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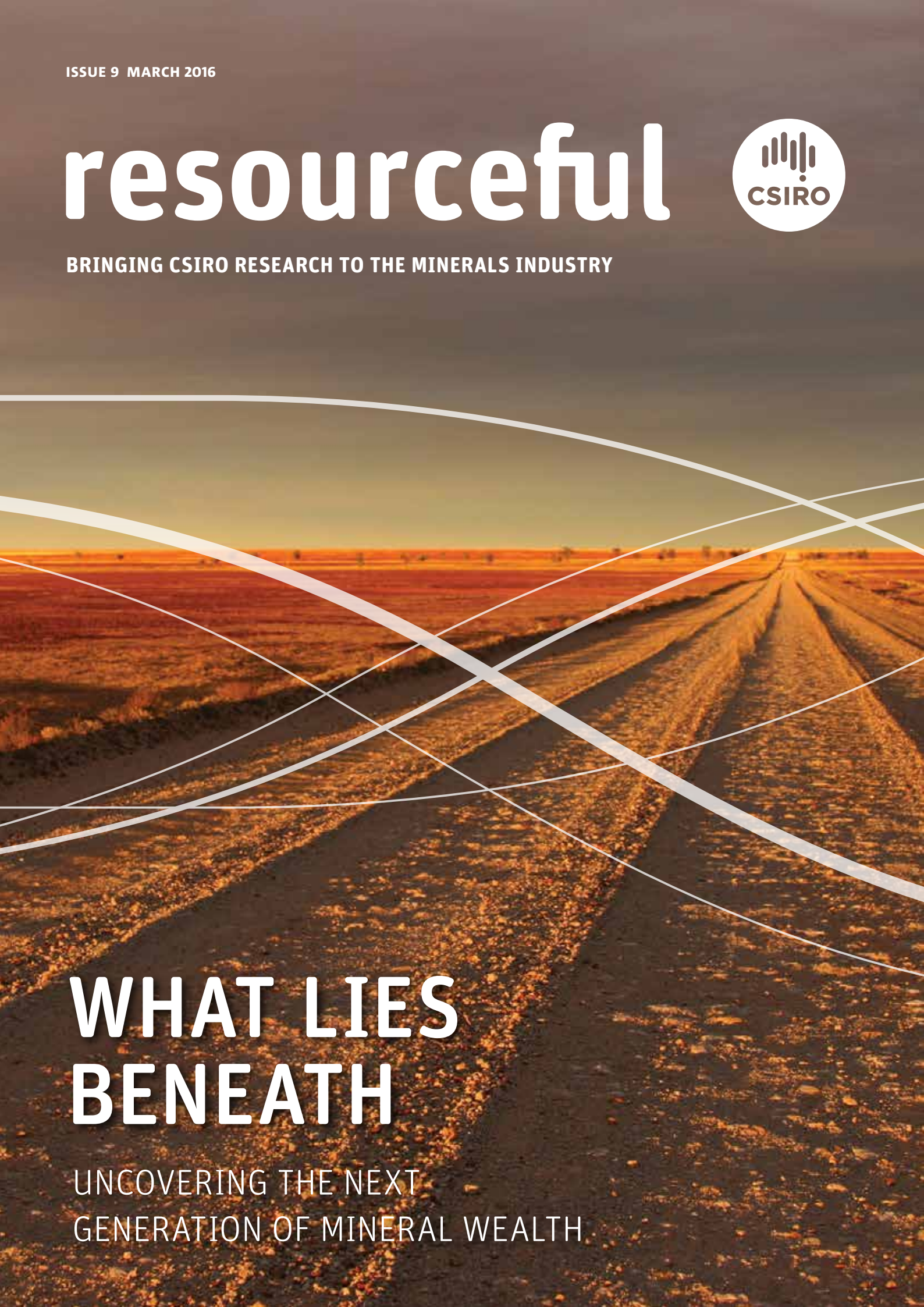
BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY



WHAT LIES BENEATH

UNCOVERING THE NEXT GENERATION OF MINERAL WEALTH

EXPLORATION THROUGH COVER

THE CHALLENGE

After 150 years of mining, most deposits near the surface have been discovered

Almost 60% of Australia is yet to be explored for minerals

80% of Australia is covered in a blanket of barren cover: sedimentary basins, volcanic sequences and regolith

Surface cover has challenged explorers to date by 'hiding' the signatures of buried mineral systems

WHAT IS COVER?

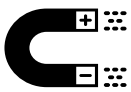
Cover is made up of younger rock and sedimentary material. It sits on top of the older thick foundation basement rock

Surface cover depth can vary significantly from nearly absent to hundreds of metres thick

One form of cover – regolith – is a result of weathering and biological processes. It can be freshly deposited or hundreds of millions of years old

There's much still to learn about Australia's cover, that's why geoscience initiative UNCOVER is focusing the efforts of researchers, government and industry

CSIRO'S MARKET-READY TOOLS | TO SEE THROUGH COVER AND DEEPER UNDERGROUND



Airborne electromagnetic systems are available to gather a great depth of geophysical data and map conductive material below the surface

Groundwater is indicative of geology under the surface and can be analysed for metals using hydro-geochemical tools

Geochemical haloes in sedimentary basins can help to understand mineralising potential and help vector toward a deposit

Natural samples of eucalyptus plants, ant and termite mounds can all point to mineralisation under cover

Calcrete and laterite geochemistry has lead to billion-dollar gold discoveries and continues to help explore through regolith

INSIDE THIS

ISSUE

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LEADER'S COMMENT

THE FUTURE OF EXPLORATION

A big new mineral discovery can, and does, transform ordinary companies into global giants. But in recent decades, as many exploration districts mature, it does feel like incremental discoveries in existing districts are the order of the day – albeit with a few notable exceptions.

As Will Robinson from Encounter Resources puts it: "the quality of ore mined ... has far exceeded the quality of ore that has been found".

One of the key reasons for this is the lack of reliable and cost-effective tools to explore those parts of Australia that are under a blanket of cover material. It wasn't that long ago that regolith – one form of unconsolidated cover derived from the weathering of rocks near the surface – was an impenetrable barrier to exploration. The research and exploration community joined forces to overcome this challenge and many world-class orebodies were discovered as a result.

The geoscience community is again mobilising around the next frontier: cover by younger materials including sediments and igneous rocks. Through the UNCOVER initiative, the key geoscience challenges holding us back have been systematically identified and CSIRO is focusing its resources on solving them.

