SOLID GROUND

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A MAGAZINE FROM
SANDVIK MINING AND ROCK TECHNOLOGY

Australia:
The inspiration for automation

Sandvik rock tools:
Productivity leap

Big Picture:
Mining myths and legends

Mexico: Agnico Pinos Altos

Best of both worlds

SANDVIK

Dear reader,

THIS ISSUE OF *Solid Ground* is full of references to safety, efficiency, productivity and automation. Those are the topics that are driving progress within our industry, both now and in the future, and I am excited to be responsible for leading that drive here at Sandvik Mining and Rock Technology as its newly appointed President. As always, our focus is on our customers and how we can best deliver innovation that contributes to your improved productivity and the ongoing development of new and improved products, and you'll find many examples of these in this issue.

We are committed to leading our industry as it takes the next significant steps in its evolution: automation and digitalization. That's why we organized a two-day summit in Chile in December, where customers were able to share the benefits they had gained by implementing the latest Sandvik technologies. As further endorsement, read about the advantages that automation and digitalization are bringing to Glencore's Lady Loretta mine in Australia, one of the world's highest-grade zinc operations.

However, it's not just about products and technology. Innovation is at the heart of everything we do, including the flexible, competitive customer finance solutions we are able to offer to meet our customers' needs in a changing business climate.

We look outward too, strengthening our organization by acquiring and partnering with others whose offerings complement our own – such as Newtrax (global leader in wireless IoT for the underground metal mining industry) and Artisan Vehicle Systems (manufacturer of battery-powered underground mining equipment).

On every step of the journey, our No. 1 priority is safety. That's why we are proud to be involved in the International Council on Mining and Metals initiative called the Innovation for Cleaner Safer Vehicles. It focuses on:

- Improving vehicle interaction technology in order to reduce collisions;
- Accelerating the reduction of diesel particulate matter emissions;
- Reducing energy costs and emissions of greenhouse gases.

What's important to you is important to us. What we deliver to our customers defines who we are.

HENRIK AGER
PRESIDENT, SANDVIK MINING AND ROCK TECHNOLOGY

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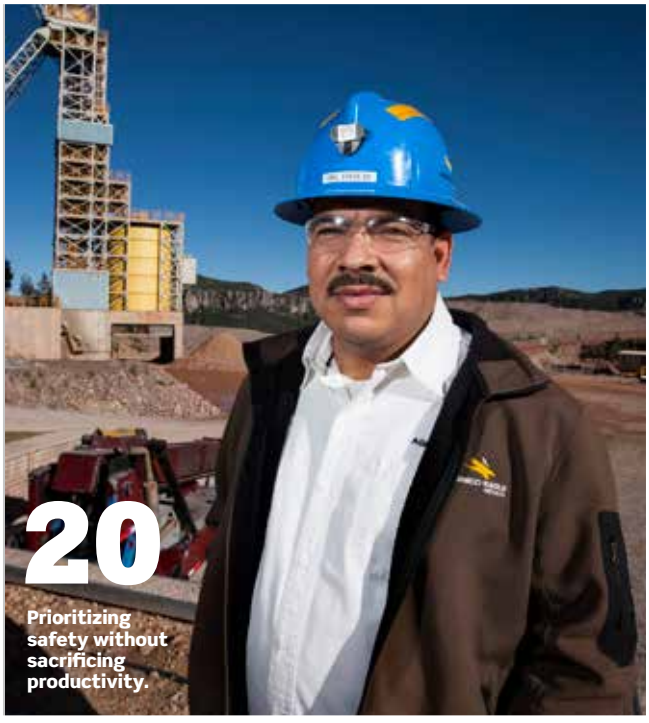


Robust, efficient, intelligent

Expanding on its existing intelligent offering, Sandvik introduces its second i-series loader, Sandvik LH621i. The new loader is ideal for rapid mine development and large-scale underground production and is a matching pair with the previously introduced Sandvik TH663i truck, considering its designed payload capacities.

With extended hydraulic power for fast bucket filling and drivetrain power for high ramp speeds, Sandvik LH621i is designed to quickly clear tunnel headings for rapid advance rates. Engineered with operator and maintenance personnel safety in mind, the rugged loader offers long component lifetimes and low costs per tonne. Sandvik LH621i also features the latest Sandvik Intelligent Control System and My Sandvik Digital Services Knowledge Box on-board hardware as standard for easy product health monitoring and faster troubleshooting.

The xSeries is ready to roll

Built on the proven design and reliability of Sandvik Mining and Rock Technology's diesel-powered rotary blasthole drills, the xSeries family features added intelligence and improved operator ergonomics. Easy to learn, operate and service, the xSeries offers a migration path to the iSeries depending on customer needs, and provides operators with a balance of reliability and technology to drill holes safely and more accurately. Some benefits of the xSeries include the following:

- Touch-screen GUI interface
- Compressor Management System Lite electronic-controlled compressor system
- Bolt-on mast locks eliminate cutting and welding, facilitating change outs
- Swivel-enabled operator's seat with integrated electrohydraulic controls simplifies operation and offers improved visibility of operating environment.

"In developing the xSeries, we've taken our customers' feedback into our research and development efforts and are proud of the newest addition to our product line," says Dave Shellhammer, president of the pedestal drill division, Sandvik Mining and Rock Technology.

A new range of possibilities

In response to customer demand, Sandvik Mining and Rock Technology has introduced the non-cabin Ranger DXR series surface rigs, expanding its Ranger DS series of surface top hammer drill rigs. The new drill rigs can reach places that can be hazardous for operators.

Suitable for construction applications, quarries and open pit mines, the new rigs – Ranger DX600R and Ranger DX800R – essentially offer the attributes of conventional Ranger DX series drill rigs, reliability and large drilling coverage area from the standard 17.6 square metres to an optional 26.4 square metres, in a lighter and more mobile package. The non-cabin Ranger DXR drill rigs flourish on unstable benches and deep cuts typical to applications such as road and railroad construction, foundation drilling, trenching and pipeline contracts.

Advancing electric solutions

Sandvik has acquired privately owned Artisan Vehicle Systems, a manufacturer of battery-powered underground mining equipment. Artisan's core technology is battery packs, electric motors, power electronics, software and control systems, and its underground mining loaders and trucks are designed with these high-powered, highly reliable and field-proven battery electric powertrains. Artisan is the market leader with the most battery electric vehicles currently operating in underground mining and will become a Business Unit in the load and haul division within Sandvik Mining and Rock Technology.

"I am pleased to see the strategic acquisition of Artisan so soon after the opening of Sandvik's state-of-the-art Battery Electrification Innovation and Development Center in Turku, Finland, in 2018," says Mats Eriksson, president of the load and haul division at Sandvik Mining and Rock Technology. "It is in line with our ambition to be leading in the market for battery electric vehicle solutions."

Rammer par Excellence

Last year, the Rammer brand celebrated its 40th anniversary. This year it has updated and upgraded its Excellence line of hydraulic hammers. One of the major features of the Excellence line is Rammer's purpose-developed RD3 remote monitoring device – the first of its kind on hammers. RD3 uses the MyFleet Telematics service to track and monitor fleet equipment usage without needing to go to the site to collect the data – ideal for dealers, rental companies and operators. This cloud-based system enables the hammers to be viewed and monitored via Google Maps.

As well as RD3, the Excellence line reflects Rammer's ever-increasing customer-focused outlook through a host of additional new features. Lower tool bushing rotating and replacement in the field increases lifetime, which helps to reduce operating costs. This is further supported by the use of two tool retaining pins that extend the lifetime of the tool, retaining pins and tool bushings.

Leading the journey — Through the Rock

More than 200 leaders of the Latin American mining industry met in Santiago, Chile, for Digitalization in Mining - Through the Rock, a two-day summit hosted by Sandvik Mining and Rock Technology.

The seminar focused on leading-edge mining technology and the digitalization journey facing today's mining operations.

Day one featured speakers from mining companies from around the Americas, as well as leaders in mining technology, process optimization and automation. The speakers detailed the benefits their companies have gained by implementing automation and process optimization, as well as the mindset it took to get there.

On the second day participants travelled to Sandvik's Santiago facility to participate in live remote visits to Sandvik customer sites around the world.

"Digitalization is helping companies to grow and optimize their operations," says Patricio Apablaza, vice president, Andean and South Cone for Sandvik Mining and Rock Technology. "Our partners participated because they know that this is critical to making their mines sustainable for the future."

Driving digitalization

In 2019, Sandvik Mining and Rock Technology will deliver the OptiMine digital platform to Hindustan Zinc at the company's Sindesar Khurd mine. The system includes a comprehensive set of features for short interval control of the underground operations, including OptiMine Monitoring, Location Tracking and Mine Visualization, Scheduler, Task Management and OptiMine Analytics.

"With OptiMine we will be able to plan, schedule and monitor overall operations in real time," says Sunil Duggal, CEO of Hindustan Zinc. "This will add major value and increase our productivity, eliminate bottlenecks and allow us to measure and monitor our key performance indicators in real time, proactively addressing problems before they occur."

THE QUOTE

Pairing Sandvik solutions with 5G-ready Nokia DAC architecture has proven to be an excellent match. We are truly motivated to continue collaborating to develop technology that meets the requirements of the often-harsh conditions they operate in.

Nokia digital automation general manager Stephan Litjens on the agreement signed to further develop Sandvik solutions for private LTE and 5G technology.

Integrate to innovate

Newtrax, the global leader in wireless IoT for the underground metal mining industry, has partnered with Sandvik Mining and Rock Technology to provide a comprehensive digital offering.

Sandvik's OEM-independent OptiMine digital platform will integrate with Newtrax's system of wireless IoT to provide all relevant data in one source, delivering both real-time and predictive insights to improve operations.

"We are eager to see our partnership with Sandvik help our customers more rapidly and effectively realize their crucial mine digitalization objectives," says Alexandre Cervinka, CEO of Newtrax.

Flexible financing

Today's consumers have creative options other than owning a product for a particular application. The question remains, what offers best value for customers: to buy, lease, co-use or share? Sandvik Mining and Rock Technology offers flexible and competitive customer finance solutions in a changing business climate.

Text: **TURKKA KULMALA** Photo: **SANDVIK**

FOR MOST CUSTOMERS, procuring mining and construction equipment means a major capex decision that inevitably raises hard questions: Is it necessary? Do we have any options to reduce the cost? Against this backdrop, it is hardly surprising that financing has long been an essential component in Sandvik's service offering.

Björn van den Berg, global customer finance director at Sandvik, says the company currently arranges in-house financing for 25 percent of all equipment sales.

"Customers find great value in financing their investment through the equipment supplier," van den Berg says. "For one thing, we really know our machines, and this is something that third-party financers can't bring to the table. We also understand our customers' businesses. For example, we are mindful of the fact that a mine cannot generate any substantial cash flow before the extraction phase and we can offer matching solutions, especially for the development stage."

Charles Watson
FMR Finance Director

To wit, when Australia's FMR Investments purchased a fleet of Sandvik equipment to modernize its Eloise operations, the company chose financing from Sandvik.

