GRAPHITE

INDUSTRY REPORT

PATERSONS
THE AUSTRALIAN STOCKBROKER

Separating the flake from the carbon

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Disclosure: Patersons Securities acted as Lead Manager to a Placement for Lamboo Resources that raised $7m in June 2012 and Lead Manager to a Placement for OMI Holdings that raised $0.2m in June 2012. Patersons Securities is acting as Lead Manager to a Placement for OMI Holdings will raise no less than $3m. It received fees for these services. The analyst holds shares in Lamboo Resources.

Investment highlights

The emergence of graphite has come as the equities markets are struggling through a phase where even gold has lost some of its lustre. Thus in the search for meaning and value in the microcap equities space we are tempted by the financial gain of investing in the next critical commodity.

- The remarkable run up in graphite prices since China placed a 20% export tax on the commodity has prompted a rush of junior exploration companies to acquire graphite properties or dust off old geology reports. Like the rapid response to a spike in prices of other specialty metals (lithium, uranium and rare earths) the graphite space will fill with many pretenders and a few contenders.

- The attraction to graphite is due to the scarcity of natural graphite, its unique physical and chemical properties and its growing importance in high technology and green energy applications. Graphite is nontoxic, chemically inert and has high resistance to corrosion. Graphite has low thermal expansion and shrinkage with high thermal shock resistance. Graphite has low density relative to conductive metals. The mineral is flexible, soft, compressible and malleable. It has low frictional resistance and is thermally and electrically conductive. Its melting point is above 3,500°C.

- The growth of the graphite market is dependent on a number of different uses of both amorphous and flake graphite. It is the production of higher purity natural graphite and the discovery of graphene that is really creating excitement. These are likely to lead to developments of new applications for graphite in high-technology fields.

- There have been many comparisons to other specialty commodities such as uranium, lithium and rare earths. China is the dominate player in the graphite market. However, we don't see Chinese supply as the main risk to future prices but the realisation that the market outside of China is considerably smaller than initially assumed. However we see the diversity of uses for graphite and the potential of natural graphite to be used as a substitute for the significantly larger synthetic graphite market as reducing this risk.

- Current prices provide enough incentive to for new mines to be bought into production and that the graphite market is insufficient to accommodate all the new projects being developed. We believe the most interesting stocks in the graphite space at this very early stage of development are AXE, LMB and SYR.

Figure 1: Highlighted ASX listed graphite stocks

Code	Name	Price	Market Cap	Cash	Resource		Primary Project	Ownership	Location	Development Stage
					Total	% cg				
AXE	Archer Exploration	0.16	13.178	12.753			Campoona	100.0%	Australia, SA	Advanced exploration
LMB	Lamboo Resources	0.36	24.175	6.115			McIntosh	100.0%	Australia, WA	Early exploration
SYR	Syrah Resources	2.83	358.626	3.875			Balama	100.0%	Mozambique	Early exploration

Source: Interria, company reports & IRESS

Market summary

The annual natural graphite production in 2011 is estimated to be worth $1B and 7 – 8% of the total graphite market worth $13B. The remainder on the market is supplied by synthetic graphite. High-purity (99.99% carbon) synthetic graphite is expensive and its conductivity inferior to natural flake graphite. Once additional and secure supply of natural flake graphite become available to end users, we could see natural flake graphite being used instead of synthetic graphite due to its relatively high conductivity and price competitiveness.

Demand

The graphite market has a wide variety of uses. We have split these uses into 4 categories. In general the amorphous graphite is used for base market uses and the flake size increases up the growth profile. There are materials that may be able to compete with graphite in a few applications but graphite's unique combination of physical and chemical properties generally excludes the possibility of substitution by other materials at current prices. The end-users of graphite are diverse in regards to location and markets. The biggest mid and high growth industries; steel making, battery and electrode producers are predominantly in China, South Korea and Japan but they are also located in the US and Europe.

1. Base market consumes 32% of current production and is used in the manufacturing of brake linings, lubricants, electric motor brushes, foundry facing mold wash and artistic mediums.

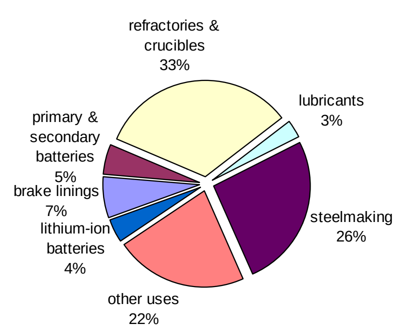
2. Mid-growth consumes the remaining 64% of current production and is used in the manufacturing of Primary battery products such as zinc-carbon and alkaline (manganese dioxide) batteries, as well as secondary rechargeable alkaline manganese batteries, refractories and crucibles and as a carbon raiser in steel making.

3. High growth consumes very little natural graphite, 4%, and includes lithium-ion batteries, fuel cells, pebble bed nuclear reactors and vanadium redox batteries.

4. Blue sky is graphene. Graphene has been touted as the potential wonder material for a host of electrical appliances including ultra fast transistors.

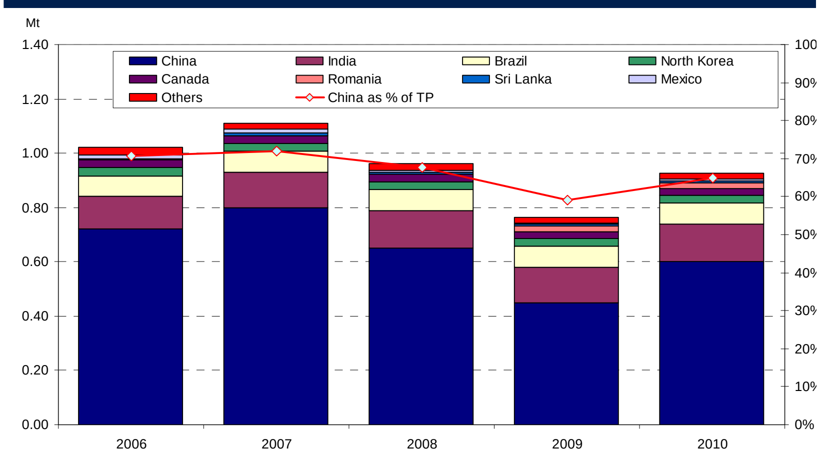
The lithium-ion battery market is the most important growth market for natural flake graphite. While all agree there is high potential for growth in this market, synthetic graphite is the current choice for battery makers, not natural flake. That is due to the consistency, security of supply and purity in synthetic material.

Figure 2: Natural graphite consumption by use



Source: USGS (2010), company reports

Figure 3: Natural graphite production by country



Source: USGS

Supply

Production of natural graphite is estimated to be 1.2Mt. This is similar to the size of the nickel market (1.4Mt) and ten times larger than the Rare Earth Oxide market (120kt). Production comes predominantly from China (70%) and India (12%). The remaining production is distributed between Brazil, North Korea, Canada, Sri Lanka, Mexico and several countries in Europe and Africa. Of the 1.2Mt produced in 2011 it is estimated that 60% was amorphous or lump and the remaining 40% was flake. Mexico only supplies amorphous graphite, and Sri Lanka supplies lump and chippy dust varieties. China, Canada, and Brazil were, in descending order of tonnage, the major suppliers of crystalline flake and flake dust graphite.

