The role of the mineralogist in the minerals industry

by H. V. R. VON RAHDEN*, M.Sc., Ph.D. (Fellow)

SYNOPSIS

The expertise of the industrial mineralogist has not always been sufficiently used in decision-making in the minerals industry in South Africa. The mineralogist can make a contribution at all stages of the exploration programme, from the time of discovery of a geological target area, through metallurgical testwork and pilot-plant studies, to the production of a saleable product. This indicates that the activities of the industrial mineralogist should be more closely integrated with those of the exploration geologist and the extraction metallurgist in order to provide management with a meaningful picture of the economic potential of an ore deposit.

SAMEVATTING

Daar is nie altyd in die besluitneming in die mineralebedryf van Suid-Afrika voldoende gebruik van die kundigheid van die industriële mineraloog gemaak nie. Die mineraloog kan in alle stadiums van die eksplorasieprogram vanaf die ontdekking van 'n geologiese teikengebied, deur die metallurgiese toetswerk en proefaanlegstudies, tot by die produksie van 'n verkoopbare produk, 'n bydrae lewer. Dit toon dat die werksaamhede van die industriële mineraloog nouer met dié van die eksplorasiegeoloog en die ekstraksiemetallurg geintegreer moet word om die bestuur 'n sinvolle beeld van die ekonomiese potensiaal van 'n ertsafsetting te gee.

Introduction

> Without minerals, man cannot possibly hope to maintain his present standard of living. In order to ensure the continued well-being of the earth's population, it is therefore imperative that more attention should be paid to mineral research and the training of specialists in the field of mineral reclamation . . . . If we are to maintain the continued availability of strategic minerals, research into mineral exploration becomes a primary need. For this we are dependent on the skills of geologists, geophysicists, mineralogists and metallurgists.

These words form part of the Presidential Address given by Mr P. A. von Wielligh in November 1977 to the members of the South African Institute of Mining and Metallurgy, under the title 'Minerals and the survival of mankind'[1].

I should like to tell you a little more about the role of the mineralogist in the minerals industry.

Mineralogy

In South Africa, mineralogy has often been treated as the unappreciated step-child of the minerals industry. Liebenberg[2] has said:

> It is not generally realized that the mineralogist has a distinct place in any organization concerned with mineral processing and extractive metallurgy. He is seldom regarded as anything but a mineralogist, and the relationship between mineralogy and metallurgy is not recognized.

In the past when new mining ventures were planned, the mineralogist was rarely, if ever, considered to play any part in the overall scheme of things — very often with somewhat disastrous results. Luckily, however, this state of affairs is very rapidly changing, and more and more use is being made of the mineralogist during the initial stages of the exploration programme, the mineral-beneficiation testing stages, and the plant-design stages.

However, the question that must be asked here is 'What is a mineralogist and what can he do?' To many people the term *mineralogist* may conjure up a picture of just another breed of geologist, a lazy type who prefers to work regular hours in a laboratory rather than go tramping through the bush looking for some mineral outcrop or other. We should examine the picture a little more closely.

A mineralogist should ideally have a post-graduate degree in geology, and should have training in chemistry, geochemistry, physics, and mathematics. Other useful attributes are a knowledge of elementary sampling theory, familiarity with current scientific literature, imagination, and the ability to venture outside his own discipline when necessary since the help of other disciplines such as chemistry and metallurgy may be needed with mineral-quantification techniques. The mineralogist should ideally be familiar with techniques such as X-ray diffraction and X-ray fluorescence, the use of the electron-microprobe analyser, and the study of rocks and minerals by means of the petrological and ore microscope. In order to be able to carry out his work satisfactorily, he requires instrumentation for most of these techniques, or must have access to laboratories that have these facilities.

The high initial capital outlay that is required to establish an adequately equipped mineralogical laboratory, coupled with ignorance on the part of management of the role that the mineralogist can play in the mineral and metallurgical industry, may be the reason that management has so far been somewhat hesitant to create as many posts for mineralogists as are really needed. The result has been that relatively few graduates in geology go on to become mineralogists.

Mineralogy can be subdivided into two distinct sections, namely theoretical and industrial mineralogy.

