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Partial pillar extraction with controlled goafing of the superincumbent strata

by J. D. FLINT*, I. F. BUCHAN†, I. D. N. STRACHAN‡, and C. A. CLARKSON§

SYNOPSIS

The geological conditions in the Vierfontein area are such that conventional pillar extraction (stooping) cannot be practised safely or efficiently. Both the open-end lift and the pocket-and-fender methods of pillar extraction have been tried with little success because of problems with roof control and ground stability. The main reasons for the difficulties are the coarse-grained sandstone roof, local weaknesses in the coal seam, and the rate at which the pillars were extracted.

The mine has practised bord-and-pillar mining since it started production in 1952, and considerable reserves of coal are contained in the pillars. As an alternative to total pillar extraction, in which hand-loading methods were practised, a system of partial pillar extraction using mechanized-mining methods with modified goaf-line support has been evolved. These remnant coal pillars (snooks) remaining after partial extraction of the pillar, together with the installation of 1,2 m² matpacks and a double line of full-column resin roofbolts, ensure control of the edge of the area that has been mined out (goaf).

Where roof conditions preclude the use of conventional pillar-extraction methods, this method holds promise as a safe and efficient alternative for the recovery of coal from pillars and for an increase in the volumetric extraction of the reserves within a mining panel.

SAMEVATTING

Die geologiese toestande in die Vierfontein-gebied is van so 'n aard dat konvensionele pilaarsloping nie veilig of doeltreffend toegepas kan word nie. Sowel die oopkantskyf as die binneholte-en-stutribmetode vir pilaarsloping is op die proef gestel, maar sonder veel sukses vanweë probleme met dakbeheer en grondstabilitiet. Die hoofredes vir die probleme is die grofkorrelrige sandsteendak, plaaslike swak plekke in die steenkoollaag en die tempo waarteen die pilare gesloop is.

Die myn het pilaarmynbou beoefen sedert dit in 1952 met produksie begin het en die pilare bevat aansienlike steenkoolreserwes. As 'n alternatief vir algehele pilaarsloping waarin handlaaimetodes toegepas is, is daar 'n stelsel van gedeeltelike pilaarsloping ontwikkel wat van gemeganiseerde mynboumetodes met gewysigde dakpuinbestutting gebruik maak. Hierdie restantsteenkoolpilare (steenkoolstompe) wat oorbly na die gedeeltelike sloping van die pilaar, tesame met die aanbring van matpakke van 1,2 m² en 'n dubbelery volkolom-harsdakboute, verseker beheer oor die rand van die gebied wat uitgemyn is (dakpuin).

Waar die daktoestande die gebruik van konvensionele pilaarsloopmetodes uitskakel, hou hierdie metode belofte in as 'n veilige en doeltreffende alternatief vir die herwinning van steenkool uit pilare en vir 'n toename in die volumetriese herwinning van die reserwes in 'n mynpaneel.

Introduction

Vierfontein Colliery is situated in the Viljoenskroon district of the north-western Orange Free State, 12 km south of Orkney. The mine started operations in 1952 to supply the requirements of the Electricity Supply Commission's Vierfontein Power Station.

It was originally expected that the station would have a generating capacity of 210 MW with the possibility of an extension to a maximum of 300 MW. In the event, during the mid 1950s, the generating capacity of the power station was increased to 360 MW and the coal requirements to 160 kt per month at maximum generating capacity. The power station, as originally planned, was expected to have an operating life of between 35 and 40 years, and could be expected to cease operations some time between 1987 and 1992. The reserves at Vierfontein Colliery were estimated to be adequate to supply the power station at the increased generating rate for this period.

* Consulting Engineer.

† Consulting Mining Engineer.

‡ Senior Divisional Mining Engineer.

All the above of the Coal Division, Anglo American Corporation of South Africa Limited, 44 Main Street, Marshalltown 2001.

§ Mine Manager, Vierfontein Colliery, Private Bag, Vierfontein, 9530.

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Geological Description

The Vierfontein coalfield has been mined intermittently since before the end of the last century, and several old mines of doubtful extent are located in the north-western part of the field along the outcrop of the seams. At Vierfontein Colliery, which is now the only operating colliery in the area (Fig. 1), there are two seams: a top seam of up to 1,5 m thick in an isolated area of the South East shaft, which is not exploited, and a bottom seam, which varies in thickness from 0,5 to 3,7 m. In general, no mining is carried out in seams that are less than 1,0 m thick. The top and bottom seams are separated by about 37 m of sediments consisting of white fine- to medium-grained sandstone in the upper half, grey to dark-grey micaceous sandstone lower down, and black micaceous shale near the base of the parting.

Production is obtained exclusively from the bottom seam, and the coal has an average calorific value of 21,2 MJ/kg (air dried). A feature of the seam is the occurrence of thicker and thinner coal-bearing areas that are orientated east–west and coincide with gentle troughs and ridges in the floor of the seam.