China's graphite production is expected to continue to increase by commissioning new mines and utilising some of the excess capacity available. One concern for investors is could China dumped large stockpiles of natural graphite onto the open market, resulting in a crash in price as it did in the 1980s. We see this as unlikely as although China produces approximately 70% of world graphite, about 60-70% of this supply is very fine flake or amorphous graphite. Also Chinese exports are expected to decline as they did when China imposed export duties on rare earths. China has imposed a 20% export duty on graphite in addition to the 17% Valued Added Tax and imports natural flake graphite from North Korea.

Pricing

Carbon content and flake size are the main parameters controlling the price of graphite. Flake distribution, iron, silicon and ash content will also impact the price. Physical prices will vary according to geographic region and will take into account the quantity purchased, application, quality assurance, exact grade, credit terms, and other parameters.

Flake graphite has the advantage of being sold into a wider range of markets and enjoys higher prices than amorphous or lump. As a general rule the larger the flake the higher the price.

Figure 4: Graphite Properties and Price

Graphite Product	Carbon Content (%)	Mesh Size	Graphite Size	Price (US$/t)	Comparable grain size
Jumbo Flake	94-97%	+48	>297μm	$4,500 - $6,000	Beach sand
Large Flake	94-97%	-48 to +80	177 - 297μm	$2,500 - $3,000	Sugar, fine sand
Medium Flake	94-97%	-80 to +100	149 - 177μm	$2,200 - $2,500	
Fine Flake	94-97%	-100 to +200	74 - 149μm	$2,200 - $2,400	Portland Cement
Amorphous	80-85%	-200	=<74μm	$850	Silt, plant pollen
Synthetic	99.95%			$7,000 - $20,000	

Source: Industrial Minerals (Mar 2012)

Commercial flake graphite products are available in a range of purities from around 80% carbon up to 99% carbon. Flake which is in the purity range of 80-98% typically represent materials which have been beneficiated using only froth floatation. Flake above 98% purity has been purified using other methods subsequent to floatation.

Highlighted stocks

Theory would have it that markets distribute funds efficiently to the most viable ventures. On the way the lithium, Rare Earths and Uranium markets have evolved it is evident that efficiency doesn't have much to do with the creation of so many surplus investment opportunities but it certainly does play a role in the eventual thinning out process.

The ASX is not as promotional as the Canadian exchanges but we do have at least 13 companies promoting graphite projects. The vast majority of these are in the process of acquiring project or they are in the very early stages of exploration. Only 3 have defined resources to date and very little metallurgical work has been done. The main problem for the late movers is that there may not be any demand for their products even if they get into production in the long-term.

Figure 5: ASX listed graphite companies

Code	Name	Price ($/sh)	Shares (M)	Market Cap ($M)	Cash	Resource		Primary Project	Ownership	Location	Development Stage
						Total (Mt)	% cg				
AXE	**Archer Exploration**	**0.16**	**82.4**	**13.2**	**12.8**			**Campoona**	**100%**	**Australia, SA**	**Advanced exploration**
BUX	Buxton Resources Ltd	0.17	41.1	7.0	1.2			Yalbra	85%	Australia, WA	Early exploration
CDT	Castle Minerals	0.22	113.7	25.0	3.4	14.4	7.2%	Wa	100%	Ghana	Advanced exploration
KNL	Kibaran Resources	0.515	38.4	19.8	0.6			Ndololo	0%	Tanzania	Acquiring
LMB	**Lamboo Resources**	**0.36**	**67.2**	**24.2**	**6.1**			**McIntosh**	**100%**	**Australia, WA**	**Early exploration**
LML	Lincoln Minerals	0.09	153.4	13.8	1.1	0.88	11.5%	Koppio-Kookaburra Gully	100%	Australia, SA	Scoping Study
MGY	Malagasy Minerals	0.075	156.6	11.7	1.9			Green Giant	25%	Madagascar	Early exploration
MOX	Monax Mining Limited	0.049	148.8	7.3	2.4			Waddikee	100%	Australia, SA	Early exploration
OMI	OMI Holdings Limited	0.004	571.8	2.3	0.2			Taewha	0%	South Korea	Acquiring
SVM	Sovereign Metals	0.35	51.6	18.1	2.3			Central Malawi	0%	Malawi	Acquiring
SYR	**Syrah Resources**	**2.83**	**126.7**	**358.6**	**3.9**			**Balama**	**100%**	**Mozambique**	**Early exploration**
TLG	Talga Gold Ltd	0.3	46.4	13.9	1.5	4.1	21.5%	Nunasvaara	100%	Sweden	Scoping Study
TON	Triton Gold Ltd	0.068	108.4	7.4	0.8			Ancuabe	0%	Mozambique	Acquiring

Source: Interria, company reports & IRESS

We believe the three companies highlighted in figure 4 are the most interesting stocks in the graphite space at this very early stage of development.

Archer Exploration (AXE) Market Cap of $13.6M, $12.6M in cash, spending ~$1.0M per quarter on exploration and admin.

AXE is attractive due to its strong cash position and the initial metallurgical work completed. The first process successfully determined that high quality amorphous graphite could be recovered using conventional flotation methods. Two samples as received passed through a 220 micron sieve making it potentially unsuitable for the recovery of flake graphite. However the recovery process for flake was completed and flake graphite is present and recoverable in small volumes.

AXEs key projects are Campoona and Sugarloaf located on the Eyre Peninsula in South Australia. RC drilling was completed earlier this year. AXE has over $12M in the bank after the sale of five West Roxby tenements to BHP Billiton for $8M and a SPP for $1.5M was completed.

Lamboo Resources (LMB) Market Cap of $20.8m, $6.1m in cash, spending ~$1.1M per quarter on exploration and admin.

Initial indications imply LMB has a very large resource at its McIntosh deposit in the East Kimberley of Western Australia with over 10km of aggregate strike length to be explored. The deposit has the potential to have a very high flake content and high graphitic content (Cg) which will only require a simple beneficiation process.

Auger drilling, which can only test to shallow levels (5m), has confirmed the width of a flake graphite schist at one of the initial targets. It also confirmed the accuracy of the EM surveying which identified the 10km of aggregate strike length to be explored. Petrographic studies have confirmed that flake graphite dominates in the graphitic schist and estimated up to 30% Cg.

LMB has commenced a drilling program to be completed by 2 drill rigs. This will provide substantial information on the stratigraphic controls including depth and provide samples to determine the initial metallurgy and define preliminary data on the carbon content.

Syrah Resources (SYR) Market Cap of $354.8m, $3.9m in cash, spending ~$2.1M this quarter on exploration and admin.

SYR is the graphite poster company at the moment. Its share price has run from 12 month low of $0.08/share to a 12 month high of $3.01/share on the back of some impressive drill results placing it in an excellent position to raise capital. Initial metallurgical work has shown fine to jumbo size flakes are evident in the host rock and some of the gauge material in a weather sample can be easily extracted.

SYR has completed 15 diamond drill holes in the western part of the Balama Graphite Project in north Mozambique over an initial strike length of over 1km. The overall outcropping mineralisation extent is 7km. Reconnaissance trenches in the drilling area returned assay results ranging from 11% TGC to 23.3% TGC. The 15 holes ranged from 250 to 320m in length. Every hole returned graphite mineralisation down the entire length other than one which encountered a 30m thick pegmatite dyke near surface. This potentially makes the deposit massive.

Samples from the trenching were sent for petrographic analysis. The samples are dominated by quartz (55-70%) with graphite (14-19%), mica–roscoelite (15-25%) and traces (<1%) of rutile and tourmaline. Earlier metallurgical testwork on a single weathered sample indicated the mica readily separates from the graphite. There was no information on the purity of the graphite recovered or whether the quartz was easily extracted.

