

resourceful



BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY

DATA MINING

HOW NEW SENSORS AND DATA
ARE DRIVING MINING DECISIONS



Data driven mining decisions

Rapidly evolving digital technologies are providing opportunities to enable both better and faster decisions by making relevant data available across the minerals value chain.



QUICK STATISTICS

- Advanced analytics applied to complex ore processing operations can lead to yield improvements in the order of \$20-\$50 billion of additional earnings globally (based on comparable applications).¹
- By 2025, data used to improve equipment maintenance may result in 5-10% reduction in maintenance costs.²
- Globally, the Internet of Things (IoT) is estimated to have an economic impact of US \$160-\$930 billion per year on mining, oil and gas and construction industries by 2025.²

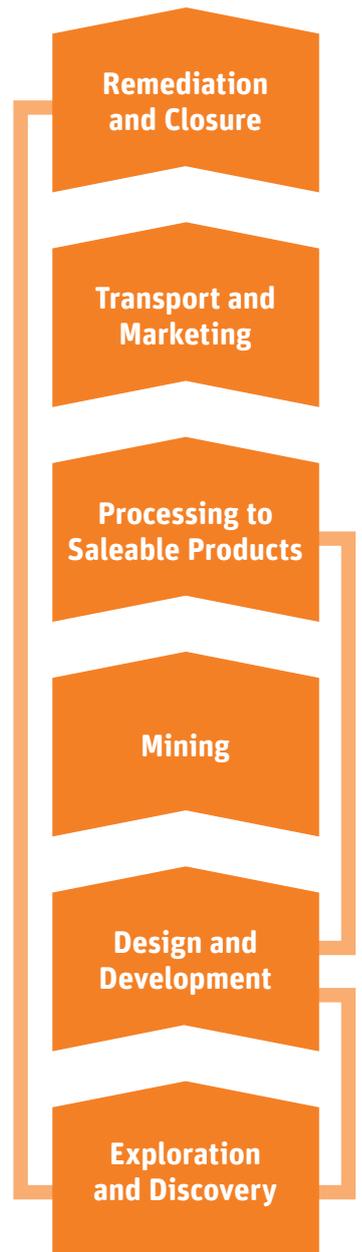


1 Durrant-Whyte, H. et al. (2015). *How digital innovation can improve mining productivity*, McKinsey & Company.

2 Manyika, J. et al. (2015). *The Internet of Things: Mapping the Value Beyond the Hype*, McKinsey Global Institute, McKinsey & Company.

Read about this key growth opportunity for mining equipment, technology and services (METS companies) in CSIRO's METS Roadmap: www.csiro.au/METSroadmap

Data driven mining decisions



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LEADER'S COMMENT

RE-IMAGINING MINING IN THE DIGITAL AGE

Digital innovation is a way to pull the levers of mining in an entirely new way – offering integration, speed and re-invention. **JONATHAN LAW** writes

Real-time sensing, data integration and interrogation, interoperability, artificial intelligence and automation are all buzzwords that battle for traction in today's mining industry. That's hardly surprising because digital innovation provides many ways to focus on the challenges facing the industry today through:

- **Integration** – the ability to optimise across the value chain and choose the scale and selectivity of operations;
- **Speed** – the ability to make decisions quickly and hence impact on operational performance in near real time; and
- **Re-invention** – the ability to consider technology options outside of the traditional mining constructs.

A KEY PART OF THIS DIGITAL TRANSFORMATION IS THE ABILITY TO PROVIDE ACCURATE, RELEVANT AND USEFUL DATA ON RESOURCES AND MINING. WITH A DEEP UNDERSTANDING OF THE VALUE OF DATA TO THE MINERALS VALUE CHAIN, CSIRO IS FOCUSED ON DELIVERING NEW DATA TECHNOLOGIES IN A WAY THAT MAXIMISES IMPACT AT THE OPERATIONAL LEVEL.

As explored in this edition of **resourceful**, the latest sensors and data technologies are bringing a new level of knowledge to underpin triple bottom line decision-making.

Lab-at-Rig brings mineral analysis to the exploration drill site – enabling million dollar decisions to be made in minutes. Meanwhile, advanced magnetic resonance technology is enabling bulk ore sorting on a conveyor for copper and iron miners, offering a step change in productivity.

The benefits of real-time analysis also flow downstream, with a new on-line analyser for gold processing plants that allow value to be recovered from waste.

While new data grows exponentially as a result of these technologies, our focus is on how to analyse it to enable precise predictions and models.

Breakthroughs are being made, such as our new software tool, Rosetta, which demonstrates how analytical data can be pulled from a range of sources to predict ore quality and build a more complete picture to plan where to mine and manage downstream processes.

Importantly though, it's not just the operational side of mining that will benefit from new data technologies.



Jonathan Law

CSIRO's new Reflexivity solution is collecting and analysing rich data to provide companies with social performance insights over space and time, in a way that's not been achieved before for resources companies. This breakthrough development is changing the way that companies, like Rio Tinto, engage with the communities in which they operate to build greater trust.

While these breakthroughs are benefiting the industry today, to realise the full value of the digital revolution – that is integration, speed and re-invention – we have to look at how each different technology comes together to form a solution for the industry's complex challenges.

Industry, government and the research sector need to come together to clearly articulate what the solutions are, so that we can map a clear pathway forward towards developing and integrating the all the required technologies. ●

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SENSING WHERE TO EXPLORE NEXT

Sensor developments through the Deep Exploration Technologies Cooperative Research Centre are enabling fast onsite analysis of a range of elements and minerals, helping explorers more cost-effectively navigate greenfields exploration.

TIM THWAITES reports

A new sensor that expands the range of elements and minerals that can be detected and assessed, as well as faster, automatic analysis software, are being added to the Lab-at-Rig technology.

By bringing the laboratory to the drill site, Lab-at-Rig allows companies to make multi-million dollar decisions in minutes rather than months.

The technology has been developed for mineral exploration by a CSIRO-led research team in the Deep Exploration Technologies Cooperative Research Centre (DET CRC).

The latest advances increase the technology's capacity to provide practical information to geologists and drillers in real time. They also bring Lab-at-Rig closer to playing a significant role in both the DET CRC and CSIRO strategies for efficient, cost-effective exploration for mineral resources underneath surface

cover – the blanket of deeply weathered rocks and transported sediments that covers about 80 per cent of Australia.

“The major advantage of Lab-at-Rig is that it obtains data on minerals in real time from a hole you are drilling,” DET CRC's CEO, Richard Hillis, says.

“That might lead you to continue a hole you would otherwise terminate if there are encouraging results. It might also permit you to drill a follow-up hole without waiting for lab analysis and expensive demobilisation and remobilisation of the drill rig and crew.”

Lab-at-Rig was initially developed for diamond drilling by a research team led by CSIRO principal research scientist, Dr Yulia Uvarova. It is designed to analyse the chemistry and mineralogy of rock chips or cuttings brought directly up from bit to surface in the constant stream of drilling fluids. The exact location of the chips can be calculated from the depth of the bit and the speed of fluid flow.

The rock particles are then dewatered, dried, packed and analysed using x-ray sensors. The first two sensing technologies used for this purpose – in collaboration with imaging company Olympus and mining technology company Imdex – were x-ray fluorescence (XRF) spectrometry and x-ray diffraction (XRD).

Lab-at-Rig has been licensed by REFLEX, a subsidiary of Imdex, and has been involved in numerous extended trials, including in the USA. The sensors provide accurate concentrations, as well as mineral abundancies, of elements such as copper, iron, zinc and silver out in the field, a process that could otherwise take months in a laboratory and cost hundreds of dollars a sample.

