ISSUE 11 APRIL 2017

resourceful

CSIRO

BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY

NEW DEPTHS

FUTURE SCIENCE TO UNLOCK THE EARTH'S DEEP RESOURCES

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INSIDE THIS

ISSUE

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IMAGE CREDITS Cover: © GettyImages
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LEADER'S COMMENT

NEW SCIENCE TO REDUCE RISK

Rapid shifts in technology are paving the way for developing innovative and potentially revolutionary imaging technologies that can reduce risks in deep earth exploration, writes JONATHAN LAW

There can be no doubt that innovation is vital to the future of the Australian economy, and our minerals and mining sector is a cornerstone of that future. Industry must take greater risks on technology to be rewarded with future growth.

CSIRO is in a unique position to help industry take this needed leap. We invest in new science that transforms the way we do things for the benefit of our customers.

Recently announced in line with CSIRO's Strategy2020, we are investing in new breakthrough science which has higher technical risk but carries with it the potential to help reinvent or create new industries for Australia.

Six new science investments were launched this year and the minerals and mining industry was one of the big winners. CSIRO's new Deep Earth Imaging Future Science Platform will tackle the challenge of enhancing exploring for mineral, energy and water resources by transforming the way we search and map the subsurface.

The platform's goal is to develop technologies to underpin a new wave of resource discoveries both on and off shore.

Exploration through cover is widely recognised as a key national challenge in enabling Australia to maintain its resource production and realise the growth opportunities provided by our national endowment.

At the orebody scale, better imaging techniques will have a major impact on the resource definition and production domain.

MAPPING THE DEEP EARTH HAS LONG BEEN A KEY PART OF ANY EXPLORATION PROGRAM, BUT RAPID SHIFTS IN TECHNOLOGY BRING NEW OPPORTUNITIES. NEW SENSORS, HARDWARE AND SOFTWARE COMBINED WITH MACHINE LEARNING AND SOPHISTICATED DATA ANALYTICS HAVE OPENED UP A NEW FRONTIER – TACKLING THE CHALLENGE OF DEEP EARTH IMAGING WILL REQUIRE A FRESH APPROACH.

This edition of resourceful highlights some of the key components that will give the platform its best chance of success with applications in minerals, oil and gas, groundwater, and engineering applications including geosequestration, geothermal power, waste storage and many others.

Deep Earth Imaging will be multi-disciplinary and experimental, involving teams of researchers drawn from around the world and integrating data and digital technology. Collaboration with local and international partners is key for both researchers and industry who will provide test data and opportunities for demonstration through case studies.

New science will reduce exploration risk. The initial focus of Deep Earth Imaging will be Australia's leadership in technology development with a longer term goal of commercial technologies for global deployment.

I hope the next few years will see an imaging revolution not unlike the rapid shift in cheap digital camera resolution. When linked to the right processing engines, the future of Deep Earth Imaging is exiting and positioned to drive major changes, beginning with exploration and continuing through the resources value chain. ●

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RESEARCH NEWS

TACKLING NEW SCIENTIFIC FRONTIERS

CSIRO has made six major science investments at the leading edge of world research trends in a bid to stay ahead of global disruption. TONY HESELEV reports

Announced in late 2016, CSIRO has grown its investment in six new areas of breakthrough science to meet emerging challenges and drive innovation for Australia.

Dubbed CSIRO's "Future Science Platforms", this investment aims to generate and reinvent industries, as well as deliver jobs and prosperity for Australians. Another key aim is to expand CSIRO's core science capabilities.

The platforms will deliver innovation in different areas including health and biology, environment, resources, agriculture, materials and manufacturing.

Among the six platforms is Deep Earth Imaging, which will develop technology to image subsurface geology to unlock the potential of minerals, energy and water resources that lie deep beneath the earth or sea (see page 6).

CSIRO Chief Executive, Dr Larry Marshall, believes investing in challenging and riskier science is needed to stay ahead of accelerating global disruption of all kinds – from economic to environmental.

CSIRO invested $17 million in 2016/17 to launch the six platforms, and this will grow to $52 million a year by 2020.

> **Our organisation is based on innovating, creating and being smart, and we need to keep generating ideas, developing new capabilities and leading in areas where we think it makes sense to do so.**

The platforms are designed to provide a basis for long-term research to solve a range of problems, similar to how gene shears research has delivered solutions for health, medical science and agriculture.

Over time, they aim to develop underpinning technologies with the potential to generate significant revenue.

In the short term, CSIRO wants researchers in each platform to explore the best ways to meet the scientific challenges with a gradual shift of emphasis to applications to deliver significant impact.

Each platform integrates data and digital technology to meet the rapidly changing needs of industry, community and the environment. Each also requires deep collaboration across scientific disciplines at CSIRO and among research partners such as universities, Cooperative Research Centres, industry and specialist organisations to deliver sustainable value to the nation.

CSIRO's Executive Manager, Science Impact and Policy, Tom McGinness, says the platforms allow researchers to develop new scientific and engineering approaches informed by some of the major challenges and opportunities faced by Australia and the world.

"Our organisation is based on innovating, creating and being smart, and we need to keep generating ideas, developing new capabilities and leading in areas where we think it makes sense to do so," he says.

Mr McGinness says that if and when the platforms make the transition from science of the future to science of today – becoming part of mainstream CSIRO research – they will be considered successful.

THE BIG SIX

The six **Future Science Platforms** are:

Deep Earth Imaging
Developing technologies to more precisely image and discover mineral, energy and water resources that lie deep under the earth or sea to unlock their potential.

Active Integrated Matter
Reinventing industry by connecting robotics, materials, sensors, data and artificial intelligence. Advances will provide global solutions and position early adopter industries ahead of the pack.

Digiscape
Developing decision tools such as sensors, data visualisation and artificial intelligence to provide insights and knowledge to environmental policy makers and help agricultural industries become more productive and sustainable.

Environomics
Developing genomic technologies for managing ecosystems and species under environmental change, detecting biosecurity threats and creating new products to help feed billions more people by matching crops to future soil and weather conditions.

Probing Biosystems
Developing devices and systems to monitor our health in real time to provide timely and customised medical interventions such as preventing diseases recurring.

Synthetic Biology
Designing and producing new biological devices, systems and machines to create synthetic vaccines, personalised 'spare parts' for our bodies and conserve biodiversity and ecosystems.

FEATURE

EXPLORATION EL DORADO

Although the deep earth remains largely unexplored, it's believed to hold vast reserves of mineral, energy and water resources. ADAM COURTENAY explores a new groundbreaking science initiative aimed to reveal what opportunities lie below.

If the world of geophysics has a vision of El Dorado it would be something like this: the ability to see into the uppermost surface of the earth's crust with the very same accuracy that we see the earth's obvious features – its rivers, rocks, mountains and plains.

