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The development and application of strip mining to previously mined underground coal workings*

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SYNOPSIS

This paper describes how a 'mined out' coalfield is being mined successfully by opencast methods. The coalfield is that at New Vaal Colliery, which is situated in the Vereeniging–Vanderbijlpark–Sasolburg industrial complex. All three coal seams at New Vaal had been mined previously, when the better-quality coal had been removed.

The coal-preparation plant at New Vaal, which is also described, supplies coal to the 3600 MW Lethabo Power Station. The Colliery has been designed to supply 600 million sales tons of coal over its forty-year life.

SAMEVATTING

Hierdie referaat beskryf hoe 'n 'uitgemynde' steenkoolveld suksesvol volgens dagboumetodes ontgin word. Die steenkoolveld is die een by die New Vaal-steenkoolmyn wat in die Vereeniging–Vanderbijlpark–Sasolburg-nywerheidskompleks geleë is. Al drie die steenkoollae by New Vaal is voorheen ontgin toe al die beste steenkool verwyder is.

Die steenkoolbereidingsaanleg by New Vaal, wat ook beskryf word, lewer steenkool aan die 3600 MW-Lethabo-kragstasie. Die steenkoolmyn is ontwerp om 600 miljoen verkoopbare ton steenkool gedurende sy lewensduur van veertig jaar te lewer.

Introduction

New Vaal Colliery is a captive mine, designed to supply Eskom's Lethabo Power Station with some 600 million sales tons of coal over its forty-year life. The mine is situated in the Maccauvlei area, in the Vaal Triangle just to the south of the Vaal River, and is part of the Vereeniging–Vanderbijlpark–Sasolburg industrial complex, as shown in Fig. 1.

Coal was discovered in the area in 1879 by George William Stow, and was first mined on the Transvaal side, at the old Bedworth Colliery, in 1880. Mining began in the New Vaal lease area in 1931 and continued until 1969, by which time some 61 per cent of the area had been undermined, but only 7 per cent of the coal reserves had been removed (Fig. 2).

The New Vaal coalfield contains three main coal seams, termed the top, middle, and bottom seams. Although all three seams had been mined previously, most of the old workings are in the middle seam. (Fig. 3 shows a simplified stratigraphic column, and Table I gives a breakdown of the coal reserves.) Where mining took place, only selected horizons of the individual seams were mined. These horizons were generally the better-quality portions of the seam, which resulted in the extraction of the lower 2½ to 3 m of each seam.

Project Planning

Careful thought was given to the planning of the new colliery project, especially to dragline stability and to drilling and blasting procedures.

Dragline Stability

To avoid contamination of the previously mined workings, it was decided that the pillars should be kept intact prior to coal removal. Thus, the idea was to drill and blast the shale above the coal and remove the broken material while disturbing the old workings as little as possible.

However, concern was expressed that the pillars could fail, which would, at best, cause the dragline to tilt and, at worst, if the failure occurred close to the highwall, the dragline could fall into the pit.

In the initial geotechnical studies, carried out by outside consultants, the 'worst case' situation in the deepest area of the mine was determined, and detailed recommendations were then made, the following being the most important.

(1) The dragline should be positioned as far away from the highwall as possible, this being good mining practice.
(2) The angle of the unsupported highwall after blasting should not be greater than
    58° for one seam mined
    50° for two seams mined.
(3) The previously mined workings should be collapsed before the dragline began stripping operations above them.
(4) A buttress, similar to an extended bench, should be placed by the dragline ahead of itself to support the highwall.

The buttress and the general arrangement of these recommendations are shown in Fig. 4.

The implications of these recommendations were a 25 per cent increase in rehandling owing to the placement and removal of the buttress and an increase in the dragline walking time.

Drilling and Blasting

The concepts of minimizing the contamination and stabilizing the dragline bench by collapsing the old workings were thought to be incompatible.

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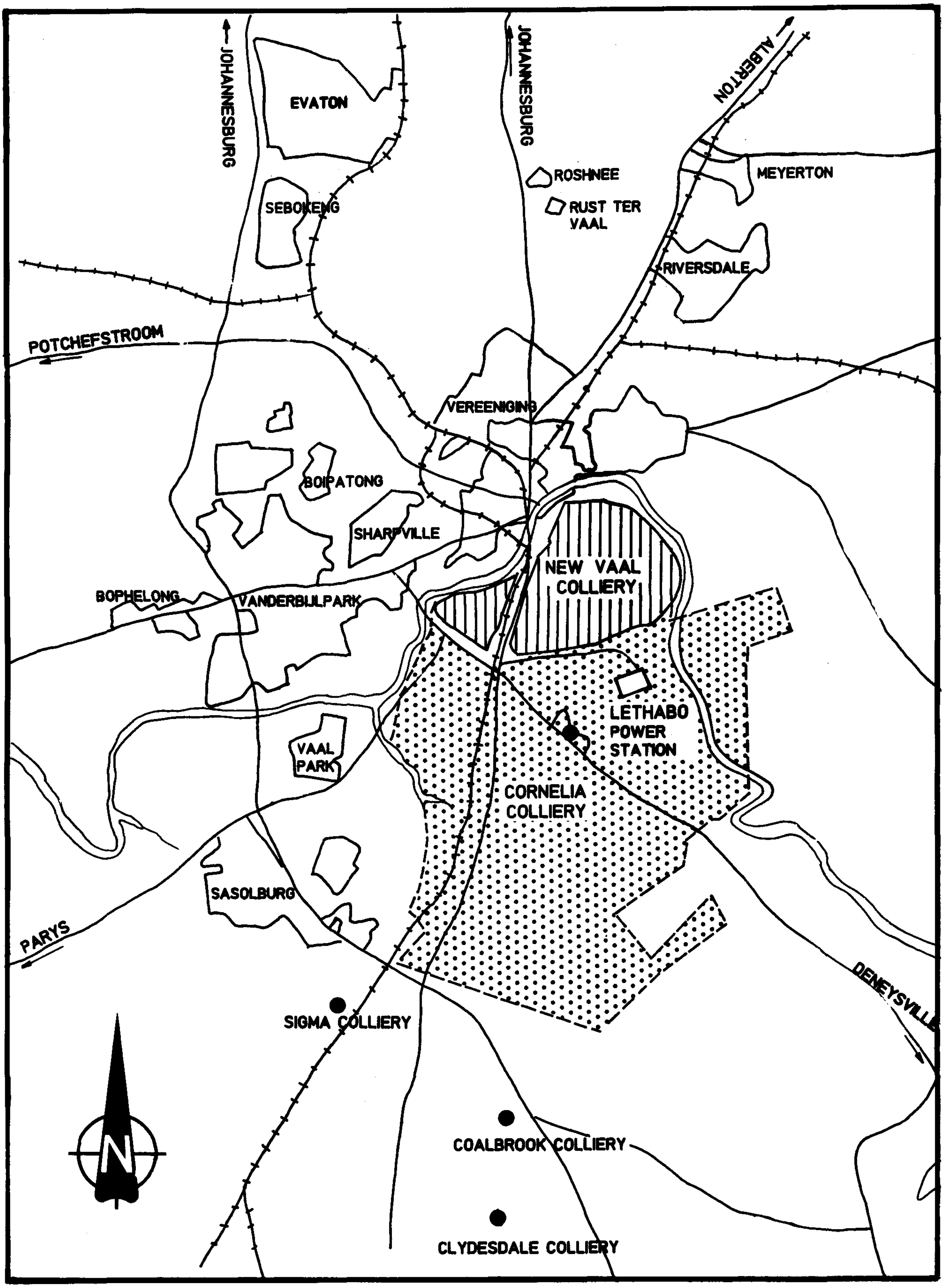