The theoretical mineralogist is usually attached to a research establishment and is primarily concerned with the identification and characterization of minerals and with the examination of the fundamentals affecting the formation of mineral deposits.

The theoretical concepts developed by the research

*Anglo-Transvaal Consolidated Investment Company, Limited, Johannesburg.

mineralogist can often be used to advantage by the industrial mineralogist for assessing various means of beneficiating ores. Chemical-processing techniques, which are used for dissolving minerals *in situ*, can be visualized as being the very opposite or reverse of the ore-genesis processes originally responsible for the emplacement of the minerals. Quite obviously, therefore, a better theoretical understanding of both the mineralizing process and the mode of emplacement can be utilized in the design of recovery methods.

Let us now turn to the industrial mineralogist employed by a mining house, and consider how his services can be used to guide decision-making throughout the process of the discovery of deposits, the evaluation of the potential of the ore, the pilot-plant stage, and the plant design and optimization, to the stage where a saleable commodity is produced; in other words, how extractive metallurgy can be aided by mineralogy.

Exploration

Once a suitable target area has been found or purchased, the problem facing management is how to allocate the available money, staff talents, and facilities in such a way as to optimize the chances of discovering a worth-while ore-body. It is from this very early stage that the services of the mineralogist should be utilized to the fullest extent.

At the average South African university, the student of geology during the course of his graduate training probably becomes familiar with a few hundred minerals and their associations, and then goes out into the field. Often the only equipment available in the field is a hand lens, and with this he is expected to attempt mineral identifications. When it is remembered, however, that the number of accredited mineral species already exceeded 2300 in 1975[3], and that this number is increasing on an almost daily basis, it is small wonder that the field geologist, whether he or she is a new graduate or an experienced worker, may unwittingly overlook a potentially worth-while mineralized area because of misidentification of the minerals involved. This is especially the case where dark brown or black minerals have to be identified in the field, and there is therefore a clear need for mineralogists to provide definitive mineral identifications to assist the exploration geologists. Similarly, the laboratory-based mineralogist may well be able to guide the efforts of exploration geologists in areas where subtle changes in the mineral facies, only detectable in the laboratory, suggest the proximity or otherwise of a specific type of ore-body. In addition, from a study of thin sections of rocks, the mineralogist can often provide a petrological basis by which rock types encountered in different borehole cores in a particular area can be correlated.

It is therefore clear that, if the exploration geologist is to perform his duties adequately, he must have frequent recourse to the services of a mineralogist. Very often, however, head-office policy unintentionally precludes this by levying charges for the mineralogist's services that materially affect the budget of the exploration geologist, who is often forced to choose between consulting the mineralogist and drilling another borehole. It is obviously desirable that head office should bear the operating costs of the mineralogical laboratory so that the mineralogist's services are freely available to the exploration department and are used to the fullest extent.

Initial Tests

Once the mineral resource has been located, the metallurgist has to conduct preliminary laboratory-scale tests based on the mineralogist's findings regarding the intermineral relationships. This he does to establish whether conventional extraction methods can be applied to concentrate the required constituent to a grade or form acceptable to the user. If positive results are obtained, the scale of exploration can be extended and further funds spent to gain some idea of the size and reserves of the deposit, and, if necessary, a full-scale process-design study can be undertaken. There has been an unfortunate tendency to bypass the mineralogist at this design stage, and to develop the mineral-processing plant purely on the basis of assay or chemical results, little attention being paid to the mode of occurrence or interrelationships of the required element or mineral with the diluent or gangue minerals. This type of false economy on the part of management can have disastrous financial results.

As an illustration of the difficulties that may arise if the mineralogy of a deposit is ignored at the process-design stage, it is necessary only to consider the mode of occurrence of low-grade nickel ores in the Transvaal. An ore may well assay over 1 per cent by mass of nickel, making it seem like a very attractive proposition, but very little of the nickel is usually in a form that can be recovered by flotation techniques. The bulk of the nickel present in these ores occurs within a magnesium silicate lattice, which would require expensive chemical processing if the nickel is to be extracted, while very little of the total nickel content of the rock occurs in the form of a nickel-containing sulphide mineral from which the nickel can be recovered by flotation. In the absence of prior mineralogical knowledge, the use of chemical assays could mislead management into wasting both time and money on a plant design totally unsuited to the ore under discussion. With a foreknowledge of the mineralogy, the decision can be made at a relatively early stage either to abandon the project and to drop any existing options, or to consider probing the potential of the deposit for a possible deep-seated source of nickel.

