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Mineral Resource Management: An Overview of an Integrated Graphics Based System

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This paper discusses a bold venture into the use of interactive computer graphics technology as the foundation of an overall integrated mining managerial system. The wide range of applications that can be addressed through the use of this technology is highlighted, and some discussion of the major facts of this project, which is still in its early stages, is provided.

Introduction

During 1986 the Gold Division of Anglo American Corporation investigated the use of interactive graphics systems for use in the day-to-day operations and management of its gold mines. With the assistance of Intergraph South Africa, whose system was finally selected, the Gold Division has begun a major programme of implementation and customisation which is showing signs of becoming one of the most significant advances in gold mine management since the computer started to become widely used in the 1960's.

This paper gives an overview of the system, and the accompanying paper by Walker et al. will provide greater detail.

Dependence on graphical data

Most of the data used in minerals resource management are dependent primarily on positional information which is intrinsically graphical in nature. In other words, all positional data in and around the orebody are co-ordinated in three dimensional space.

It was found after analysis that the key data required across all disciplines in mining are contained on drawings, which are either in the form of a layout, a plan, a map or cross-section. Several plans, drawn to scales of 1:200, 1:1 000 or 1:2 500, are used.

All graphical data represented on the 1:200 drawing are derived from underground measurements taken using a variety of surveying methods by the Survey Department. The data are tied into three dimensional space using survey pegs as reference points. All other disciplines on the mine place additional data onto these drawings using a copy of the drawing or an overlay on top of the drawing. For example:

- Samplers produce underground sampling reports based on a plan and transpose sample section values on to a 1:200 assay plan.
- Valuators delineate ore reserves blocks and areas on 1:1 000 ore reserve plans and later transcribe these to 1:200 plans.
- Geologists map borehole positions and underground geological strata intersections on to 1:200 plans and later

rescale and transcribe these data on to 1:1 000 plans and overlays.

- Environmental Observers use a copy of 1:1 000 drawings for workplace environmental surveys and superimpose environmental conditions from air and barometric surveys on to 1:1 000 ventilation plans.
- Mine Production staff superimpose estimated and measured face positions and record the positions of mining equipment on to 1:200 plans. These drawings are also used to communicate instructions to contractors and other levels of management.
- Mine Planners superimpose future mining proposals on top of 1:200 and 1:1 000 copies of these drawings.

This multi-disciplined use of graphical data shows that all mining departments depend on the most current graphical data produced by the Survey Department.

The working environment

All technical disciplines associated with mining use pictures for the display of data and information. It is therefore imperative that any computer systems developed for use by these disciplines should use pictures and drawings to represent data and information. These pictures must be accurate and independent of scale factors, and must readily depict the position of the data in true three-dimensional space.

Systems have been developed to translate (i.e. capture and process) raw data into coordinated working data. For the purposes of clarity in this paper, these systems will be termed 'front-line computer systems'. Some major characteristics of these front line systems are as follows :

- Graphic input devices such as a mouse or digitiser are required.
- Substantial processing power is required for processing graphical data, and it is required locally. Remote communications for these functions are likely to be frustratingly slow.
- Plotting facilities are required locally for producing hard copies of drawings as required.
- Systems must be responsive and interactive. It is important that the 'front-line' user be able to view and interact with his data as they are displayed.

Once data have been captured and coordinated by these front-line computer systems, they are stored in common data bases which can be accessed by all other dependent disciplines (assuming that they are allowed access). This prevents duplication of effort and redundancy of data. Ideally, each piece of data should only be stored once on the system.

The role of interactive graphics

In the past computer systems for mining have used large mainframe systems, and more recently, personal computers. These both have their place in mining systems, but their disadvantages are that they are largely non-graphical in nature, and tend to produce 'printouts' rather than the pictures that the users are accustomed to reading.

The interactive graphics environment allows the user to interact dynamically with graphical and non-graphical data. With this technology the user is able to control the picture content, format, size and colour of objects on a display screen using a graphics input device such as digitising tablet or mouse.

Interactive graphics uses a graphic data base for storage. A non-graphic data base is used to store non-graphic data (or attri-

butes) about each graphics element in the picture. This non-graphical data base ranges from a simple table to a conventional full-blown data base.

