

# From mine to magnet

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AN INVESTOR'S ROADMAP TO  
RARE EARTH ELEMENTS

**THEMATICA REPORT**

# Roadmap to REE magnets

## A Exploration

Building **MINEABLE** REE resources

## B Concentrates

**FIRST** sellable product

- Monazite
- Bastnasite
- Xenotime

**CAPEX REQUIRED**  
**\$100-200M**

## C Mixed Rare Earth Carbonate (MREC)

**SECOND** sellable product

- Lynas produces MREC in Malaysia but plans to soon produce in Kalgoorlie.
- Iluka Resources plans to produce MREC at Eneabba, south of Geraldton.
- Hastings is planning to produce MREC at Onslow.

**CAPEX REQUIRED**  
**\$500M-1B**

## D REE Oxide

**THIRD** sellable product

- Iluka Resources, Arafura Rare Earths & Australian Strategic Materials are planning to progress towards production of REE Oxide.
- Major government investment starts here in collaboration with US, Europe, UK & Japan.

## E REE Metal

**FOURTH** sellable product

- 95% in China.
- Small production elsewhere - US, Japan, Europe & UK.

**MISSING**

## F REE Alloys

**FIFTH** sellable product

- Made in China.
- Small production elsewhere - Japan, Europe & UK.

**MISSING**

## G REE Magnets

**SIXTH** sellable product

- 95% made in China.
- Small production elsewhere - Japan, Europe & UK.

**MISSING**

## Destination Products

**TECHNOLOGY,**  
renewables and more

- Wind turbines
- EV motors
- Catalysts
- Ceramics & glass
- Metallurgy & alloys
- Polishing



The Rare Earth Elements market is worth more than

**USD\$7,000 million**

(MORE THAN AUD\$10,500 MILLION)

and, going by the 9.1% compound annual growth rate (CAGR), it's predicted to reach nearly

**USD\$15,500 million by 2030**

(MORE THAN AUD\$23,000 MILLION)

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Some **80%** of REEs produced go into permanent magnets

## FROM MINE TO MAGNET

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ABOUT THE MARKET HERALD

# See the bigger investment picture

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The Market Herald, in conjunction with HotCopper, Advisir and Stockhouse, is proud to launch Thematica's latest report.

Self-directed investors make up nearly 40 per cent of the Australian and Canadian stock markets and they need information to build their investment thesis.

With in-depth research, interviews and insightful data, Thematica gives investors a chance to look at the bigger picture and allows companies to be part of this exclusive global insights series.

Along with Thematica, The Market Herald and its Australian platform are viewed more than 41 million times each month by active and engaged investors.

With an investor database of almost 210,000 in Australia and 390,000 in Canada, The Market Herald is one of the fastest-growing business and finance platforms in the world.



## INTRODUCTION

# What's rare about Rare Earth Elements?

Rare Earth Elements aren't rare at all, but finding a deposit of the scale, with the concentration and location advantages to equate to a feasible mining operation – that can be like finding a needle in a haystack.

These rare discoveries have never been more important because rare earth permanent magnets are critical to clean energy solutions as well as defence industries.

Australia and its allies need to secure mining-scale REE deposits and fast-track production, because without domestic supplies, the western world remains vulnerable to supply chains dominated by China.

**China produced 210,000 tonnes of rare earth oxides last year or 70 per cent of the world total.**

A long way behind was the second largest producer, the United States, with 43,000 tonnes. The US still required \$200 million of additional REE imports, mostly from China.

Australia was the third largest producer with 18,000 tonnes.

Australia's known reserves are 4.2 million tonnes (2.98 million tonnes being JORC compliant), which is more than the US reserves of 2.3 million tonnes, but again, those numbers are far surpassed by China (44 million tonnes), as well as Vietnam (22 million tonnes), Russia and Brazil (both 21 million tonnes).<sup>1</sup>

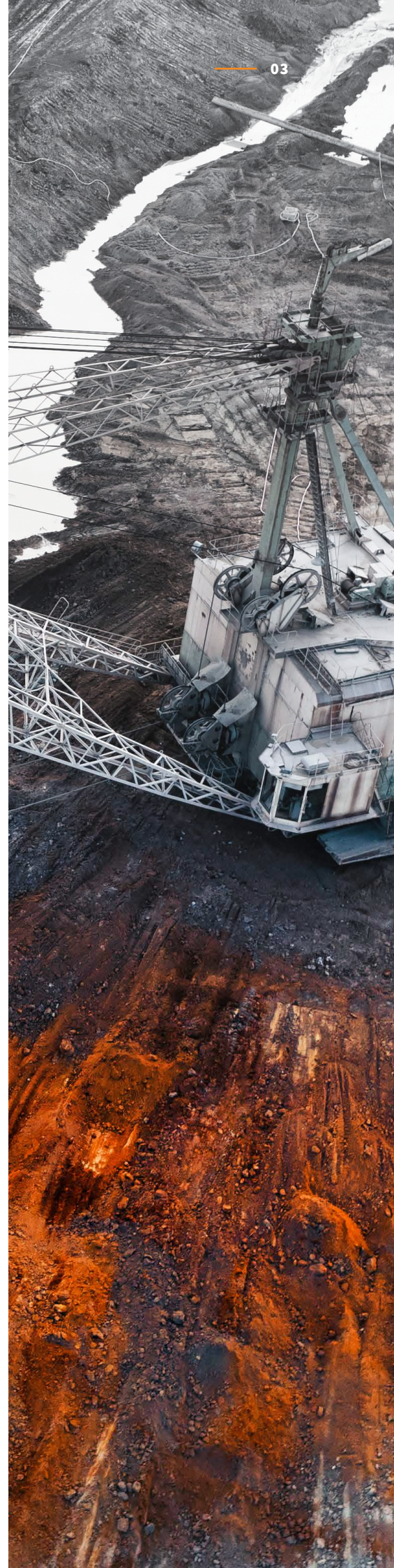
The Federal Government recognises the risks of being reliant on China for future supplies which are essential to manufacturing in the clean energy, aerospace and defence industries.

Australia's Resources Minister Madeleine King said there was an increasing need for resilient and diverse supplies of rare earths.

"Supply is as much a national security issue as one of energy and economic security," she said.

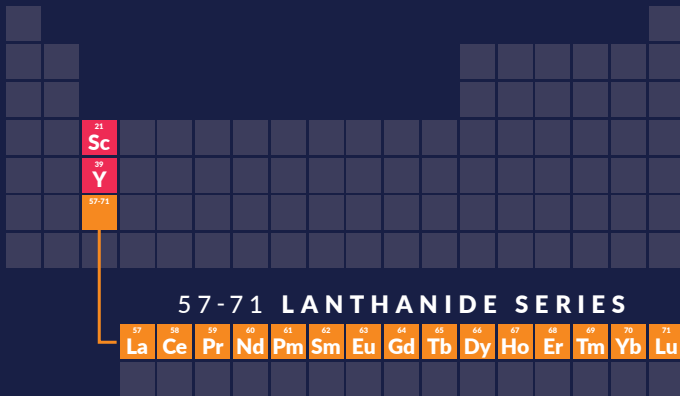
**"It could be said that Australia's critical minerals are at the centre of an important moment in history which could dictate the shape of the world that we will live in for the next century."**