A fantasy? Nobody is pretending that "seeing" 50 metres or even a kilometre beneath the surface of the earth is going to be easy.

The electromagnetic, gravitational and other sensing tools currently used to chart even a few metres below the ground are constantly being developed and improved. However, in order to see that kind of geological detail lower down, scientists have to aim higher.

For Australia's mining and resources sector, the move towards a geophysical El Dorado has reached a critical phase. The country is running out of shallow, easy-to-access mineral deposits. They are either non-existent or close to fully prospected. We are still producing from mines that our forefathers discovered in the late nineteenth and early twentieth centuries. Prospecting needs to go underground.

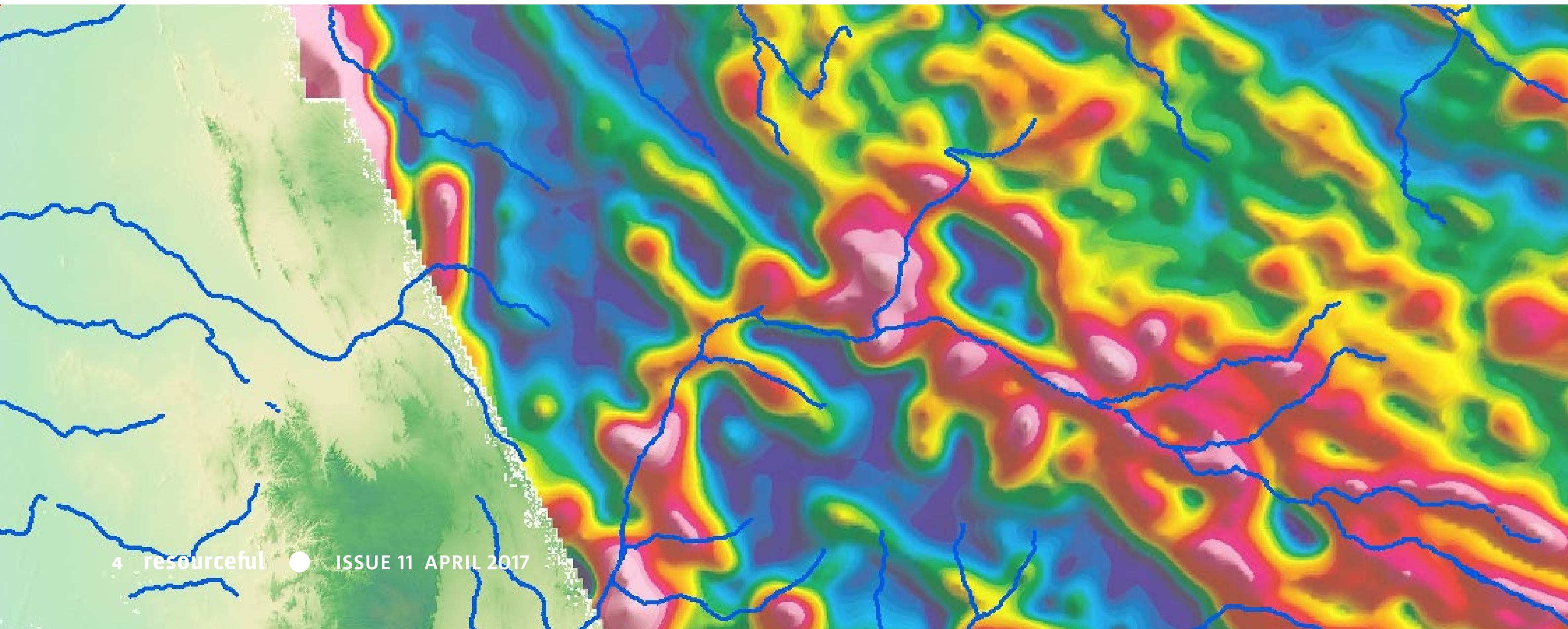
How are Australian scientists hoping to change this? Already well under way is the UNCOVER initiative, a collaboration of government, research institutes, universities and industry. It is an overarching project that combines all actors in the search for valuable underground mineral resources.

Aligned with the UNCOVER vision, is CSIRO's new Deep Earth Imaging Future Science Platform. This new science initiative will be run by CSIRO and admits to being highly experimental with a unique set of characteristics. It will initially focus on invention and creativity over applied science or industrial innovation.

Currently as part of Deep Earth Imaging, CSIRO is looking to hire some of the best exploration geophysicists across the world to create a world-first "exploration geophysics hub". There are, of course, experts in this field everywhere, but they have never been cross-fertilised within the same incubator.

An exercise of this size and nature calls for other skills as well. Physicists, chemists and mathematicians will also have to be part of the mix. As important as the geophysicists, will be the data scientists and software engineers, because Deep Earth Imaging is equally an exercise in developing predictive data analytics tools as it is about discovering subsurface phenomena.

The creation of this hub is not just restricted to minerals and mining. It will be just as involved in seeking out other important resources such as energy and water. The open-ended



nature of CSIRO's Future Science Platform investment is to mix and match a number of different disciplines, the combinational results of which are as yet unknown. The earth's the limit.

"We're looking for areas where we can develop generic science around the prediction of the subsurface – and it could be relevant to all of the above – water, energy and minerals," CSIRO's minerals exploration research director, Dr Rob Hough, says.

"We're not looking at any one thing – this is more about putting together a suite of generic tools and software, which will allow us to simulate, model and predict the subsurface in a way we simply can't do today."

The Deep Earth Imaging platform is funded to the tune of $3 million per annum over the next three years.

The platform will be run by Dr Mike McWilliams, a former CSIRO executive, under whom there will be five team leaders. It will also include 18 post-doctoral, early-career researchers who have been carefully selected from around the world.

Dr Hough says the aim is to develop tools that can simulate and predict the geology of the subsurface and offer the best possible measure of quantification around the predictions.

"It's about how we're going to develop a beautiful multi-coloured image that accurately reflects the geophysics of any subsurface. And, determining if it's possible to interpret the subsurface using these tools to not just see, but to predict, what the underlying geology is going to look like," he says.

The team will be developing new analytical software tools that are founded in rock physics, but that also draw from predictive technology, machine learning, geological uncertainty analysis and geoscience modelling. The tools will manage real-time data streams and fuse multiple inputs from geology, hydro-geochemistry and geophysics.

