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OREBODIES AND MINE PLANNING 2D AND 3D MODELLING

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OREBODIES AND MINE PLANNING 2D AND 3D MODELLING

by

ANDRÉ BOYER*, N. BILLETTE** AND RUSSELL BOYLE***

ABSTRACT

The present report is the basis of a presentation on " 3D modelling of orebodies and mine planning "made at the International Symposium on Mine Planning and Equipment Selection, Calgary, November 3-4, 1988.

A major CANMET research objective is the development of expert systems for use by the mining industry. The development of graphical representation methods for CANMET's CADD/GEM system is a first step in achieving this objective. The development of 2D graphics for the CADD/GEM system are nearly complete and the development of 3D graphics will be initiated in the near future.

Software permitting 2 and 3D representation of orebodies is considered a basic tool for advanced research on visual and mathematical modelling. Future research will be directed at developing models and software to assist mine planning and operational control with 2D and 3D graphics as a component.

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keywords: expert system, 3D modelling, orebodies, computer, mine planning, operation research.

MODÉLISATION EN 2D et 3D DES GISEMENTS ET LA PLANIFICATION MINIÈRE

par

ANDRÉ BOYER*, N. BILLETTE** ET RUSSELL BOYLE***

RÉSUMÉ

Le présent rapport sert de matériel de base pour la présentation sur la "modélisation tridimensionnelle des gisements et la planification minière "au symposium international sur la planification minière "à Calgary les 3 et 4 novembre 1988.

Le développement de systèmes experts miniers fait partie des objectifs des Laboratoires de recherche minière du CANMET. L'adaptation du progiciel CADD/GEM du CANMET pour la modélisation bidimensionnelle des gisements est en grande partie complétée. Les développements récemment initiés dans le domaine du 3D sont aussi décrits.

Tous ces travaux correspondent à une étape intermédiaire de la recherche principale dont le but est de développer les outils informatiques nécessaires qui permettront d'entreprendre des travaux de pointe dans le domaine de la modélisation visuelle et mathématique des gisements.

Des développements ultérieurs verront l'introduction de progiciels bi- et tri-dimensionnels en planification minière et, à plus longue échéance, des outils standardisés de planification minière, des algorithmes mathématiques et autres méthodes de recherche opérationnelle.

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Mots clés: système expert, modélisation 3D, gisements, ordinateur, planification minière, recherche opérationnelle.

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INTRODUCTION

Periods of mineral commodity oversupply, which are characterized by low prices and highly competitive market, are periods of high risk where the best possible use of available data is required. In this regard, the graphical display of geological and mining information for mine planning and operational purposes is becoming extremely important in terms of improving the productivity of geology and mine planning departments.

This paper deals mainly with the development of computer-assisted 2D graphical methods for drilling information representation and orebody modelling to solve problems such as geological interpolation and global reserves estimation. A sequence of data analysis and calculations are involved in solving such problems which are greatly assisted by graphical presentation of the orebody and mine parameters.

Initially, the CADD/GEM package is explained and linkage to the drilling data base established. The development of the 2D graphics modelling methods started with the conversion of some CADD/GEM computer programs to FORTRAN 77 and GKS (Graphical Kernel System).

The current status of 3D graphics facilities available for the short and long term mine planning is relatively poor. 3D graphics modelling development will be initiated in the near future and will be directed at addressing these weaknesses with respect to mine geology, design and planning needs. A 3D standard package will be used as a basis for developing 3D graphic modelling methods.

INTERACTIVE DATA ENTRY AND OREBODY DATA BASE

To facilitate drilling data entry into computer file, the Ore Reserve Assessment Group (ORAG) of Canada Centre for Mineral and Energy Technology (CANMET) developed a major computer program called **CDDE/1.0** (see Boyer and Boyle 1987). It is an interactive, menu driven and user friendly computer program based on a rapid question and answer sequence. It facilitates and optimizes the speed of drilling data entry and validation into a data base. The program is written in VAX-11 Fortran language and runs on a VAX 11/750 VMS type mini-computer.

The CDDE/1.0 program has been designed to utilize standard drillhole information recorded by mine geologists during their routine surveys. Rapid data entry and validation is achieved with the program by:

— utilizing the distance from the collar as basic program information;

— entering data columnwise, rather than rowwise;

— having a program provision to enter repetitive data extremely rapidly;

— having a program provision to rapidly correct errors of commission and/or omission.