AUSTRALIAN RESOURCES MINISTER, MADELEINE KING

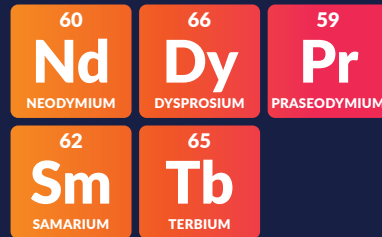


INSIGHTS

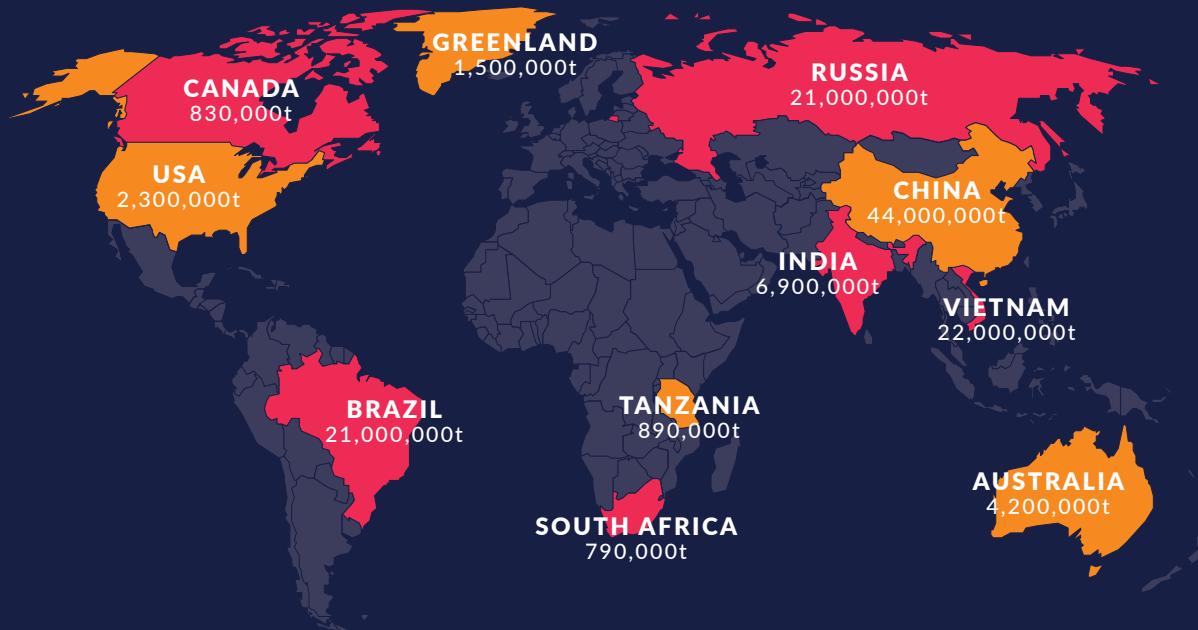
# The Rare Earth Elements



## Rare Earth Elements used in permanent magnets



## Global REE reserves at January 2023 METRIC TONS



INSIGHTS

# Australia's place on the rare earths map



## Top REE producing nations in 2022 METRIC TONS<sup>1</sup>





INSIGHTS

# Thematica investor survey: Exposure to rare earths



Of these,

# 79%

also have exposure to **clean energy** or **EV battery** metals:



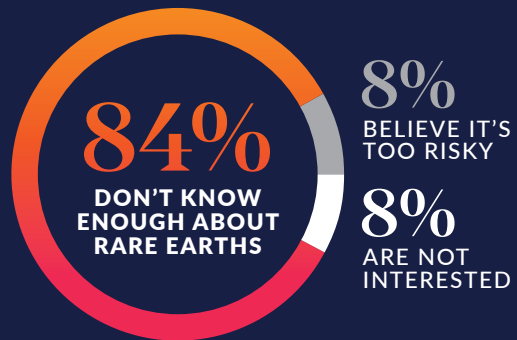
Of those with no REE exposure,

**14%** have historically held REE.

**66%** are interested in REE

**34%** are not interested

Of those,

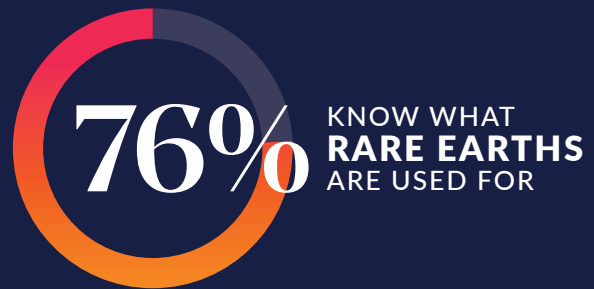


INSIGHTS

# Investment priority:



Without much thought or research,



**83%** of investors are interested in **learning more** about REE explorers, developers and producers

Survey respondents:



\*Survey of 470+ investors.

## INSIGHTS

# What REEs mean for clean

Renewable energy accounted for just over 35 per cent of Australia's total electricity generation last year, up from 32.5 per cent in 2021 – so there's a long way to go to meet the Federal Government's target of 82 per cent by 2030.

Clean Energy Council Chief Executive Kane Thornton said the pace of new large-scale clean energy projects needed to 'at least double'.

"Large-scale clean energy investment reached \$6.2 billion in 2022, a 17 per cent increase from 2021," he said. "The final quarter of 2022 saw investment in financially committed large-scale generation and storage projects reach \$4.29 billion, the second-highest quarterly result since data collection began in 2017.

"However, we cannot take the sustained growth of renewable energy for granted."

**"At present, processing components within the supply chain for rare earth elements are largely concentrated offshore when compared to other critical minerals."**

CLEAN ENERGY COUNCIL  
CEO, KANE THORNTON

"This presents an inherent challenge to Australia's sovereign manufacturing capability for renewable energy technologies," he said.

## THE ROLE OF REES

Rare earth permanent magnets are required in wind turbines and electric vehicle motors, so secure supplies that can be sustainably mined and processed will be critical globally to genuinely meeting clean energy targets.

All but two of the REEs – scandium and yttrium – are in the lanthanide chemical group.

Nearly all are categorised as light or heavy, according to their atomic weight.

Several rare earth elements are used in the production of permanent magnets, including neodymium, praseodymium, dysprosium and terbium.

Light rare earths neodymium and praseodymium are also used in electric vehicle motors. Harder to come by – and therefore more valuable – heavy rare earths, dysprosium and terbium, are added into the mix for wind turbine magnets.

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## INSIGHTS

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**SO TOP OF THE LIST FOR EXPLORATION IN AUSTRALIA ARE NEODYMIUM, PRASEODYMIUM, DYSPROSIUM AND TERBIUM:**

- **Neodymium:** High strength permanent magnets are known as neodymium magnets and they have high energy density for use in electric vehicles, wind turbines and hard disk drives. These magnets are critical in missile guidance systems. Neodymium is also used in mobile phones and medical equipment and is a violet colorant for glass and ceramics.  
AUD \$120.86/kg
- **Praseodymium:** When used together with neodymium in magnets, it increases the temperature resistance and magnetic strength. This REE is also used in alloys for aircraft engines and in fibre optic cables, studio lighting, didymium glass welders' goggles, as a yellow-toned colorant in glass and enamel, and, also is tipped to play a role in hydrogen storage solutions and other clean energy technologies.  
AUD \$132.66/kg
- **Dysprosium:** Enhances the magnetic properties of neodymium magnets, particularly at high temperatures. It's also required for other advanced technologies, such as lasers, nuclear reactors, and data storage devices.  
AUD \$577.03/kg
- **Terbium:** Like dysprosium, terbium enhances the high-temperature properties of magnets. It is also used in naval sonar and defence systems, in alloys, in solid-state devices as a crystal stabiliser, in actuators, in the cathode-ray tubes of televisions and monitors, in fluorescent lamps and in sensors.  
AUD \$2329.68/kg

Light rare earth **Samarium** is also used in magnets, in optical lasers, in studio lighting, lighter flints and with its neutron-absorbing qualities, it's in nuclear reactor control rods. **Holmium** is also used in magnets and for lasers