Fig. 1—Map showing the location of New Vaal Colliery

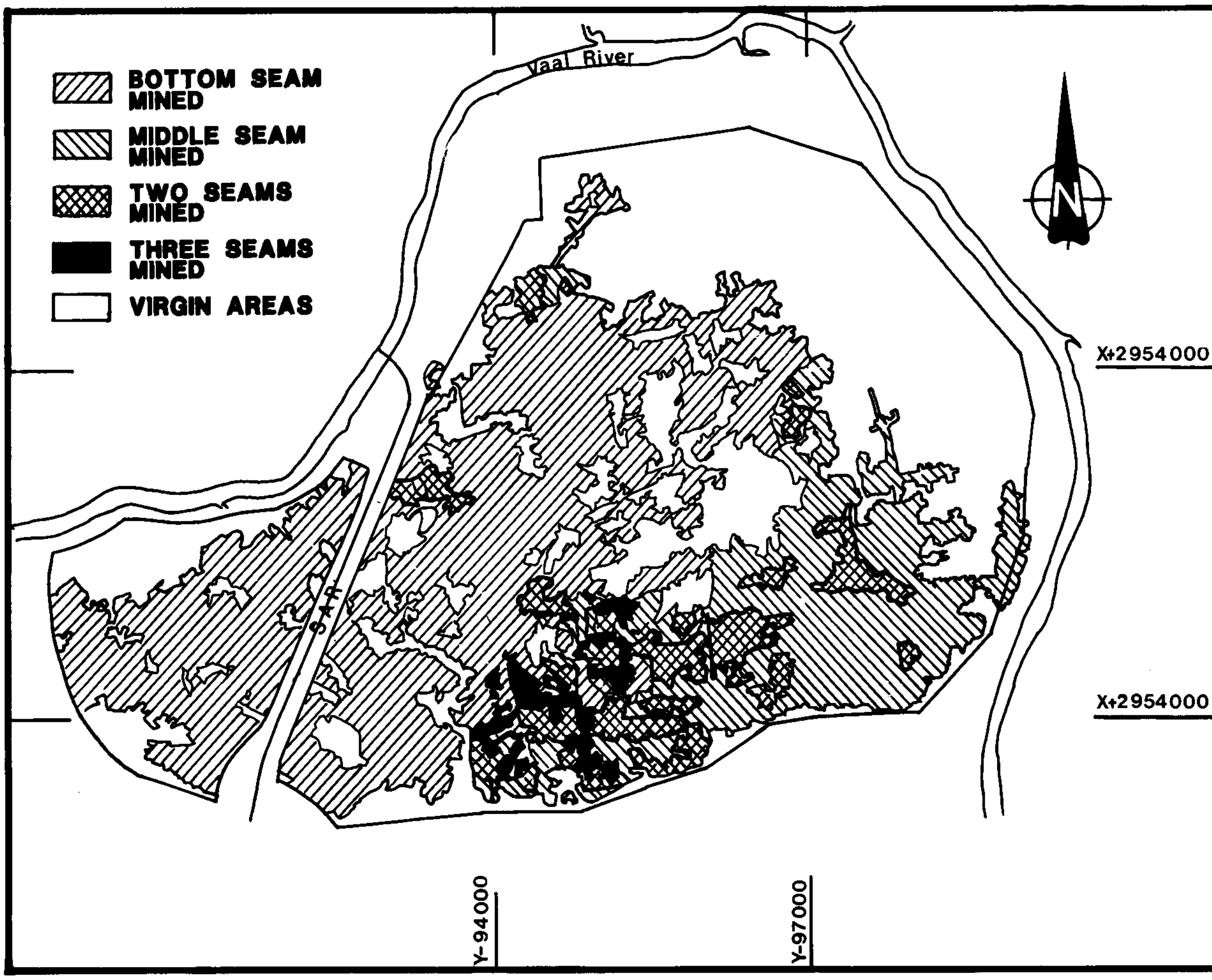

Fig. 2—Areas where one, two, or three seams had been mined previously

TABLE I
NEW VAAL COLLIERY COAL RESERVES

	Unit	Top seam	Middle seam	Bottom seam	Total
In situ reserves	tx10^6	278,6	328,7	198,3	801,9
Tonnage removed by U/G working	tx10^6	2,0	17,0	32,0	51,0
Total tonnage remaining	tx10^6	276,6	311,7	162,6	750,9
% of tonnage remaining	%	99,3	94,8	82,0	93,6
Area covered by seam	ha	2035,3	2851,2	2879,2	2879
Area in which U/G workings occur	ha	88,3	783,6	1166,1	1756
% of area affected by U/G workings	%	4	25	40	61
Average thickness of seam	m	6,73	6,90	4,16	17,79

U/G = Underground

The original idea was to drill to the top of the coal seam and overblast the shales, thus collapsing the weaker areas. The dragline would then remove the waste from a stable platform, and the coal would be drilled and blasted separately.

It was thought that the thicker (3 m) top coal would fall to the floor, and a minimum of waste would lie on top of this coal.

Development of the Mining Method

The proposed mining method was put into effect but, as described below, was found to be unsatisfactory.

The First Attempt

Previously mined areas were encountered in the initial box cut but, because of their limited extent, had little or no effect on the mining.

In the third cut, some 500 m of old workings were encountered, and the proposed mining method was put to the test. The 10 m of shale above the coal was drilled on a square pattern of 8 m × 8 m, and the holes were charged with 200 kg of emulsion, giving a ratio of 0,31 kg of explosive per bulk cubic metre of material to be blasted (0,31 kg per b.c.m.).

The shale was well-fragmented, but the effect on the old workings was variable: some areas collapsed, while others remained intact. During the dragline operations, there were further collapses and, although the dragline stability was never jeopardized, cleaning the top of the coal behind the dragline was extremely hazardous. It was therefore decided that all the machinery should be removed from the area, but this presented the following problems.

