Top 10 Technologies

The ones to watch

MM highlights the ten technologies that it feels have the greatest potential to bring about a step-change in mining over the next five years

1 Rapid development

Strategic drivers within the mining industry, such as an operational shift from open-pit to underground mining and a greater interest in mass-mining techniques as well as an enhanced focus on safety, mean that miners are now seriously interested in drill-and-blast alternatives for mine development.

Mechanical rock excavation has had limited success so far in the hard-rock mining industry, mainly due to difficulty with cutting tools in highly competent and abrasive rock formations, but also because standard equipment does not possess the flexibility to cope with the variable nature of the rock, the geometry of mineralisation and the layout of an underground metal mine.

However, the potential that mechanical cutting holds for creating faster accessibility to orebodies and significant reductions in development costs if these challenges can be overcome is phenomenal.

Large-scale explosive-free rock-breakage techniques are being investigated by major miners, including Agnico-Eagle, AREVA, Barrick Gold, CAMECO, IAMGOLD, KGHM, Vale and Rio Tinto. These eight companies, along with Hydro-Quebec, the Société de Recherche et Développement Minier (SOREDEM) and CanmetMINING, formed a co-operative in 2012 to develop a toolbox of technologies for underground development at significantly higher advance rates than, but at the same cost and order of magnitude as, drill and blast.

Four projects were identified that centre around state-of-the-art intellectual property related to current technologies, ultrasonic rock breakdown, microwave rock weakening and thermal fragmentation. The latter two projects were designed to develop a technology to weaken the rock ahead of mechanical cutting.

Aside from this co-operative, others miners and OEMs are developing their own concepts, either singularly or through collaborative innovation projects.

Rio Tinto’s Mine of the Future project is one of the best known. In 2010, the company announced partnerships with three equipment producers to develop new systems for deep underground mines.

Aker Wirth and Atlas Copco worked individually with Rio Tinto to develop two new tunnelling boring systems (TBS) for horizontal infrastructure development, and Herrenknecht created a shaft-boring system (SBS) for vertical...
infrastructure development. All three concepts are the result of civil tunnelling industry technologies, combined with input from Rio Tinto mining experts and contractor partners Redpath and Cementation. Rio estimates that by combining the benefits of the three systems, it can reduce the construction period of an average block-cave mine by at least 40%.

**GET SMART**

Through its FutureSmart programme which was established in 2014, Anglo American has over 50 different initiatives under way to find safer, more efficient, environmentally friendly and, ultimately, more sustainable ways to mine. The Rapid Mine Development System (RMDS), which was developed with Atlas Copco, is one of these.

Based on traditional tunnel-boring machine (TBM) technology, the system aims to secure rapid access to the orebody and safely develop infrastructural mine tunnels for mechanised mining in hard rock.

Donovan Waller, group head of technology development for Anglo American, explains to *MM*: “The equipment is being developed to be able to rapidly, cost-efficiently and safely develop low-profile tunnels in hard rock. It differs from the conventional TBM by offering the same performance but with a flat roof and rectangular tunnel cross-section. Conventional TBMs drill round tunnels, which are not suitable due to a need for flat floor for mine vehicle traffic and a flat roof for stability purposes.”

The machine (pictured below) features standard TBM-type steel cutting discs, and has the potential to cost-effectively cut abrasive rocks with a unconfined compressive strength (UCS) of up to 250MPa.

Dragan Janicijevic, project manager for mining and engineering technology at Anglo American, explains how the collaboration came about in 2012: “Under the FutureSmart approach, Anglo American was looking for a development party that would join forces with its technology team to develop various hard-rock cutting solutions.

“In developing this concept together we have proven the tremendous benefits that can be gained by this type of collaboration. Atlas Copco technical knowhow combined with Anglo American’s skills as a mining company have proven to be a very worthwhile combination.”

The prototype system will undergo first trials at a test mine later this year, and will later prove itself in a real operating environment, according to Mikael Ramstrom, manager of global strategic projects and alliances for Atlas Copco. After the system has been operationally proven, it will be made commercially available by Atlas Copco to interested parties.

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1. **Rapid development**
2. **Hard-rock cutting for production**
3. **Directional well placement**
4. **Tunnel boring machines**
5. **Laser cutting**
6. **UAVs and drones**
7. **3-D printing**
8. **Mineral indicators**
9. **Acid digestion for assaying**
10. **Microwave & thermal fragmentation**

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*MM* is the leading monthly publication for the mining industry.
Hard-rock cutting

Hard-rock cutting technologies hold huge potential, not just for development purposes but also in a production setting.

For many years, the coal industry along with soft-rock applications such as salt, trona and potash, have been reliant on machines such as longwalls and shearsers, road headers and borer miners to safely and cost-effectively cut material from the face rather than drill and blast it free.

