The role of the computer in the evaluation of geological and mine-design data

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SYNOPSIS

This paper, which adopts a philosophical approach, attempts to analyse the contribution that the computer is capable of making in geological analysis, financial evaluation, and mine project control. Also examined are some reasons for non-utilization of these capabilities. As with most computer-associated problems, the cause is primarily human and not mechanical.

The paper gives one numerical example of the analysis of geological data and one of the evaluation of mine-design data. The values used in the examples are intended only to emphasize certain points and are not necessarily reproducible.

SAMEVATTING

Hierdie referaat, wat die saak filosofies benader, probeer om die bydrae wat die rekenaar tot geologiese ontledings, finansiële evaluering en mynprojekbeheer kan maak, te ontleed. Van die redes waarom hierdie vermoëns nie benut word nie, word ook ondersoek. Soos in die geval van die meeste probleme in verband met rekenaars is die oorsaak in die eerste plek menslik en nie meganies nie.

Die referaat gee een syfervoorbeeld van die ontleding van geologiese data en een van die evaluering van mynontwerpdata. Die waardes wat in die voorbeelde gebruik word, is net bedoel om sekere punte te benadruk en is nie noodwendig reproduseerbaar nie.

Organization of the Computer Centre

Until 1972, with two notable exceptions, the computer in mining was used primarily as an accounting tool, able in a reasonably up-to-date fashion to calculate and print payroll cheques, keep general ledgers, and maintain accounts payable and receivable. The exceptions were in Africa and the U.S.A., where from the early 1960s Desmond Devilliers-Oxford, and later P. H. Williams of Nchanga and Alfred Weiss of Kennecott Copper Company, saw the computer as an engineering and production tool, essential if the mining industry were to benefit from operations research, management science, and statistics.

In 1972, the computer centre began to be viewed as a service entity with the primary function the receipt, storage, retrieval, and presentation of data pertinent to the geology, design, finances, and operations of a mine, real or potential. In this new concept, the manipulation of data became the responsibility of the user, not of the operator.

Certain other functions evolved as computer-centre responsibilities under this new integrated concept: the maintenance and administration of a unified data base, and the support of a user application library that adequately fulfilled the user's needs. In both the selection of the application library and of the design and structures of the data base, this new perspective revealed that it is essential for the actual requirements of the users to be fulfilled, and not the requirements that the staff of the computer centre believe the users should have. The end-user is the only one capable of defining his own requirements.

Fig. 1 represents a very generalized corporate mining organization chart of the late 1960s. The computer centre, already a significant expense, is under the management of the chief financial officer. This was logical because it was the processing of accounting data for the corporation and subsidiaries that justified the capital expenditure, operating cost, and staff of the computer centre in the first place.

Several large 1960-type computer centres made paper provisions 'to support' the geological and engineering phase of corporate mining activities by establishing an engineering application staff within the computer centre. To have been successful, this approach required two factors, neither of which was always present: a computing capacity capable of handling the erratic peak load typical of geological and engineering work, and an engineering applications staff consisting of geologists and engineers cross-trained as computer scientists.

The costs of this extra capacity and duplication of staff were so excessive that very few such organizations ever existed, certainly not in the low-profit mining industry of the U.S.A. Financial justification for such services was almost impossible for two reasons: the manager of the computer centre had no knowledge of the technical aspects of geology, mining, concentrating, smelting, or any of the other myriad activities that are often lumped together under the heading of mining; and the geologists, engineers, and operators in the field did not know about computers. Evaluation of the benefits of a cross-trained applications staff and greater capacity was beyond the ability of the current people. Only those who were cross-trained in both mining and computers could see the whole picture.

A long-term approach (one used by the 'exceptions' – Weiss of Kennecott, and Devilliers-Oxford and Williams of Nchanga) was to create a group of cross-trained consultants at the level of top operations management. It was their job to conduct worth-while design and analysis exercises for the operating companies by whom they were paid. At the same time the group trained one or more local technical people in the use of the computer and in the specific applications program being used. The result of ten years' implementation of this philosophy is a constantly growing utilization of modern management techniques, and of analysis and design methods