(a) In addition to the contamination falling into the old workings, there was contamination from poor top-

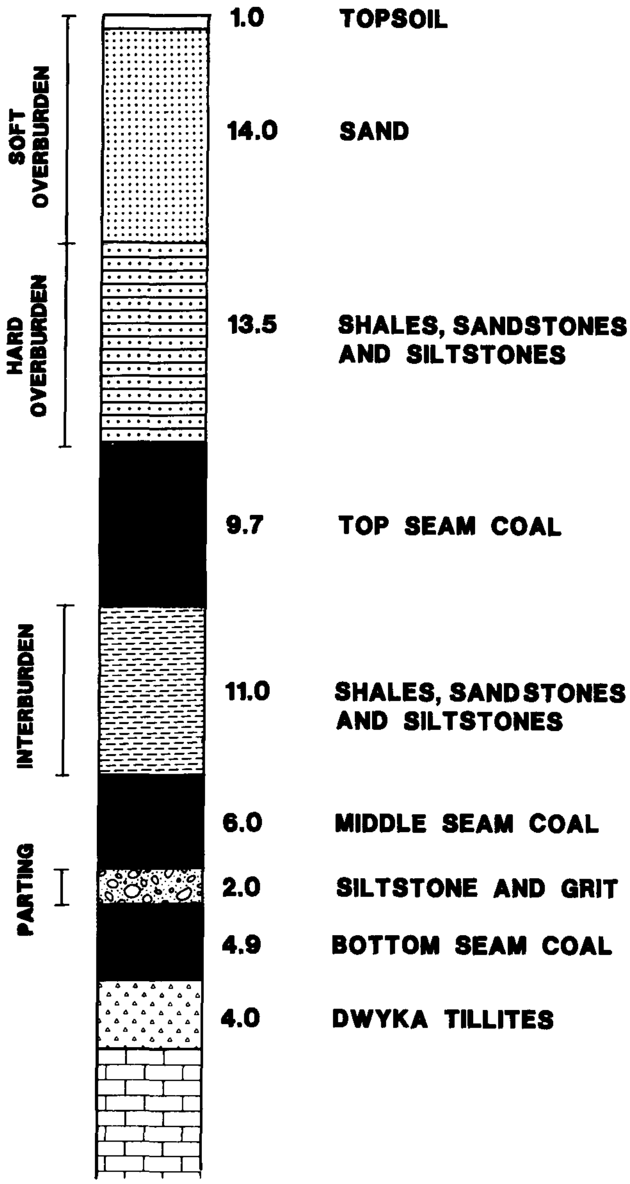

Fig. 3—A typical stratigraphic column through New Vaal Colliery

of-coal cleaning.

(b) The coal drills were unable to gain access to the top-of-coal to drill, leading to (c).

(c) The digging was difficult for the rope shovels, which were unable to free-dig the solid pillars.

The Later Decision

Following the problems encountered during the first attempt, it was decided to abandon the idea of minimizing contamination by keeping the pillars intact, and to examine the possibility of deliberately collapsing everything.

It was decided to apply a method that had been used successfully at the Landau Colliery in July 1985 after a fire in the old workings in an area where an old mini-pit had stopped operations.

When initial attempts at controlling the fire by the building of walls underground had proved unsuccessful, it had been decided to isolate the fire by collapsing the adjacent workings, thus effectively placing a sealed barrier round the affected area. This had produced the desired effect, and the fire had been extinguished.

It had then been decided to mine the coal from within the collapsed area in order to extract the coal within the blasted perimeter. In an attempt to drill, where possible, into the pillars in order to collapse the workings, a large charge had been placed in the pillar. When detonated, this had thrown the pillar coal into the empty bords before the roof fell, thus giving a uniform layer of broken coal beneath the overburden. This had proved very successful for, on the removal of the overburden, it had been found that there was surprisingly little contamination of the old workings by waste.

Simul Drilling and Blasting

Having decided to completely destroy the pillars, all that remained was to establish the correct technique of simul drilling and blasting (blasting of two layers of material at the same time).

The first method tried (Fig. 5) involved drilling the overburden and coal together, and blasting off the solid. This resulted in a highwall angle of 65°, which prevented the drill from reaching the front row of pillars and required the drilling of angle holes, which is both time-consuming and unreliable.

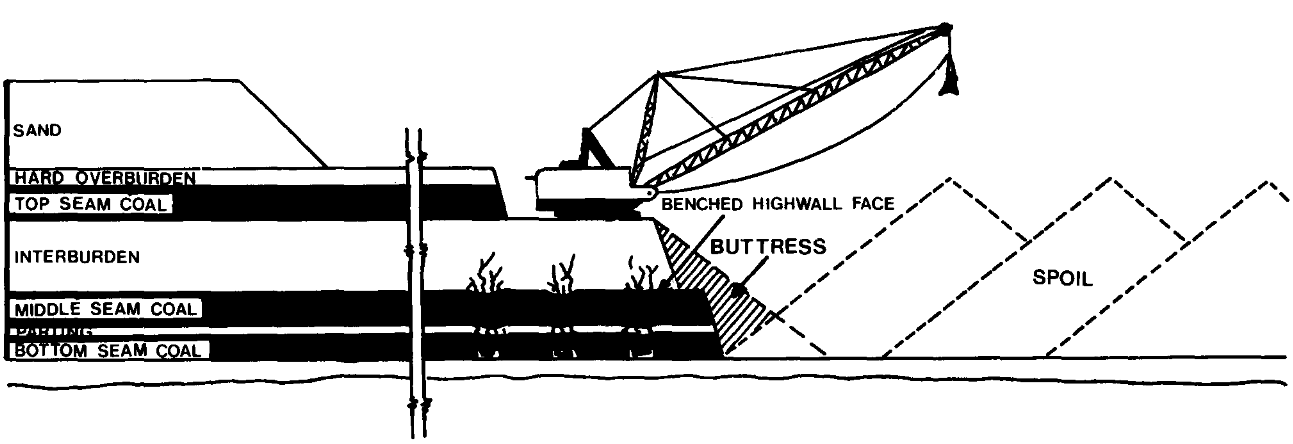

Fig. 4—Proposed use of a buttress to support the highwall in the previously mined areas

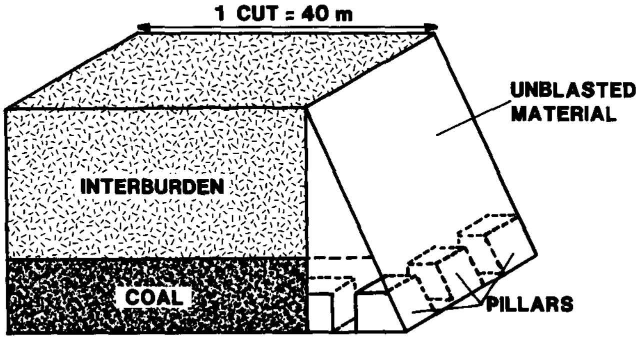

Fig. 5—The first simul blasting method that was attempted

This resulted in unblasted pillars at the toe of the highwall, where the shovel had difficulty digging. An attempt to re-drill the unbroken pillar proved to be too dangerous.

The second method tried (Fig. 6) was to buffer-blast the unbroken pillar, leaving a 20 m buffer of broken coal and overburden on the new highwall. However, there was a major drawback: it resulted in spontaneous combustion of the coal, which spread into the old workings.