The use of these technologies in hard-rock mines has until now been constrained by the ability of cutting tools to deal with the rock strengths encountered and associated costs. However, a number of miners and manufacturers have been focusing their efforts in this field and trials are now beginning to bear some very promising fruit.

Caterpillar has been working on its Rock Header and Rock Straight systems – essentially a road header and a longwall-type cutting system – for some time. The company first presented them at the MassMin conference in 2012 and showcased its activated cutting technology (ACT), which was first trialled at KGHM’s Polkowice mine in Poland, at MINExpo later the same year.

ACT utilises picks (rather than discs) to undercut the rock mass, based on the fact that the tension and shear strength of rock is generally less in terms of magnitude than the compressive strength. Cutting forces and, in turn, tool wear, are significantly lower in undercutting compared with conventional frontal attack methods, making it more suitable for hard-rock cutting.

It was reported after MINExpo that the Cat RH35 concept had been designed and built; RH stands for Rock Header and the numbers refer to the machine’s 3m x 5m heading dimensions.

The Rock Straight system is designed for fully mechanised mining of low seams and narrow reefs, such as copper, gold or platinum applications. It comprises a hard-rock miner (HRM220) cutting head, a hard-rock chain conveyor (HRC30) and a hydraulic roof support (HRS1220).

The link to the system on the Caterpillar website has recently been removed. However, the HRM220 was listed as being 6.8m long, while the conveyor is thought to be 100m in length and the hydraulic roof support can extend to 2.15m.

Caterpillar confirms to MM that the Rock Header is closer to commercialisation than the Rock Straight system, but the company is reluctant to give further details at this time.

Additionally, in early 2014, competitor Joy Global successfully trialled CRCMining’s Oscillating Disc Cutter (ODC) for hard-rock mining. The technology, which was branded Dynacut by Joy Global following its licensing to the company in 2006, combines a number of rock-breakage concepts into a single technology enabling the continuous excavation of hard rock using relatively lightweight equipment in both surface and underground mining applications. The ODC uses lower forces than those associated with conventional disc cutting and has the added advantage of producing large chips and little dust.

The company cited safety and an expected 20% increase in advance rates as key development drivers along with less disturbance to the rock mass and a smooth final rock profile. Two trials ensued soon after with Joy Global; one at Anglo Platinum’s Bathopele mine in South Africa, and a second at a Joy Global test site in Wollongong, Australia, although the results are yet to be announced.

Reef mining

Sandvik Mining officially inaugurated a new hard-rock cutting test rig on March 3, at its competence centre for mechanical cutting in Zeltweg, Austria. The engineering design, planning, construction and assembly of the rig started in August 2013 and were completed at the end of 2014. Since the beginning of the year, various cutting tests have taken place that Sandvik says will “contribute to the development of different cutting technologies for applications in rapid mine development and production machine concepts”.

The company is also working on its MN220 reef miner. The prototype was originally launched in 2000, and from 2001 to 2006 the machine was operated at both Lonmin and Impala platinum mines, but “unfortunately it was not able to initiate the transformation from drill and blast to mechanical excavation”, Uwe Rastner, product line and sales support manager for hard-rock continuous mining at Sandvik tells MM.

At the time, the cost of drill-and-blast operations versus mechanical excavation was not favourable given platinum prices and the idea was shelved. However, “due to the fact that labour costs have significantly increased over the last few years, the picture today does look different, and this is why mechanical excavation is being given a second chance now. Currently, we do everything to use this chance and to meet the excavation cost target,” Rastner adds.

The MN220, which also uses the undercutting technique and incorporates simultaneous cutting and roof bolting, is currently under trial at Bathopele and Sandvik is working to make the machine more cost-effective.

The aim is to optimise the cutting process and cutting-tool consumption as well as the loading and conveying of the cut material.

“For material loading and conveying we also break new ground by applying pneumatic ore-handling systems based on air flow suction,” said Rastner.

“Out of the experience of this trial we also plan an upgrade of the MN220 to a new machine version optimised for narrow-reef platinum mining, but also keeping an eye on narrow-reef gold mining. Most probably, this should happen within the next three years.”

When asked about the potential of hard-rock cutting technologies in mining, Rastner states: “In my opinion mechanical excavation will offer a step change, both in mine development and ore production. But this change will require some time and patience and very good co-operation between mining companies and equipment manufacturers. Only this tight co-operation will be the key to success.

“Looking back on the coal-mining industry, the step change from conventional mining to mechanised and partly automated mining easily took 10-20 years. Now, mechanical excavation is the standard in coal mining, I believe that a...
Most large open-pit mines are eventually affected by groundwater inflow.

**Directional well placement**

A typical pit dewatering programme involves vertical in-pit wells and perimeter wells.

**IN THE RIGHT DIRECTION**

Most large open-pit mines eventually encounter groundwater and, depending on their hydrogeological setting, may require proactive mine dewatering. A robust and effective programme is critical to minimising slope instabilities and advance mining.

