

Perspectives on Mineral Commodity Price Cycles and their Relevance to Underground Mining

A Trench^{1,2,3} and J P Sykes^{4,5}

ABSTRACT

Mineral commodity prices are subject to volatility over both the short and longer run – driving fluctuating operating margins for mining companies over time. Such market dynamics influence mine operating decisions depending on the interplay of company-specific and mineral market factors. The company factors include corporate financial strength and price-risk management strategy, as well as mining practices and methods at the operation level. The critical mineral market factor is the price of the ex-mine product. This results from underlying microeconomic and macroeconomic root-causes pertaining to mineral supply and demand, in addition to the activities of financial participants within commodity markets.

Significant changes in commodity prices of an extended duration, either up or down, remain the principal influence upon mine economics – and therefore on mining practices too. Accurate and precise forecasting of commodity prices (and of relevant exchange rates) continues to prove elusive both to mineral economists and market analysts. Thus, at any given point in time, there are often widely differing price forecasts available for both the relevant commodity and currency.

Companies as a result are unclear how to respond in practical operating terms to such price-side uncertainty – other than to manage incremental capital and operating expenditure. Typical company – and industry financier – responses to the difficulty in predicting future mineral commodity prices are to take measures to manage uncertainties in mining project revenues and costs. These operating practices are prudent – yet come at an economic cost: that is, lost revenue and margin opportunity is inevitable in any such system not easily capable of responding to price volatility in the market. The mine of the future will seek to capture this lost economic opportunity. This paper presents a three-stage framework for analysing commodity price forecasts to aide understanding of the commodity price cycle and the periods of high-margin opportunity.

INTRODUCTION

The price of mineral commodities is fundamental to the development of the mining industry. Upward shifts in prices can result in the opening up of entirely new mineral fields. Conversely, downward shifts in prices can lead to the closure of not just single mines, but whole mineral districts, with widespread negative economic consequences.

Commodity prices can change quickly – both positively and negatively. When prices turn up, companies need to quicken their response time in order to more fully capture the economic opportunity – and to amass the financial strength to see out subsequent periods of lower prices.

This paper reviews the current high-level split of underground versus surface mining by commodity – looks at the trend towards deeper orebodies over time – and considers the role of commodity price cycles on mining sector practices. No silver bullet is offered to forecast future commodity prices

with accuracy – but a high-level framework as to the position of a commodity at a given time within the inevitable commodity price cycle of highs and lows is introduced to assist corporate thinking on strategic and operating responses.

THE RELEVANCE OF UNDERGROUND MINING TO THE PRINCIPAL MINERAL MARKETS

Underground mine supply is more critical for some commodities rather than others – with precious metals and base metals to the fore. As discoveries continue their trend of becoming deeper on average into the future, the proportion of underground mining in individual mineral markets will generally increase.

Figure 1 shows the relative amount of production from underground versus open pit sources across mine supply for

1. MAusIMM, Professor, Department of Mineral and Energy Economics, Graduate School of Business, Curtin University of Technology, Perth WA 6000.

2. Centre for Exploration Targeting, University of Western Australia, Perth WA 6000.

3. Associate Consultant (Perth), CRU Group, Gngara WA 6077. Email: allan.trench@crugroup.com

4. MAusIMM, Department of Mineral and Energy Economics, Graduate School of Business, Curtin University of Technology and Centre for Exploration Targeting, University of Western Australia

5. Director, Greenfields Research, Harrogate HG3 3HA, UK. Email: john.sykes@greenfieldsresearch.com

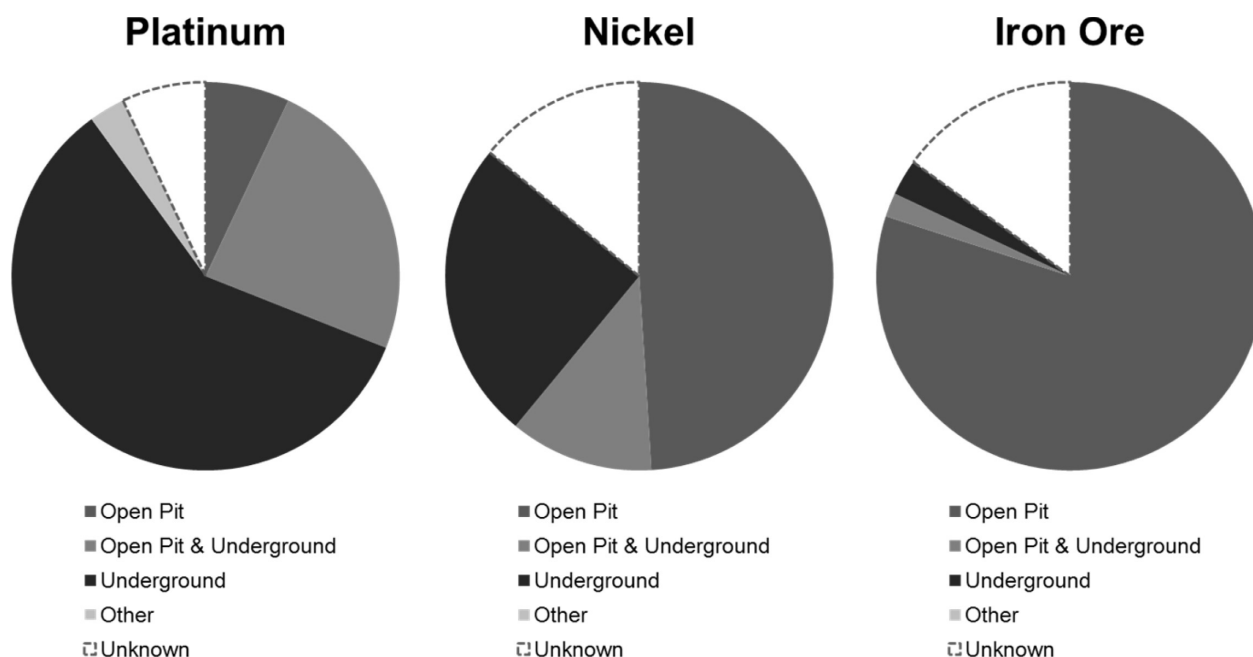


FIG 1 – Precious metals most important to underground mining; Other = either tailings, placer or offshore operations (or *in situ* leach for uranium) (data: IntierraRMG, 1990).

three significant mineral markets: platinum, nickel and iron ore. Not surprisingly, platinum shows the greatest relative proportion of underground mine production, followed by nickel and finally iron ore.

These markets were chosen as illustrative of the more general case that precious metals have the greatest relative share of underground mine supply followed by base metals and finally bulk commodities.

Figure 2 breaks out the data for individual mineral markets in this respect ordered from predominantly underground to the left of the chart through to those mineral markets where supply is sourced predominantly from open pit operations to the right of the chart. Therefore, it is these markets that underground operators are most interested in the economics of.

With the recent very tough mine economics for underground operators in some of their key mineral markets and locations – gold and platinum miners in South Africa; and nickel and zinc miners in Australia and Canada for example, readers will

be acutely aware of the material impact of commodity price volatility on the business of mining.

THE IMPORTANCE OF UNDERSTANDING COMMODITY PRICE-RISK MANAGEMENT AND THE COMMODITY MARKET PRICE CYCLE

Although mining companies derive their revenues from the sale of mineral commodities extracted at their operations, scant attention is paid to the subject of revenue-side risk in the technical literature from a decision-making point of view. In contrast, much energy is devoted to identifying and mitigating ‘technical risks’ in the mining sector, in what is a ‘technical industry’, as demonstrated by the fact that ostensibly ‘economic’ studies are actually usually almost universally technical in nature, with very little market-based project evaluation economics (Sykes, 2013).