“These x-ray sensors do not deliver accurate concentrations for gold and rare earths, and can't be used to detect elements lighter than magnesium, such as sodium and carbon, which are important to geologists,” Dr Uvarova says.

To address this gap, Dr Uvarova's team is working on a third sensor based on laser-induced breakdown spectroscopy (LIBS).

Until now, this technology had been more of a laboratory research tool for the analysis of pharmaceuticals, alloys and other non-geologic materials. However, there have already been encouraging results from prototypes developed for Lab-at-Rig with the help of technical and user advice from the CRC's partners.

Dr Uvarova's team is also working on what it calls a fluid management system – an ability to analyse the drilling fluids using ion-selective electrodes. This can provide information to drillers on pH, temperature and conductivity – for protecting equipment – and also on concentrations of ions such as calcium, chloride and sulfide that are used in geological interpretation.

All these facets of Lab-at-Rig are in the process of being recast to fit in with coiled-tubing (CT) drilling, a technology from the petroleum industry that the CRC has modified for mineral

“The major advantage of Lab-at-Rig is that it obtains data on minerals in real time from a hole you are drilling.”

Richard Hillis, DET CRC

exploration. Instead of the standard, three-metre rods used in diamond drilling, a continuous coil of 500 metres of tubing is used. The tubing is carried on a light (15-tonne) mobile drilling rig mounted on caterpillar tracks that can easily be transported on a low loader. Drilling with a continuous coil removes the need to connect and disconnect drill rods, making it faster, cheaper and safer than conventional drilling.

THE CT TECHNOLOGY CAN DRILL ABOUT HALF A DOZEN HOLES FOR THE SAME COST AS ONE CONVENTIONAL DIAMOND HOLE. WITH THE MOBILITY AND RELATIVELY SIMPLE SET-UP OF THE NEW LIGHTWEIGHT RIG AND USING LAB-AT-RIG'S REAL-TIME DATA, IT WILL BE POSSIBLE TO UNDERTAKE AN EXPLORATION PROGRAM OF DRILLING MULTIPLE HOLES THAT PROGRESSIVELY VECTOR TOWARDS MINERAL DEPOSITS.

The rapid speed of CT drilling makes the new software critical.

“SwiftMin, the new software for processing of XRD data, for instance, replaces time-consuming laboratory analysis,” Prof Hillis says.

“That’s critical because the new CT drilling should be covering about 50 centimetres a minute. Therefore if you want metre-by-metre analysis down the hole, you need an XRD reading and analysis every two minutes – and that’s a huge challenge. Such automated processing of XRD data is critical for Lab-at-Rig to keep up with the rapid, cheap drilling we’re doing.”

The CT drilling technology has just been offered to DET CRC’s supplier participants Boart Longyear and Imdex for commercialisation. ●

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A ROSETTA STONE FOR ORE

A new software tool, dubbed Rosetta, pulls together analytical data from a range of sources to understand the characteristics of an orebody, enabling exploration and mining companies to predict ore quality and evaluate and plan for mining and processing. **TIM TREADGOLD** reports

Taking its name from the world-famous Rosetta Stone, which provided the clues to deciphering ancient Egyptian hieroglyphics, is a pointer to what a new technology does for mining companies. CSIRO's Rosetta provides an illustrated guide to the characteristics of ore.

Unlike the Egyptian Rosetta Stone, which is now the most popular exhibit in the British Museum, the new Rosetta is not something that can easily be seen. It is effectively a data-driven software tool that involves pulling together analytical data gathered from measuring one or more samples and then using that knowledge to predict the character of rock to know where to mine.

The importance of studying the physical and chemical composition (e.g. mineralogy, chemistry and lithology) or "characterisation" of ore, lies in the way the acquired knowledge helps in understanding the quality of the rock during exploration targeting and how it will behave when mined and processed.

The machine learning process is how Rosetta gets its name, because on the Egyptian stone, three languages bearing the same message enabled a scholar who knew one of the languages (ancient Greek) to read the hieroglyphics and a third language on the stone, demotic script.

Multiple layers of historical analytical data can be fed into the Rosetta tool. Hyperspectral information is one, but other examples of low cost data being fed into the learning process include x-ray fluorescence, and even core photography.

FROM A REPRESENTATIVE SAMPLE, ROSETTA BUILDS A CHARACTERISATION IMAGE OF THE OREBODY. THAT KNOWLEDGE BECOMES PART OF A PROCESS THAT PROGRESSIVELY ELIMINATES UNCERTAINTY THROUGH THE ADDITION OF MORE REPRESENTATIVE SAMPLES – ALL LEADING TO A POINT WHERE A PREDICTION ABOUT ORE QUALITY IN EXPLORATION AND ORE BEHAVIOUR IN MINING AND PROCESSING CAN BE MADE.

Trials of Rosetta in brownfields exploration at one of Australia's biggest base metal mine sites have been successfully undertaken. It's added a layer of confidence in the tool and its

future use as a cost-saving process for existing mines with future potential in greenfields exploration.

CSIRO's resources data science research manager, Ryan Fraser, says the challenge that led to developing Rosetta, was finding a way to utilise the vast amounts of data gathered in mining and processing.

"Miners have many ways of analysing the rocks they're proposing to mine, as well as the material they're planning to process," Mr Fraser says.

"Ultimately, the data integration solution at a mine is to use all of these sources to predict, for example, how much effort and cost it will take to dig the ore and put it through some kind of process.

"One way of answering the question of characterisation is to drill additional holes and assay the samples recovered.

"That would tell you a lot about the rocks in the mine, but it is an awfully expensive way of doing it.

"So, not all characterisation is equal in terms of the cost and the time it takes to get it."

Rosetta's advantage is that geoscience principles are "baked" into machine learning and analytical models to provide relevant predictions.

CSIRO geologist and resources data science lead, Jess Robertson, says a simple example of characterisation might be assessing rock chemistry, such as measuring how much gold or copper is present.

Looking deeper it can be important to know what other minerals are in the rock because some of them will go through the flotation stage of the treatment process, while other minerals do not.

“Hardness is another important measure, so we use characterisation as an umbrella term for all the different facets of a rock,” Dr Robertson says.

Both agree with a suggestion that the hunt for characterisation can be loosely equated with seeking “soul of the rock”, or its DNA to describe it another way.

Gaining the knowledge of what makes up a particular rock type is not cheap, which means bracketing the data being gathered into cheap-to-get data, and expensive-to-get data.

For example, one step involves using hyperspectral scanning, which is relatively low cost to use, although the machine itself is expensive.

When applied to drillcore, hyperspectral scanning provides a highly detailed picture of the mineralogy of a core sample that can be produced within minutes. An expensive alternative is sending rocks for assay and waiting weeks for the results.

Other tests become part of the overall Rosetta software tool, such as measuring how well a rock crushes and how easily a mineral can be liberated.

As more samples are processed, a library of information is developed, providing a picture of the mine and its orebody that can help determine inputs such as the energy required in processing.