In this issue, we examine some of the research and partnerships that are poised to focus on UNCOVER's vision: a national team fit for a national challenge. These key initiatives focus on practical outcomes that either attract and/or enable new exploration investment in covered regions and fall under four key areas.

Pushing into new regions – covered areas are difficult to explore and there is inherently poor data with respect to even the most basic geological maps, rock types and geological process understanding. Integrated research and exploration initiatives, such as in the Capricorn province of Western Australia, build geological understanding to attract investment, and at the same time, deliver the tools for effective exploration outcomes.

WE'VE FACED THE REGOLITH CHALLENGE AND WON. NOW FOR THE BIG PRIZES UNDER GREATER DEPTHS OF COVER.

Cost-effective access – working beneath cover means looking deeper, but always keeping the economic constraints in mind and hence restricting the available research space. New drilling technologies and onsite analytical facilities will change the costs and pace of exploration drilling and are being developed through the Deep Exploration Technologies Cooperative Research Centre. These new technologies will provide the base geoscience data to attract exploration investment in covered areas, and at the same time, reduce the cost and increase the value of drilling.

Rapid, cheap and integrated data – accessing sample material through drilling is a major expense in exploration. New technologies are looking to cut drilling costs, increase the amount and quality of the resultant data, and drive effective integration of all datasets for the best exploration outcomes. Partnerships with Geoscience Australia and the state and territory geological surveys are key to unlocking the value.

Transitioning to new mining technologies – technology tends to keep pace with demand and so mining technologies have increasingly adapted to deliver profitable outcomes as the best resources are exhausted. As we explore deeper, we must mine deeper and so two alternative scenarios are in play: we find increasingly better resources to offset the cost of exploration at depth using existing technologies; or we innovate and change the mining and processing paradigm to take advantage of new opportunities. CSIRO is focused on the latter to open up Australia's wealth of under cover resources.

None of this would be possible without UNCOVER's clarity of purpose. We've faced the regolith challenge and won. Now for the big prizes under greater depths of cover. ●

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RESEARCH NEWS

LESS UNCERTAINTY, MORE PRECISION

A combination of geophysical techniques, data and sensing is taking the uncertainty out of minerals exploration, allowing companies to focus their efforts on where it counts early on and hit targets with greater precision. TIM THWAITES reports

The company was immediately able to dismiss 90 per cent of the potential orebodies as commercially unviable and concentrate on the ones that showed the greatest promise for development.

Seeking exploitable ore deposits beneath the Earth's surface has many features in common with an x-ray of the human body.

In both cases, a volume is scanned to detect and interpret changes in the measurements of physical properties. And equally, the search is for something out of the ordinary – an anomaly.

But, there is a critical difference. When scanning the human body, we already know its boundaries, where we ought to find the bones, organs and tissues, and how they should appear.

Whereas under the Earth's surface the territory is boundless and we typically only have a vague idea of where the anomalies – ideally mineral deposits – should occur and what form they might take.

CSIRO researchers are working with mining companies and other government agencies on ways to increase the effectiveness of geophysical techniques, which can be used to explore for minerals under cover.

Mineral deposits are typically dense, often magnetic and usually metallic. That means they're likely to cause a distinct change in the gradients of magnetic or gravity fields or an ability to conduct electricity.

Gravity, magnetic and electromagnetic surveys can often be used to detect orebodies under cover, in combination with other geophysical techniques, data from geochemistry and remote sensing using light and radio waves.

Dr James Austin, a CSIRO geoscientist, has been using magnetics data to assist mining exploration in northern and central Australia. One of the useful outcomes of the work is the ability to identify poor exploration targets early, allowing more funds to be spent on better prospects.

In one case, a company working in the Arunta block in Central Australia had magnetic data that suggested potential nickel and copper resources.

"We measured the magnetic properties of the rocks in the area and they all corresponded to a specific geological event," Dr Austin says.

"This allowed us to model the potential deposits accurately. Once we knew their volume and how close to the surface they were, we could estimate how expensive they would be to mine.

"If we assumed a conservative percentage of mineralisation, we could also estimate how much they were potentially worth."

The company was immediately able to dismiss 90 per cent of the potential orebodies as commercially unviable and concentrate on the ones that showed the greatest promise for development.

To take a step back to the human body analogy, we know where things should be, so we can model the information we would typically expect to find in our measurements and then use that model to detect and interpret anomalies.

With geophysics, the opposite is true. It becomes an inverse problem. We only have a vague idea as to what to expect, so we attempt to determine the nature of the orebody from our actual measurements.

Unfortunately, there is an infinite number of models of different rock types and orebodies at different depths that can fit a particular set of measurements.

It's possible to eliminate many of these models, because they don't make geological sense. And the more information that's accumulated about the area of interest (such as geology, other geophysical and chemical measurements, and the history of its development) the more the models can be refined to explain the measurements.

Mining exploration companies want accurate answers rapidly and at a reasonable cost.

CSIRO geophysicist Dr Juerg Hauser is working with industry to give answers using Bayesian approaches, which are updatable and provide a likelihood as to how correct they are.

"Given an unlimited amount of time and an infinite amount of computational resources, you could try all the models you could think of," Dr Hauser says.

"Or, you could cut costs by using an efficient deterministic inversion that quickly finds you one single model, but by doing this you would learn little about equally plausible alternative models.

"What I'm trying to find are pragmatic compromises – techniques that are fast enough, but comprehensive enough so that we have an understanding of the uncertainty – the range of models that fit the measurements made in the field."

Leader of CSIRO's exploration through cover research group, Dr Tim Munday, has been working in parallel, applying Dr Hauser's and other software to airborne electromagnetic data.

Dr Munday says this data is good for targeting some ores directly, but also for gaining a picture of the regolith cover.

"The regolith information can also be used to trace ancient water courses, which can indirectly point to orebodies, particularly uranium," he says.

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DATA MAPS SHOW PROSPECTIVITY

Researchers from CSIRO's mineral resources business and digital innovation company Data61 – the largest data innovation group in Australia – have been looking at ways of sifting through and adding value to the vast amount of data gathered and held by Australian and state-based government geoscience agencies.

As first cab off the rank, they have developed cloud-based machine-learning techniques that integrate different types of geological data to generate maps that show potential for successfully prospecting for nominated minerals across the entire continent of Australia.

According to CSIRO's Dr Jesse Robertson, the software is able to learn from geophysical data and information from other sources such as geochemistry, mine databases, remote sensing and geological mapping. And, it can continue to learn and improve as new data flows in.

"It basically gives you a prospectivity map: a probability that an orebody is sitting at a particular location plus how certain we are of that estimate," Dr Robertson says.

