The influence of a fluctuating gold price on the potential of mining low-grade areas*

by A. N. BROWN†

This title of is not that originally chosen for the Colloquium, which was 'A high gold price'. Such a title would have been unfortunate because it would have related the Colloquium only to the high gold price of the past two years, which reached the dizzy peak of 850 dollars per ounce in January 1980. The chosen title is, of course, the right one because it places the whole problem in the right perspective. It relates to a situation that has occurred many times before. Over the course of the past century, the gold price has periodically been inhibited from rising, so that it has undergone a succession of stepwise increments. With each increase, the relationship of the working cost to the gold price alters, and gives rise to a jump in ore reserves.

A steady relentless upward progression of working cost serves to continually elevate the pay limit. With each re-calculation, the ore reserve steadily diminishes until the earlier advantage gained is generally lost. History repeats itself, and changes in the gold price have a profound effect on pay limits and cut-off grades.

Increase in Gold Price

The most recent increases in the gold price, because of the free market influence rather than a fixed price, have been unusual. A relatively steady upward trend from 1972 to 1978 was followed by erratic, wild fluctuations and complete uncertainty regarding the long-term future of the gold price. The problem of assessing the mining potential of low-grade areas has assumed intriguing proportions. What seems to be important is that the gold price is far more seriously affected by political events and other strategic or monetary considerations than by the normal market forces of supply and demand. The present situation is quite ironic. Because of the various fixed levels of the gold price over the years and an assured market for the product, people in the gold-mining industry never needed to worry about price fluctuations. The gold price became a constant in all calculations. This was in sharp contrast to all other sectors of the minerals industry, where metal prices, concentrate grades, and marketing have always been predominant issues. It is ironic that the gold-mining industry should now be subject to such erratic and dramatic fluctuations in the price that decision-making has become unduly onerous and even hair-raising. With such wild fluctuations between, say, 370 and 850 dollars an ounce in the course of two months, how on earth does one decide on cut-off grades? The best answer seems to be to apply a smoothing technique of some sort, and to work with a moving average such as one of 10 weeks or 30 weeks. Where this has been applied, it appears to work well.

New Ore Reserves

With the recent exceptionally high gold price pitched at between 450 and 850 dollars an ounce, it has become possible to mine and process ore of ridiculously low grade at a profit. Vast quantities of mineral-bearing rock that was never previously regarded as ore has now become material that can be processed at a handsome profit. The unexpected windfall of high profits to mining companies, as well as to individuals with an interest in the industry, has meant the availability of capital to exploit the newly converted ore reserves in the form of extensions to existing mines and the re-opening of abandoned mines. Also, there is interest in exploiting areas in existing mines that were not payable at lower levels of gold price.

Trend of Gold Price

Almost everyone with an interest in the gold-mining industry has made an attempt to predict the future trend of the gold price. That trend, together with the trend in the increase in working cost and in the average rate of inflation, are exceedingly important issues. Will the increase in the price of gold keep up with the rate of inflation? The steady upward trend in the gold price from 1976 through to 1980 has been considerably higher than the rate of inflation of between 12 and 15 per cent per annum that has made gold and gold shares such a good investment. However, there are signs of a steady decline in the gold price to what many people consider to be a more realistic, stable level in the long term.

What about the working cost? After all, it is the relationship between working cost and price that determines profitability. Over the past few years with the inflation spiral, working costs have increased at a rate considerably above the inflation rate owing mainly to the improvement of Black wages, more expensive energy (of which the industry consumes vast amounts), and expensive mining machinery. These trends could serve to progressively increase pay limits and reduce ore reserves: conversely, it makes the mining of low-grade ore less attractive. However, gold is a scarce commodity and has many uses, of which its monetary value is most important.

In these troubled times, gold has become the most popular asset as a hedge against inflation. Over the past two or three years, the overall amount of gold produced has decreased so that consumption is greater than new gold produced by approximately 30 per cent. The consumption of gold by the jewellery industry is the largest

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† Professor of Mining, University of Pretoria, Hillcrest, Pretoria 0001.

sector and accounts for some 70 per cent. It tends to be a fickle market particularly at the present time, when there is a slow-down in world economy.

Mining Pioneers

In conducting some research for this address, I had occasion to refer to the proceedings of the Association of Mine Managers going right back to the earliest edition of 1931–36. It is indeed a humbling experience, for the proceedings form a chronicled record of the ability, experience, and acumen of the pioneers, and of the mining techniques, working methods, and equipment they so painstakingly developed. It is from these humble beginnings that the South African mining industry developed its world-wide reputation for knowledge and ability.

