Australia's

21st Century rocks: Talga finds the cutting edge

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COVER

Talga serves up acesin graphite game

A fascinating journey. Talga Resources has embarked on a journey which could lead it to the very heart of the 21st Century's most innovative technologies

ast month, Talga Resources Ltd emerged from north of the Arctic Circle with a scoping study that points to a positive future for its Vittangi graphite project in Sweden.

At a time when investors are only willing to consider low-risk start-ups, the Vittangi numbers made it a standout, not only in the graphite space but the entire junior end of the market.

The study focused on a 250,000 tpa operation producing 46,000 tpa graphite and 1,000 tpa graphene for a capital cost of just \$29 million. Capital payback was estimated at 1.4 years with the study producing an NPV for the project of \$490 million.

The company's job now is to convince investors the project has the right characteristics to justify its claims and set itself apart from the myriad graphite plays that have bloomed in the last 18 months.

Since emerging as an in-vogue commodity in late 2012, graphite has proven a tough market for investors to get their head around. Although the carbon-based product has been widely used for more than a century, its market is murky.

Graphite – like many industrial minerals – has no tradeable market with concentrates sold by private contract. Complicating the matter further is the variety of price streams inherent in the industry. Far from homogenous pricing as is the case with gold or base metals, graphite prices are determined by



Talga managing director Mark Thompson on site at Vittangi. The founder of the company, Thompson has been the driving force in Talga's transformation from West Australian gold explorer to European graphite developer

flake size, carbon content and in some cases shape.

The largest sector in the \$US1 billion a year industry is for the microcrystalline flake or amorphous graphite product. Used in steelmaking and refractories, it accounts for about 45% of the global graphite market. China has dominated this sector for more than 50 years but has in recent years placed restrictions on its export and tightened environmental regulations surrounding it.

The other half of the market is the emergence of new applications for the higherquality, large-flake graphite projects. The new drivers for graphite demand have come in the macrocrystalline flake space, where the widespread adoption of lithium ion (Li-ion) batteries – there is typically 10 times more graphite than lithium in a Li-ion battery – is driving demand for the larger flake products. However, prices continue to be dependent on the flake size in individual deposits and as such the flake graphite market is even more opaque than the amorphous sector.

This has led to much confusion among investors as companies produce vastly differing (and often conflicting) pricing assumptions in their studies and presentations.

If all these different pricing structures were not confusing enough, Talga has also marketed its ability to produce another product from its high-grade graphite resource: graphene.

For its pioneers and proponents, graphene will be to the 21st Century what plastics were to the 20th Century and steel to the 19th Century; a new material that will usher in a new technological age and become an essential



Vittangi's location 140km north of the Arctic Circle has attracted questions over Talga's ability to operate but as this picture shows, climatic conditions are far from harsh

building block of modern life.

First identified by the University of Manchester's Andre Geim and Kostya Novoselov – for which the two researchers received a Nobel Prize in 2010 – graphene is the first two-dimensional material ever discovered.

Its properties are like something out of a superhero comic. It is stronger than diamond but retains flexibility. It is the best thermal conductor known and one of the best electrical conductors. It is also transparent with only 2.4% of light passing through it

being absorbed.

In just a decade, its discovery has led to an exciting and elaborate array of potential applications, from the glamorous (tablet devices able to be folded up like a newspaper, or touchsensitive ink), to the life-altering (bioelectronic applications in humans), to the more mundane but equally transformational (anti-corrosion additive to paints and strengthening additive to concrete or other building materials).

The problem is, if the graphite market is opaque, the graphene market – much like the material itself – is unobservable to the naked eye.

Whereas graphite may not have a clear pricing structure, it does have a discernible market with clearly identifiable applications and end-users. In comparison, graphene is still in its infancy and outside of its presence in a new range of Head tennis racquets, the market for its consumption is restricted to research groups around

We'd looked at projects in Africa but I've always liked Sweden as a jurisdiction and we managed to peg some graphiteprospective ground ourselves. the world, who are just starting to imagine its application possibilities. Commercialisation of such possibilities is still to be achieved.