Extraction Methods

Mineralogy can make a very positive contribution to the design of recovery methods in certain cases. As already mentioned, the theoretical mineralogist, as a result of his study of the ore-genesis processes originally responsible for the emplacement of certain minerals, can suggest chemical-processing techniques to dissolve these same minerals *in situ*, since the dissolution techniques can be visualized as being the opposite of the mineralzing process. Where metals have to be recovered from low-grade and deep-seated deposits, *in situ* mining and leaching can sometimes be considered; the metals are then converted into their ionic form by a reversal of the mechanism of deposition, and are easily recovered by simple solution flow and pumping[4]. The *in situ* leaching of copper and uranium provides examples of this approach. However, the success of this method of recovery depends largely on the mode of occurrence of these metals, and, for the recovery process to be satisfactorily designed, a mineralogical report is again a prerequisite. In the case of 'oxide'-type copper ores, the mineralization is often found to occur along fissures in the host rock, while in the case of uranium the secondary uranium minerals generally occur as precipitates coating poorly consolidated sand grains in a sandstone host. In either of these cases, the presence of carbonates in the host rock would obviously preclude the use of acids for the dissolution of the copper or the uranium. Similarly, reduced porosity caused by compaction and welding of sand grains may prohibit the passage of the acid through the sandstone and therefore rule out the use of *in situ* leaching. This would make it necessary to resort to dump leaching, which might render the deposit economically unviable. If the mineralogy of the deposit has been studied at an early stage, management can make the correct decisions regarding the overall viability of the project and avoid any unnecessary outlay of capital.

Pilot Plant

Once the potential of an ore has been evaluated, the next stage in the mineral-reclamation process is that of setting up a pilot plant. Throughout the pilot-plant studies, it is essential that there should be a close degree of co-operation between the mineralogist and the metallurgist, and the plant products should be examined mineralogically prior to being comminuted for assay purposes. Very often a mineralogical investigation will pinpoint problem areas, such as mineral locking, that would not be revealed by chemical analysis. In this way, it may be possible to reduce the number of chemical analyses required, leading to a more rapid optimization of the extraction process.

Ideally, the metallurgist, when planning the order in which a deposit should be beneficiated, should have been provided with both mineralogical and geological information. A thorough knowledge of the approximate grain sizes of the minerals, the specific gravity and hardness of the ore, and the classification of the ores in a deposit into distinct geological categories or types is thought by Kitagawa[5] to be essential. He further points out that it is necessary to know whether the ore-body is homogeneous or not, since this could affect the order in which the ore will be mined to take best advantage of current conditions on the metal market. Furthermore, the different metallurgical responses of various types of ore from a particular deposit may sometimes influence the mining plan in that there might be a basis for either blending or separate treatment of the ores.

Optimization of the extraction of two such highly priced commodities as gold and uranium must be foremost in the minds of many metallurgists on the Witwatersrand. Very often, however, attempts to improve extraction by radical changes to the plant are frustrated because the real factors responsible for poor dissolution of the gold and uranium are a function of the mode of occurrence of these elements, and are thus not fully understood or appreciated. A typical example is that of uranium extraction. Very basically, uranium occurs in the Witwatersrand as uraninite and also in another form variously described by mineralogists as uraniferous leucoxene or altered brannerite[6, 7]. Both the latter minerals are in fact non-stoichiometric mixtures o uranium and titanium; that is, the uranium content associated with the titanium varies over very wide limits[6]. The real problem here is that the proportion of altered brannerite or uraniferous leucoxene can vary with respect to the amount of uraninite present as a function of the provenance area and local sedimentological conditions of deposition. Work by Feather and Snegg[8] has confirmed the predictions made by Von Rahden and Hiemstra[6] that the friable uraniferous leucoxene–altered brannerite (now positively identified as brannerite by Feather and Snegg[8]) would slime readily and would tend to accumulate in the slimes fraction of the recovery circuit. Furthermore, altered brannerite–brannerite is not necessarily recovered by gravitational means or flotation (owing in the main to its fine particle size and its intimate association with phyllosilicates in particular), and it is relatively unattacked by the conventional leaching reagents commonly used for the dissolution of uraninite. Without knowledge of these mineralogical parameters, the metallurgist who tries to improve uranium extraction with only chemical assays for total uranium to guide him is attempting the wellnigh impossible, since once again assays cannot reveal the true picture. Feather and Snegg[8] have shown that pressure leaching is necessary to improve uranium extraction.