Balama is an exciting prospect but at 13 times the market capitalisation of the next largest graphite company it is likely the excitement is already priced into the share price. More extensive metallurgical work on weathered and fresh ores samples is required to get a better understanding of the graphite flake recovery.

What is Graphite?

Graphite is a non-metallic, opaque mineral of grey to black colour with metallic lustre. It is a crystalline mineral of pure carbon (allotrope) which normally occurs in the form of platelet-shaped crystals. The basic structure of graphite consists of a hexagonal arrangement of carbon atoms which form stable planar lattices with only weak inter-layer bonding. It was named in 1789 from the Ancient Greek γράφω (graphō) meaning to draw or write. Graphite occurs naturally or it can be made synthetically. It is nontoxic, chemically inert and has high resistance to corrosion. Graphite has low thermal expansion and shrinkage with high thermal shock resistance. Graphite has low density (1.1-1.7 g/cm3) relative to conductive metals such as aluminium and copper. The mineral is flexible, soft (0.5-2 on the Mohs scale), compressible and malleable. It has low frictional resistance and is thermally and electrically conductive. Its melting point is above 3,500°C in a non-oxidizing environment and the vaporization temperature is around 4,500°C.

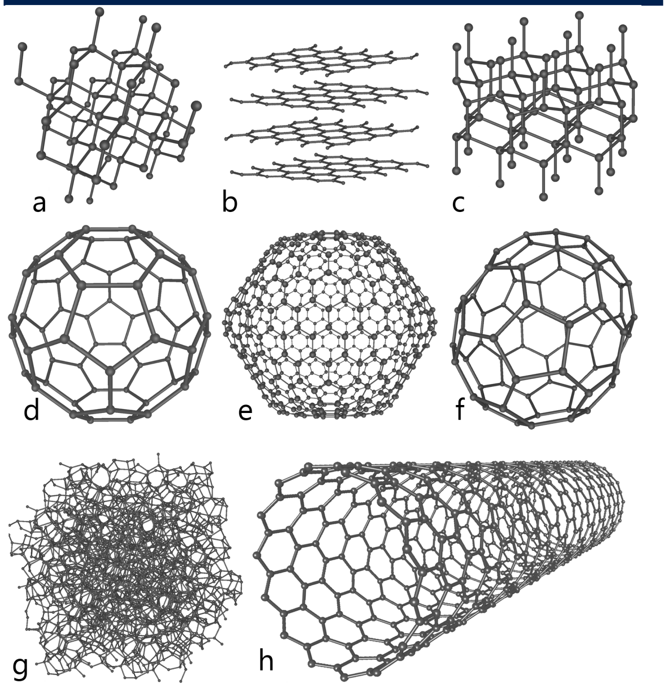
Natural graphite is formed in metamorphic environments. High temperature and high pressure are the pre-requisites that affect the conversion of amorphous carbon materials to crystalline graphite. Carbon is the 15th most abundant element in the Earth's crust, and the fourth most abundant element in the universe by mass after hydrogen, helium, and oxygen. It is one of the few elements known since antiquity but only a very small proportion of the carbon in the Earth's crust is present in elementary form as either graphite or diamond. Most carbon is contained in carbonate rocks, such as limestone, and in organic matter, bituminous rock, and fossil fuels. Due to the scarcity of natural graphite and its unique physical and chemical properties along with its growing importance in high technology and green energy applications, it has been declared a strategic mineral by both the USA and the European Union. A strategic mineral generally refers to mineral ore and derivative products that come largely or entirely from foreign sources, that are difficult to replace, and that are important to a nation's economy, in particular to its defence industry.

Synthetic graphite is a manufactured product made by high-temperature treatment of amorphous carbon materials. The morphology of most synthetic graphite varies from flakey in fine powders to irregular grains and needles in coarser products. Synthetic graphite is processed at ultra high temperatures (between 2500 C and 3000 C), and impurities contained in the precursor carbons are significantly reduced during processing.

Figure 6: 1-mm graphite crystal in calcite

Source: John A. Jaszczak collection

Figure 7: Allotropes of Carbon



Source: Created by Michael Ströck

a) Diamond, b) Graphite, c) Lonsdalite, d) C60, e) C540, f) C70, g) amorphous carbon, h) single-walled carbon nanotube

Types of graphite

There are three principal types of natural graphite;

1. Crystalline flake graphite occurs as isolated, flat, plate-like particles with hexagonal edges if unbroken and when broken the edges can be irregular or angular.

2. Amorphous graphite occurs as fine particles and is the result of thermal metamorphism of coal, the last stage of coalification, and is sometimes called meta-anthracite. Very fine flake graphite is sometimes called amorphous.

3. Lump graphite (also called vein graphite) occurs in fissure veins or fractures and appears as massive platy intergrowths of fibrous or acicular crystalline aggregates, and is probably hydrothermal in origin.

Factors to consider when evaluating a graphite project

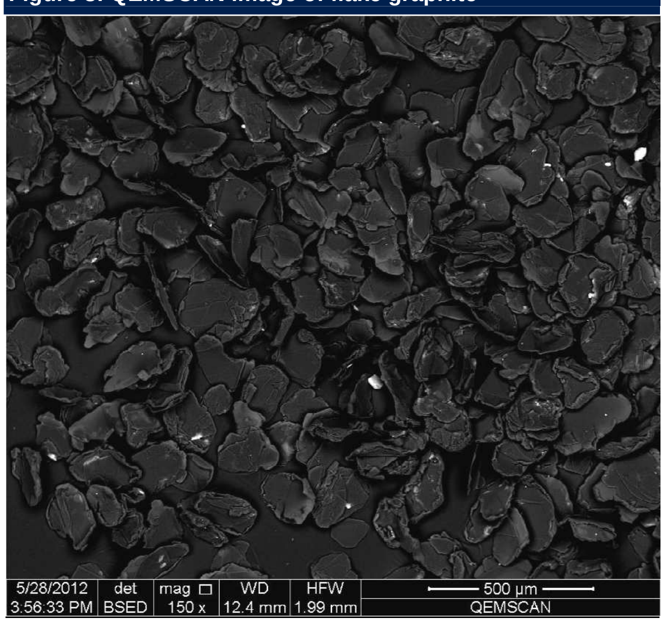
The remarkable run up in graphite prices since China place a 20% export tax on the commodity has prompted a rush of juniors to acquire graphite properties or dust off old geology reports. Like the rapid response to a spike in prices of other specialty metals (uranium, lithium and rare earth elements) the graphite space will fill with many pretenders and a few contenders.

A graphite company is no different than any other junior resource company. In addition to evaluating its projects, a company's share structure, cash position, management and peer market valuation must be considered. The first step is the economic evaluation of graphite deposits and we believe the following factors are important in this evaluation;

1. Carbon content and flake size

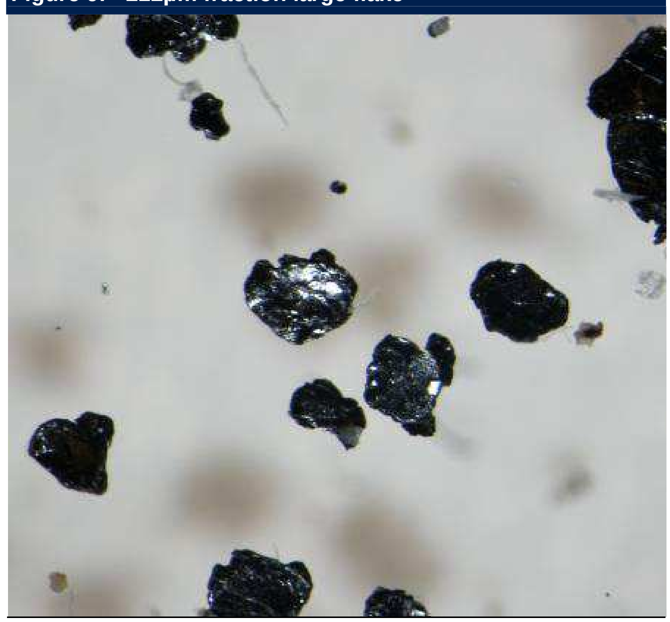
Confirmation of mineralisation is essential. In graphite projects, evidence of mineralisation is usually announced with initial indications of carbon content and evidence of flake graphite. The distribution and size of any flake graphite is a significant value driver of a deposit. Definition is done in several steps starting with a petrographic and a microprobe analysis. This gives an indication of flake sizes in the sample but this does not indicate whether these flakes would be easily liberated, concentrated and whether their size would be conserved.