Figure 1 provide an illustration of one of the main features of this program.

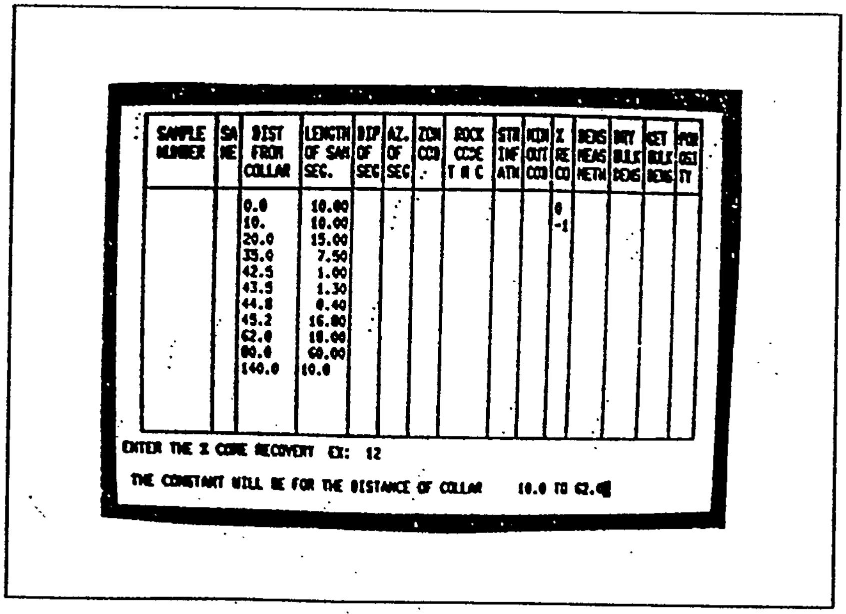

Fig. 1 — Fast entry procedure for repetitive data

The CADD/GEM computer system, first developed in Fortran 66 and Cobol 66, was recently converted to Fortran 77 and Cobol 77 (see Sabourin 1983). It was developed to handle uranium deposits drilling data and assess uranium mineable reserves. The system requires the use of a supermicro or a mini-computer with a minimum of 1 megabyte of accessible memory and with disk capacity of 50 megabytes. The CADD part of system is used to establish the drilling data base which is a major step in orebody modelling. Table 1 lists the various programs which compose the CADD/GEM system.

Table 1 — Description of the CADD/GEM system computer programs

	DESCRIPTION OF COMPUTER PROGRAMS	PROGRAM NAME	RESOURCES EVALUATION METEODOLOGY: GEOMETRIC METHODS: SECTION		GEOMETRIC METHODS: POLYGON		MOVING AVERAGE AND OTHERS		GEOSTATISTICAL METHODS	
	TABULAR DEPOSITS 2 DIMENSIONAL		2D		2D		2D		2D	
	ALL DEPOSITS 3 DIMENSIONAL			3D		3D		3D		3D
	STEP I									
CADD	DRILLHOLE DATA PROCESSING	1000	2D	3D	2D	3D	2D	3D	2D	3D
		1600	2D	3D	2D	3D	2D	3D	2D	3D
	STEP II									
GEM SYSTEM	ECONOMIC INTERSECTIONS	100	2D	3D	2D		2D		2D	
	ECONOMIC COMPOSITES	2010			2D		2D		2D	
	GRAPHICAL PROJECTION OF DRILLHOLES ON PLAN OR SECTION	3000	2D	3D	2D	3D				
	STEP III									
GEM SYSTEM	EQUAL LENGTH SEGMENTS	2040				3D		3D		3D
	GROUPING OF EQUAL LENGTH SEGMENTS WITHIN UNIT BLOCKS	2050					3D	3D		3D
	GRADE ESTIMATION OF BLOCKS BY MOVING AVERAGE OR INVERSE DISTANCE METH.	2055					3D	3D		
	STEP IV									
	BASIC STATISTICS — HISTOGRAM DISTRIBUTION TESTS — REGRESSION	2100							2D	3D
	VARIOGRAM AND TREND: BY SECTORS	2200							2D	3D
	VARIOGRAM AND TREND: BY BLOCKS	2250							2D	3D
	STEP V									
	NORMAL, LOGNORMAL, CLUSTER KRIGING, UNIVERSAL: POINT, BLOCK OR POLYGON	2300							2D	3D
	TABLES: RESERVES INVENTORY	2400							2D	3D
	ISOCURVES TRACING	2560	2D	3D	2D	3D	2D	3D	2D	3D

2D MODELLING OF OREBODIES

A computerized drillhole data base is the modern way to store data for use in orebody modelling. Such drilling data files should contain all basic data obtained from the analysis of core samples or from drillhole probing. All basic values should be easy to retrieve and to combine for the creation of sub-files. The user can proceed with 2D modelling using values contained either in the main drilling data file, a sub-file created from the main data file, or a sub-file developed through the CADD/GEM system.

