SPOTLIGHT

on the role of the geologist in the estimation of ore reserves*

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The crux of reliable estimates of ore reserves lies in a comprehension of the related geological events and their controls on the formation and distribution of the economic mineralization, and on the rock types, lithology, and structures. Furthermore, mine geometry is based on the shape of the orebody, the types and distribution of the economic minerals, and the ground conditions. Yet the mining industry has suffered, and is still suffering, from many unnecessary costly mistakes arising from a combination of insufficient competent geological input, and the traditional practice of isolating geologists to a remote service function rather than involving them in a well-balanced inter-disciplinary management structure.

Estimations of Tonnage and Grade

Tonnage and grade are generally calculated from the analysis of sample data in geometrical configurations, and the analytical results are weighted according to their spheres of influence. The type of geometrical configuration used in the calculation is related to the sampling pattern, which should be guided by the characteristics of the mineral deposit. Configurations include polygons, triangles, squares, rectangles, and various sectional outlines.

Classical statistics can be applied as an additional tool for evaluations, and has useful applications in the analysis of samples, the determinations of grade, and the indication of the level of confidence of the results. The validity of classical statistical analysis depends on the random variation of the sample values, i.e. when individual sample values are independent of one another. If statistical methods are to be used in deposits that have distinct grade trends as a result of various geological controls, then it is advisable to incorporate the geological trends in the statistical analyses.

Geostatistics is an extension of conventional statistics, and incorporates the spatial correlations and geometrical characteristics of samples. The object is to overcome the limitations of classical statistics, which arise from geological controls on mineral trends. Some excellent work has been done in the field of geostatistics, particularly in the practical application of kriging to the determination of the influence of analytical values.

Choice of Estimation Techniques

All the techniques utilized in the calculation of ore reserves have their limitations, and are tools to be employed in the most appropriate circumstances. The main goal is an understanding of the capabilities and limitations of the methods so that they can be utilized suitably for moulding the geological characteristics and the engineering options into the most profitable operation.

Statistics and geostatistics have not been employed to full advantage because most geologists and engineers find the mathematics too complex. Conversely, there have been cases where estimates of ore reserves have been derived solely by statistical analysis without due consideration of the geology and the proposed mining methods. This is particularly undesirable for newly discovered deposits, for which the substitution of sound geological investigation by statistics should not be contemplated.

Forms of Ore Estimation and Presentation

Fig. 1 gives an example of how ore reserves can be compiled in different forms to suit particular objectives. The left-hand column shows the approach that might be taken for feasibility studies. In this case, the emphasis is on obtaining a reasonable estimate of the overall potential ore reserves of the property so that the production rate, capital estimates, financial risks, and rate of return can be evaluated. If it is a virgin deposit, it is likely that the mining reserves will be derived from the *in situ* figures by wallrock addition.

Feasibility studies generally deal with projected millhead estimates based on unreliable information. In recent years, the influence of erratic metal prices, double-digit inflation, political uncertainties, and considerable capital outlays and restrictions to satisfy environmental controls, have all added to the risk element.

For operating mines, the right-hand column shows a number of factors that could account for the differences between *in situ* estimates and those actually materializing at the millhead. Tonnage and grade adjustment factors can be derived from historical records for the conversion of *in situ* reserves to millhead estimates, followed by formal production schedules and financial estimates. Furthermore, the differences between *in situ* and millhead figures indicate the potential scope for the improvement of grade control, maximization of ore recovery, and minimization of waste dilution. As such, the figures for the *in situ* ore reserves should be presented alongside the mining ore reserves for constant comparison.

The *in situ* ore reserves represent the material that one is striving to mine cleanly, safely, efficiently, and cheaply. One can lose sight of this objective if the *in situ* reserves are buried in the calculation sheets, and the figures after dilution and other safety factors become the accepted ore reserves. It is the latter figures that become the

