Flipping the Paradigm

If Australia's minerals industry is to be world leading and sustainable we need to move beyond our comfort zone

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AI illustration of a complacent boardroom

Declaration: The author, Kevin Galvin, is the inventor of a range of single stage technologies. His university has a direct relationship with the relevant industry partners, and he is a beneficiary of his University's IP policy.

Synopsis - The risk of complacency

Beneficiation creates value by separating minerals from so-called waste and delivering the minerals to downstream processes as a concentrate. Highly effective beneficiation greatly reduces the scale, cost, complexity, and environmental impacts of those processes required for maximising the conversion of mineral resources into metals.

There is a belief that the 20th Century mineral beneficiation paradigm is good enough. There is a belief that Australian industry is world leading in its delivery of projects. There is a focus on "technical bottlenecks" to address the critical minerals supply chain implying we should focus on advancing downstream processing, in effect neglect the need to advance first stage mineral beneficiation.

This is a high-risk mindset and narrative that misses the entire point of beneficiation, which is to create value and in fact deliver a competitive and sustainable downstream industry. Those who dismiss or are unaware of step-change advances in beneficiation risk outright disruption. While beneficiation is not fundamental to the "technical bottleneck" per se, its fundamental to the "economic and environmental bottlenecks", which are fundamental to having a sustainable industry.

First stage mineral beneficiation needs a complete rethink. We need to flip the existing paradigm. This paper examines what we might flip to. We need an alternative. The volatile pricing of commodities such as lithium and nickel over the past two years has led to the closure of several Australian mines (put into care and maintenance). This has occurred primarily because these mines had difficulty competing on price with overseas producers working in conditions where Environment, Society and Governance concerns have been neglected. Australian industry needs the toolkit to enable processing that produces higher mineral recovery and grade while using a smaller environmental footprint, all at a lower cost.

There will be no supply chain into downstream processing, period, if we do not get the first stage of mineral beneficiation right. Australian industry is sinking capital into inefficient plants, potentially creating stranded assets. If the producers cannot compete then they will put their operations into care and maintenance or close them entirely. Then Australia loses its competitive advantage, its endowment of mineral resources. Australia will not become a mainstream importer of concentrate. The sustainability of the Australian industry warrants *lowest cost producer of concentrate status*.

Flipping the paradigm

The mining industry is sophisticated in many respects but is also recognised as one of the most conservative, risk averse sectors in Australia. It has highly entrenched practices and is historically a slow-moving sector that is still relying on 20th Century methods while attempting to meet the many new challenges facing minerals processing in the 21st Century. We need to question the "age-old practices", to identify the intrinsic nature of the paradigm, and the drivers that reinforce and perpetuate the paradigm. This paper looks to identify the paradigm and the relationships between the end-users and the service providers, and the absence of a "conversation", which is the precursor for change.

This paper argues for the need to leverage knowledge and technology advances with a much stronger lever for effecting change. That lever is the Paradigm Shift, a powerful organic force that manifests change from within, permeating gradually at first, before accelerating and cascading like an avalanche. Once the change commences, it is unstoppable.

But this approach can only gain traction if an alternative value adding paradigm can be articulated, ideally aligned with new knowledge and robust technology advances. There are signs of change, a realisation by some in the industry, the champions of innovation, that there is a better way.

The ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals, referred to as COEMinerals, now seeks to exploit its research findings and its advances in science and technology to create value in the industry. In partnership with equipment manufacturers, COEMinerals is building a portfolio (see table) of single-stage technologies that is already recognised globally. There are other new and emerging technologies concerned with breakage and comminution, dewatering, and others involving novel reagent delivery and new polymers and biomolecules, including peptides, that may offer unprecedented selectivity and game-changing solutions.

While innovation can exist within a given technology, the more pervasive innovation lies with the way it is configured and applied. It is argued that this higher-level innovation, concerned with deployment through new circuits, could ultimately deliver a paradigm shift, creating the momentum for change. It is, however, important to have a realistic sense of the sector, to appreciate in full the considerable inertia that exists in what is a high risk, capital intensive, and therefore very conservative industry.

Defining the problem

Many of the problems that exist across the industry are too diverse for detailed discussion, concerning mineral chemistry, and the complexity of polymetallic ores. The focus is therefore on the ordinary performance of technology. If a cyclone separates inefficiently (and they all do), then fine particles are returned to the mill for more grinding. Energy consumption is higher, mill productivity is lower, but there are no losses prescribed to the cyclone – it's an internal circuit. Or are there? If the flotation fails to recover the ultrafine particles, it is because the particles lack the inertia and hence the necessary bubble-particle flotation kinetics. This is just accepted as a limitation of flotation, rather than a deficiency of upstream separation. The tailings volume is larger than it should be, but that outcome is not viewed as failure of the cyclone. It is time to question everything.