"Once upon a time we were an underground mining contractor," says Charles Watson, FMR finance director. "When we picked up the first five Sandvik trucks for Eloise we found ourselves in a novel situation. That was the first debt we had incurred since selling the contracting business, and we'd lost touch with our previous lenders. Financing underground equipment is quite novel for some people, so when I could get a competitive rate from Sandvik it was a bit of a no-brainer."

FOR FMR, THERE were clear benefits for going with Sandvik rather than a traditional lender for financing. "Sandvik knows its equipment," he says. "That automatically gives them knowledge of our business and how we operate so that is distinct from a bank, which may or may not understand us. Sandvik really does bring a lot of value for us so it's a win-win situation. The rate was competitive, and it was quite a seamless process. You bring a lot of value to the table offering that to a client."

The vision of Sandvik's customer

SANDVIK CUSTOMER FINANCE – BENEFITS TO THE CUSTOMER

- Sandvik knows mining and construction industries and understands cash flows and business cycles
- Single source for equipment and financing – fewer points of contact, possibility to bundle with other services
- Broad range of solutions – from conventional ownership to paying for use, tailored and flexible repayment schedules
- Sandvik financing solutions match your equipment and its application
- Global presence, including vendor solutions and export credits – flexibility for global companies and international projects.

Australia's FMR Investments chose financing from Sandvik when it purchased a new fleet of trucks for its Eloise site.

finance solution is to help mines, contractors and construction companies to improve their financial performance by offering flexible solutions ranging from conventional ownership to paying for use. The organization has also been streamlined for better interaction with the markets. While customer financing was previously handled by the Sandvik Group, it has been a part of Sandvik Mining and Rock Technology since 2017 – in other words, closer to front-line sales.

TO CREATE FLEXIBILITY to meet customer needs, Sandvik offers three customer finance products – essentially three different ways to divide the ownership and the associated risks and rewards. With asset-based lending, the financed equipment serves as collateral and the customer has ownership of the machine in all senses. Finance lease is a form of finance in which the ownership of the equipment remains with Sandvik while the customer leases the equipment, and the customer then takes over ownership at the end of the lease term. In an operational lease, the equipment remains in the ownership of Sandvik both legally and financially, and the customer pays only for its use; at the end of the lease term, the equipment returns to Sandvik.

> **Financing underground equipment is quite novel for some people, so when I could get a competitive rate from Sandvik it was a bit of a no-brainer**

The appropriate financing solutions vary according to the type of equipment, the customer's industry and the geographical area. In areas where none of the above options are viable, Sandvik Group can still offer export credit services.

"Furthermore, we can bundle financing with other types of services that the customer might need, such as maintenance contracts," van den Berg says. "Also, financing arranged by us allows customers to use their existing credit lines for other purposes."

SANDVIK HAS A simple and efficient decision-making process. An indicative quote can usually be provided within 24 hours of the request, starting from limited initial data on the equipment, duration of financing and down payment. A somewhat lengthier process is of course necessary for the final binding offer, including a review of the customer's audited financial statements.

The overall credit risk has three main components: country risk, customer risk and equipment risk. Assessing these is not a rigid, replicative process. It is necessary to estimate any cross-over effects that may change the outcome on a case-by-case basis. Higher country risk or equipment risk, for example, may be acceptable for a financially strong customer. This enables Sandvik to follow A-level customers in geographies where credit is difficult to obtain.

"If financing the acquisition of new or reconditioned Sandvik equipment is in any way a challenge for a customer, we can tailor a solution to their specific needs and deliver added value for their operation," van den Berg says. ■

Q&A

A UNIQUE ASSET

Since becoming President and CEO of Canadian miner North American Palladium in 2015, Jim Gallagher has led significant improvements in operating performance at the company's Lac des Iles mine in northern Ontario. He shares his thoughts with *Solid Ground* on using new methodology and technology to reduce operating costs while increasing the bottom line.

Q WHAT IS ESPECIALLY CHALLENGING ABOUT RUNNING NORTH AMERICAN PALLADIUM?

North American Palladium (NAP) is a unique asset, as most palladium is produced as a by-product of other production. We are the only pure palladium producer in the world.

Our Lac des Iles mine has a very large vertical orebody that's quite amenable to mass mining approaches. The challenging part is that we are not a high-grade ore body – but we are a big bulk mine and we've been able to increase our mineable reserve by getting the production rate up and getting operating costs down, and technology has played a big part in that.

Q WHAT ARE YOU DOING DIFFERENTLY?

NAP has gone through a fundamental mining method change. We're now using a version of sub-level cave mining and we've converted a blasthole mine to a sub-level cave, which has only been done a few times around the world.

Q HOW HAS TECHNOLOGY HELPED INFLUENCE PRODUCTIVITY?

We're using real-time data to look at trends and areas for improvement, and we've also recently introduced real-time management and automation technology. With automation we can reach up to 21 operating hours per day, which is a 15 to 20 percent improvement above current manual operation. That contributes to a significant impact to unit cost and to the bottom line.

Q HOW HAS SANDVIK HELPED WITH YOUR CHANGE IN OPERATIONAL PHILOSOPHY?

We went looking for a partner in technology a couple of years ago as we were starting to upgrade our fleet. It became obvious that we didn't just want to buy more iron. Our new equipment needed to include the technology that would support our longer-term business strategy. We were impressed with where Sandvik was in their automation approach and were very interested in battery-electric technology and in autonomous ramp haulage. That's a huge area for us. It was important that we work closely and collaboratively to get there as fast as possible. There is a lot of excitement on both sides, with Sandvik and with the NAP team at Lac des Iles mine, and that is a critical part – the level of enthusiasm that the people bring to the implementation of new technology. ■

ADAM LACH

The Expert

Karen Hudson-Edwards, professor of sustainable mining, University of Exeter, UK.

CREATING BETTER AIR quality in underground mining environments is one of the most pressing issues facing mining companies today. Goldcorp's Borden project in Canada is developing the world's first all-electric mine using Sandvik Mining and Rock Technology equipment to help minimize emissions underground. More will have to be done, however, to combat the health risks associated with poor air quality. *Solid Ground* spoke with Karen Hudson-Edwards, a professor of sustainable mining at the University of Exeter, to get her views on what can be done to help improve the air down there.

Q: WHAT ARE SOME OF THE HEALTH ISSUES ASSOCIATED WITH POOR AIR QUALITY IN UNDERGROUND MINES?

A: Poor underground air quality caused by contaminants such as heat, humidity, dust and toxic, flammable, radioactive and suffocating gases can lead to a variety of health issues. These include loss of concentration, heat stress, respiratory tract irritations, poisoning and diseases such as pneumoconiosis, fibrosis, silicosis, black lung disease and lung cancer.

Q: WHAT ARE SOME OF THE HURDLES TO SUPPLYING UNDERGROUND ENVIRONMENTS WITH GOOD-QUALITY AIR?

A: One of the main hurdles mine operators face is to supply good-quality underground air in the most cost-effective manner. This requires a good understanding of the air volumes and velocities required, together with the potential contaminants produced. This is particularly true as mining moves deeper, because the geothermal gradient increases and ventilation systems must deliver more air or refrigeration over longer distances.

Q: WHICH HAZARDS THAT ARE CONTROLLED BY VENTILATION AFFECT AIR QUALITY UNDERGROUND THE MOST?

A: Ventilation systems can be associated with fires and gas outbursts. Power failures resulting in the shutdown of the systems can lead to a lack of oxygen and a build-up of toxic gases for mine workers. Underground dusts can accumulate on, and be redistributed by, ventilation components, or be produced by corrosion of these components by wear or reaction with contaminated air.

Q: HOW CAN MODERN TECHNOLOGY HELP IMPROVE AIR CONDITIONS UNDERGROUND?

A: Computer technology is increasingly playing a role in all underground mining activities, including ventilation. For example, Ventilation on Demand (VOD) systems are able to supply mine faces being worked with high-quality and efficient ventilation, while reducing or not ventilating those that are not being worked. The VODs operate through mine sensors that send data on air quality, personnel location and other factors to centralized computer systems that in turn adjust and supply the ventilation. This sustains good air circulation to workers while at the same time reducing costs. Other innovations include heat exchange ventilation, currently used at Vale's Creighton mine in Ontario, and hydraulic compressed air cooling for deep mines.

Q: WHAT CAN BE DONE TO MITIGATE EXPOSURE TO AIRBORNE CONTAMINANTS?

A: Modern and well-maintained suppression, ventilation or exhaust-extraction systems are essential to eliminate or minimize airborne contaminants and ensure that fresh air is consistently supplied. Ideally these systems should adhere to legal frameworks, approved codes of practice and management plans for underground mining practice that aim to regulate and reduce workers' exposure to these contaminants. To reduce diesel emissions, battery-powered electric vehicles and remotely controlled mobile machines are being increasingly used. These have many added benefits, including reduced emissions, costs, heat, noise and vibration.

Q: IS THERE A MODERN-DAY VERSION OF THE "CANARY IN THE COAL MINE"?

A: Smart technologies are the modern equivalents of the canaries in the coal mines. These can be used to monitor, detect, control and share information and be operated remotely and for 24 hours a day. The variety of such technologies is wide and growing. Examples include wireless sensor networks, radio frequency identification, smart grids, mobile sensing and cloud computing. The Internet of Things combines many of these technologies into a remotely controlled network. ■

A BRAND NEW FLEET FOR LADY LORETTA

MOUNT ISA, QUEENSLAND. Automation and equipment monitoring are helping Redpath Australia exceed expectations at Glencore's restarted Lady Loretta mine, one of the world's highest-grade zinc operations.

TEXT: **ERIC GOURLEY** PHOTO: **ADAM LACH**

GLENCORE AWARDED REDPATH Australia the Lady Loretta zinc mine contract in December 2017, encompassing the entire underground and surface operations and associated facilities management. Redpath's responsibilities range from crushing the ore it extracts and loading it onto road trains for haulage to Glencore's processing facility in Mount Isa, to managing the camp and keeping lawns manicured.

Redpath also holds full statutory responsibility for the operation, a unique role for a contractor typically tasked with driving a decline or undertaking development and production.

The broad scope intrigued John McKinstry, who came onboard as Redpath's operations manager for Lady Loretta. McKinstry has managed mines across Australia and North America during a 30-year career.

"Operating a mine is an exciting proposition for Redpath," says McKinstry, the senior site executive at Lady Loretta. "A normal contractor scope is to put down a heading or undertake a specific task, but we have a much broader scope here. The infrastructure's already in place, so it's quite a different role for a contractor. Being a life-of-mine contract is unusual in itself. Most mines evolve as you develop and find more ore, but this orebody is very well-defined."

Redpath recommissioned the mine within months of winning the contract, firing the first development round in March 2018. Production ramped up quickly and by July 2018 Redpath was meeting Glencore's production and development targets. Monthly production grew to 100,000 tonnes, with a full production capacity targeting 133,000 tonnes per month.

THE CONTRACT LENGTH enabled Redpath to invest in a brand-new fleet for Lady Loretta.

"We wanted to meet or exceed targets right from the start, so we brought in new, cutting edge technology to minimize operating costs and maximize productivity, knowing that we've got a good life to work the

Two Sandvik LH621 loaders are equipped with AutoMine Lite at Lady Loretta, helping Redpath stay productive during shift changes.