For example, Figure 3 shows the number of pages devoted to coverage of each subject in a Preliminary Economic

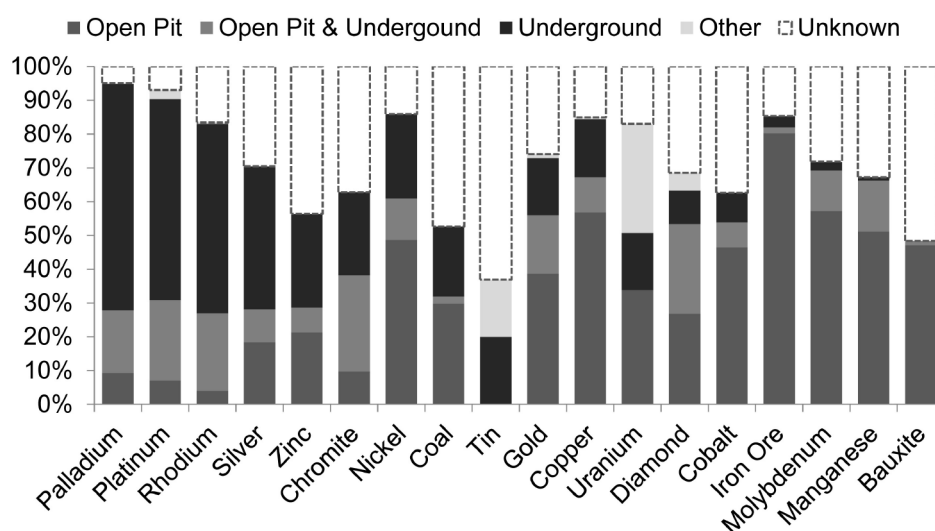


FIG 2 – Platinum group metals and silver most reliant on underground; Other = either tailings, placer or offshore operations (or *in situ* leach for uranium) mining (data: IntierraRMG, 1990).

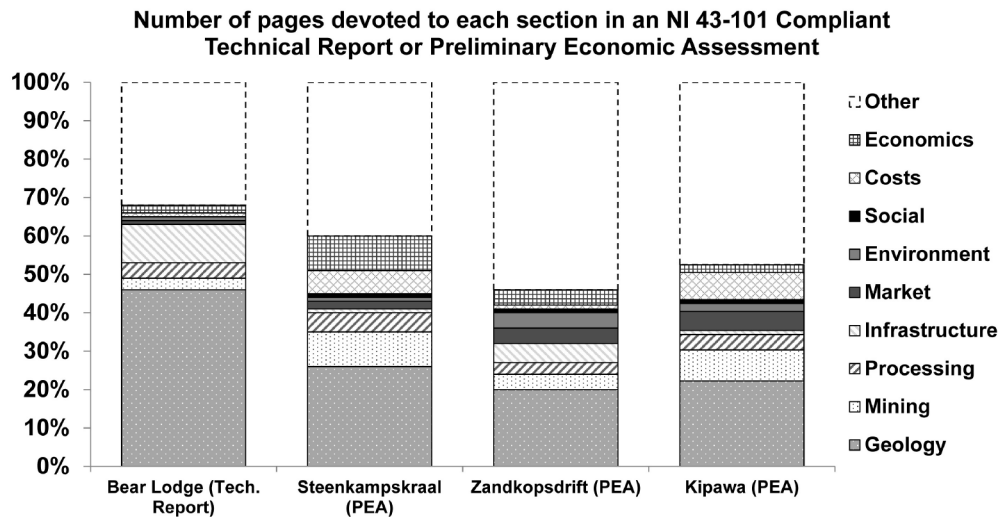


FIG 3 – Most of the content of ‘economic’ project evaluation studies is actually technical in nature (data: Rare Element Resources, Great Western Minerals Group, Frontier Rare Earths and Matamec Explorations; source: Sykes, 2013).

Assessment of four different rare earths mine projects under the Canadian NI 43-101 (Canadian Institute of Mining, Metallurgy and Petroleum, 2010; 2011) compliance code.⁴ Although these are economic assessments, the economic and market sections are very limited in comparison to the technical sections on geology, mining and processing (Sykes, 2013).

Less attention is often paid to ‘non-technical risks’ (Trench, Packey and Sykes, 2014). Primary, amongst these ‘non-technical risks’ is price risk, along with the related exchange rate risk, as the economic sensitivity analysis spider diagrams for two mine projects show in Figures 4 and 5.

Figure 4 shows the net present value (NPV) sensitivity spider diagram for Matamec Explorations Kipawa open pit rare earths project in Quebec, Canada, from the 2012 preliminary economic assessment (Saucier *et al*, 2012). This chart shows the project is most sensitive to a combined movement in rare earths prices, then capital costs and then operating costs.

Figure 5 shows the NPV sensitivity spider diagram for Taseko Mines open pit Prosperity gold-copper project in British Columbia, Canada from the 2007 feasibility study (Jones, 2007). This chart shows that this time the most critical risk factors in order of importance are exchange rate risk, operating costs, copper prices, gold prices, capital costs and then TC/RCs (treatment and refining charges on the concentrates sold). Again it is a non-technical risk that the project is most sensitive to.

The result of this ‘price risk’ sensitivity is that the earnings of mining companies closely relate to movements in the price of the respective mineral commodities produced. Declines in the market price of copper, for example, could cause commercial production from a copper mining company’s projects to be rendered uneconomic, particularly for those copper mines operating on low margins at the upper end of the industry’s cost curve (Trench, Packey and Sykes, 2014).

Commodity prices fluctuate and are influenced by numerous factors outside the control of an individual

company. Again, taking copper as an example, the price of copper is affected by both supply and demand factors and macro- and micro-economic level factors. Factors affecting the level of supply include, but are not limited to geological and technical problems at mines, labour strikes, mining costs including fuel prices, infrastructure and environmental issues and political strife, as well as non-mine supply, such as scrap

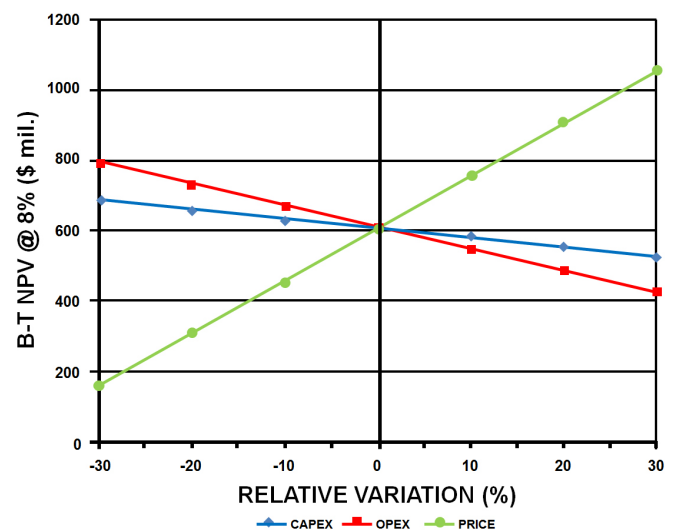


FIG 4 – The Kipawa Rare Earth Project is most sensitive to commodity price risk (source: reproduction of Saucier *et al*, 2012).

