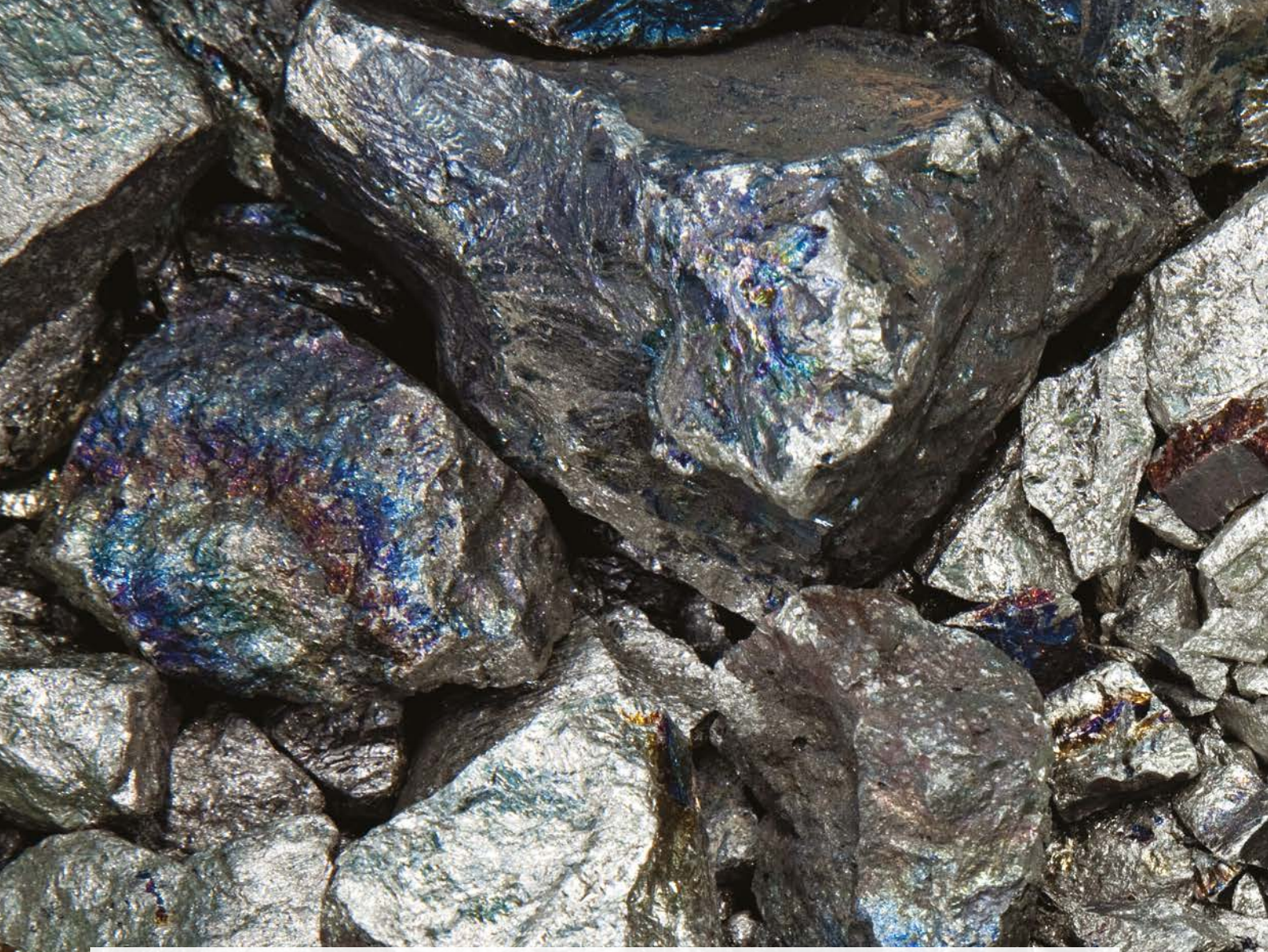
AUSTRALIA

AUSTRALIAN CRITICAL MINERALS PROSPECTUS 2020

Australian Government
Australian Trade and Investment Commission
Geoscience Australia
Department of Industry, Science, Energy and Resources



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INTRODUCTION

Critical Minerals

Critical minerals are essential to the economic development of industrialised countries. These minerals have a range of high-tech applications across a variety of sectors of growing economic and strategic significance, including:

- renewable energy
- aerospace
- defence technologies
- automotive (particularly electric vehicles)
- telecommunications
- agri-tech.

Forecast demand growth for critical minerals presents an important economic opportunity. Australia is an important global supplier of many critical minerals and has the resource potential to scale up to meet rising global demand and drive the upstream diversification of global supply chains.

The Prospectus

This second edition of the *Australian Critical Minerals Prospectus* showcases Australia's significant capability in critical minerals. The Prospectus provides technical details on Australian critical minerals projects — both operating and at an advanced stage of development — where Australia has the potential to make a significant contribution to the global upstream supply chain.

The Prospectus also identifies Australia's broader geological potential in critical minerals, supported by maps and other relevant geological data. The Prospectus only presents Australia's national resource potential: it does not cover minerals processing, nor does it includes overseas resources in which Australian companies may have a development or investment interest.

Why Australia?

Australia is among the most-technically advanced, innovative and efficient global mining jurisdictions, with a long history of successful project development. Australia's world-class resource base is supported by its leadership in mining equipment and technology services, skilled labour, infrastructure, legal and regulatory frameworks, and attractive investment settings.

With a large mining industry and robust regulation, Australia has also developed world leading environmental management practices that underpin sustainability and corporate responsibility. This depth of experience and expertise has shaped Australia's competitive advantages as a global supplier of choice for key, ethically-sourced critical minerals.

Australia's critical minerals capability is complemented by the Australian Government's focus on building a supportive policy environment. Recognising Australia's critical minerals potential, the Australian Government has recently implemented a range of practical policy measures. These include:

- Publishing *Australia's Critical Minerals Strategy (2019)*
- Establishment of a Critical Minerals Facilitation Office to lead and co-ordinate a national approach
- Supporting Export Finance Australia funding of critical minerals projects through the Defence Export Facility
- A A$4.5 million further boost to critical minerals research by Australian scientific agencies, particularly in downstream applications
- Expanding Austrade's programs to facilitate trade and investment in Australian critical minerals
- Stimulating investment in exploration through the A$125 million injection into the Exploring for the Future (EFTF) program over four years to expand the program nationwide
- Funding to Geoscience Australia to establish a web-based Critical Minerals Portal that will be a tool for users to assess the economic and geological potential of selected critical minerals within Australia
- A$20 million funding towards critical minerals projects as part of the Cooperative Research Centre Projects and A$25 million funding for the Future Battery Industries Cooperative Research Centre.

These Commonwealth Government policy measures are complemented by a range of supportive policy instruments at the state and territory level.

AUSTRALIAN CRITICAL MINERALS PROSPECTUS 2020

Prospectus overview

The first edition of the *Australian Critical Minerals Prospectus (the Prospectus)* was published in March 2019 and it proved effective at promoting critical minerals projects in Australia. With many projects rapidly advancing – and many new critical minerals projects emerging – it has become necessary to update the Prospectus with this 2020 edition.

To facilitate investment and offtake in Australia's critical minerals sector, the Prospectus includes:

- An introduction to critical minerals and rare-earth elements, Australian potential, and global supplies
- A profile of Australia's current production of critical minerals and rankings against global supplies
- A summary of how Australian agencies support the development of critical minerals in Australia
- An analysis of each critical mineral, including characteristics, current supply and demand
- A list of all critical minerals projects in Australia, including mineral inventory, infrastructure and funding.

The Prospectus should be read in conjunction with other Australian Government and industry publications on critical minerals – especially those focused on downstream opportunities. While care has been taken to ensure the information in this volume is accurate, readers should conduct their own due diligence of projects of interest. All data was up-to-date, as of June 2020.

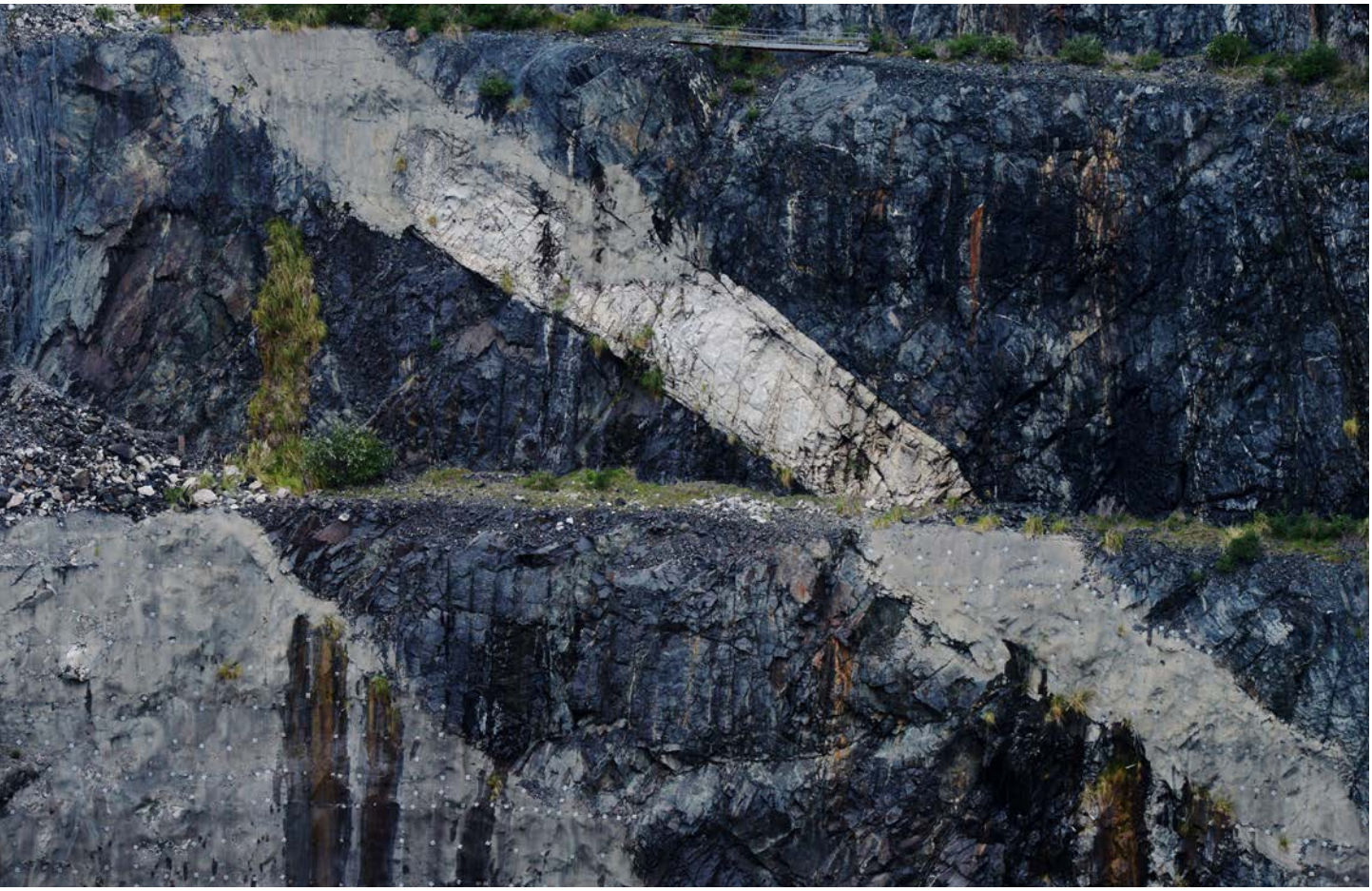
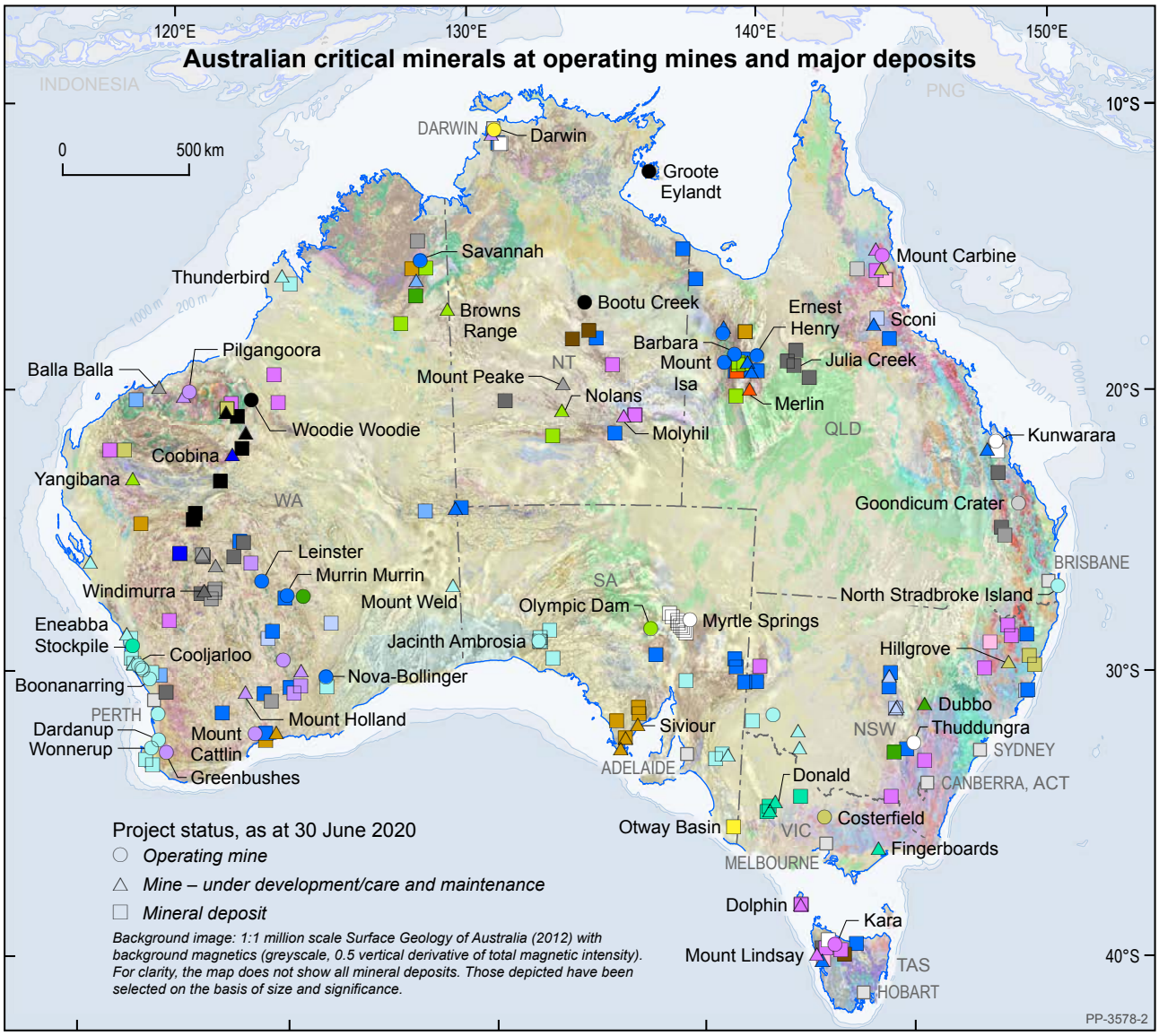


Figure 1: Critical mineral deposits and major mines in Australia[1]



Commodity type

- *Antimony*
- *Bismuth, +/- cobalt, +/- indium*
- *Chromium, +/- cobalt, +/- PGE*
- *Cobalt*
- *Platinum-group elements (PGE), +/- cobalt*
- *Scandium, +/- cobalt, +/- PGE*
- *Graphite*
- *Helium*
- *Indium*
- *Lithium, +/- tantalum, +/- niobium*
- *Magnesium*
- *Manganese ore*
- *Heavy mineral sands (HMS) – titanium, zirconium*
- *HMS – titanium, zirconium, REE*
- *Rare-earth elements (REE)*
- *REE – Zirconium, niobium, +/- hafnium, lithium, tantalum, gallium*
- *Rhenium*
- *Tungsten*
- *Titanium*
- *Titanium, vanadium*
- *Vanadium*

Critical minerals and Australia

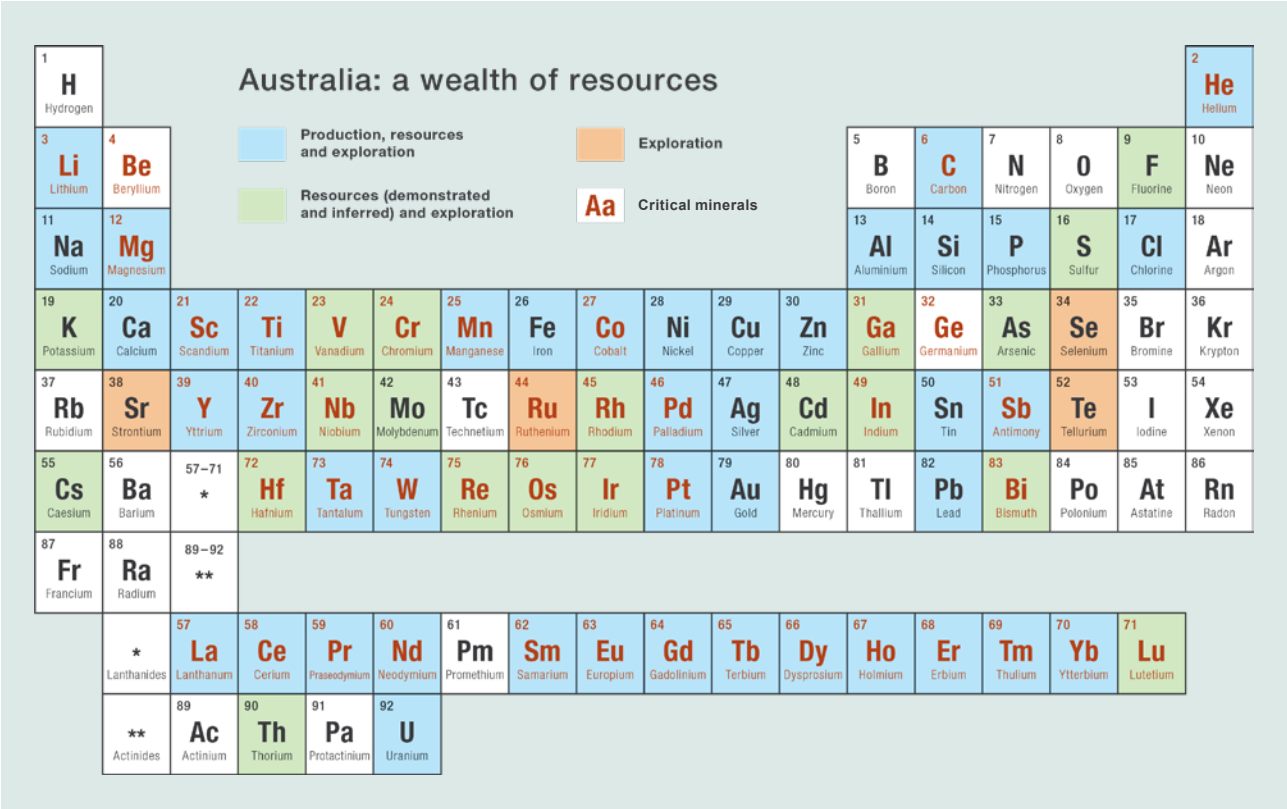
Geoscience Australia identifies critical minerals as metals, non-metals and minerals that are considered vital for the economic well-being of the world's major and emerging economies, yet whose supply may be at risk due to geological scarcity, geopolitical issues, trade policy or other factors.[2]

Individual countries develop their own lists of critical minerals based on the relative importance of particular minerals to their industrial and strategic requirements. Assessments of criticality reflect conditions at a particular time, and are subject to change.

Production and resources in Australia

The Australian Government examined lists of critical minerals published in markets such as the United States, the European Union and Japan, and matched those against Australia's known geological endowment. The result is a list of 24 critical minerals that are either being produced or could be produced in Australia. The list was first identified in *Australia's Critical Minerals Strategy 2019* and can be found in this edition at Table 2.[3] These 24 minerals are also identified in the Periodic Table in Figure 2.

Figure 2: Periodic table of the elements overlain with Australia's mineral production, resources and exploration activities. Critical minerals are shown with red letters.



Rare-earth elements and current suppliers

Rare-earth elements comprise the fifteen lanthanide series of elements (lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu) as well as yttrium (Y). Scandium (Sc) is also commonly included in the rare-earth elements grouping. However, in this Prospectus, scandium (Sc) has been treated as a separate critical mineral to the other sixteen rare-earth elements as its geological occurrences and chemical properties differ from the lanthanides and yttrium.[4]

Variously referred to as 'rare-earth metals', 'rare-earths', 'rare-earth oxides', and 'total rare-earth oxides (TREO)', rare-earth elements have unique catalytic, metallurgical, nuclear, electrical, magnetic and luminescent properties.

The lanthanide series of elements can be further subdivided into light rare-earth elements and heavy rare-earth elements. Light rare-earth elements are generally more abundant and less valuable than the heavy rare-earth elements. The major physical and chemical properties – and application examples of the rare-earth elements – are presented in Table 1.

Global producers

Demand for rare-earth elements has historically been met by a relatively small number of producers and mines. In 1992, China surpassed the United States as the world's largest producer of rare-earth oxides. And since the mid-1990s, China has dominated the global supply of rare-earth elements. Most production is derived from the very large Bayan Obo iron–niobium–rare-earth elements deposit in Inner Mongolia, China, and from lateritic clays in southern China.

In 2019 The United Stated Geological Survey estimated that the largest holders of world economic resources of rare-earth elements were: China (37 per cent); Brazil (18 per cent); Vietnam (18 per cent); Russia (10 per cent); India (6 per cent); and Australia (3 per cent). In relation to world production of rare-earths, China produced 63 per cent, followed by the United States (12 per cent), Myanmar (10 per cent) and Australia (9 per cent).[5]

Image courtesy of Renascor Resources Ltd

Table 1: Major physical and chemical properties of the rare-earth elements[6]

Element	Symbol	Atomic number	Atomic weight	Density (gcm^{-3})	Melting point (°C)	Boiling point (°C)	Crustal abundance (ppm)[7]	Application examples[8]
Light rare-earth elements								
Lanthanum	La	57	138.90	6.146	918	3469	20	Rechargeable car batteries, high quality camera lenses, night vision goggles, to treat kidney disease and in hydrogen storage
Cerium	Ce	58	140.11	8.160	789	3257	43	Catalytic converters, treatment of burns, self-cleaning ovens, carbon-arc lighting and to reduce UV transmission through glass
Praseodymium	Pr	59	140.90	6.773	931	3127	4.9	High-intensity permanent magnets for electric motors / generators for electric cars and turbines, aircraft engines, and specialised glass
Neodymium	Nd	60	144.24	7.008	1021	3127	20	Powerful magnets for computers, phones, medical equipment, electric cars, turbines and audio systems, and laser crystals
Promethium	Pm	61	145.00	7.264	1042	3000	<0.001[9]	Thickness gauges and atomic batteries for spacecraft and guided missiles
Samarium	Sm	62	150.36	7.520	1074	1900	3.9	Magnets for small motors, cancer treatment and nuclear reactors
Europium	Eu	63	151.96	5.244	822	1597	1.1	Red and blue colours in LCD screens, anti-forgery marks on banknotes and in nuclear reactor control rods
Heavy rare-earth elements								
Gadolinium	Gd	64	157.25	7.901	1313	3233	3.7	Green phosphors in LCD screens, magnetic resonance imaging and in steel to improve resistance to high temperatures
Terbium	Tb	65	158.92	8.230	1356	3041	0.60	Green phosphors in LCD screens, to combat banknote counterfeiting, to detect microbes, and magnets for electric cars and turbines
Dysprosium	Dy	66	162.50	8.551	1412	2562	3.6	Magnets for electric cars and turbines, metal halide lamps, to treat rheumatoid arthritis and to measure exposure to ionising radiation
Holmium	Ho	67	164.93	8.795	1474	2720	0.77	Nuclear control rods, sonar systems, data storage and laser materials
Erbium	Er	68	167.26	9.066	1529	2510	2.1	Nuclear control rods, for pink colour in glass and ceramics, photographic filters, amplifiers, lasers and for skin treatments
Thulium	Tm	69	168.93	9.321	1545	1727	0.28	Lasers, as a radiation source in x-ray machines and to combat banknote counterfeiting
Ytterbium	Yb	70	173.04	6.966	819	1466	1.9	In portable X-ray machines, lasers, earthquake monitors and for improving strength of stainless steel
Lutetium	Lu	71	174.97	9.841	1663	3315	0.30	Positron Emission Tomography (PET) scanners for 3D images of cellular activity, cancer therapy and for cracking hydrocarbons
Other rare-earth elements								
Yttrium	Y	39	88.90	4.469	1522	3337	19	Red colours in televisions, cancer treatments, satellites and superconductors

Australia's competitive position

Australia possesses some of the world's largest recoverable resources of tantalum, zirconium, titanium, lithium, cobalt, tungsten, vanadium, niobium, antimony and manganese ore.[10] Australia is also the world's largest producer of lithium and a top five producer of the rare-earth elements: cobalt, manganese ore, antimony, zirconium and titanium mineral sands. Australia's rare-earth element production includes neodymium, praseodymium and dysprosium, which are important for permanent magnet production.

Australia has the world's sixth largest rare-earth elements resource base and is one of the few sources of dysprosium outside of China.

Australia's potential to supply critical minerals is demonstrated in Figure 1, which shows Australia's critical minerals deposits and major mines. With demand forecast to rise over the medium term, Australia has a commercial opportunity to build competitive critical minerals export markets, and to improve the domestic and global strategic supply of critical minerals. Australia's current competitive position – in terms of resources and production – is shown in Table 2.

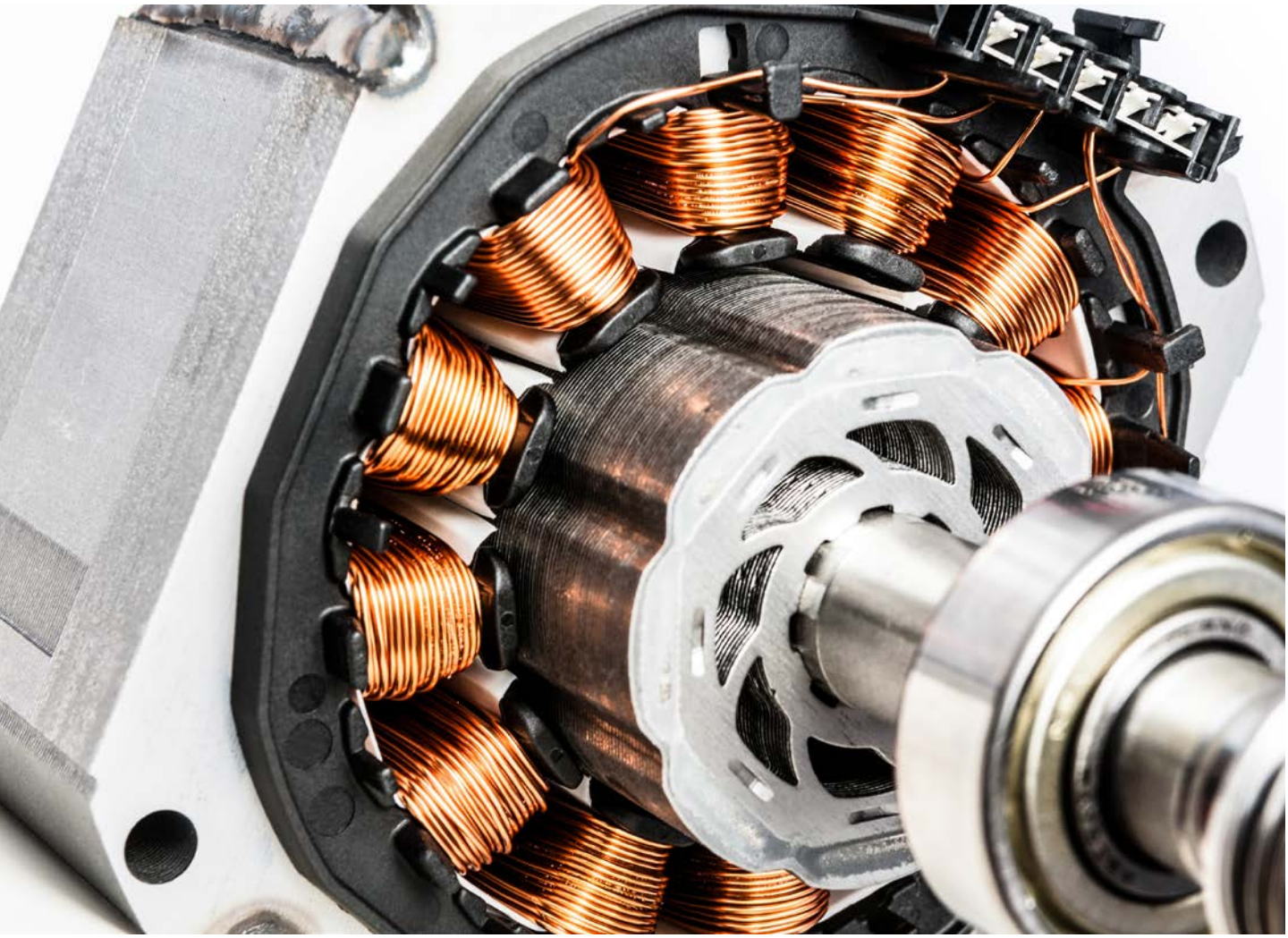
Table 2: Australian list of critical minerals (balancing the future mineral needs of Australia's strategic and economic partners with Australia's potential to supply such minerals)

Critical Mineral	Australia's geological potential[1]	Economic resources				Production				World market value (US$m)[4]	Largest producer 2019[3]
		Australia 2018[2]	World 2019[3]	Australia's ranking 2018[2]		Australia 2018[2]	World 2019[3]	Australia's ranking 2018[2]			
				Position	(%)			Position	(%)		
Antimony	Moderate	142.7 kt	1,500 kt	4	9%	3.57 kt	160 kt	4	3%	153	China (63%)
Beryllium	Moderate	0	N/A	0	0	N/A	260 t	N/A	N/A	15	US (65%)
Bismuth	Moderate	4.9 kt	N/A	N/A	N/A	N/A	19 kt	N/A	N/A	51	China (74%)
Chromium	High	0	570,000 kt	0	0	0	44,000 kt	0	0	408	South Africa (37%)
Cobalt	High	1,353 kt	7,000 kt	2	19%	4.9 kt	140 kt	3	5%	1,576	DRC (71%)
Gallium	High	0	N/A	0	0	0	410 t	0	0	5,275	China (97%)
Germanium	High	0	N/A	0	0	0	130 t	0	0	2,855	China (65%)
Graphite	Moderate	7,250 kt	300,000 kt	8	2%	0	1,100 kt	0	0	341	China (63%)
Hafnium	High	14.5 kt	N/A	N/A	N/A	0	N/A	0	0	5,275	N/A
Helium	Moderate	N/A	N/A	N/A	N/A	4 hm^3	160 hm^3	4	3%	4,826	US (53%)
Indium	High	0.1 kt	N/A	N/A	N/A	N/A	760 t	N/A	N/A	5,275	China (39%)
Lithium	High	4,718 kt	17,000 kt	2	30%	57 kt	93 kt	1	63%	1,978	Australia (61%)
Magnesite	Moderate	316 Mt	8,500 Mt	6	4	<1	28 Mt	Minor	Minor	841	China (68%)
Manganese[7]	High	~104,000 kt 232,000 kt ore	810,000 kt ~365,000 kt ore	5	13%	~3,150 kt 7,000 kt ore	19,000 kt ~42,000 kt ore	3	15%	1,361	South Africa (29%)
Niobium	High	216 kt	>13,000 kt	3	4%	N/A	74 kt	N/A	N/A	15,905	Brazil (88%)
Platinum-group elements	High	31.5 t	69,000 t	Minor	Minor	0.541 t	370 t	Minor	Minor	51,234	South Africa (57%)
Rare-earth elements	High	4,120 kt	120,000 kt	6	3%	19 kt	170 kt	2	11%	4,338	China (72%)
Rhenium	Moderate	0.16 kt	2.4 kt	Minor	Minor	0	0.049 kt	0	0	5,275	Chile (55%)
Scandium	High	26.05 kt	N/A	N/A	N/A	0	N/A	0	0	4,338	N/A
Tantalum	High	99.3 kt	>110 kt	1	67%	–	1.8 kt	7	3%	6,029	DRC (41%)
Titanium	High	Ilmenite: 276,300 kt Rutile: 35,400 kt	Ilmenite: 800,000 kt Rutile: 55,000 kt	Ilmenite: 2 Rutile: 1	Ilmenite: 19% Rutile: 50%	Ilmenite: 1,400 kt Rutile: 200 kt	Ilmenite: 7,700 kt Rutile: 700 kt	Ilmenite: 3 Rutile: 1	Ilmenite: 15% Rutile: 27%	4,485	Metal sponge: China (40%) Ilmenite: China (27%) Rutile: Australia (29%)
Tungsten	Moderate	394 kt	3,700 kt	2	11%	<1 kt	85 kt	Minor	Minor	571	China (82%)
Vanadium	Moderate	4,646 kt	22,800 kt	3	20%	0	73 kt	0	0	5,099	China (54%)
Zircon	High	79,900 kt	92,500 kt	1	63%	500 kt	2,000 kt	2	25%	407	South Africa (26%)

Table notes:

N/A = not available.

1. Critical Minerals in Australia: A Review of Opportunities and Research Needs, Record 2018/51, Geoscience Australia, Canberra.
2. Australia's Identified Mineral Resources 2019, Geoscience Australia, Canberra.
3. Mineral Commodity Summaries 2020, United States Geological Survey, Reston.
4. United Nations Comtrade Database, http://comtrade.un.org
   Note: not all commodities have individual market values available; see individual commodity tables for aggregation details.
5. Aggregated data for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium. Germanium also includes germanium oxides and zirconium dioxide. Niobium also includes niobium, tantalum and vanadium ores and concentrates, ferro-alloys and ferro-niobium.
6. Aggregated data for rare gases other than argon.
7. Geoscience Australia reports manganese ore and the USGS reports manganese content. Worldwide, manganese content in ore ranges from 35% to 54%. A conversion factor of 0.45 has been used to enable approximate comparisons between Australian and world resources and production.
8. Aggregated data for alkali or alkaline-earth metals, rare-earth metals, scandium, yttrium and mercury.
9. Aggregated data includes niobium, tantalum and vanadium ores and concentrates in addition to specific commodity.



Australian agencies that support the critical minerals sector

Australia's federal, state and territory governments have developed policies, incentives, programs and strategies to support the mining industry. This section identifies the key federal government agencies that support the critical minerals sector. State and territory-level programs are omitted from this Prospectus.

Austrade

Austrade is the Australian Government's lead agency for international trade and investment promotion. Austrade continues to facilitate foreign investment and offtake arrangements in critical minerals to help develop Australian critical minerals projects.

Austrade aims to attract international investment and offtake into critical minerals. The agency does this by leveraging its extensive offshore network – and relationships with federal, state and territory governments – to connect Australian project proponents with targeted opportunities for investment and offtake agreements.

Interested investors, project proponents and offtake partners can contact Austrade via our website (www.austrade.gov.au) or through one of our offshore offices.

Critical Minerals Facilitation Office

The Critical Minerals Facilitation Office (CMFO) is the Federal Government's central coordination point to help grow Australia's critical minerals sector and position Australia globally as a secure and reliable supplier of critical minerals.

The CMFO was established in January 2020 and is part of the Department of Industry, Science, Energy and Resources. The CMFO has three focus areas:

1. Leading a national approach on critical minerals, including by delivering a National Critical Minerals Development Roadmap (agreed by resources ministers in all jurisdictions). The CMFO also works closely with state and territory governments, regulators, academics, industry and investors to ensure policy settings support the development and growth of Australia's critical minerals sector. This includes improving approvals processes, unlocking our full resource potential, supporting technological innovation and developing downstream capabilities.
2. Working closely with DFAT and Austrade to develop international partnerships. The aim is to improve the functioning of global markets and to promote investment in Australia's critical minerals sector
3. Providing a focal point across all levels of government to support strategically important projects. The office will also help projects to navigate investment and regulatory requirements, and may provide project finance and offtake agreement support.

To find out more about the CMFO's initiatives to grow the critical minerals sector, visit: www.industry.gov.au/criticalminerals, subscribe to Australian Critical Minerals News or email criticalminerals@industry.gov.au.

Export Finance Australia

Export Finance Australia (EFA) is an export credit agency that operates on behalf of the Australian Government. Recently, the Government has directed EFA to place a greater focus on critical minerals projects and related infrastructure. Consequently, EFA will support the diversification of critical minerals supply chains and the expansion of downstream processing in Australia.

Where critical minerals are important to the defence supply chain, finance may be available through the government's Defence Export Facility, which is administered by Export Finance Australia.

In general, EFA's eligibility criteria are as follows:

- The mineral is identified in *Australia's Critical Minerals Strategy 2019*
- The extracted or processed minerals are for export
- A comprehensive feasibility study has been completed
- Buyers are committed to purchase the project's production
- The project proponents have the necessary financial, technical and commercial capacity.

For access to financing under the Defence Export Facility, projects must be important to defence end-use applications. To find out more about Export Finance Australia's support for Australia's critical minerals sector, visit: exportfinance.gov.au/criticalminerals or call 1800 093 724.

Geoscience Australia

Geoscience Australia is the Australian Government's trusted source of information on Australia's geology and geography. It provides technical capability, geoscience information, innovation and advice on critical minerals.

The agency works with its partners in the state and territory geological surveys to support the responsible development of a diverse critical minerals sector through its programs of continental-scale data acquisition, and the development of tools for mapping, prediction and decision making.

Geoscience Australia is also part of the Australian Government's critical minerals trade-development program and coordinates the activities of the cross-government minerals agency, Australia Minerals.[11]

Through Australia Minerals, the CMFO and Austrade, Geoscience Australia helps promote Australian critical minerals opportunities and attract investment into the sector. Geoscience Australia's critical minerals activities aim to underpin new exploration technologies, stimulate mineral exploration investment, drive new discoveries and open up new, producing critical minerals provinces.

In 2020, activities are focused on:

- understanding the geology of critical minerals occurrences for better prediction of new deposits
- developing new methods for determining Australia's critical minerals endowment, including unexploited by-product opportunities
- integrating critical minerals and other data (both scientific and economic) through the Australian Critical Minerals Portal to better support prediction and decision-making for the minerals industry and governments
- working with the geological agencies of the United States and Canada on a critical minerals mapping initiative that will help expand and diversify global critical minerals supply chains.

To find out more about Geoscience Australia's critical minerals activities, publications and data, visit: https://www.ga.gov.au/about/projects/resources/critical-minerals.

Additional support

Other forms of support are available at the federal level for the critical minerals sector. For an overview, visit: https://www.industry.gov.au/funding-andincentives/supporting-critical-minerals-projects

The **Major Projects Facilitation Agency (MPFA)** provides a single entry point for major project proponents (including for critical minerals) seeking tailored information and facilitation of their regulatory approval requirements. The CMFO works with the MPFA to help companies as they navigate regulatory approvals.

The Australian Government's **Cooperative Research Centre (CRC)** Grants program provides funding to support Australian industries. It supports industry-led collaborations with researchers and the community to address industry-identified problems facing Australia. CRC Projects (CRC-P) Grants provide funding for short-term, industry-led research projects for up to three years.

Financial support may be available for critical minerals projects in Australia through the **Northern Australia Infrastructure Facility (NAIF)** and the **Clean Energy Finance Corporation (CEFC)**.

NAIF is a A$5bn lending facility to provide loans to infrastructure projects in northern Australia. NAIF investments can be used for the development of new infrastructure or materially enhancing existing infrastructure. NAIF can lend up to 100 per cent of the debt, provided there is appropriate risk-sharing. Loans can be on concessional terms, relative to what a private sector financier can deliver – as long as the infrastructure generates public benefit and there is an ability repay or refinance. Access to dual funding through the EFA as well as the NAIF may be available to eligible projects.

The **Clean Energy Finance Corporation (CEFC)** is a specialist investor charged with increasing investment in technologies and businesses with the potential to lower Australia's emissions. The CEFC pursues investment opportunities across the economy. It can support achievement of the Critical Minerals Strategy where there is a demonstrated contribution to renewable energy, energy efficiency or low emissions technologies. The precondition of strong offtake agreements is an essential component to the development of these resources.

CRITICAL MINERAL SUMMARIES: CHARACTERISTICS, SUPPLY, DEMAND AND CRITICALITIES

A summary of each selected critical mineral is set out below.

ANTIMONY (Sb)		
CHARACTERISTICS		
Properties	Silvery-white, shiny, very brittle metal that is a semiconductor and resistant to acids.	
Usages	Antimony is used in flame retardants, as an alloying material for lead and tin, and in micro-capacitors.	
Geological occurrence	Crustal abundance is 0.2 ppm; major antimony-bearing minerals include stibnite and tetrahedrite.	
Mineral system group	Porphyry-epithermal, subaqueous volcanic-related, orogenic and basin-hosted.	
Extraction	Main product or co-product (with gold).	
SUPPLY		
World production 2019[1]	160 kt	
Major producing countries 2019[1]	China (100 kt) 63% Russia (30 kt) 19% Tajikistan (16 kt) 10%	
World resources 2019[1]	1,500 kt	
Major resource holders 2019[1]	China (480 kt) 32% Russia (350 kt) 23% Bolivia (310 kt) 21%	
Australian production 2018[2]	3.57 kt	
Australian resources (EDR) 2018[2]	142.7 kt	
Australian exports	Not available.	
Australian potential for new resources	Developments in processing technologies are allowing recovery from zinc-lead-silver ores and discovery of new antimony-gold deposits in orogenic mineral systems.	
Recycling	Small amounts recycled from lead-acid batteries.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Antimony; articles thereof, including waste and scrap	Belgium	56
	US	49
	Japan	34
	UK	3
	China	2
SUBSTITUTION	Flame retardant substitutes are organic compounds and hydrated aluminium oxide.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

BERYLLIUM (Be)		
CHARACTERISTICS		
Properties	Steel-grey, low-density metal that is hard and brittle at room temperature, is highly toxic and has a high melting point (1,287 °C).	
Usages	Beryllium is used in telecommunications equipment, automotive electronics, and aerospace, defence and industrial components.	
Geological occurrence	Crustal abundance is 1.9 ppm; major beryllium-bearing minerals include bertrandite, beryl, chrysoberyl and phenakite.	
Mineral system group	Granite-related.	
Extraction	Main product.	
SUPPLY		
World production 2019[1]	260 t	
Major producing countries 2019[1]	US (170 t) 65% China (70 t) 27% Mozambique (15 t) 6%	
World resources 2019[1]	World beryllium resources are not sufficiently well delineated to report consistent figures for each country.	
Major resource holders 2019[1]	Not available.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Discovery of new pegmatitic resources in the igneous-related mineral system.	
Recycling	Beryllium is recycled mostly from new scrap generated during the manufacture of beryllium products. About 19% of consumption is recycled from scrap.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Beryllium and articles thereof; wrought, unwrought beryllium, powders; slag, ash and residues; waste and scrap	South Korea	4
	UK	3
	US	3
	Poland	1
	Canada	1
SUBSTITUTION	A few substitutes are available for beryllium but are less effective.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

BISMUTH (Bi)		
CHARACTERISTICS		
Properties	Silvery-white brittle metal that has low thermal conductivity and is diamagnetic.	
Usages	Bismuth is often used in free-machining steels, brass, pigments, solders (as a non-toxic replacement for lead) and pharmaceuticals. It is also used as an additive to enhance metallurgical quality in foundry applications and as a triggering mechanism in fire sprinklers.	
Geological occurrence	Crustal abundance is 0.18 ppm; major bismuth-bearing minerals include bismuthinite. Bismuth can also be an important trace to minor constituent in galena.	
Mineral system group	Porphyry-epithermal, granite-related, subaqueous volcanic-related, orogenic and basin-hosted.	
Extraction	By-product of lead smelting.	
SUPPLY		
World production 2019[1]	19 kt	
Major producing countries 2019[1]	China (14 kt) 74% Laos (3 kt) 16% South Korea (0.9 kt) 5%	
World resources 2019[1]	Not available.	
Major resource holders 2019[1]	Not available.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Recovery of bismuth from ore and concentrates from existing mining operations; minor potential for skarn and related deposit types in the porphyry-epithermal and granite-related mineral systems.	
Recycling	Bismuth is recycled from new and old scrap.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Bismuth; articles thereof, including waste and scrap	US	17
	China	13
	Belgium	13
	Canada	2
	Japan	2
SUBSTITUTION	Titanium dioxide coated mica flakes are substitutes in pigments; indium can replace bismuth in low-temperature solders; resins can replace bismuth in machining; and glycerine-filled glass bulbs can replace bismuth alloys in fire sprinkler triggering devices.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

CHROMIUM (Cr)		
CHARACTERISTICS		
Properties	Hard metal with a high melting point (1,907 °C) that is resistant to tarnish. Chromium is antiferromagnetic at room temperature and paramagnetic above 38 °C. It is passivated by oxygen, making it stable to acids.	
Usages	Chromium is used in stainless and heat-resistant steels, superalloys, non-ferrous alloys and pigments.	
Geological occurrence	Crustal abundance is 135 ppm. Chromium-bearing minerals include chromite.	
Mineral system group	Mafic-ultramafic orthomagmatic and surficial.	
Extraction	Main product.	
SUPPLY		
World production 2019[1]	44,000 kt	
Major producing countries 2019[1]	South Africa (17,000 kt) 37% Turkey (10,000 kt) 23% Kazakhstan (6,700 kt) 15%	
World resources 2019[1]	570,000 kt	
Major resource holders 2019[1]	Kazakhstan (230,000 kt) 41% South Africa (200,000 kt) 36% India (100,000 kt) 18%	
Australian production 2018[2]	0	
Australian resources (EDR) 2018[2]	0	
Australian exports	0	
Australian potential for new resources	Development of known deposits and discovery of new deposits in large igneous provinces.	
Recycling	Recycled from scrap chromium-bearing steel and alloys. Recycled chromium accounts for about 30% of consumption.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Chromium ores and concentrates; chromium and articles thereof; wrought; unwrought, powders; slag, ash and residues; waste and scrap	US	191
	Japan	76
	Belgium	23
	Italy	21
	South Korea	21
SUBSTITUTION	Chromium has no substitute in stainless steel. Chromium-bearing scrap can substitute for ferrochromium in some metallurgical uses.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

COBALT (Co)		
CHARACTERISTICS		
Properties	Ferromagnetic metal that is hard and lustrous.	
Usages	Emerging technologies that could use cobalt include lithium batteries and synthetic fuels. The most important present use is in superalloys, steel and pigments.	
Geological occurrence	Crustal abundance is 26.6 ppm; major cobalt-bearing minerals include cobaltite and cobaltian pyrite.	
Mineral system group	Mafic-ultramafic orthomagmatic and basin-hosted.	
Extraction	By-product, co-product of copper mining.	
SUPPLY		
World production 2019[1]	140 kt	
Major producing countries 2019[1]	Democratic Republic of the Congo (100 kt) 71% Russia (6.1 kt) 4% Australia (4.9 kt) 4%	
World resources 2019[1]	7,000 kt	
Major resource holders 2019[1]	Democratic Republic of the Congo (3,600 kt) 51% Australia (1,353 kt) 19% Cuba (500 kt) 7%	
Australian production 2018[2]	4.9 kt (5%)	
Australian resources (EDR) 2018[2]	1,353 kt (19%)	
Australian exports	Not available.	
Australian potential for new resources	Development of known deposits and discovery of new deposits in large igneous provinces. Extraction of cobalt from basin-hosted copper deposits.	
Recycling	Cobalt recycling is insignificant.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Cobalt ores and concentrates; cobalt mattes and other intermediate products of cobalt metallurgy, cobalt and articles thereof, including waste and scrap	US	559
	Japan	415
	UK	166
	Belgium	149
	South Korea	90
SUBSTITUTION	Nickel-based superalloys can substitute for cobalt superalloys; various materials can substitute in steel and various substitutions are possible in batteries. In some applications substitution results in a loss of performance.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

GALLIUM (Ga)		
CHARACTERISTICS		
Properties	Silvery-white metal that has a low melting point (29.7 °C), a high boiling point (2,204 °C) and is a semiconductor.	
Usages	Gallium is used in integrated circuits, laser diodes, LEDs, photodetectors and thin layer photovoltaics.	
Geological occurrence	Crustal abundance is 16 ppm; in nature gallium occurs as a trace element in bauxite and sphalerite.	
Mineral system group	Subaqueous volcanic-related; orogenic basin-hosted and surficial.	
Extraction	By-product of zinc mining.	
SUPPLY		
World production 2019[1]	320 t (primary production) 205 t (high-purity refined production)	
Major producing countries 2019[1]	Primary gallium: China (310 t) 97% Russia (4 t) 1% Ukraine (4 t) 1% Refinery production: China, Japan, Slovakia, US.	
World resources 2019[1]	Quantitative estimates are not available. Gallium is a by-product of treating bauxite and from zinc-processing residues. Less than 10% of gallium in bauxite and zinc is potentially recoverable.	
Major resource holders 2019[1]	Not available.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Extraction from ore and concentrates from existing mining operations, particularly bauxite and zinc mines.	
Recycling	Recycled from scrap generated in the manufacture of gallium-arsenide-based products.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for gallium. Data are aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders.	US	233
	Japan	119
	UK	42
	South Korea	34
	Belgium	18
SUBSTITUTION	Organic compounds liquid crystals substitute for LEDs in visual displays; indium phosphide components can substitute gallium-arsenide-based infrared laser diodes in some cases and silicon substitutes in solar cell technology.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

GERMANIUM (Ge)		
CHARACTERISTICS		
Properties	Grey-white metalloid that is hard, lustrous and semiconducting.	
Usages	Germanium is used in fibre and infrared optics, as a polymerisation catalyst and in electronic and solar electric applications.	
Geological occurrence	Crustal abundance is 1.3 ppm; in nature germanium occurs as a trace element in sphalerite and coal.	
Mineral system group	Subaqueous volcanic-related, orogenic and basin-hosted.	
Extraction	By-product of zinc processing.	
SUPPLY		
World production 2019[1]	130 t refinery production. (US production not included).	
Major producing countries 2019[1]	China (85 t) 65% Russia (6 t) 5% US not available.	
World resources 2019[1]	Data on the recoverable germanium content of zinc ores are not available.	
Major resource holders 2019[1]	The USGS notes that US reserves of zinc may contain as much as 2,500 tons of germanium.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Extraction from ores and concentrates from existing mines particularly zinc mines and possible coal mines.	
Recycling	Germanium metal used in the optics industry is routinely recycled from new scrap. Worldwide, approximately 30% of germanium consumption is from recycled materials.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for germanium. Data are aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders; plus germanium oxides and zirconium dioxide.	US	89
	Japan	61
	South Korea	35
	Italy	20
	China	18
SUBSTITUTION	Silicon substitutes for germanium in some electronic applications. Zinc selenide can be substituted in infrared applications but at a performance loss. Tantalum, antimony and titanium can be substituted as a polymerisation catalyst.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

GRAPHITE (C)		
CHARACTERISTICS		
Properties	Iron-black mineral with a metallic-earthy lustre that is an electrical and thermal conductor, has high thermal resistance, is inert and can be used as a lubricant.	
Usages	Uses of graphite include carbon-graphite composites, electronics, foils, friction materials and special lubricants applications. Flexible graphite products and large-scale fuel cell application developments may become high users of graphite.	
Geological occurrence	Crustal abundance is 1,800 ppm (total C). In nature, graphite is one of a number of forms of carbon.	
Mineral system group	(Metamorphosed) basin-hosted.	
Extraction	Main production.	
SUPPLY		
World production 2019[1]	1,100 kt	
Major producing countries 2019[1]	China (700 kt) 63% Mozambique (100 kt) 9% Brazil (96 kt) 9%	
World resources 2019[1]	300,000 kt	
Major resource holders 2019[1]	Turkey (90,000 kt) 30% China (73,000 kt) 24% Brazil (72,000 kt) 24%	
Australian production 2018[2]	0 kt	
Australian resources (EDR) 2018[2]	7,250 kt	
Australian exports	0 kt	
Australian potential for new resources	Development of existing resources and new discoveries in metamorphosed reduced-C basins.	
Recycling	Refractory graphite material is recycled into products including brake linings and thermal insulations. Recovery of high-quality flake graphite is technically feasible but not currently practised.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Natural mineral	Japan	103
	South Korea	92
	US	60
	Poland	25
	Hungary	20
SUBSTITUTION	Graphite has few suitable substitutes. Synthetic graphite powder may be used in steel and some battery applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

HAFNIUM (Hf)		
CHARACTERISTICS		
Properties	A shiny, silvery, corrosion-resistant metal.	
Usages	Hafnium is used in the control rods of nuclear reactors, and in vacuum tubes, and has been used as an alloying agent with iron, titanium, niobium and other metals. Hafnium oxide may be used as an electrical insulator in microchips.	
Geological occurrence	Crustal abundance is 5.8 ppm. Substitutes for zirconium, especially in zircon.	
Mineral system group	Heavy mineral sands, pegmatites, carbonatite intrusions.	
Extraction	By-product, co-product of zircon mining.	
SUPPLY		
World production 2019[1]	Not available.	
Major producing countries 2019[1]	Not available.	
World resources 2019[1]	World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources are not available.	
Major resource holders 2019[1]	Not available.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	The Dubbo Zirconia Project has a Measured Resource containing 14.5 kt of hafnium, including 6.4 kt within Proved Ore Reserves.	
Australian exports	Not available.	
Australian potential for new resources	The Dubbo Zirconia Project proposes to produce zirconium carbonate and more than 200 t per year of hafnium oxide, as well as niobium, rare-earth, and tantalum products.	
Recycling	Hafnium recycling is insignificant.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for hafnium. Data is aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders.	US	233
	Japan	119
	UK	42
	South Korea	34
	Belgium	18
SUBSTITUTION	Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear power plants.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

HELIUM (He)		
CHARACTERISTICS		
Properties	Colourless, odourless, tasteless, non-toxic gas that has the lowest boiling and melting points of all the elements.	
Usages	Helium is used in cryogenics, cooling systems, MRI scanners, LCD and fibre optics.	
Geological occurrence	Helium, a product of radioactive decay of heavy elements, accumulates with natural gas in hydrocarbon traps.	
Mineral system group	Basin-hosted.	
Extraction	By-product of natural gas production.	
SUPPLY		
World production 2019[1]	160 hm3[4]	
Major producing countries 2019[1]	US extracted from natural gas fields (64 hm^3) 40% Qatar (45 hm^3) 28% US extracted from Cliffside Field (26 hm^3) 16%	
World resources 2019[1]	World helium resources are not sufficiently well delineated to report a consistent figure for all countries.	
Major resource holders 2019[1]	US (3,900 hm^3) 53% Algeria (1,800 hm^3) 24% Russia (1,700 hm^3) 23%	
Australian production 2018[2]	4 hm^3 (source USGS)	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Extraction of helium from existing and new natural gas fields.	
Recycling	Helium is seldom recycled. Japan and Western Europe recycle when economically viable.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for helium. Data is for rare gases other than argon.	Japan	117
	UK	94
	US	74
	Belgium	73
	Canada	26
SUBSTITUTION	There is no substitute for helium in cryogenic applications if temperatures are below -256 °C. Argon can substitute in welding and in lighter-than-air applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.
4. Helium is measured in million cubic metres (hm^3).

