Rank and file: Assessing graphite projects on credentials

The fervour for graphite exploration shows few signs of letting up, but with more and more companies piling into the industry, despite warnings about the comparative narrowness of the future demand window, judging the quality of projects is tricky. *Andrew Scogings, Jason Chesters* and *Bill Shaw* take a look at the field and suggest some parameters for assessing individual developments.

The junior graphite industry remains as crowded as ever, despite weak price levels following the 2011 market boom and scarce capital for financing the development of new projects.

For those looking at the industry from the outside, it is difficult to rank projects by potential, owing to significant variations between resource profiles and the companies which are developing them.

By comparing 21 listed flake graphite plays (12 ASX, eight TSX and one AIM-listed company), it may be possible to shed some light on important factors to consider when assessing flake graphite projects.

This is an update on a previous report – "Graphite: The six steps to striking success" – published in the December 2014 edition of **IM**, which covered listed flake and vein graphite plays and highlighted some of the progress made by certain companies.

The project list is by no means exhaustive. While the previous review of this topic included vein and hydrothermal graphite projects, in addition to projects that did not have stated resources or reserves, the present report focuses only on flake graphite projects with published mineral resources.

Three projects that have recently commenced production are also included (although one has since paused operations in response to weak prices and market conditions) – these are brownfield deposits that were previously mined and, in some cases, already had processing plants in place.

One historical mine, the Kearney graphite project in Ontario, Canada, which has so far failed to restart production is also afforded some consideration. On 30 March 2015, capital pool company Vector Resources Inc. announced it was to acquire the issued and outstanding shares of Kearney's operator, privately held Canadian explorer, Ontario Graphite Ltd. Although this agreement was terminated on 1 June, and financial data for Ontario Graphite has proved to be unobtainable, the Kearny deposit, which reportedly produced 17,000 tonnes graphite in its lifetime, is included in some graphs for comparative purposes.

Markets

The natural graphite market remains weak, characterised by lacklustre demand and high stockpiles exacerbated by a resurgence in supply from Chinese producers. Therefore, prices of most flake categories remain under pressure.

However, Chinese producers are facing increased scrutiny around the environmental impact of their operations and this is likely to dominate the supply/demand balance in the short term. Looking ahead a few years,

Table 1 Graphite prices

Graphite type	Purity	Size	Description	Pricing Method	Low price	High price
	(% Graphitic Carbon)	(Mesh)			$/tonne	$/tonne
Synthetic	99.5			Switzerland	7,000	20,000
Synthetic	98-99			CIF, Asia	1,000	1,500
Synthetic	97-98			CIF, Asia	950	1,450
Flake	94-97	+80	Large	FCL, CIF European port	1,050	1,150
Flake	94-97	+100 - 80	Medium	FCL, CIF European port	900	1,000
Flake	94-97	-100	Small	FCL, CIF European port	750	800
Flake	90	+80	Large	CIF, European port	750	850
Flake	90	+100 - 80	Medium	FCL, CIF European port	700	800
Flake	90	-100	Small	FCL, CIF European port	600	650
Flake	85-87	+100 - 80	Medium	FCL, CIF European port	550	600
Amorphous	80-85	-200	Fine	FCL China, CIF Europe	400	430

Source: IM July 2015

Table 2: ASX-listed flake graphite projects ranked in June 2015 (listed alphabetically)

	Archer	Buxton	IMX	Kibaran	Lamboo	Lincoln	Magnis	Sovereign	Syrah	Talga	Triton	Valence
Code	AXE	BUX	IXR	KNL	LMB	LML	MNS	SVM	SYR	TLG	TON	VXL
Project	Campoona & Wilclo South	Yalbra	Chilalo	Epanko	McIntosh	Kookaburra Gully	Nachu	Duwi	Balama	Nunasvaara	Nicanda Hill	Uley
Country	Australia	Australia	Tanzania	Tanzania	Australia	Australia	Tanzania	Malawi	Mozambique	Sweden	Mozambique	Australia
Factor 1	7	7	7	8	2	4	7	9	9	6	10	3
Factor 2	8	7.5	4.5	4.5	7.5	8	4.5	3	3	9	3	9
Factor 3	4	2	8	10	2	0	10	8	6	0	8	8
Factor 4	6	2	6	6	2	4	6	4	6	2	8	6
Factor 5	0	0	4	6	6	0	6	0	6	0	6	6
Factor 6	4	2	2	6	2	2	2	2	4	4	4	10
Score	29	20.5	31.5	40.5	21.5	18	35.5	26	34	21	39	42

