

Minjng Magazine
INTELLIGENCE



EXPLORATION

2021: data evolving,
culture lagging

LANTERN



SEE YOUR NEXT DRILLING PROJECT IN A NEW LIGHT.

With Lantern, a few dollars per timesheet is all it takes to track every shift, expense, hole and metre in the field, online or off. Streamline your paperwork. Invoice faster. Manage everything from one place, including crew, materials, site audits, manuals and safety docs. Lantern lights the way.

Get started for free at drillwithLANTERN.com



**TRACK COST PER METRE
& DAILY SHIFT PERFORMANCE**



**RECORD & VIEW EXPENSES
FOR EVERY SHIFT ON EVERY DRILL**



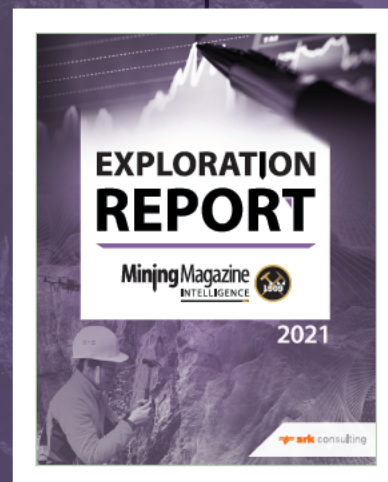
**ENTER TIMESHEETS
& GENERATE INVOICES**

Contents

	CREDITS	4
	FOREWORD	5
1	EXECUTIVE SUMMARY	7
	i Discussion	8
	ii Data	10
	iii Discovery heat map	14
2	REVIEW	17
	i Thought leadership	18
3	CASE STUDIES	21
	i Technology	22
	ii Exploration	28

In the full 92-page report

	CREDITS	2
	FOREWORD	3
1	EXECUTIVE SUMMARY	5
2	SURVEY RESULTS & COMMENTARY	11
3	TECHNOLOGY & TECHNIQUES	29
4	DISCOVERIES	55
5	INTERCEPTS & RESOURCES	81



This report is available online

www.miningmagazine.com/exploration2021

Editorial

Head of Aspermont Research & Intelligence Chris Cann

E-mail: chris.cann@mining-journal.com

Senior Research Analyst Rebecca Meeson-Frizelle

E-mail: rebecca.meeson-frizelle@mining-journal.com

Intelligence Researcher Samantha Hall

E-mail: samantha.hall@mining-journal.com

Contributing Researcher Nadav Shemer

Editorial enquiries

Tel: +44 (0)20 8187 2330

E-mail: editorial@mining-journal.com

Design

Group digital & creative director Abisola Obasanya

Advertising

Sales director Nathan Wayne

Tel: +61 (08) 6263 9126 **E-mail:** nathan.wayne@aspermontmedia.com

Subscriptions and circulation enquiries

Sales director: Roger Cooke

Tel: +44 (0)20 8187 2330 **E-mail:** roger.cooke@aspermontmedia.com

Senior global subscriptions manager: Emily Roberts

Tel: +61 (0) 432 245 404 **Email:** emily.roberts@aspermont.com

For *Mining Magazine* subscriptions, please contact

Tel: +44 (0) 208 187 2299 **E-mail:** subscriptions@aspermontmedia.com

www.aspermont.com

www.miningmagazine.com/exploration2021

Published by Aspermont Media, WeWork, 1 Poultry, London, EC2R 8EJ, UK.

Printed by Stephens & George Magazines, Merthyr Tydfil, UK.

Subscription records are maintained at Aspermont Media Ltd, 21 Southampton Row, London, WC1B 5HA

Chairman Andrew Kent

Managing director Alex Kent

Group chief operating officer Ajit Patel

Group chief financial officer Nishil Khimasia

Chief commercial officer Matt Smith

Aspermont Media, publisher and owner of the Exploration Report Handbook ('the publisher') and each of its directors, officers, employees, advisers and agents and related entities do not make any warranty whatsoever as to the accuracy or reliability of any information, estimates, opinions, conclusions or recommendations contained in this publication and, to the maximum extent permitted by law, the publisher disclaims all liability and responsibility for any direct or indirect loss or damage which may be suffered by any person or entity through relying on anything contained in, or omitted from, this publication whether as a result of negligence on the part of the publisher or not. Reliance should not be placed on the contents of this publication in making a commercial or other decision and all persons are advised to seek independent professional advice in this regard.

Needed: Discoveries to feed green economy

James Gilbertson & Chris Woodfull

A paradox of the mineral exploration sector is that it is both distinct and inseparable from the broader mining industry. Although the odds of a greenfields exploration project ever becoming a mine have been estimated at around one in one thousand, every mine begins life as an exploration project.

With this in mind, explorers should always be mindful of the challenges facing the industry. In the coming decade, there will be no two greater challenges than the need to consistently demonstrate strong sustainability credentials, including appropriate environmental, social and governance (ESG) principles and practices, and to meet the growing material needs of the world economy and emerging green economy.

ESG: An opportunity, not a hindrance

More projects than ever are failing to advance not because of technical issues, but because of environmental and social issues. It is incumbent on the exploration sector to address sustainable work practices, including ESG, early in project life cycles rather than set it aside for when projects reach a development stage. Integrating sustainability into decision making right from the start of an exploration project provides the foundation for constructive long-term engagement with all stakeholders, thereby serving to significantly de-risk a project. Therefore, sustainability should be viewed not as a hindrance to exploration but as an opportunity.

Establishing a respectful, open, engaged and supportive relationship with the local community, where shared values can be established, is critical to establishing a sustained social licence to operate (or explore). While part of the engagement may include highlighting the types of activities involved in exploration, and thereby highlighting the differences between exploration and mining, there are many other aspects to this engagement – responsible behaviour, being open to considering alternatives (e.g., non-invasive versus invasive activities, moving around properties, etc.), looking for collaborative opportunities, understanding the



James Gilbertson
managing director
SRK Exploration Services



Chris Woodfull
corporate consultant
(geology), SRK Australia

rights and perspectives of various stakeholders and maintaining open, regular and effective communication, just to note a few.

Establishing a positive and constructive track record at the early stages builds trust and respect and helps lay the foundation should discovery and exploration success occur. Establishing success in this area, coupled with discovery success, should lead to better outcomes with investors (and by extension, exploration funding).

Uptake of non-invasive and lower impact, more environmentally sustainable on-site technologies will serve to make projects more environmentally friendly and assuage fears from communities who may only know about mining from negative depictions in film or the wider media.

These non- to less invasive technologies include:

- ◆ **Drones**, in low impact acquisition of geophysical or other remote sensing imagery;
- ◆ **Passive-geophysics**, techniques that allow for a greater understanding of subsurface geology and structure without the use of disruptive seismic or electrical sources;
- ◆ **Non-invasive geochemical surveys**, most surface geochemical surveys are relatively non-invasive, but the use of technology such as ionic geochemistry allows for rapid anomaly detection with the smallest of impact possible;

James Gilbertson & Chris Woodfull

A paradox of the mineral exploration sector is that it is both distinct and inseparable from the broader mining industry. Although the odds of a greenfields exploration project ever becoming a mine have been estimated at around one in one thousand, every mine begins life as an exploration project.

With this in mind, explorers should always be mindful of the challenges facing the industry. In the coming decade, there will be no two greater challenges than the need to consistently demonstrate strong sustainability credentials, including appropriate environmental, social and governance (ESG) principles and practices, and to meet the growing material needs of the world economy and emerging green economy.

ESG: An opportunity, not a hindrance

More projects than ever are failing to advance not because of technical issues, but because of environmental and social issues. It is incumbent on the exploration sector to address sustainable work practices, including ESG, early in project life cycles rather than set it aside for when projects reach a development stage. Integrating sustainability into decision making right from the start of an exploration project provides the foundation for constructive long-term engagement with all stakeholders, thereby serving to significantly de-risk a project. Therefore, sustainability should be viewed not as a hindrance to exploration but as an opportunity.

Establishing a respectful, open, engaged and supportive relationship with the local community, where shared values can be established, is critical to establishing a sustained social licence to operate (or explore). While part of the engagement may include highlighting the types of activities involved in exploration, and thereby highlighting the differences between exploration and mining, there are many other aspects to this engagement – responsible behaviour, being open to considering alternatives (e.g., non-invasive versus invasive activities, moving around properties, etc.), looking for collaborative opportunities, understanding the rights and perspectives of various stakeholders and maintaining open, regular and effective communication, just to note a few.

Establishing a positive and constructive track record

at the early stages builds trust and respect and helps lay the foundation should discovery and exploration success occur. Establishing success in this area, coupled with discovery success, should lead to better outcomes with investors (and by extension, exploration funding).

Uptake of non-invasive and lower impact, more environmentally sustainable on-site technologies will serve to make projects more environmentally friendly and assuage fears from communities who may only know about mining from negative depictions in film or the wider media.