Fig. 2 depicts a typical stratigraphic column.

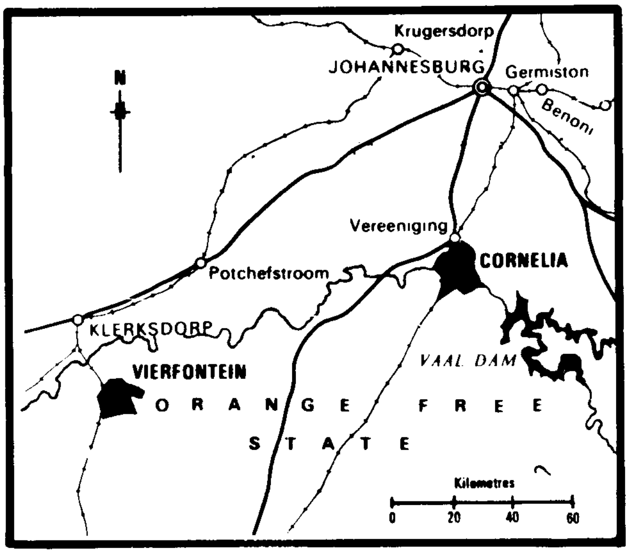

Fig. 1—Location of Vierfontein Colliery

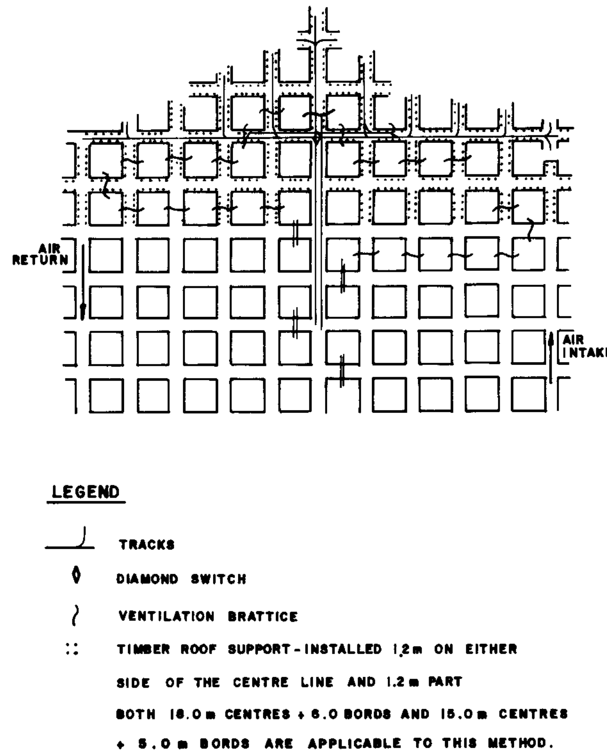

Fig. 3—The layout of a typical hand-got section as mined at Vierfontein Colliery

Method of Mining

To exploit the coalfield, two shaft systems, east and west, were provided, both equipped with endless-rope haulages for transporting the coal. The mine was planned to operate on the bord-and-pillar system, developing 6 m wide bords (roadways) on 15 to 18 m centres, depending upon the depth of the seam, forming 9 to 12 m square pillars (Fig. 3). Coal was hand loaded into mine tubs of 1 t capaicty.

The use of tubs limited the minimum seam thickness that could be worked to approximately 1,3 m. To improve the recovery of the reserves, a system of scraper mining was introduced in the mid 1960s. Although this method of mining enables seams only 0,7 to 0,8 m thick to be worked, productivity from the sections was low and production costs were relatively high, and the system was discontinued in 1973. With the cessation of scraper mining, trials on pillar extraction (stooping) commenced. Conventional pillar-extraction methods were introduced during the years 1973 to 1978 but with little success. The roof at Vierfontein is a coarse-grained sandstone containing many mica intrusions, which result in poor mechanical strength of this massive sandstone. While the roof is competent in developing areas, it does not break easily during stooping operations but tends to bend rather than shear off along the goaf line. When goafing did occur during stooping operations, it was, on occasions, such that support lines were overrun, snooks crushed, and intersections outbye the stooping line collapsed. It was during one such goaf in 1978 that six men were fatally injured. The method of extracting pillars was revised, and the pocket-and-fender method was introduced (Fig. 4). During these trials, no serious falls occurred, but the convergence and weight were such that fenders crushed to the extent that the lifts could no longer be worked safely. As a result, all forms of pillar extraction were discontinued.

Notwithstanding these setbacks, various methods of recovering the coal reserves remaining in the pillars have received attention on an ongoing basis.