demand growth from new applications will be the driving force for investor sentiment and pricing. The industry's supply readiness, if and when this demand materialises, is a central question for the market.

While the growth in new applications for graphite is wide and varied, the one that has received the most attention is the lithium-ion (Li-ion) battery segment, which is being driven by the growth in electric (EV) and hybrid electric (HEV) market.

Tesla Motors Inc.'s expansion plans are well known and its battery-making Gigafactory in Nevada is reportedly ahead of schedule to reach its Phase 1 production capacity (sufficient for 100,000 EVs) by the end of 2015. The facility is due to ramp up to produce 500,000 units by 2020. At full capacity, the factory is estimated to consume the equivalent of up to 120,000 tpa flake graphite, although these projections are based on assumptions about Tesla's Li-ion battery chemistry and associated raw material requirements.

Plans by LG Chem, Foxconn, Boston-Power, Samsung and, more recently, Apple, to build and devote more resources to expanding Li-ion battery manufacturing capacity are also expected to add significantly to demand.

The question of where new supply will come from to meet this rising consumption has spurred an increasing number of exploration companies to rapidly develop new graphite projects in regions like Australia, Africa, Scandinavia and North America.

There is a window of opportunity for new flake graphite supply to enter the existing 500,000-600,000 tpa (flake) market. However, given the extent of new discoveries, which if developed could yield extra production of 1-1.5m tpa for all flake sizes by 2020, this appears to be well in excess of the opportunity. Accordingly, it seems likely that many projects will fail to reach production.

That being said, industrial minerals projects often require significant time to ramp up; hence the lead time to nameplate production is likely to be longer than most players have predicted.

It is also worth bearing in mind the potential exapansion in the market for graphene applications, as many of the companies mentioned in this report either conduct or financially support R&D into future commercial uses for graphene. While the market is in its infancy and is unlikely to become a volume consumer of natural graphite, the value-added potential of the industry is considerable.

Graphite deposit quality

Many graphite explorers espouse the notion that biggest is best. Although resource tonnes and graphitic carbon content (grade) are important metrics in evaluating mining projects, the overall picture is more complex.

Key attributes include flake size distribution, the purity of the graphite, the existence of binding sales agreements, the economics of mining, processing and delivering the products to customers.

The influence of flake size distribution and flake purity on project economics cannot be underestimated, as the these parameters control the basket price that may be anticipated. A marketable flake concentrate product should have a minimum total graphitic carbon content (TGC) of 90%, although a range of 94-97% TGC is now often accepted as the norm. Not all graphite explorers or producers report flake size distribution according to equivalent sieve sizes and it can be difficult to compare this factor between projects.

Six key factors

A quantitative matrix of six key factors in ranking graphite plays in the current market includes: i) deposit size, contained graphite and enterprise value; ii) location (country risk) and logistics; iii) flake size distribution; iv) product purity; v) offtake agreements; and vi) timeframe to production (see *Tables 2* and *3*).

Each factor receives a maximum score of 10 points, with equal weighting given to each compiled factor. This results in a maximum score of 60 for each listed stock under consideration. Earlier stage explorers may be detrimentally impacted by some of the quantitative factors, however this partially compensates for the increased risk associated with their stage of development and illustrates the dynamics of the graphite space.

The project rankings could be impacted in a number of ways, including changes in political landscapes, fluctating graphite prices and exchange rates, or shortage of funding for exploration and development. In addition, an economic deposit (ore reserve) may or may not be delineated, especially when deposit dimensions, product flake size and purity, processing characteristics and logisitcs are taken into account. Furthermore, lab or pilot process test methods may not scale up to meet anticipated yields, flake size distribution or product purity.