These non- to less invasive technologies include:

- ◆ **Drones**, in low impact acquisition of geophysical or other remote sensing imagery;
- ◆ **Passive-geophysics**, techniques that allow for a greater understanding of subsurface geology and structure without the use of disruptive seismic or electrical sources;
- ◆ **Non-invasive geochemical surveys**, most surface geochemical surveys are relatively non-invasive, but the use of technology such as ionic geochemistry allows for rapid anomaly detection with the smallest of impact possible;
- ◆ **Deep 3D geophysics inversion modelling**, utilising new geophysical techniques to assess deep signatures coupled with using geological models to assist in constraining them during inversion modelling;
- ◆ **Remote sensing and hyperspectral platforms**, greater use of these tools early on to guide exploration ensures fewer areas require invasive exploration; and
- ◆ **Downhole monitoring**, using downhole tools and probes to maximise data capture and utilise every borehole to its full extent.

Greater adoption of non-invasive technologies offers the added benefits of reducing costs and improving technical efficiency–KPIs that will only grow in importance as explorers go to increasingly greater depths to discover the minerals needed to fuel the post-COVID economic recovery and assist in the decarbonisation of the global economy.

Better technical efficiency reduces risk

The exploration sector is also a rare case of an industry that becomes harder the more successful we become.



EXECUTIVE SUMMARY

i	Discussion	8
ii	Data	10
iii	Discovery heat map	14

Data, safe havens likely keys to discovery uptick

Cultural concerns around exploration could be overcome by technology and data availability

Our inaugural Exploration Report combines an industry-wide survey, expert commentary from exploration professionals, previously published research, a review of prominent exploration technologies, and a summary of the most notable intercepts, maiden resource statements and discoveries in recent times.

The goal was to paint a picture of what the exploration space looked like today and then review the avenues to improvement or growth.

The worrying picture of the current predicament is based largely on numbers farmed in from major research groups. Outlooks for most mineral commodities expect demand to grow anywhere from materially to exponentially out to 2030 and beyond. Meanwhile, the discovery rate has fallen back to levels last seen 70 years ago and the cost of making significant discoveries has risen some 190% since the late 1980s.

Some of the reasons for this are clear and partly beyond industry control. Geologists today rarely encounter an outcropping economic deposit. The low hanging fruit has been picked and we are looking increasingly deeper. The depth of discoveries

being made has increased 256% since the 1950s (also a chief cause of rising costs).

This means the industry needs to spend more on exploration. However, year-on-year exploration budgets are down; exploration spend has decoupled from rising commodity prices over three years; and majors continue to underspend on exploration relative to their industry dominance (the money they are spending is largely on brownfield programmes).

This lack of budget is not because the industry isn't interested in exploring. Rather, major miners have failed to convince investors that systematic greenfield exploration is a valuable pursuit. Traditional juniors, meanwhile, have failed to win back investors, many of which are understandably wary having supported one of the many disappointments.

But there are less tangible, cultural problems contributing to both falling discovery rates and reluctant investors.

At the top end, major investment in cash-poor junior exploration groups has too often stopped at an equity stake designed to position a large miner for acquisition. Small groups also need expertise.

At the junior end, there are still too many small teams working with limited expertise and budgets, quite often on uneconomic assets – in many cases, they are assets that have failed in previous cycles. When assets are worthy of investment, explorers too often wilt under market pressures and skip basic exploration processes necessary for success in search of a quick result.

In addition, both large and small resources firms are facing down environmental, social and governance (ESG) challenges, which make mining an easy target and turn off both investors and future generations of would-be geoscientists, desperate to side-step industries associated with environmental damage.

But there are reasons to be hopeful.

There is much talk about a stimulus-fuelled boom in commodity prices that should be aided and abetted by the energy transition. If this is correct, the industry will naturally start seeing higher revenues among miners and greater interest from speculative investors at the junior end. Both theoretically provide more exploration budget.



Photo: Learning

How that cash is used is important. We are hoping to see two things. First, major investment into juniors should come with more than a cheque. Major exploration teams should provide guidance at the very least, and more genuine joint ventures would be welcomed. Second, and less likely, cash in the junior space should be used for more systematic exploration efforts, rather than to float new companies (with old assets).

There are other opportunities that could see the next commodity upswing return discovery rates to levels of last century; both centre on data.

First, as you'll read later, technology advances in the exploration space are centred largely around better management, communication and integration of data, as well as machine learning technologies. This doesn't need to be exclusively mineral data but data sets from other industries, most commonly petroleum, can be integrated to build a more complete geological picture.

More and more, sophisticated exploration teams are using data services and technology to design drill programmes and then dynamically manage those programmes to preserve cash – which is ultimately directed toward more holes.

Second, is the availability of government and commercial data. Currently, data policies across the world vary greatly, while historical data was seen as crucial to exploration success across the world, according to our survey. In places like Australia, government data is freely available along with commercial data handed over by companies when they relinquish their licences. At the other end of the spectrum, many places in the developing and third world see even government data as an opportunity for immediate revenues and charge explorers for access. There is a continuum between these extremes.

As data becomes more prevalent in the exploration process, the availability of data will weigh more heavily when companies decide where to invest. There is an opportunity for jurisdictions with restrictive data policies to provide access, which would not only increase investment but improve discovery rates for dollars invested – the greater the current restrictions, the larger the opportunity.

We can do it

Though discovery numbers are down, there have been some significant discoveries of late, as well as brownfield exploration success. We have focused

on the top five from each. Some trends jump out immediately, particularly among greenfield finds.

First, very few of the recent discoveries used disruptive technologies. Yes, they generally had a forward-thinking approach to data management and integration to assist with targeting and to keep costs low, but they have not been attempting to reinvent the wheel. Rather, they have relied on systematic exploration processes using tried and tested techniques, along with creative geological thinking and data interpretation.

Second, they are all in the precious metal space or have a previous-metal element (the Warintza project, for example, is primarily a copper project with a likely gold by-product). In the greenfield space, this speaks to the rising gold price over the past few years.

This means base metals that play a dual role in established demand areas but also in key areas of electrification – such as copper or nickel – are yet to see a discovery response to rising demand. The recent price movement – copper is up 63% in the past 12 months and nickel 30% (it was up by almost twice that until a lockdown-related drop in demand hit in late February) – should see more base metal projects in our best-discovery listings in the coming years. At this point, it is worth giving the Marimaca copper project in Chile a mention, which stands out for its rarity as the only copper discovery of note in the past five years.

And finally, all but two of the projects we have highlighted are hosted in safe-haven jurisdictions (A-AAA-rated according to the Investment Risk Index within the *Mining Journal* World Risk Report (feat. MineHuthe ratings)), which signals the risk-off attitudes of explorers and the potential greater ESG challenges of frontier jurisdictions.

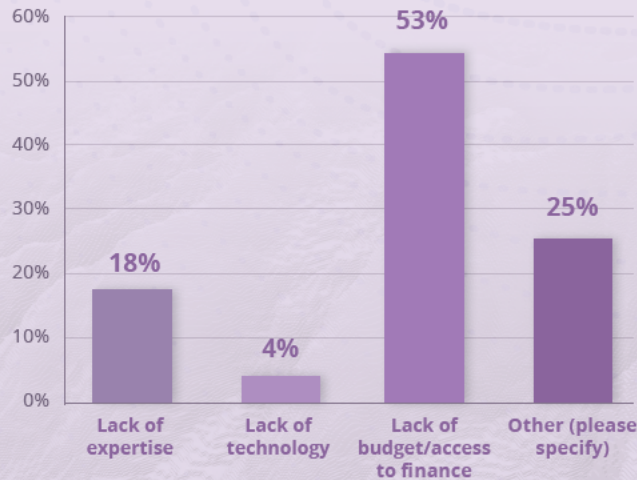
Of the five greenfield discoveries, two were in Australia (both Western Australia; A-rated; Hemi and Havieron), one in Canada (Ontario; AAA-rated; Dixie), one in Finland (AA-rated; Ikkari), with just Warintza in Ecuador (CC-rated). If we include Marimaca, we add another A-rated jurisdiction. For brownfield, four are from Australia (though we have one each from South Australia and Victoria, which are BBB and BB-rated), with just K92's efforts at the Kainantu mine in PNG (CC) hosted in a frontier jurisdiction.

The fact the majority of these safe-havens also have liberal data policies has played no small part in this trend and we would expect that to not only continue, but to build.

Mining Magazine Intelligence data

Our research suggests evolving data technologies, centred on integration and artificial intelligence for improved targeting, could combine with more liberal data policies from governments to deliver a drastically needed step change in discovery rates. Data from a survey of 347 industry professionals over December 2020-February 2021.

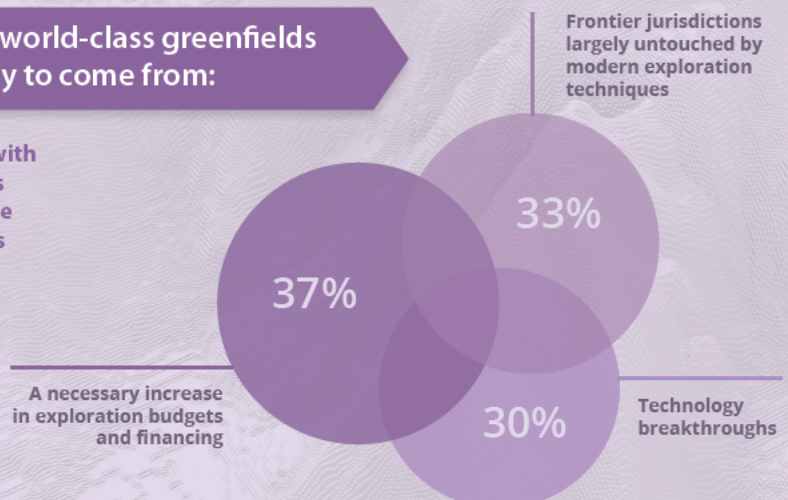
What is the biggest impediment to greenfields exploration success?