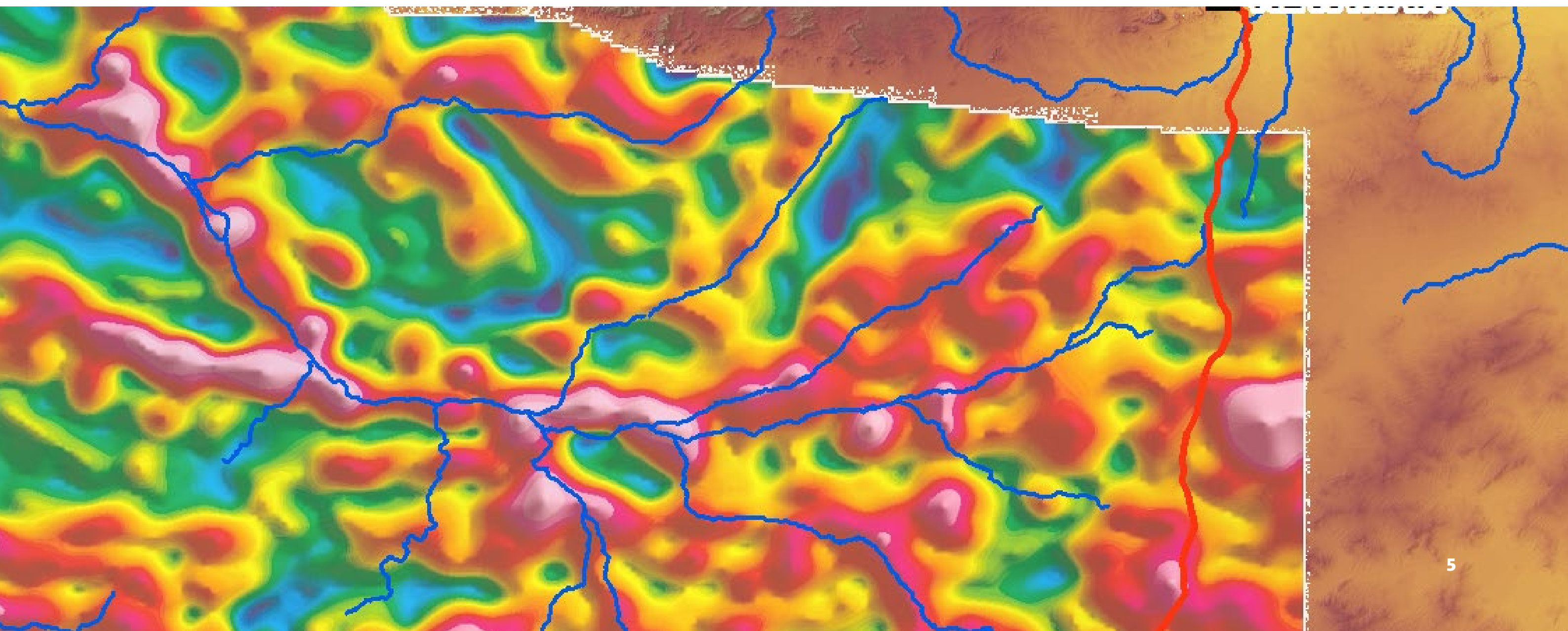
Tools to actually see under the surface, are currently a scientific work in progress. Airborne systems are becoming progressively sophisticated at collecting the electrical properties of the earth. There are also earth sensor tools and others measuring magnetics and gravity, all of which will be used to explain various expressions of the earth in relation to the other.

Recently, South Australia's Department of Manufacturing, Innovation, Trade, Resources and Energy released information about surface cover over orebodies based on data already available from mining company reports. The industry is working on coordinating all the state geological maps, building knowledge of the larger mineral systems and their potential.

Researchers are looking deeper into the architecture of the earth – the igneous intrusions, the cracks and the potential mineral traps – in a way that would have been impossible just a few years ago.

There are new stratigraphic drilling methods that reveal the buried geology, which can be intelligently extrapolated across larger areas. The Deep Exploration Technologies Cooperative Research Centre is now pioneering coil tubed drilling – similar to petroleum industry methods – that allows analysis of rocks as drilling occurs. We have new drill sampling technologies that allow us to test samples live so that companies can make smarter decisions about the existence of nearby ores.

These are just a few examples of a whole new suite of emerging technologies available. These technologies provide more detailed information at greater speed in order to take much of the guess work and expense of mining exploration out of the equation.



Despite these increasingly sophisticated methods of seeing deeper and more accurately, Dr Hough says we still sit at a fairly primitive point in predicting subsurface geophysical properties and the geology. We often use one or two geological models produced by geophysics, test them by drilling some holes and then make a decision based on the results.

"What we now have to do is design real, live tools for forecasting what the subsurface geology is going to be. There may be several models, possibly even thousands of iterations from the geophysical data, but in terms of managing risk we need to be able to measure the uncertainty around our predictions."

The ultimate development of the tools comes down to one thing: how will they be used to significantly reduce the risk of exploration beneath the surface. How will explorers – whether for oil, water or minerals – be able to use predictive models to eliminate the uncertainties? Dr Hough hopes to see the day when geophysical models can predict underground phenomena as accurately as weather models predict rainfall.

In the end the platform's level of invention will be applied to industry.

A consultant to the Australian Mineral Industries Research Association (AMIRA), Tim Craske, says that while he applauds the ideals of the Deep Earth Imaging platform, it must not operate in a vacuum.

"Deep Earth Imaging is going to have to deliver something meaningful about the top couple of kilometres of the surface of the earth, otherwise it is in danger of being an academic exercise," Mr Craske says.

"It's not going to change how we do work unless it's relevant."

Mr Craske, who is working on the roadmap with CSIRO and industry in the UNCOVER project, would like to see a kind of open-source software philosophy applied to Deep Earth Imaging.

"As long as the products are planned for open source – which it sounds like they are – then this will be an exciting endeavour," Mr Craske says.

"CSIRO needs to be putting stuff out for people to play with and use.

"What I hope to see is Deep Earth Imaging setting itself up a bit like Linux and Wikipedia – people can see it and pass comment on it. For this to become valuable, then value has to be created along the way as well as at the end."

What Mr Craske doesn't want to see is what he terms "the cathedral model" where the monks write the book but don't show it to anybody until it's finished. That's the traditional software model, he says.

"What we need is the bazaar model where anybody can come along with a basket of stuff and get involved. Nobody is an owner and nobody is not an owner. They jump into that space without asking permission and generally the products get spectacularly better than anyone imagined in the first place."

Dr Hough agrees that industry must be informed along the way as developments occur in the Deep Earth Imaging platform, and beyond this, he recognises that industry may possess valuable data and technology the platform could work with.

"Of course, we'll be looking in time to partner with industry but we need to devise the methodologies before we can do that. We don't want to define the business model from the start," Dr Hough says.

"Don't get me wrong, we may be at the pre-methodology phase but we have some very good ideas as to what our priorities and major research themes will be, as well as encouraging possibilities to attract people to work with us using the very latest data and technology. Just watch this space."