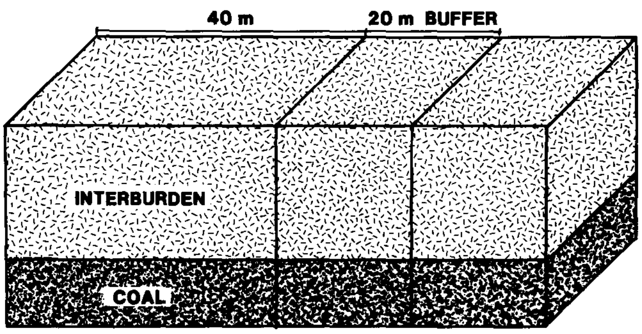

Fig. 6—The second method of simul blasting

The third method used (Fig. 7) was to pre-split the high wall to obtain a vertical face that could be drilled easily. This is the basis of the method in use at present, which has been extremely successful.

In this method, a line of pre-split 252 mm holes is drilled from the top of the overburden to the base of the coal. The holes, spaced 3 m apart, are charged with about 25 kg of Energex or Anfo. This line of holes, 40 m or one-cut width from the old highwall, is either lightly stemmed at the top of the hole or has no stemming at all. The holes are fired simultaneously, and the gases expanding into the empty holes cause a split between the closely spaced drill holes, creating a new vertical highwall.

The additional benefits of pre-splitting are that it dewaters the cut, allowing Anfo to be used in the main blast, and it gives a cleaner, safer highwall. The main drawback is its cost.

Procedure for Pillar Blasting

The system of pillar blasting used at New Vaal is based on pre-determined pillar positions. The drilling pattern is marked out on the surface (depending on the pillar centres) in a square pattern by the Survey Department, the holes in the pillars being marked with a circle, and the bord holes with a cross (Fig. 8).

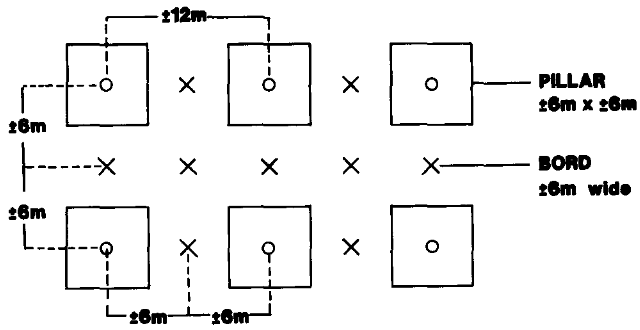

Fig. 8—Marking of the holes

The pillar holes are drilled until the driller sees white stone chippings from the parting below the seam. The bord holes are then drilled through the overburden and 0,5 m into the roof coal (Fig. 9).

Once drilled, the holes are cleaned 0,3 m radially from the collar to prevent the entry of extraneous material. The hole depth is logged and then marked by the driller.

Blasting Procedure

The mass of explosive charge per deck is indicated in Table II. Anfo is used in the dry holes and Powergel in the wet holes. Typical deck charges are shown in Fig. 10.

The top deck is located a minimum of 4 m and a maximum of 4,9 m below the collar. When middle decks are used, the base of this deck is located 0,5 m below the overburden–coal interface.

In the pillar holes, the charge is at the bottom of the hole.

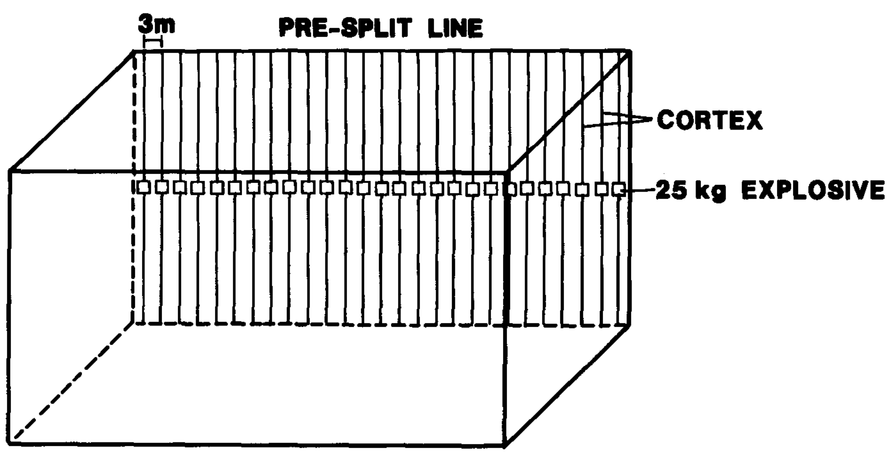

Fig. 7—The third method of simul blasting, which is the method used at present

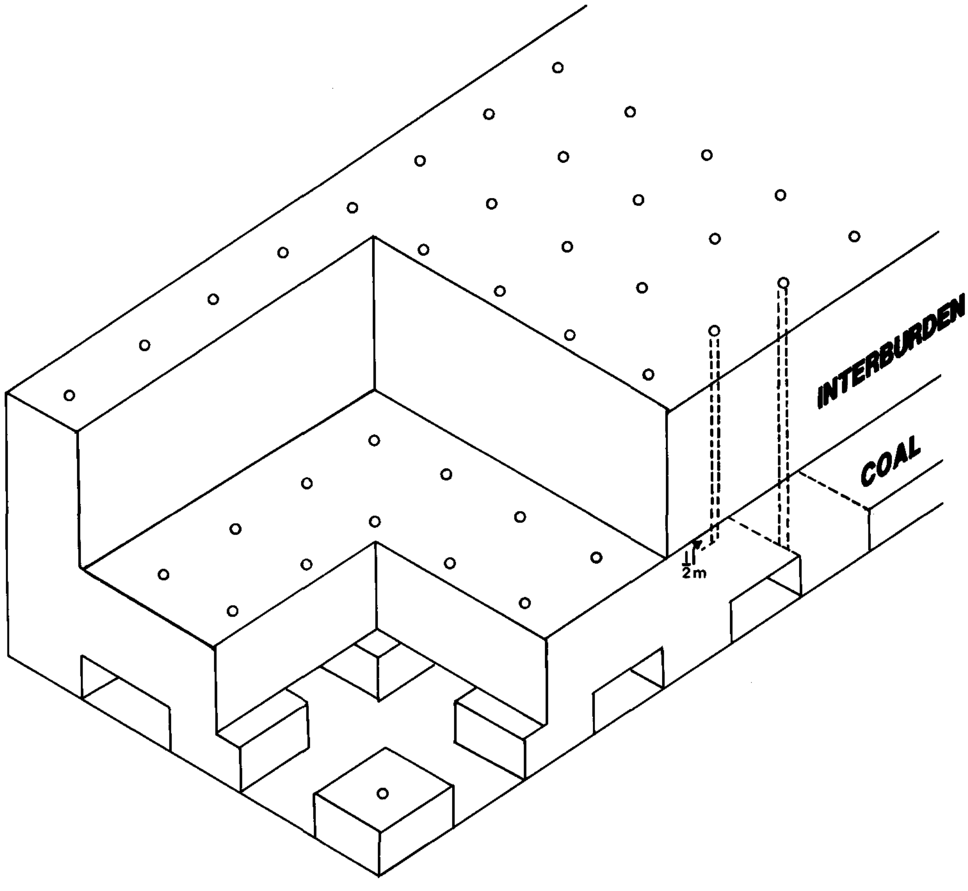

Fig. 9—Depths of bord-and-pillar drill-holes

TABLE II
MASS OF EXPLOSIVE* IN THE BLASTING OF OLD WORKINGS
(6 × 6 m pattern, IB/MSC combination)