Graphical representation of basic data or derived values is an important tool in basic data validation, in the insertion of interpolated values to compensate for missing data on a drillcore section, and in data interpretation.

Several other graphics representations used in ore reserve estimation of a tabular shaped orebody are described in this chapter.

The graphical part of the CADD system was adapted to permit the use of Graphical Kernel System (GKS) in the 2D modelling of orebodies. The new version of the CADD/GEM package is designed for use on a Microsystem SUN 3/160 UNIX.

The CADD's program for the visual representation of drilling information (MEG3000) has been converted to GKS. It allows the user to assign colours of his/her choice to rock type and grade profiles, information that appears on orebody geological section maps. The grade profile can be replaced by grade intervals with an assigned colour for each grade interval or group of intervals (see figure 2).

Another common visual representation of grade or grade-thickness distribution in relation with the geology of an orebody can be provided in the form of contour maps (in colour). Graphical representation of this type within a regular grid (fig. 3) can be used to compute orebody global (in situ) reserves.

Part of the CADD/GEM system comprises standard statistics. This part is being developed to permit the use of graphical representation (GKS) such as histograms of original data, cumulative frequency diagrams on probability scale and regression curves between variables. The development of such visual representation is in progress.

GEM's graphical part is being converted to GKS for the display of program results.

At different stages of an ore reserve estimation exercise, graphical illustration of geostatistical calculations can be used to improve the 2D modelling of an orebody. It should be mentioned at this point that simulation studies can be involved in the process.

The selection of a non-bias cell unit size is important, when undertaking a geostatistical estimation exercise, especially when irregular drilling patterns are involved. In such cases, use of the declustering method is required, involving the weighted average grade of various cell unit sizes. Figure 4 shows an example where the minimum value