Only 4% of respondents felt lagging technology development was a problem for exploration.

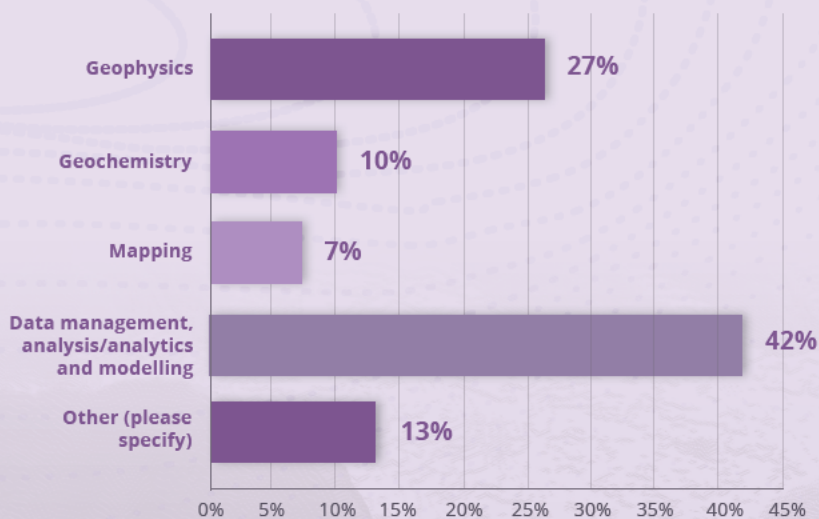
The next generation of world-class greenfields discoveries is most likely to come from:

Technology shared the stage with increased exploration budgets and frontier jurisdictions as the keys to uncovering world-class deposits.



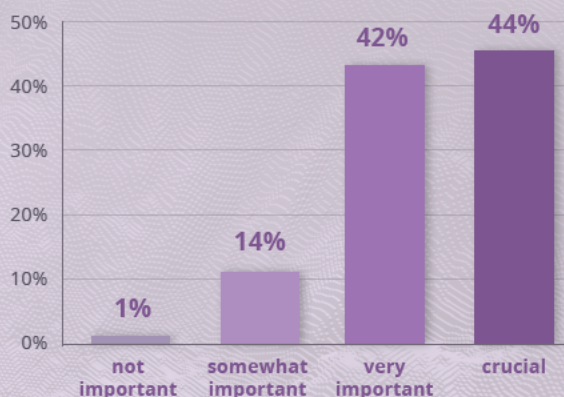
The most promising areas of technology development in exploration are in:

Data technology dominates the exploration technology landscape.



How important is it for government to make historical exploration data freely available to encourage and expedite discovery success?

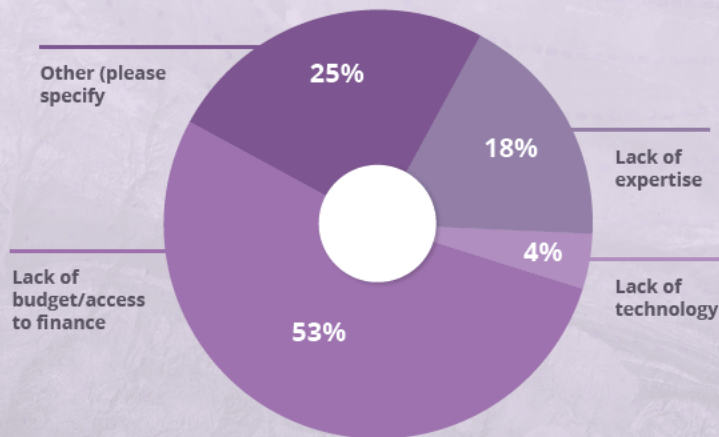
Explorers regard access to historical data as fundamental to efficient and successful exploration but many governments continue to hold them back.



Mining Magazine Intelligence data

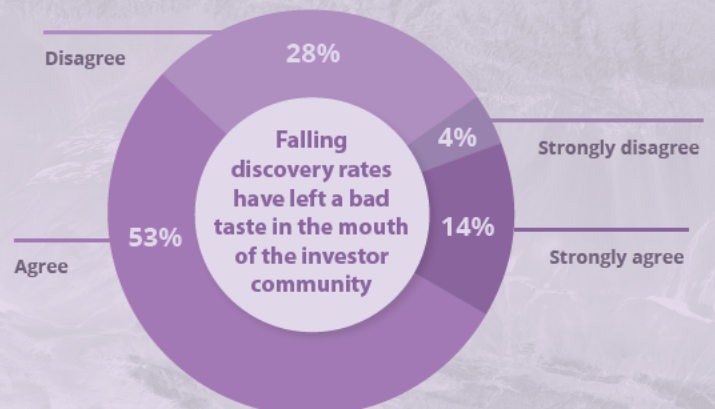
Our research shows the exploration sector needs to make several cultural adjustments from the top to the bottom if it is to attract finance and improve discovery rates. Data from a survey of 347 industry professionals over December 2020-February 2021.

Access to capital major hurdle to greenfield discoveries

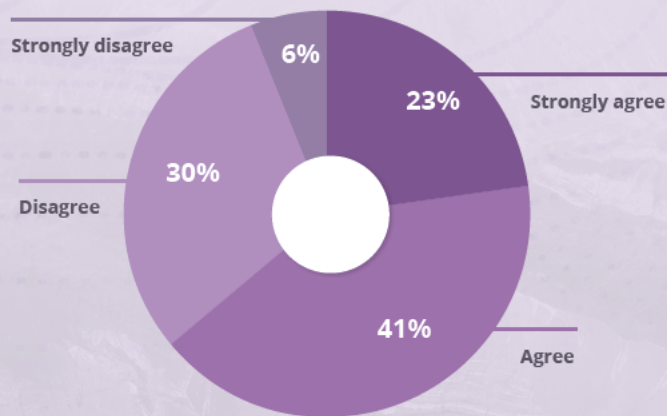


Majors are struggling to convince investors to free up capital greenfield exploration and juniors are failing to woo retail investors who have left because of poor returns and better speculative opportunities elsewhere.

Investors have been reluctant to finance exploration because of poor success rates/returns over the past 20 years



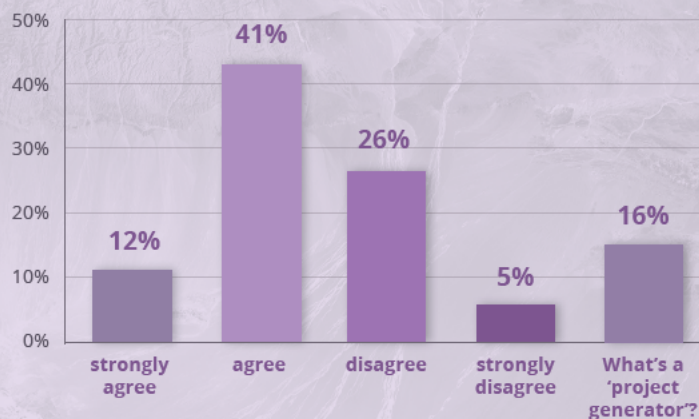
Major miners need to take responsibility for large-scale systematic exploration programmes rather than relying on corporate partnerships/ acquisitions in the junior space:



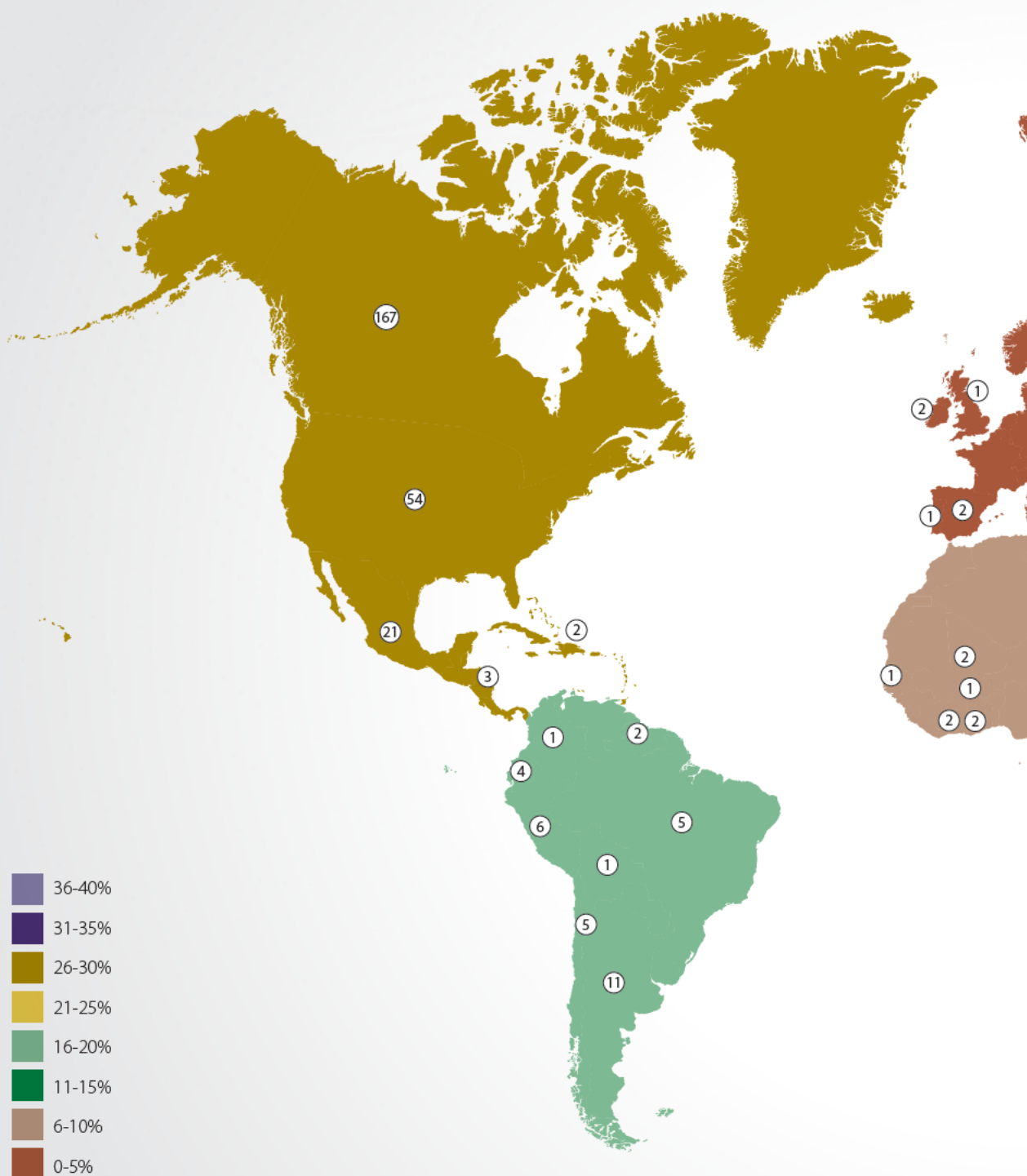
Majors cannot rely on juniors to be their proxy exploration units any longer. Rather, they should actively joint-venture with the junior sector, lending expertise alongside cash.

Dedicated 'project generators' represent a more efficient exploration model than the traditional junior resources company, which seeks to take discoveries through to development then production?

Too many juniors fail to execute basic and systematic exploration practices and should look to the project generator model for guidance.

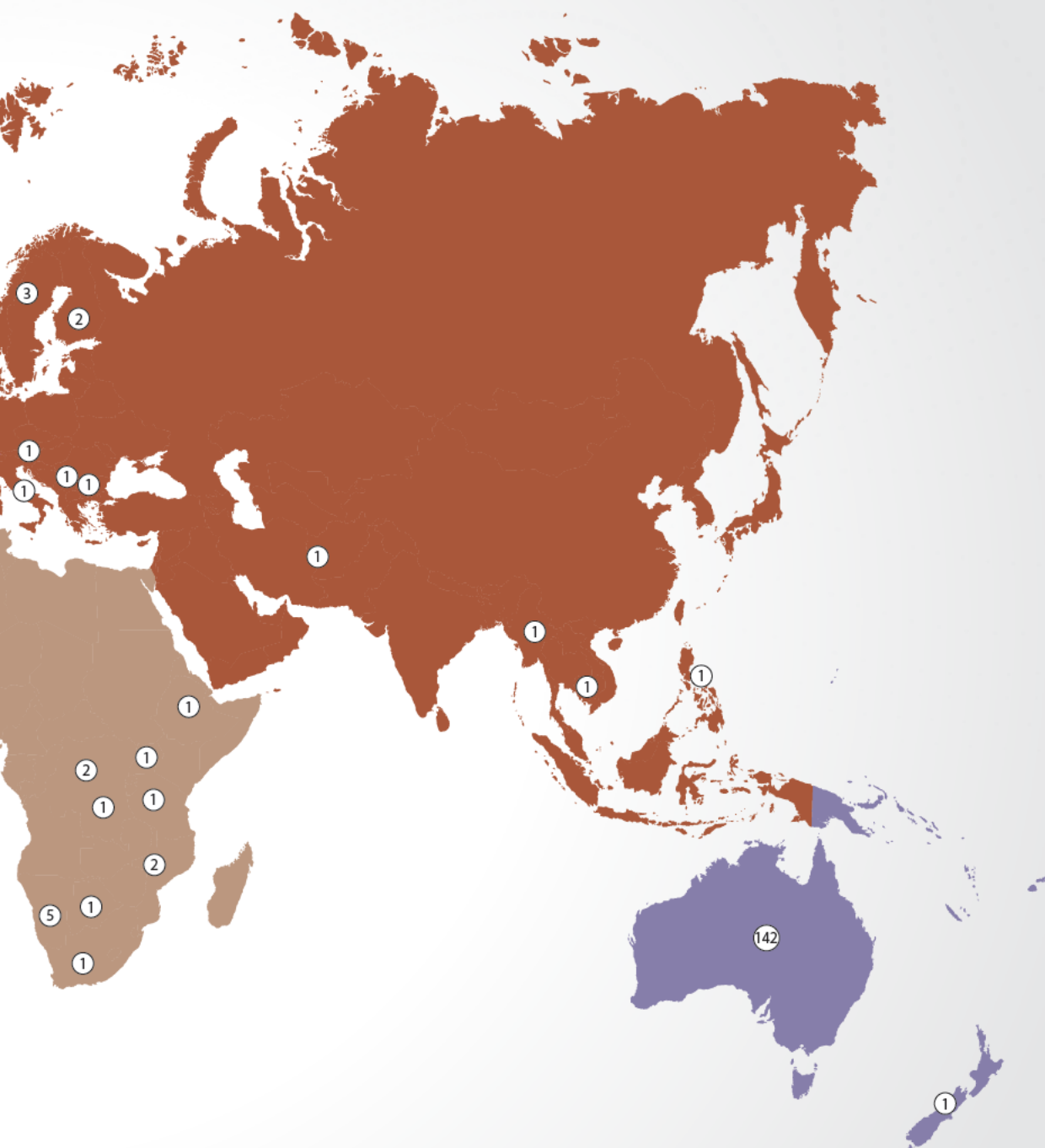


Percentage of top drilling intercepts by location



Based on intercepts reported between January 1 2019 to December 31 2020
provided by smart software platform opaxe





The shading indicates concentrations of the top 20 drilling intercepts 'all commodities' (though dominated by gold) and top 20 copper-only drilling intercepts combined, as determined by the opaxe index. Details can be found on page 82.

Circles with numbers indicate concentrations of planned exploration programs for a given jurisdiction based on planning reports published between January 1 2021 to March 16 2021.



The leading source of comprehensive and collated mineral exploration data since 2015

- ✓ drilling results
- ✓ resource and reserve data
- ✓ the opaxe Index of leading intercepts globally
- ✓ set-up and save your own searches
- ✓ customise and export search results data
- ✓ email alerts for new company announcements
- ✓ 100s of new business leads every week

Subscribe today at www.opaxe.com



A photograph of two construction workers in a tunnel. They are wearing white hard hats, safety glasses, and high-visibility jackets. One worker is holding a clipboard and a pen, while the other is holding a hammer. They are looking at the clipboard together. The background is a rough, rocky tunnel wall. The image is overlaid with a semi-transparent dark blue filter.

REVIEW

i Thought leadership

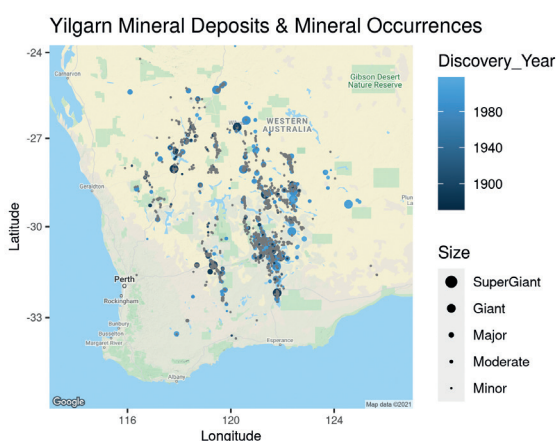
18

Using system science and analytics to target exploration capital

James Gilbertson and Chris Woodfull*

Despite the huge amounts of exploration expenditure in the last mining boom between 2011–2013¹, there has been a noticeable lack of new mines in development. One reason is that mineral exploration is naturally subject to diminishing returns; the more deposits discovered, the fewer left to discover in future. Also, much of this capital was focused on brownfield, often low-grade expansion projects, with only a handful of new, truly greenfield, discoveries. Now, with another economic boom on the horizon, and substantial deficits potentially looming for commodities such as copper, expectations will be placed on the exploration sector to improve discovery rates in both brownfields and greenfields environments or otherwise face a 'commodity crunch'.

