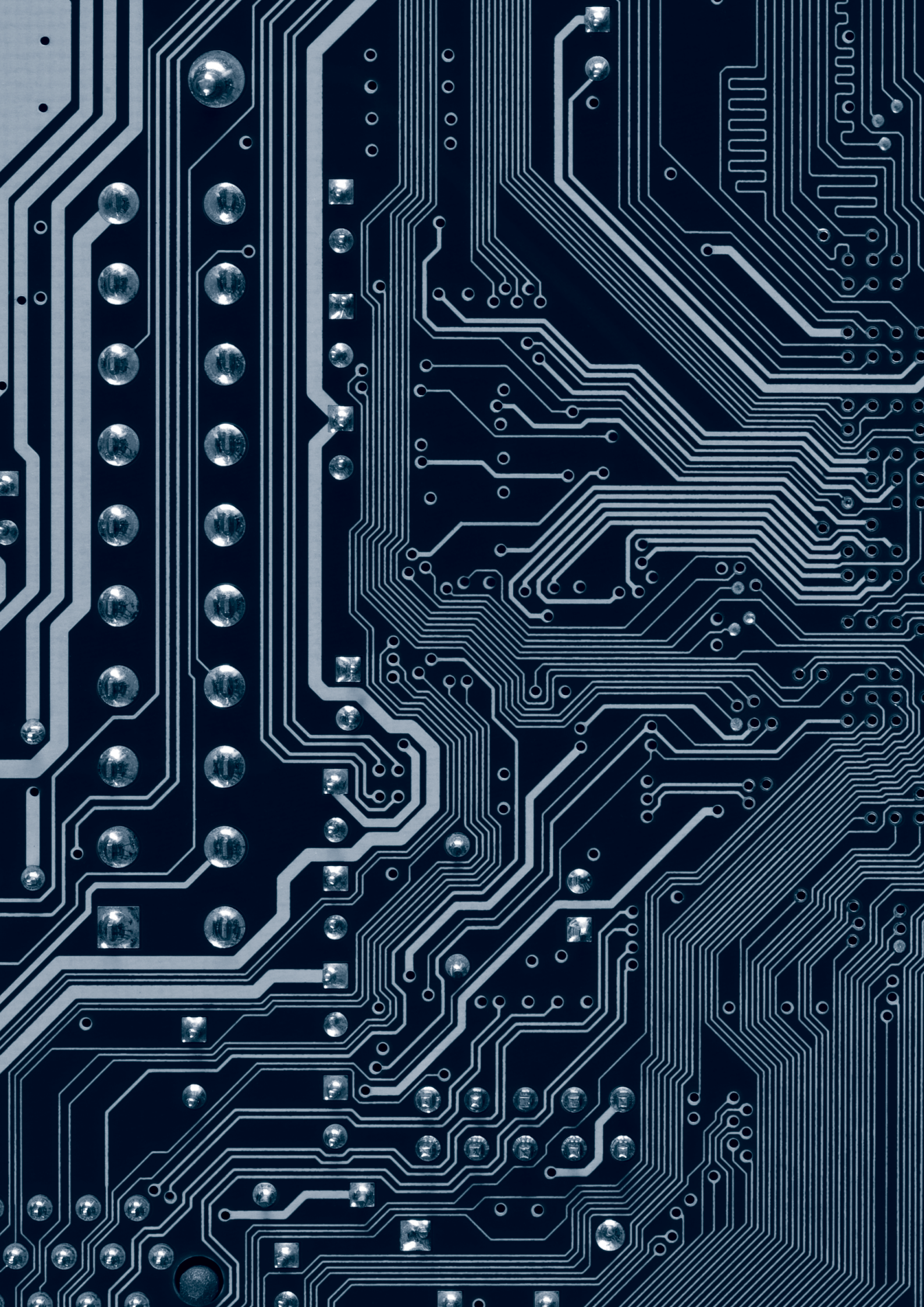




Australian Government
Geoscience Australia

Australia's Identified Mineral Resources 2020





Australia's Identified Mineral Resources 2020



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Minister's Foreword

Australia is a leading global supplier of mineral resources. The resources sector has enabled our economy to remain resilient throughout the global pandemic. The ongoing investment and interest in Australia's mineral potential enables us to grow an innovative and successful resources sector that delivers sustained prosperity and social development for all Australians, particularly in the regions.