The uncertainty measure incorporates the quantity and quality of the data on which the estimate is made and can suggest where more exploration work should be focused.

"It's another tool in the tool box, flagging areas as interesting or not," Dr Robertson says.

"If an area is interesting, you could go and do a proper inversion of geophysical data or collect more data."

The new tool is yet to be publicly released.

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FEATURE ARTICLE

THE UNDER COVER MISSION

Five years after UNCOVER was first mooted by the Australian Academy of Sciences, the concept – which some call the biggest initiative in geoscience for the past 100 years – is throwing up as many questions as it answers. ADAM COURTENAY reports

UNCOVER – a collaboration of government, research institutes, universities and industry – is about finding and extracting the hidden wealth that lies beneath the top surface regolith.

It's a project that's dimensions are likely to increase before they diminish – the complexity and make-up of the earth just a kilometre below us still remains largely unknown.

Knowing so little about buried natural treasure has not daunted Australia's geoscience community. UNCOVER hopes to take Australia from a country that has barely scratched the surface of its own geology to one that is confident in exploiting the full extent and value of its subsurface mineral wealth using a completely new set of exploration tools and research methods.

Australia's mineral wealth is not confined only to the near-surface search space. As much as 80 per cent of the country is considered prospective, hosting hitherto unseen, high-quality, large economic resources, which demand new infrastructure development and new mines replacing the surface operations that are in long-term decline.

"The petroleum industry made the change many years ago when their discovery rate went into decline – they needed to open new search space, and in particular explore and mine deeper," says Dr Steve Beresford, chief geologist at First Quantum Minerals, who also chairs the UNCOVER Geoscience Committee.

"But, the mineral industry hasn't been forced to do this with the same level of urgency. Miners still think they can make money from the minerals lying close to the surface in riskier countries, so the commitment to do this hasn't been nearly as urgent as it should be.

"UNCOVER is about Australia and replacing the decline in resource quality in this country. To achieve this need, we have to encourage companies to invest, explore, discover and mine in Australia," Dr Beresford says.

Mineral exploration is often talked about being a process of sequential volume reduction until you find the deposit, but according to Dr Beresford, this isn't how the majority of the industry has explored.

"Crucially, it isn't how successful exploration at the surface has been undertaken. In fact, it builds its story around facts, around certainty."

As Dr Beresford explains, this approach is unsustainable at depth and has led to higher discovery costs and poorer discovery rates. In other words, diminishing returns.

"Again, we have lessons to learn from other industries that have been through this same decline due to searching for their goal in a sea of uncertainty.

"These industries have transitioned through the focusing of their science (e.g. rare disease pharmaceuticals, airport scanning) and collaboration with other sciences (e.g. human connectome, terrorism intelligence) to bring new decision-making approaches, new technologies, and new extrapolative and interpolative science."

The industry is going through a transition in where and how it explores. This transition requires a collaboration with government agencies and research agencies on a scale we haven't seen in geoscience before.

UNCOVER is about Australia and replacing the decline in resource quality in this country. To achieve this need, we have to encourage companies to explore, discover and mine in Australia. – Dr Steve Beresford

"Our country has a long proud history of leading the world in minerals collaboration but we are being asked to lead a bigger change because this is a bigger challenge," Dr Beresford says.

Dr Rob Hough, CSIRO's exploration research director and one of UNCOVER's leading members, realises there's unlikely to be a 'eureka' moment in the UNCOVER story. Rather, there's more likely to be a number of smaller moments of understanding that add to the whole picture.

The industry is in the midst of one of the heaviest commodities downturns in years and there is little incentive for greenfield exploration. But, there is no alternative if Australian mining is to survive.

"If we do not invest in the research and development that feeds into the next level of exploration technology, there will be nothing left to mine here," Dr Hough says.

The big players will simply go and scratch the surface elsewhere. We are seeing that already with the likes of Barrick and Anglo American effectively exiting Australian exploration in recent times.

Mineral systems understanding is at the heart of the UNCOVER initiative and both Dr Hough and Dr Beresford agree that it requires a new way of thinking.

As an exemplar, a $17 million project based in northern Western Australia's Capricorn involves a team of 25-strong researchers and a number of junior miners who are working to find mineral 'signatures'. These may be related to groundwater or ancient weathering events or anomalies that remain unseen under cover.

"We don't know what may have caused these 'hot spots' or anomalies. We think they could be an expression of a mineral system or they could simply be a normal geological event," Dr Hough says.

"We haven't done enough modelling to test and simulate what we might encounter and analyse the regional data to put the results into context. We don't know what the far-field systems look like – what the distal footprints are.

"What, for instance, does Olympic Dam look like 10 kilometres away from the orebody? We haven't done that yet.

"If it's a null result, we need to reverse engineer models to retest and re-simulate into things like our geophysical data and ask what that teaches us about where we go next. We don't celebrate failure enough – it can still teach us a lot about the geology," he says.

Dr Hough is optimistic about UNCOVER with good reason. Among its successes is the growing intelligence being gathered as part of the Capricorn project.

Progress on an 'exploration tool kit suite' is encouraging and progressively enabling researchers to support industry in lowering the risk of exploring in deeper environments.

If we do not invest in the research and development that feeds into the next level of exploration technology, there will be nothing left to mine here. – Dr Rob Hough

An example is the knowledge being gained on mineral grains, each with their own chemical and magnetic signatures, which is helping scientists navigate towards mineral systems.

CSIRO researchers are also applying magnetotellurics and passive seismic monitoring, which use sound to collect images of deep earth at high resolutions.

"These models take a long time to develop and the team is constantly updating them based on the data that is coming in.

"It's providing a whole new image of the Earth's crust in the area," Dr Hough says.

What is most important for the research team is how they work with industry on the project. The researchers spend time with the industry partners in the field, often staying in their exploration camps or at mine sites. It's this kind of close and regular interaction that helps get the research outcomes across to industry more quickly.

"This also serves to encourage industry to get more engaged in the research, which is great," Dr Hough says.

Also under the UNCOVER umbrella, the South Australian Government is now working closely with industry and the Deep Exploration Technology Cooperative Research Centre (DET CRC) on a mineral systems drilling program. Together, they are working to produce a transect of drillholes while demonstrating the new technologies at the drill sites.

The Geological Survey of South Australia has also been highly proactive in producing a seismic survey across its part of the Nullarbor Plain. In tandem with its counterpart in Western Australia, the survey gives us a whole new understanding of the underground geology.

According to Dr Hough, South Australia is being very proactive because much of its mineral wealth is literally under cover and it wants to be a major global player in the copper industry and attract overseas mining companies.