The impacts of a poorly dewatered mine often include:

- Wet drilling and blasting, requiring more expensive blasting agents and reduced fragmentation efficiency;
- Wet working benches, which increase equipment wear and introduce additional safety risk factors;
- Inundation of the pit floor and a
slowing of mine advancement; and
• Reduced geomechanical performance of pit slopes that in some cases leads to the design of more conservative slope angles, resulting in higher strip ratios and deferral or loss of ore.

For ore deposits in moderate-to-high permeability settings, where wall stability and reducing groundwater inflow are the main dewatering objectives, conventional dewatering is normally implemented with a combination of:
• In-pit vertical pumping wells to remove storage and lower groundwater levels within the pit shell;
• Pit perimeter wells to intercept and remove groundwater moving toward the mine; and
• A series of sumps and surface pumps to remove standing and near-surface groundwater.

In-pit vertical dewatering wells are often challenging to implement and maintain over the life of the project. They typically have a limited life span of one or two years due to mine advancement or loss of access, and their vertical orientation limits the opportunity of crossing multiple fault or fracture zones, which are groundwater conduits in a hard-rock aquifer setting.

Additionally, submersible pump run-time is drastically reduced due to operational interruptions leading to less groundwater withdrawal.

Maintenance of infrastructure such as piping and surface equipment is also labour-intensive and cumbersome. The annual costs required to operate a conventional dewatering programme can be significant.

Good dewatering results are difficult to attain, and it is common to have groundwater continue to impact mine performance even when a conventional vertical well dewatering programme is implemented.

PIONEERING PAIR

Recognising the limitations of conventional dewatering practices, Schlumberger Water Services and Freeport-McMoRan have collaborated to develop, test and implement a new generation of high-performance mine-dewatering well systems, combining mine hydrogeology and dewatering expertise with cross-over technology from oil-and-gas directional well placement.

Directional well placement is normal practice for oil and gas production wells. Objectives typically involve maximising hydrocarbon productivity through optimising ‘hydraulic contact’ with the reservoir, accessing resources unreachable with vertical drilling, and minimising the surface footprint of production well placement and operation.

However, directional well placement in hard-rock mining has a very limited track record and was previously untested for the application of open-pit mine dewatering.

The geological and geomechanical environments, size and scale of equipment, flow and production pumping regime, and the associated well design requirements are significantly different.

The technology transfer involves significant adaptation and modification, but Schlumberger and Freeport recognised that the principal benefits of directionally placed dewatering wells can far outweigh the challenges.

Benefits include the ability to:
• Enhance hydraulic contact between multiple fractures zones and production well/s;
• Access permeable water-bearing zones unreachable with vertical drilling; and
• Position the well-heads permanently outside the planned mine operating areas.

The combined impact of these benefits was envisioned to create step-change improvement in dewatering-well efficiency, performance and overall effectiveness of the mine-dewatering programme, resulting in significant cost and risk reductions.

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Anticipated improvements include:
- Increased well yield due to the design trajectory and enhanced hydraulic contact;
- Improved well run times with the well-heads located outside of operating areas thereby eliminating the issue of interference between dewatering infrastructure and mine operations;
- High well yield and improved run times leading to a step-change increase in long-term volumes of groundwater produced from the dewatering programme; and
- Reduced number of well-head installations with associated burdens of procurement, implementation and interactions with in-pit operation.

**WELL PLACEMENT AT MORENCI**

The directional placement of a well to a pre-planned trajectory to accomplish the above goals involves complex interactive consideration of multiple factors. These include the ore deposit geology, geological structure and geomechanical environment, the ranges of performance for directional tooling, downhole surveying, and ability to control and steer the well to the target.

The trade-offs between alternative options, risk factors, the final dewatering goal and overall value to the mine operation are integral to the matrix of planning, design and implementation decisions.

Adapting techniques from the oil-and-gas industry, Schlumberger and Freeport developed a mine-dewatering project integration matrix, which was subsequently implemented at the Morenci copper mine in Arizona.

To date, two directionally placed dewatering wells have been successfully implemented at the mine as part of the Garfield open-pit mine-dewatering programme. An initial well was constructed on a ‘proof of concept’ basis and was commissioned in early April 2013.

The well was located on the west wall of the open pit, outside planned mining limits. The borehole was steered underneath the centre of the planned pit on a pre-planned directional trajectory.

Attaining a measured depth of approximately 700m, the well intercepted hydrogeologic targets associated with major northeast-trending geologic structures and hydrogeologic compartments. After completion, the well was equipped with an oilfield-style high-lift, slim-hole electric submersible pump system designed to minimise well placement and construction-hole diameters, while permitting high production pumping rates for variable head pressure conditions.