LADY LORETTA MINE

The high-grade Lady Loretta zinc mine is located 110 kilometres northwest of Mount Isa. Production began in 2013 and the mine was placed on care and maintenance in 2015 before its restart in March 2018. Redpath operates the mine with a workforce of 227 people. With a nameplate annual ore capacity of 1.6 million tonnes, Lady Loretta can produce as many as 160,000 tonnes of zinc per year over its remaining six-year mine life.

equipment over and amortize assets," McKinstry says.

Two Sandvik DD421 jumbos with 10/16 split feeds have outperformed since commissioning. Redpath has consistently achieved 400 development metres per month using one Sandvik DD421, with the second serving as a backup and handling any rehabilitation work.

"We've had an excellent run out of the jumbos since they've been here," McKinstry says. "From day one, we've consistently exceeded expectations that we had."

ORE IS REMOVED by a fleet of four Sandvik LH621 loaders. Two are operated conventionally for development, manual production and truck loading while the other two are equipped with AutoMine Lite for remote operation.

"The 621 I think in a lot of people's eyes at the moment is probably the loader to be using in the bigger operations," McKinstry says. "It's a big machine. It's a very productive machine, very comfortable machine for operators, and then having the AutoMine on top of that just means it really sells itself in many ways."

Redpath's motivation for implementing automated loading from the surface was simple: regain the productivity lost during each shift change.

"There's a long period of time from when a blast occurs to when you can re-enter the mine," McKinstry says. "If we can operate those machines from the surface over shift change, we can pick up up to a couple of hours a day in productivity. The other thing about AutoMine is that it does the same thing time and time and time again without banging the walls. It really does just run the perfect line each time."

REDPATH RUNS THREE levels at any one time, optimizing the loading process.

"It enables us to be moving a level from one stope that's complete to a new stope that's online, enables us to remote one at the same time from a hut underground or from the surface, which means the other one that they've remoted from and put the dirt into the stockpile, they can be loading trucks at the same time as that," says Rafe Horsington, Lady Loretta electrical manager.

From the comfort of a remote hut on a nearby level, operator Tony Rosvall trams ore to the stockpile with precision. He's developed an

It will help to keep our prices down and our productivity up

It's a very productive machine, very comfortable for operators, and then having the AutoMine on top of that just means it really sells itself

appreciation for AutoMine's mapping capability.

"It can show you where you are in a stope," Rosvall says. "If you get out there and if there's a bit of dust around you can get half lost and you're sort of not sure where you are. With the AutoMine at least you can see where you are, you know where the walls are and you know your angle. You've got a level in there and you can go 'Oh, I'm about to tip over.' You can correct yourself, so that's good."

The connectivity provided by a Wi-Fi network has not only enabled Redpath to implement the automated loading from the surface, the contractor can also monitor and manage its fleet in real time through My Sandvik Productivity, the cloud-based version of OptiMine Monitoring.

OptiMine has been synonymous with equipment monitoring in the Australian mining industry since its first installation in 2014. My Sandvik Productivity mobile fleet monitoring allows Redpath to keep tabs on equipment condition online and act more quickly to remedy any issues that arise.

THE SOLUTION PROVIDES detailed, readily analyzed data. Each connected loader collects data onboard and uploads it when it comes within range of a Wi-Fi antenna. The data can be accessed from any computer or tablet.

The condition monitoring helps Redpath's Lady Loretta maintenance manager Shane Timothy and his team improve their predictive maintenance planning. My Sandvik Productivity also identifies trending behaviours that can damage equipment or shorten component life, revealing training opportunities.

"When it brings up log codes and faults and alarms, it actually tells you

Glencore awarded Redpath a life-of-mine contract for surface and underground operations for the Lady Loretta zinc mine in 2017.

Operator Tony Rosvall values AutoMine's mapping capability along with the improved safety of operating the loader remotely.

REDPATH

The Redpath Group has provided full-service mining solutions in more than 30 countries since its establishment in 1962. Redpath's services include underground construction, shaft sinking, raiseboring, mine contracting, raise mining, mine development, engineering and technical services and a variety of specialty services. The company has more than 6,100 employees worldwide and regional offices in Australia, Canada, Chile, Germany, Indonesia, Mongolia, South Africa, the United States and Zambia.

what that means," Timothy says. "So you can hover across your icons, for instance, where it says that there's a brake fault, and it would tell you that, your operator is perhaps pressing the brake and accelerator pedal at the same time, which isn't something that we want them to be doing unless they're going at a very low ground speed."

McKinstry believes having better-informed operators who understand their equipment and its limitations will reduce downtime.

"We hope that by giving operators the feedback that they'll change their behaviour in their operation of the machines," McKinstry says. "And if we can address it early, then I believe we're going to get better availability out of this equipment."

Timothy sees vast potential in the equipment monitoring solution.

"The opportunity to jump online and have a look and see exactly where that loader is or that piece of plant is at any one time, see how our operators are operating that equipment, see if they're operating that equipment effectively and efficiently, and being able to pick up those very minor improvements if something isn't going the way that it's meant to, and then being able to share that knowledge across our fleet, across our operators, it will drive improvements across this mine site," Timothy says. "It will help to keep our prices down and keep our productivity up." ■

PRODUCTIVITY LEAP

Sandvik has significant new rock tool product launches in the pipeline for tunnelling and mine development applications. The new bits, tool systems and carbide grades boost the productivity of drilling operations through higher drill speeds and better hole straightness, offering cost savings through longer tool life and improved safety.

TEXT: **TURKKA KULMALA** PHOTO: **SANDVIK**

ROCK TOOLS AND tool materials represent one important ingredient in the performance and productivity of a drill rig, in addition to pneumatics, hydraulics, engine and other main components. Sandvik's in-house production of the cemented carbide bits for rock tools, all the way from carbide powder raw material to finished drill bits, has long been a differentiator. Now the company is introducing new rock tools.

"We wanted to make a real difference in the performance of rock tools in top hammer applications," says Robert Grandin, product manager, top hammer tools – underground applications, with Sandvik Mining and Rock Technology. "Conventionally, there wasn't that much difference between spherical and semi-ballistic buttons in terms of real productivity – no more than 5 percent or so. With our new grades and bits, we can achieve quite a lot more."

The productivity leap described by Grandin consists of three components: two innovative carbide button grades, a new fast bit design and an extension of the successful Alpha thread concept.

We wanted to make a real difference in the performance of rock tools in top hammer applications

PowerCarbide

THE NEW CARBIDE grades, referred to jointly as PowerCarbide – along with Sandvik's other premium and most powerful carbide grades – are the GC80 gradient grade and the self-hardening SH70.

Conventional, so-called straight carbide grades, such as Sandvik XT48, show the same hardness and toughness values throughout the entire bit. This results in linear performance over the entire cross-section of the bit. The new gradient grade GC80 has instead a hard, wear-resistant tip and a tough core, and thanks to this it has exceptional wear resistance in abrasive rock conditions with high silica (SiO_2) content. In non-abrasive rock conditions, the improvement is smaller or non-existent.

The self-hardening SH70 grade is above all highly resistant to button breakages, thanks to a work hardening effect in the surface of the button. This characteristic also maintains the resistance to high wear and breakage even as the button wears down. The hardening effect is greatest in hard and competent ground – in other words, when high MPa values are generated during drilling. There is little or no improvement in soft or fractured rock.

Together, GC80 and SH70 offer mutually complementing solutions for different rock conditions: the gradient grade excels in abrasive rock with high silica content, while the self-hardening SH70 improves performance in hard rock. Field tests indicate that performance, in terms of drilled metres, can be improved by up to 30 percent compared with a conventional straight carbide grade.

A very tangible benefit is the direct reduction in cost per metre, thanks to a longer tool life. This also cuts the time spent changing bits, a major safety benefit. There are also benefits in the tool room, as grinding intervals are 20 to 30 percent longer compared with standard carbides.

The elevated front of the Speedy bit produces a bit capable of a 10 percent improvement and longer life.

Speedy bit

THE SECOND MAJOR rock tool launch is the Speedy bit: a new top hammer bit with a patented elevated front geometry and substantially more aggressive, fully ballistic buttons for deeper penetration per blow. "Fully ballistic" means more pointy buttons to cut deeper and to produce bigger cracks and chips. In simplified terms, fully ballistic buttons put more energy into the rock, resulting in more rock crushed per kilowatt of drill output.

To balance out the more aggressive button shape and to enable greater energy expenditure into the rock, the new buttons have an updated carbide grade. The enabling technology here is an improved manufacturing process with a new aftertreatment that makes the buttons more resilient to breakage.

The elevated front of the Speedy bit means that the three centre buttons are raised above the perimeter buttons. Initially, only the elevated centre buttons make contact with the rock face, resulting in action somewhat similar to a pilot drill in metal cutting: the raised bits first produce a smaller pilot hole, which is subsequently enlarged by the perimeter buttons. This results in an extremely fast bit, capable of a 10 percent improvement in performance and longer tool life compared with conventional bits. The penetration rate also remains high even as the bit wears down, which makes the Speedy bit a great option for applications with a specific penetration rate as the discard criterion.

The higher penetration rates of the Speedy bit are also a result of another design feature: more efficient flushing. The patented design includes large sludge grooves to effectively flush even big cuttings and to provide maximum flushing flow at the front of the bit. The large, deep and wide flushing grooves increase the flow and help to carry away the larger volume of cuttings to balance out the more aggressive cutting action and avoid wasting energy in recutting.

"We have seen in trials on mining jumbos that it's possible to save 15 minutes in drilling time for each face with the Speedy bit," Grandin says. "So if the rig drills four faces per day, which is fairly typical, this can save 60 minutes each day. Taking into account the typical hourly cost for a mining jumbo, this easily amounts to hundreds of dollars per day in savings for each rig. On an annual level, that can mean more than 100,000 dollars per rig."

Alpha 360

SANDVIK IS ALSO launching a new, larger version of the patented Alpha 330 tool system that since 2004 has dominated 43- and 45-millimetre mining applications with higher penetration rates, more accurate drilling and improved uncoupling of bits. Larger, longer holes are becoming more and more common, and Sandvik responds to this with the new larger Alpha 360 tool system.

The shorter coupling thread in these bits, a key feature of the Alpha system, relocates the sensitive thread section into the bit skirt. Thanks to lower leverage forces, better protection from wear and tear and decreased vulnerability to bending, this substantially decreases the bending stresses exerted on the thread. The shorter thread also makes the bit easier to uncouple.

While the above benefits are the same for Alpha 360, the new "big brother" is optimized for 48- and 51-millimetre hole sizes. This makes it a unique new concept for this hole size range. The new solution offers up to 100 percent longer service life for rods thanks to reduced bending stresses. The exact collaring and better straightness result in better hole quality. Fast and easy uncoupling action is an additional benefit.

"We have some initial experience with Alpha 360 from a major infrastructure project in Scandinavia," Grandin says. "While the average service life of drifter rods was between 2,800 and 3,000 metres with the previous drill tools, we could now achieve even up to 6,000 metres. Perhaps not surprisingly, the rig operators don't want to use anything else anymore."