Because of the significant changes in seam thickness over short distances at Vierfontein, the advantages of

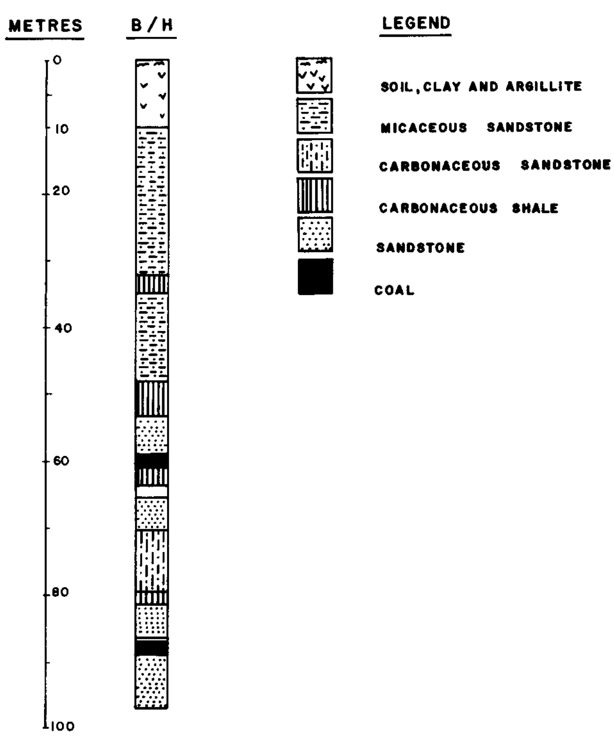

Fig. 2—A typical stratigraphic column, Vierfontein Colliery

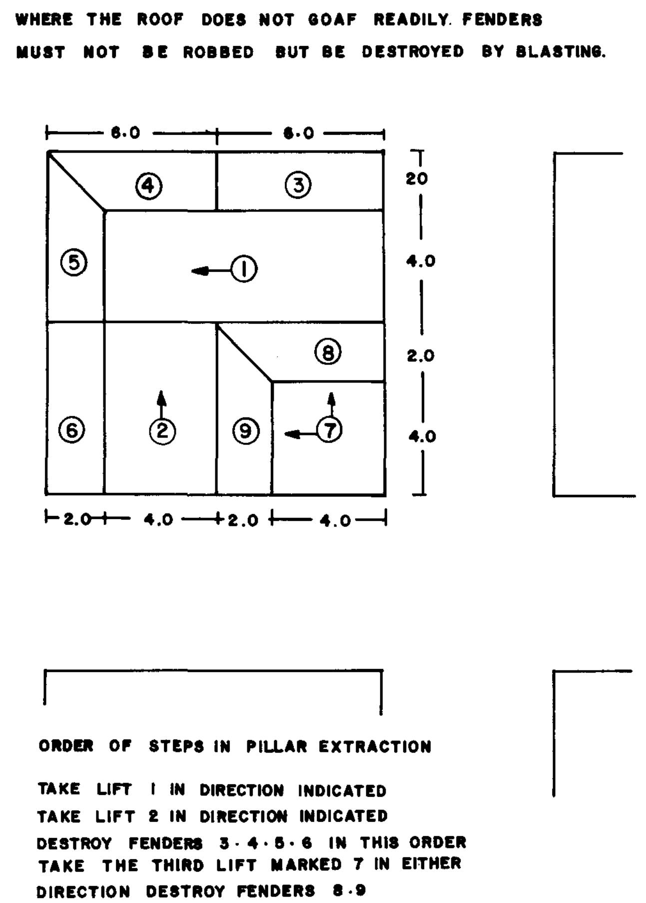

Fig. 4—Pocket-and-fender method of pillar extraction

successfully and economically extracting coal from developed pillars where mining conditions are known are obvious.

At the end of 1981 it became apparent that the burning rate of the power station would continue at a higher rate than originally anticipated; and that the power station would operate for a further fifteen years, to 1996, and would require an additional 4 to 5 Mt of run-of-mine coal.

The reserves remaining at the end of 1981 were re-estimated to be 15 Mt of run-of-mine coal made up of 7 Mt of underground coal and 8 Mt of open-cast coal. The need for a re-examination of methods for improved recovery of the coal from the underground reserves was thus highlighted.

The possible methods of stooping were re-examined, and the following alternatives were considered:

(1) mechanized retreat shortwall mining,
(2) single-pillar extraction with a continuous miner,
(3) modified pillar extraction involving handloading into tubs or mechanized loading (scooptrams) onto conveyors.

Mechanized Retreat Shortwall Mining (*Fig. 5*)

A modified shearer, an armoured-face conveyor, and self-advancing hydraulic supports would be required for the operation of a shortwall face. The face would be restricted in length to three pillars, i.e. 60 m, of which only 36 m would be coal. Faces longer than 60 m would present support problems both in the face line and in the roadways ahead of the face line.