"UNCOVER can play an important role in supporting the South Australian Government's recently announced copper strategy.

"It will provide stronger links between industry, government and research organisations in South Australia where a research hub for copper excellence is explicitly recognised," Dr Hough says.

Another DET CRC project is developing a new deep and rapid drilling technology known as coiled tube drilling. It will be capable of zipping through earth to create a readily analysable rock powder as opposed to the standard heavy cores.

"It allows a team to move along a very large region cheaply and quickly with far less people and with a far smaller environmental footprint.

"It can literally zip through the Earth's crust, navigate the subsurface and provide both geochemical and geological pictures in real time using deep samples.

"At CSIRO, we are delighted to have a new partnership with the Northern Territory Geological Survey, for the first time we are embedding two researchers in Darwin with the survey.

"The project aims to develop the UNCOVER tool kit in areas like the McArthur Basin that are so important to metal production in Australia," Dr Hough says.

Geoscience Australia is also doing innovative work trying to standardise the depth of cover products it produces. It has also undertaken deep stratigraphic drilling in parts of Australia that have up until now been ignored, covering areas in western Victoria and moving into northern New South Wales and southern Queensland.

All this points to a collection of technologies and research methodologies that will take Australian geoscience to the highest levels internationally.

Dr Hough says success will breed success.

"If early adopters take it up, others will follow. It then leads to an increase in exploration and a greater ability to raise funding to support companies who will then take on more employees," he says.

Dr Beresford agrees, "At the end of this, we have to be as good at exploring to a depth of one kilometre as we currently are at exploring just 100 metres below us."

For more information on UNCOVER, visit uncoverminerals.org.au

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UNCOVERING THE FUTURE

Managing Director of Encounter Resources, WILL ROBINSON, talks about the landscape for junior explorers and what it's going to take to secure the future of mining in Australia. Interview by TIM TREADGOLD

Roy Woodall, when heading Western Mining Corporation's exploration effort, first raised the importance of "peering beneath the regolith" in the 1970s. Are today's explorers any closer than Roy was?

Based on the small number of major discoveries in recent decades in Australia, you could argue that we aren't much closer than in Roy's day. However, there has been a lot of progress in defining what needs to be done to improve success beneath cover.

In particular, the UNCOVER roadmap launched last year – developed collaboratively by industry, government geological surveys, academia, CSIRO, the Academy of Science and AMIRA – is a vitally important national initiative.

The number one driver of productivity in the resources sector is the quality of the resource.

In recent decades, the quality of ore mined from the national resources inventory has far exceeded the quality of ore that has been found.

'Under cover' exploration science should be central to the innovation priorities of Australia.

What tools do you have that Roy lacked to see what might lie at depth?

Detection limits for geochemical assays have improved, which has assisted in identifying and defining low-level anomalies through cover. As have the quality and coverage of precompetitive datasets available to explorers today. The greenfield exploration sector is heavily reliant on these datasets, which are provided by the government surveys.

On a more basic level, the use of handheld x-ray fluorescence (XRF) machines has enabled us to quickly obtain almost immediate assay estimates on site. So when conducting regional first-pass exploration, this allows for rapid follow up and infill drilling without the drill rig leaving site.

Another important development is that the depth penetration of electro-magnetic (EM) surveys has developed remarkably since Roy's time.

> **Places like Australia may actually be at a competitive advantage over Africa and other locations where sometimes the best geological map might have been made in the 1960s. – Will Robinson**

Can small companies make use of the latest technology or is it too costly and only available to the major companies?

They certainly can, and with the way exploration budgets have been slashed in most major companies in recent times, the junior sector is hardly disadvantaged in this area.

The value that can be generated for explorers by partnering on projects with CSIRO and universities is underappreciated.

Encounter has sponsored honours students from Monash University for five years running now. We provide the university with a set of research questions in relation to a project and the results to date have helped shaped future exploration programs.

WE HAVE ENOUGH EVIDENCE NOW TO KNOW THAT WE NEED TO DO SOMETHING DIFFERENTLY IF WE WANT A DIFFERENT RESULT.

Australia's exploration sector is made up largely of junior companies and historically they've been responsible for much of the country's mineral ore discoveries. The climate is tough right now. What are the greatest challenges they face?

Right now, maintaining shareholder interest and faith is a challenge. We are competing for risk capital against many others and at this time mineral exploration is right out of favour. That will change, we just don't know when.

It's also a great time to be working with high-quality people, contractors and equipment, which are readily available.

This point in the cycle is usually when the best exploration work is done. The challenges of capital raising sharpen the focus of the exploration sector on the best projects.

Exploration success in the 1960s and 1970s has allowed the resources industry to defer important investment on exploration. I suspect that the major companies could be forced back into greenfield exploration in a big way in the future.

Exploration is the future lifeblood of the resources sector. Yet at this time, it's being viewed as just another cost.

Imagine if Apple came out and announced that it had slashed all new product development and was going to focus its efforts only on improving the productivity of their existing product line.

How important is research and development to the survival and longevity of junior explorers?

We have enough evidence now to know that we need to do something differently if we want a different result. Greenfield exploration, by its very nature, requires a strong focus on research and development (R&D).

We hypothesise, we test, we interpret the results and we adjust the model. If warranted, we test again. It's a continuous learning loop. You always have to be generating new ideas and concepts.

How does Encounter Resources approach research and development?

At Encounter, we're always testing new ideas, technologies and methodologies to improve our success rate under cover in the Paterson Province in Western Australia, which is dominated by sand cover.

You know the prize is huge, but if it was easy to find, there would already be a hole in the ground.

We have trialled all sorts of geophysical and geochemical methods to help us see through the cover. Right now, we're participating in a research project with CSIRO looking at ultrafine fraction soil and this has huge potential.

Will new exploration tools that can look beneath the regolith encourage a return by explorers to Australia from the greener pastures of Africa and elsewhere where outcrops remain abundant?

Firstly, I would challenge the premise of the question that easily discoverable outcropping orebodies – at least major ones – remain abundant in Africa and elsewhere. For example, two big recent African discoveries, Kamoa and Flatreef, were both blind.

Secondly, I would argue that if we are in a world where most of the big new discoveries are more or less blind – even in Africa – then critical factors become precompetitive data, the supporting geoscience infrastructure, region-specific R&D, the regulatory framework and overall cost of doing business.

As such, places like Australia may actually be at a competitive advantage over Africa and other locations where sometimes the best geological map might have been made in the 1960s and doesn't go beyond the outcrop.

So in short, yes, I believe that the next wave of major mineral developments can occur in a developed jurisdiction like Australia.

