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Computer Support in Scheduling the Iscor Grootegeluk Coal Mine – A Case Study

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Modelling and scheduling for Grootegeluk coal mine, situated in the north-western Transvaal, is by means of a series of modular systems. Modelling of the multilayered body, which is part of the Waterberg coalfield, was based on a detailed study of the behaviour of coal and waste qualities and the subsequent use of standard geostatistical techniques. A notable improvement on previous methods was attained. Scheduling procedures and systems were developed to model a multibench pit producing coal for several metallurgical plants as well as a power-station. Scheduling was done by producing a series of longitudinal cuts, the cuts being subdivided into increments. By allocating cuts to certain periods, the resulting calculated product tonnages were compared with production targets, and by iteration a final scheduling sequence was determined.

Introduction

The Grootegeluk coal mine is situated in the Waterberg coalfield in the north-western Transvaal (see Figure 1). The mine is owned and operated by The South African Iron and Steel Industrial Corporation, Limited (Iscor). Iscor is the largest producer of steel in South Africa. The Grootegeluk coal mine is an opencast mine currently mining a succession of thin coal and shale layers to produce blend coking coal for Iscor and coal suitable for use in a power-station as a secondary product (see Figure 2). The mining is presently confined to the top 50 m of a total 120 m succession of thin coal and shale layers.

The Electricity Supply Commission (Escom) operates a number of power-stations in South Africa as well as the national electricity supply network. Escom awarded Iscor the contract to supply coal for its new Matimba power-station. The fact that the contract had been given to Iscor, as well as changing technology in steel-making processes, necessitated the re-evaluation of the Grootegeluk mine plan and the development of a method which would facilitate the rapid updating of the plan.

At full production approximately 29×10^6 tons ROM will be mined per year at the Grootegeluk coal mine from which $1{,}976 \times 10^6$ tons of coking coal and approximately 12×10^6 tons of power-station coal will be produced. In addition, approximately $12{,}5 \times 10^6$ tons of overburden and internal waste will be mined. Tables 1 and 2 show some of the parameters that had to be taken into account in the scheduling of the pit development.

The purpose of this paper is to illustrate how a straightforward approach to the computational aspects of the problem can lead to good results at low cost. Computerization of the problem proved to be a valuable tool in attaining sound geological models and for creating detailed short- and long-term plans.

Geological modelling

The coal at the mine is part of the Upper and Middle Ecca groups. The Upper Ecca consists of approximately 60 m of thin (2 – 3 cm) bright coal layers interbedded with shale, sandstone and carbonate lenses, and is referred to as zones 11 – 5. The Middle Ecca coal consists of five separate seams and is referred to as zones 4, 4a, 3, 2 and 1 (see Figure 3).

In general the zones 11 – 6 are coal of blend coking quality and of a low P_2O_5 content. Zone 5 is also blend coking coal, but the P_2O_5 content renders it unsuitable for metallurgical use. Zones 4 – 1 are non-coking coal, occurring as thick coal seams with a calorific value relatively higher than that of zones 11 – 5 (see Figure 3). A potential use for the coal in direct reduction processes may also exist.

A few major faults occur in the Waterberg coalfield. The most important is the Daarby fault with a displacement of 350 m to the east. This fault forms a natural boundary for mine operations. All surface structures are therefore located on the eastern side of the fault. Numerous small faults occur within the mine area with displacement of less than 10 m. The mapping and prediction of these faults in the unmined areas is very difficult owing to the lack of surface exposure.

Iscor maintains an extensive geological data base. The data base is created and updated by means of micro-