The face line would, however, be difficult to support during the extraction of the final one-third of each pillar because the rib of coal remaining between the face and the split being approached would be subject to severe stress, and the probability of face-line collapse would be high.

In addition, this system would be capital-intensive; would require expertise in the mining and engineering disciplines of longwalling/shortwalling, which was not readily available; and would be inflexible in relation to other methods, in that the time required for moving from area to area would be excessive and the continuity of production could not be guaranteed.

This method was therefore not pursued after the preliminary investigation stage.

Single-pillar Extraction with a Continuous Miner (*Fig. 6*)

This method of mining, while being capital-intensive and requiring certain skills and expertise in engineering that were not readily available at Vierfontein, was investigated in depth.

The main advantages in the use of a continuous miner in single-pillar extraction are as follows:

(a) there is a concentration of supervisory effort;
(b) the absence of blasting ensures minimum disturbance of the surrounding pillars and the immediate roof;
(c) the area of operations is protected on two sides by coal pillars that have not been worked; and
(d) a straight-line stooping operation can be undertaken.

This method of mining was rejected because of the high capital cost.

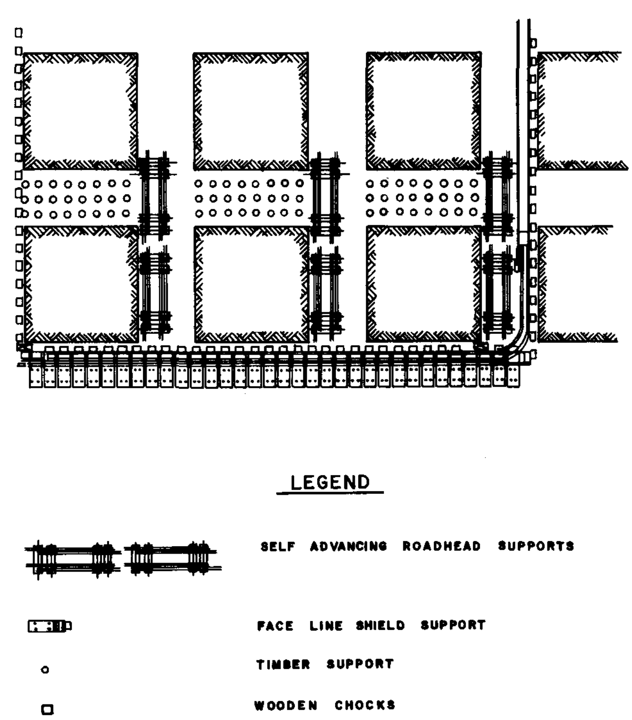

Fig. 5—Mechanized retreat shortwall mining

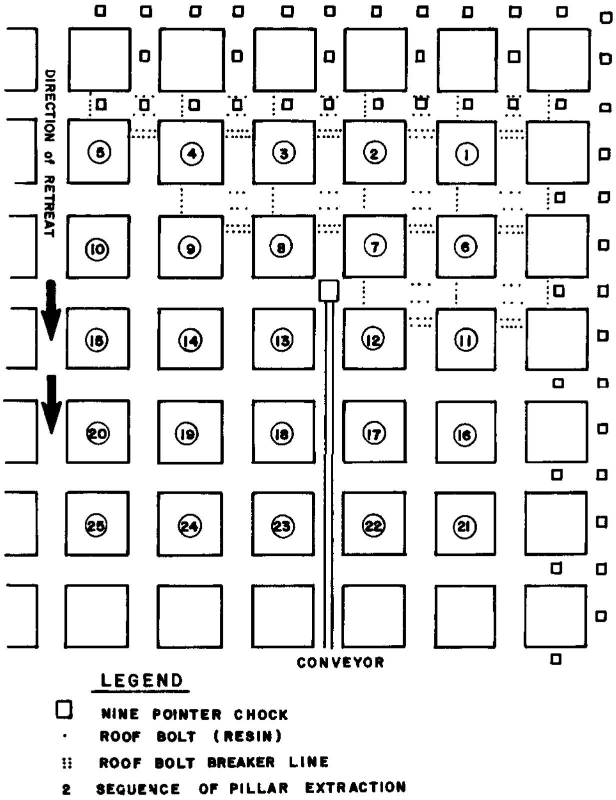

Fig. 6—Single-pillar extraction with a continuous miner

Modified Pillar Extraction

Pillar extraction, in which four-pointer chocks are systematically installed as the pillars are extracted and which allows controlled convergence of the roof to take place, has been successfully applied in mines in the Vryheid and Kliprivier coalfield in Natal. An examination of the conditions prevailing at Vierfontein indicated that this method of working, with certain modifications, could be applied successfully in selected areas of the mine.

Two of the main causes of the failure of stooping trials in the past had been the slow rate at which the pillars were extracted when loading was done by hand and the excessive width of the panel. To accommodate the six activities necessary to produce coal in a handloading situation (i.e. support, lay tracks, cut, drill, blast, and make safe), together with six faces for the loading spans, the panel was some 180 m wide and the stooping line more than 250 m long (Fig. 7).