Since 1975, Geoscience Australia has produced Australia's Identified Mineral Resources (AIMR) publication. AIMR provides a unique insight into our diverse and abundant ore reserves and mineral resources. The timing of the 2020 edition of AIMR provides an important baseline for measuring our COVID-19 economic recovery. Understanding what we have overcome and what still needs to be achieved is fundamental to ensure the ongoing prosperity of all Australians.

Compiled from the mining industry, these figures reveal trends in reserve estimates, resource estimates and mine production, and provides a strong evidence base to inform policy decisions and international investment, as well as managing the sustainable development of our mineral resources.

At the end of 2019, Australia remained a global leader in mineral exploration and production, and one of the world's most desirable locations for investing in mineral resources. Some highlights from the 2020 edition of AIMR include:

- We remain the **number one producer** of bauxite, iron ore, rutile and lithium,
- we are one of the **top 5 global producers** of cobalt, gold, rare earths, uranium and zinc,
- we continue to have the **largest resources globally** for gold, iron ore, lead, rutile, uranium, zinc and zircon, and
- we had the **largest nickel resources**—up from number two in 2018.

Advancements in technology are driving the world's appetite for critical minerals. The Government supports Australia's mineral industry to build on the

opportunities arising from this growing global market. Australia's Critical Minerals Facilitation Office is assisting companies in securing investment and market access and Geoscience Australia is leading science collaboration with partners in the United States, Canada and India to better understand our respective geological resource potential.

The Government's investment of \$225 million in the Exploring for the Future program, led by Geoscience Australia, recognises that a strong pipeline of new exploration opportunities is essential for Australia's future economic prosperity. The program has already resulted in significant new investment in resource exploration across Northern Australia, with over 120,000 square kilometres of greenfield exploration tenements under application.

Australia is ready to maintain and grow its global leadership in supplying critical and other essential minerals to the world. Our National Resources Statement paves the way for attracting additional investment, including in new technologies, developing new resources and markets, creating well paid and secure jobs, many in regional and rural Australia, and ensuring that all Australians share the benefits of mining success.

Our resources sector is more important than ever, and I look forward to seeing it expand and continue to drive Australia's economy for years to come. I welcome the launch of the 2020 edition of Australia's Identified Mineral Resources.

The Hon Keith Pitt MP

Minister for Resources, Water and Northern Australia

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Exploration in Australia 2019

Gold, copper and iron ore are the top three commodities explored in Australia. A strong gold price has led to a modern gold rush in 2019 with a large increase in exploration expenditure for the commodity.



EXPLORATION EXPENDITURE

\$2.648B
AUD

GOLD ACCOUNTS FOR 40%*

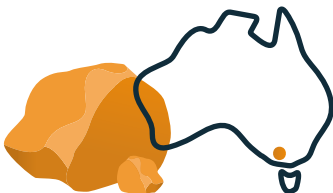
**Less than 5% of gold export value*

EXPLORATION INVESTMENT
INCREASED
21% compared to 2018



Gold in Australia 2019

Australia continues to be the world leader in identified gold resources and has seen an increase in gold production in 2019.



FOSTERVILLE, VIC
The world's highest-grade* gold mine

**millhead grade 39.6 g/t in 2019*



AUSTRALIAN GOLD accounts for (10,795t) or **ONE FIFTH** of the world's resources

\$25 BILLION EXPORTED



RECORD GOLD PRODUCTION



~\$1 billion increase in 2019

AUD \$2007 ^{+15%}
PER OUNCE



A\$309 per ounce increase in 2019

Australian Critical Minerals resource wealth

OUR MINERALS SUPPLY THE WORLD



- CRITICAL MINERALS
- OTHER MINERAL RESOURCES

CRITICAL MINERALS
 Antimony, Cobalt, Graphite, Lithium, Magnesium, Manganese, Platinum Group Elements*, Rare Earths*, Tantalum, Titanium, Tungsten, Vanadium, Zirconium

BATTERIES

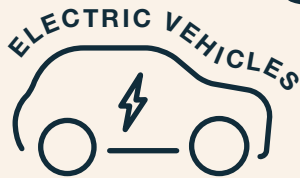
CRITICAL MINERALS
 Lithium, Graphite, Cobalt, Vanadium, Manganese