The well initially produced between 2,461L/min and 2,650L/min (650 and 700gpm), which was at the high end of the planned expectations, and is five to ten times greater than the previously installed in-pit wells.

The well was immediately commissioned into the active dewatering programme and during the initial year operated at 96% availability.

The combination of the high production rate and high availability means that it effectively produced up to two orders of magnitude more groundwater than any of the existing in-pit vertical wells, and exceeded the combined groundwater production from the rest of the dewatering system, comprising six vertical production wells.

Following the success of the first well, Freeport and Schlumberger commissioned an additional programme to construct a second well collared on the pit perimeter of the east high wall. The target for the second well was a set of northeast-trending geological structures and lower-permeability compartments.

With a more aggressive drill-bit trajectory, design modifications were made during implementation to control risk while attaining the planned hydrogeological target.

Drilling of the second well was recently completed on schedule. Commissioning and performance testing are ongoing, and early results are extremely positive.

Since initiation of the programme, monitoring data has shown a distinct acceleration in the rate of the groundwater level reduction in the open pit. A number of piezometers located within and around the edges of the pit have shown a 60-75m decline in static water elevation.

The companies continue to evaluate the success and value of the programme and are looking for opportunities to implement directional well placement at other mining operations.
Tunnel boring machines or ‘TBMs’ are not new to mining, but their potential is often underestimated and, as a result, the technology is underutilised across the industry. Modern technologies mean that TBMs offer the potential to develop infrastructure faster, more safely and more economically, particularly at deep operations.

In addition to the development of access and ventilation drifts, TBMs can also be used to create declines, as demonstrated at Gem Diamonds’ Ghaghoo operation in Botswana where Redpath created a 458m-long shaft through soft Kalahari sand using an open-face tunnel shield, and determined the extent of orebodies.

Benefits include enhanced safety and ground stability when compared with drill-and-blast techniques, increased advance rates and lower operating costs – a significant boon in today’s tight times – making them well worth a second look.

Success stories include Anglo American’s US$1.9 billion 5Mt/y Grosvenor coal project in Moranbah, Central Queensland, Australia, which reached a key milestone in February when its TBM broke through the second of two drifts at the mine 29 days ahead of schedule.

The US$38.4 million earth pressure balance machine was used to create two drifts – one for the conveyor that transports coal from the underground longwall to the stockpile area on the surface and another for people and equipment to access the mine.

Grosvenor’s underground construction manager Adam Foulstone says: “From an industry perspective, we have achieved the highest levels of collaboration and production through tunnelling. On our best production day, we installed 18 concrete rings to support the tunnel, so about 25m, and our best week was 78 rings, or 110m.”

In order to find out more about the technique’s potential and the benefits on offer, MM teamed up with OEM Robbins to look at how the Stillwater mine in the US, a long-time convert to TBM technology, is making use of it.

Montana mettle
The Beartooth Mountain Range in Stillwater, Montana, is home to the J-M Reef – a substantial deposit of platinum and palladium that winds through the range, making it a prime spot for mining. It was in this reef that Stillwater Mining Co (SMC), North America’s largest supplier of platinum-group metals, began its operations.

The mine’s history includes nearly three decades of TBM use, starting with the excavation of a development tunnel in 1988. In all, the mine has excavated nearly 30km of tunnel using TBMs, with more work ongoing. The mine’s latest effort, a 7km-long tunnel for haulage and ventilation, is utilising a 5.5m-diameter Robbins Main Beam TBM.

As the mine sees it, there are many advantages to using a TBM in a mine given the right application. “A TBM is not viable in all areas, but in deep areas it definitely is. For us, it provides both an exploration platform and ventilation for the life of the mine, so we are getting two services in one.”

“This is particularly advantageous when the tunnel course is long and straight,” says Curt Jacobs, project superintendent for SMC.

The versatile Robbins TBM is equipped with pockets in the roof shield, allowing for installation of steel slats using the McNally Ground Support System in difficult ground

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Curt Jacobs, project superintendent for Stillwater Mine, works to prepare the TBM for launch from its inner chamber.
The geometry of the orebody and locations of reef access at Stillwater make for long, straight tunnels. “In our mine the orebody runs perpendicular to a river valley, east to west for 45km. That lends itself well to TBMs, because you can develop large reserve blocks that are easier to ventilate and don’t require as much ground support as a drill-and-blast tunnel,” says Mike Koski, chief geologist at SMC.

The mine has carefully weighed its options for its development tunnels, opting for TBMs for a number of reasons. While the capital cost for TBMs is approximately 1.5 times that of conventional mining fleets, the mine has shown over time that TBMs need 33% of the operating costs. Their advance rates are also significantly higher – anywhere from three to over five times that of a comparable drill-and-blast operation.

TBMs also eliminate blasting and leave a circular cross-section, which increases tunnel integrity and reduces ground-support requirements. In addition, blasting requires evacuation of the blast area and results in lost work time due to shutdown of areas near the blast zone for safety.