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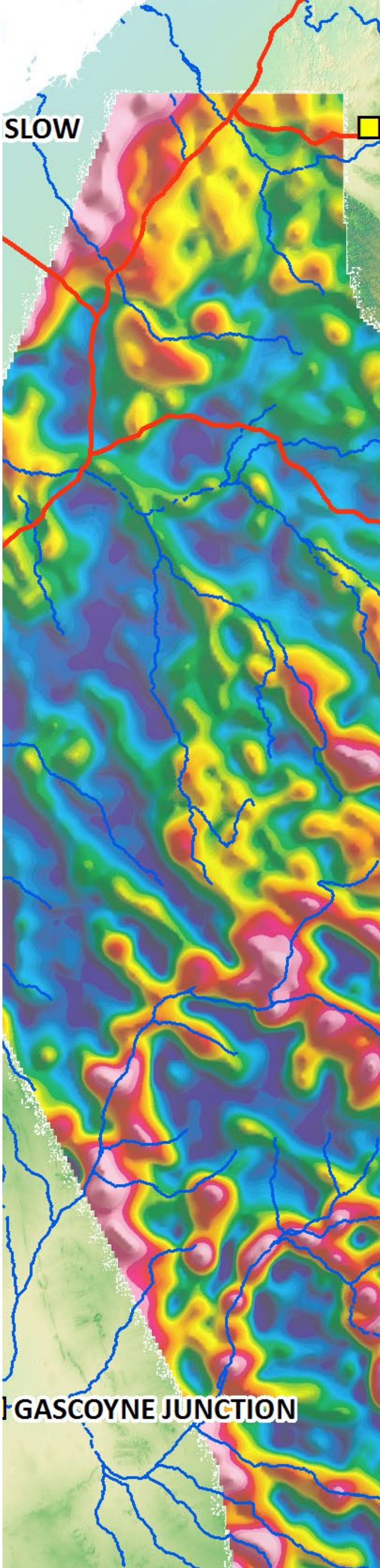

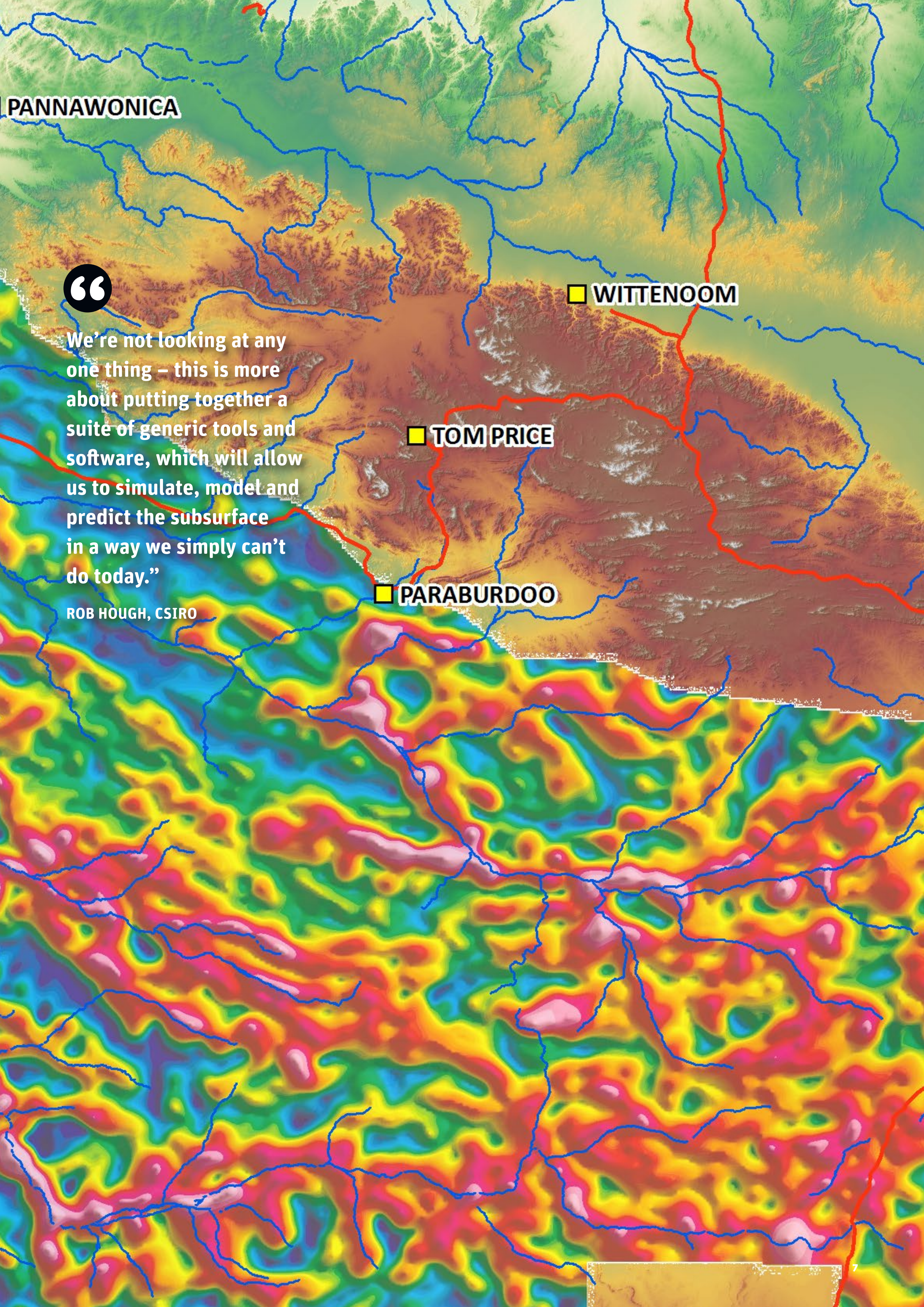

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ROB HOUGH, CSIRO

NATIONAL PERSPECTIVE

HIDDEN OPPORTUNITY

Chris Pigram

The society of the future will still need the earth's mineral and energy resources, says former head of Geoscience Australia, CHRIS PIGRAM. But, with near-surface resources depleting, it's time for the industry to take a giant leap and do things differently. Interview by JOHN MILLER

What opportunities exist for Australia to continue to benefit from its abundance of mineral and energy resources?

Australia has always exploited its natural endowment and can continue along this path for many years. With growing global demand for minerals like copper and zinc there is an enormous opportunity for Australia to continue being a leading supplier of resources. For instance, in the next 30 years the world will need as much copper as has ever been produced to sustain development of modern technology and renewable energy.

The need for energy is also growing, particularly in developing northern and eastern Asia, and Australia has a major role to play in feeding this demand.

> **Deep Earth Imaging research will keep Australia at the forefront of resources sector capability and provides an enormous opportunity for the mining, equipment, technology and services (METS) sector to not only find those resources, but to show others how to go about it.**

What tools and techniques are needed to explore, develop and exploit these resources?