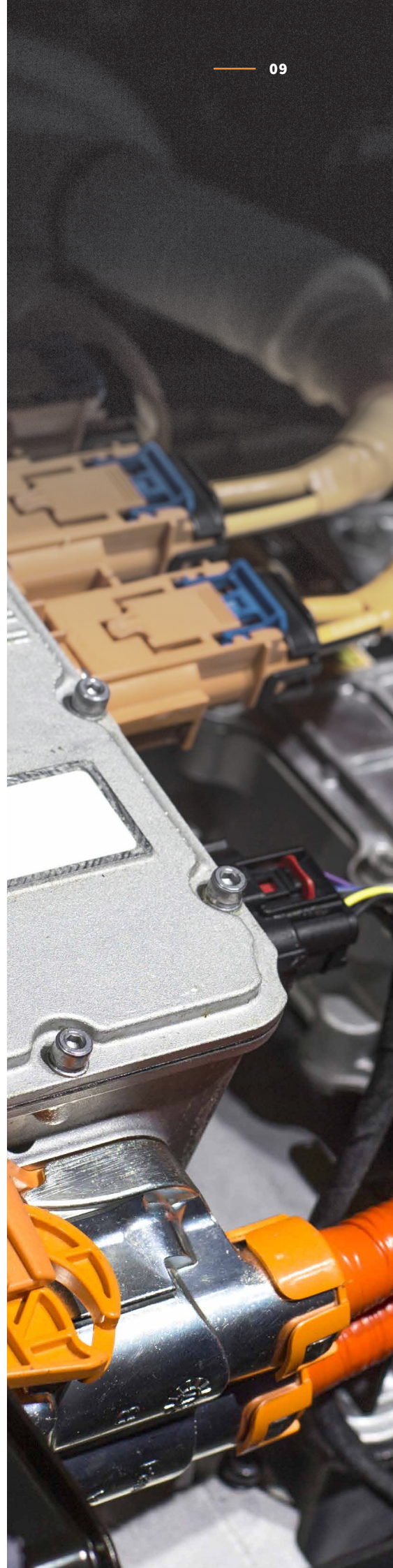
**Europium** is known for its phosphorescence which make LEDs and plasma displays possible. It is also in nuclear reactor rods. **Promethium** is used in nuclear batteries and luminous paints, **Erbium** is in infrared lasers, vanadium steel and fiber-optics. **Thulium** is used in lasers, as well as portable x-ray machines, lamps and lasers.

**Ytterbium** is in infrared lasers, flares, nuclear medicine and earthquake monitoring. **Lutetium** is used in radioactive imaging (Positron Emission Tomography (PET)), in LEDs and for refinery catalysts.

**Gadolinium** is used in x-ray and Magnetic Resonance Imaging (MRI) technology and monitor screens and **cerium** is used for catalytic converters in vehicles, it's used for polishing, yellow glass and ceramic colourings and in oil refinery catalysts.

**Lanthanum** is used for camera and telescopic lenses, night-vision goggles and surveillance equipment, while glass clarifying **yttrium** is important in defence targeting, combat vehicle weapons, in metal alloys and coatings for aircraft engines and turbines, and **scandium** is used in alloys for aerospace components.<sup>3</sup>

Prices source:  
Shanghai Metals Market – [www.metal.com](http://www.metal.com)  
Prices at May 2, 2023



## PRODUCTION

# Transitioning to green: Staying true to sustainability goal

Whilst it's clearly important to increase supplies of critical raw materials outside of China for the move to cleaner energy, it's equally important that these can be mined and produced reliably, environmentally sustainably and energy-efficiently.

History has shown that mining, refining and recycling of rare earths can have severe environmental and health consequences if not properly managed due to acid-rich, radioactive and toxic processes.

## LEARNING FROM THE PAST

Baotou, in Inner Mongolia, has been called the capital of rare earth mining. Surrounding mines are believed to contain as much as 70 per cent of world reserves. But Baotou also has the Weikuang Tailings Dam, an environmental mess of toxic wastewater, contaminated soil and air pollution, which has reportedly impacted local water supplies, air and soil qualities.<sup>4</sup>

There is also extensive pollution at other rare earth hot spots in the Jiangxi province of China.

Whilst the quest for profitability and cost-cutting would no doubt take some blame, Chinese officials may have prioritised economic growth and job creation amidst rapid urbanisation and industrialisation. There has been a lack of regulatory enforcement around the industry, and, insatiable international hunger for electronics and renewable

energy solutions has added to REE production pressures.

In recent times, Chinese officials have cracked down on illegal and small operations, with tougher regulations on mining, extraction and leaching processes. Some companies are implementing environmentally sustainable practises.

The pollution issues haven't been limited to the world's main rare earths producer.

Mining and processing operations during the 1980s and 1990s at the Mountain Pass cerium, lanthanum, neodymium and europium mine in California, were also linked to environmental contamination through radioactive materials spills.

And, a now closed yttrium processing plant in Bukit Merah, Malaysia, was blamed by local residents for health impacts including leukemia and birth defects.

Chemical engineer Michael Walshe is CEO of **Voltaic Strategic Resources** (ASX:VSR) which is exploring in the Gascoyne region of Western Australia.

He said rare earths could be processed in an environmentally sustainable

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## PRODUCTION

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way, by adopting responsible approaches to waste, tailings, energy, and emissions management. This required additional technology and unit operations compared to irresponsibly designed processes, and hence, significant additional capital expenditure.

“That’s one of the reasons why the West hasn’t been able to compete with China,” Mr Walshe said.

“But sustainability in REE production is incredibly important to achieving genuinely clean energy supplies and not defeating the whole purpose of energy transition.

“One way in which Australia can implement a more sustainable REE industry is to undertake more downstream processing in country and thereby not only capture more value for Australia, but also enhance visibility of the supply chain.

“This would require long-term strategic thinking from the Government and significant financial support to transition away from being an exporter of low-cost bulk commodities to a value-adding manufacturing powerhouse.”

Mr Walshe said that goal was possible to achieve.

“Australia has the best light and heavy REE deposits in the world, an abundance of solar and wind energy, and is home to some of the world’s premier engineering companies; there really is no excuse,” he said.

An additional approach to meeting the burgeoning supply needs, will be recycling and reuse of rare earth metals, and several companies are actively working on this issue.

**“If resource-poor and small land mass countries like Japan and South Korea can have thriving industrial manufacturing industries, what is stopping the world’s most resource-rich nation?”**

VOLTAIC STRATEGIC RESOURCES  
CEO, MICHAEL WALSH

**Mount Ridley Mines (ASX:MRD)** is advancing its REE project near Esperance in Western Australia. Technical Manager David Crook said modern projects are expected to manage operations in a socially and environmentally-conscious manner.

“As an industry we aspire to a much higher standard of heritage and environmental responsibility in Australia today, exceeding past performance and what might exist in the industry in other parts of the world,” he said.

“Our industry has highly structured regulations and processes in place to guide exploration, mining and processing operations to meet the expectations of today’s Australia.

“Investors expect responsible and environmentally sustainable operations and there’s no reason that future REE production can’t deliver on these demands.”



## PRODUCTION

# China holding tight to its rare earths tech

As the western world addresses concerns around the rare earth supply chain, the clear market leader China is making that job harder.

China is considering keeping its rare earths magnets-related technology and Intellectual Property close, by prohibiting or restricting exports.

It's looking to ban or restrict exports of technology for processing and refining of REEs, as well as tech around the manufacture of permanent magnets.<sup>5</sup>

The move has only continued to fuel urgency around securing the industry outside of China.

Earlier this year, the US and Japanese Governments signed an agreement aimed at strengthening the critical minerals supply chain and aligning industrial policies.

The European Union recently released its **Critical Raw Materials Act** which is designed to fast-track permitting and offer financial support for strategic mining and processing projects.<sup>6</sup>

The document outlines supply concerns: "EU demand for the rare earth elements from which the permanent magnets used in wind turbines or electric vehicles are manufactured is expected to increase six to seven-fold by 2050".