It is possible to query the non-graphic data base using graphic commands and view the results of this query in a graphics picture. Queries and updates of both graphic and non-graphic data bases are also possible by means of a conventional non-graphic terminal and application system.

The ability to store all graphics instructions in a simple program (macro) has allowed the building of complex application systems which extend the basic tools available under the interactive graphics environment.

Development philosophy

One of the major problems encountered at the outset of this project was that a different approach to software development was necessary. The standard 'systems analysis' approach was deemed to be inappropriate, because of the inherent delays, 'red tape', and bulky documentation that would be required. In addition, this approach in the past has alienated the mining users from the software developers, a situation that we wished to avoid at all costs.

It was therefore decided to adopt what has been called a 'prototyping methodology'. In this philosophy, the user and the developer work together as a team, and the modules of software are developed at a rapid rate, with changes being made as soon as the user perceives shortcomings. This approach helps to achieve the ultimate objectives of providing the right software first time, and avoids many of the communication problems associated with the more traditional route. Work being done now will follow the more structured approach.

Minerals resource management

A minerals and resource management system must provide the following:

- Better and more accurate information on the orebody, the only revenue-generating asset of a mine.
- Better planning to determine how this orebody can be exploited to maximum advantage by the mine.
- Better control of the exploitation and utilisation of this orebody by money, men, material and machines.

The initial work on this interactive graphics project was self-limiting, but as more experience of the available technology was gained, an awareness grew that it would be possible to define and provide for an architecture which could encompass an extensive mineral and resource management system. It would be able to address nearly all of the day-to-day production needs of a mine from exploration through to full production and final shutdown. Some of the disciplines that either are or will be addressed are listed below.

Pre-production phase

The pre-production design phase of a mining operation will encompass the following:

Feasibility planning

Geological exploration

This includes the capture of data from surface boreholes and geophysical exploration techniques, and the modelling and interpretation of these data using interactive three-dimensional modelling techniques.

Geostatistical analysis

The statistical analysis of value and other trends in the orebody which must then be available to planners and others in the same graphics environment.

Potential ore reserve evaluation

The graphics system will then allow the user to investigate interactively potentially mineable sections of the orebody, and dynamically generate evaluation of the reserves.

Economic analysis

The extraction of both graphical and non-graphical data from the system will allow 'what if' economic analyses to be generated in the same environment, and, if required, to post some graphical or textual results back into the pictures.

Mining method decisions

The three-dimensional representation of all graphic data which can be viewed from any direction or perspective has shown that many alternative mining methods can rapidly be investigated, and their economic implication assessed.

Mine configuration

Surface layouts

All standard survey and photogrammetic work is readily captured in the graphics system and is easily referenced by any other disciplines that may need it as a basis for their work. The system ensures that only the most current data are available.

Underground layouts

Much work has already been done in customising the system to allow very easy modelling of underground workings, with the automatic capture of lengths and tonnages.

Process plant design

Sophisticated process plant design software is available which can be used if this type of engineering design is to be used on the mine.

Shaft design

The ability to design shafts within a three-dimensional model of the current status of geological interpretation is a vital attribute of the system. This is especiallv evident when uncertainty is high and alternatives must be generated rapidly.

Engineering

The system can also be used for standard engineering applications, if required. Typically, these might be :

- Architectural Design
- Electrical Design
- Civil Engineering Design
- Mechanical Engineering Design

Production control

In the production phase, the following need be addressed:

Detailed design

Primary development

Detailed design of haulages, crosscuts and major ore passes is currently being done on two mines in the group. This capability is being integrated with development scheduling software.

Geological interpretation

The ability to model, in considerable detail, the orebody, as well as faulting, dykes and other features has proved to be a most valuable attribute of the system. The ability to modify interactively the interpretation in three dimensions, to rotate dynamically the model into any orientation and to generate 'solid' models of all features makes this an ideal medium for geological interpretation.