INDIUM (In)		
CHARACTERISTICS		
Properties	Silvery-white, dense metal that forms alloys with most other metals and generally increases strength, corrosion resistance and hardness.	
Usages	Indium tin oxide (ITO) thin-film coatings are used for electrically conductive purposes in flat-panel, TV and smartphone devices. Other uses include electrical components and semiconductors, solders, alloys and compounds.	
Geological occurrence	Crustal abundance is 0.052 ppm; indium occurs mostly as a trace element in sphalerite.	
Mineral system group	Subaqueous volcanic-related, orogenic and basin-hosted.	
Extraction	By-product of zinc-lead, copper and tin mining and smelting.	
SUPPLY		
World production 2019[1]	Refinery production 760 t	
Major producing countries 2019[1]	China (300 t) 39% South Korea (240 t) 32% Japan (75 t) 10% Canada (60 t) 8%	
World resources 2019[1]	Not available.	
Major resource holders 2019[1]	Not available.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Extraction from ores and concentrates from existing mining operations, particularly zinc mines.	
Recycling	Indium is recycled from scrap tungsten-bearing steel and superalloys. Recycling is very inefficient and constitutes a very small (<1%) fraction of supply.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for indium. Data is aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders.	US	233
	Japan	119
	UK	42
	South Korea	34
	Belgium	18
SUBSTITUTION	Antimony can substitute for indium in ITO. Carbon nanotube coatings and organic compounds substitutes for ITO in solar cells, flexible displays and touch screens; hafnium can replace indium in nuclear reactor control rod alloys.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

LITHIUM (Li)		
CHARACTERISTICS		
Properties	Shiny, silvery, tough and soft metal that forms strong alloy, is very reactive and has the lowest density of all known solids at room temperature.	
Usages	Lithium is used in batteries, ceramics and glass.	
Geological occurrence	Crustal abundance is 16 ppm; lithium occurs mostly in spodumene and lepidolite, but also in salt lake and oil field brines.	
Mineral system group	Intrusion-related and surficial.	
Extraction	Main product.	
SUPPLY		
World production 2019[1]	93 kt (excludes US production)	
Major producing countries 2019[1]	Australia (57 kt) 61% Chile (18 kt) 19% China (7.5 kt) 8%	
World resources 2019[1]	17,000 kt	
Major resource holders 2019[1]	Chile (8,600 kt) 51% Australia (4,718 kt) 28% Argentina (1,700 kt) 10%	
Australian production 2018[2]	57 kt	
Australian resources (EDR) 2018[2]	4,718 kt	
Australian exports	Not available.	
Australian potential for new resources	Identification of lithium resources associated with known and new pegmatite fields, and discovery of lithium-enriched salt lakes.	
Recycling	Small amounts of lithium are recycled from batteries; recycling is increasing.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Lithium oxide and hydroxide; lithium carbonates	South Korea	869
	Japan	798
	US	123
	Belgium	110
	Canada	21
SUBSTITUTION	Battery substitution includes calcium, magnesium and zinc. Various substitutions are available for ceramics and glass.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

MAGNESIUM (Mg)		
CHARACTERISTICS		
Properties	Shiny, grey, light metal.	
Usages	Magnesium is used in aluminium alloys, die-casting (alloyed with zinc), removal of sulphur during the production of iron and steel, and the production of titanium.	
Geological occurrence	Magnesium is the seventh most abundant element in the Earth's crust at about 2.5%.	
Mineral system group	Metamorphosed mafic-ultramafic orthomagmatic and basin-hosted.	
Extraction	Extracted from dolomite, talc and magnesite; main product.	
SUPPLY		
World production 2019[1]	1,100 kt metal 28 Mt magnesite	
Major producing countries 2019[1]	Metal: China (900 kt) 75%; Russia (80 kt) 7%; Kazakhstan (25 kt) 2% Magnesite: China (19 Mt) 68%; Turkey (2 Mt) 7%; Brazil (1.7 Mt) 6%	
World resources 2019[1]	Magnesium metal: not available. Magnesite: 8,500 Mt Magnesium metal is derived from seawater, natural brines, dolomite, serpentine and other minerals. The resources for this metal are sufficient to supply current and future requirements.	
Major resource holders 2019[1]	Magnesium metal: not available. Magnesite: Russia (2,300 Mt) 27%; North Korea (2,300 Mt) 27%; China (1,000 Mt) 12%	
Australian production 2018[2]	Magnesite: <1 Mt	
Australian resources (EDR) 2018[2]	Magnesite: 316 Mt	
Australian exports	Not available.	
Australian potential for new resources	Australia currently produces talc, from which magnesite can be processed. Potential sources are abundant (e.g. serpentinised mafic magmatic rocks, dolomite) but must be cheap to produce.	
Recycling	Magnesium is recovered from both old and new scrap.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Magnesium; articles thereof, including waste and scrap	US	221
	Canada	218
	Japan	92
	Mexico	60
	Romania	59
SUBSTITUTION	Aluminium and zinc may substitute for magnesium in castings and wrought products. The light weight of magnesium is an advantage over them; however, the high cost of magnesium is a disadvantage.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

MANGANESE (Mn)		
CHARACTERISTICS		
Properties	Silvery-grey metal that is hard, very brittle and paramagnetic.	
Usages	Manganese is alloyed in steel and aluminium, and is used in batteries and fertiliser.	
Geological occurrence	Crustal abundance is 770 ppm; the main manganese mineral is pyrolusite.	
Mineral system group	Basin-hosted and surficial.	
Extraction	Main product.	
SUPPLY		
World production 2019[1,4]	19,000 kt	
Major producing countries 2019[1,4]	South Africa (5,500 kt) 29% Australia (3,200 kt) 17% Gabon (2,400 kt) 13%	
World resources 2019[1,4]	810,000 kt	
Major resource holders 2019[1,4]	South Africa (260,000 kt) 32% Ukraine (140,000 kt) 17% Brazil (140,000 kt) 17%	
Australian production 2018[2]	7,000 kt manganese ore	
Australian resources (EDR) 2018[2]	232,000 kt manganese ore	
Australian exports	Approximately 90% of Australian manganese ore is exported. The remainder goes to South32 Ltd's TEMCO smelter in Tasmania.	
Australian potential for new resources	Further discoveries are possible in shallow environments of marine basins.	
Recycling	Minor amounts of manganese are recovered along with iron from steel slag.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Manganese ores and concentrates, including ferruginous manganese ores and concentrates with a manganese content of 20% or more, calculated on dry weight; manganese articles thereof, including waste and scrap	Japan	480
	South Korea	456
	US	228
	Belgium	38
	Poland	34
SUBSTITUTION	Manganese has no satisfactory substitute in major applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.
4. The USGS reports manganese content. For Australia, a conversion factor of 0.45 is used to convert manganese ore to manganese content.

NIOBIUM (Nb)		
CHARACTERISTICS		
Properties	Soft and ductile metal with good resistance to organic and inorganic acids.	
Usages	Niobium is used in micro-capacitors, steel and ferroalloys.	
Geological occurrence	Crustal abundance is 8 ppm; niobium occurs as a minor element in minerals such as columbite, pyrochlore and euxinite.	
Mineral system group	Granite-related and alkaline intrusion-related.	
Extraction	Co-product, by-product.	
SUPPLY		
World production 2019[1]	74 kt	
Major producing countries 2019[1]	Brazil (65 kt) 88% Canada (7.6 kt) 10%	
World resources 2019[1]	>13,000 kt	
Major resource holders 2019[1]	Brazil (11,000 kt) 77% Canada (1,600 kt) 17%	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	216 kt	
Australian exports	Not available.	
Australian potential for new resources	Production as a by-product of rare-earth element mining operations in alkaline intrusion-related systems and also from pegmatites from granite-related mineral systems.	
Recycling	Recycled from scrap niobium-bearing steel and superalloys, possibly up to 20%.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for niobium. Data is aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders. Also niobium, tantalum, and vanadium ores and concentrates. as well as, ferro-alloys and ferro-niobium.	US	599
	Japan	317
	South Korea	217
	Belgium	71
	Italy	34
SUBSTITUTION	Substitution by molybdenum and vanadium in high-strength, low-alloy steel and by tantalum and titanium in stainless and high-strength steels is possible, but it may involve higher costs and/or a loss in performance.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

PLATINUM-GROUP ELEMENTS		
CHARACTERISTICS		
Properties	Metals characterised by catalytic properties, resistance to wear, tarnish and chemical attack, and by stable electrical properties.	
Usages	Platinum and palladium are both used in catalytic converters. Platinum is used in electronic applications and fuel cells, and palladium is used in seawater desalination.	
Geological occurrence	Crustal abundances of platinum-group elements are 0.57 ppb (ruthenium), 0.2 ppb (rhodium), 1.5 ppb (palladium), 0.041 ppb (osmium), 0.037 ppb (iridium) and 1.5 ppb (platinum). Platinum-group elements occur as metallic alloys, sulfide and arsenide minerals.	
Mineral system group	Mafic-ultramafic orthomagmatic, alkaline intrusion-related and surficial.	
Extraction	Main product, by-product.	
SUPPLY		
World production 2019[1]	Platinum 180 t Palladium 190 t	
Major producing countries 2019[1]	South Africa (210 t) 57% Russia (108 t) 29% Canada (27.4 t) 7%	
World resources 2019[1]	69 kt	
Major resource holders 2019[1]	South Africa (63 kt) 91% Russia (3.9 kt) 6% Zimbabwe (1.2 kt) 2%	
Australian production 2018[2]	0.541 t	
Australian resources (EDR) 2018[2]	31.5 t	
Australian exports	Not available.	
Australian potential for new resources	The greatest potential for platinum-group elements production is from mafic-ultramafic bodies associated with major large igneous provinces. Platinum-group elements can be produced as by-product from existing nickel mines.	
Recycling	Recycling from industrial process catalysts and of platinum-group elements equipment.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Platinum, palladium, osmium, iridium, ruthenium, rhodium, unwrought, semi-manufactured, powder. Also metal, wire cloth or grill catalysts.	US	13,505
	UK	10,318
	Japan	9,556
	China	7,904
	Belgium	2,546
SUBSTITUTION	Motor vehicles substitute palladium for platinum in catalytic converters. Some platinum-group elements can be substituted for the other platinum-group elements.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

Rare-earth ELEMENTS (excluding scandium Sc)		
CHARACTERISTICS		
Properties	The 15 lanthanide elements plus yttrium are here grouped as rare-earth elements (chemists often include scandium). These 16 rare-earth elements have a variety of properties.	
Usages	Rare-earth elements are used in magnets, catalysts, metal alloys, polishing powders, phosphors, energy storage and superconductors.	
Geological occurrence	Crustal abundances are 31 ppm (yttrium), 20 ppm (lanthanum), 43 ppm (cerium), 4.9 ppm (praseodymium), 20 ppm (neodymium), 3.9 ppm (samarium), 1.1 ppm (europium), 3.7 ppm (gadolinium), 0.6 ppm (terbium), 3.6 ppm (dysprosium), 0.77 ppm (holmium), 2.1 ppm (erbium), 0.28 ppm (thulium), 1.9 ppm (ytterbium), and 0.30 ppm (lutetium). Rare-earth elements occur as minor to trace elements in many minerals, but major rare-earth element-bearing minerals include carbonates (e.g. bastnäsite), phosphates (e.g. monazite, xenotime) and silicates (e.g. allanite).	
Mineral system group	Granite-related, iron-oxide copper-gold, alkaline intrusion-related, surficial (lanthanides).	
Extraction	Main product, co-product.	
SUPPLY		
World production 2019[1]	170 kt rare-earth oxides (REO)	
Major producing countries 2019[1]	China (120 kt REO) 72% Australia (19 kt REO) 11% US (15 kt REO) 9%	
World resources 2019[1]	120,000 kt REO	
Major resource holders 2019[1]	China (44,000 kt REO) 38% Brazil (22,000 kt REO) 19% Vietnam (22,000 kt REO) 19%	
Australian production 2018[2]	19 kt REO	
Australian resources (EDR) 2018[2]	4120 kt REO + Y_2O_3	
Australian exports	Not available.	
Australian potential for new resources	Alkaline intrusion-related and iron-oxide copper-gold systems have high potential for rare-earth and associated elements. The Olympic Dam mine is one of the two largest rare-earth element deposits globally, but currently these elements are not recovered.	
Recycling	Small amounts; mostly magnet scrap.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Alkali or alkaline-earth metals; rare-earth metals, scandium and yttrium, whether or not intermixed or interalloyed; mercury	Japan	274
	US	82
	UK	31
	Switzerland	12
	Canada	11
SUBSTITUTION	Substitutes are available but less effective.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

RHENIUM (Re)		
CHARACTERISTICS		
Properties	Very dense metal with a very high melting point (3,186 °C).	
Usages	Rhenium is used in superalloys for high-temperature turbine engine components and in catalytic converters.	
Geological occurrence	Crustal abundance is 0.188 ppb; the major source of rhenium is as a minor element in molybdenite.	
Mineral system group	Porphyry-epithermal and iron-oxide copper-gold.	
Extraction	By-product.	
SUPPLY		
World production 2019[1]	49 t	
Major producing countries 2019[1]	Chile (27 t) 55% Poland (9.3 t) 19% US (8.3 t) 17%	
World resources 2019[1]	2,400 t	
Major resource holders 2019[1]	Chile (1,300 t) 55% US (400 t) 17% Russia (310 t) 13%	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	Not available.	
Australian exports	Not available.	
Australian potential for new resources	Further discovery of molybdenum-rich deposits in the iron-oxide copper-gold mineral system, and possible recovery as a by-product from existing porphyry copper mines.	
Recycling	Rhenium in spent platinum-rhenium catalysts are routinely recycled. Some rhenium is recycled from other alloys.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for rhenium. Data is aggregated for gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, unwrought and other, including waste and scrap, powders.	US	233
	Japan	119
	UK	42
	South Korea	34
	Belgium	18
SUBSTITUTION	Rhodium and rhodium-iridium can substitute in high-temperature thermocouples; numerous metals may substitute for rhenium in catalyst applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

SCANDIUM (Sc)		
CHARACTERISTICS		
Properties	A silvery-white metallic element.	
Usages	Uses include in aluminium-scandium alloys, solid oxide fuel cells, ceramics, electronics, lasers, lighting and radioactive isotopes. Scandium isotopes may be used as tracing agents in oil refining.	
Geological occurrence	Average crustal abundance is 22 ppm.	
Mineral system group	Mafic-ultramafic igneous-related mineral systems.	
Extraction	By-product or main product.	
SUPPLY		
World production 2019[1]	Not available.	
Major producing countries 2019[1]	Production in recent years from China, Kazakhstan, Russia and Ukraine.	
World resources 2019[1]	Not available.	
Major resource holders 2019[1]	Identified scandium resources has occurred in in Australia, Canada, China, Kazakhstan, Madagascar, Norway, the Philippines, Russia, Ukraine and the US.	
Australian production 2018[2]	Not available.	
Australian resources (EDR) 2018[2]	26.05 kt	
Australian exports	Not available.	
Australian potential for new resources	Good potential in weathered mafic intrusions.	
Recycling	None.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Alkali or alkaline-earth metals; rare-earth metals, scandium and yttrium, whether or not intermixed or interalloyed; mercury	Japan	274
	US	82
	UK	31
	Switzerland	12
	Canada	11
SUBSTITUTION	Titanium and aluminium high-strength alloys and carbon-fibre materials; may substitute in high-performance scandium-alloy applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

TANTALUM (Ta)		
CHARACTERISTICS		
Properties	Blue-grey, lustrous, hard, tough and ductile metal that is very resistant to corrosion from acids, has high thermal and electrical conductivity, and has a high melting point (3,107 °C).	
Usages	Tantalum is used in electronic micro-capacitors and medical technology.	
Geological occurrence	Crustal abundance is 0.7 ppm; the major source of tantalum is tantalite and columbite, although there are a number of other rare tantalum minerals.	
Mineral system group	Granite-related.	
Extraction	Main product, co-product, by-product.	
SUPPLY		
World production 2019[1]	1.8 kt	
Major producing countries 2019[1]	Congo (0.74 kt) 41% Rwanda (0.37 kt) 21% Brazil (0.25 kt) 14%	
World resources 2019[1]	>110 kt	
Major resource holders 2019[1]	Australia (99.3 kt) 74% Brazil (34 kt) 26%	
Australian production 2018[2]	0.06 kt	
Australian resources (EDR) 2018[2]	99.3 kt	
Australian exports	Not available.	
Australian potential for new resources	Reopening of historic mines (e.g. Wodgina) and discovery of tantalum-bearing pegmatites in known and greenfield pegmatite fields.	
Recycling	Recycling is limited, mostly from new scrap, tantalum-bearing steel and superalloys.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Tantalum; articles thereof, including waste and scrap. Also includes niobium, tantalum, vanadium ores and concentrates.	US	301
	South Korea	79
	Japan	55
	Mexico	30
	Czech Republic	30
SUBSTITUTION	Titanium and aluminium high-strength alloys and carbon-fibre materials; may substitute in high-performance scandium-alloy applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

TITANIUM (Ti)	
CHARACTERISTICS	
Properties	Low-density metal with high mechanical strength, high melting point, low thermal expansion coefficient and a high resistance to saltwater and acids.
Usages	Titanium is used in titanium oxide pigments, carbides and chemicals, and as an alloy in steel and superalloys.
Geological occurrence	Crustal abundance is approximately 0.43%; the major source of titanium is ilmenite but other significant titanium minerals include titanite and rutile (and other TiO_2 polymorphs).
Mineral system group	Mafic-ultramafic orthomagmatic and surficial.
Extraction	Main product, co-product.
SUPPLY	
World production 2019[1]	Metal sponge: 210 kt Pigment: not available Ilmenite: 7.7 Mt ilmenite Rutile: 0.7 Mt rutile
Major producing countries 2019[1]	Metal sponge: China (84 kt) 40%; Japan (54 kt) 26% Pigment: Not available Ilmenite: China (2.1 Mt) 27%; Australia (1.4 Mt) 18% Rutile: Australia (0.2 Mt) 29%; Sierra Leone (0.12 Mt) 17%
World resources 2019[1]	Metal sponge capacity: 305 kt Pigment capacity: 7,660 kt Ilmenite: 800 Mt Rutile: 55 Mt
Major resource holders 2019[1]	Metal sponge capacity: China (117 kt) 38%; Japan (68 kt) 22% Pigment capacity: China (3,250 kt) 42%; US (1,370 kt) 18% Ilmenite: Australia (276.3 Mt) 35%; China (230 Mt) 29% Rutile: Australia (35.4 Mt) 64%; India (7.4 Mt) 13%
Australian production 2018[2]	Metal sponge: not available Pigment: not available Ilmenite: 1.4 Mt Rutile: 0.2 Mt
Australian resources (EDR) 2018[2]	Metal sponge capacity: not available Pigment capacity: 260 kt Ilmenite: 276.3 Mt Rutile: 35.4 Mt
Australian exports	Not available.
Australian potential for new resources	Discovery of new heavy mineral sand deposits and lesser potential from mafic-ultramafic orthomagmatic systems.
Recycling	Titanium is recycled from scrap titanium-bearing steel and alloys.

Continued over page...

DEMAND 2019[3]	Country	Import value (US$ million)
Titanium ores and concentrates; titanium oxides; titanium; articles thereof, including waste and scrap	US	1,509
	UK	865
	Japan	652
	Belgium	404
	Canada	232
SUBSTITUTION	Substitutions for high-strength applications include aluminium, composites, intermetallics, steel and superalloys. Corrosion-resistant substitutions include aluminium, nickel and zirconium alloys. Pigment substitutions include calcium carbonate, talc and kaolin.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

Image courtesy of Northern Minerals

TUNGSTEN (W)		
CHARACTERISTICS		
Properties	Steel-grey metal that is brittle, and has a very high melting point (3,422 °C), the lowest vapour pressure (at temperatures above 1,650 °C) and the highest tensile strength. Tungsten has the lowest coefficient of thermal expansion of any pure metal.	
Usages	Major uses of tungsten include electronic applications, lighting, construction, steel and alloys, and mining.	
Geological occurrence	Crustal abundance is approximately 1 ppm; the major source of tungsten are wolframite and scheelite.	
Mineral system group	Granite-related and surficial.	
Extraction	Main product.	
SUPPLY		
World production 2019[1]	85 kt	
Major producing countries 2019[1]	China (70 kt) 82% Vietnam (4.8 kt) 6% Mongolia (1.9 kt) 2%	
World resources 2019[1]	3,700 kt	
Major resource holders 2019[1]	China (1,900 kt) 51% Australia (394 kt) 11% Russia (240 kt) 6%	
Australian production 2018[2]	<1 kt	
Australian resources (EDR) 2018[2]	394 kt	
Australian exports	Not available.	
Australian potential for new resources	New discoveries and redevelopment of historic mines/districts, particularly in the Tasmanides Belt of eastern Australia.	
Recycling	Recycled from scrap tungsten bearing steel and superalloys.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Tungsten ores and concentrates; articles thereof, including waste and scrap.	US	287
	Japan	107
	UK	42
	Mexico	36
	Czech Republic	21
SUBSTITUTION	Substitutes for tungsten carbide include molybdenum carbide, titanium carbide, ceramics, ceramic-metal composites and tool steel. Molybdenum steel can substitute for tungsten steel, and there are several substitutes for tungsten in lighting. Depleted uranium can be substituted in armaments, and lead can be used for radiation shielding.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

VANADIUM (V)		
CHARACTERISTICS		
Properties	Silver-grey ductile and malleable metal that is hard, not brittle, and has good resistance to corrosion and acids.	
Usages	Vanadium is used as alloy in iron and steel, superalloys, chemical catalysts and batteries.	
Geological occurrence	Crustal abundance is approximately 138 ppm; the major source of vanadium is from vanadium-bearing magnetite, although it also occurs as vanadinite, carnotite and other uncommon minerals.	
Mineral system group	Mafic-ultramafic orthomagmatic, basin-hosted and surficial.	
Extraction	Co-product.	
SUPPLY		
World production 2019[1]	73 kt	
Major producing countries 2019[1]	China (40 kt) 54% Russia (18 kt) 25% South Africa (9.1 kt) 12%	
World resources 2019[1]	22,800 kt	
Major resource holders 2019[1]	China (9,500 kt) 42% Russia (5,000 kt) 22% Australia (4,646 kt) 20%	
Australian production 2018[2]	0	
Australian resources (EDR) 2018[2]	4,646 kt	
Australian exports	0	
Australian potential for new resources	Development of known vanadium-rich magnetite deposits, e.g. Windimurra and Balla Balla, and sediment-hosted deposits, e.g. Julia Creek, and discovery of new deposits associated with large igneous provinces.	
Recycling	The majority of recycled vanadium comes from spent chemical process catalysts; a small amount is recycled from vanadium-bearing tool scrap metal.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
No specific data for vanadium. Niobium, tantalum, vanadium ores and concentrates; vanadium oxides and hydroxides.	Czech Republic	212
	US	171
	Canada	58
	Japan	40
	China	11
SUBSTITUTION	Manganese, molybdenum, niobium, titanium and tungsten are interchangeable with vanadium, to some degree, as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.

ZIRCONIUM (Zr)		
CHARACTERISTICS		
Properties	Soft metal that is resistant to corrosion, with a melting point of 1,855 °C and a boiling point of 4,371 °C.	
Usages	Zirconium metal is used for cladding nuclear reactor fuels, and zirconium compounds are used in a variety of high-temperature applications, such as moulds for molten metals.	
Geological occurrence	Crustal abundance is approximately 132 ppm; the major source of zirconium is zircon ($ZrSiO_4$), although there are a number of other minor to trace zirconium-bearing minerals.	
Mineral system group	Alkaline intrusion-related and surficial (heavy mineral sand deposits).	
Extraction	Main product, co-product.	
SUPPLY		
World production 2019[1,4]	2,000 kt zircon	
Major producing countries 2019[1,4]	South Africa (550 kt zircon) 26% Australia (500 kt zircon) 25% US (150 kt zircon) 11%	
World resources 2019[1,4]	92,500 kt zircon	
Major resource holders 2019[1,4]	Australia (79,900 kt zircon) 73% South Africa (9,700 kt zircon) 9% Mozambique (2,700 kt zircon) 2%	
Australian production 2018[2]	500 kt zircon	
Australian resources (EDR) 2018[2]	79,900 kt zircon	
Australian exports	Not available.	
Australian potential for new resources	Discovery of new heavy mineral sand deposits; possible by-product of certain rare-earth element deposits.	
Recycling	Most recycled from new scrap, during metal production and fabrication. Some old scrap is also recycled.	
DEMAND 2019[3]	**Country**	**Import value (US$ million)**
Zirconium ores and concentrates; articles thereof, including waste and scrap.	US	151
	Japan	81
	Canada	53
	Belgium	31
	UK	28
SUBSTITUTION	Chromite and olivine can be substituted for some foundry applications. Dolomite and spinel can also substitute in high-temperature applications. Niobium, stainless steel and tantalum provide limited substitution in nuclear applications.	

Notes:

1. World production and resources sourced from the United States Geological Survey, *Mineral Commodity Summaries 2020*. Figures for 2019 are estimates.
2. Australian production and resources sourced from Geoscience Australia, *Australia's Identified Mineral Resources 2019*.
3. Trade data sourced from the United Nations Comtrade Database, http://comtrade.un.org.
4. Zirconium oxide content (ZrO_2) has been converted to zircon ($ZrSiO_4$) with a conversion factor of 1.49%.

ADVANCED PROJECTS

The following information provides an overview of key advanced projects in Australia that represent potential investment and offtake opportunities in rare-earth elements and other critical minerals. This is not an exhaustive list of advanced critical minerals projects, but is intended to guide readers to a range of potential opportunities. Readers interested in specific projects can contact the companies directly, or seek further information from Austrade.

Project selection

The following key advanced projects in the following section were selected by Austrade in close consultation with the geological surveys and trade and investment agencies of Australia's states and territories.

Project summaries were prepared in consultation with the companies owning the selected projects.

Key advanced projects were selected using the following criteria:

- The project has potential to produce (or continue producing) one or more of the 24 critical minerals on the Australian list.
- The project is active.
- The project has, at a minimum, a completed pre-feasibility study (PFS).

In addition:

- Operating mines were excluded from selection other than Costerfield, Groote Eylandt, Eneabba Stockpiles and Mount Weld, which were selected as examples to showcase Australia's production of antimony, rare-earth elements and manganese ore.
- Projects in construction stage were excluded from selection.
- Inactive projects were not included regardless of PFS status; and
- Smaller advanced projects with relatively low amounts of critical minerals contained in their total mineral resource were excluded from selection.

In some cases, companies did not accept Austrade's invitation to include project summaries for selected projects, so these projects have not been included.

Project status

The status assigned to Australian critical minerals projects is based on industry standard mineral project development stages as shown below.

Project status	Description
Early-stage exploration	Early-stage greenfield exploration prospects prior to reporting significant exploration results.
Exploration	Exploration-stage projects with exploration results reported but prior to establishment of a Joint Ore Reserves Committee (JORC) Mineral Resource. Exploration results would typically include anomalous soil geochemistry results and/or significant drilling intercepts. Results may include defined JORC Exploration Targets.
Advanced exploration	JORC Mineral Resources defined but no project studies completed. Commonly referred to as 'resource definition' stage.
Scoping study	Scoping study completed and JORC Mineral Resources defined.
Pre-feasibility study	Pre-feasibility study completed, JORC Mineral Resources defined and JORC Ore Reserves also typically defined.
Feasibility study	Feasibility study completed and JORC Mineral Resources and Ore Reserves defined. Also includes feasibility study updates.
Pre-construction	Feasibility study completed and key approvals in place for project development. Typical project activities include project financing, front-end engineering design and early construction activities.
Construction	Construction funded and underway onsite.
Operating	Operating mine.
Tailings	Tailing retreatment project.
Care and maintenance	Previously operated mines now on care and maintenance.

Project ranking and conversion factors

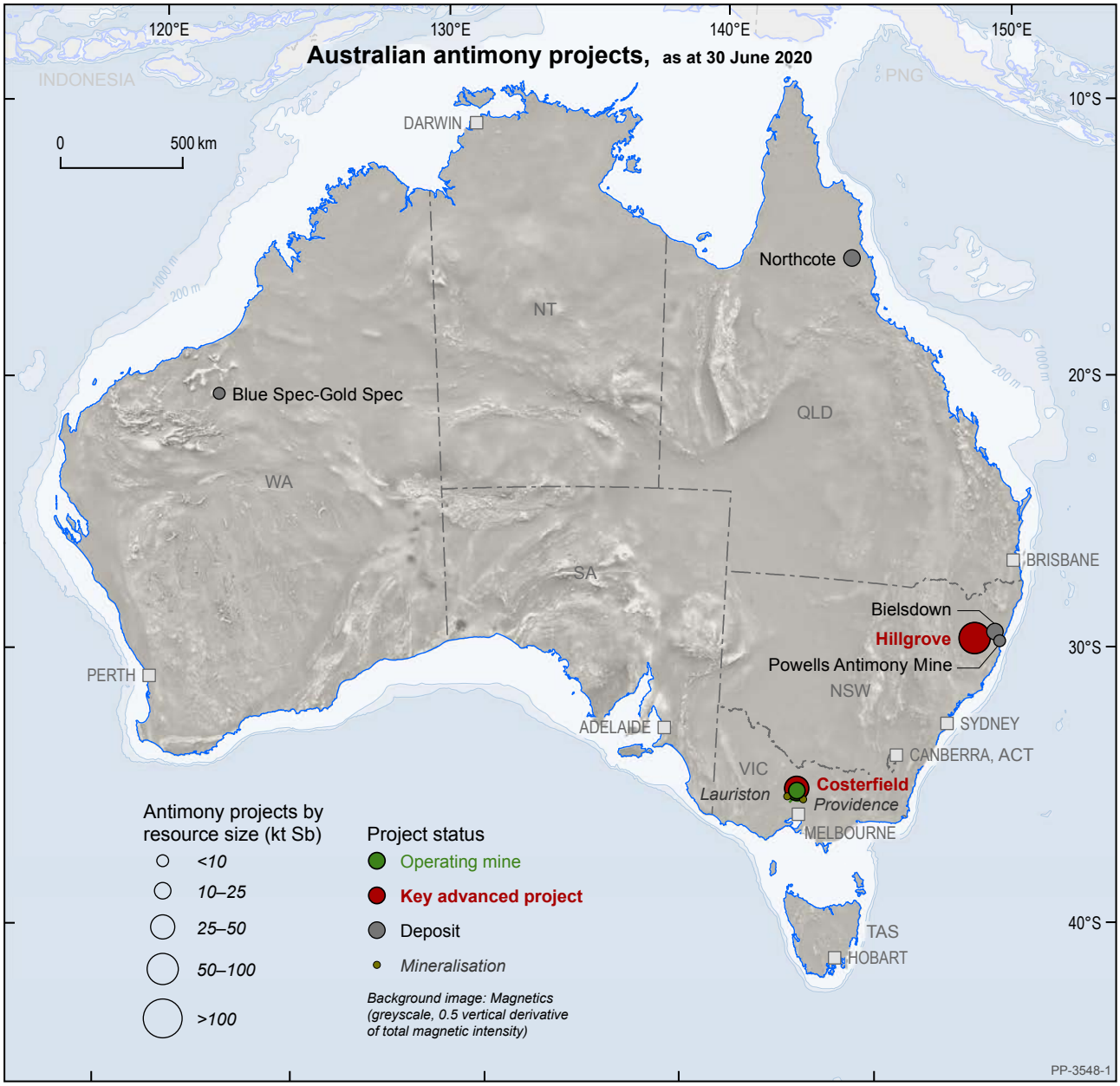
Lists of advanced projects ranked by the contained critical mineral within the total mineral resource (largest first) are provided at the start of the advanced project section for each critical mineral.

Conversion factors were applied to some minerals to enable comparisons between hard rock and mineral sands projects that include resources of titanium, zirconium or rare-earth elements (see Appendix A).

Critical mineral maps

Geoscience Australia has prepared maps for each critical mineral, illustrating the location of deposits, key advanced projects and operating mines. Project sizes on these maps correlate to the amount of contained critical mineral within the total mineral resource for each project. The red circles indicate key advanced projects that have a project summary in the Prospectus.

Antimony (Sb)



Advanced antimony projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Antimony	**Costerfield**	Mandalay Resources Corporation	Operating	Sb, Au	1.6	2.80	%	Sb	46	44
Antimony	**Hillgrove**	Red River Resources Ltd	Care and maint	Au, Sb	6.7	1.50	%	Sb	96	46
Antimony	**Northcote**	Territory Minerals Ltd	Care and maint	Au, Sb	4.0	0.30	%	Sb	11	–

CRITICAL MINERAL(S)	ANTIMONY VIC
PROJECT NAME	**COSTERFIELD MINE**
Location	The Costerfield Mine is centred on the small settlement of Costerfield in Central Victoria, 10 km north-east of Heathcote, 50 km south-east of Bendigo and 100 km north-west of Melbourne.
Company name	**Mandalay Resources Corporation**
Company ownership	Publicly listed TSX-listed **(MND)**
Project description	Mandalay acquired the Costerfield Gold-Antimony Mine in 2009 and has since operated the mine, increasing production via ongoing investment in the project. Costerfield is Australia's only antimony producer of any significance. Costerfield currently produces ore from two veins, Brunswick and Youle, both of which are accessed from the Augusta mine portal. The mining method employed is long-hole stoping with cemented rock fill. Ore is accessed by a primary spiral ramp. Level spacing is at 10 m centres and horizontal development is advanced in 1.8 m wide drives in both directions to the extents of the deposit. Levels are then retreated though production stopes drilled to a width of ~1.5 m. Stopes are then backfilled with cemented rock fill for stability, to reduce dilution and allow for mining above/below mined-out levels. Ore is trucked on the surface from the Augusta mine portal to the Brunswick plant, where it is stockpiled and blended into the crusher. The circuit includes: primary mobile crusher, primary and secondary ball mills, gravity separation, rougher, scavenger, cleaner flotation and filtering. Gravity gold concentrate is sold to refineries in Melbourne, and gold-antimony flotation concentrate is trucked to the Port of Melbourne, from which it is shipped to smelters in China. Mandalay's main objective is to accelerate mining of the high-grade Youle vein, which is critical to increasing production. Mining commenced on the Youle vein in August 2019. The Youle vein has markedly higher grades as well as better recoveries than the previously mined Brunswick vein and is central to Mandalay's organic growth plan. Production increases are expected at Costerfield in 2020 as production increases from the high-grade Youle vein. Exploration is ongoing and currently aimed at extending the Youle Indicated Resource. The Youle resource is still open, up dip, west of historical workings, along strike to the north and at depth. Regional target generation has included extensive surface mapping, drillhole database integration, soil geochemistry and evaluation of geophysical data, and has given rise to drill-ready targets. As Mandalay continues to increase momentum within the Youle expansion program, in 2019 it also undertook targeted testing at depth below Youle, to expand on Mandalay's developing understanding of gold enrichment environments. The first hole of Costerfield's deep drilling program was completed in 2019, at a drilling depth of 1700 m.
Products	Gold-antimony concentrate. Gold gravity concentrate.

<table>
<tr><td>Mineral inventory</td><td>Mineral resources (as at 31 December 2019):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Sb (%)</th><th>Au (g/t)</th></tr>
<tr><td>Measured</td><td>0.283</td><td>4.5</td><td>9.6</td></tr>
<tr><td>Indicated</td><td>0.830</td><td>2.9</td><td>9.6</td></tr>
<tr><td>Inferred</td><td>0.533</td><td>1.7</td><td>6.8</td></tr>
<tr><td>Total</td><td>1.646</td><td>2.8</td><td>8.7</td></tr>
<tr><td>Contained (Sb kt), (Au koz)</td><td></td><td>45.7</td><td>461</td></tr>
</table>
Ore reserves (as at 31 December 2019):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Sb (%)</th><th>Au (g/t)</th></tr>
<tr><td>Proved</td><td>0.114</td><td>4.8</td><td>9.5</td></tr>
<tr><td>Probable</td><td>0.360</td><td>3.4</td><td>14.6</td></tr>
<tr><td>Inferred</td><td>0.533</td><td>1.7</td><td>6.8</td></tr>
<tr><td>Total</td><td>0.474</td><td>3.8</td><td>13.4</td></tr>
<tr><td>Contained (Sb kt), (Au koz)</td><td></td><td>17.8</td><td>204</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>The Augusta mine has been operational since 2006. The underground mine is accessed by a 4.5 m wide and 4.8 m high decline mined at a gradient of 1.7 degrees. The decline provides primary access for personnel, equipment and materials to the underground workings.</td></tr>
<tr><td>Production</td><td>Production for 2019:
Processed ore: 141 090 t
Concentrate produced: 7460 dry t at 62.2 g/t Au and 51.5% Sb
Au produced in gold gravity concentrate: 5378 t
Au produced in gold-antimony concentrate: 9880 oz
Total Au produced: 15 258 oz
Sb produced in gold-antimony concentrate: 2,032 t
mandalayresources.com/wp-ontent/uploads/2020/03/MND_AIF_Mar-30_2020.pdf</td></tr>
<tr><td>Infrastructure</td><td>All ore is processed at the Brunswick Processing Plant, 2 km from the Augusta mine. The Youle deposit is located 2.2 km north of the Augusta workings, accessed from the Augusta portal. Surface infrastructure facilities are typical of a conventional gravity circuit and flotation-style concentrator and underground mine operation of this size.</td></tr>
<tr><td>Project development capital costs</td><td>Capital expenditures A$17–21m expected in 2020.</td></tr>
<tr><td>Project economics</td><td>Production and cost guidance for 2020:
Gold produced (oz): 32,000–38,000
Antimony produced (t): 3000–3500
Cash cost per oz gold eq. produced: A$725–$875
All in cost per oz gold eq. produced: A$1,175–1,325
More information: mandalayresources.com/wp-content/uploads/2020/03/MND_AIF_Mar-30_2020.pdf</td></tr>
<tr><td>Project funding</td><td>Not seeking investment. Market listed on TSX.</td></tr>
<tr><td>Other</td><td>mandalayresources.com/properties/costerfield/</td></tr>
</table>

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>ANTIMONY AND TUNGSTEN NSW</th></tr>
<tr><th>PROJECT NAME</th><th>HILLGROVE</th></tr>
<tr><td>Location</td><td>23 km east of Armidale in New South Wales, 1 hr 20 min flight from Sydney</td></tr>
<tr><td>Company name</td><td>Red River Resources Ltd</td></tr>
<tr><td>Company ownership</td><td>ASX-listed (RVR)</td></tr>
<tr><td>Project description</td><td>Hillgrove is a world-class antimony-gold-tungsten project. It is one of the top-five global antimony resources (outside of China) and accounts for approximately 55% of Australia's antimony resources.

Hillgrove has a high-grade mineral resource base of ~1 moz Au and regular 100 kt Sb and the mine has had historic production of >730 koz Au, >50 kt Sb, plus by-product tungsten production. Over A$200m in capital has been invested at the Hillgrove site since 2004.

The Hillgrove underground mine, 250 ktpa million and site infrastructure are currently under active care and maintenance. The mine is production ready with extensive modern underground development in place.

The Hillgrove deposit has over 200 known antimony-gold-tungsten occurrences of which only 18 have had significant mining activity. All mineral resources are open at depth and/or strike.

Very little modern exploration has been undertaken and there is great potential to increase the existing resources and for further discoveries.</td></tr>
<tr><td>Expected products</td><td>The Hillgrove Project is expected to produce the following products:

• antimony-gold concentrate (52-57% Sb, 12-22 g/t Au)

• gold concentrate (45 g/t Au, 8% Sb, 7% As)

• gold doré (bullion).

In addition, there is potential for production of antimony metal and gold bullion from concentrates on site by utilising the existing plant.</td></tr>
<tr><td>Mineral inventory</td><td>Hillgrove's JORC 2012 resources consist of four deposits: Sunlight, Brackin's Spur, Clark's Gully and Syndicate.

JORC 2012-compliant Mineral Resources (as at 2019):

<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Au (g/t)</th><th>Sb (%)</th></tr>
<tr><td>Measured</td><td>0.7</td><td>5.8</td><td>2.6</td></tr>
<tr><td>Indicated</td><td>1.1</td><td>4.9</td><td>1.5</td></tr>
<tr><td>Inferred</td><td>1.0</td><td>5.0</td><td>1.1</td></tr>
<tr><td>Total</td><td>2.8</td><td>5.1</td><td>1.7</td></tr>
<tr><td>Contained (Au koz, Sb kt)</td><td></td><td>463</td><td>46</td></tr>
</table>

The JORC 2004 resources will progressively be updated to JORC 2012. These resources consist of 12 deposits, of which the main ones are: Blacklode, Elanora, Garibaldi, Cox's Lode and Freehold.</td></tr>
</table>

<table>
<tr><td>Mineral inventory</td><td>JORC 2004 compliant Mineral Resources (as at 2019):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Au (g/t)</th><th>Sb (%)</th></tr>
<tr><td>Measured</td><td>0.7</td><td>6.1</td><td>1.4</td></tr>
<tr><td>Indicated</td><td>2.0</td><td>4.7</td><td>1.1</td></tr>
<tr><td>Inferred</td><td>1.2</td><td>3.9</td><td>1.5</td></tr>
<tr><td>Total</td><td>3.9</td><td>4.7</td><td>1.3</td></tr>
<tr><td>Contained (Au koz, Sb kt)</td><td></td><td>597</td><td>50</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>Red River Resources is planning a staged restart process for Hillgrove.

Stage 1 of the project will restart on the Bakers Creek Gold Dump using crushing, grinding, gravity separation, flotation and leach circuits to produce a gold doré.

Stage 2 plans include commencement of underground mining and utilising the processing plant to produce antimony-gold and gold concentrates, which will be transported by road to the Port of Brisbane for export.

Additional processing stages Red River is investigating include to further process the antimony-gold and gold concentrates to produce antimony metal (>99% Sb) and gold doré (bullion) onsite, utilising the existing antimony leach/EW circuit, furnaces and pressure oxidation circuit.</td></tr>
<tr><td>Expected production</td><td>Red River has not yet publicly disclosed its Hillgrove Project production forecasts.</td></tr>
<tr><td>Infrastructure</td><td>Existing 250 ktpa processing plant, which consists of a crusher, ball mill, flotation cells, thickeners and filters, plus an antimony alkali leach and electrowinning circuit, furnaces, gold cyanide leach circuit, pressure oxidation circuit (POX) and a gold room.

Offices, warehouses, assay lab and maintenance facilities.

Extensive modern UG development – production ready.

UG mining fleet and surface vehicle fleet.

Lined tailing storage facility with approximately two years capacity.

Residential workforce (Armidale).

Grid power (66 kV) onsite.</td></tr>
<tr><td>Project development capital costs</td><td>Stage 1 restart capital costs estimated to be less than A$5m.

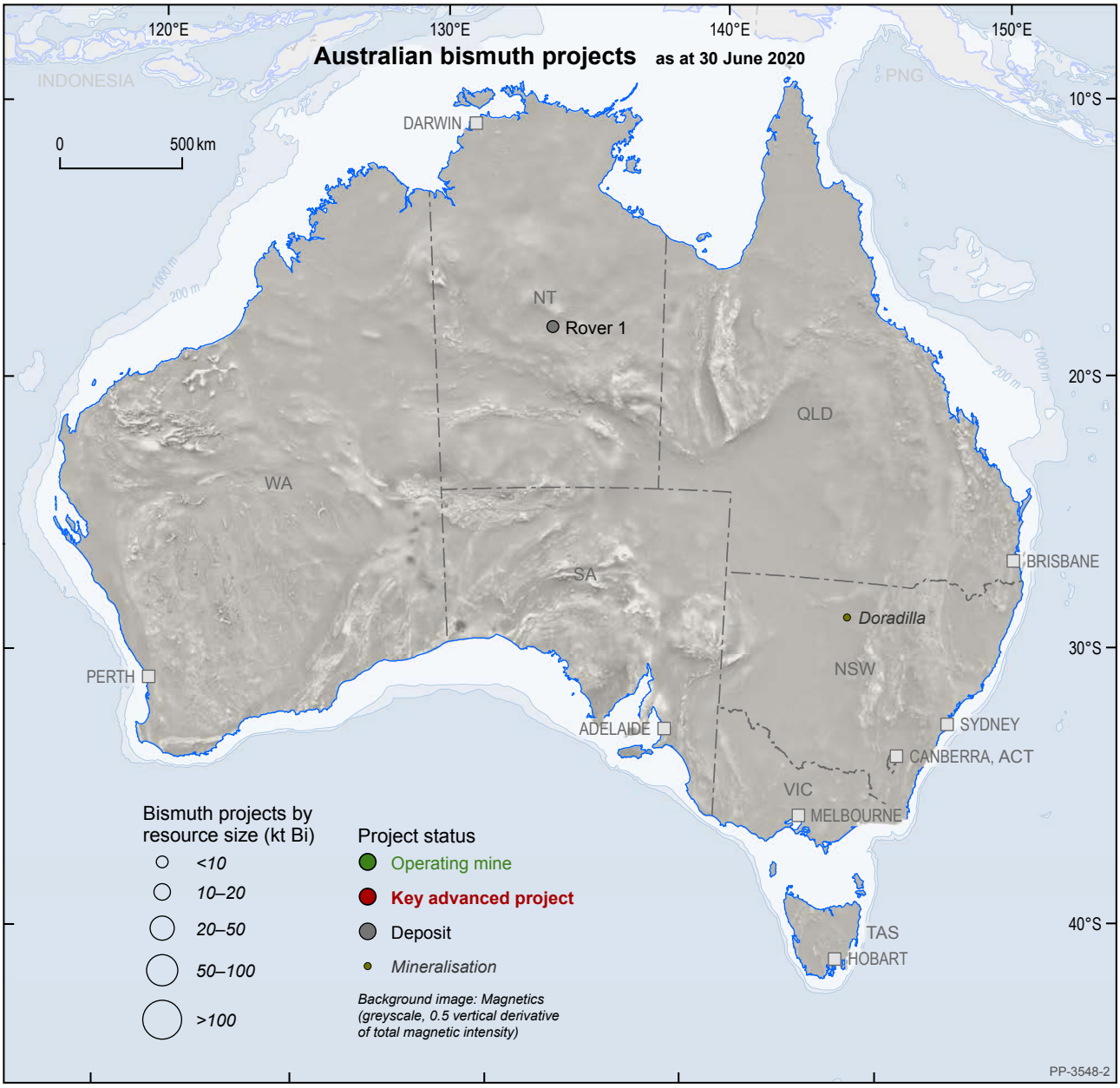
Red River is in the process of estimating Stage 2 restart capital costs.</td></tr>
<tr><td>Project economics</td><td>Red River has not yet publicly disclosed economics for its Hillgrove Project.</td></tr>
<tr><td>Project funding</td><td>Red River intends to fund Stage 1 restart capital cost from internal sources.

