Establishment and Calculation of Mineral Reserves

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Introduction

Mining enterprises normally require heavy machinery and a large labour force thus involving huge initial investments, besides being very risky and hazardous in nature. It is owing to these characteristic features of mining industry that capitalists hesitate to adopt this business. In order to ensure regain of invested amount, of course with substantial profit, necessity of sufficiently establishing mineral reserves and their quantity becomes of paramount importance.

Broadly speaking, establishing of mineral deposits can be categorised in 3 terms namely (1) Surficial method, (2) Alluvial method and (3) Underground method, and each has its own significant process of quantity calculation. In a short communication, as this is, it is hardly possible to elucidate, even with brevity, all the aspects of the problem. The author has, therefore, concisely discussed only the method of establishing and calculating mineral reserves through surficial method (Boreholes).

Circumstances Warranting Boring

A prospective mineral reserve needs further exploration in order to prove the deposit. During preliminary stage of exploration for a prospective deposit, necessary geological data rae usually obtained viz. surface exposures, if any, with their dip, strike, thickness, mineral constituents, series of beds overlain and underlain by it, etc. Stratigraphical information of the surroundings is also collected along with its topography, position of nullahs, river and stream beds, e.g. faults, folds, cracks, and other rock structures. Sometimes help is also taken from exposures or previous mine workings near the deposit under investigation for correlative study. Main idea of exploration for the purpose of proving a deposit is to find probable position, form, size, extension, mineral character, and value of an ore mass. Correct geological information as obtained during primary work on prospective ore body often proves helpful in determining one or more of the above requisites quite prior to exploration for proving the ore body. In some cases such information offers no clue, and exploration is almost based on experience and is merely a guess work. In both the above cases, it becomes essential to adopt boring for all or remainder of the requisite information.

Surficial boring for the establishment of the reserve is only taken in hand when the existence of a deposit has already been disclosed either by exploratory boring, by neighbouring workings, by actual outcrops, or by other comprehensive indications. In case the overburden does not exceed 3 feet to 4 feet in thickness when it is required to follow short, narrow, irregular veins lying flat or nearly horizontal, close trenching or complete stripping of overburden may be resorted to. If the soil 4 feet exceeds in thickness to 8 feet and it is necessary to trace and pursue wide veins, beds, and masses, it is economical as well as effective to adopt trenching at wider spaces. For sufficiently large and uniform ore bodies and also when overburden is thicker, test pits are expected to give good results, and these furnish fair data of the ore body, its size, shape, etc. Experience has revealed that boring from surface adequately suits for larger deposits of fairly uniform grade, as masses or beds dipping upto a range of 50° or 55°.

It is from the boring results that information is available on the basis of which it will be decided to abandon further exploration or to continue it under careful planning for subsequent work. In most cases boring is prerequisite to underground exploration because it furnishes much valuable information with comparably smaller total footage of openings than uncovering the deposits blindly and in a slipshod manner through underground workings which entail heavy expenditure and might be wasted with no profit. Boring is quite an expensive process and, therefore, should not be resorted to except when cheaper methods like trenching, pitting, drifting and shafting are unable to give sufficient information enabling conclusive proof of the deposit. Among other things, choice of these methods as well as boring calls for thorough consideration of factors like type of ore body, cost of operation, speed of penetration, purpose of work, and transport problems.

Choice of Equipment for Boring

Applications of boring in connection with prospecting and exploration may be location of minerals covered by rock, soil, swamp or water; search for extensions on strike or dip of known ore bodies, and water-bearing strata; detailed exploration of ore bodies for estimating tonnage and value. From these applications it may be seen that the present discussion is for detailed exploration of ore bodies for establishment and estimating tonnage and value of mineral reserves. With this view, generally the following three kinds of drilling are adopted.

(1) Churn-Drill Boring

(2) Diamond-Drill Boring

(3) Shot-Drill Boring

Churn-Drill Boring. It is cheaper than other types of boring but the disadvantage is that only sludge is obtained from the borehole and not the core. It is, therefore, usually utilized for penetrating upper beds in case of deep holes. It is also reliable and conveniently used with thick, relatively flat-lying shallow deposits in which mineral distribution is uniform and underground water problem is such as to produce a relatively thick sludge. However, it does not give any indication of the inclination of beds, but sludge obtained from it provides reliable results if carefully carried for assay value.