IB† thickness m	Top stemming m	Explosive on top deck kg	Middle stemming m to top of	Explosive on middle deck‡ kg	Explosive on bottom deck‡ kg
6,0	4,2	85‡	6,5		140
6,5	4,6	90‡	7,0		140
7,0	4,9	95‡	7,5		140
7,5	4,0	45	8,0	55	140
8,0	4,0	45	8,5	60	140
8,5	4,0	50	9,0	60	140
9,0	4,0	55	9,5	60	140
9,5	4,0	60	10,0	60	140
10,0	4,0	60	10,5	65	140
10,5	4,0	60	11,0	70	140
11,0	4,0	60	11,5	75	140
11,5	4,0	60	12,0	85	140
12,0	4,0	60	12,5	90	140
12,5	4,0	60	13,0	95	140
13,0	4,0	60	13,5	100	140
13,5	4,0	60	14,0	105	140
14,0	4,0	60	14,5	110	140
14,5	4,0	60	15,0	115	140
15,0	4,0	60	15,5	120	140

* Pillar charge calculated to destroy pillar
† Blasting ratio in IB taken at 0,3 ± 0,1
‡ Includes charge in roof coal

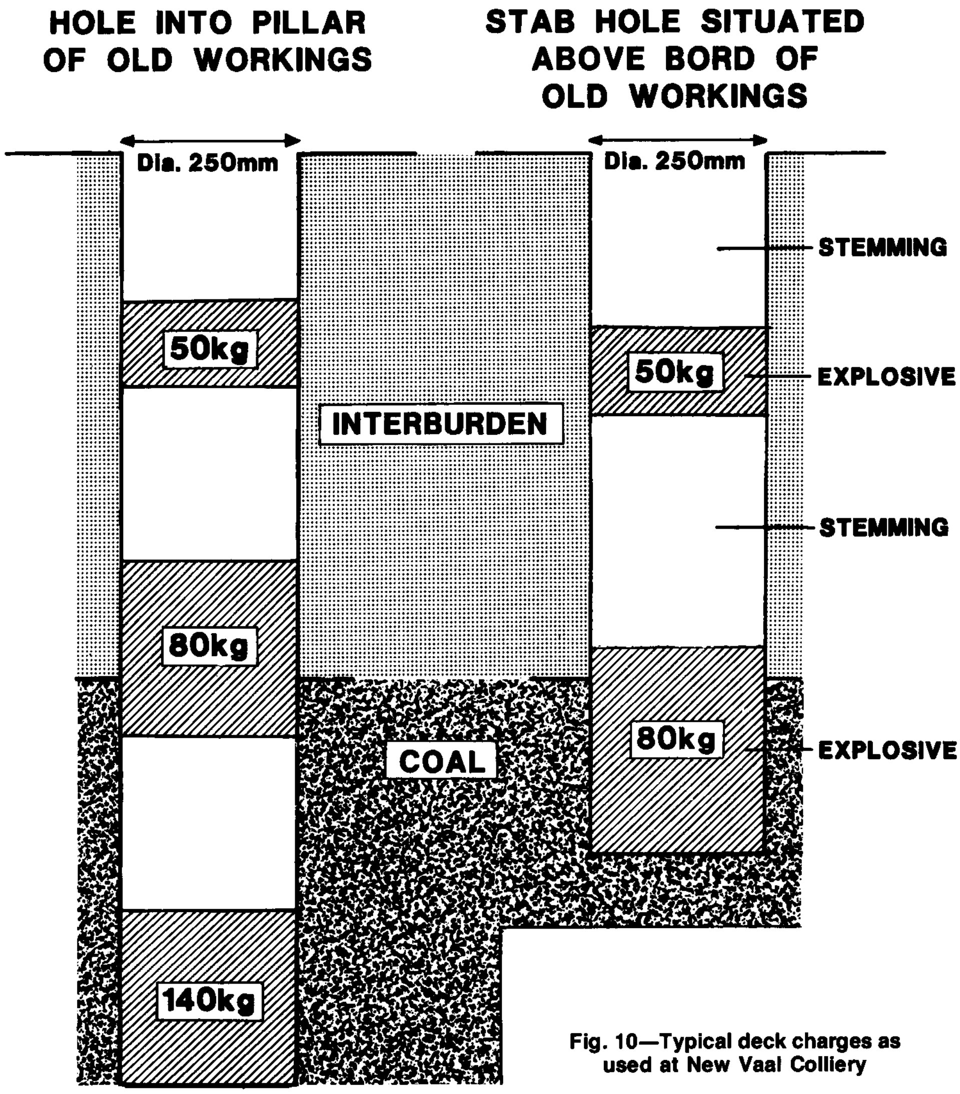

Fig. 10—Typical deck charges as used at New Vaal Colliery

Sand is used as stemming and spacing between decks. All three decks are blasted simultaneously using Cordtex 10 to initiate the charge.

The row and hole delays are shown in Fig. 11.

Coal Preparation

The coal-preparation plant at New Vaal Colliery is shown schematically in Fig. 12.

Run-of-mine coal is tipped into two bins, which feed the primary crushing complex. Each of these bins supplies one leg of the primary crushing complex and, subsequently, one of two coal streams to the preparation plant. The streams are designated 'contaminated' and 'uncontaminated', and can either be treated in the dense-medium plant or be by-passed to product crushing and into the Lethabo stockyard.

Coal is drawn from each bin by a plate feeder, which feeds the coal over a 300 mm inclined grizzley and onto an observation feeder. As the coal passes across this feeder, the large rocks are broken by a hydraulic breaker, and the tramp material is removed before the oversize passes into the jaw crusher and is crushed to minus 300 mm.

The coal from the primary crushing plant then passes under large overhead electromagnets, which remove the last tramp metal before the coal is fed to the plant or stacked out on the primary stockpiles.

Coal is delivered into the plant at a designed rate of 4000 t/h. The feed is screened in the primary and secondary plants into minus 20 mm, 20 × 75 mm, and 750 × 300 mm fractions. The minus 20 mm fraction is directed to the delivery belt to the power-station stockyard. The 20 × 75 mm and 75 × 300 mm fractions are directed either to the dense-medium separating (DMS) plant for de-stoning, or to the power-station stockyard if the coal is from seams where mining has not taken place previously.

Feed diverted into the DMS plant is wet-screened to remove fine material adhering to the plus 20 mm lumps. The fines are de-watered on vibrating screens or horizontal vacuum-belt filters, and join the feed to the power-station stockyard. The water recovered is re-used in the plant.