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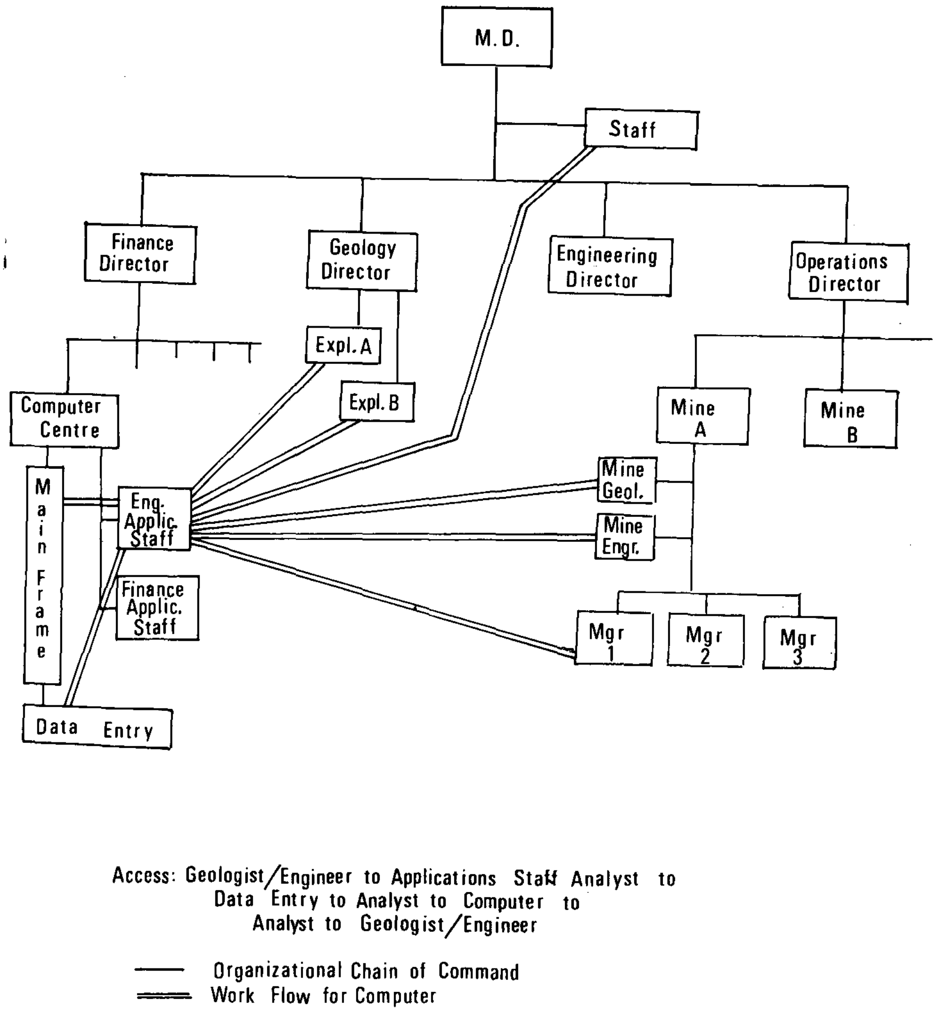

Fig. 1—The organizational chart of a fictitious mining corporation in the 1960s

in mining and processing operations, and the creation of a group of sophisticated operators to whom the computer is a tool to be used for increased efficiency and profit. The process was simultaneously self-financing. In addition, the system was self-correcting in that a technique that proved unpractical or excessively costly was quickly rejected. For both Kennecott and Nchanga, the original source of computing power was a small in-house processor and the extensive use of bureaux. In-house computer power was increased as the work load justified it. Unfortunately, the leadership, vision, and salesmanship required to follow this growth pattern are rare, and the responsibility of providing technical computing is often vested in the financial computer centre.

Since 1974 a trend towards interactive computing, i.e. direct interaction between computer and user, has become the dominant computing philosophy. Fig. 2 illustrates the change that this new development makes in an organizational structure. Computing capability is now made directly available to the user, implying a user ability to utilize this power. Instead of waiting in line or requesting time from friends in the computer centre, the user now has direct access to the computer and receives output at his own terminal.

Terminals are located at the user's site and are specifically tailored to the user's need. For example, a financial terminal might consist of a large number of data-entry stations, video display units, one or more high-speed printers, and several interactive terminals. This financial terminal would probably have some stand-alone processing capability for the editing, compression, and expansion of data that are essential for efficient data transmission.

A mine may have a 'Mining Mini' terminal, consisting of a stand-alone processor supporting several interactive terminals, a line printer, a plotter, a digitizer, and a graphics terminal. This Mining Mini would have extensive data entry, data edit, interactive graphics, and plotting and digitizing capabilities in its stand-alone configuration. It would also act as communication multiplexor connecting the interactive terminals and other peripheral equipment to the large corporate computer centre. With the development of this configuration, the field mining staff can, for the first time, actually utilize the power of the computer.

Implementation of this type of distributed computing design implies that the computer centre strips itself of all except maintenance and systems programmers,