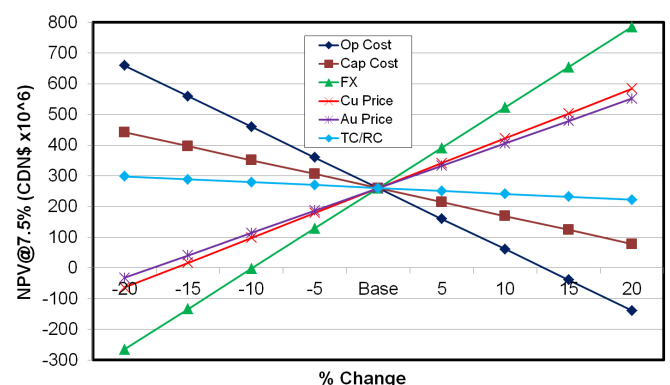


FIG 5 – The Prosperity Copper-Gold Project is most sensitive to exchange rate risk (source: reproduction of Jones, 2007).

4. The authors recognise that many of the attendees of this AusIMM conference will work under the JORC Code (2012) rather than the NI 43-101 Code from Canada (Canadian Institute of Mining, Metallurgy and Petroleum, 2010; 2011). However, companies are not compelled under the JORC Code to publish their technical studies in full, as is this case in Canada, thus this kind of analysis of the technical reports is not possible in Australia. It is of the authors’ view that the situation is no different in Australia, or indeed elsewhere in the world, where other or no compliance codes apply.

(Trench, 2013). On the demand side of the equation, global domestic product (GDP), global industrial production (IP) and the economic strength of key fast-growing economies, such as China and India are just some of the things that can affect commodity demand and ultimately prices (Trench, 2013). Micro-level factors in the previous list would include technical problems at mine and labour strikes, whilst macro-level issues would include global industrial production and domestic product.

Further complicating the issue is the increasing role of the financial community in commodity markets as either long only (buyer) investors (such as pension funds), long and short (buyer and seller) investors (such as hedge funds), risk managers (looking to hedge commodity price risk) or investors of a more speculative nature (such as those investing in exchange traded funds (ETFs)).

Figure 6 demonstrates this, showing an example of the copper price at one point in 2013, where the price (of US\$7700/t) was estimated by analysts at CRU Group to be 79 per cent (US\$6075/t) due to economic fundamentals, such as supply and demand, but also 21 per cent (US\$1625/t) due to the net effect of investors, such as hedge funds and index funds. The CRU Group analysts make the point that investors tend to accentuate the economic fundamentals already in place, rather than override them. This ratio between the influence of economic fundamentals and investor influence is constantly evolving and is now an important part of the practice of fundamental commodity price forecasting.

It is clear that even for 'true' commodities like copper (and the other base metals and most other mined commodities), where the fundamental economics of supply and demand apply, economic analysis is complex, uncertainty high and thus accurate forecasting very difficult indeed, especially when considering the increased role of finance.

The situation is yet more complicated for precious metals, in particular gold, where these metals show characteristics of both commodities and currencies from the point of view of the economist (Bernstein, 2000). Thus the number of factors influencing gold (and precious metals prices) widens even further. Factors include traditional drivers such as supply and demand, the latter including both industrial and retail demand. Additional factors also apply however, not least the rise and fall in Central Bank gold holdings (impacting physical supply-demand balance), inflation rate fluctuations, the performance in global economies, confidence in gold as a part of the international monetary system, forward sales of

precious metals by producers and speculators as well as other one-off global and regional political, social and economic events (Trench, Packey and Sykes, 2014; Trench and Packey, 2012).

From the point of view of the underground operator where the precious metals industries (platinum group metals, gold and silver) are perhaps the most important sectors (as highlighted earlier), this makes understanding commodity price and exchange rate risk even more complicated and uncertain than for their counterparts in primarily open pit mining sectors (such as most base metals and bulk commodities).

MANAGING COMMODITY PRICE RISK

There is no single 'correct' answer to the management of commodity price risk for mining operations. The price-risk management deemed optimum will vary from company to company; depending upon the company's mines, financial capacity and commitments, as well as the risk tolerance of the company and its shareholders (Trench, Packey and Sykes, 2014).

Perhaps the most common method of commodity price risk management is hedging. This takes place through forward sales contracts and/or commodity derivatives (such as 'put' and 'call' options) that are typically available for exchange traded metals. This allows mining companies to 'lock in' a set future price for selling their commodity (similarly buyers or consumers can 'lock in' a future set price for buying commodities). As such, commodities forward sales can be considered a form of 'certainty equivalent' (Guj, 2006) thereby mitigating volatility-related commodity price-risk (Trench, Packey and Sykes, 2014).

Clearly, the directors and senior management of mining companies need to be aware of the level of exposure of the company to commodity price risk. In this regard, the directors then have choices on strategy, with the exception of occasions where a company is in financial distress and economic choices become severely restricted (Trench, Packey and Sykes, 2014).

On one hand, company decision-makers could act to lock-in a commodity price into the future to remove the risk that is associated with adverse price movements. However, this is not a clear-cut decision, with many complicating factors, not least of which is setting up a hedging strategy that reduces risk in the manner the board hopes.

For example, should the company also hedge key cost inputs? Locking in a future revenue stream from the sale of a commodity leaves the company open to the risk of future rises

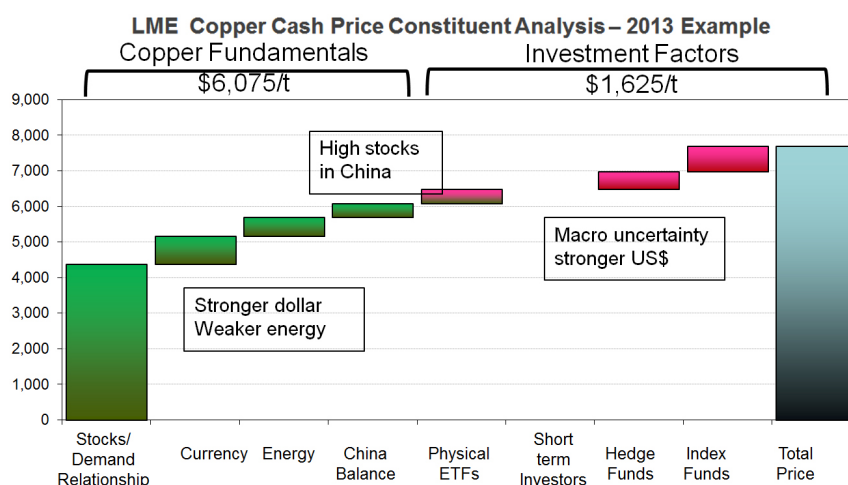


FIG 6 – It is not just economics that drive commodity prices, but also financial factors (source: Trench, 2013).

in the cost of production, without the compensatory effect of a rising commodity sale price.

Next is the issue of hedging currency exposure (with currencies' values themselves having an important influence on commodity prices). With most commodities denominated in US dollars, but most mine operations elsewhere, most mining companies as a result carry at least this basic level of exchange rate risk exposure. For companies, with head offices in one locale, multiple operations in other places and commodities sold in another currency yet again, hedging becomes very complicated.

Furthermore, even if a sufficiently advanced hedging system can be put in place to mitigate all these factors, there is then a transaction cost to implement them and of course, another transaction cost should the company wish to remove them at a later date (Trench, Packey and Sykes, 2014).

Conversely, the company decision-makers may choose to leave the company exposed to commodity price risk. In this case, they deem a fall in commodity prices to be an acceptable risk to the company and to its shareholders. Companies confident of their low cost production position tend to adopt this policy.

