A Proposed Method of Dynamic Ore Reserve Assessment for a Caving System of Mining

By A. F. SPINKS,* and S. P. NICHOLLS,* B.Sc.

SYNOPSIS

The Lower Orebody at Chingola Division of Nchanga Consolidated Copper Mines, Limited, is a stratified orebody that is mined by a continuous caving system. The accurate determination of the developed and semi-developed ore reserves has always been difficult. The new system proposed in 1971 is designed to update and, as new information becomes available, to account for the depletion of, the reserves.

There are three main inputs to the system. These are borehole data, survey data and extractions data. The borehole data are input to a geological borehole master file system, which holds every recorded detail of a borehole in an easily extractable form. These data can be extracted for ore reserve calculations or for contour mapping of orebodies and rock types. The grades for use in the ore reserve calculations are extracted from the relevant boreholes.

The survey data are information on the position of the blocks and drifts, taken from plans, and information on the scraper driff and trough drive positions taken from sections. The information is extracted from the plans and sections using a D Mac pencil follower. The ore reserve is calculated from the survey data and the borehole data.

Data on extractions are taken from scraper operators' logs, tramming records, skips hoisted records and accepted mill tonnages and grades. Using these data, the mill tonnages are reconciled back to the drifts, to deplete the current ore reserves.

As new workings are brought into operation and further evaluation holes are drilled, the relevant data are input and the new developed ore reserve is calculated.

INTRODUCTION

Various computer systems for the calculation of ore reserves for the Lower Orebody have been run at Nchanga Consolidated Copper Mines, Limited, in the past, as well as a lengthy manual system. All computer systems have proved faulty in some way and have produced inaccurate values. The programs in use in 1969 had been re-written twice as a result of changes in computer hardware and a complete re-design was agreed upon, using more sophisticated methods of calculation. A project team was formed in 1970 and the system is scheduled to be implemented in 1972 on the IBM 360/65 computer installed at Kitwe.

MINING METHOD

Primary development of the Lower Orebody at Chingola is confined to the footwall rocks. The primary haulages and material crosscuts serve as sites for initial evaluation drilling.

Ore is extracted by the 'advancing continuous caving' method. Trough drives are mined approximately 1.8 metres below assay footwall (A.F.W.) and blast holes drilled to the top of the Arkose (usually top of solids) prior to blasting. The trough drives are situated above the finger raises on the south side of the scraper drifts which are arranged in a herring-bone pattern approximately 14 metres below assay footwall (A.F.W.) within each mining block as shown in Figs. 1 and 2. Above the Arkose the orebody rock is not strong enough to support mining workings and with the extraction of the Arkose the remaining ore caves readily.

The caving of the orebody progresses down dip. Broken rock gravitates through finger raises into scraper drifts and is transferred by scraper units into loading boxes above the haulages.

BOREHOLE MASTER FILE

In order to perform calculations involving grades of ore within the orebody, a file of grade values over the relevant sections of all relevant boreholes is required. These data, in the past, have been extracted manually from borehole logs, converted into a usable form and punched on cards as computer input. The new system will require more detail than the old, so that all relevant data from the borehole logs would have to be extracted and treated again. The dangers of repeated manual handling of these data are the possibilities of coding errors, and of not entering relevant data. The possibility of compiling a general borehole master file system, containing every detail about every hole on the mine, was then explored. The grades and ore contacts could be extracted from this file, without any loss or mis-coding.

The file would have other uses for the geology departments, enabling contour plans and sections of rock types, assay hanging and footwalls to be kept up to date by machine, thus relieving the geologists of this work. In the past it was not always possible, using a manual system, to keep the contour plans and sections updated on a day-to-day basis and, as a result, they quickly became out of date. Errors in the laying-out of new development workings caused by the use of out-dated information were proving to be very costly.

The decision to proceed with a geological borehole master file was taken late in 1970. The basic work on as to which data in what form were to be included in the system was completed early in 1971. This permitted the starting of the system design and programming. As the inputs were finalized, the programs were modified to suit. The work on input data and associated checks were completed by September, 1971, and the coding of all new boreholes on new input documents started.