Another significant factor affecting separation performance is the exponential effects of slimes-viscosity, caused primarily by ultrafine colloidal clays. This factor is far more significant and wide ranging than is often realised and so obscures objective assessment of different technologies. Its effects must be measured, acknowledged and formally addressed either by dilution or by efficient removal at the finest possible size. However, conventional approaches deslime at relatively coarse sizes resulting in excessive loss of valuable minerals.

These problems which have perpetuated for decades do not resonate as being worthy of attention even though they are worthy of attention. The minerals industry is very diverse and lacks a suitable forum for securing consensus, unlike the coal industry, which is far less diverse, and has benefited from the ACARP program over a thirty-year period, which brings representatives from all the key producers together on a regular basis. The lack of meaningful evaluation of plant performance leads to indifference, and acceptance of the status quo. The problem is only addressed when "everyone" agrees there exists an intractable problem in need of a solution.

What is the paradigm?

Mineral beneficiation is immersed within a 20th Century paradigm, often drawing inspiration from technologies that only perform partial separations. The comminution stage uses cyclones to extract and return relatively coarse particles to the mill for more grinding. However, the cyclones only perform a partial separation due to a problem called by-pass, meaning that ~ 30% of the particles that are already finer than the target particle size are returned to the mill with the coarse particles for more grinding. A similar problem arises when the cyclones are used to remove fine clays called "slimes". The failure to properly prepare the feed leads to a cascade of problems through the plant, impacting on the subsequent mineral separation processes involving for example gravity and flotation technologies.

There is a philosophical mindset embedded in the way mineral processing circuits are conceived. The partial separators rely on multi-stage processing to achieve a relatively simple goal. We invent the term "rougher", an excuse for the process that captures the target mineral together with unwanted material - a rougher concentrate. We then need a "cleaner" stage to remove the unwanted material, but because this stage performs poorly, we then invent the term "re-cleaner" to describe the next stage. Recycle streams are then introduced, a clever strategy, but the tendency is to build excessive recirculating loads, fearful of "letting go". We also invent the term "scavenger", the process that captures the unrecovered target mineral from the rougher stage. With poorer quality ores that liberate the valuable mineral at finer sizes, these circuits have become increasingly complex, with an ever-expanding footprint, requiring yet another layer of processing to capture the ultrafine particles. Inevitably, the approach ceases to be fit for purpose. You can choose to present a modular plant, but if it is still full of the same inefficient technology, then it remains complex, large in footprint, and ineffective in adapting to variability and the need for more complex decision making.

AI illustration of a large complex plant-the destination if we do not change now

Creating a new paradigm for mineral beneficiation

The COEMinerals' vision is for single-stage technologies that connect in simple ways to produce the most robust and effective minerals processing circuits possible. Our pipeline of technologies is listed below, and no doubt there are others available globally. Ideally, upfront separators process all the feed, possibly in a single stage for a fully liberated feed, while for low grade ores the next phase of the plant need only focus on a small portion of the original feed, permitting more powerful and effective forms of separation. Then, only small portions of this material need to undergo additional comminution, thus minimising the production of ultrafine particles across the entire feed. Recycle is then limited to very small portions of the original feed.

A guiding philosophy to realise this vision is given below:

- Mineral beneficiation requires the production of particles through breakage and comminution, and the introduction of technologies to sort the particles. The final phase ideally targets separation at a common incremental level of mineral quality or grade.
- The breakage and comminution should enable the rejection of unwanted gangue particles from the circuit at a relatively coarse size, so-called pre-concentration. This strategy, which is already gaining traction around the world, delivers, in part, a relatively coarse and lower grade concentrate. This concentrate requires targeted grinding to achieve liberation. The pre-concentration reduces the size of the next phase of the plant and minimises grinding energy and water consumption.

- Efficient methods of classification with no fine particle by-pass are essential in comminution circuits for ensuring fully liberated particles are not returned for further grinding.
- If desliming is used to overcome the effects of suspension viscosity, the separation size should be relatively fine ~10 μm, with no by-pass. Alternatively, the feed should be diluted. Excessive viscosity must be addressed.
- Single stage beneficiation should then deliver slimes-free concentrate while meeting the target recovery. The goal is to maximise the recovery of the targeted mineral while rejecting as much of the gangue mineral and ultrafine slimes as possible. This represents a further opportunity for pre-concentration. The mineral grade of the concentrate typically declines monotonically with increasing particle size. For higher grade ores that are fully liberated, this single stage of separation should deliver the final grade in one stage, fully deslimed and thickened for filtration.
- For low grade feeds, the next stage of processing occurs at a much smaller scale, governed by the solids yield of the previous stage. Sharp classification of the concentrate at a given particle size provides a simple and direct pathway to securing high-grade concentrate while allowing the small portion of coarse concentrate to be milled and returned for upgrading.
- Alternatively, efficient beneficiation can be applied to secure the high-grade concentrate, returning the small portion of poorly liberated concentrate to a small mill for grinding and then upgrading. This re-cleaning stage could involve simultaneous desliming and gravity separation, providing a means to control the final concentrate grade. This approach overcomes the problem of mixed mineral grades in flotation concentrate. Recovery must extend to the finest of the concentrate particles.