To maximise success, a key goal of the exploration sector should be to objectively allocate capital to projects with the most potential for financial gain, in terms of production and not just share growth. On the reverse side, this means redirecting cash away from projects with low probability of an economically viable discovery. This is easier said than done. Therefore, the question must be asked: can we develop better methods of assessing prospectivity against the cost of acquiring, exploring and developing a prospect?



Underlying data courtesy of MinEx Consulting

There are various initiatives attempting to answer this question, among them Project Murchison, an R&D project led by SRK in partnership with the University of Exeter through the Knowledge Transfer Partnership scheme, supported by Innovate UK and the Welsh Government.

Project Murchison aims to replace current approaches, which can rely on qualitative analysis and/or subjective judgment during boom times, with a new approach aimed at establishing Absolute Prospectivity. The objective is to estimate this through modelling in-situ mineral wealth and coupling this with mineral endowment predictions while aligning to real-world mineral exploration performance/success. This would allow for the assessment of the probability of various exploration outcomes and how these vary across an area of interest. Later, the project will focus on the creation of a dynamic exploration model to assist explorers in efficiently apportioning capital to projects, with valuations and strategic decision making.

Leading with a mineral systems approach

To arrive at a map of Absolute Prospectivity, a mineral systems-based approach is utilised, which seeks to move away from a focus on direct detection of anomalous ground using analogues from known deposits and towards a more holistic determination of factors controlling deposit generation and preservation. The approach combines geodynamics with geological constraints on the location of key mineral system ingredients to highlight new regions (known as new search spaces) of potential mineralisation. An important tool for studying the distribution and endowment of mineral deposits in space and time, it is particularly useful for assessing under cover.

Traditional endowment analysis estimates the natural endowment of a terrane and deducts discovered mineralisation to calculate a residual endowment. However, it can take decades for a terrane to reach full exploration maturity. Therefore, Project Murchison

* James Gilbertson is SRK Exploration Services managing director. Chris Woodfull is a corporate consultant (geology) with SRK Australia

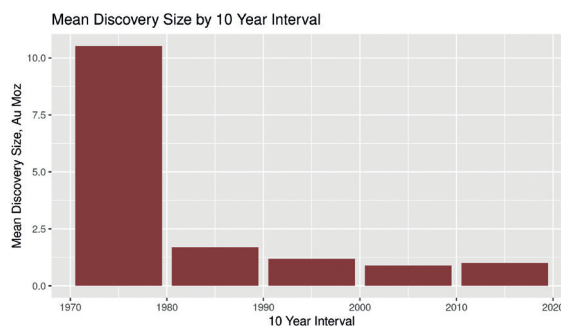
¹ Global non-ferrous exploration expenditure totalled \$52.18 billion in 2011–2013, compared to \$33.38 billion in 2008–10 and \$26.46 billion in 2014–16 (source: [S&P Global Market Intelligence](#))

aims to model how the distribution of discoverable resources evolves over time in order to predict the distribution of discoverable deposits within a terrane.

Juniors, who still account for the bulk of exploration expenditure, are never going to be capable of amassing the quantum of data required for robust mineral systems modelling on their own. As the mineral systems approach becomes more adopted across the industry, jurisdictions can encourage exploration by broadening access to pre-competitive data and breaking the paradigm of data secrecy that is prevalent in much of the world.

Australia is a world leader in pre-competitive data, hence why the Yilgarn in Western Australia was chosen as the testing ground for Project Murchison. Canada and Finland are further good examples, and other countries can attract exploration by following their lead.

As more data becomes available, machine learning can be utilised to accelerate the pace of data analysis and look for seemingly invisible connections between different data sources. Thorough and systematic statistical modelling of the relationship of these data to mineralisation can quantify the importance of these connections, creating a platform from which to make strategic decisions.



Underlying data courtesy of MinEx Consulting

Greenfield exploration requires a step change in efficiency

The 2021 *Mining Magazine Intelligence* exploration survey asked whether future demand can be catered by brownfield exploration alone – and the response was an overwhelming ‘no’. The challenge with greenfield exploration is that it carries higher risk and, initially at least, a substantially lower probability of discovery – hence why greenfields are left largely to the more risk-tolerant junior explorers. Greenfield success therefore requires a sound, staged exploration strategy, founded on good science, technical capability and investors who are understanding of and tolerant towards risk.



EXPLORATION MAPPING

GLOBAL LEADERS
*Base, Precious and Battery Metal
Geological Remote Sensing*

CONTACT US
FOR A FREE IMAGE SEARCH
info@ExplorationMapping.com
www.ExplorationMapping.com

WorldView-3
**THE WORLD'S MOST ADVANCED
EARTH IMAGING SATELLITE**

- 5-Day Revisit Time
- 90-Min Polar Orbit
- 680,000 km² / Day
- 17 Spectral Bands
- 15cm Pixel Size



It is important to understand that due to the ease of their discovery, larger deposits tend to be discovered earlier in an area's exploration history; for example, mean gold discovery in Western Australia has systematically fallen from roughly 10 million ounces in the 1970s to a little over 1Moz since 2000.

The probability distribution for discoveries of different magnitude is therefore steeper but with the probability of a large discovery and no discovery often heightened at the expense of the probability of making a modest discovery. As the downside risk of no discovery is limited to exploration cost as opposed to a modest discovery, which may entail extensive resource and engineering expenditure, this can make quite an attractive potential return profile for a risk-tolerant explorer. An important insight here is that the moderate to world-class discoveries that exist in the long tail of the probability distribution are what makes exploration worthwhile and seeking projects with a large range of uncertainty can often make sense, even if overall probability of discovery is lower than average.

Absolute Prospectivity works on the basis of the different financial value of exploration outcomes weighted by the probability of each happening. By following such a quantitative approach, capital

can be directed to those projects with the highest expected financial gain, maximising exploration efficiency. In a world where a significant proportion of exploration expenditure can be spent on non-productive programmes, increased efficiency means walking away sooner from projects with low probability to attain any results better than marginal, and for it to be redirected to projects with a greater probability of return. These projects may be greenfield projects that conversely have a lower chance of discovery of any kind, but a higher probability of high-value outcomes such as a world-class discovery.

We believe that minerals system-based thinking, supported by greater access to data and guided by the use of advanced analytic tools and approaches to evaluating ground and exploration performance, will aid the exploration sector to more objectively assess the prospectivity of greenfield sites. This will ensure that capital flows to those projects with the best chances of becoming an operating and profitable mine, resulting in an increase in overall efficiency in the sector.



The new era of safety.

CX LINE

Safety is the challenge, CX Line is the answer. Compact design, hands-free rod handling system for fully automated and remote controlled operations: it's the new range of exploration drilling rigs. Are you ready for the new era?



comacchio.com



The background of the entire page is a solid dark red color. A large, semi-transparent, light red number '3' is centered in the background. On the left side, there is a silhouette of a person wearing a cap and holding a remote control device. On the right side, there is a silhouette of a drone in flight. A thin vertical line is positioned on the right side of the page.

CASE STUDIES

- i Technology 22
- ii Exploration 28

Lantern: Casting light on the drilling process

Nadav Shemer

Launched in 2020, the Lantern app aims to illuminate every aspect of the drilling programme in real time, enabling greater transparency between drilling companies and their clients. *Mining Magazine Intelligence* sat down with Chris Kostyal, director of business development, Mike Fiorentino, director of sales, and David Aitken, senior technical lead, to find out more.

Q: What problems does Lantern solve for the mining industry?

CK: Traditionally, the whole engagement between driller and client has been relatively archaic, with drilling companies relying on paper timesheets or spreadsheets to keep abreast of progress in the field. We've seen drillers use all kinds of jerry-rigged solutions, such as Google Docs, to record timesheets, materials, services, tests, and other

costs. These usually get funnelled from a foreman at the drill site to the head office of the drilling company and then on to the client who sends it back down to the field geologist or project manager at the drill site to cross check what has been reported.

Very often, the client doesn't receive these timesheets until several days, if not weeks, after the actual date of work. This can create a bit of friction, particularly when what the driller reports is different from what the client expects or remembers. Obviously, this kind of delayed, analogue approach to the drilling function prevents clients from getting a real-time view of their progress in the field.

Lantern automates all of this, starting with timesheets, materials, services, and tests, but also all the documentation that's required on the drill site,



such as SDS sheets and site audits. Everything gets captured on one platform that works both online and offline. The offline functionality works courtesy of an app we developed where drillers in very remote sites can enter their data and have it sync up when they reach an active data connection.

Lantern helps drilling companies run better, more efficient operations. On the client side, it allows for greater transparency with regards to drilling progress and costs – allowing both companies to run more efficiently and ultimately drill more metres for their money.

Q: What are the main benefits for drilling companies?

MF: First off, Lantern helps drillers monitor their progress, crew performance, equipment and costs on a single site, across a larger multi-drill project, and across multiple projects. Scale is often a challenge for both small and medium-sized drillers. When they go from a few drills on one project to several drills on multiple projects, it can be a real challenge for them to keep up with their business.