Figure 8: QEMSCAN image of flake graphite



Source: AXE company report

Figure 9: +212μm fraction large flake



Source: AXE company report

Flake sizes are reported in either microns or mesh sizes. The microns describe the size of the particles that pass through or are retained by a sieve. The mesh size describes the numbers of holes in a sieve of a given size. Therefore the smaller the number of holes the larger the particles the sieve will let pass through. All graphite deposits will have a distribution of flake sizes and these are divided into large, medium and fine categories. The "+" and the "–" before the mesh size are used to describe a range, with "+" indicating that particles larger than that specific size are retained in a sieve while the "–" indicates that particles finer than that specific size pass through the sieve. For example, "–80 +100" means that the majority of the flakes are retained by the 100 mesh sieve but are able to pass through the 80 mesh sieve.

In-situ carbon content is generally defined as total graphitic content (TGC) or Graphitic Carbon (Cg) and expressed as a percentage. The TGC of resources defined recently varies widely from 1.28% at the Black Crystal Graphite Mining in BC Canada to 22.4% at the Golden Grove Graphite Project in New Brunswick Canada. The amount of graphite contained in a resource will not give an indication to type of graphite recoverable but the lack of structure in amorphous deposits tend to return higher carbon content in assays. The carbon content needs to be considered when evaluating the economics of any project as the lower the head grade of the product to be beneficiated the higher the operating costs per unit of graphite produced.

2. Resource definition

The size and quality of a mineralisation is the first step in determining the potential size and life of a project. A fair proportion of graphite geological and metallurgical expertise has been lying idle since the 1990's when graphite prices were suppressed forcing producers and explorers to close operations. The recent revival in prices has prompted many exploration companies to revisit historical exploration data. Graphite exploration companies often quote historical graphite grades, visual grades and flake size. This only works as an indication and modern techniques need to be utilised to fully ascertain the viability of a project; these include geophysical surveying, RAB and diamond drilling and a full suite of metallurgical tests.

Geophysical surveying

Ground-based and airborne electromagnetic surveys are highly effective at identifying graphite mineralisation due to graphite's conductivity. The ground-based survey is effective in delineating near-surface mineralisation, while the airborne survey is effective in detecting graphite mineralisation at depth. Due to the structural complexity of many graphite deposits, anomalies may result from interfering conductive effects. However, follow up drilling on a number of projects globally has confirmed a high correlation between the geophysics and drill core.

Rotary Air Blast & Diamond drilling

Cost effective resource definition will engage a combination of Rotary Air Blast (RAB) and Diamond drilling. This will provide material for assays to determine the carbon content and quality samples for metallurgical test work. A composite database is created by mining software from assay data collected from the assays of the drill holes across the mineralised zones.

Metallurgy

The process of extracting graphite from the host rock can vary from simple to complex. The more complex the mineralisation, the harder and more expensive it is to extract what you want. Metallurgical sampling should begin as soon as possible to determine the viability of the project in terms of recovery, separation, purity and flake distribution. Ideally, a resource estimate should be produced after initial metallurgical testing has been completed. Even a large deposit might prove to be uneconomical if recoveries, purity or flake distribution is not favourable. It should also be noted that metallurgical results may vary between weathered ore samples and fresh ore samples.

The full suite of metallurgical tests includes lab and bench scale work, a bulk sample/pilot plant test, and variability testing to ensure recoveries and flake size distribution are consistent across the deposit. These will be completed as a project moves from initial drilling through to a bankable feasibility study.

3. Host rock

The rock that contains the graphite is the main determinant in evaluating how the graphite will be liberated, concentrated and if flake graphite is contained whether its size would be conserved. In many cases, the processing and beneficiation procedure will break down some of the larger flakes and create finer graphite particles. The petrographic and a microprobe analysis can give an initial indication to the grinding needed to liberate the flakes using floatation. However, this may not be announced when this analysis is conducted as it is not definitive.

Graphite ores generally occur in strongly foliated rocks in which the foliation is defined by the parallel orientation of graphite flakes. A variation of factors such as the composition of the host rock, tectonic setting, temperature, pressure, oxygen and other conditions will determine the deposit style and the type of graphite present. The main gangue minerals are quartz, plagioclase and K-feldspar. The graphite grains are situated interstitially between grain boundaries of gangue silicates, and more rarely as inclusions in the silicate minerals.

There are basically three different processes leading to the formation of economic graphite deposits

a. Contact metamorphism of coal deposits: such deposits are usually of low quality and produce low-priced products.

b. Epigenetic graphite deposits. It is believed that this process was active during the formation of the Sri Lankan type of vein graphite deposits.

c. Syngenetic flake graphite deposits. The formation of these deposits involves the alteration of organic matter to graphite during metamorphism. From studies of coal and anthracites, the operating processes have been shown to be highly complex

Syngenetic graphite deposits in siliceous metasediments and, to a lesser extent marbles, are the major commercial sources of crystalline flake graphite; these deposits may also contain amorphous graphite and are divided into 2 main categories.

a. Silica metamorphosed rock deposits

Silica metamorphosed rock deposits are typically associated with quartz-mica schist, quartzite and gneiss. These types of deposits show average grades of around 10%-12% Cg, but can go as low as 2% and as high as 60% Cg. The mineralised zones are in the form of lenses or layers depending on the degree of structural deformation and range from flat lying to sub vertical. Even though these deposits are known for their large flakes, crystal size varies, reflecting the grain size of the parent sedimentary rock. In length, individual deposits can extend over several thousands of meters. The purity of the graphite in these deposits tends to be between 85% and 98% carbon. Examples of such deposits are McIntosh in northern WA and Campoona in the Eyre Peninsular.

b. Carbonate rich metamorphosed rock deposits

Carbonate rich metamorphosed rock deposits are hosted within marbles often intertwined with quartzite and gneiss. The average grade in marble hosted deposits ranges from 1% to 10% Cg. These deposits tend to be structurally complex with large variations in grade over short distances. These deposits can produce the entire range of flake sizes with purities between 85% and 98% carbon. An example of such a deposit is Ndololo in Tanzania.

4. Mining Method

The vast majority of graphite deposits are exploited using open pit mining methods however a small number employ underground mining methods. Graphite is mined using standard hard or soft rock mining techniques. If the ore is hard-rock, it must be drilled and blasted while soft-rock ore is free dig and hauled to the floatation plant.