The end-user is the ultimate agent for change as they are the principal beneficiary. They need to invest internally in a culture that is prepared to ask questions and is prepared to do the homework to secure the benefit of knowledge, to fundamentally understand the robustness of a given technology. The end-user can then collaborate with the engineering company, the equipment supplier, the researchers to build the paradigm.

COEMinerals Technology Pipeline

Technology	TRL	Technology	TRL	Technology	TRL
Jameson Cell	9	CoarseAIR™	6-8	Acoustic Flotation	2-3
Reflux™ Classifier	9	ExtractORE™	5	PV silver extraction	2-3
Concorde	7-9	G Force Dewatering	4-5	Selective Peptides	2-3
Reflux™ Flotation Cell	7-9	Graviton	4	Bio-inspired RAFT	2-3
NovaCELL™	6-8	High Pres. Dewatering Rolls	3-4	Pelletiser	2-3
GradePro™	6-9	G Rolls®	3-4	Hydrophobic Clay	2-3
Oscillatory Dewatering	6	High Voltage Pulse	3-4	Gas phase collector	2-3
GradePro™ + Rake	5	Sink Hole Fluidiser	3		

Why does the legacy paradigm persist?

End-users are the mining companies that have a need for beneficiation. Many know the current systems are not ideal, and yet, they perpetuate. Most avoid risk (or the perception of risk) when considering new alternatives and continue to operate within their comfort zone through existing relationships and therefore existing technology. They might have an interest in something new, but that will likely be peripheral. They might even invite "the consultant" to assess the proposition - the problem here is if the consultant says no, they still get paid, better still, there is no risk to them. The standard plant is adopted, and the end user suffers in silence. These plants are difficult to upgrade for higher production because the footprint is so large, hence respond poorly when management inevitably demands "more tonnes".

For the engineering company that seeks to win the contract to build new plants, the appetite for risk is contingent on what they must do to compete, which is a reasonable position. If they believe they can secure the next job continuing to do what they normally do, and if they believe the status quo of a large complex plant is favoured by the decision maker, then there is no appetite for change. In fact, the dividend for the engineering company increases with the complexity and scale of the task. If the end-user is convinced to adopt the more expensive standard plant, and that delivers lower than expected mineral recovery, and commodity prices fall, then the project could be at risk. But in many ways, the engineering company is well placed for creating change, by drawing together new technology from different equipment suppliers in new ways to deliver greater value to an end-user. This is contingent upon the evidence and hence belief that there is a better way and that there is a prize for seeking a major competitive advantage through that vision.

For small producers with limited financial capacity and process experience, the starting point will usually be the standard model. They will be influenced by the common view which emanates from the industrial eco-system. The industry is immersed within a legacy paradigm, with little impetus for change. The university professors dust off their tired lecture notes and perpetuate the old ways. From every quarter the legacy is reinforced. Therefore, they will raise the capital they require on the back of the legacy paradigm. However, if they connect early with the right knowledge their pathway to profit may be impowered as they do not carry traditional baggage.

We can all relate to the status quo, being content with what we do, templating what appears to be a successful business model. If the technology is proven, why would you change? There is a sense of community in one's love of the subject, a familiarity with the tool kit, having a capability that is recognised. Negative perceptions, or here-say, concerning new technology, naturally reinforces the belief system. In the end there is little risk appetite for anything new. This then locks in the legacy paradigm.

What comes next?

In a mature phase of the paradigm shift, the engineering companies would compete with the expectation of delivering simpler, more effective plants, requiring less energy and water consumption, higher grades and recoveries, with less engineering. The approach would support a more competitive and sustainable industry for Australia and open the sector for more international work. The paradigm shift is a framework that offers a common purpose for researchers, equipment suppliers, engineering companies, and end-users, a common mission to effect change. The key to success is the building of technological capability, knowledge, feasibility, engagement, and adoption. We need to build the conversation, the realisation, the belief, that there is a better way.

This vision will be expanded in forthcoming keynote presentations with reference to data that underpins scalable solutions.