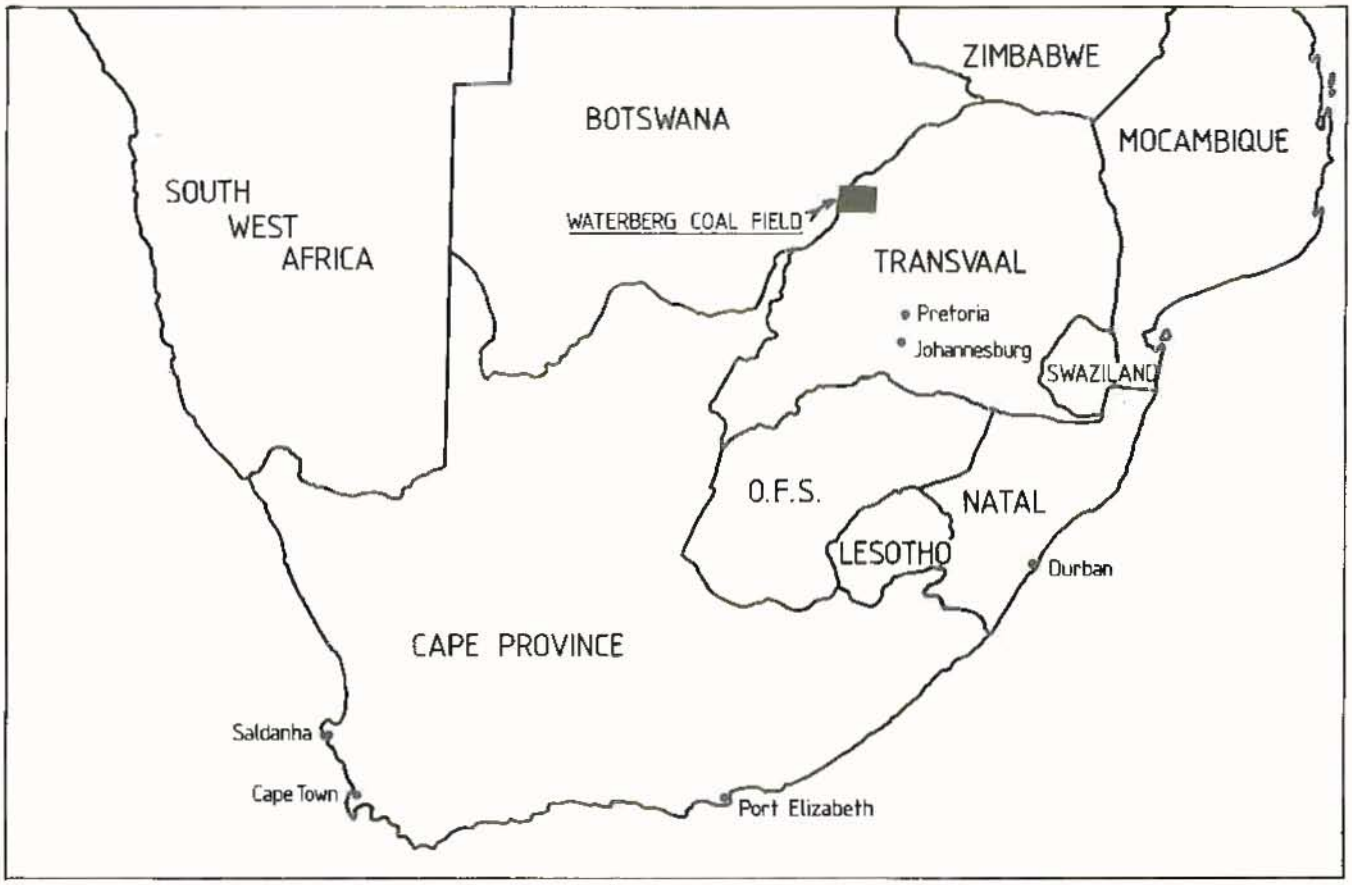

FIGURE 1. Location map of the Waterberg coalfield

computers which are used to input and validate the approximately 1500 geological descriptions and 300 proximate ash and petrographic analyses for each borehole. Data on completed boreholes are transferred to the data base resident in a mainframe computer. The data base for the mine area alone consists of 128 400 geological descriptions and 82 000 proximate analyses.

Geological modelling is a man-machine process. The CDC SEAMSYS system is used, the modelling process being in this case accomplished in two phases. The first phase is to define and model mine benches. This is followed by a second phase aimed at modelling the coal product values for each bench.

Modelling mine benches

To model mine benches mining horizons must be selected. The mining horizons are selected manually and, together with the current structural interpretation, entered into the mainframe computer. As a first step structural modelling is done with the CPS/1 system by means of fine gridding using the faults as boundaries. Numerous dummy boreholes are added to facilitate the construction of an accurate structural model. After a series of gridding, contouring, section plotting and re-updating runs the final acceptable grids of the mining horizons are stored.

Modelling coal product values

The mining horizons are applied to each borehole and the analysis for each horizon is extracted. A direct logarithmic curve fitting method was developed to replace the previously used lagrangian method. This new, more acceptable interpolation technique is used to interpolate the composite washability curves. The aim is to obtain a product with an ash value of 10,4% for benches 2, 3 and 4.

Files are created with products of each horizon for each borehole. A block seam structural model is then created by loading the structural grids into the predefined seam model.

The biggest single obstacle in the past proved to be the interpolation of product yield values (see Figures 4, 5 and 6). The predicted values did not correlate well with the actual results achieved. The problem, especially for bench 2, proved to be related to the drastic effect of the interbedded waste, where thicknesses vary dramatically over short distances.

The yield variability of the coal fraction alone is very low. The interpolation of single samples or the separation of coal and shale proved to be very cumbersome. The final results were obtained by using a product yield value with all material composited for each bench and each borehole as a point value.

Experimental semivariograms were constructed and, after filtering values of uncertain quality, acceptable semivariograms were found. Spherical models were fitted and a remarkable improvement in the quality of prediction was noted. Results were tested by using the point kriging method. After using these models the yield product values are kriged and interpolated into the seam block model.

