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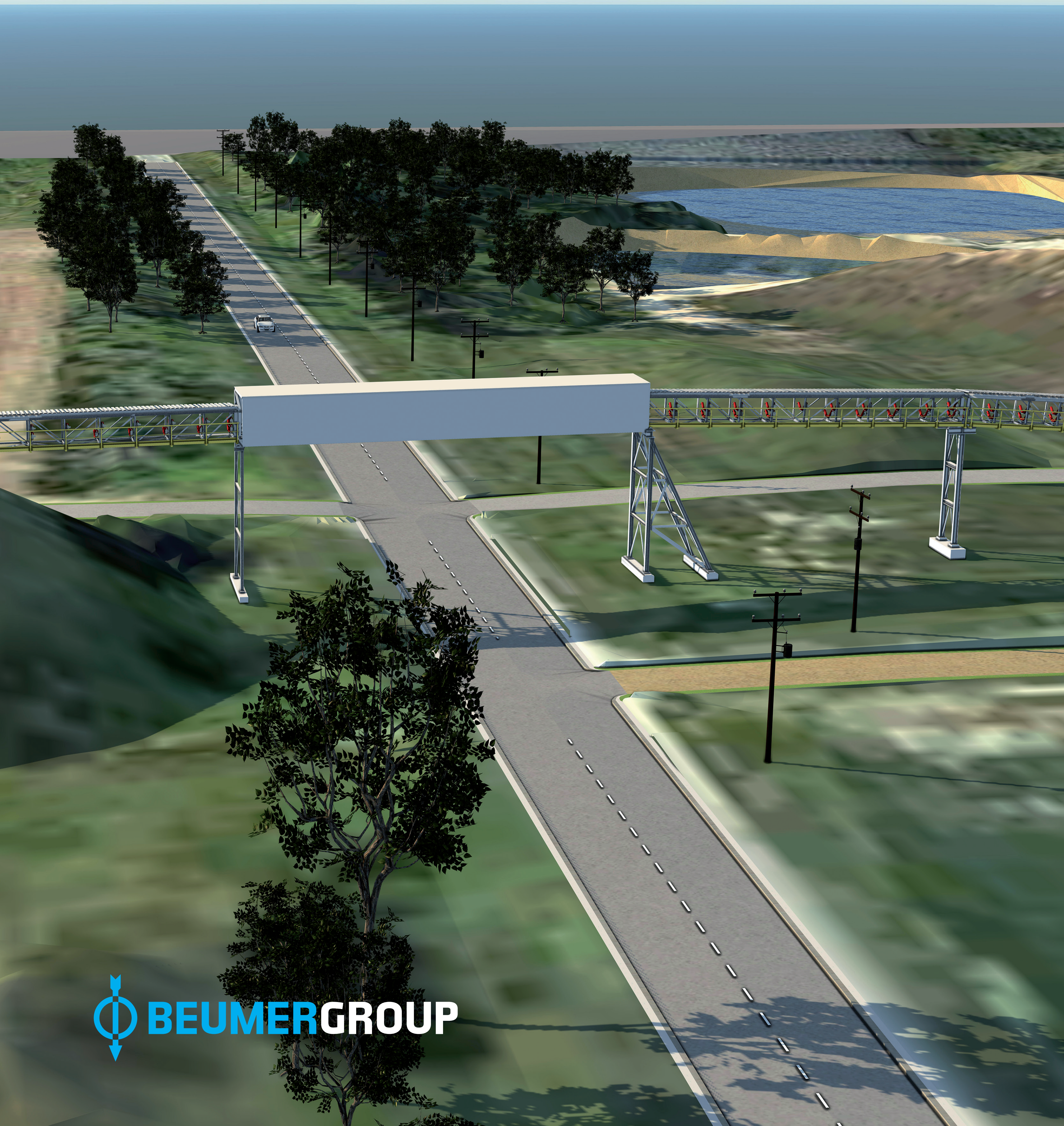

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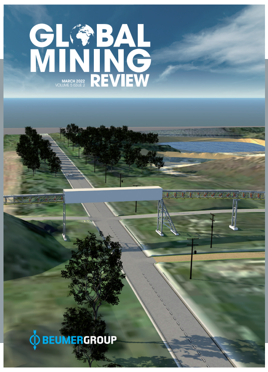

ON THE COVER

Since the late 1960s, BEUMER Group has been developing and producing curved overland conveyors, making the company one of the pioneers in this industry. Nothing has fundamentally changed in the functional principles of this technology since then – except for the feasible limits: With highly developed core components, precise calculation methods and own planning tools, the system provider continues to push the limits of what is technically feasible – while drastically reducing the time and costs involved both in the planning phase and in the handling of projects.

