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Mining engineering. Some perspectives on managing risk

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Mineral resource deposits are what they are and are where they are and each brings its own particular challenges to the table.

The title of my Presidential Address was *Mining Engineering, a Discipline for the Future*. The focus was largely on South African-based operations, deep gold mining, and other underground mining.

Twenty-three years later, I shift that attention onto a broader scale. What is the current real driver behind mining engineering? The focus needs to be on world minerals demand and for the medium term at least. Even after netting off possible reductions in demand due to more responsible and efficient future behaviour patterns, and also reductions due to development of suitable substitutes, the demand for minerals is likely to far outstrip foreseeable resources, mining projects, and mining operations.

The boundaries will be significantly stretched for the location and characteristics of prospective mineral deposits, for the technologies required in identifying and exploiting mineral deposits, for achievement of safety excellence, for achievement of excellence in environmental interaction, and for achievement of excellence in social interaction.

Competent mining professionals will be required, and in adequate numbers, including geologists and resource evaluators, mining engineers, and virtually all engineering disciplines, and the metallurgical processing disciplines, also professionals in Earth sciences and social practitioners. Much input is required in conceptualizing, identifying, evaluating, developing, and exploiting sufficient viable minerals production capacity.

Up to my presidential year, I had been involved in deep gold mining and underground base metals mining, with some limited international exposure. Since then I was involved in surface and underground mining for a range of technologies and mineral products, in project development, in new business opportunities and also gained much wider international exposure. I would like to share a few thoughts on the risks and constraints of developing increased minerals production capacity, some obvious, all certainly pertinent.

Mineral resource deposits are what they are and are where they are, and each brings its own particular challenges to the table.

Well recognized risks include that the resource may not be of the size and quality evaluated, capital blowout in cost and time, inability to meet the anticipated mining selectivity and unit cost, inability to achieve the anticipated processing recovery, quality, and unit cost, and inability to achieve the anticipated revenue stream, as well as the range of infrastructure, safety, environmental, and social risks. Now let's move on from here.

'Unidentified or unforeseen issues' may constitute a serious risk to viability, or to safety, or to the environment, or to social interaction, or may even become a fatal flaw. It is necessary to diligently and exhaustively review and attempt to identify all such possibilities upfront using whatever specialist input and broad experience is available. 'What could possibly occur?' Even then you will invariably miss something, so recognize this risk in your planning. A most daunting task, and so often neglected.

(While this note addresses the risk, the 'upside or blue sky dimension' may equally occur in large steps rather than incremental opportunities. The ability to recognize both is a recipe for success.)

Digital modelling is an indispensable tool in evaluation, mining, processing and throughout the operation. It is also used to assess risk and impacts. Serious risks, however, tend to occur in significant step changes rather than incrementally, and must be considered in terms of scenarios and not merely in terms of sensitivity distributions. Scenarios need to include extreme cases. For example a prolonged period of drought immediately prior to process start-up, a prolonged period of excessive rain for a flood-sensitive project, a significant change in employee or social or political relations, or the impacts of a seismic event on a waste or tailings storage facility. And so many other circumstances.

Significant positive breakthroughs in mining and processing will be required if production is to come anywhere close to meeting world minerals demand. Consider for example earlier developments of heap leaching of gold from very low-grade weathered resources, the solvent extraction/electrowinning process (SX/EW) enabling scavenging of copper from very low-grade resources and marginal waste materials, the massive scale-up in surface mining equipment size and major advances in equipment control and monitoring, significant advances in exploration tools, progressive improvements in underground mechanization, monitoring and communication, on-going improvements in accuracy and efficiency of mining methods, and significant digital contributions all round. What lies ahead?

Feasibility studies may, and very often do, turn out to be some long distance from reality for a variety of reasons, including significant unidentified or unforeseen issues. This must be recognized. Planning and operations need to be sufficiently robust to cope.

Capital cost and capital schedule overruns are again likely to involve significant step changes rather than incremental impacts, so it is necessary to run some extreme scenarios to assess the extent of any possible embarrassment and the necessary remedial action.