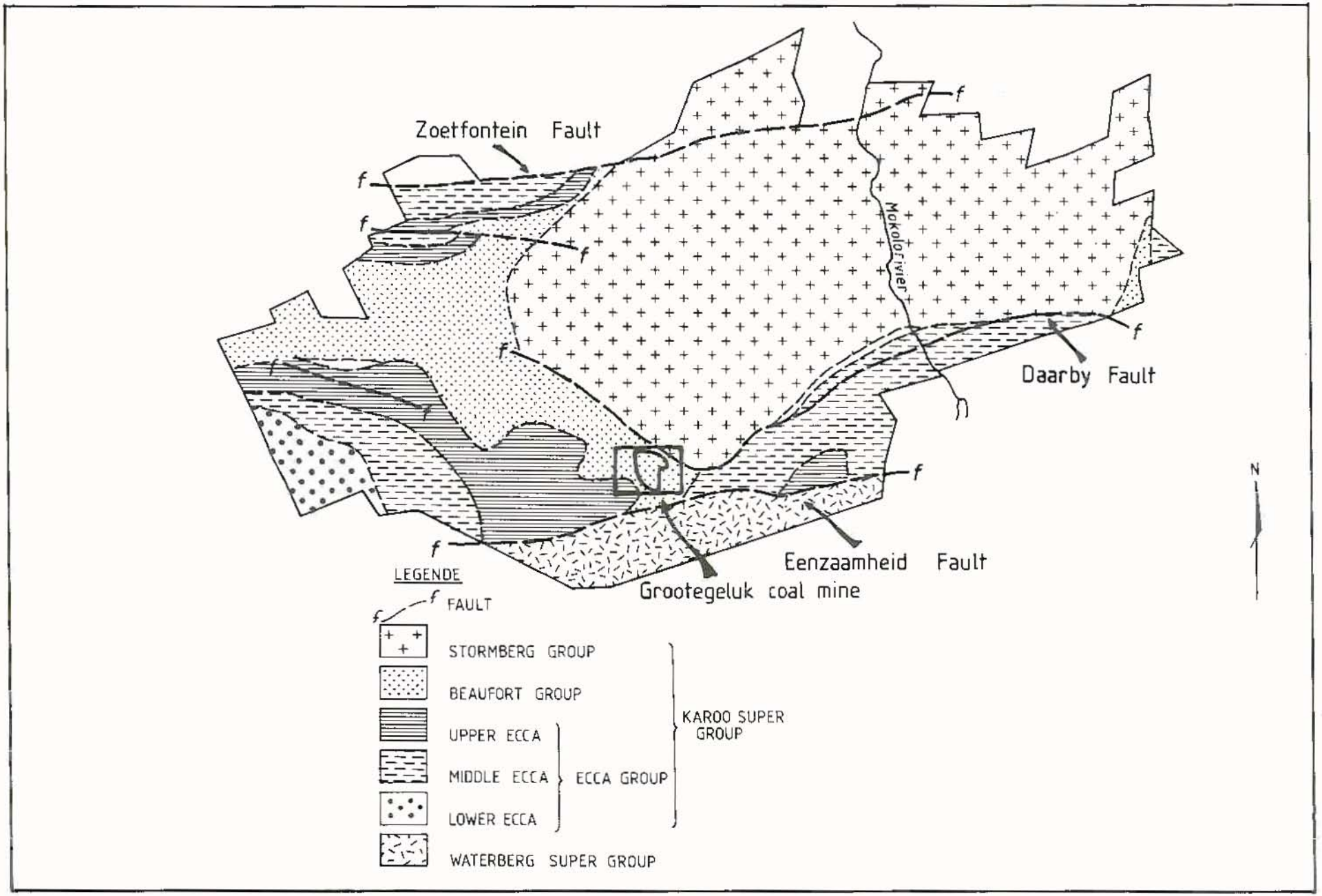

FIGURE 2. Geology of the Waterberg coalfield and location of the Grootegeluk coal mine