Although exciting, such a scenario is not exactly encouraging to a junior explorer trying to sell the economics of a project. Fortunately for Talga, its managing director Mark Thompson has a history of searching for hidden treasures, and is unperturbed by the cuttingedge nature of graphene.



A sample of the core from the Nunasvaara deposit. At 24.4% Nunasvaara is by far the highest grade graphite project in the world

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Talga commercial manager Jeremy McManus and chairman Keith Coughlan discuss the company's progress at Vittangi

Every graphite deposit is capable of producing graphene because graphite is made up of millions of layers of graphene. The question is whether it can be produced cheaply enough and in large enough volumes to prove economic.

Thompson is a geologist by profession but he has far from the one-track mind of many of his professional colleagues. When the exploration sector was experiencing a downturn at the end of the 1990s, Thompson eschewed the traditional route for out-of-work geologists towards the taxi-driving industry and went off hunting dinosaurs around the world.

He is credited with being the



Thompson speaks with consulting geologist Simon Coxhell and in-country manager Bruce Cripps on site at Vittangi

first person to discover the fossilised remains of the Julieraptor – named after his sister, Julie – in Malta, which garnered worldwide headlines when it was "stolen" by an erstwhile colleague.

On returning to the exploration industry, Thompson headed to the Pilbara region of Western Australia as head of newly incorporated Talga Gold Ltd. Talga listed in 2009 on the back of a suite of gold assets but it was the company's arrival in Sweden in 2011 that changed its trajectory.

"I'd been looking around the world for graphite projects for some time," Thompson told **Paydirt** during a recent visit to the company's Vittangi project in northern Sweden. "We'd looked at projects in Africa but I've always liked Sweden as a jurisdiction and we managed to peg some graphite-prospective ground ourselves."

The company followed its initial pegging exercise with a deal to take 100% of Teck Resources Ltd subsidiary TCL Sweden Ltd for a group of assets in the Kiruna district of Norrbotten province in north-east Sweden.

Talga paid \$450,000 for TCL with a total 3% net smelter royalty but "crucially no clawback clause", according to Thompson. The deal included a number of iron ore and IOCG targets but Talga was always interested in the graphite potential of Vittangi.

In the Nunasvaara prospect at Vittangi – first tested with trenching by state-owned miner LKAB in 1916 – Talga had just the kind of project it was looking for.

"There had been 20 holes drilled for graphite and LKAB had mined a 3,000t bulk sample," Thompson said. "So, it meant we had access to a lot of historical data which we could use to very cheaply produce a modern, JORC-compliant resource."

With a 3.6mt @ 23% graphitic carbon inferred resource already attached to the project on acquisition, Talga quickly launched into its own drilling programme in July 2012.

By November that year, the company announced an indicated-inferred resource of 7.6mt @ 24.4% graphitic carbon for Nunasvaara for 1.8mt of contained graphite. The resource places the deposit among the largest ASX-owned graphite projects in the world and by far the highest grade – Lincoln Minerals Ltd's Koppio-Kookaburra Gully project in South Australia is the second-highest grade at 15.03% graphitic carbon – and the company is ready to expand the size of the resource to fit the project's requirements.

"We have exploration licence applications which will expand our footprint to 32km of strike," Thompson said. "We have lots of drilling, rock chip and soil sampling which shows that the 15km of strike shown in the geophysics is all likely to be the same rock unit so we can easily expand the resource with more drilling."

However, it is the mineralogy of Nunasvaara, rather than its size, that has Talga convinced it will prove a unique player in the graphite space.

With applications for the commodity expanding, many graphite juniors have struck partnerships with research houses to expand the understanding of their specific ore types. In January this year, Talga announced it was partnering with the commercial development arm of the University of Adelaide to assess whether Nunasvaara's uniquely high-grade make-up could make it more amenable to producing graphene.