The layout of the proposed stooping panels and the subsequent sequence of operations were discussed with personnel from the Chamber of Mines Research Organization. It was agreed that an adaptation of the Natal system of extraction with a mechanized coal-winning operation should be undertaken and that the following would result.

(1) The mining sequence would ensure the simultaneous weakening of a series of pillars.
(2) Sudden collapse of the roof in the working area would be prevented and caving would be more controlled.
(3) The density of a four-pointer chock is such that significant support is provided only when the chock is compressed to 50 per cent of its original height. In order to offer substantially better roof support, 1,2 m square nine-pointer chocks would be installed and would be set initially at 9,0 m centres around the pillars.
(4) All intersections and breaker line positions would be roof-bolted prior to the mining of any pillars. Because of the nature of the superincumbent sandstone resin anchor, or full column resin, roofbolts would be installed.
(5) The breaker lines would consist of double lines of roofbolts set in the same pattern as a conventional timber breaker line, i.e. 1 m between supports in the same row and 1 m between rows.
(6) The stooping panel would be so planned that the width between the barrier pillars would be less than 100 m, and the panel would be mined on a conventional 45° stooping line.

Fig. 8 shows the method of extracting pillars that was adopted. Scooptrams were introduced into Vierfontein in 1978 as a means of mining the thinner-seam areas, i.e. where the seam thicknesses are 1,0 to 1,3 m and handloading methods cannot be employed. These machines are used in conjunction with AB15 arcwall coal cutters mounted on crawlers and FMC rubber-tyred roofbolters.

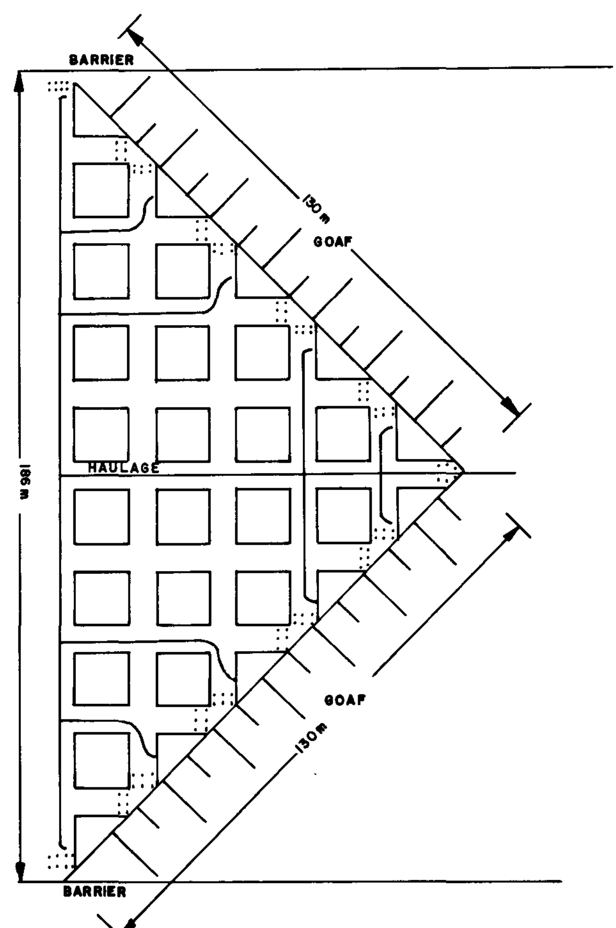

Fig. 7—Ten pillars worked simultaneously

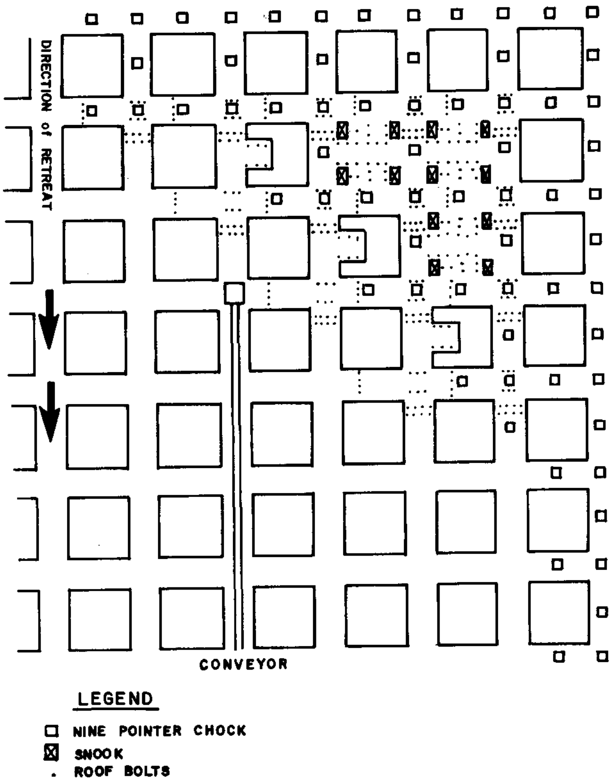

Fig. 8—Original method of mining pillars, showing chock support

Mechanized methods of coal winning have been favoured over hand loading because of the more rapid rate of retreat that can be achieved.