A team of three clerks under the supervision of a geologist was formed to transcribe all the old borehole logs onto the new input sheets.

*Computer Department, Centralised Services Division, Nchanga Consolidated Copper Mines, Limited.

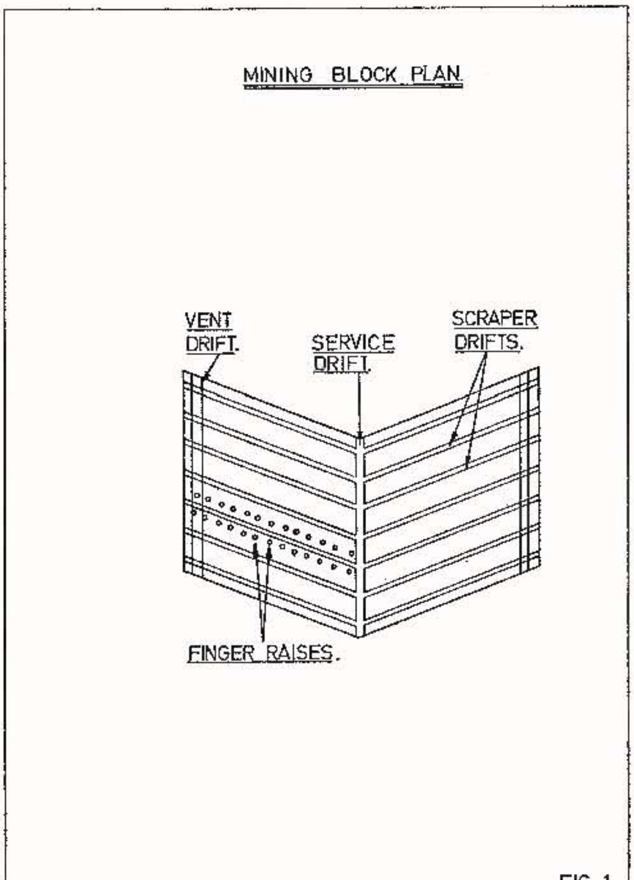

FIG. 1.

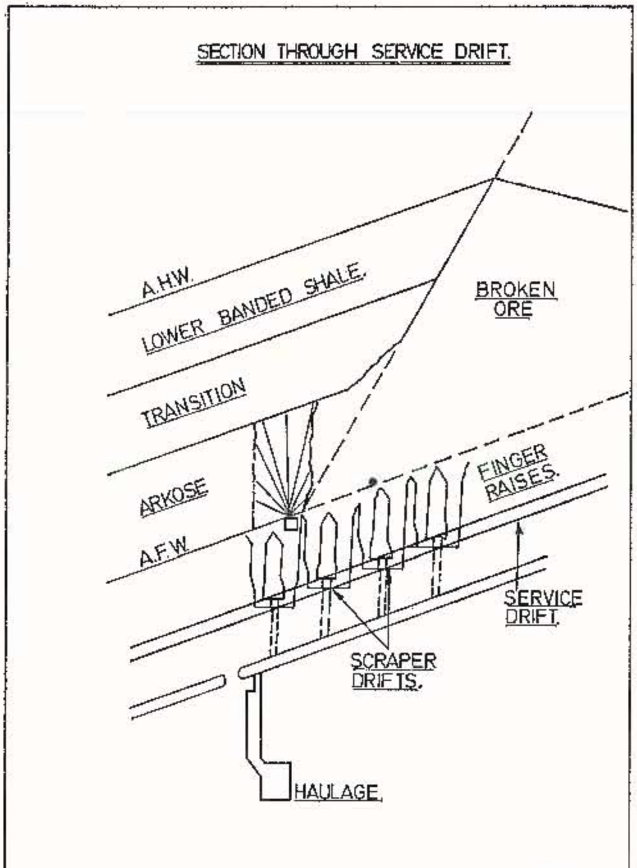

FIG. 2.