"Preliminary metallurgical work suggested that characteristics of the Nunasvaara graphite ore may be unique and differ substantially from most other graphite deposits," Thompson said at the time of the announcement. "This follows from Nunasvaara being not only the highest-grade graphite resource in the world but also because it is hosted within volcanic greenstones rather than the gneissic rocks most typical for graphite deposits. This rare setting gives Nunasvaara ore potentially unique mineralogy, crystallinity and other characteristics that may support extraction options that are cheaper in capital and processing terms than traditional methods."

The first set of results – announced in February – confirmed graphene could be directly liberated from Nunasvaara ore using a onestep process. Larger studies in June further confirmed the viability of the graphene liberation, paving the way for the company to include graphene recovery in its scoping study.

Other ASX-listed juniors are also investigating ways of producing graphene from their graphite orebodies but Talga remains the only company to commit the process to full economic study.

For Thompson, other companies may eventually prove their ability to produce graphene, but Nunasvaara's unique qualities of grade, mineralogy and crystallinity give it an inherent advantage.

"Every graphite deposit is capable of producing graphene because graphite is made up of millions of layers of graphene," he said. "The question is whether it can be produced cheaply enough and in large-enough volumes to prove economic."

The October scoping study was Talga's first opportunity to show some proof-of-concept work for Vittangi and for Thompson, the results did not disappoint.

Away from the complexity of the graphene story, the headline numbers are quite obviously impressive.

The study focused on a project producing 46,000 tpa graphite concentrate and 1,000 tpa graphene over a 20-year mine life from Nunasvaara. Throughput for the operation would be 250,000 tpa allowing for a capex of just \$29 million and a payback period of 1.4 years.

Pre-tax NPV for the project is \$490 million, based only on the 7.6mt @ 24.4% TGC indi-

North Drill was completing a 10-hole drilling programme at Nunasvaara when Paydirt visited the project in September. The programme was successful in defining mineralisation along strike from the Nunasvaara resource

cated resource.

Thompson said the company has been particularly conservative with resource figures, operating costs and mining scenarios, an easy decision given the simple nature of the geology, mining and processing at Nunasvaara.

"It is a scoping study with all the 'badness' factored in," he said. "Geologically it is not a challenging story. The study only uses the

indicated resources and we have a further 30km of strike that we are yet to drill but are confident of defining further resources on.

"The mineralisation is from surface, it is contiguous and homogenous, making





A sample of graphite mineralisation from the Nunasvaara deposit. Its highgrade nature is obvious when samples are used as makeshift pencils



The pit from which LKAB excavated a 3,000t bulk sample in the 1980s. Talga will likely return to the area during its own trial mining exercise

for a simple open pit mining scenario with a 4:1 strip ratio. Even then, we have based the mining on a single open pit. In reality, we will probably bring in other shallow resources along strike with a series of 0-50m open pits which will bring the strip ratio down to 1:1.

"The processing is just as simple with no crushing and grinding required. It is really just a lot of gravity and some magnetic separation." Designed by Independent Metallurgical Operations Pty Ltd, the 250,000 tpa plant uses conventional processing steps but in a non-conventional way.

The circuit will see whole ore blocks processed through a physio-chemical technique which liberates graphene, graphite and waste products without any primary crushing, grinding or screening.

The graphene and graphite products will be



Drilling on strike extensions at Nunasvaara. Talga has tested less than 2km of more than 15km of strike on the Vittangi project

separated in a single step and sent into individual recovery streams.

The graphene stream will be further filtered, sized and dispersed into specific solutions meet customer requirements (more than 99.9% carbon purity) while the graphite material will go through wet magnetic, gravity and other standard processes to produce an ultrafine amorphous graphite concentrate of 80-85% carbon purity.

"The plant will produce 47,000 tpa of graphitic carbon; it is then a choice of what form we want that to take. In the scoping study we go for 2% graphene, 10% as high purity graphite then the rest as traditional graphite but the final mix will depend on further recovery optimisation work as we bed down the process."