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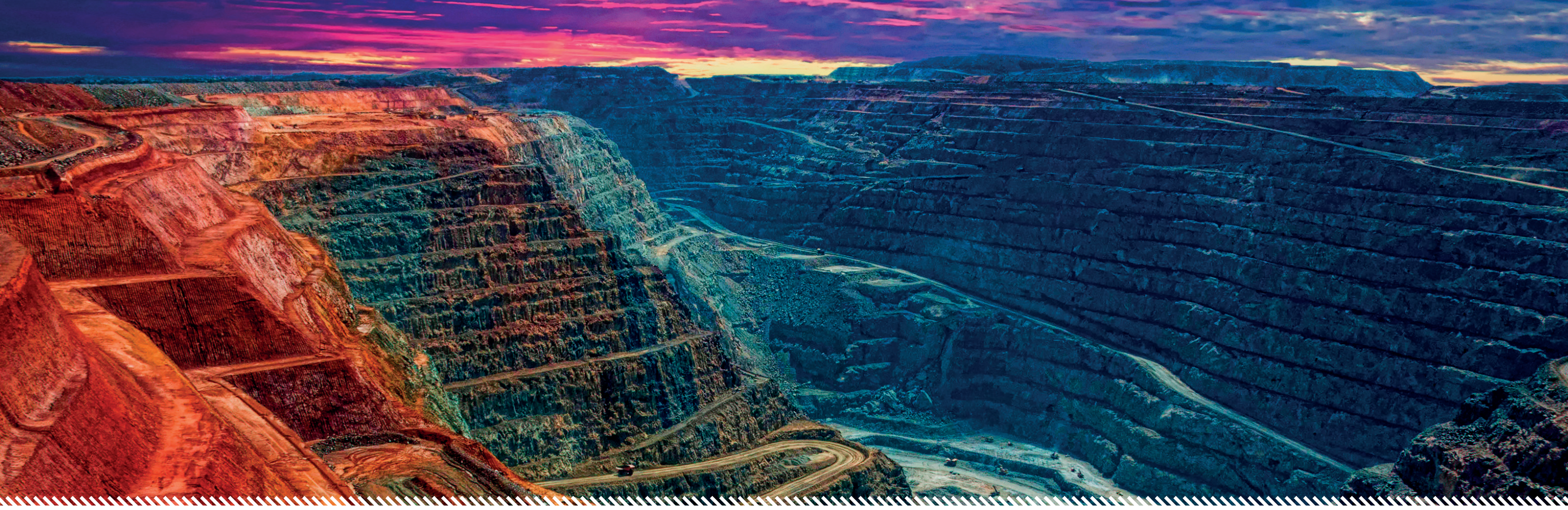

GUEST COMMENT

ALLAN PEDERSEN (PRINCIPAL ANALYST)

WOOD MACKENZIE

In recent years, the mining industry has seen very large fluctuations in the prices of lithium products, and the methodology of pricing is becoming an increasing point of discussion.

Historically, lithium products have been priced consistently as an agreement between buyer and seller. This practice was fine in a market which had a high level of stability and limited growth; however, with the emergence of electric vehicles (EVs), demand for rechargeable batteries grew and the demand for lithium chemicals subsequently followed. The growth essentially reset the entire industry from a mature industry to one in its infancy. At the same time, the quality requirements for lithium chemicals are increasing, and the market is moving away from a commodity market towards a specialty chemicals market.

The question is: how do you price a product in a transitioning market?

The need for long-term offtake agreements by EV manufacturers, battery manufacturers, cell manufacturers, and cathode manufacturers is very strong. Each producer is required to prove their ability to deliver the quantities needed. To do this, they must have consistent supply in terms of qualified volume. On the other hand, producers will, in most cases, need to ensure they have offtake agreements in place. Before financiers, including their own boards, commit hundreds of millions of dollars to construct new plants, these agreements are required to prove they can sell their products in the future. These requirements will be very similar for mineral concentrate producers as well.

Other markets, such as iron ore, moved away from annual pricing towards a market where spot trades are taking place on public platforms daily. The 'industry accepted' reference prices are then used by buyers and sellers in their contract agreements. But what happens when there is no, or very little, spot market? This is where the lithium industry is now.

Looking forward, there are some options for the industry to consider. Firstly, a spot market can be created where cargoes are placed for sale and buyers can bid. The volume available needs to be sufficient to be representative of the whole market and not just the marginal tonne. However, providing sufficient volume to the spot market, given the need for producers to meet offtake agreements, could be challenging. A further challenge with the creation of a liquid spot market for lithium chemicals is the need to have the product qualified by cathode producers – a process that can take several months.

Another option is value-in-use pricing, where the value lithium brings into the cathode is calculated and the lithium chemical is priced accordingly. This would require the buyers to open their books to a large degree, which could be controversial.

A third option is profit sharing. Here, the cost of the lithium chemical would be calculated and buyer and seller would split the net profit of the cathode sales. This option could present several challenges, and it will require a high level of trust between partners.