Figure 10: Characteristics of types of graphite ore from metamorphic environments

Characteristic	Ore type: Crystalline graphite – Disseminated flake	Ore type: Crystalline graphite – Lump ore	Ore type: "Amorphous" graphite
Description of ores (crystallinity, crystal size).	Well-developed crystal platelets (grain size greater than 0.04 mm disseminated or segregated) displaying metallic luster disseminated in metamorphic rocks (gneisses, quartzites, marbles).	Interlocking aggregrates of coarse graphite crystals.	Microcrystalline (grain size less than 0.004 mm, 400 mesh) aggregates, earthy black, rarely displaying submetallic or metallic luster of graphite. Aggregates may contain nongraphitized carbonaceous material (such as anthracite).
Grade (percent carbon).	5 to 30 percent fixed carbon	Up to over 98 percent fixed carbon.	40 to 85 percent fixed carbon; dependent on carbon content of parent coal.
Ore body	Tabular, rarely lenticular; locally as irregular bodies in hinge zones of folds.	Veins (comb structure at margins) generally crosscutting structures related to metamorphism; stockworks, vugs, and nests.	Seams, often folded and faulted.
Geologic environment and setting.	Syngenetic graphite deposits; regionally metamorphosed metasediment sequences and migmatitic terranes.	Epigenetic deposits; regionally metamorphosed (granulitic, charnockitic) rocks. Contact metasomatic origin has been proposed for some deposits (such as Botogol'sk).	Syngenetic deposits of metamorphosed coal seams near younger igneous rocks (contact metamorphism) or in regional metamorphic terranes.
Examples			
	Madagascar deposits, Skaland (Norway), Kropfmüehl (Germany), and Reindeer Lake (Canada).	Sri Lanka deposits, Botogol'sk (Soviet Union), and Dillon (Montana, United States).	Sonora deposits (Mexico), Kureika (Soviet Union), Pinerolo (Italy), Kaiserberg-Trieben (Austria), Malonga-Mutale and Mtubatuba (South Africa), and deposits in North Korea.

Source: USGS

5. Beneficiation process

The size of the graphite flake is a very important commercial consideration and it is in the best interest of a flake graphite producer to maximise the amount of large flake removed from the deposit. This means that any processing which will tend to grind or reduce the size of constituent flake must be minimised. The crushing and grinding of ore to release entrapped flake is the main force responsible for reducing the size of the individual flakes extracted.

Beneficiation processes for graphite may vary from a complex four-stage flotation to simple hand sorting and screening of high-grade ore. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Typically, such ores contain the highest proportion of coarse flakes. Ore is sluiced to the field washing plant where it undergoes desliming to remove the clay fraction and is subjected to a rough flotation to produce a concentrate. This concentrate is transported to the refining mill for further grinding and flotation to increase purity. It is then screened to produce a variety of products to be marketed.

Crushing & grind size

Processing starts by trucking the ore to a crusher. Crushing must be done in order to release the flake from the enclosing host rock. Hard rock may require further crushing, the ore will then be fed into a mill. Milling may be done in water slurry. At this point the individual flakes have been freed from the enclosing ore rock.

Flotation and use of reagents

The slurry is then fed to froth floatation cells. In the cell the ore is mixed with water and floatation agents. Mixing is followed by injection of air into the cell. As air bubbles float to the top of the cell the floatation agents, which coat the graphite flakes, are attracted and stick to the air bubbles.

As for flotation reagent, kerosene or diesel oil are commonly used. Reagents such as heavy oil, phenols, sulphonic acid ester, and carboxylic acid are also used. Sometimes several regents are mixed. There are often mica and other silicate minerals in graphite ores. During flotation, to curb these minerals, water fluctuations, starch, dextrin, organic gum cellulose and other reagents are be used. If pyrite content is high, lime and oxides can be added.

The buoyancy induced by the attached air bubble causes the individual flakes to float to the top of the bath where they are skimmed off. The floatation reagents do not stick to the host rock; therefore these particles sink to the bottom of the cell and are removed from the process.

The main problem expected at the beneficiation stage is complications with overall recovery of the larger graphite flakes. Depending on the host rock finer grinding may be required that will eventually destroy the larger flakes and reduce the graphite selling price. Recoveries are expected to exceed 90% in most cases but ore bodies flooded with silica or which are significantly oxidized might show much lower recoveries. A potential solution could be acid upgrading or acid liberation, but this is cost intensive.

6. Infrastructure

The location of any project and proximity of infrastructure will impact the capital requirements and operating expenses. The exploration or mine site will need to accommodate the requirements of mining, treatment of the ore and transport of the saleable product to market. The level and cost of infrastructure is based on access, potentially including road (all weather), an airstrip, a rail loop or dedicated line. Graphite is not a bulk commodity and therefore a dedicated rail line is unlikely to be required. However, access to a rail line would assist in reducing costs. Other considerations are proximity to potable water, power and labour. Waste and tailings also need to be considered and the requirement will be dependant on the beneficiation process and reagent used.

Current and future uses of graphite

We have split the uses of graphite into 4 categories; base market, mid-growth, high growth and blue sky. In general the amorphous graphite is used for base market uses and the flake size increases up the growth profile.

1. Base market drivers

   a. Brake Linings

      Amorphous and fine flake graphite is used in brake linings or brake shoes for heavy vehicles. Graphite was initially used as a substitute for asbestos but non-asbestos organic (NAO) compositions are beginning to gain market share.

   b. Lubricants

      Graphite based lubricants are specialty items for use at very high or very low temperatures. These uses include forging die lubricant, anti-seize agent, a gear lubricant for mining machinery, and to lubricate locks. It can be used as a dry powder in water or oil, or as colloidal graphite (a permanent suspension in a liquid).

   c. Other Uses

      Natural graphite has found uses in electric motor brushes, and various specialised applications such as a foundry facing mold wash which is a water-based paint of amorphous or fine flake graphite. Painting the inside of a mold with it to create a fine graphite coat will ease separation of an object cast after the hot metal has cooled. Graphite is also commonly used in the form of powders, and sticks for the purpose of writing or drawing. Graphite of various hardness results in different qualities and tones when used as an artistic medium.

2. Mid-growth drivers

   a. Batteries

      Primary battery products such as zinc-carbon and alkaline (manganese dioxide) batteries, as well as secondary rechargeable alkaline manganese (RAM) batteries utilise graphite as the cathode material. The graphite powder additive used in these applications improves the electrical conductivity and the compression of the cathode mass. It increases the mechanical stability and process-ability of the cathode rings.

   b. Refractories and Crucibles

      Flake graphite is used in the manufacture of crucibles and molds, graphite heating elements, heat treating furnace fixturing, chemical processing equipment, molten metal extrusion, pressure casting, vertical and horizontal continuous casting, centrifugal casting, graphite susceptors, heat shields and furnace linings.