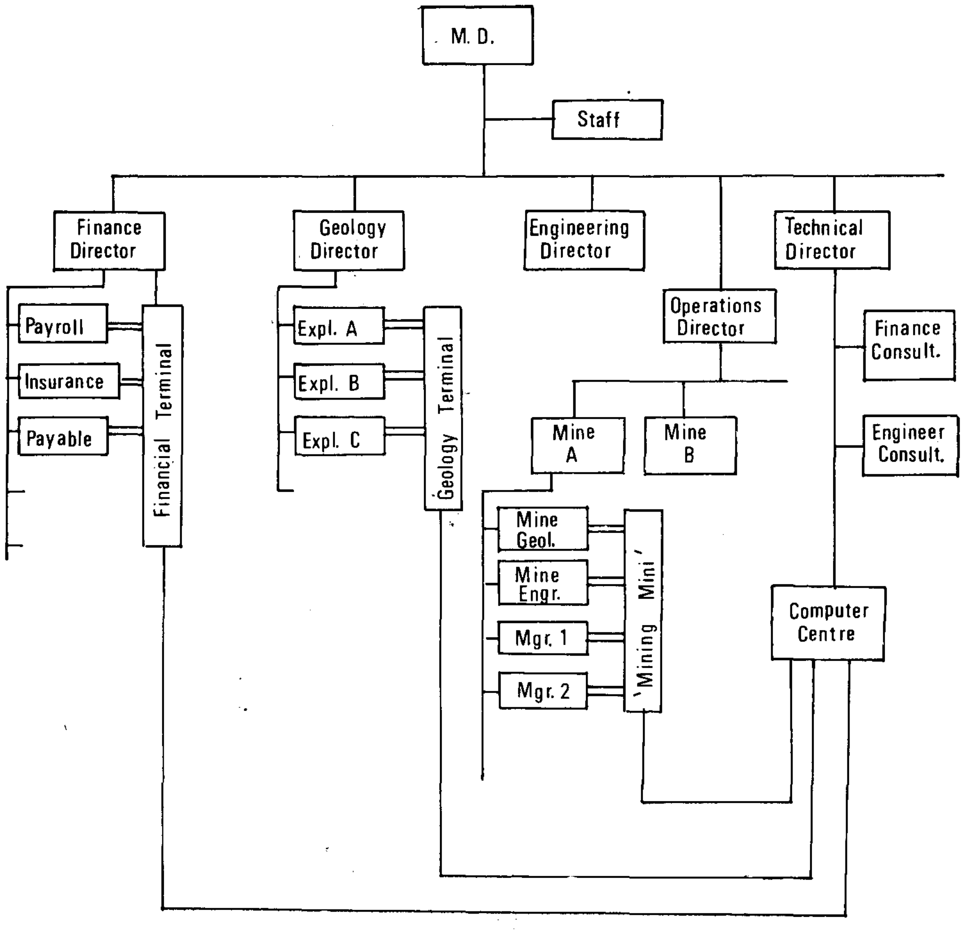

Fig. 2—The organizational chart of a fictitious mining corporation after 1974

acquiring special analysts who will be responsible for the maintenance communications (both software and hardware) between the mainframe and all the various terminals, and that it surrenders applications responsibility to the user.

However, one reason that this change has been slow in coming is attributable to the peculiar position of the manager of the computer centre. He is a 'dead-end kid', i.e. the position requires extensive background but there is little chance for advancement. A lawyer, accountant, or chief geologist can aspire to company presidency. Not so the manager of the computer centre – his only chance to grow is based on his centre's enlargement

Geological Analysis

Fifty-three holes were drilled in a coal property, call it the Van der Merwe farm, by an exploration team as part of a large exploratory effort covering more than a dozen properties. Although the borehole locations were plotted after surveying, the map was not updated with analytical data owing to a lack of drafting staff. The geologist in charge of this project asked a computer analyst used to handling exploration data to develop averages for all the basic characteristics of each coal seam. Management had decided that no property with less than a 50 per cent yield would be developed. Table I shows calculations received some five or six days after the initial request. As the average yield for the property was well below the required 50 per cent, the property was summarily rejected. This was an action typical of 1960.

About a year later, the technical computing requirements had completely outstripped the corporation's computer capability, and a bureau using an interactive, user-oriented applications program was requested to provide support. As a test case for the bureau programs, and to train a geologist in the use of the system, data from the Van der Merwe farm were chosen.

After repeating the original calculations (and getting the same result), the geologist noticed that there was a great variance from hole to hole in the yield figures. Having an interactive terminal available, he asked for a contour plot of yield over the project area. Fig. 3 is the contour map generated by this request, delivered in about 60 minutes. Notice that many of the low-yield holes (with a yield of less than 50 per cent) seem to be concentrated in the southern half of the property.

The geologist then sketched a line that approximately divided the property into two parts: one containing the predominantly high-yield boreholes and the other those with less than 50 per cent yield. This division was not absolute, since there are two holes, NIM114 and NIM110, with yields of more than 50 per cent in the low-yield area.

A practical area for mining was necessary, and this looked to be a reasonable configuration. The two areas were digitized from the contour map, and coal reserves within the high-yield area were then requested. Within five minutes the output in Table II was produced at the terminal.

Fig. 4 shows the polygon areas generated for the high-yield area. It is apparent that a deposit of more than 42 million tons of material with an average yield of 61,7 per cent exists on this property, and the high-yield area is open to the northwest and west.

