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OREBODIES AND MINE PLANNING 3-D MODELLING, PHASE I: GEOLOGICAL CONTOURS AND ORE RESERVES

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OREBODIES AND MINE PLANNING 3-D MODELLING, PHASE I: GEOLOGICAL CONTOURS AND ORE RESERVES ASSESSMENT

by

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ABSTRACT

In 1985, the Mining Research Laboratories carried out preliminary resources and project planning to permit future in-house research directed at developing mine expert systems. With the acquisition of the necessary graphical computer equipment and completion of previous research commitments, a project was initiated in 1986 to develop a 3-D mine modelling and planning system.

The first phase of the project which was completed earlier this year involved the adaptation of the CANMET's well known CADD/GEM package to permit the 2-D and 3-D modelling of orebodies. The adaptation is the subject of the presentation.

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Keywords: Ore reserves assessment, CADD/GEM System, 2-D & 3-D Modelling, graphics representation.

GISEMENTS ET CONCEPTION MINIÈRE MODÉLISÉS EN 3-D: PHASE I: CONTOURS GEOLOGIQUES ET ESTIMATION DES RÉSERVES

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RÉSUMÉ

En 1985, les Laboratoires de recherche minière de CANMET ont fait un examen approfondi de leurs ressources et projets, afin de définir l'orientation de leur recherche interne en matière de systèmes experts miniers. L'acquisition des outils informatiques et graphiques requis et l'aboutissement des projets en cours ont permis de démarrer en 1986 un projet de modélisation tridimensionnelle des gisements et leur planification informatisée.

La première phase du projet qui a été complétée plus tôt cette année concernait la conversion en Fortran 77 du progiciel CADD/GEM bien connu, afin de permettre la modélisation graphique des gisements, bidimensionnelle d'abord, puis tridimensionnelle par la suite. La présentation se limite à décrire les résultats de ce travail.

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Mots clés: estimation des réserves, système CADD/GEM, modélisation 2-D & 3-D, représentation graphique.

INTRODUCTION

The Mining Research Laboratories' Ore Reserves Assessment Group (ORAG) was established in 1975 to provide independant assessment of Canada's uranium reserves and mine production capabilities to meet Federal uranium policy information requirements. In carrying out the reserve assessment task, the group was faced with handling a large quantity of core log data from occurrences, deposits and orebodies across Canada. To efficiently store and manipulate the data and subsequently carry out ore reserve estimation studies, ORAG developed data acquisition and ore reserve assessment systems for use on Control Data Corporation CYBER computers. Both systems have since been commercialized and are presently used by companies and agencies in Canada and abroad in the assessment of very diverse commodities.

The CADD system (Coding and Analysis of Drillhole Data) is used to code, edit and register basic drillhole data for use in the subsequent evaluation of reserves. The GEM system (Geostatistical Evaluation of Mines) is a set of computer programs allowing generation of statistics, variogram computation and kriging estimations with respect to the reserves. The two systems combined consist of twenty-five FORTRAN and COBOL computer programs.

Recently, the CADD and GEM programs have been converted to FORTRAN 77, to end machine dependency. Debugging is now completed; the new GEM software can also be used on VAX and SUN systems. Presently, effort is being made to modify some of the GEM programs to take advantage of graphics modelling.

BACKGROUND

Despite the persistent need of geologists and mining engineers to visualize complex geological structures in space, ameanable or not to economic exploitation, there has been resistence on their part to use mathematical models as an aid. This attitude stems from the complexities of ore reserve delineation and the oversimplifications that can be provided by mathematical models. Also, when only imprecise data is available, the use of rough methods of estimation and planning are reasonable.

With the drop of commodity prices in the 1980s, geologists developed a need for upgraded raw geological data for decision making purposes. The availability of upgraded data bases has led to greater use of improved analytic methods in ore reserve assessment. It is still necessary, however, for a mine planner using these improved methods to understand the structure and how they should be zoned for modelling.

Visual representation of ore deposits for study purposes, however, remains a major handicap to the development of mathematical models in the mineral industries.

Quantum advances in computer miniaturization over the last decade, however, has resulted in new graphical tools that are capable of representing orebodies and other structures in three dimensions. Until now, most software has developed to provide only 2-D representation of underground structures. However, three-dimensional modelling is becoming increasingly popular, but at additional costs to the user. Its use also requires a more powerful computer system – a super-micro or better, if a suitably fast response graphics terminal is to be available for design studies.

It is MRL's view that it is important for the mining industry to develop a system which will permit the three-dimensional representation of geological and mine structures with facilities. Adaptation of the GEM packages for use on super-micro computers to meet this objective will make more accessible to geologists and mine planners models to more realistically assess limits, grades and stope sizes of orebodies.

CADD SYSTEM

Over the last decade, ORAG accumulated a very extensive primary geological data base on Canadian uranium deposits using various coding techniques. The analysis of large amounts of drillhole data is required to perform valid ore reserve calculations. The purpose of the CADD system is to code and edit such data, as well as to prepare data for use by GEM packages. The CADD system was designed using a sequential rather than a randomly indexed file system for the following reasons:

1. with a few exceptions, the amount of drillhole data per file is not excessive and can be handled by sequential files;
2. drillhole data sets are complete when received by ORAG; and
3. for most uranium deposits, all drillhole data are used in reserve estimation.

CADD can accomodate the entry of data from any standard logging system used by a mine geologist. Preferably, the data should include the following drillcore information:

— drillhole collar location;
— drillhole deviations;
— drill core density;
— percent core recovery;
— chemical assay of core, and/or radiometric readings;
— simple geological, lithological and structural information.