Management of a company may impact significantly on the economic success of a project. Some of the companies mentioned in this report have attracted key executives with hands-on experience of graphite mining, production and marketing, which could increase their chance of success.

The three highest ranked ASX-listed graphite projects based on the updated

Table 3 TSX- and AIM-listed flake graphite projects ranked in June 2015 (listed alphabetically)

	Alabama	Energizer	Flinders	Focus	Graphite One	Mason	Northern	Stratmin
Code	ALP	EGZ	FDR	FMS	GPH	LLG	NGC	STGR
Project	Coosa	Molo	Woxna	Lac Knife	Graphite Creek	Lac Guéret	Bissett Creek	Loharano
Country	US	Madagascar	Sweden	Canada	US	Canada	Canada	Madagascar
Factor 1	5	8	6	7	8	10	3	2
Factor 2	6	3	9	7	5.5	7	6.5	3
Factor 3	8	8	8	8	4	6	10	8
Factor 4	8	8	6	8	2	4	6	4
Factor 5	0	0	2	6	0	0	0	10
Factor 6	2	2	10	4	2	6	6	10
Score	29	29	41	40	21.5	33	31.5	37

quantitative analysis are, in alphabetic order, Kibaran Resources Ltd, Triton Minerals Ltd and Valence Industries Ltd, as illustrated in *Table 2*. The three top rated TSX graphite projects are owned by Flinders Resources Ltd (although the company announced in late June 2015 that it had halted production at its Woxna mine and plant in Sweden until market demand and prices for graphite pick up) Focus Graphite Inc. and Mason Graphite Inc. while AIM-listed StratMin Global Resources Plc looks equally attractive with its Loharano project (*Table 3*).

New entrants in the rankings include IMX Resources Ltd with its Chilalo project in southern Tanzania and Graphite One Resources Inc. with its Graphite Creek project in Alaska. As mentioned above, Ontario Graphite has been excluded from formal ranking, but included in certain charts for comparison.

Given the continued interest in exploring for and developing graphite deposits, it is reasonable to anticipate that the rankings will continue to change as projects evolve. In this regard, East Africa appears to be an exploration hotspot, with at least four listed explorers operating in Mozambique and nine in Tanzania.

Deposit size and quality

The first factor scores the size (20%) and grade (30%) of the deposit, as well as the enterprise value/tonne (EV/tonne) of contained graphite (50%). This factor encompasses the traditional size and grade metrics of a non industrial mineral deposit (where bigger and higher is better) and adds an element of valuation to the mix with the EV/tonne metric. The size (tonnage) is given the lowest weighting of the three parameters, as this is considered to be less important than grade.

Mason and Triton score the highest (10) on this factor, mainly as a result of significant size and/or grade of resource and commensurately a low EV/tonne, while Sovereign Metals Ltd and Syrah Resources Ltd (9) followed by Energizer Resources Inc., Graphite One and Kibaran (8) also score well.

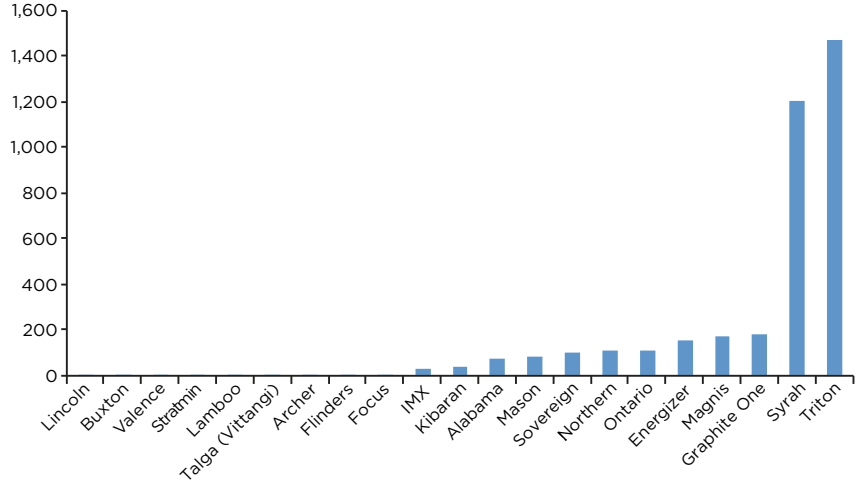
Figures 1-4 below show the results of this comparison. *Figures 1* and *2* compare the size of deposit in tonnes; *Figure 3* ranks projects by graphite grade and *Figure 4* ranks projects by EV/tonne of contained graphite. As a result of the distortion created by the size of Syrah's and Triton's resources, these have been excluded from *Figure 2*.