      Both amorphous and flake graphite is used in refractories where graphite increases durability, erosion resistance, thermalshock resistance, and thermal conductivity. The majority of refractories (75%) are used to make steel; the rest are used by a variety of industries, such as cement.

   c. Steelmaking

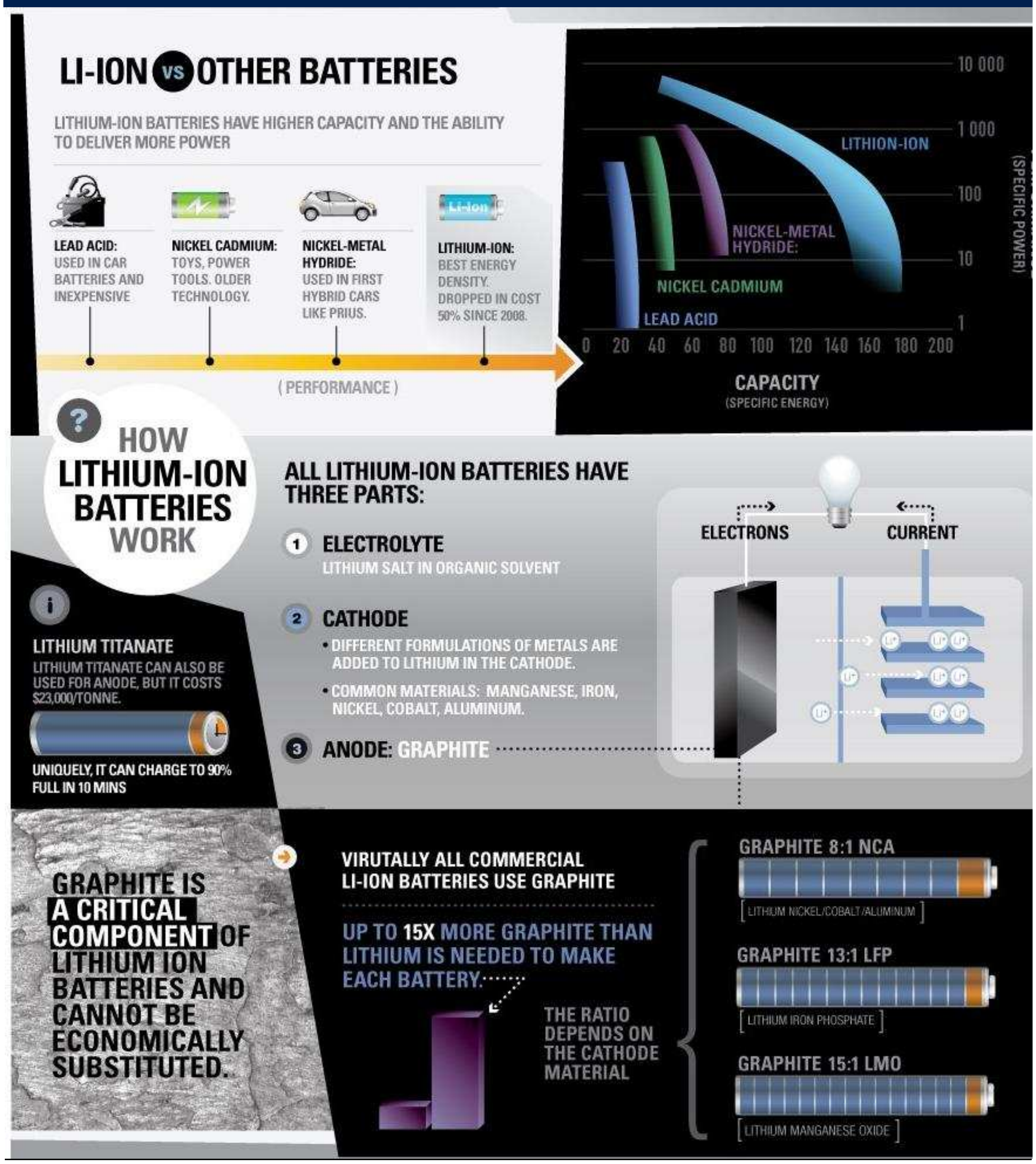
      Graphite in the steelmaking process predominately goes into carbon raising in molten steel or to raise the carbon content of the steel to be able to manufacture ductile, cast and synthetic irons. Supplying carbon raisers is becoming very competitive and alternatives such as synthetic graphite powder, petroleum coke, and other forms of carbon are some of the substitutes available.

3. High growth drivers

   a. Lithium-ion batteries

The growth potential for graphite in lithium-ion batteries is arguably the most exciting and comprehendible. Lithium-ion batteries are currently used in consumer electronics. However, the conversion to lithium-ion batteries from nickel-metal hydride and nickel-cadmium batteries, expanded applications including hybrid and electric cars and bikes, smartphones and tablet PCs are the main areas of growth.

Figure 11: Lithium-ion battery infographic segment



Source: Visual Capitalist

Lithium-ion batteries commonly use carbonaceous materials as anodes. Graphite is the most widely used material due to its stable specific capacity, small irreversible capacity, and good cycling performance. A growing requirement is that the graphite be milled into a spherical shape to improve compaction and density within the battery compartment. This process results in 15 – 20% wastage of flake graphite purchased for the production on anodes by component or battery makers.

Graphite powder additives used in battery applications improves the electrical conductivity and the compression of the cathode mass, and increases the mechanical stability and process-ability of the cathode rings.

There are a number of different lithium-ion batteries currently being produced and these tend to be described by the cathode material - lithium cobalt oxide, lithium manganese oxide, lithium iron phosphate, and lithium nickel oxide. An Argonne National Laboratory study in 2009 estimated there is between 8 to 15 times the graphite contained in these lithium-ion batteries as the cathode material.

Carbon materials such as natural graphite, hard carbon and synthetic graphite are used in lithium ion batteries. Carbon has the ability to reversibly absorb and release large quantities of lithium without altering the mechanical and electrical properties of the material.

Titanate, silicon and silicides, as well as tin and tin alloys, are the new anode materials that have been discussed in the context of research and development. These alternative anode materials have attractive attributes as the high mobility of lithium within the anode material. However they are far more expensive and less developed. This means it will be some time before materials and parts are approved and mass production can commence. There are also some attributes that need to be overcome such as the volumetric changes in batteries of silicon and tin which make them unworkable to date.

b. Fuel cells

The demand for efficient energy systems, the desire to reduce greenhouse gas emissions and the demand for high energy density portable power sources has created the environment to develop better fuel cell materials and fuel cell systems.

A fuel cell is a device, which chemically oxidizes its fuel generating heat and electricity. There are a number of difference types of fuel cells, two that utilize graphite products in several parts are Proton Exchange Membrane Fuel Cells (PEM) and Direct Methanol Fuel Cells (DMFC). Graphite powders are used in carbon-based bipolar plates, in gas diffusion layers and catalyst supports.

Graphite dispersions can be applied to metal-based bipolar plates and to gas diffusion layers. Graphite is included in thermoplastics, thermosets, and electronically conducting polymers used to manufacture the bipolar plate. The isometric particle shape and bulk density result in excellent electrode performance and also make the electrode manufacturing process easier. Graphite can be used as substrates in gas diffusion layers because of the porosity, high tap density, and electrical conductivity.

c. Pebble bed nuclear reactors (PBR)

PBR is one of the Generation IV reactors. Current reactors in operation around the world are generally considered second or third generation systems, with most of the first generation systems having been retired some time ago. Research into these reactor types was to achieve improved nuclear safety, proliferation resistance, minimise waste and natural resource utilization, and decrease the cost to build and run. Countries designing generation IV reactors include the United States, Germany, France, Japan, Britain South Africa and China.

China appears to be the most advanced in the development of PBRs. A 10-megawatt-electric pebble bed prototype was built in 1992. This prototype was completed in 2000 but was not connected to the grid until 2003. By 2008, the Chinese changed the design to have two smaller reactors connected to one steam turbine, which together would produce about 200 megawatts of electricity. The Shandong site, where the demonstration plant is located, could eventually host up to 18 pebble bed reactor modules. However news is difficult to obtain.