Wood Mackenzie believes that in time a representative spot market will develop. In the meantime, there will be different methodologies incorporated into contracts and some will be a hybrid of the above. The individual contracts will depend on the commercial risk appetite of both buyers and sellers. GMR

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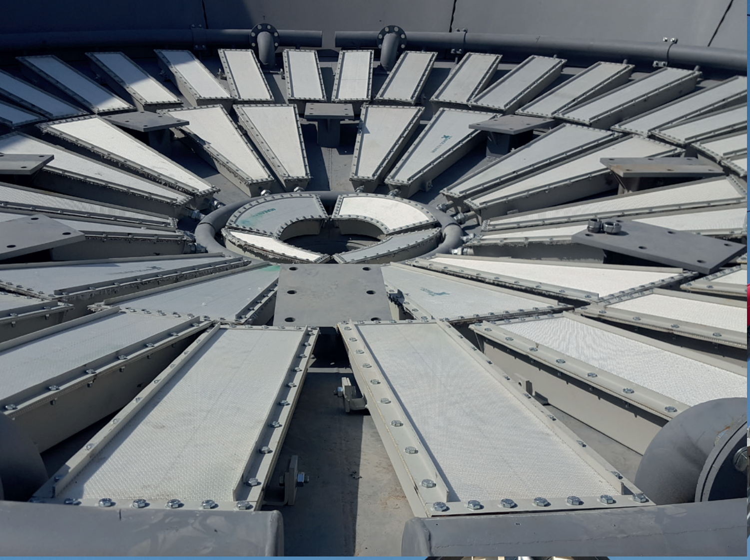


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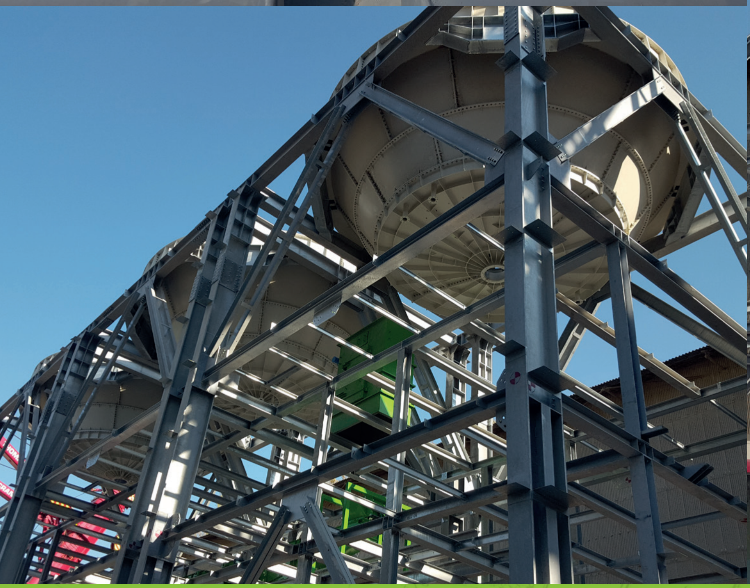


JCB

WORLD NEWS

EGYPT Akobo Minerals renews license

Akobo Minerals has renewed its existing exploration license of 182 km^2 in the Akobo region. This will secure a strong long-term position for both mining and exploration activities for the company.

The renewal came through many years of positive relationships with the Ministry of Mines, and is a result of Akobo's continued efforts to develop and progress its in-country activities.

The renewal gives the company: a three-year exploration period, plus yearly renewals of up to 10 years in total; a solidified future presence in the Akobo project and removes any concerns regarding the license's length; the ability to think long-term around how to maximise exploration activities; and the freedom to drill and mine the best targets across the entire 182 km^2 license area.

CHILE Anglo American operations in Chile awarded the Copper Mark

Anglo American has announced that its managed copper operations in Chile – the Los Bronces and El Soldado mining operations, and the Chagres smelter – have been awarded the Copper Mark in recognition of responsible copper production practices.

The Copper Mark framework has been developed to demonstrate the copper industry's commitment to both the green energy transition and the United Nations Sustainable Development Goals, using the Risk Readiness Assessment (RRA) of the Responsible Minerals Initiative (RMI) as the basis for evaluating participants' performance.

The process of assessing Los Bronces, El Soldado, and Chagres against the Copper Mark's Assurance Process began in late 2021. The sites were assessed against 32 different criteria, including environmental risk management, energy consumption, waste and tailings management, mine closure and reclamation, occupational health and safety, business integrity, community and stakeholder engagement, human rights, and cultural heritage.

AUSTRALIA SafeAI and MACA partner to create autonomous heavy equipment fleet

SafeAI and MACA have announced a partnership to retrofit a fleet of 100 mixed vehicles. Together with SafeAI's Australian partner, Position Partners, the companies will create one of the largest autonomous heavy equipment fleets in Australia, powering safer, more productive and more cost-effective mine sites.

SafeAI has built a next generation autonomous platform that brings the latest in artificial intelligence (AI) to heavy industry. The company's platform is interoperable and vehicle-agnostic, enabling mining and construction companies to retrofit any vehicle, from any manufacturer, with autonomous technology. With advanced multimodal sensors and significant onboard processing power, SafeAI-enabled equipment can independently make efficient, accurate decisions to keep operations running smoothly and safely, 24/7.

MACA needed a solution capable of scaling with its business. SafeAI's interoperable retrofit technology unlocks newfound scalability and versatility by enabling the company to optimise its existing fleet, rather than forcing it to complete a highly time-consuming and costly transition to an entirely new fleet of autonomous vehicles.

Through this partnership, SafeAI and Position Partners will work with MACA to retrofit its large, mixed fleet of haul trucks with autonomous hardware and software. MACA will be the first contract miner to deploy AI-powered autonomy for its customers; establishing safer, more productive, and more cost-effective operations.

This partnership follows a successful proof of concept between the three companies at the Karlawinda gold mine, owned by Capricorn Metals.