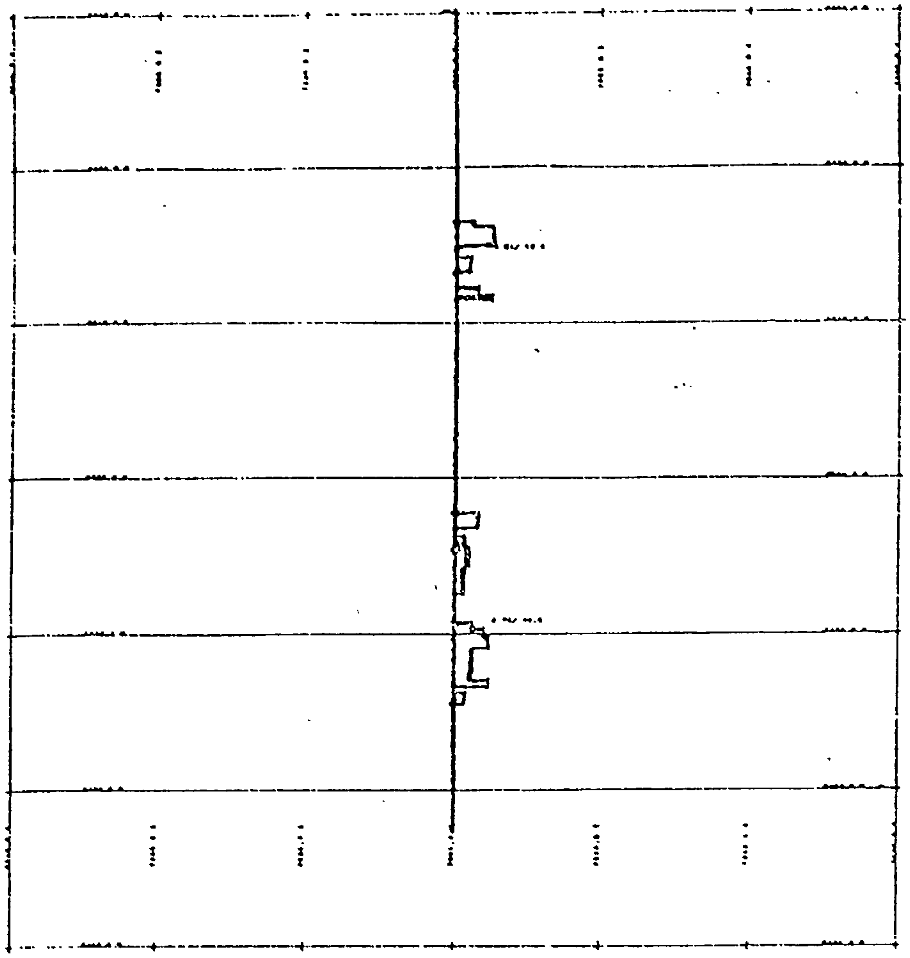

Fig. 2 — Grade profile and economic section along a vertical drillhole

of the curve determines the non-bias cell unit size. That value will be used to establish the geostatistical estimation grid.

The graphical representation of experimental values of the variogram and the curve of the mathematical model (fig. 5) is a routine step in such studies. To display experimental values of variograms in various directions in a plane, a 2D colour graph presentation method is developed to show their contours (fig. 6) to permit visual analysis of an orebody's isotropic nature (or else) and configuration .

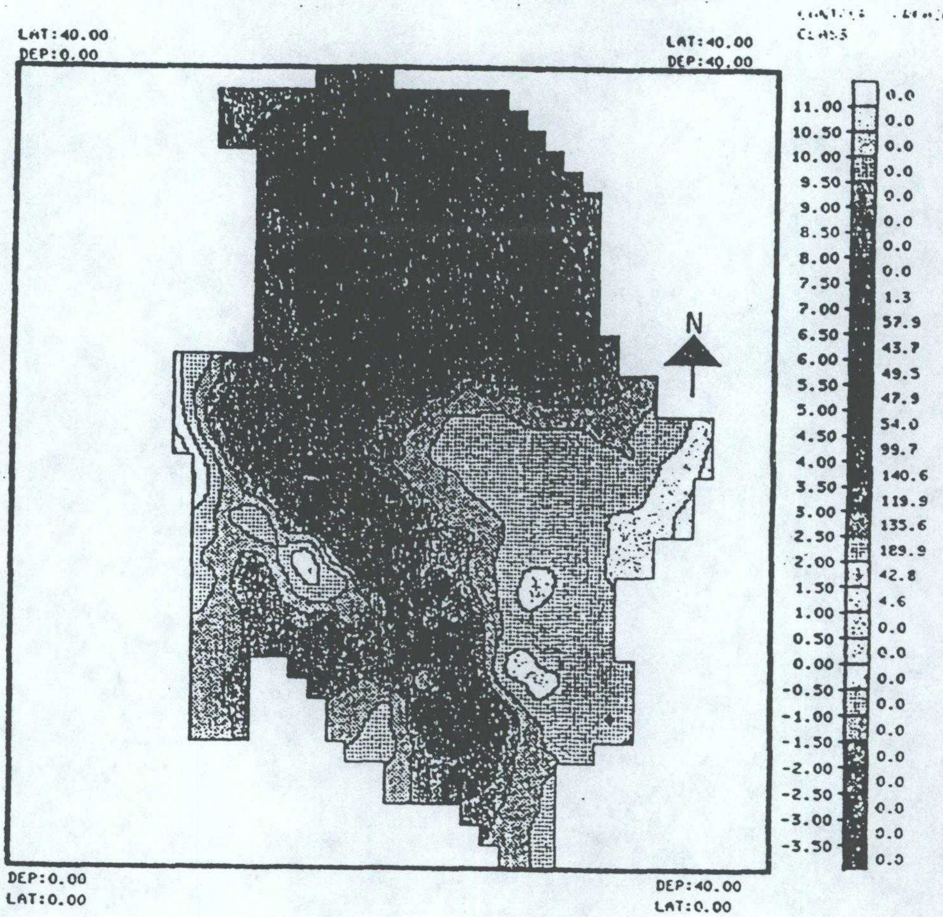

Fig. 3 — Isocurves of grade values

3D MODELLING OF OREBODIES

First, it must be mentioned that a 3D modelling package will require more powerful micro computers than presently available with a suitable memory and a fast central processing unit (CPU). It is anticipated that suitable micro computers will be on the market in the near future at reasonable price.