The circular, smooth tunnel profile produced by TBMs reduces air flow resistance when compared with conventional tunnelling methods that leave the wall uneven and rough.

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“BliTz Tunnel T akes off”

Stillwater’s latest endeavour is the Blitz Tunnel, a development tunnel of at least 6.8km that will provide information about the reef along the eastern portion of the mine.

A 5.5m-diameter Robbins TBM is being used to create a rail-haulage tunnel that will be used for the life of the mine and to determine the extent of the reef. Launched in September 2012, the Robbins Main Beam TBM was fitted with 19in (48.3cm)-diameter disc cutters for excavation in rock averaging 130MPa UCS. Five major, potentially water-bearing faults are expected along the TBM drive.

Up to 1,892L/min of water have been encountered at the Stillwater mine in the past, and this same amount is possible at fault zones along the TBM alignment. To combat these conditions, the TBM is equipped with 360° probing and grouting capabilities in order to grout in areas where excessive water is encountered.

In addition, the TBM is equipped with a ring beam erector capable of installing 150mm ring beams. In areas of expected weak rock, SMC requested that the ring erector be capable of installing 200mm ring beams. This required the gripper shoes and other components of the TBM to be designed around using the 200mm beam size.

In very difficult ground conditions, the machine is capable of installing 400ton steel McNally Slats using the McNally Roof Support System. A curved assembly of pockets installed below the roof shield allows workers to bolt continuous steel slats to the tunnel crown as the machine advances, containing highly unstable rock.

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“Steering the TBM is an interesting process because we have very complex geology here. We do diamond [core] drilling ahead of the machine, above the machine, and to the side after every 150m,” says Tyler Luxner, senior production engineer for SMC.

The operators make adjustments to the TBM bore path based on the perceived distance to the reef. “We don’t want to get too far away from or too close to the orebody. The ore zone is located in a very distinct layer of igneous rock, so if we penetrate the right rock types then we know we are in the right place, and if we see some ore, we know exactly where we are,” says Koski.

At the same time that excavation began in the Blitz Tunnel, a parallel drill-and-blast operation began 180m overhead as the primary exploration of the reef at the Blitz location. The drill-and-blast operation, a 4.6m x 4.6m heading, began in September 2012.

While a straight-across comparison cannot be drawn due to differences in crew size, heading size, and water inflows in the two headings, broad trends can be observed by comparing the drill-and-blast and TBM tunnels. 

REEF DETECTION

Detecting the reef in relation to the TBM requires careful analysis using two core drills mounted on the machine. “Steering the TBM is an interesting process because we have very complex geology here. We do diamond [core] drilling ahead of the machine, above the machine, and to the side after every 150m,” says Tyler Luxner, senior production engineer for SMC.

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a recent paper, the mine recorded average productivity of 1.2m/shift in the drill-and-blast heading, compared with 7m/shift in the TBM heading. That means the TBM was progressing at a rate 5.75 times faster than the drill-and-blast heading directly above it.

THE NEXT DRIFT

TBMs can also be used for decline access tunnels and other types of tunnels at mines. The technology can be customised and can use any type of ground support currently supported by drill-and-blast operations.

“Mines owe it to themselves to take a serious look at TBMs because of the increased productivity, improved ground support and final tunnel shape. It’s worth looking at. My advice is to take your time, and try not to cut costs in order to set it up right the first time.

“At Stillwater that is part of our success – taking the time to set up each project properly, and doing thorough training to make it successful. If you focus too much on the capital cost and what you can cut, that can wind up hurting you later on,” says Cole Deringer, development engineer for SMC.

5 Laser cutting

Speaking to Mining Magazine’s sister title, Mining Journal, late last year, Tony O’Neill, group director, technical and sustainability at Anglo American, outlined his thoughts on the potential for laser-cutting technology in mining.

“I’m absolutely convinced that in the next 10 years we will be cutting rocks with lasers as a production tool. Out of all the technology changes, cutting, to me, will be the most significant,” he said.

O’Neill said there were drills in the US geothermal industry using lasers in the heads for rock penetration. The US company doing this, Foro Energy, said its drill bit featured a rotating laser beam that fractured and weakened the rock, combined with a set of polycrystalline diamond compact (PDC) cutters that scraped the weakened rock from the area exposed to the laser beam.

Foro started up in 2009 and was built on a decade of academic work at the Colorado School of Mines.

“They have worked out, through people I have been dealing with at Cambridge University, that if it [the technology] can’t cut rock, it can certainly soften it and then you can cut it. I think that will lead to a fundamental change in some of our mines. You will be able to cut rock, rather than drill and blast,” O’Neill said.

The knock-on effects of such technology could be great. “If you cut it, then you don’t necessarily need traditional haulage, you could put it onto a conveyor belt or into a pipe,” he adds.

