Lessons in Sustainability from the Mining Industry

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Lessons in sustainability from the mining industry

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Abstract

Environmental concerns, water and energy availability and costs as well as the public's license to operate all contrive to demand more efforts targeting sustainability. In this paper we discuss the broad lessons learnt in the wider mining industry that may be relevant to the phosphate rock industry. In particular, we suggest that it is innovation, particularly in technology that holds the key to more sustainable mining. Breakthrough developments in automation, in sorting, comminution and flotation are highlighted together with some suggestions as to how a more collaborative approach is needed to bring through step changes in the industry.

Peer-review under responsibility of the Scientific Committee of SYMPHOS 2013

Keywords: Sustainability; innovation; mining

1. Sustainability in the phosphate industry

Phosphorus use in fertilizers has shown long-term growth, reflecting the essential nature of phosphorus in nutrition. It is however a non-renewable resource and this frequently raises questions as to the sustainability of the rock phosphate industry. The track record of some parts of the rock phosphate industry in the past has been far from ideal in terms of sustainability. The earlier mining techniques used on some of the Pacific Islands such as Nauru [1] and Banaba [2] are not compatible with the standards demanded today for sustainability. Reviews of current practices [3] indicate that sustainability is taken seriously and significant advances are being made. The relative size of the rock phosphate industry (198 Mt/y in 2011 [4]) against the shear size of the rest of the mining industry suggests that there are many more opportunities for sustainability practice to develop in the wider mining industry. For every tonne of phosphate rock mined, there are over 50 tonnes mined, just in coal (7678 Mt/y in 2011) and iron ore (2940 Mt/y in 2011) alone. This is not to imply that transfer is only in one direction; there are good examples of the rock phosphate industry being quick to adopt leading edge innovations, eg the use of thickened slurries to minimize water usage in placement of slimes from wet screening [4,p45], much like tailings disposal in hard rock mining.

In many countries, mining and sustainability are considered to be incompatible because of the obvious depletion that inevitably occurs with any particular mine. The confusion arises from two directions: firstly from a fundamental misunderstanding that sustainability requires or implies that something is endlessly available, like sunshine. The original Bruntland definition [5] however is quite clear – sustainability is about needs, in particular "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In the case of phosphorus, the key is whether the known and likely resources are adequate for the forseeable future to meet the needs of future generation. The price hike in 2008 caused by shortages

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associated with food supply, generated much debate on peak phosphorus. The considered opinion in most quarters [6,7] is that with reserves of almost 300 billion tonnes, peak phosphorous is not a concern in the next 50 years. This is not in any way to downplay the importance of efforts to improve recovery in mining, to use less in agriculture and to recover phosphorus from waste streams – all are important elements of sustainability of a finite resource. The reality is however that with an abundant resource, as the easier to mine materials are won and grades become lower, with stripping ratios higher and more expensive processing becomes necessary, we simply move to the harder to win materials and rely on innovation to keep the real costs of production competitive. This is inescapable in all forms of mining.

Sustainability in mining is thus not about a particular mine being endless, it is about the global nature of the resource and then, importantly, that individual mines operate within the guiding principles of sustainability. Concerns about peak phosphorus have been mistaken in taking the resource figure as a constant. As with any other commodity, higher prices inevitably drive exploration and development of new resources together with better exploitation of existing resources.

2. Recent trends in sustainability

Sustainability in modern mining influences every part of mining, from discovery to closure. This is the only way that the multiple objectives of social well-being, environmental stewardship and economic prosperity can be met. The better performers focus on four directions: people, environment, economic performance and wider stakeholders. Let us consider some best practice examples [8].