OTHER MINERALS
 Aluminium, Lead

ALLOYS



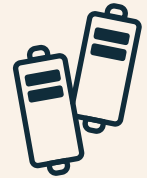
CRITICAL MINERALS
 Vanadium, Magnesium, Chromium, Tungsten



CRITICAL MINERALS
 Lithium, Cobalt, Rare Earths*

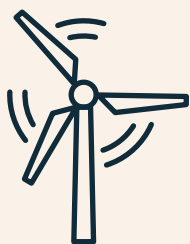
OTHER MINERALS
 Copper, Nickel

He Helium	Li Lithium	Be Beryllium	C Carbon (Graphite)				F Fluorine	
Na Sodium	Mg Magnesium	Al Aluminium	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine		
K Potassium	Ca Calcium	Sc Scandium	Ti Titanium	V Vanadium	Cr Chromium	Mn Manganese	Fe Iron	Co Cobalt
Ni Nickel	Cu Copper	Zn Zinc	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium		
Sr Strontium	*Y Yttrium	Zr Zirconium	Nb Niobium	Mo Molybdenum	Ru Ruthenium	Rh Rhodium		
Pd Palladium	Ag Silver	Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium		
Cs Caesium	*La Lanthanum	*Ce Cerium	*Pr Praseodymium	*Nd Neodymium	*Sm Samarium	*Eu Europium		
*Gd Gadolinium	*Tb Terbium	*Dy Dysprosium	*Ho Holmium	*Er Erbium	*Tm Thulium	*Yb Ytterbium	*Lu Lutetium	Hf Hafnium
Ta Tantalum	W Tungsten	Re Rhenium	Os Osmium	Ir Iridium	Pt Platinum	Au Gold		
Pb Lead	Bi Bismuth					Th Thorium		
U Uranium								



AEROSPACE

CRITICAL MINERALS
 Niobium, Beryllium, Tantalum, Scandium



RENEWABLE ENERGY

CRITICAL MINERALS
 Cobalt, Platinum Group Elements*, Germanium, Rare Earths*, Titanium

OTHER MINERALS
 Aluminium, Copper, Zinc, Silicon

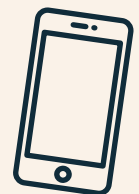
MEDICAL

CRITICAL MINERALS
 Helium, Beryllium, Tantalum, Bismuth



ELECTRONICS

CRITICAL MINERALS
 Rare Earths*, Antimony, Chromium, Indium, Platinum Group Elements*



Acronyms, Abbreviations and Symbols

kg	kilogram	JORC	Joint Ore Reserves Committee
t	tonne	JORC Code	Joint Ore Reserves Committee Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves
kt	kilotonne (thousand tonnes)	IAEA	International Atomic Energy Agency
Mt	million tonne	OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
L	litre	USA	United States of America
GL	gigalitre	USGS	United States Geological Survey
c	carat	AEDR	Accessible Economic Demonstrated Resources
Mc	million carat	EDR	Economic Demonstrated Resources
oz	ounce	RAR	Reasonably Assured Resources
m	metre	\$	dollar (Australian)
km	kilometre	US\$	United States of America dollar
%	per cent	AG	Aktiengesellschaft (joint-stock company)
ktpa	kilotonnes per annum	Co	Company
Mtpa	million tonnes per annum	Inc	Incorporated
ppm	parts per million	Ltd	Limited
PGE	platinum group elements	PLC	Public Limited Company
REE	rare earth elements	Pty	Proprietary
REO	rare earth oxides	COVID-19	Infection caused by the SARS-CoV-2 virus strain
SOP	sulphate of potash		
AIMR	Australia's Identified Mineral Resources		
ASX	Australian Security Exchange		
CRIRSCO	Committee for Mineral Reserves International Reporting Standards		

1. Introduction

Australia has a robust and world-leading mining industry evidenced by a top five position as a producer for some 15 commodities including gold, bauxite, iron ore, rare earths, mineral sands, zinc, nickel and coal. In 2019, Australia's mineral exports (excluding petroleum products) amounted to \$234 billion which was 60% of all export merchandise and 47% of all exported goods and services¹. In 2019, mining accounted for 12% of gross domestic product². In addition, the mining industry employed some 243,000 people in 2019, with many more employed by related industries³.