Diamond-Drill Boring. In this type of drilling cost is greater but it produces generally two samples, one in the form of core and the other as sludge. Cent percent recovery of core is rarely possible, even if the ground penetrated is compact and hard, but efforts should be made to get core recovery as high as possible, because this core produces a more precise information about the general stratigraphy and texture of the beds traversed by the drilling bits. It furnishes accurate information of inclined deposits to find out the angle between the beds traversed and the core-axis and thus from this angle and length of penetration through deposits, estimation of true width can be made. In peculiar cases, which are rare, results may be far from true conditions. Figures (1) and (2) depict two cases whereby erroneous results can be very easily and convincingly interpreted. From the boring results, it may be taken in Fig. (1) as if there were one thick horizontal seam 'CD', whereas it is a thin seam folded as a syncline. Similarly in Fig. (2) there appear two seams though in fact it is one, and two parts of the same seam overlap due to a reverse fault. Therefore, to guard against such possibilities of misleading characters, boring results

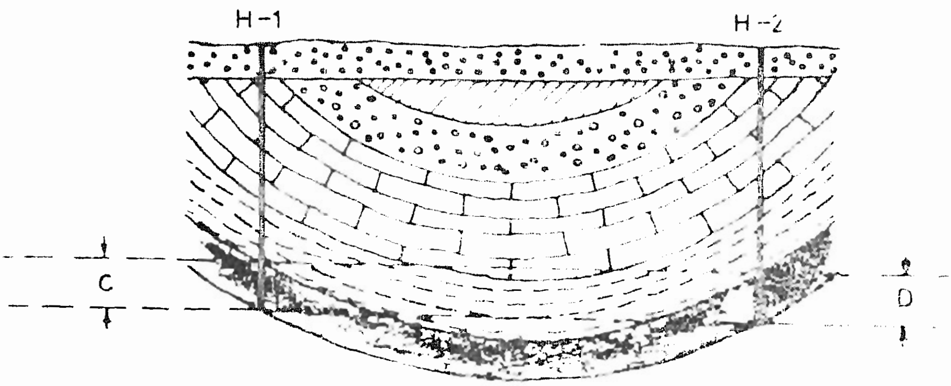

Fig. 1

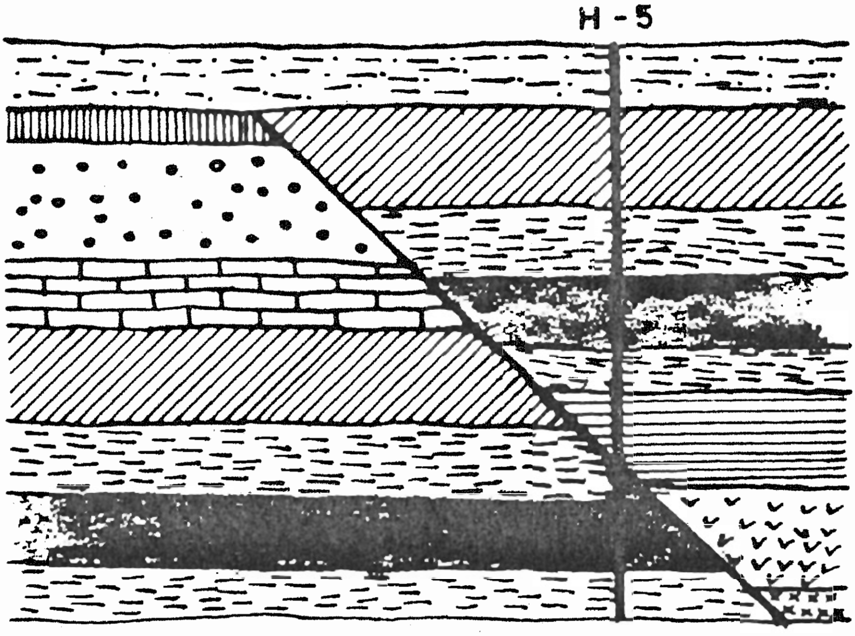

Fig. 2

should always be inferred giving due consideration to collateral geological evidence. However, in such cases deflected diamond drill holes may be bored for getting a duplicate section of the formation from the same hole, and thus additional data may be obtained cheaply.