As noted above, those limited by their financial position and/or poor operational performance may also be forced to adopt this policy, where counterparties may be unwilling to enter into hedging contracts due to the risk of default by the company. Finally, debt providers (particularly project development providers for companies with no existing revenue stream) also typically require a level of commodity price protection to be entered into as part of the project financing conditions (Trench, Packey and Sykes, 2014; Guj and Trench, 2013).

Ultimately the aim of commodity price hedging is to deliver certainty in revenue generation, by balancing the protection against a fall in commodity prices, against the loss in upside should commodity prices rise. When executed well (again particularly at the project development phase), such hedging strategies can minimise equity dilution to a company's shareholders and thus is sound business practice (Trench, Packey and Sykes, 2014).

The inability to predict future mineral commodity prices comes at an economic cost: lost revenue and margin opportunity is inevitable. Hedging is perhaps therefore most justifiable in what mineral economists define as the 'immediate' term (Maxwell, 2013) – the period during which companies do not have the ability to make an operational response to a change in commodity prices (caused by an underlying change in the supply-demand economics) and the 'short' term – the period during which only a limited operational response can be made, such as varying production, within capacity limits (Maxwell, 2013).

Over the longer term, economists assume an efficient market and any change in demand will be met by a change in supply. A significant increase in demand will, over the 'long' term (Maxwell, 2013), allow new mines to be built and capacities expanded and over the 'very long' term encourage the discovery of new mineral deposits and development of new technologies (Maxwell, 2013).

There is no set period of time for 'immediate', 'short', 'long' and the 'very long' term (Maxwell, 2013), the distinctions between the different time horizons are merely defined by the types of supply response seen. Each of these periods can be shorter or longer in length dependent on an industries' collective response to increased demand (Maxwell, 2013).

Thus, the lagging, 'inelastic' nature of mine supply, in response to the (generally) price-elastic nature of demand, creates cycles in the mining industry, with periods of generally rising and falling commodity prices (Govett and Govett, 1978).

Most importantly from an operational perspective the cycles of higher and lower prices, combined with variable supply response speeds creates an economic opportunity for those able to react faster than the rest of the industry and thus capture the periods of higher prices (or indeed limit the damage of periods of lower prices). The mine of the future will seek to better capture this lost economic opportunity. It is for this reason that hedging is a less effective strategy over the longer term, as the cumulative net benefit of protection from falling commodity prices is outweighed by the cumulative net economic loss of not taking advantage of high and rising commodity prices. Over the longer term, the burden shifts to operational decision-making.

Ideally, in the future mine owners will be able to better incorporate commodity price uncertainty into both mine design and site-based operating practices. For example, the real-option value of changes in mine design (eg Maybee, Lowen and Dunn, 2010) or the use of scenario planning techniques (eg Vann *et al*, 2012) will be more easily applied and importantly better communicated and understood by mine managers – and thus enacted more so than at present. Ultimately, the key to advancement in this respect towards economic efficiency in mining operations is less about knowing the 'absolute truth' of future commodity prices through more accurate forecasting – and more about the ability to recognise and act upon economic opportunity (higher prices) when the time arises in the most efficient and practical manner.

The techniques highlighted above and the others available are, however, vocational specialities in themselves, beyond the standard expertise currently expected of the underground operator and similar technical professionals in the industry. As discussed however the communication and understanding the results of these practices is critical, so it is important for technical professionals to at least consider the principles and concept of how economic opportunity can present itself throughout the commodity cycle and how future price information can link with corporate strategy formation. As such this paper next presents a three stage framework for using the various types of commodity price forecast to understand 'where we are', 'where we are going' and 'how we get there' in converting commodity price information into a decision-making tool throughout successive mining and economic cycles.

UNDERSTANDING ECONOMIC OPPORTUNITY IN MINERAL COMMODITY PRICE CYCLES USING A QUALITATIVE CHARACTERISATION FRAMEWORK

A variety of approaches exist for commodity price forecasting, with the two primary methods being historical analysis (of which technical analysis or 'charting' is a subset) and fundamental analysis, which principally studies supply and demand balances. Both techniques can apply varying levels of detail and mathematics. Both can be approached from either a top-down (finding correlating existing data sets, ie GDP as a proxy for demand) or a bottom-up perspective (collecting data on each mine and source or supply and each source of demand). In reality, most analysts use a compilation of these approaches, balancing what they believe to be the best output with the cost and effort of production. Although price

forecasting is inherently subjective (Silver, 2012), varying levels of effort are made to create 'objective' outcomes.

There is no shortage of commodity price forecasts available across the mining industry, provided by mining companies themselves, broking institutions, investment banks, independent mineral consultancies and mining and metals analysts. In turn, compilations of these commodity price forecasts, where they have been made public, are undertaken by media agencies such as Bloomberg (Larkin, 2013) and Reuters (Home, 2013) on a regular basis (Trench, Packey and Sykes, 2014).

Mining companies either choose to use commodity price forecasts of a preferred provider, the 'consensus' forecast numbers, prevailing spot prices or historical price information for decision-making. The listing rules of particular exchanges and the preferences of the debt provider in cases where project financing is sought will also influence the choice. Typically, the impact of potential changes on the cash flow profile of a company will be modelled, presented to the board and decisions on either hedging contracts or develop new capacity and projects will be made (Trench, Packey and Sykes, 2014).

From an operators point of view however, it is how these forecasts impact decision-making that is critical and given the multitude of forecasts, the link here is far from clear. Further adding to the confusion is that commodity prices and mining margins do not all move up and down synchronously. So for some metals and minerals the 'sun' may well be shining at a given point in time (high commodity price) – whereas for others the better analogy refers to the dark of the night – or at least to twilight (low commodity price). To help navigate this uncertainty this paper suggests a qualitative framework that allows decision makers to intuitively navigate commodity price forecasts, moving from 'where we are now' to 'where we are going' and finally 'how we get there'.

Commodity Price Barometer: where we are now?

The simplest type of analysis conducted on commodity prices is basic statistical analysis of historic prices. Extrapolated forward these create a rudimentary forecast, though the standard financial industry disclaimer that '*past performance is no indication of future performance*' would certainly apply. Despite this, the practice is commonplace as it is relatively simple and quick in comparison to fundamental economic forecasting.

The gold industry (amongst others) has however found much to complain about in recent years as forecasters have consistently under forecast the gold price (Holland, 2012; Lassonde, 2012), as demonstrated in Figure 7, which

shows consensus gold price forecasts underestimating the eventual, actual price, from 2006 to 2012. As a result mine project developers may have found it more difficult to design (remembering that a commodity price is now a critical metric in an ore reserve model) and finance (if the debt providers are using a more conservative price forecast in their financial models) projects. Another example of how economic upside can be lost through a lack of understanding of mineral price movements in the mining industry.

Analyses of historic commodity prices are perhaps then more useful for context and understanding 'where we are' currently. From a corporate strategy point of view, it is difficult to move forward without first understanding where you are starting from.

For this purpose, Greenfields Research (Sykes, 2014) has developed the Commodity Price Barometer⁵ to describe the 'weather' across a number of different commodities. In line with the qualitative theme, the Barometer ranks commodity prices on a rating of stormy (low) through rain, change (medium) and fair to dry (high) comparing current spot prices to five-year prevailing averages. Again, as with a barometer, commodity prices are further divided into those rising and falling from their previous year's position.

