware developers and users to share information.

The Organizing Committee welcomes abstracts of papers on any of the following topics:

- **Exploration**
  Use of Satellite Data
  Reconnaissance
  Target Investigation
  Automated Data Acquisition
  Geochemical and Geophysical Exploration
  Drilling Investment Decisions
  Exploration Data Management
- **Orebody Modelling and Ore Reserve Estimation**
  Orebody Modelling Techniques
  Extension and Estimation Techniques
  Grade–Tonnage Estimates and Comparisons
  Geostatistical Techniques and Advances
  Computer Graphics Applications
- **Mine Planning, Design and Operations**
  Mine Systems Modelling
  Open Pit Limits Analysis
  Long-range Planning
- **Short-Range Planning**
  Production Scheduling
  Unit Operations: Ground Control, Ventilation, Environmental Systems, and Materials Handling
  Project Management
  Interactive Graphics
- **Mineral Processing and Plant Operations**
  Analysis of Mineral Extraction Processes
  Computers in Control Strategies
  Real-time Data Acquisition and Control
  Coal Preparation Process and Plant Models
- **Investment Planning and Evaluation**
  Coast Estimation and Projection
  Feasibility Studies
  Risk Evaluation
  Capital Project Planning and Control
  Case Studies and Comparisons
- **Management Information Systems**
  Mine Monitoring and Control
  Manpower Training and Evaluation
  Mine Maintenance and Inventory Control
  Financial Reporting and Control
  Information Networks
- **Industry-Wide Projections**
  Economic Modelling of Mineral Sector
  Supply, Demand, and Price Studies
  National and International Planning for Minerals.

Abstracts should be no longer than 250 words and should be submitted to: Dr James D. Bennett, Mining Continuing Education, Department of Mineral Engineering, 126 Mineral Sciences Building, University Park, Pennsylvania 16802, U.S.A.

Completed manuscripts of approved papers will be required by 1st December, 1985, and should be submitted to the same address. The papers will be published as a bound volume by the Society of Mining Engineers of AIME.

Wire exposition

Interwire 85, the year's largest international wire and cable exposition, is to be held in Atlanta, U.S.A., from 5th to 8th November, 1985.

Held in conjunction with the 55th Annual Convention of the Wire Association International, the show's sponsoring organization, Interwire 85 will feature demonstrations of working machinery and visual displays of the latest wire-drawing and wire-fabricating technology from about 500 exhibiting companies.

The exposition and Association-sponsored technical sessions, plant tours, and social events are all part of a week of activities designed to bring the international wire and cable community together to exchange information and ideas on design, technology, and production.

Early indications from exhibitors, who have already contracted for nearly 80 000 square feet of exhibit space, point to this being the most successful and well-attended event in the history of the biennial wire expositions, which began in 1981.

For additional information on how to exhibit at or attend North America's only 1985 wire and cable show, contact the Interwire Sales Department, Wire Association International, P.O. Box H, Guilford, CT 06437 U.S.A. Telephone: (203) 453-2777. Telex: 956015.