2.1. Sustainability for people

Health, safety and the wellbeing of workers is the highest priority for many companies. The notion of zero harm is widespread and is achievable. The adage that “accidents will happen” is no longer acceptable. Achieving zero harm requires focus and specific campaigns around injuries, occupational health, and noise and an overarching approach to risk. Risk reduction must be managed through a quantitative approach that involves hazard identification, risk assessment and risk management. Most important is the cultural leadership that is required. Many in the mining industry bring an approach that accepts risks and, even when they are identified, many are reluctant to change behavior. Leadership in changing culture must come from the top but must be implemented at all levels. Daily performance measures all the way through to annual performance reviews are necessary. At a mundane level as an example, if two workers walked past a trip hazard, the only question would be which one took the responsibility of initiating action to have the risk ameliorated.

The culture and systems of mining companies now are very similar to those found in other process industries. In particular, the risk based approach of the chemical and oil and gas industries have been fully embraced by the mining community. This requires that for all steps of the mining process, there is a detailed description of the step and a risk assessment that covers hazards, pathways, receptors and operating procedures. Risk and its assessment and control are not an adjunct to operations but are an integral part of operations. Mining companies are now just as familiar with LOPA (Layers of Protection Analysis) as companies in the chemical and oil and gas industries.

Health considerations no longer stop with occupational health but embrace wellness and mental health. Voluntary programs on health and wellness are now commonplace, including group sessions at the work place and during work hours, whereas it was common 30 years ago to see group exercise at work in some Asian countries. Now one is seeing this activity in many countries with voluntary annual health screenings also being encouraged.

2.2. Sustainability for the environment

Environmental stewardship remains a central value for mining companies. The actions have to be clearly visible and credible to workers, to surrounding communities and stakeholders wider afield. Transparency of actions is quite critical and this is tackled in many ways. Involvement of workers and their families and surrounding communities in surveys is an interesting part of transparency. Some have gone further and use external Non-Government Organizations as contractors to audit operations as compliant with both regulations and the stated policies of a company.

Minimizing the environmental impacts and risks associated with operations is the starting point. Further extension is needed to improve operations and to tackle long-term legacy issues well beyond that required by regulations. A risk based approach such as the International Standard ISO 14001 ensures that environmental risks are assessed and controlled and performance is continually improved. There are many operations where land is rehabilitated as soon as it comes out of direct use, rather than waiting until mine closure.

The phosphate rock industry has to handle hazardous waste no differently to other parts of the mining industry. The wealth of information on how acid mine drainage is prevented is relevant when considering the necessary disturbance of selenium containing rocks as part of the extraction process. Secure placement of material is essential, as happening at the Monsanto Blackfoot Bridge Mine in Idaho [9]. In the Monsanto case, a laminated geosynthetic clay liner is used in a similar way to that used to stabilize some tailings dam or to line impoundment ponds for the jarosite produced in zinc smelting. Equally, capture and treatment of any run off is also necessary. There is much experience in capturing run off and also intercepting contaminated ground water and subsequent treatment. Of interest for selenium removal may be the use of algae in much the same way that certain aquatic plants are routinely used to concentrate heavy metals from contaminated water. Full scale bio-treatment for selenium removal is becoming practical [10].

All mining involves concerns with water and much of the rock phosphate mining is in water scare regions. Experience in mining suggests that water demands stewardship in economic, social and environmental terms. It is much more than simply minimizing fresh water extraction. Re-use often forces process changes. That flotation is possible with high dissolved salt contents is well established. That the reagent cost will be cheaper than when using fresh water is not and there is still much to learn. Discharge to the environment of used water is now seen as an opportunity for changed practices in land management with irrigation enabling more productive farming in the neighborhood of a mine as an example. Sustainable water management generally runs far beyond the boundaries of a mine.

Biodiversity is also taken very seriously. Previously the disturbance of rare or endangered species was often used by pressure groups to prevent mining. Best practice now is to target increasing biodiversity within the area of influence of a mine. To do this of course requires good baseline and ongoing sampling. It also requires a deep understanding of the flora and fauna in an area, including what might have existed well before mining operations started. Partnerships with experts here including even paleobotanists are important [8]. A key factor with biodiversity is active land management of the mine and its surrounds. This can mean limiting human activity such as subsistence agriculture, or as in the case of some coal mines, eradicating non-native feral animals such as cats and rabbits, fencing areas to keep out the feral animals and then allowing the original populations of flora and fauna to re-establish.