Table 1 shows the Commodity Price Barometer, as of January 2014, looking back at average 2013 commodity prices and comparing them to the five-year 2008–2013 average. As the commodities 'boom' is still unwinding in 2014 it is unsurprising to see more commodities falling, than rising, with a number in the 'rainy' and 'stormy' categories indicating these commodities are experiencing cyclical lows.

The first point of observation is that all commodity markets and prices are not synchronous with some commodities still rising and at relative historic highs, highlighting the

5. Prices are 2013 annual averages compared to the five-year average (January 2008–December 2013), except for uranium and iron ore where the December 2012–November 2013 annual average prices are compared to the December 2007–November 2013 five-year average prices, as the data has a one month time lag. All commodity prices are from Metal Pages (2014), except gold and silver, which come from the London Bullion Market Association (LBMA, 2014a); and iron ore and uranium, from Index Mundi (2014). The product specifications for the commodities are Antimony Regulus min 99.65 per cent Grade II (EU); Bismuth min 99.99 per cent (EU); Cobalt min 99.3 per cent Russian (EU); LME Cash Copper; Gallium 99.99 per cent CIF Main Airport (EU); LBMA Gold morning fixing; Indium min 99.99 per cent (EU); China import Iron Ore Fines 62 per cent FE spot (CFR Tianjin port); LME Cash Lead; Molybdenum Roasted Concentrates (Oxide) Mo 57 per cent (EU) Mo; LME Cash Lead; Platinum 99.95 per cent AM/PM fixes (EU); Palladium 99.95 per cent AM/PM fixes (EU); Rhodium min 99.9 per cent (EU); LBMA Silver Fixing; Tantalite basis 30 per cent Ta2O5 (EU) Ta2O5; LME Cash Tin; Tungsten APT (EU); Index Mundi UxC Uranium U3O8 Swap Futures End of Day Settlement Price; LME cash zinc.

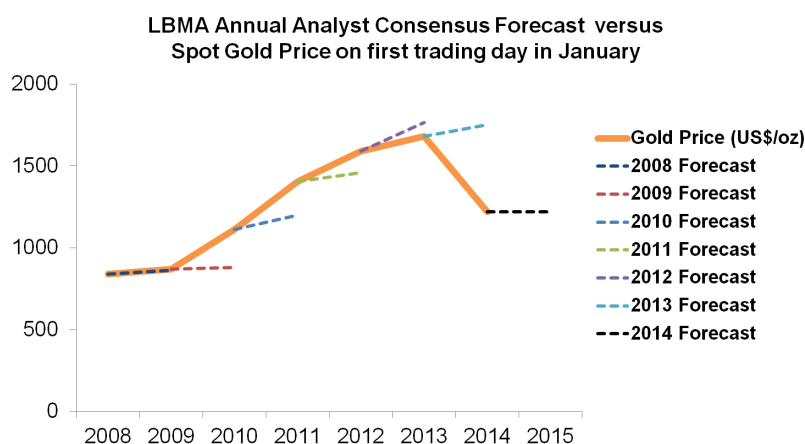


FIG 7 – Analysts have consistently underestimated the gold price, partly due to the use of historical analysis techniques (source: LBMA, 2008–2013, 2014b, 2014c).

TABLE 1

The Commodity Price Barometer uses 'historical analysis' of prices
(source: Sykes, 2014; copyright: Greenfields Research).

	Rising (year-on-year average increase)	Falling (year-on-year average increase)
Dry (25% above five-year average)	N/A	N/A
Fair (10% above five-year average)	Indium and palladium	Tungsten
Changeable (between $\pm 10\%$ of the five-year average)	Iron ore, lead and tin	Antimony, bismuth, copper, gold and zinc
Rainy (10% below five-year average)	Tantalum	Nickel, platinum, silver
Stormy (25% below five-year average)		Cobalt, gallium, molybdenum, rhodium and uranium

The emboldened commodities are those most relevant to the underground mining industry, as a large share of production comes from underground mining. As highlighted in Figure 2.

importance of commodity price analysis to ensure economic opportunities are not missed even during so called 'industry downturns'. Secondly, from the point of view of underground operators, many of the commodities most associated with underground mining (platinum group metals (PGMs), silver and nickel) are experiencing cyclical lows, no doubt pressuring operating margins.

From the point of capturing economic opportunity however, as the example of gold (Holland, 2012; Lasseonde, 2012) showed, merely extrapolating prices forward would be over-simplistic. Similarly, inferring that opportunity exists in palladium and tin merely on the basis of past price patterns is also an over-simplification. A deeper analysis is clearly required than can be achieved through analysis of historical prices alone.

Commodity Price Heat Chart: where we are going?

Fundamental economic forecasting of commodity prices aims to do exactly this, through analysis of the intricacies of

projected supply and demand to forecast commodity prices. As discussed above, individual commodity markets and prices do not all move synchronously, so to help highlight and explain these contrasts, CRU Group (Trench, 2013) use a simplified commodity heat chart (with the 2013 Q3 version shown in Figure 8), which demonstrates whether future prices for specific commodities will either heat up (rise) or cool down (fall), based on a compilation of fundamental economic forecasts from the various commodity research teams at the company.

Clearly, the heat chart of itself is merely a communication tool – but armed with the information that supports such analyses, decision makers can now advance beyond simple historic price in their deliberations. As demonstrated above, whilst both the commodities highlighted by the historic 'barometric' analysis as 'opportunities' for underground operators (tin and palladium) are potentially confirmed as 'opportunities' in the heat chart summation, the opposite is not true for those commodities identified to be in cyclical lows. For example, whilst silver in a cyclical low is forecast to stay there, nickel, zinc and platinum are forecast to leave their cyclical lows.

Commodity Price Sundial: how we get there?

The heat chart has its limitations, however – with forecast percentage changes in prices not specifically linked to (or indicative of) the relative margins available at given points in time across the commodity spectrum.

As gold miners (Holland, 2012) in particular have found, if rising prices are accompanied by rising costs, there is no overall improvement in margins in the industry and essentially the industry remains as difficult as it was previously (and possibly even harder as the excuse of low commodity prices is removed), as demonstrated by the conceptual matrix in Figure 9. It is therefore important from a corporate strategy point of view to understand how the cycles in costs relate to cycles in prices. As discussed earlier, by understanding these cycles, a true 'economic opportunity' is found.

The commodity price cycles in turn are linked to a general cycle in the mining industry (Govett and Govett, 1978).

The presence of high cost 'marginal' producers in an industry, creates substantial operating margin or 'economic rent' (Tilton, 2003) for those lower down the cost curve. In

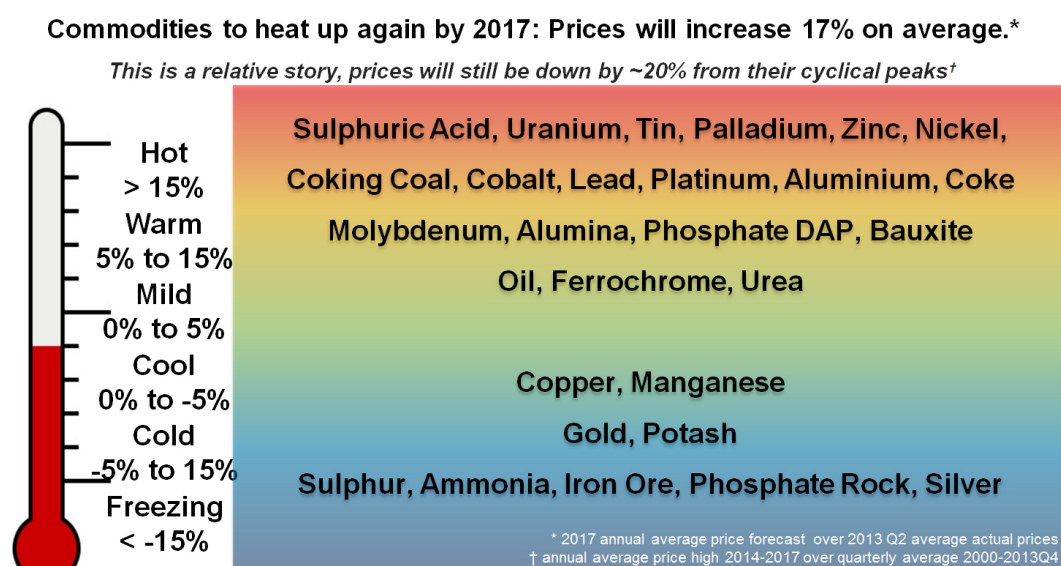


FIG 8 – The Commodity Price Heat Chart communicates 'fundamental analysis' (source: Trench, 2013; copyright: CRU Group).