The programming was well advanced by this stage and was completed at the end of October, 1971. The data items considered in this system fall into four types. The first type are basic data, that is, location of collar, co-ordinates of collar, dates of drilling, etc. The second type are survey data consisting of the inclination and azimuth of the hole at various distances from the collar. The third type of data consists of the intersections of the hole with rock types, geological features such as faults, and assayed hanging and footwalls. The last type of data is the log of core samples, that is, a complete description of each core sample. The system design had to cope with a variable amount of data as the length of holes was not constant, and short prospect holes were not, in general, surveyed.

Prospect raise information is included on the master file as being a hole with contacts information only. The data concerning one mining block originate from an average of 13 diamond drill holes and 36 prospect raises. This information is collected over a period of approximately two and a half years, and it is essential that contour plans and drift sections should be kept up to date during the various development phases of the block. About 30 mining blocks are under development at any time, so the amount of work involved is considerable. The area contour plans, each covering several blocks, may need modification almost daily for several years as a continuous stream of new data becomes available.

The basic file design consists of a set of four linked files. The basic data for a borehole are always present and do not vary in quantity, and were chosen to form a single master record for each borehole on an Index Sequential File, keyed on borehole number.

The other three files are direct-access files, one for each data type. Thus, a borehole may have a number of survey points along its length. Each point becomes a logical survey record with borehole number, drilled distance, angles, and calculated absolute co-ordinates. A counter field in the basic data record holds the number of logical survey records associated with that borehole, and an address field gives the address of the first survey record for that particular borehole on the survey data file. In order to conserve disc space, the logical survey records are blocked by the update program to form physical records. Each physical record contains borehole number, ten sets of survey data, and an address field carrying the address of the next physical record for that borehole.

A similar organization is used for the contacts file and the core data file.

A program for the analysis of core data is used to determine the positions of footwall and hanging wall contacts, and lithological, that is, rock type, contacts. The calculated contacts are checked by a geologist before the file is updated and can be deleted or overwritten if so desired. The only other calculation involved is the calculation of co-ordinates of survey points. An algorithm is used which assumes an arc of a circle between survey points, and calculates the absolute co-ordinates of the survey points in a series starting at the borehole collar. The same routine is used to calculate the absolute co-ordinates of all contact points.

Routines are available for the easy retrieval of this information from the files. Subsidiary indexes are set up as required for boreholes relating to mining blocks or plan areas. These indexes are updated automatically as boreholes are added to the files. Thus, using the plan area index, it is possible to draw automatically contour plans of top of rock types or assay footwall or assay hanging wall, using the CALCOMP G.P.C.P. package. It is also possible using the mining data file to draw sections of drifts.

For ore reserve purposes a derived file is generated. This file contains the assay hanging and footwall, the top of Arkose, the top of Transition Contact Points and a table of grades equispaced for each of the three main rock types, which are Arkose, Transition and Shale. There are 10 grades in Arkose, five in Transition and 10 in Shale. Both total copper and acid-soluble copper grades are held.

MINING DATA FILE

The D Mac Pencil Follower is used to establish for each 1/250 plan of a mining block the scraper drift centre lines, together with ventilation and service drift outlines. For each scraper drift within the block, the top of trough drive and top of scraper drift are obtained from 1/250 sections.

These pencil-followed data are transformed to absolute co-ordinates on the Chingola grid system and stored in the relevant drift record on mining data file.

Generated from the contacts on the boreholes file are interpolated sections of orebody and strata along the drift centre line. Using these sections and the input scraper drift and trough drive section data, a full drift centre line section can be plotted on the CALCOMP plotter.

The proposed basic 'ore reserve' calculation unit is an interpolated quarter drift, and adjacent boreholes are associated with each unit for grade calculations. Normally the list of boreholes for each unit is selected automatically by the system through an examination of the borehole file. It is possible on input to override this selected list if, for instance, faulting occurs in the neighbourhood of the drift.

PROPOSED CALCULATION METHOD

The calculation of original tonnage and grade of ore will be performed using data derived from the borehole data file and the mining data file.