Other considerations when evaluating graphite projects include the economics of mining and processing, as these are impacted by factors such as the size and geometry of the deposit, contained graphite and recoveries. The deposit geometry affects the strip ratio and the higher the contained graphite, the less ore has to be mined and processed, all things being equal. Processing less ore results in lower production costs and less waste going to tailing dams, all of which can have a major impact on capital and operating expenditure.

For projects where reserves have been declared, in most cases the reserve has a smaller tonnage and higher grade than the original resource, or alternatively the company has targeted a smaller and higher grade portion of the resource for consideration in a conceptual study. Examples include Syrah, which has declared a reserve of 81m tonnes grading at 16.6% TGC and Mason, which has declared 3.9m tonnes at 27.4% TGC for their initial life of mine plans.

The mineability of any deposit must be understood and acknowledged. In order for the resource planning process to be effective and reliable, issues that should be considered are the width and orientation of the ore body, the thickness of overlying waste, the

Figure 1: Projects ranked by resource tonnes, including indicated, measured and inferred categories (millions of tonnes)



proposed scale of mining and the costs these impose on the mining operation. Perfect extraction may be technically feasible, but uneconomic.

One of the first important steps in evaluating a project is to look at the potentially recoverable material using an exercise such as Strategic Envelope Planning, which uses pit-optimising software to assess the potential impact of costs and revenues. Using a simplistic block model at the conceptual planning stage, this approach quickly identifies which targets are most worthy of more detailed investigation.

Location

The second factor scores the risk of project location using the Fraser Institute Annual Survey of Mining Companies 2014 (Policy Perception Index), supplemented with a subjective score for non-ranked countries. Country risk is often underestimated until the risk is realised, often with significant consequences for investors. An additional factor to take into consideration is the accessibility and cost of logistics, including access to power, water, labour and transport routes.

The top scoring stocks according to this factor are Flinders and Talga Resources Ltd (9) with deposits in Sweden and Valence (also 9) with a project in Australia. Archer Exploration Ltd and Lincoln Minerals Ltd (8) scored well with their projects in Australia. As a general rule, the projects in Australia, Canada and the US ranked fairly highly, ahead of projects in Africa.

Flake size distribution

The third factor scores flake size distribution, which is one of the more debated project factors. Two facts that generally seem to be agreed are; first, the larger the flake in a deposit, the higher the purity of the graphite; and second, the larger the flake size, the higher the price, all else being equal. In addition, as certain end use applications require minimum specifications, the demand profile for different flake sizes (among other factors) is a key driver in project decisions. For this reason, projects with particularly large proportions of ultrafine flake graphite may have less chance of proceeding into development, as this is the segment of the market most at risk of oversupply.

Flake size is one of the more difficult factors to rank, given that not all explorers report comparable size fractions and many explorers have not progressed to the stage of detailed metallurgical testwork.

Figure 5 shows projects ranked by flake size distribution, based on interpretation of available information. With reference to *Tables* 2 and *3*, Kibaran, Magnis Resources Ltd and Northern Graphite Corp. score the highest on this factor (10), ahead of a large number of other plays including Alabama Graphite Corp., Energizer, Flinders, Focus, IMX, Sovereign, StratMin, Triton and Valence (8) owing to their greater proportions of larger flake sizes relative to small and fine graphite flakes.