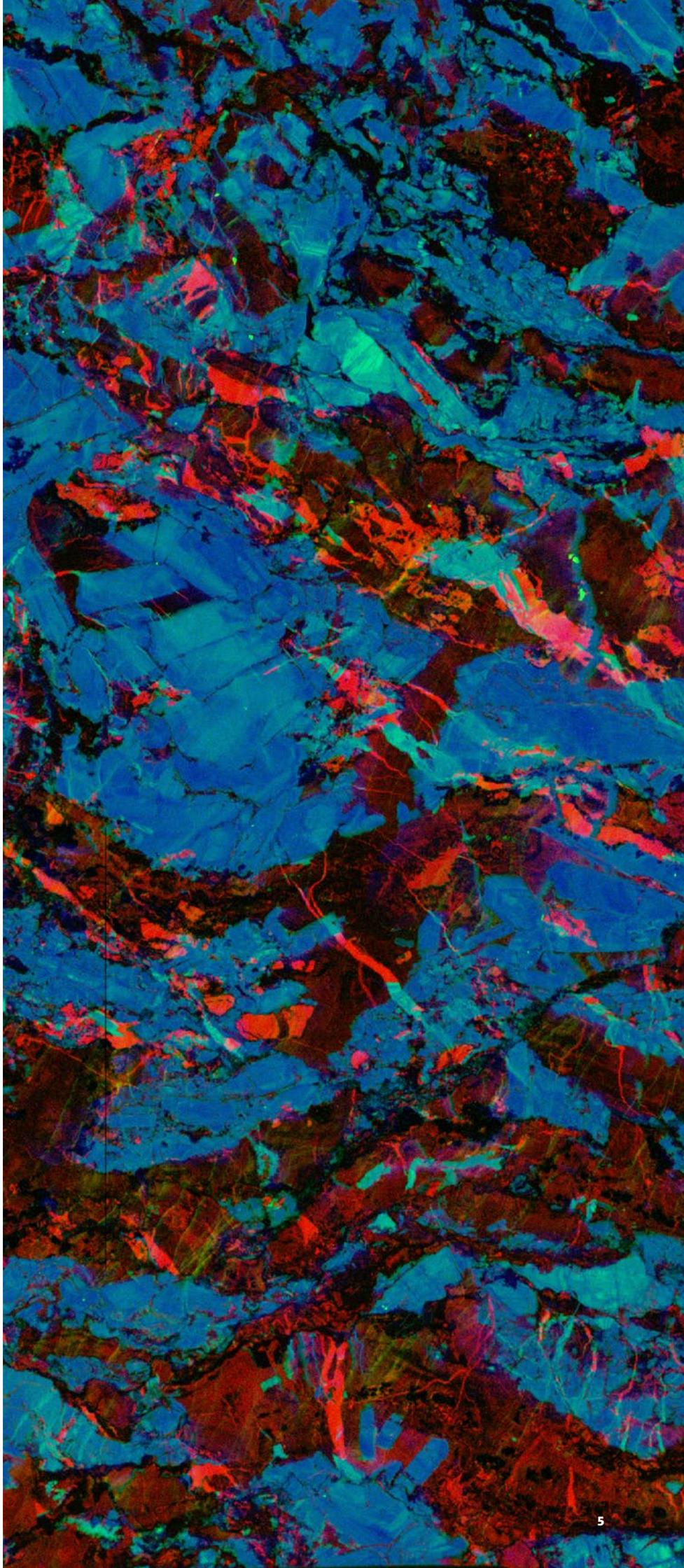
Rosetta is a tool to aid rapid characterisation of ore, building orebody knowledge to drive efficient planning, improved control and decision-making. ●

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GOLDEN ALTERNATIVE

The tiny West Australian town of Menzies is the setting for a gold processing demonstration plant that aims to reinvigorate small gold miners with a cost-effective and environmentally-friendly alternative to cyanide. **TONY HESELEV** reports

A low cost demonstration plant for technology that can overcome the environmental risks and regulatory barriers associated with the use of cyanide in gold recovery, could hold the key to unlocking stranded Australian deposits.

The demonstration plant, which will open in 2018, is at the centre of a collaboration between CSIRO and small producer Nu-Fortune Gold.

The plant is being built in the West Australian goldfields at Menzies, 130 kilometres north of Kalgoorlie, where Nu-Fortune Gold leases the old stamp battery site from Perth Mint and currently produces small-scale gold bars with a mill and gravity circuit.

The plant will demonstrate CSIRO's thiosulfate-based recovery process – a non-toxic reagent to dissolve the

fine gold out of ores (the gold that is not recovered by gravity) and its application – in the next stage towards its commercialisation.

The method has undergone intensive testing in the laboratory to understand its leaching performance in association with reagent recovery and recycle. Results indicate that it can be applied to a range of ore types, as opposed to a highly specific alternative to cyanide developed by Barrick Gold together with CSIRO at its Goldstrike mine in Nevada in 2014.

The demonstration plant aims to prove at scale that the reagent (or lixiviant) can economically recover gold in an alternative process to techniques using cyanide, overcoming a range of health, safety and environmental risks and associated regulatory obstacles.

Nu-Fortune Gold director, Paul Hanna, says the company believes there is a risk that within the next few years many countries will ban cyanide in gold production. It has already been banned in some states in the USA and parts of Europe.

"It piqued our interest because we were searching high and low for an alternative to cyanide at our battery," Mr Hanna says.

"We're an entrepreneurial company, and the fact that we could be market leaders in the application of this technology is very appealing to us. Also appealing is the relatively low capital expenditure requirement, which essentially gives us a low cost entry into being able to treat our own gold."

CSIRO and Nu-Fortune Gold envisage the plant being used as a gold processing research hub. This would provide opportunities for the research organisation to demonstrate the method on a greater range of ore types from other gold miners, enable equipment suppliers to trial and develop customer-driven solutions in collaboration with industry and researchers, and provide opportunities for research and training of metallurgical students.



It piqued our interest because we were searching high and low for an alternative to cyanide at our battery.

Paul Hanna, Nu-Fortune Gold

Processing infrastructure is being built out of modular components and the Menzies site is expected to be used for ongoing research and development for several years.

The longer-term vision is for mobile processing facilities that can unlock gold deposits stranded by factors such as resource size and transport costs.

“It works for us because we’ve got the infrastructure there and we get first look at any new technologies developed,” Mr Hanna says.

Having gone through the CSIRO-managed national science and technology accelerator program, ON, the team has gone beyond the science to look at the whole process and its economics. Through ON, they interviewed potential customers to identify opportunities where the thiosulphate could be applied and examined “investment readiness”, such as business and equity models, funding options and founder agreements.

The team identified a lack of opportunities for miners with smaller deposits that did not fit into the large-scale economics of gold processing plants using cyanidation.

CSIRO team leader, Paul Breuer, says they started by taking a step back and looking at the miners with gold deposits who can’t use cyanide or can’t afford the capital expenditure of a typical processing plant (costing about \$30 million).

“We asked ourselves whether we could come up with a solution for these miners, in this case a novel processing plant costing \$1 million or \$2 million that could be used without having all the regulatory hurdles to jump over.

“We realised we could knock down a lot of those hurdles.”

Dr Breuer says that gold recovery rates would be very similar with the alternative reagent. However, higher concentrations were needed than with cyanidation, meaning that initiatives such as dry tails stacking and nanofiltration were required to recover and recycle the reagent and minimise water use to make the process economic.

While more components are needed in the new process and the configuration is unfamiliar to the industry, it is not complex because standard off-the-shelf equipment is used. The plant can also

be customised to deal with different ore types.

“One of the main challenges of the new process is overcoming the perceived risk of adopting a new technology that is unproven at scale,” Dr Breuer says.

“The best way of proving this is with a demonstration plant. We could have built a pilot plant at CSIRO but we wanted to get operator/end user involvement early so that we make sure the developed process is robust and practical.