The Lantern app allows them to manage multiple projects with different crews and different sites. It gives them a better sense of how they're doing, to really track the job in real time. They're essentially 12 hours out from the capture of data, based on the last shift.

Another big element is that it allows them to invoice directly from the platform. Instead of having a situation where they might be sitting on 30 days of timesheets, they can bring all the timesheets together to form one invoice that they can push to the client based on different windows of billing. These guys are often waiting to get paid and it can be a strain on their business. This ability to invoice from the platform allows them to get paid faster.

CK: Then you get to the very large drillers. In some cases, these guys are having to manage over 100 drills around the world, leaving head office in the dark in regards to how things are going worldwide. At that level, what Lantern does is it circumvents any kind of enterprise-class solution where you see these companies spending millions of dollars a year on systems that in many cases are so robust they're unruly.

Q: And what are the main benefits for their clients?

CK: On the client side, Lantern gives them the ability to see how their projects are doing in the moment. This includes a multi-contract view where they are able to manage multiple contracts with multiple drillers. Ultimately, it's about going macro to micro: getting a full view of your operations, having the

ability to drill down to any one site, any one drill, any one shift, and to get a robust understanding of the progress of that drill and the associated costs.

Q: Can you provide examples of insights generated from Lantern?

MF: Because they're tracking crew to metres drilled and all the associated costs, the drilling companies can extrapolate that to say that based on a certain environment, this particular crew does better, drills more metres, etc. This can help them to be more efficient so that when they get a job – let's say a fly job – they can put together a crew that's really effective in that environment.

DA: Vice-versa, I think it can help identify crews that require more work. Being able to track metres per shift, track materials, services, and test costs, track crew productivity – this all adds up to becoming a much more efficient drilling company. At the end of the day, this is really a tool for minimising downtime. Anything that's causing downtime, Lantern can pick up on, and the driller can see it and respond in a very timely way.

Q: Have you had any interesting requests from customers?

CK: Having just launched a little over a year ago, a lot of our work has been on gathering feedback from the drilling companies and their clients. A lot of it has centred on productivity by shift, metres drilled per shift and cost per shift. Both sides have shown a real interest in understanding how the project is progressing compared to the projected completion date.

DA: We're constantly rolling out new widgets that visualise all sorts of interesting data points in different ways. Drilling companies have shown interest in comparing different drills from the same project, which helps them realise when they need to service certain drills. Because we're tracking metres drilled against crew, they can see which of their drillers are most productive.

Another thing we implemented in response to feedback was the ability to take all the crew hours and their drilling metrics and integrate that with payroll software.

MF: Some of the less glamorous stuff that has been implemented has been around site audits and documentation – SDS sheets, technical docs, all the documents that are mandatory to the drill site that traditionally have been kept in a giant binder in a truck.

Q: Are you adding any new features to the platform?

CK: We're rolling out the next iteration of the client environment, where clients can simply go to our

website, sign up and they're immediately inside the Lantern space. Even prior to entering a contract of their own, they will be able to bring in sample historical data from other contracts to field test Lantern for their own purposes.

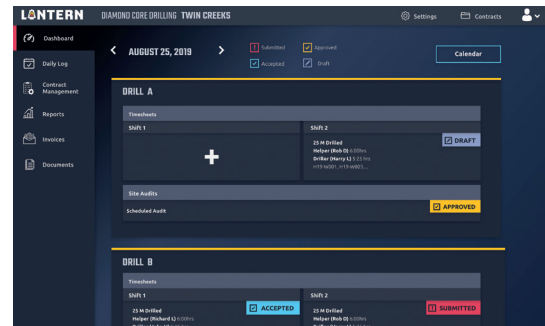
If a client wants to see their past results and reverse engineer what productivity looked like – but they don't want to enter all the details of a contract – they can enter past invoices into the system and it will show them how they did last year. That's what we're working on now.

MF: Another nice thing we've brought on board is a projection calculator. We can see clients really leveraging that in the future, and saying: 'Here's how we see this project. The data suggests that this action would run like this with this sort of crew and this number of drills and these resources'.

Q: Tools of this nature have typically been priced for all but the largest mining companies. What has Lantern done to address this?

CK: Our pricing model is \$5-\$10 per timesheet, that would be \$10-\$20 per day. Given that a timesheet is worth thousands of dollars, it's basically a drop in the bucket.

From the client perspective, it's free. Once a client shares a contract with their drilling company, it goes



Daily Timesheet Log

back to the driller's environment, where the driller has full control. That's where the pricing model kicks in; whether the driller passes the cost back to the client or eats it is entirely up to them. It's a very marginal cost for what they're getting.

Q: Would you like to offer any closing remarks?

CK: If I were to sum this up: I would say that with all the technology out there around geophysical data, mine management and the like, Lantern is that last piece of the puzzle. We're bringing innovation to the drilling sector in a whole new way, and it's aimed at everybody.

Lantern works the way we believe the industry is going. We haven't presented this platform to a single client that hasn't said that this ought to be a prerequisite for future contracts. The level of in-the moment transparency is very valuable to them.



Customizable Dashboard Elements

How innovation in the use of portable XRF contributes to better discovery rates

Nadav Shemer

Portable X-ray fluorescence (pXRF) analysers have become an important part of the exploration geologist's toolkit over the past 20 years, and innovation around the application of this technology in mineral exploration continues apace.

Manufacturers have focused on improving detector technology, instrument stability, heat resistance and data connectivity in an attempt to ruggedise and modernise the latest versions of these instruments. pXRFs are now capable of measuring up to 35 elements between Mg and U on the periodic table with some elements measuring down to 1 part per million.

One of the main reasons pXRF contributes to better discovery rates is that it allows companies to conduct fast, effective field sampling at the early exploration stage, according to Todd Houlahan, Director of International Mining at Olympus.



Olympus Vanta pXRF analyzing RC samples in the field

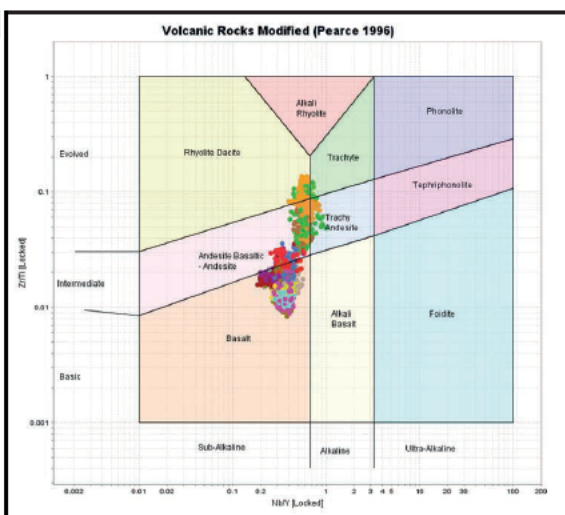
"Use of portable XRF enables quantitative analysis of a large number of samples in the field and adaptation of sampling programmes in real time. Portable XRF assists explorers in focusing their activities on more prospective areas within a tenement and on more prospective zones within a drill hole," Houlahan says.

To give a recent example, an Olympus pXRF analyser contributed to the discovery of Cobre Limited's Perrinvale Project, a VHMS deposit enriched in high-grade copper, silver, gold and zinc in Western Australia's Goldfields region. This area is mainly known for its gold prospectivity but pXRF identification of copper, zinc and silver mineralisation within sulphides at surface led to intensive follow up and subsequent drilling success.

The other main benefit to pXRF is the cost savings, with most users reporting a return on investment within three to six months, according to Houlahan. Listed explorers have reported hundreds of thousands of dollars in savings using pXRF by limiting the number of holes requiring re-drilling due to calling the end of holes too early, through optimised fieldwork and rapid follow up, and through a reduction in samples sent to the laboratory. More efficient and intelligent use of exploration budgets should decrease the time to discovery.

Olympus portable XRFs have advanced to the point where their effectiveness is now highly dependent on three factors unrelated to the instrument hardware: 1) the person operating it; 2) the workflow; and 3) the sample type being analysed. The ideal sample type is one that has been pulverised into a fine pulp, according to Houlahan. However, XRF's portability is such that people want to test any and all types of non-homogenous samples. As a result, success depends on developing a "fit-for-purpose methodology."

In a paper published in *Geochemistry: Exploration, Environment, Analysis* in 2019, a team from the Centre of Ore Deposit and Earth Sciences at Australia's University of Tasmania described a study of pulp powders and rock slabs from six porphyry districts (Yerrington – Nevada, US; Resolution – Arizona, US; Las Bambas – Peru; and Cadia, Northparkes and Cowal – all in New South Wales, Australia). After calibration of their Vanta pXRF using



Lithological discrimination in ioGAS using Vanta pXRF

whole-rock laboratory data, the team concluded that pXRF data can be used in place of conventional whole-rock analytical data to inform strontium/yttrium and strontium/manganese oxide copper-prospectivity discrimination diagrams.



Index's In Field Geoanalysis Solution

Work was done to demonstrate a fit-for-purpose methodology directly on fine, medium and coarse-grained rock slabs. The team found that collecting three spot analyses from the coarse sample at random was sufficient to overcome the intrinsic heterogeneity of the sample and provide useful information about copper fertility.