From the mining data file, the corner points of the drifts and quarter drifts will be calculated. For each quarter the plan area is calculated from the co-ordinates of the corner points.

The elevations of assay hanging wall, assay footwall, top of Arkose and top of Transition can then be derived at intervals along the centre line of the drift, by interpolation from the borehole data. The sectional areas of footwall waste and the three rock types within pay ore will be calculated from these and from the data on trough drive elevations held on the mining data file. The areas will be calculated for each quarter drift, from the drift centre line section, and then divided by the length of the quarter drift, to give the mean thickness of footwall waste, Arkose ore, Transition ore and Shale ore.

It is proposed that the footwall waste be divided into small slices and the pay ore into 25 slices. These 25 slices consist of 10 equal slices in the Shale ore, five equal slices in Transition ore and 10 equal slices in the Arkose ore. The quarter drift area is multiplied by the slice thickness to give volume and divided by specific volume to give weight of ore or waste in tonnes. Thus, the weight of each slice for each quarter drift is calculated. The grades associated with each slice are interpolated from the grades in the corresponding slice in the boreholes associated with the quarter drift. The interpolation function will use inverse square of distance, with a directional weighting. This ensures that little account is taken of boreholes which are overshadowed by a nearer borehole at about the same direction from the point of interpolation. The tonnage, together with total copper and acid-soluble copper grades can thus be calculated.

For partly-developed blocks where the trough drives are not yet in existence, a calculation will be performed to give rough values of tonnage and grade for the slices over the whole block. The orebody thickness will be taken as the mean of the thickness in all associated boreholes and the grades for each slice taken as the mean of grades for that slice in the associated boreholes. The footwall waste is presently fixed at an arbitrary thickness of 1.8 metres.

The size of slice thought to be required by the mine planning and control departments is, however, thicker than the slices used for calculation. For planning, the optimum size of slice is about five metres. Each quarter drift, within each rock type in the orebody, will be split into a number of slices of about five metres. The number of slices varies between rock types and within rock types over the orebody. The calculated slices will be assigned in whole or in part to form the new five-metre slices. For each five-metre slice within a quarter drift, information on original tonnage, grades, thickness and rock type will be stored on the Ore Reserve Master File.

ORE RESERVE MASTER FILE

The Ore Reserve Master File contains a dynamic record of the development and depletion of each quarter drift within the system.

Whenever information from a new borehole becomes available, the latest original ore reserve can be re-calculated and stored on the master file together with an updated grade table and slice tonnages for that quarter drift. A complete record of the depletion of each quarter drift will also be held on the master file, together with a mining category to signify the present stage of development.

As the total ore reserve has to be declared annually by law, the start of year balance will be held on the master file throughout the year. As new information becomes available the computer will update the reserve on a quarter drift basis and will, therefore, be able to maintain an accurate reserve as depletion proceeds.

EXTRACTIONS

Data on extractions will be taken on a monthly basis from scraper operators' logs, tramming records, skip hoisted records and accepted mill tonnages. Using all these data, the mill tonnages will be reconciled back to each quarter drift, enabling the total extracted tonnages to mill and to waste to be calculated for each quarter drift each month. These reconciled tonnages will be fed into the monthly 'Ore Reserve Accounting' system which updates the extraction information on the 'Ore Reserve Master File' and produces an accounting report.

The accounting report will consist of:

(i) the latest original reserve,
(ii) the start of year balance,
(iii) the extractions this month to mill and to waste,
(iv) the extractions this year,
(v) the total extractions to date, and
(vi) the latest balance.

Each of the above categories is broken down into Pay Ore strata, Footwall Waste strata and combined total strata (that is, Pay Ore + Footwall Waste), giving the tonnage of material and the tonnage and grade of total and acid-soluble copper in each strata.

The drift reports will be summed to give a similar report on reserves, extractions and balances for each mining block.

ACKNOWLEDGEMENT

The authors wish to thank the management of Nchanga Consolidated Copper Mines, Limited, for permission to publish this paper.