According to StratMin's annual report for 2014, "smaller flakes" make up 40% of the end product, therefore it is assumed that 60% of the concentrate product consists of medium, large and extra large flake.

It appears that, as a general rule, the Tanzanian projects have coarser flakes than the Mozambique projects, suggesting an underlying difference in geological conditions. This may be related to original host rock composition and/or higher metamorphic grade/temperature of formation. For example, several of the Tanzanian deposits contain sillimanite, indicative of high temperature metamorphism.

Talga has two projects – Nunasvaara and Raitajarvi – for which resources have been reported. Nunasvaara (Vittangi) has to date been the company's main project, however, Raitajarvi is predominantly medium to extra large flake, hence this could change the Talga score as the projects progress. Although difficult to quantify in terms of flake quality, it is noted that Talga has claimed in its Vittangi scoping study the ability and intention to initially produce 1,000 tonnes (scalable) graphene as part of its overall 47,000 tpa production rate.

In this regard, Talga recently announced that it had chosen a site in Germany on

Figure 2: Projects ranked by resource tonnes, including indicated, measured and inferred categories. Excludes Syrah and Triton (millions of tonnes)

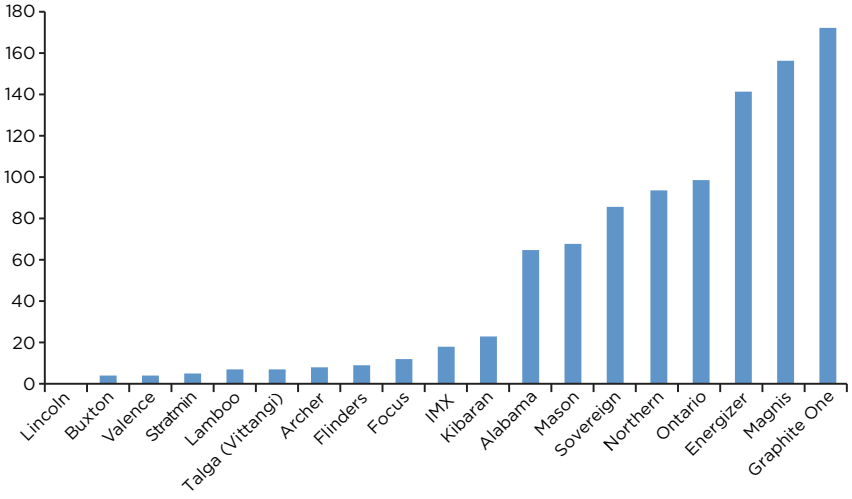


Figure 3: Projects ranked by grade (% graphite)

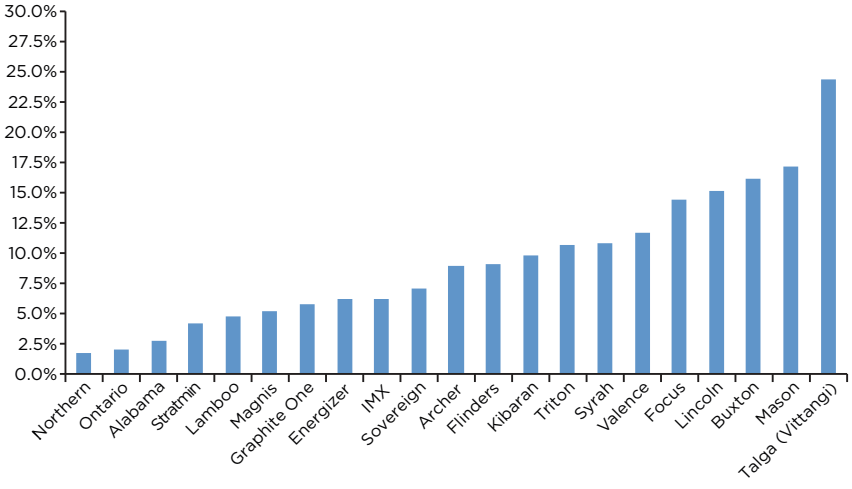


Figure 4: Projects ranked by EV/t of contained graphite (A$/tonne)