TABLE I
ANALYSIS OF DATA FOR TOTAL AREA, VAN DER MERWE FARM

Seam	Hectres	THK	Coal T./K	Joul
2	1 287 1 287	6,3 6,3	121 232. 121 232.	23. 23.
Sul	FX C	Vol	Ash	Yield
,3 ,3	48,8 48,8	23,2 23,2	23,4 23,4	47,8 47,8

The foregoing certainly does not suggest that a viable mining property was found, but it does show that the property was rejected without being properly analysed. If the original geologist had possessed the tools needed to generate plan and contour maps, and to calculate averages on subsets of the data, this obvious possibility would probably not have been missed. It was the responsibility of the geologist to demonstrate the need for such tools, and of the computer centre to provide them. Above all, management must realize the untapped potential of computer-aided evaluation.

In today's computer organization, the following is a list of some of the computer-oriented tools now available for the evaluation of geological exploration data. It seems they should be available as a matter of routine, much like calculators and drafting boards, rather than on special request only.

1. Storage, retrieval, and display of borehole data (borehole logs, plan maps, cross sections).
2. Statistical analysis packages for performing cross-correlation analysis in transformed or untransformed data.

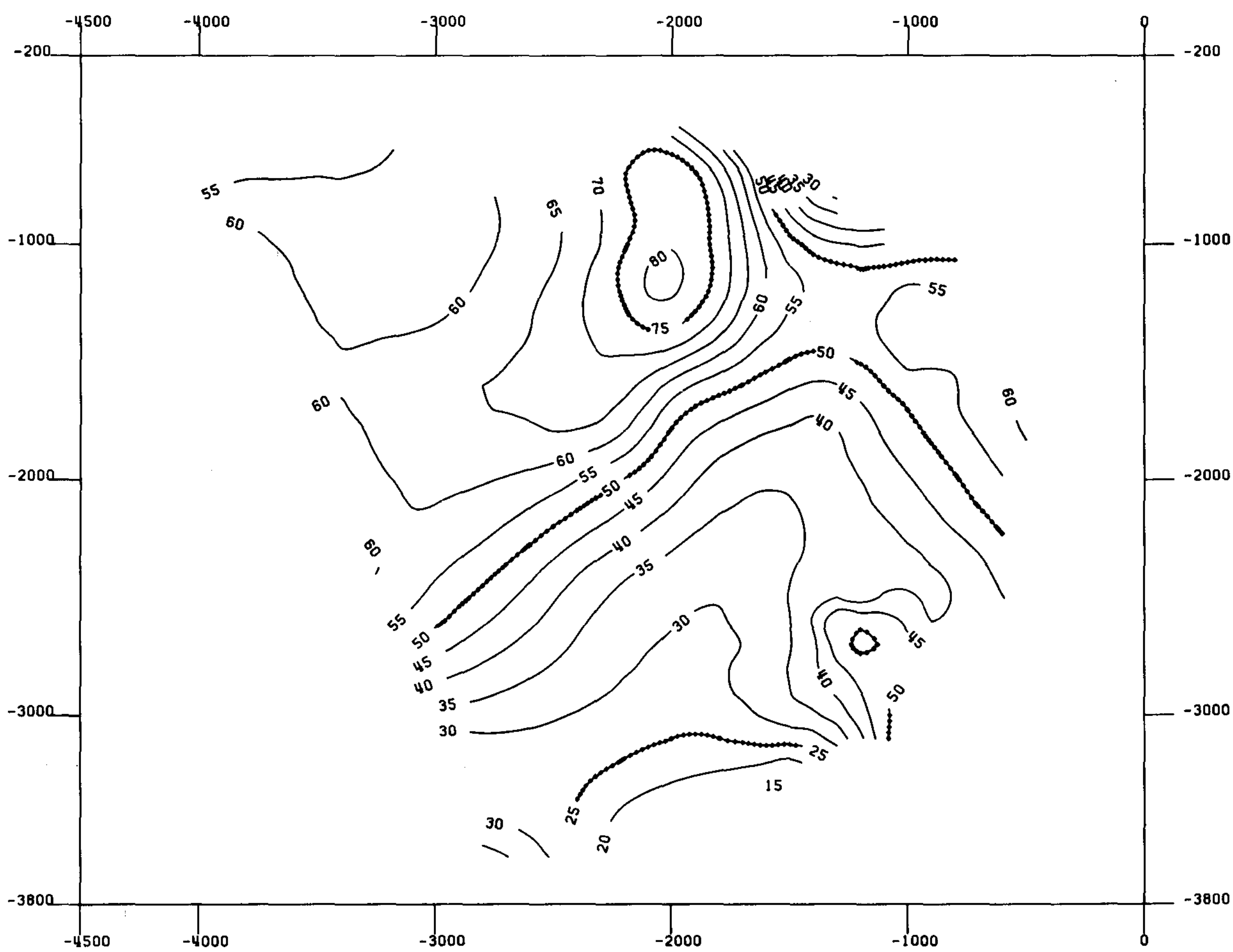

Fig. 3—A contour plot of the total area, Van der Merwe farm (scale 1:20 000)

