
Tomorrow's Mines - Cadia as a Case Study

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There have been enormous shifts in the trends within the mining industry during the past 20 years. These trends are a result of changing economic factors and the need to develop larger, low grade deposits using improvements in technology and the ever increasing ability to manipulate data.

Twenty years ago, the gold industry was dominated by South Africa using very established mining and metallurgical technology. The base metal industry was largely built around established mining operations in the south west of the USA, Chile, central Africa and a number of historical districts such as Broken Hill and the Missouri lead belt. Many of these mines were aging and were shackled by inefficient work practices. The large modern mines of the time such as Bougainville and Kidd Creek were becoming more automated but still used multiple crushing, grinding and flotation streams. Mine planning was guided by very conventional cut-off principles. Trucks and shovels were by today's standards small.

The mining industry is a vastly different game today. Whilst South Africa is still an important area, the focus in gold mining has shifted to Australia, Nevada, the circum pacific rim and back into old gold districts like West Africa. Copper has seen a surge of new developments in South America and a modernisation of the North American industry with dramatically different work practices. Equipment has become much larger. Single line comminution circuits can now treat 40-50,000 tonnes per day. Flotation cells have increased in size to tanks of 150 cubic metre capacity. Hydraulic mining equipment have come onto their own and trucks of 300 tonnes capacity are now available. Satellite positioning is now allowing the potential for automation of hauling

operations to be developed. "Expert" control circuits build upon historical plant trends.

Much of the above has become possible because of computer technology. Development of suitable materials would not have been possible without computers and design would have been impossible without sophisticated finite element modelling. Computer driven simulations allow circuit/mine design with a high degree of confidence.

Whilst computer technology may be driving changes in the industry, the data base upon which new developments are predicated is paramount. Often inadequate attention is given to quality control and checking of the drilling, assaying and metallurgical data points which go into a model. Great efforts go into model manipulation with detailed plans being generated on faulty or inadequate data.

There is a strong basis for an iterative approach toward planning. This allows constant focus on where the project is heading. Conceptual modelling and planning should be done at very early stages of the project. The manager and engineer can then assess whether the project has the potential to meet the corporate objectives. Confidence grows as results come in and the project moves progressively into the prefeasibility and final feasibility study stage. All along the way the model is improved. Various alternatives are tested and sensitivities are run. This way the Project Manager keeps his fingers on the pulse. Surprises can be avoided. It can be disastrous to spend millions of dollars on drilling and technical studies only to find a fundamental fatal flaw had been lurking all the time or that project viability was never a possibility.

Today many projects are not lay down starters. They have to be made into good, viable mines. Testing of alternatives and optimising are essential

exercises to guide project management in the right directions.

A good example of the above is Newcrest's Cadia project. Around the world there are other similar projects moving ahead such as Kemess South, Fort Knox, Kumtor and Batu Hijau to name a few. The common thread is size and metal content. These are large deposits with many millions of ounces of gold and/or millions of tonnes of copper but with modest grade. They are the mines of the future and the technology is now here to move forward into this next generation.

In the early 1990's, Cadia grew out of a concept. It had long been recognised that the mineralised system at Cadia was large. Mining history in this central west of New South Wales location goes back to before Hargraves discovered gold at nearby Ophir when copper was already being mined at Cadia. Over the past century and a half progressive eras of gold, copper and iron ore mining came and went. There was clear evidence of large but low grade mineralisation when Newcrest began drilling at Cadia Hill in September 1992.

There are many factors which contribute to the viability of a project such as Cadia. That grade is low is taken as a given. Thus size becomes a fundamental criteria. This is needed to amass adequate metal inventory and to be able to make use of the needed economies of scale. Thus the exploration and drilling programs needed to be tailored toward the big picture. A conceptual model was required along with indicative dimensions. At Cadia the conceptual objective was 100 million tonnes of ore grading 1.2 g/t gold. International benchmarking demonstrated that others were operating good, viable mines in this range.

Of course objectives are never precisely achieved in this business. It could be bigger and better. But the reality of drilling projects is that most often its smaller and lower grade and, of course, many fall by the wayside.

At Cadia, having recognised that grade was going to be low, Newcrest began looking for all the positives that were available to offset this factor. It was obvious that unit operating cost and metallurgical efficiencies were the next most important issues after size. This translated into the need for low mining and treatment costs resulting from a low stripping ratio and the ability to efficiently deliver

ore to be a very large treatment plant. It also meant we had to have a very good understanding of the metallurgy.