It's entirely possible that Australia's resources industry of the future will be underpinned by cutting edge, under cover greenfield exploration.

What is the outlook for Australia's mining industry without big new discoveries?

It's one where we are mining larger tonnage and lower quality orebodies, usually by open cut mining, with bigger and bigger equipment, using more and more water and energy to extract a smaller and smaller amount of metal from a large body of rock.

If this is the future of mining then we will have failed as a sector.

In this scenario, Australia's resources industry continues to move further and further up the cost curve while we mine the leftovers from previous generations' exploration success. Slowly but surely marginalising ourselves down the quality curve and out of business.

No amount of driverless trucks can compensate for what Mother Nature leaves out.

Will Robinson is chairman of the Association of Mining and Exploration Companies and an executive member of the UNCOVER initiative.

‘ONSITE LAB’ ANSWERS MILLION DOLLAR QUESTION

Thanks to an analytical system that brings the laboratory to the drill site, greenfield explorers can now make multi-million dollar decisions in minutes rather than months. TONY HESELEV reports

A new system, known as Lab-at-Rig, is just one of the important breakthrough innovations recently made available to industry to dramatically reduce the cost of exploration.

By enabling explorers to analyse the chemistry and mineralogy of rocks within minutes of drilling, Lab-at-Rig cuts costs while improving effectiveness.

As part of the technology, data obtained from drillhole cuttings can be streamed directly and almost immediately to meet the specific needs of the geologist or miner.

Complex mineralogical and geochemical zoning can be identified in real time at a level of detail and consistency not captured by traditional geological logging – which is subjective, inconsistent, qualitative and time consuming.

The Lab-at-Rig technology was developed by a CSIRO-led team, including private sector partners Imdex Limited and Olympus, within the Deep Exploration Technologies Cooperative Research Centre (DET CRC).

The initial system is designed for diamond drilling operations and collects cuttings separated from drilling fluids in a solid removal unit, at the back of which composite mud is sub-sampled, dried and x-rayed by sensors that deliver data on the chemistry and mineralogy of samples.

The prototype is mounted on a trailer for ease of mobilisation. It’s being commercialised by REFLEX (a business in the ASX-listed Imdex group), with the aim of making it available to the market.

The fully developed system will be mobile, small and light, and have little environmental impact.

“The technology delivers quantitative, consistent and objective data, and is a major development in terms of efficiency and productivity,” project leader from CSIRO, Dr Yulia Uvarova says.

“Real-time delivery of Lab-at-Rig data allows mineral explorers to log downhole geology and validate exploration targets during the drilling process, informing decisions such as whether to terminate or extend drillholes or to modify the location or trajectory of subsequent holes.

“Such decisions, made in a timely manner, can result in highly significant cost savings.”

According to Dr Uvarova, other benefits of the technology are:

- reduced mobilisation and camp costs
- reduced cost per analysis
- rapid turnover of targets and tenements
- reduced likelihood of near misses
- drilling programs can be monitored at any location
- fast tracking of discovery rate and conversion of a prospect to a mine.

Fluid analysis will be used to optimise drilling operations and further increase efficiency.

The system will be fully automated, so operator training will be minimal and specialists will not be needed to run it.

The project is one of several sponsored and coordinated by the DET CRC that helps explorers analyse ore deposits buried deep under cover.

The technology was developed after DET CRC researchers observed a diamond drilling rig operating near Adelaide. They realised that the drilling fluids were carrying cuttings to the surface, and these cuttings, that were previously regarded as waste, could be analysed in real time using top-of-hole analytical systems, turning them into a valuable resource.

A key to the project’s success has been how the DET CRC has brought together expertise from geologists, geochemists, engineers and end-user representatives from mining houses and service providers.

“We put together our partnerships carefully,” DET CRC’s Professor David Giles says.

“All projects have an industry ‘mentor’ who engages with our science steering committee. The relationship between the participants is very close.”

The project is being further developed to work in very thick cover to analyse basement samples using coil tube drilling.

The next generation system will also include new sensor technologies and improved data analysis.

It’s being developed as part of a four-year, $11 million collaborative project between CSIRO, Imdex, Olympus, University of Adelaide, Curtin University and the DET CRC.

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RESEARCH PERSPECTIVE

NEXT STOP, THE CAPRICORN

Head of CSIRO's exploration research, DR ROB HOUGH, writes about why research into Western Australia's largely unexplored and deeply covered Capricorn region holds much promise for future prospectivity.

Of the many projects within the UNCOVER vision, one stands out as being of paramount importance. The Capricorn project in northern Western Australia is UNCOVER's foremost testing ground.

The region was selected because it's a great unknown – a greenfield site that lies between two proven areas of mineralogical wealth – the Yilgarn and Pilbara cratons.

The Capricorn project will help us to determine the geological and geochemical signatures that point to the prospective mineral systems clusters that we know of in the region and possibly to others that we have yet to see.

It's not just about potential mineral finds, but about finding the right pathways towards minerals discovery, we want to be able to navigate and prospect the subsurface.

The $17.3 million project – a collaboration between CSIRO, The University of Western Australia and Curtin University, together with the Geological Survey of Western Australia and nine exploration companies – has been running for two years now.

The project has funding from the Science and Industry Endowment Fund as well as from the Minerals Research Institute of Western Australia. It's a rare opportunity for young researchers to work closely with industry, starting from a *tabula rasa*, a virtually unknown stretch of land.

THE CAPRICORN IS JUST THE START OF A REVOLUTION IN EXPLORATION TECHNOLOGY THAT AIMS TO POSITION AUSTRALIA FOR THE NEXT 120 [YEARS].

The research team incorporates 25 full-time researchers and another 25 students from a wide variety of backgrounds and disciplines. There are six teams incorporating expertise in geophysics, mineralogy, structural geology, geochemistry and geochronology. Each team is working on specific themes, which include structural geology, geochemistry and geochronology; mineral systems evolution; cover characterisation; how mineral hosts can act as distal footprints; the hydro-geochemistry for deep geological sensing; the geochemical mapping for lithospheric evolution and predictive targeting.

We also have a team putting together a 3D digital model using virtual environments for data integration and visualisation.

We do know something of the geology of the Capricorn region already and there are a small number of working gold and base metal mines there, but because it's around 800 kilometres from one end of the region to the other, much of it remains largely under-explored.

The research teams, together with the industry explorers on site, are using the latest analytical equipment to understand the chemistry and ages of the rocks below, as well as the chemical pathways of rocks and the potential ore-bearing fluids around them. Some of the most exciting new science being done in the Capricorn is about understanding the chemistry of individual mineral grains, which can act as orientation tools towards mineral systems.