The developing nature of the flow sheet is highlighted by Talga's intention to build a pilot plant and trial mining operation at Vittangi next year, dependent on permitting.

"That will provide a very true test of the project's capability," Thompson said. "There will be a lot of optimising to do but it will give us a clear indication of the mining and processing."

The company intends to conduct a sixweek trial mining campaign which will remove 5,000t of ore from Nunasvaara. This will be processed through a 5 tph pilot plant which will provide not only answers to the validity of the company's mining plan and flowsheet but also larger samples of graphene for prospective customers and partners to use.

Scoping study in hand, Thompson is now

Talga ready to branch out in Sweden

Although Vittangi, particularly the Nunasvaara deposit, has dominated Talga Resources Ltd's time and effort in the last two years, the company has also been working to develop its other Swedish assets.

"We have four other graphite projects with 2mt of contained graphite across a variety of product types including the jumbo flake sized product which attracts the highest unit price," managing director Mark Thompson says. "They are all at different stages and remain very exciting."

In September, Talga announced that its Jalkunen project, 50km south-east of Vittangi, was likely to share the same graphite formation as Vittangi. Rock chip sampling along the 28km of strike produced samples of up to 41.3% graphite which is comparable to those from the Nunasvaara deposit at Vittangi.

A 5kg Jalkunen sample from the Nybrännan prospect was sent to Talga's metallurgical consultants in Perth who successfully liberated graphene and graphite in exactly the same manner as the material processed from Vittangi, further enhancing the theory that the two projects are the same geological unit.

At Raitajärvi, Talga has defined a coarse flake graphite resource of 4.3mt @ 7.1% for 307,300t contained graphite.

Raitajärvi – 160km south-east of Vittangi – is just 2km from the sealed Överkalix-Övertorneå Highway, 25km by road to the nearest railhead and 130km by road to the Port of Luleå. Raitajärvi has been declared an area of national interest by the Swedish Geological Survey, providing protection against competing land uses.

Further north at Pajala, both graphite and copper-gold have been identified by the Swedish Geological Survey and Anglo American plc which drilled 13 holes into large coincident magnetic and electrical anomalies.

The Piteå project is the least drilled of the company's five graphite projects in Sweden. Situated just 40km by road from Luleå, it is the least drilled project in the portfolio but limited



Talga has a suite of graphite projects throughout northern Sweden

sampling by the Swedish Geological Survey identified coarse flakes as being with 70-90% being jumbo flake, which attracts more than \$US1,800/t. With the company fully focused on graphite, Thompson is looking to offload Talga's portfolio of iron ore and copper-gold assets in Sweden as well as its gold assets in the Pilbara, Western Australia.

He describes the Kiskama IOCG project as one of the most "exciting technically" exciting projects he has ever worked on.

"It has lots of cobalt – the same cobalt ratio as the world-famous Outokumpu deposit in Finland – and we have found the Japanese and Korean cobalt users are very motivated by Swedish cobalt because it is conflict-free.

"It was first drilled before Olympic Dam was discovered so before the entire IOCG family of deposits was well understood.

"What we are really looking for is a high-profile JV partner to take the project on," Thompson said.

on a northern hemisphere road show designed to convince investors of the merits of the project.

"For a long time, we have been talking to technical people and the investors and institutions and they have all been waiting for the numbers so they could do their own modelling of the project," he said. "The scoping study gives us access to investors and institutions we couldn't get to before."

As in the technical aspects of the project, the company has taken a conservative approach to pricing assumptions, which Thompson believes will give further credibility to its economics.

The study uses Industrial Minerals magazine's natural graphite report for a price of \$US480/t for the ultrafine graphite product (40,000 tpa) and Benchmark Mineral Intelligence's \$US1,600/t for the micronised graphite product.