“These plants need a little bit more intuition and control around the chemistry and we’re working to make it as simple as possible so that it can be adopted as widely as possible.”

The \$2.1 million project to construct, commission and operate the demonstration plant in 2017-18 is being supported by an \$860,000 grant from the Science and Industry Endowment Fund. ●

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CAVE TRACKING

The Australian-developed Cave Tracker provides valuable information and insight into the previously, almost invisible process, of block cave mining.

DAVID SIMPSON reports

The scale of block caving operations ranges from large to enormous – stretching hundreds of metres to kilometres in length, as well as depths of up to thousands of metres.

The risks and uncertainties of dealing with substantial amounts of material collapsing, in often unpredictable fashions, can lead to inefficient processes and hazardous situations.

This is where the Cave Tracker is delivering significant improvements to conventional block caving. The technology has been developed by Mining3, Newcrest Mining, Rio Tinto and Elexon.

Typically used to mine large, low grade orebodies, block caving involves the creation of an undercut level and haulage access, known as drawpoints.

Caving has two distinct phases: cave initiation/propagation and cave flow or steady-state production. Caves are initiated with blasting and extraction of the orebody immediately above the drawpoints, so that the now unsupported rock above the undercut breaks gradually (caves), while more rock is being removed at drawpoints.

This caving process continues until the zone of broken rock typically extends to surface. It effectively produces a large-scale bin of broken rock that is available for extraction at drawpoints during the steady state production phase. The advantages of this method include that most of the rock doesn't need blasting for fragmentation and that, once ramped up, mining processes are highly efficient and standardised.

During this phase, techniques known as cave engineering are used to control the caving process. The volumes of caved material can be massive and the rock sizes range from dust to very large boulders during production.

During the process, it's difficult for operators to assess how the caving process is progressing and where the ore originated from. Besides the ability to exert control over the recovery of ore, monitoring cave propagation is critical for managing safety risks such as air-blasts.

CAVE TRACKER PROVIDES A MORE PRECISE UNDERSTANDING OF MOVEMENT DURING THE CAVING PROCESS, SUCH AS HOW THE ORE MOVES TOWARDS DRAWPOINTS, TO ENABLE FASTER DECISION-MAKING. MEANWHILE, MORE ACCURATE KNOWLEDGE OF THE LOCATION AND SIZE OF VOIDS (AIR-GAPS) CAN DECREASE THE LIKELIHOOD OF A COLLAPSE, FOLLOWED BY A CATASTROPHIC RAPID DISPLACEMENT OF AIR (AIR-BLAST) THAT MAY SPREAD AIR-PRESSURE WAVES THROUGHOUT THE MINE.

Before Cave Tracker, monitoring the flow of caved ore was only possible using markers. Embedded in the orebody, these markers are detected at drawpoints. This method was limited as movement could only be identified retrospectively. Also, the exact path of the ore could not be tracked as it moved inside the cave.

The Cave Tracker uses extremely rugged devices (beacons) containing strong permanent magnets embedded in the orebody, which are spun to generate a magnetic field.

These magnetic signals are measured by detectors through up to 200 metres of rock. The signal is used to determine the 3D location of beacons and when combined with the locations of other Cave Tracker beacons, can enable 3D modelling of the cave and an indication of how the material within it is breaking up and flowing.

"Being able to measure ore flow and modifying draw strategy in real-time substantially reduces waste and avoids significant loss of value," Mining3 chief executive officer, Paul Lever, says.

Available for commercial purchase through Elexon Mining, the Cave Tracker advantages include: real-time material movement mapping, improved process control and mine planning, maximised recovery, reduced risks and uncertainties, minimised dilution and increased safety. ●

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LOW IMPACT MINING

THE VIRTUAL MINE

Mining3 is commercialising a 3D-based software platform that can create and simulate a virtual mine. By positioning precisely where things are underground, it opens up opportunities such as controlling robots and tracking movement of ore of different grades. **TIM THWAITES** reports

Imagine being able to control a vehicle or drone inside a mineshaft from anywhere in the world without fear of it crashing into mine walls or workers.

Picture being able to track the metal in a car chassis from ore to finished product.

Or, consider the ability to store data so that it interacts automatically with information from other sources to provide a more profound understanding of a mine and its grade.

Such things are fast becoming possible using a new 3D-based internet platform known as VoxelNET. The technology has been developed through Mining3 – an industry-funded partnership between industry, original equipment manufacturers (OEMs) and several research groups that include CSIRO.

“VoxelNET is all about a more efficient way of storing, analysing, sharing and visualising spatially-based information,” CSIRO 3D system researcher and Mining3 technology leader, Charlotte Sennersten, says.

“It is ideal for spatially-based enterprises, but particularly for the mining and minerals industries.”

The internet system we currently use to store, analyse, transmit and display information was built for handling 2D text and documents. It has to be modified with software plug-ins to work and display information in 3D and VoxelNET supports this directly.

VoxelNET can be used to generate a virtual mine and simulate its operation in 3D. It stores remote sensing information on the fly and enables the tracking or control equipment or material remotely. It’s also able to be shared and accessed by different devices simultaneously and can pull data from a range of sources such as sensors, CAD files and point cloud devices.

The virtual 3D space is made up of voxels, an equivalent to 2D pixels on a screen. Voxels are cubes, the size of which can be defined to fit the task at hand. Each voxel in VoxelNET can be precisely located.

The voxels can hold information such as density, ore grade, rock hardness, or even safety regulations and legal requirements. They can be programmed to store, integrate and cross-correlate data from many different sources. They can also act autonomously to find and process data, and to interact with each other in precise ways.

The voxels come in several different varieties. “Spatial voxels”, for instance, are linked directly to a precisely defined one-metre by one-metre grid of the Earth’s surface – from five kilometres underground to 20 kilometres above ground. They can be used to simulate and connect to reality.

Whereas, the matter within “material voxels” can be labelled and traced wherever it moves. Every step and

change can be accounted for using the new blockchain technology. The provenance of ores of different grades can be sourced and traced to enable precise planning for mining with lower impact.

Voxels and the data they contain can also be subject to different defined layers of security. Broad access can be allowed to some information or simulations, while access to more confidential information can be restricted. Data can be spatially tagged or completely anonymised.

The platform already allows input of drillhole data, real-time vehicle data, remote-sensing data and 2D and 3D maps by a single client or user. The applications supported include simulation, remote vehicle control and interactive visualisation.

At present, VoxelNET is only available through consultation with researchers at Mining3.

Next year, it is hoped it will be released as a commercial product. Mining3 is looking at how to support its ongoing development into a cloud-based distributed platform. ●

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SORTING OUT WASTE

Mining low grade ores is costing companies heavily on processing tonnes of waste rock. By rapidly sorting high value ore from waste on a conveyor using magnetic resonance technology, bulk ore sorting offers a step change in productivity for copper miners.

ADAM COURTENAY reports

CSIRO's partnership with industry players Advisian and RFC Ambrian to produce the next generation bulk ore sorting technology is now being closely looked at by potential buyers.

NextOre, the company being formed by the three partners, has developed an advanced sensor system that takes advantage of magnetic resonance technology. It illuminates batches of ore with short pulses of radio waves, assessing ore grade and enabling high tonnage sorting at extremely high speeds.

NextOre's ore sorter is able to detect the magnetic resonance signatures of many minerals, including the most common economically significant iron- and copper-bearing minerals. It also has the ability to detect arsenic-bearing minerals that are often positively correlated with gold in sulphide ore deposits. It can see through large ore batches in real time as they pass by the sensors contained in an open-ended chamber.