Risk consists of the probability of occurrence and the consequences of occurrence. The probability of occurrence is the minor issue, what is really importance are the consequences. Consequences require exhaustive evaluation no matter how remote the chances are of actually happening. Consider for instance a most unlikely tailings wall overtopping or failure that actually takes place with devastating consequences. Consider backfilling a very large void in the upper levels of an operating mine. Despite whatever controls are put in place, the consequence of failure would be devastating. Consequence identification and management is the name of the game.

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Environmental requirements have become truly internationalized, and are equally challenging wherever your operation. (In the United States, I understand new mining operations are effectively not permit-able. Now many other countries come close.) Cyanide is always an emotive issue. The impacts however of acid minewater drainage via mining and processing operations or via waste rock and tailngs storage are difficult to control, are becoming just as emotive, and involve a much a longer period of impact . (Interestingly certain environmental contaminant constraints are now approaching levels so low that reliable measurement itself becomes difficult.) Well-established industry information describes the risks and requirements that may be encountered. But always consider carefully what you may have missed, it is almost inevitable that you will walk past something.

Consider the often quoted ‘in-perpetuity commitments’ regarding contamination mitigation or other protection requirements which may be contained in an operation’s closure documents. What does this really mean, 10 years, 20 years, or literally in perpetuity? How can this realistically be achieved? This needs to be carefully considered, and defined and documented and understood.

While formal environmental permitting requirements may be clear, the importance of ‘informal social permitting’ is not always fully recognized and is at least as critical to an operation. The ability to achieve the latter may be project defining or even project excluding. This requires extensive work on the ground in consultation with local communities, rather than with higher authority. (You first need to walk the walk and talk the talk in the hills.) Social permitting commitments may be challenging, for instance when considering large-scale relocations, or in addressing extensive informal mining, or in water management commitments. Be aware that apparently minor issues can trigger serious social confrontation.

Consider communities becoming wiser to relocation ‘opportunities’ the second time around, may be exclusionary. Consider informal miners being paid elevated prices for gold as part of underworld money laundering. Consider also the responsibility for the safety of informal mining operations on the property. Stability of underground rat-holes, or people swarming over surface blasted rock.

A further example was the requirement that in excess of 75% of the capital contractors and operating employees of a project had to be drawn from local communities, (where hardly anyone even owned a motor vehicle). This situation resulted for instance in anyone capable of operating (more or less) a back-actor became a contractor overnight, often as a front for an outsider investing in the equipment. So instead of maybe five major contractors on site, in addition 30 or 40 smaller contractors had to be managed. Mining equipment and process operators had to be sourced from local villages and extensive training had to be implemented. Eventually it all worked.

There are any number of site-specific issues that must be tied down (formally) through (informal) social permitting, and with no short cuts.

Water supply is a multi-faceted risk facing most projects, and often a nightmare, sometimes sinking an otherwise ‘viable’ project. Overall, demand for water is increasing and supply or access to supply is more than likely to decrease in the future.

Provision of water is often ‘the most important issue’. The massive water processing and delivery infrastructure provided for some large high-value projects (which can afford it), makes for sobering and enlightening reading. Also consider the importance of extracting the maximum amount of water from process tailings. The seasonal impacts on water supply for a smaller project may be highly significant. Caution is required when dealing with more complex water rights agreements. Excess water, surface or underground, can also be project defining.

Any impact on local/traditional water supplies is an extremely emotive issue in most project developments. (Just don't mess around with anyone's streams.) An example was a very large project involving impact on streams supplying the town and local villages. Appropriate and permit-able reservoirs were included in the planning, however, public opinion was strongly negative, resulting in lengthy periods of resistance and even substantial violence. The project was cancelled and the town was left to ruefully contemplate the lost opportunity for employment and for the local economy.

Then there is pollution through discharge or seepage. Broadly speaking, such pollution is supposed to be a well understood risk, but the devil is in the detail. Contain or treat and discharge? Specialist input and broad experience is required. This may involve a very high cost and long-term commitment. This can be project defining or even a fatal flaw, and certainly can lead to serious social confrontation. Environmental constraints to contaminant levels will inevitably tighten over time and must definitely not be underestimated.