**"Heavy rare earth elements, used in permanent magnets, are exclusively refined in China."**

#### EUROPEAN UNION **CRITICAL RAW MATERIALS ACT**

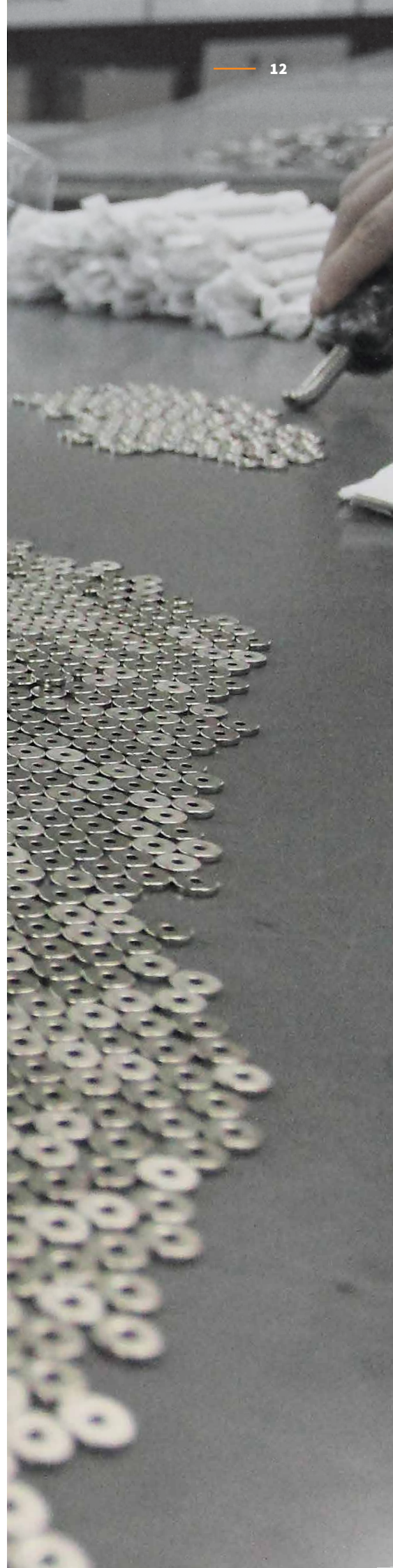
"These critical raw materials (CRMs) are often indispensable inputs for a wide set of strategic sectors including renewable energy, the digital industry, the space and defence sectors and the health sector."

The **US Inflation Reduction Act** introduced last year, sets a path for the US and trade partners to make a greater contribution to the mining and processing of rare earth elements for permanent magnet production.<sup>7</sup>

Clean Energy Australia CEO Kane Thornton said benefits could flow through to Australia.

"The passage of the Inflation Reduction Act by the Biden Administration in the United States provides generous tax credits to American companies using minerals extracted, processed, or recycled from countries party to a free trade agreement with the US, including Australia," he said.

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## PRODUCTION

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### AUSTRALIA AND GERMANY FORGE CRITICAL MATERIALS PARTNERSHIP

Meanwhile, Australia and Germany are set to work together on critical materials opportunities after signing a Declaration of Intent in Perth in April, 2023.

The declaration, signed by Resources Minister Madeleine King, will support a joint study to help Australia meet its ambitions to develop value-added industries around critical minerals - from extraction to refinement and recycling. It'll also help Germany secure reliable supplies of critical minerals to underpin its manufacturing and recycling activities.

**“Both Australia and Germany recognise the important opportunity we have to build diverse, resilient and sustainable critical minerals value chains.”**

AUSTRALIAN RESOURCES MINISTER, MADELEINE KING

“Australia has vast reserves of critical minerals, which are essential components for clean-energy technologies such as electric vehicles, batteries, solar panels and wind turbines.

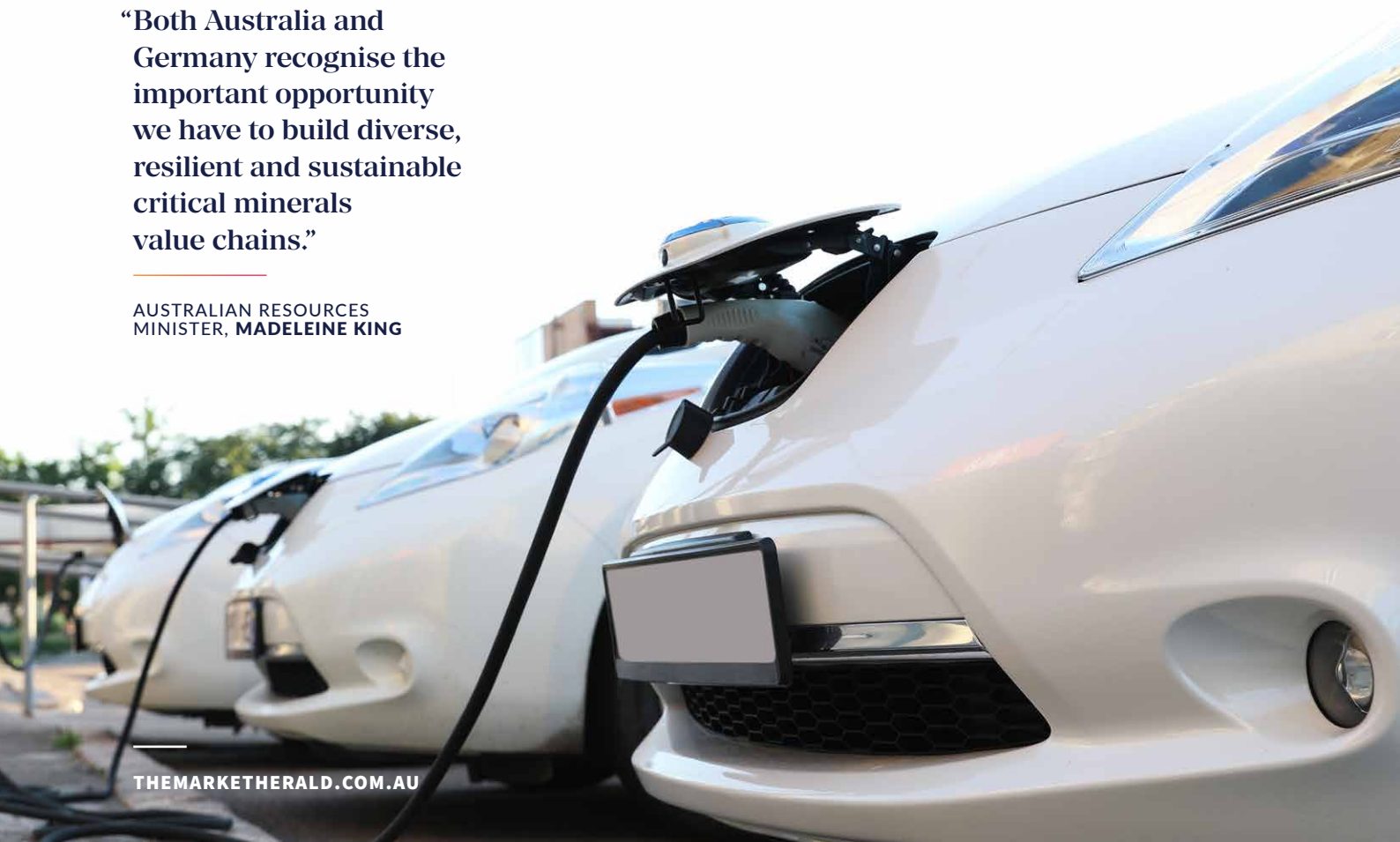
“Both countries have complementary climate, energy and strategic ambitions. The Declaration of Intent with Germany will help us understand which critical minerals are most important to support Germany’s industries and how Australia can be a partner of choice in meeting these needs.”<sup>8</sup>

And, to accelerate a pipeline of promising critical minerals projects, the Government has committed \$100 million through its **Critical Minerals Development Program**.<sup>9</sup>

### AUSTRALIA PREPARES FOR NEW ‘CRITICAL MINERALS STRATEGY’

Minister King has promised to release Australia’s new **Critical Minerals Strategy** later this year, to ‘articulate priorities’ and ‘ensure the development of new sources of supply and establish robust, diverse supply chains’.

“We are also working to streamline the approvals process to enable industry to bring on projects more efficiently,” Minister King said.<sup>10</sup>





## PRODUCTION

# How Australia will play its part

Australia has an emerging rare earths industry, with junior rare earths exploration pioneers working to firm up viable project propositions.

At the same time, miners **Iluka Resources** (ASX:ILU), **Hastings Technology Metals** (HAS), **VHM Ltd** (VHM), **Arafura Rare Earths** (ARU), and **Northern Minerals** (NTU) are advancing production and processing capabilities.

The local leader in the industry is **Lynas Rare Earths** (LYC) which claims to be 'the world's only significant producer of separated rare earth materials outside of China'.

It's now a \$6 billion market cap company.