The screened stone–shale and coal feed directed to the DMS plant goes into a Drewboy washing vessel containing a mixture of magnetite and water at a relative density of approximately 2,0. The heavier stone–shale sinks while the coal floats. The stone–shale is extracted by a rotating wheel fitted with baskets, and is then returned to the opencast mine spoils. The coal is skimmed off the sur-

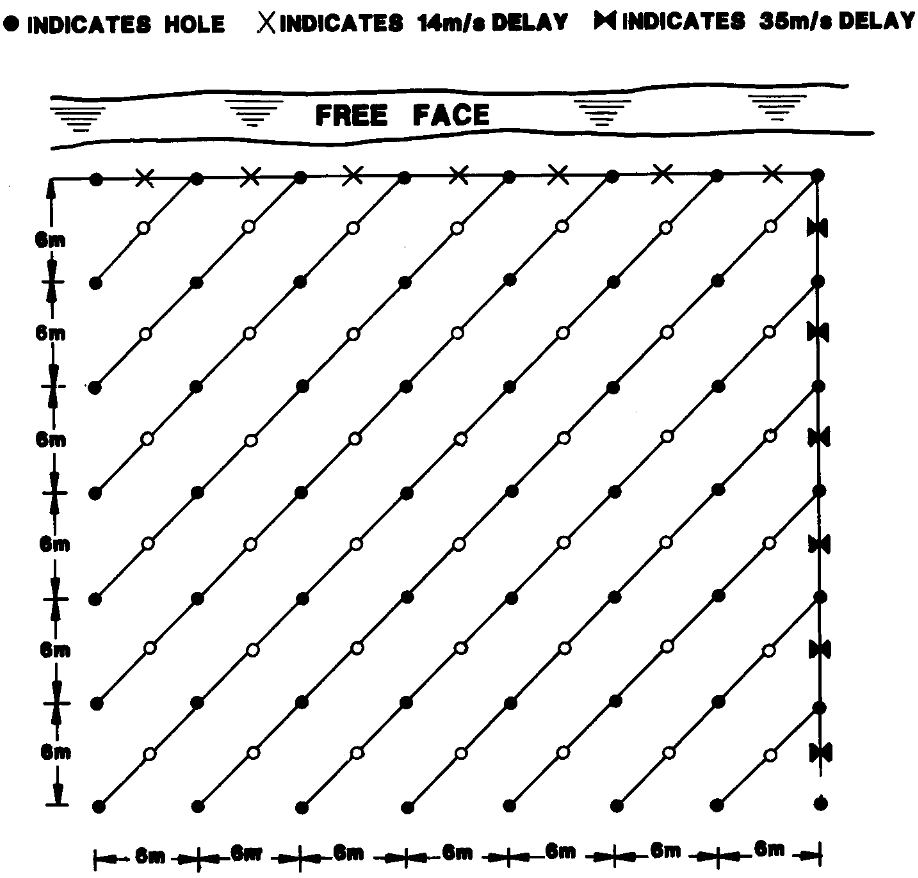

Fig. 11—The tie-in pattern of holes and delays over the old workings

face by a rotating paddle wheel, and joins the plus 20 mm material from the screening plants, which is to be reduced to minus 20 mm by the product crushers. The combined minus 20 mm products are then conveyed to the power-station stockyard by overland conveyor.

De-watering the Old Workings

Since 1974 the Rand Water Board has been pumping residue into the old mine workings. This residue contains 40 g of solids per litre in the size range 3 to 20 μm. The chemical composition of the residue varies, but is generally 46 per cent silica and 22 per cent lime plus some organic material.

Since pumping began, the Rand Water Board has deposited 103 277 Ml of slurry and extracted 540 Ml of clear water for re-use. This leaves the mine with the problem of removing the water remaining in the old workings and dealing with the de-watered residue.

De-watering

The mine has identified the areas of the old workings that are completely flooded. Although all the old workings are interconnected, the undulations in the coal seams have caused the water to be contained in a number of low-lying compartments that are separated by ridges of high ground.

It is planned to de-water these areas ahead of mining operations by installing strategically placed pump stations in the low points of each compartment (Fig. 13).

De-sludging

Having de-watered the old workings, the mine will be left with a residue of sludge, which has a moisture content of between 30 and 80 per cent. The mine is currently drilling into the sludge areas to determine the thickness and extent of this residue and, to date, has encountered nothing thicker than 1 m.

It is planned to remove the sludge during mining by slurrying and pumping the wet material, and loading out the drier sludge with truck and shovel.

Obviously, some of this material will find its way to the plant, and the mine has carried out tests to determine the effect it will have on the dense-medium flotation and fines de-watering. There are indications that the sludge is beneficial in small concentrations—up to 20 per cent—but, beyond this figure, it gives rise to problems with density control and flocculent dosing in the belt filters and thickener.

Spontaneous Combustion

The old mine workings have been flooded since underground operations ceased in 1969, and it was felt that spontaneous combustion might occur as the mine was de-watered. However, several miners who worked the old areas have indicated that spontaneous combustion was never a problem. The only incident had been a minor heating in the bottom-seam workings, which are limited in extent.