Welcomes discussions from third parties regarding offtake or additional investment to take the concentrate to antimony metal and gold doré.</td></tr>
<tr><td>Other</td><td>Red River website: redriverresources.com.au

Hillgrove acquisition presentation: redriverresources.com.au/investor-centre/corporate-presentations.html

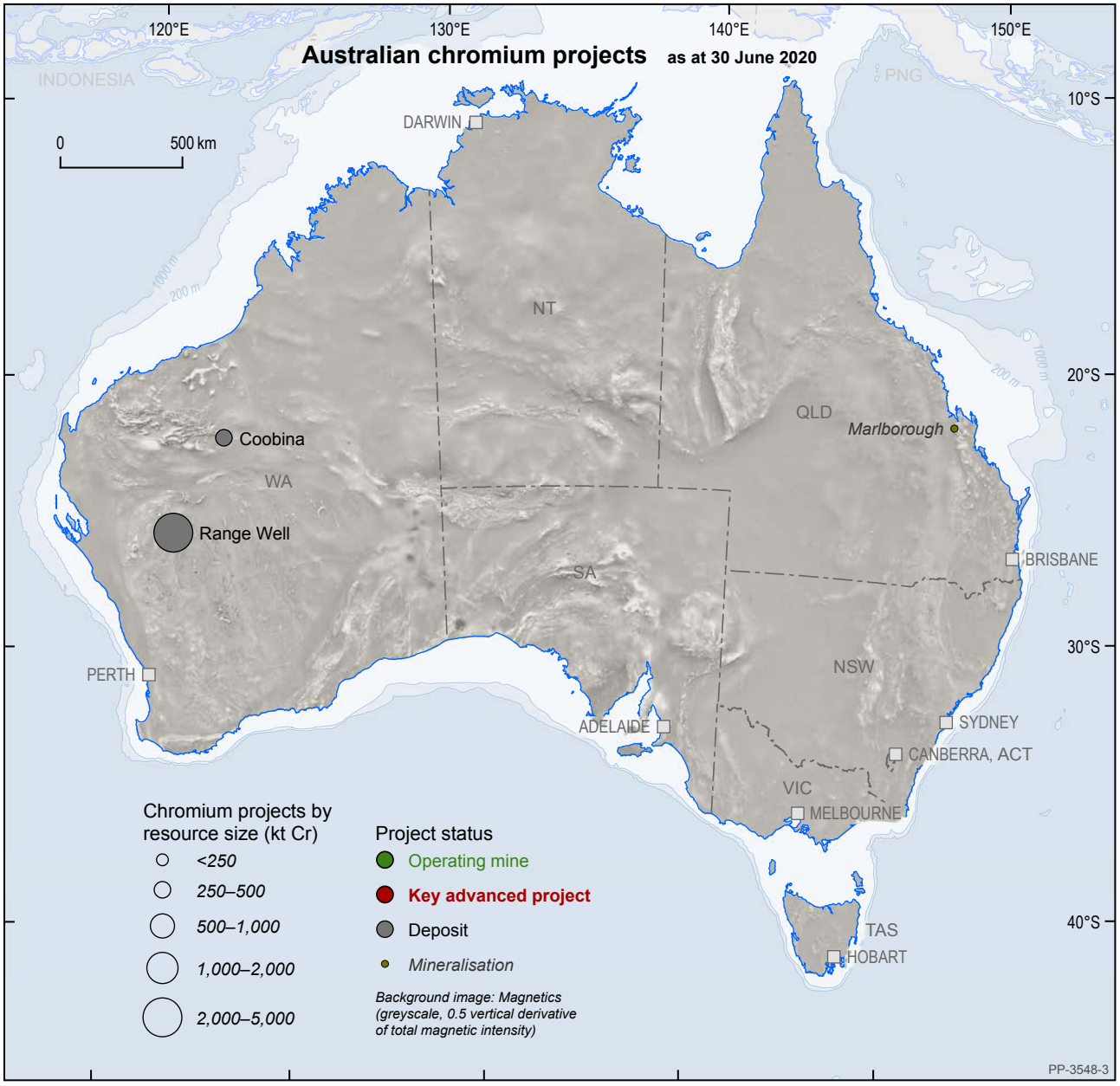
Hillgrove site video: redriverresources.com.au/gallery/videos.html</td></tr>
</table>

Bismuth (Bi)



No advanced bismuth projects in Australia.

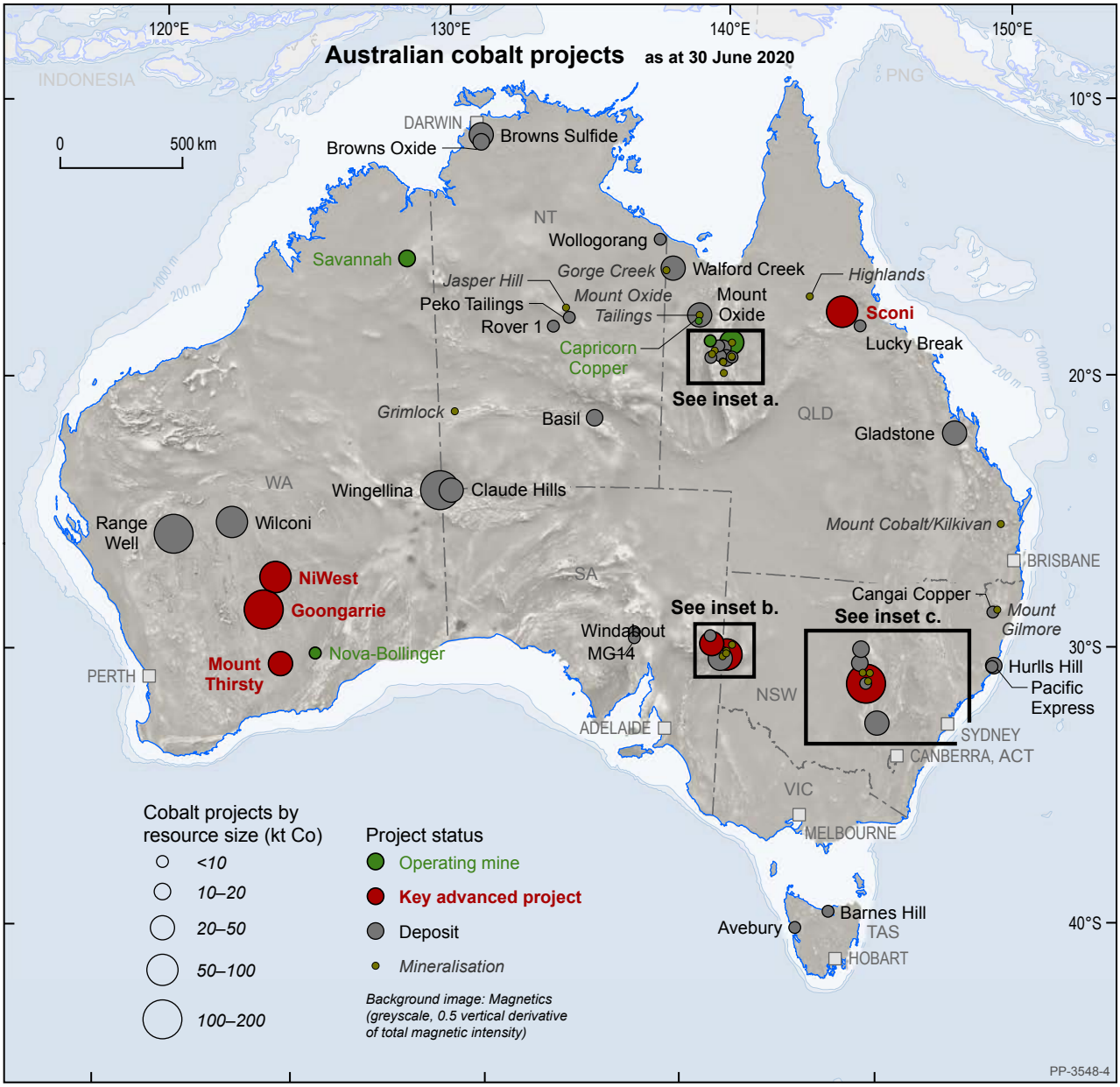
Chromium (Cr)

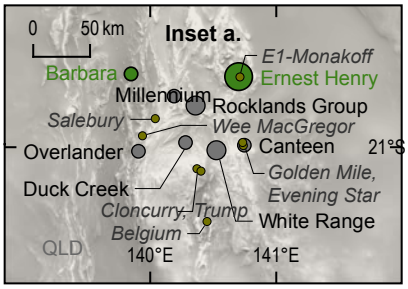


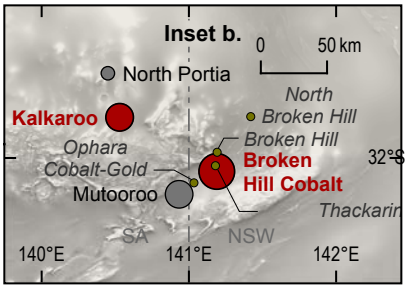
Advanced chromium projects (total mineral resource tonnage, grade and contained mineral)

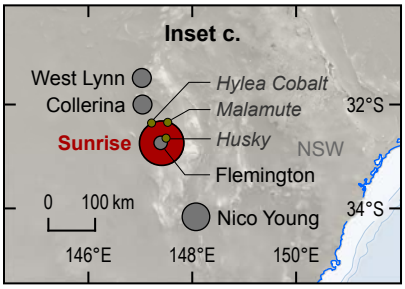
Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Chromium	**Coobina**	Mineral Resources Ltd	Care and maint	Cr	1.5	29.40	%	Cr	441	–
Chromium	**Range Well**	EV Metals	PFS	Ni, Cr, Co	385.3	0.78	%	Cr	3,005	–

Cobalt (Co)


Australian cobalt projects as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
Browns Oxide
Browns Sulfide
NT
Wollogorang
Savannah
Gorge Creek
Walford Creek
Jasper Hill
Peko Tailings
Rover 1
Mount Oxide Tailings
Mount Oxide
Highlands
Sconi
Lucky Break
Capricorn Copper
See inset a.
Grimlock
Basil
QLD
Gladstone
WA
Wingellina
Claude Hills
Range Well
Wilconi
Mount Cobalt/Kilkivan
BRISBANE
SA
NiWest
Goongarrie
See inset b.
See inset c.
Cangai Copper
Mount Gilmore
Windarra
MG14
Nova-Bollinger
Mount Thirsty
PERTH
Hurlls Hill
Pacific Express
NSW
ADELAIDE
SYDNEY
CANBERRA, ACT
VIC
MELBOURNE
Barnes Hill
Avebury
TAS
HOBART
Cobalt projects by resource size (kt Co)
<10
10–20
20–50
50–100
100–200
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics (greyscale, 0.5 vertical derivative of total magnetic intensity)
PP-3548-4


Inset a.
0
50 km
Barbara
E1-Monakoff
Ernest Henry
Millennium
Rocklands Group
Salebury
Wee MacGregor
Overlander
Canteen
21°S
Golden Mile, Evening Star
Duck Creek
Cloncurry, Trump
White Range
Belgium
QLD
140°E
141°E


Inset b.
0
50 km
North Portia
Kalkaroo
North Broken Hill
Broken Hill
Ophara
Cobalt-Gold
Broken Hill Cobalt
32°S
Mutooroo
Thackarin
SA
NSW
140°E
141°E
142°E


Inset c.
West Lynn
Collerina
Hylea Cobalt
Malamute
32°S
Sunrise
Husky
NSW
Flemington
0
100 km
Nico Young
34°S
146°E
148°E
150°E

Advanced cobalt projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Cobalt	**Savannah**	Panoramic Resources Ltd	Operating	Ni, Cu, Co	13	0.11	%	Co	14	–
Cobalt	**Nova-Bollinger**	IGO Ltd	Operating	Ni, Cu, Co	11.6	0.07	%	Co	8	–
Cobalt	**Barbara**	ASX:SOL	Operating	Cu, Au	4.8	0.03	%	Co	1	–
Cobalt	**Capricorn Copper**	Capricorn Copper Holdings	Operating	Cu					NA	–
Cobalt	**Ernest Henry**	Glencore Plc	Operating	Cu, Au					NA	–
Cobalt	**Sunrise**	Clean TeQ Holdings Ltd	Pre-const	Ni, Co, Sc	183.3	0.09	%	Co	162	52
Cobalt	**Wingellina**	Metals X Ltd	FS	Ni, Co	215.8	0.07	%	Co	151	–
Cobalt	**SCONI**	Australian Mines Ltd	FS	Ni, Co	75.7	0.08	%	Co	57	54
Cobalt	**Gladstone**	Gladstone Pacific Nickel Ltd	FS	Ni, Co	70.9	0.06	%	Co	43	–
Cobalt	**Mount Oxide**	Zhongjin Lingnan Mining	Care and maint	Cu, Ag	25.1	0.08	%	Co	21	–
Cobalt	**Rocklands Group**	CuDeco Ltd (in liquidation)	Care and maint	Cu, Au	56.7	0.03	%	Co	17	–
Cobalt	**White Range**	Young Australian Mines Ltd	FS	Cu, Au	29.1	0.04	%	Co	11	–
Cobalt	**Avebury**	Allegiance Mining Pty Ltd	Care and maint	Ni, Co	29.3	0.02	%	Co	7	–
Cobalt	**Range Well**	EV Metals	PFS	Ni, Cr, Co	385.3	0.04	%	Co	154	–
Cobalt	**Goongarrie**	Ardea Resources Ltd	PFS	Ni, Co	215.6	0.06	%	Co	131	56
Cobalt	**Broken Hill Cobalt**	Cobalt Blue Holdings Ltd	PFS	Co (S, Fe)	111	0.07	%	Co	79	59
Cobalt	**NiWest**	GME Resources Ltd	PFS	Ni, Co	85.2	0.07	%	Co	55	62
Cobalt	**Mt Thirsty**	Conico; Barra Resources	PFS	Co, Ni	26.8	0.12	%	Co	32	64
Cobalt	**Kalkaroo**	Havilah Resources Ltd	PFS	Cu, Au, Co	193.3	0.01	%	Co	23	66

CRITICAL MINERAL(S)	COBALT, SCANDIUM NSW
PROJECT NAME	**CLEAN TEQ SUNRISE**
Location	370 km west of Sydney in New South Wales; within the Lachlan Shire near the village of Fifield.
Company name	**Clean TeQ Holdings Limited**
Company ownership	ASX/TSX listed **(CLQ)** Project held by wholly owned subsidiary Clean TeQ Sunrise Pty Ltd.
Project description	The Clean TeQ Sunrise Battery Materials Complex has been designed as a fully integrated supplier of high-purity battery-grade nickel and cobalt sulphate for the electric vehicle (EV) supply chain, as well as one of the world's largest producers of scandium. With over A$200m invested to date, Sunrise is development-ready, with all key permits secured, a 40+ year mine life and operating costs forecast to be in the lowest quartile of the industry. A project execution plan (PEP) is due for completion in Q2 2020, updating the 2018 feasibility study. The project development will consist of a shallow open-cut mine, hydrometallurgical processing plant (pressure acid leach followed by Clean TeQ's proprietary ion exchange technology, Clean-iX®, to separate nickel, cobalt and scandium) and associated infrastructure.
Expected products	Battery-grade nickel sulphate ($NiSO_4 \cdot 6H_2O$). Battery-grade cobalt sulphate ($CoSO_4 \cdot 7H_2O$). Scandium oxide (Sc_2O_3). Ammonium sulphate ($(NH_4)_2SO_4$).
Mineral inventory	Proved and Probable Ore Reserves (JORC 2012) are sufficient to support approximately 40 years of supply. Mineral resource estimate (as at 9 October 2017):

Resource category	Tonnes	Ni (%)	Co (%)	Sc (ppm)
Measured	68.8	0.63	0.10	62
Indicated	93.9	0.47	0.08	86
Inferred	20.6	0.23	0.09	283
Total	**183.3**	**0.50**	**0.09**	**99**
Contained (kt)		**921**	**162**	**18**

0% cobalt cut-off

Ore reserves (as at 22 June 2018):

Reserve category	Tonnes (Mt)	Ni (%)	Co (%)	Sc (ppm)
Proved	65.5	0.65	0.10	48
Probable	81.9	0.49	0.08	57
Total	**147.4**	**0.56**	**0.09**	**53**
Contained (kt)		**825**	**133**	**8**

Stage of development	Sunrise has obtained all key approvals: • NSW development consent, an approved environmental impact statement and heritage clearances • the mining lease has been granted (ML1770) • water supply obtained via +3.2 GLpa ground water allocation • excellent regional infrastructure including road, rail and power • initial binding offtake contract secured with established battery precursor/cathode manufacturer for approximately 20% of forecast production in years 1–5, with strong demand for the balance. With front-end engineering complete and a detailed capital estimate and schedule delivered, Clean TeQ is focused on identifying strategic partnerships to fund construction of the project.
Expected production	Expected annual production (first decade average): • Ore mined and processed: 2.5 Mtpa • Nickel sulphate: 89,270 tpa (19,620 tpa contained Ni metal) • Cobalt sulphate: 21,260 tpa (4,420 tpa contained Co metal) • Scandium oxide: 80 tpa (expandable) • Ammonium sulphate: 82,000 tpa
Infrastructure	Sunrise is regulated by development consent DA 374 11 00 issued by the NSW Government under Part 4 of the EP&A Act in 2001. The area is well serviced by road and rail, a highly skilled workforce and power supply. A 70 km water pipeline will connect the project site to a fully licensed bore field. Sunrise is adjacent to one of Australia's largest solar developments and a possible source of 100% renewable power.
Project development capital costs	The feasibility study provided a pre-production capital cost estimate of approximately US$1.5 bn (including contingency). This estimate will be updated on delivery of the PEP in Q2 2020.
Project economics	The feasibility study projected a post-tax net present value ($NPV_{8\%}$) of US$1.392 bn and post-tax internal rate of return (IRR) of 19.1%. The definitive feasibility study economics will be updated on delivery of the PEP in Q2 2020.
Project funding	Clean TeQ is targeting at least 50% of Sunrise's construction capital to be provided under a standard, non-recourse project debt facility. Four leading international banks – Société Générale, National Australia Bank, Natixis and ICBC – have been appointed as Mandated Lead Arrangers for the debt funding. In June 2019, Clean TeQ announced that it had appointed a division of Macquarie Bank to run a partnering process for the Sunrise Project, whereby parties would be offered an investment in the project in conjunction with long-term offtake arrangements. The partnering process remains ongoing.
Other	Company website: cleanteq.com Investor information: cleanteq.com/investors/

CRITICAL MINERAL(S)	COBALT, SCANDIUM QLD
PROJECT NAME	**THE SCONI PROJECT (SCONI)**
Location	Located in North Queensland, within easy driving distance to the nearby towns of Greenvale, Charters Towers and Ingham, and only 250 km from the Port of Townsville (via existing sealed roads).
Company name	**Australian Mines Limited**
Company ownership	Australian ASX: **AUZ** US OTCQB: **AMSLF** Frankfurt Stock Exchange: **MJH**
Project description	Sconi is a Tier-1 cobalt, nickel and scandium asset with ore reserves that support an open-pit mine life of at least 30 years. Once in production, Sconi will produce battery-grade cobalt sulphate and nickel sulphate, and high-purity scandium oxide. According to an independent market study by CRU International, Sconi is expected to be one of the lowest-cost cobalt-producing nickel projects in the world.
Expected products	Sconi uses a latest-generation pressure acid leach + solvent extraction and final product precipitation/crystallisation processing plant for processing nickel and cobalt ore through to battery-grade nickel sulphate crystals ($NiSO_4.6H_2O$) and cobalt sulphate crystals ($CoSO_4.7H_2O$) with scandium recovery and production of high-purity scandium oxide (Sc_2O_3).
Mineral inventory	Mineral resources (as at 14 February 2019): **Resource category** / **Tonnes (Mt)** / **Ni (%)** / **Co (%)** Measured / 8.3 / 0.75 / 0.09 Indicated / 49.2 / 0.60 / 0.08 Inferred / 18.2 / 0.54 / 0.05 **Total** / **75.7** / **0.60** / **0.08** **Contained (kt)** / / **456** / **57** Ore reserves (as at 13 June 2019): **Reserve category** / **Tonnes (Mt)** / **Ni (%)** / **Co (%)** / **Sc (ppm)** Proved / 8.1 / 0.72 / 0.09 / 44 Probable / 49.2 / 0.55 / 0.08 / 33 **Total** / **57.3** / **0.58** / **0.08** / **35** **Contained (kt)** / / **332** / **46** / **2.0**
Stage of development	A feasability study was completed in November 2018 and revised in June 2019 to reflect updated mineral resource. Australian Mines operates a demonstration-scale processing plant, which has been producing cobalt sulphate and nickel sulphate throughout the past two years.

Stage of development	In March 2020, a series of production runs were completed at its Perth-based pilot-plant site. These production runs will supply samples of battery-grade cobalt sulphate and nickel sulphate for testing by and to facilitate discussions with potential offtake and financing partners for Sconi. The production runs are also being used to produce high-purity scandium oxide for supply to potential research and development partners. In January 2019, Sconi was declared a 'prescribed project' by the Queensland Government. This support helps with streamlining Sconi's progression through the final stages of regulatory approvals and facilitates the fast-tracking of its future development. Australian Mines also holds an Indigenous land use agreement and cultural heritage management plan with the Gugu Badhan Traditional Landowners for mining at Greenvale where Sconi is located.
Expected production	Expected annual production (life of mine average): • Strip ratio over life of mine (waste:ore): 0.87:1 • Ore mined and processed: 2.0 Mtpa • Nickel sulphate production: 46,800 tpa • Cobalt sulphate production: 7,000 tpa • Scandium oxide production: 48 tpa
Infrastructure	Sconi is well supported by existing infrastructure, including an established bulk commodities port at Townsville and an existing road network capable of facilitating road haulage of material between Sconi and Port of Townsville. Australian Mines has committed to invest over A$100m to upgrade this shared infrastructure as part of developing Sconi.
Project development capital costs	Total capital costs of US$974m, being: • US$730m – processing-plant costs • US$103m – non-process costs • US$31m – mine construction costs • US$110m – contingencies
Project economics	Over its expected minimum mine life of 30 years, Sconi is expected to generate at least A$13.27bn in revenues and an estimated A$5bn in free cash flow. Key financial highlights include: • Average annual revenue: A$730m • Average annual EBITDA: A$420m • Project payback period (post-tax): 5.2 years • Pre-tax IRR: 20% • Post-tax $NPV_{8\%}$: A$1,167m
Project funding	Australian Mines' primary focus in 2020 is securing offtake and financing agreements for Sconi. The company is progressing negotiations with potential offtake and financing partners, supported by current production runs, which are delivering battery-grade cobalt sulphate and nickel sulphate samples for testing.
Other	Company website: www.australianmines.com.au Sconi Project: australianmines.com.au/resource-supply Contact: australianmines.com.au/contact

CRITICAL MINERAL(S)	COBALT WA
PROJECT NAME	**GOONGARRIE NICKEL COBALT PROJECT (GOONGARRIE, GNCP)**
Location	80 km north of Kalgoorlie on the main Goldfields Highway, in Western Australia.
Company name	**Ardea Resources Ltd**
Company ownership	ASX-listed **(ARL)** – 100%
Project description	The Goongarrie Nickel Cobalt Project (Goongarrie or GNCP) is among the developed world's premier nickel-cobalt projects, with world-class supporting infrastructure in the well-established Kalgoorlie mining district and an environmentally benign arid setting. Conventional open-pit mine with low strip ratio and in excess of 25-year mine life (2.25 Mtpa expansion study case) feeding high-quality goethite dominated cobalt-nickel ore into a fifth-generation high-pressure acid leach (HPAL) hydrometallurgical process plant. The GNCP resource of 215 Mt at 0.06% Co and 0.71% Ni is already one of the world's largest Ni-Co resources and is expected to support multi-decades of additional mine life beyond the artificial 25-year mine life chosen for the expansion study. GNCP is part of Ardea's nearby Kalgoorlie Nickel Project (KNP), which is the largest cobalt-nickel project in the developed world with total resources of 773 Mt at 0.05% Co and 0.70% Ni (405 kt contained Co and 5,458 kt contained Ni). The KNP provides optionality to develop multiple nearby processing hubs and substantially expand GNCP production and/or extend mine life. Studies are also underway to add scandium, manganese and rare-earth elements to the KNP resources and potentially uncover these metals. The GNCP ore body has formed as a conventional nickel laterite through weathering of the ultramafic basement, but with significantly higher cobalt than usually seen in laterites, resulting in the following: • intense leaching and upgrading of cobalt, nickel and manganese (the building blocks of lithium-ion batteries) • crustal-scale faulting intersecting the deposit, resulting in intense deformation and weathering to depths of >120 m • alkaline intrusions containing rare-earth elements and scandium abutting the ore zone have also been enriched by weathering resulting in elevated concentrations of scandium and the rare-earth minerals cerium, neodymium and praseodymium in selected areas • cobalt, nickel, manganese, scandium, cerium, neodymium and praseodymium all go into solution in the HPAL process, and potential exists to selectively recover them through ion exchange at little additional cost, which will be further studied by Ardea.
Expected products	Cobalt sulphate ($CoSO_4.7H_2O$) – battery grade, high purity. Nickel sulphate ($NiSO_4.6H_2O$) – battery grade, high purity. Potential exists to produce other high-purity oxides and sulphates as required for the battery and technology industries, including scandium, rare-earth elements, high-purity alumina and manganese. There is also potential for gold from underlying/adjacent primary gold mineralisation.

Mineral inventory

GNCP mineral resources (as at 14 March 2018) Ardea 100%:

Resource category	Tonnes (Mt)	Co (%)	Ni (%)
Measured	10.3	0.10	0.98
Indicated	105.0	0.07	0.72
Inferred	100.3	0.05	0.67
Total	**215.6**	**0.06**	**0.71**
Contained (kt)		**131**	**1,522**

GNCP ore reserves (as at 28 March 2018) Ardea 100%:

Reserve category	Tonnes (Mt)	Co (%)	Ni (%)
Proved	9.0	0.10	0.96
Probable	31.2	0.09	0.78
Total	**40.1**	**0.09**	**0.82**
Contained (kt)		**36**	**329**

Stage of development

Pre-feasibility study completed in March 2018 and expansion study completed in July 2018.

Feasibility study underway. All Goongarrie resources and reserves are on granted mining leases with a native title agreement in place.

Nearby borefields with quality suited to reverse osmosis.

Environmental reports finalised and ready for statutory approvals submission once the scale of operation and final products settled.

Expected production

Expected annual production (post ramp-up average):

- Ore mined and processed: 2.25 Mtpa
- Cobalt sulphate: 10,000 tpa
- Nickel sulphate: 81,000 tpa

Infrastructure

Kalgoorlie in Western Australia offers world-class infrastructure in an established mining district. Located on the Goldfields Highway 80 km north of Kalgoorlie, with railway, powerlines and gas pipeline nearby.

Project development capital costs

US$918m pre-production start-up capital cost; 2.25 Mtpa expansion case for production of battery sulphate crystals.

Capital expenditure can be reduced by approximately 20% for a mixed sulphide product only.

Project economics

Expansion case:	2.25 Mtpa
Unleveraged post-tax $NPV_{8\%}$:	US$1.805bn
Post-tax IRR:	27%
Payback:	5.1 years
NPV/capital expenditure ratio:	1.97:1
Mine life:	25 years; potential to extend from GNCP and KNP resources

Project funding	Ardea is undertaking a strategic partner process coordinated by KPMG to identify a development partner within the LIB and/or EV sector, with 100% offtake available. Virtual data room available for potential partners to review the A$50m of project data.
Other	ardearesources.com.au Andrew Penkethman, Managing Director and Chief Executive Officer Phone: +61 8 6244 5136 Email: apenkethman@ardearesources.com.au

Image courtesy of Cobalt Blue Holdings Ltd

CRITICAL MINERAL(S)	COBALT NSW
PROJECT NAME	**BROKEN HILL COBALT PROJECT**
Location	Located 23 km west of Broken Hill, New South Wales.
Company name	**Cobalt Blue Holdings Ltd**
Company ownership	ASX-listed **(COB)** Broken Hill Cobalt Project (100% COB) Major shareholders: • management/insiders (8.0%) • Broken Hill Prospecting (5.6%) • LG International (5.0%).
Project description	The Broken Hill Cobalt Project includes the development of an open-cut mining operation, downstream ore processing and a refinery to produce cobalt sulphate (suitable as a battery cathode precursor) and elemental sulphur. It is expected that the life span of the mine and processing operations will be at least 20 years. Cobalt Blue has confirmed that the cobalt is locked inside the pyrite mineral. The company has subsequently developed and patented a tailored metallurgical process with the following characteristics: • high cobalt recoveries • no sulphur dioxide emissions • produces high-quality cobalt sulphate and high-purity elemental sulphur • relatively low capital and operational costs compared to other processing methods.
Expected products	$CoSO_4.7H_2O$ (cobalt sulphate heptahydrate). S (elemental sulphur).
Mineral inventory	Mineral resources (as at July 2020):

Resource category	Tonnes (Mt)	Co (ppm)	S (%)	CoEq (ppm)
Measured	18	928	9.9	1094
Indicated	64	619	6.7	731
Inferred	40	604	6.9	720
Total	**123**	**660**	**7.3**	**792**
Contained (kt)		**81.4**		

Ore reserve and mining target (as at July 2020):

Resource category	Tonnes (Mt)	Co (ppm)	S (%)	Co mined (kt)
Probable	71.8	710	7.4	
Production Target	97.7	690	7.4	67

Stage of development	Pre-feasibility study (+/- 20-25%) completed in July 2018 and a project update in July 2020. Cobalt Blue undertaking new feasibility study (+/- 10–15%) in 2020 for the Broken Hill Project. The main elements include: • Metallurgical pilot and demonstration plant processing approximately 3,000 t ore to produce several hundred kilograms of $CoSO_4.7H_2O$ and elemental S for user acceptance testing and FS engineering design criteria for plant cost estimation • Project leader in $10m Co-operative Research Centre – project (financially supported by Australian Government). This involves research with UNSW, ANSTO, and ANERGY to optimise calcine, leach and recovery stages at the demonstration plant • participation in the Future Battery Industries CRC (FBICRC), to help develop NMC batteries using raw materials from Australian producers. The FBICRC includes A$25m support from the Australian Government. Contributions from sixty partners has resulted in a total budget of $130 million over five years • An ore reserve update • A NSW Significant Development Approval application • Waste, power and water optimisation studies Cobalt Blue aims to complete the feasibility study by the end of 2002/23.
Expected production	Average annual production post ramp-up of: • Ore mined and processed ~5–6.5 Mtpa • Co (metal in sulphate) ~3,500 tpa • S (elemental sulphur) ~300,000 tpa
Infrastructure	The Broken Hill Cobalt Project is located 23 km to the west of Broken Hill, an established mining community. The project site is located adjacent to the Barrier Highway and a rail line that extends to Port Adelaide for domestic/international shipping. Power and water supplies are available in Broken Hill for connection to site.
Project development capital costs	Project Update 2020: Pre-production capex of A$560m (includes A$70m contingencies)
Project economics	Project update 2020: based on production target (including nickel) NPV (pre-tax) at 7.5% discount rate = A$861M, pre-tax IRR = 22.8% NPV (post-tax) at 7.5% discount rate = A$554M, post-tax IRR = 18.9% Project payback (simple) = 4.5 years C1 cash cost (Co US$/lb) = US$10.34/lb All in sustaining costs = US$12.13/lb Assumptions: LT Co US$27.50/lb, LT S US$145/t, FX 0.7
Project funding	Cobalt Blue is seeking potential partners to take equity, offtake, or debt interest in the project. Advanced discussions are expected with identified parties as the demonstration plant comes into operation and the feasibility study nears completion in 2021–22.
Other	cobaltblueholdings.com PFS announcement (4 July 2018) Business update (31 March 2020) 1H 2020 company presentation (4 May 2020)

Image courtesy of Ardea Resources Ltd

CRITICAL MINERAL(S)	COBALT WA
PROJECT NAME	**NIWEST**
Location	The project area is located approximately 250 km north of Kalgoorlie in the North Eastern Goldfields of Western Australia.
Company name	**GME Resources Limited**
Company ownership	ASX-listed **(GME)** and owns 100% of the NiWest Project.
Project description	Eight shallow nickel-cobalt laterite deposits, each up to several kilometres long and 750 m wide, with typical thicknesses of 5–30 m. Conventional open-pit mining at a low projected strip ratio of 2.0:1. Heap leach processing followed by highly efficient direct solvent extraction. Initial 27-year operating life at a nameplate processing capacity of 2.4 Mtpa, based on mining of three (Mt Kilkenny, Eucalyptus and Hepi) deposits only. Total life-of-mine production of 456 kt nickel (in nickel sulphate) and 31.4 kt cobalt (in cobalt sulphate). Average annual production of 19.2 kt nickel and 1.4 kt cobalt over the first 15 years.
Expected products	Nickel sulphate hexahydrate ($NiSO_4 \cdot 6H_2O$). Cobalt sulphate heptahydrate ($CoSO_4 \cdot 7H_2O$). The targeted content of nickel and cobalt metal in the sulphate form is extremely high purity at approximately 99.95% and >99.9% by mass, respectively.
Mineral inventory	Mineral resources at 0.8% nickel cut-off grade (as at 14 June 2020):

Resource category	Tonnes (Mt)	Nickel (%)	Cobalt (%)
Measured	15.2	1.08	0.064
Indicated	50.4	1.04	0.068
Inferred	19.5	0.95	0.057
Total	**85.2**	**1.03**	**0.065**
Contained (kt)		**878**	**55.4**

Ore reserves at 0.5% nickel cut-off grade (as at 14 June 2020):

Reserve category	Tonnes (Mt)	Nickel (%)	Cobalt (%)
Proved	0.0	0.00	0.00
Probable	64.9	0.91	0.06
Total	**64.9**	**0.91**	**0.06**
Contained (kt)		**592**	**38**

Stage of development	Pre-feasibility study completed in August 2018. The study presents a standalone development pathway for the NiWest Project that incorporates detailed consideration of: • results from metallurgical test work and engineering conducted on the NiWest Project by GME over a five-year period • a review of the various studies conducted by other nickel-cobalt laterite industry participants and the history of underperforming/failed high-pressure acid leach laterite nickel developments over the past 20 years

Stage of development	• a review of the nickel and cobalt supply/demand outlooks, including the emerging battery raw materials demand from the EV market. An environmental baseline study at the proposed Mt Kilkenny mining and processing area, Hepi mining area, Waite Kauri deposit and a haul road alignment was completed in March 2019. The results were consistent with previous surveys and did not identify any material issues of concern.
Expected production	Expected annual production over the first 15 years: • Ore mined: 3.6 Mtpa • Ore processed: 2.4 Mtpa • Nickel sulphate: 86 ktpa • Cobalt sulphate: 6.7 ktpa • Contained nickel: 19.2 ktpa • Contained cobalt: 1.4 ktpa
Infrastructure	The project area has a 20-year history of nickel and cobalt mining operations at the nearby Murrin Murrin operation. The regional rail infrastructure extends to the Malcolm siding near Leonora. An existing commercial airstrip is located at Leonora. Sulphuric acid demand requirements are planned to be met by a sulphur-burning acid plant. All requisite site power and steam demand is expected to be met by the acid plant operation. Major imported consumables and final saleable products are expected to be shipped via the Esperance Port facility and trucked to and from site via existing roads.
Project development capital costs	Pre-production capital expenditure estimate of A$966m, representing a globally attractive pre-production capital intensity of sub-US$20 per pound of average annual nickel production. Forecast project construction period is 24 months from final investment decision. The forecast commissioning and plant ramp-up phase extends for approximately 20 months from completion of the project construction.
Project economics	Key results from the August 2018 pre-feasibility study* include: • ungeared post-tax $NPV_{8\%}$ of A$791m and internal rate of return of 16.2% (equivalent pre-tax values of A$1,390m and 21.2%, respectively). Payback period (pre-tax) of 4.4 years. • project free cash flow (post all capital expenditure and tax) of A$3,342m. • average life-of-mine cash unit operating cost (post royalties and cobalt credits) of US$3.24/lb contained nickel. All-in sustaining cost, inclusive of all sustaining capital expenditure, of US$3.68/lb contained nickel. *Assumptions include life-of-mine price estimates of US$8/lb nickel (includes US$0.75/lb sulphate premium) and US$25/lb cobalt (zero sulphate premium). AUD:USD assumption of 0.75.
Project funding	The company welcomes discussion regarding joint venture participation in the project, and financing of the project construction or offtake. Of the forecast nickel and cobalt sulphate production from the NiWest Project, 100% remains uncommitted.
Other	gmeresources.com.au

CRITICAL MINERAL(S)	COBALT WA
PROJECT NAME	**MT THIRSTY**
Location	Norseman, Western Australia.
Company name	**Mt Thirsty Joint Venture**
Company ownership	Conico Ltd **(ASX:CNJ, 50%)**, Barra Resources Ltd **(ASX:BAR, 50%)**
Project description	The Mt Thirsty Cobalt-Nickel Project is an advanced, high-grade, low capital expenditure, sustainable source of cobalt and nickel located in the mining jurisdiction of Western Australia. Mining will be by conventional open-pit over a 12-year initial mine life. Extensive test work has demonstrated that the metal can be leached at atmospheric pressure using sulphur dioxide as the main reagent, which is a key competitive advantage to higher capital expenditure, high-pressure acid leaching projects. An onsite processing plant will produce an intermediary mixed sulphide product (MSP), which will be dried, loaded into bulka bags and trucked in shipping containers to Australian end users or exported via anyone to several container ports in Western Australia.
Expected products	An MSP has been strategically selected, because not only does it suit the metallurgical process, but it is also targeted to attract interest from global firms looking to secure a sustainable source of cobalt for further downstream refining for metal, chemical and battery markets. Product offtake is therefore reserved and 100% available for the future mine development partner. The MSP is especially rich in cobalt at 43% of the payable metals by mass, and due to the higher price that cobalt attracts over nickel, cobalt accounts for 71% of the projected project revenue. There is also the potential to produce a manganese by-product, which is not included in the pre-feasibility study financials.
Mineral inventory	Mineral resources (as at 30 June 2020):

Resource category	Dry tonnes (Mt)	Cobalt (%)	Nickel (%)	Manganese (ppm)
Indicated (main)	22.8	0.121	0.53	0.79
Inferred (main)	2.5	0.103	0.45	0.66
Inferred (north)	1.5	0.092	0.55	0.48
Total	**26.9**	**0.117**	**0.52**	**0.76**
Contained (kt)		**31.5**	**140**	**204**

Ore reserves (as at 30 June 2020):

Reserve category	Dry tonnes (Mt)	Cobalt (%)	Nickel (%)	Manganese (ppm)
Probable	18.8	0.126	0.54	0.80
Contained (kt)		**23.7**	**102**	**150**

Stage of development	• Pre-feasibility study completed in March 2020. • Baseline biological surveys completed. • Native title negotiations with the Ngadju Traditional Owners are at an advanced stage. • The next stage of engineering development will be determined by the future development/offtake partner for the project.
Expected production	Expected annual production (LOM average dry tonnes): • Ore mined and processed: 1.8 Mtpa • Mine life: 12 years • Concentrate: 5–10 ktpa • Contained cobalt: 1.6 ktpa • Contained nickel: 2.1 ktpa Metal production is significantly higher in the early years.
Infrastructure	The project benefits from its location only 16 km north-west from the mining town of Norseman and only 4 km from Highway 1, an infrastructure corridor with road, rail, gas, power, water and fibre-optic cables. The export quantities will be 1–2 shipping containers of high-value product per day, which can be easily handled by any of several container ports.
Project development capital costs	• Direct capital expenditure: A$277m • Indirect capital expenditure: A$31m • Growth allowance (9%): A$28m • Contingency (10%): A$33m • Owner's costs (4%): A$13m • Total capital expenditure: A$371m
Project economics	All-in sustaining cost (AISC): US$35,400/t cobalt metal price. NPV (pre-tax 8%): A$44m Material assumptions: Forex 0.67, Co Price US$61,000/t, Ni Price US$17,850/t, Co payability 80%, Ni payability 85%. Post-tax NPV A$25.7m. Refer to ASX announcement (see below) for full details. AISC is before amortisation and after nickel co-product credits.
Project funding	The project is available for investment from downstream partners, either as an outright sale or as a development farm-in in exchange for the 100% offtake rights.
Other	barraresources.com.au conico.com.au PFS executive summary ASX 20 March 2020

CRITICAL MINERAL(S)	COBALT SA
PROJECT NAME	**KALKAROO**
Location	Located in north-eastern South Australia, near Broken Hill.
Company name	**Havilah Resources Limited**
Company ownership	ASX-listed **(HAV)** Havilah owns 100% of the Kalkaroo copper-gold-cobalt deposit.
Project description	Kalkaroo is the largest undeveloped open-pit copper-gold deposit in Australia on a CuEq ore reserve basis, with a 0.74% CuEq grade. The primary sulphide deposit comprises structurally controlled replacement style strata bound chalcopyrite/pyrite mineralisation that is amenable to standard sulphide flotation. The deposit is over 3 km long and 40–80 m thick, with minimal internal waste. At the top of the deposit there are 50–60 m thick, oxidised, supergene-enriched gold and native copper ore zones that can be treated by a conventional gravity and carbon-in-pulp (CIP) plant. This oxide gold cap resource of 21.7 Mt at 0.74 g/t Au is included in the overall mineral resource. Mining will be by open-pit methods to potentially >200 m depth, with the top 120–140 m being free dig. Kalkaroo is open in all directions and there is substantial near-mine exploration potential.
Expected products	Main products are gold doré from CIP, native copper (near pure copper metal) via gravity concentration and copper-sulphide concentrates from a copper flotation circuit. By-product pyrite concentrate, recovered by cleaning of the copper concentrate tails, contains appreciable cobalt and gold. The most economical means of recovering cobalt is the subject of ongoing study both for Kalkaroo and the nearby Mutooroo copper-cobalt-gold deposit also wholly owned by Havilah. Kalkaroo also contains appreciable rare-earth elements and molybdenum, and studies are currently investigating recovery of these by-product metals.
Mineral inventory	JORC Mineral Resources as at 31 July 2019 (Havilah 2019 Annual Report):

Resource category	Tonnes (Mt)	Cobalt (%)	Copper (%)	Gold (g/t)
Cobalt (note: cobalt resource is not added to the total tonnage)				
Inferred	193.3	0.012		
Total	**193.3**	**0.012**		
Copper-gold (Oxide gold cap + sulphide copper-gold)				
Measured	97.6		0.50	0.47
Indicated	34.9		0.39	0.41
Inferred	113.0		0.42	0.33
Total	**245.5**		**0.45**	**0.40**
Contained (kt Co and Cu, koz Au)		**23.2**	**1,097**	**3,105**

Note: Numbers in tables are rounded.

Havilah's total cobalt metal inventory stands at 43.4 kt, including the nearby wholly owned Mutooroo copper-cobalt-gold project (12.53 Mt of 1.53% Cu, 0.16% Co and 0.20 g/t Au in sulphide JORC resources).

<table>
<tr><td>Mineral inventory</td><td>JORC Ore Reserves as at 31 July 2019 (Havilah 2019 Annual Report):

<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Copper (%)</th><th>Gold (g/t)</th></tr><tr><td>Proved</td><td>90.2</td><td>0.48</td><td>0.44</td></tr><tr><td>Probable</td><td>9.9</td><td>0.45</td><td>0.39</td></tr><tr><td>Total</td><td>100.1</td><td>0.47</td><td>0.44</td></tr><tr><td>Contained (kt Cu, koz Au)</td><td></td><td>474</td><td>1,407</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>The June 2019 pre-feasibility study (PFS) supports a large-scale open-pit copper-gold mine. Havilah is presently updating the PFS with improved gold recoveries based on new metallurgy test work, revised mining plans, updated metal prices and realising value for the cobalt-rich pyrite concentrates. The option of a lower capital expenditure start-up gold mine, to exploit the oxide gold cap, is also being investigated.

Havilah has secured mining leases over the deposit and owns 100% of the surrounding exploration licences. It also owns the Kalkaroo pastoral property in order to avoid any land use conflicts.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):

• Ore mined and processed: 11 Mtpa

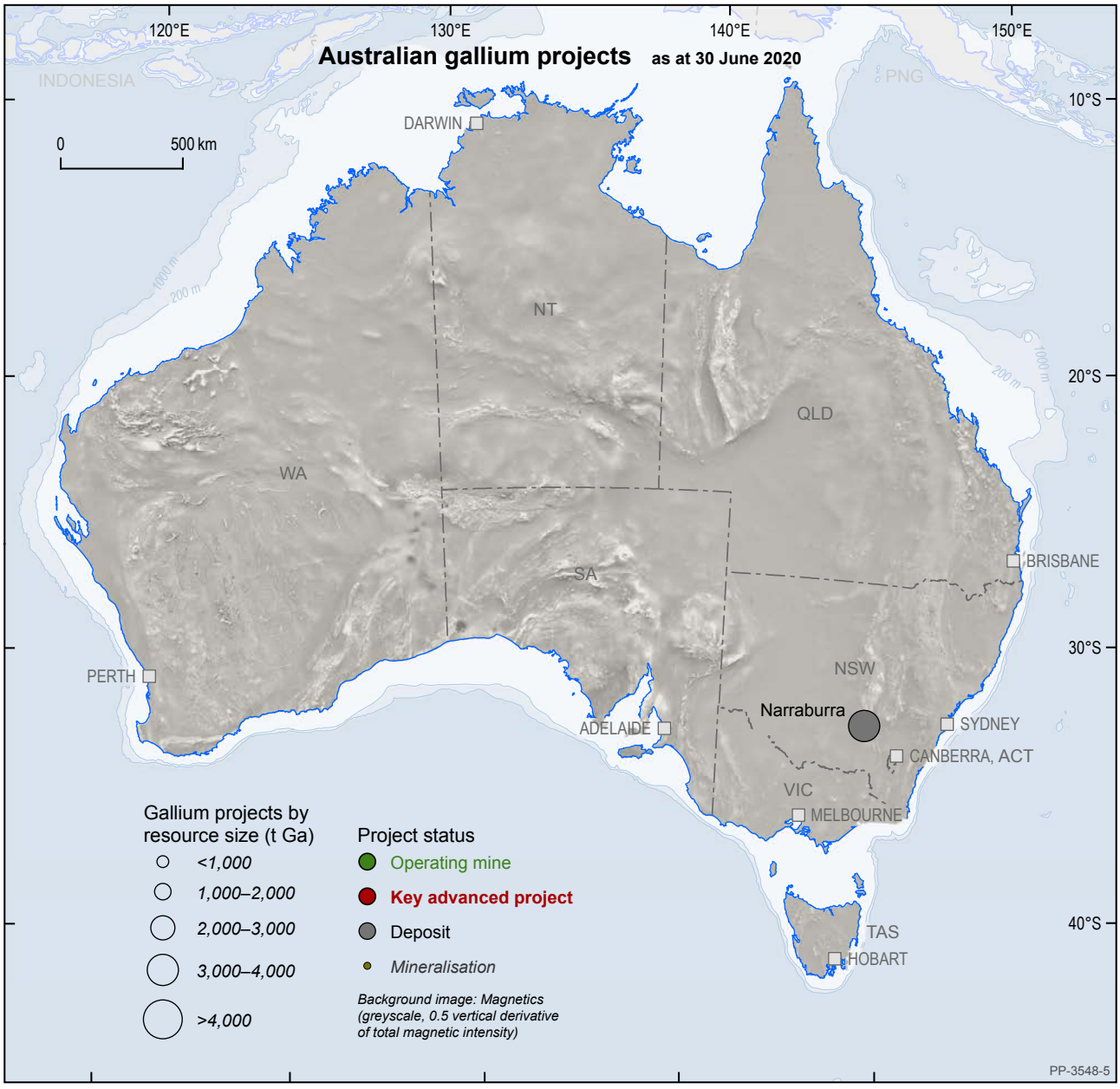
• Copper (metal and in concentrate): 30,000 tpa

• Gold (metal and in concentrate): 72,000 Oz pa

• Cobalt (in pyrite concentrates): ~500 tpa

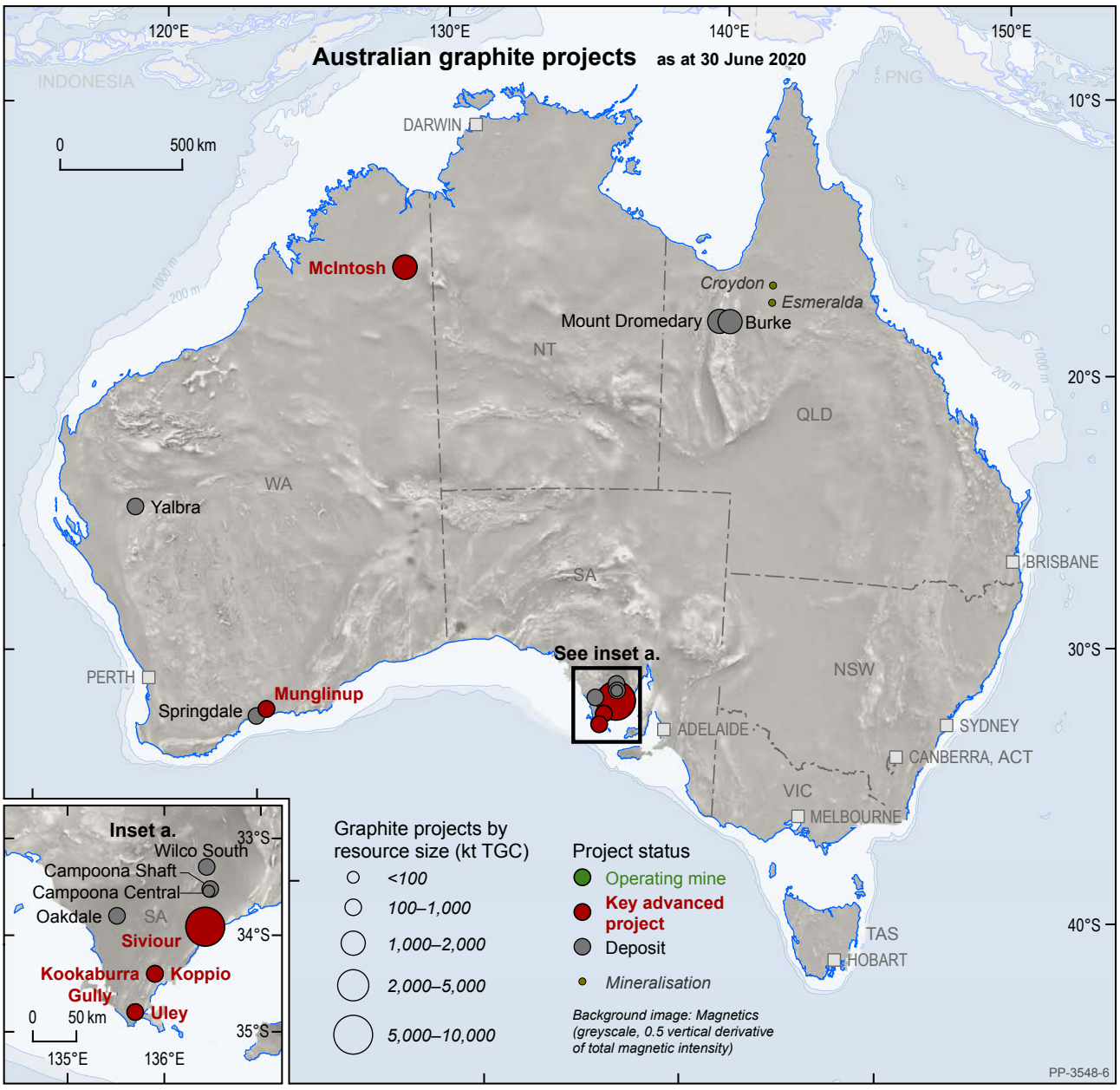
The oxide plant (4 Mtpa) will produce gold bullion and copper metal, and the sulphide plant (7 Mtpa) will produce approximately 100,000 tpa of copper-gold concentrates and 150,000 tpa of pyrite concentrates over a 13-year production period. The copper-gold concentrates are estimated to contain 26–29% copper and 10–16 g/t gold, while the pyrite concentrate contains 0.29–0.34% cobalt, 2.5-3.6 g/t gold and 1% copper.</td></tr>
<tr><td>Infrastructure</td><td>The deposit lies 50 km north of the transcontinental railway line and Barrier Highway, just over one-hour drive west-north-west of the regional mining centre of Broken Hill. Grid power comes within 8 km of Kalkaroo. Havilah owns the land on which the Kalkaroo deposit is located and has a regional exploration base camp nearby.</td></tr>
<tr><td>Project development capital costs</td><td>Estimated pre-production capital expenditure of A$332m including mining fleet of A$76m and a contingency of A$46m.</td></tr>
<tr><td>Project economics</td><td>2019 PFS results, based on recovery of copper and gold only, include: estimated pre-tax $NPV_{7.5\%}$ of A$564m and IRR 26% at US$2.89/lb Cu, US$1,200/oz Au, AUD:USD $0.75. Estimated C1 cost of US$1.67/lb Cu.</td></tr>
<tr><td>Project funding</td><td>Havilah is seeking a major investment funding partner to assist in the financing and development of the project. Discussion is welcomed with interested parties who have the financial capability.</td></tr>
<tr><td>Other</td><td>Key upside potential: improved gold recoveries; additional revenue from recovery of cobalt, rare-earth elements and molybdenum; resource expansion; near mine discoveries; and improved metal prices against those used in PFS. For more Kalkaroo project information, refer to havilah-resources-projects.com/kalkaroo</td></tr>
</table>

Gallium (Ga)



No advanced gallium projects in Australia.