Location

The trial stooping section was established in the South East area of the mine, where the seam is approximately 2,0 m thick and is overlain by brownish-grey sandstones with some shale partings at intervals of between 0,1 and 5,0 m. The area was developed on 18 m pillar centres, and the pillars are approximately 12 m square.

Operation and Results

Training and Communication

To ensure the success of the trials, training and communication received high priority, and the following steps were taken.

(a) A technical report on the proposed sequence of mining operations was prepared, followed by a detailed account of the standard procedures complete with large-scale plans and diagrams.

(b) Copies of the technical report and standard procedures were distributed to the supervisory personnel of the mine, both mining and engineering: Mine Overseers, Shift Overseers, Miners, Foremen, Artisans, Training Officer, and Loss Controller.

(c) Formal discussions and training seminars were held at all levels.

Mining Procedure

Fig. 9 depicts the originally proposed cutting sequence for the mining of a pillar, in which a normal splitting and quartering operation would be carried out. Mining of the headings 6,0 m wide would leave four snooks 3,0 m square after a pillar had been worked. It was considered that snooks of this size would be too large, and that roof control would be difficult as a result. Snooks 1,5 m by 2,5 to 3,0 m would crush more readily and allow controlled convergence to occur. When the mining of the pillar had been completed, two additional chocks would be installed at A and B as shown in the diagram.

It became apparent very early in the mining operation that this method of reducing the pillars was leaving snooks too small to offer any resistance to the roof and that larger snooks would have to be formed. In order to leave more robust snooks, only one roadway was to be mined through the pillar and, in order to give the scooptram the easiest access to the working face, a diagonal entry into the pillar was designed (Fig. 10).

After 21 pillars had been extracted, a primary goafing occurred, indicating the following.

(1) The nine-pointer chocks set in the vicinity of intersections did not offer any significant resistance to the roof and collapsed under the weight of the goaf. The chocks that were set in the splits and had a snook on either side did not completely collapse with the goaf, but crushed with the snooks. When the snook failed, the roof broke around the chocks.

(2) The roofbolt breaker line was not totally effective

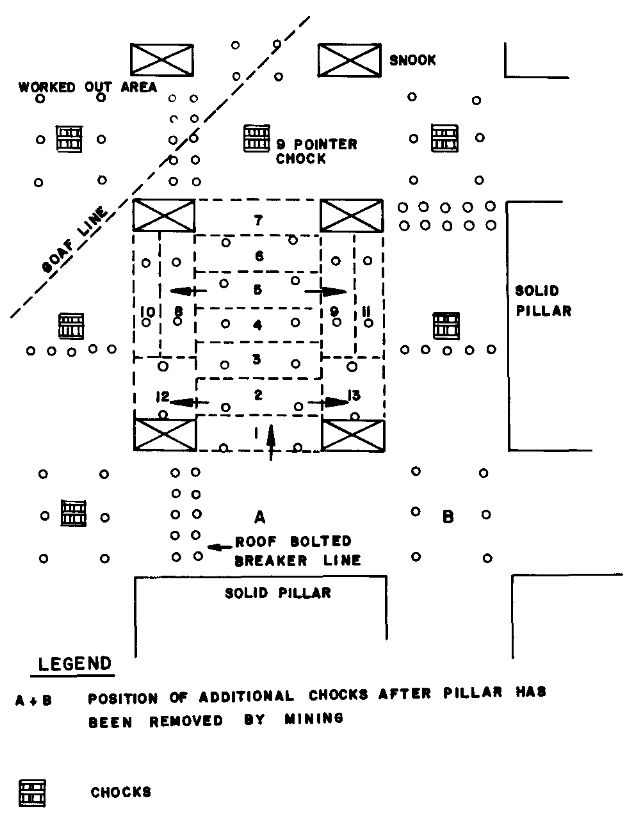

Fig. 9—Sequence of mining a pillar, 6 m wide bords on 18 m centres and 12 m square pillars