In an environment where deposits are obscured by cover material of 100 metres or greater, today's tools and techniques are ineffective and a whole new range is required. Drilling is one tool and there is encouraging research being carried out by the Deep Exploration Technologies Cooperative Research Centre.

The big challenge facing the geological community is to better define what we can't see by developing vastly improved subsurface imaging techniques, which will provide a better idea of the geology lying ahead of the drill.

CSIRO's Deep Earth Imaging Future Science Platform aims to take the limited number of physical properties that can be measured and develop the capacity to turn them into better geological models than those now being created.

The petroleum industry provides an analogy. Coming out of World War II the industry didn't have the tools needed to explore for hydrocarbons in the subsurface, but over time these were developed, enabling explorers to target areas of interest. Minerals present a more complex geological scenario, but should be approached in a similar way.

Why does the Australian minerals industry need Deep Earth Imaging?

Australia is very well explored, at or near the surface, by a capable and highly successful industry. However, the next generation of resources to sustain the pipeline will come from more than 100 metres below surface. There is no reason to assume that the next level of depth doesn't have the same endowment as what we have already exploited.

For Australia to attract future mining investment, it needs to be attractive and the potential for mineral and energy resources at depth needs to be demonstrated.

Deep Earth Imaging research will keep Australia at the forefront of resources sector capability and provides an enormous opportunity for the mining, equipment, technology and services (METS) sector to not only find those resources, but to show others how to go about it. It will also enable the resources sector to continue contributing significantly to Australia's economy.

All information collected through geophysics is ambiguous and there are always multiple interpretations. Having stronger geological statements is a priority of the work, because reducing interpretations and having more confidence in geological models at depth will make a big difference with the effectiveness of follow-up drilling.

How will Geoscience Australia be involved in development of Deep Earth Imaging?

Geoscience Australia (GA) is participating in the Exploring for the Future program, which is focused on northern Australia and is supported by government funding. The program aims to open the doors to exploring under cover at depth and provide pre-competitive information in the commercialisation process. GA will work with CSIRO and state geological surveys to help apply and test techniques and methodologies in a real world environment.

An important aspect of the work is Deep Earth Imaging, through which CSIRO will develop the tools and techniques, and GA will help apply them, demonstrate their effectiveness and assist industry to adopt them.

In what other ways has Geoscience Australia worked with CSIRO?

A recent collaboration involved piloting UNCOVER work in a geological context in western Victoria with the aim of determining prospectivity. During this project, CSIRO developed some of the capabilities around the Lab-at-Rig concept, which provides geochemical analysis in real time. Analytical information is obtained while the rig is onsite without the need to send samples offsite and wait for the results.

It was an effective collaboration that provided rapid results onsite and the partnership demonstrated that the CSIRO concepts were valid. It is amazing that you can obtain instant results, rather than waiting weeks before realising that perhaps the hole should have been a metre or so deeper or inclined one degree further. It proved an efficient and effective use of resources and the concept is now being commercialised.

What will the barriers be to implementing Deep Earth Imaging?

The program has been set up well and the concepts around implementation are excellent, but the issue will be how to get the mining industry to think laterally. The technology is not about incremental improvement of what we already know, but involves some radical steps and the industry will have to show enough courage to take that giant leap.

It is also a big opportunity. As well as doing some of the more predictable things, it is important that miners are out-there, developing a new way of doing business to overcome the challenge of exploiting resources at depth.

Scientific leadership is also needed to ensure the industry does things differently. This is what research is about – at the end of the day you want to be at the cutting edge. CSIRO has created this opportunity and I commend them for doing so.

Are there similar opportunities beyond these shores?

Going under cover is a global issue and Australia leads the way from the early stages as well as the upstream, pre-competitive phases where GA and CSIRO operate. We are pioneers and if we can find a way to crack these problems, it will lead to global application.

INDUSTRY PERSPECTIVE

DEEP THINKING PRESENTS NEW OPPORTUNITIES

Technologies developed through CSIRO's new Deep Earth Imaging research will deliver the best results with broad collaboration, says a leading industry geoscientist, JON HRONSKY, of Western Mining Services.

As a company providing high-level consulting services to the global mineral exploration industry, we utilise concepts and data put into the public domain by CSIRO.

Deep Earth Imaging is about producing enabling technologies for the industry by better integrating and making sense of geoscientific data.

Ultimately, it will help the industry if that research can be distilled into providing practical imaging software that can be applied to datasets.

CSIRO is using its skills in big data and access to super computers to develop the algorithms that will integrate datasets and deliver a seamless product.

Its goal will be to integrate various 3D datasets to provide a product that "looks like geology" and therefore can be readily applied to target new deposits.

The potential impact of being able to do this is demonstrated by an earlier imaging breakthrough in the late 1980s, which was one of the most significant in exploration geoscience in the past 50 years.

This was research conducted by AMIRA, which applied image processing to potential field. All of a sudden we had magnetic maps that looked like geology and helped us see beneath the shallow cover. This led to many new discoveries and provided the basis for the pre-competitive geoscience data collection revolution.

Now, we're talking about the next level of imaging. We've recognised that significant orebodies are not going to be found sticking out of the surface.

I think that's true of Africa, South America or anywhere else in the world, it's just that we have been in this space longer in Australia and have long recognised that seeing through the earth's cover is our big opportunity and challenge.

This reflects the strategic maturity of our industry. One of the things we've done well in this country is to organise the triumvirate of the industry, government instrumentalities and the academic sector to focus on the problem in a coherent way, which is the envy of other countries like Canada.

This problem of seeing through cover is totally generic, and if Deep Earth Imaging solves this problem, it will have a positive impact on discovery in Australia and globally.

Our advantage in Australia is that we're able to combine our capability of collecting, analysing and utilising data with the very significant investment (amounting to billions over the years) we make in pre-competitive data.

There is no such thing as a silver bullet in our industry but if Deep Earth Imaging is successful in using available data to develop software that enables us to produce relatively high confidence geological models or maps of these concealed areas, it will help our industry be more effective, capable and competitive.

However, collaboration is vital. Deep Earth Imaging needs to get feedback from pragmatic users of the technology. Strong industry advice and links are also needed to make sure it's appropriately focused, as are interfaces with the rest of the minerals value chain – the data providers at the beginning and the geological experts near the end of the process.

CSIRO must be externally focused in this research, openly seek input from a wide range of sources and actively engage with the various centres of innovation such as our universities.

RESEARCH PERSPECTIVE

FRESH PERSPECTIVE

A new pool of young and diverse talent is being brought on board to tackle the next frontier in geoscience – Deep Earth Imaging. The vision is to build a start-up culture where risk-taking is encouraged, writes CSIRO's DR MIKE MCWILLIAMS, the newly appointed platform leader.