The magnetic resonance technology (MRT) is often compared with the way MRI technology is capable of "seeing into" human bodies.

RFC Ambrian associate director and acting CEO of NextOre, Chris Beal, says the industry reaction to this ore sorting technique has been very positive. It can pass material through at the rate of 5000 tonnes per hour, being able to distinguish "the wheat from the chaff" in seconds.

"The R&D phase is over," Mr Beal says. "It's now about getting the industry to implement it and while we can't yet mention names, most of the global mining houses investigating operational improvements through the application of advanced technologies are looking at this solution."

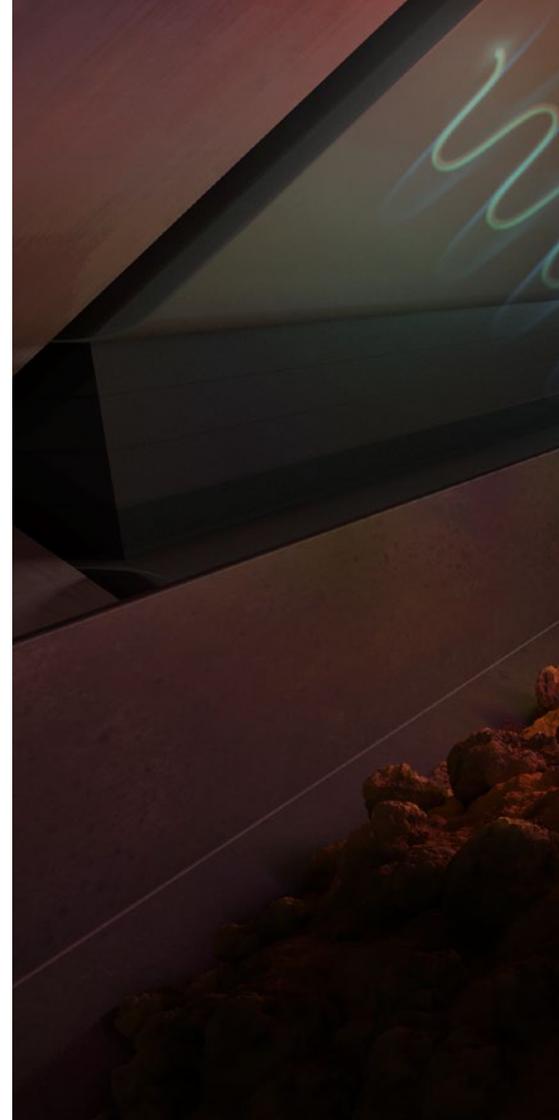
As a corporate finance company specialising in resources, RFC Ambrian has taken on an unusual additional role of working as the commercialiser and lead marketer of the product in conjunction with Advisian and CSIRO.

Mr Beal says mining companies are not normally taken to the early adoption of radical new technologies, even if the benefits are clear and significant.

"Selling equipment and getting it in front of the right people in some of these big mining companies is not normally what investment bankers or corporate finance people do.

"Our job is not just to get companies considering this solution, but to ensure they consider it at the right point in their development process or at the right approval level."

Advisian was also brought into the partnership because of its expertise in engineering solutions including bulk ore handling. The sensing mechanism has to be paired with conveyor and materials handling equipment and suitably matched with the size of the operation.

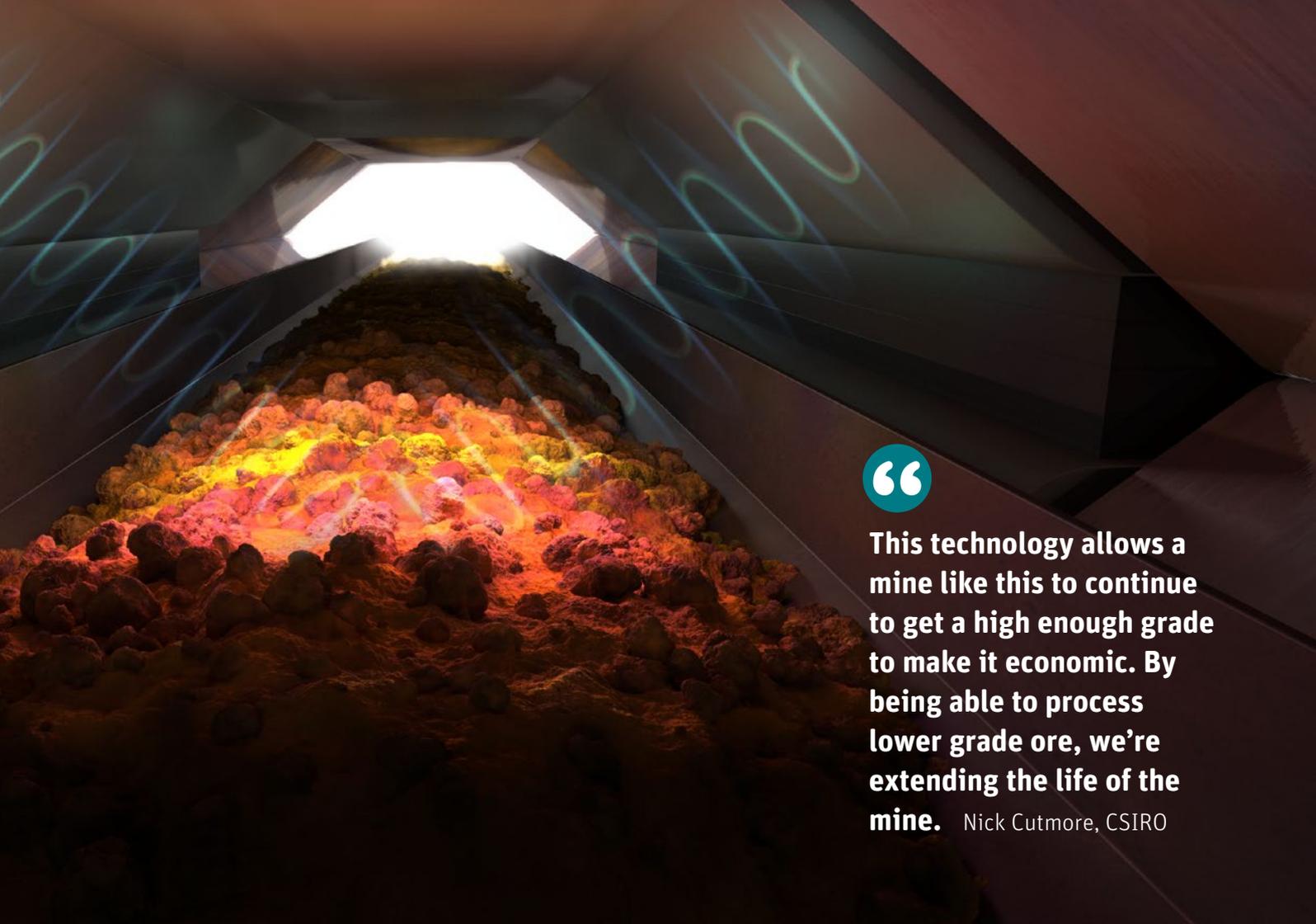


CSIRO team leader, David Miljak, says the ore sorter is likely to be most suited to the copper mining industry as it can detect copper minerals at extremely low grades. He calls high tonnage ore sorting the "holy grail" of the mining industry.

Other ore sorting conveyor machines tend to do the sorting on a rock-by-rock basis, with sensors often only penetrating "skin deep" – in other words, detecting ore particles on the surface of the passing material.