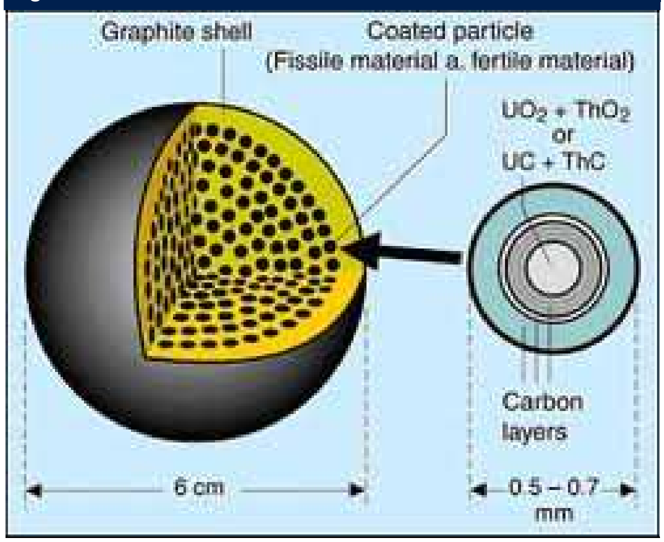
PBRs are a graphite-moderated, gas-cooled, nuclear reactor. The basic design of pebble bed reactors features spherical fuel elements called, pebbles (figure 9). These tennis ball-sized pebbles are made of pyrolytic graphite (which acts as the moderator), and they contain thousands of micro fuel particles called TRISO particles. In the PBR, thousands of pebbles are amassed to create a reactor core.

New fuel pebbles are continuously added at the top of a cylindrical reactor vessel and travel slowly down the column by gravity, until they reach the bottom and are removed. Cooling uses an inert gas such as helium, rather than a liquid, which simplifies many of the reactor systems. As each pebble makes its way through the system and is drawn out at the bottom of the reactor, it can be tested and either reinserted at the top of the reactor (the average pebble would cycle through the reactor about ten times before it was expended) or withdrawn if it was spent.

Operational issues have become apparent with the PBR design. Contaminated graphite dust is created from the pebbles from friction as they move down through the reactor. Tests carried out with dummy pebbles found overheating conditions occurred inside the reactor (>1,200°C) that can lead to contaminating the reactor components. Also the volume of radioactive waste from a PBR is larger than that from other designs; however the waste is contained in the pebble.

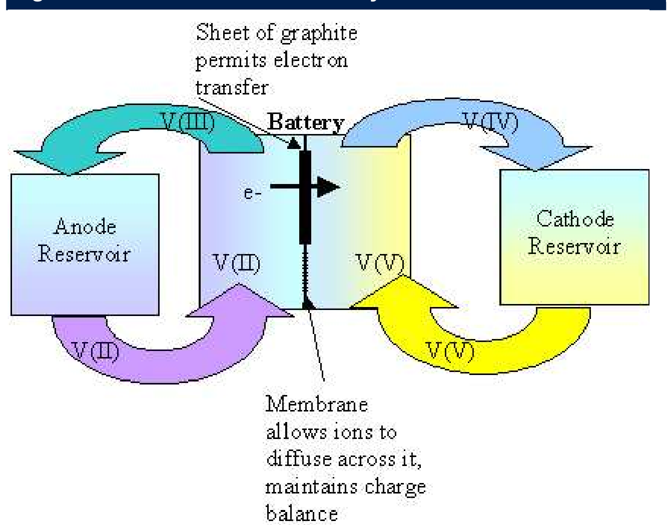
In 2003 The Massachusetts Institute of Technology (MIT) investigated the key safety features of the pebble bed reactor under challenging conditions. The first part of the thesis explored the "no meltdown" claim of the proponents of the technology without the use of any active emergency core cooling systems after a loss of coolant accident. It was shown that the peak fuel temperature was approximately 1640 °C after the initial loss of coolant which is about 1500 °C below the UO_2 fuel melting temperature. The conclusion was that although the core will not melt even under these conditions by a large margin, some form of reactor cavity cooling system will be required to keep the reactor vessel and reactor cavity concrete within design limits.

Figure 12: Pebble Ball Reactor



Source: European Nuclear Society

Figure 13: Vanadium redox battery



Source: Cellstrom Gmbh

d. Vanadium redox batteries

Vanadium redox batteries are a type of rechargeable flow battery that employs vanadium ions in different oxidation states to store chemical potential energy (figure 10). There are currently a number of suppliers and developers of these battery systems globally. The main advantages of the vanadium redox battery are that it can offer almost unlimited capacity simply by using larger and larger storage tanks, it can be left completely discharged for long periods with no ill effects, it can be recharged simply by replacing the electrolyte if no power source is available to charge it, and if the electrolytes are accidentally mixed the battery suffers no permanent damage. The main disadvantages with vanadium redox technology are a relatively poor energy-to-volume ratio, and the system complexity in comparison with standard storage batteries.

Currently installed vanadium batteries include:

- 1.5 MW UPS system in a semiconductor fabrication plant in Japan.
- 275 kW output balancer in use on a wind power project in Hokkaido.
- 200 kW output leveller in use at the Wind Farm on King Island, Tasmania.
- 250 kW, 2 MW·h (7.2 GJ) load leveler in use at Castle Valley, Utah.

- Two 5-kW units installed in St. Petersburg, Florida, under the auspices of USF's Power Center for Utility Explorations.

4. Blue Sky

a. Graphene

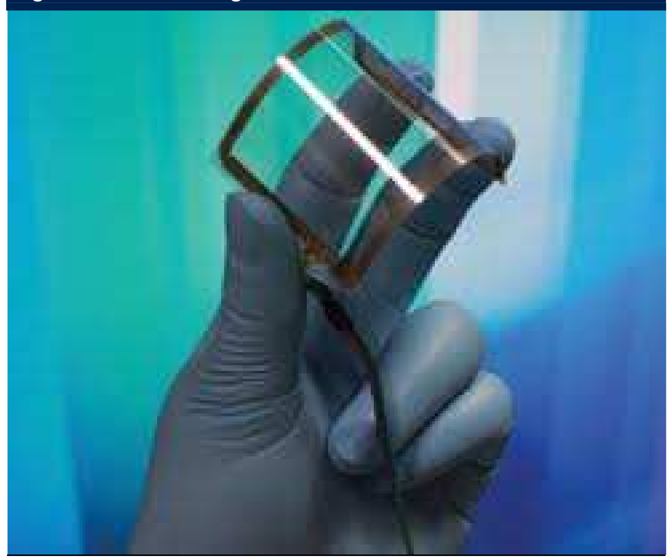
Perhaps no other material is generating as much excitement in the electronics world as graphene. Sheets of pure carbon, one atom thick through, which electrons can race at nearly the speed of light (100 times faster than they move through silicon). Super thin, super flexible and super fast as an electrical conductor, graphene has been touted as a potential wonder material for a host of electronic applications, starting with ultrafast transistors. For the vast potential of graphene to be fully realised scientists must first learn more about what makes graphene so super. Investors hoping to cash in on graphene could be in for a long wait. The process of separating it from graphite is in the research stage and it will require significant technological development before it is economically feasible to be used on a commercial scale.

The first steps of that race have already been taken by the Korean researchers. In 2010 they bonded a pure sheet of Graphene to copper foil and plastic by pressing them together through rollers them, creating a see through touch-screen sheet (figure 12).

Figure 14: Graphene

Source: MIT

Figure 15: See through touch-screen sheet



Source: Seoul University

Graphene was theorised around the time of World War II, but it took scientists Andre Geim and Konstantin Novoselov until 2004 to isolate the material and in so doing win the Nobel Prize in Physics in 2010.