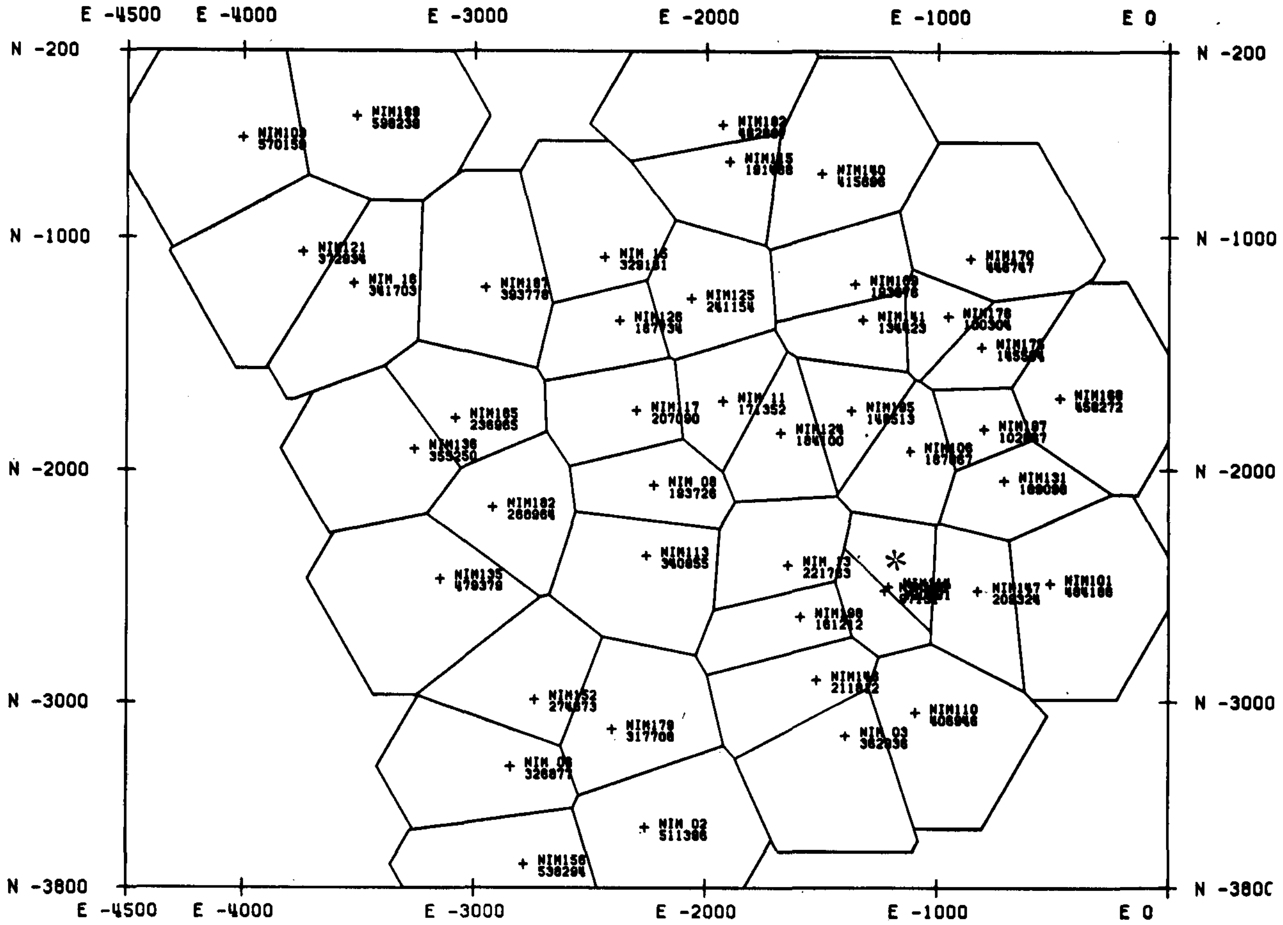

Fig. 4—The polygon areas for the high-yield area, Van der Merwe farm (scale 1:20 000)
*Note: Example of problem with automated plotting, overplotting

3. Geostatistical analysis packages.
4. Ability to input data from graphical sources such as a contour map.
5. Programs for the generation of polygons based on borehole locations.
6. Programs for the estimation of mineral reserves.
7. Programs for the generation of mathematical models of mineral distributions.
8. Ability to display graphic models.

Today the provision of such tools to a user is a much easier and more efficient process than was possible under the typical 1960 computer-centre structure (Fig. 1). The modern user is already experienced in computer usage, and needs only the method of accessing the computer – not someone to do it for him.

Financial Analysis

As an exploration project passes further along the evaluation line, one, or, it is hoped more than one, mine design for the extraction of the ore will be produced.