I once told a student that only the Papers and Discussions of the past ten years were of topical and technical interest, and that the earlier editions were outdated but contained some good humour. I am still of that opinion and, on paging through, I came across two gems that I would like to share with you. The first concerns an air-driven sweeping machine and the discussion in 1941 went as follows:

> Two natives – with electric cap lamps – are required for each sweeping machine. The machine being of somewhat delicate mechanism requires careful attention and should be overhauled daily.

The second, dating from 1943, concerns the theory of rock pressure – a precursor to the science of rock mechanics.

> In writing on the Theory of Rock Pressure, it is suggested that none but the simplest of mathematics need be employed and the reasoning, if sound, should be so simple that the layman could understand it.

That sounds like good advice, and it certainly says nothing for Fourier functions or Laplace transforms!

These proceedings do, however, contain some classical papers dealing with the subject of reclamation mining that form invaluable reference material for all who have an interest in the subject. For example, 'Reclamation of ore from current and previously abandoned workings' by J. Browning of Wit Gold Mine in 1942 is such a paper. It deals with reclamation — the mining of wide reefs by pillar and stall methods, and fill and concrete piers. A discussion by Redfers Greaves, of Rose Deep, is more important than the paper to which it was contributed since it deals with wide reefs, additional reef bands, and wide widths up to 7 metres in flat and steeply dipping circumstances; it contains excellent graphical illustrations.

Certain persons stand out in the field of reclamation mining. Those I know of and some whom I knew personally are people like G. Hildick-Smith, C. Gordon-Davies, J. S. Ford, Redfers Greaves, Herbert Simon, J. X. Harrington, P. G. D. (Piet) Pretorius, and Eric Dunston. Others from whom I personally learnt a great deal were Ian Stewart, Ken Mickeljohn, and Neville Pienaar at Crown Mines, whom some of you might have known. These were the type of people who insisted on prospects being blasted into hangingwall and footwall to test for additional bands of reef or to sample additional reefs like the Main Reef, which on the Central Rand lies close to the Main Reef Leader.

Mining Practices

Previous mining practices make interesting study. Resue mining was widely practised to upgrade low-value reef bands or to eliminate waste. Many areas were sand-filled, and the exercise of emptying the stopes to remine or reclaim was an interesting experience as well as hair-raising. Shrinkage piles or scatter walls were used from an early date to prevent scatter of fines into the back areas. As mining progressed to a depth of 1500 metres (5000 feet), problems began to be experienced because of wall convergence, pinching the scatter walls and leaving the areas behind the faces narrow and uncomfortable to work in. Particularly during the war years 1939 to 1946 with labour shortage and pressure on production, much unclean mining was done and many accumulations of ore were left underground.

Many people will remember the practice of 'dry mining' in order to improve ventilation conditions. It also had, according to them, the advantage of restricting gold losses. In the 1950s the liberal use of water for sweeping and washing the mined-out areas had allegedly led to gold losses by washing gold into cracks and fractures in the footwall. This is a credible argument if, as was the case, the removal of scatter walls and sweeping was done as far as 20 metres back from the face, when cracks in the footwall had had time to open and bedding separation in hangingwall and footwall had taken place. The systems applied at present – the use of rubber blast barricades 2 to 3 metres from the face and the washing out of broken ore with high-pressure water-jets — ensures that there are no accumulations, even in the mat packs, and that the cracks have not yet had the chance to open up.

Gold is a remarkable substance – it has a propensity for being soaked up into the environment. Those who have sampled spillages or have been concerned with cleaning-up operations in reduction works, or who have been concerned with low gold recovery on the start-up of a new reduction plant, have an appreciation of the phenomenon.

One word of caution when doing calculations: the size of boundary pillars may not always be as depicted on working plans. I remember, as a shift boss, receiving a stopping note the day after we had holed into the mine next-door!

Low-grade Ore

Another intriguing aspect of low-grade ore concerns the approach of the entrepreneur and shareholder, who would like to maximize the return on investment in terms of present values but are constrained by law to mine the 'average ore reserve'. Because a kilogram of gold is worth, to the State, more than its market price by a factor of 3 or 4 when everything is taken into account, the aim is to maximize the extraction from the deposit. This is part of the reason for State assistance to mines, even those concerned only with reclamation such as the Boshoff Group.