Other capabilities

Many other capabilities will be addressed in the same graphics environment as and when the bulk of the previous capabilities have stabilised. These will include such aspects as:

- Ventilation

Underground services

Panel and stops design

Rock Mechanics

Material handling

Production planning

Production planning in the mining environment covers a wide range of functions which are to be addressed within the overall graphics system. Some of these are :

Geostatistical analysis

The incorporation of both geostatistical analysis and display of the results is currently being generated. This work is by its nature somewhat academic, and considerable ingenuity is needed in creating methods for using the data that are simple and straightforward. This is necessary if non-mathematical personnel are to be able to use these results in order to do their work (such as creating ore reserve blocks).

Dynamic ore reserves

The ability to compute ore reserves dynamically is a relatively recent innovation in the mines, and this technology appears likely to suit this requirement admirably. Current data only are displayed in graphical form, and thus whenever data extractions are made, they will always be up to date.

Scheduling

The system is to be used to extract time values from the graphical data and allow these to be scheduled, with graphic representation of the times and dates being displayed in the three dimensional model (or on plans as required).

Economic modelling

The integration of all the data captured or generated in the graphics system with economic modelling software available for gold mines (in the same environment) is currently receiving much attention. The economic modelling software is currently almost completely customised, and the group management is waiting for the graphics environment to stabilise somewhat before starting on actual integration.

Resource planning

In parallel with the economic modelling software mentioned above, the group will be addressing resource planning in the same environment. Certain of the data for this will naturally drop out of the graphics environment.

Production control

Underground survey data

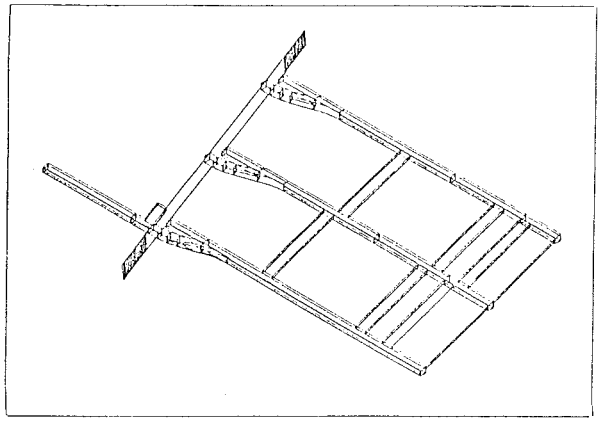
The system has been used to capture underground survey data and translate these into graphical representations of pegs and offsets that are placed in three-dimensional space. Current developments are associated with making the data capture as friendly as possible by emulating the field-book formats on the terminal screens, and having automatic placement of graphics.

Sampling

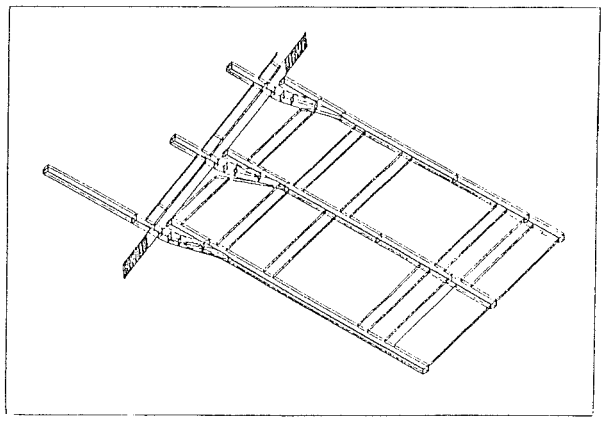
Sampling data will be colour-coded and placed in true three-dimensional space. Various validation techniques are under investigation, including visual inspection of the data to ensure that correct placement has occurred. The values associated with the graphic representations can be readily scrutinised and corrected from the graphic environment.