In collaboration with Olympus, several third-party companies are addressing how best to deal with sample heterogeneity in multiple and contrasting ways.

Meffa Lab Oy and Geotek are integrating Olympus pXRFs into automated sample and core scanning systems to allow intensive multi-point analysis of samples to "average out" the heterogeneity in drill



Geotek Boxscan analysing core with an integrated Vanta pXRF

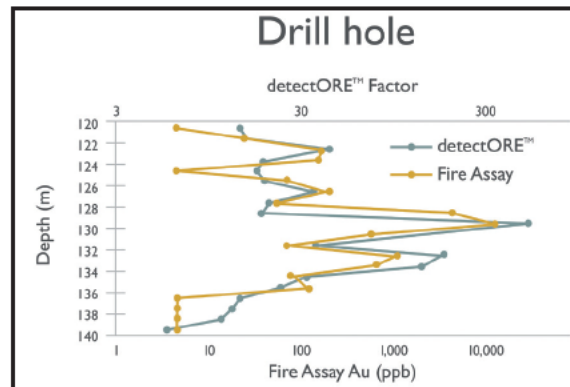
core using pXRF. To create more homogenous samples, Onsite and lmdex have designed field-based sample preparation tools—such as crushers, mills and presses—specifically for pXRF.

Additionally, lmdex has developed a solution that allows the user to operate the Olympus pXRF, force a QA/QC component into the workflow, securely transfer field-validated data to the cloud, and apply advanced data analytics to pXRF data. This is the first offering that attempts to address the three biggest variables associated with pXRF use (the user, the workflow and the sample) in one end-to-end package.

Commodity-specific innovation in pXRF has largely focused around cobalt, lithium and gold. As elemental lithium is too light for any pXRF to measure, the application of pXRF to lithium deposits has focused on pathfinder elements. The main focus has been on potassium/rubidium ratios, a potential indicator of lithium prospectivity in pegmatites.

Cobalt mineralisation is often associated with the presence of iron and/or nickel, with the presence of both these elements having a detrimental impact on the ability to accurately measure cobalt with pXRF. Fortunately, advances have been made in algorithms which have now demonstrated pXRF can be used more effectively on cobalt at concentrations less than 0.05%, a particular area of interest for cobalt explorers.

Like cobalt, gold can occur in spectrally complex matrices, making it difficult to measure with a pXRF at the low concentrations typically required. However, gold explorers make a up



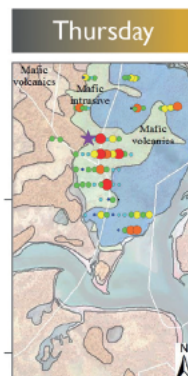
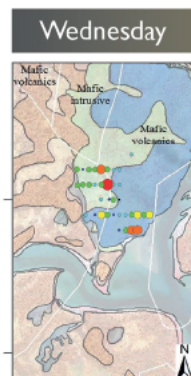
Drill hole data showing detectORE results versus fire assay

a large part of the global pXRF customer base using the technology for lithogeochemistry and chemostratigraphy to better understand the geological system being investigated and by identifying pathfinder elements (e.g. As, Cu, Pb, Zn, Bi, Hg, W) to vector towards gold.

Houlahan points to Australia's Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) patented and trademarked detectORE technology as "a particularly exciting development for gold." DetectORE combines a consumable, a pXRF and customised software, aiming to quantify Au down to below 20 parts per billion within eight hours of sample collection. Perth-based Portable PPB holds the exclusive licensing rights to this invention. Houlahan says that with a proven management team, an impressive list of companies signed up as industry partners/sponsors and several years of global R&D under their belt, "they may just be on the cusp of achieving the holy grail" — low-level gold detection with pXRF.

ARRIVAL

DISCOVERY



Reactive Soil Sampling

Daily sampling
plus daily testing

=

Daily exploration
program adjustments
to maximise benefits

Case Study data illustrating the value proposition of adoption of the Portable PPB process

Marimaca timing its run to meet resurgent demand for copper

Nadav Shemer

Copper projects are in the spotlight amid growing forecasts of a severe supply crunch for the king of base metals. One of the projects currently in development is Marimaca Copper's Marimaca project in northern Chile, which president Hayden Locke says is uniquely positioned to meet resurgent demand for copper.

The company's flagship Marimaca oxide deposit boasts a measured and indicated resource of 70.4 million tonnes at a cut-off of 0.60% total copper, according to a December 2019 mineral resource update, which saw a 100% increase over the maiden estimate from 2018.

Better yet, according to Locke, are the results of an August 2020 preliminary economic assessment, which put the Marimaca project firmly in the lowest quartile of copper projects in terms of capital intensity and operating costs. The PEA showed a pre-production capital cost of \$285 million, or \$7,125/tonne of copper production capacity, 46% below the industry weighted average and 23% below the threshold for the bottom quartile. It estimated life-of-mine average all-in-sustaining costs of \$1.29/lb of copper, putting Marimaca in the lowest 15% of the all-in sustaining cost curve (based on September quarter 2020 data from Wood Mackenzie).

Other highlights of the PEA included a post-tax net present value of \$524 million and post-tax internal rate of return of 33.5%. The company is targeting completion of a feasibility study and all permitting in 2022, which would put it on track to commence production in 2024.

"The vast majority of copper discoveries are very large scale and have high development capex and long lead development times. This project has a very low capital cost, very short development time, and very low execution risk from a financing perspective and from a construction and operational aspect," Locke said.

"The reason is that it's a simple openpit mine whereas a lot of new discoveries now are getting deeper and deeper underground at lower and lower grades, meaning they have to move more tonnes. Marimaca is relatively high grade for a low strip openpit. It involves simple processing, so has a much lower capital intensity than a typical big sulphide copper project."

Another obvious benefit is the location in northern Chile, the highest-ranked Latin American jurisdiction in the Investment Risk Index within Mining Journal's World Risk Report (feat. MineHutten ratings), and a country well-known for being by far the world's largest producer of copper. Locke, who spent a large part of the last decade with junior companies in Africa – among other roles, he was CEO of Moroccan-focused potash developer Emmerson and had an executive role at West Africa-focused Papillon Resources before that company was bought by B2Gold – says having a project in Chile is "amazing".

Adding to the low jurisdictional risk is the fact that the project is situated in the low Andes, only about 1,000m above sea level, close to roads and powerlines, and within 60km of two port cities (Antofagasta and Mejillones) boasting large pools of skilled workers.

Marimaca also plans to take advantage of a seawater pipeline running 7km to the north of the deposit. "That means we're not going to be tapping any freshwater aquifers that might be used for drinking. We're not going to risk polluting these aquifers by

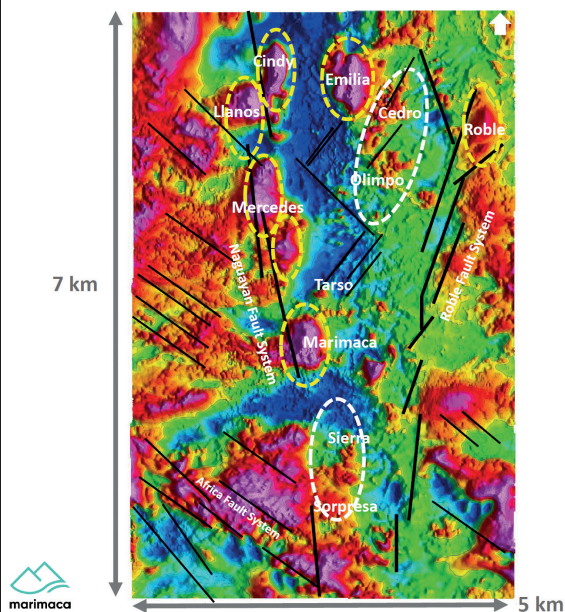


Photo: Marimaca District map

drilling down into them. This will eliminate one huge risk associated with mining in this part of the world.”

Marimaca was discovered in 2016 and had the honour of being the only major greenfield copper discovery anywhere in the world between 2015 to 2019, according to S&P Global Market Intelligence. Despite this achievement, Locke says the Marimaca project’s “only weakness” is its scale. However he believes that there are more Marimaca-style discoveries to come, noting that Sergio Rivera – the former director of Codelco’s exploration activities in Chile who made the Marimaca discovery and is now VP of exploration for Marimaca Copper – “thinks we’re potentially on to a new copper district in Chile”.

The Marimaca deposit is a new type of copper deposit in this part of northern Chile, and the breakthrough was made by challenging the consensus and generally accepted wisdom of the geological potential in the region, according to Locke. He says his company has an amazing opportunity to apply the lessons learned from the Marimaca discovery to the surrounding area.

“Now we control this whole belt that’s never been explored, and we intend to go out and drill the targets we have identified pretty aggressively,” he said.

A recent drone-mounted high-resolution magnetic survey of Marimaca Copper’s licence area identified five large-scale anomalies believed to be potential Marimaca-style deposits. Follow-up work involving surface geochemical sampling and reconnaissance mapping at two of these targets – Cindy and Mercedes – delivered encouraging results. Geochemical sampling at Cindy identified a copper anomaly extending over 1km of strike with grades as high as 2.9% Cu. Sampling at Mercedes identified another large anomaly with grades as high as 0.6% Cu.