BENEFITS

- PowerCarbide GC80 and SH70: new innovative button grades – part of the bigger PowerCarbide family of Sandvik's most powerful carbide grades – for better wear resistance in abrasive rock conditions and in hard rock
- Speedy bit: more aggressive bit design with an elevated front for substantially higher penetration rates
- Alpha 360: a stronger new tool system in 48- and 51-millimetre holes for improved service life, higher productivity and better hole quality.

AGNICO EAGLE PINOS ALTOS GOLD MINE

CROWNING GLORY

BASASEACHI, MEXICO. At the heart of Mexico's vast western Sierra Madre mountain range, an award-winning pillar recovery project keeps people safer while meeting tough production targets.

TEXT: **DAVID NIKEL** PHOTO: **SAMIR SOUDAH**

The flexibility and precision of Sandvik DL411 keeps operations at Pinos Altos on time and safer.

WHILE CHIHUAHUA CITY is every bit the modern metropolis, the rest of Chihuahua state, Mexico's largest, is mostly desert. Yet Agnico Eagle's Pinos Altos is one of several mines that lie in the westernmost region of Chihuahua, near the small town of Basaseachi. Famed for its slender waterfall, Basaseachi lies at the very north of Mexico's copper canyon region, known globally for its natural beauty.

Despite its altitude of almost 3,000 metres above sea level and the desert-like nature of the rest of the state, this mountainous region is surprisingly green. 'Pinos Altos' means Tall Pines in English, a good descriptor. But these mountains aren't just picturesque; they hide valuable metals that have driven Mexico's economy for decades.

International interest in Mexican mining remains strong with the country's abundant resources of gold, silver, zinc, copper and iron. Unlike many other Latin American countries, Mexico's top miners increased spending in 2017 and the outlook remains optimistic. Mexico is the world's largest producer of silver and a top-10 gold producer. The Mining Chamber of Mexico recently listed gold as the country's number one target mineral.

SANDVIK SOLUTION

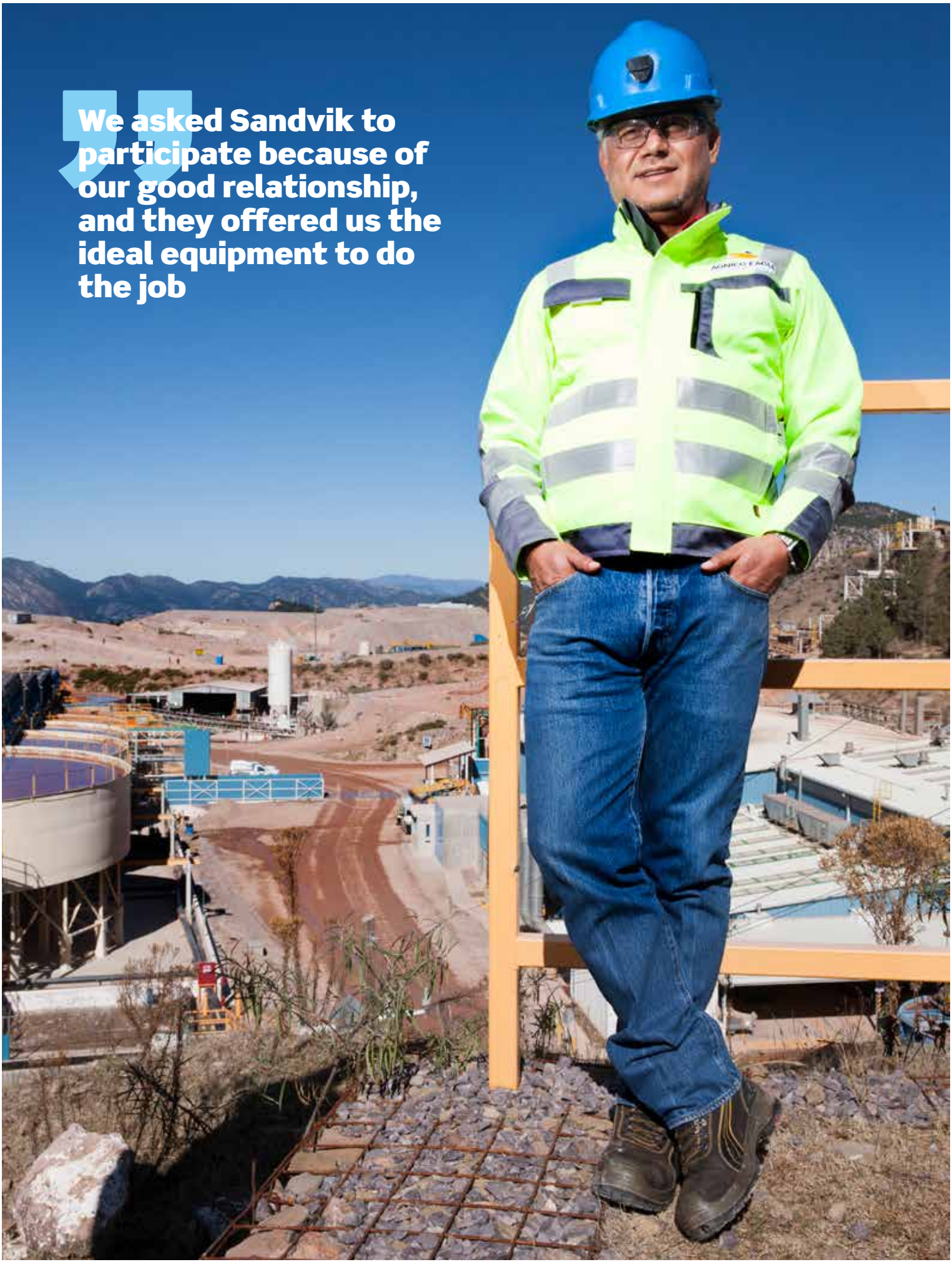
Sandvik DL411 is an electro-hydraulic, longhole drill rig engineered for large-scale production drilling in underground mines. The tele-remote functionality allows a trained operator to control the drill rig from a safe distance when there is a higher rockfall risk.

Agnico Eagle also uses Sandvik rock bolters and retains three Sandvik technicians who work full-time at Pinos Altos to provide immediate support, maintenance and advice when needed.

WHILE AGNICO EAGLE has been present at Pinos Altos since 2006, the history of mining on the site stretches back to the 18th century. While there are proven reserves, the amount of mining that has taken place previously creates added complexity today.

"After 282 metres of surface mining in the Santo Niño open pit, economic and geotechnical studies revealed it was better to continue the project underground rather than to continue with deeper surface mining," says Fernando Viezcas, underground operations manager at Pinos Altos.

AS THE GOLD mine transitioned from a combined surface and underground operation to a fully underground operation, maximizing yield and recovering the mineral-rich crown pillar without exposing employees to any additional risks became a priority. The pillar, which lies between the bottom of the open pit and upper level of the underground, challenged the


We asked Sandvik to participate because of our good relationship, and they offered us the ideal equipment to do the job

technical knowledge and operational experience of the team. The quantity and quality of its ore justified the time spent finding a method to extract the pillar with minimal risk. For this project and the ongoing underground operation, safety was paramount.

"We launched a technical feasibility study to establish if it was possible to recover ore from the pillar without generating instability for the underground operation and the pit slope," says Marco Antonio Perea Gallegos, general manager of Pinos Altos.

IN ADDITION TO its being the first project of its kind in Mexico, the technical study and proposal gained recognition from the American Rock Mechanics Association, a professional and international engineering and scientific society that promotes interaction among rock mechanics and geomechanics specialists, practitioners and academics.

"We asked Sandvik to participate because of our good relationship, and they offered us the ideal equipment to do the job," Gallegos says. "Sandvik DL411, a longhole drill rig with remote control capability, is exactly what we needed to reach our desired production targets in a safer way. I can absolutely say that our success at Pinos Altos is partly due to the long-term working relationship with Sandvik."

The good relationship extends through all levels of the organization. Fred Camuñez, one of several Sandvik DL411 operators at Pinos Altos, says the test of any relationship is when a challenge arises.

"If I have a minor issue with the rig, I just have to quickly explain it to the Sandvik technician and they get straight to work," he says. "That said, in two years working with the machine I've not yet experienced a major problem."

AGNICO EAGLE IS responsible for the full mining cycle, including drilling, blasting, extraction and backfill, currently producing at a rate of 5,500 tonnes of ore per day. Typically, operators drill in a fan pattern through rectangular blocks of 15 by 15 by 30 metres. Due to the risk of instability, a Sandvik cable bolter is used to support the drifts and excavations.

The extraction is situated in a bottom sub-level, below the stope, so there is a regular feed of broken ore available for loading. The longhole sub-level mining method improves safety and increases production, while keeping costs competitive with surface operations.

Minor issues are not uncommon at Pinos Altos because of the hard, fractured characteristics of the rock. In such a challenging environment, the flexibility of Sandvik DL411 is a timesaver.

It can drill holes with a diameter ranging from 64 to 115 millimetres and a depth up to 54 metres while the boom offers 360-degree rotation with a wide-tilt angle. Camuñez values this flexibility.

"I enjoy controlling the rig, whether I'm close up or far away," he says. "I've used other rigs, and the precision technology in Sandvik DL411 is far superior. There are so many sensors that reveal important real-time information and if we do happen to

The remote operation capabilities of Sandvik DL411 puts safety at a premium.

The existence of high-quality ore in the crown pillar at Pinos Altos necessitated the Sandvik DL411 solution.

lose a rod it's no hassle to find it and continue working. It helps me do my job in the best possible way, every day."

Sandvik DL411 features a remote operation mode that gives the operator complete control. Full functionality is offered using the same control unit. The operator can watch the drill in action in real time on a monitor thanks to the networked camera that can be placed in a suitable position next to the rig.

WHILE THE RISK of rock fall remains very low, the team at Pinos Altos take no chances. By remotely operating Sandvik DL411, the operator and support staff can be well clear of any potential problems with no drop in productivity.

This focus on safety filters through every part of the operation at Pinos Altos. As the mine can only be reached by a slow, twisting road through the mountains, employees stay locally. The mine runs buses to and from the adjacent communities and has even built a full-service camp with all services to accommodate external staff.

Within the mine complex, Sandvik has a temporary office facility in place, which allows its three service engineers to work in relative comfort with everything they need to do their jobs quickly and efficiently.

Marco Delgado is Sandvik's key account manager covering this part of northern Mexico. "Because of the time it takes to travel from Chihuahua, it's important for Sandvik engineers to be based here," he says. "A four-hour delay to a service call would make a real impact to production. The Sandvik service engineers have a great rapport with the operators. They're very much a part of one team working towards one goal here at Pinos Altos, yet backed by the support of an organization in Chihuahua City, our country headquarters in Guadalajara, and our technical experts all around the world."

More than 1 million ounces of gold reserves remain at Pinos Altos, so the future here looks bright for both Agnico Eagle and Sandvik. ■

AGNICO EAGLE

Agnico Eagle is a Canadian-based gold producer with operations in Canada, Finland and Mexico, and exploration activities in the USA. Pinos Altos was the company's first Mexican mine. The mine produced 229,243 gold ounces in 2017. Currently around 1,200 employees work at Pinos Altos.

AHEAD OF THE CLASS

In response to several current needs and trends in underground mining, Sandvik Mining and Rock Technology has relaunched and upgraded its 400i-class drill family. A common denominator across the series is strong symbiosis of sound engineering design and advanced automation solutions.