The major commodities of iron ore, black coal, gold, aluminium and copper contributed some \$207 billion to Australia's export income in 2019⁴. Australia is also richly endowed with many other minerals, particularly those that are regarded as critical⁵, or strategic, minerals by many trading partners. Growing markets for these commodities, particularly for those associated with emerging technologies such as battery storage, renewable energy and electric vehicles have stimulated exploration and resource delineation in Australia in recent years. Critical minerals such as lithium, cobalt and graphite are essential for the development of low-carbon technologies such as wind, solar and energy storage batteries. Demand for these minerals is projected to significantly rise—by 965% for lithium, 585% for cobalt and 383% for graphite, relative to 2017 production—by 2050⁶.

Geoscience Australia and its predecessors have prepared the annual assessment of Australia's mineral resources since 1975. Thus, this publication—Australia's Identified Mineral Resources (AIMR)—is able to draw on 45 years of data to reveal trends in reserve estimates, resource estimates and mine production over a range of periods. This assessment also provides useful long-term indicators of potential resource life and future supply capability, including for 13 of the 24 critical minerals listed in *Australia's Critical Minerals Strategy 2019*⁷. AIMR is designed to assist government policy decision making, enable mineral sector program planning, and contribute to the sustainable development of Australia's mineral resources.

AIMR presents Australia's Ore Reserves at operating mines (Table 1) and all deposits (Table 2), and also longer-term estimates of the nation's Identified Mineral Resources (Table 3) and changes in resource estimates

from the previous year (Table 4). AIMR also provides useful comparisons of the mine inventory as a proportion of the national inventory (Table 5), national reserves as a proportion of national resources (Table 6) and insights into the distribution of Australia's mineral wealth within the largest deposits (Table 7). It is also of interest to note Australia's ranking as a global source of minerals as many countries are dependent on reliable supply from Australia for their own economies (Table 8).

The estimates in AIMR 2020 of Australia's Ore Reserves and Mineral Resources are as at 31 December 2019 and thus precede the COVID-19 pandemic. The data in this report will therefore form an important reference point going forward as government and industry assess the short and long-term effects of this health and economic emergency in coming years.

The data in the national minerals inventory is sourced primarily from published company reports but includes some confidential and historical data. The category of highest geological and economic confidence in the national inventory is Economic Demonstrated Resources (EDR) which, in essence, combines the Joint Ore Reserves Committee (JORC) Code categories of Proved and Probable Ore Reserves and most of Measured and Indicated Mineral Resources.

Mine production figures are sourced from the Office of the Chief Economist at the Department of Industry, Science, Energy and Resources, state government publications and company reports. World rankings of Australia's mineral resources have been calculated mainly using information published by the United States Geological Survey (USGS).

1. Office of the Chief Economist (Department of Industry, Science, Energy and Resources), Resources and Energy Quarterly, Historical Data spreadsheet September 2020, Table 17.
2. Australian Bureau of Statistics (ABS), Australian National Accounts, National Income, Expenditure and Product, cat. no. 5206.0, Figure of 12% calculated by dividing Mining (B) Table 45 by Gross Domestic Product Current Table 1.
3. ABS, Labour Force, Australia, Detailed, Quarterly, cat. no. 6291.055.003, February 2020, Table 4.
4. See above n 1.
5. Critical minerals are elements and minerals regarded as vital for economic well-being, but for which supplies could be disrupted by factors including geological scarcity, geopolitical issues, or trade policies. The proliferation of technologies used in everyday life, as well as specialist applications, that rely on critical minerals has led to increased government interest in the sector, both domestically and abroad. See below n 7.
6. World Bank, Climate-Smart Mining: Minerals for Climate Action (Infographic, 8 October 2019). See <https://www.worldbank.org/en/news/feature/2019/10/07/changing-mining-practices-and-greening-value-chains-for-a-low-carbon-world> (accessed 18 December 2020). This supplements a recent World Bank Report which projected that meeting obligations under the Paris Agreement by 2050 using clean energy technologies would require an annual production increase of 494% for graphite, 488% for lithium, 460% for cobalt, and 189% for vanadium relative to 2018: Hund, Kirsten, La Porta, Daniela, Fabregas, Thao P., Laing, Tim, and Dexhage, John. Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition (World Bank Report, 2020), Table B, p 103. See: <http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf> (accessed 18 December 2020).
7. Australian Government, *Australia's Critical Minerals Strategy 2019*, Canberra. See <https://www.industry.gov.au/data-and-publications/australias-critical-minerals-strategy>

JORC Code

The following terminology and definitions are used by the Joint Ore Reserves Committee (JORC) Code for reporting of Mineral Resources and Ore Reserves (2012 Edition). A full copy of the JORC Code can be found at www.jorc.org.