WORLD NEWS

DIARY DATES

Mines and Money Online Connect – April 2022
05 – 07 April 2022
Online
https://minesandmoney.com/online/

CIMBC22 – CIM Annual Convention
01 – 04 May 2022
Vancouver, Canada
https://convention.cim.org/

Mines and Money Connect – May 2022
04 – 05 May 2022
London, UK
https://minesandmoney.com/connect/

Investing in African Mining Indaba 2022
09 – 12 May 2022
Cape Town, South Africa
https://miningindaba.com/Home

PDAC 2022 Convention
13 – 15 & 28 – 29 June 2022
Toronto, Canada & Online
www.pdac.ca/convention

Euro Mine Expo 2022
14 – 16 June 2022
Skellefteå, Sweden
www.euromineexpo.com

Electra Mining Africa
05 – 09 September 2022
Johannesburg, South Africa
www.electramining.co.za

To stay informed about the status of industry events and any potential cancellations of events due to COVID-19, visit Global Mining Review's events page: www.globalminingreview.com/events

TANZANIA Katoro Gold signs joint venture agreement with Lake Victoria Gold

Katoro Gold PLC, a gold and nickel exploration and development company, has announced that it has entered into a joint venture (JV) agreement with Lake Victoria Gold (LVG) for the development of the company's Imweru Gold Project. Under the JV agreement, LVG will earn up to 80% in the project, with the balance of 20% being held by Katoro as a carried interest.

The company previously announced that the project was disposed of by virtue of a sale transaction. The administrative process to finalise registration of the sale transaction, and therefore trigger ongoing milestone payments due to Katoro, was subsequently indefinitely delayed due to unforeseen statutory barriers related to the transfer of ownership at project level. This created a situation where no definitive schedule date could be established for transfer of ownership and issue of the relevant milestone convertible loan notes. In light of this unsustainable situation, the company and LVG agreed to cancel the sale transaction and to enter into a JV agreement instead.

LVG will earn a JV-interest of up to 80% in the JV and will be responsible for 100% of the JV funding requirements; all debt funding required by the JV will be procured or provided by LVG. The JV will also reimburse Katoro for previous expenditures in the amount of €792 000 on or before 31 December 2023.

AUSTRALIA Joint statement of cooperation between Arafura and KOMIR

Arafura Resources Ltd has announced the signing of a joint statement of cooperation with Korea Mine Rehabilitation and Mineral Resources Corp. (KOMIR) that will support the development of Arafura's Nolans Project and assist in the export of product from Nolans to the Republic of Korea.

Arafura and KOMIR will focus on expanding cooperation in several areas, including: information sharing on the development of the Nolans project for participation by Korean investors; the import of rare earth products into Korea; and the use of strategic stockpiling.

Nolans will produce neodymium-praseodymium (NdPr) oxide – a product integral to the production of rare earth magnets used in industry, including the production of electric vehicles. Cooperation between Arafura and KOMIR recognises the strategic importance of a secure supply of critical minerals including NdPr to the Korean market.

The signing between Arafura and KOMIR took place in the same week as talks in Canberra between the Australian government and a Korean delegation led by Ministry of Trade, Industry and Energy Vice Minister, Ki-young Park. The delegation's visit also included the signing of a memorandum of understanding between the Minerals Council of Australia and KOMIR, in order to strengthen cooperation on the exploration and development of critical minerals in Australia.

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WORLD NEWS

USA Sandvik introduces underground mining's largest-capacity BEV truck

Sandvik is introducing the largest-capacity battery-electric truck for underground mining. With a 65-t payload capacity, the Sandvik TH665B prototype is completing factory testing in California, USA. Finalisation of the trial agreement with Barminco and AngloGold Ashanti Australia will soon see the truck trialled at the Sunrise Dam gold mine to prove its viability in a long ramp haulage application before commercial production of Sandvik TH665B is expected to commence in late 2023.

Following the introduction of the Sandvik TH550B 50-t BEV at MINExpo INTERNATIONAL® 2021, Sandvik is continuing to execute on its BEV strategy by expanding its line of battery-electric trucks and loaders to include both larger and smaller size classes. Sandvik TH665B is engineered to improve productivity, sustainability, and cost efficiency in mining operations.

Sandvik TH665B blends Sandvik design and advanced technology built around electric drivelines and battery systems. Due to an efficient electric driveline, a fully loaded Sandvik TH665B is expected to be up to 30% faster on a 1:7 ramp than a comparable conventional diesel underground truck. Each of the truck's four wheels is equipped with independent drives, resulting in a simpler driveline, improved overall efficiency and maximum power output. The Sandvik TH665B electric drivetrain delivers 640 kW of continuous power, enabling high acceleration and fast ramp speeds.

The truck is equipped with Sandvik's patented self-swapping system, including the AutoSwap and AutoConnect functions, which enables quick and easy battery swap in a matter of minutes, and without any major infrastructure, such as overhead cranes or other heavy handling equipment. Sandvik TH665B also features a new battery lifting system for improved reliability. Sandvik has redesigned the battery cage design to improve serviceability, enabling battery module changes without a need to remove the battery packs from the cage for service.