TEXT: **TURKKA KULMALA** PHOTO: **SANDVIK**

Sandvik DL432i delivers faster and more accurate drilling due to an advanced automation package and intelligent drilling systems.

THE SANDVIK 400i class offers a well-rounded package for mining and construction in drifts and tunnels 4 by 4 metres or larger: development drills for mine development, tunnelling jumbos for underground construction, cable bolters for mine safety and rock reinforcement, and longhole drills for production drilling and service support.

"While the product development for this drill family is ongoing, we particularly want to address the significant productivity, cost-effectiveness and sustainability challenges the mining industry faces today," says Jukka Naapuri, product manager for underground longhole drills at Sandvik Mining and Rock Technology. "On top of that, we also make use of the new possibilities created by big data and mining automation."

Sandvik launched its first 400i-class drill, Sandvik DD422i development jumbo, in 2013 and subsequently expanded with the electric Sandvik DD422iE. The upcoming relaunch includes Sandvik DL432i and Sandvik DU412i longhole drills and Sandvik DS422i cable bolter, as well as an extensive automation update.

"There are three crucial factors that we need to address and improve in all of the 400i-class applications: safety, productivity and process control," Naapuri says. "That requires in-built intelligence, but then you need to manage the significant amount of data the equipment generates and use it to optimize operations."

All 400i-class drills are based on standardized mechanical solutions and component commonality, with obvious benefits in terms of operator training, maintenance and spare part logistics. Common interfaces and consistent layouts are easy to learn, making it simple for operators to switch rigs when necessary.

BENEFITS

- Advanced solutions for top hammer and ITH longhole drilling and rock support drilling
- Latest components for excellent functionality and productivity
- Component commonality in all 400i drills for cost-efficient maintenance and spare part logistics
- Common user interfaces and control layouts for steeper learning curves and easier interoperability
- Advanced automation solutions for teleremote control, less downtime, higher productivity and improved safety.

SANDVIK DL432i: TOP HAMMER DRILL FOR LONG HOLES

Sandvik DL432i is the first fully automatic and digitalized longhole drill by Sandvik. Like all 400i-class drills, it links up with advanced mining automation via the AutoMine fleet management system. The main

A new adaptive air system and onboard booster increases the air system pressure from 4–7 bar up to 28 bar.

application for top hammer longhole drills is ore production with Ø64–102-millimetre holes up to 38 metres in depth, using T38, T45 and T51 MF rods or Ø65-millimetre (T45) and Ø76-millimetre (ST58) tube rods.

Sandvik DL432i offers major improvements in all three key design criteria of longhole drills that have remained unchanged for years: process control, safety and productivity.

The new drilling system, including the powerful RD927L rock drill, proven drilling module, telescopic boom with large drilling coverage and iSOLO drilling control system, lays the basis for high capacity and good process control. Jointly, these features help to produce more accurate holes at the correct length, resulting in optimal ore recovery and minimal dilution. Another benefit is optimal fragmentation for efficient loading and material handling operations.

The main safety features of Sandvik DL432i include the ergonomic FOPS/ROPS safety cabin, excellent carrier stability and accessible ground-level service points. The sound level inside the cabin during drilling has been reduced to less than 75 dBA.

In terms of productivity, Sandvik DL432i offers improvements through faster and more accurate drilling, thanks to the intelligent drilling control system, and advanced automation packages. "Our future targets include multi-fan operation based on carrier navigation, as well as remote tramming and positioning between fans," Naapuri says.

SANDVIK DU412i: IN-THE-HOLE DRILL FOR MASS MINING

Sandvik DU412i is an ITH longhole drill designed for underground mining in production drifts of 4 by 4 metres or larger. Equipped with 3-inch to 8-inch ITH hammers and Ø3-inch to Ø5-inch (76–127-millimetre) drill pipes, it can drill vertical and inclined fans and single or parallel Ø3½–8½-inch (90– 216-millimetre) long holes. In addition to conventional production and development drilling duties, the mission profile of Sandvik DU412i includes service support, where single long holes are drilled for service use or as pilot holes, to be reamed to 30 inches in slot raising applications.

The compressed air system of Sandvik DU412i relies on an onboard booster and new efficient adaptive air system control to increase the 4-to-7-bar mine air system pressure up to 28 bar. Several booster sizes are available to match the needs of different hammer sizes and specific requirements in different mines.

How do you decide when to use top hammer drills and when ITHs are better? "The primary criteria to take into account are the hole size and hole length; top hammer drills are generally used for smaller and shorter holes, while the ITH drill is more accurate in drilling longer holes and in challenging rock conditions," Naapuri says. "Then there is production volume. Larger ITH drills are better for greater production rates. Another factor is the blasting method. Some methods favour larger-diameter holes. And finally, people have their customary preferences; ITH technology originated in North America and still remains very strong there."

SANDVIK DS422i: FOR SAFE AND PRODUCTIVE ROCK SUPPORT

While Sandvik DL432i and Sandvik DU412i have in common the longhole drilling application, Sandvik DS422i is a cable bolter tasked to install steel cable bolts into the walls and ceilings of rock tunnels to prevent caving in. The productivity of the machine leans on an RD414 high-frequency rock drill and a new SICA-based drill control system to achieve a high penetration rate.

"Sandvik DS422i combines a powerful and ergonomic rig for rock support and advanced automation options, such as the cement mixer that eliminates all manual cement bag handling," says Anssi Kouhia, product manager for rock support drills. "This is a productive and safer machine for hard use."

The fully covered onboard cable reel can carry a total of 775 metres of steel strand. Thanks to the well-thought-through design of the cable reel and cement transfer screw, Sandvik DS422i has very compact external dimensions to leave safe clearance between the machine and the tunnel walls and to enable cement refills and replacing cable reel without having to tram the bolter away from the work area.

A new asset in Sandvik DS422i is the advanced boom manipulator mode, a functionality where the operator navigates the bolter boom to the tunnel segment to be bolted and locks the

Updates with Sandvik DD422i and Sandvik DD422iE development rigs include a new boom collision avoidance system and semi-automatic drill bit changer.

boom X, Y or Z axis, after which the automation system is capable of independent movement for specific boom movements.

Advanced Silver- and Gold-level automation solutions are a welcome addition for bolters. In practice the operator manually trams the rig to the correct position, after which the automation system handles the drilling cycle. Positioning the grout pipe and pumping cement into the hole again require manual control.

The automation gives the bolter automatic drilling and cement mixing capabilities, eliminating most of the tasks that would require the operator to leave the cab. The water/cement ratio and the batch size are simply typed in, and the automatic cement mixing process takes care of the rest. In addition to operator safety, this also improves the consistency of cement mixes and consequently the quality of bolting.

AUTOMATION UPDATE: BOOSTED CAPABILITIES

The new Sandvik 400i launches are also designed for continuous 24/7 operation through an automation upgrade package made available for the proven Sandvik DD422i and Sandvik DD422iE development drill rigs.

"The productivity and cost-effectiveness challenges the industry faces leave less and less room for downtime caused by shift changes, blasting and ventilation breaks," says Johannes Välivaara, product manager for underground development drills. "This is something we wanted to address with the new upgrade package."

The upgrade includes a new boom collision avoidance system based on dynamic recalculation of the boom path during automatic movements between holes, enabling identification of potential collision risks and avoiding them in advance by rerouting. This not only avoids collisions and potential damage to the equipment, but it also keeps the production running, even during unmanned operation, which significantly improves the overall reliability of automated drilling operations.

A patented semi-automatic drill bit changer addresses one of the key limiting factors of drilling productivity: manual bit changes in front of the rig. The concept includes limited automatic controls and a changer with a rack for 12 or 18 standard bits plus two reaming bits located underneath both feed rails. Worn bits are simply inserted into the rack for uncoupling and replacement with a new one.

"In addition to the productivity increase, this is also a huge safety improvement," Välivaara says. "The bit changer not only reduces the risk of ankle and knee injuries by cutting back the times the operator needs to exit and re-enter the cabin, but it also effectively limits the overall time the operator needs to spend at the face changing the bits manually."

The third key part of the upgrade is teleremote drilling control that enables uninterrupted productivity as well as improved safety and reliability through supervision and operation of the drill from a remote location. The system allows the operator to help the unit drill more holes, particularly at the profile, without taking excessive risks of wall collisions. It can also reduce the time the operator spends at the heading, improving the overall safety of underground development, particularly in geotechnically challenging mine areas.

"The great thing is that each of these new automation capabilities can also be selected as a stand-alone solution or in any combination," Välivaara says. "If there is no need for remote control in a specific mine, for example, the mine can still choose to adopt the bit changer to improve the health and safety of its operators." ■

TECH SPECS

SANDVIK DL432i TOP HAMMER LONGHOLE DRILL

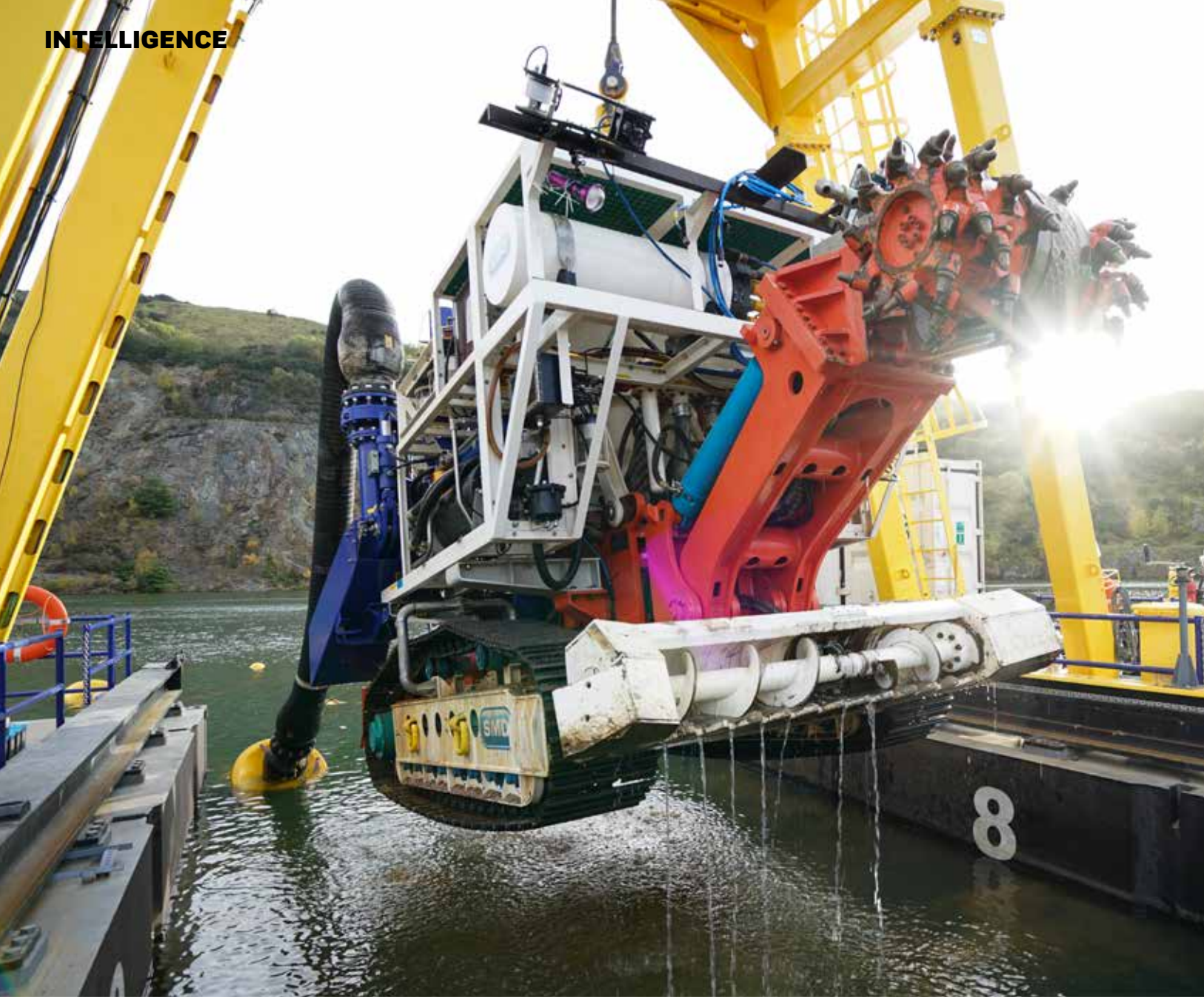
Rock drill percussion power: 27 kW
Drill rod length: 1,220–1,830 mm
Rock tools: T38, T45, T51, ST58
Hole diameter: 64–102 mm
Max. hole length: 38.1 m
Drilling coverage (vertical holes): 6 m
Diesel engine: Cummins QSB4.5, 119 kW
Safety cabin: FOPS/ROPS (ISO3449)
Automation: Single-hole and fan automation
Teleremote drilling: Full remote control
Transport weight: 26,500 kg