TABLE II
ANALYSIS OF DATA FOR HIGH-YIELD AREA, VAN DER MERWE FARM

Seam	Hectres	THK	Coal T./K	Joul
2	455. 455.	6,3 6.3	42 704. 42 704	25. 25.
Sul	FX C	Vol	Ash	Yield
.4 ,4	55,8 55,8	23,8 23,8	15,8 15,8	61,7 61,7

There are several good mine-design programmes to aid an engineer in this task. From the viewpoint of the computer centre, most of the comments made concerning geological evaluation are equally applicable to the mining engineer who is trying to design the most profitable pit possible for a given mineral deposit.

A different set of requirements, so far as the computer centre is concerned, comes into play when the finances associated with a particular mine design are to be evaluated. The engineer creating the design is usually not a financial expert; in fact, his expertise in this area is usually severely limited.

A tool the computer centre should provide is a relatively simple financial analysis program such as John Whitney's MINECAN*. Like the other tool discussed previously, MINECAN is meant to be used by engineers and geologists, not financial engineers. One of this tool's primary purposes is to allow a designer to compare several mine designs that are equally viable from a mining point of view but differ in cash flow. While the actual use of such programs as MINECAN is simple, the acquisition of the input data necessary for the program is not such an easy task.

Tables III and IV represent two runs made on the same mine design with different data sources. Unfortunately, the young engineer failed to realize that these dissimilar sources of information produced non-compatible figures. Table III shows part of the financial analysis of a proposed small uranium project. Note the

*Trademark registered by John Whitney Assoc., Reno, Nevada, U.S.A.

milling cost ranging from R15 to R23 per ton. These figures were received from a clerk in the cost accounting department who was responsible for ascertaining the milling costs for the corporate monthly operating report.

The mining costs in the column headed Explore/Develop were obtained from the mine accountant, and reflected the cost as submitted to management every month. The milling cost was burdened with its portion of fixed corporate overhead, while the mining cost was unburdened. The analysis program also asked for a fixed overhead cost for the mill, which was obtained from a different clerk in corporate accounting. The result was the inclusion of a double overhead, which in turn produced a net present value (N.P.V.) of only 3,85

TABLE III

EXTRACTS FROM A FINANCIAL EVALUATION REPORT FOR A PROPOSED URANIUM PROJECT

Capital Investment (R million)

Year	Explore/ Develop	Milling Plant	Ore Grade %	Recovery %	Yrly Prodn (Mill)	Unit Price R/kg	Gross Revenue
1979	,460	0,000	0,000	92,000	0,000	74,25	0,00
1980	0,000	8,988	0,000	92,000	0,000	79,45	0,00
1981	0,000	30,912	0,000	92,000	0,000	85,01	0,00
1982	0,000	0,000	,150	92,000	1,380	90,96	125,52
1983	0,000	0,000	,180	92,000	1,656	97,33	161,17
1984	0,000	0,000	,120	92,000	1,104	104,14	114,97
1985	0,000	0,000	,150	92,000	1,380	111,43	153,77
1986	0,000	0,000	,110	92,000	1,012	119,23	120,66
1987	0,000	0,000	,160	92,000	1,472	127,58	187,79
1988	0,000	0,000	,130	92,000	1,196	136,51	163,26
	,460	39,900	,130	92,000	9,200	136,51	1027,15

Operating Cost (R Million)

Year	Ore Mining	Waste Mining	Milling	Var. O.Head	Fixed O.Head
1979	0,000	0,000	0,000	0,000	0,000
1980	0,000	0,000	0,000	0,000	0,000
1981	0,000	0,000	0,000	0,000	0,000
1982	16,844	15,313	50,839	9,188	6,125
1983	18,023	16,385	54,398	9,831	6,554
1984	19,285	17,532	58,206	10,519	7,013
1985	20,635	18,759	62,280	11,255	7,504
1986	22,079	20,072	66,640	12,043	8,029
1987	23,625	21,477	71,305	12,886	8,591
1988	25,279	22,981	76,296	13,788	9,192
	145,771	132,519	439,964	79,512	53,008

After Tax Net Cash Flow (R million) (Deflated)

Year	Cash Flow	Cumulative	Present Value	Future Value	Value Ratio
1979	−,46	−,46	−,46	−,46	0,00
1980	−8,40	−8,86	−8,10	−8,91	0,00
1981	−43,80	−52,66	−44,29	−53,60	0,00
1982	16,07	−36,59	−32,22	−42,89	,27
1983	30,99	−5,60	−11,05	−16,18	,75
1984	−3,20	−8,80	−13,04	−21,00	,72
1985	12,16	3,36	−6,18	−10,94	,87
1986	−9,62	−6,16	−11,11	−21,66	,78
1987	18,68	12,42	−2,40	−5,14	,95
1988	14,74	27,16	3,85	9,08	1,08
FINAL	27,16	27,16	3,85	9,08	1,08

million rands. Fortunately, the chief engineer, when reviewing the analysis, questioned the milling costs, which were subsequently adjusted as shown in Table IV, and a more realistic estimated N.P.V. of 12,29 million rands for the project was actually reported.