Marimaca Copper is fully financed to conduct the drilling campaign, thanks to the completion of a C\$28.98 million (\$23 million) equity financing in December 2020 and a follow-up placement of just over C\$30 million to a strategic, long-term, investor in February 2021. Drill rigs were mobilised in January 2021, with the plan being to drill at the Cindy, Mercedes and Llanos anomalies and to test for extensions at depth at the Marimaca deposit, where there is copper sulphide potential below the already defined oxide deposit.

Locke says results from the Marimaca drilling campaign are expected by the end of March quarter and results from the three new targets are expected by the end of June quarter.

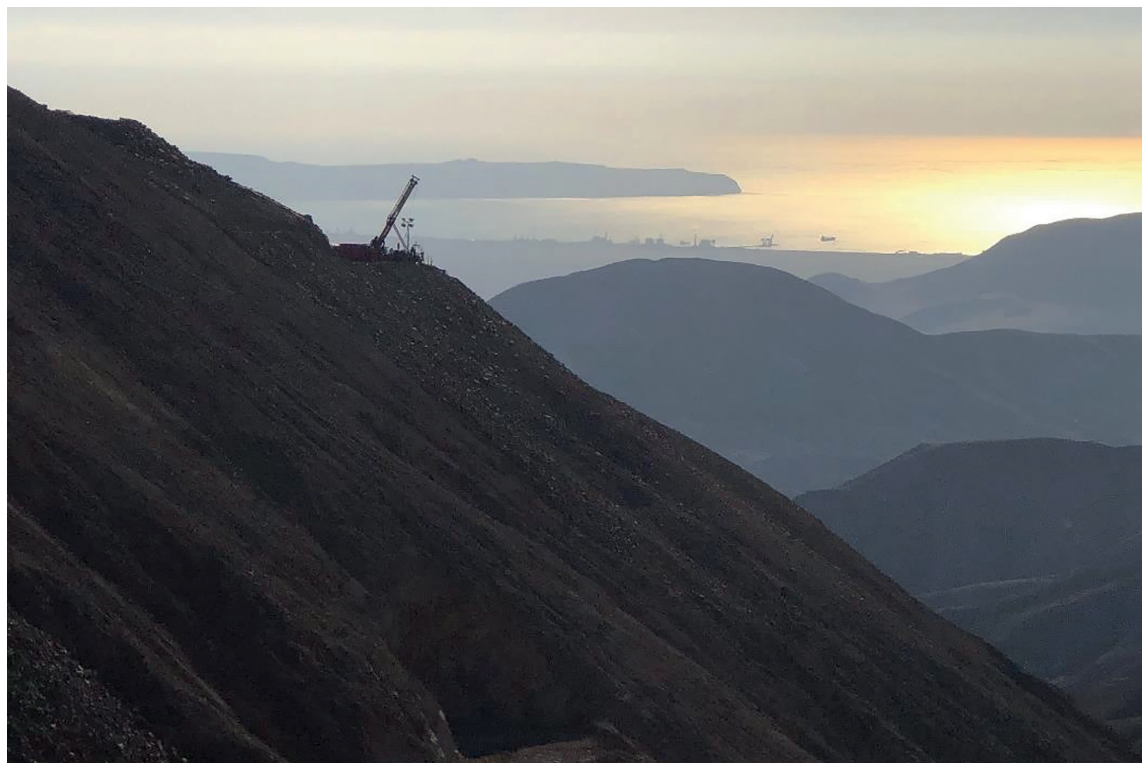


Photo: Marimaca drill rig overlooking the coast

Solaris Resources on winning streak in Ecuador

With the management of the Augusta Group, which has an unrivalled track-record of value creation in exploration and development within the mining sector, totalling over \$4.5 billion in exit transactions in the past decade, Solaris Resources is emerging as a force to be reckoned with as it pushes ahead with an expanded drilling programme at its flagship Warintza copper project in Ecuador.

Spun out of Equinox Gold, the company has been on a winning streak since listing in Toronto in July with the shares up a mouth-watering 360% in the last eight months. Solaris graduated from the TSX-V to a full listing in Toronto on 9 February – flush with cash after closing on a private placement worth more than C\$80 million.

That's more than enough funding to complete an ambitious exploration programme at Warintza and reach preliminary-economic-assessment stage by the end of this year, or early 2022.

Several important disclosures have excited the market recently: November's results from drilling at Warintza Central that included 1,004m at 0.71% CuEq from surface, nicely dovetailing with similarly positive results in the target area in September.

Then on 16 February, the company announced a new discovery at Warintza West where maiden drilling and the first detailed geophysical survey of the project revealed a more extensive porphyry system than

previously understood. The first hole drilled at West marked a new discovery with results of 798m grading 0.31% CuEq with the entire interval residing outside of the high-conductivity anomaly that corresponds to high-grades at Central.

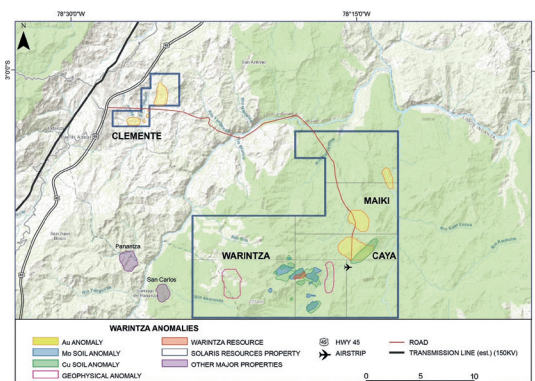
CEO, Daniel Earle, said he had his foot "on the accelerator" as he and the board authorised a larger drilling programme across the whole Warintza project involving 12 rigs instead of six – one of the largest drill programs on the continent. The increased drill programme would allow for further testing the mineral continuity of the property's known zones: Warintza Central and Warintza West, while simultaneously testing the discovery potential at Warintza South and Warintza East targets, all within close proximity to Warintza Central.

Warintza Central has been the priority up to now and work will continue there for several more months, alongside drilling elsewhere. Solaris is looking to unveil a measured and indicated resource estimate for Warintza in 2021, a year expected to demonstrate growth potential throughout the project.

The plan is to drill at least 40,000m at Warintza Central, an expansion from the historic 7,000m that trails back to the early 2000's when the first discovery was made by legendary geologist and explorer David Lowell.



Aerial view of Warintza Project, Ecuador



Solaris Property Boundary

Lowell is probably best known for co-authoring the Lowell-Guilbert Model, where he used the model to discover some of the most profitable mineral finds in the history of mining, such as La Escondida in Chile, the largest copper producer and deposit ever discovered to this day.

Solaris is also on the look-out for significant gold discoveries at Warintza with drilling soon to be underway at the Caya gold anomaly, one of three multi-km scale gold anomalies identified northeast of Warintza Central.

Earle said the plan this year was to confirm where there was the most potential before focusing on an area “where we want to do the most work, and before we move onto economic and engineering studies”.

Warintza, he said, showed all the signs of being a world class property, every bit as promising as flagship copper discoveries elsewhere in the world, such as Oyu Tolgoi in Mongolia.

Earle became CEO in 2019, after making a name for himself as a Bay Street analyst known for making canny calls on exploration and development projects such as Ventana Gold.

“Just looking at Warintza Central, there’s potential here for a large, high-grade openpit with the grade starting right from surface, with a very low waste to ore strip ratio, and access to primary infrastructure, including renewable power and abundant fresh water – critical for modern copper projects.”

“This is almost totally unique in industry today, where you won’t find many other projects that are drilling holes over a kilometre stretch with high-grade copper mineralisation right from surface.”

Earle reckoned 40,000m testing a 1.35 billion tonne volume would be drilled in the first half with a drill-spacing sufficient for an indicated category

resource at Warintza Central. That would be sufficient for a detailed resource estimate, mine plan and the basis for a PEA and subsequent feasibility study.

Solaris has recently brought in former Ivanhoe executive, Chad Wolahan, to deliver an engineering and economic assessment for Warintza. At Ivanhoe, Wolahan was responsible for project planning and management of technical programs supporting the advancement of the Democratic Republic of the Congo’s Kakula project from PEA through to feasibility.

A factor behind Solaris’s growing popularity is that it is managed by the Augusta Group founded by well-known mining executive Richard Warke, Solaris’ executive chairman, and specialises in exploration and development-stage projects, most recently growing and eventually selling Arizona Mining for C\$2.1 billion in 2018.

“Having experience and knowledge about how to manage these early-stage projects is a critical feature of being part of the group, and access to capital comes along with that,” said Earle.

Solaris is about more than Warintza, however. The company has showcased discovery potential on the grass-roots Tamarugo project in Chile and the Capricho and Paco Orco projects in Peru. And it has exposure to the Ricardo project in Chile via a joint venture and farm-out agreement with Freeport-McMoRan.

Additionally, it has significant leverage to increasing copper prices through a 60% interest in the development-stage La Verde joint-venture project with Teck Resources in Mexico.

To round things off, the copper market is on a tear, amid hope for a strong economic recovery, and with green-policy agendas at the heart of spending plans around the globe.



Drilling at Warintza Central



Minjng Magazine
INTELLIGENCE



 **srk** consulting