The new truck operator cabin offers premium operator ergonomics with a significant number of adjustment possibilities to facilitate a comfortable operating environment. The central oscillation frame design results in stability, and front axle suspension ensures a smooth ride on rough roads. The cabin is equipped with joystick steering, large touchscreen colour display and the newest control system, providing easy access to equipment data.

USA Exyn Technologies partners with Maestro Digital Mine

Exyn Technologies, a pioneer in multi-platform autonomy for complex, GPS-denied industrial environments, has announced a partnership with Maestro Digital Mine, a manufacturer specialising in Industrial Internet of Things (IIoT) devices, to give mining teams up-to-the-minute information about worker safety underground by integrating critical gas sensors onto the ExynAero™ and ExynPak™. This partnership highlights both companies' continued efforts to improve worker safety and productivity in the mining industry.

Hazardous gasses underground are an invisible threat to mining teams, who often do not know they are in danger until it is too late. This gas build-up can be created through the exposed strata, blasting, daily 'mucking', and even runaway battery fires on critical machinery. Traditionally, the gas levels are measured by the ventilation system at the return air raises or wearable sensors donned by miners. And while these innovations have saved countless lives, they do not allow for an unmanned inspection of the headings before re-entry or in emergency situations.

Now the ExynAero, a fully autonomous drone for exploring and mapping GPS-denied environments, equipped with Maestro's IIoT gas sensor, can be flown down drifts or into stopes to detect and localise any hazardous gasses without putting mining and survey teams in danger. Survey teams can easily add different gas sensors onto an ExynPak and mount it to the front of a truck or loader, in order to capture the same gas sensor data while mapping drifts or moving ore, collecting critical data while not slowing down daily production.

Powered by ExynAI's multi-sensor fusion capabilities, gas sensor readings are captured while the robot is in flight and displayed in real-time via a ruggedised tablet. These sensor readings are saved with precise coordinates in a high-fidelity point cloud that can be exported and examined in a variety of mining software.

THE LURE OF LITHIUM

M Suresh Raju, Clariant Mining Solutions, India, provides insight into the growing demand for lithium, and the most effective methods of meeting this need.

Lithium is a soft, silver-white coloured element, the lightest alkaline metal, with an atomic weight of 6.94. It is the 25^{th} most abundant element (at 20 mg/kg) in the Earth's crust. Lithium compounds such as lithium carbonate, lithium hydroxide, and lithium bromide are used in glass and ceramics, in lubricant and grease manufacturing to improve extreme temperature resistance, in aluminium production, as catalysts in the pharmaceuticals and rubber industries, and in air conditioning and de-humidification systems. However, the development of the rechargeable lithium-ion batteries, coupled with the global trend towards electrification of transportation, has led to a dramatic increase in the demand for lithium. The distribution of the consumption of lithium across end-use markets is as follows: batteries 71%, ceramics and glass 14%, lubricating greases 4%, continuous casting mold flux powders 2%, polymer production 2%, air treatment 1%, and other uses 6%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for portable electronic devices, and increasingly in electric tools, electric vehicles, and grid storage applications. For example, the demand for electric vehicles is expected to grow from 2.3 million in 2019 to 44 million in 2030.[1]

There are two major sources of lithium: brines and hard rock ores. At present, most of the global lithium production comes from brines (approximately 60%), while hard rock ores account for the remaining (approximately 40%) production.

Lithium resources

Almost 70% of the global lithium estimated reserves are concentrated in South America's ABC (Argentina, Bolivia, and Chile) region in salt flats. Brines around the world have a very low content of lithium, with the ones in Chile being the richest with a maximum of 0.2% lithium. Nevertheless, lithium extraction from brines is very common due to low production costs. Chile has the highest estimated reserves of lithium globally followed by Australia, Argentina, China, and the US (Figure 1).

The major lithium producing countries are Australia, Argentina, Brazil, Chile, and China. Australia accounted for almost 49% of the total lithium mine production followed by Chile (22%), China (17%), Argentina (8%), and Brazil (2%) in 2020 (Figure 2). Five mineral operations in Australia, and one in China, account for the majority of global lithium mine production.

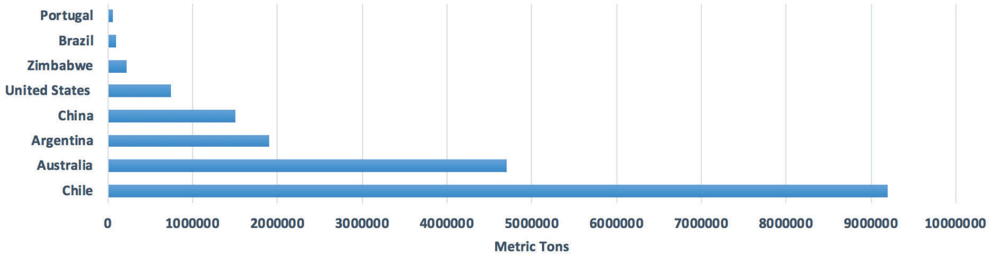

Figure 1. Global lithium reserves in 2020.[2]