Mineral Resource: A 'Mineral Resource' is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade (or quality), continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

Inferred Mineral Resource: An 'Inferred Mineral Resource' is that part of a Mineral Resource for which quantity and grade (or quality) are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade (or quality) continuity. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. An Inferred Mineral Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to an Ore Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

Indicated Mineral Resource: An 'Indicated Mineral Resource' is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to assume geological and grade (or quality) continuity between points of observation where data and samples are gathered. An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Ore Reserve.

Measured Resource: A 'Measured Mineral Resource' is that part of a Mineral Resource for which quantity, grade (or quality), densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Geological evidence is derived from detailed and reliable exploration, sampling and testing gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes, and is sufficient to confirm geological and grade (or quality) continuity between points of observation where data and samples are gathered. A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Ore Reserve or under certain circumstances to a Probable Ore Reserve.

Modifying Factors: 'Modifying Factors' are considerations used to convert Mineral Resources to Ore Reserves. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social and governmental factors.

Ore Reserve: An 'Ore Reserve' is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.

Probable Ore Reserve: A 'Probable Ore Reserve' is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors applying to a Probable Ore Reserve is lower than that applying to a Proved Ore Reserve.

Proved Ore Reserve: A 'Proved Ore Reserve' is the economically mineable part of a Measured Mineral Resource. A Proved Ore Reserve implies a high degree of confidence in the Modifying Factors.

2. Australia's Estimated Ore Reserves

In December 2019, 2,192 companies and securities were listed on the Australian Securities Exchange (ASX). Of these, 842 (38%) were categorised as belonging to the materials and energy sectors, which includes mining and exploration companies. Recognising that confidence in such a large part of the Australian economy is paramount, the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Minerals Council of Australia have developed the JORC Code for reporting exploration results and estimates of Mineral Resources and Ore Reserves to the public.

The JORC Code has been adopted by the ASX as part of its listing rules and its use is mandatory for all mining companies listed on the ASX and New Zealand Stock Exchange. Variations of the JORC Code have been adopted in many parts of the world and the code is compatible with the international CRIRSCO⁸ and United Nations Framework Classification for Resources templates.

Recently, the Joint Ore Reserves Committee commenced a review of the 2012 edition of the JORC Code. In commencing the review, the Committee noted that while the key focus of the JORC Code remains to provide principles-based disclosure transparency, there are a number of areas where industry, regulator and public expectations have evolved since the last update⁹.

As part of the Australian Government's annual assessment of the national minerals inventory, Geoscience Australia compiles all known estimates of Ore Reserves and Mineral Resources reported publicly by mining companies in compliance with the JORC Code, or JORC-equivalent codes. In addition, reserve and resource estimates from private companies and foreign companies operating in Australia are also included in the annual compilation wherever possible.

Determining how much of a particular mineral commodity is in the ground and how much is extractable is not an exact science, hence Ore Reserves and Mineral Resources are always referred to as estimates, never calculations. Ore Reserves and Mineral Resources are categorised by confidence in both the geology of the deposit and the economic viability of production. Of all the different categories (see description of JORC Code

on page 2), an Ore Reserve is the category of highest confidence. From a commercial point of view, this category is the most applicable to understanding the state of Australia's minerals industry now and in the near future (say, the next five years).

Geoscience Australia began publishing amalgamated national totals for Ore Reserves in 2002. Prior to this, these estimates were included within the national inventory of EDR (and continue to be included) but were not specifically noted.