Characterization of waste rock (and any other potential construction material) may be somewhat overlooked. In fact it needs to be very thorough, including an adequate drilling programme. Wall stability and contamination issues are better established. Waste rock as an early construction component or for longer-term construction requirements of the ongoing operation can be critical.

Characteristics of the surrounding host rock, as well as the water table and the local topography need to be very well understood. Absolutely there is potential for a fatal flaw. Such an example was an extensive network of complex finer karst structures quite capable of transporting contamination for kilometres, and which then reappears somewhere as surface seepage. (Even seepage equivalent to the flow of a garden hose would be quite unacceptable.) The role of project elevation and of water table in this case was decisive. The potential social impact could have been massive. The issue became project defining and without very high-cost ongoing mitigation measures involving a thick lining of compacted material to the tailings storage facility, may well have become a fatal flaw in the project.

Space for accommodating waste rock and tailings storage may be constrained to a lesser or greater degree. This can in more extreme cases limit the total exploitation of mineable ore and the life of the operation. An example is an operation where tailings dam capacity limited ore available for extraction to the extent that life of mine planning, cut-off grades, and process optimization had to be altered so as to extract only the more payable ore. (Maybe 15% of potentially available metal was excluded.) Waste rock storage constraints followed closely those of the tailings storage.

Mining companies, especially in South Africa, have scaled down on in-house technical expertise. The use of external consultants on a wide scale is now an inescapable part of the industry and works well.

We must recognize that specialist consultants, (world class), may be required in certain circumstances. An example is a review board, representing the appropriate disciplines, interacting on a regular basis over a long period of time for the construction of a large tailings storage facility. Also in association with a specialist ground water consultant to ensure continuity of community springs and water supply from streams. Also in this case a specialist consultant (from Belgrade) on karstic structures. (Karstic systems are massive in the Balkan countries). Such review boards may be essential, (but must also be recognized as not infallible). Specialist consultants in environmental and social issues were also on board, making vital contributions.

We learn time and time again, that if in doubt, consult an appropriate specialist right away.

Instances of non-standard capital construction and of non-standard operating procedures are very real. Clearly adequate controls need to be in place, however, provision for such instances happening must be made through design, construction and operations, and in contingency planning. Examples include significant seepage from even a small defect on a tailings dam, loss of viability due to deviations in selective mining, severe risk to the underground workings arising from deviations in backfill material preparation, inappropriate robbing or poorly planned pillar stability, and inadequate rock-breaking discipline. Any discontinuity between process plant backfill production and mine backfill placement creates a significant area of risk as a number of severe examples have shown.

Responsible mining requires benchmarking and then more benchmarking. This can only be achieved through studying up-to-date literature, attending professional conferences, engaging appropriate consultants, having direct communication with operators, and visiting operations to gain on-the-gound information and guidelines. You must identify both the best and the most vulnerable practices in order to see your planned operation in perspective. If your planning is outside of the norms, question it, is this due to improvements on the one hand or to shortfalls on the other. Test also 'has it been done before' or 'at this scale' In my own experience, this is an essential and invaluable activity.

The SAIMM and similar professional bodies certainly play a strong benchmarking role.

It is always necessary to find a functional balance between extreme conservatism on the one hand and an operation that may be considered aggressive or even vulnerable on the other.

I suggest that it is necessary to define contingency planning for a range of scenarios, including extreme examples, at an early stage of the planning process. Once construction and operations commence and are ongoing, you will quickly move from planning to reality, maybe some way apart. (You can't then afford to be caught with your pants down when circumstances/opportunities change.)

Always try to identify and define the 'key issues' for the particular project? Very often we don't get this right.

So there it is, my few thoughts on risks relating to a minerals demand driven, and potentially development intensive industry. Now, twenty-three years later, the industry will more and more demand well qualified and diligent professionals capable of clear, exhaustive and incisive thinking, and with the ability to put this thinking into practice. ✷