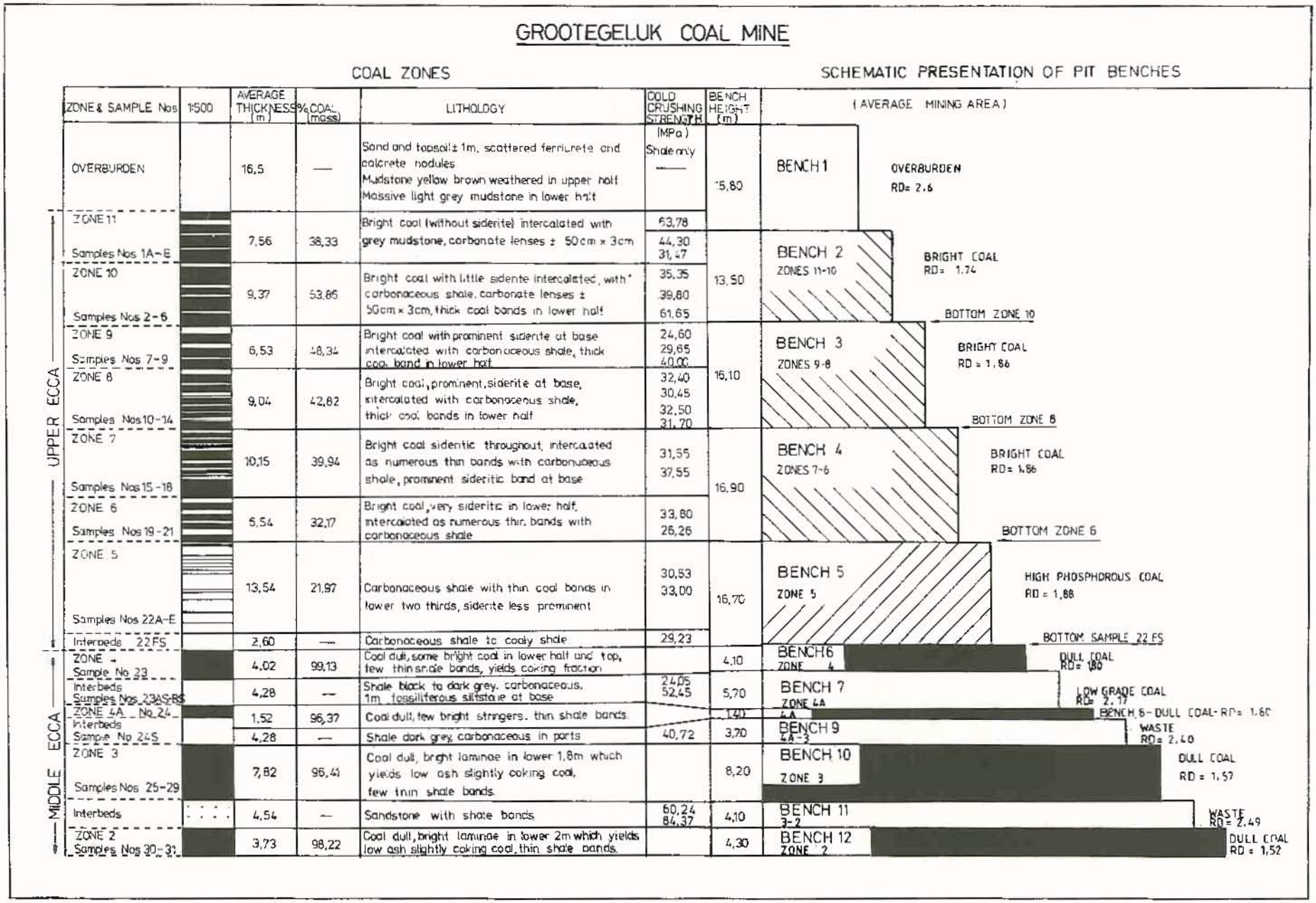

FIGURE 3. Lithology and mining benches in the Grootegeluk coal mine

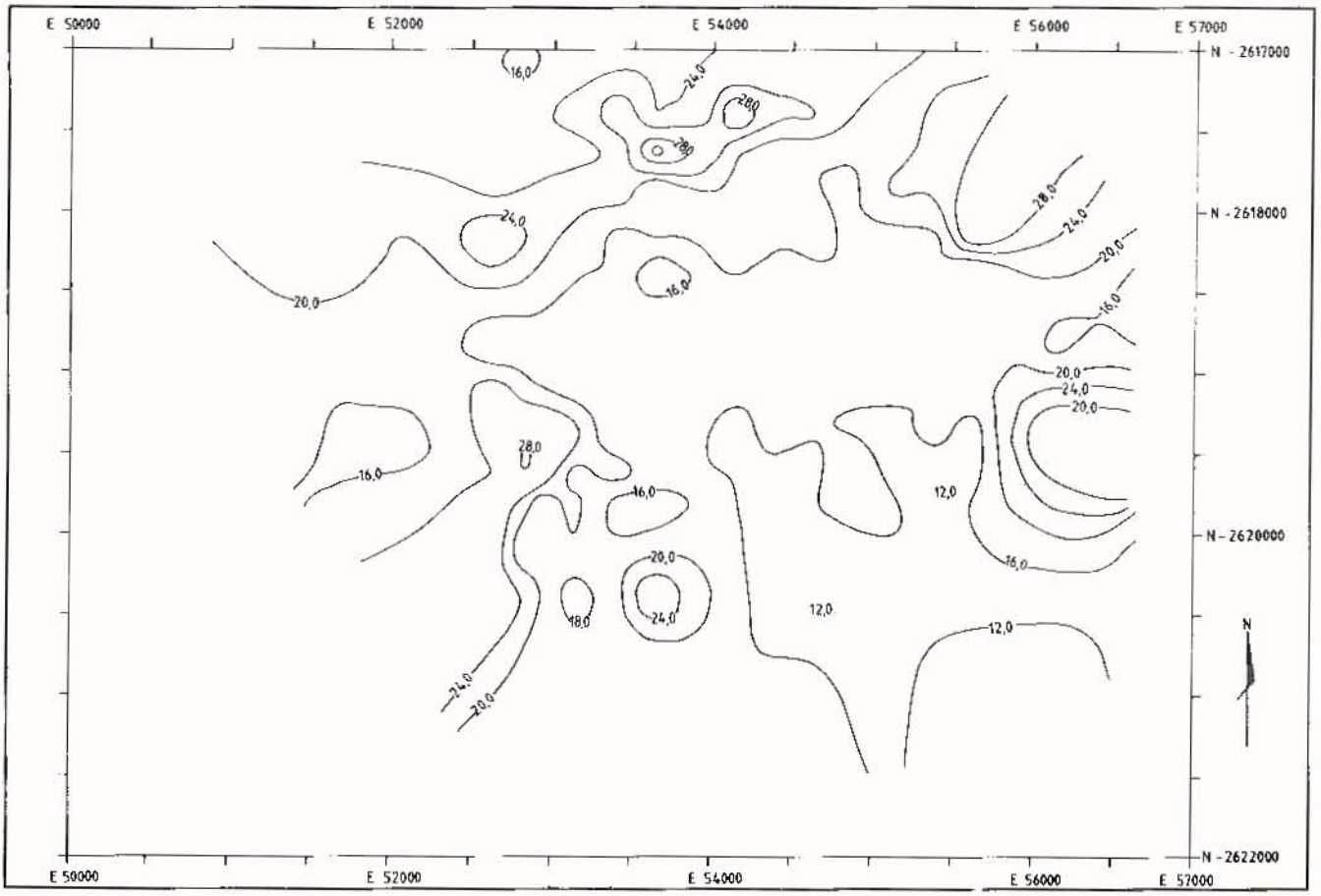

FIGURE 4. Coking coal yield isolines – bench 2

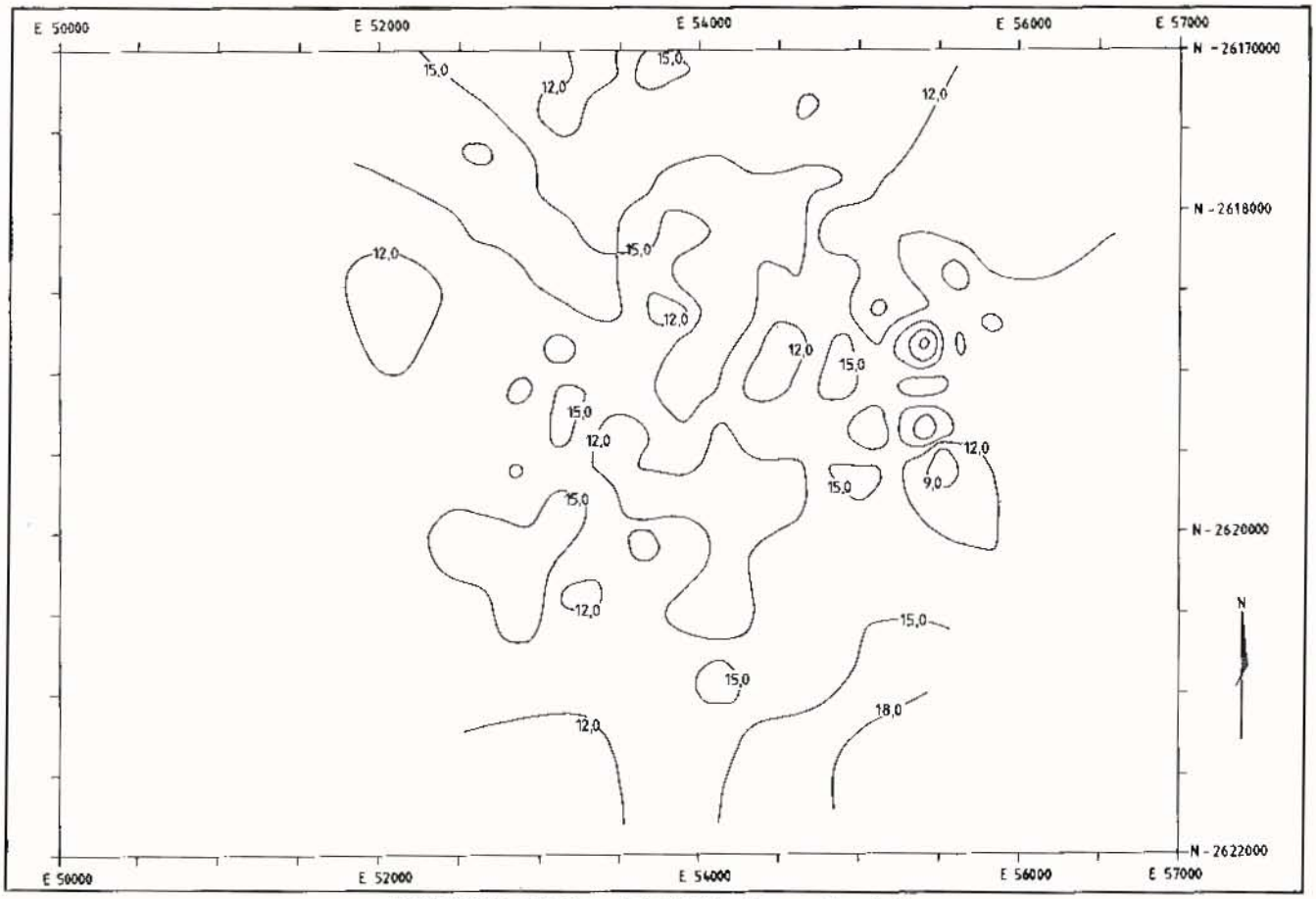

FIGURE 5. Coking coal yield isolines – bench 3

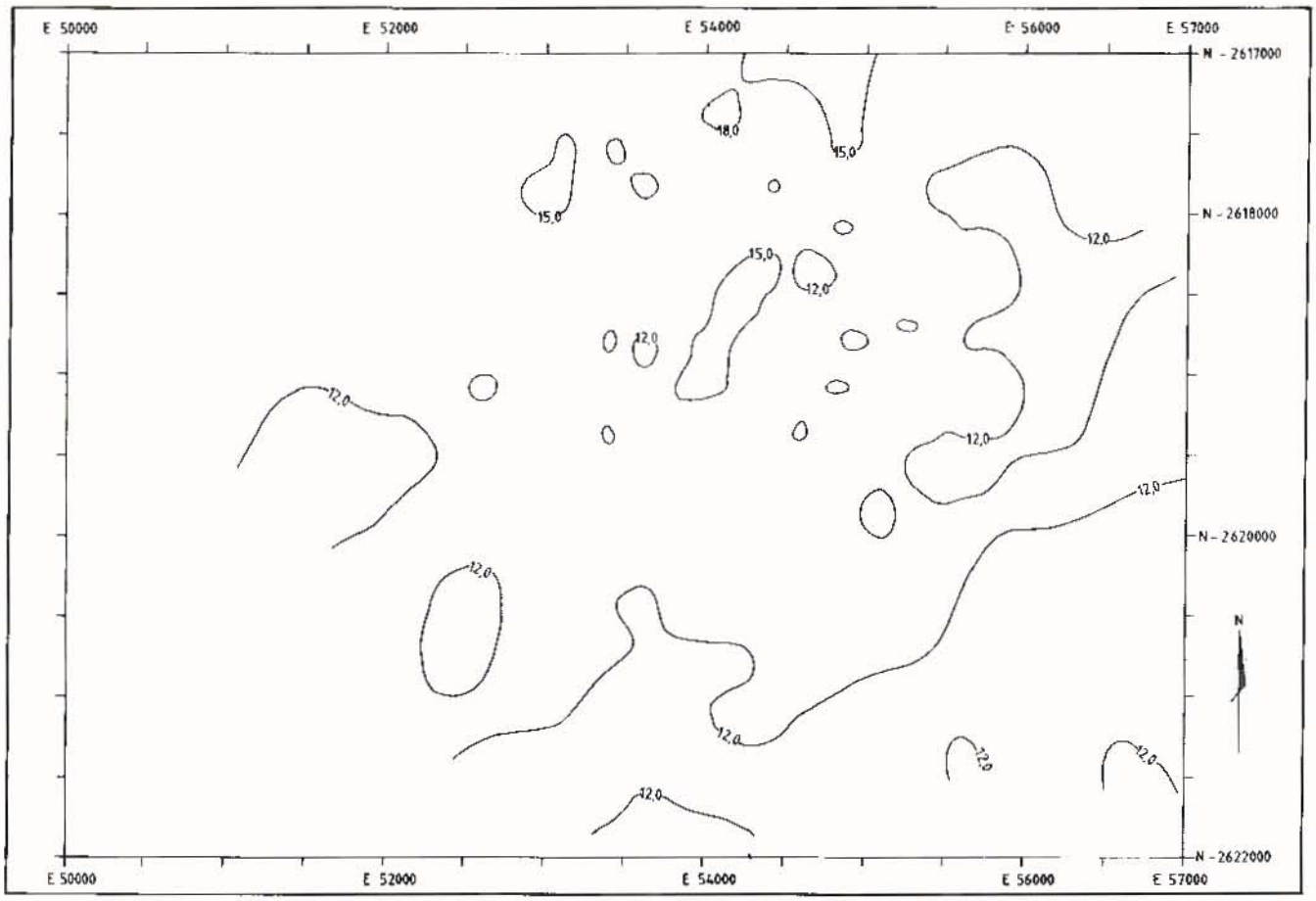

FIGURE 6. Coking coal yield isolines – bench 4

TABLE 1
Products and average yields and qualities for the Grootegeluk coal mine

Bench	Coking coal: Yield	Middlings product: Yield	Ash %	MJ/kg CV	Power-station product: Yield	Ash %	MJ/kg CV
1							
2	20,19	43,2	37,2	19,5	65,1	28,2	22,1
3	13,88	39,8	37,2	19,5	50,9	29,7	21,4
4	13,37	40,9	37,2	19,5	53,1	32,2	20,5
5					53,2	38,7	18,8
6					90,0	34,0	20,6
7					23,6	45,4	16,2
8					78,8	33,2	20,9
9							
10					90,0	24,3	24,0
11							
12					90,0	22,7	24,5

Scheduling

The pit

Based on the geological model and operating considerations, a pit layout as depicted in Figure 8 was eventually chosen.

The scheduling problem.

The pit shown indicates a scheduling sequence. The development of the pit must be scheduled in such a way that account is taken of:

- the material volumes to the different plants (illustrated in Figure 7);
- the geometrical constraints in the pits;
- the planning and utilization of plant capacities as well as the smoothing of run-of-mine peak volumes to the plants;
- aspects of waste dumping and backfilling;
- product quality requirements (see Table 1 for average