2.3. Sustainability for wider stakeholders

Stakeholders include neighboring communities, traditional owners, local, regional and country based governments, non-governmental organizations, the wider and worldwide community, customers, suppliers, joint-venture partners, contractors, shareholders – the list seems and to some extent is endless. Employees are of course on the list and were covered as a special case in Section 2.1 above.

Handling the wider set of stakeholders in order to maintain the license to operate is becoming ever more complex. That said, there are clear success stories and they have a common element, viz that of leadership, resourcing and patience. As the list of stakeholders is so extensive, a focused approach is necessary. Stakeholders need to be identified with two directions in mind, a sense of the impact of operations on the stakeholders and a sense of how the stakeholders can impact on the business.

In terms of detailed methodologies, the approach outlined by Lane and Ndlovu [11] is noteworthy as it considers the difficult case of mining where foreign direct investment is involved. This might be seen as particularly relevant to some rock phosphate operations where indigenous nomadic people may be in dispute as to sovereignty of an area. High cost, long-term investments simply cannot be made without comprehensive stakeholder engagement, not just at the start but for the duration of the mine and onwards. The closure of the Bouganville Copper Limited mine at Panguna is an example of what can happen if stakeholder management is inadequate. Interestingly, the current discussions to re-open the mine are very much along the lines of comprehensive and patient stakeholder engagement [12].

The first step in the Lane and Ndlovu approach is to undertake a stakeholder analysis. They indicate that the more comprehensive this is, the greater the chance of success. Figure 1 from their work illustrated that the list is long, the expectations can be very different and that in the end, a compromise position suitable to all stakeholders will never be fully possible. At one end of the spectrum will be stakeholders who want no mining on any terms and at the other, the ability of a company to share wealth is limited and finite.

The second step is to explore the narratives that each group have. These are the ideas or stories that particular groups tell themselves in order to define themselves. The narratives may be historical, or religious, or ethnic, or political or a long held custom. Local narratives can be very deeply held and any proposition from a company that runs counter to a narrative will face difficulties. Lane and Ndlovu suggest narratives define the boundaries of what a stakeholder will consider fair and reasonable.