Shot-Drill Boring. Shot-Drill boring, though cheaper than diamond drilling, is generally not recommended for sampling purposes. The chief disadvantage is that it offers difficulty in computing results. Core obtained in this case is of a larger diameter than that obtained by diamond drilling, but due to much vibration of the equipment, samples are diluted from wall cavings and wearing of shots. A great disadvantage of this method is that holes drilled are seldom truly vertical.

Location and Spacing of Boreholes

Location and spacing of boreholes is quite important and calls for serious consideration of all other geological data available prior to commencement of drilling. Positions of boreholes are first marked on a topographic map of the area under investigation. Usually co-ordinate system is employed for marking such positions. Point of origin of such a system and direction of axes are best selected by keeping in view the prevalent workings or presumed run of mineralization. Borehole positions can easily be chosen if there exist surface exposures of deposits and their dip and strikes are known. Sometimes East-West and North-South co-ordinate lines are primarily selected and sometimes co-ordinate lines are selected along the diagonals of the squares formed by the above lines. In few cases both systems are initially included. Topography highly influences position of boreholes and hence deserves serious thoughts. Co-ordinate lines are drawn on the map at a distance of 100 feet to 400 feet apart. This distance depends upon inclination and structural formation of deposits. Then marking of positions of boreholes on points of intersection of co-ordinate lines is done. Spacing between boreholes along the direction of strike may normally be greater than across it. No hard and fast rules could be

DIAGRAM SHOWING

BOREHOLE LOCATION and SPACING

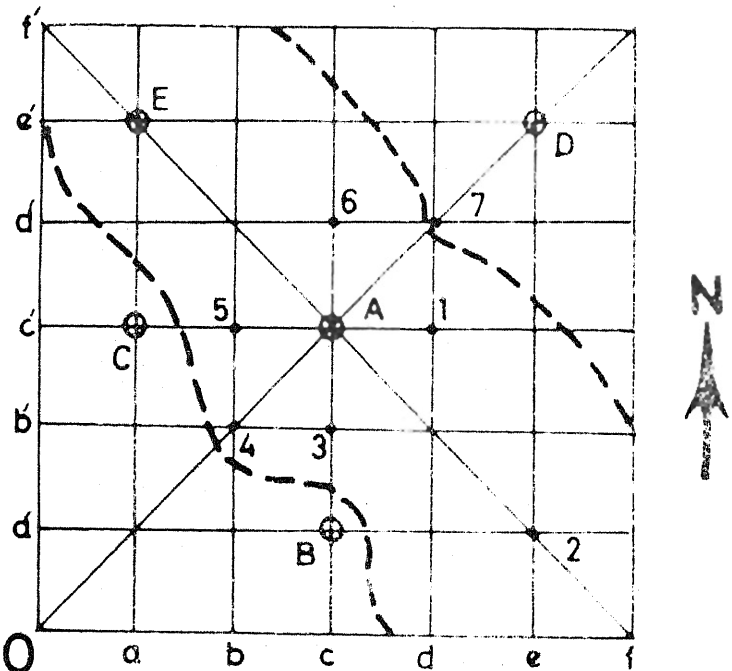

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Fig. 3

quoted for it, yet for less disturbed and uniformly inclined deposits (moderately inclined, say upto 40°) the distance in the direction of strike as well as dip can still be longer to any range upto 1000 feet or more. A diagram (Fig. 3) showing likely position of an ore body along with systems of co-ordinate lines and position and spacing of holes is given here to throw more light on the above discussion. But diagrams are mostly independently prepared for each deposit according to various conditions and circumstances.

In this diagram, point O is origin of the co-ordinate system and co-ordinate lines at a, b, c, d. e, f, and a′, b′, c′, d′, e′, f′ are each 100 feet apart and primarily selected along East-West and North-South directions respectively. Dotted lines show the boundary of ore body. It is first presumed that trend of ore body is along the North-South direction. Therefore, holes A & B are to be first selected and bored. Let there be ore at A and hole B barren. Then it may be presumed that trend of ore body is East-Westerly; therefore hole C can be drilled. In this diagram it is also a barren hole. Now choice is only left to suggest trend of ore body either North-Easterly or North-Westerly. Hole D if selected now, gives barren result and then hole E proves beyond doubt that direction of ore body is North-Westerly. After having concluded as regards the general trend of ore body, close drilling can be commenced at holes 1, 2, 3, 4, 5 and 6. It would be seen that hole 2 is along general trend of the ore body. It is at a larger distance and proves in advance that boring in this direction may be continued further.