New Vaal has experienced a number of heatings, main-

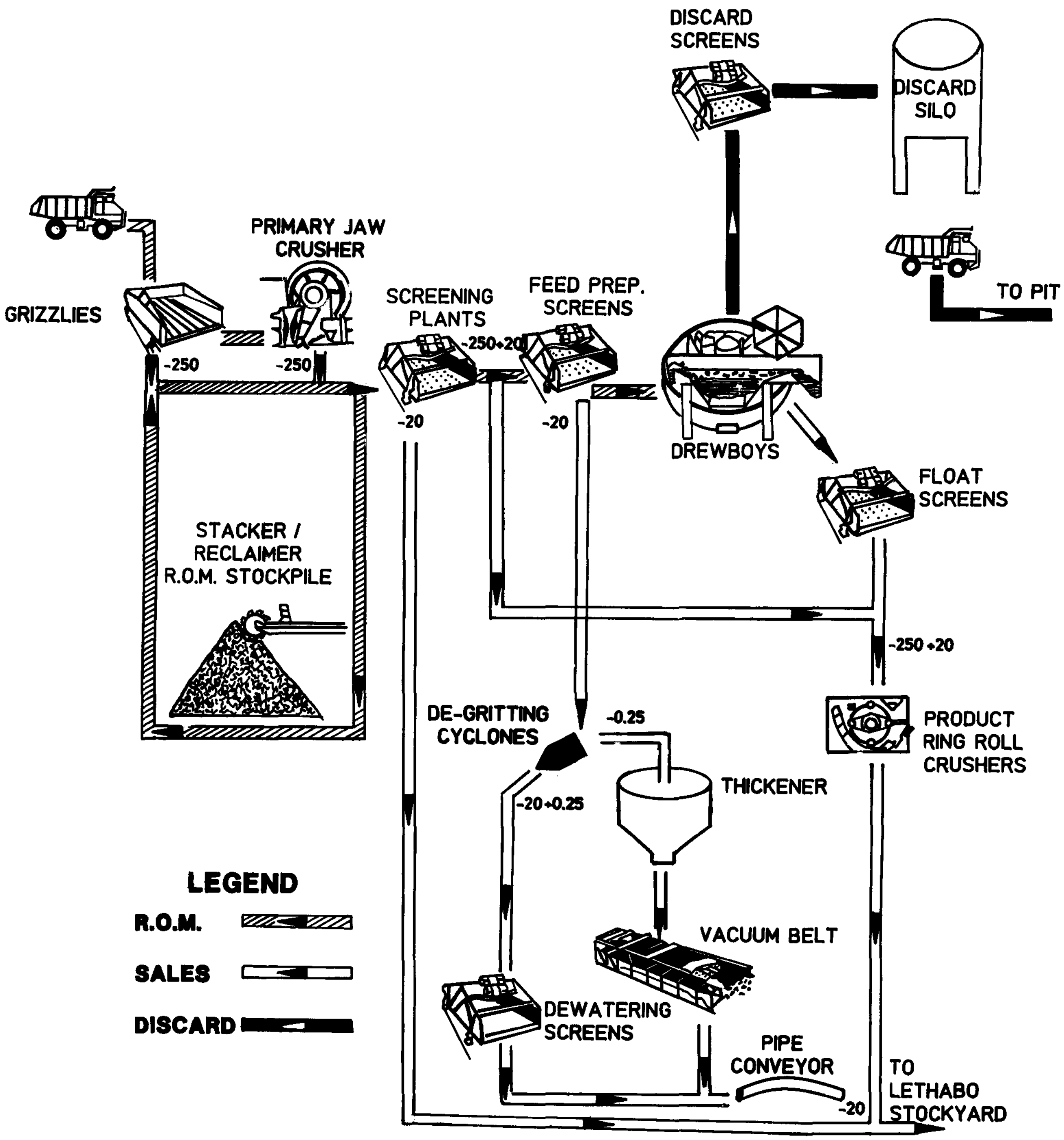

Fig. 12—A simplified flowsheet of the coal-preparation plant at New Vaal Colliery

ly in the spoils, which were caused by spontaneous combustion of the low-quality upper-top seam, which had been discarded. The heatings that occurred in the exposed workings were believed to have been caused by blasting operations.

The atmosphere in the old workings is being monitored continuously by gas analysers. To date, there has been no indication of any heating in the worked-out areas ahead of the opencast operations.

Contamination

During the planning of New Vaal Colliery, considerable contamination of the old workings was envisaged. It was expected that shale from the roof would enter the old bords and that considerable quantities of tramp material would be found in the old workings.

The extent of the contamination from roof shales was expected to amount to 10 per cent and, before serious attempts were made to collapse the pillars, this was close to the truth. However, since the introduction of proper pillar collapsing, the roof contamination has fallen to 6 per cent, with obvious benefits to the preparation plant.

As for the tramp material, the plant was designed to cope with this. Non-magnetics and large steel would be removed from the observation feeder, and the remain-

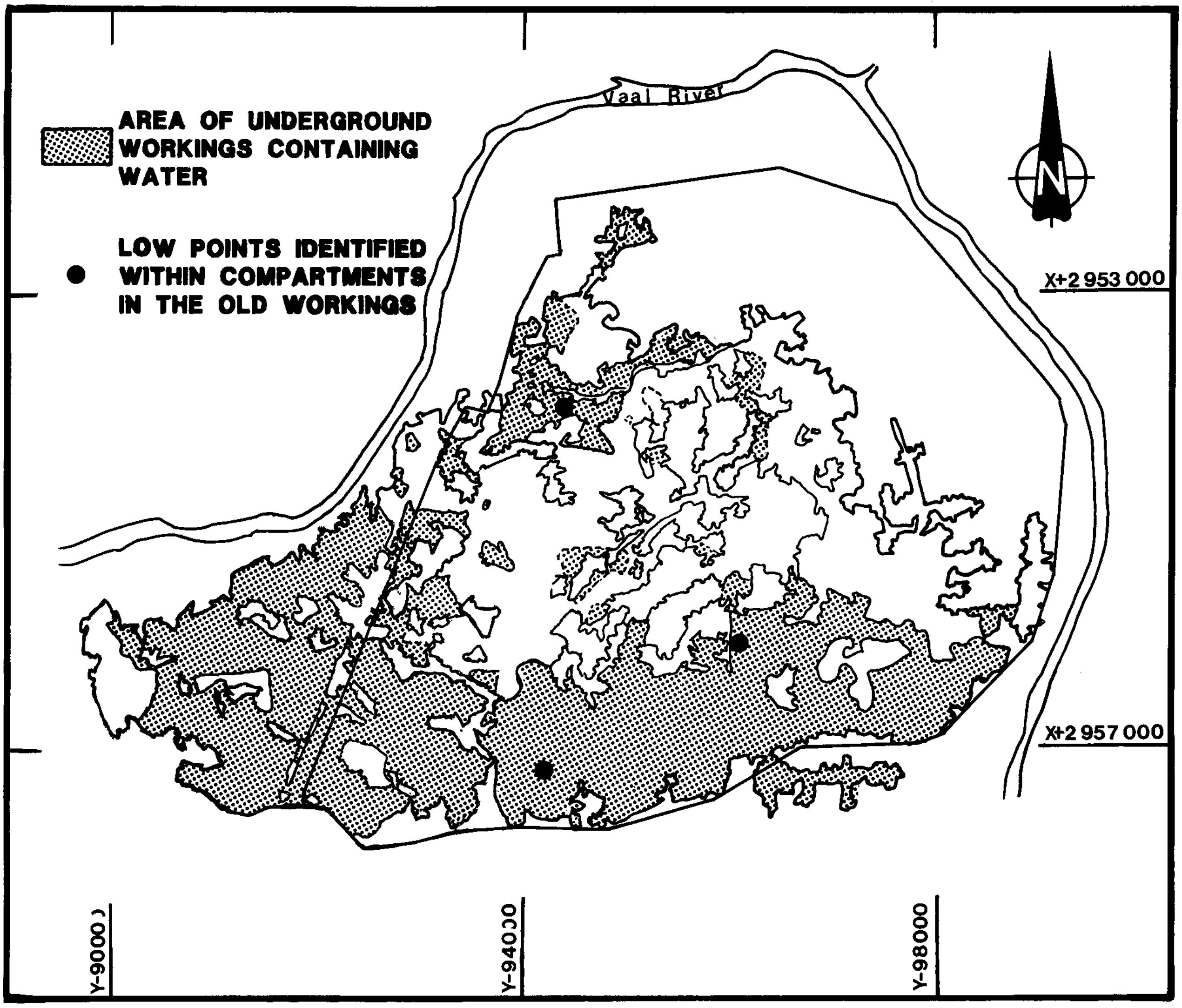

Fig. 13—Plan showing the compartments of water within the underground workings

ing steel would be removed by the magnets.

In general, the system worked adequately, but problems were experienced with old haulage rope, which became entangled with the plant machinery; timber props, which blocked the Drewboys; and small steel items, which missed the magnets.