Then there is the safety impact. With no need for blasting, human beings could be removed from one of the most dangerous areas of the whole ore-extraction process.

“I think laser cutting and lessons from the fracking industry can potentially enhance the whole use of targeted nanotechnology around orebodies, just by the way you access the orebodies without opening up large areas and reducing the amount of waste rock you have to move. “This would represent a major step change from drill and blast,” O’Neill concludes.
UAVs and drones

A prime example of a military technology that has found its niche in mining, unmanned aerial vehicles (UAVs) or drones can be used to generate 2-D or 3-D maps for exploration, monitoring and surveying at existing mines.

They can be used for complementary mapping of haulage road profiles, mine security, revegetation mapping, volumetric surveying of stockpiles and waste dumps, pipeline and conveyor monitoring, slope stability monitoring, tailings pond and equipment inspections, and environmental management tracking. In short, their uses are endless and at a fraction of the cost of helicopter or winged survey services (and with significantly fewer regulatory restrictions), UAVs offer a highly effective alternative to traditional surveying solutions.

MM spoke to senseFly, a leading UAV manufacturer, to find out about a recent mapping project in Madagascar.

Off the coast of East Africa, in Madagascar, Energizer Resources’ flagship Molo graphite mine is coming to life. Part of the 1,000km² Green Giant graphite project in the country’s arid south, Molo spans 5km² and is thought to contain 80-120Mt of high-quality, all-flake graphite — used in refractories, batteries and consumer electronics – making it one of the largest such deposits in the world.

Having released its preliminary economic assessment for Molo in February 2013, Energizer contracted an engineering company, DRA, to perform a full bankable feasibility study, in order to determine whether or not it was viable to bring Molo into production.

As part of this study, a full land survey was required to create a 3-D contour map of the site. The team would use this output to determine the location of the mine’s dam and that of its accompanying pipeline, as well as the positions of plant assets such as buildings and equipment.

“For this survey we examined various approaches,” explains Eric Steffler, geomatics manager at Energizer Resources.

“We chose drones for two reasons,” Steffler says, “first, the price was very low compared with a LiDAR survey, which would have cost hundreds of thousands of dollars, even with the reduced survey area. The second was that, by making a capital investment in two eBee drones, we could use these on our other properties.”

UNMANNED VALUE

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The 150km² area of interest comprised several parcels:

- Three square areas were flown to ascertain the best location for the site’s dam;
- An additional corridor covered the preferred route of the dam pipeline;
- Three further parcels were flown to the west of the site;
- The site of the plant itself; and
- A rectangular parcel, the possible route of a road heading to nearby Fotodrevo.

In terms of creating the project’s
required outputs, Steffler planned first to create a digital terrain model (DTM) in grid format. This would then be used to generate 3-D contour maps of the site (eight sets in total), featuring half-metre and two-metre contours. "Air photo interpretation was also required to determine the locations of villages, roads, crops, and culturally significant items such as tombs and historic trees," Steffler says, "plus, we needed to examine the quality of various roads."

**DRONE METHODOLOGY**

With the survey’s 150km² total coverage easily at the larger end of UAV mapping projects, Steffler planned approximately 300 flights, each with an average flight time of 35 minutes. Average flight coverage was 2.5km² with each capturing some 150RGB images (15,000 photos in total). "We set a ground resolution of 9.9cm in the drone’s software," Steffler explains. "This meant that after processing the images, we could still achieve the 20cm accuracy DRA required. We also used the software’s multi-drone function to manage flying two UAVs at the same time."

Since no existing control data was available, Steffler’s team also used a GPS system to locate and post-process 70 ground control points (GCPs) across the project area. However, this GCP work was not without its challenges. "After flying for a few days we noticed that our control points would go missing. These were made from plywood, painted white, with crosses marked in black duct tape. Local residents would take them and use them for fixing their roofs, or as tables. So, to stop this happening, we hired locals from the nearby town to sit close and guard the control points as we flew," Steffler explains.

Energizer’s three staff spent a total of 90 days in the field, setting GCPs and flying the drones. Steffler then managed the data processing himself, spending up to 12h/d on this task – over 120 days in total. "With 10-12 flights flown every day we had 16-18GB of data to process every night," he says. "We needed to buy a more powerful computer for this. Then, once the entire survey had been flown, we had to merge the data together. We used SAGA GIS for this and it took us over two months."

**THE RESULTS**

The final products achieved a ground sample distance of 9.75cm, with positional accuracy within DRA’s requested +/- 20cm range. "Our mean re-projection error was 0.179 pixels," Steffler adds.

Having successfully completed Molo’s UAV survey and the outputs used to inform DRA’s feasibility study, Steffler is effusive in his praise of drone technology. "The return on our investment has been amazing," he says.
As existing easy-to-access, high-grade ore deposits become depleted, miners must find innovative ways to detect those at greater depths and in more challenging geologies.