The price for graphene is far harder to decipher as there is relatively no precedent for what Talga is proposing. Most the graphene sales so far have been for research – and development-scale quantities – grams rather than tonnes. According to a report by Fullerex Ltd, the average sale value of bulk graphene (graphene nanoplatelets of more than 10 layers) is \$US100,000/t with the two- to five-layer product Talga has been able to produce being sold for \$US100-250,000 for order sizes of 1,000kg lots. Meanwhile, Talga has received confirmation from aviation and additive industry end-users that sales prices would have to be around \$US60,000/t before large-scale multinational manufacturers would adopt its use.

This is part of the problem for Talga when marketing the project to the investment climate. At the moment, not only is the graphene end-use application market small, it is nonexistent.

However, a recent trip to several highprofile research hubs in Britain and Ireland has given Thompson the confidence that the Nunasvaara product will be actively sought by groups working on graphene applications.

"It was very gratifying – following some bouts of scepticism – to witness these groups see the light during our discussions and express their interest in coming on board and collaborating with us. It confirmed the potential for Talga to be a large and cheap producer of graphene."

"I was surprised that a lot of the products are more advanced than the public probably realises. I was very excited about the different products being developed, from paints to electrical products.

"Thomas Swan in the UK and lots of other groups right now are buying graphene and there are already things – like the Head tennis racquets – which use it. It really is no different to the earliest days of plastics; once the applications can be produced relatively cheaply, there will be wide-scale adoption."

When that occurs, Thompson intends for Nunasvaara to be the primary source of supply and it is again the cheap processing route that points the way to Nunasvaara's potential.

"Most investors are setting their sail on whether graphene has a future as a commodity. When they decide the answer is yes, they will then look to who can do the most volume through the most profitable process.

"We can produce bulk graphene at such a low cost that we could essentially become a market maker. It may be a very small market now but we could supply the graphene in

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A piece of core from the Nunasvaara resource is used to conduct electricity from a battery to the flashing light, highlighting the high-grade nature of the mineralisation at Vittangi

enough quantity that researchers could find applications that require 10 times what we can currently supply."

To accelerate its understanding of the commercial opportunities in front of it, Talga has appointed former stockbroker Jeremy Mc-Manus as commercial manager. McManus joined Thompson on the recent trip to the UK and Ireland and the managing director is convinced the company will get up to speed with potential clients very quickly.

Before the project gets to that point, Talga must fund its development. The first step will be financing the move into a PFS.

Talga had \$3.4 million in the bank at the end of the September quarter. While conscious of the company's funding needs in a tough market environment, Thompson is satisfied the PFS and pilot plant/trial mining campaign can be funded.

"Because the capex for the whole project is less than \$30 million, it is not necessarily the case that we will go through the traditional PFS-DFS route anyway; we have more financing options than that."

Signing an off-take agreement now would be an obvious answer but the Talga board and management team is so confident in the prospects for the project it is determined to recognise maximum value from it.

"We want flexibility in what we do with

Graphene: The thing dreams could be made of

Background: Graphene is a two-dimensional allotrope of carbon, and sits alongside C60 (0-D), carbon nanotubes (1-D), and graphite (3-D) in the family of sp2-bonded forms of carbon. It consists of single atomic layers of carbon (around 0.3nm thick) while extending many hundreds of nanometres in the lateral dimension. It was first isolated by Andre Geim and Kostya Novoselov at the University of Manchester in 2003. Their results were published in 2004 and in 2010 they were awarded the Nobel Prize for Physics for their work.

Properties: Graphene's properties are like something from a work of science fiction. It is the thinnest and strongest material ever discovered (breaking strength of 42 Nm-2, 100 times greater than steel). It shows electrical and thermal conductivity greater than copper at a fraction of the weight and absorbs only 2.3% of the light passing through it. These properties are expected to see graphene revolutionise many industries.