SANDVIK DU412i ITH LONGHOLE DRILL

Onboard booster: Up to 34 m^3/min at 28 bar (1,200 cfm at 406 psi)
Drill pipe length: 1,220–1,830 mm
ITH hammers: 76–203 mm
Hole diameter: 90–216 mm
Max. hole length: 62.2 m
Drilling coverage (vertical holes): 3 m
Diesel engine: Cummins QSB4.5, 119 kW
Safety canopy: FOPS/ROPS (ISO 3449)
Automation: Single-hole and fan automation
Teleremote drilling: Full remote control
Transport weight: 26,500 kg

SANDVIK DS422i ROCK SUPPORT DRILL

Hydraulic rock drill: 14 kW
Max. hole length: 38 m
Max. cable bolt length: 25 m
Hole diameter: 51 mm–57 mm
Automated cement hopper: 600 kg
Diesel engine: Cummins QSB4.5, 119 kW, Tier3
Safety cabin: FOPS/ROPS (ISO 3449/3471)
Transport weight: 29,000 kg



ONWARD AND DOWNWARD

The EU-funded underwater mining project ¡VAMOS! proved that conventional thinking can be overcome through canny collaboration and an innovative approach to an age-old problem.

Text: **JEAN-PAUL SMALL** Photos: **SAMIR SOUDAH**

The prototype underwater mining vehicle combined novel cutting-edge technologies to accomplish a new application.

The control cabin is where real-time data generates a virtual reality image of operations underwater.

AN OPEN-PIT MINE might be flooded for a variety of reasons, from failures in the dewatering process to groundwater filling it up. Accessing the minerals after flooding, however, has always been impossible due to an obvious hurdle: namely, thousands of litres of water standing in the way. That is, until now.

During the second trial of the Viable Alternative Mine Operating System project, or ¡VAMOS!, in October 2018, the 16 European companies collaborating to make the project a reality demonstrated that hurdles are meant to be cleared. The goal of ¡VAMOS! was to build a scale-sized prototype underwater mining vehicle to show that mining in flooded open-cast mines is not only possible but economically viable. Part of the EU-sponsored, 80-billion-euro Horizon 2020 programme, ¡VAMOS! continued with its field testing phase at the flooded Magcobar mine pit in Silvermines, Ireland.

"We're pushing everything to its limit here," says Paul Arthur, project manager at Soil Machine Dynamics (SMD), of the ¡VAMOS! trial phases. SMD integrated the industrial partner hardware at its facilities in the UK to build the actual prototype. "We're getting into beyond what we know right now, but that's the reason for the trial and why we're here."

INDEED, THE SECOND trial was time to find out what the prototype could do. "We had our first trial in Lee Moor, testing it at a kaolin mine, which is a very soft material," says Jenny Rainbird, senior research project manager for BMT group, project coordinators of ¡VAMOS!. "Coming here to Silvermines, we really wanted to test the cutting ability of the machine, how much material we can process and cutting volumes, amongst other things. So we're cutting much harder rock here at this mine."

That's where Sandvik Mining and Rock Technology's contribution came in. For the prototype mining vehicle, Sandvik provided the chassis and back stabilizer along with the cutting arm, cutter gears, cutter motors and, most importantly, the cutting head.

"We supplied a 150-kilowatt hydraulic-driven cutter head, the MA620, which is the ideal tool in this power class when it comes to cutting of stronger rocks," says Uwe Restner, product manager, Roadheaders and Digitalization, Sandvik Mining and Rock Technology. "Here at Silvermines we want to close the loop and engage the mining vehicle in hard rock formations so that we can basically interpolate between the softer and harder rock to get a complete picture about the cutting ability of the prototype."

HORIZON 2020

Horizon 2020 is the biggest EU Research and Innovation programme ever, with nearly 80 billion euros of funding available over seven years (2014 to 2020), in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world firsts by taking great ideas from the lab to the market.

WALTER RIEGLER, SERVICE technician, Sandvik Mining and Rock Technology, says Sandvik brought four different types of cutting picks with different tungsten carbide inserts for the trial. "The reason we supplied different inserts is to test the capability of the cutter under water, as we don't know what we'll encounter down below," he says.

The overall system is both complex and simple: complex due to the many different state-of-the-art technologies working together to accomplish a completely new application; simple because, at the end of the day, it's open-pit mining without some of the typical considerations such as dewatering costs, blasting, ground vibration, dust or people in the mine.

The process works like this: the underwater mine environment is mapped by EVA, a complementary system to the mining vehicle. EVA is a unique robot built specifically for the ¡VAMOS! project by INESC

> **We're getting into beyond what we know right now, but that's the reason for the trial**

Sandvik supplied an MA620, a 150-kW hydraulic-driven cutter head for the project.

TEC, a research institution in Portugal. EVA works while the prototype vehicle is cutting to continuously update the map in real time, moving autonomously on the surface and under the water body, using acoustic sonar, a camera and lasers to provide 3D images of the submerged environment to the control cabin. The mining vehicle is controlled remotely at the control cabin on land. This is where all the real-time data generates a virtual reality image of the operations underwater. The control cabin is also where the human-machine interface occurs, and operators manoeuvre the mining vehicle into cutting position.

ONCE AN AREA is chosen to begin cutting, the Launch and Recovery Vessel (LARV), which carries the mining vehicle on the water, moves to the specified location using four winches anchored to land. The LARV, designed and built by Netherlands-based Damen Dredging Equipment, can then lower the mining vehicle through the water to the mine floor, after which the vehicle can be positioned to begin cutting. Once cutting starts, the material that has been excavated from the mine floor is sucked to the surface and pumped to the dewatering facility onshore where the slurry is deposited.

The project has not been without its challenges, particularly when you consider that 16 different companies from nine countries are providing input for the creation of completely novel equipment working in a new application. "When you have different suppliers and when you merge the parts to make new equipment, then basically you have to make sure that everything fits together," Restner says. "So this was more or less the biggest challenge, but you see, the machines, the equipment, they're all operating, so we were able to get it done."

RAINBIRD CONCURS: "EVERYBODY has really pulled together. Many of the components have been manufactured in different locations and then brought together to be assembled on site. It's really been a collaborative effort.

"The collaboration with Sandvik has been excellent," Rainbird says. "They've provided the cutter head, obviously ensuring that it fits in well with the whole design of the mining vehicle. They've also been very instrumental in making sure that the whole mining vehicle itself, all the components, work together. They're a key partner in the project, so it's been great working with them."

The viability of the project for underwater mining isn't the only use being determined during the ¡VAMOS! project. The components can be used separately for different applications outside of mining. Rainbird says: "The results of the research and new technology can be used for seabed mapping, investigation for water sampling, defence, not to mention in underwater sewers or clearing submerged tunnels."

PROJECT !VAMOS! CONCLUDED in early February 2019, and the partners want to ensure that everyone gets the most out of the endeavour. "We've all agreed to see how we can take this forward to make the best of the prototype, and take this into a commercial venture," says Rainbird. ■

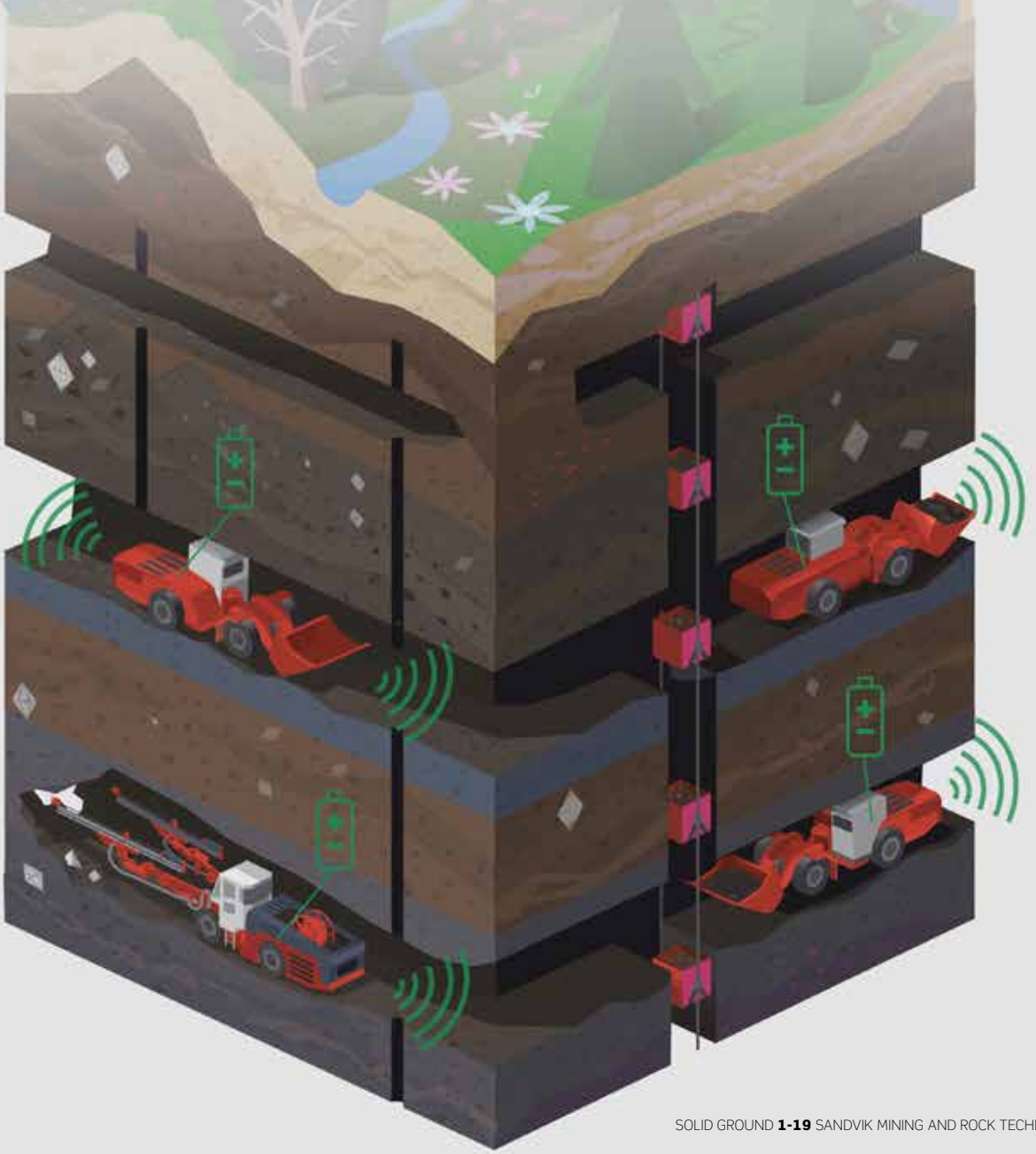
PARTNERS IN ¡VAMOS!