In an interview with MM last year, Stephen McIntosh, global head of exploration at Rio Tinto, outlined some of the methods his team was investigating. “Post-mineral cover can mask deposits very effectively, and while we have improving technologies, they aren’t perfect yet so we are investing in better geophysical methods to better probe and image the subsurface,” he told editor Carly Leonida. “Whenever we drill a hole, we aim to make the best possible use of it – not just standard core logging, but also peer even deeper into the mineralogy and alteration.”

McIntosh explained that there are materials in some boreholes that can indicate the presence of a potential target nearby. “We’re developing techniques around mineralogy, looking at the fertility of mineral systems and whether the alteration system that’s at work has the potential to contain metals in economic concentrations,” he said. The concept comes from the diamond exploration industry where kimberlitic indicator minerals – special grains only found in kimberlites – are used to identify potential drill targets. Rio Tinto is looking for analogues in other commodities and rock types. The company is leveraging expertise from its micro-analytical facility in Australia to understand the mineral concentrates that are coming out of its copper-production facilities, and apply that knowledge to improve the success of its exploration teams.

“We are really talking about the needle in the haystack, single grains that might present themselves in a creek drainage system, but which might have originated in an ore-forming system that hopefully has metals in it,” McIntosh told MM. “Rio Tinto feels quite confident in the technology-development space, and it sees this as one of its key strengths. It’s something that we are turning into a competitive advantage through our Mine of the Future programme.”

**8 Mineral indicators**

“Rio Tinto feels quite confident in the technology development space, and it sees this as one of its key strengths.”

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Acid digestion for assaying

ColdBlock Technologies and its acid-digestion process are set to revolutionise the way mining companies assay metals, according to the company.

The start-up company came onto the scene back in 2009, collaborating on its R&D project with Brock University in Ontario, the Centre for Excellence in Mining Innovation (CEMI), the Natural Sciences and Engineering Research Council of Canada (NSERC), the Ontario Centres for Excellence (OCE) and Barrick Gold.

Six years and just over C$500,000 (US$400,000) of work later, the company is ready to launch what CEO Nick Kuryluk calls a “platform technology” to a mining audience in dire need of ways to improve its cost base and productivity.

A sample digestion technology using short-wave infrared radiation to primarily energise sample particles, ColdBlock rapidly dissolves solid matter into a solution for instrumental multi-element analysis. It does this through a unique process, which unlike traditional acid digestion, heats the sample particles and not the acid, while ensuring that minimal reagent escapes through a cooling mechanism at the top of the test tube.

“Most of the technologies that use acid digestion are heating the acid first instead of the particles, and the limiting factor is the temperature you can heat the acid. Once you hit the boiling point, it [the acid] vaporises,” co-inventor and president of sales and marketing, Ron Emburgh, told MM from the company’s test laboratory at Brock University ahead of the company’s PDAC debut.

The boiling point of such acids and reagents is typically 300°C. After this point, the acid evaporates, the digestion process breaks down and more reagent is needed. This limits the speed of digestion and can lead to some ores not being fully digested, inhibiting accurate analysis of metal concentrations.

ColdBlock doesn’t have this problem. Any acids that do vaporise are pulled out of the process through overhead fans at the work station, improving the environment for technicians and the technology’s ‘green’ credentials. The infrared emitter that is placed around the test tube and directed at the sample particles can effectively heat sample particles up to 1,000°C in a matter of seconds, reducing the time taken for the digestion process to work.

Within 10 to 15 minutes the full digestion of the targeted metals is complete, whereas conventional methods can take one to two hours, according to Kuryluk.

Add to this the fact that harmful reagents such as perchloric acid – a potentially explosive reagent – are not required in the process, and ColdBlock suddenly has a few unique selling points to show off to the mining contingent.

MINING APPLICATIONS

This broad technology can be applied to many industries, including the pharmaceutical, agriculture and food sectors, but mining is where ColdBlock intends to start commercially.

“This is being launched in mining because there is a great opportunity to address some unmet needs facing the mining industry right now,” Kuryluk said.

“Over the years, the desire to get quicker digestion times to give analytical data back to the mine and mill operators to make their critical decisions was all-important. That was our starting point; trying to figure out a way we can speed up the digestion time for easy-to-digest and very difficult-to-digest samples, such as chromite,” Emburgh said.

While Kuryluk couldn’t put a figure on how big the potential market for its product was, he said the process “brings many benefits” to an industry facing a “challenging business environment”.

“By significantly reducing the time spent on sample preparation, mining laboratories can look to this technology to increase their sample throughput and improve productivity and efficiencies. This does not solve all of the challenges facing the mining industry, but, it is an

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Innovation that will play a part to advance this industry forward,” he said. The company has so far tested the process on gold, copper and chromium samples, all producing results consistent with what mining laboratories expect, but the focus for now is base metals, according to Dr Ian Brindle, professor at Brock University’s department of chemistry, and a collaborator on the process.