Had a standard source of information been available to the junior engineer, this 'near miss' would never have been possible, and one wonders how many such errors become 'facts'.

Corporate Data Base

The question naturally arises as to how the financial engineers and other professional estimators obtain cost data. It seems that these men have accumulated their own personal data bases over the years and have many contacts in all areas of the industry. From their experience, these professionals know exactly the structure of the cost figures given them by each contact, and how to adjust these figures to arrive at a set of consistent cost estimates applicable to a proposed project. These men are the original builders of data bases.

One great benefit that is possible only in a corporate computer centre is the establishment of a single database structure from which consistent (not necessarily correct, but at least always consistent) data can be obtained. In such a data base, the term *mining cost* would have a predefined meaning. The term might, for instance, be defined as 'the sum of all non-supervisory labour costs, including fringes plus the direct cost of all supplies consumed times 1,82 plus the depreciation cost of mine equipment, multiplied by the period being covered, plus daily mine overhead costs, times the number of days being measured; this sum is then divided by the sum of the daily tons of material mined during the period being measured'.

The establishment of such definitions for all the terms used in a corporate data base is the responsibility of a Data Base Administrator. The success of a corporate data base depends to a great extent on the Data Base Administrator, who must approve the definition of every element in a data base. In order to do this, the Administrator must understand the needs of all the users of the data base so that each user will be able to generate figures applicable to his need from the data base.

As an example, consider the labour-cost data associated with just one mine mechanic. Assume that the man reports his time by 0,1 hour units, by the number of the equipment he works, and by the type of repairs he performs, i.e. electrical, mechanical, hydraulic, etc. If the maintenance department wishes to calculate the labour cost on a specific piece of equipment for a type of repair, the data base must record permanently all the data on the original time sheet or keep duplicate files generated from the same data by equipment, type of labour, or man.

The original data-base definition can be seen to be a tremendous task but, once accomplished, it has been proved to be of great value, especially as an accurate source of clearly defined data about a mining operation. The existence of data bases on the historical costs of mining operations permits great improvement in the estimation of costs for proposed mining projects.

The value of a consistent, accurate source of all data (not only financial) concerning mining is hard to overestimate. When a proposed design is evaluated, the availability of the equipment for a specific set of operating conditions should be available. Conveyor haulage could be accurately compared against truck haulage. Best of all, these comparisons could be made by junior engineers, and not senior operating personnel, who can make such comparisons based on personal experience.

The data-base concept is a totally new idea, which was made possible by the computer and easy access to the data base via interactive terminals.

Project Control

Just as more recently graduated geologists and engineers (more recently than those who are currently in top management) have an academic background in computer usage, operations research, and statistics, so

TABLE IV

EXTRACTS FROM A FINANCIAL EVALUATION REPORT FOR A PROPOSED URANIUM PROJECT (MILLING COST CORRECTED)

Capital Investment (R million)

Year	Explore/ Develop	Milling Plant	Ore Grade %	Recovery %	Yrly Prodn (Mill)	Unit Price R/kg	Gross Revenue
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1986	0,000	0,000	,110	92,000	1,012	119,23	120,66
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1988	0,000	0,000	,130	92,000	1,196	136,51	163,26
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1982	16,844	15,313	44,714	9,188	6,125
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After Tax Net Cash Flow (R million)

Year	Cash Flow	Cumulative	Present Value	Future Value	Value Ratio
1979	−,46	−,46	−,46	−,46	0,00
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1981	−43,80	−52,66	−44,29	−53,60	0,00
1982	21,07	−31,59	−28,47	−37,89	,36
1983	28,58	−3,01	−8,95	−13,10	,80
1984	2,60	−,41	−7,33	−11,81	,83
1985	11,00	10,59	−1,12	−1,99	,97
1986	−4,62	5,97	−3,49	−6,80	,93
1987	16,23	22,20	4,08	8,74	1,09
1988	19,37	41,57	12,29	28,29	1,26
FINAL	41,57	41,57	12,29	28,99	1,26

too is the modern operating management staff more sophisticated than their predecessors. The supervision of new projects – be they sinking shafts, driving new development drifts, opening a new mine, or erecting new crushing facilities – is part of the everyday job assigned to operating management.

Because of their more recent education, many of these supervisors know about PERT and CPM (critical path method) as tools to manage such projects. The heart of such a tool is a purely manual analysis of the project that must be completed before starting. This analysis breaks the project down into a series of sequential activities, and defines which activities must precede which and what labour and resources each activity will need. Some systems include what capital items must be purchased and the lead time for the delivery of such items. A budget segment can also be appended to each activity in some systems.