- BMT Group Limited – United Kingdom
- Soil Machine Dynamics Limited – United Kingdom
- Damen Dredging Equipment BV– The Netherlands
- INESC PORTO – Portugal
- Fugro EMU Limited – United Kingdom
- Zentrum für Telematik e.V. – Germany
- Montanuniversität Leoben – Austria
- MINERALIA – Portugal
- Marine Minerals Limited – United Kingdom
- SANDVIK – Austria
- GeoloskiZavodSlovenije – Slovenia
- CENTRO FUTURO – Spain
- European Federation of Geologists – Belgium
- Trelleborg Ede B.V. – The Netherlands
- Federalni zavod za geologiju – Bosnia and Herzegovina
- Fondacijaza Obnovui Razvoj Regije Vares – Bosnia and Herzegovina

Driving each other to safety

Dedicated to safe, fair and sustainable mining, the International Council on Mining and Metals is a collaboration among 27 of the world's leading mining companies and OEMs and more than 30 regional and commodity associations. Its latest programme, the Innovation for Cleaner Safer Vehicles, is an initiative to develop a new generation of sustainable mining equipment.

Text: **ISABELLE KLIGER** Illustration: **NILS-PETTER EKWALL**



MINING IS A business that will always have inherent risks, but improved safety practices and technology have been reducing these risks significantly over many years. Still, transport and mobile equipment accidents accounted for 22 percent of fatalities at major mines in 2017, making this the second-highest cause of fatalities in the sector after fall-of-ground accidents.

The industry leaders took note, and last autumn a new, ambitious plan to make mining vehicles safer and cleaner was announced at the International Mining and Resources Conference in Melbourne, Australia.

The International Council on Mining and Metals (ICMM) seeks to address the core sustainable development challenges faced by the industry. The group's latest initiative, the Innovation for Cleaner Safer Vehicles (ICSV), has brought together an unprecedented number of mining companies and suppliers in the pursuit of three common objectives: to improve vehicle interaction technology in order to reduce collisions, to accelerate the reduction of diesel particulate matter emissions, and to reduce energy costs and emissions of greenhouse gases.

PÄIVI KAUTIAINEN, DIRECTOR engineering services, Sandvik Mining and Rock Technology, explains that what makes this initiative so unique is that it has united the mining industry and OEMs around a trailblazing set of ambitious goals.

"For us, getting involved in this programme was a no-brainer," she says, adding that the issues being discussed in the ICSV are so essential to the future of mining that Sandvik's participation was a given from the moment it was invited to join the initiative.

"In this forum, companies that would otherwise view each other as customers and suppliers, and in some cases direct competitors, are sitting down together at the same table to discuss their visions and goals," she says. "This proves just how important the issue of safety is – when competitors are willing to join forces to develop the technologies that will shape the future of the industry."

THE STEERING GROUP is the operational branch of the programme, responsible for planning the work and carrying out the activities. Meanwhile, each of the three objectives has been assigned a working group to oversee it, while the CEO advisory board is the executive decision-making branch of the programme.

Sandvik is proud to be involved at every level of the ICSV organization. Kautiainen is representing Sandvik in the steering committee, while each of the three working groups includes at least one Sandvik employee. Henrik Ager, president of Sandvik Mining and Rock Technology, is one of six members on the prestigious CEO advisory board.

"One of the things that makes this programme so incredibly impactful is that it has CEO-level support within all the participating mining companies and equipment manufacturers," Kautiainen says, adding that it is an honour for Sandvik to be one of only six companies – and only three OEMs – represented on the CEO advisory board.

"I believe this is a testament to our strong reputation in the mining sector and the fact that Sandvik Mining and Rock Technology is a forerunner in key technology areas such as automation and emissions reduction," she says.

THE TIMING OF the ICSV initiative is no accident. Not only have sustainability and environmental issues never been higher on the international political

ABOUT THE INNOVATION FOR CLEANER SAFER VEHICLES (ICSV) PROGRAMME

The ICSV programme brings together 27 of the world's leading mining companies and some of the best-known truck and mining equipment suppliers to accelerate innovation to develop a new generation of mine vehicles. Its stated aims are to:

- Introduce greenhouse-gas-emission-free surface mining vehicles by 2040
- Minimize the operational impact of diesel exhaust by 2025
- Make collision avoidance technology available to mining companies by 2025.

agenda, but this has also coincided with major technology shifts in digitalization and automation. It is thanks to these technological advancements that OEMs such as Sandvik will be able to deliver the product enhancements needed to make the ICSV objectives feasible in the years to come.

ON THE AUTOMATION side, one of the principal objectives of the programme is to promote the innovation of collision avoidance technology for mining vehicles, with a view to seeing this kind of automated technology introduced by 2025. Sandvik has already developed technology with the capability to automate an entire mine, and it currently offers the most advanced automation and tele-operation systems in the industry. Its AutoMine product family covers all aspects of automation, from the autonomous operation of single pieces of equipment to full-fleet automation.

When it comes to emissions reduction, the ICSV initiative is pursuing two parallel objectives: to introduce greenhouse-gas-free surface mining vehicles by 2040, and to minimize the operational impact of diesel emissions by 2025. Sandvik is in the process of developing the next generation of battery-driven mining equipment and vehicles, with a view to being able to achieve zero carbon and particulate emissions in the future.

"The ICSV programme allows us to work with our customers, bringing our research and development activities closer to them and finding out exactly what the industry needs and wants for the years to come," Kautiainen says.

The first formal meeting of the ICSV CEO advisory board took place in October 2018, and in January 2019 the three working groups started their activities. In the next phase, the working groups met for more detailed planning and execution of the programme.

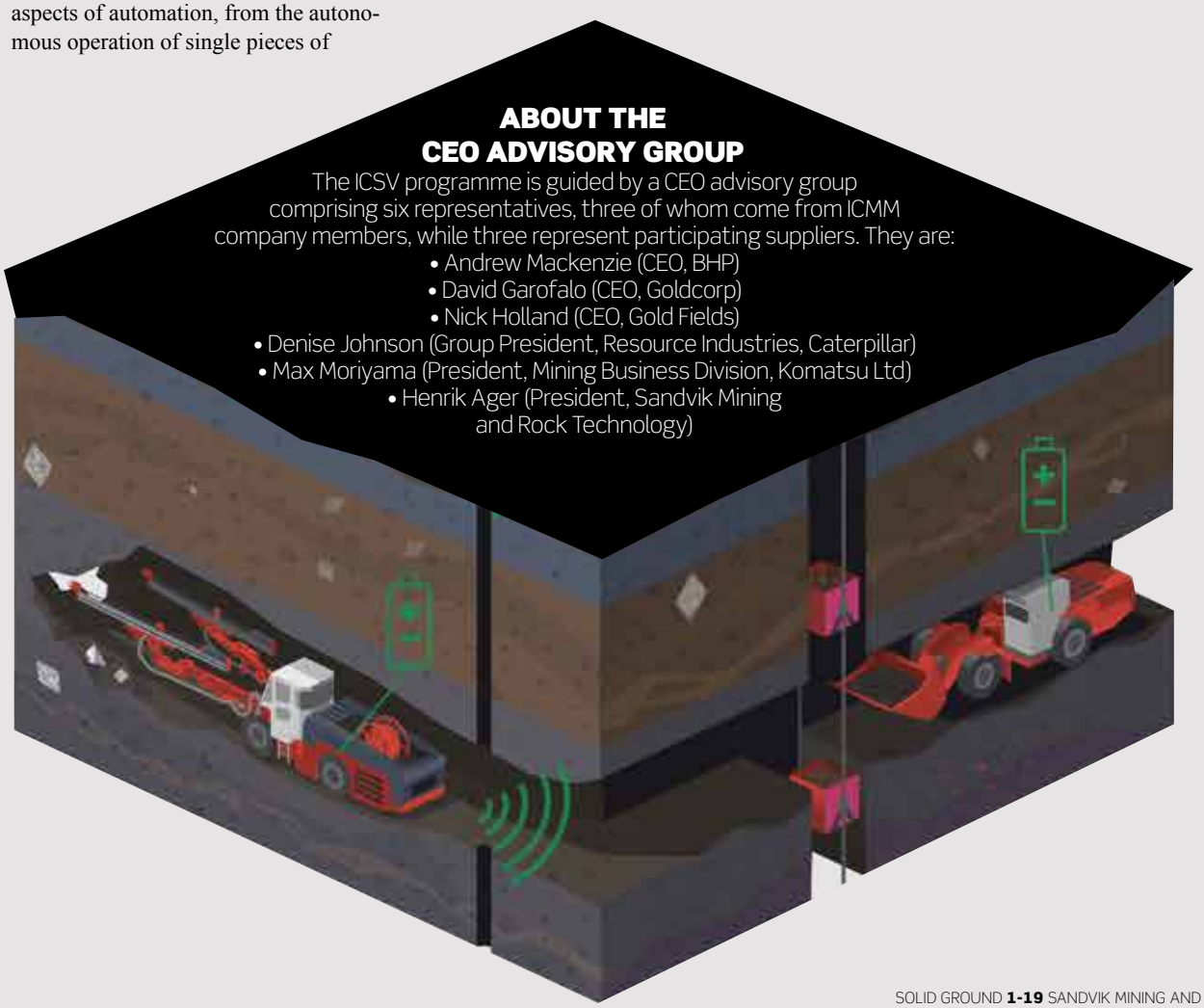
"I'm convinced the work we do here will benefit the entire mining sector, not just ICMM members," she says. "Even though Sandvik's equipment is only one aspect of the mine, we're here to do our part, to work with the mines to achieve our mission statements and secure access to cleaner, safer mining vehicles in the future." ■

> **I believe this is a testament to our strong reputation in the mining sector**

ABOUT THE CEO ADVISORY GROUP

The ICSV programme is guided by a CEO advisory group comprising six representatives, three of whom come from ICMM company members, while three represent participating suppliers. They are:

- Andrew Mackenzie (CEO, BHP)
- David Garofalo (CEO, Goldcorp)
- Nick Holland (CEO, Gold Fields)
- Denise Johnson (Group President, Resource Industries, Caterpillar)
- Max Moriyama (President, Mining Business Division, Komatsu Ltd)
- Henrik Ager (President, Sandvik Mining and Rock Technology)



What lurks beneath

Miners are a superstitious lot. This should come as no surprise given the nature of their work, which was traditionally both dark and perilous, giving rise to a range of sinister stories about what was hiding in the shadows below ground. Here are some of the most widespread legends from the mining industry around the world that continue to echo all the way down to us in the modern day.