“There is a huge amount of interest in base metals, particularly metals such as copper, nickel, zinc, lead and so on and that’s where we’re going at the moment,” Brindle said. “So far, we have not come across a sample containing base-metal concentrations we have not liked, so we are very positive in the sense of looking for base-metal applications for this [process].” Base metals are by no means where the company is planning to stop, though, according to Brindle, who has been instrumental in designing the chemistry that allows the process to work.

“Of course, as soon as we have got this validated, we are going to look at other matrices and more complicated forms such as tungsten, aluminium and out into the rare earth elements,” he said.

Platinum-group metals could follow soon after, as could gold. “Some of them are easy like palladium, but gold is difficult because of this thing called the 'nugget effect' [uneven gold distribution throughout the ore]. In platinum we have managed to get up to 75% of the platinum out of the samples and that is the toughest one we have come across so far,” he said.

While ColdBlock is validating its process in-house, the company is aware that miners and explorers will want to do their own analysis. “We’re satisfied, but people will need that external validation from third parties where their interest is in the sample itself and not the process,” Brindle said.

As a result, it is inviting companies to bring samples to its test laboratory at Brock University’s chemistry department. Emburgh is pretty sure those in the know will realise the significance of the process.

“I would suggest chemistry has been pretty boring on the mining side for quite a long time. I guess the last big event was the development of microwave and that was approximately 40 years ago,” he said.

“We started this off where we really wanted to address one of the biggest themes for the mine and mill operations. They want close to know what concentration of gold is in the ore as close to real-time as possible. Number three they want to establish that what they are mining is worthwhile and above the critical point. The reverse is also true. If it is below the critical point, it is not worth mining, which is a productivity issue,” he said.

E mburgh is confident that ColdBlock has given the industry a tool to do exactly this. It could also be used on the exploration front where companies are analysing drill core.

When considering how many samples some of the big mining laboratories are processing – Emburgh estimates it could be as many as 3,000-5,000 samples a day – and the fact that ColdBlock uses three or four times less acid than traditional methods, the potential cost and productivity savings could be huge.

As a result, traditional acid-digestion technologies and fire assays that laboratories have been using for many years could soon have a quicker, greener rival on the market to spar with.

**SAMPLES, NOT ORDERS**

During the collaboration phase, ColdBlock worked with Barrick Gold, with the mining company providing samples for it to work on. The gold miners’ laboratory technicians in Vancouver would compare results of fire assays with ColdBlock’s own acid-digestion results and vice-versa.

It has received samples from other sources, but it is yet to sign up any official customers on the mining side.

Despite this, Emburgh was very bullish on orders following.

“We’ve already made the rounds through the technology centres for a number of mines and the playback we get is they are very interested in picking up the ColdBlock as it sits right now [the six channel, six sample stations], which for some mines is all they need,” he said.

“As it is a new technology, they will want to take their old samples from their mine and run it through, developing the chemistries to imply that what we’re saying about the technology is true.

Once that is accomplished, I have a feeling that about 50% of them will come back to us and say ‘well this is great, but for productivity value and because our workload is heavier, we would like a workstation [basically a number of the channels strung together] and some form of robotics to actually do the deposition of the acids or any reagents.”

After this, automation is the next logical step.

“We’ve had a few of the mines come back and say this opens the door for total laboratory automation,” Emburgh said. Reacting to this, ColdBlock has started up a working relationship with an automation group, which could take this technology on and build it into workstations.

**Microwave and thermal fragmentation**

According to the Coalition for Eco-Efficient Comminution (CEEC), comminution – the reduction in the size of solid rock particles – accounts for approximately 53% of mine-site energy consumption, which equates to a minimum of 10% of production costs.

Around 3% of the electricity generated globally is taken up by comminution – that’s enough to power Germany. With declining average ore grades, rising energy costs and greater pressure from stakeholders to reduce their environmental impacts, many miners are looking for alternatives, or even aids, to traditional crushing, milling and grinding techniques.

Certain ore-bearing formations lend themselves particularly well to thermal fragmentation. This approach has been used to create and enlarge holes in rock masses, but not directly in comminution. However, the use of high-temperature torches could offer significant savings in grinding by reducing the size of recovered fragments, and selective ore recovery would limit the amount of waste being milled and deposited on surface as tailings.

Thermal shock breakage is not only limited to direct heat applications. Microwaves, while selective as to the types of minerals affected, can impart sufficient thermal shock to create micro-fractures that weaken rock considerably, in some cases by more than 35%, according to Natural Resources Canada.

While still in the early stages, Rio Tinto has mentioned that it is investigating using microwaves as part of the comminution process. The project is a long-term strategy as part of the company’s Mine of the Future programme.