By using magnetic resonance radio waves NextOre's solution not only penetrates all of the ore presented on the conveyor, but reads the different mineral radio signals, informing sorters what is present in seconds.

Dr Miljak adds that it is extremely effective at detecting levels of arsenic that often occur along with gold orebodies. If the sensors detect abnormally high concentrations of arsenic minerals, then it can instruct equipment to selectively reject pods of ore, enhancing a deposit's economic viability.



This technology allows a mine like this to continue to get a high enough grade to make it economic. By being able to process lower grade ore, we're extending the life of the mine. Nick Cutmore, CSIRO

He believes the processing costs for a big mining operation will drop radically for each pound of copper or ounce of gold produced – as much as 20 per cent in some mines.

“THAT’S ACCORDING TO THE NUMBERS WE’VE PUT TOGETHER. FOR AN OPERATION WHICH SPENDS HALF A BILLION DOLLARS A YEAR JUST TO KEEP MINING, THAT’S A BIG DEAL.”

THERE IS ALSO THE POSITIVE ENVIRONMENTAL ASPECT OF THE PROCESS.

“IF WE CAN SEE WHAT’S IN THE PASSING MATERIAL FASTER, IT MEANS A SMALLER PROCESSING PLANT THAT USES LESS ELECTRICITY, LESS WATER AND PRODUCES LESS WASTE MATERIAL THROWN INTO TAILINGS AND DAMS.

“For every tonne of metal, we offer a much lower environmental footprint. For mines that are constrained by water usage, that’s a bonus,” Dr Miljak says.

CSIRO’s Nick Cutmore, who heads up the project’s research team, says the sensing technology was evaluated at the Newcrest Ridgeway mine near Orange in New South Wales, Australia. The testing demonstrated throughput capacity, accuracy and response times that improve significantly on competing sensing technologies.

“NextOre’s ore sorter should prove useful for both older, mature mines as well as undeveloped mines. It can extend the life of older mines and make undeveloped mines viable in the first place,” Dr Cutmore says.

The big problem for mines is that once they have worked out the higher grade material, they’re left with the lower grade, which may be uneconomic without advances in mining or processing technologies.

“This technology allows a mine like this to continue to get a high enough grade to make it economic. By being

able to process lower grade ore, we’re extending the life of the mine.”

There are many undeveloped copper mines throughout the world, particularly in North and South America as well as in Australia.

“This could help these countries to decide to develop a mine in the first place,” Dr Cutmore says.

The South Australian Government has set a bold target to triple copper production over the next fifteen years as an important part of boosting its economy. NextOre’s ore sorting technology would dovetail nicely with that push.

“A lot of these projects in South Australia are dealing with low grade material, and for it to be viable, we need brand new ways to process the copper and grow the economy. The technology we are offering is one way to do this,” Dr Cutmore says.

NextOre’s bulk ore sorting solution is currently available for deployment at mine sites. ●

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NEW ERA FOR GOLD ANALYSIS

Two commercially-available technologies, each with their own advantages, offer a new level of data on gold concentrations and can be used to optimise processes for greater value recovery.

LOUIS WHITE reports

Gold is one of our most precious commodities, worth \$1,281 per ounce at the time of writing. Its value on the stockmarket is as fascinating as its history and it continues to be one of the most popular investment options for many people today.

Everyone wants to extract more value out of their own investment and gold is no exception to that rule of thumb. Recognising the potential to capture more value in the processing step, CSIRO has developed new analysis technologies for gold and other precious metals.

These technologies will help the gold industry to recover more value from ore and waste streams at the processing stage.

“Over the last few years we have developed two technologies for use in gold mining and processing,” CSIRO group leader, Michael Millen, says.

“One is based on gamma activation analysis (GAA) and the other uses x-ray fluorescence (XRF).

“The GAA technique, marketed as PhotonAssay, was launched in late 2016 via a new company, Chrysos.”

Ausdrill will be the first company to install PhotonAssay in 2018.

As an advanced laboratory method to replace conventional fire-assay technology, PhotonAssay uses high powered x-rays to bombard ore samples and activate atoms of gold and other metals. A sensitive detector then picks up the unique gamma-ray signatures

from these elements to determine their concentrations in just a few minutes.

By reducing the turnaround time for analysis from days down to minutes, PhotonAssay provides mining companies with the opportunity to monitor their operations in real time, and to respond to problems more rapidly than ever before. As a result, miners can more readily optimise their processes and make better-informed decisions.

With unique sensitivity for gold, PhotonAssay is suitable for use across the mining value chain, including exploration, resource definition, mine planning and process monitoring. With sample sizes at least 10 to 20 times those used for fire-assay, analysis of heterogeneous ores much simpler using this technology.

The second CSIRO-developed analyser, which is based on XRF, is capable of detecting ultra-low levels of gold and other elements on a continuous process stream or ‘on-line’, hence its name the OnLine Gold Analyser (OLGA).

“OLGA is now available to the market through leading Australian mining equipment, technology and services company, Gekko systems,” Mr Millen says.

“This analyser is a true on-line analyser providing data in real time.”

Conventional XRF is widely used in the base metals industry for monitoring and control of concentration plants, however these systems generally have detection

limits in the tens to hundreds of parts-per-million (ppm) range, precluding their use in precious metal concentrators.

OLGA is specifically designed to enable direct measurement of gold in tailings, feed and concentrate slurry streams at ppm and sub-ppm levels.

It incorporates new developments in x-ray detectors and x-ray tubes combined with CSIRO’s patented x-ray optics technology and spectral analysis techniques to detect previously unachievable trace concentrations for elements.

“A rapid on-line measure of gold at a few ppm to sub-ppm has never been available to the industry before this technology,” Mr Millen says.

“This adds value as the data can be used to optimise process control and prevent gold going to waste streams.”

This critical new tool will enable plant metallurgists and operators to monitor and adjust their operations in real time in order to increase recovery and minimise gold losses from process excursions.

“We have been a world leader in the development of analysis systems for the mining, minerals processing and other industries for over 30 years,” Mr Millen says.

“These analysers have been under development for several years by a team of physicists, and mechanical, electronic and software engineers.”

CSIRO plans to extend the XRF technology for other precious metals that conventional analysis techniques cannot measure at trace levels. ●

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A rapid on-line measure of gold at a few parts-per-million (ppm) to sub-ppm has never been available to the industry before this technology. This adds value as the data can be used to optimise process control and prevent gold going to waste streams.

Michael Millen, CSIRO

DATA TO ELEVATE SOCIAL PERFORMANCE

Community disapproval can cost hundreds of millions of dollars in delays or the complete abandonment of a mining project. A new science-based solution that provides deep social insights aims to elevate the industry's social performance to the same measurable rigour as other aspects of business.

EMILY LEHMANN reports

Community conflict can be costly.

A paper published in the *Proceedings of the National Academy of Sciences* in 2014, found that delays as a result of community conflict cost companies US\$20 million per week on major mining projects worth US\$3 to \$5 billion.

At the same time, it was reported that community opposition caused five mining projects to be abandoned globally between 2006 and 2013. This includes a coal mining project in Australia's Hunter Valley.

Community expectations have grown and evolved over time, which means a sophisticated approach is needed

to properly address community issues and the potential negative impacts of mining.

CSIRO's Dr Kieren Moffat says a social licence to operate is about communities having a way to shape the development trajectory of industry.

"If the community doesn't have a constructive way to have a voice and speak to issues, they will find creative ways to influence developments.