We're also using magnetotelluric and passive seismic sensors, both of which are geophysical imaging tools using sound that can produce images to a depth of 60 kilometres. As a result, we're now seeing evidence of a thicker crust than first anticipated through imaging the older, colder rocks against the warmer, younger rocks.

What will we develop from the Capricorn? By the end of the project in January 2018, we intend to have a tool kit for footprints of mineralising systems, which could be applied in similar geological environments across Australia – and possibly globally.

If it's successful, there's every chance we can take this elsewhere. What happens if we go under the Nullarbor Plain or if we look at parts of the central Australian sedimentary basin and venture deep beneath the Northern Territory and far north Queensland? The point is, if we have the tool kits to do this, we can go into increasingly more complex geological environments with a strong confidence that we can reduce the risk and help with navigating the subsurface.

We will be supporting Australia to be as prosperous from its under cover geology as it has been from its surface geology for the last 120 years. The Capricorn is just the start of a revolution in exploration technology that aims to position Australia for the next 120.

THE BIG PICTURE FOR JUNIORS

Challenging times are opening up exciting opportunities for smaller mining and exploration companies; and, those who are prepared to think and do differently will reap the greatest rewards. LOUIS WHITE reports

Australia's smaller mining and exploration companies face some interesting times. Investment is tapering off, business confidence is either static or falling and it's almost as if the Australian economy is on hold, while we wait to see what China is going to do.

Grant Thornton Australia's 2014 JUMEX (Junior Mining and Exploration Companies) Survey states that Australia is in desperate need of "consistency of policies for planning purposes in order to restore Australia as a strong investment destination in this sector".

The report encourages junior mining and exploration companies "to continue to explore innovative ways to create shareholder value".

Times are tough at the moment and in all likelihood are only going to get tougher.

"Of the Australian Stock Exchange (ASX) listed junior mining and exploration companies with a market cap of less than $500 million, only four per cent of junior miners are in the mining or production phases – the majority are still exploring," Ausindustry research facilitator, Ken Green says.

"Right now, the commodities price is making new mining projects an unattractive investment for the money markets.

"This means companies can't go 'back to the well' as freely as they were before and so they need to rethink how to make the most out of their biggest investment: exploration drilling," Mr Green says.

CSIRO business development manager, Wayne Robertson, believes that companies will have to become innovative in their thinking about their research and fundraising.

"Now that investment has been curtailed, the biggest challenge for mineral exploration companies in the future will be to determine new and innovative ways to explore both greenfield areas and the areas close to, and within, current deposits with a significantly reduced budget," Mr Robertson says.

According to Mr Robertson, while there will always be a level of uncertainty in exploration, science can play a big part in limiting the risk and helping focus the exploration opportunities.

"Smarter and better informed exploration campaigns can be designed through the understanding of scientifically based new and novel approaches to exploration. And, when coupled with new leading-edge data analytical techniques, these new approaches can greatly assist in lowering the level of uncertainty in exploration and the overall cost," he says.

In fact, exciting opportunities await smaller resource companies, as they face the challenges of a more diversified investment market and greater restrictions upon their funding. Not only can they utilise the benefits of applying more scientific rigour to their drilling and general research, these results should enable them to focus more efficiently on prospects.

"When money is readily available we naturally get lazy because we have the resources to throw at scaling the opportunity, but in doing so, all we do is scale the inefficiencies too," Mr Green says.

"Innovation occurs best in a constrained environment. This current environment is Australia's opportunity to develop competitive world-class mining projects by innovating throughout their development, starting with the characterisation of the project."

CSIRO is currently working with Sandfire Resources, a mid-tier Australian mining and exploration company with the 100 per cent-owned DeGrussa Copper-Gold Mine, located 900 kilometres north of Perth in Western Australia.

The project is investigating the chemical footprint of the company's DeGrussa deposit by summarising previous research and company data. It's also providing a framework of the cover stratigraphy, mineralogy and geochemical characterisation of the palaeochannel, with insights on physical and chemical proxies for element dispersion associated to the DeGrussa deposit. This is providing interpretation of the palaeo drainage geometry itself.

The project includes activities that will enable the company to determine the optimal mineral extraction strategies for the mine ensuring full economic return.

There are many privately funded organisations and research organisations, like CSIRO, working with smaller mining companies in their quest to develop their projects or refine their exploration to assure greater success upon drilling.

"There are various state government-based incentives particularly in Western Australia, South Australia and Queensland when it comes to attaining finance," Mr Green says.

"At a federal level the Entrepreneurs Programme 'Innovation Connections' is the simplest grant scheme for companies wishing to collaborate with the research sector. A facilitator will help with the project definition and contract formation stages as well as access to funding."

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COLLABORATION AT THE TOP END

A new partnership between CSIRO and the Northern Territory Geological Survey is building a better picture of prospectivity in unexplored areas of the McArthur Basin. EMILY LEHMANN reports

The McArthur Basin spans an area of about 180,000 square kilometres in the Northern Territory (NT) and Queensland and is home to one of Australia's largest lead-zinc-silver mines at McArthur River, as well as copper, diamond, iron ore and uranium deposits. Yet, large expanses of the basin's north are still yet to be explored.

A new collaboration agreement between the Northern Territory Geological Survey (NTGS) and CSIRO is set to change this. Together, they will gain new insights into the geology and mineral potential of strategic regions, such as the McArthur Basin, and provide industry with new, valuable datasets and concepts.

The first project will see CSIRO embed two post-doctoral researchers with the NTGS in Darwin to do a large-scale geophysical and mineral system assessment of the McArthur basin over two and a half years.

"We have a long history of working together with the geological surveys around the country, but this is a new way of working," CSIRO head of the partnership agreement, Dr Louise Fisher says.

"The advantage of having expertise on the ground in their offices means that we can align our goals and better support our collaborative projects."

The project links in to the NTGS' four-year, $23.8 million program called the Creating Opportunities for Resource Exploration (CORE) initiative.

CORE aims to enhance their regional geoscience programs including a resources assessment for base metals, copper, nickel, zinc and lead. The focus of this work is on strategic, largely under-explored areas that the NT government is seeking to develop.

NTGS Director of Regional Geoscience, Dorothy Close, says the ultimate aim is to attract industry investment in exploration to increase chances of new mineral discoveries.

"Like the rest of Australia, most of the 'easy' to discover mineral deposits on the surface have been found, so it's important that we're applying the best possible science and technology in the NT to assist explorers in finding hidden deposits that aren't exposed at the surface.