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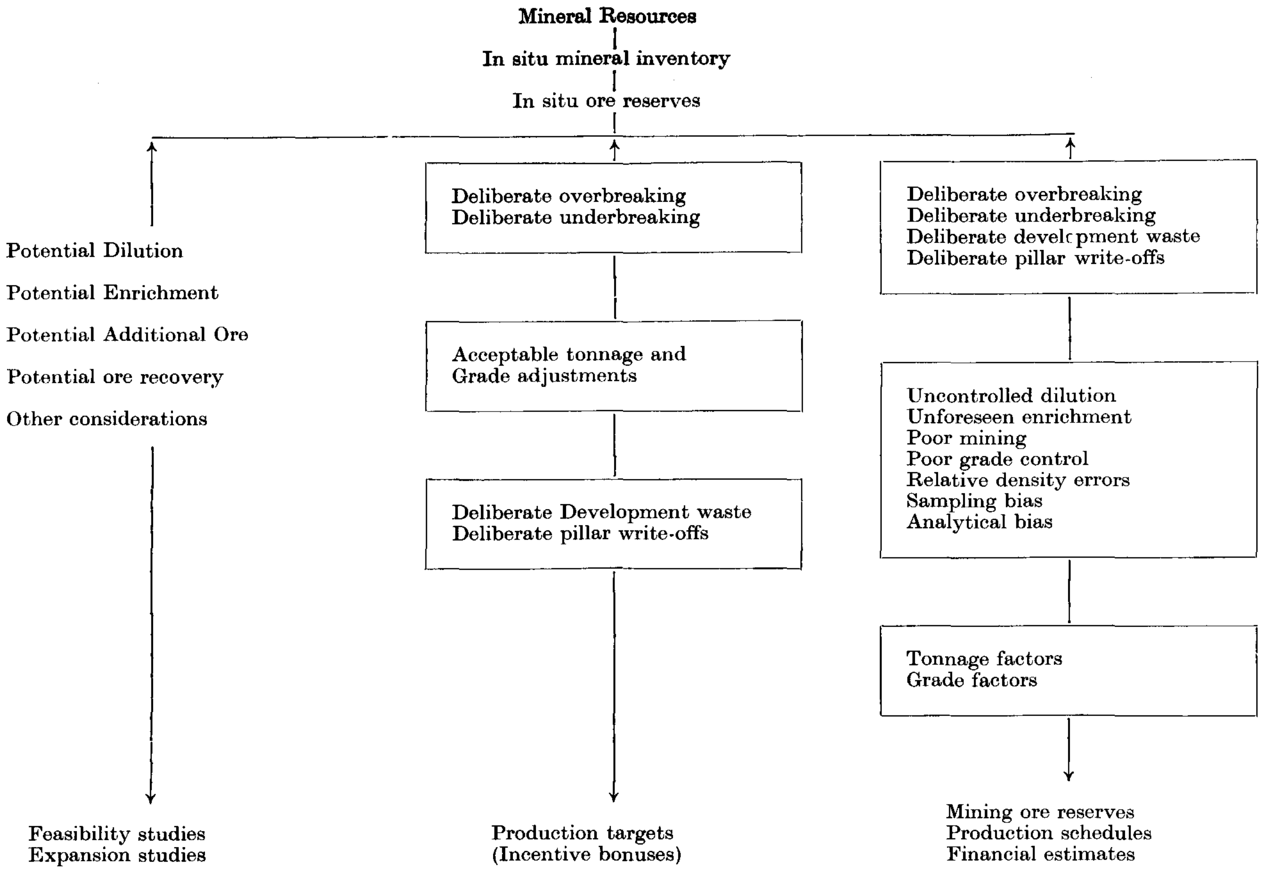

Fig. 1—The uses to which ore-reserve figures can be put

production targets and a yardstick for efficiency. Thus, the importance of keeping the *in situ* mineral inventory constantly under review cannot be over-stressed, together with making a frank assessment of whether the tons and grades are realistic, pessimistic, or optimistic.

Production schedules are normally conservative. An organization relies on the achievement of its production schedules, and production teams are personally sensitive to shortfalls in their commitments. Thus, to stimulate improved performance, production targets can be calculated as shown in the centre column of the figure.

Geological Input

Many of the dilemmas arising from the generation of ore reserves and feasibility studies is that geologists, engineers, and metallurgists are not aware of the role that geology should play in the area between mineral discovery and mine development. Of the vast number of mineral deposits, only a few are sufficiently large and rich to be transformed easily into orebodies. The technical division between mineral deposit and orebody can be a fine line, which can be crossed only by people with subtle geological appreciation and engineering ingenuity.

Exploration geologists frequently embark upon mineral delineation programmes without giving sufficient consideration to calculations of future ore reserves, to feasibility studies, and to the possible ultimate mining operations. It is often possible, from surface expressions or early exploration results for the approximate attitude of a mineral deposit to be deduced, and the orientation of the subsequent work can then be planned to enhance the geological interpretations, the calculations of ore reserves and the control of mine design and grade. Geological mapping, geochemistry, geophysics, and drilling that are laid out on a probable mining grid and plotted on scales common to mine records (e.g. 1:200, 1:500, and 1:1000) can be gainfully utilized through to mine operating. With some foresight, one can make the exploration records an integral part of the mine records. However, these comments do not suggest that there is no need for off-pattern drilling to improve interpretations or to serve as tests of hypotheses.