When talking about low-grade areas or low-grade ore, what are the sources? In mines, I suggest there are three categories: shallow abandoned mines (less than 700 metres deep), closed or abandoned mines of medium depth (less than 1300 metres deep), and existing operating mines. The closed mines concern those in which the ore had been exhausted at the then-ruling pay limits but from which all the gold had not necessarily been extracted. Particularly on the East, Central, and West Rand, a large variety of reefs were mined such as the Main Reef Leader, South Reef Leader, South Reef, Main Reef, Composite Reef, Bastard Reef, Kimberley Reef, Livingstone Reef, Battery Reef, Bird Reefs, Elsburg Reefs, Black Reef, banded pyritic quartzites, and others. All had varying gold values and uranium content. Potential ore is in the form of stability pillars, remnant pillars, boundary pillars, reef in hangingwall and footwall, hangingwall bands, footwall bands, additional reefs, ore accumulations, stone walls, vampings, spillages, ore in ore passes and ore ways, and previously unpay blocks. Much information concerning closed or abandoned mines can be obtained by reference to the ore-reserve plans lodged with the Mines Department. An interesting tabulation exists in the Chamber of Mines Annual Reports, which contain a comprehensive record of ore tonnages, gold produced, and grade from all the principal gold mines going back to 1887. The ore grade has varied from 4,23 to 29,54 grams per ton. It is also interesting to reflect on the closing stages of a dying mine. There is generally a shortage of pay ore, so that other reefs, and hangingwall and footwall bands are exploited, pillars are attacked, and reclamation and Com-Rec work is done so that not much remains.

Re-opening of Mines

The re-opening of a mine in a now built-up urbanized area brings many problems that must be solved such as rejuvenated ground movement and surface subsidence, acquisition of freehold rights, tailings disposal, industrial water and effluent, siting of the treatment plant, transportation or haulage of ore to the mill, explosives transport and storage, ventilation, and accommodation of employees.

Although these problems seem formidable, do take heart: the Village Main mine has continued to exist and operate near the heart of Johannesburg for more years than many people would wish to remember. A problem with low-grade reclamation work concerns the availability of suitable labour, which can be an ongoing battle. High rates of pay and optimism for the future draw people to new, developing mines. Thank goodness for the experienced old timers who tend to remain in established areas where they are settled.

Dump Mining

An aspect not covered in this Colloquium concerns dumps: slimes dumps such as at Ergo exploiting gold, uranium, and pyrite for sulphuric acid; or sand dumps, which could have attractive values at today's prices; or waste dumps, where the washed fines are well worth treating as evidenced at Vlakfontein and Free State Geduld, for example. Incidentally, the 'waste rock' used to build our sky-scrapers, roads, and precast walls have often rendered a better return to the shareholder than much of the low-grade ore that has been mined and milled!

Mining in Abandoned Mines

Abandoned mines at shallow depth are ideal for reclamation of the Boshoff type. There are few problems in regard to ventilation, rock mechanics, or heat; access is easy, ore is hoisted from shallow depth, used equipment is reclaimed for re-use, and the working cost is low. As there is no capital expenditure to talk of, the scale of operation is exceedingly flexible and can be built up from scratch. Spillages, ore accumulations, vampings, and sweepings are the main sources of ore. Abandoned or closed mines to a limited depth (1200 to 1300 metres) generally contain some known ore reserves, as well as moderate tonnages of previously unpay ore. Some opening up for sampling purposes and evaluation may be necessary, but the high capital associated with the sinking of shafts may be spared by the use of existing shafts, duly repaired and renovated. The housing of White employees may also not be a problem near built-up areas. However, the pumping of water to dewater the mine and coping with new inflow could be a serious problem. Such an undertaking would follow through the stages of sampling and valuation, opening up shaft and access or haulage ways, feasibility studies, pumping arrangements, mining practices, etc., in order to determine whether the undertaking is viable.

Low-grade Ore in Existing Mines

In the event of an existing mine turning its attention to low-grade areas, these could concern additional bands, previous unpay blocks, remnants, and stability pillars. The philosophy of exploiting low-grade ore should be clearly understood. Marginal costing concepts as enunciated by Mr S. C. (Sid) Newman at Durban Deep in 1962 (AMM Papers and Discussions) is of particular significance.

> Nett profit is not made per unit produced but from total activity during a period, and the units produced each make contributions to a pool from which the profit emerges.
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> Costs of mining in different sections of a mine may differ materially and it may be necessary to determine pay limits for different sections or zones of a mine. No expenses of a capital nature should be included in marginal costing and marginal pay limits should not be confused with grade to be mined in any area. Before an area is exploited, an assessment should be made of the capital expenditure necessary to make exploitation possible and this, together with marginal costs, should be balanced by the revenue that the area is likely to produce. Mining is only justified when the marginal costs are being met.