With respect to the last point, it is often necessary for the geologist entering the data into the CADD system to sort and select the necessary lithological information from total available drill log information.

The coding, correction and adaptation of drillhole data to permit ore reserve estimation studies, in ORAG's experience, is a major task. A major percentage of a reserve estimation study must be spent in data validation. Error detection requires that specialized staff be used to create the computer data files. Drillhole coordinate or grade errors can have dramatic effects on forthcoming estimations. Most errors can be easily identified, when expert technical staff is used in data assemblage, but there are always some undetected errors in the final files. Some of these will be identified later in the final stage of the estimation study, because values are provided which are inconsistent with other geological information.

To aid user use of the initial card system, an interactive data entry has been developed, called Computer Drilling Data Entry/version 1.0 (CDDE/1.0). The present version is written in VAX 11 Fortran – and presently being used on a VAX 11/750 VMS.

The CDDE/1.0 program was designed to utilize standard drillhole information, and to allow very rapid data entry and validation(Fig. 1 & Fig. 2):

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

— by entering data columnwise, rather than rowwise;

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

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

After completion of each form, and again at the completion of all forms, the user has an opportunity to view, correct, modify the completed form(s), and/or to proceed. After data storage, however, no more data modification is possible with the CDDE/1.0 program. Further modification of entered data is possible with system editors.

The same data entry procedure may be adapted in the future for use with the Laboratories' graphics terminal, using a mouse or window menu-driven software. However, it is not a priority area of development for the Laboratory. It is presently planned to enter data to the Laboratory's SUN system from the Laboratory's VAX mini-computer.

GEM SYSTEM

The GEM system is comprised of about 20 software programs assembled into four different option groups (Fig. 3). The first software option is oriented towards providing the user means of displaying diamond drillhole intersections, a profile of grades and economic intersections in two dimensions (Fig. 4 & 5). The second software option divides the data into equal length segments and evaluates reserves using moving average or inverse squared distance methods. The third software option produces for further analysis basic statistics, histograms and other graphics (Fig. 6), variograms by either the sector or the blocking methods, and trend and generalized covariance data (Fig. 7). The fourth software option permits access to various estimation procedures: polygons, kriging – point, block, cluster or universal, and generates isocurves or tables of reserve inventory.

It is thus clear that the GEM system can access many different estimation procedures. These procedures can be classified as follows (Fig. 3):

— geometrical models: sectional or polygonal;

— inverse distance models: squared or moving average;

— geostatistical models: block, cluster, normal, lognormal or universal.

Evaluations made on tabular or 2-D deposits are distinct from evaluations made on all other types of deposits (3-D).

The GEM software used to construct geometrical models starts the process by computing composite intersections (Fig. 4) or equal length segments along drillholes. The location of the composite segments defined by the geometrical modelling are indicated as 2-D model plans. Graphical representation can also be made as isocurves when the variable to highlight is distributed on a regular grid.

For the purpose of discussion, the inverse distance models are considered a moving average method of estimation. For stratabound or tabular orebodies, two-dimensional variables are defined. The same procedure of composite intersections is used to generate basic data for the model. Programs are then run to assess the average grade of regular blocks using the moving average model. Maps are printed to scale, showing tonnages, amounts of metal and average grade of each block and of the deposit, in relation to cut-off grades as specified by the user. Mineralized block contour maps can also be generated.

Discussion of GEM's geostatistical capabilities will be limited to discussion of three-dimensional geostatistical estimation. In the simplest case, only one variable, the grade, will be assessed using equal length segments. With the GEM system, three-dimensional experimental variograms are first produced (Fig. 7) and with them a study is carried out of the proportional effect, looking at local variances and means. Theoretical models are then fitted on experimental variograms and used for kriging purposes: normal, lognormal, block, random or universal. Estimated variable within blocks with its kriging variance is then printed on maps generated to scale. Isocurves of estimated variables and variances can be produced as well.

All original software was developed using a Control Data Corporation Fortran compiler with extensions. In the last few years, our Laboratory has converted all GEM software to Fortran 77, a universal language for most computers. GEM and CADD programs can now be run as well on IBM and VAX machines. It is evident that a VAX 11/750 system cannot produce results at the same speed as mainframe computers. Until now, however, this has not been a major handicap.

MRL is presently in the process of modifying the GEM package so that it can be used on the Laboratories SUN computer, a super-micro enhanced with a colour graphics monitor. Initially, only 2-D software will be transferred. In a few months, 3-D graphics will be considered. Mining Research Laboratories' personnel believes that 3-D modelling of orebodies is an essential key to better and safer mine design.

CONCLUSION

The Ore Reserve Assessment Group of CANMET's Mining Research Laboratories has been active in developing tools permitting more precise and elaborate ore reserve estimation studies of orebodies. Information contained within the national Uranium reserve data bank is made available to owners in various ways for their use on request. Recently, the new owners of a prospect asked to be provided with the most updated information about their new deposit.

The first phase of modernization of the CADD/GEM package is underway. On the second phase of the project, it is planned to develop a mine modelling and planning system for one mining method, which will permit simulation of openings and assessment of stability, taking into consideration the uncertainties of orebody shape. In subsequent phases, research will be directed at extending the project so that other mining methods can be treated, ore reserves assessment carried out and expert criteria for mining method selection become available for use.

CANMET is interested in providing the Canadian mining industry with the most advanced tools for making the best possible decisions concerning resource utilization. The introduction of 3-D graphics is seen within CANMET as a major step in improving decision making. MRL is responding to this perceived need by transforming existing proven software to a suitable new computer system. Future steps will involve the development of new software to support 3-D modelling of mining methods, and simulation of long term stability. CANMET hopes to provide industry with a new sophisticated decision tool in the next few years.

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