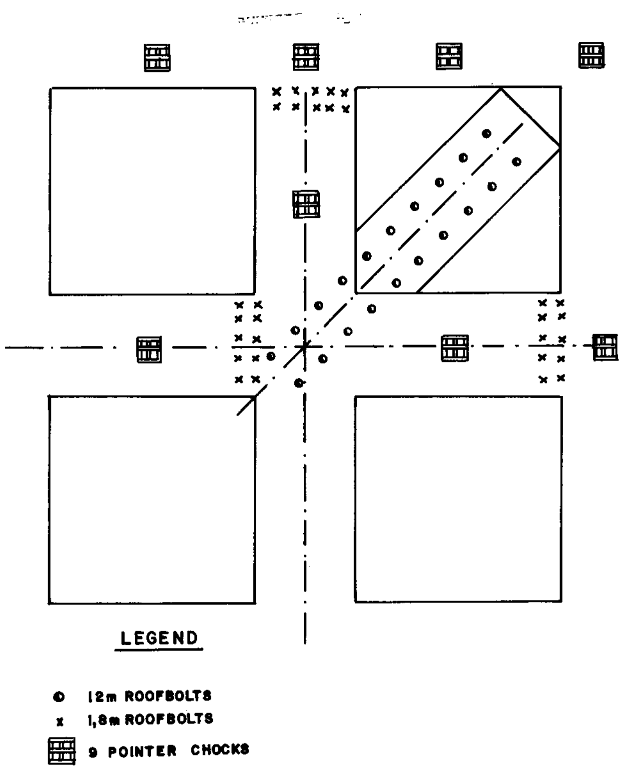

Fig. 10—Controlled-convergence pillar extraction

in that the goaf overran one breaker line.

(3) In one instance the roof around one of the partially mined pillars collapsed and closed the entry of the split into the pillar. The roof of the split into this pillar did not fall.

The strata gave warning of the impending goaf, and all the personnel, together with the mobile equipment, were moved away from the area some 30 minutes before the goaf took place.

To eliminate these shortcomings, the standard procedures were modified as follows.

(a) The density of the chocks was increased, the distance between chocks being reduced from 9,0 to 4,5 m.

(b) The roofbolt breaker line had been installed with 1,2 m long bolts. Future breaker lines would be installed with 1,8 m long bolts, and a single row of 1,8 m long bolts would be installed in each drive in line with the inbye ribside of the diagonal being driven into the pillar.

(c) The size of the final snook was reduced by the taking of a cut on either side of the diagonal split on the retreat.

As a result of these additional precautions, there was a marked improvement in section conditions except at the entry into the pillars currently being worked, where roof cracks were observed. Procedures were again revised, and Fig. 11 depicts the current support pattern.

Two double rows of supports are set across the intersection in line with the ribside of the diagonal. The outer line of each row consists of wooden props and the inner row of hydraulic props. Two rows of roofbolts with headboards are set between the double rows of support across the intersection, and are carried into the pillar as the split is advanced. It was found that, if the diagonal split was driven right through the pillar, there was a tendency for the goaf to run through the split. The mining system was revised so that the final cut into the goaf area is not made, and the corner of the pillar remaining is adequate to prevent the goaf over-running the pillar into the split. This alteration to the system makes it imperative that the pillars should be measured before mining commences so that the distance to which the split must be advanced can be determined timeously and accurately. When the mining of the pillar has been completed, only the hydraulic supports are withdrawn. In addition, the number of pillars being worked at any one time was reduced from 6 to 3, thereby effectively reducing the stooping line by half and doubling the rate at which a pillar is extracted. Fig. 12 depicts a typical shift-production cycle.

Surface Stability

Although only one panel has been mined to date, there are no signs of any surface ground movement and no subsidence has been measured. However, it is expected that subsidence will occur in the future.

Conclusions

The preliminary results of these trials at Vierfontein are encouraging and hold promise for more widespread applications in other areas of the mine.

The additional reserves generated by the successful introduction of this method of pillar extraction amount to some 2,5 Mt of saleable coal. No account has been taken of the possible reserves contained in pillars less than 12 m square, and this is still under investigation.