The following are some of the geological considerations that can be used in ore-reserve estimating and feasibility studies.

(a) The structural geology, the rock types comprising the mineral deposits and the country rocks, and their relationships with the mineral distribution.
(b) The size, shape, and attitude of the orebody relative to surface and underground features, as shown in plans, sections, and models.
(c) The economic minerals, together with their distributions and their relationships with other minerals and rock types.
(d) Oxidation, leaching, enrichment, and primary and special metamorphic features.
(e) Sizes and shapes of grains and crystals, and their relationship to the mineral distribution.
(f) Analytical populations, grades, and thicknesses, as illustrated by graphs and contours.

In addition to the above, the engineers and metallurgists will be interested in the following.

(i) The ground conditions for mine, plant, and infrastructure. The mining sequence, the orientation and size of mine openings, batter slopes, bench heights, pre- and post-mining ground support, and ground monitoring are factors that the engineers must consider at an early stage. From the initial drilling, geologists should be observing and recording faults, shears, fracture patterns, fissures, grain of the rock (bedding and schistosity), and rock strength. Core should not be broken and split for sampling before consideration is given to the counting of core-breaks and the determinations of rock strength.

(ii) The depths and potential amounts of ground water.

(iii) Abrasiveness, grindability, and sliming characteristics of the ore.

(iv) The potential for liberating the economic minerals and the presence of deleterious elements.

Some of these functions may appear to be beyond the responsibilities of geologists, but at the time of most feasibility work it is the geologist who has had the broadest exposure to the orebody and the property as a whole. Moreover, material for metallurgical testwork must represent all the types of ore that are present, since the indicated metallurgical recoveries for the respective ore types or their blends must be incorporated in the production planning. The geologist is in a very favourable position to ensure that the varying characteristics of mineral deposits receive metallurgical, engineering, and even financial (cash flow) consideration.

A feasibility study is suspect if there is no measure of the reliability of the sampling methods, sample preparation, and analysis used. All these methods have some error and bias, the extent of which should be determined by geological investigation, statistical analysis, and experimentation.

Established mines usually follow routine practices that they have developed to meet their specific technical requirements. The characteristics of the mineralization and the structures of the orebodies may permit a number of geological functions to be performed by the application of routine sampling and mathematical computations. However, since each orebody is essentially unique in character, the dangers in the arbitrary application in one mineral environment of routine procedures that are suitable for another cannot be over-stressed.

Involvement of Geologists

The accuracy of ore estimates, the competency of mine design, and the reliability of feasibility studies hinge on an appreciation of the characteristics of the mineral deposit and the country rocks. Many deposits are technically abused because geologists are not involved in the estimation of mineral reserves; they have not been taught or have not acquired the fundamentals of economic geology and of ore-reserve estimating; or the geological reports and maps are handed over to engineers without any further involvement of those who were responsible for the geological investigation.

The estimation of ore reserves lies in the grey area between geology, engineering, metallurgy, and finance. It is fully exposed to the vagaries of professional exclusiveness, discrimination, and jealousies. In Africa, the tendency has been to regard geologists as strictly service personnel outside the line management and the decision-making process. Many of the dilemmas in the generation and operation of mines would be avoided if geologists were properly involved in the management process. At the same time, geologists must acquire technical competence in those areas and be prepared to develop management skills.

Asian mining

The Institution of Mining and Metallurgy has been invited to organize an international conference on the occasion of the *Asian mining 81* international exhibition. Aims of the proposed conference, which is to be held in Singapore from 23rd to 26th November, 1981, include the provision of a forum for the discussion of mining projects and developments in Asia and opportunities for investment in mining within the region.

The exhibition, *Asian mining 81*, will be held at the World Trade Centre, Singapore, from 23rd to 27th Nov, 1981. Enquiries relating to the exhibition should be addressed to the organizers, ITF Pte. Ltd, Suite 804, 8th Floor, World Trade Centre, 1 Maritime Square, Singapore 0409 (telephone: 2711013; telex; RS 26085), or to Industrial and Trade Fairs International Limited, Radcliffe House, Blenheim Court, Solihull, West Midlands, B91 2BG (telephone: 021 705 6707; telex: 337073).

Enquiries about the conference should be addressed to the Meetings Secretary, The Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR (telephone: 01-580 3802; telex: 261410).