"Traditional ways of engagement and investment in community relationships are often mismatched with the expectations of the community. Relationships are nuanced and dynamic,

and therefore need an approach that factors that in."

Through his team's earlier research, Dr Moffat found that the social performance function within mining companies didn't have the same level of quantitative characterisation of the issues and risk they were trying to manage as other aspects of their business.

"We started to explore quantitative ways to understand a social licence to operate – what it is, how you obtain it and hold it, and combined it with social science methodologies."



After testing their methodologies in a five year project with Santos GLNG, Dr Moffat's team published a groundbreaking integrative model to explain community acceptance of mining. The model shows that building trust is key.

It was applied at the Waihi gold mine by Newmont Mining who were seeking to make a potentially controversial extension to their existing underground operation directly beneath homes in the town. Applying CSIRO's model during the extensive consultation and negotiation with the community, led to the complex proposal proceeding without legal challenge – the first of the four extensions to do so.

Building on this model, Dr Moffat's team has created an innovative commercial solution to improve social performance, called Reflexivity, that has drawn the attention of global mining executives. The solution provides deep social insights in three steps – surveys, sophisticated modelling of data and insight delivery.

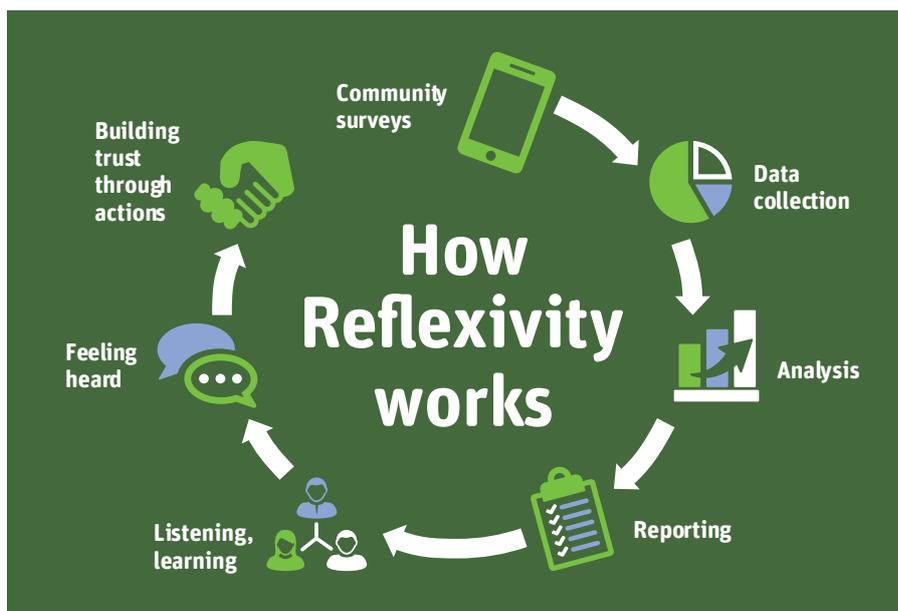
"What we've come up with is a way for companies to understand their social performance across time and across sites, in the same way that companies would for, say, safety," says Dr Moffat.

"What's different about Reflexivity is that we regularly collect data so that a company can engage directly with a much broader set of people within the community – not just via committees or representatives, but one-on-one with individuals in near real time, in an ongoing way.

"Reflexivity doesn't just tell you what people in the community think, but why they think a certain way. This tells you where to focus your energy in your engagement activity to improve the relationship, enabling a company to focus on the issues that matter most to the community."

The team's social science expertise comes to the fore in helping the company distil the data into meaningful messages and a set of actions that they can communicate internally and to the community.

It allows community engagement functions to lobby for resources to focus on those issues that matter most to communities and represent the best return on investment for the company.



In 2014/15, Reflexivity was piloted by Anglo American at scale across four sites in South Africa and one in Australia where issues relating to trust and acceptance were tracked in each community, every month for a year.

Anglo's headquarters in London, along with operation managers on the ground at mine sites, had access to the rich data at the same time, allowing them to understand the issues at that moment, plan what to do next and track the effectiveness of those interventions in terms of their engagement with the community.

"We saw the level of trust in the company at their most challenging site improve from quite low to the same solid level as the other three sites – it was an amazing turnaround."

NOW, RIO TINTO HAS ENGAGED CSIRO IN A THREE-YEAR PROJECT TO ROLL OUT THE REFLEXIVITY SOLUTION IN THE TOWNS SURROUNDING ITS IRON ORE OPERATIONS IN THE PILBARA. THE PROJECT IS CALLED LOCAL VOICES AND LAUNCHED IN JULY 2017. SINCE THEN, THE FIRST ROUND OF SURVEY DATA HAS BEEN COLLECTED AND SHARED WITH THE COMMUNITY.

"We want our host communities across the Pilbara to have a voice and to know that we are listening to what they have to say," Rio Tinto's general manager communities and communication, Linda Dawson, says.

"Whilst we have conducted community perception surveys in the past, we wanted to take a longer-term view. We are keen to understand what people think about Rio Tinto on a range of issues, our role in the community and why they hold those views."

An important aspect of the Reflexivity solution is that all the data is collected, owned and managed independently by CSIRO.

"Partnering with a credible organisation like CSIRO was important to us. We wanted our host communities to have confidence in who they shared their views with, so that together we can build stronger and more trusting relationships," Ms Dawson says.

"When CSIRO shares the data gathered, the community sees what we see, and I really like that transparency.

"Over time we hope to better understand the priorities and concerns of the communities and what we might need to do differently. We know the data will better inform how we engage, develop and invest in the Pilbara." ●

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FORECASTING EVAPORATION

It's now possible to manage evaporation on mine pit lakes using an accurate, autonomous system. It takes daily water measurements and combines them with local weather data to predict how evaporation rates will change in the future.

LOUIS WHITE reports

One of the industry's pressing tasks is to manage discontinued mining sites to minimise environmental impacts with water management a top priority.

To tackle this problem, CSIRO has developed a monitoring system that improves evaporation estimates through a combination of measurements and improved computer models.

"The main purpose of the system is to understand evaporation losses from mine pit lakes, water storages, tailings dams or any other open water surface," CSIRO principal research scientist, David McJannet, says.

A disused open-cut mine that has been excavated beneath the water table is likely to fill with water from rising groundwater and rainfall, forming a pit lake with a unique chemical composition.

Effective environmental management of such a site depends on information about the geology and any possible contaminants remaining in the mine

tailings, as well as the lake's water balance – the ebbs and flows of water and its evaporation from the lake.

The evaporation data collected is then coupled with information from surrounding weather stations to generate computer models to help predict how evaporation rates will change as pit lake levels rise in the future.

The system is designed to float upon the surface of open-cut mine lakes and take daily evaporation measurements, with its durability allowing it to remain on the water for long periods of time. Because it's autonomous, it requires minimal labour once deployed.

"The main data we are aiming to provide is daily evaporation rates," Dr McJannet says. "We do this through an intensive monitoring period where we make measurements from two technologies.

"We deploy a floating evaporation pan to directly measure evaporation and we also deploy a buoy that measures meteorological conditions such as humidity, wind speed, temperature and water temperature."

The system has been applied in the Pilbara in three locations for BHP iron ore and in the Hunter Valley for Anglo American coal operations. Most recently, CSIRO installed the monitoring system at Mogalakwena mine in South Africa, and Las Tortolas tailings facility in Chile.

"We typically run the system for six to 12 months, and during that time, we develop a model that relates lake evaporation to the meteorological variables measured by the buoy," Dr McJannet says.