Technological Aids

In this day and age we have the advantage of the science of rock mechanics and aids like the resistance analogue or computer. This enables an assessment to be made of the consequences of pillar removal and the best way of doing so. However, the theory underlying the use of stability pillars to limit energy release predicts the presence of high stresses in the pillars. There is usually a very good reason why random pillars have been left in a mine. Only when you struggle to remove them and experience the seismic activity does it become clear why our predecessors abandoned their efforts to remove such pillars.

In general, going back into deep mines for the purpose of doing reclamation work is unattractive. This may be due to rock pressure, ground movement, intense fracturing of hangingwall and footwall, and support problems. At depth most mining is done by longwalling, in which complete closure follows 60 to 100 metres behind the face. All mining is thus in the form of new development.

Many mining engineers have wrestled with reefs with multibands (such as the Kimberley or Main Reef) where the values vary from one horizon to another, which makes mining extremely difficult. It is interesting to note that low-cost bulk-mining methods in which all the bands are mined simultaneously often produces the most viable result. Waste filling or caving could be practised.

Other favourable aspects of our technology at this time concern the science of geostatistics, developed by Dr Krige and others, to rival the guesswork associated with early 'spotted dog' value plans. The use of photometric or radiometric sorters (working on the uranium) are successful methods under suitable conditions for eliminating waste and upgrading low-grade ore. After all, sorting seems to be a key to the successful Boshoff method of mining.

Conclusion

Here we are concerned with low-grade propositions. This demands an accurate assessment of ore values, a thorough examination of all the factors concerned, sound feasibility studies, good operations planning, adequate and diligent supervision, and favourable levels of productivity and efficiency. The necessary sensitivity studies will assist in accounting for inflationary effects, cost changes, and metal-price changes. There is no doubt that a valuable contribution will in future be made to the country's economy from low-grade ore sources.

Award for CMI fuelling technique

Consolidated Metallurgical Industries Limited – the Lydenburg-based ferrochromium producer in the J.C.I. group – was one of the five recipients of the 1981 National Productivity Institute annual award.

The award was made to CMI in recognition of the company's development of a technique by which imported oil fuel is replaced by locally mined coal, resulting in a saving of some 2 million rands a year.

CMI was formed in 1974, when J.C.I. entered into a technical licence agreement with Showa Denko KK of Japan to design and build a plant to exploit chromium ore deposits in the eastern Transvaal.

The technical licence and guarantee given by Showa Denko KK was based upon a kiln-firing system using oil only. Realizing the importance of alternative energy, J.C.I. insisted on feasibility tests using a coal-fired system for prereduction. The pilot-plant test showed that coal firing was possible but only at a low efficiency.

The production facility at Lydenburg was built with a firing system that made it possible to use oil or coal or a mixture of the two. Coal firing was started in 1978 but with limited success, since the operating temperature required for prereduction was very close to the ash-fusion temperature of coal. Modifications were then carried out in the control circuit that made it possible to eventually reduce the oil consumption from 100 to 10 per cent. The stability and emissivity of the flame were such that a 100 per cent coal operation gave rise to unacceptably low prereduction.

After several trials on modified burners, a design was eventually evolved that permitted total coal firing during normal operation. However, when the plant throughput was increased, the efficiency was again lowered and, in addition, excessive accretions formed in the kilns when conditions were created to improve prereduction of the pellets.

To reduce the cost of the energy input to the kilns even further, off-gas rich in carbon monoxide — was introduced to the kilns from the electric furnaces after a control system had been developed to guard against possible explosions. This practice improved the kiln performance, and the quantity of gas utilized was increased to the maximum available. It resulted in a saving of between 12 and 15 per cent of the coal input.

A programme of experiments on burner design is currently under way to improve the form of the flame resulting from the mixed burning of gas and pulverized coal, and although not yet completed, improved results have already been obtained.

In essence, the manufacturing process at CMI consists of chromite ore fines and coke being proportioned on belt weighers and thereafter being fed by conveyor belts to a dryer in order to reduce the moisture content of the raw material. The dried material is charged to ball mills, where a fine powder is produced. This powdered material is then mixed with bentonite and water, and is conveyed to pelletizing discs, where pellets are formed. The pellets are then transported by conveyor belt to a travelling grate, where they are dried and preheated. At a temperature of approximately 1000°C, the pellets are fed into a rotary kiln in which the chromium and iron oxides are partially reduced at a temperature in the region of 1300 to 1500°C. The hot pellets are then collected in a transfer car and weighed. Fluxes and lumpy coke are weighed, charged onto a pellet batch, and conveyed to the charging floor. The hot material is continuously fed from the charging bins to the electric furnace – which is tapped every four hours – by a choked-feed system. Slag and metal are separated by a skimmer and the metal is then granulated in water or cast in moulds.