Graphite (C)



Advanced graphite projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Graphite	**Siviour**	Renascor Resources Ltd	FS	Graphite	87.4	7.50	%	TGC	6,600	70
Graphite	**Munglinup**	Mineral Commodities Ltd	FS	Graphite	8.0	12.20	%	TGC	975	72
Graphite	**Uley**	Quantum Graphite Ltd	Care and maint	Graphite	6.3	11.10	%	TGC	697	74
Graphite	**Kookaburra Gully**	Lincoln Minerals Ltd	FS	Graphite	2.0	15.20	%	TGC	309	76
Graphite	**McIntosh**	Hexagon Energy Materials	PFS	Graphite	23.8	4.45	%	TGC	1,060	78

CRITICAL MINERAL(S)	GRAPHITE SA
PROJECT NAME	**SIVIOUR**
Location	Located on South Australia's Eyre Peninsula, approximately 15 km west of Arno Bay and 120 km north-east of Port Lincoln.
Company name	**Renascor Resources Ltd**
Company ownership	ASX-listed **(RNU)** Major shareholdings: Clarke family 11%, directors 9%. Renascor, through its wholly owned subsidiary Ausmin Development Pty Ltd (Ausmin), owns a 100% interest in Siviour.
Project description	The Siviour Graphite Project is Australia's largest graphite project and has one of the largest graphite reserves in the world. The project consists of an open-pit mine and concentrator producing graphite concentrate with 94–96% total graphitic carbon (TGC). Siviour's low operating cost is due in large part to shallow, horizontal orientation of a single massive ore body that offers comparatively low mining costs. Metallurgical testing has established the ability to produce high-quality graphite products at low operating cost using conventional flotation. During Stage 1 of the Siviour Project, 825 ktpa ore will be mined and processed to produce an average of 80 ktpa graphite concentrate for four years, which will be transported by road to Port Adelaide for export. In Year 5, Stage 2 of the project will expand Siviour's production to 1,650 ktpa mined and processed to produce an average of 115 ktpa graphite concentrate for the remainder of the 40-year mine life. Renascor also plans to build a battery anode material manufacturing facility, proposed to be located at Port Adelaide, to convert graphite concentrate into high-value purified spherical graphite (PSG) for the lithium-ion battery (LIB) supply market. A pre-feasibility study on producing PSG was completed in January 2019. The company is currently producing PSG for customer sample purposes and is undertaking advanced technical studies on an integrated mine and PSG production operation. Being located in a stable OECD jurisdiction presents a source of LIB raw materials for global battery and electric vehicle manufacturers that is diversified outside of China.
Expected products	Graphite flake fractions (94–96% TGC).
Mineral inventory	Mineral resources (as at April 2019):

Resource category	Tonnes (Mt)	TGC (%)
Measured	15.8	8.8
Indicated	39.5	7.2
Inferred	32.1	7.2
Total	**87.4**	**7.5**
Contained (kt)		**6,600**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at March 2019):<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr><tr><td>Probable</td><td>45.2</td><td>7.9</td></tr><tr><td>Contained (kt)</td><td></td><td>3,571</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>Siviour Graphite Project feasibility study completed in November 2019.

Anode material spherical plant pre-feasibility study completed February 2019.

Mineral lease granted in April 2019.

Program for Environment Protection and Rehabilitation (PEPR) to be submitted in 2020.

In-principle project finance support from Dutch and Australian export credit agencies secured in April 2019 and March 2020 respectively.

Offtake and financing negotiations to be completed in 2020.</td></tr>
<tr><td>Expected production</td><td>Expected annual production:<table><tr><th></th><th>Stage 1</th><th>Stage 2</th></tr><tr><td>Ore mined and processed:</td><td>825 ktpa</td><td>1,650 ktpa</td></tr><tr><td>Graphite concentrate (94–96% TGC):</td><td>80 ktpa</td><td>115 ktpa</td></tr><tr><td>Anode material facility PSG production:</td><td>30 ktpa</td><td>30 ktpa</td></tr></table></td></tr>
<tr><td>Infrastructure</td><td>Siviour is located near a range of infrastructure on the Eyre Peninsula, which further underpins project economics, including roads, grid power, and townships for sourcing of materials, services and labour.</td></tr>
<tr><td>Project development capital costs</td><td>Stage 1 pre-production capital expenditure of A$118m, including A$4m mining pre-strip.

Stage 2 expansion capital expenditure of A$77m at year five planned to be funded out of project cash flows.</td></tr>
<tr><td>Project economics</td><td>The November 2019 feasibility study on the Siviour Graphite Project, based on a concentrate operation only (no PSG production), delivered a post-tax $NPV_{10\%}$ of A$388m, post-tax IRR of 33% and an average EBITDA of A$83m.

Pre-feasibility study on the anode material facility producing purified spherical graphite delivered a post-tax $NPV_{10\%}$ of A$487m, post-tax IRR of 69% and an average EBITDA of A$79m.</td></tr>
<tr><td>Project funding</td><td>Renascor intends to finance the project through a combination of debt and equity. Renascor has secured in-principle export credit agency coverage, which is expected to assist with debt financing.</td></tr>
<tr><td>Other</td><td>Company website: renascor.com.au/

Feasibility study results: asx.com.au/asxpdf/20191111/pdf/44bfswj9ztw100.pdf

Pre-feasibility study results: asx.com.au/asxpdf/20190221/pdf/442tds94fc2vg0.pdf</td></tr>
</table>

CRITICAL MINERAL(S)	GRAPHITE WA
PROJECT NAME	**MUNGLINUP**
Location	Located 640 km south-east by road of Perth, 4 km north of the township of Munglinup on the South Coast Highway, 107 km west of Esperance and 81 km east of Ravensthorpe in Western Australia.
Company name	**Mineral Commodities Ltd**
Company ownership	ASX-listed **(MRC)** In November 2017, MRC's wholly owned subsidiary MRC Graphite Pty Ltd entered into a joint venture (JV) agreement with Gold Terrace Pty Ltd, to farm-in to the Munglinup Graphite Project. Under the JV agreement, MRC's initial ownership of the Munglinup Project is 51%. Following the completion of the Munglinup Project feasibility study in January 2020, MRC has now met the Stage 2 earn-in requirements under the JV and may now increase its ownership in the project to 90% by paying A$0.8m cash and issuing 30 million ordinary shares to the vendor. The vendor has the right under Stage 3 of the JV to elect that MRC acquires the remaining 10% of the project via one of the following: (a) MRC issuing 10 million ordinary shares; (b) MRC granting the vendor a 1% gross royalty on all minerals produced; or (c) otherwise standard vendor contribution or watering down provisions to apply. MRC also owns the Skaland graphite mine in Norway and the Tormin mineral sands mine in South Africa.
Project description	The Munglinup Graphite Project is free-dig, conventional truck and excavator, open-pit mining of high-grade graphite mineralisation, located within a granted mining lease. The resource is open at depth and along strike. ROM ore is processed through a relatively conventional, multi-stage milling and flotation process to produce high-grade graphite concentrates across a range of flake sizes over a 14-year mine life. Graphite concentrates will be trucked to the Port of Fremantle and shipped to export markets. MRC is working with partners, including CSIRO and Doral Fused Materials, under a Cooperative Research Centres Project (CRC-P) to develop a non-hydrofluoric acid purification process that could produce high-purity value-added products from Munglinup concentrate ('Munglinup Downstream Project'), targeting production of battery anode materials in Kwinana.
Expected products	Flake graphite concentrates (>95% TGC). Conversion of flake graphite concentrates into high-value products, including battery anode materials from Munglinup Downstream Project, is also being studied.
Mineral inventory	Mineral resources (as at 8 January 2020):

Resource category	Tonnes (Mt)	TGC (%)
Indicated	4.5	13.1
Inferred	3.5	11.0
Total	**8.0**	**12.2**
Contained (kt)		**975**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at 8 January 2020):
<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr><tr><td>Probable</td><td>4.2</td><td>12.8</td></tr><tr><td>Contained (kt)</td><td></td><td>543</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>Feasibility study completed in January 2020.

Mining lease granted, native title extinguished on mining reserve and environmental approvals expected in Q3 2020.

Studies to support Munglinup Downstream Project are underway.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (life-of-mine average):

• ROM ore mined and processed: 400–500 ktpa

• Flake graphite concentrate (95% TGC): 52 ktpa</td></tr>
<tr><td>Infrastructure</td><td>Power is proposed to be supplied by a 4.0MW power station supplying power to the plant at 415V. Water is supplied from several production bores that have been pump tested to ensure that the bore field will support the operation.

Project access is via the South Coast Highway. Product will be transported via road train travelling 610 km for delivery to the Port of Fremantle for export.</td></tr>
<tr><td>Project development capital costs</td><td>Total start-up capital cost of US$61m including US$56m project development capital and US$4m pre-strip capital.</td></tr>
<tr><td>Project economics</td><td>January 2020 feasibility study results, based on producing graphite concentrates for export via the Port of Fremantle, include:
<table><tr><td>Project post-tax IRR: 30%</td><td>Post-tax NPV (7%): US$111m</td></tr><tr><td>Post-tax payback period: 2.7 years</td><td>LOM EBITDA: US$426m</td></tr><tr><td>Average annual EBITDA: US$31m</td><td>Operating cost/t(FOB): US$491m</td></tr></table>Additional value creation may be possible from the Munglinup Downstream Project under study.</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussion regarding financing of the project or offtake and seeks a strategic partner for project equity, joint venture or long term offtake arrangements in both the concentrate and downstream businesses.</td></tr>
<tr><td>Other</td><td>Company website: mineralcommodities.com/

Feasibility study results: www.asx.com.au/asxpdf/20200108/pdf/44d43bfrfj3drg.pdf

Contact: Peter Fox, IR and Corporate Development, peter.fox@mncom.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	GRAPHITE SA
PROJECT NAME	**ULEY**
Location	The Uley graphite mine (Uley) is located on the southern tip of the Eyre Peninsula in South Australia, approximately 20 km west-south-west of the deep water port of Port Lincoln, an agricultural and fishing centre with a population of approximately 14,000.
Company name	**Quantum Graphite Ltd**
Company ownership	ASX-listed **(QGL)** The major shareholders are Chimaera Capital Limited and Lycopodium Limited. Board members and interests associated with board members represent approximately 40% of the issued and outstanding share capital holding.
Project description	Uley is recognised as a significant area of graphite mineralisation and one of the largest coarse flake deposits in the world. The graphitic mineralisation at Uley is disseminated high-grade flake style. The Uley graphite mine commenced production in the 1890s, producing over 100,000 tonnes of >90% purity large and extra-large graphite flake, until the mine was closed in the early 1990s. The Uley plant and mine was then placed on care and maintenance. From 2013 to 2015 Valence Industries reprocessed the low-grade ore stockpiles at Uley using the existing processing plant. Valence Industries also obtained environmental permits and completed associated work toward restarting of in-pit mining at Uley. Quantum acquired 100% of the Uley project in 2018 and completed an updated feasibility study on restarting production in 2021. This next stage of development at Uley, which includes pre-stripping of the mine and construction of a new processing plant onsite, is called the Uley 2 Project. Uley flake is characterised by high-quality large flake with very low impurities and proven metallurgical performance with graphite purity exceeding 96% and up to 98% for very large flake. Uley has a history of supplying leading refractory manufacturers in Europe and North Asia and Uley 2 targets a proven customer demand base with excellent knowledge of Uley flake characteristics. Mining at Uley 2 consists of a free-dig, open-cut mining operation with a strip ratio of 4.6:1 utilising local mining and haulage contractors. The first stage of Uley 2 is 12 years with significant expansion to the east, south and west within the existing tenement boundaries. Consistent with historical processing, the Uley 2 process plant will accept run-of-mine ore and liberate graphite particles through crushing and grinding. The flotation and polishing sections will be the critical processing functions for recovering graphite, upgrading the graphite flake to maximise purity, and maintaining coarse flake to the maximum extent possible. Graphite flake product will be packaged into 1,000 kg baffled bulk bags and transported to the Port of Adelaide for export in standard 20 ft and 40 ft shipping containers.
Expected products	Uley 2 production will consist of three main graphite flake products: • +50 mesh – 97.5% purity • +80 mesh – 97% purity • +100 mesh – 96.5% purity.

<table>
<tr><td>Mineral inventory</td><td>Mineral resources (as at 15 July 2019):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr>
<tr><td>Measured</td><td>0.8</td><td>15.60</td></tr>
<tr><td>Indicated</td><td>4.2</td><td>10.40</td></tr>
<tr><td>Inferred</td><td>1.3</td><td>10.50</td></tr>
<tr><td>Total</td><td>6.3</td><td>11.10</td></tr>
<tr><td>Contained (kt)</td><td></td><td>697</td></tr>
</table>
Ore reserves (as at 11 December 2019):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr>
<tr><td>Proved</td><td>0.8</td><td>11.66</td></tr>
<tr><td>Probable</td><td>3.2</td><td>11.95</td></tr>
<tr><td>Total</td><td>4.0</td><td>11.89</td></tr>
<tr><td>Contained (kt)</td><td></td><td>476</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>Uley 2 is fully permitted with all approvals in place pursuant to the Program for Environmental Protection and Rehabilitation (PEPR) dated 24 December 2014. The PEPR covers the Uley 2 mining leases ML5561 and ML5662 that are 100% owned by the company.

The updated feasibility study for Uley 2 has been completed and the company is now seeking offtake agreements to support its project funding for the Uley 2 process plant.</td></tr>
<tr><td>Expected production</td><td>Expected Uley 2 (first stage) annual production:

• Ore mined and processed: 0.5 Mtpa

• Graphite flake: 55–60 ktpa

Subject to market conditions, significant increases in production at minimal capital costs are planned through the adoption of various levels of optimisation identified in the feasibility study.</td></tr>
<tr><td>Infrastructure</td><td>Uley’s proximity to Port Lincoln is a major advantage, delivering a labour force with strong technical skills and excellent infrastructure including town water, grid-connected electricity and sealed roads to port. As an existing mine, Uley’s infrastructure includes a tailings storage facility and plant and equipment facilities.</td></tr>
<tr><td>Project development capital costs</td><td>The Uley 2 capital costs are estimated at US$60m, which will be principally applied to the construction of the new Uley 2 process plant.</td></tr>
<tr><td>Project economics</td><td>For the first stage of Uley 2, the key project economics are:

Total undiscounted cash flow: A$207m

Cost (Av LOM): US$368/dmt

Product price (ex-works): US$919/dmt</td></tr>
<tr><td>Project funding</td><td>The company is currently pursuing various offtake arrangements and seeks to utilise concluded offtake agreements to support the project funding of Uley 2. The company welcomes discussion regarding financing of the project construction or offtake.</td></tr>
<tr><td>Other</td><td>Company website: quantumgraphite.com</td></tr>
</table>

CRITICAL MINERAL(S)	GRAPHITE SA
PROJECT NAME	**KOOKABURRA GULLY**
Location	Located on South Australia's Eyre Peninsula, 35 km north of Port Lincoln.
Company name	**Lincoln Minerals Limited**
Company ownership	ASX-listed **(LML)** Australian ASX-listed company – Chairman James Zhang, Managing Director Johnson Zhang and Non-Executive Directors Kee Saw, Zhuojia (Georgia) Liu and Ruiyu Zhang (CFO). Lincoln has 575 million shares on issue with the top five shareholders owning 57% of the company. The company has no debt and A$1.1 m in cash as at 31 March 2020.
Project description	The Kookaburra Gully Graphite Project is one of the highest-grade graphite projects globally, and has a very low start-up capital cost of A$44m and a production profile suited to world graphite demand and supply volumes. Kookaburra Gully is a well-advanced project with the mineral lease granted and the environmental approvals process commenced. The project has an ore reserve and completed feasibility study based on a processing rate of 250,000 tpa to produce 35,000 tpa graphite flake concentrates on site over a 10-year open-pit mine life. The Kookaburra Graphite Gully Project has significant opportunities for further value enhancement including: • extension of project life beyond 8–10 years • incorporating further value-adding product development, including spherical graphite manufacture for the battery market • potential savings on implementation costs due to conservative design and costings adopted. Exploration upside at Koppio and Kookaburra Gully extended satellite deposits with an inferred mineral resource of 1.9 Mt at 9.8% TGC defined at Koppio.
Expected products	Graphite flake concentrates 94–97% loss on ignition (LOI) with recoveries of 86–92%. Graphite flake concentrate breakdown: >150 µm 10% distribution at +97% LOI +75 µm <150 µm 25% distribution at +97% LOI <75 µm 65% distribution at +95% LOI
Mineral inventory	Mineral resource classification (5% TGC cut-off) (as at 27 November 2017):

Resource category	Tonnes (Mt)	TGC (%)
Measured	0.39	14.9
Indicated	1.08	14.9
Inferred	0.56	16.0
Total	**2.03**	**15.2**
Contained (kt)		**309**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at 27 November 2017):
<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr><tr><td>Probable</td><td>1.3</td><td>14.6</td></tr><tr><td>Contained (kt)</td><td></td><td>196</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>Feasibility study completed in November 2017.

Mineral lease granted.

Program of Environment Protection and Rehabilitation (PEPR) government approval process commenced. Further work on progressing the PEPR is currently on hold due to market conditions.

Freehold land tenure.

No offtake agreements are yet in place.</td></tr>
<tr><td>Expected production</td><td>Expected annual production:

• Ore mined and processed: 0.25 Mtpa

• Graphite flake: 35 ktpa</td></tr>
<tr><td>Infrastructure</td><td>To be undertaken:

• Power demand 1.5 MWh – via grid and/or onsite hybrid renewables;

• Water demand 220 kL/day – via onsite borefield,

• Road – upgrade Pillaworta Road to all-weather road ~8 km, and

• Port – Port Adelaide, with Lucky Bay and Cape Hardy viable in future.</td></tr>
<tr><td>Project development capital costs</td><td>Total start-up capital cost of A$44m:

• A$22m ore processing plant

• A$7m onsite infrastructure, tailings storage facility, roads

• A$10m government approvals, vegetation offset, bond, property purchase

• 20% contingency</td></tr>
<tr><td>Project economics</td><td>Per November 2017 published feasibility study (onsite production of graphite concentrates):

• Pre-tax $NPV_{10\%}$ of A$81m over the life of mine (10 years)

• Internal rate of return of 33%

• Payback period of 3–4 years

• Operating cost of A$705m (US$550m) per tonne concentrate for LOM

The project has a very low A$44m start-up capital expenditure and a low cost per tonne of graphite concentrate produced on a global basis.</td></tr>
<tr><td>Project funding</td><td>To discuss this project or other possible opportunities, please contact the company directly.</td></tr>
<tr><td>Other</td><td>lincolnminerals.com.au

Email: info@lincolnminerals.com.au</td></tr>
</table>

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>GRAPHITE (PGE POTENTIAL) WA</th></tr>
<tr><th>PROJECT NAME</th><th>MCINTOSH</th></tr>
<tr><td>Location</td><td>Located 100 km north of Halls Creek, in the East Kimberley region of Western Australia.</td></tr>
<tr><td>Company name</td><td>Hexagon Energy Materials Ltd</td></tr>
<tr><td>Company ownership</td><td>ASX-listed (HXG)</td></tr>
<tr><td>Project description</td><td>The McIntosh Project, which comprises 16 tenements spanning approximately 550 km^2 in the East Kimberley region of Western Australia, is a large-scale, high-quality flake graphite deposit. JORC Mineral Resources for the project currently stand at 23.8m tonnes (Mt) grading 4.5% total graphite carbon (TGC) for 1.1m contained tonnes (5 April 2019). In addition, there is a significant exploration target comprising 50 to 100 Mt grading between 2.0 and 5.0% TGC.

Hexagon has deliberately focused on verifying the quality of the graphite flake as a driver of commercial value, rather than simply increasing the tonnes. Graphite is an industrial mineral where the focus needs to be on product quality and suitable commercial applications that match the product specifications. Hence much of its work has focused on the downstream transformation into a range of high-purity battery and industrial applications.

In Hexagon's PFS level study (May 2017) the upstream, Stage 1 project was estimated to comprise open-pit mining operations supplying 2.4 Mtpa of graphite ore to a flotation concentrator plant to produce 80–90 ktpa of flake graphite concentrate, exported via the Port of Derby.

In September 2019, declining flake graphite concentrate prices prompted Hexagon to focus more on its downstream Stage 2 graphite transformation, as reported in May 2019, downstream scoping study outcomes. This was based on a standalone operation with graphite precursors that could include McIntosh materials but was not reliant on it. The company expects the flake graphite market to return from surplus to balance in around 2024–25.

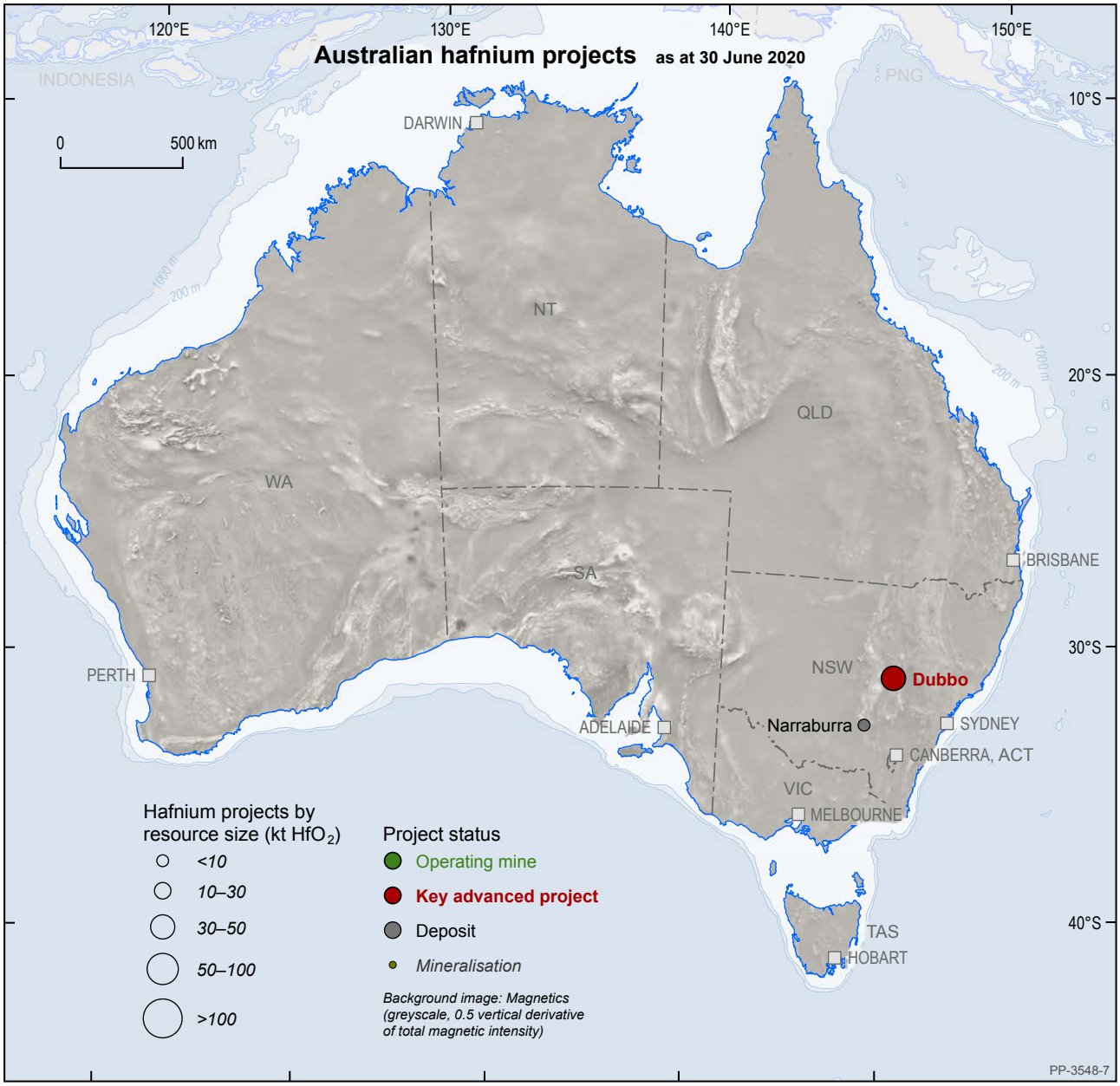
The McIntosh Project is also considered highly prospective for magmatic nickel-copper and PGE deposits. No data compilation or exploration work targeting these types of deposits has been undertaken on this tenement package since around 2005.</td></tr>
<tr><td>Expected products</td><td>Graphite flake concentrates grading 94–98% TGC, sorted to size classifications – Stage 1 upstream.

The downstream Stage 2 project assumed a product suite of approximately 12 distinct, refined, milled and sometimes shaped graphite materials to be used to make expanded graphite, battery anode material, conductivity enhancement materials, ultra-fine powders and precursor for synthetic diamonds, as well as an expanded graphite precursor.</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources (as at May 2017):

<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>TGC (%)</th></tr>
<tr><td>Indicated</td><td>19.2</td><td>4.44</td></tr>
<tr><td>Inferred</td><td>4.6</td><td>4.50</td></tr>
<tr><td>Total</td><td>23.8</td><td>4.45</td></tr>
<tr><td>Contained (kt)</td><td></td><td>1,060</td></tr>
</table>
</td></tr>
</table>

Stage of development	An upstream pre-feasibility study was completed in May 2017. The company submitted mining lease applications in November 2017 but withdrew these in early 2020. Pending an improvement in flake graphite concentrate prices, expected in 2024–25, Hexagon has largely suspended development work for graphite.
Expected production	Expected Stage 1 annual production as per Hexagon's pre-feasibility study completed in May 2017: • Ore mined and processed: 2.4 Mtpa • Graphite concentrate (94–98% TGC): 80–90 ktpa Work undertaken in 2018–19 included additional drilling, which led to the upgrade of the mineral resource and ongoing metallurgical test work. Further metallurgical test work and flow sheet design is required to be able to progress a feasibility study when graphite prices improve.
Infrastructure	The project is within 12 km of the sealed Great Northern Highway. There is also an all-weather haul road traversing the tenements in close proximity to the main graphite deposits, providing useful access to the highway and around the project.
Project development capital costs	Hexagon's pre-feasibility study completed in May 2017 estimated start-up capital costs. However, these are under review due to likely changes to the process flow sheet, costs for capital equipment and the underlying mining inventory.
Project economics	An assessment of the project economics is contained in Hexagon's May 2017 pre-feasibility study announcement. However, this has not been included as it is no longer current due to changes to graphite prices and updated technical information.
Project funding	The company welcomes discussion regarding financing of the project construction or offtake in regard to graphite, or alternatively, exploration joint ventures for the nickel-copper and PGE potential.
Other	hxgenergymaterials.com info@hxgenergymaterials.com

Hafnium (Hf)



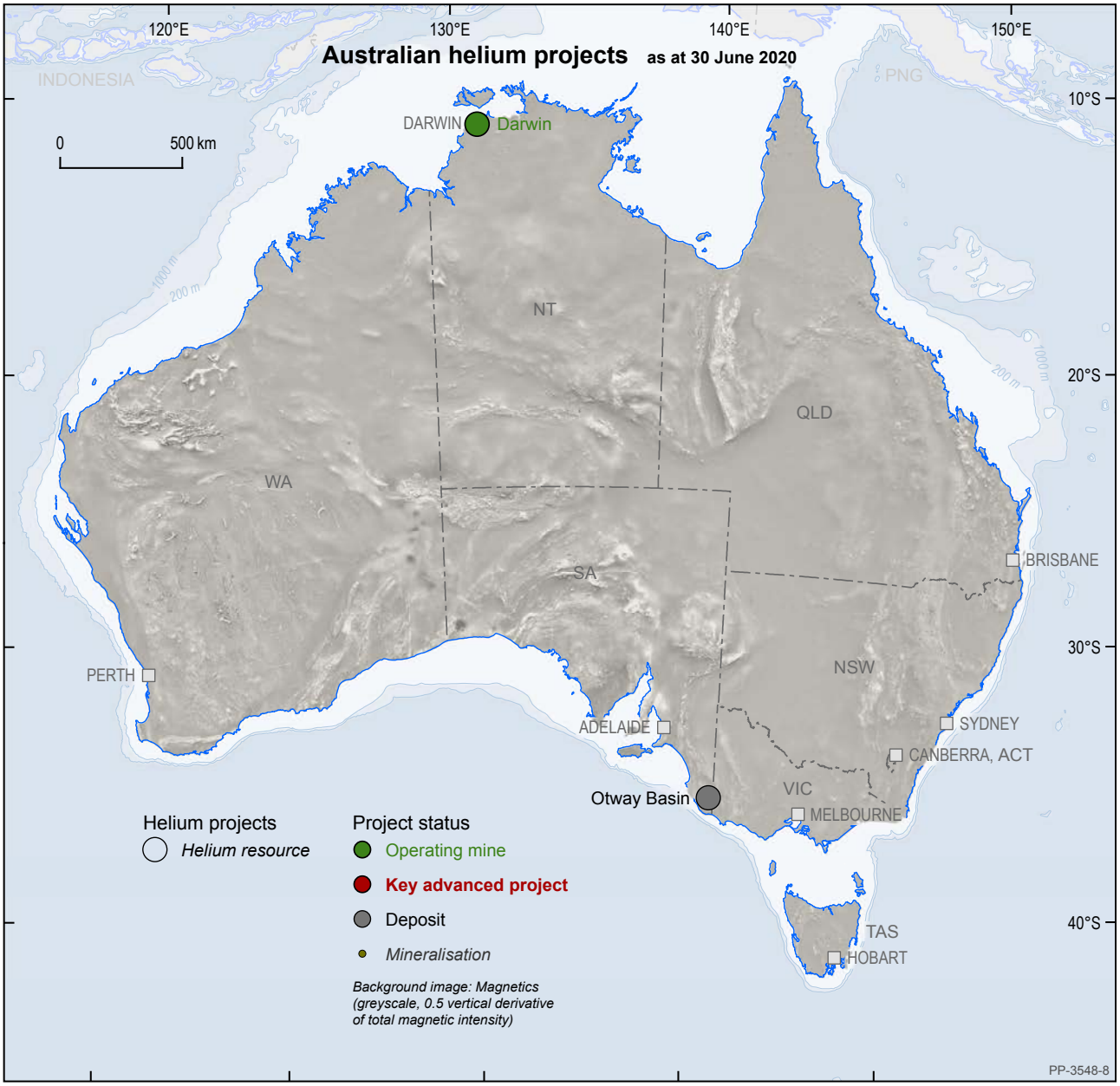
Advanced hafnium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Hafnium	**Dubbo**	Alkane Resources Ltd	Pre-const	Zr, Nb, Hf, Ta, REE	75.2	0.04	%	HfO_2	30	107

Dubbo project summary included in the rare-earth elements section.

Image courtesy of Alkane Resources Ltd

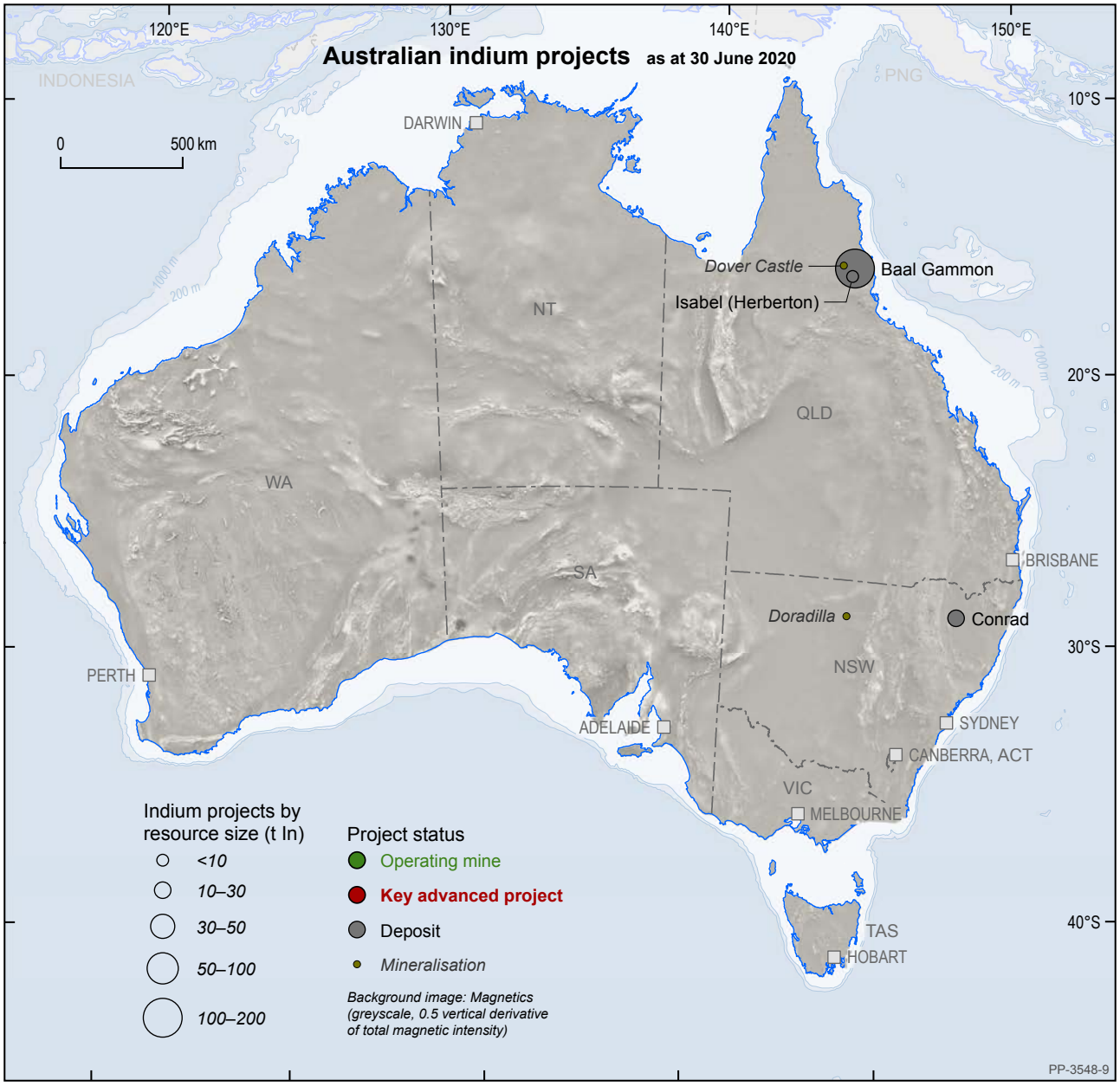
Helium (He)



Advanced helium projects (total mineral resource tonnage, grade and contained mineral)

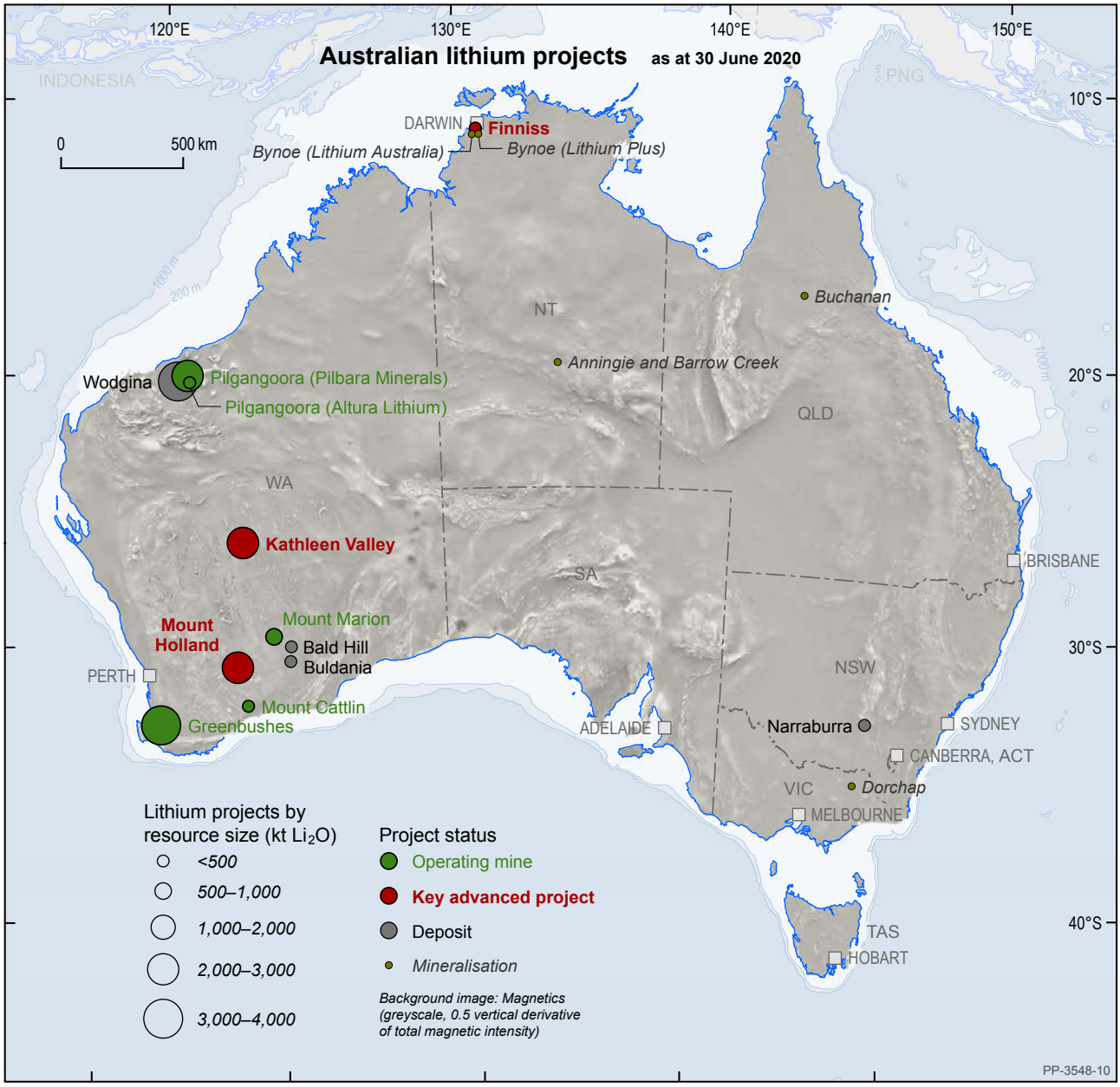
Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Helium	**Darwin**	BOC/ Linde Group	Operating	He					NA	–

Indium (In)



No advanced indium projects in Australia.

Lithium (Li)


Australian lithium projects
as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
Finniss
Bynoe (Lithium Australia)
Bynoe (Lithium Plus)
NT
Buchanan
Anningie and Barrow Creek
Wodgina
Pilgangoora (Pilbara Minerals)
Pilgangoora (Altura Lithium)
QLD
WA
Kathleen Valley
SA
BRISBANE
Mount Holland
Mount Marion
Bald Hill
Buldania
PERTH
NSW
Mount Cattlin
Greenbushes
ADELAIDE
Narraburra
SYDNEY
CANBERRA, ACT
VIC
Dorchap
MELBOURNE
TAS
HOBART
Lithium projects by resource size (kt Li2O)
<500
500–1,000
1,000–2,000
2,000–3,000
3,000–4,000
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics (greyscale, 0.5 vertical derivative of total magnetic intensity)
PP-3548-10

Advanced lithium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Lithium	**Greenbushes**	Talison Lithium Au Pty Ltd	Operating	Li	157.1	2.25	%	Li_2O	3,532	–
Lithium	**Pilgangoora (Pilbara Min)**	Pilbara Minerals Ltd	Operating	Li, Ta	223.2	1.27	%	Li_2O	2,835	–
Lithium	**Mt Marion**	ASX:MIN; Gangfeng Lithium	Operating	Li	72.9	1.37	%	Li_2O	995	–
Lithium	**Pilgangoora (Altura)**	Altura Mining Ltd	Operating	Li	45.7	1.06	%	Li_2O	482	–
Lithium	**Mt Cattlin**	Galaxy Resources Ltd	Operating	Li, Ta	14.6	1.29	%	Li_2O	188	–
Lithium	**Wodgina**	Mineral Resources Ltd	Care and maint	Li, Ta	259.2	1.17	%	Li_2O	3,032	–
Lithium	**Mount Holland**	Wesfarmers Ltd; SQM	FS	Li	189.0	1.50	%	Li_2O	2,843	86
Lithium	**Bald Hill**	Alita Resources Ltd	Care and maint	Li, Ta	26.5	0.96	%	Li_2O	255	–
Lithium	**Finniss**	Core Lithium Ltd	FS	Li	14.7	1.32	%	Li_2O	209	88
Lithium	**Kathleen Valley**	Liontown Resources Ltd	PFS	Li, Ta	156.0	1.40	%	Li_2O	2,184	90

Image courtesy of Liontown Resources Limited

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>LITHIUM WA</th></tr>
<tr><th>PROJECT NAME</th><th>MOUNT HOLLAND LITHIUM PROJECT</th></tr>
<tr><td>Location</td><td>The lithium deposit and proposed mine and concentrator is located approximately 120 km south-south-east of Southern Cross, and 410 km east of Perth in Western Australia. The refinery will be located in the Kwinana Strategic Industrial Area, 40 km south of Perth.</td></tr>
<tr><td>Company name</td><td>Covalent Lithium Pty Ltd</td></tr>
<tr><td>Company ownership</td><td>The Mount Holland Lithium Project is owned 50% by Wesfarmers Lithium Pty Ltd (a wholly owned subsidiary of Wesfarmers Limited) and 50% by SQM Australia Pty Ltd (a wholly owned subsidiary of Sociedad Química y Minera de Chile S.A.) (SQM).</td></tr>
<tr><td>Project description</td><td>The Mount Holland Lithium Project comprises the development of a globally significant lithium operation. The joint venture partners are pursuing:
• development of the lithium deposit to mine spodumene ore
• construction of a concentrator at Mount Holland, capable of processing the ore to produce spodumene concentrate
• construction of a lithium hydroxide refinery in Kwinana to process the concentrate and produce approximately 45,000 tonnes per annum of battery-grade lithium hydroxide.</td></tr>
<tr><td>Expected products</td><td>The Mount Holland Lithium Project will produce spodumene concentrate. This concentrate will then be transported to Kwinana to be refined into value-added battery-grade lithium hydroxide.</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources (as at 19 March 2018):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Li_2O (%)</th></tr>
<tr><td>Measured</td><td>66</td><td>1.58</td></tr>
<tr><td>Indicated</td><td>106</td><td>1.52</td></tr>
<tr><td>Inferred</td><td>17</td><td>1.11</td></tr>
<tr><td>Total</td><td>189</td><td>1.50</td></tr>
<tr><td>Contained Li_2O (kt)</td><td></td><td>2,842</td></tr>
<tr><td>Contained LCE (kt)</td><td></td><td>7,030</td></tr>
</table>
Ore reserves (as at 18 December 2018):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Li_2O (%)</th></tr>
<tr><td>Proved</td><td>54</td><td>1.50</td></tr>
<tr><td>Probable</td><td>40</td><td>1.50</td></tr>
<tr><td>Total</td><td>94</td><td>1.50</td></tr>
<tr><td>Contained Li_2O (kt)</td><td></td><td>1,410</td></tr>
<tr><td>Contained LCE (Mt)</td><td></td><td>3,490</td></tr>
</table></td></tr>
</table>

Stage of development	In November 2019, Covalent Lithium completed a feasibility study on the Mount Holland Lithium Project. The feasibility study confirmed that the project presents a world-class opportunity to develop an integrated large-scale, long-life and high-grade operation in Western Australia. Work is progressing to optimise the project and obtain all necessary approvals. A final investment decision is expected in Q1, CY2021.
Expected production	Expected annual production (post ramp-up average): • Ore mined and processed: 1.7 Mtpa • Concentrate: 350 ktpa • Battery-grade lithium hydroxide: 45,000 tpa
Infrastructure	**Mine:** The mine is located approximately 120 km south of Southern Cross. All of the required infrastructure to support the construction and operation of the project will be purpose built to meet the project requirements. **Refinery:** Covalent Lithium has a lease for 76 ha of area in the Kwinana Industrial Estate. The refinery location has access to well-established infrastructure including logistics (rail, road and port), energy (electricity and natural gas) and chemical reagents and supplies.
Project development capital costs	Confidential information – not for public disclosure.
Project economics	Confidential information – not for public disclosure.
Project funding	The project will be funded by the shareholders from existing/future facilities. No external debt is required to fund the construction of the project.
Other	www.covalentlithium.com

CRITICAL MINERAL(S)	LITHIUM NT
PROJECT NAME	**FINNISS LITHIUM PROJECT**
Location	Located 20 km south of Darwin in the Northern Territory.
Company name	**Core Lithium Ltd**
Company ownership	ASX-listed **(CXO)**
Project description	Core Lithium is developing the construction-ready Finniss Lithium Project, which is now at the front of the line of new global lithium production, developing one of the most capital-efficient and cost-competitive lithium projects in Australia. Core's 2019 feasibility study highlights conventional open-pit mining of high-grade (1.4% Li_2O) ore over an initial 3.5-year mine life, with onsite processing using simple and efficient dense media separation (gravity) producing 175,000 tpa of high-quality 5.5–6% lithium concentrate at competitive operating cost and low A$73m capital expenditure. Located only 25 km from Darwin Port, the Finniss Lithium Project has arguably the best supporting logistics chain to markets in Asia of any Australian lithium project. Finniss project mineral resource upgrade to 14.72 Mt at 1.32% Li_2O was announced in June 2020. The increased portion of indicated and measured resources positions Core well for a material increase in ore reserve classification expected to be completed in June 2020. Mining studies targeting a 7–10 year mine life are also expected to be completed in June 2020 and will be used to update the project feasibility study. Resource drilling is also planned later in 2020, aimed at further extending the Finniss mineral resource and mine life.
Expected products	175,000 tpa of high-quality 5.5–6% Li_2O spodumene concentrate. In addition to the primary spodumene concentrate product, Core is studying commercial production of Fines Lithium (DSO) at approximately 1.2% Li_2O and also Feldspar by-products.
Mineral inventory	Mineral resources (as at 15 June 2020):

Resource category	Tonnes (Mt)	Li_2O (%)
Measured	3.2	1.47
Indicated	4.4	1.37
Inferred	7.1	1.22
Total	**14.72**	**1.32**
Contained (kt)		**209**

Ore reserves (as at 17 April 2019):

Reserve Category	Tonnes (Mt)	Li_2O (%)
Proven	1.0	1.40
Probable	1.2	1.43
Total	**2.2**	**1.41**
Contained (kt)		**32**

<table>
<tr><td>Stage of development</td><td>Finniss project feasibility study completed in April 2019.