"The benefits flow both ways – CSIRO will be able to access our extensive datasets and unique knowledge of the NT's geology, while we'll be able to gain from CSIRO's minerals expertise and state-of-the-art technologies," Ms Close says.

Drawing on National Resource Science Precinct capability, the project will see CSIRO's researchers use geophysical modelling and advanced characterisation tools to test and refine NTGS's 3D models of geology under cover. The research will help identify where mineral deposits are most likely to occur.

Dr Fisher says that embedding their researchers into organisations like the state geological surveys is beneficial for both parties.

"It's definitely something we're keen to do more of, so we're exploring opportunities to collaborate with the other state geological surveys using the same model," Dr Fisher says.

The datasets generated at the end of the project will be a valuable outcome for industry.

The team will present these as a series of maps, digital datasets and reports to support exploration targeting in the region which will be freely available through the NTGS open access portal.

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READY TO MARKET

ACCELERATING INNOVATION

A new program has sped-up the process of taking a unique and promising new sensor technology to market. DAVID SIMPSON writes about CSIRO's new accelerator program.

One of the popular memes about Australia and innovation is that we are good inventors, but are less successful at bringing our ideas to commercial fruition.

CSIRO's new innovation and entrepreneurship program, ON, aims to address this by creating teams of customers, partners and staff to fast-track the development of new technologies.

The creation of ON is a timely development that received a welcome boost in the form of a $5 million annual commitment from the Australian Government, as outlined in their recent innovation statement.

The funds will be directed to expanding the AcceleratiON program to other research institutions. This will expedite collaboration between CSIRO, participating universities and other publicly funded research agencies while also helping to build relationships between researchers, entrepreneurs, investors, start-ups and established companies.

AcceleratiON is an intensive three-month activity in which participants – comprising CSIRO staff and external collaborators – are given the opportunity to explore the commercial potential of selected technologies.

One of the keys to the success of the program is that staff take temporary time away from their other responsibilities so they can focus solely on the task at hand – in this case the new Sensei technology.

Sensei comprises robust solid-state electrochemical sensors. Traditional leaching process monitoring generally involves taking samples, analysing them outside the process stream and making adjustments accordingly. This has the

The Sensei ON team from left to right: David Molenaar, Jean-Pierre Veder, Liz Eadie and Mikko Vepsalainen.

drawback of delayed results and the risk that the sampling itself may change the results.

Using Sensei, sensors are embedded in the material being processed and can be set to transmit readings at whatever time intervals are required.

The golf ball-sized Sensei sensors can either be hard-wired or wireless, and can deliver readings including physical parameters such as temperature, redox potential, conductivity and chemical parameters including pH and levels of dissolved metal ions.

Inserted in low numbers, or at particular points in the process, Sensei can provide operators with a simple picture.

Embedding hundreds of Sensei sensors into a material stream can enable complex 3D maps to be generated, digitising the entire process.

The CSIRO team's challenge began before the start of the 12-week AcceleratiON program and took the form of a knock-out round of activities with some 70 other applicants. This process culminated in a residential camp in which 20 shortlisted teams competed for one of the nine prized places.

"They were able to articulate a sizable market opportunity and explain that their competitive strength was due to unique aspects of the Sensei technology that enable it to operate in extremely hostile environments," ON program director, Liza Noonan, says.

"Additionally, they put forward a very diverse team; it wasn't solely a research team. They also had an intellectual property manager and people with previous business development, industry and commercialisation expertise.

"I think this diversity helped them demonstrate good early stage thinking that enabled them to envisage what a successful strategy would look like."

While the team may have had an idea of what a successful strategy might comprise, the AcceleratiON program provided them with the opportunity to identify where it might be best targeted.

According to one of the team members, Dr Mikko Vepsalainen, they went in to the program thinking that they were going to apply the Sensei technology to a specific area – heap leaching.

"During the first couple of weeks we decided to broaden our horizons and see whether there were other areas in which we could apply the technology.

"We looked for extreme operating environments in the oil and gas industry, in water treatment and processing, environmental monitoring and even food and beverage manufacturing."

Another CSIRO team member, Jean-Pierre Veder, adds that it was "a valuable exercise".

"Because it involved talking to potential clients in such a wide range of industries it gave us insights into how they saw their requirements or, if you like, their needs.

"We were almost surprised, but reassured in our own thinking, when we found that the greatest need and opportunity was in the mining industry," Dr Veder says.

One thing the team realised, as they spoke to 150 potential customers, was that the market did not necessarily see Sensei solely as a technology solution. While initially they thought they would be selling sensors, client feedback made them realise that there could be opportunities to sell systems, data or a complete service, all based on Sensei.

"Different companies see the technology in different ways," CSIRO's Dr Miao Chen, who developed the technology, explains.

"Some want to buy a service, including everything – software, hardware, operating it – the lot. Others just want to get the devices and integrate them into their existing systems.

"The process made us realise that we probably need to be flexible about delivering different solutions to different customers."

Today, the Sensei team are embarking on a pilot program and AcceleratiON is looking towards its second round of team selection and program implementation.

"WE'RE HELPING CSIRO DO THINGS A LITTLE DIFFERENTLY SO IT CAN BECOME THE INNOVATION CATALYST. THIS PROGRAM COULD POSSIBLY HAVE THE BIGGEST IMPACT OF ALL," DR VEPSALAINEN SAYS.

The team also included CSIRO's Liz Eadie and David Molenaar. Each found the experience hugely rewarding and valuable and are looking forward to seeing Sensei brought to market.

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NEW RESEARCH

TRACING FOOTPRINTS FROM A DISTANT PAST

Following the clues of mineral signatures could allow explorers to cast their nets wider and trigger a new era of discoveries under cover, finds TIM TREADGOLD.

The entire Capricorn region, which covers thousands of square kilometres, is like a giant haystack waiting to be examined for clues pointing to potential orebodies.

An alternative way of thinking about minerals exploration through cover begs the question: why look for a needle when the haystack might be more valuable?

In very simple terms that sums up a project investigating distal footprints – a scientific hunt for the telltale signs of giant mineralised systems formed eons ago that now lie hidden deep beneath the modern Earth's surface.

Using the latest geochemical and geophysical tools, a team led by CSIRO has embarked on a four-year program to identify the clues that could trigger a new era of discovery.

The initial focus of the study is the Capricorn region of Western Australia (WA), a poorly explored area that lies between two of the world's best-endowed mineral provinces, the iron ore-rich Pilbara and the precious metal-rich Yilgarn.