Very early in the diamond drilling program an extensive metallurgical testwork was commenced. The options and alternatives were defined and studied. The ore was tested for heap leaching, CIP and flotation. It was found that fairly fine crushing was required to achieve acceptable heap leach recoveries. A coarse grind gave good liberation. Efficient gold recovery could be achieved by conditional CIL/CIP. Both gold and copper material responded well to flotation.

With the comfort that metallurgical response was good, more numbers were needed. Early stage conceptual engineering was commissioned to investigate capital and operating costs for the three treatment routes over a range of throughput rates. At that stage 5, 7.5 and 10 million tonnes per annum were studied.

The early drilling, preliminary metallurgical results and conceptual cost provided the numbers to begin progressive use of the Whittle Four-D program. Over the ensuing two years this was a key tool which guided planning and optimisation.

Several conclusions were reached at an early stage. Flotation was clearly the most attractive process route with the benefit of an important copper credit. The larger the scale the better the economics looked.

The data base was a prime consideration. It was clear that as a large project, Cadia would attract a high capital cost. It would also be revenue sensitive. The grade model had to be right.

From the project inception, emphasis was placed upon a quality drilling program. All drill holes, many to 700 or 800 metres in depth, were HQ diamond core. Competent monzonite ensured 100% core recovery. A computerised core logging and data management program was developed. All core was cut by diamond saw and high quality fire assaying for gold and Atomic Absorption Spectrophotometry for copper was carried out over one metre sample intervals. Sample assays were routinely checked and statistically analysed. Due to the importance of an accurate grade, notwithstanding the wide, consistent, tabular nature of the orebody, the drill spacing was tightened up to a 50 by 50 metre grid. By the time the project was complete the 369 holes in the model contained

142,000 sample points. The spacing and quality allowed the resource to be classified as measured and, ultimately, the reserve as proven. The resource at Cadia Hill is now reported at 356 million tonnes grading 0.63 g/t gold 0.16% copper.

This is a significant deviation from the original objectives. However, the 100 million tonnes in the core of the deposit at a 1.2 g/t gold equivalent, after considering copper contribution, was achieved.

The metallurgical modelling was a major undertaking. Once a standard flotation procedure was established, over 400 flotation tests were carried out spatially distributed throughout the orebody. The ore was categorised into six response types and a three dimensional model was developed. A flowsheet was developed that was conventional and straight forward and would take all ore types. The modelling allowed the differing metallurgical responses throughout the orebody to be predicted in the production schedule.

Throughout the project duration, extensive technical reviews and audits, both internal and external, took place. This was conducted for all disciplines and provided further confidence in the project projections.

The three dimensional grade and metallurgical models provided the base data upon which the detailed Whittle Four-D optimisation was carried out. Grades, recoveries and operating costs were assigned to each of the 25m x 25m x 10m blocks to work out their respective revenue contributions. Altogether 520,000 blocks were used in the Whittle programming.

The Four-D analysis quickly focussed the project group on the need to increase design processing rates to greater than the initially planned 10 mtpa. It was also instrumental in focussing the subsequent design and scheduling on the optimum sized pit from an N.P.V. point of view.

For a project where the economics were tight, this was essential for ensuring that the very best economic project scenario was selected.

The preliminary engineering and cost estimates were carried out by a joint venture between Fluor Daniel and Davy John Brown who also pulled together the Feasibility Study. Not surprisingly the initial capital cost was higher than expected, at over \$500 million. The feasibility study was commenced at 15 mtpa but

quickly revised it to 17 mtpa. Comprehensive and innovative review over several months allowed this to be reduced to \$440 million by using the very largest mining and treatment equipment available.

In fact Cadia will be installing the worlds first 40 foot diameter SAG mill.

As a major new standalone project, there are many other aspects not covered in this paper. These include the Environmental Impact Study and ensuing permitting through the New South Wales Government, the infrastructure planning, community related aspects, land acquisition, marketing, financial engineering and, of course planning towards operations. By the time the project was committed some \$75 million had been spent on feasibility work, land acquisition and royalty buy-out. This again highlights another aspect of large projects. It is expensive to get to the starting gate and by that time management need to be confident of the outcome.

Today, Cadia is under construction with a joint venture between Bechtel and Minproc acting as Managing Contractor. Commissioning is planned for mid-1998 and the Cadia Hill pit will have a 12 year life generating some 300,000 ounces of gold and 23,000 tonnes of copper metal each year. Exploration has confirmed another 150 million tonnes of resource at Cadia East and drilling to below 1600 metres gives encouragement that in the longer term a large tonnage underground operation may be possible.

Cadia represents a good example of the new generation of mines which will dominate the 21st century. Modern science and technology has made it possible. The ability to assess, plan and optimise projects and mines is essential. Tools such as the Whittle computer programs are fundamental in achieving our objectives.

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