3D graphics representations are useful for geological modelling and mine planning, especially in the case of orebodies with complex geometries and with high variability of grade and/or thickness. In such situations, 3D modelling can greatly facilitate follow-up of underground mining activities.

CANMET's Mining Research Laboratories are still investigating the acquisition of a basic 3D package to accelerate development for 3D modelling of orebodies. Table 2 summarizes MRL's 3D modelling technology development plan for the coming

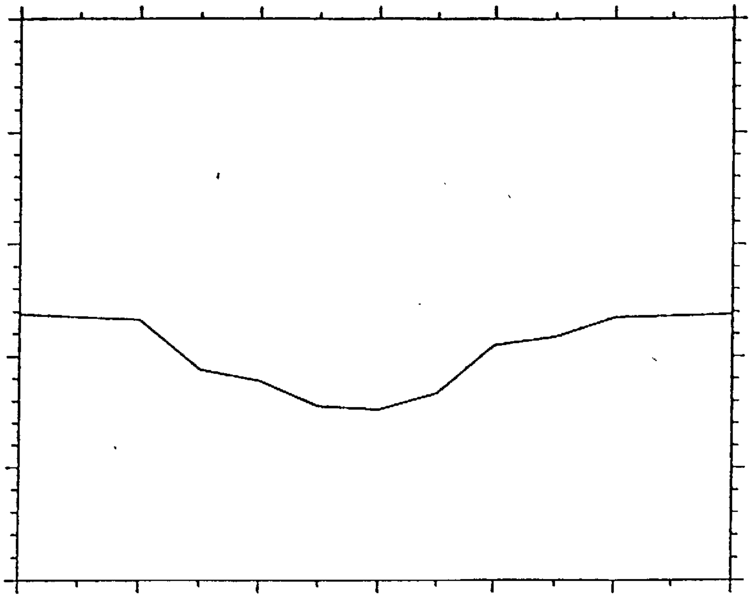

Fig. 4 —Unit cell size vs weighted average grade

years. The modelling packages will be applicable to exercises concerned with geological modelling, mine layout and mine planning.

Geological modelling

During the past 20 years various computer methods have been proposed to solve stratigraphic correlation problems. These methods were based on the use of descriptive lithological and petrological drill logs to correlate several boreholes. Much of the emphasis was placed on the development of statistical techniques for cross-correlation studies to optimize matching between data recorded from boreholes (Day and Tucker 1987).

Recently attempts have been made in 2D and what could be called 2 1/2-D geological modelling to interpret and interpolate geophysical properties from borehole or core measurements. Magnetic susceptibility measurements on core from a granitic pluton mass to quantitatively assess the degree of alteration in the pluton mass, is one of several recent examples in this field of research (Lapointe et al. 1986). Statistical techniques were used in this study. Methods based on computer algorithms for correlation between sampling points was not used.

The development of methods involving algorithms for the 3D solids modelling is practically in its infancy. The hidden-line algorithm method using the picture subdivision technique (Lo 1988) is one of the few methods recently available.