Lynas's Mt Weld mine produces Neodymium, Praseodymium, Lanthanum, Cerium and mixed Heavy Rare Earths.

Oxides are initially treated at the Mt Weld concentration plant before being shipped to Malaysia, where Lynas produces high-quality separated rare earth materials for export to manufacturing markets in Asia, Europe and the United States.

Lynas CEO Amanda Lacaze told The Market Herald that the company's Kalgoorlie Rare Earths Processing Facility would be the first in Australia to undertake value-added processing of rare earths.

"Lynas's new rare earths processing facility in Kalgoorlie will process the rare earth concentrate from Mt Weld and has been designed to be able to process potential third-party feedstocks as they become available," she said.

"We are open to considering additional processing operations where it makes sense for our business and our customers.

"Demand for critical minerals, including rare earths, is accelerating and Lynas welcomes industry development and believes it will benefit all participants.

**"Achieving critical mass in any industry is a good thing and it means that there will be more development and more innovation in those industries."**

LYNAS CEO **AMANDA LACAZE**

"Our country's outstanding mineral endowment, skilled workforce, environmental credentials and safety standards will support the energy transition."

Construction of the first stage of **Hastings Technology Metals** (ASX:HAS) Western Australian Yangibana REE mining and processing operations will begin within months.

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## PRODUCTION

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CEO Alwyn Vorster said demand for rare earths would continue to be fuelled by the broader electrification trend.

“Electric vehicles are forecast to increase to dominate over half of market share by the end of this decade,” he said.

“Wind power has been identified by the International Renewable Energy Agency as the fastest growing renewable energy technology, driving increasing need for permanent magnet direct drive generators in wind turbines, which eliminates the need for a gearbox.

“Rare earth magnets make turbines lighter, cheaper, more reliable, easier to maintain and capable of generating electricity at lower wind speeds.

“As a result, it’s expected that the demand for rare earth elements – neodymium and praseodymium – will exceed current production rates by 2025, resulting in a sizeable supply

gap due to the time lag for new mine investment outside of China.

“Australia is well-positioned to seize the opportunity and work rapidly to secure domestic supplies of these materials that are only going to become more sought after in the years to come.”

Gascoyne exploration company **Dreadnought Resources** (ASX:DRE) Managing Director Dean Tuck agreed that Australia had the resources and the capabilities to address the supply chain issues.

**“Australia can’t ignore the importance of contributing to a complete ex-China Rare Earth Elements supply chain.”**

DREADNOUGHT RESOURCES  
MD **DEAN TUCK**

“Australia has an amazing ability to turn the tap on for primary production and providing raw materials for the supply chain with some of the highest environmental, community and governance standards in the world.

“You saw that with lithium over the span of a few years: Australia has become the biggest producer, from producing about a third of the world’s production, to over 50 per cent from Western Australia alone.

“We are also starting to see the midstream processing coming on board as we have seen in the lithium and nickel space in WA where we’re no longer just producing rock, but also refined product.

“There remains significant potential for Western Australia to do the same with rare earths.”



## ASX COMPANY PROFILE

# Construction ready: Australia's next REE producer

Hastings Technology Metals is set to become Australia's next rare earth producer through its flagship Yangibana project in Western Australia's Gascoyne region.

The project is about 250 kilometres to the north-east of Carnarvon and covers an area of 650km<sup>2</sup>.

Two of the highest valued rare earth elements, Neodymium and Praseodymium (NdPr) are predicted to experience the highest demand growth in the next decade. With an NdPr ratio of 36 per cent, the Yangibana deposit has almost double the NdPr content than most other orebodies globally.

Hastings CEO Alwyn Vorster said the company's focus was on stage one of the project which included the mining and beneficiation of one million tonnes of ore a year, producing 35,000 tonnes of rare earth concentrate.

"The project's metallurgical development work has been comprehensively studied and de-risked, with the results validating the processing flowsheet of the beneficiation plant, which upgrades the rare earth content of the Yangibana deposit by more than 25 times," Mr Vorster said.

Stage two would then see concentrate transported to a proposed Onslow hydrometallurgical plant for cracking, leaching and drying to produce 15,000 tonnes of Mixed Rare Earth Carbonate (MREC) at 59 per cent rare earth oxides.

Early infrastructure is being

completed, including the Kurrbili accommodation village and an airstrip made to cater for 70-seater aircrafts. Main construction is set to begin in the third quarter of this year.

"We believe our path to first concentrate production at the end of 2024 is well-timed to meet increased demand for rare earth elements," Mr Vorster said.

"Once operational, we anticipate Yangibana will fill six to eight per cent of the gap set to arise through global growth in NdPr demand.

"We are confident that this world-class project will establish Hastings as a significant player in the critical minerals sector and as a generator of strong returns for our shareholders, the domestic economy and local communities."

Last year, Hastings acquired 19.9 per cent of TSX-listed rare earth processing and permanent magnets producer, Neo Performance Metals (TSX:NEO).

"As one of the only 'western' magnet companies, this strategic investment in Neo provides Hastings with favourable exposure to global downstream processing and the opportunity to explore the creation of a fully-integrated mine-to-magnet business," Mr Vorster said.

[www.hastingstechmetals.com](http://www.hastingstechmetals.com)

HASTINGS  
TECHNOLOGY METALS

## CEO

ALWYN VORSTER

## PUBLIC/PRIVATE

PUBLIC ASX-LISTED

## TICKER

ASX:HAS



## ASX COMPANY PROFILE

# Building upon sellable 14m tonne NdPr resource in WA

Dreadnought Resources has moved quickly to establish a neodymium and praseodymium-rich rare earth resource at its Yin project in the Gascoyne region of Western Australia.

The Yin deposit is a hard rock rare earths deposit containing some of the highest NdPr:TREO mineralisation of anywhere in the world. It's a concentrate that Dreadnought hopes to supply into the rapidly expanding midstream processing market.

"I believe that our concentrate has the highest proportion of NdPr of any project in the world," Mr Tuck said.

"Globally, rare earth concentrates NdPr:TREO ratios range between 15 and 25 per cent. The NdPr:TREO ratio of our deposit is above 30 per cent and our initial concentrate produced was over 40 per cent.

"We can produce a high value concentrate with numerous parties already interested in that product."

Mr Tuck said there were learnings from Hastings Technology Metals' (ASX:HAS) early work in the Gascoyne.

"The first and greatest risk to a rare earth resource is the ability to produce a viable concentrate," he said.

"We had second-mover advantage and the market responded so favourably to us because Hastings Technology Metals had already shown that they can produce a sellable concentrate in the region, and, before we drilled anything at Yin, we had metallurgy done to prove that we could also

produce a sellable concentrate," he said.

"We de-risked the project and then we started drilling. We have been able to piggyback on the metallurgical research that existed.

"We have an initial resource and are undertaking further metallurgy work to add to the scale of our deposit."

Dreadnought also has the early-stage heavy rare earths project, Bresnahan, which lies 350km northeast of Yin. It's targeting Dysprosium and Terbium and appears geologically similar to Northern Minerals (ASX:NTU) Browns Range rare earths project in the Northern Territory.

"We had a proof-of-concept last year so we have been flying airborne surveys and will begin ground exploration shortly to generate and define drill targets for 2024," Mr Tuck said.

"At Dreadnought we focus on what matters and what can be mapped to make our discoveries and set ourselves up to move quickly to deliver resources and prove up the project.

"Why is it worth it? Our low carbon future is built on mining and these critical metals and there is no better place to mine responsibly than in Western Australia."