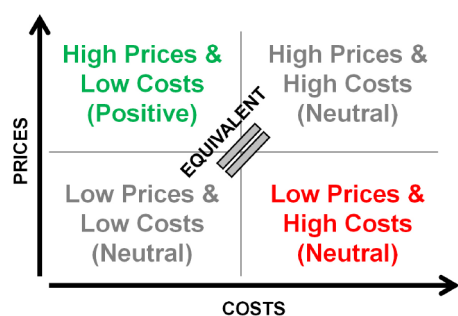


FIG 9 – From a corporate point of view high prices and high costs are equivalent to low prices and low costs.

these cases, the cost curve is relatively steep. As these lower cost producers expand however, seeking further production share, the high-cost marginal producers can be forced to exit production in favour of the additional lower cost production volumes that satisfy demand. Downward pressure is exerted on commodity prices as a result. Often at the very same period of time, companies involved in either mine expansions or new project development experience rising costs just as prices are falling. Eventually cost cutting allows companies to take control of the situation and stabilise margins once again. This is the 'race to the bottom' that characterised the cost-cutting minerals sector of the 1990s. An upturn in commodity prices starts the cycle all over again.

The cost curves (aggregate supply curves) in Figures 10 to 13 demonstrate the commodities price and cost cycle shown conceptually in Figures 9 and 14. The tin industry has a large amount of artisanal and alluvial supply, which responds very quickly to the price cycle (Kettle *et al*, 2011), so it makes a good case study of the commodities price-cost interaction. This combined with the price volatility associated with the 2008–2009 commodities boom and collapse allows a full price-cost cycle to occur over just a few years, whereas normally this would occur over a decade or even longer (Jacks, 2013).

Figure 10 shows the first stage of the cycle where a period of long depressed tin prices has led to substantial cost cutting and underinvestment in the industry (Kettle *et al*, 2011), creating a low, flat cost curve, with thin operating margins for all tin miners.

Figure 11 shows the second stage of the cycle, where prices have increased dramatically both due to the adoption of tin in solders, as an environmentally acceptable alternative to lead (Kettle *et al*, 2011), and because of the strong economic growth in China, which has driven the broader mineral commodities boom over the last decade (Jacks, 2013). This leads to substantial operating margins for those lower on the cost curve, and even reasonable margins for high cost producers. There are also fewer uneconomic producers. There is however already evidence of the next stage of the cycle in the increasing operating costs, particularly amongst those that were higher cost producers in the first place.

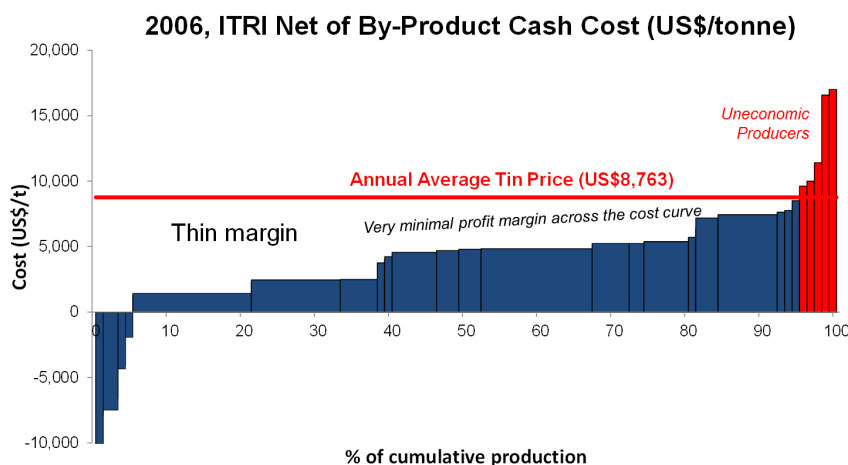


FIG 10 – The 2006 tin cost curve is an example of the first stage of the commodity price cycle (low prices and low costs) (data: International Tin Research Institute (ITRI) and Greenfields Research; copyright: ITRI).

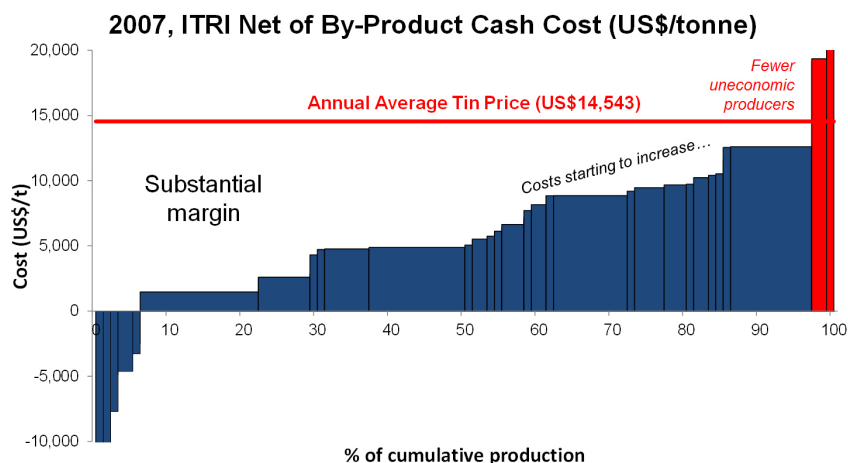


FIG 11 – The 2007 tin cost curve is an example of the second stage of the commodity price cycle (high prices & low costs) (data: International Tin Research Institute (ITRI) and Greenfields Research; copyright: ITRI).

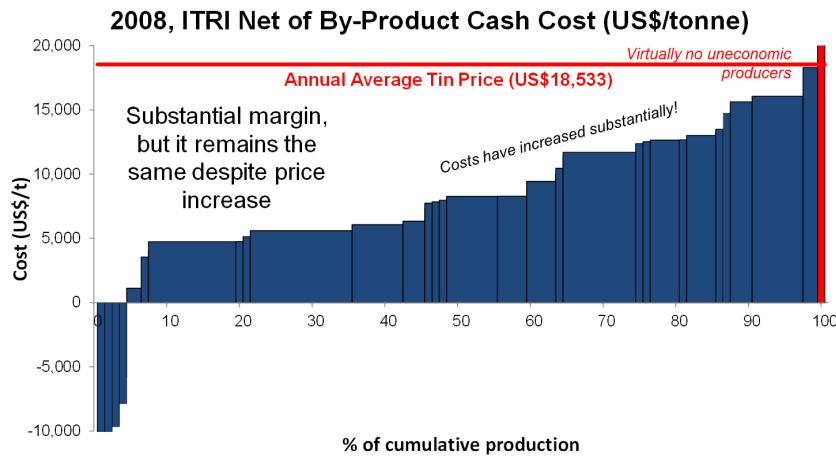


FIG 12 – The 2008 tin cost curve is an example of the third stage of the commodity price cycle (high prices & high costs)
(data: International Tin Research Institute (ITRI) and Greenfields Research; copyright: ITRI).