"The Capricorn offers the best chance of finding chemical and physical markers left during the formation of giant orebodies," Dr Alistair White, a CSIRO research scientist specialising in mineral and hydrothermal geochemistry says.

"We're looking for the signatures left by major orebodies, often at a considerable distance from the deposit itself, and what sort of tools explorers need to identify the signatures left during mineralising periods that led to the formation of those orebodies."

Rather than trying to pinpoint a particular orebody, which is what most explorers try to do, the 30 geologists involved in the project are looking at the bigger, background picture for the chemical and physical signatures left during the mineralising process.

In that regard, the entire Capricorn region, which covers thousands of square kilometres, is like a giant haystack waiting to be examined for clues pointing to potential orebodies.

One way of looking at the $19 million project is to see it adopting the tactics of a hunter tracking an animal across the outback, looking for telltale signs such as footprints, droppings and damaged foliage, which might lead to the prey.

The big difference in the geological hunt is that the target is underground, perhaps very deep underground, covered in a thick layer of weathered rock and sediments deposited and shifted over billions of years – with the surface cover hampering most explorers.

Finding ways to 'see through' the cover has not been a priority for Australian mining companies until recently because they have been able to focus on outcropping orebodies, including in famous locations such as Broken Hill, Mt Isa and Mt Newman – with a clue to their discovery in the name, either a hill or a mountain, peeping up above the flat surrounding country.

But, with no major new discoveries in decades and with Australia still heavily reliant on its mining industry for export income, the search for hidden orebodies has taken on a greater urgency and knowing where to start looking is the challenge.

In the two years since their work started, the distal footprints team have been focusing on developing the right set of tools to enable them to find the pathways of magma and fluid migration in the layers of ancient rock units that lie under cover. They are, in effect, examining the 'haystack' which is the cover – regolith, sediments and igneous rocks – for signs. In some cases the hunt goes down to the atomic level.

In a way the team, which includes researchers from The University of Western Australia and Curtin University, are following up a proposition first put by one of Australia's leading exploration geologists, Roy Woodall.

Almost 40 years ago Woodall, when head of exploration at Western Mining Corporation and a key player in the discovery of the deeply buried Olympic Dam copper and uranium orebody in South Australia, said that the key to future big discoveries lay in the ability to "peer beneath the regolith".

In a paper contributed to a 1979 book published to mark the 150th anniversary of white settlement of Western Australia, Mr Woodall wrote that:

"FOR FUTURE EXPLORATION TO HAVE THE BEST CHANCE OF BEING ECONOMICALLY VIABLE, GEOPHYSICAL AND GEOCHEMICAL EXPLORATION TECHNIQUES NEED TO BE IMPROVED AND THE NATURE OF CONCEALMENT NEEDS TO BE BETTER UNDERSTOOD.

"THE CONCEALMENT MAY BE SHALLOW RESIDUAL SOILS, WIND-BLOWN SANDS, ALLUVIAL SHEET-WASH, THICKLY VARIABLY STRIPPED LATERITE PROFILES, ALLUVIUM IN FOSSIL OR CURRENT DRAINAGE SYSTEMS, SALINAS, OR TERTIARY MARINE SEDIMENTS.

"OF SPECIAL RELEVANCE TO EXPLORATION IS AN UNDERSTANDING OF ALL THE PARAMETERS INFLUENCING THE MOBILISATION, TRANSPORTATION AND PRECIPITATION OF METALS IN THE NEAR-SURFACE ZONE, SO THAT GEOCHEMICAL SURVEYS CAN BE MADE MORE COST-EFFECTIVE AND RESULTS MORE CONFIDENTLY INTERPRETED."

Mr Woodall was ahead of his time, partly because mining companies had enough surface outcrops to explore without bothering with the costly business of attempting to peer beneath the cover, and partly because geochemical and geophysical tools in 1979 were primitive compared with what's available today.

Now, new tools – ranging from measuring gravity and magnetic signatures to testing water in pastoral station wells for molecular indications of minerals – are being harnessed as part of the distal footprints project.

Dr White says the collaborative, multidisciplinary project would seek to deconstruct the Capricorn region to better identify the weak and remote signals of deeply buried ore deposits and enhance the potential for a major future discovery.

"We are at the early stages of looking for Australia's next generation of mines," he says.

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CSIRO blog

USING FAST RADIO BURSTS TO WEIGH THE UNIVERSE

Consider this. Every day thousands of spectacular flashes emitting as much energy in a millisecond as our sun does in 10,000 years are taking place across the sky. Despite being astonishingly powerful they are also elusive, with just 16 detected since first discovered by our Parkes telescope in 2007.

WE'RE TALKING ABOUT FAST RADIO BURSTS.

Now, for the first time, scientists have pinpointed the location of a fast radio burst (FRB), confirming that they originate in the distant universe. This particular burst, cutely named FRB 150418, happened a long time ago in a galaxy far, far away. It's taken six billion years for the afterglow to reach us.

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

THE CONVERSATION

WHY BATS DON'T GET SICK FROM THE DEADLY DISEASES THEY CARRY

Bats are a natural host for more than 100 viruses, some of which are lethal to people. These include Middle Eastern Respiratory Syndrome (MERS), Ebola and Hendra virus. These viruses are among the most dangerous pathogens to humans and yet an infected bat does not get sick or show signs of disease from these viruses.

The recent Ebola outbreak in West Africa showed the devastating impact such diseases can have on human populations.

As treatments in the form of therapeutics or vaccines rarely exist for emerging diseases, future outbreaks of disease have the potential to result in similar outcomes.

Understanding disease emergence from wildlife and the mechanisms responsible for the control of pathogens in their natural hosts provides a chance to design new treatments for human disease.

Until recently, bats were among the least studied groups of mammals, particularly in regard to their immune responses.

But even early studies of virus-infected bats provided clues that there may be differences in the immune responses of bats. It was observed that some bats were capable of clearing viral infection in the absence of an antibody response.

Antibodies are one of the hallmarks of the immune response and allow the host to respond more rapidly to subsequent infection when the same pathogen invades the body. The absence of a detectable antibody response within the bat was striking and drew our attention to the earliest stages of the immune response, called the innate immune system.

The recent sequencing of the first bat genome provided some of the first clues that the innate immune system may be key to the ability of bats to control viral infection. There is intriguing evidence for unique changes in innate immune genes associated with the evolution of flight, and bats are the only mammal capable of sustained flight.

Read the full article at: theconversation.com

RESOURCEFUL

UP NEXT

IN THE NEXT ISSUE OF RESOURCEFUL WE WILL LOOK AT THE FUTURE OF MINING INNOVATION.

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