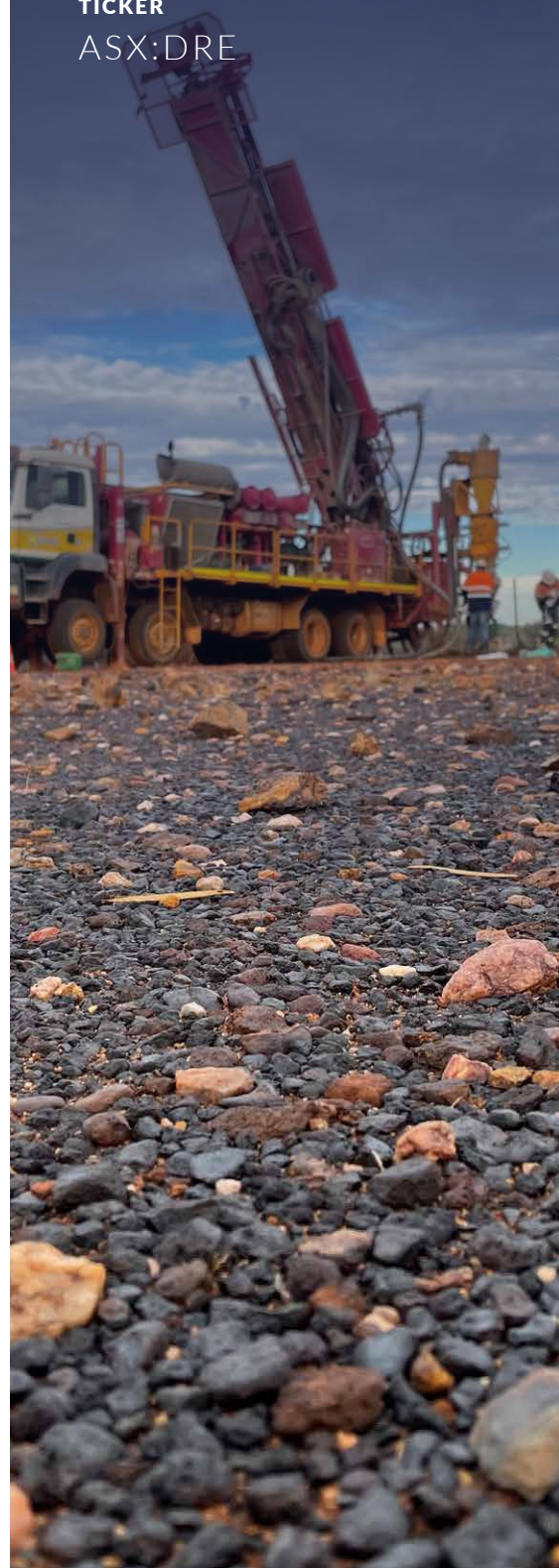
[www.dreadnoughtresources.com.au](http://www.dreadnoughtresources.com.au)

## DREADNOUGHT RESOURCES

MANAGING DIRECTOR  
DEAN TUCK

PUBLIC/PRIVATE  
PUBLIC ASX-LISTED

TICKER  
ASX:DRE



## ASX COMPANY PROFILE

# Two years until first REE production

VHM Limited's advanced, low-capex Goschen Project in Victoria is one of the world's largest rare earth and mineral sands deposits with more than 413,000 tonnes of contained Total Rare Earth Oxides (TREO).

VHM has just refreshed its Definitive Feasibility Study (DFS) for the Project and has commenced Front-End Engineering Design (FEED) for Phase 1. Goschen is in the Loddon Mallee region, about 35km south of Swan Hill and 275km north of Melbourne.

The Goschen Project is one of only four active projects in Australia to have completed a DFS in the past three years and that DFS clearly shows the low-cost operating model. The DFS reveals robust average pre-tax free cash flow of A\$270 million per year with an approximate Net Present Value of A\$1.5 billion pre-tax, over the first 10 years of operation (based on Phase 1 and 1A metrics).

VHM's tenements, including the Goschen footprint, cover some 2,800km<sup>2</sup> of contiguous ground, with 629 million tonnes of Mineral Resource estimate and 199Mt of JORC-compliant ore reserve (JORC). The company has also discovered new high-grade rare earth, zircon and rutile deposits at Cannie (13km to the south) and Nowie (13.5km north).

Managing Director Graham Howard said Goschen would be developed in stages to deliver a 5Mt per annum mining and treatment operation with a mine life of more than 20 years.

"VHM is on track for commissioning and first concentrate production in

the first half of 2025," Mr Howard said.

"The minerals are already fully liberated in sand – not hard rock. This means there'll be no drilling or blasting needs and as indicated by drilling results, the rare earths and zircon-titania minerals are mostly near-surface."

Goschen's REE mineral concentrate test results indicate 'exceptionally high rare earth grades, up to 60 per cent Total Rare Earth Oxide and a very high proportion of high-value critical rare earths neodymium, praseodymium, dysprosium and terbium'.

"It helps to be in a premier mining jurisdiction with existing infrastructure, a skilled workforce and strong community, as well as local, state and federal government support," Mr Howard said.

"We signed Memorandums of Understanding with both the Gannawarra and Swan Hill shires providing strong support for the Project by the local community and Government.

"We've been granted 'Major Project Status' by the Australian Government, given its significance, and further offtake conversations continue with potential partners in the US, Japan and Europe."

[www.vhmltd.com.au](http://www.vhmltd.com.au)

## VHM LIMITED

MANAGING DIRECTOR  
GRAHAM HOWARD

PUBLIC/PRIVATE  
PUBLIC ASX-LISTED

TICKER  
ASX:VHM



## ASX COMPANY PROFILE

# 800 holes down: Drilling to build REE resource

Mount Ridley Mines has been framing out large deposits of rare earths in clays near Esperance in Western Australia. And they've found them in the region's kaolin clays.

Technical manager David Crook claims the company's 100 per cent-owned Mount Ridley project was the most advanced of the WA clay-hosted junior REE projects, having completed over 800 drill holes totalling over 36,000m of drilling, covering at least 1200km<sup>2</sup>.

"The more we're drilling, the higher the grades we're seeing, so we're now in a position where we can refine our leading targets based on physical characteristics," he said. "We've prioritised areas with a high ratio of critical magnet REE elements in our preferred clay type, in areas with thinnest overburden for detailed drilling.

"We've got a lot of our ducks in a row and we're moving towards revealing our first JORC resource around the Mia deposit later this year, with more high-grade targets to follow."

Mr Crook said Mount Ridley had the advantage of finding REEs at shallow depths, with high grades 'commonly 1000-4000 parts per million Total Rare Earth Oxide, with the highest grades up to 28,000ppm TREO'.

He said the project was close to infrastructure including an airport,

port, railway, gas supplies and green energy projects. Company policy was to peg tenements across vacant Crown land, to avoid competition with other land uses, such as agriculture.

Drilling is continuing at the Mia and Marvin targets, where there's a 30km by 4km trend of mineralisation.

"We're still waiting for assay results and we're conducting very early stage metallurgy to identify components of the processing flowsheet that will eventually be required," Mr Crook said.

Chairman Peter Christie agreed the company was progressing quickly.

"We believe that Mount Ridley has discovered a large REE deposit and are pursuing its delineation and development apace," Mr Christie said.

"This response aligns with action by many countries to implement green strategies to limit climate change and its effect."

Mount Ridley Mines also holds tenements prospective for iron and gold in the Weld Ranges, in WA's mid-west.

[www.mtridleymines.com.au](http://www.mtridleymines.com.au)

## MOUNT RIDLEY MINES

**CHAIRMAN**  
PETER CHRISTIE

**TECHNICAL MANAGER**  
DAVID CROOK

**PUBLIC/PRIVATE**  
PUBLIC ASX-LISTED

**TICKER**  
ASX:MRD



## ASX COMPANY PROFILE

# Building a major clay-hosted resource – low market cap

Krakatoa Resources' rare earths deposit, Tower, was the first major discovery made at the company's 100 per cent-owned Mt Clere project.

Tower has a Mineral Resource Estimate of 101 Million tonnes at 840 parts per million Total Rare Earth Oxides (JORC, 2012), which means it's one of the largest clay-hosted REE resources in Australia, and the biggest in Western Australia, with considerable upside as only a fifth of Krakatoa's large landholding has been explored.

Tower lies between the Murchison and Gascoyne rivers on the north-western margins of the Yilgarn Craton.

Executive chair Colin Locke said the company had recorded recoveries of permanent magnet rare earths, including up to 64 per cent Neodymium and 61 per cent Praseodymium.