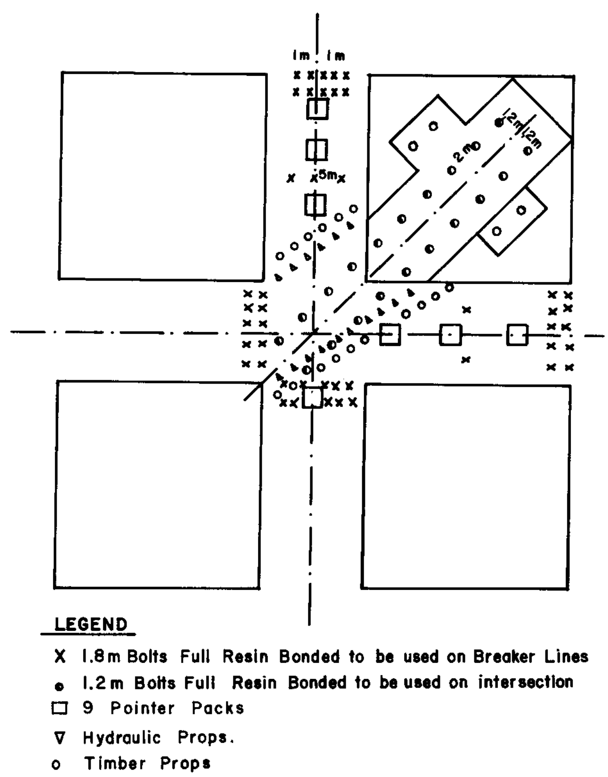

Fig. 11—Revised method of controlled-convergence pillar extraction

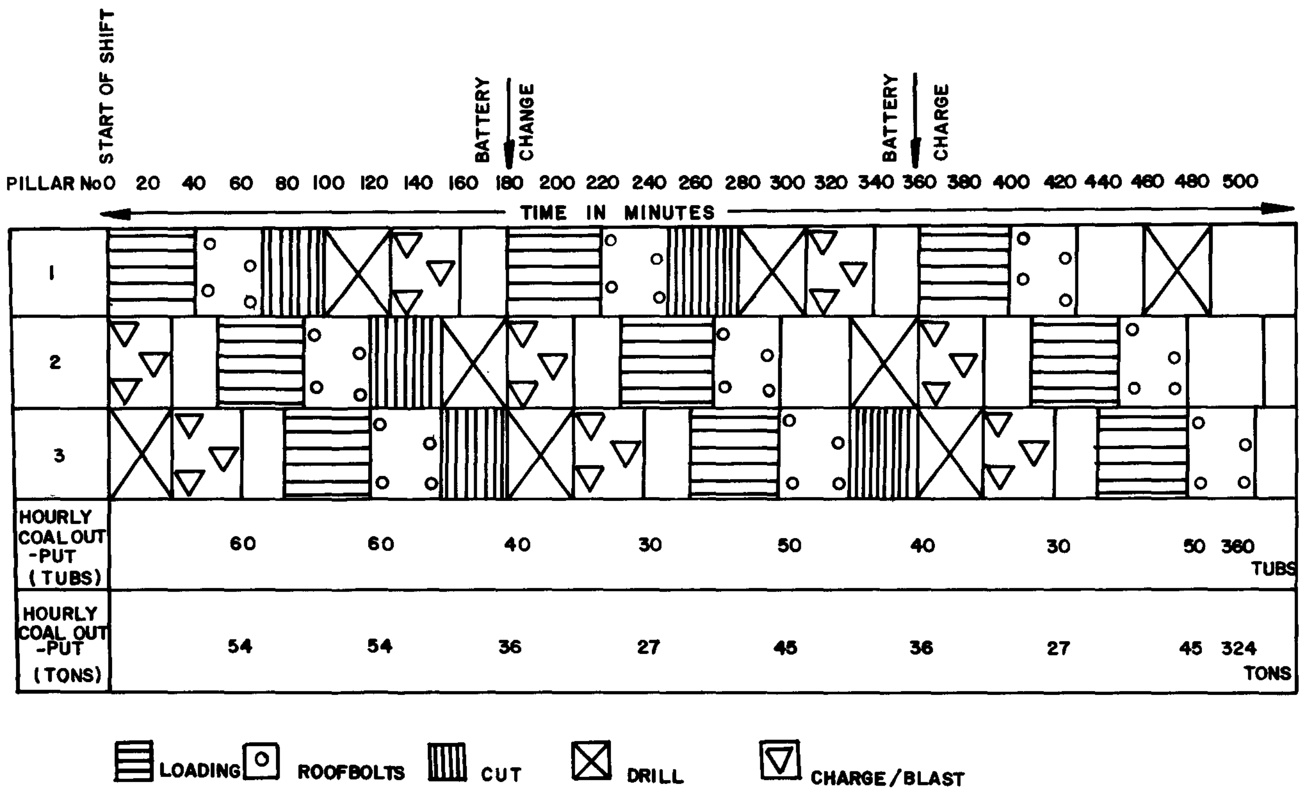

Fig. 12—Typical shift-production cycle

Mechanized-mining techniques have proved to be superior to hand loading because of the rate at which the pillars can be extracted and the fewer pillars that are required to provide the necessary working faces to maintain production.

The installation of packs and the use of hydraulic supports have changed the concept of pillar extraction at the mine, and have shown that the massive sandstone overlying the coal seam can be supported during pillar extraction. The packs and timber props set alongside the hydraulic support fail only after the hydraulic supports have been withdrawn and do not cause any weight to be thrown onto the unworked pillars. In addition, all the snooks remaining in the goaf have crushed and have not caused any roof-support problems.

The coal at Vierfontein is not liable to spontaneous combustion, and no hazardous conditions result from the leaving of coal in the goafed area.

This method of pillar extraction may be extended to other collieries that in the past have considered stooping to be impracticable in their prevailing conditions.

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