As a result of this, the magnets were replaced by units with twice the power, and an attempt was made to enter the old workings to remove large items such as rails and ropes; this proved to be extremely dangerous and was stopped. To prevent the loading of large tramp material, the areas where such material was likely to have been left were identified—main haulages, etc.—and the operators are briefed before coal is loaded from these areas.

Economic Considerations

Although only 7 per cent of the reserves in the Maccauvlei area had been mined by bord and pillar, the coalfield was considered to have been mined out. The underground miners had removed only the better-quality coal by following the bright-coal horizons, but the drop in quality over the New Vaal lease area was a mere 0,12 MJ/kg. (The virgin field would have yielded 16,9 MJ/kg as against a projected value of 16,78 MJ/kg.)

Based on this, Amcoal decided to offer this field to Eskom for the 3600 MW Lethabo Power Station. The boilers of Lethabo were designed to burn coal with an ash content of 38 per cent, a volatile-matter content of 19,5 per cent, and a calorific value of 16 MJ/kg. Thus, a 'sub-economic' coalfield is now supplying a major power station with fuel for 40 years.

The economic success of this project will no doubt lead to a more critical evaluation of shallow coalfields that have been abandoned as 'mined out', and in some cases left to burn. If this coal is re-mined by opencast methods and the land is rehabilitated, not only will lost coal reserves have been gained, but waste land will be made available for agriculture and other development.

Conclusion

During the initial planning of the New Vaal Colliery, an attempt was made to predict mining conditions and thus devise a method of extracting, with minimum contamination, coal seams that had been mined previously. During the five years of operating experience, the initial ideas have been developed into a routine that produces coal more easily and with less contamination than had been expected.

However, this is only the beginning. New Vaal has to face areas that were previously mined not only in one seam but in two or three seams superimposed one on another.

It is not yet known how the sludge flowed in the old workings, where it accumulated, and how thick it is. These, and many other unknowns associated with the old Maccauvlei Mine, will have to be addressed in the years to come, and this paper will be one of many that are yet to be written on mining in this area.

Geostatistics

This year the Centre de Géostatistique at Fontainebleau (France) is offering its post-graduate course in mining geostatistics in English.

This is a 9-month course designed to train engineers, geologists, and others from the mining industry to be experts in one of two fields: geostatistics or project planning. The option specializing in geostatistics has now been running for over ten years; the project-planning option is new and will be starting in 1991. The responsibility for the programme is shared by the Centres for Geostatistics and for Mining Engineering of the Ecole des Mines de Paris. The programme is partly funded by the French government through the CESMAT.

Organization of the Programme

The programme runs from 1st October to 30th June, and is divided into two parts; coursework and preparation of a project, which are spread over three academic terms. During the first term, from October to December, the programme includes linear geostatistics, mining engineering and computing, and case studies. After this, the two options are separate. In the second term, the courses in the geostatistics option cover advanced geostatistical methods (non-linear geostatistics, simulations, reserve parametrization, and non-stationary geostatistics), whereas the project-planning group continue with coursework on mining planning and project feasibility. In addition to the coursework, participants are required to work on a project individually or in pairs. A report on this must be submitted, and an oral presentation made in public. At the completion of the programme, successful students will be awarded a diploma.

Most of the courses will be held at the research centres in Fontainebleau (50 km south-east of Paris). The lectures are given in French in odd-numbered years, and in English in even-numbered years starting from 1990. Participants are expected to be fluent in the appropriate language at the outset of the year. The number of students in each option is strictly limited.

Conditions of Admission

As this course is designed for engineers, geologists, and others from the mining industry who wish to become experts in geostatistics or project planning, preference will be given to candidates with industrial experience; however, recent graduates may also apply. All candidates should have a strong mathematical background.

Tuition Fees and Scholarships

The tuition fees for the CFSEG course are 50 000FF per year. As the programme is partly funded by the French government via the CESMAT, selected participants from developing countries may be exempted from paying the tution fees. All students must demonstrate that they have a monthly allowance of at least 4000FF in the form of a scholarship, or an allowance from their company, or from personal resources.

For information and applications contact:

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Materials World '91

Materials World '91 is an international exhibition of advanced materials, processing equipment, and components.

The co-sponsors for this major event, which is to be held in the Brussels Exhibition Centre, Belgium, are The Federation of European Materials Societies, the Plastics & Rubber Institute from the UK, and ASM International and TMS from the USA.

The event, being held from 16th to 18th April, 1991, will be a European window for companies worldwide to display state-of-the-art technology.

For further information, contact

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Reduction in gold-recovery costs*

Engineers at Mintek have developed a carbon-concentration measuring device based on ultrasound that will make possible significant improvements and cost savings in gold-recovery plants.

The carbon-concentration meter makes it possible for the first time to achieve precise on-line measurement of critical carbon concentration levels during the carbon-in-pulp gold-recovery process. This process involves the addition of carbon granules to the gold slurry after the initial cyanide-leaching stage.

Optimum Recovery

After the gold has been leached by cyanide, the gold-cyanide complex within the slurry is deposited on the carbon granules in the CIP section of the plant. The concentration of carbon is a critical factor in achieving optimum gold recovery, but up to now there has been no way of continuously and accurately assessing this through the six to eight absorption stages involved as the carbon-in-pulp is pumped from one tank to another in counterflow to the pulp or slurry.

Director of the Measurement and Control Division at Mintek, Mr Günter Sommer, says that the meter is an international first developed by Mintek with original sponsorship from the Chamber of Mines Research Organization. 'The carbon-concentration meter is the product of four years of in-depth research and development, and gives a measurement accuracy of approximately 2 ml per litre in a process where the acceptable concentration by volume is typically up to 60 ml per litre', he said.

'A typical plant would use several of the meters, one for each vessel in the agitation stage. Prior to the development of this instrument, the carbon concentration was a major problem because the necessary measurement technology simply did not exist. Gold plants can now operate at higher levels of efficiency, and that, of course, means more cost effectiveness.'

Debex Agreement

Having completed the research programme to commercialization stage, Mintek has now entered into an agreement with the Debex group covering the manufacturing and marketing rights worldwide.

'We are comfortable with the Debex organization, having enjoyed a long association on other new measurement devices such as the particle-size monitor', says Mr Sommer. 'Because of our prior collaboration on ultrasonic technology, it is natural that Mintek should select Debex for the next phase of the carbon-concentration meter programme'.

During that phase, Debex will take the extensively tested research prototypes a stage further to commercial prototypes, which will be evaluated exhaustively by Mintek prior to full production.

Demand

Debex managing director, Dennis Haywood, says that considerable interest has already been shown in the meter, with a request for eight instruments from one gold-extraction plant alone.

'We expect to have the meter on the market at about R30 000 per unit by the end of this year', he said. 'We are anticipating significant demand for the equipment because of the impact it can have on the bottom line of gold-recovery plants'.

* Released by De Beers Industrial Diamond Division, P.O. Box 916, Johannesburg 2000.

Debex M.D., Dennis Haywood (right) and the Director of the Measurement and Control Division of Mintek, Günter Sommer, recently signed the manufacturing and marketing agreement for the new carbon concentration meter