Another example of the contribution that mineralogists can make in helping to improve metallurgical recoveries, even in well-established plants, is provided by the investigation carried out by Feather and Koen[9]. During the course of a mineralogical examination of suites of plant products from four gold mines of the Anglo American Corporation, they found that almost all the gold in the minus-600 μm fractions of the plant feed and the other premilling circuit materials was already liberated, and that the liberated gold represented some 50 per cent of the total gold content. They felt that the gold recovery would benefit greatly if the liberated gold were removed from the circuit at that point, prior to ball-milling, since copious quantities of finely divided tramp iron that is susceptible to rapid oxidation are produced during ball milling. This iron contributes to the formation of coatings of hydrated iron oxide on individual gold grains, and leads to the formation of rusty mineral aggregates, rendering gold recovery more difficult. Lloyd[10] points out that the data provided by Feather and Koen concerning the early liberation of large gold particles in the milling circuit run totally counter to the conventional beliefs about Witwatersrand ores, and he agrees with them that it would be advisable to recover as much gold as possible in the early stages of the recovery process if plant efficiencies are to be increased any further.

Conclusions

In essence, therefore, we should view mineral extraction and beneficiation as a process that requires a multi-disciplinary approach. The exploration geologist or prospector who has to find the ore, the mineralogist who must then examine it critically and report on its possible value, the analyst who must carry out the required qualitative and quantitative analyses, the statistician who evaluates the complex distributions of values often found in mineral deposits, the mining engineer who must work out the best way of mining what at that stage is still a useless commodity, and, finally, the metallurgist who must process the ore to recover the mineral or element in question, all have their necessary parts to play, the mineralogist not least among them.

References

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Amendment to S.A.I.M.M. Constitution

At a Special General Meeting of the South African Institute of Mining and Metallurgy, held at the Highveld Club, Witbank, on 3rd October, 1979, at 09h00, it was agreed that the following amendment should be made to the Constitution:

Clause 3.2.5 of the Constitution, which called for the inclusion of Ten Corporate Members elected according to Section 9 of the by-laws, now reads *Fourteen* Corporate Members.

APCOM 80

The 17th International Symposium on the Application of Computers and Mathematics in the Mineral Industries, sponsored by the Ministry of the Coal Industry of the U.S.S.R., will be held in Moscow from 20th to 25th October, 1980.

The aim of the Symposium is to bring together all those engaged in the application of computers and computer methods, automatic systems of management, operational research, management, and planning in the mineral industry, and to promote the exchange of ideas and experience, as well as to discuss current practice and new developments in this field.

The following are the main topics of the Symposium.

Mineral Exploration

1. Evaluation of coal and ore deposits.
2. Decision-making in mineral exploration.

Mining

1. Mine planning, systems of opening, systems of development and operation of underground and surface mines (coal and metalliferous).
2. Systems of mine management and operational control.

Mineral Processing

1. Systems design, optimization, and control as applied to coal preparation and ore-dressing.
2. Process analysis.

Management

1. Automatic systems of management.
2. Data processing.
3. Automatic systems of equipment maintenance adn repair.
4. Econometric modelling.

The official Symposium languages will be Russian, English, and German. Simultaneous interpreting in all three languages will be provided during the Symposium sessions.

Dr D. G. Krige, the S.A.I.M.M. representative on the International APCOM Committee, is co-ordinating all the arrangements for the South African delegates. Interested persons should contact him at Anglo Transvaal Consolidated Investment Co. Ltd, Johannesburg.