"Recoveries compare favourably to other globally-significant clay-hosted rare earth projects with studies indicating simple beneficiation processing to increase grade and recovery," Mr Locke said.

"Having made the Tower discovery, we're now moving toward economic assessments and refining the metallurgical solutions.

"Krakatoa has a much lower market capitalisation than its peers, presenting a potential value proposition to investors."

Mr Locke said the clay-hosted deposit potentially allowed for both economic and environmentally-friendly development.

"The soft clay material has already been broken down with elevated Heavy Rare Earth Oxides (HREO) and Critical Rare Earth Oxides (CREO), so no crushing nor explosives will be required, which means significantly lower operating expenses than for hard rock projects," he said.

"There'll be lower capital expenditure too, because simple acid solubilisation and conventional separation produces the potential payable product. Milling wouldn't be required, eliminating emissions and vastly reducing the power draw and we won't need a tailings dam because the washed clays can be disposed of locally and revegetated."

[www.ktaresources.com](http://www.ktaresources.com)

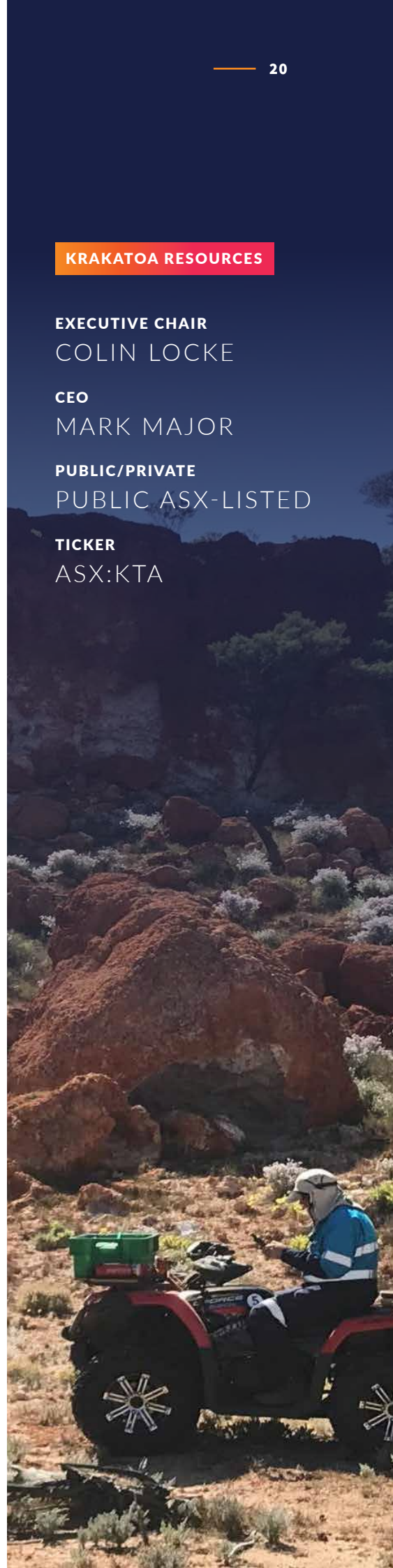
## KRAKATOA RESOURCES

EXECUTIVE CHAIR  
COLIN LOCKE

CEO  
MARK MAJOR

PUBLIC/PRIVATE  
PUBLIC ASX-LISTED

TICKER  
ASX:KTA



## ASX COMPANY PROFILE

# Working backwards: VSR's unique approach

Voltaic Strategic Resources is taking a different approach to exploration at Paddy's Well in the Gascoyne region of WA.

Since listing on the ASX in October, VSR has completed its maiden drilling campaign. But instead of getting straight into following up the promising results with further drilling, under the leadership of CEO and chemical engineer Michael Walshe and exploration manager Claudio Sheriff-Zegers, it's instead looking well down the road to production.

"At Paddy's Well, we have both primary hard rock (carbonatite) and clay-hosted REE targets," Mr Walshe said.

"Our maiden drilling targeted clay-enriched REEs that were identified by historical explorers and confirmed by us; we intersected several wide zones of REE anomalism and we've only tested less than 5% of the entire area to date.

"Now we're working to determine if the rare earths are 'ionic', meaning that they will extract using benign, low-acid operating conditions, or whether they are 'refractory', requiring large amounts of acid and high temperature to leach.

"Any clay-hosted rare earths deposit needs to have a significant 'ionic' component to be economically viable.

"We have identified halloysite, which is a kaolinitic clay mineral commonly found in true REE ionic adsorption deposits, which is highly encouraging."

The maiden drilling identified multiple REE intercepts of up to 30m true width from near surface, with values up to 9000 parts per million Total Rare Earth Oxides (TREO).

"But TREO results don't always tell the whole story when comparing projects," Mr Walshe said. "The Gascoyne has some of the best rare earths in the world due

to the enrichment in magnet metals neodymium and praseodymium, and amenability to upgrading from simple beneficiation," he said.

"The concentrate that is produced from Gascoyne-based projects such as Yangibana, is more valuable on a per kilo basis than other projects with far higher TREO head grades".

Paddy's Well lies to the south of Hasting's (ASX:HAS) Yangibana and Dreadnought's (ASX:DRE) Yin projects and is also along strike from Kingfisher Mining's (ASX:KFM) Mick Well discovery.

Paddy's Well was the focus of uranium exploration in the 1990s and Voltaic's team has been able to analyse core samples from that time, which are proving promising to the company's clean energy materials aim.

Should the metallurgical testing on the clay-hosted REEs not go as hoped, VSR has a Plan B.

"If the REE-enriched clays do not demonstrate significant "ionic" potential, we will explore our hard rock REE targets - and we have more than 50 already pinpointed across our 1300km<sup>2</sup> Paddy's Well project," Mr Walshe said.

VSR also has the Ti Tree lithium project 60 kilometres to the east of Paddy's Well, along strike from Red Dirt Metals' (ASX:RDT) Yinnetharra lithium project. where Red Dirt are currently undertaking a 90,000m lithium-focused drill campaign. Voltaic also has gold / base metals projects in the Meekatharra region and a nickel, copper and cobalt project in Nevada.

[www.voltaicresources.com](http://www.voltaicresources.com)

## VOLTAIC STRATEGIC RESOURCES

## CEO

MICHAEL WALSH

## PUBLIC/PRIVATE

PUBLIC ASX-LISTED

## TICKER

ASX:VSR





## ASX COMPANY PROFILE

# New REE focus complements gold and base metals exploration

Rare Earth Elements have become a clear focus for Western Australian explorer Caprice Resources since it acquired the Mukinbudin project late last year.

The Mukinbudin project lies 250 kilometres northeast of Perth and MD Andrew Muir has classed it as a 'natural complement' to the company's gold and base metals portfolio.

The project is at an early stage of exploration, with works including rock chip and soil sampling and mapping. Caprice is targeting pegmatite-hosted REEs at Mukinbudin, a region known to contain elevated values of dysprosium, terbium and praseodymium used in magnets and electric vehicle batteries, as well as the critical metal niobium.

"The region has many known pegmatites, which have long been known to have REE associations, however, there has been next to no historical exploration for REEs," he said.

"Several quarries in the region also give some excellent exposure to the pegmatites we are looking for."

Mr Muir said the Mukinbudin project provided an opportunity for the

company to tap into the burgeoning demand for critical materials.

"The shift to EVs and electrification is only going to increase, driven by demand and technological change, so we see the need for these key battery metals only increasing, along with the critical metals space that includes niobium," he said.

"There is also a significant push towards security of supply chains for such crucial elements, which we expect will enhance demand in western economies.

"Caprice has exposure to three strong projects across a suite of commodities:

- Rare earths at Mukinbudin;
- Base metals at Northampton; and,
- Gold in the Murchison.

"All have the potential to develop into something significant and add substantial value to Caprice.

"With our low EV (enterprise value), we are highly leveraged to exploration success on all fronts."