Continuous technological development and innovation are critical for improving the global competitiveness and productivity of the Australian resources sector – and are therefore vital to the nation. Australia has a clear competitive advantage in its ability to conduct the research needed, with the mining sector accounting for nearly one quarter of all business research and development (R&D) investment.

The Deep Earth Imaging Future Science Platform aims to more precisely and more accurately image the subsurface and understand its geophysical and geochemical properties, unlocking the resource potential of a vast, under-explored part of Australia.

This nucleus for collaboration will be a unique exploration and environmental geoscience capability hub in deep earth imaging – perhaps the first ever that crosses the boundaries of minerals, energy, water and data science. Success in this endeavour would represent an enormous opportunity to discover future mineral, energy and water resources for the nation.

Global response to the establishment of Deep Earth Imaging has far exceeded expectations. Beginning in December 2016, nearly 500 very qualified people from Australia and overseas have applied for early career researcher and leadership positions in the platform.

Universities, geological surveys and industry service providers both here in Australia and abroad have expressed their keen interest in participating. The talent pool represents a wide range of traditional geoscience disciplines, but a significant fraction comes from less traditional fields such as machine learning, data analytics, quantitative image analysis, applied mathematics and statistical inference.

BY BRINGING SUCH DIVERSE TALENT TOGETHER IN A DYNAMIC ENVIRONMENT WHERE CROSS-DISCIPLINARY TEAMS CONTINUOUSLY ASSEMBLE AND REASSEMBLE, WE EXPECT TO BUILD AND SUSTAIN AN INNOVATIVE "TRY-IT-AND-SEE" CULTURE THAT WILL LEAD TO NEW TOOLS AND WORKFLOWS THAT CAN HELP US TO BETTER EXPLORE THROUGH COVER.

Undoubtedly, many of the things we try will ultimately fail, but what we learn from those trials will help to guide us in choosing new and innovative paths to explore.

While recruiting our teams, I have suggested to candidates that it may be helpful to think of Deep Earth Imaging as if it were a small start-up company, embedded within the larger CSIRO. We have been given a truly unique opportunity that by all accounts is unlike any other past exploration research initiative.

By collaborating with industry to understand their future needs and by incorporating fresh thinking from the global academic sector, we hope to provide new ideas that will become the exploration and imaging tools of the future.

To effectively commercialise these research outcomes, the platform will connect with METS Ignited and the Oil, Gas and Energy Resources industry growth centres, which were built to promote innovation by accelerating commercialisation and encourage better collaboration between R&D and industry needs.

Our teams will have the opportunity to see their ideas fast-tracked through technology pre-accelerators to create connections between research, science and business, enabling us to validate our research outcomes and translate them into real-world geoscience imaging applications.

If we are successful, CSIRO will play a central role in serving as the innovation catalyst for the earth science community in Australia.

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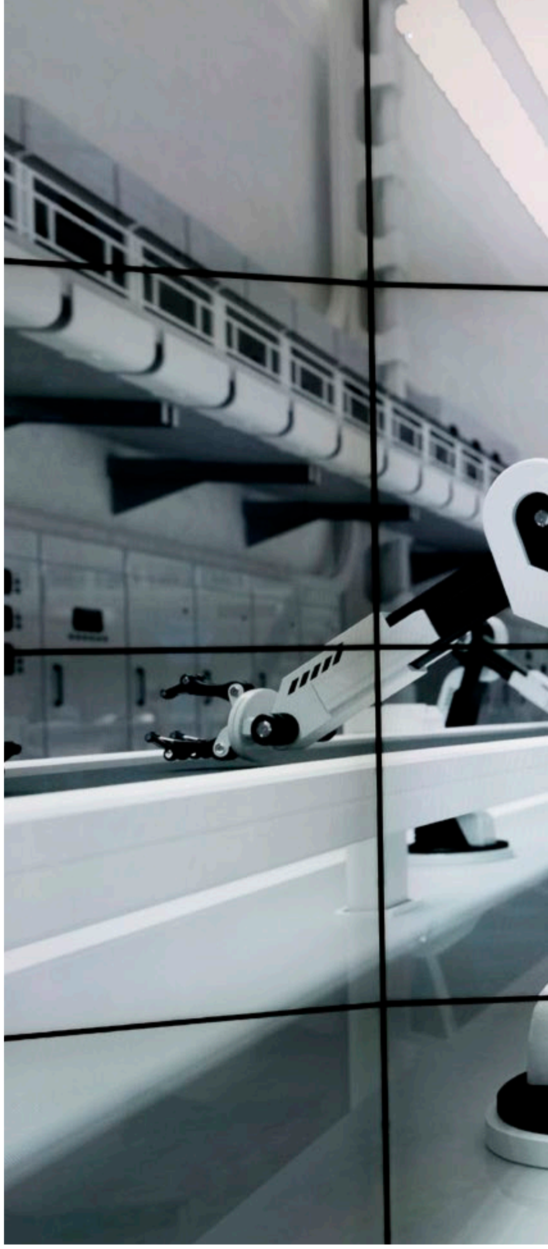
RESEARCH NEWS

NEXT REVOLUTION



A diverse pool of researchers have been brought together to integrate big data, materials, processing, sensors and robotics to deliver the underpinning science that will drive the next industrial revolution. ADAM COURTENAY reports

It's not often that researchers in one branch of science are called upon to apply their diverse skill-sets to problems that may not only be of use to their own discipline, but possibly to many other, unrelated fields.

This is how one could loosely describe the 12 test beds within CSIRO's Active Integrated Matter Future Science Platform (AIM). That is, a vast number of highly-qualified scientists and researchers from across the organisation are brainstorming projects relating to the challenges all industries will face in the next 20 years.

It's about food science people talking to data technology experts, who in turn are talking to manufacturing and mining experts, because the megatrends relate to them all. All industries need to be across the coming changes in big data, materials, processing, sensors and robotics, and take advantage of them.

The AIM test beds relate to food technology, manufacturing, water technologies, chemical processing and far more.

Dr Kathie McGregor, who leads CSIRO's innovative process chemistry group, calls it "foundation science" – developing the central, underlying principles of future technologies that will eventually be taken out and applied in a number of fields and disciplines.

The autonomous chemical processing test bed, run by principal research scientist, Mike Horne, is a mining and minerals "led" idea, but not restricted to it.

As Mr Horne himself says, the nature of the AIM platform work is collaborative, with teams drawing staff from across all business units within CSIRO to undertake this work.

"It's an unprecedented and cooperative effort that leverages skills from a diverse range of scientific disciplines and brings them to bear on some of the most significant problems we are currently facing," he says.