Geological mapping and borehole logging

Traditional geological mapping can also be done on the system, with the added advantage that it is placed into the three-dimensional model in its correct orientation. This means that all the geological data from all sources can be viewed in true



Step 1: Ability of stoping method to negotiate a fault is analysed



Step 2: Negotiating the fault is demonstrated

FIGURE 1. Negotiating a fault

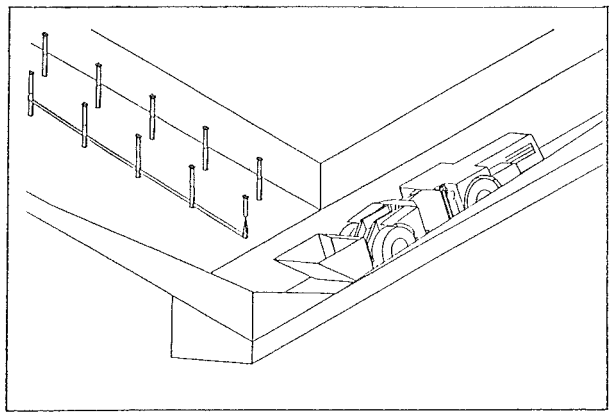


FIGURE 2. Detailed stoping methodology is analysed to determine man/machine interface

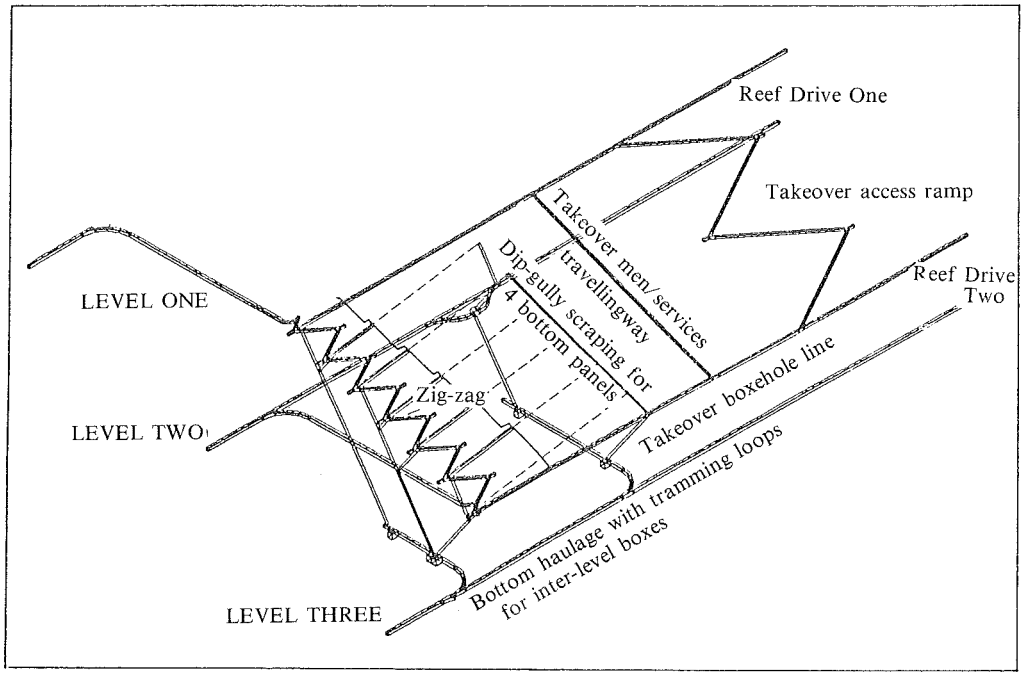


FIGURE 3. Idealised stoping layout

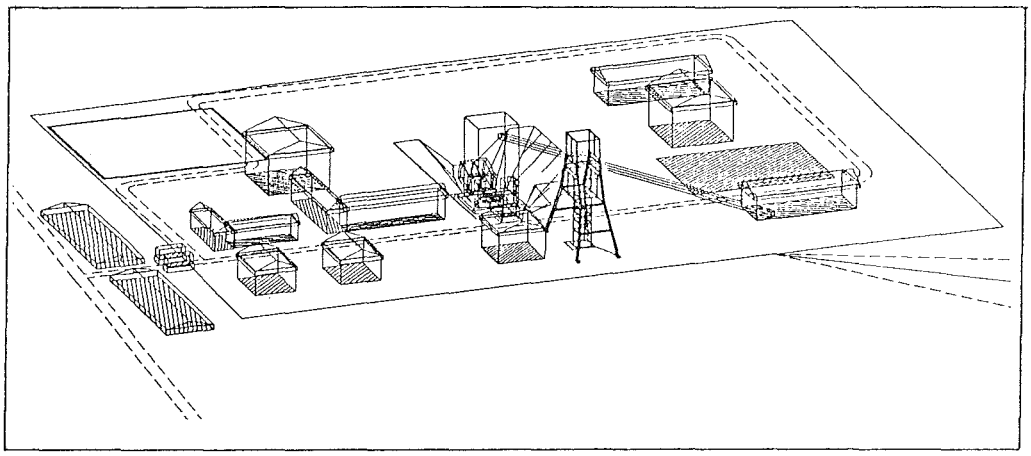


FIGURE 4. Surface shaft layouts

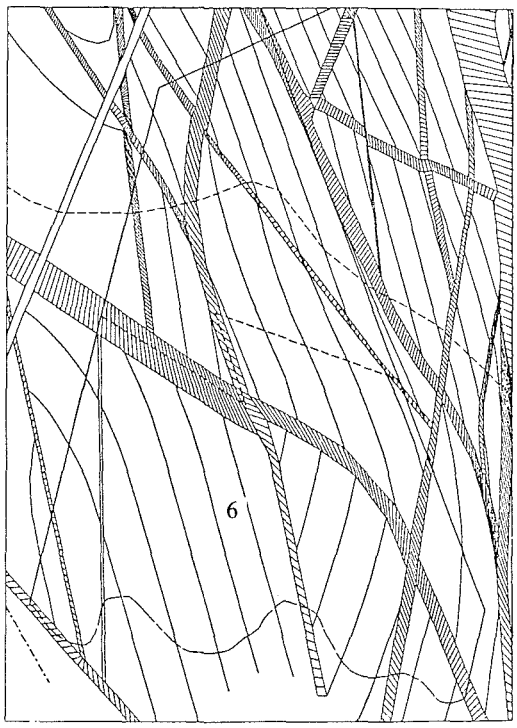


FIGURE 5. Large, complex geological structures are easily accommodated

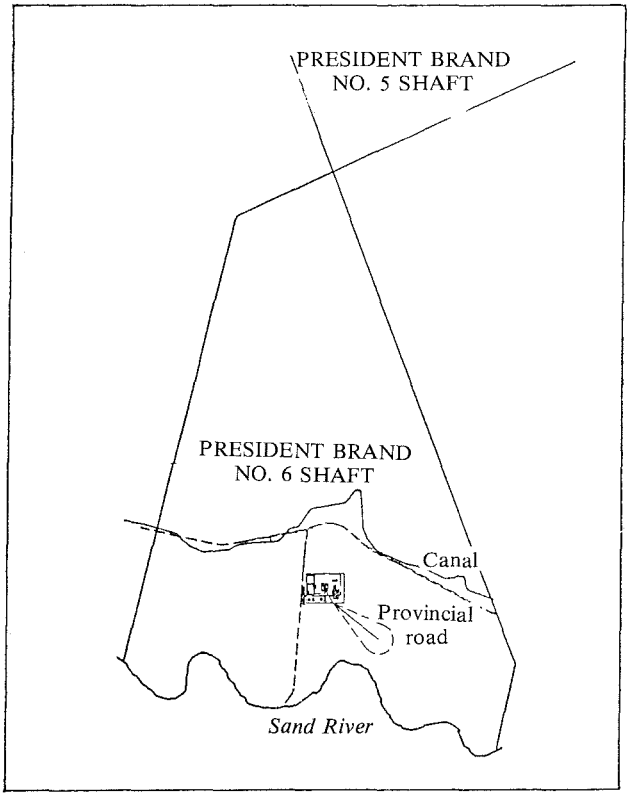


FIGURE 6. Surface topography is digitised direct from aerial photogrammetry and layouts of new mines/shafts facilitated.

positional space at the same time, making the job of interpretation easier.