Red-haired women (US and UK)

One of the first legends with origins in Cornwall that became established during the American Gold Rush of the mid-19th century is the superstition about red-haired women. In general, women in or near a mine are considered bad luck in many cultures, most probably because women historically only ever descended into the mines in times of tragedy. Seeing a red-haired woman on your way to work at a mine was an especially bad omen, as she was considered a portent of imminent death. It is not known why redheads in particular were seen as bad news, but it is perhaps no coincidence that the same superstition about redheaded people can also be found in maritime folklore. ■

El Tio (Bolivia)

In some parts of the world, mining can still be a hazardous business. The mines around Potosi, in Bolivia, are believed to have claimed the lives of as many as 9 million people over three centuries of colonial mining. These days, conditions have improved but risks remain. As a result, workers pray to *El Tio* (the uncle), lord of the underworld. This demonic spirit is believed to be fond of sweet treats, alcohol, cigarettes and coca leaves, which are showered over altars of his likeness by those requesting his protection. ■

Kobold (Germany)

The *kobold* (or *cobold*) is a sprite dating back to medieval Germanic mythology that has survived into modern times in popular German folklore. Normally invisible, kobolds can materialize in the form of an animal, doll, human being or fire, though they are most commonly depicted as humanlike figures the size of small children. Kobolds who live in human homes wear peasants' clothes and often inhabit dolls. Those who live in mines are hunched and ugly, while the ones found on ships smoke pipes and dress like sailors. The mining kobolds were the least friendly of the lot, known as mean-spirited, hot-tempered underground dwellers who spent their days mining precious metals. The element cobalt was named after these mischievous beings, because medieval miners blamed the sprites for the poisonous nature of the arsenical ores of cobaltite that polluted other mined elements. ■

Knockers or Tommyknockers (Cornwall)

Tommyknockers is a word perhaps best known because of Stephen King's science fiction novel of the same name, about aliens trapped underground, but in mining terms it means something else. The term knocker or tommyknocker originated in Cornwall, where superstitious miners believed goblins lived inside the mines. These supernatural creatures were believed to knock on the walls to alert the miners that something was about to happen. The knocks were usually seen as a portent of impending death, but some optimistic miners believed it meant they were about to strike it rich. When the Cornish miners eventually sought their fortunes in America, they brought their folklore with them. Belief in these diminutive beings is documented well into the 20th century, even though latter-day American miners tended to believe the knockers were the spirits of dead miners rather than goblins. ■

Boost your effectiveness

With a diverse range of equipment, software and services, Sandvik Mining and Rock Technology not only knows your business and challenges, but has the portfolio to help you augment productivity. You have a need? We've got the solution that will ensure a safer, more efficient operation above or below the ground.

ENVIRONMENT, HEALTH AND SAFETY (EHS)

Stay safe. Our objective is to eliminate harm to people and the environment. EHS is a fundamental consideration in all Sandvik operations, especially product development. Our ambition is to provide the safest products on the market. From our emission-reducing Compressor Management System for surface drills to fire protection, our products are designed to minimize environmental impact and reduce health and safety risks in your operations.

GENUINE PARTS AND SERVICES

Prioritizing uptime. In an industry where an hour of downtime can cost thousands, Sandvik 365 parts and services can save you millions, with round-the-clock service, qualified engineers and genuine parts on demand. When you can predict your productivity, you predict profitability. We not only supply industry-leading mining and construction equipment, our comprehensive aftermarket offering includes service solutions to add even more value to your operation, and genuine parts to extend your equipment lifetime.

SURFACE DRILLING

Power and precision. Sandvik surface drilling equipment is renowned for durability, reliability and productivity. For decades, our surface top hammer, surface down-the-hole and dimensional stone drilling rigs have delivered low total cost of ownership in quarrying, opencast mining and construction applications. We specialize in engineering surface drilling equipment that marries power and precision while improving operator safety and productivity.

UNDERGROUND DRILLING

Know the drill. Sandvik underground drill rigs are engineered to maximize your productivity in mining and tunnelling applications. Equipped with high-performance hydraulic rock drills, they are ergonomic, efficient and reliable. Every underground drill rig and rock drill we engineer is designed to deliver you the lowest possible cost per metre drilled and a low life-cycle cost. Our drills range from robust, simple rigs to automated units that deliver extraordinary production rates.

CONTINUOUS MINING AND TUNNELLING

Always advancing. Sandvik continuous mining and tunnelling equipment reflects the unique advantages of total in-house control over the equipment and cutting tools alike. Optimized cutting technology and machine design result in high productivity, long service life and low total costs.

LOADING AND HAULING

Reliable loaders and trucks. Sandvik underground loaders and haul trucks are engineered for safety, productivity and reliability in the toughest of applications. Rugged, compact and highly manoeuvrable, the ergonomic products offer enormous capacity for their size and return a very low cost per tonne.

CRUSHING AND SCREENING

Maximum size reduction. Sandvik crushing and screening solutions are engineered for productivity in mines, quarries and civil engineering projects. We offer advanced solutions for any size-reduction challenge, stationary or mobile. We can upgrade existing plants, deliver complete solutions and effect turnkey installations. We also supply individual crushers and screens, as well as key components and consumables. Whether you're crushing tonnes of hard rock or producing several-sized aggregates with our mobile screens, our solutions deliver the robustness and versatility you need.

BREAKING

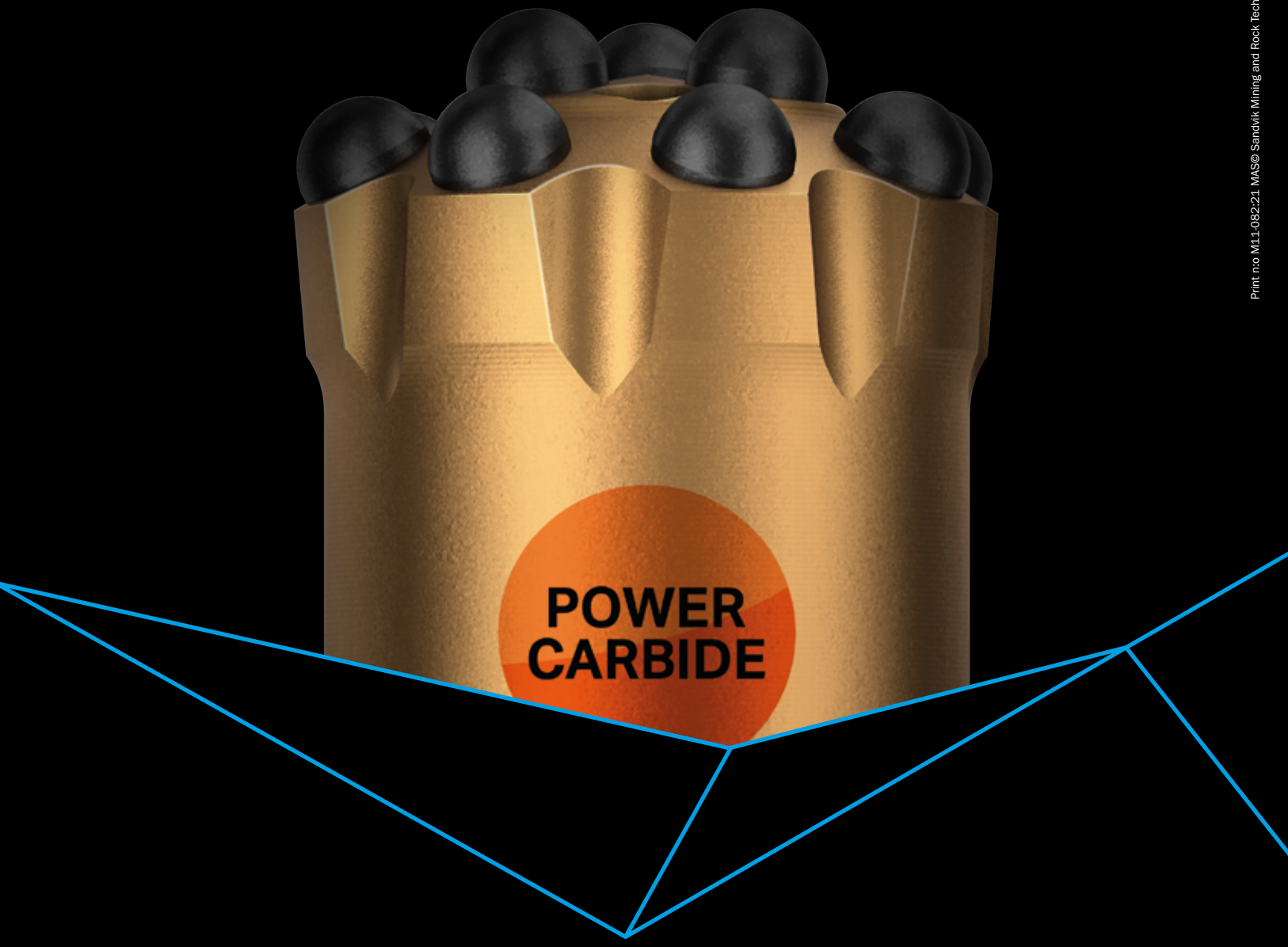
Hit harder. Sandvik breakers and demolition tools make short work of difficult jobs. They are optimized to deliver high-impact cutting or crushing forces, with high power-to-weight ratios, easy interfaces and simple connections. Whether you're looking for breaker booms for your crushing applications or hydraulic breakers for your demolition projects, we have the precision tools and equipment you need to get the job done efficiently.

MINE AUTOMATION

Complete control. The AutoMine family covers all aspects of automation, from single equipment to full fleet control. In the safety and comfort of a control room, operators can simultaneously control and monitor the movements of a fleet of driverless loaders, trucks or drill rigs. By adding remote monitoring and process management capabilities, supervisors are able to directly communicate with equipment and operators from wherever they are working.

ROCK TOOLS AND SYSTEMS

Deep impact. Sandvik offers the world's most comprehensive range of tools for exploration, rock drilling, raise boring, coal cutting, mineral mining, tunnelling, trenching, road grading and cold planing. As world leaders in steel and cemented carbide technology, our products have revolutionized the rock drilling industry, while our advanced tool systems for mining equipment raise productivity sharply.



IT'S THE INSIDE THAT MATTERS TO THE BOTTOM LINE

PowerCarbide is a gathering of our most powerful carbide grades. With its outstanding performance PowerCarbide improves your results. In your drilling operation as well as in your business.

ROCKTECHNOLOGY.SANDVIK/POWERCARBIDE

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