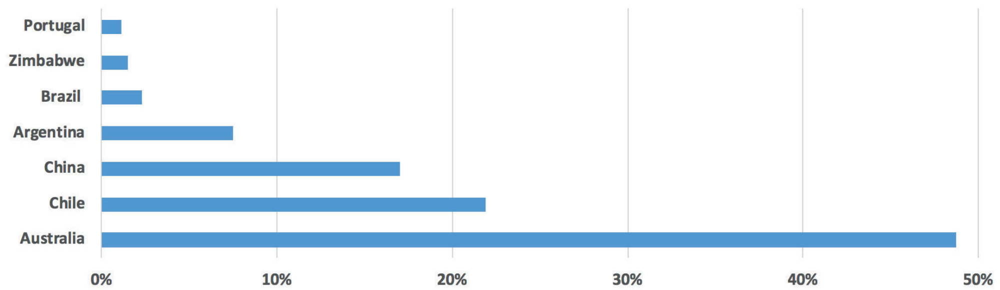

Figure 2. Global lithium mine production by country in 2020.[2]

Lithium minerals

Hard rock lithium ores often occur as complex aluminium silicate deposits, known as pegmatites. Pegmatites are coarse-grained igneous rocks formed by the crystallisation of post magmatic fluids, frequently in close proximity to large magmatic intrusions. Pegmatites often bear tin and tantalum. Lithium rich granite pegmatites are less common (<1% of all pegmatites). The lithium minerals that occur in granite pegmatites are spodumene, lepidolite, and amblygonite. These minerals are usually associated with feldspars, quartz, and mica. Other lithium minerals, such as zinnwaldite, triphylite and eucryptite, are also reported in literature. Among the lithium-rich pegmatite minerals, spodumene is of primary economic importance. Table 1 shows lithium minerals of economic significance and their physical properties. The typical lithium grade in exploitable pegmatite deposits ranges from about 1 – 4% Li_2O.

Spodumene

Spodumene is a monoclinic pyroxene with a single-chain structure consisting of lithium aluminum silicate, and it is a tabular hard rock which is insoluble in dilute acid. It has a prominent longitudinal cleavage. Spodumene is found in pegmatite deposits in association with other silicate minerals, such as: feldspar, micas, and quartz.

Petalite

Petalite is a monoclinic mineral with a framework silicate structure and is commonly associated with other pegmatites such as spodumene, eucryptite, and lepidolite. The theoretical lithium content of petalite is 2.3% (4.9% Li_2O) although the lithium (Li) content in many deposits varies from 1.4 – 2.2% Li (3.0 – 4.7% Li_2O).

Table 1. Lithium minerals[3,4,5]

Mineral	Formula	Content Li_2O%		SG	Hardness
		Theoretical	Actual		
Spodumene	$LiAl[SiO_3]_2$	8.1	4.5 – 8.0	3.1 – 3.2	6.5 – 7.0
Petalite	$LiAlSi_4O_{10}$	4.9	3.0 – 4.7	2.4 – 2.5	6.0 – 6.5
Lepidolite	$KLiAl_2Si_3O_{10}(OH,F)_3$	5.9	1.2 – 5.9	2.8 – 2.9	2.0 – 3.0
Amblygonite	$LiAl[PO_4][F,OH]$	10.1	7.4 – 9.2	3.0 – 3.2	5.5 – 6.0
Zinnwaldite	$K[Li,Al,Fe]_3[Al,Si]_4O_{10}[F,OH]_2$	4.1	3.3 – 7.7	2.9 – 3.2	2.0 – 3.0
Eucryptite	$LiAlSiO_4$	11.9	4.5 – 6.5	2.7	6.5
Triphylite	$Li(Mn,Fe)PO_4$	9.5	4.4 – 9.7	3.4 – 3.6	4.0

Large deposits of petalite occur in Zimbabwe, Canada, Brazil, and Australia. A significant amount of petalite has also been reported in Namibia, China, and Russia.

Lepidolite

Lepidolite is a mica mineral with a complex and variable composition. It is used in the production of glasses and ceramics. Its Li content can vary significantly from 1.2 – 5.9% Li_2O. Lepidolite is less common than spodumene. Commercial lepidolite deposits are found in Zimbabwe, Canada, Namibia, Brazil, Portugal, and Argentina. The main gangue minerals found in association with lepidolite include calcite, muscovite, feldspar, and quartz. Flotation can be used to separate calcite, muscovite, feldspar, and quartz from lepidolite.

Amblygonite

Amblygonite is the fluorine-rich end member of a lithium alumino-phosphate group. Its theoretical lithium content is 4.8% (10.1% Li_2O), but most economic ores contain 3.5 – 4.4% Li (7.4 – 9.2% Li_2O). Although sizeable deposits are relatively rare, it is mined in Canada, Brazil, Suriname, Zimbabwe, Rwanda, Mozambique, Namibia, and South Africa.

Zinnwaldite

Zinnwaldite is considered as an impure variety of lepidolite with relatively high iron content (up to 11.5% Fe as FeO) and manganese (3.2% MnO). The high iron content of zinnwaldite, combined with the relatively low Li_2O in zinnwaldite ores, makes it relatively unattractive as a lithium source. A significant reserve of zinnwaldite is in Europe close to the Czech-German border.