Project regulatory approvals received in April 2020 to commence construction and operation of the first lithium project in the Northern Territory. Approvals include the environmental impact statement and mining management plan (MMP).

Binding offtake agreements signed accounting for 50% of planned Finniss production, including:

• 75,000 tpa spodumene concentrate offtake with Szechuan Yahua, one of China's largest lithium producers, signed in 2019

• 50,000 tpa of spodumene concentrate offtake and prepayment term sheet with Transamine, a Swiss-based commodities trading company, signed in May 2020, diversifying end-markets and strengthening channels into Europe.

Discussions continue with other potential offtake partners.

The company has selected preferred lead contractors for various work packages of the Finniss project construction.

Core is well funded through to the final investment decision expected in the next six months. Construction is expected to commence in 2021 and commercial production in 2022.</td></tr>
<tr><td>Expected production</td><td>Average annual production, post ramp-up:

• Ore mined and processed: 0.5–1.1 Mtpa

• Li_2O spodumene concentrate: 175,000 tpa</td></tr>
<tr><td>Infrastructure</td><td>The project has the advantage of close proximity to the capital city infrastructure and stable workforce of the city of Darwin. Available infrastructure includes a sealed road within 1 km of the project, and nearby grid power, gas and rail. The project is only 75 km by road from the Port of Darwin, which is Australia's closest deepwater and bulk commodity export port to East Asia. Darwin Port is fully equipped with existing storage and ship-loading facilities available to Core.</td></tr>
<tr><td>Project development capital costs</td><td>The project has a low start-up capital cost estimate of A$73m, one of Australia's lowest capital intensity lithium mining projects.</td></tr>
<tr><td>Project economics</td><td>Key results from the Finniss Project's April 2019 feasibility study, which will be enhanced with the forthcoming revised feasibility study:

<table>
<tr><th>Key feasibility metric</th><th>April 2019 FS</th><th>Update objectives</th></tr>
<tr><td>Ore reserves</td><td>2.2 Mt</td><td>Significant increase</td></tr>
<tr><td>Project mine-life</td><td>3.5 years</td><td>7–10 year target</td></tr>
<tr><td>Mining method</td><td>Open-pit</td><td>Open-pit & underground</td></tr>
<tr><td>Concentrate product quality</td><td>5.5% Li_2O</td><td>5.8–6% Li_2O</td></tr>
<tr><td>Product recovery</td><td>+70%</td><td>+/- 5%</td></tr>
<tr><td>Start-up capital (CAPEX)</td><td>A$73m</td><td>+/- 5%</td></tr>
<tr><td>C1 operating cost (OPEX)</td><td>US$300/tonne</td><td>1st/2nd quartile</td></tr>
</table>
</td></tr>
<tr><td>Project funding</td><td>Core is planning to approach global debt and equity finance markets with the aim of reaching financial closure and a final investment decision in the next six months. Project finance is expected to include significant contribution from customer finance in the form of pre-payment or similar.

Core Lithium welcomes the opportunity to discuss equity investment opportunities with investors in Australia's next lithium resource.</td></tr>
<tr><td>Other</td><td>corelithium.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	LITHIUM, TANTALUM WA
PROJECT NAME	**KATHLEEN VALLEY**
Location	The Kathleen Valley Project is located in Western Australia, approximately 680 km north-east of Perth and approximately 350 km north-west of Kalgoorlie, within the Eastern Goldfields of the Archaean Yilgarn Craton.
Company name	**Liontown Resources Limited**
Company ownership	ASX-listed **(LTR)** Top 50 shareholders own approximately 52% of company. The main shareholder is Tim Goyder with approximately 18%.
Project description	Kathleen Valley is a wholly owned, Tier-1, hard-rock, lithium-tantalum resource with excellent grade and scale located in an established mining district well serviced by modern transport, energy and social infrastructure. Mining will be via open-pit and underground techniques, with mine life expected to exceed 30 years. An onsite processing plant will produce spodumene (lithium) and tantalum concentrate for exporting overseas or processing locally in WA. The company is also investigating the viability of building its own downstream processing facilities. The mineralisation remains open along strike and at depth with good potential for the resource to be increased.
Expected products	Spodumene concentrate (6% Li_2O). Tantalum concentrate (up to 25% Ta_2O_5).
Mineral inventory	Mineral resources (as at May 2020):

Resource category	Tonnes (Mt)	Li_2O (%)	Ta_2O_5 (ppm)
Measured	20	1.3	140
Indicated	105	1.4	130
Inferred	32	1.3	110
Total	**156**	**1.4**	**130**
Contained (kt)		**2,184**	**20.3**

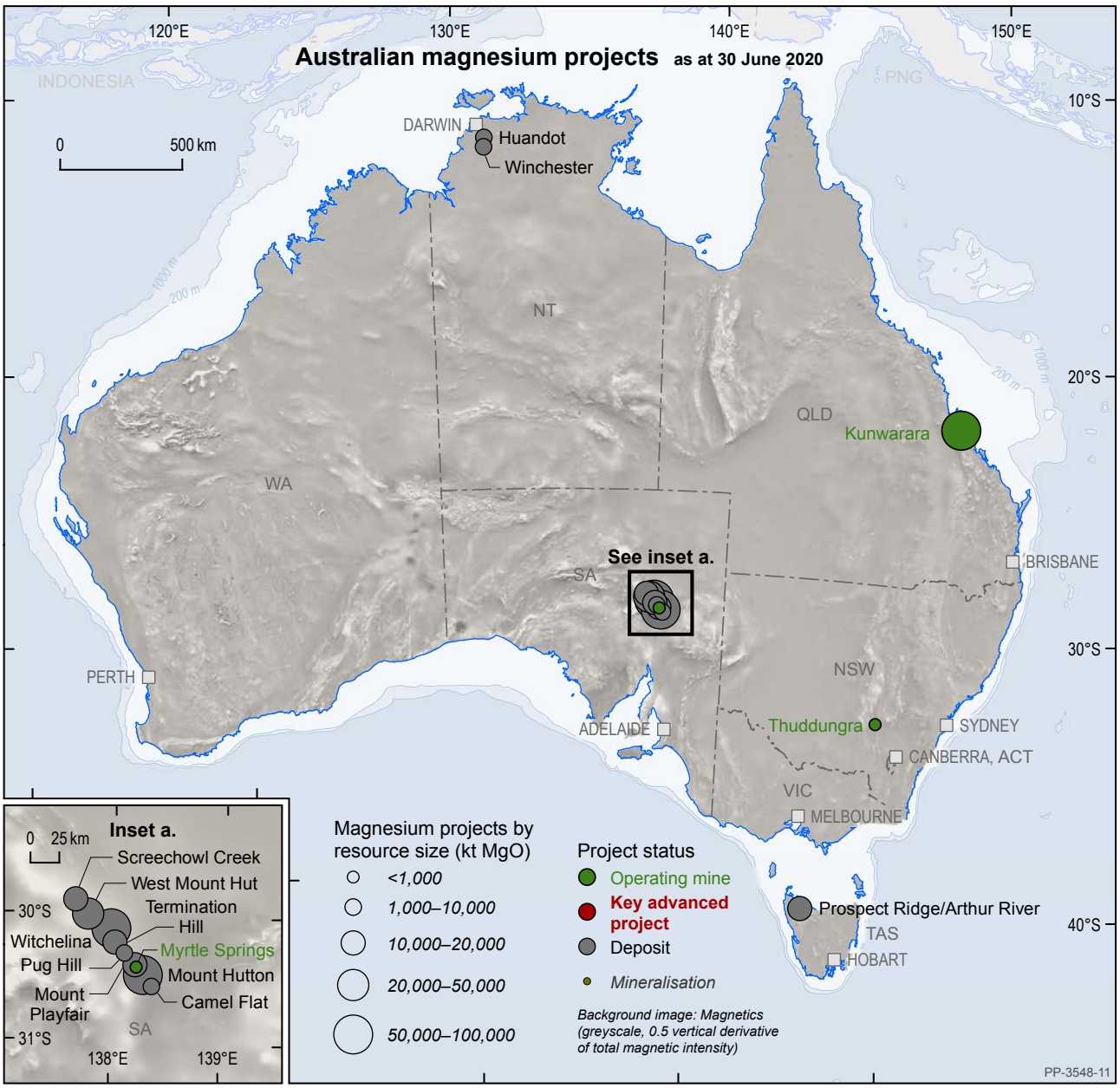
Ore reserves (as at December 2019):

Reserve Category	Tonnes (Mt)	Li_2O (%)
Proved	17.1	1.2
Total	**50.4**	**1.2**
Contained (kt)		**604**

Note: This reserve is based on a mineral resource estimate (MRE) of 74.9 Mt at 1.3% Li_2O released in July 2019.

Stage of development	Pre-feasibility study completed in December 2019. Updated pre-feasibility study based on the May 2020 MRE is in progress and due for completion in early Q4 2020. Mineral resource largely located on approved mining leases. Baseline environmental studies completed with formal environmental and development approvals to be sought once design of the final mine plan and related infrastructure is established. No red flags have been identified. Discussions with traditional owners are ongoing. Project is currently uncommitted with no offtake agreements or funding arrangements in place
Expected production	Expected annual production (post ramp-up average): • Ore mined and processed: 2 Mtpa • Spodumene concentrate (6% Li_2O): 295 ktpa • Contained Li_2O: 18,000 tpa • Tantalum concentrate (~25% Ta_2O_5): 672 tpa • Contained Ta_2O_5: 170 tpa
Infrastructure	The project is located immediately adjacent to the sealed Goldfields Highway, which connects to mineral exporting ports at Geraldton and Esperance. Other infrastructure located close to the project includes a powerline, a natural gas pipeline and mine camps with sealed airstrips capable of taking large passenger aircraft.
Project development capital costs	A$240M pre-production capital expenditure based on 2019 PFS (open-pit/lithium only).
Project economics	Financial outcomes of the 2019 PFS (open-pit/lithium only): • A$1.94bn LOM free cash flow after-tax (averaging approximately A$84m per annum during production) • 4 years payback period • A$507m post-tax $NPV_{8\%(real)}$ • 25% post-tax IRR • cash costs of A$564/dmt Li2O concentrate (excluding tantalum credits). The updated 2020 PFS scheduled for completion in early Q4 2020 is expected to deliver significantly improved financial outcomes, and will incorporate tantalum concentrate by-product production.
Project funding	Liontown Resources is adequately funded through to feasibility study completion on the project. The company welcomes discussion regarding financing of the project construction, including parties with expertise in downstream processing.
Other	Company website: ltresources.com.au Investor presentation: ltresources.com.au/sites/default/files/asx-announcements/6982059.pdf

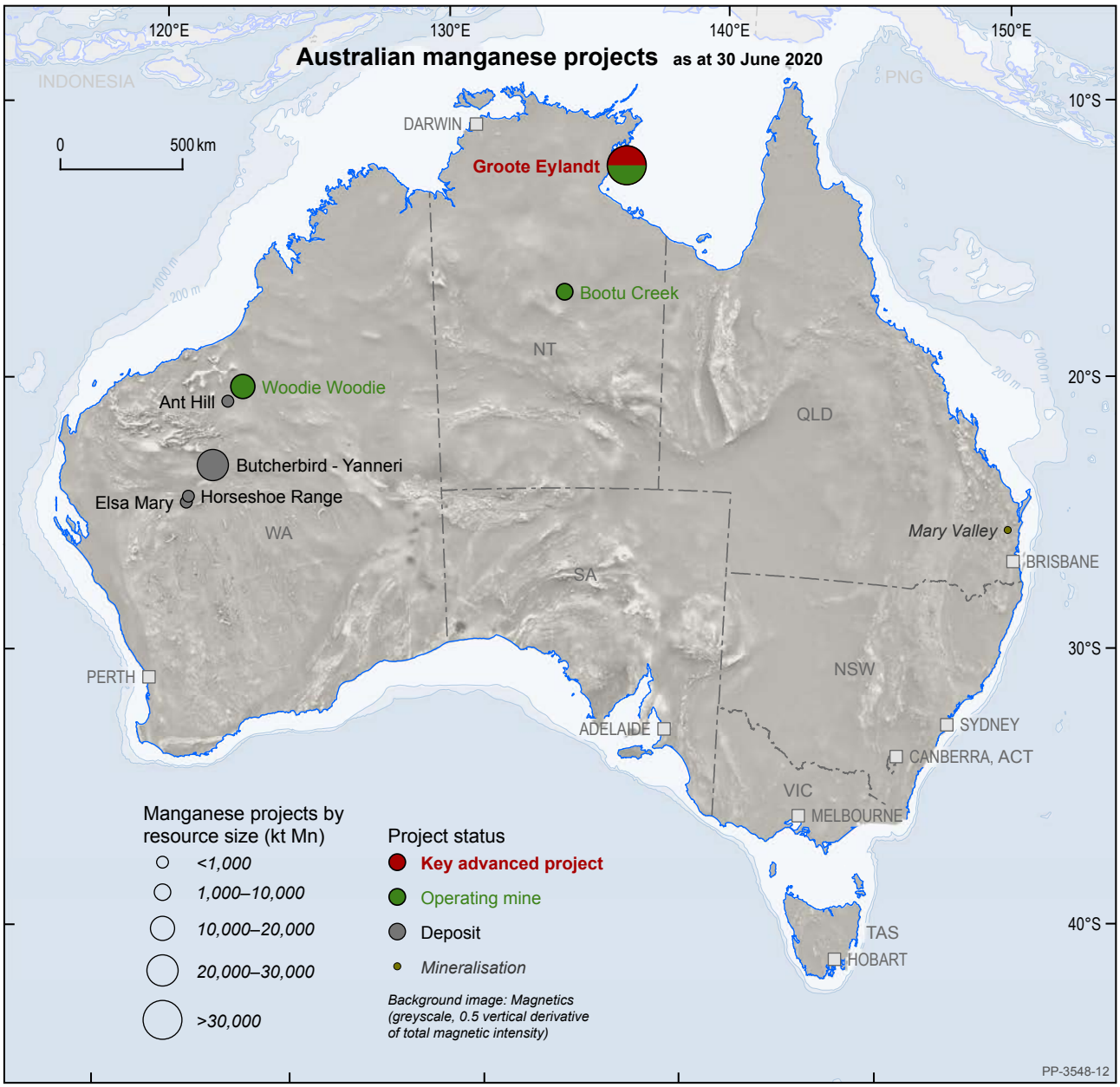
Magnesium (Mg)



Advanced magnesium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Magnesium	**Kunwarara**	Sibelco Australia Ltd	Operating	Mg	430.0	16.73	%	MgO	71,948	–
Magnesium	**Myrtle Springs**	Calix Ltd	Operating	Mg	0.9	38.80	%	MgO	333	–
Magnesium	**Thuddungra Magnesite**	Young Mining Company	Operating	Mg	1.3	15.30	%	MgO	194	–
Magnesium	**Winchester**	Korab Resources Ltd	PFS	Mg	16.6	43.20	%	MgO	7,171	–

Manganese (Mn)



Advanced manganese projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Manganese	**Groote Eylandt (ROM)**	South32	Operating	Mn					N/A	94
Manganese	**Groote Eylandt (Sands)**	South32	Operating	Mn					N/A	94
Manganese	**Woodie Woodie**	Consolidated Minerals	Operating	Mn	48.5	30.60	%	Mn	14,841	–
Manganese	**Bootu Creek**	OM Holdings Ltd	Operating	Mn	4.8	22.89	%	Mn	1,094	–
Manganese	**Ant Hill**	ASX:MIN; ASX:MAS	Care and maint	Mn	3.1	24.70	%	Mn	766	–

CRITICAL MINERAL(S)	MANGANESE NT
PROJECT NAME	**GROOTE EYLANDT MINING COMPANY (GEMCO)**
Location	GEMCO is located on Groote Eylandt in the Gulf of Carpentaria, approximately 650 km south-east of Darwin in the Northern Territory.
Company name	**South32 Limited**
Company ownership	ASX-listed **(S32)** Joint venture between S32 (60%) and Anglo American Plc (40%).
Project description	GEMCO has been producing high-grade manganese ore for more than 50 years. A high-quality ore body, low strip ratio and proximity to Asian customers has made GEMCO one of the lowest-cost producers in the world. Ore is concentrated onsite before being hauled 16 km north to GEMCO's Milner Bay port – a deep-water berth where ore is loaded onto ships for export. GEMCO has grown its operations over the decades and now produces more than 10% of the world's seaborne manganese.
Products	High-grade manganese ore
Mineral inventory	Mineral resources (South32 Annual Report 2019):

ROM[1,2] Resource category	Tonnes (Mt)	Mn (%)	Yield (ppm)
Measured	75	45.8	49
Indicated	54	41.8	48
Inferred	22	39.9	48
Total	**151**	**43.5**	**48**

Sands[1,3] Resource category	Tonnes (Mt)	Mn (%)	Yield (ppm)
Measured			
Indicated	8.8	20.8	
Inferred	2.3	20.0	
Total	**11**	**20.6**	

Ore reserves (South32 Annual Report 2019):

ROM[1,4] Reserve category	Tonnes (Mt)	Mn (%)	Yield (ppm)
Proved	44	43.6	60
Probable	14	42.5	61
Total	**58**	**43.3**	**60**

<table>
<tr><td>Mineral inventory</td><td>
<table>
<tr><th>Sands[1,4]
Reserve category</th><th>Tonnes
(Mt)</th><th>Mn
(%)</th><th>Yield
(ppm)</th></tr>
<tr><td>Proved</td><td></td><td></td><td></td></tr>
<tr><td>Probable</td><td>7.2</td><td>40</td><td>22</td></tr>
<tr><td>Total</td><td>7.2</td><td>40</td><td>22</td></tr>
</table>
Notes:
1. The following cut-off grades have been used: (a) >=35% Mn washed product used for reporting ROM Mineral Resources, (b) >=40% Mn washed product for ROM Ore Reserves, and (c) no cut-off grades applied to Sands Mineral Resources or Ore Reserves.
2. ROM Mineral Resource tonnes are stated as in situ manganese grades are reported as per washed ore samples and should be read together with their respective mass yields.
3. Sands Mineral Resource tonnes and manganese grades are stated as in situ.
4. Ore Reserve tonnes are states as delivered to process plant manganese grades are reported as expected product and should be read together with their respective mass yields.
5. Mineral Resources and Ore Reserves are reported in 100% terms and represent estimates as at 30 June 2019. Mineral Resource estimations include Measured and Indicated Mineral Resources which, after the application of all modifying factors, and development of a mine plan, have been classified as Ore Reserves.
</td></tr>
<tr><td>Stage of development</td><td>Exploration commenced in the 1960s with GEMCO producing its first shipment of manganese ore in 1968.

Since then, GEMCO has undergone several significant expansions and developments to produce more than 5 Mt of manganese ore per annum in 2019.

Additional growth has been achieved through the reprocessing of tailings through the sands beneficiation plant (SBP) to produce the premium sands concentrate product.</td></tr>
<tr><td>Production</td><td>• Mn ore production (South32 share): 3,349 ktpa

South32 Annual Report 2019</td></tr>
<tr><td>Infrastructure</td><td>The GEMCO mining fleet includes 18 D11 dozers, 30 CAT 777 haul trucks, 8 road trains and ancillary equipment.

Ore is concentrated onsite using gravity separation processes to remove waste and generate a range of saleable products.

Operating a blended FIFO and residential workforce, GEMCO fully manages and maintains the township of Alyangula and the Groote Eylandt Airport.</td></tr>
<tr><td>Project development capital costs</td><td>N/A</td></tr>
<tr><td>Project economics</td><td>South32 share (US$m) – (South32 Annual Report 2019):

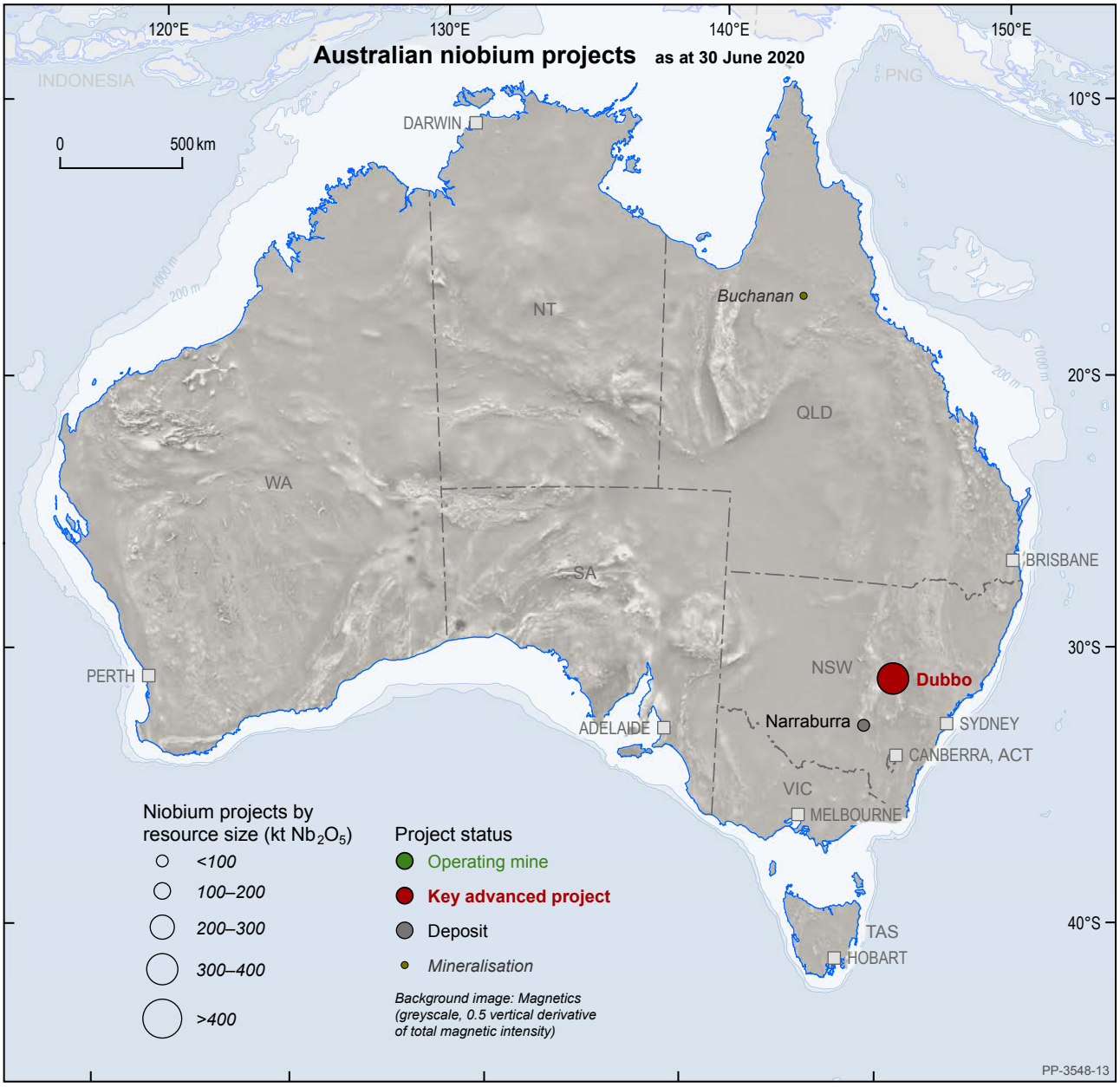
Revenue: $930m

Underlying EBITDA: $643m

Underlying EBIT: $588m</td></tr>
<tr><td>Project funding</td><td>N/A</td></tr>
<tr><td>Other</td><td>Project website: south32.net/our-business/australia/gemco

Annual reports: south32.net/investors-media/investor-centre/annual-reporting-suite</td></tr>
</table>

Niobium (Nb)

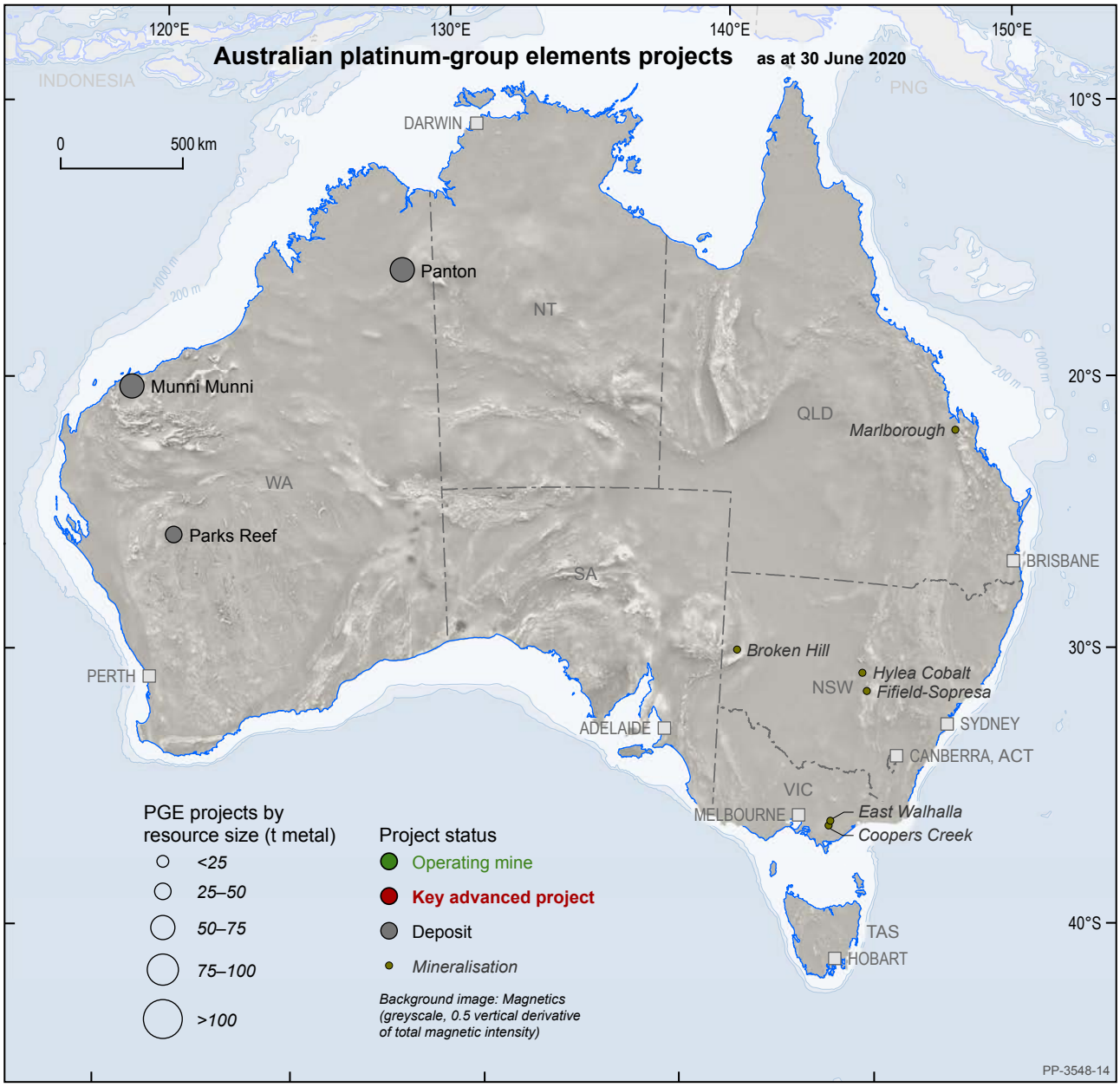


Advanced niobium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Niobium	**Dubbo**	Alkane Resources Ltd	Pre-const	Zr, Nb, Hf, Ta, REE	75.2	0.44	%	Nb_2O_5	331	107

Dubbo project summary included in the rare-earth elements section.

Platinum-group elements (PGE) (Pt, Pd, Rh, Ru, Ir, Os)

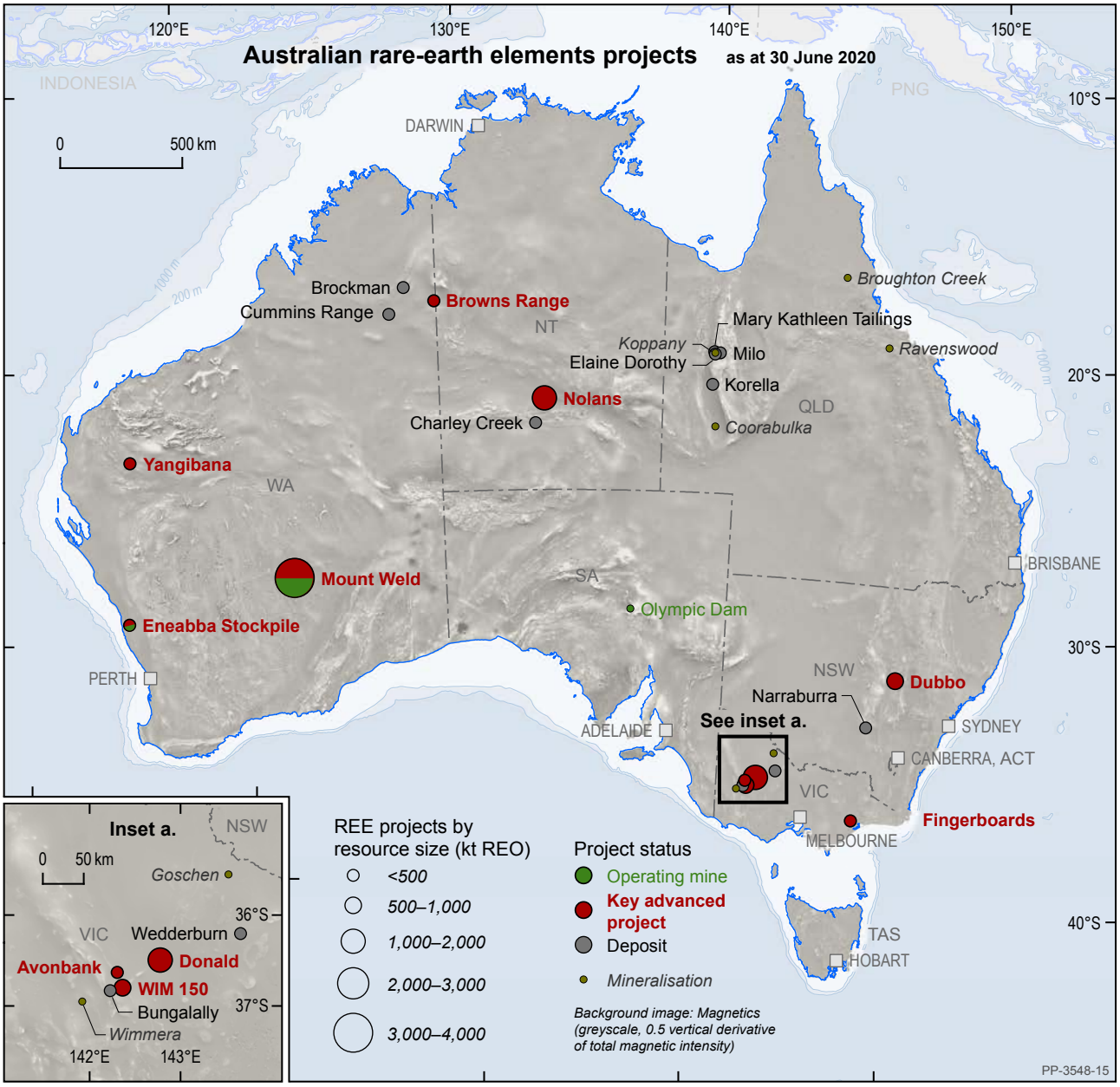


Advanced PGE projects (total mineral resource ronnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
PGE	**Panton**	Panoramic Resources Ltd	FS	Pt, Pd	14.3	5	ppm	PGE	0.07	–

Image courtesy of Lynas Corporation

Rare-earth elements (REE)
(Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) Excluding Sc



Advanced REE projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
REE	**Mount Weld**	Lynas Corporation Ltd	Operating	REE	55.4	5.40	%	TREO	3,000	101
REE	**Olympic Dam**	BHP	Operating	REE					N/A	–
REE	**Eneabba Stockpile**	Iluka Resources Ltd	Operating	Zr, REE, Ti	1.0	10.34	%	TREO	103	103
REE	**Nolans**	Arafura Resources Ltd	Pre-const	REE, P	56.0	2.60	%	TREO	1,456	105
REE	**Dubbo**	Alkane Resources Ltd	Pre-const	Zr, Nb, Hf, Ta, REE	75.2	0.88	%	TREO	662	107
REE	**Yangibana**	Hastings Tech. Metals Ltd	Pre-const	REE	21.3	1.12	%	TREO	238	109
REE	**Browns Range**	Northern Minerals Ltd	Pre-const	REE	9.3	0.67	%	TREO	57	111
REE	**Donald**	Astron Ltd	FS	Zr, Ti, REE	2,427.0	0.06	%	TREO	1,398	128
REE	**WIM 150**	Murray Zircon Pty Ltd	FS	Zr, Ti, REE	1,650.0	0.06	%	TREO	908	132
REE	**Fingerboards**	Kalbar Resources Ltd	FS	Zr, Ti, REE	530.0	0.09	%	TREO	490	134
REE	**Avonbank**	WIM Resource Pty Ltd	PFS	Zr, Ti	490.0	0.06	%	TREO	308	140

REE heavy mineral sands project summaries (Donald, WIM 150, Fingerboards and Avonbank) are included in the titanium section.

CRITICAL MINERAL(S)	RARE-EARTH ELEMENTS WA
PROJECT NAME	**MOUNT WELD**
Location	Located approximately 35 km south-west of Laverton, in the Kalgoorlie Gold Fields district of Western Australia.
Company name	**Lynas Corporation Ltd**
Company ownership	ASX-listed **(LYC)**
Project description	Lynas has a proven track record as the world's second-largest producer of rare-earth materials. The company operates the only rare-earths separation facility of scale outside China and is the leading supplier to customers in Japan, Europe and the US in high-technology markets, including green technology such as electric vehicles. Lynas is an ethical and environmentally responsible producer, and is certified under international standards. Lynas sources its rare-earth elements from its deposit at Mount Weld in Western Australia, one of the world's highest grade rare-earth mines with 25+ – year mine life at August 2018. Mount Weld ore is mined and concentrated at the Mount Weld processing plant. The concentrate is shipped to Lynas's Malaysian refinery, the largest, most advanced rare-earths chemical processing plant in the world. Lynas is developing a processing facility in Kalgoorlie, Western Australia, to undertake first-stage processing of the concentrate (cracking and leaching). Once the plant is operational, material from the Kalgoorlie plant will be shipped to Lynas's Malaysian refinery for further processing. Lynas is also developing a processing facility in Texas, US, which will refine the mixed heavy rare-earth compound similar exposure group (SEG), which is produced by Lynas Malaysia from Mount Weld concentrate.
Products	Lynas produces NdPr oxide, Nd oxide, Pr oxide, Ce carbonate, Ce oxide, LaCe carbonate, LaCe oxide, SEG oxide – mixed heavy rare-earths (samarium, europium, gadolinium, terbium, dysprosium, yttrium).
Mineral inventory	Mount Weld rare-earth deposit mineral resources 2019 (as at 30 June 2019):

Resource category	Tonnes (Mt)	TREO* (%)	TREO ('000 tonnes)
Measured	17.3	7.9	1,370
Indicated	12.0	5.5	660
Inferred	25.9	3.6	930
Total	**55.2**	**5.4**	**2,980**

*TREO = total rare-earth oxides (La_2O_3, CeO_2, Pr_6O_{11}, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_4O_7, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3) + Yttrium (Y_2O_3). Totals may not balance due to rounding of figures.

<table>
<tr><td>Mineral inventory</td><td>Mount Weld rare-earth deposit ore reserves 2019 (as at 30 June 2019):
<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TREO* (%)</th><th>TREO ('000 tonnes)</th></tr><tr><td>Proved</td><td>14.4</td><td>8.7</td><td>1,258</td></tr><tr><td>Probable</td><td>5.1</td><td>7.7</td><td>390</td></tr><tr><td>Total</td><td>19.5</td><td>8.5</td><td>1,648</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>Lynas has been developing the Mount Weld ore body since 2001 and has produced finished rare-earth products for customers since 2013.

In February 2020, Lynas was awarded major project status by the Australian Government to establish its new rare-earths processing plant (cracking and leaching) in Kalgoorlie, Western Australia. In December 2019, the project was awarded lead agency status by the Government of Western Australia. The company expects to invest up to A$500m in the new facility, and create up to 500 jobs during peak construction and over 100 new ongoing jobs in Kalgoorlie. The new plant will be operational by July 2023.

In May 2020, the US Department of Defense awarded Phase 1 funding to Lynas for the development of a heavy rare-earth processing plant in Hondo, Texas. This facility will address a key supply-chain deficiency for US consumers and is a key element of Lynas's 2025 growth plan.

These investments in WA and the US will support Lynas' continued growth.</td></tr>
<tr><td>Production</td><td>FY19 actual annual production:

• TREO (Malaysia): 19,737 t

• NdPr (Malaysia): 5,898 t</td></tr>
<tr><td>Infrastructure</td><td>Lynas benefits from fully installed operating facilities in two locations, which have been optimised over several years of operation.

Mine and concentration plant at Mount Weld, Western Australia, near Laverton.

Advanced materials plant in an industrial estate in Gebeng, Malaysia (near Kuantan).</td></tr>
<tr><td>Project development capital costs</td><td>Planned A$500m 'Lynas 2025' growth project including new rare-earths processing plant (cracking and leaching) in Kalgoorlie and associated investments in Mount Weld and Kuantan.

Additional capital investment in Texas subject to USG tender.</td></tr>
<tr><td>Project economics</td><td>FY19 financial results (AUD): net profit after tax (NPAT) of A$80.0m; profit from operating activities (EBIT) of A$56.4m; EBITDA of A$100.7m; net sales revenue of A$363.5m; cash flows from operating activities of A$104.1m.</td></tr>
<tr><td>Project funding</td><td>Lynas is an operating and profitable business with substantive growth plans. Operating cash flow will be used to fund growth with additional support expected from non-traditional sources, including existing and new government stakeholders.</td></tr>
<tr><td>Other</td><td>lynascorp.com

general@lynascorp.com</td></tr>
</table>

CRITICAL MINERAL(S)	TITANIUM, ZIRCONIUM, RARE-EARTHS WA
PROJECT NAME	**ENEABBA**
Location	Located in Eneabba, 150 km south of Geraldton in Western Australia.
Company name	**Iluka Resources Ltd**
Company ownership	ASX-listed **(ILU)**
Project description	The Eneabba mineral sands recovery project involves the extraction, processing and sale of a strategic stockpile of historical monazite-rich material that is currently stored in a mining void at Eneabba, Western Australia. The focus of Phase 1 is to monetise monazite concentrates contained in the mineral resource. This has required the development of a viable processing methodology and the selection of a channel to market, which satisfies product stewardship protocols. The deposit is at surface and material is mined and screened at site before transport to the Port of Geraldton for shipment. Phase 1 is a low-risk, low-capital re-entry for Iluka into the rare-earth market. Studies into Phase 2 of the project are well underway and being progressed as a high priority. Phase 2 involves further processing of the concentrate to produce separate and much higher grade monazite and zircon concentrate products.
Expected products	Phase 1: monazite-zircon concentrate (~20% monazite). Phase 2: monazite and zircon concentrates (~80% monazite).
Mineral inventory company ownership	Mineral resources as at 24 July 2019 (HM assemblage basis):

Resource category	Tonnes (Mt)	Total HM grade (%)	Ilmenite (%)	Zircon (%)	Monazite (%)	Xenotime (%)
Measured	0.84	83.7	33	26	20	1.2
Indicated	0.16	77.5	37	28	15	1.2
Total	**1.0**	**82.7**	**34**	**26**	**20**	**1.2**
Contained (kt)		**827**	**282**	**216**	**165**	**10**

Ore reserves as at 18 February 2020 (HM assemblage basis):

Reserve category	Tonnes (Mt)	Total HM grade (%)	Ilmenite (%)	Zircon (%)	Monazite (%)	Xenotime (%)
Proved	0.81	84.4	33	26	20	1.2
Probable	0.15	78.3	37	28	15	1.2
Total	**0.96**	**83.5**	**34**	**26**	**20**	**1.2**
Contained (kt)		**802**	**273**	**208**	**160**	**10**

<table>
<tr><td>Mineral inventory company ownership</td><td>Notes:
1. In situ (dry) metric tonnage is reported.
2. Ore Reserves are a subset of Mineral Resources.
3. Mineral assemblage is reported as a percentage of HM.
4. Rounding may generate differences in the last decimal place.</td></tr>
<tr><td>Stage of development</td><td>Phase 1 – operating, offtake agreement for 50 ktpa concentrate for 2 years

Phase 2 – feasibility study underway</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):

<table><tr><th></th><th>Phase 1</th><th>Phase 2</th></tr><tr><td>Concentrate</td><td>~50 ktpa</td><td>~100 ktpa</td></tr><tr><td>Contained zircon</td><td>~9 ktpa</td><td>12–16 ktpa</td></tr><tr><td>Contained monazite</td><td>~10 ktpa</td><td>~16–20 ktpa</td></tr></table>
Note: Phase 1 concentrate will contain ~20% monazite, whereas Phase 2 concentrate will contain ~80% monazite.</td></tr>
<tr><td>Infrastructure</td><td>Phase 1: mining unit, screening plant and product handling facilities in place.

Phase 2: additional upgrading facilities, subject to study outcomes.</td></tr>
<tr><td>Project development capital costs</td><td>Phase 1: A$10m.

Phase 2: A$20–40m
(subject to study outcomes and necessary approvals).</td></tr>
<tr><td>Project economics</td><td>No figures available.</td></tr>
<tr><td>Project funding</td><td>Internally funded from cashflow or available debt facilities.</td></tr>
<tr><td>Other</td><td>iluka.com

Presentation to 2020 Bank of America Merrill Lynch Global Mining Conference</td></tr>
</table>

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>RARE-EARTH ELEMENTS NT</th></tr>
<tr><th>PROJECT NAME</th><th>NOLANS</th></tr>
<tr><td>Location</td><td>Located 135 km north-west of Alice Springs in the Northern Territory.</td></tr>
<tr><td>Company name</td><td>Arafura Resources Ltd</td></tr>
<tr><td>Company ownership</td><td>ASX-listed (ARU)</td></tr>
<tr><td>Project description</td><td>The Nolans Project is supported by one of the world's largest rare-earth mineral resources with substantial growth potential. Ore reserves are sufficient to support mining and processing operations for 33 years and capable of sustained production to meet 5–10% of global demand for NdPr oxide, the key rare-earth input to high-strength NdFeB permanent magnets.

The metallurgical process developed by Arafura leverages the natural characteristics of the Nolans ore body and has been comprehensively de-risked in pilot plant operations during 2016–2020.

The project will encompass an open-pit mine, a process plant (including a rare-earth separation facility) and related infrastructure to be constructed at the Nolans site.</td></tr>
<tr><td>Expected products</td><td>NdPr oxide.

SEG/HRE (middle/heavy rare-earth) carbonate.

Cerium hydroxide.

Fertilizer-grade (54% P_2O_5) phosphoric acid.</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources (as at 7 June 2017; 1% TREO cut-off grade):

<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>TREO (%)</th><th>P_2O_5 (%)</th><th>NdPr (% of TREO)</th></tr>
<tr><td>Measured</td><td>4.9</td><td>3.2</td><td>13</td><td>26.1</td></tr>
<tr><td>Indicated</td><td>30.0</td><td>2.7</td><td>12</td><td>26.4</td></tr>
<tr><td>Inferred</td><td>21.0</td><td>2.3</td><td>10</td><td>26.5</td></tr>
<tr><td>Total</td><td>56.0</td><td>2.6</td><td>11</td><td>26.4</td></tr>
<tr><td>Contained (kt)</td><td></td><td>1,456</td><td>6,160</td><td>384</td></tr>
</table>

Ore reserves (as at 16 March 2020):

<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TREO (%)</th><th>P_2O_5 (%)</th><th>NdPr (% of TREO)</th></tr>
<tr><td>Proved</td><td>5.0</td><td>3.0</td><td>13</td><td>26.2</td></tr>
<tr><td>Probable</td><td>24.6</td><td>2.8</td><td>13</td><td>26.5</td></tr>
<tr><td>Total</td><td>29.5</td><td>2.9</td><td>13</td><td>26.4</td></tr>
<tr><td>Contained (kt)</td><td></td><td>856</td><td>3,835</td><td>226</td></tr>
</table>
</td></tr>
<tr><td>Stage of development</td><td>Nolans is in execution readiness and Arafura is progressing with pre-front-end engineering and design (pre-FEED) of the project's base case configuration, established in the February 2019 feasibility study.

All NT Government and Australian Government environmental approvals are in place, and the project is on track to receive final mining (development) approval from the NT Government in mid-2020.</td></tr>
</table>

<table>
<tr><td>Expected production</td><td>Subject to securing project funding, first product from Nolans is expected to be delivered in 2023.
<table><tr><th>Production (post ramp-up)</th><th>Tonnes per annum</th></tr><tr><td>Ore feed</td><td>923,000</td></tr><tr><td>Concentrate</td><td>291,000</td></tr><tr><td>TREO</td><td>12,010</td></tr><tr><td>Products</td><td></td></tr><tr><td>NdPr oxide</td><td>3,920</td></tr><tr><td>SEG/HRE carbonate</td><td>540</td></tr><tr><td>Cerium hydroxide</td><td>7,540</td></tr><tr><td>Phosphoric acid (54% P_2O_5)</td><td>133,390</td></tr></table></td></tr>
<tr><td>Infrastructure</td><td>The project is located 12 km west of a transnational highway, which also passes through Alice Springs 135 km to the south. Alice Springs is also connected by rail to ports in Darwin and Adelaide. The project site is adjacent to an operating natural gas pipeline and within 25 km of an extensive groundwater aquifer that can meet the project's operational life requirements.</td></tr>
<tr><td>Project development capital costs</td><td>Pre-production capital costs of A$1,003m including contingency.</td></tr>
<tr><td>Project economics</td><td><table><tr><th>Project metric</th><th>Result</th></tr><tr><td>Operating costs
(net of phosphoric acid credit)</td><td>US$27.02/kg NdPr oxide</td></tr><tr><td>NPV (after tax with 10% discount rate)</td><td>A$782m</td></tr><tr><td>IRR</td><td>17.29%</td></tr><tr><td>EBITDA (average)</td><td>A$337m per annum</td></tr><tr><td>Payback</td><td>Year 5</td></tr></table></td></tr>
<tr><td>Project funding</td><td>Arafura is actively engaging with potential offtake and supply-chain partners in Japan, Europe, South Korea, the US and China, targeting NdPr users that are not aligned with the Made in China 2025 strategy. The overall objective is to attract an export credit agency (ECA) syndicate linked to product offtake in some of these jurisdictions.

Arafura's engagement with banks, key advisor groups and ECAs supports the view that the strategic nature of NdPr, the alignment with clean-energy applications and the specialised capital equipment requirements of the project are a good fit with the mandate of a number of ECAs. The company is also investigating opportunities for debt funding linked to engineering and procurement.