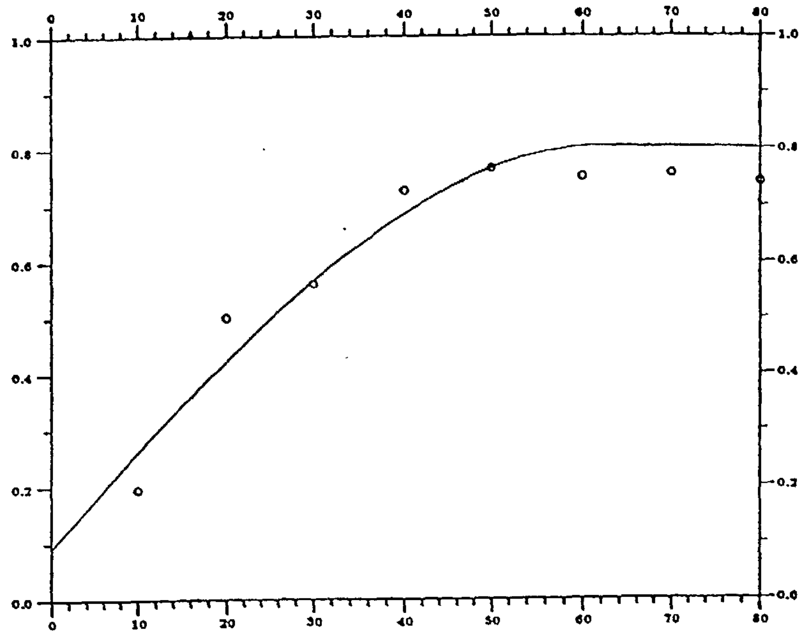

Fig. 5 — Average semi-variogram: spherical model

CANMET's Mining Research Laboratories are presently modifying the GEM package so that it can be used on the Laboratories' SUN computer. In the near future, 3D modelling research will be focussed on the development of geological modelling methods and software. The main objective is to develop computer techniques to handle any 3D shape. Results can be achieved only if proper linkages between descriptive and quantitative data permit the development of computer algorithms. Suitable algorithms are crucial to improve correlation between sampling points and hence to the derivation of more accurate 3D models.

Mine planning

Based on all the models required from the 3D system (table 2), the mine planning model will consist of one or several graphic representations of 3D models showing mining units in relation to the mine layout, including ore transportation and all the required services of an underground operation.

As an example, the design of long-hole drilling patterns with their repetitive calculations can be helped and speeded up by the availability of 2 1/2-D models on

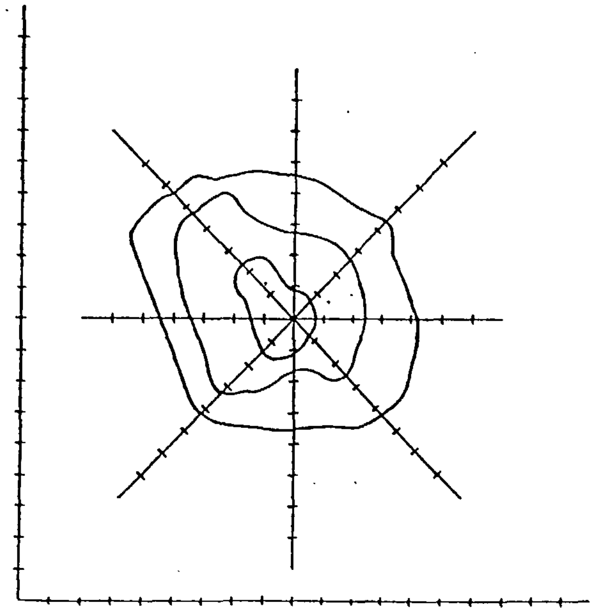

Fig. 6 — Isocurves: experimental values of variograms in various orientations

Table 2 — 2D and 3D graphics modelling

	DOMAIN		APPLICATION		END RESULT
	EXPLORATION	→	DATA MANAGEMENT	→	DRILLING DATA BASE
			(CADD/GEM SYSTEM)		
			↓		
2-D	STATISTICS	→	DATA ANALYSIS	→	STATISTICAL MODEL
			↓		
2-D			INTERPRETATION		GEOLOGICAL AND
	MINING GEOLOGY	→	INTERPOLATION	→	GEOSTATISTICAL
AND			GEOSTATISTICS		MODELS
			↓		
3-D	ROCK MECHANIC	→	STRUCTURAL	→	GROUND CONTROL
			GEOLOGY		MODEL
			↓		
	ENGINEERING	→	MINE LAYOUT	→	MINE DESIGN
3-D	OPERATIONS	→	MINE PLANNING	→	PRODUCTION
	RESEARCH		(3-D algorithms from		MODEL
			accessible 3-D system)		

perspective view. It should become practical to consider several possible design options in order to optimize explosive fragmentation potential. Structural information could also be incorporated and its impact on rock fragmentation simulated to compare with field results.

Once 2D and 3D programming is completed for basic applications, operations research techniques will be introduced in the software to improve planning procedures. This step will involve many facets of mining activity: best location of levels and services (raises, sumps, ore and waste passes) to minimize transportation costs (capital plus operation); best design of stopes, pillars, secondary and tertiary stopes, taking into consideration rock strength and structural properties; schedules of operations based on personnel productivity and/or materials quality; updating of orebody changing geometry because of production taking place, using daily surveying and geological data.

Mine planning involves consideration of a large number of factors in an often complex geometry. The planner must carefully select the best mining plan taking into consideration these factors. The mine planner is in need of additional tools to optimize his/her usual time.

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