Eucryptite

Eucryptite ores were once an important source for lithium and contain an average of 2.1 – 3.0% Li (4.5 – 6.5% Li_2O). The Bikita deposit in Zimbabwe has an average grade of 2.3% Li (5% Li_2O). Eucryptite deposits are fairly uncommon and are generally small.

Other lithium occurrences

Lithium-bearing clays are regarded as additional sources of lithium. Among these clays is hectorite ($Na_{0.33}[Mg,Li]_3Si_4O_{10}[F,OH]_2$), a trioctahedral smectite rich in lithium and magnesium, which contains 0.3 – 0.6% Li (0.7 – 1.3% Li_2O). The best known hectorite deposit with 0.7% Li is found in Hector, California, USA. Jadarite ($LiNaSiB_3O_7OH$) is a lithium-boron containing mineral found in Serbia. A less common lithium-bearing smectite from Kings Mountain, North Carolina, USA, known as swinefordite is reported to have the highest lithium content known in clays, with Li_2O content ranging from 4.3 – 5.7%.

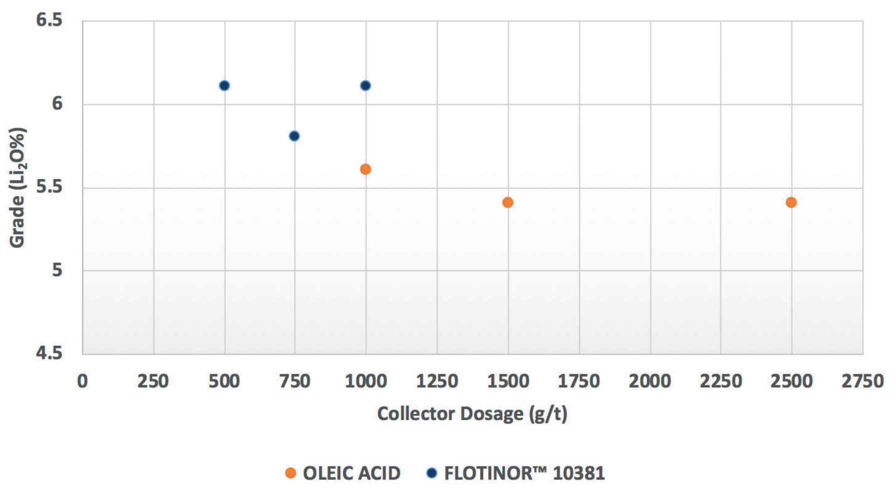

Figure 3. Comparison of spodumene flotation with oleic acid and FLOTINOR™ 10381.

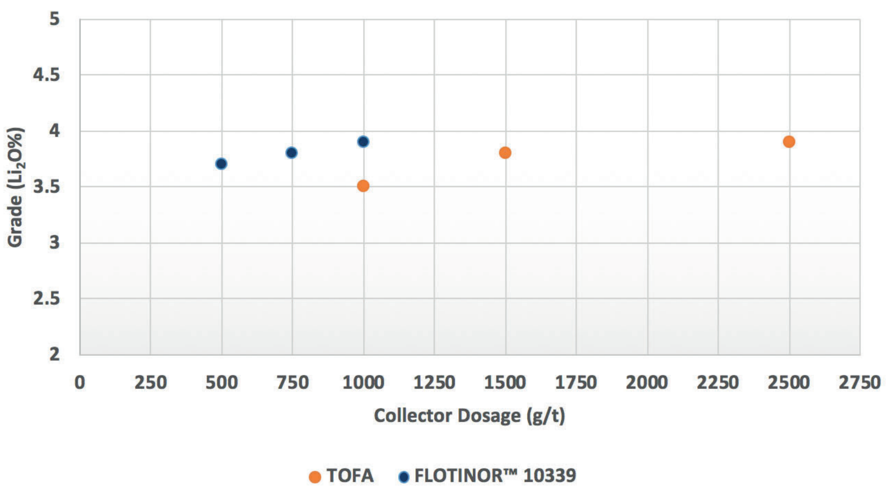

Figure 4. Comparison of spodumene flotation with tall oil fatty acid (TOFA) and FLOTINOR 10339.

Beneficiation of lithium ores

The major techniques used in the beneficiation of lithium minerals include gravity separation employing dense media separation, magnetic separation, and froth flotation. Dense media separation is usually employed for coarse gangue rejection, but it can also be used to produce lithium concentrates from high grade ores. Magnetic separation is used to remove large quantities of iron bearing gangue minerals to make the concentrate suitable for use in ceramics and glass manufacturing. Flotation is used for processing fine particle


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size feed, complex ore deposits, and where high-grade concentrates are required. Because both the lithium-bearing minerals and the gangue minerals have similar densities, it is difficult to achieve the required metallurgical performance with only gravity concentration. However, flotation using collectors customised for the specific surface properties of the minerals can be used to achieve the required lithium grades in the concentrates.

Froth flotation

Froth flotation is the most widely used technique for the beneficiation of lithium bearing minerals, such as: spodumene, petalite, and lepidolite. Anionic direct flotation is the most common approach for spodumene concentration. However, reverse flotation is also used in some cases. For complex ores containing quartz, micas and feldspars, flowsheets with multiple flotation steps are common.