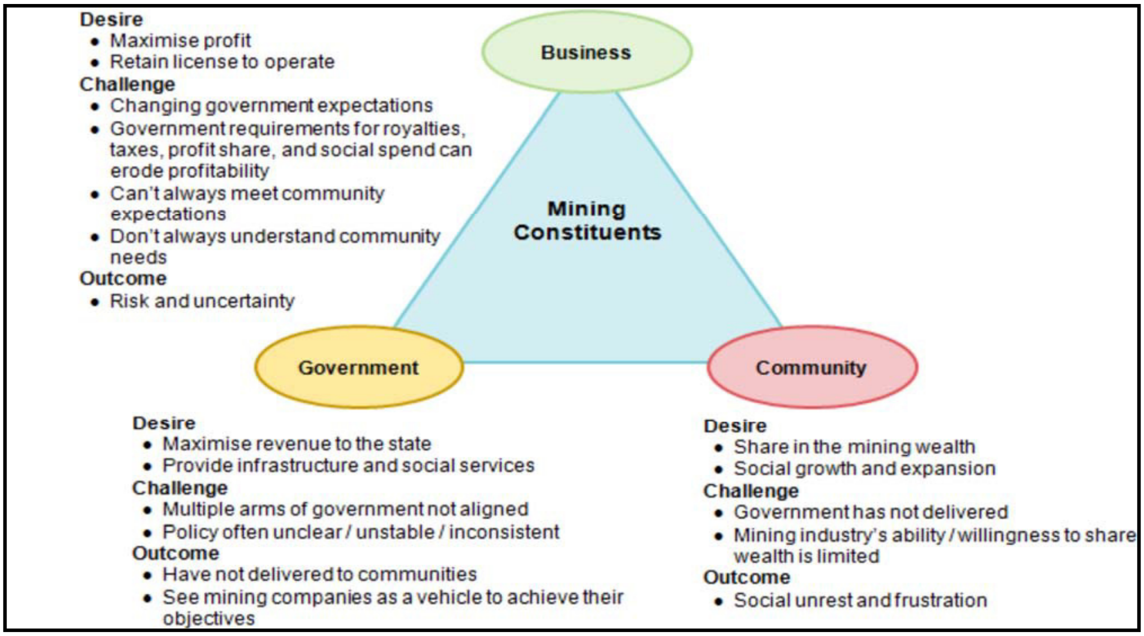

Figure 1. Understanding stakeholders requires a comprehensive approach and realisation that all desires cannot be fully met [13]

The third step suggested is the use of scenario planning, as pioneered by the Royal Dutch Shell Group in the 1970's and now routinely used in strategic planning. In all of this it is clear that stakeholders must be engaged in a patient, respectful, and deliberate manner with the aim of building long-term relationships. Success of the approach has been well documented. As an example, Lane and Ndlovu quote the Rio Tinto engagement with the indigenous community in the Pilbara region of Western Australia. The negotiations took 7 years and involved communities assessment, relationship and partnership building and finally community programs that reflected the assessments and consultations. Examples of the programs include support for indigenous firms, employment readiness training and guaranteed jobs for those that complete schooling. In the end, a $2bn agreement over 30 years was signed which gave the company access to an additional 70,000 square kilometres.

2.4. *Sustainability for economic performance*

A mining operation must generate wealth (however defined) otherwise it cannot operate. In economic terms, an operation must be positive, otherwise there is no chance of satisfying the stakeholder expectations. Sustainable development is not possible without sustainable economics. The question then comes as to how best to increase the economic performance of a mine. The answer is very much related to innovation, especially technological innovation. It is innovation that can reduce costs, that can give better product stewardship through generating less waste or recovering more of the valuable ore and that can reduce the cost of infrastructure and transport. Incremental innovation can be undertaken at any time. Like the other elements of sustainability, it requires leadership and resourcing. Step change innovation takes more effort.

3. The role of innovation

Production and consumption of rock phosphate has increased for well over 100 years. The interesting point is that from 1920 onwards, the market price in real terms (the 1998 $ shown in Figure 2) has not increased commensurately other than the spike in the 70's associated with oil price and the recent excursion in 2008 on which we will comment later. In 1920, world production was of order 7 million tonnes compared with around 200 million tonnes now. This is an extraordinary result as during this period, the average grade mined has fallen. The answer as to why demand can rise, mining conditions move adversely yet selling price in real terms hardly change, is that innovation has steadily occurred. As an example, beneficiation by flotation was introduced in Utah in 1980, Jordan 1998, Morocco 2000 and Syria 2005 [13].