Strategic equity either at the project or company level is an integral component of project funding. If the right strategic equity partners can be attracted to the project, it is likely the remaining equity requirement can be built around this position.</td></tr>
<tr><td>Other</td><td>Contact: Gavin Lockyer, Managing Director

Company website: arultd.com/

Definitive feasibility study summary: arultd.com/projects/nolans/definitive-feasibility-study.html

Updated Ore Reserves: wcsecure.weblink.com.au/pdf/ARU/02214717.pdf</td></tr>
</table>

CRITICAL MINERALS	ZIRCONIUM, NIOBIUM, HAFNIUM, TANTALUM, REE NSW
PROJECT NAME	**DUBBO**
Location	Located at Toongi, 25 km south of Dubbo (population 45,000), 400 km north-west of Sydney in New South Wales.
Company name	**Australian Strategic Materials Limited**
Company ownership	Australian Strategic Materials Limited **(ASX:ASM)** is focused on producing specialty metals and oxides for advanced technologies and is the 100% owner of the Dubbo Project.
Project description	The Dubbo Project is a large in-ground resource of zirconium, hafnium, niobium, yttrium and other rare-earth elements. It is the most advanced poly-metallic project of its kind outside China, making it a strategic supply of critical minerals for a range of sustainable technologies and future industries that is independent of China and traditional titanium sands production. The project has an initial mine life of 20 years with the potential to extend to 70+ years. ASM is progressing the production of zirconium and hafnium metals and has entered into an agreement to acquire 95% of its joint venture partner Ziron Tech, which owns patented low emission, high purity metal-refining technology. ASM will also acquire the pilot plant constructed in 2020 to confirm the technology. The technology has application to produce rare-earth elements (REE) metals. It is intended that these materials will be produced onsite at the Dubbo Project or within Australia, or components located in South Korea and Australia.
Expected products	ASM expects to produce zirconium (ZrO_2), hafnium (HfO_2), niobium (Nb_2O_5) and a range of rare-earth elements including: high-demand magnet rare-earths, praseodymium (Pr) and neodymium (Nd), dysprosium (Dy), terbium (Tb), gadolinium (Gd) and yttrium (Y), with the possibility of producing other REE based on market demand and processing options.
Mineral inventory	Mineral resources (as at 30 June 2017):

Resource category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	TREO (%)
Measured	42.8	1.89	0.04	0.45	0.03	0.88
Inferred	32.4	1.90	0.04	0.44	0.03	0.88
Total resource	**75.2**	**1.89**	**0.04**	**0.44**	**0.03**	**0.88**
Contained (kt)		**1,421**	**30**	**331**	**23**	**662**

Ore reserves (as at 30 June 2017):

Reserve category	Tonnes (Mt)	ZrO_2 (%)	HfO_2 (%)	Nb_2O_5 (%)	Ta_2O_5 (%)	TREO (%)
Proved	18.9	1.85	0.04	0.44	0.03	0.87
Contained (kt)		**350**	**8**	**83**	**5**	**165**

Stage of development	Pre-construction – feasibility study completed in 2013, a full front-end engineering design completed in 2015 and an engineering and financial update completed in 2018. The project has been substantially engineered and is construction-ready, subject to financing, with the mineral deposit and surrounding land acquired. All major state and federal approvals are in place, and the project has a well-established flow sheet, with over 10 years of successful pilot plant operation.
Expected production	At full production, the project is expected to have a mine production and processing plant feed rate of 1 Mtpa, producing: • Zirconium: 16,374 t p.a. (~40% revenue) • Hafnium: 200 t p.a. (~10% revenue) • Niobium: 1,967 t p.a. (~20% revenue) • Rare-earths: 6,664 t p.a. (237 t p.a. – Pr_6O_{11}, 921 t p.a. – Nd_2O_3 as well as Tb and Dy) (~30% revenue)
Infrastructure	Located 25 km south of the city of Dubbo in NSW, the project has excellent surrounding infrastructure. ASM owns 3,456 hectares of land at Toongi, encompassing the ore resource and the land required for the processing plant. The project is accessed via local main roads for the construction and operation phases. Water for the project will be supplied from ASM-issued licences estimated at approximately 2 gigalitres annually. The installation of a approximately 16 km new single-circuit 132 kV overhead transmission line from the existing 132 kV line is required to provide power for the project. ASM has secured the power line easement from Toongi to Geurie.
Project development capital costs	The front-end engineering design (high accuracy) estimate is A$1.3bn capital cost to build mine and full plant to oxide production (to be located in Australia). ASM continues to progress optimisation work designed to reduce the capital to develop the project.
Project economics	The project could generate A$4.7bn free cash flow over the 20-year base case mine life with a forecast base case capital cost of A$1.3bn. Internal rate of return is estimated between 16.1% and 17.5%, depending on whether capital is managed to build the project in two stages or proceeds to a single 1 Mtpa plant, with both alternatives confirmed viable. There is potential for the optimisation work being advanced to increase the internal rate of return to over 25%.
Project funding	The company is progressing the planned demerger of ASM as a poly-metallic producer of critical materials. ASM is progressing strategic partners discussions within South Korea but welcomes discussion regarding financing of the project construction or offtake.
Other	Project website: alkane.com.au/media-research/resources-for-download/dubbo-project-2/

CRITICAL MINERAL(S)	RARE-EARTH ELEMENTS WA
PROJECT NAME	**YANGIBANA**
Location	Located in the Gascoyne region of Western Australia, approximately 250 km north-east of Carnarvon.
Company name	**Hastings Technology Metals Ltd**
Company ownership	ASX-listed **(HAS)** Hastings Technology Metals Ltd is a rare-earth elements (REE) company focused on its flagship Yangibana rare-earths Project in Western Australia. Market capitalisation of A$124m as of 03/06/2020.
Project description	The project involves the development, construction, mining and processing operations to produce 15,000 tonnes (t) per annum of mixed rare-earth carbonate (MREC). MREC product will be trucked to the Port of Fremantle. Yangibana's MREC boasts extremely high concentrations of the high-value neodymium (Nd) and praseodymium (Pr) elements compared to other RE projects, with an NdPr: total RE oxides (TREO) ratio of up to 48% in some deposits. Nd and Pr elements are essential raw materials used in the production of permanent magnets, which are critical in many high-tech products, including electric vehicles, renewable energy wind turbines, consumer electronics and others. The definitive feasibility study was completed in 2017. More than 300 metallurgical flotation tests and two bulk pilot plant studies have been completed. Mining will be operated in a conventional open-cut mining manner (drill, blast, load and haul). The beneficiation process consists of crushing, grinding, rougher flotation, regrinding, and cleaner flotation. The hydrometallurgical process consists of acid bake, water leach, impurity removal and MREC product precipitation. The current reserves and resources support a 13-year mine life, with multiple targets existing; substantial exploration potential also exists.
Expected products	The final MREC product derived from the ore contains a mixture of REEs (15 in total), with a significantly high proportion of the high-value 'magnet' oxides Nd and Pr. Nd_2O_3 (Nd oxide) and Pr_6O_{11} (Pr oxide) account for 89% of the economic value of the MREC product.
Mineral inventory	Mineral resources (as at 31 October 2019):

Resource category	Tonnes (Mt)	TREO (%)	Nd_2O_3+Pr_6O_{11} (%)
Measured	4.15	1.15	0.43
Indicated	10.92	1.13	0.38
Inferred	6.18	1.09	0.35
Total	**21.25**	**1.12**	**0.38**
Contained (kt)		**238**	**81**

The established Yangibana Mineral Resources are 86% within tenements held 100% by Hastings. The remaining 14% are within tenements controlled 70% by Hastings.

Hastings's 100%-owned Brockman Project also hosts JORC resources totalling 41.4 Mt at 0.21% TREO.

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at 4 November 2019):
<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TREO (%)</th><th>$Nd_2O_3+Pr_6O_{11}$ (%)</th><th>$Nd_2O_3+Pr_6O_{11}$ as % of TREO (%)</th></tr><tr><td>Probable</td><td>12.20</td><td>1.13</td><td>0.40</td><td>37</td></tr><tr><td>Contained (kt)</td><td>12.20</td><td>138</td><td>49</td><td></td></tr></table></td></tr>
<tr><td>Stage of development</td><td>All Tier-1 permits for project development received including:
Commonwealth Environmental Permit (April 2020).
Western Australia Environmental Permit (August 2019).
Native title agreement finalised (November 2017).
Schaeffler offtake supply agreement signed in June 2020 for up to 33% of product.
Offtake contract signed with Baotou Sky Rock Rare-earth (November 2018).
Advanced front-end engineering and design optimisation and detailed design engineering work largely completed. Long lead items have been ordered.
EPCM contract for project construction signed (October 2019).
Project commissioning expected during 2023.</td></tr>
<tr><td>Expected production</td><td>Average annual production (post ramp-up) of:
Ore mined and process plant throughput: 1.0 Mtpa
Concentrate: 35,000 tpa
Mixed REE carbonate: 15,000 tpa
Contained TREO: 8,500 tpa
Contained NdPr oxide: 3,400 tpa</td></tr>
<tr><td>Infrastructure</td><td>Early infrastructure works including construction of a 380-room accommodation village have commenced with all houses onsite. Site clearance of the village has been completed and site access roads from the Shire roads have been installed.</td></tr>
<tr><td>Project development capital costs</td><td>A$593m total start-up capital, including 15% contingency has been confirmed through a cost validation program completed jointly by DRA Global and Hastings.</td></tr>
<tr><td>Project economics</td><td>Post-tax $NPV_{10\%}$ A$549M – IRR 21% – Payback 3.4 years</td></tr>
<tr><td>Project funding</td><td>The project’s total funding requirements are A$593m up until end of the construction period and practical completion.
A$250m loan from UFK and KFW for process plant equipment and construction is in final discussions.
A$210m infrastructure loan from Northern Australia Infrastructure Facility is currently under assessment.
This leaves approximately A$150m to be raise via equity placements and strategic cornerstone investors.</td></tr>
<tr><td>Other</td><td>Company website: hastingstechmetals.com
Investor presentations: hastingstechmetals.com/investor-relations/presentations
Charles Lew, Chairman: +65 9790 9008 or +61 8 6117 6118
Andrew Reid, Chief Operations Officer: +61 432 740 975</td></tr>
</table>

CRITICAL MINERAL(S)	RARE-EARTH ELEMENTS WA
PROJECT NAME	**BROWNS RANGE**
Location	Located 160 km south-east of Halls Creek in northern Western Australia.
Company name	**Northern Minerals Limited**
Company ownership	ASX-listed **(NTU)** Northern Minerals Limited (ASX:NTU) has 100% ownership and marketing rights for all tenements covering the Western Australian portion of the Browns Range Dome. Northern Minerals owns 100% of the rare-earth rights to tenements in the Northern Territory covering the Browns Range Dome.
Project description	The company constructed and commissioned the Browns Range pilot plant in 2017–18 and has been operating the pilot plant to undertake test work to determine the technical and economic viability of the process and the full-scale commercial project. The full-scale project comprises the development of a dysprosium-rich heavy rare-earths (HRE) mining and mineral processing operation at Browns Range. The current mineral resource supports a 12-year mine life, with significant scope to expand this in the future. Ore will be mined using a combination of open-pit and underground mining methods, and processed onsite through a beneficiation plant and a hydrometallurgical plant. Based on the Browns Range feasibility study completed in March 2015, the beneficiation plant will treat up to 585,000 tpa of ore to produce approximately 16,700 tpa of concentrate at 20% total rare-earth oxides (TREO). The concentrate will be further treated in the hydrometallurgical plant to produce 6,000 tpa of high-purity mixed rare-earth carbonate product containing 3,098 tpa total TREO including 279 tpa of dysprosium. The mixed RE carbonate product will be trucked to the Port of Darwin or Wyndham for export to international markets for further downstream processing. The company has commenced studies on individual rare-earth separation methods and this will form part of the future plans of the company to produce separated heavy rare-earth oxides. Dysprosium is the key value driver of the project, accounting for 60% of its forecasted revenue. The NdFeB permanent magnet sector, which is the leading application for rare-earth demand, and in which dysprosium is a significant constituent, is expected to grow in line with new-energy technologies, specifically wind turbines and the growth in e-mobility drivetrains.
Expected products	High-purity mixed rare-earth carbonate containing predominantly heavy rare-earth oxides including Dy, Tb and Lu. The company plans to produce additional products as part of its 2030 aspirations, including separated HRE oxides and Dy metal and Tb metal.
Mineralinventory	Mineral resources (as at 7 April 2020):

Resource category	Tonnes (Mt)	TREO (%)	Dy_2O_3 (%)	Y_2O_3 (%)	Tb_4O_7 (%)	HREO (%)
Indicated	4.6	0.71	0.06	0.40	0.01	86
Inferred	4.7	0.64	0.05	0.37	0.01	87
Total	**9.3**	**0.67**	**0.06**	**0.38**	**0.01**	**87**
Contained (kt)		**57**	**5**	**33**	**1**	**49**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at 30 June 2019):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>TREO (%)</th><th>Dy_2O_3 (%)</th><th>Y_2O_3 (%)</th><th>Tb_4O_7 (%)</th></tr>
<tr><td>Probable</td><td>3.3</td><td>0.68</td><td>0.06</td><td>0.39</td><td>0.01</td></tr>
<tr><td>Contained (kt)</td><td></td><td>22</td><td>1.9</td><td>13.0</td><td>0.3</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>Mining lease granted in June 2014 for an initial period of 21 years.

Feasibility study completed in March 2015.

Environmental approvals in place for pilot plant, and primary approval in place for the full-scale plant.

Pilot plant constructed in 2018 and continues to assess the technical and economic feasibility of a full-scale commercial operation.

First mixed rare-earth carbonate shipment of 2.6 tonnes from pilot plant shipped for customer testing in China in December 2018.

Offtake agreement in place with Thyssenkrupp Materials Trading GmbH for the mixed rare-earth elements carbonate produced from the pilot plant.

Pilot plant operations temporarily suspended in March 2020 due to COVID-19 outbreak.</td></tr>
<tr><td>Expected production</td><td>Pilot plant capacity is 60,000 tpa ore processed to produce 1,200 tpa mixed RE carbonate containing for 49 tpa dysprosium.

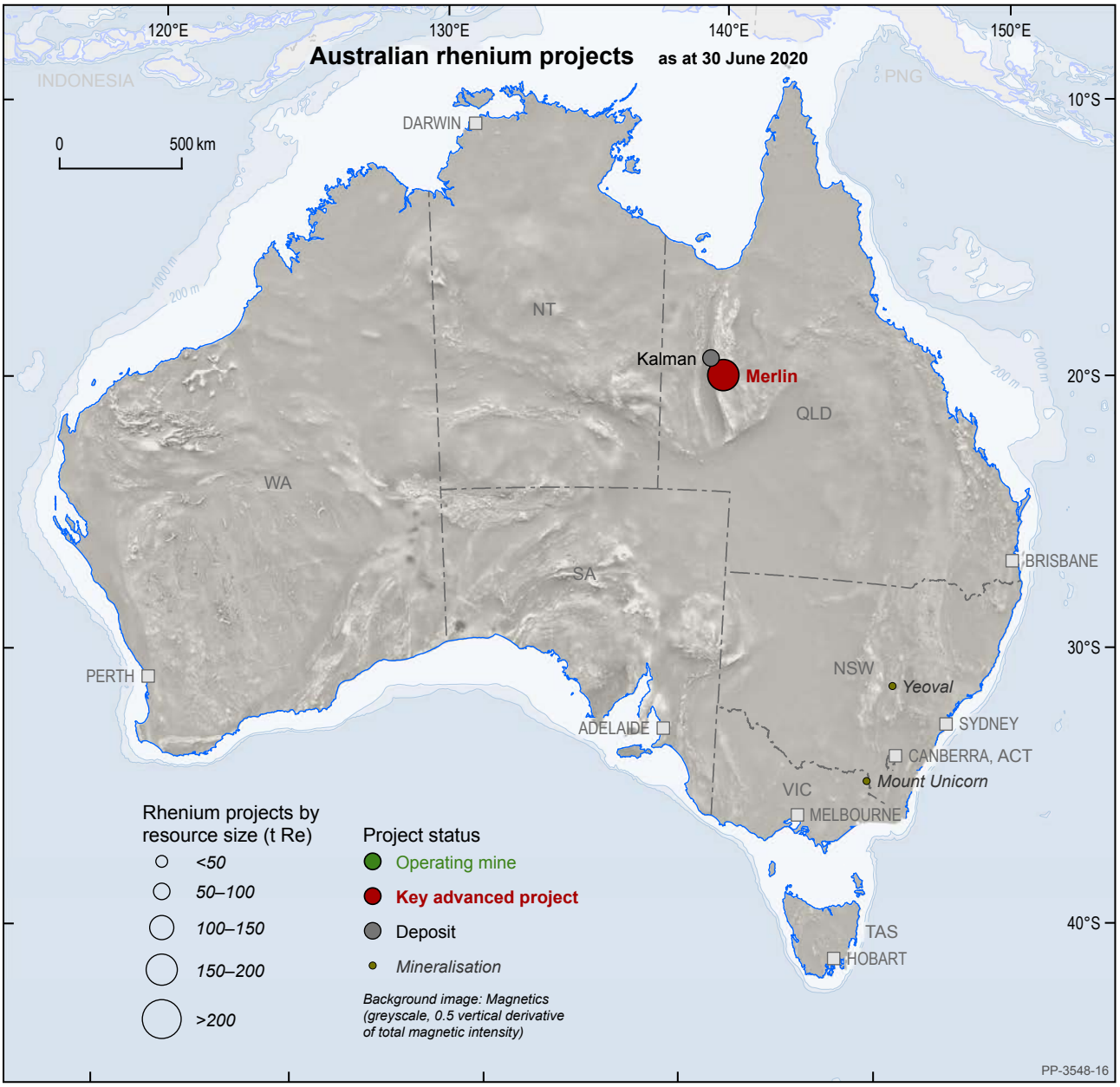
Average annual full-scale commercial production (post ramp-up) of:

• Ore mined and processed: 0.58 Mtpa
• Concentrate: 16,700 tpa
• Mixed RE carbonate product: 6,000 tpa
• Contained TREO: 3,098 tpa
• Contained dysprosium: 279 tpa</td></tr>
<tr><td>Infrastructure</td><td>Infrastructure in place includes the pilot plant processing facility, camp, airstrip, water supply and ancillary infrastructure. Additional infrastructure will be built or upgraded as the project moves to full scale.

The Shire of Halls Creek and Main Roads WA are upgrading the Duncan and Gordon Downs roads that provide access to the project area and the local community of Ringer Soak.</td></tr>
<tr><td>Project development capital costs</td><td>A$329m pre-production capital cost as per 2015 feasibility study.</td></tr>
<tr><td>Project economics</td><td>Results from 2015 feasibility study include: a post-tax $NPV_{10\%}$ of A$552m, with a post-tax IRR of 34% and a payback period of 3.2 years.</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussions regarding financing and/or offtake.</td></tr>
<tr><td>Other</td><td>northernminerals.com.au</td></tr>
</table>

Image courtesy of Lynas Corporation

Rhenium (Re)



Advanced rhenium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Rhenium	**Merlin**	Chinova Resources	Care and maint	Re	6.4	26	ppm	Re	0.17	115
Rhenium	**Mt Unicorn**	Dart Mining	PFS	Mo, Cu, Ag, Re					NA	–

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>RHENIUM QLD</th></tr>
<tr><th>PROJECT NAME</th><th>MERLIN</th></tr>
<tr><td>Location</td><td>Located in north-west Queensland, approximately 145 km south-east of Mount Isa and 700 km west-south-west of Townsville. The project is near the gazetted locality of Selwyn.</td></tr>
<tr><td>Company name</td><td>Chinova Resources Pty Ltd</td></tr>
<tr><td>Company ownership</td><td>Chinova Resources is 100% owned by Shanxi Donghui Coal Coking and Chemicals Group Co., Ltd. – a privately owned Chinese company.</td></tr>
<tr><td>Project description</td><td>The Merlin Project is based on the world's highest-grade molybdenum and rhenium deposit, discovered in late 2008. The high-grade Little Wizard zone of mineralisation located up-dip and south of the main Merlin zone was discovered in October 2009. The Little Wizard zone lies only 90 m below surface and has been incorporated into the declared Merlin mineral reserve.

Construction of an exploration decline at Merlin began in late 2010, with Phase 1 of the decline development completed in January 2012. Decline development enabled a cross-cut to be developed into the Little Wizard deposit.

Proposed mining methods for the project include a combination of long hole open stoping and drift and fill.

The project is anticipated to mine and process a nominal 500,000 tpa of ore at peak production over a 13-year mine life. Ore will be treated by an onsite concentrator using a flotation process to produce a molybdenum-rhenium concentrate as well as a low-grade copper-gold flotation concentrate.

The molybdenum-rhenium concentrate is then refined using a specialised roaster to produce ferro-molybdenum, as well as rhenium in the form of ammonium perrhenate.

The Merlin molybdenum/rhenium feasibility study was completed in November 2014 and although the viability of the project was considered promising, a subsequent downturn in the molybdenum prices caused the project to be placed into care and maintenance in 2015. In this study, the refinery was proposed to be located in China, with the concentrate being shipping there by sea, via Townsville.

Merlin is a construction-ready molybdenum/rhenium mining project ready to quickly take advantage of an upturn in prices of these metals.</td></tr>
<tr><td>Expected products</td><td>Molybdenum-rhenium concentrate (54.5% Mo, 0.095% Re).

Low-grade copper-gold flotation concentrate (15% Cu, 0.07 ppm Au).</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources (as at 14 November 2014):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Mo (%)</th><th>Re ppm</th><th>Cu (%)</th></tr>
<tr><td>Measured</td><td>0.8</td><td>2.30</td><td>34</td><td>0.3</td></tr>
<tr><td>Indicated</td><td>4.2</td><td>1.50</td><td>26</td><td>0.2</td></tr>
<tr><td>Inferred</td><td>1.4</td><td>1.10</td><td>24</td><td>0.5</td></tr>
<tr><td>Total</td><td>6.4</td><td>1.50</td><td>26</td><td>0.3</td></tr>
<tr><td>Contained (kt)</td><td></td><td>96</td><td>0.17</td><td></td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at 14 November 2014):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Mo (%)</th><th>Re ppm</th><th>Cu (%)</th></tr>
<tr><td>Probable</td><td>5.2</td><td>1.30</td><td>22</td><td>0.24</td></tr>
<tr><td>Total</td><td>5.2</td><td>1.30</td><td>22</td><td>0.24</td></tr>
<tr><td>Contained (kt)</td><td></td><td>68</td><td>0.12</td><td>12.5</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>A feasibility study on the Merlin Project was completed in November 2014.

Construction of an exploration decline began in 2010, with Phase 1 of the decline development completed in 2012. Decline development enabled a cross-cut to be developed into the Little Wizard deposit.

Trial mining from a single drive in the highly weathered upper parts of the Little Wizard zone was completed in 2014 to obtain bulk metallurgical sample and to test ground stability.

Since 2014 the project has been on care and maintenance.

The Merlin deposit is located on granted mining leases that will allow mining development to commence quickly upon a construction decision and project funding.

Development of the Merlin Project will leverage off existing infrastructure including the decline, underground development and mine site infrastructure already in place.

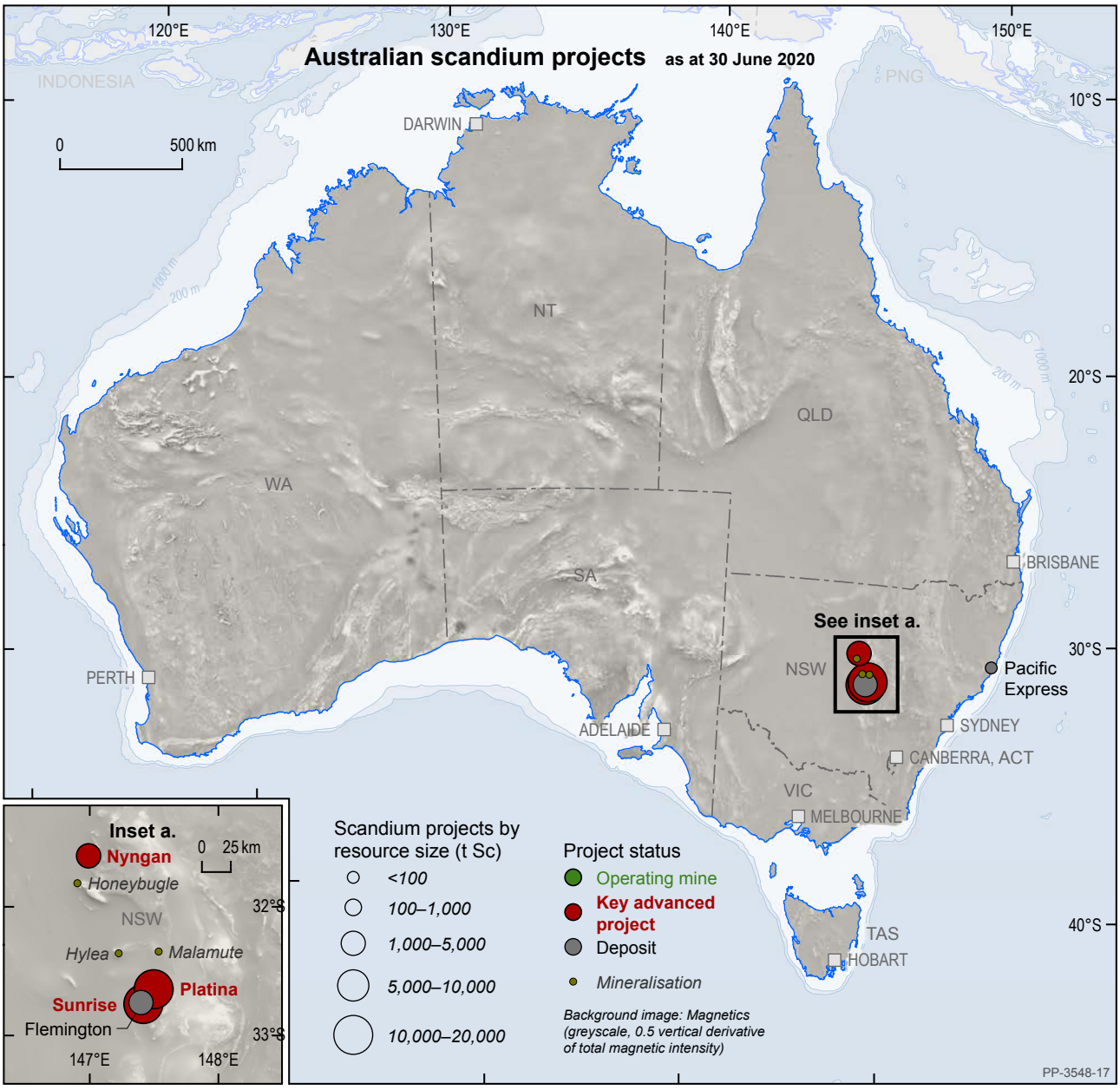
Cultural heritage agreement and key development approvals in place for producing Mo/Re concentrate in Australia. Approval for refining/roasting either in China or Australia will need further application.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):
• Ore mined and processed: 0.5 Mtpa
• Molybdenum in concentrate: 5,300 tpa
• Rhenium in concentrate: 7 tpa
• Low-grade copper-gold concentrate: 600 tpa</td></tr>
<tr><td>Infrastructure</td><td>Decline and exploration drive with ventilation and underground pumping stations. Mobile vehicle and engineering workshops, office, change rooms, laydown areas and fuel bay.

Power station and airport 50 km away at Chinova’s Osborne mine.</td></tr>
<tr><td>Project development capital costs</td><td>Start-up capital costs of A$354m, consists of A$261m for the Australian portion and A$93m for the China-based refinery/roaster.

Capital costs based on the 2014 feasibility study. These costs are no longer current.</td></tr>
<tr><td>Project economics</td><td>Economic results from the 2014 feasibility study:
• IRR: 13%
• $NPV_{10\%}$: A$67.52m
• After-tax cash flows: A$556m</td></tr>
<tr><td>Project funding</td><td>Project on care and maintenance.</td></tr>
<tr><td>Other</td><td>chinovaresources.com/the-big-picture/projects</td></tr>
</table>

Image courtesy of Clean TeQ Holdings Ltd

Scandium (Sc)



Advanced scandium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Scandium	**Sunrise**	Clean TeQ Holdings Ltd	Pre-const	Ni, Co, Sc	183.3	99	ppm	Sc	18	52
Scandium	**Platina Scandium**	Platina Resources Ltd	FS	Sc (Co, Ni, Al)	35.6	405	ppm	Sc	14	119
Scandium	**Nyngan Scandium**	Scandium Int. Mining Corp.	FS	Sc	16.9	235	ppm	Sc	4	121

Sunrise project summary included in the cobalt section.

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>SCANDIUM</th><th>NSW</th></tr>
<tr><td>PROJECT NAME</td><td colspan="2">PLATINA SCANDIUM PROJECT</td></tr>
<tr><td>Location</td><td colspan="2">Mine site is approximately 53 km north-east of Condobolin and 11 km south-west of Tullamore in central New South Wales. The plant site is approximately 5 km north-west of Condobolin.</td></tr>
<tr><td>Company name</td><td colspan="2">Platina Resources Limited</td></tr>
<tr><td>Company ownership</td><td colspan="2">ASX-listed (PGM)</td></tr>
<tr><td>Project description</td><td colspan="2">The project feasibility study has confirmed the technical and financial viability of constructing a simple, low-strip ratio, open-cut mining operation and staged ore processing facility utilising the high-pressure acid leach process to produce scandium oxide.</td></tr>
<tr><td>Expected products</td><td colspan="2">Primary product is Sc_2O_3 (scandium oxide) of 99.99% purity.

There is potential potential future opportunity to generate cobalt, nickel, platinum and aluminium products when Stage 2 plant expansion is undertaken.</td></tr>
<tr><td>Mineral inventory</td><td colspan="2">Mineral resources (as at 16 August 2018):
<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>Sc (ppm)</th></tr>
<tr><td>Measured</td><td>7.8</td><td>435</td></tr>
<tr><td>Indicated</td><td>12.5</td><td>410</td></tr>
<tr><td>Inferred</td><td>15.3</td><td>380</td></tr>
<tr><td>Total</td><td>35.6</td><td>405</td></tr>
<tr><td>Contained (kt)</td><td></td><td>14</td></tr>
</table>
Ore reserves (as at 18 December 2018):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Sc (ppm)</th></tr>
<tr><td>Proved</td><td>3.1</td><td>575</td></tr>
<tr><td>Probable</td><td>1.0</td><td>550</td></tr>
<tr><td>Total</td><td>4.0</td><td>570</td></tr>
<tr><td>Contained (kt)</td><td></td><td>4</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td colspan="2">A feasibility study was completed in December 2018, which proposed a two-stage development of the project over its 30-year mine life:

• Stage 1: small-scale scandium oxide production (20 t/y)

• Stage 2: increased scandium oxide production (40 t/y) by upgrading the processing train. There is potential to also produce cobalt, nickel and high-purity alumina (HPA) by-products following this plant upgrade.

Stages 1 and 2 encompass:

• development of an open-cut mine using conventional free-dig, load and haul mining methods

• transportation of ore by public road from the mine site to the plant site and back-loading of dewatered and neutralised residue

• development of a high-pressure acid leach processing plant to leach and extract the contained scandium from the ore</td></tr>
</table>

Stage of development	• development of a range of ancillary infrastructure including waste rock emplacements, water storage and management facilities, site access road and intersections • rehabilitation of the mine site and plant site to achieve final landforms suitable for agriculture and/or nature conservation. A mining lease application (MLA) covering the mine site has been lodged. The lease measures approximately 9.3 km north-south and 7.8 km east-west. This MLA is within the exploration licence EL7644 which is 100% owned by Platina Resources Limited and is due for renewal on 2 December 2020. A property lease with option to purchase by July 2021 was signed by Lachlan Shire Council and Platina Resources Limited in July 2018, covering land, formerly used by the Condobolin Abattoir, for the scandium ore processing facility and project administration office.
Expected production	**Mine ore production** • Year 1 – 11,650 tpa; Year 2 – 17,475 tpa; Year 3 – 23,300 tpa; Year 4 – 39,610 tpa; Year 5 onward – 46,600 tpa. **Scandium oxide production Stage 1:** • Year 1 – 10 tpa; Year 2 – 15 tpa; Year 3 – 20 tpa. **Scandium oxide production Stage 2:** • Year 4 – 34 tpa; Year 5 onward – 40 tpa.
Infrastructure	**Existing mine site infrastructure:** • Access via sealed regional road from Tullamore (11 km) and Condobolin (53 km) • Domestic power supply **Existing plant site infrastructure:** • Domestic water supply • Domestic and HV power supply • Access via sealed road from Condobolin and the mine site • Site dams, fencing, industrial concrete pads, bulk water storage tanks • Site roadways • Two residences
Project development Capital Costs	Capital cost for the development of the mine, process plant and associated infrastructure for Stage 1 of the project is US$48.1m. The capital cost for Stage 2 of the project is US$11.1m.
Project economics	Cash-flow modelling of the Platina Scandium Project demonstrates a post-tax 100% equity net present value (NPV) at an 8% discount rate of U$166m (A$234m). This generates a post-tax IRR of 29% and a payback period of 5.3 years.
Project funding	Project funding options continue to be pursued. The company welcomes discussion regarding financing of the project construction or offtake.
Other	platinaresources.com.au

CRITICAL MINERAL(S)	SCANDIUM NSW
PROJECT NAME	**NYNGAN SCANDIUM PROJECT**
Location	Located in New South Wales, approximately 450 km north-west of Sydney and approximately 25 km due west from the town of Nyngan, a rural town of approximately 2,100 people.
Company name	**Scandium International Mining Corporation**
Company ownership	TSX-listed **(SCY)** The Nyngan Scandium Project is 100% owned by SCY's wholly owned Australian subsidiary, EMC Metals Australia Pty Ltd. SCY is majority (>50%) owned by US investors and 33% owned by the current board and management.
Project description	The Nyngan Scandium Project represents the world's first scandium-only mining project. It is based on a shallow and surface-mineable lateritic clay deposit with an attractive scandium enrichment, but relatively little other mineral enrichment. Commercial activity in the area is predominantly farming and mining copper, gold and silver. Annual mining activity will be conducted in short campaigns lasting 4–6 weeks each. Mining and ore sizing will produce feedstock for a continuous high-pressure acid leach autoclave system (HPAL), followed by a solvent extraction (SX) concentration of scandium. Final oxide product is made through an oxalate stage, calcine finish, and packaging. All of this product recovery, refinement and packaging is planned as mine site activity, to produce a saleable oxide product (Sc_2O_3, or scandia). The process flow sheet resembles a conventional laterite recovery system most comparable to nickel processes. Considerable bench scale and small pilot metallurgical test work has been conducted with third-party laboratories to finalise the flow sheet and SX specifics. US patents have been filed to protect rights in scandium-unique areas. An independent feasibility study (NI 43-101) was completed on the project by Lycopodium (Brisbane) in 2016. The feasibility study considered a 20-year project and utilised approximately 8.5% of the total established mineral resource (M&I), grading 409 ppm Sc average over the Phase 1 project period.
Expected products	High-grade scandium oxide powder (Sc_2O_3). Scandium product, as oxide, is expected to be offered in various grades to meet customer requirements, with price adjustment for purity. Technical and electrical applications will likely want 99.9% purity, and aluminium alloy applications generally prefer 98–99% purity. Product volumes are relatively small, and transport to global end-use markets is likely standard air freight to customers/container sea freight for distribution centres.
Mineral inventory	Mineral resources (as at May 2016):

Resource category	Tonnes (Mt)	Sc (ppm)
Measured	5.7	256
Indicated	11.2	225
Total	**16.9**	**235**
Contained (kt)		**4.0**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves (as at May 2016):
<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Sc (ppm)</th></tr>
<tr><td>Proved</td><td>0.8</td><td>394</td></tr>
<tr><td>Probable</td><td>0.6</td><td>428</td></tr>
<tr><td>Total</td><td>1.4</td><td>409</td></tr>
<tr><td>Contained (kt)</td><td></td><td>0.6</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>NI 43-101 compliant feasibility study completed in May 2016.

Development consent granted in August 2016.

Mine lease granted in October 2017 and revised in 2019.

The current ML covers >50% of the resource included in the feasibility study, sufficient to build and operate the project for 20 years, essentially as designed in the feasibility study, plus expansions to footprint, mining volumes, and product output.

The company is currently seeking scandium product offtakes with customers, in order to proceed to project financing and construction.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):

• Ore mined and processed: 75,000 tpa

• Scandium oxide (Sc_2O_3): 38.3 tpa</td></tr>
<tr><td>Infrastructure</td><td>The Nyngan area offers excellent local infrastructure with nearby water pipeline, rail line adjacent to the project, electrical powerlines adjacent to the project and a local skilled mining workforce. The project is 3 km from an all-weather sealed road, 25 km from the town of Nyngan and 20 km from the AGL Solar Farm, which is currently the largest solar farm in Australia, at 102 MW.</td></tr>
<tr><td>Project development capital costs</td><td>The feasibility study capital cost is estimated at US$87m, and includes: US$3m of pre-strip/mining, US$26 m in infrastructure costs, and US$8m (11%) contingency.</td></tr>
<tr><td>Project economics</td><td>Results of the 2016 feasibility study (to a +15/-5% accuracy) include:

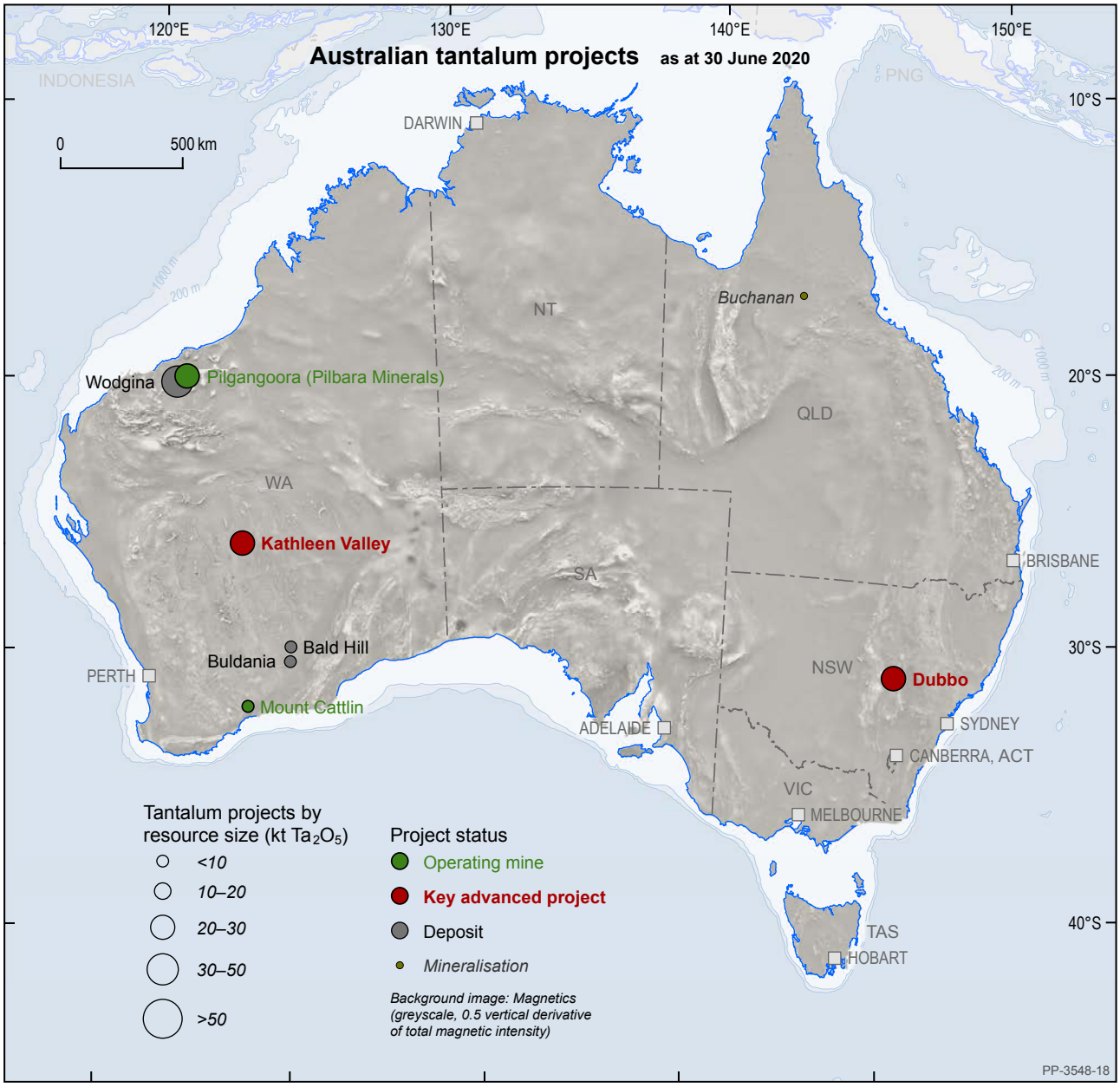
• IRR of 33%

• after-tax $NPV_{8\%}$ of US$225m

• payback period of 3.3 years from initial production.</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussion regarding financing of the project construction or scandium product offtake agreements.</td></tr>
<tr><td>Other</td><td>Investor briefings, presentations, videos, company history, and the Nyngan feasibility study can be found on the company website: scandiummining.com.</td></tr>
</table>

Image courtesy of Clean TeQ Holdings Ltd

Tantalum (Ta)


Australian tantalum projects
as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
NT
Buchanan
Wodgina
Pilgangoora (Pilbara Minerals)
QLD
WA
Kathleen Valley
SA
BRISBANE
Bald Hill
Buldania
PERTH
NSW
Dubbo
Mount Cattlin
ADELAIDE
SYDNEY
CANBERRA, ACT
VIC
MELBOURNE
TAS
HOBART
Tantalum projects by resource size (kt Ta_2O_5)
<10
10–20
20–30
30–50
>50
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics (greyscale, 0.5 vertical derivative of total magnetic intensity)
PP-3548-18

Advanced tantalum projects (total mineral resource tonnage, grade and contained mineral)

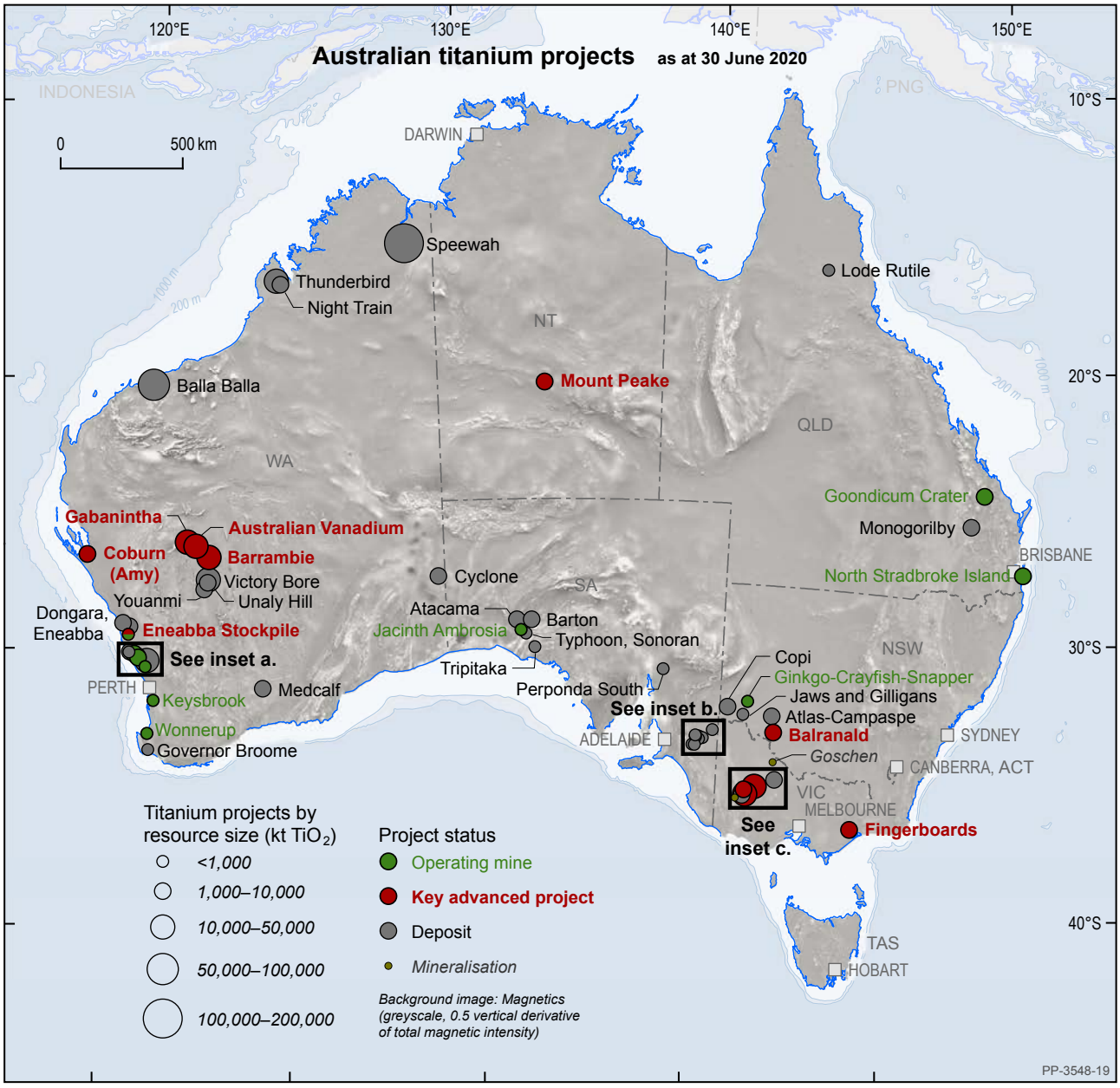
Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Tantalum	**Pilgangoora (Pilbara Min.)**	Pilbara Minerals Ltd	Operating	Li, Ta	223.2	0.01	%	Ta_2O_5	26	–
Tantalum	**Mt Cattlin**	Galaxy Resources Ltd	Operating	Li, Ta	14.6	0.02	%	Ta_2O_5	2	–
Tantalum	**Dubbo**	Alkane Resources Ltd	Pre-const	Zr, Nb, Hf, Ta, REE	75.2	0.03	%	Ta_2O_5	23	107
Tantalum	**Wodgina**	Mineral Resources Ltd	Care and maint	Li, Ta	259.2	0.02	%	Ta_2O_5	41	–
Tantalum	**Bald Hill**	Alita Resources Ltd	Care and maint	Li, Ta	26.5	0.01	%	Ta_2O_5	4	–
Tantalum	**Kathleen Valley**	Liontown Resources Ltd	PFS	Li, Ta	156.0	0.01	%	Ta_2O_5	20	90

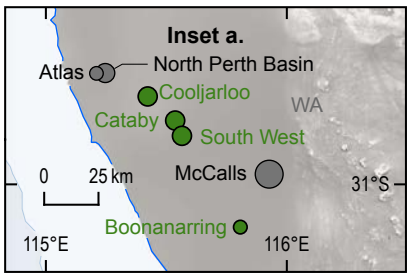
Dubbo project summary included in the rare-earth elements section.

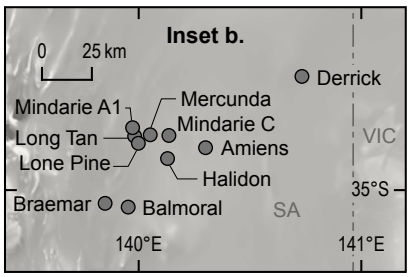
Kathleen Valley project summary included in the lithium section.

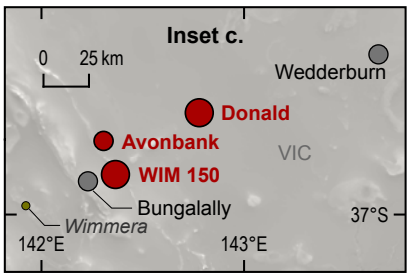
Image courtesy of Alkane Resources Ltd

Titanium (Ti)


Australian titanium projects as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
Speewah
Thunderbird
Night Train
Lode Rutile
NT
Mount Peake
Balla Balla
QLD
WA
Goondicum Crater
Monogorilby
BRISBANE
North Stradbroke Island
Gabanintha
Australian Vanadium
Coburn (Amy)
Barrambie
Victory Bore
Youanmi
Unaly Hill
Dongara, Eneabba
Eneabba Stockpile
See inset a.
Cyclone
SA
Atacama
Jacinth Ambrosia
Barton
Typhoon, Sonoran
Tripitaka
Perponda South
Copi
Ginkgo-Crayfish-Snapper
Jaws and Gilligans
See inset b.
Atlas-Campaspe
Balranald
Goschen
NSW
PERTH
Keysbrook
Medcalf
Wonnerup
Governor Broome
ADELAIDE
SYDNEY
CANBERRA, ACT
VIC
MELBOURNE
See inset c.
Fingerboards
TAS
HOBART
Titanium projects by resource size (kt TiO2)
<1,000
1,000–10,000
10,000–50,000
50,000–100,000
100,000–200,000
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics (greyscale, 0.5 vertical derivative of total magnetic intensity)
PP-3548-19


Inset a.
Atlas
North Perth Basin
Cooljarloo
WA
Cataby
South West
0
25 km
McCalls
31°S
Boonanarring
115°E
116°E


Inset b.
0
25 km
Derrick
Mindarie A1
Mercunda
Mindarie C
Long Tan
Amiens
VIC
Lone Pine
Halidon
35°S
Braemar
Balmoral
SA
140°E
141°E


Inset c.
0
25 km
Wedderburn
Donald
Avonbank
VIC
WIM 150
Bungalally
Wimmera
37°S
142°E
143°E

Advanced titanium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Titanium	**Cataby**	Iluka Resources Ltd	Operating	Ti, Zr	308.0	1.75	%	TiO_2	5,394	–
Titanium	**Goondicum Crater**	Melior Resources Inc	Operating	Ti,P	92.8	5.20	%	TiO_2	4,828	–
Titanium	**Cooljarloo**	Tronox Holdings Plc	Operating	Ti, Zr	416.0	0.79	%	TiO_2	3,299	–
Titanium	**South West**	Iluka Resources Ltd	Operating	Ti, Zr	83.0	3.96	%	TiO_2	3,289	–
Titanium	**Keysbrook**	Doral Pty Ltd	Operating	Ti, Zr	78.2	1.26	%	TiO_2	982	–
Titanium	**Jacinth Ambrosia**	Iluka Resources Ltd	Operating	Zr, Ti	184.0	0.47	%	TiO_2	866	–
Titanium	**Ginkgo-Crayfish -Snapper**	Tronox Holdings Plc	Operating	Ti, Zr (REE)	74.0	1.06	%	TiO_2	783	–
Titanium	**Boonanarring**	Image Resources Ltd	Operating	Ti, Zr	30.3	1.98	%	TiO_2	601	–
Titanium	**Wonnerup**	Tronox Holdings Plc	Operating	Ti, Zr	21.0	2.63	%	TiO_2	552	–
Titanium	**Eneabba Stockpile**	Iluka Resources Ltd	Operating	Zr, REE, Ti	1.0	16.92	%	TiO_2	169	103
Titanium	**North Stradbroke**	Sibelco Australia Ltd	Operating	Ti, Zr					NA	–
Titanium	**Atlas-Campaspe**	Tronox Holdings Plc	Construction	Ti, Zr	88.0	3.16	%	TiO_2	2,785	–
Titanium	**Balla Balla**	BBI Group Pty Ltd	FS	V, Ti	455.9	13.80	%	TiO_2	62,914	–
Titanium	**Donald**	Astron Ltd	FS	Zr, Ti, REE	2,427.0	1.98	%	TiO_2	47,996	128
Titanium	**Thunderbird**	Sheffield Resources Ltd	FS	Zr, Ti	3,230.0	1.45	%	TiO_2	46,893	–
Titanium	**Barrambie**	Neometals Ltd	FS	Ti, V	280.1	9.18	%	TiO_2	25,713	130
Titanium	**WIM150**	Murray Zircon Pty Ltd	FS	Zr, Ti, REE	1,650.0	1.29	%	TiO_2	21,218	132
Titanium	**Fingerboards**	Kalbar Resources Ltd	FS	Zr, Ti, REE	530.0	1.60		TiO_2	8,689	149
Titanium	**Mount Peake**	TNG Ltd	FS	V, Ti, Fe	160.0	5.30	%	TiO_2	8,480	158
Titanium	**Coburn (Amy)**	Strandline Resources Ltd	FS	Ti, Zr	1,606.0	0.48	%	TiO_2	7,693	136
Titanium	**Balranald**	Iluka Resources Ltd	FS	Ti, Zr	45.5	15.68	%	TiO_2	7,136	154
Titanium	**Cyclone**	Diatreme Resources Ltd	FS	Zr, Ti	203.0	0.73	%	TiO_2	1,488	–
Titanium	**Dongara**	Tronox Holdings Plc	FS	Ti, Zr	68.0	1.91	%	TiO_2	1,297	–
Titanium	**Atlas**	Image Resources Ltd	FS	Ti, Zr	18.1	2.23	%	TiO_2	404	–
Titanium	**Mindarie C**	Murray Zircon Pty Ltd	Care and maint	Ti, Zr	19.3	1.28	%	TiO_2	246	–
Titanium	**Mindarie A1**	Murray Zircon Pty Ltd	Care and maint	Ti, Zr	8.8	1.20	%	TiO_2	105	–
Titanium	**Australian Vanadium**	Australian Vanadium Ltd	FS	V, Ti	208.2	9.00	%	TiO_2	18,738	162
Titanium	**Avonbank**	WIM Resource Pty Ltd	FS	Zr, Ti	490.0	1.54	%	TiO_2	7,534	140
Titanium	**Medcalf**	Audalia Resources Ltd	FS	V, Ti	32.0	8.98	%	TiO_2	2,874	–
Titanium	**Copi**	Relentless Resources Ltd	PFS	Ti, Zr	75.4	1.79	%	TiO_2	1,353	–

All heavy mineral sands project summaries are included in the titanium section (other than the Eneabba Stockpile Project, which is included in the rare-earth elements section).