[www.capriceresources.com](http://www.capriceresources.com)

## CAPRICE RESOURCES

MANAGING DIRECTOR  
ANDREW MUIR

PUBLIC/PRIVATE  
PUBLIC ASX-LISTED

TICKER  
ASX:CRS



## ASX COMPANY PROFILE

# Historic pit reveals high-grade Rare Earth Elements in NSW

Eastern Metals has increased its footprint around the Currawalla mine at its Tara Project, south of Cobar in New South Wales.

It's centred around a shallow prospecting pit that was historically developed for base and precious metals exploration.

Whilst that type of mining didn't continue at Currawalla, Eastern Metals chairman Bob Duffin said the key elements identified there were valuable rare earths Neodymium and Praseodymium, with assays showing Total Rare Earth Oxide (TREO) up to 3.38 per cent.

"These results from Tara are very exciting as rarely do you see such a close correlation between a discreet aeromagnetic anomaly, a shaft on an old mine and highly anomalous values in rock specimens," Mr Duffin said.

"It all suggests the deposit has significant tonnage potential.

"We have the Currawalla mine under secure tenure, but the trend of the mineralised zone goes off our tenement and into ground not formerly held by Eastern Metals.

"We have applied for an additional exploration licence to cover this potential and have been advised by the NSW mining regulator that our

application has been successful.

"So, we now have a large footprint in what could be an unrecognised REE geological domain in NSW. We have first mover advantage in this area."

Eastern Metals trades on the ASX with a market capitalisation below \$5 million.

"With a very low market capitalisation and a tight share structure, the potential uplift in shareholder value from further successes at our polymetallic deposits and our new REE project is enormous," Mr Duffin said.

"We have good people with a demonstrated history of delivering strong results for our shareholders."

Results of geological mapping, soil sampling and ground magnetic surveys at the Currawalla site will guide plans for a drilling exploration campaign.

Eastern Metals also has projects covering copper, gold, zinc, silver and lead in the Northern Territory and in central western New South Wales.

[www.easternmetals.com.au](http://www.easternmetals.com.au)

## EASTERN METALS

**CHAIRMAN**  
BOB DUFFIN

**PUBLIC/PRIVATE**  
PUBLIC ASX-LISTED

**TICKER**  
ASX:EMS



## SUMMARY

# Key takeaways for investors

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1. Australia and **much of the western world is missing** along most of the permanent magnet supply chain and are totally reliant on China for these products.
2. The market for the key permanent magnet rare earths is **set to more than double by 2030**. REEs remain the most effective materials for producing magnets and whilst researchers are looking at alternatives, including iron-based magnets, nanostructured magnets and organic alternatives, none are at a point that they could replace REEs.
3. To address reliance on China and the forecast future rare earth elements shortages, **western governments are backing the permanent magnet supply chain** with both dollars and policies to fast-track permitting and development of strategic REE projects. Australia's Resources Minister Madeleine King has vowed to release a new Critical Minerals Strategy later this year.
4. The rare earths industry will operate under tougher regulations than in China, which means **Australian production can be responsible** and meet investor and community expectations around Environmental, Social and Governance (ESG) sustainability.
5. The key to successful exploration projects will be less about the size of the resource and more about **whether the REEs lie in host clay or rock** that can be efficiently mined and sellable.



## THE PLAYERS

## REE exposure on the ASX

ASX TICKER	COMPANY NAME	MARKET CAP (AUD) AT 02.05.23	ASX TICKER	COMPANY NAME	MARKET CAP (AUD) AT 02.05.23
ADC	ACDC Metals Ltd	\$7.59m	KFM	Kingfisher Mining Ltd	\$11.81m
AR3	Australian Rare Earths Ltd	\$51.87m	KOR	Korab Resources Ltd	\$9.91m
ARN	Aldoro Resources Ltd	\$20.16m	KTA	Krakatoa Resources Ltd	\$11.99m
ARR	American Rare Earths Ltd	\$91.74m	LIN	Lindian Resources Ltd	\$441.72m
ARU	Arafura Rare Earths Ltd	\$866.47m	LNR	Lanthanein Resources Ltd	\$20.18m
ASM	Australian Strategic Materials Ltd	\$173.37m	LRV	Larvotto Resources	\$24.29m
ASR	Asra Minerals Ltd	\$14.67m	LYC	Lynas Rare Earths Ltd	\$5.99b
ATR	Astron Corporation Ltd	\$66.78m	MEI	Meteoric Resources NL	\$270.05m
BUS	Bubalus Resources Ltd	\$5.04m	MEK	Meeka Metals Ltd	\$45.90m
CBE	Cobre Ltd	\$32.70m	MRD	Mount Ridley Mines Ltd	\$27.24m
CCZ	Castillo Copper Ltd	\$19.49m	MTM	Mt Monger Resources Ltd	\$15.90m
CLA	Celsius Resources Ltd	\$31.88m	NTU	Northern Minerals Ltd	\$198.19m
CRS	Caprice Resources Ltd	\$5.37m	OD6	OD6 Metals Ltd	\$31.75m
DRE	Dreadnought Resources Ltd	\$202.07m	OSM	Osmond Resources Ltd	\$7.93m
DY6	DY6 Metals Ltd (IPO for June 2023 ASX listing)		PEK	Peak Rare Earths Ltd	\$113.53m
EMS	Eastern Metals Ltd	\$3.29m	PIM	Pinnacle Minerals Ltd	\$5.45m
EMU	Emu NL	\$3.62m	PRS	Prospect Ltd	\$6.70m
ETM	Energy Transition Minerals Ltd	\$54.22m	PVW	PVW Exploration Pty Ltd	\$7.87m
ENV	Enova Mining Ltd	\$5.08m	REE	RareX Ltd	\$33.60m
GBZ	GBM Resources Ltd	\$18.58m	RGL	Riversgold Ltd	\$15.12m
GRE	Greentech Metals Ltd	\$3.68m	THR	Thor Energy Plc CHESS	\$11.96m
HAS	Hastings Technology Metals Ltd	\$264.81m	TMT	Technology Metals Australia Ltd	\$71.34m
HRE	Heavy Rare Earths Ltd	\$9.55m	VHM	VHM Ltd	\$181.50m
ILU	Iluka Resources Ltd	\$4.66b	VML	Vital Metals Ltd	\$68.97m
IPX	IperionX Ltd	\$189.92m	VSR	Voltaic Strategic Resources Ltd	\$10.52m
IXR	Ionic Rare Earths Ltd	\$106.54m	WCN	White Cliff Minerals Ltd	\$6.71m
JAV	Javelin Minerals Ltd	\$9.45m			

## ABOUT THIS REPORT

# Contributors



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EXECUTIVE PRODUCER,  
THE MARKET HERALD  
AUTHOR, THEMATICA REPORT

Sonia has 30 years' experience in journalism and communications roles across Australia and New Zealand.

Sonia now leads the broadcast and editorial departments of The Market Herald. Previously, she reported for the Nine Network's news and A Current Affair and TVNZ New Zealand's Close Up and One News.

She has worked across metropolitan and regional newspapers and radio.

Prior to joining The Market Herald, Sonia was a media advisor to WA Government Ministers and worked as a corporate communications advisor to a bank.

She has interviewed hundreds of Managing Directors and CEOs in her role with The Market Herald, providing investor news and insights.



## CALE ARNOLD

GRAPHIC DESIGNER

Cale has over 10 years' experience as a designer in both private enterprise and the public sector.

After a stint with a WA Government department, he climbed the ranks at Seven West Media before pivoting to the digital marketing scene.

Since joining The Market Herald as a senior designer, he's worked across all facets of the business and built a coherent brand identity for what is fast becoming one of the largest online news businesses in Australia.



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Osama supports clients and internal stakeholders through his strategic engagement advice and comprehensive understanding of capital markets.

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She holds both a Bachelor of Biomedical Sciences and Commerce, as well as a Master of Applied Finance from the University of Western Australia, which she has used throughout her career.

Prior to joining The Market Herald, Serena worked within rural communities, delivering affiliate accounting and financial services to local businesses and farmers. Most recently, Serena worked within the capital investment space as a sales associate.

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In particular, you should seek independent financial advice and read the relevant product disclosure statement (PDS) or other offer document prior to making an investment decision in relation to a financial product (including a decision about whether to acquire or continue to hold).

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