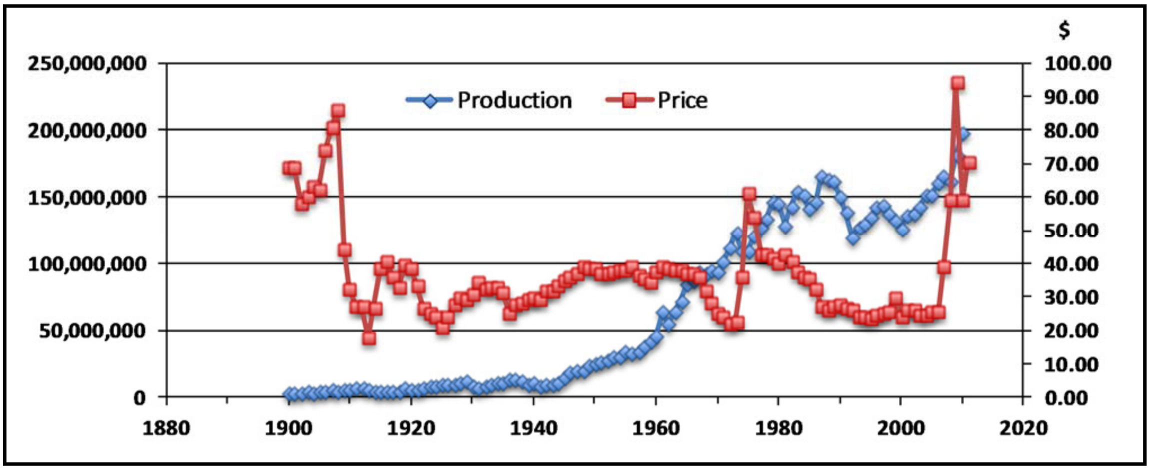

Figure 2. Historical production and price in constant 1998 $ for Phosphate rock USGS [4]

Let us now return to the question of the 2008 spike in prices and whether the long-term price will fall back to the real price levels of 2000 or will remain somewhat higher. The traded rock phosphate is only 16% of the total rock phosphate produced [6], indicating the high degree of vertical integration in the industry. This is similar to the alumina industry and means that any shortages of supply or increases in demand result in an exaggerated swing in prices until new capacity is installed. In the period up to July 2007, food and oil prices had not risen by much in real terms for several years. Equally and correspondingly, the demand for rock phosphate had been rising slowly but was still below 1998 levels. The rapid rise in food and oil prices from July 2007 dragged the rock phosphate price steeply up, as in such a short space of time it is not possible to bring on enough capacity to meet demand.

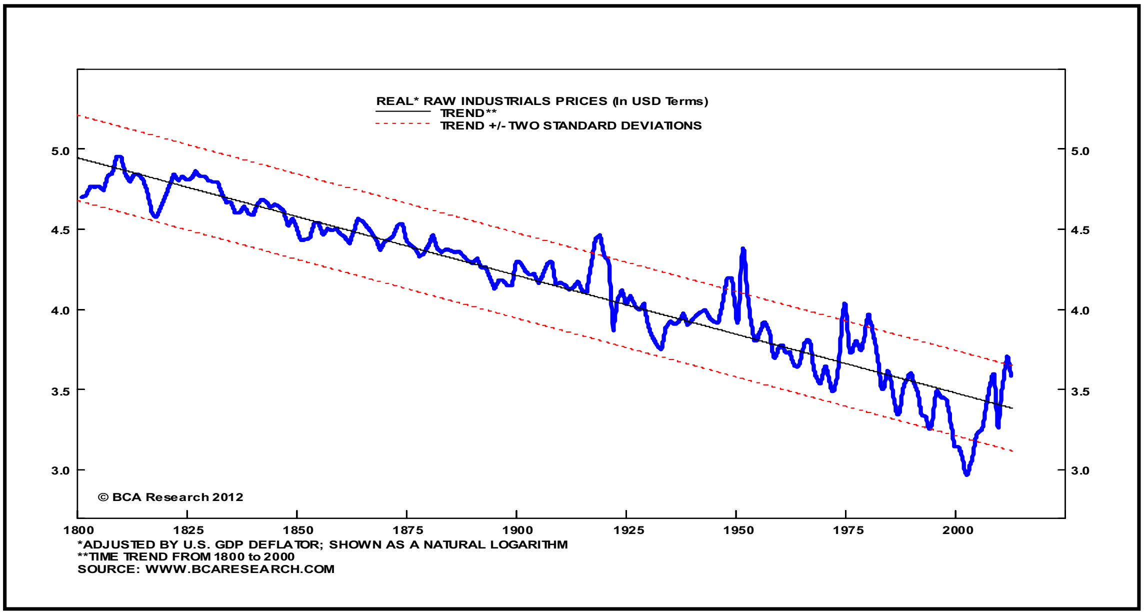

Figure 3. The long-term trend is for commodity prices to fall in real terms.