"We then develop code for the buoy that enables it to directly estimate evaporation. That buoy is then left at the water body to provide ongoing daily evaporation numbers. We then remove the pan for work at other sites.

"The evaporation pan uses state-of-the-art instruments, ultrasonic algae control systems, and fully automated filling and emptying routines."

The combination of accurate data and evaporation modelling will enable the team managing the mine to predict pit lake levels and possible negative impacts from changing water levels on the surrounding environment. Anticipating the evolution and impact pit lakes pose for adjacent water resources is crucial for effectively managing the long-term legacy of mining.

In the end, the CSIRO system will not only save companies money but also provide for far more accurate water reporting.

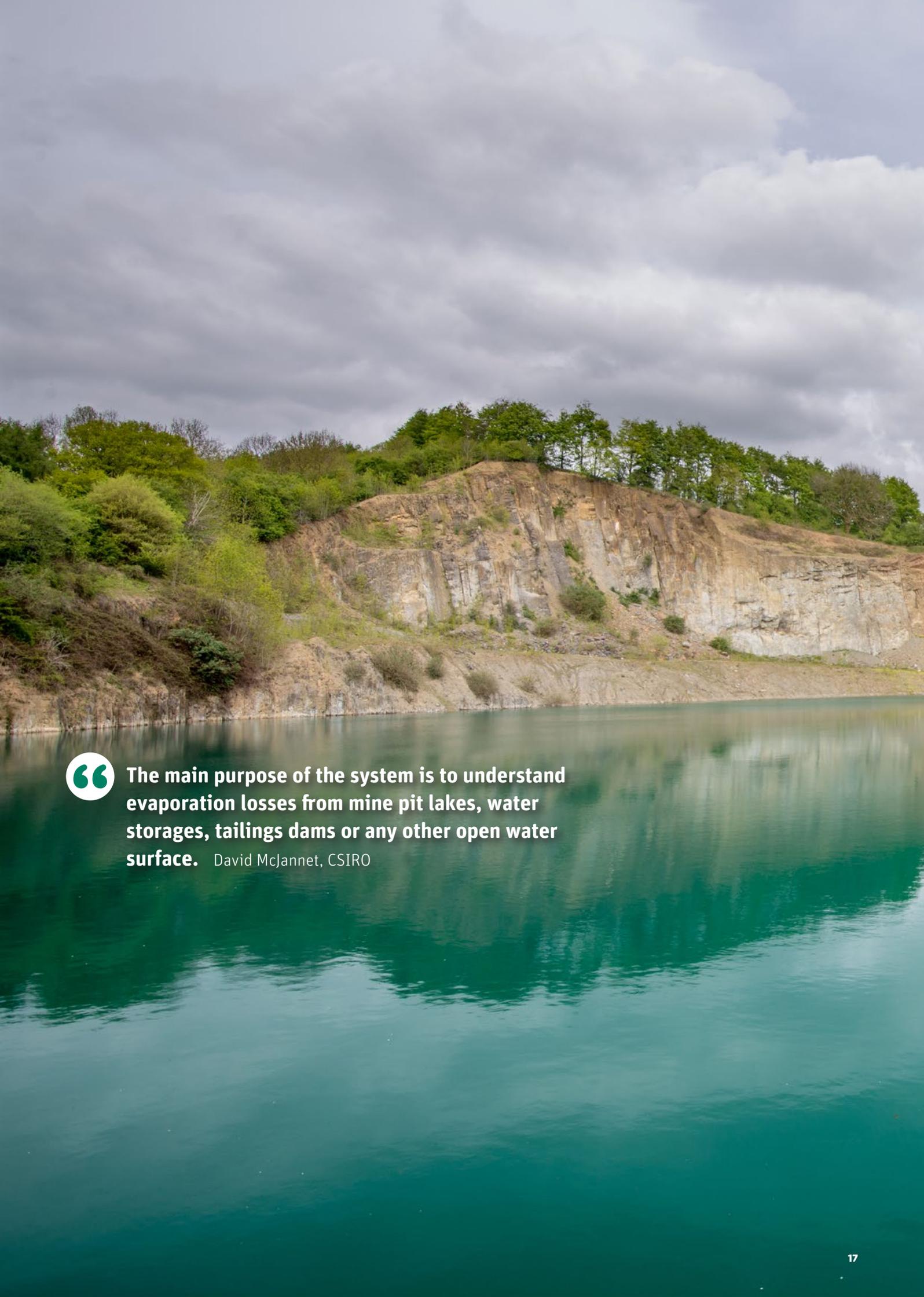
"In water balance reporting for many of these mine pits, evaporation is the most uncertain component," Dr McJannet says.

"By improving accuracy of these estimates mining companies can better predict available water resources.

"Evaporation numbers can be used to help understand evolution of pit lakes, which form after extraction activities have ceased and can potentially save rehabilitation costs particularly around earth works costs, as rehabilitation occurs to the predicted mature lake level.

"Better evaporation numbers also help in other mining water bodies such as dams to help understand potential flood retention capacity and ability to store and evaporate excess water." ●

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The main purpose of the system is to understand evaporation losses from mine pit lakes, water storages, tailings dams or any other open water surface. David McJannet, CSIRO

CSIROScope

APPLES NO LONGER CRUISING FOR A BRUISING

Ever wondered why apples turn brown when you cut them up? It's all thanks to a naturally occurring enzyme called polyphenol oxidase (PPO). This enzyme is released when the fruit's cells are 'broken' and it reacts with other parts of fruit cells turning the fruit brown. Once this reaction has taken place, nothing can be done to reverse it and quite often the fruit is thrown away.

You can destroy the PPO enzyme through cooking or reduce enzymatic browning by covering the fruit. Another popular way to stop further browning is to put lemon juice on it. This works because the ascorbic acid in lemons delays the PPO enzyme reaction.

We took a different approach to stop browning. First, we isolated the genes that encode the PPO enzyme, then we constructed an anti-PPO gene. Inserting this gene into plants blocks the production of PPO and therefore stops the browning.

Australians are throwing out over 4 million tonnes of food each year. That's over \$1000 of food wasted by the average Australian household. This waste not only hurts our bank accounts, it also hurts our world, with global food loss and waste generating 8 per cent of total greenhouse gas emissions annually. Sounds like a big problem, doesn't it? And we haven't even mentioned its impact on global food security and our growing waistlines. As with any complex problem, the solution involves a number of different tactics. One of which is trying to keep food fresher for longer.

Now, a special kind of apple slice will go on sale at select US supermarkets and, thanks to our research, these apples won't turn brown when they're cut, bitten, or bruised.

For the full story, visit:
blog.csiro.au

GENETIC DISCOVERY GIVES HOPE FOR SWINE VACCINE

Vaccines are one of the most important developments in medical history. They provide successful and cost-effective medical intervention and have dramatically reduced the incidence of infectious diseases that have killed hundreds of millions of people.

Vaccination is also an effective way to protect our livestock and companion animals from life-threatening diseases.

In fact, more animals are vaccinated each year than humans.

It is no simple feat to develop a new vaccine, but scientists at CSIRO's national biocontainment facility, Australian Animal Health Laboratory (AAHL), are not letting that stop them. CSIRO researchers, along with colleagues from Kansas State University and Lawrence Livermore National Laboratory, have presented new genetic data that may hold the key to developing a vaccine for African Swine Fever (ASF) virus, in a recently published paper.

For the full story, visit:
blog.csiro.au

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