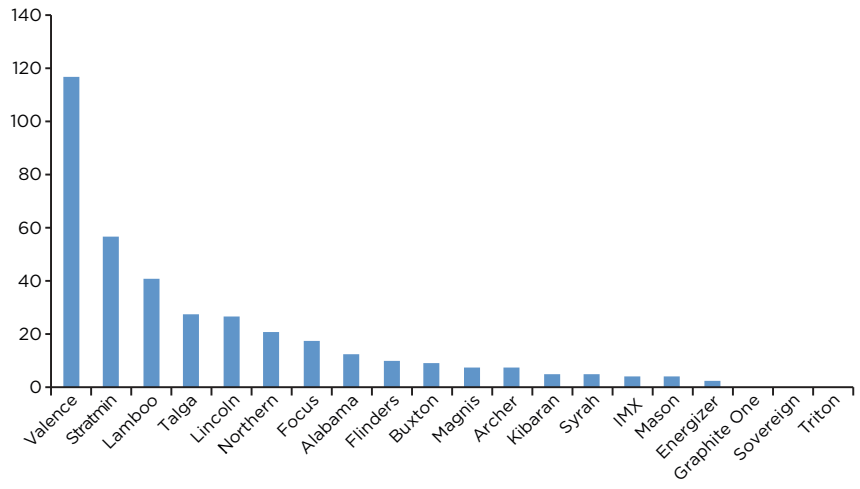
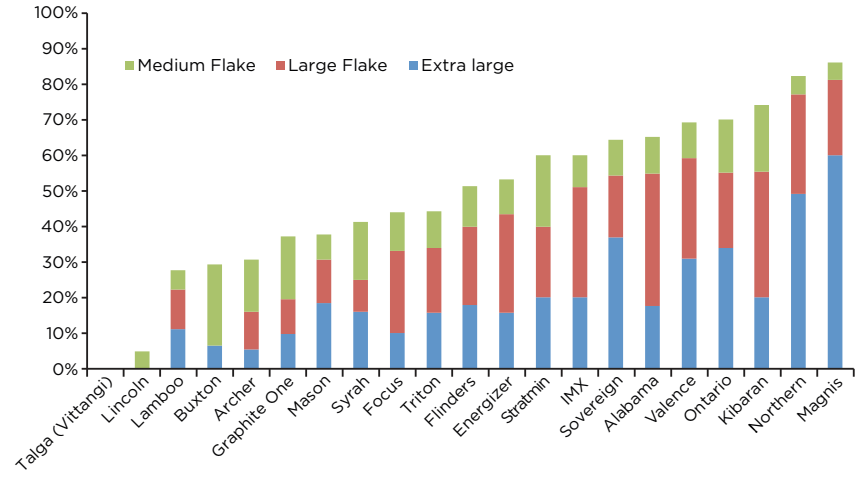


Figure 5: Projects ranked by flake size distribution (%)



which to build a graphite-to-graphene demonstration plant, with the objective of capitalising on commercial opportunities in the region.

Product purity

The fourth factor scores the purity of the graphite after simple crushing, milling, flotation and/or gravity processing (i.e., before acid or thermal upgrading). As with flake size, product purity is especially difficult to ascertain from public reports, as is predicting the effect of scaling up from lab and trial testing to full-scale plant production.

Graphite purity is particularly important for the higher value end uses like Li-ion batteries and is a key determinant in saleability of the product. It is also a key factor in the cost of production, as if further processing is required to make the product saleable, this could dramatically increase the operating cost. There is also an environmental consideration in whether acid leaching or thermal treatment is needed and whether this may impact the attractiveness of the product for certain applications, such as 'eco-friendly' products.

Simple processing can be altered in certain cases by including further grinding or polishing and flotation to produce a purer concentrate (to a point). However, this does decrease the proportion of larger flake sizes in the final concentrate and increase the cost of production, which may be offset by higher market prices (see *Table 1*).

Alabama, Energizer, Focus and Triton (8) score highest on the purity metric, followed by Archer, Flinders, IMX, Kibaran, Magnis, Northern, Syrah and Valence (6).