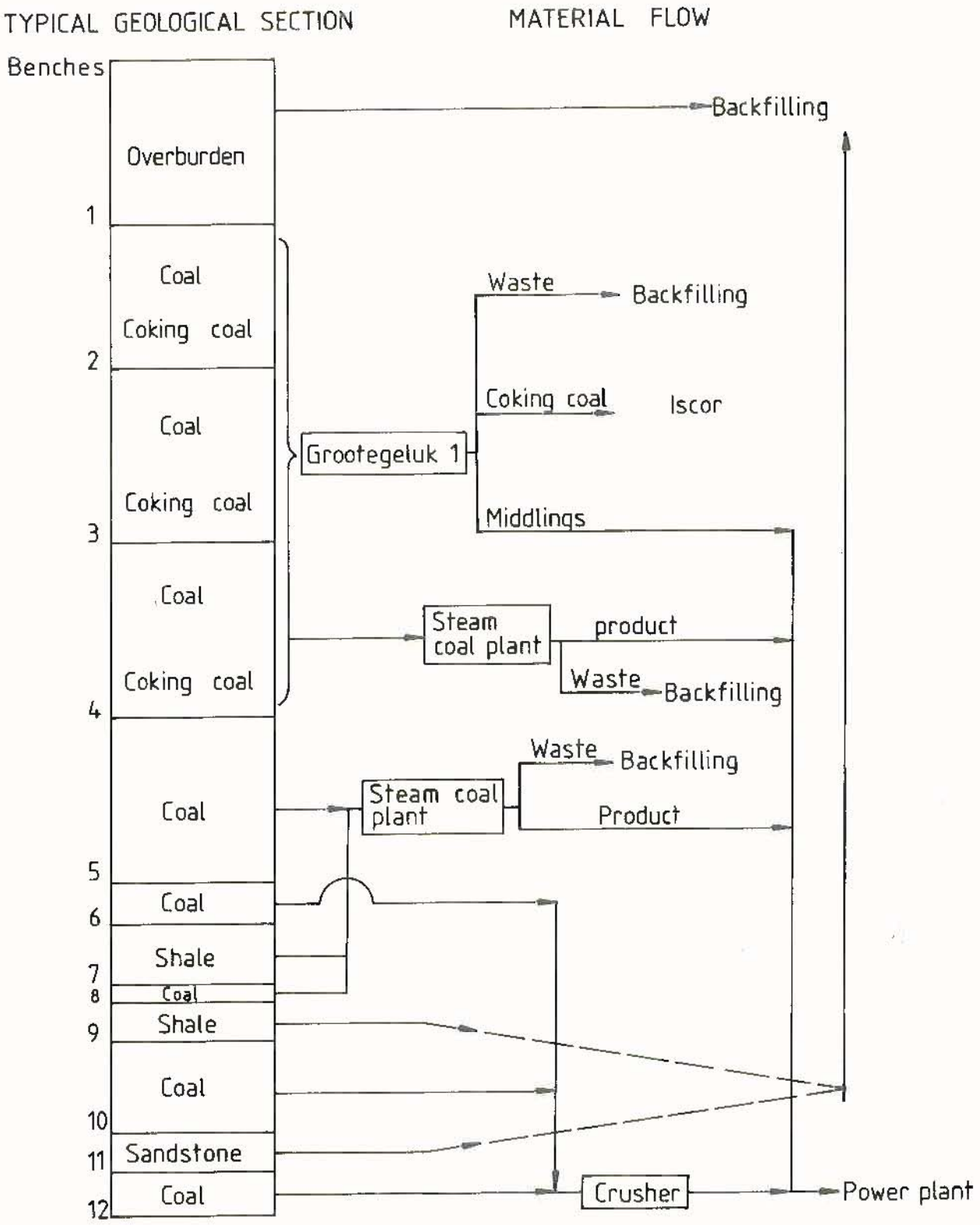

FIGURE 7. Relationship between geology and material flow

yields and qualities and Table 2 for quality requirements).

Computer support to the mine planner

As mentioned earlier, a coal modelling system is available in the Corporation. A scheduling system was, however, lacking. To provide computer scheduling support to the planner, a low-cost scheduler was developed.

The basic principles of the scheduler are as follows:

(a) The total area of the final pit was divided into segments, each segment being assumed to consist of material of a homogeneous quality. Figure 8 represents a typical segment division.

(b) The segments were generated by making use of a facility in the SEAMSYS package, namely that a