Mr Horne's test bed will generate new ideas, devices and data, taking what are essentially processing techniques and replanting them across the scientific landscape.

There is also a strong manufacturing bent to the test bed. Distributed manufacturing is one of the megatrends predicted to have a big impact globally and is already disrupting traditional models by relocating processing activities to the sites themselves rather than to the traditional remote processing centres.

"We want to be able to hold processing activities where the raw materials are generated or where markets exist, rather than transporting everything to and from a central facility," Mr Horne says.

"This type of thinking is essential for legacy mine site rehabilitation, waste processing and tailings reworking.

> **We want to be able to hold processing activities where the raw materials are generated or where markets exist, rather than transporting everything to and from a central facility.**

"Moreover, onsite manufacture of machinery spare parts using combinations of techniques such as additive and subtractive manufacturing is another possible field where this idea will have impact."

Mr Horne says AIM will have a more specific impact on the mining industry through projects that link novel and robust sensors with waste treatment, using a newly-developed high intensity electrochemical processing technique.

There will also be new methods of remote sensing which can be used to measure and control high-temperature operations, such as smelting and refining from a distance, as well as the ability to extract lithium from brines using selective electrochemical refining.

Dr McGregor, who sits on the AIM Science Council, says the interest for the mining industry is not just about improving mineral and chemical processing, but about technology that leads to the next level – a more efficient extractive process which is remotely operated and which continuously flows.

"We're interested in process intensification. It's really about revolutionising processes which involve chemical transformations of mineral and materials," Dr McGregor says.

Much of this is about increasing the inter- and intra-molecular interactions that simultaneously increase the mixing rate and reactive surface area.

"What we're trying to do is get more from less – how do you get dramatically enhanced efficiency and yield in the desired chemical transformation? We can do that with catalysts and innovative solvents, but we still have to design new, compact and efficient devices."

The new techniques, if successfully deployed, will lead to a win-win situation not just for mineral and chemical processing but for the environment, improving minesite environmental performance.

"Certainly in the longer term this is true," Dr McGregor says. "This kind of process intensification will bring about dramatic improvements in technologies for environmental remediation, processing and recycling."

Mr Horne's autonomous chemical processing test bed is now at the final planning stage.

The test beds were pitched to the AIM Director, Dr Danielle Kennedy, and the AIM Science Council for funding in February and a decision will follow soon on what will be funded.

"There are about 120 project ideas under 12 test beds," Dr McGregor says.

"AIM is a $28 million investment by CSIRO over three years. There is plenty of competition for this."

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RESEARCH NEWS

UNTAPPED SOURCES

The ability to identify and access sustainable sources of water from deep underground will be critical for developing northern Australia and other arid regions of the country. TIM THWAITES reports

Water, critical to life, health and the maintenance of communities, is also essential for the development of mineral, and oil and gas resources. It is simple – no water, no production.

"We've had issues where potential mine development was proceeding and the companies had to delay their programs and do extensive searches to try and come up with a water supply," South Australian Department of Environment, Water and Natural Resources' director for state research coordination, Neil Power, says.

In most of Australia where exploitable mineral deposits occur, particularly in the arid outback, a reliable water supply is typically sourced from groundwater in the top few hundred metres of sediments under the surface, which itself is often buried under a similar depth of the ancient weathered rock known as regolith.

Under CSIRO's Deep Earth imaging Future Science Platform, the research organisation is bringing together the skills and capabilities to peer through the earth and determine with greater certainty where usable sources of water are likely to be.

"For the resources industry, this would reduce up-front costs by developing more effective drilling for groundwater," CSIRO senior principal research scientist, Dirk Mallants, says.

"It could further provide a demonstration of the potential impact on water resources where they are used by neighbouring communities or to sustain precious ecosystems or cultural heritage sites. This is critical to obtaining a licence to operate. In short, it would reduce business risks.

"Governments could develop groundwater management plans with better understanding and more certainty, allowing them to set sustainable extraction rates and limits more precisely, so water resources can be developed to their full potential."

But, better knowledge and understanding of the location of water resources is only part of the story.

It is also important to understand their connectivity, that is, how water flows underground connect with surface water and underground resources.

"If you take water from a bore, how does that affect the spring a couple of kilometres downstream," Dr Mallants says.

This information is also of critical significance in areas where water underpins sustainable economic development, including the development of coal seam or shale gas deposits. And that's where the underground imaging of water meets the much deeper earth imaging of mineral and energy resources (see page 4 and 16).

CSIRO HAS BEEN DEVELOPING THE USE OF ENVIRONMENTAL TRACERS, NATURAL CHEMICAL COMPOUNDS WHOSE PRESENCE AND CONCENTRATION DETECTED ACROSS MANY LOCATIONS AND DEPTHS CAN PROVIDE INFORMATION ON THE SOURCE AND AGE OF WATER AND THE MINERALS WITH WHICH IT HAS COME INTO CONTACT.

Although the initial three-year phase of Deep Earth Imaging has only just begun, CSIRO has been working on projects relevant to the underground detection and description of water resources for some time.

Since 2010, CSIRO has played a leading role in the Facilitating Long-term Outback Water Solutions (FLOWS) program of the Goyder Institute for Water Research, established by the South Australian Government as an independent body to provide expert scientific evidence to support water policy development.

The FLOWS work started with reinterpreting AEM data to image ancient watercourses, known as paleochannels, in the north of the state, before moving on to the Eyre Peninsula to reinterpret existing mineral company AEM data. This research has already led to the announcement of a new silver deposit.

Now, a new project is being explored to field test and improve mapping and quantification of groundwater availability in the Musgrave Province in South Australia's north, a priority area for mineral exploration. It will utilise new AEM surveys flown to expand the data available.

In Western Australia, the developed capabilities will be relevant to managing large groundwater resources such as in the Perth Basin, the main source of water supply for Perth and its industries.

"For the north of Australia," leader of CSIRO's water in the resources sector group, Olga Barron says. "hydrogeological assessment to support regional development is critical." ●

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RESEARCH NEWS

BEYOND LIMITS

Lowering the cost of finding onshore and offshore oil and gas resources many kilometres below the surface is the focus of new research. TIM THWAITES reports

Australia has vast amounts of gas and possibly also of oil in its onshore and offshore frontier basins.

But, much like is the case with Australia's mineral resources, most of the easy-to-find oil and gas resources have already been discovered, leaving only reserves that are typically deeper than four kilometres under the ground or ocean.

These reservoirs are mainly in poorly explored regions where little geophysical data has been acquired and/or they are so deep that they defy established methods used to identify hydrocarbons from their geophysical signatures.

Through its Deep Earth Imaging Future Science Platform, CSIRO is working on reducing the business costs of finding new reserves by rendering the blanketing layers of earth transparent and sharpening the image of what's underneath.