Some deposits such as Coosa (Alabama), Epanko (Kibaran), Chilalo (IMX), Duwi (Soveriegn) and Loharano (StratMin) are deeply weathered. Weathering causes oxidation and hydration, which softens the rock and breaks down gangue minerals such as entrained carbonates, sulphides and silicates; this may enhance flake liberation and hence purity. On the other hand, weathering may result in the development of swelling clays, such as montmorillonite, which could prove difficult to remove from the graphite flakes. Highly oxidised ore may also generate excess fines, which make the flotation process less effective; in this case it may be necessary to blend oxidised with unoxidised ore.

The issue of product purity and geological/weathering domains is important to consider when evaluating graphite projects, since such factors can have a significant impact on mining and processing methods, in addition to final product quality. In this regard, graphite explorers are urged to use thin section petrography as a basic tool to help address treatment/processing aspects.

It is suggested that petrographic examination of polished thin sections be done early on in the project and during the subsequent resource drilling phase. Polished thin sections are relatively inexpensive and can be used to estimate the size and shape of *in situ* graphite flake populations, relationships with other minerals including contaminants such as sulphide minerals (see *Figure 6*) and mica, which can be difficult to mechanically separate from graphite. *In situ* flake size does not necessarily translate directly to liberated flake sizes produced by metallurgical processes such as gravity separation or froth flotation, however.

Bearing these factors in mind means being smarter early on in the project and can guide more informed selections of composite drill samples for metallurgical testing, in addition to benefitting mine planning and metallurgical processing further down the line.

As a final point on this factor, it should be noted that graphite companies are increasingly considering moving further downstream and performing further product beneficiation themselves in order to differentiate their businesses to potential customers and achieve a higher price for the final product. While this involves additional capital and operating costs, the advantages of stronger customer relationships and higher margins are attractive. In this instance, we highlight the intentions of Archer, Flinders, Syrah and Valence and expect that others may be considering the same.

Product offtakes

The fifth factor scores the company's success in signing binding offtake agreements and

memoranda of understanding (MoU) for substantial portions of their intended production.

The graphite market largely comprises contracted sales agreements between buyers and sellers for products meeting the buyer's specific requirements. For this reason, a formal sales agreement with buyers for a substantial portion of the intended production is of particular importance. We have given greater weight in our scoring to binding off take agreements as opposed to MoUs and have rewarded greater proportions of production covered by such agreements.

It should be noted that the value attached to some of these agreements at an early project stage should treated with caution, as they are likely to contain caveats or 'get-out' clauses, contingent on final product qualification from pilot or full-scale plant production.

On the product offtake factor, StratMin (10) scores the highest, followed by Focus, Kibaran, Lamboo Resources Ltd, Magnis, Syrah and Valence (6).

Timeframe to production

The sixth factor scores the expected time to commercial production.

The interest in securing ex-China sources of supply coupled with Chinese closures and the growth in demand for higher specification products has resulted in a window of opportunity to introduce new supply to the market. The race to bring the right product to the market and secure offtake agreements means that companies further advanced towards first commercial production have an advantage over those further behind (assuming they have the required product specifications).

This factor scores Flinders, StratMin and Valence the highest (10) as they are either operational (Flinders is maintaining the Woxna operation on a "production-ready" basis for when the market improves), or ramping up to commercial production. These are followed by Kibaran, Mason and Northern (6). It is worth noting that Valence and Flinders are brownfield projects with a record of previous mining and production, which shortens the development timeline. StratMin's Loharano project was also previously mined on a small scale prior to 1947, while the Alabama Coosa project was mined until the 1950s.