Recording, Sampling and Averaging of Boreholes

While boreholes are drilled, an accurate and careful record is maintained by the drilling engineer, a sampling chemist, and a geologist. The daily logs from the first two persons, along with report of geologist, are recorded on proper chart for each hole indicating separately consolidated position of each run (a unit of drilling), which is normally taken as 5 feet. Such charts include information like hole number, its location (in co-ordinates), and collar elevation; date; depth and size of hole; sludge colour; assay values and their averages; nature of ground traversed e. g. soft, hard, medium etc.; condition of wall cavings; loss of water; core recovery in length and percentage, depth penetrated; quantity of sludge and core obtained in weight and volume. Samples from run are then assayed separately from sludge and core.

From the discussions in previous paragraph, it will be seen that in case of only churn drilling, sludge samples alone are obtained. But in diamond and shot drilling, core and sludge are recovered separately. Since cent percent recovery of core in both the latter cases is rarely possible, some part of core gets crushed and mixed with the sludge.

There are many practices for averaging assay values of these mixed types (partly core and partly a mixture of core and sludge), but the best of these would be assaying core and sludge separately and finally their values combined in proportion to their volumes. This gives reliable result.

Formulae applied in this type of averaging for a single run are:

$$A = \frac{A_1V_1 + A_2V_2}{V} = A_1\frac{V_1}{V} + A_2\frac{V_2}{V} \qquad \text{(i)}$$

Because, $V_1/V = C/L \times D^2_1/D^2$ and

$V_2/V = 1 - (C/L \times D^2_1/D^2)$

Therefore, substituting above values,

$$A = (C/L \times D^2_1/D^2)\,(A_1 - A_2) + A_2 \qquad \text{(ii)}$$

Where D = Diameter of hole in inches (diameter of hole is taken as diameter outside bit carbons plus a tolerance of 1/32 inch).

D_1 = Diameter of core in inches (diameter of core is taken normally the diameter of bit inside carbons after deducting a tolerance of 1/16 inch from it).

L = Length drilled in inches for the run.

C = Core length in inches for the run.

V_1 = Volume of core in cubic inches.

V_2 = Volume of sludge in cubic inches ($V - V_1$).

V = Volume of core and sludge in cubic inches ($V_1 + V_2$).

A_1 = Assay of core only in any unit.

A_2 = Assay of sludge in same unit.

A = Average assay of core and sludge in same unit.

After having calculated average assay of each run in a hole, average assay value of ore in one complete hole is determined. The formula applied in this case is :-

$$A_H = \frac{A_1L_1 + A_2L_2 + \ldots\ldots + A_nL_n}{L_1 + L_2 + \ldots\ldots + L_n}$$

where A_H = Average assay value of a single hole.

$A_1, A_2 \ldots\ldots A_n$ = Average assay value of 'n' number of runs in a hole.

n = Number of total runs in a hole

$L_1, L_2, \ldots\ldots L_n$ are respective lengths of these runs in a hole in one and the same unit.

Estimation of Ore Tonnage and Value

There are various methods of stating quantity of mineral reserves. Some prefer to mention ore reserves in tons, along with their assay value per ton. In some cases only metal content of the reserve is stated in tons. In case of alluvial deposits the reserve is reported in cubic yards and metal content per cubic yard. In respect of precious metals like gold and silver, it is declared in yardage and metal in ounces per cubic yard as well as total metal content in ounces. The advantage in giving tonnage or yardage is that proper type of machinery, transport problem, mining cost, labour employment, and total organization can be calculated and determined. And in case of total metal content, it is helpful in calculating cost of metal per unit weight and, therefore, market value and profit can be compared and fixed. It is advisable to give tonnage as well as metal content per ton.

By the method described above, average assay value for each hole having been determined, computation for the average assay value and then tonnage of whole deposit can be obtained by the following formulae :

(a) *For holes spaced at regular intervals*

$$A_D = \frac{A_1L_1 + A_2L_2 + \ldots\ldots + A_n L_n}{nL_D}$$

$$L_D = \frac{L_1 + L_2 + \ldots\ldots + L_n}{n}$$

$$T_D = \frac{S_D \times L_D}{C}$$

Where,

A_D = Average assay value of deposit.