Potential uses;

- An atom thick sheet sufficient to cover a soccer field would weigh less than 1 gram;
- Is the strongest material in nature at roughly 200 times the strength of structural steel;
- Can be included in composite materials that are ten times tougher than Kevlar;
- Can be used to make memory chips and transistors allowing electrons to move faster than silicon;
- Could significantly lower the cost of display screens that could be flexible, stretchable and transparent;
- Be used as a ten times more accurate sensor for disease and gas detection;
- Be used in ultra-capacitors that may be able to have as much or more storage capacity as lithium ion batteries though recharge in minutes, and last three times as long;
- Could be used as the world's thinnest anti-corrosion coating; and
- Can allow plastics to conduct electricity.

Other ASX listed stocks

Buxton Resources (BUX)

BUX has a market Cap of $13.6m, $1.2m in cash, spending ~$0.2M next quarter on exploration and admin. BUX recently exercised an option to acquire 85% of the Yalbra Graphite Project in the North West Gascoyne region of Western Australia. Substantial grades and widths of graphite mineralisation were identified in a number of holes of a drilling program conducted in 1974. BUX is planning on conducting an initial field reconnaissance and rock chip sampling program to be followed by an RC drill program. It will need to raise capital in the near future to accomplish these goals.

Castle Minerals (CDT)

CDT has a market Cap of $27.3m, $3.4m in cash, spending ~$0.7M per quarter on exploration and admin. CDT is only one of three companies listed on the ASX with a defined resource, 14.4Mt @ 7.2% Cg. Drilling on its tenement in Ghana has confirmed that the graphitic schist remains open along strike and samples have been submitted for metallurgical testing. CDT is also drilling a number of gold targets and the company's ultimate goal is defining sufficient standalone gold resources capable of commercial development.

Kibaran Resources (KNL)

KNL has a market Cap of $15.0m, $1.8m in cash and an estimated spend of $0.9M next quarter on exploration and admin. It recently secured $1.25M in funding through the successful completion of a placement and entitlements issue. KNL recently executed of a Heads of Agreement for the acquisition of a company that has the option to acquire two highly prospective graphite projects, Mahenge and Merelani-Arusha in Tanzania. Sizing analysis on surface samples shows the highest total graphite carbon grade is in the 0.5mm (+500 micron) fraction, indicating the presence of coarse graphite flakes for both the Ndololo and Merelani-Arusha project. KNL has commenced on a RC drilling program at these projects.

Lincoln Minerals (LML)

LML has a market Cap of $13.8m, $1.1m in cash and an estimated spend of $0.9M next quarter on exploration and admin. This will leave LML very short on funds after an independent scoping study is completed. LML have completed airborne electromagnetic surveys, the projects have a JORC compliant resource based on historical data and metallurgical testwork undertaken in the early 1980s. The Kookaburra Gully mineralisation was readily amenable to concentration by metallurgical processes including size classification, flotation and gravity concentration. Recently extracted bulk samples are currently undergoing metallurgical testwork and have been assayed at grades ranging up to 32.0% TGC.

Malagasy Minerals (MGY)

MGY has a market Cap of $11.9m, $1.9m in cash and an estimated spend of $0.6M next quarter on exploration and admin. MGY formed a joint venture company with Canadian-based Energizer Resources Incorporated. The JV specifically defined permits cover approximately 40% of MGYs tenement holding in southern Madagascar. MGY is free carried for 25% until completion of a Bankable Feasibility Study. On the other 60% of MGY tenements MGY has completed reconnaissance sampling and mapping to identify a number of follow up targets. Within the JV tenements Energizer has completed 22 diamond drill holes (over 4,600 metres) at the Molo deposit. All drill holes will be used to produce a NI 43-101 compliant graphite resource, which is expected to be released in the December quarter.

Monax Mining (MOX)

MOX has Market Cap of $8.0m, $2.4m in cash and an estimated spend of $1.0M next quarter on exploration and admin. MOX have one graphite and four copper-gold projects in South Australia. MOX has identified a number of priority target on the 100% owned Waddikee Graphite Project on the Eyre Peninsula based on surface sampling, historical drill holes and interpretation of regional airborne electromagnetic data. MOX recently completed a 40 holes drilling program across five prospect areas. Graphite was observed at all five areas tested and all samples have been submitted for analysis.

OMI Holdings (OMI)

OMI has a market Cap of $2.3m, $0.2m in cash. OMI is in the processes acquiring three graphite projects in South Korea. The graphite projects all have historical workings and the company will be renamed Peninsula Graphite. It is raising capital to develop the projects and evaluate the extent of the mineralisation.

Sovereign Metals (SVM)

SVM has a market Cap of $18.6m, $2.3m in cash and an estimated spend of $0.2M next quarter on exploration and admin. The low cash burn is due to Xstrata Copper managing and funding all tenements comprising the Carpentaria Joint Venture. This allowed SVM to enter into an agreement to acquire a company which holds a large and highly prospective Central Malawi Graphite Project. Three initial prospects have been identified based on the historical and recent exploration activities. SVM has successfully completed a placement to raise up to $1.1M.

Talga Gold (TLG)

TLG has a market Cap of $15.8m, $1.5m in cash and an estimated spend of $0.7M next quarter on exploration and admin. TLG recently acquired nine Swedish graphite, iron and copper/gold projects. The exploration permits contains JORC compliant Mineral Resources in the Kiruna mining district of north Sweden. This includes the JORC compliant inferred mineral resource 3.60Mt @ 23% Cgr at Nunasvaara. TLG have completed 19 hole diamond drill programme at Nunasvaara. All holes intersected the targeted graphite unit. Core samples are being processed and will be submitted for analytical and metallurgical test work. Results will be used to update the current resource estimate and commence a scoping study.

Triton Gold (TON)

TON has a market Cap of $7.8m, $0.8m in cash and an estimated spend of $0.3M next quarter on exploration and admin. TON is in the process of conducting due diligence on five graphite prospecting license applications, divided into two projects, in the Cabo Delgado Province of Mozambique. One project is to the east and west of an old graphite mine, the Ancuabe mine. The other is situated approximately five kms to the north and along a north-east trending structure which appears to continue south into the Syrah Resources Balama graphite project.

Risks

The following risks may all impact the valuation of the company and need to be considered in any investment. They include but are not limited to the following;

Market risk: The market prices of the investments may vary due to changes in the economic and market environment, the money policy of the central banks, the business activity of the issuers, the demand and supply of the market.

Financial: With significant capital outlay assigned for exploration and development activities a company may need to access markets for finance. There can be no assurances that this capital will be available at a reasonable cost which could see dilution issues in the future.

Foreign Exchange Risk: As an Australian company, fluctuations in foreign currency exchange rates between the Australian dollar and US dollar have the potential to decrease the profitability of the company.

Resource prices: Prices can fluctuate widely. The graphite markets are physical prices markets, opaque, potentially illiquid without any financial instruments for price discovery. Published prices are only an indication. Actual pricing will vary according to geographic region and will take into account the quantity purchased, application, quality assurance, exact grade, credit terms, and other parameters.

Environmental Risk: A Company's operations are subject to several environmental risks. A breach of such an act may result in imposition of heavy fines and penalties, impacting the Company's activities adversely. Current and future environmental laws, regulations and measures could entail unforeseeable additional costs; capital expenditures; and restrictions or delays in the Company's activities. Environmental regulations and standards are subject to constant revision and could be substantially tightened which could have a serious impact on the Company and its ability to develop its properties economically.

Political risk: The companies listed in this research note are operating in a number of different jurisdictions. The laws governing these jurisdictions may change and there is the risk of the government imposing new taxes, regulative or legal obligations.

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