Applications: The possibilities for graphene-based applications are endless and are limited only by the imagination. It has many potential applications which include mechanical reinforcement, transparent conductive materials, flexible and printable electronics, super-capacitors, thermoelectric materials and thermal management materials. In 2004 there were just 33 inventions described in published patents, to more than 5,000 inventions last year. China leads the way with more than 2,200 patents with Korean electronics giant Samsung the largest single patent owner with more than 400 graphene related patents. Graphene's applications cover many fields, including:

Construction: where it could be used to strengthen concrete, steel and other building materials as well as acting as an anti-corrosive property in industrial paints.

Vehicles: graphene could dramatically reduce the weight of aeroplanes and spacecraft as well as other vehicles

Water filtration: its impermeable qualities mean it could be developed to allow water to pass through it, allowing for cheaper and more efficient desalination

Energy: used in the ethanol distillation process, it could produce higher alcohol concentrations with the application of heat or vacuum as in traditional distillation methods. It could be also used in solar cells, where its transparent properties could allow it to be a transparent conductor

Storage: graphene is being viewed as a potential supercapacitor because of its high surface area to mass ratio. Researchers have built a lithiumion battery from graphene and silicon which last for one week on a 15 minute charge

Electronics: researchers have already built transistors just one atom thick by 10 atoms wide using graphene. It has the ability to be used in transparent conducting electrodes; making it more suitable than the brittle indium tin oxide currently used in touchscreens, liquid crystal displays, light emitting diodes, etc

Medicine: researchers are testing graphene's ability to be used in tissue engineering, bioimaging, drug deliver (particularly in cancer treatment) and blood glucose testing

Production: To date, the biggest obstacle to widespread application of graphene has been in its production. Geim and Novoselov's process involved using adhesive tape to split their graphene. Other processes include nanotube slicing, carbon dioxide reduction, epitaxy, spin coating and supersonic spray however, at this stage none have resulted in a commercially-viable process capable of making bulk quantities of graphene.

Talga Resources' October scoping study suggested it could produce 46,000 tpa graphite and 1,000 tpa graphene for a total cost of \$83.80/t through. If the feasibility studies reinforce these figures, Talga could become the world's first bulk supplier of the material



Talga Resources' Vittangi project in northern Sweden. In just under two years the company has developed Vittangi and the Nunasvaara deposit into the highest grade graphite project in the world and potentially the first ever bulk-scale producer of the highly sought after, cutting-edge material, graphene

the supply. If we do an off-take agreement it would be specific; for instance to fund the pilot plant or trial mining. The longer we can exist, the higher our value will be. We are dedicated to getting this done. The upside against the cost of advancing it is immense."

Funding could also take other forms, including grants and discounted debt finance from the Swedish and other European governments keen to become leaders in the graphene space.

Closer to home, the company is also aiming to divest its non-graphite projects.

"We have the Kiskama IOCG project in Sweden which is technically very interesting, in Australia we have our suite of gold assets in the Pilbara. Selling those could fund the pilot plant which we could build for as little as \$1 million."

During his northern road show, Thompson

will also be at pains to point out that regardless of the graphene element to the Nunasvaara story, the project still works as a conventional graphite operation.

"Before the scoping study came out we had a lot of questions about it. But the study has proven that flake size doesn't matter much when you've got a high-grade resource. The amorphous market accounts for 45% of world graphite production and the scoping study shows the project as being profitable in that market.

"The larger flake products can suffer from oversupply because they are such small markets, but because the amorphous product is spread across the market, it is a lot more stable. And, as production in the premier graphite producing regions of Heilongjiang and Shandong comes under increasing modernisation and environmental pressures, supply pressures are predicted to increase.

"For Talga, if we target low-end products but still have a profit and have got more volume, we are proving a good source of supply."

The likes of Henry Bessemer probably felt the same when developing methods of modern steel production during the Industrial Revolution of the 19th Century. If Talga's plans for low-cost, high-volume graphene come to fruition, Mark Thompson's name could make the history books yet.



The sample pit dug by LKAB in the 1980s is clearly visible from the air for the Vittangi project while on site in September



Thompson explains Talga's exploration intentions for the Vittangi project while on site in September

⁻ Dominic Piper