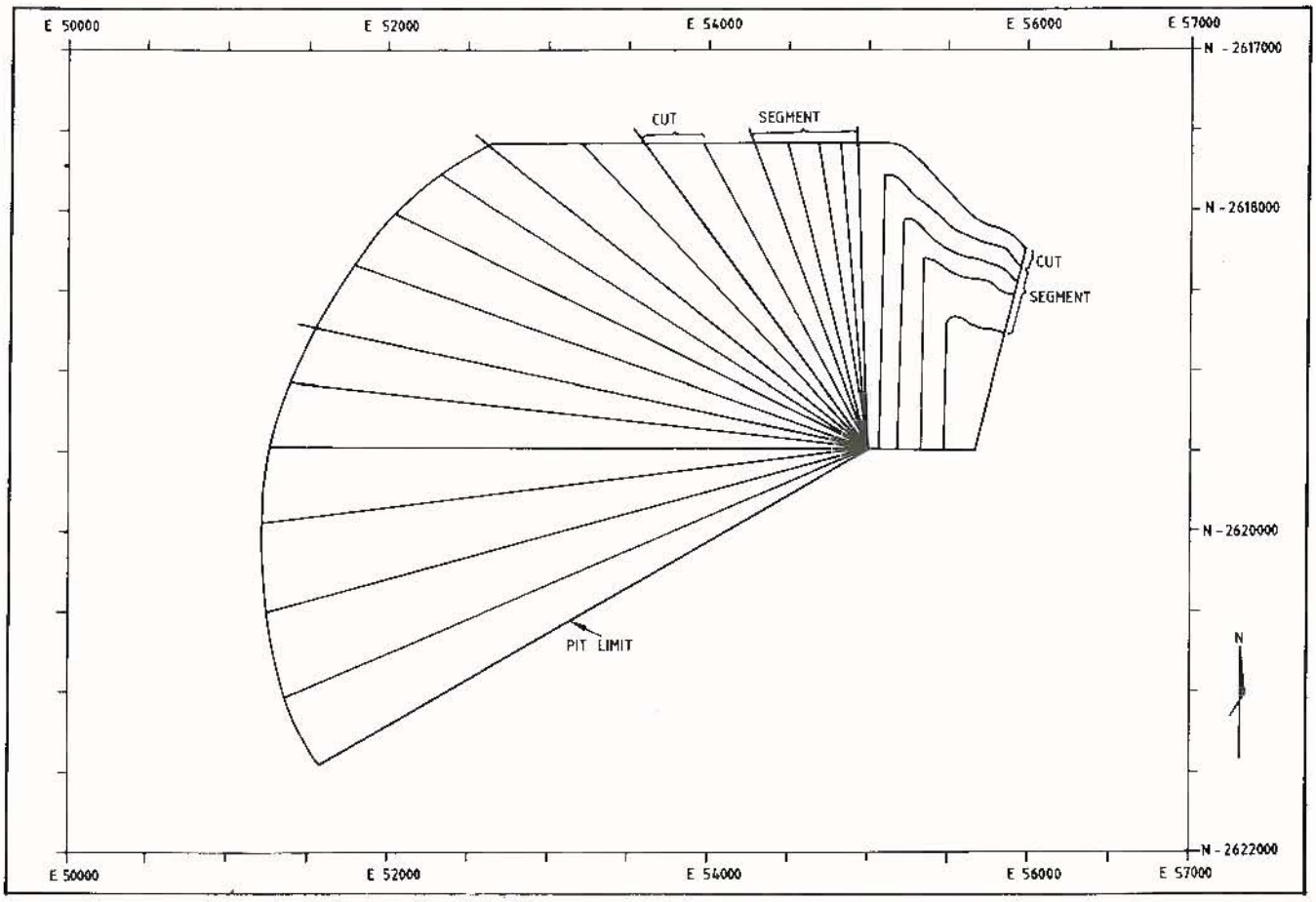

FIGURE 8. Pit layout showing plan view of one bench with segments and cuts

TABLE 2
Quality requirements

Iscor:	1,976 × 10^6 tons coking coal per year.
Escom: Energy:	40 GJ per year per set (a set produces 600 kW); 6 sets must be phased in for an eventual total of 240 MGJ per year.
Quality:	20 to 22 MJ/kg, with a penalty applying below 20 MJ/kg and a bonus applying above 22 MJ/kg; 30 to 35% ash, with a penalty applyable to an ash content exceeding 35% ash and a bonus applicable to an as content below 30%.

polygon can define a bench outline and that two lines intersecting the polygon define a segment (see Figure 8). The system is capable of generating a user specified number of cuts subdividing a segment (see Figure 8). Each cut is generated by the system as a closed polygon.

(c) Such a cut (polygon) is then evaluated against the model to determine the tonnages of the different material types and qualities in the segment.

(d) Each cut, uniquely defined by bench, segment and cut number relative to the segment, is stored with the information on material volumes and qualities as input to the scheduler.

(e) To keep the number of cuts in the system to manageable proportions, while maintaining scheduling accuracy, the concept of increments was introduced. Each cut is considered to consist of a number of increments of equal value, say 1 000, as determined by the user.

(f) The data for the scheduler consist of the cut values and target values planned for each period.

(g) The scheduler is driven by a file specifying the number of increments to be used for each level for a specific period. From Figure 8 it can be seen that the cut sequence in scheduling is implied by the way the cuts are generated.

The logical working of the scheduler is as follows:
For a specific period:

(h) Use the number of cuts and partial cuts as specified by the number of increments for the period.

(i) Accumulate material volumes and average the qualities per material type. The material flow as depicted in Figure 7 was simulated in the accumulation process.

(j) Report the totals against target values for the period.

(k) If the target value for coking coal for a specific period is reached – allocate the material from the coking coal benches to the steam plant.

Repeat for all periods.

By modifying the number of increments to be used from a specific bench for a specific period, different schedules can be considered.

By means of this scheduling system the user can consider a large number of different schedules for opening the mine, and he is then in a position to choose the best schedule from the various alternatives generated.

Conclusion

The scheduling system was developed at a low cost – in the order of 400 man-hours over a period of about two months. This was accomplished by determining the minimum practical requirements of the system and fully utilizing modules of existing systems in the Corporation.

The approach as outlined in the paper was used to schedule at least two long-term mine plans for Grootegeluk and is still in use. It was found that it gave good practical results, and the planning engineers were able to schedule a number of alternatives in order to be able to determine a 'best evaluated option'. The facility to evaluate different options also provided the planning engineers with the opportunity to develop a feel for the characteristics of a good pit development sequence.

The solutions finally accepted met requirements as to pit geometry, material volumes and quality.

Based on the experience gained with this system Iscor is presently developing a scheduling system for both short- and long-term planning at Grootegeluk.

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