While projects of a hundred activities or fewer can be analysed and monitored normally, larger projects require a computer. As the new managers are assigned special projects, many are trying to obtain computer support to allow them to control these assigned projects via a PERT/CPM type of system. All major computers and most large minicomputers have such programs available. Unfortunately, companies still operating with the old type of computer centre (Fig. 1) find it almost impossible to help these managers. The remote (from the computer) location of the projects makes data entry and correction difficult. Such programs are extremely sensitive to minute errors in input data and the making of corrections. Re-running in the old system is time-consuming for computer-centre analysts, who really do not understand the project, have other work to do, or are not funded to do these alterations. For these reasons many local smaller projects exceed their budgets and are late in completion. The application of a project control program would aid many such projects by identifying time-critical activities, directing trends toward over-cast, and predicting the effects of delayed deliveries.

The conversion from classical organizational structures (Fig. 1) to a distributed computing/interactive structure (Fig. 2) would allow such small projects to be totally controlled from a local level. Data entry and corrections are always a big problem in project control, but it is a great deal easier to have the data entered by staff to whom the data have real meaning. They make data corrections out of their own knowledge or, at worst, by telephoning the adjoining office.

Project control is not in itself a significant factor in justifying conversion from the classical computer-centre organization to the distributed/interactive system shown in Fig. 2. Rather, it is symptomatic of the loss of an entire area of modern management benefits to the operational side of the mining industry because of a lack of proper support from corporate computing management to the management of local mining operations.

Conclusion

Today the technical staff of mining companies is well qualified to clearly define their requirements in terms of computer availability, applications program capability, data-base structure, graphic requirements, and terminal locations. It is now the job of the computer specialist to meet these software, hardware, and communications needs in as efficient and cost-effective a manner as the state of the art permits.

Future requirements can be planned by a committee of active computer users who express their needs, as currently seen, to the management of the computer centre. The computer specialist, in turn, advises the user group on new advances in hardware and software so that the users can better define their future needs within the framework of new developments in the computer industry.

Because of the computer's very widespread utilization by all groups in a mining corporation (top management, staff, finance, purchasing, personnel, legal, and operations) it would be more practical if the final management responsibility for computing rested with a Technical Director. This person should be a user, cross-trained either academically or experimentally, with a broad knowledge of the industry – obviously a fine candidate for the post of Managing Director.

The computer centre is a true service organization. Its existence can be justified only where it performs activities more quickly and efficiently than manual labour, or where it provides tools that allow people to produce work of better quality, in a more expeditious manner, and in greater volume, than could be done without the computer.

If the concept of service organization were applied strictly to all the computer centres in the world, there would be significantly fewer of the classical type of computer-centre organization and many more of the distributed/interactive type, especially in the mining industry.

Acknowledgements

The author is indebted to Control Data (Pty) Ltd, CYBERNET Division, for providing the support and computing resources needed to generate the tables and diagrams in this paper, and for the co-operation and assistance received by Mr Dankhard Erber.

Organic analysis

A Joint Symposium organized by the Analytical Chemistry Section of the Royal Netherlands Chemical Society and the Analytical Division of the Royal Society of Chemistry will be held at the Leeuwenhorst Congress Centre, Noordwijkerhout, The Netherlands, on Thursday and Friday, 23rd and 24th April, 1981.

The scientific programme will include five plenary lectures covering the areas of

The analytical chemistry of drugs and drug metabolites
The impact of microprocessors on quantitative organic analysis
The analysis of polymers, resins, and additives
Aspects of quantitative analysis of organic vapours in working and other atmospheres
Functional group analysis and chemical derivation methods.

Contributed papers on techniques and results, including the interpretation of data, relevant to the general theme of the Symposium, will be welcome. Further details about this and other aspects of the conference are given in the First Circular, which can be obtained from Miss P. E. Hutchinson, Secretary, The Analytical Division, Royal Society of Chemistry, Burlington House, London W1V OBN.

Economics and expansion of small mines

The editors of *World Mining* and *World Coal* magazines have announced plans to sponsor the First International Symposium on Small Mine Economics and Expansion. The Symposium will be held in Queretaro, Mexico, from 17th to 20th May, 1981. Queretaro is about 120 miles north of Mexico City.

While large mines often receive the headlines, the mainstay of the industry in many countries is the smaller-tonnage operation — mines that process less than 10 000 tons per day. According to Donald A. Pazour, Symposium Chairman, Mexico was selected for the site of this Symposium because its major mining industry is made up of small- to medium-sized operations.

On a recent trip to Latin America, *World Mining* editors visited several small-tonnage operations. Although these mines are unfamiliar to many in the industry, they are using new ideas unique to their size, which makes them important both domestically and on an international scale. The idea for a symposium on the problems and technology of smaller mines arose as a result of this editorial trip.

The programme chairman for the symposium will be Joseph M. Keane, Manager of the Process Engineering Division of Pincock, Allen & Holt in Tucson, Arizona. The programme will include five half-day technical sessions on the following topics: 'Economic Geology — Evaluating the Smaller Deposit', 'Starting Up and Expanding Small Mines', 'Design and Economics of Small Tonnage Mills', 'Evaluating and Choosing Underground Mining Methods — Economic Considerations', and 'Evaluating the Economics of Hydrometallurgical Plants'.

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