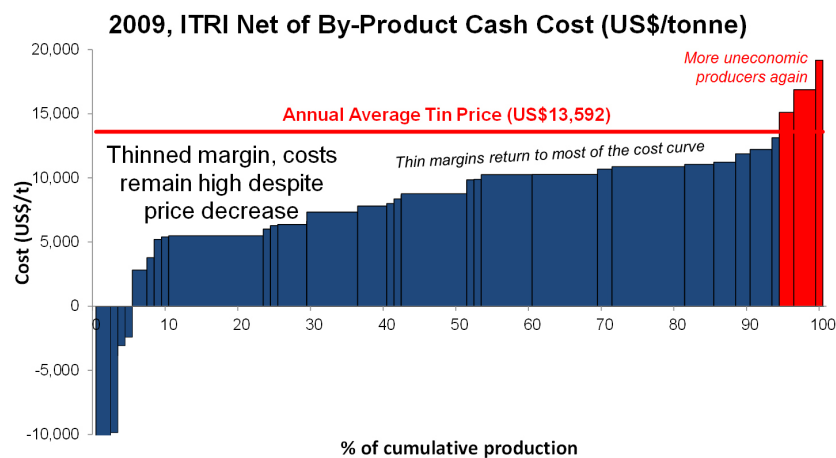


FIG 13 – The 2009 tin cost curve is an example of the final stage of the commodity price cycle (low prices & high costs)
(data: International Tin Research Institute (ITRI) and Greenfields Research; copyright: ITRI).

Figure 12 demonstrates this third stage, where costs have begun chasing prices upwards. Even though the tin price has increased substantially, the cost of production across the entire cost curve has risen, but particularly amongst the higher cost producers. The large number of artisanal and alluvial miners in the tin industry means they were able to rapidly respond to the higher prices and bring new, high cost marginal production on stream very quickly (Kettle *et al*, 2011). This production supports the high prices, maintaining the substantial margins for the low cost producers. This situation continues until either the high prices encourage new investment in low cost supply, which pushes the marginal producers out of business allowing the commodity price to fall. Or the high prices cause some kind of demand destruction, and a price collapse occurs, again driving the marginal producers out of business (though in this case less new, low cost supply has come on stream in the interim).

The latter case (a price fall) was the cause of the fourth stage in this tin price-cost cycle, demonstrated in Figure 13. The Global Financial Crisis of 2008–2009, caused a substantial drop in tin prices (Kettle *et al*, 2011). The industry was not able to cut costs as quickly, with many producers becoming uneconomic again, and margins being compressed across the cost curve, even for the ‘low cost’ producers. Although the average tin price in 2009 was still about 55% higher than in 2006, the margins were very similar, due to the cost of production increases in the interim. In this case, if prices do not improve, the industry moves into a cost cutting phase, similar

to that seen in Figure 10, with all producers fighting to keep costs below the tin price. Or prices increase again, allowing profitable production again, a situation more analogous with Figure 11. In the case of the tin industry, like many other mineral industries, commodity prices recovered rapidly post-2011 (Kettle *et al*, 2011), restoring operating margins, at least for the low cost producers.

To help further explain how this mining cycle relates to commodity price forecasts, the Mineral Commodity ‘Sundial’ (Trench and Robinson, 2013), which is outlined further below, overcomes some of these limitations. Taking each of its commodity prices forecasts in turn, it seeks to explain the micro-economic forces at work in each mineral market as the mining business cycle plays out separately for each commodity. Figure 14 explains the concept behind the cycle with the cost cycle lagging the price cycle creating a rising and falling margin cycle.

For the four-stage mining cycle, the four stages of the day are a useful analogy – here referred to as Dawn, Noon, Evening and Twilight. A not dissimilar analogy would be the four seasons of the year – Spring, Summer, Autumn and Winter. Perhaps the latter analogy has most relevance – as it better emphasises that the duration of each phase of the commodity cycle can vary between cycles, reflecting the varying supply responses defined by mineral economists and discussed earlier in the paper (Maxwell, 2013).

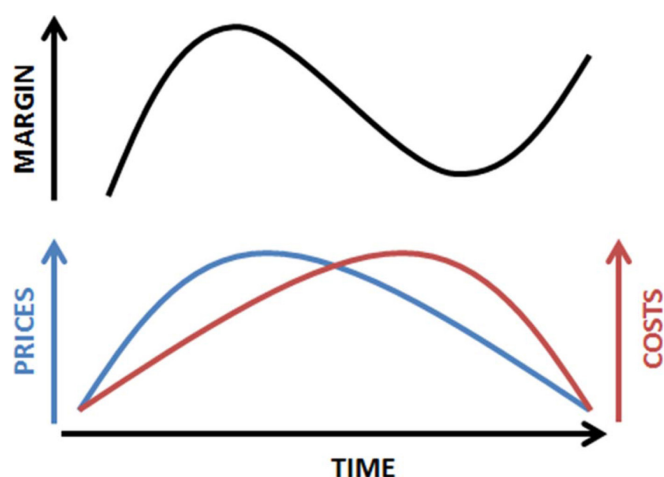


FIG 14 – The concept behind the mining cycle, driven by cost and price cycles.

That is, a commodity may enjoy a long balmy evening or Indian summer in one commodity price cycle – whereas in the next cycle the summer months are cut short: no commodity cycle is exactly the same as the last due to the evolution in interplay between demand growth and new supply growth (whether from mine supply else secondary sources such as scrap supply). This also emphasises the point that often multiple cycles are at work, be they short, medium or long-term price cycles (Jacks, 2013) or cost and price cycles referred to above (Maxwell, 2013; Govett and Govett, 1978), or debt and credit cycles, or any of the many other cycles that impact upon the industry.

In a commodity price context, the day/seasons evolve as follows.

'Dawn' or 'spring' – commodity amongst those viewed as the 'next big thing', poised for higher prices

- Price at around long-run marginal cost (equilibrium level).
- Solid producer margins attracts interest.
- Strong and easily understood demand story. For example, Chinese growth or technology led demand.
- Supply concerns on tightening market.
- Market opportunity for early movers.

'Noon' or 'summer' – commodity considered 'hot', due to recent price rises

- Price above the cost curve.
- Record producer margins (price-driven), particularly in the 1st and 2nd quartile.
- Producers focus on volume growth over cost control.
- Consumers respond via substitution and economisation.
- Reliability of supply an industry issue.
- New production technologies, low grades, tailings rework all considered 'viable'.
- A market optimism that proclaims market conditions as 'the new normal'.

'Evening' or 'autumn' – commodity still in favour – but doubters emerge

- Prices gradually eroding.
- Strong margins (volume-driven).
- Demand growth solid but not spectacular.
- Supply growth rates meet and exceed demand expectations.

- As short-term signals weaken optimists have to rely on 'medium-term fundamentals' to maintain optimism.