Mount Peake project summary included in the vanadium section.

Australian Vanadium project summary included in the vanadium section.

CRITICAL MINERAL(S)	ZIRCONIUM, TITANIUM, RARE-EARTH ELEMENTS VIC
PROJECT NAME	**DONALD MINERAL SANDS PROJECT**
Location	Located in Minyip, Victoria.
Company name	**Astron Corporation Ltd (Astron)**
Company ownership	ASX-listed **(ASX:ATR)**
Project description	Known as a world-class zircon and rare-earths rich heavy mineral sand (HMS) deposit in the Victorian Murray Basin, the Donald Mineral Sands (DMS) Project is a wholly owned subsidiary of Astron. Priding itself on the size of the deposit, together with the ease in conventional methodologies in excavating and processing, the DMS Project is well positioned to be a significant player in the mineral sands and rare-earth markets. Conventional gravity separation processing and large-scale bulk earthmoving efforts will see optimum efficiencies from both the mining front and separation process located onsite. Opportunities for concentrate upgrade plant (CUP) implementation allows for diversified product qualities that can be tailored to end-customer demand.
Expected products	Heavy-mineral concentrate 85% HMC grade – ZrO_2, TiO_2, rare-earth oxide (REO) content and assemblies are consistent across the ore zones.
Mineral inventory	Mineral resources (as at 7 April 2016):

			Percentage of total heavy metals				
Resource category	**Tonnes (Mt)**	**Total HM (%)**	**Zircon**	**Rutile + anatase**	**Ilmenite**	**Leuco-xene**	**Monz-anite**
Measured	448	5.4	20	8	31	21	2
Indicated	1,171	4.6	18	8	32	18	2
Inferred	807	4.7	19	9	33	17	2
Total	**2,427**	**4.8**	**19**	**8**	**32**	**18**	**2**
Contained (kt)		**116,496**	**22,134**	**9,320**	**37,279**	**20,969**	**2,330**

Stage of development	The project has benefited from several iterations of pre-feasibility and feasibility studies as technologies and global demands have evolved. Having completed a feasibility study in 2015, the DMS Project is now poised to commence the detailed engineering, optimisation and financing stages. Mining lease ML5532 was granted 2011. Retention licences and exploration licences are maintained for future stages and developments beyond the initial start-up zones. Major environmental approvals have been granted, with the EES approved. Submission of the work plan is pending, to be based on detailed design criteria.

Stage of development	Two stages of bulk sample pilot plant testing were completed in 2019 for both wet and dry separation concepts. Astron has recently completed a large-scale piloting program where run-of-mine material was successfully separated into a final heavy-mineral concentrate exceeding past performances in both quality and grade.
Expected production	550–600 kt per annum HMC – Stage 1, with the following approximate production: • Ore mined and processed: 9.0 Mtpa • Concentrate: 600 ktpa • Contained ZrO_2: 116 ktpa • Contained TiO_2: 254 ktpa • Contained REO: 16.5 ktpa
Infrastructure	External power, water and renewable energy systems are in feasibility stages – diversification and environmental stewardship will be ongoing efforts beyond project start. Water volumes purchased 2011 – 6.975 GL at A$18m
Project development capital costs	Not publicly available. Please contact the company for further information.
Project economics	Not publicly available. Please contact the company for further information.
Project funding	Astron is currently exploring funding opportunities.
Other	Cautionary statement: certain sections of this project summary contain forward-looking statements that are subject to risk factors associated with, among others, the economic and business circumstances occurring from time to time in the countries and sectors in which the Astron group operates. It is believed that the expectations reflected in these statements are reasonable, but they may be affected by a wide range of variables that could cause results to differ materially from those currently projected. For further information or project details, refer to: astronlimited.com.au.

CRITICAL MINERAL(S)	TITANIUM, VANADIUM WA
PROJECT NAME	**BARRAMBIE**
Location	Located approximately 80 km north-west of Sandstone and 475 km east of the port of Geraldton in Western Australia.
Company name	**Neometals Ltd**
Company ownership	ASX-listed **(NMT)** Neometals – 11% board and management
Project description	The Barrambie titanium and vanadium project is one of the world's highest-grade hard-rock titanium-vanadium deposits. Barrambie is unique owing to its exceptionally high-grade titanium resource grade, coupled with high vanadium content and the weathered nature of the orebody (low contaminants). Due to the combination of both high-grade titanium and vanadium, a number of flow sheets are being evaluated for the project with a final decision expected to be made in mid-2021. Common to all processing options is low strip ratio open-cut mining combined with simple beneficiation.
Expected products	Potential products available from the various flow sheets options include: • mixed concentrate • ilmenite and iron/vanadium concentrate • vanadium pentoxide flake and/or ferrovanadium with approximately 80% vanadium content (FeV80) • titanium hydrolysate.
Mineral inventory	Mineral resource estimate (as at April 2018) at > 0.2% V_2O_5 or > 10% TiO_2 cut-off:

Resource category	Tonnes (Mt)	TiO_2 (%)	V_2O_5 (%)
Indicated	187.1	9.61	0.46
Inferred	93.0	8.31	0.40
Total	**280.1**	**9.18**	**0.44**
Contained (kt)		**25,713**	**1,232**

A high-grade titanium subset of the total mineral resource estimate of 53.6m tonnes at 21.17% TiO_2 and 0.63% V_2O_5 using higher cut-off grades has also been identified.

A high-grade vanadium subset of the total mineral resource estimate of 64.9m tonnes at 0.82% V_2O_5 and 16.90% TiO_2 using higher cut-off grades has also been identified.

Ore reserves (as at May 2019) at 0.6% V_2O_5 cut-off:

Reserve category	Tonnes (Mt)	TiO_2 (%)	V_2O_5 (%)
Probable	39.9	15.10	0.78
Total	**39.9**	**15.10**	**0.78**
Contained (kt)		**6,025**	**311**

<table>
<tr><td>Stage of development</td><td>A number of flow sheet options are at various stages of studies. Due to space limitations, only the results from the 2019 feasibility study on production of ferrovanadium are presented here.

The project has a granted mining licence and Ministerial approval to develop a fully integrated mine, concentrator and chemical processing facility.

Neometals has received strong interest in the Barrambie Project from a number of parties in China, and in October 2019 announced that it had entered into a memorandum of understanding with a Chinese research organisation, the Institute of Multipurpose Utilization of Mineral Resources Chinese Academy of Geological Sciences, to jointly advance development of Barrambie.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):

• Ore mined and processed: 3.14 Mtpa

• Concentrate: 1.061 Mtpa

• FeV80 produced: 6,337 tpa</td></tr>
<tr><td>Infrastructure</td><td>The Barrambie Project is located next to the Meekatharra-to-Sandstone road. The project is 80 km north-west of the town of Sandstone. Sandstone has a regional airport and is serviced with a bitumen road through to the Port of Geraldton.</td></tr>
<tr><td>Project development capital costs</td><td>Capital costs from the 2019 Barrambie feasibility study:

<table><tr><th>Capital</th><th>A$m</th></tr><tr><td>Infrastructure</td><td>99</td></tr><tr><td>Mining</td><td>2</td></tr><tr><td>Crushing and beneficiation</td><td>162</td></tr><tr><td>SRL kiln and hydromet refinery</td><td>246</td></tr><tr><td>Gas lateral from GGP</td><td>62</td></tr><tr><td>Ferro vanadium circuit</td><td>35</td></tr><tr><td>Contingency (~15%)</td><td>87</td></tr><tr><td>Total</td><td>692</td></tr></table></td></tr>
<tr><td>Project economics</td><td>Key economic results from the 2019 Barrambie feasibility study:

• Mine life: 15 years

• Pre-tax $NPV_{10\%}$: A$430m

• Pre-tax IRR: 21%

• Payback period: 5.1 years</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussions regarding equity ownership, joint venturing, and financing of the project construction or offtake.</td></tr>
<tr><td>Other</td><td>neometals.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	ZIRCON, TITANIUM, RARE-EARTH ELEMENTS VIC
PROJECT NAME	**WIM150**
Location	Located in the Wimmera region of Western Victoria, approximately 20 km south-east of Horsham and 280 km north-west of Melbourne.
Company name	**Murray Zircon Pty Ltd**
Company ownership	Private unlisted company. The WIM150 Project is a joint venture between Orient Zirconic Pty Ltd and Million Up Ltd, a Hong Kong-based investment fund. Murray Zircon Pty Ltd has been appointed to manage the project on behalf of the joint venture. Murray Zircon assumed management of the WIM150 Project in July 2016.
Project description	WIM150 is one of the largest known mineral sands deposits in the world, with 55 years of production underwritten by reserves. The large-scale, shallow deposit has a low strip ratio of 0.5:1 allowing for low-cost conventional mining methods and continuous rehabilitation. The deposit is conveniently located close to key infrastructure including water supplies, roads, rail and powerlines. A skilled local workforce is also available. Ore processing methods use industry-standard equipment and technology.
Expected products	Zircon flour. Titanium concentrates (containing rutile, leucoxene and ilmenite). Rare-earth elements concentrate (containing monazite and xenotime)
Mineral inventory	Mineral resources (as at 18 June 2013):

			Percentage of total heavy metals					
Resource category	**Tonnes (Mt)**	**Total HM (%)**	**Zircon**	**Rutile**	**Leuco-xene**	**Illem-inte**	**Monz-anite**	**Xeno-time**
Measured	415	4.3	21.7	11.5	5.8	32.3	2.3	0.41
Indicated	580	4.0	20.4	11.6	6.1	31.0	2.0	0.37
Inferred	655	3.1	20.1	11.8	6.2	31.1	1.9	0.35
Total	**1,650**	**3.7**	**20.7**	**11.7**	**6.0**	**31.4**	**2.1**	**0.38**
Contained (kt)		**61,050**	**12,637**	**7,143**	**3,663**	**19,170**	**1,282**	**232**

Ore reserves (as at 18 June 2013):

			Percentage of total heavy metals					
Reserve category	**Tonnes (Mt)**	**Total HM (%)**	**Zircon**	**Rutile**	**Leuco-xene**	**Illem-inte**	**Monz-anite**	**Xeno-time**
Proven	268	4.5	22.0	11.7	5.9	32.7	2.4	0.4
Probable	283	4.2	21.3	11.6	5.9	30.8	2.2	0.4
Total	**552**	**4.3**	**21.6**	**11.7**	**5.9**	**31.7**	**2.3**	**0.4**
Contained (kt)		**24,000**	**5,184**	**2,808**	**1,416**	**7,608**	**552**	**96**

Stage of development	A feasibility study and project optimisation has been completed. Key environmental studies have been undertaken. A retention licence has been secured for 10 years. A strategic review of the proposed project is currently being undertaken.

Expected production	• Ore mined and processed:	10.1 Mtpa
	• Heavy mineral concentrate:	413 ktpa
	• Zircon flour:	73.6 ktpa
	• Titanium concentrate (total combined):	86.1 ktpa
	• Rare-earth concentrate:	14.1 ktpa
Infrastructure	Interstate highway intersects project. 275 kV powerline nearby. Water supply on site. Intermodel rail freight terminal 10 km from processing plant site.	
Project development capital costs	A$482m	
Project economics	Not publicly available.	
Project funding	The company welcomes discussion regarding financing of the project construction or offtake.	
Other	murrayzircon.com.au	

CRITICAL MINERAL(S)	RARE-EARTH ELEMENTS, ZIRCONIUM, TITANIUM VIC
PROJECT NAME	**FINGERBOARDS**
Location	Located 200 km east of Melbourne and 25 km west of the town of Bairnsdale in Victoria.
Company name	**Kalbar Operations Pty Ltd**
Company ownership	A private joint venture between public unlisted Kalbar and private equity through operating company Kalbar Operations Pty Ltd.
Project description	The Fingerboards high-grade resource (FHGR) is one of the largest high-grade zircon resources in the world, comprising enriched units in the upper part of the much larger 3 Bt Glenaladale mineral sands deposit. During the first full 10 years of production, the project will produce mineral sands concentrates containing an average of 150,000 tpa of zircon and 13,500 tpa of rare-earths, representing over 10% of global zircon and 5% of global rare-earths supply. Low-cost conventional dry mining is planned to commence in 2022, with the initial mine life forecast to be 15 years, during which approximately 150 Mt of ore will be mined. The project plans to produce a zircon-rich non-magnetic concentrate (non-mags), and ilmenite- and rare-earth-rich magnetic concentrate (mags). Kalbar has signed offtake contracts for over 50% of non-mags with major zircon consumers in China and a mineral processor in Thailand. Kalbar is also advancing studies on downstream processing of the mags to produce higher-value rare-earth and ilmenite products.
Expected products	Non-magnetic concentrate (zircon rich) with by-products rutile and rare-earths mineral monazite. Magnetic concentrate (ilmenite- and heavy rare-earth elements-rich) containing significant amounts of heavy rare-earths as xenotime. The zircon produced from Fingerboards non-mags is of premium grade, is low in impurities such as iron and alumina, and is suitable for high-value applications such as ceramics.
Mineral inventory	Fingerboards mineral resource (as at 2019):

Resource category	Tonnes (Mt)	TiO_2 (%)	TREO (%)	Zircon (%)
Measured	69.1	1.91	0.11	1.26
Indicated	206.0	1.75	0.10	1.10
Inferred	250.0	1.50	0.08	0.90
Total	**530.0**	**1.60**	**0.09**	**1.00**
Contained (kt)		**8,689**	**490**	**5,349**

Fingerboards ore reserves (as at 2019):

Reserve category	Tonnes (Mt)	TiO_2 (%)	TREO (%)	Zircon (%)
Proved	73.0	1.80	0.11	1.20
Probable	100.0	1.90	0.11	1.20
Total	**173.0**	**1.90**	**0.11**	**1.20**
Contained (kt)		**3,230**	**191**	**2,110**

<table>
<tr><td>Mineral inventory</td><td>The FHGR is part of a total Fingerboards mineral resource defined in 2018 of 910 Mt at 1.2% TiO_2, 0.06% total rare-earth oxides (TREO) and 0.7% zircon, which in turn is part of the Glenaladale Mineral Sands Project, which was defined in 2016 as 2.7 Bt at 1.95% heavy mineral.</td></tr>
<tr><td>Stage of development</td><td>A feasibility study was completed in August 2018 and updated in April 2020.

Project funding of A$144m has been secured as a staged private equity investment into Kalbar Operations Pty Ltd (KOPL). Kalbar Ltd expects to remain the majority shareholder of KOPL through to production.

There are offtake agreements in place for more than 50% of the non-mag concentrate.

An environmental effects statement is being completed and is expected to be ready for public review in 2020 at the time of publication.

A financial investment decision is expected in early 2021, followed by construction and commissioning within 18 months.</td></tr>
<tr><td>Expected production</td><td>Average annual production:

<table><tr><th></th><th>Stage 1
Years 1–2</th><th>Stage 2
Year 3</th></tr><tr><td>Ore mined</td><td>7.2 Mtpa</td><td>11.8 Mtpa</td></tr><tr><td>Magnetic concentrate</td><td>205 ktpa</td><td>294 ktpa</td></tr><tr><td>Non-magnetic concentrate</td><td>223 ktpa</td><td>324 ktpa</td></tr><tr><td>Contained zircon</td><td>110 ktpa</td><td>155 ktpa</td></tr><tr><td>Contained TREO</td><td>10 ktpa</td><td>14 ktpa</td></tr><tr><td>Contained titanium oxide</td><td>135 ktpa</td><td>191 ktpa</td></tr></table></td></tr>
<tr><td>Infrastructure</td><td>The project is located 25 km west of the town of Bairnsdale, the commercial and local government centre of East Gippsland. The project area is well served by sealed roads and benefits from ready access to good infrastructure, services, and accommodation. A significant advantage for the project is that a dedicated rail siding is planned on the regional rail line, which lies 5 km south of the project.</td></tr>
<tr><td>Project development capital costs</td><td>The initial pre-production capital is A$213m with additional Stage 2 capital estimated as A$155m.</td></tr>
<tr><td>Project economics</td><td>• Post-tax $NPV_{8\%}$ of A$1,172m
• Post-tax IRR of 64%
• Payback period (post-tax) of <3 years
• EBITA of A$3.6bn over life of mine
• Total net cash flow of A$2.3bn
• NPV/capital cost ratio of 5.3:1
• Revenue to cash cost ratio (R:C) of 2.97
• Lowest zircon inducement price of <US$400/t for new zircon projects</td></tr>
<tr><td>Project funding</td><td>With A$119m of equity funding locked in place, the company is actively seeking funding for the remaining project debt.</td></tr>
<tr><td>Other</td><td>Contact: Jozsef Patarica, CEO, Kalbar Operations Pty Ltd.

jozsef.patarica@kalbarresources.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	TITANIUM, ZIRCONIUM, RARE-EARTH ELEMENTS WA
PROJECT NAME	**COBURN MINERAL SANDS PROJECT**
Location	Located in the Shark Bay (Gascoyne) region of Western Australia, some 240 km north of the port city of Geraldton. Covering 1,200 km^2 of a fossil coastline, which hosts a world-class heavy-mineral sand deposit.
Company name	**Strandline Resources Limited**
Company ownership	ASX-listed **(STA)**. Top five shareholders: Tembo Capital (37.6%), C&H Investments (7.3%), Gasmere/Hatch (4.9%), Pie Funds (4.4%), Perennial Value (3.7%).
Project description	Coburn is a large advanced mineral sands project, with a high-value mineral suite, low-cost operation and strong financial returns. • World-class project in WA, great jurisdiction, close to Geraldton's mineral sands export port located approximately 240 km south. • Conventional open-pit dry mining in free-dig sand with progressive backfill and full rehabilitation. • Mine life 22.5+ years ore reserve with scoping study confirming potential mine life extension by 15 years along strike, to 38 years. • Proved processing technology with high mineral recoveries. • During initial ramp-up phase, a wet concentrate plant (WCP) will produce high-grade (95%) saleable heavy minerals concentrate (HMC) using high-capacity gravity separation and classification. • Following commissioning of the mineral separation plant (MSP), the HMC will be processed in the MSP using electrostatic separation, gravity and magnetic fractionation to produce a high-value product suite comprising a premium zircon, zircon concentrate, rutile product and a chloride ilmenite product. • Products are used in manufacture of ceramics (tiles, kitchen/bathroom fittings), TiO_2 pigment (paint, plastics), titanium metal and rare-earth applications (electric vehicles). • First production within 18 months from project start. • Coburn to generate significant socio-economic benefits.
Expected products	Premium zircon product (66% ZrO_2). Zircon concentrate product (28% ZrO_2, 7% TiO_2 and monazite). Rutile-leucoxene product (93% TiO_2). Chloride grade ilmenite product (62% TiO_2).
Mineral inventory	JORC-compliant Mineral Resources (as at 14 November 2018):

			Percentage of total heavy metals			
Resource category	**Tonnes (Mt)**	**Total HM (%)**	**Ilmenite**	**Zircon**	**Rutile**	**Leuco-xene**
Measured	119	1.3	45	24	5	6
Indicated	607	1.3	48	22	7	5
Inferred	880	1.2	49	21	7	4
Total	**1,606**	**1.2**	**48**	**22**	**7**	**5**
Contained (kt)		**19,604**	**9,468**	**4,239**	**1,342**	**891**

<table>
<tr><td>Mineral inventory</td><td>JORC-compliant Ore Reserves (as at 16 April 2019):
<table><tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Total HM</th></tr><tr><td>Proved</td><td>106</td><td>1.10</td></tr><tr><td>Probable</td><td>417</td><td>1.12</td></tr><tr><td>Total</td><td>523</td><td>1.11</td></tr><tr><td>Contained HM in-situ (kt)</td><td></td><td>5,828</td></tr></table></td></tr>
<tr><td>Stage of development</td><td>Coburn's updated feasibility study was completed on 4 June 2020 by a range of experienced independent consultants.

With key development approvals in place (including environmental, mining leases (seven), native title and heritage agreements, and water extraction licence), Coburn is now development ready. Strandline also owns the pastoral lease where the first 20 years of ore reserves lie.

Project financing and pre-construction activities are well underway.

Binding offtake agreements have been secured covering 66% of Coburn's production with some of the world's leading consumers across Europe, China and America.

Discussions are advancing with Northern Australia Infrastructure Facility (NAIF) for potential debt funding of the project.

Coburn aligns strongly with Australian and WA government policies and strategic objectives, including Australia's critical minerals strategy, Australia's infrastructure plan, the Shark Bay Shire's economic prospectus and strategic community plan, as well as WA's state planning strategy 2050.

Targeting a final investment decision 2H 2020.</td></tr>
<tr><td>Expected production</td><td>Mining at a rate of 23.4 Mtpa, with full mineral beneficiation and separation onsite producing a suite of high-quality mineral products:
• Premium zircon (66% ZrO_2): 34 ktpa
• Zircon concentrate (incl TiO_2 + monazite): 54 ktpa
• Chloride-grade ilmenite (62% TiO_2): 110 ktpa
• Rutile-leucoxene (93% TiO_2): 24 ktpa</td></tr>
<tr><td>Infrastructure</td><td>Coburn is situated in the key mining state of WA and benefits greatly from access to existing port, road, LNG gas and services infrastructure.</td></tr>
<tr><td>Project development capital costs</td><td>Efficient pre-production capital expenditure of A$260m including: open-pit mine, process facilities, accommodation village, site offices and buildings, bore field, roads, dams, waste facilities and contingency.</td></tr>
<tr><td>Project economics</td><td>Key results from the June 2020 updated feasibility study include:
• A$705m pre-tax $NPV_{8\%}$ for first 22.5 years (A$:US$ 0.70)
• 37% pre-tax IRR, with first-quartile revenue: opex ratio of 2.4
• A$2.3bn EBITDA of over the first 22.5 years of reserves
• A$104m average annual EBITDA
• 2.1 years payback period from first production.

Coburn is poised for development, underpinned by conventional designs, Tier-1 jurisdiction, exceptional products, strong customers and high-margin returns over a long mine life.</td></tr>
<tr><td>Project funding</td><td>Project funding is expected to comprise 60–70% senior debt and 30–40% equity (or similar) funding. Investor discussions are welcomed.</td></tr>
<tr><td>Other</td><td>strandline.com.au

Coburn Information Memorandum.</td></tr>
</table>

CRITICAL MINERAL(S)	TITANIUM, ZIRCONIUM NSW
PROJECT NAME	**BALRANALD**
Location	Located in the northern Murray Basin in New South Wales.
Company name	**Iluka Resources Ltd**
Company ownership	ASX-listed **(ILU)**
Project description	The Balranald Project comprises of the mining of the Balranald and Nepean deposits – two large, deep, high-grade rutile-rich deposits in northern Murray Basin, New South Wales. Iluka has been working on an internally developed, innovative underground mining method to access the orebody more economically than through conventional means. The technology involves the use of directional drilling equipment to access the mineral sands ore, which is located below the water table. A third trial to determine whether the mining technology is economically viable in a continuous mining and processing environment has been approved. The mining operation will produce a heavy mineral concentrate (HMC). It is then planned that magnetic material will be sold or transported to Iluka's synthetic rutile kiln at Capel, Western Australia. Non-magnetic material is planned to be shipped to Iluka's Narngulu mineral separation plant (MSP) in Geraldton, Western Australia for final processing. The mine will produce final products of zircon, rutile and ilmenite. The ilmenite assemblage includes sulfate and chloride ilmenite. The chloride ilmenite could be upgraded to synthetic rutile, subject to trial and study outcomes and assuming adequate kiln capacity.
Expected products	Zircon. Rutile. Ilmenite (sulfate and chloride, with chloride ilmenite potential synthetic rutile feedstock).
Mineral inventory	Company ownership mineral resources as at 31 December 2016 (HM assemblage basis):

Resource category	Tonnes (Mt)	Total HM grade (%)	Ilmenite (%)	Zircon (%)	Rutile (%)
Nepean					
Indicated	8.4	27.5	59.8	14.4	14.5
Inferred	0.8	11.2	57.3	14.6	14.0
Balranald					
Measured	11.9	31.9	64.1	10.8	12.2
Indicated	19.9	35.1	64.3	11.3	12.2
Inferred	4.5	26.5	62.4	8.3	9.4
Total	**45.5**	**31.6**	**63.1**	**11.5**	**12.4**
Contained (kt)		**14,378**	**9,072**	**1,653**	**1,782**

Notes:

1. In situ (dry) metric tonnage is reported.
2. Mineral assemblage is reported as a percentage of HM.
3. Rounding may generate differences in the last decimal place.

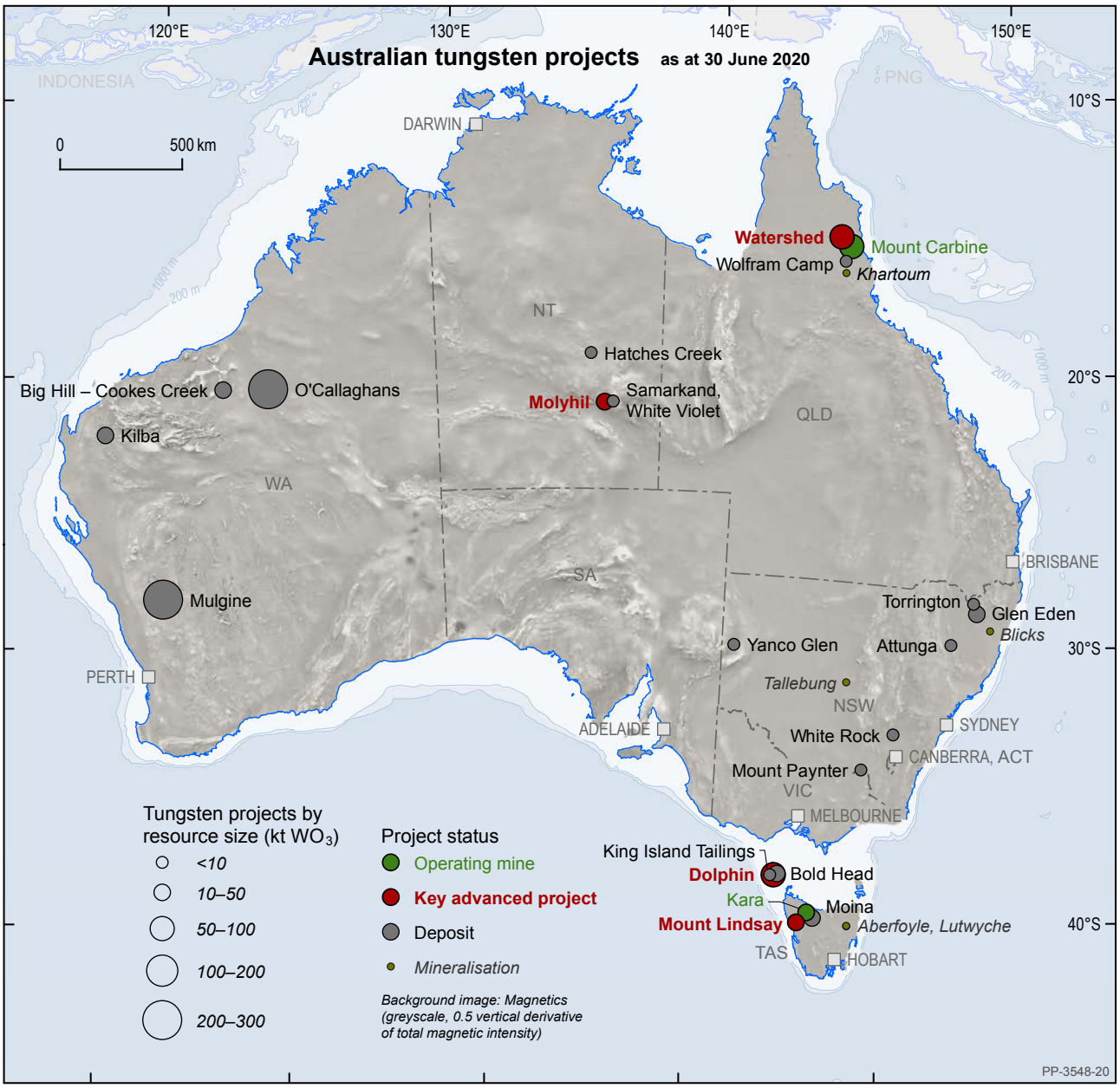
Stage of development	Updated feasibility stage. Pre-production trials. Subject to appropriate approvals and land access.
Expected production	Expected annual production (post ramp-up average): • Concentrate – ~180 ktpa – 200 ktpa Resource assemblage: • Zircon: ~13% • Rutile: ~14% • Ilmenite: ~73% Expected production given above is per mining unit with the number of units being scalable. Note the ilmenite assemblage includes sulfate and chloride ilmenite. The chloride ilmenite could be upgraded to synthetic rutile, subject to trial and study outcomes and assuming adequate kiln capacity.
Infrastructure	Mining trial infrastructure in place.
Project development capital costs	One mining unit: ~A$80–100m Additional mining unit: ~A$55–75m Capital estimate includes concentrator.
Project economics	No figures available.
Project funding	Internally funded from cash flow or available debt facilities.
Other	iluka.com Presentation to 2020 Bank of America Merrill Lynch Global Mining Conference

CRITICAL MINERAL(S)	ZIRCONIUM AND TITANIUM VIC
PROJECT NAME	**AVONBANK MINERAL SANDS PROJECT**
Location	Located in Dooen, near Horsham, approximately 300 km north-west of Melbourne in Victoria.
Company name	**WIM Resource Pty Ltd**
Company ownership	Private unlisted company
Project description	Avonbank is a world-class zircon-rich heavy mineral sands project, with proved and probable reserves underpinning a 30-year mine life. WIM will produce a high-quality heavy-mineral concentrate (HMC) at site, for export overseas, where mainly zircon and titanium will be produced, with minor rare-earth by-products. WIM has completed a test pit and demonstration-scale wet concentration plant at site, demonstrating successfully that the Avonbank ore is very amenable to standard mineral sands gravity separation using spirals. The Avonbank orebody is consistent and the topography is flat, making it very amenable to standard dry mining and a moving-hole, rapid-rehabilitation mining approach. Avonbank has existing rail at site and power and surface water pipelines nearby to the proposed process plant – meaning a lower capital expenditure and simple project start-up and operation.
Expected products	Avonbank will produce an average of 400,000–500,000 p.a of heavy mineral concentrate at site – comprising on average 30% zircon, 55% titanium and 3–5% rare-earth by-products.
Mineral inventory	Mineral resources as at 31 December 2016 (HM assemblage basis):

			Percentage of total heavy metals					
Resource category	**Tonnes (Mt)**	**Total HM (%)**	**Zircon**	**Rutile**	**Leuco-xene**	**Ilme-nite**	**Monz-anite**	**Xeno-time**
Measured	300	4.3	20	15	8.5	26	2.0	0.6
Indicated	150	3.6	19	17	9.3	28	1.9	0.6
Inferred	40	3.0	21	16	9.0	27	2.3	0.6
Total	**490**	**4.0**	**20**	**16**	**8.8**	**27**	**2.0**	**0.6**
Contained (kt)		**19,600**	**3,920**	**3,136**	**1,725**	**5,292**	**392**	**118**

<table>
<tr><td>Mineral inventory</td><td>Ore reserves as at 1 June 2018 (HM assemblage basis):
<table>
<tr><th></th><th></th><th></th><th colspan="6">Percentage of total heavy metals</th></tr>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>Total HM (%)</th><th>Zircon</th><th>Rutile</th><th>Leuco-xene</th><th>Illme-nite</th><th>Monz-anite</th><th>Xeno-time</th></tr>
<tr><td>Proved</td><td>220.4</td><td>4.4</td><td>20.2</td><td>14.9</td><td>8.4</td><td>26.4</td><td>2.0</td><td>0.6</td></tr>
<tr><td>Probable</td><td>91.4</td><td>4.0</td><td>19.3</td><td>16.9</td><td>9.1</td><td>285.0</td><td>2.0</td><td>0.6</td></tr>
<tr><td>Total</td><td>311.8</td><td>4.3</td><td>19.9</td><td>15.4</td><td>8.6</td><td>27.0</td><td>2.0</td><td>0.6</td></tr>
<tr><td colspan="2">Contained (kt)</td><td>13,407</td><td>2,668</td><td>2,065</td><td>1,153</td><td>3,620</td><td>268</td><td>80</td></tr>
</table></td></tr>
<tr><td>Stage of development</td><td>With a pre-feasibility study completed in 2018, Avonbank is now in the feasibility study and approvals stage. The feasibility study is well advanced and will be underpinned via a recently completed test pit and a pilot-scale demonstration wet concentration plant.</td></tr>
<tr><td>Expected production</td><td>WIM proposes to produce on average:
• Ore mined and processed: 10–12 Mtpa
• HM concentrate: 400 ktpa
• Contained zircon: 80,000–120,000 tpa
• Contained titanium minerals: 150,000–200,000 tpa
• Associated monazite and xenotime: 5,000 –7,500 tpa</td></tr>
<tr><td>Infrastructure</td><td>Avonbank has existing rail and loading terminal adjacent to the proposed process plant and central to the mine footprint. Existing surface water pipelines run nearby to the mine site, and existing high-voltage power supply lines run into the project area.</td></tr>
<tr><td>Project development capital costs</td><td>Available on request.</td></tr>
<tr><td>Project economics</td><td>Available on request.</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussion regarding financing of the project.</td></tr>
<tr><td>Other</td><td>wimresource.com.au
Michael Winternitz, Project Director: admin@wimresource.com.au</td></tr>
</table>

Tungsten (W)


Australian tungsten projects
as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
NT
QLD
WA
SA
NSW
VIC
TAS
PERTH
ADELAIDE
BRISBANE
SYDNEY
CANBERRA, ACT
MELBOURNE
HOBART
Watershed
Mount Carbine
Wolfram Camp
Khartoum
Hatches Creek
Big Hill – Cookes Creek
O'Callaghans
Molyhil
Samarkand,
White Violet
Kilba
Mulgine
Torrington
Glen Eden
Blicks
Yanco Glen
Attunga
Tallebung
White Rock
Mount Paynter
King Island Tailings
Dolphin
Bold Head
Kara
Moina
Mount Lindsay
Aberfoyle, Lutwyche
Tungsten projects by
resource size (kt WO3)
<10
10–50
50–100
100–200
200–300
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics
(greyscale, 0.5 vertical derivative
of total magnetic intensity)
PP-3548-20

Advanced tungsten projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Tungsten	**Kara**	Tasmania Mines Ltd	Operating	W	36.3	0.06	%	WO_3	20	–
Tungsten	**Mt Carbine – Tailings**	Speciality Metals Int. Ltd	Operating	W	2.0	0.11	%	WO_3	2	–
Tungsten	**Mt Carbine – Hard Rock**	Speciality Metals Int. Ltd	Construction	W	47.3	0.13	%	WO_3	61	–
Tungsten	**Mt Carbine – LGO**	Speciality Metals Int. Ltd	Construction	W	18.0	0.08	%	WO_3	14	–
Tungsten	**Dolphin**	King Island Scheelite Ltd	Pre-const	W	9.6	0.90	%	WO_3	86	144
Tungsten	**Watershed**	Tungsten Mining NL	FS	W	20.7	0.25	%	WO_3	51	146
Tungsten	**Mount Lindsay**	Venture Minerals Ltd	FS	Sn, W, Cu, Fe	13.5	0.20	%	WO_3	26	148
Tungsten	**Molyhil**	Thor Mining PLC	FS	WO3, Mo	4.7	0.28	%	WO_3	13	150
Tungsten	**O'Callaghans**	Newcrest Mining Ltd	PFS	W	78.0	0.33	%	WO_3	257	–

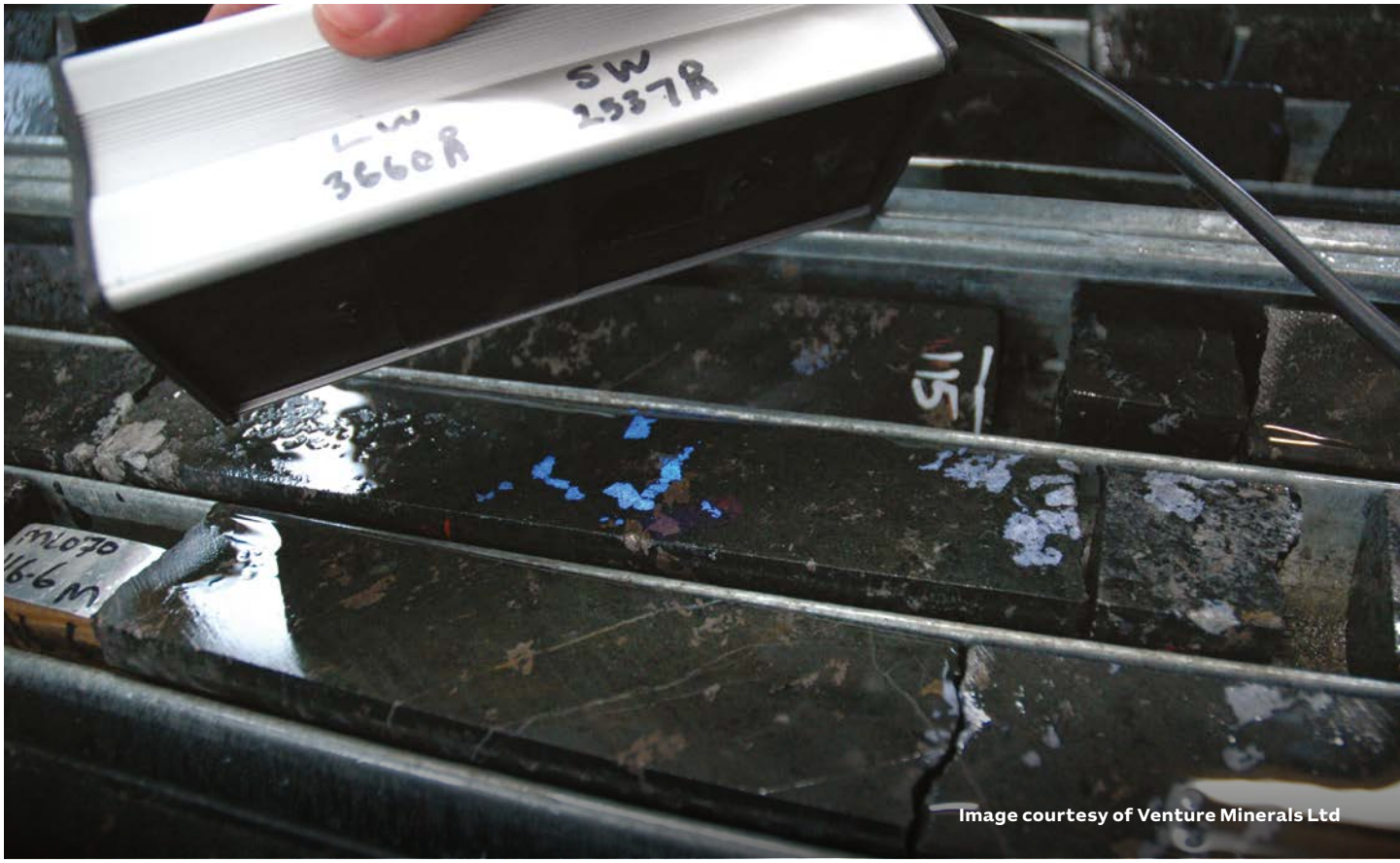


Image courtesy of Venture Minerals Ltd

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>TUNGSTEN TAS</th></tr>
<tr><th>PROJECT NAME</th><th>DOLPHIN</th></tr>
<tr><td>Location</td><td>The Dolphin Project is located near the town of Grassy on the south-east coast of King Island, Tasmania, in the Bass Strait. Grassy was developed to service the Dolphin Mine, which produced tungsten between 1917 and 1992.</td></tr>
<tr><td>Company name</td><td>King Island Scheelite Ltd – owns 100% of Dolphin Project</td></tr>
<tr><td>Company ownership</td><td>ASX-listed (KIS) – approximately 670 shareholders.

Top 20 shareholders own approximately 75%.</td></tr>
<tr><td>Project description</td><td>Between 1917 and 1990, the Dolphin Mine, together with the adjacent Bold Head Mine, mined some 10 Mt of tungsten ore at 0.67% WO_3, which was processed into a concentrate prior to exporting. Mining was conducted by both open-cut and underground methods.

The current redevelopment plan of the Dolphin Project envisages mining, by open-cut methods, approximately 400,000 tonnes of ore per year, at 0.73% WO_3, over eight years.

This project hosts the highest-grade known tungsten reserve outside China. Tungsten is ranked as a critical mineral, being a key input to industries vital to national security and in light of supply risk, given China’s dominance of the tungsten market.

Ore will be crushed and processed, primarily through a gravity circuit, supplemented by a simple flotation circuit to produce a tungsten concentrate for export through the Port of Grassy, less than 1 km away.

This redevelopment plan has been fully approved by both Mineral Resources Tasmania and the Environment Protection Authority.

The opportunity exists to also mine the adjacent Bold Head resource, both as open-cut and underground, as well as the Dolphin underground resource, thus extending the project life by approximately 10 years.</td></tr>
<tr><td>Expected products</td><td>Tungsten concentrate – 65% WO_3 – gravity circuit.

Tungsten concentrate – 50% WO_3 – flotation circuit.</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources (as at September 2019):

<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>WO_3 (%)</th></tr>
<tr><td>Indicated</td><td>11.21</td><td>0.90</td></tr>
<tr><td>Contained WO_3 tonnes</td><td></td><td>102,480</td></tr>
</table>

Ore reserves (as at July 2019):

<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>WO_3 (%)</th></tr>
<tr><td>Probable</td><td>3.0</td><td>0.73</td></tr>
<tr><td>Contained WO_3 tonnes</td><td></td><td>22,000</td></tr>
</table>
</td></tr>
<tr><td>Stage of development</td><td>The Dolphin Project feasibility study for the redevelopment of the open-cut mine was completed in June 2019.</td></tr>
</table>

Stage of development	All significant approvals have been granted, with operational plans currently in progress. The company has a signed offtake agreement in place with Wolfram Bergbau und Hutten AG, a subsidiary of the Sandvik Group. The contract is for a total of 1,400 tonnes WO_3 over a four-year period, 20% of proposed annual production. Negotiations on further offtake contracts with other ammonium paratungstate (APT) producers are at an advanced stage. It is anticipated that once the offtake agreements and financing are finalised, it would take approximately 15 months to construct and commission the project. Discussions regarding financing via debt and equity are ongoing.
Expected production	Expected annual production (post ramp-up average): • Ore mined and processed: 400,000 tpa • Tungsten concentrate: 3,300 tpa • WO_3 in concentrate: 2,150 tpa (215,000 mtu)
Infrastructure	King Island is self-sufficient in terms of power; however, the network will require an upgrade to accommodate the redevelopment of the project. Discussions are well advanced with the local utility to finalise a supply agreement. The principal source of water will be from the Lower Grassy Dam, situated on project property; however, alternative backup sources have been identified in the event of a prolonged dry spell. There is a good network of roads leading from Grassy to the project, as well as access to the port, substantially reducing capital expenditure requirements.
Project development capital costs	Anticipated development capital costs can be broken down broadly into: Mobile mining equipment: A$14.0m Processing plant: A$42.0m Site services and other infrastructure: A$9.0m **Total: A$65.0m** Additional funding of approximately A$10m will be required for working capital.
Project economics	The 2019 feasibility study demonstrated the Dolphin Project has robust economics including: Pre-tax and pre-gearing $NPV_{8\%}$: A$146m Internal rate of return: 47% Capital payback: 2.75 years Tungsten recovery: 77% Operating costs (per MTU WO_3 produced): A$129 (US$84)
Project funding	The company continues to seek investment funds by way of joint venture, debt funding or equity funding. It has no restrictive covenants, preventing any, or a combination, of the options.
Other	Company website: kingislandscheelite.com.au Investor presentation: kingislandscheelite.com.au/wp-content/uploads/2019/09/KIS-Investor-Presentation-Dolphin-Project-September-2019.pdf johann.jacobs@kisltd.com.au

<table>
<tr><th>CRITICAL MINERAL(S)</th><th>TUNGSTEN QLD</th></tr>
<tr><th>PROJECT NAME</th><th>WATERSHED</th></tr>
<tr><td>Location</td><td>Located 130 km north of Cairns in Far North Queensland.</td></tr>
<tr><td>Company name</td><td>Tungsten Mining NL</td></tr>
<tr><td>Company ownership</td><td>ASX-listed (TGN)

Tungsten Mining NL is an Australian-based resources company whose primary focus is the exploration and development of tungsten projects in Australia. Major shareholders include public companies, high-net-worth individuals and institutional investors.</td></tr>
<tr><td>Project description</td><td>The Watershed Project is well positioned for development, with the aim of producing tungsten concentrate for the ammonium paratungstate (APT) market over a 10-year project life.

The project will be developed as an open-pit with mining by drill and blast, then excavator and truck.

There will be 2.5 Mtpa of ore processed on site through a circuit containing crushing, X-ray transmission ore sorting, rod milling, gravity separation with spirals, ball milling and flotation.

Tungsten concentrate produced will contain >65% WO_3 with very low levels of contaminants, making it attractive to APT producers. The concentrate will be trucked to Townsville for export.</td></tr>
<tr><td>Expected products</td><td>Tungsten concentrate – >65% WO_3.</td></tr>
<tr><td>Mineral inventory</td><td>Mineral resources at 0.05% WO_3 cut-off (as at 18 July 2018):

<table>
<tr><th>Resource category</th><th>Tonnes (Mt)</th><th>WO_3 (%)</th></tr>
<tr><td>Measured</td><td>9.47</td><td>0.16</td></tr>
<tr><td>Indicated</td><td>28.36</td><td>0.14</td></tr>
<tr><td>Inferred</td><td>11.49</td><td>0.15</td></tr>
<tr><td>Total</td><td>49.32</td><td>0.14</td></tr>
<tr><td>Contained WO_3 (kt)</td><td></td><td>70.4</td></tr>
</table>

Ore reserves (as at 31 July 2014):

<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>WO_3 (%)</th></tr>
<tr><td>Proved</td><td>6.4</td><td>0.16</td></tr>
<tr><td>Probable</td><td>15.0</td><td>0.14</td></tr>
<tr><td>Total</td><td>21.3</td><td>0.15</td></tr>
<tr><td>Contained WO_3 (kt)</td><td></td><td>31.4</td></tr>
</table>
</td></tr>
</table>

Stage of development	Feasibility study completed in 2014 by previous owners, which defined the scope, design features and economic viability of the Watershed Project. The project is well positioned for development, with all necessary environmental and traditional owner approvals in place, including seven mining leases covering a total area of 1,904 hectares that are valid until 1 December 2033.
Expected production[1]	• Mining rate: 10 Mtpa • Design process throughput: 2.5 Mtpa • Tungsten concentrate: ~4,800 tpa • Contained WO_3 in concentrate: 2,500 tpa
Infrastructure[1]	The project is accessible by means of a 24 km formed and graded, unsealed access road running from the state-controlled dual-lane Mulligan Highway. A state-owned powerline runs parallel to the Mulligan Highway, and the line currently has excess capacity which would meet the project's requirements. Due to the history of mining in the region, there is access to skilled workers from the town of Mareeba and also from the Cairns/Port Douglas region.
Project development capital costs[1]	A$171m
Project economics[1,2]	• NPV (pre-tax): A$107.5m • IRR (pre-tax): 21.2% • EBITDA per annum (average): A$41.4m • Free cash flow (pre-tax): A$253.1m • Payback from first production: 3.1 years
Project funding	The company is assessing options for the future development of the project and welcomes enquiries from potential offtake and financing partners.
Other	tungstenmining.com **Notes:** 1. As per DFS dated February 2015. 2. Financial analysis base case inputs include an average APT price of US$375/mtu, AUD:USD FX rate of 0.80 and debt-to-equity ratio of 70%:30%.

CRITICAL MINERAL(S)	TUNGSTEN TAS
PROJECT NAME	**MOUNT LINDSAY**
Location	Located in north-western Tasmania.
Company name	**Venture Minerals Ltd**
Company ownership	ASX-listed **(VMS)** Venture Minerals owns 100% of the Mount Lindsay Project.
Project description	Mount Lindsay is an advanced tin-tungsten-magnetite project located within the world-class west coast of Tasmania tin-tungsten province, hosting the Renison Bell tin mine and the high-grade King Island tungsten mine. The project has access to existing infrastructure, including hydropower, water, sealed roads, rail and port facilities. Venture Minerals plans to extract 1.75 Mtpa of tin, tungsten, magnetite and copper-bearing ore initially from a conventional open-pit mine, progressing to an underground mine to access deeper mineralisation towards the end of the nine-year mine life. Venture has completed over 83,000 m of diamond core drilling, within its two high-grade orebodies defining a tin-tungsten resource containing over 110,000 tonnes of metal. This work, along with extensive engineering, environmental, hydrogeological and metallurgical studies, culminated in a feasibility study completed in November 2012. The process plant consists of crushing and grinding circuits, magnetite concentration, copper and a bulk sulphide flotation circuit, tin gravity and flotation circuits, and scheelite flotation followed by an ammonium paratungstate (APT) circuit. The process plant will produce tin, magnetite and copper concentrates and APT, which will be trucked to the Port of Burnie for export to Asia and/or Europe. Venture has a large resource base to draw on and is now looking at a number of strategies to optimise the higher-grade portions at Mount Lindsay. Additionally, the company has focused efforts on identifying further high-grade tin-tungsten targets in close proximity with a recent electromagnetic survey confirming 12 priority targets.
Expected products	Tin concentrate (45% – 50% Sn). APT with an option to produce tungsten concentrate (65% WO_3). Iron (magnetite) concentrate (65% Fe). Copper concentrate (~24% Cu).
Mineral inventory	Mineral resources at 0.45% SnEq cut-off (as at 17 October 2012):

Resource category	Tonnes (Mt)	WO_3 (%)	Sn (%)	Cu (%)
Measured	4.3	0.20	0.30	0.10
Indicated	5.2	0.20	0.30	0.10
Inferred	3.9	0.10	0.30	0.10
Total	**13.0**	**0.20**	**0.30**	**0.10**
Contained (kt)		**26**	**38**	**13**

<table>
<tr><td>Mineral inventory</td><td>At a lower 0.2% SnEq cut-off grade, the total resource increases to over 110 kt of contained Sn + WO_3 + Cu.