Advance measurement

Investigations are currently under way to establish the extent to which legal constraints will affect the automation of stoping and development advance calculations. The difficulties associated with adequately modelling advances in true space are not insignificant, when it is realised that all the existing laws relating to the presentation of the data are based on the fact that only two-dimensional media have traditionally been available. This situation has resulted in transformations being made to the coordinate peg data to allow for varying dips of the reef. Once solved, the ability of the system to generate advance areas (and lengths) rapidly will be utilised to the full and will result in considerable productivity gains.

Environmental control

The job of the environmental control staff will be made much easier once they are able to work on the three-dimensional data of the other disciplines. Proper visualisation of air-flows etc., especially between levels will considerably enhance the quality of their work and, with suitable graphical representation, will enable other disciplines always to be able to access the latest environmental data.

Equipping schedule

The ability to depict equipment, cabling, piping, tracks etc. in the same three-dimensional space will enhance the ability to track and monitor these items, and these data, too, will be available to the other disciplines as and when necessary.

Phase I facilities available

The following sections briefly describe the facilities available as at the end of May, 1987.

Mining

Via the graphical workstation

(a) Development Planning: for the design of development layouts.

(b) Stope Planning: for the design of stoping layouts.

(c) Development scheduling: for the interrogation and modification of timing of planned development sequences.

(d) Stope scheduling: for the specification of stoping schedules as well as their interrogation and modification.

(e) Workplace/contract specification: for the specification of workplace and contract numbers in relation to graphical representation.

Via the alpha-numeric workstation

(a) Housekeeping: this is for data entry or modification of planned contract data, development standards data, and all code lists necessary to support the mining functions.

(b) Reports

In addition to those mentioned earlier, reports for all housekeeping items are available.

Geology

The geological system consists of four major modules:

Borehole
Mapping
Interpretation
Plotting

The modules are fully integrated and in-

formation may be entered (where applicable) via an alpha-numeric terminal or a full graphics workstation. The preferred workstation for geological work is the Intergraph Interview because of the large digitising surface which it offers.

The Borehole Module

Underground Boreholes
Surface Boreholes

Borehole data placement directly into the three dimensional graphical data base is done through simple menu driven routines on a terminal. Review and interogation of the data via the graphics workstation is possible.

The Mapping Module

Historical Information
Current Mapping

Standard mapping visual representations are speeded up with the use of customised function keys on the keyboard.

The Interpretation Module

With the assistance of this module, curves and surfaces incorporation known data points can be created. Once generated, such surfaces can be contoured, modified, extrapolated or cut to allow for further interpretation.

The Plotting Module

Any combination of images from the graphics files can be assembled and sent to a plotter for reproduction within a chosen frame to any scale.

Utilities

A variety of routines have been developed which allow the user to alter his views, background colours or status of mapping easily. In addition he is able to window in on to specified boreholes or pegs, generate sections at will and take 'snapshots' of tentative interpretations, etc. for later viewing.

Help is available on screen at any time.

Minerals estate management

Peg Placement

The system handles alpha-numeric designations, and is used for the placement of survey pegs into a three dimensional graphical environment.

New Pegs

The system allows entry of survey data for a peg via an alpha-numeric terminal screen. It has built-in calculations and checks, with present tolerances for checking for discrepancies of angular and linear measurement. On acceptance of calculation, the peg is placed in three dimensions.

Backlog pegs

The system allows for the transfer of peg data from the existing old system's tapes directly into the new three-dimensional graphics system.

Sampling

This module allows sampled values and other related data to be entered and placed in the graphical environment, and written to the data base.

Measurement

In this module, actual measured dimensions of mining excavations are accepted, and the usual reports on volumes, distances, are generated.

Ore Reserves

Geostatistical techniques are employed in the valuation of the orebody.

Conclusion

It is our firm opinion that the use of powerful interactive graphics systems in addressing the profusion of interlinking and interdependant data display and interpretation requirements on a producing mine will become the standard for all large mines in the near future. The natural ability of the system to integrate data from diverse disciplines into a unified picture of the mine and its workings creates a feature that no comparable computer or manual system has had in the past.

We have only just started along this path, and new ideas and applications are constantly being identified. Just how far this technology will let us go in mineral resource management we will not be able to tell for some time. But the beginnings show exciting prospects for this new method.

Acknowledgements

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