However, rock phosphate is not in short supply globally and any sustained increase in price in real terms will encourage more exploration and development of alternative resources. This is the fundamental lesson of commodities. If prices stay high for a few years, new capacity will be brought on stream. Equally, with the passage of time, innovation will be introduced and inevitably reduce the price in real terms. When we consider a weighted average of all commodities for the last 200 years, the trend is clear and inexorable.

For all commodities, while supply and demand are important in the shorter term, the longer term price is determined by technology and its rate of adoption, ie by innovation. For rock phosphate, while the Arab Spring may have resulted in supply reductions [7], in the longer term the real price is likely to revert to the levels seen prior to 2007.

4. Recent innovations

4.1. Mining and automation

The scale of some open pit operations is now so large that new approaches are being introduced. While bucket wheel excavators, drag lines, shovels and trucks grow ever larger and we now see in pit crushers and sizers, there are other innovations that are considerably changing the economics of mass movement. The most significant to date is the automation of drills, trucks and trains. Already, this has been demonstrated in the iron ore industry and the expectation is that within 3 years, in one company alone there will be 150 autonomous trucks hauling 20 Mt/d [14]. The key here to the productivity improvements is not so much the elimination of drivers, or the more regular loading and travelling of vehicles that reduces maintenance requirements and improves reliability; the key is that an automated mine is laid out and operated differently. It is designed to allow the smooth operation of the automated machines and resembles a railway system much more than a road system with its intersections and halts.

Another and related advance from the large scale miners is the introduction of remote operation centres. In concept these are not new as LKAB was operating crushers in the north of Sweden from a control centre in the south of the country over 20 years ago. What is new is the extent and comprehensive nature of the remote control centres or Integrated Operations Centres as they are frequently called. In Perth, two of the major iron ore producers have gone down this path. The Rio Tinto Iron Ore Centre was established in 2010 and the BHP-Billiton Centre is under installation [15]. Both of these companies plan further centres for copper and coal. At one level these centres offer savings as it is no longer necessary to have so many people fly in and fly out or to live in remote areas. More importantly, the centres allow an integrated approach where despatch, mine control, maintenance scheduling and operational planning can be done by dedicated teams of specialists. These centres satisfy the need that the highly trained people needed to run the mines generally want to live in cities.

The integrated nature of the centres also allows a more effective approach to grade control. Mining is about data and with much more complete tracking of grade information, mining becomes more like a manufacturing operation with ore delivered bucketful by bucketful to suit customer requirements. With multiple mines and extensive data from blast hole sampling (and earlier core samples), the mining operation is dominated by data. The mathematical techniques of data mining become relevant in developing new ways of scheduling operations with a focus on eliminating as much as possible, placing material on the ground in stockpiles with subsequent reclaiming.

Finally, with much more detail on grade and impurities being available, either from the sampled data sets or increasingly from on-line scans on excavators and buckets (or as a minimum, on-line scans of a face before it is excavated), it is now possible to consider bucket by bucket that material is sent to different processing routes. Sensor technology similar to that used in airborne geophysics turns each scoop into a piece of data. The realities of most ore bodies are that there are pockets where gangue material can be liberated and removed dry at coarse sizes. The liberation may be by dry screening or by sorting, particularly relevant to much of the rock phosphate industry. Individual sorting machines are now up to 400 t/h and with dual beam sensing (and other combinations such as micro-wave heating and subsequent infra red imaging) can cope with quite complex mineralogy [16].

In the minerals area the technique of much finer attention to metallurgy before excavation is termed geo-metallurgy. In one company, trials indicated that using geo-metallurgical measurements and then dry screening some of the ore after primary crushing, it would be possible to reduce the milling energy requirements by up to 50% [17]. Geo-metallurgy should find application in rock phosphate processing.