Ore reserves (as at 7 November 2012):

<table>
<tr><th>Reserve category</th><th>Tonnes (Mt)</th><th>WO_3 (%)</th><th>Sn (%)</th><th>Cu (%)</th></tr>
<tr><td>Proved</td><td>6.4</td><td>0.20</td><td>0.20</td><td>0.10</td></tr>
<tr><td>Probable</td><td>7.3</td><td>0.10</td><td>0.20</td><td>0.10</td></tr>
<tr><td>Total</td><td>14.0</td><td>0.10</td><td>0.20</td><td>0.10</td></tr>
<tr><td>Contained (kt)</td><td></td><td>16</td><td>30</td><td>14</td></tr>
</table>

Resources and reserves also contain 15% mass recovery of iron with a grade of 65% Fe.</td></tr>
<tr><td>Stage of development</td><td>A feasibility study was completed on the Mount Lindsay Project in November 2012 and the mining lease was granted in July 2014.

A draft Development Proposal and Environmental Management Plan has been submitted to the Environment Protection Authority (EPA) for the predominantly open-pit mine, though Venture is now assessing the option of mining high-grade solely from underground, with a significantly reduced environmental footprint.</td></tr>
<tr><td>Expected production</td><td>Expected annual production (post ramp-up average):

Ore mined and processed: 1.75 Mtpa

Tin concentrate: 5,000 tpa for 2,350 tpa contained tin

ATP: 1,500 tpa

Magnetite concentrate: 240,000 tpa

Copper concentrate: 3,500 tpa for 800 tpa contained copper</td></tr>
<tr><td>Infrastructure</td><td>The project is located between the Renison Bell tin mine and the Savage River magnetite mine, and has access to existing infrastructure including hydropower, water, sealed roads, and rail and port facilities.</td></tr>
<tr><td>Project development capital costs</td><td>A$198m (2012 estimate).</td></tr>
<tr><td>Project economics</td><td>Key results from the 2012 feasibility study include:

• total life-of-mine sales revenue of A$1,435m

• total life-of-mine cash generation of A$554m

• pre-tax $NPV_{8\%}$ of A$143m

• pre-tax IRR of 21%

• pre-tax internal rate of return of 33%

• payback period of 4 years

• operating cost per tonne of A$59 including royalties.

Commodity prices and exchange rate used are: T=tin US$23,800/t, tungsten US$392/mtu WO_3, magnetite (62% Fe) US$125/t, copper US$8,000/t and an exchange rate of USD:AUD = $0.90.</td></tr>
<tr><td>Project funding</td><td>The company welcomes discussion regarding financing of the project construction and/or offtake.</td></tr>
<tr><td>Other</td><td>ventureminerals.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	TUNGSTEN NT
PROJECT NAME	**MOLYHIL**
Location	Located 220 km north-east of Alice Springs (320 km by road) in the Northern Territory.
Company name	**Thor Mining PLC**
Company ownership	ASX- and AIM-listed **(THR)**
Project description	An open-pit tungsten/molybdenum project with mineralisation from surface. The project has a seven-year life as an open pit, along with likely production from JORC 2012 tungsten and copper resources at Bonya, approximately 30 km from Molyhil, and followed by underground mining at Molyhil of known resource extensions. Mining and processing activities onsite will produce tungsten, molybdenum and copper concentrates for sale using industry-standard flotation processing techniques.
Expected products	Tungsten concentrate (65% WO_3). Molybdenum concentrate (51.4% Mo). Copper concentrates (minor).
Mineral inventory	Molyhil mineral resources (as at 10 October 2019): **Resource category 100% Thor** / **Tonnes (Mt)** / **WO_3 (%)** / **Mo (%)** / **Cu (%)** Indicated / 3.8 / 0.29 / 0.14 / 0.05 Inferred / 0.9 / 0.25 / 0.15 / 0.04 **Total** / **4.7** / **0.28** / **0.14** / **0.05** **Contained (kt)** / / **13** / **7** / **2** Bonya Tungsten mineral resources (as at 29 January 2020): **Resource category 40% Thor** / **Tonnes (Mt)** / **WO_3 (%)** / **Cu (%)** Inferred / 0.74 / 0.21 / 0.09 **Total** / **0.74** / **0.21** / **0.09** **Contained (kt)** / / **1.5** / **0.6** Molyhil ore reserves (as at 8 January 2018): **Reserve category 100% Thor** / **Tonnes (Mt)** / **WO_3 (%)** / **Mo (%)** Probable / 3.5 / 0.29 / 0.12 **Contained (kt)** / / **10** / **4**
Stage of development	Updated feasibility study completed in August 2018. Environmental and traditional owner approvals are in place. In 2013, Thor received a letter of intent from US-based Global Tungsten and Powders Corp, for purchase of 70–75% of tungsten concentrates produced from Molyhil over the life of the mine.

<table>
<tr><td>Stage of development</td><td>Next steps are to secure offtake agreements for the balance of tungsten and molybdenum concentrates, and finance to support the development of the Molyhil Project.

Once finance is secured, the construction and development phase is expected to take approximately 12 months.</td></tr>
<tr><td>Expected production (excluding underground and satellite deposits)</td><td>Expected annual production (Years 1–7 average):

• Mine ore production: 0.59 Mtpa

• Processing plant throughput: 0.53 Mtpa

• Tungsten concentrate: 1,850 tpa

• Molybdenum concentrate: 850 tpa

• WO_3 in concentrate: 1,204 tpa

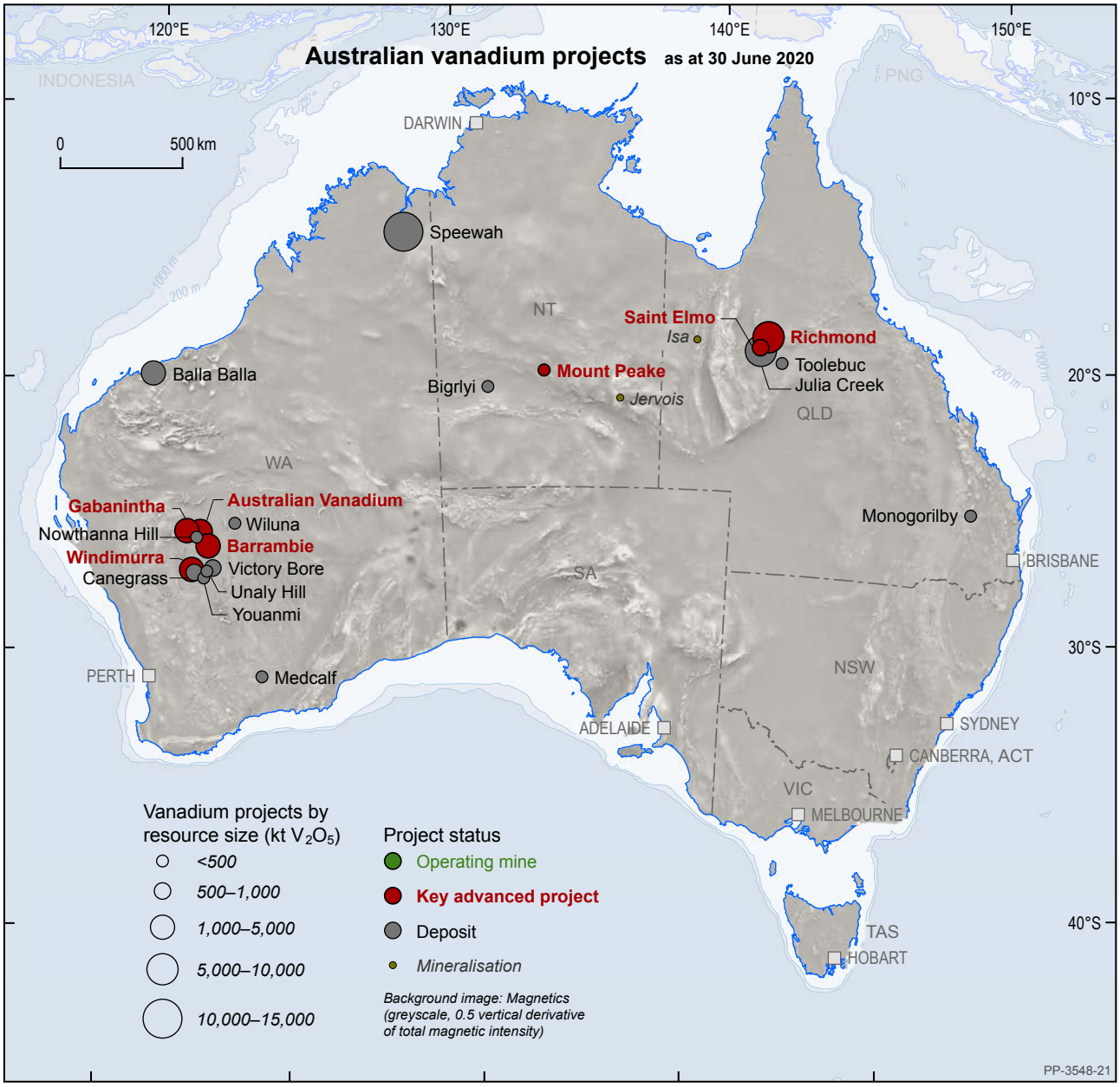
• Mo in concentrate: 433 tpa</td></tr>
<tr><td>Infrastructure</td><td>The partially sealed Plenty Highway runs within 25 km of the site and connects to the Northern Territory's major arterial road, the Stuart Highway. Like the Stuart Highway, the Adelaide-to-Darwin railway provides modern transport connections between Alice Springs and the ports of Darwin and Adelaide. The project has ample water from nearby underground aquifers. Molyhil will operate as a fly-in, fly-out operation with provision for camp and electricity-generation facilities provided for within the cost estimates of the current feasibility study.</td></tr>
<tr><td>Project development capital costs</td><td>A$69m (US$43m) low start-up capital cost:

<table><tr><th></th><th>A$m</th></tr><tr><td>Process plant</td><td>28</td></tr><tr><td>Infrastructure</td><td>15</td></tr><tr><td>Mining fleet</td><td>7</td></tr><tr><td>Owners costs/rehabilitation bonds</td><td>7</td></tr><tr><td>Engineering</td><td>6</td></tr><tr><td>Contingency</td><td>6</td></tr><tr><td>Total</td><td>69</td></tr></table></td></tr>
<tr><td>Project economics</td><td>The August 2018 updated feasibility study projected a 59% IRR, A$101m NPV and a 1.5-year payback period based on a A$69m capital cost and a 7 year mine life with average annual production of 120,400 mtu (1,204 t) contained WO_3 in concentrate (1 mtu = 10 kg). Operating costs were projected at US$90/mtu, compared with the global spot price for tungsten prices at the time of US$300/mtu.

Since the definitive feasibility study, metal prices and exchange rates have varied; however, the operating costs remain in the second quartile of global production costs. In addition, the Molyhil resource has been upgraded, increasing molybdenum content by 9% and incorporating copper, while satellite resources approaching 1.0 Mt have also been defined.</td></tr>
<tr><td>Project funding</td><td>The company is seeking project loan finance, equity investment in the company and/or joint venture participation, and product offtake agreements to progress the development of the Molyhil Project.</td></tr>
<tr><td>Other</td><td>Company website: thormining.com

Project presentation: thormining.com/sites/thormining/media/pdf/interviews/molyhil-202002.pdf</td></tr>
</table>

Vanadium (V)


Australian vanadium projects as at 30 June 2020
120°E
130°E
140°E
150°E
10°S
20°S
30°S
40°S
INDONESIA
PNG
0
500 km
DARWIN
Speewah
NT
Saint Elmo
Isa
Richmond
Toolebuc
Julia Creek
Balla Balla
Bigrlyi
Mount Peake
Jervois
QLD
WA
Gabanintha
Australian Vanadium
Wiluna
Nowthanna Hill
Barrambie
Windimurra
Victory Bore
Canegrass
Unaly Hill
Youanmi
Monogorilby
BRISBANE
SA
NSW
PERTH
Medcalf
ADELAIDE
SYDNEY
CANBERRA, ACT
VIC
MELBOURNE
TAS
HOBART
Vanadium projects by resource size (kt V_2O_5)
<500
500–1,000
1,000–5,000
5,000–10,000
10,000–15,000
Project status
Operating mine
Key advanced project
Deposit
Mineralisation
Background image: Magnetics (greyscale, 0.5 vertical derivative of total magnetic intensity)
PP-3548-21

Advanced vanadium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Vanadium	**Windimurra**	Atlantic Ltd	Pre-const	V	234.0	0.49	%	V_2O_5	1,146	154
Vanadium	**Balla Balla**	BBI Group Pty Ltd	FS	V, Ti	455.9	0.66	%	V_2O_5	2,988	–
Vanadium	**Barrambie**	Neometals Ltd	FS	Ti, V	280.1	0.44	%	V_2O_5	1,234	132
Vanadium	**Gabanintha**	Technology Metals Au Ltd	FS	V, Ti	131.0	0.80	%	V_2O_5	1,179	156
Vanadium	**Mount Peake**	TNG Ltd	FS	V, Ti, Fe	160.0	0.28	%	V_2O_5	448	158
Vanadium	**Richmond – Julia Creek**	Horizon Minerals; RVT	PFS	V, Mo, Ni	1,838.0	0.36	%	V_2O_5	6,650	160
Vanadium	**Australian Vanadium Project**	Australian Vanadium Ltd	PFS	V, Ti	208.2	0.74	%	V_2O_5	1,541	162
Vanadium	**Saint Elmo**	Multicom Resources	PFS	V, Mo	304.5	0.25	%	V_2O_5	762	164
Vanadium	**Medcalf**	Audalia Resources Ltd	PFS	V, Ti	32.0	0.47	%	V_2O_5	149	–
Vanadium	**Wiluna**	Toro Energy Ltd	PFS	U, V	96.3	0.03	%	V_2O_5	31	–
Vanadium	**Bigrlyi**	Energy Metals Ltd	PFS	U, V	7.5	0.12	%	V_2O_5	9	–

Barrambie project summary included in the titanium section.

Image courtesy of Australian Vanadium Ltd

CRITICAL MINERAL(S)	VANADIUM WA
PROJECT NAME	**WINDIMURRA**
Location	The Windimurra Project is located 80 km east of Mount Magnet in the Mid West region of Western Australia.
Company name	**Atlantic Vanadium Pty Ltd (AVPL)**
Company ownership	AVPL is part of the Salim Group, one of Indonesia's largest conglomerates. AVPL owns 100% of the Windimurra Project.
Project description	Windimurra will be the world's next major primary vanadium producer, leveraging significant existing infrastructure at the project site. In particular, Windimurra enjoys the following competitive advantages: • significant historic investment, making it the lowest capital intensity primary vanadium project development in the world • all development approvals in place • JORC 2012–compliant reserves deliver initial 31-year mine life with upside through additional large JORC 2012 resources • all critical infrastructure already developed (roads, mine pit, gas pipeline, kiln, power station) • attractive economics based on low strip ratio, legacy investment and long mine life • attractive market fundamentals with forecast strong vanadium demand growth driven by new Chinese rebar standards and battery demand.[1] The Windimurra Project will produce a high-purity V_2O_5 flake product utilising proven open-cut mining and vanadium production processes including ore milling, magnetic separation, salt roasting, leaching and furnace processing to produce the final product. [1] Vanadium industry reports
Expected products	Approximately 7,600 tonnes per annum of high-purity V_2O_5 flake. The high-quality product ensures access to the steel and premium vanadium chemical/battery markets.
Mineral inventory	JORC 2012 Mineral Resources (as at 30 April 2020):

Resource category	Tonnes (Mt)	V_2O_5 (%)
Measured	34.6	0.49
Indicated	123.5	0.50
Inferred	51.6	0.50
Total	**209.7**	**0.50**
Contained (kt)		**1,048**

JORC 2012 Ore Reserves (as at 30 April 2020):

Reserve category	Tonnes (Mt)	V_2O_5 (%)
Probable	87.5	0.49
Total	**87.5**	**0.49**
Contained (kt)		**429**

<table>
<tr><td>Stage of development</td><td>AVPL completed a feasibility study for the Windimurra Project development in April 2020. The Windimurra Project is ‘shovel ready’ with all environmental and mining approvals in place.

The construction period for the project development is approximately 14 months and a first-class contractor is planned to be engaged for the design, construction and commissioning of the process plant, under a guaranteed maximum price construction contract with a process warranty for plant performance.</td></tr>
<tr><td>Expected production</td><td>Summary operating metrics for Windimurra Project are set out below (steady state averages post ramp-up).

<table><tr><td>Life of mine</td><td>Years</td><td>31</td></tr><tr><td>Mine strip ratio</td><td>Waste:ore</td><td>1:1</td></tr><tr><td>Ore grade</td><td>% V_2O_5</td><td>0.49</td></tr><tr><td>Mill throughput</td><td>Mtpa</td><td>2.8</td></tr><tr><td>Kiln throughput</td><td>Mtpa</td><td>0.8</td></tr><tr><td>V_2O_5 production</td><td>tpa</td><td>7,608</td></tr></table></td></tr>
<tr><td>Infrastructure</td><td>Windimurra is the only existing vanadium production facility in Australia with significant infrastructure already in place, including one of the largest roasting kilns in the world, a 24 MW power station and a 290-room village, and is served by the existing Mid West Gas Pipeline.</td></tr>
<tr><td>Project development capital costs</td><td>A$213m</td></tr>
<tr><td>Project economics</td><td>The Windimurra Project is forecast to deliver strong steady state pre-tax free cash flows of A$91.8m per annum at long-term average vanadium prices.</td></tr>
<tr><td>Project funding</td><td>AVPL is currently in advanced discussions with prospective project financiers and strategic offtake partners for the Windimurra Project development; however, it welcomes interest from other project financiers and offtake partners.</td></tr>
<tr><td>Other</td><td>atlanticptyltd.com.au

More detailed information is available in the Windimurra data room on execution of an appropriate confidentiality agreement with AVPL.

Enquiries should be directed to Tony Veitch, Executive Director
Phone: +61 8 6141 7100,
Email: tveitch@atlanticptyltd.com.au</td></tr>
</table>

CRITICAL MINERAL(S)	VANADIUM WA
PROJECT NAME	**GABANINTHA**
Location	Located approximately 40 km south-east of Meekatharra, 650 km north-east of Perth in the Mid West region of Western Australia.
Company name	**Technology Metals Australia Ltd**
Company ownership	ASX-listed **(TMT)**
Project description	Gabanintha is one of the highest-grade V-Ti-Fe deposits in the world with a resource of 131 Mt at 0.9% V_2O_5, containing a high-grade component of 71.2 Mt at 1.1% V_2O_5. The coarse grain size and very low impurities of the high-grade ore result in a very high-purity premium (>99%) V_2O_5 product with forecast lowest quartile operating costs. The proposed production scale will make the project the largest single primary vanadium producer in the world. The high-grade orebody outcrops, with mining to be by conventional open-pit methods with ore from surface and a low strip ratio. Processing will be completed onsite and consists of a magnetite beneficiation stage to produce a magnetic concentrate, and salt roasting of the magnetic concentrate to convert the vanadium to a soluble form, followed by water leaching and subsequent precipitation to produce a high-purity vanadium pentoxide product. The current reserve of 29.6 Mt at 0.88% V_2O_5 supports an initial long mine life of at least 16 years, with significant scope within the resource base to expand this well beyond 20 years. Final product, suitable for the steel industry, vanadium redox flow battery and chemical markets, is to be packed in drums and transported in standard 20-foot shipping containers for export from the Port of Fremantle.
Expected products	High-purity vanadium pentoxide (V_2O_5) +99% purity. Scope to produce a mixed base metal – Co-Cu-Ni concentrate from tailings stream.
Mineral inventory	Mineral resources (as at March 2019):

Resource category	Tonnes (Mt)	V_2O_5 (%)	TiO_2 (%)	Fe (%)
Measured	1.2	1.00	11.40	44.70
Indicated	28.9	0.90	10.90	41.80
Inferred	101.0	0.60	7.20	27.40
Total	**131.0**	**0.90**	**10.10**	**39.00**
Contained (kt)		**1,179**	**13,231**	**51,090**

Ore reserves (as at July 2019):

Reserve category	Tonnes (Mt)	V_2O_5 (%)
Proved	1.1	0.96
Probable	28.5	0.88
Total	**29.6**	**0.88**
Contained (kt)		**260**

Stage of development	Feasibility study completed in August 2019. The project's first binding offtake agreement, covering 16% of forecast annual production, was signed in April 2020. Offtake discussions with a range of other parties are progressing. The project tenure is being converted to a mining lease, with discussions with all stakeholders progressing well. The project was self-referred to the WA Environment Protection Authority in November 2018 with preparation of the environmental review document underway and on track for lodgement later in 2020. Discussions are progressing with a number of groups with regard to project development funding, including advanced engagement with the Australian Government–backed Northern Australia Infrastructure Facility (NAIF).
Expected production	Expected annual production (post ramp-up average): • Ore mined and processed: 1.7 – 2.3 Mtpa • V_2O_5: 12,800 tpa[1] [1] – peak steady state production of 13,700 – 14,200 tpa years 3–12.
Infrastructure	Gabanintha is well placed to access infrastructure at the regional centre of Meekatharra, including an airport, accommodation for the construction workforce, hospital and other ancillary services. TMT is engaged with the NAIF in regard to support for funding of infrastructure plus potential for third-party development of a natural gas pipeline to service the operation.
Project development capital costs	Pre-production process plant and associated non-process infrastructure capital expenditure is estimated at A$454m. Additional mining pre-production capital is estimated at A$16m.
Project economics	The August 2019 feasibility study delivered a pre-tax $NPV_{8\%}$ of A$1,320m (US$924m) and a pre-tax IRR of 34.2% from an initial 16+-year mine life. Life of mine EBITDA is A$4,063m on total revenue of A$7,019m. Anticipated payback period is 3.2 years.
Project funding	The company is progressing discussions with a range of groups with regard to project financing, including NAIF and potential product offtake and EPC groups. The company recently announced a binding offtake agreement with CNMC (Ningxia) Orient Group Company Ltd. The company welcomes discussions with strategic investors with regard to investment in TMT and/or direct asset level investment/joint venture designed to support project development.
Other	Company website: tmtlimited.com.au Quarterly activities report: tmtlimited.com.au/sites/default/files/asx-announcements/6977569.pdf Project presentation: tmtlimited.com.au/sites/default/files/asx-announcements/6957540.pdf

CRITICAL MINERAL(S)	TITANIUM, VANADIUM NT
PROJECT NAME	**MOUNT PEAKE**
Location	Mine site is located approximately 230 km north of Alice Springs in the Northern Territory. TIVAN® Processing Facility is located 10 km from the Darwin Port, NT.
Company name	**TNG Limited**
Company ownership	ASX-listed **(TNG)** TNG wholly owns all Mount Peake mining, exploration and ancillary licences as well as the TIVAN® process and patents.
Project description	Mount Peake is an advanced world-scale vanadium-titanium-iron project with existing infrastructure in place and mining licence, native title and environmental approvals already granted for the mine development. The deposit is close to surface and flat lying with a JORC–compliant resources of 160 million tonnes, making it one of the largest undeveloped vanadium-titanium-iron projects globally. TNG has also developed a processing operation to produce three high-value, high-purity products from this resource – vanadium pentoxide, titanium dioxide pigment and iron oxide – through the application of its 100%-owned TIVAN® process to the magnetite concentrate produced at the mine site, where ore will be mined in a conventional open-pit mine over a 37-year initial mine life. The Mount Peake Project has major project status with the NT Government which supports its development.
Expected products	Titanium dioxide pigment (TiO_2), vanadium pentoxide (V_2O_5) and iron oxide (Fe2O3).
Mineral inventory	Mineral resources (as at 26 March 2013): **Resource category** / **Tonnes (Mt)** / **V_2O_5 (%)** / **TiO_2 (%)** / **Fe (%)** Measured / 118 / 0.29 / 5.50 / 24.00 Indicated / 20 / 0.28 / 5.30 / 22.00 Inferred / 22 / 0.22 / 4.40 / 19.00 **Total** / **160** / **0.28** / **5.30** / **23.00** **Contained (kt)** / / **448** / **8,480** / **36,800** Ore reserves (as at 31 July 2015): **Reserve category** / **Tonnes (Mt)** / **V_2O_5 (%)** / **TiO_2 (%)** / **Fe (%)** Probable / 41.1 / 0.42 / 7.99 / 28.00 Note: currently being updated by Snowden.
Stage of development	After completing an updated feasibility study in 2017 and an optimised delivery strategy in 2019, TNG is currently undertaking a front-end engineering and design (FEED) study for the Mount Peake Project with the leading German-based engineering firm SMS, in support of a final investment decision for the project. The FEED study will provide confirmation of the final capital expenditure required for the beneficiation plant and TIVAN® processing facility. TNG is also progressing design for the project's non-process infrastructure to confirm complete capital expenditure requirements.

Stage of development	In parallel with the FEED study, TNG is progressing final permissions and approvals for the Mount Peake Project, including negotiations with the NT Government on a site allocated to the company in the Middle Arm Industrial Precinct at Darwin for the TIVAN® Processing Facility, and finalisation of the environmental impact statement for the TIVAN® facility. The company has secured grant of the mining leases and environmental approvals for the mine site. The company is advancing the project financing structure for both the debt and equity components, having mandated Germany's state-owned KfW IPEX-Bank GmbH as its exclusive senior debt advisor and arranger, and is actively progressing and evaluating a number of different options for equity financing. TNG has entered into life-of-mine offtake agreements for up to 100% of the titanium dioxide and up to 60% of the vanadium pentoxide to be produced by the Mount Peake Project. The company has also executed binding term sheets for iron ore products and the remaining vanadium pentoxide production.
Expected production	Scheduled mined processed material: 69 Mt LOM / average 2 Mtpa Magnetic concentrate: 23.3 Mt LOM / average 0.7 Mtpa Titanium dioxide pigment: 3.5 Mt LOM / average 100,000 tpa Vanadium pentoxide: 0.231 Mt LOM / average 6,000 tpa Iron oxide: 17.6 Mt LOM / average 0.5 Mtpa
Infrastructure	The project is planned to comprise an open-cut mining operation, a beneficiation plant, the TIVAN® Processing Facility, and supporting non-processing infrastructure additions and upgrades, including haul roads, logistics, utilities, camp facilities and airfield upgrades.
Project development capital costs	Pre-production capital expenditure is A$824m including infrastructure, mine site, concentrator and process plant.
Project economics	Interim Financial Model – Aug 2019 IRR pre-tax: 33% NPV (at 8% discounted): A$2.8bn Payback: 2.8 years Pre-tax net annual average cash flow: A$359m Life-of-mine net cash flow: A$12.2bn OPEX per tonne processed: A$210 Mine life: 37 years
Project funding	Funding of the capital expenditure for development, which will be confirmed at the completion of the FEED study, will require both debt and equity components, currently expected to be split 65:35 (subject to confirmation). • Debt funding mandate awarded to Germany's state-owned KfW IPEX-BANK to raise up to US$600m (AU$850m). • Different equity financing options currently being evaluated by TNG, and include existing shareholders and institutional investors, strategic investors, offtake partners and existing project development partners.
Other	tngltd.com.au Twitter: @tng_limited

CRITICAL MINERAL(S)	VANADIUM QLD
PROJECT NAME	**RICHMOND–JULIA CREEK VANADIUM PROJECT**
Location	Located in the Richmond–Julia Creek area, 500 km west of Townsville and 400 km east of Mount Isa, in northern Queensland. The project comprises four main prospects covering an area of 1,300 km^2.
Company name	**Horizon Minerals Limited (75%) / Richmond Vanadium Technology Pty Ltd (25%)**
Company ownership	75% ASX-listed **(HRZ)**. 25% Richmond Vanadium Technology Pty Ltd – a private unlisted company. In September 2017, Horizon entered into a joint venture agreement with Richmond Vanadium Technology (RVT) over the Richmond–Julia Creek Vanadium Project. Under the joint venture, RVT has earned a 25% interest in the project which can be increased to 75% by funding A$5m expenditure and completing a pre-feasibility study on the project within three years to September 2021.
Project description	The Richmond–Julia Creek Vanadium Project is one of the largest undeveloped vanadium resources in the world. The deposit commences from the surface and is hosted in soft marine sediments within oxidised limestone-rich clay. The shallow, soft nature of the deposit makes it amendable to an open-cut free-dig mining operation. Initial development work will focus on the upper coquina, a soft sedimentary layer comprised of shell fragments, of the Rothbury, Lilivale and Manfred deposits, which are included in the Richmond–Julia Creek Vanadium Project. The project is expected to have low-strip, conventional open-pit mining with a potential mine life of over 100 years at a production rate of 4.2 Mtpa ore mined and processed on site, to produce 790,000 tpa vanadium concentrate as base case, or alternatively 12,700 tpa vanadium pentoxide flake (V_2O_5). Test work has shown that over 90% of the contained metal lies in the -38µm size fraction. This fine fraction is amenable to low-cost removal via scrubbing, trommelling, screening, cycloning and potentially flotation to produce a high-grade vanadium concentrate of 1.82% V_2O_5, for smelting.
Expected products	Vanadium concentrate (base case) containing 1.82% V_2O_5
Mineral inventory	Mineral resources (as at May 2020) at 0.30% V_2O_5 cut-off:

Resource category at 0.30% V2O5 cut-off	Tonnes (Mt)	V_2O_5 (%)
Indicated	430	0.50
Inferred	1,408	0.32
Total	**1,838**	**0.36**
Contained (kt)		**6,650**

The mineral resource includes the Rothbury, Lilivale and Manfred deposits.

Stage of development	RVT completed a pre-feasibility study in May 2020.

Expected production	• Ore mined and processed: 4.2 Mtpa • Vanadium concentrate: 790,000 tpa • Expected mine life of over 100 years.
Infrastructure	The Richmond–Julia Creek Vanadium Project lies on the Flinders Highway and Great Northern Railway, providing direct access to the Townsville Port. A high-voltage electricity transmission line connecting the North West Minerals Province to the national electricity market grid south of Townsville passes directly south of the project. Planned copper string upgrades to the grid have been announced by the Queensland Government. The location of the project in Queensland's North West Minerals Province provides eligibility to apply for Northern Australia Infrastructure Facility concessional loans.
Project development capital costs	Not currently publicly available.
Project economics	Not currently publicly available.
Project funding	The company welcomes discussion regarding financing of project construction or offtake agreements.
Other	richmondvanadium.com.au horizonminerals.com.au/richmond-vanadium-jv

CRITICAL MINERAL(S)	VANADIUM, TITANIUM WA
PROJECT NAME	**AUSTRALIAN VANADIUM PROJECT**
Location	Located in the Murchison Province approximately 43 km south of Meekatharra and 740 km north-east of Perth in Western Australia.
Company name	**Australian Vanadium Ltd**
Company ownership	ASX-listed **(AVL)**
Project description	The Australian Vanadium Project is one of the highest-grade vanadium projects currently being developed in the world. The project is based on an open-pit mine with onsite crushing, milling and beneficiation, and a processing plant located east of Geraldton for final conversion of high-quality vanadium pentoxide (V_2O_5). The crushing, milling and beneficiation (CMB) flow sheet is based on industry-standard processes and includes magnetic beneficiation producing a magnetic concentrate of nominally 1.4% V_2O_5. The project has a high LOM vanadium ore grade to the CMB plant (1.03% V_2O_5), thereby realising a high concentrate mass yield; possibly the highest of all current operations worldwide. The Geraldton processing plant flow sheet is based on an alkaline roast leach and ammonium vanadate (AMV) extraction process, producing a high-purity V_2O_5 flake product. The initial mine life used for the pre-feasibility study (PFS) was 17 years, but a subsequent resource upgrade will allow for extension of the mine life to 20+ years.
Expected products	The project will produce V_2O_5 flake (suitable for steel industry use) and as high-purity powder (suitable for chemical, master Al-Ti-V alloys and vanadium redox flow battery electrolyte). Test work has upgraded the calcine iron by-product to an average of 66% Fe. Test work has been conducted to further separate titanium to a concentrate product. CRC-P funding has been received for high-purity processing including work on titanium-specific recovery. The material contains around 15% titanium oxide.
Mineral inventory	Total mineral resource (as at March 2020):

Resource category	Tonnes (Mt)	V_2O_5 (%)
Measured	10.1	1.14
Indicated	69.6	0.72
Inferred	128.5	0.73
Total	**208.2**	**0.74**
Contained (kt)		**1,541**

Ore reserves (as at December 2018):

Reserve category	Tonnes (Mt)	V_2O_5 (%)
Proved	9.8	1.07
Probable	8.4	1.01
Total	**18.2**	**1.04**
Contained (kt)		**190**

Mineral inventory	Within the total mineral resource, a total high-grade portion of the resource of 87.9 Mt at 1.06% V_2O_5 was also defined in March 2020.
Stage of development	Pre-feasibility study completed in December 2018. The company is currently well advanced in completing a definitive study to support final funding and construction. The project was awarded major project status in September 2019 in recognition of its national strategic significance. In April 2020 the project was awarded lead agency status by the WA Government. Pilot-scale test work on LOM average feed blend achieving high vanadium recoveries of 76% at a grade of 1.37% V_2O_5 in concentrate. Mining licence application underway. Environmental approval application being finalised. MOU signed with third-largest vanadium producer in China.
Expected production	Average annual production (post ramp-up) of: • Ore mined: 1.64 Mtpa • Process plant throughput: 1.45 Mtpa • Concentrate: 900 ktpa • V_2O_5 as mix of flake or powder: 10,200 tpa
Infrastructure	The remote and greenfields location requires construction of all infrastructure. The major non-process infrastructure required includes: gas supply to processing plant (located near to Geraldton and existing infrastructure); electrical power at the mine site including renewable energy generation paired with vanadium redox flow batteries; water supply via a bore field or through a water access agreement currently being negotiated with Westgold Resources to access water from its pits; regional road access including potential local road access from the Sandstone Road to Great Northern Highway, particularly useful in the wet season; and the construction of personnel accommodation.
Project development capital costs	Initial indicative capital costs for the project, which were announced in the PFS, were US$354m (±25%). This figure is currently being revised to provide a more accurate figure and a staged approach to construction is being considered.
Project economics	Based on the PFS completed at the end of 2018, the project shows an internal rate of return (IRR) ranging from 12.4% to 47.5% and a pre-tax net present value (NPV) 8% ranging from US$230m to US$2,031m. One of the company's main goals is to reduce both the capital and operating costs. The project demonstrated its financial viability utilising conservative figures used in the PFS, therefore any improvement to the economics makes it more attractive to investors and offtake partners. A detailed cost model is available for review along with all available technical data under an NDA.
Project funding	The company is seeking both debt and equity, in addition to offtake and project development.
Other	australianvanadium.com.au

CRITICAL MINERAL(S)	VANADIUM QLD
PROJECT NAME	**SAINT ELMO**
Location	Located 25 km east of Julia Creek in north-west Queensland.
Company name	**Multicom Resources Ltd**
Company ownership	Unlisted public company
Project description	Multicom's Saint Elmo Project is being developed to take advantage of the increasing supply gap in the vanadium market. There is an increasing global demand for lighter-weight and higher-strength steels as well as an increasing global demand for renewable and reliable energy, making vanadium a valuable metal. The project is situated in the globally renowned North West Minerals Province, only 260 km from Mount Isa. The Saint Elmo Project will be a shallow, low strip ratio, open-cut mine. Ore will be processed on site via a roast, leach and solvent extraction process to produce a >98% purity vanadium pentoxide (V_2O_5) product. This low-impact, low-carbon-footprint project builds on Australia's exemplary record in the development and supply of ethically and responsibly sourced raw materials. The Saint Elmo Project has been granted major project status by the Australian Government and is designated a 'prescribed project' and a 'project of regional significance' by the Queensland Government. This is welcomed support, as the company finalises approvals for bringing vanadium as a critical mineral to the global market.
Expected products	>98% V_2O_5 (vanadium pentoxide). Currently investigating potential for a molybdenum by-product.
Mineral inventory	Mineral resources at 0.2% V_2O_5 cut-off (as at July 2018):

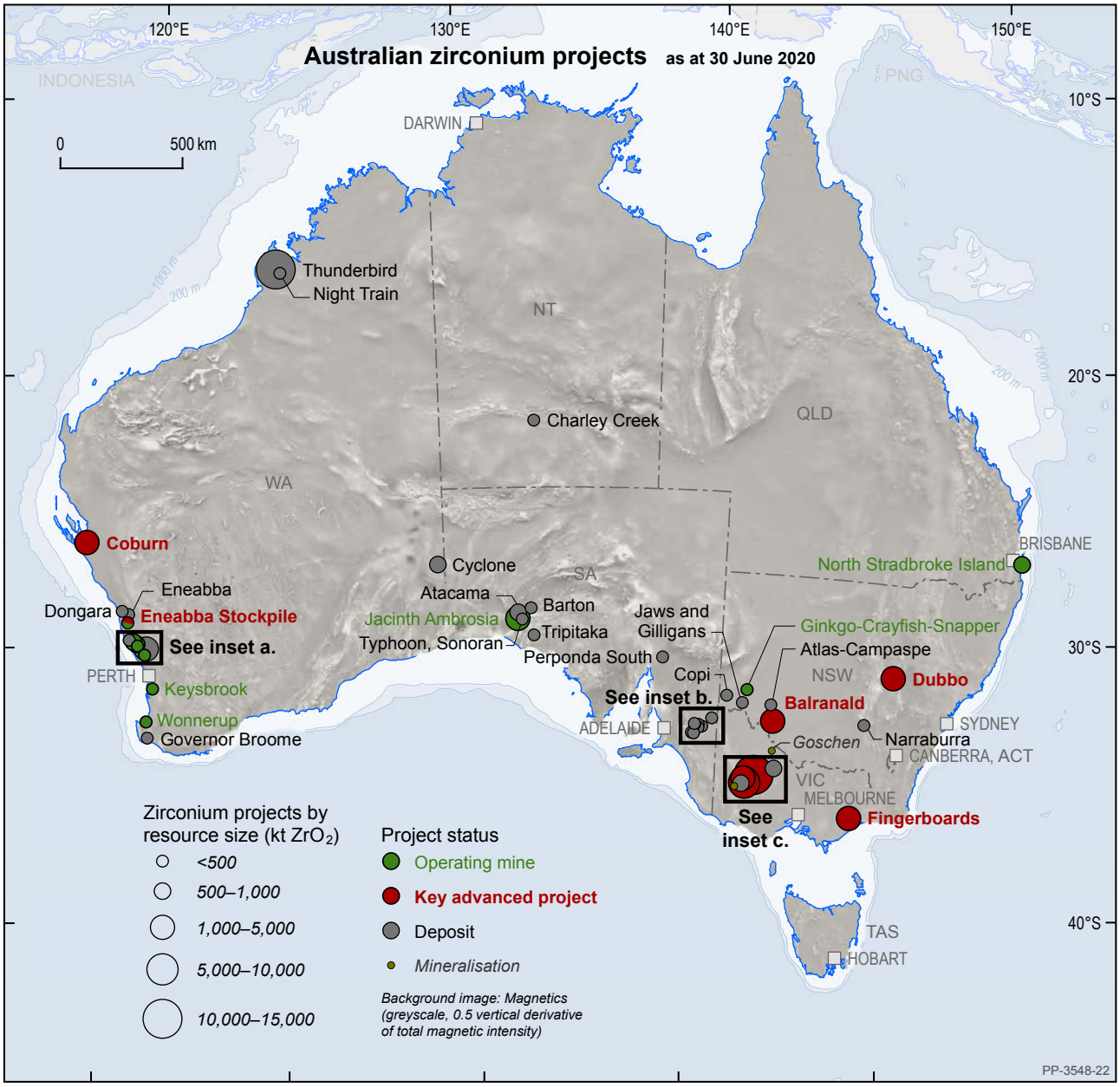
Resource category	Tonnes (Mt)	V_2O_5 (%)
Measured	15.5	0.26
Indicated	89.0	0.25
Inferred	200.0	0.25
Total	**304.5**	**0.25**
Contained (kt)		**762**

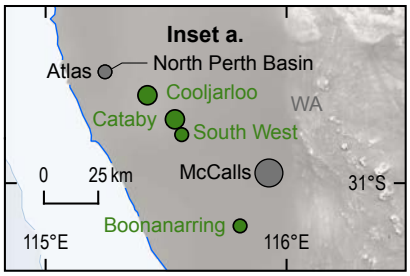
*Extensive drill program and updated geological model currently underway – due mid 2020.

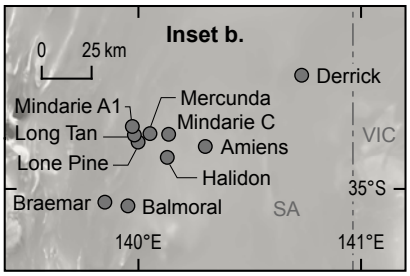
Stage of development	Multicom Resources has been rapidly developing the Saint Elmo Project over the past three years. Following commencement in early 2017, the project's environmental impact statement was lodged for public advertising in October 2019. Responses and clarifications are being provided to the Queensland Department of Environment and Science for outstanding comments and queries. This work is due to be completed in mid-2020. In support of the mining lease application, the company has resolved native title and cultural heritage assessment and approval, while having also advanced land compensation negotiations to final stage.

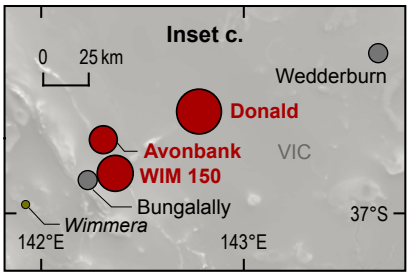
Stage of development	A pre-feasibility study was completed in November 2019, detailing the economic and technical viability of the project. Multicom has since moved onto its feasibility study and expects to have this completed in 2020. With the continued support from both state and federal governments, the project's approvals are well advanced, with the mining lease expected in the second half of 2020. Subject to financing, production is expected to commence in 2022.
Expected production	Average annual production (initial stage) of: • Ore mined and processed: 2.5 Mtpa • V_2O_5 (>98%): 4,000 tpa The company anticipates the scaling up of production capacity once in operations to 10 ktpa and then 20 ktpa, subject to market conditions.
Infrastructure	The project is ideally located adjacent to the Flinders Highway and Mount Isa rail line, which both connect Townsville to Mount Isa. Gas-fired, site-generated power will provide reliable onsite electricity, with the company also considering renewable energy sources. Site water will be obtained from onsite and offsite surface water. Multicom is well advanced in working with the Queensland Government to obtain the necessary water allocation from the Flinders River. The project workforce will be accommodated in the town of Julia Creek and integrate into the existing community. Both Cloncurry and Mount Isa, as major centres, are within a 2.5-hour drive and can support the company's commitment to local employment and supply.
Project development capital costs	A$205m (including 18% contingency) as per the November 2019 pre-feasibility study.
Project economics	The November 2019 pre-feasibility study demonstrated that the project is robust at the initial production capacity of c.4000 tpa with the following economies: • Life-of-mine: 30 years • Life-of-mine revenue: A$3,886m • Life-of-mine EBITDA: A$1,813m • $NPV_{8\%}$ (post-tax): A$250m • IRR (post-tax): 20.0%
Project funding	Multicom Resources is progressing discussions for project funding with current shareholders, potential investors, offtake partners, traditional debt providers and government-supported debt/grant programs, including NAIF. Completion of the feasibility study and advancement of offtake discussions in the second half of 2020 will support these discussions, with a view to reaching financial close in early 2021.
Other	Company website: mcres.com.au Government announcement: minister.industry.gov.au/ministers/karenandrews/media-releases/big-boost-qld-critical-minerals-project Shaun McCarthy, CEO: shaun@mcres.com.au

Zirconium (Zr)









Advanced zirconium projects (total mineral resource tonnage, grade and contained mineral)

Critical mineral	Project name	Company	Project status	Primary mineral(s)	Tonnage (Mt)	Grade	Units		Contained (kt)	Page
Zirconium	**Jacinth Ambrosia**	Iluka Resources Ltd	Operating	Zr, Ti	184.0	0.71	%	ZrO_2	1,314	–
Zirconium	**Cataby**	Iluka Resources Ltd	Operating	Ti, Zr	308.0	0.26	%	ZrO_2	796	–
Zirconium	**Cooljarloo**	Tronox Holdings Plc	Operating	Ti, Z	416.0	0.13	%	ZrO_2	548	–
Zirconium	**South West**	Iluka Resources Ltd	Operating	Ti, Zr	83.0	0.48	%	ZrO_2	401	–
Zirconium	**Boonanarring**	Image Resources Ltd	Operating	Ti, Zr	30.3	0.82	%	ZrO_2	248	–
Zirconium	**Eneabba Stockpile**	Iluka Resources Ltd	Operating	Zr, REE, Ti	1.0	14.47	%	ZrO_2	145	103
Zirconium	**Keysbrook**	Doral Pty Ltd	Operating	Ti, Zr	78.2	0.17	%	ZrO_2	135	–
Zirconium	**Ginkgo-Crayfish-Snapper**	Tronox Holdings Plc	Operating	Ti, Zr (REE)	74.0	0.16	%	ZrO_2	122	–
Zirconium	**Wonnerup**	Tronox Holdings Plc	Operating	Ti, Zr	21.0	0.37	%	ZrO_2	77	–
Zirconium	**North Stradbroke**	Sibelco Australia Ltd	Operating	Ti, Zr				ZrO_2	NA	–
Zirconium	**Atlas-Campaspe**	Tronox Holdings Plc	Construction	Ti, Zr	88.0	0.53	%	ZrO_2	470	–
Zirconium	**Dubbo**	Alkane Resources Ltd	Pre-const	Zr, Nb, Hf, Ta, REE	75.2	1.89	%	ZrO_2	1,421	107
Zirconium	**Donald**	Astron Ltd	FS	Zr, Ti, REE	2,427.0	0.61	%	ZrO_2	14,830	128
Zirconium	**Thunderbird**	Sheffield Resources Ltd	FS	Zr, Ti	3,230.0	0.39	%	ZrO_2	12,462	–
Zirconium	**WIM150**	Murray Zircon Pty Ltd	FS	Zr, Ti, REE	1,650.0	0.51	%	ZrO_2	8,467	132
Zirconium	**Fingerboards**	Kalbar Resources Ltd	FS	Zr, Ti, REE	530.0	0.67		ZrO_2	3,584	134
Zirconium	**Coburn (Amy)**	Strandline Resources Ltd	FS	Ti, Zr	1,606.0	0.18	%	ZrO_2	2,840	136
Zirconium	**Balranald**	Iluka Resources Ltd	FS	Ti, Zr	45.5	2.43	%	ZrO_2	1,108	138
Zirconium	**Cyclone**	Diatreme Resources Ltd	FS	Zr, Ti	203.0	0.42	%	ZrO_2	846	–
Zirconium	**Dongara**	Tronox Holdings Plc	FS	Ti ,Zr	68.0	0.37	%	ZrO_2	248	–
Zirconium	**Atlas**	Image Resources Ltd	FS	Ti ,Zr	18.1	0.37	%	ZrO_2	68	–
Zirconium	**Mindarie C**	Murray Zircon Pty Ltd	Care and maint	Ti, Zr	19.3	0.35	%	ZrO_2	67	
Zirconium	**Mindarie A1**	Murray Zircon Pty Ltd	Care and maint	Ti, Zr	8.8	0.27	%	ZrO_2	23	
Zirconium	**Avonbank**	WIM Resource Pty Ltd	PFS	Zr, Ti	490.0	0.54	%	ZrO_2	2,626	140
Zirconium	**Copi**	Relentless Resources Ltd	PFS	Ti, Zr	75.4	0.31	%	ZrO2	236	–

All heavy mineral sands project summaries are included in the titanium section (other than Eneabba Stockpile in the rare-earth elements section).

Dubbo project included in the rare-earth elements section.

APPENDIX A

Titanium, zirconium and rare-earth element (REE) projects include both hard rock and heavy mineral sands (HMS) projects, which generally use different mineral forms for reporting of grades in mineral resource statements. To put grades and contained critical mineral within the total mineral resource on a comparable basis for titanium, zirconium and REE projects, it was necessary to convert into standard mineral forms using the conventions and conversion factors described in Table 3. It should be noted that HMS projects are generally large, low-cost bulk sand mining operations with lower cost structures and the ability to economically extract lower-grade resources than is generally the case with hard rock projects.

Table 3: Titanium, zirconium and REE projects – mineral form grade conventions and conversion

Critical Mineral	Mineral forms commonly used for reporting grades in mineral resource statements		Conventions used in prospectus for project ranking and conversion factors		
	HMS projects	Hard rock	Convention	Conversion	Conversion factor
Titanium	Ilmenite	TiO_2	TiO_2	Ilmenite -> TiO_2	60%
	Rutile	TiO_2	TiO_2	Rutile -> TiO_2	95%
	Anatase	TiO_2	TiO_2	Anatase -> TiO_2	95%
	Leucoxene	TiO_2	TiO_2	Leucoxene -> TiO_2	80%
Zirconium	Zircon	ZrO_2	ZrO_2	Zircon -> ZrO_2	67%
REE[1]	Monazite	TREO[2]	TREO	Monazite -> TREO	60%
	Xenotime	TREO[2]	TREO	Xenotime -> TREO	62%

1. Rare-earth elements
2. Total rare-earth oxides

REFERENCES

1. Geoscience Australia, June 2020.

2. Skirrow RG, Huston DL, Mernagh TP, Thorne JP, Dulfer H and Senior AB (2013). 'Critical commodities for a high-tech world: Australia's potential to supply global demand', Geoscience Australia, Canberra. http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76526/

3. Australia's Critical Minerals Strategy (2019), Australian Government, Department of Industry, Innovation and Science, Australian Trade and Investment Commission. https://www.industry.gov.au/sites/default/files/2019-03/australias-critical-minerals-strategy-2019.pdf

4. During recent times there has been much controversy about the actual number of elements included in the group of rare-earth elements. For example, the International Union of Pure and Applied Chemistry (IUPAC: http://old.iupac.org/ dhtml_home.html) has defined rare-earth elements as a group of 17 chemically similar metallic elements that comprise the 15 lanthanide elements (lanthanum to lutetium), scandium and yttrium. Although scandium also has similar physical and chemical properties to the lanthanides, its chemical properties do not resemble the lanthanide metals as closely as yttrium. For this reason, the Prospectus will treat scandium as a separate element to the other rare-earth elements.

5. United States Geological Survey, Mineral Commodity Summaries 2020. Figures for 2019 are estimates.

6. Hoatson DM, Jaireth S and Miezitis Y (2011). 'The major rare-earth element deposits of Australia: geological setting, exploration, and resources', Geoscience Australia. https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/71820

7. Skirrow RG et al. (2013) (ibid.).

8. www.chemicool.com/elements

9. Hoatson DM et al. (2011) (ibid.).

10. Australia's Identified Mineral Resources (AIMR) 2019, Geoscience Australia, www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/aimr

11. *Australia Minerals* is a collaboration of Australia's federal, state and Northern Territory government geoscience agencies working together to attract investment into the Australian minerals sector. See: http://www.australiaminerals.gov.au/

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