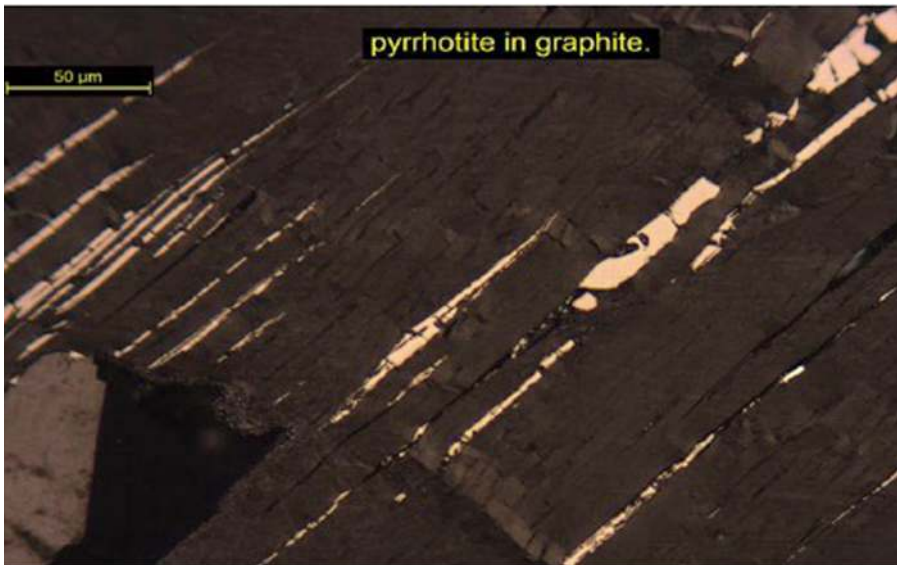


Figure 6: Photomicrograph illustrating pyrrhotite interleaved with graphite. Scale bar = 50 micron.

Conclusions

The flake graphite sector is dynamic, with numerous new deposits discovered recently and continually evolving applications and product specifications.

Although analytical problems exist in comparing companies based on publicly available information, the factors and analysis contained in this study, in the opinion of the authors, encapsulate the key drivers of a successful graphite project.

There exists a growing window of opportunity for new flake graphite supply to enter the market, but given the extent of new discoveries, slated new production by 2020 appears to be well in excess of this opening. Therefore, while many of the projects discussed above may continue through to successful development and expansion, ultimately more will be disappointed.

Drivers for success include having a sufficiently high-grade flake graphite deposit with low stripping ratio that is economic to mine and process to yield highest-quality marketable products. In addition, jurisdiction, logistics, timeframe to production and last but not least, offtake agreements must be taken into consideration.

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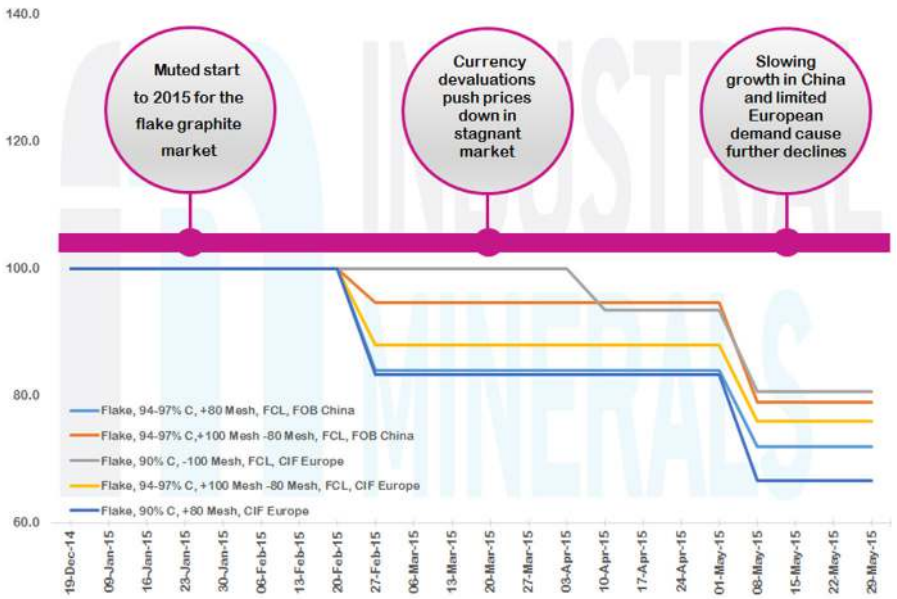
IM Graphite Price Index



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