4.2. Recent process innovations

The importance of dry separation or sorting at coarser sizes is that it can significantly reduce the amount that must then be milled and handled wet, eg by flotation. An advance in flotation by Jameson [18] extends the size range from a few hundred micron up to millimeter scale. While not yet tested for rock phosphate applications, this advance is showing promise in sulphide mineral applications.

Also of interest is recent work using dry sand fluidized beds as density separators. The dry sand air fluidized bed produces a dry dense medium in which the lump (typically 10 to 50 mm) ore is fed. The particles are separated by float-sink on the basis of their density relative to the density of the fluidized sand bed. The technology could be used to replace conventional wet dense medium separators in the coal [19] and iron ore [20] industries resulting in reduced water consumption. In addition, for copper ores that need to be finely ground to liberate the valuable mineral, the early rejection of lump gangue using a dry sand fluidized bed before grinding could reduce the energy consumed and reduce the carbon footprint of the process [21]. The approach appears promising, but has not yet been investigated for rock phosphates.

4.3. Making innovation more effective

Innovation of necessity involves change and any change in a mining or processing operation may or may not deliver the intended benefits. In a capital intense industry, where disruption to production is generally not possible, bringing innovation through to success is often more difficult than in manufacturing where the innovation process is well developed [22]. The track record for step change innovations such as open pit mining or flotation or SX-EW for copper is that there are less than 5 such innovations per

100 years. BHP-Billiton experience over many years was that in moving from pilot scale to full commercial application, innovations they were developing took at the 90^{th} percentile range from 3 to 14 years [23].

In leading and managing innovation, most companies use a stage gate approach where each project progresses through stages and at each stage, a go/no go decision is made. Common gates are after idea generation; early stage development and laboratory testing; pilot testing; early commercial scale prototype testing; finally full production implementation. The challenges facing the rock phosphate industry of demands for more sustainable production, lower prices in real terms and more difficult materials to process all contrive to suggest a re-think as to how to get more out of innovation. The approach adopted by the Newcrest company deserves special attention [17]. There are some key steps which distinguish their success:

- Respectfully create dissatisfaction with the present state
- Select game changing targets, eg halve energy useage
    - Targets to be implementable within a 5 year plan
    - Bring new views and new actions but insist on simplicity as a principle
- Run a balanced portfolio involving clear priorities
    - First preference is to adopt, second to adapt and last is to develop
- Invest enough ($5-10m) at the large scale prototype level for rapid field testing
    - Non-disruptive testing at field scale
    - Rapid implementation when successful

One further notes that a part of the Newcrest success is a willingness to adopt open innovation and to collaborate with others. This is especially important in that the equipment suppliers often need to be involved in any significant innovation.

The topic of how best to collaborate is also worth investigation. Without arguing the merits of open innovation versus proprietary innovation, one simply notes that there is an excellent track record of collaborative innovation through jointly supported research and development in the minerals industry through AMIRA [24] and similarly through shared research in the coal industry in Australia through ACARP [25]. The AMIRA International model in particular may be relevant to the rock phosphate industry.

5. Concluding comments

The rock phosphate industry is on a sustainable long-term path despite recent concerns around peak phosphorus. In terms of how sustainability is handled, it is clear from the wider mining industry that this is becoming ever more challenging but that with leadership, patience and resourcing, advances can be made. Seven years to settle large scale negotiations is to be expected.

The nature of any commodity when there is an adequate global resource (as in this case) is that high prices in real terms are not sustainable. Innovation has always been the engine of improvement of performance and in the face of increased demands for more attention to sustainability and simultaneously, falling prices in real terms, innovation becomes doubly important. The recent advances in mass mining, in geo-metallurgy and in automation in very large mines suggest that these technologies are ready for implementation in the rock phosphate industry.

There are some companies who are more successful at innovation than others and the key attributes are described in the paper.

Finally, there are breakthrough developments in processing; especially dry processing that may be relevant to the rock phosphate producers. A collaborative approach as encouraged by AMIRA International may be appropriate to rapidly test the suitability of these new developments.

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