Flotation of spodumene and petalite

Fatty acids are often used as collectors for direct flotation of spodumene from pegmatite ores. However, with ore deposits becoming more complex, flotation of spodumene to achieve a concentrate quality of above 6% Li_2O with good recovery is increasingly challenging.

Clariant Mining Solutions has developed alternative chemistries to achieve the specified quality concentrates at an improved recovery. For example, a typical spodumene ore containing 1% Li_2O was floated using Clariant's FLOTINOR^{TM} 10381, resulting in 84.3% Li_2O recovery at 6.2% Li_2O grade, whereas oleic acid could only achieve 5.5% Li_2O grade and 74.9% Li_2O recovery at same dosage rates (Figure 3). Another spodumene ore containing 1.4% Li_2O resulted in similar grades of above 3.5% Li_2O with FLOTINOR 10339 at much better recovery of 87.2%, compared to 82.6% with fatty acid at double the dosage (Figure 4). The improved metallurgical performance along with lower reagent consumption improves the overall performance of the mine.

Complex ores with very low content of spodumene, petalite, and lepidolite are very difficult to float in order to achieve the required quality of concentrate. In such cases, gangue minerals – such as micas, feldspar, and sometimes quartz – are pre-floated using cationic collectors, such as Clariant's FLOTIGAM^{TM} 7100, FLOTIGAM EDA and FLOTIGAM 4343, so that the spodumene and petalite quality and recovery can be enhanced in the final concentrates. Flotation of gangue minerals, such as micas and feldspars, requires different conditions than spodumene and petalite. Flotation of micas and feldspars is done at acidic pH conditions, where the collectors are more selective against spodumene and petalite. Petalite, being an aluminium silicate, is also floated using similar cationic collectors, but the flotation conditions need to be adjusted for effective separation. For example, in the case of Frontier Lithium in Canada, micas were pre-floated using Clariant's FLOTIGAM EDA at a pH of 3.5, and then the tailings of the mica flotation stage were subjected to flotation of spodumene using Clariant's FLOTINOR FS2 and oleic acid, in order to achieve a concentrate grade of 7% Li_2O.[6]

Flotation of lithium bearing clays

Lithium bearing clays are not very common and are usually found associated with other lithium minerals, such as spodumene. In such deposits spodumene is first floated using anionic collectors such as FLOTINOR 10381 in slightly basic pH conditions, followed by cationic flotation of lithium bearing clays using FLOTIGAM 7100, FLOTIGAM 7072, and FLOTIGAM 7550. Lithium clays may become an important source of lithium in addition to brines and pegmatitic ores.

Conclusion

With a growing focus on clean energy sources for light passenger vehicles, the demand for lithium is forecast to rise multifold in the next 10 years. Hard rock ores are becoming an increasingly important source of lithium; the global production of lithium from hard rock ores has seen a rapid growth in the past five years (80% increase). Improvements in beneficiation flowsheets using more sophisticated collectors and process conditions are undoubtedly helping to support this growth. GMR

Figure 5. Metallurgist conducting spodume flotation testing with Clariant collectors for direct flotation.

References

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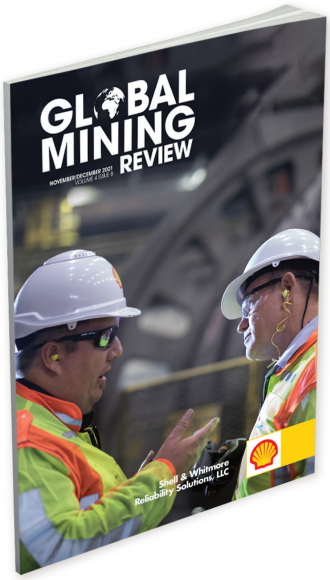

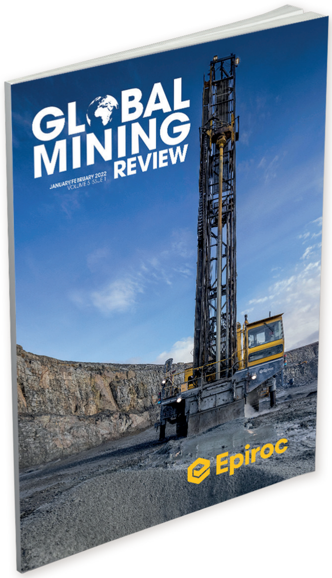

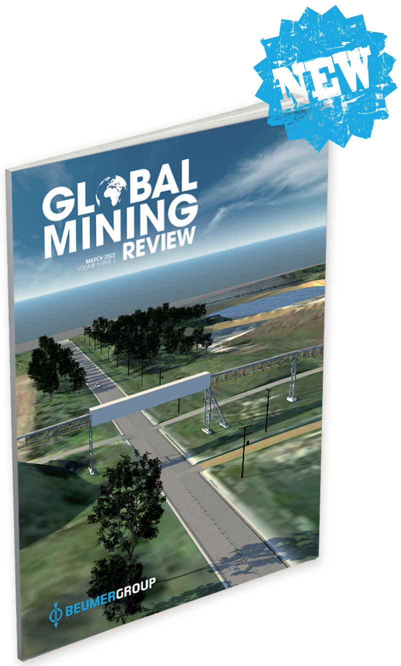

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