L_D Average length (depth) of holes of a deposit in feet.

S_D = Surface area of whole deposit in square feet (computed from surface, as per map for boring).

T_D — Total tonnage of ore deposit.

$A_1, A_2, \ldots\ldots A_n$ are average assay value of respective holes $1, 2, 3, \ldots\ldots n$.

$L_1, L_2, \ldots\ldots L_n$ are respective depth of these holes in feet.

C Cubic feet of ore per ton in place.

n Number of holes bored.

(b) *For irregularly spaced holes.*

$$A_D = \frac{S_1A_1L_1 + S_2A_2L_2 + \ldots\ldots + S_n A_n L_n}{S_1L_1 + S_2L_2 + \ldots\ldots + S_n L_n}$$

$$L_D = \frac{S_1L_1 + S_2L_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + S_n L_n}{S_D}$$

$$T_D = \frac{(S_1 + S_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + S_n)\, L_D}{C}$$

Where,

$S_1, S_2 \ldots\ldots\ldots\ldots\ldots S_n$ are respective areas of influence of '$_n$' number of holes for a deposit in sq. ft. and rest of the terms have the same meaning as assigned to them in sub para (a) above.

It will be noticed that terms C, S_D and S_1 S_2,. ....S_n can not be easily determined. They may be found out by the following methods :-

While finding out value of 'C', a single moderate size representative chunk of ore may be taken and its specific gravity found.

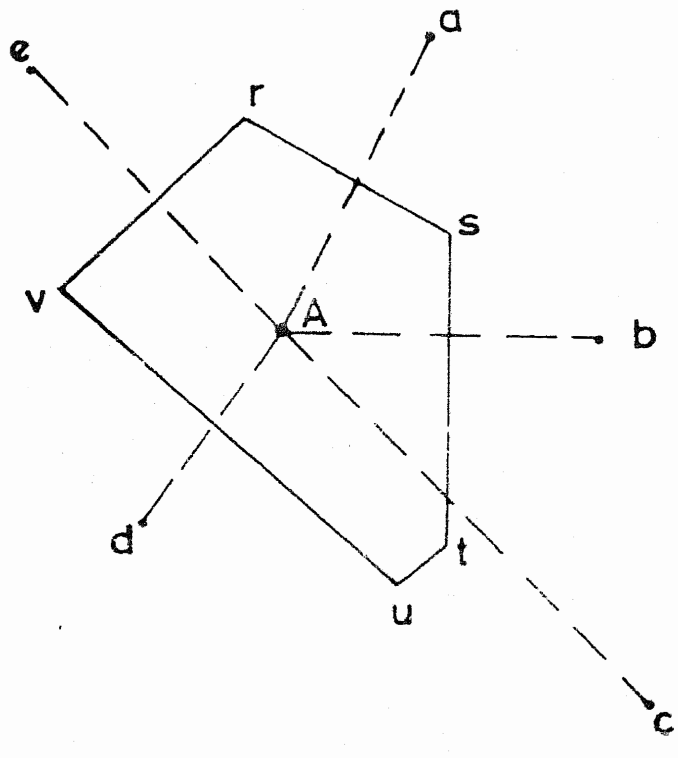

Fig. 4

Sp. gr. = wt. in air/(wt. in air—wt. in water.)

Therefore, lbs./cubic ft. = sp. gr. x 62. 5

and tons/cubic ft. = sp. gr. x 62.5/2240 = 0.028x sp. gr.

While calculating area of influence of a bore hole, S_1, S_2......, S_n, the following procedure may be adopted. This method is based on the assumption that assay values vary at a uniform rate between sample points. This condition is fulfilled by so taking area of influence of a hole that every point within it is nearer to that hole than to any other. In fig. (4) below, area of influence of hole A is found out by drawing lines Aa, Ab, Ac, etc. and connecting hole 'A' with all those around it viz. a, b, c, d and e. Lines rs, st, tu, uv and vr are perpendicular bisectors of lines Aa, Ab, Ac, Ad and Ae respectively. They form polygon 'rstuv', which is area of influence of hole No. 'A'. The area of this polygon can be measured with a planimeter or calculated mathematically by measuring bases and altitudes of its component triangles. Likewise, area of '$_n$' number of holes can be determined separately and arithmetic sum of these areas would be 'S_D', surface area of whole deposit when holes are irregularly spaced.