It will take clever science to do it, but according to the director of CSIRO's onshore gas research, Dr Damian Barrett, the multidisciplinary and multidimensional nature of the work suits an organisation like CSIRO rather than the traditional service suppliers of innovation to the energy industry.

Looking for oil and gas is a very different proposition to searching for water or minerals. For starters, we are talking about working at depths of kilometres, rather than hundreds of metres, as for water.

"With oil and gas, 90 per cent of the data we use is seismic, especially offshore," CSIRO's research group leader for energy exploration geosciences, Dr Ben Clennell, says.

"We are only looking in sedimentary sequences, and the range of possible geometries we encounter is smaller — typically a flat layer, rather than a blob or some other weird shape."

The approach to sharpening up the image of the deep earth, Dr Clennell says, will be centred on a technique called Bayesian updating.

"You start with a model of what the geologists think might be there – which can be very fuzzy – and then you update it using real geophysical data."

The process is informed by a lot of geological understanding, which constrains and focuses the answers you get from analysing geophysical data.

"The end goal is to get fluids within the rock out to the world," Dr Barrett says.

"That depends on the nature of the pore structure and the stresses on the rock. The leap of science is to be able to relate the large-scale measurements of seismic signals to the small-scale characteristics of pore structure of the rock, which determine how fluids, such as oil and gas, flow. And it requires very sophisticated mathematical modelling."

The Deep Earth Imaging platform is only just at its beginning, but there are several areas where researchers are looking to develop and demonstrate their capabilities. The team will focus its offshore efforts on the Browse Basin off north-west Western Australia and the Great Australian Bight. Whereas, onshore, the focus will be on the Beetaloo Province in central Northern Territory, the Cooper Basin on the border of Queensland and South Australia, the Canning Basin in the Kimberly and the Perth Basin in Western Australia.

Dr Barrett says that currently the cost of drilling a well in Australia is more than two and a half times that in the United States. That's a barrier to the development of oil and gas.

"In general, Deep Earth Imaging is looking to provide a productivity jump – a quantum leap," he says. ●

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RESEARCH NEWS

DATA-DRIVEN EXPLORATION

The data revolution will enable greater certainty and reduce risks in deep exploration.
TIM THWAITES reports

As part of the new Deep Earth Imaging Future Science Platform, geologists and geophysicists will work alongside researchers from one of CSIRO's newest business units, Data61.

Data61 was formed in October 2015 from a merger of CSIRO's existing Digital Productivity Flagship with the National Information and Communications Technology research centre, NICTA. Developing and commercialising new data-driven approaches to complex problems is exactly what Data61 is all about.

"We bring together many skills, including mathematics, machine learning, spatial analysis, computational modelling, statistics and software engineering," Data61's director of analytics research, Dr Simon Barry, says.

"That means we can conceptualise the problem, and work out how we can make inferences from the available data. We can develop algorithms and computational approaches to learn more about these complicated systems.

"With this work comes all the challenges related to accessing data, formatting it, developing processing techniques, and finally reporting and visualising the results – in short, to using data to learn about the world."

Although the data team is only just starting to work out how it is going to approach the problem of imaging the deep earth, Dr Barry says, some significant barriers are already apparent. Good data is limited, and any set of data can be consistent with a whole range of concepts about the underlying geology it represents. There is inherent uncertainty.

"Nevertheless, we are confident we will be able to make more accurate predictions as to where economic deposits are likely to be, and we will also be able to better represent the uncertainty in those predictions. This will feed into better risk-based decision-making."

Improved estimates of uncertainty are important because they suggest whether the expense of gathering further data and analysing it is most likely to pay off, which should lead to a better allocation of limited resources.

The potential products expected to emerge from Deep Earth Imaging include better exploration tools, algorithms and software platforms for analysing data, all of which can eventually be incorporated into industry software. Equally important is the indirect benefit of coming up with new ways of thinking about how to approach these sorts of problems.

"Data61 has strong links with the universities, and we are hoping to use those links to bolster our work and ensure it is at the cutting edge," Dr Barry says. ●

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In other news

WORLD MINING CONGRESS SET TO SHINE A LIGHT ON AUSTRALIAN RESOURCES INDUSTRY

A strong united Team Australia has secured one of the world's biggest international mining events, helping to affirm Australia's leadership within the global mining community.

In a first for Australia, Brisbane will host the 26th World Mining Congress (WMC) at the Brisbane Convention & Exhibition Centre (BCEC) in July 2021.

The winning bid, led by the CSIRO in partnership with the Australasian Institute of Mining and Metallurgy (AusIMM) was supported by a consortium of convention partners, including Tourism and Events Queensland, Brisbane Convention & Exhibition Centre and Brisbane Marketing who collaborated to bring the coveted congress to Queensland, one of Australia's richest mining regions.

The Congress is expected to welcome 2000 delegates from 40 member countries responsible for 80 per cent of the world's mineral production.

The four day Congress will be a catalyst for showcasing Australia's innovation leadership and industry predominance in the mining sector.

Dr Hua Guo, CSIRO Energy Research Director for Coal Mining and Chair of the WMC National Organising Committee of Australia said that mining innovation would be key to maximising the value of natural resources and minimising the environmental footprint.

'The 26th WMC in Brisbane will provide a great opportunity for research bodies, industry and government to collaborate on challenges facing the mining sector,' Dr Guo said.

AusIMM's Acting Chief Executive Miriam Way said: 'AusIMM members are the leading minerals professionals in the country and are key contributors to Australia's mining sector. The World Mining Congress presents our members with a fantastic opportunity to participate and contribute to one of the world's biggest mining conferences.'

Tourism and Events Queensland CEO, Leanne Coddington, said the Congress would profile the State to an influential international audience.

Brisbane Lord Mayor Graham Quirk said securing this premier mining event once again demonstrated Brisbane's ability to work strategically with its partners and stakeholders to attract major conferences.

Source: AusIMM Bulletin

CSIRO blog

MANAGING TYPE 2 DIABETES

The obesity epidemic in Australia is resulting in an alarming increase in the prevalence of type 2 diabetes.

Approximately 1 million Australian adults have type 2 diabetes and it is estimated over 2 million people are pre-diabetic and are at high risk of developing this disease.

That's around 13 per cent of our entire population! It's easy to see why our health researchers have made it a priority to discover better ways to prevent and manage this serious disease.

To better understand the importance of diet when managing type 2 diabetes, we undertook one of the largest and complex diet and lifestyle intervention studies in Australia, in collaboration with the University of Adelaide, Flinders University and the University of South Australia.

The two year study compared different dietary approaches for managing type 2 diabetes: a low carbohydrate, high protein, high healthy fat diet and a traditional high-unrefined carbohydrate, low fat diet. All participants also participated in a supervised exercise program.

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

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