'Twilight' or 'winter' – commodity out of favour due to lowered prices and market expectations

- Prices well down 'into' the cost curve, 3rd and 4th cost quartile assets fight for survival with state owned 'protected' assets (which resist closure despite their economics becoming marginal or else loss-making).
- Margins squeezed across the industry.
- Producers sacrifice volume for cost reductions.
- Demand-side, even if healthy, fails to influence price.
- Supply growth and future expectations far higher than demand growth.
- Supply (and stocks) overhang.
- A market pessimism that proclaims market conditions as 'the new normal'.

At the time of writing in early 2014, copper and iron ore are probably heading into a 'long balmy evening', whilst uranium and nickel are most definitely in the night time. Commodities such as zinc and metallurgical coal maybe amongst those about to experience a new dawn: underground operators in these sectors should prepare for the arrival of a new 'day'.

Individual commodity forecasts aside, the point of this paper is to emphasise that mine owners need to be cognisant of these 'seasons' of the commodity price cycle. At a given point in time, one commodity may be enjoying a 'summer' whilst another sits within the depths of winter or is emerging into spring.

Decisions at the mine operational scale can be taken in anticipation of future prices – whether higher or lower. That is, even if precise and accurate commodity price forecasts elude analysts, there is often consensus as to whether a specific commodity is 'warming' or 'cooling' in price.

In the authors' experience, even sizeable miners with the balance sheet strength to prepare for a resurgence in price by, for example, undertaking additional underground mine development to create the potential to open up several new production areas are reluctant to do so when prices are low. Inevitably, these miners as a result then fail to capitalise upon higher prices when they arrive as the lead-time to escalate production 'uses up' what may be a relatively short window of economic opportunity to benefit from higher prices. Similarly, underground mining service providers need to be aware of their clients' needs in these cycles with the price 'warming' likely to be focused on expansions and the price 'cooling' on cost control.

Finally, the focus so far has been on one main forecast for each commodity. With even the best economic forecasts more often wrong than not (Silver, 2012), this approach still lacks some sophistication. As was counselled earlier in respect of incorporating flexibility into mine planning using techniques such as real options (Maybee, Lowen and Dunn, 2010) and scenario planning (Vann *et al*, 2012), the very same approaches can be adopted for economic forecasting, including commodity prices. The petroleum industry has long used these techniques and the authors' expect to see their use become more prevalent in the mining industry in years to come.

EMERGING ECONOMIC TRENDS AND UNDERGROUND MINING

Perhaps the most important insight from the Commodity ‘Sundial’ framework is how it demonstrates the interaction of commodity prices with the business of mining, in particular the operations themselves. In this spirit, this paper will conclude with some thoughts on long-term trends in mining economics.

The prevailing paradigm in mining has been one of ever-large surface mining for over a century now. That said, as large open pits at existing mines make the transition underground (such as the large copper mines of Grasberg and Chuquibambilla, both of which are undergoing conversion to underground block caves) and new mineral discoveries are revealed at greater and greater depths (Schodde, 2013) as demonstrated in Figure 15, so underground mining remains a competitive development concept that could in key areas win back ‘market share’ from open pits.

Secondly – and partly relating to the depletion of surface deposits in mature mining districts, is that non-technical risks relating to environmental and social issues have come to the forefront of project development decisions in recent years. Similarly, as companies expand beyond established and politically ‘safe’ jurisdictions in Australia, North America and Europe, political risk also becomes a material issue in decision-making.

Although there may still be substantial surface deposits awaiting discovery in frontier regions, the large-scale open pit mines required to exploit them economically may not be the ideal type of mine to develop environmentally or socially in such a region. With a much greater environmental and social footprint such mines are likely to generate frictions with local communities, particularly in parts of the world without an established culture of mining (Trench, Packey and Sykes, 2014). More generally a greater awareness globally of environmental and social issues, often grouped as ‘sustainability’ issues (Eggert, 2013), means that a number of prevailing socioeconomic factors may favour underground mine developments in the future.

Finally, the cost structure of the mining sector as a whole is a constantly changing landscape. Large open pits work best with low fuel costs, water costs and land prices, alongside of the rapid development of scale-leveraging technology,

such as ever larger trucks. In the future, it is questionable whether evolutionary technology developments will be able to mitigate what may become permanently high fuel prices and falling ore grades. Perhaps the economic forces of the 21st century will swing back in favour of underground developments – versus the 20th century economic forces that allowed the capture of scale economies through ever-larger open pit developments? Time will tell.

CONCLUDING REMARKS

- Currently, underground operations are more prominent in the supply of precious metals markets than base metals – where in turn underground supply is more prevalent for base metals than for bulk materials commodity markets. The concentration of underground mining in the precious metals industries, which have complex price economics, makes understanding the commodity price cycle important for underground miners.
- Mineral commodity prices fluctuate over time producing periods of both strong and tight operating margins for miners. Current industry practices typically fail to capture the full economic opportunity afforded by periods of elevated price as miners cannot quickly raise production to match the market opportunity that higher prices create.
- Commodity price forecasts – and currency exchange forecasts – are not sufficiently accurate in quantitative terms to allow miners to predict periods of higher margin and the economic opportunity that lies therein with confidence. This fact exacerbates the challenges referred to in the above point.
- Commodity markets can however be forecast as either strengthening in price or else weakening in qualitative terms with more confidence – one tool to do so that likens prevailing prices to times of the day or seasons of the year: ‘Daytime’ or ‘Summer’ being hotter, meaning that margins will be stronger – and ‘nighttime’ or ‘winter’ heralding weaker margins for miners due to relatively lower commodity prices.
- A basic strategic framework exists that allows decision makers to make use of the available commodity price forecast information by moving from ‘where we are now’ (historic analysis) to ‘where we are going’ (more detailed fundamental economic forecasting) to ‘how we get there’

Depth of cover for Gold and Base Metal discoveries in the World: 1900-2012

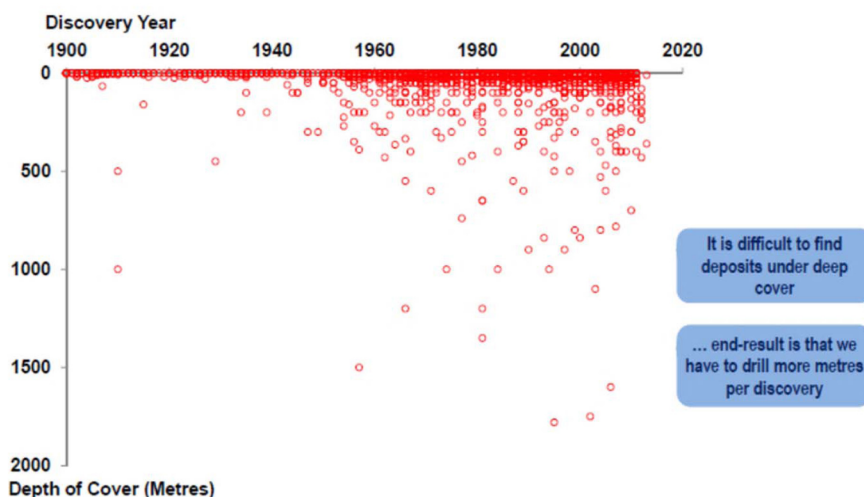


FIG 15 – The increasing depth of mineral discoveries may increase the share of underground mining (source: Schodde, 2013; copyright: MinEx Consulting).

(considering the operating margins available at different parts of the mining cycle).

- Industry trends show that a greater proportion of mine supply may, over time, be sourced from deeper orebodies such that the relative proportion of underground mine supply increases. The trend towards an increased importance of underground mines may continue, in part driven by environmental factors placing pressure on 'large footprint' open pit developments – and in part through the gradual trend towards deeper mineral discoveries over time.

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