Operating mines

In 2019, Australia had over 300 operating mines producing 26 major and minor mineral commodities. In addition, there were a large number of excavations for a range of industrial materials and gemstones (not covered in this publication). Mining contributed 12% to Australia's gross domestic product in 2019¹⁰ and 47% of Australia's export income. In determining the outlook for the industry in Australia, it is useful to look at the Ore Reserves and Mineral Resources associated with operating mines (Table 1) as it is usually easier and cheaper to expand current mines than to start new ones. While some of the mines that operated in 2019 have since closed or been placed on care and maintenance, subject to favourable economic, environmental and regulatory conditions, most will continue mining for the foreseeable future.

One way of gaining an impression of future viability of a mine or resource is to calculate the ratio of reserves or resources to production, thus establishing a reserve or resource 'life' (Table 1). The resulting reserve and resource life must be treated with caution as it is an average and it assumes three things: (1) that production rates in the future will remain the same as those used in the calculation, (2) deposits deemed economic/uneconomic remain so in the future and (3) that depleted resources are never replaced. In reality, production rates vary from year to year, mining companies continually reassess the economic viability of their deposits and companies typically do upgrade resources or discover new resources to replace ore depletion. Nonetheless, this ratio provides a potentially useful 'snapshot in time' that can help reveal trends in Australia's ability to supply a range of mineral resources into the future.

8. CRIRSCO is the Committee for Mineral Reserves International Reporting Standards. See <http://www.criirSCO.com>

9. Australian Institute of Geoscientists. JORC Code Update. See <https://www.aig.org.au/jorc-code-update/> (accessed 1 March 2021).

10. See above n 2.

Table 1 Australia's Ore Reserves and Mineral Resources of selected commodities at operating mines in 2019.

Commodity	Unit	No. of Operating Mines ⁽¹⁾	Ore Reserves ⁽²⁾	Measured and Indicated Mineral Resources ⁽³⁾	Inferred Mineral Resources ⁽⁴⁾	Mine Production ⁽⁵⁾	Reserve Life (years)	Resource Life 1 (years)	Resource Life 2 (years)
Antimony	kt Sb	1	17.7	36.8	9.1	2.03 ⁽⁶⁾	9	23	27
Bauxite	Mt	10	2,039	1,586	3,649	105.5	19	15	50
Black Coal	Mt	96	11,670	30,586 ⁽⁷⁾	14,227 ⁽⁷⁾	588 ⁽⁸⁾	20	52	76
Copper	Mt Cu	43	19.82	83.99	26.47	0.93	21	90	118
Diamond	Mc	1	9.69	0	0	12.99	1	0	0
Gold	t Au	150	2,966	6,646	2,669	326	9	20	29
Iron Ore	Mt	36	11,800	30,340	40,133	919	13	33	77
Lead	Mt Pb	19	9.15	23.12	4.74	0.509	18	45	54
Lithium	kt Li	7	3,091	4,033	1,322	45 ⁽⁹⁾	69	90	119
Manganese Ore	Mt	3	33	47	5	7.5 ⁽¹⁰⁾	4	6	7
Mineral Sands									
Ilmenite	Mt	12	16.7	50.8	10.2	1	17	51	62
Rutile	Mt	10	2.4	5.2	0.8	0.2	13	28	32
Zircon	Mt	10	4.5	11.7	2.0	0.5	8	22	25
Nickel	Mt Ni	10	2.4	7.6	1.1	0.16	15	49	56
Rare Earths ⁽¹¹⁾	Mt	2	1.67	2.08	1.37	0.018 ⁽¹²⁾	88	109	182
Silver ⁽¹³⁾	kt Ag	31	19.09	54.08	13.63	1.325	14	41	51
Tin	kt Sn	1	179	348	38	7.6 ⁽¹⁴⁾	24	46	51
Uranium	kt U	3	266	1,483	718	6.613	40	224	333
Zinc	Mt Zn	20	19.60	47.71	12.51	1.337	15	36	45

Abbreviations

t = tonne; kt = kilotonne (1,000 t); Mt = million tonne (1,000,000 t); Mc = million carat (1,000,000 carats).

Where an element symbol follows the unit it refers to contained metal content.

Notes

Reserve Life = Ore Reserves ÷ Production.

Resource Life 1 = Measured and Indicated Resources ÷ Production.

Resource Life 2 = Measured, Indicated and Inferred Resources ÷ Production.

- The number of operating mines counts individual mines that operated during 2019 and thus contributed to production. Some of these mines may belong to larger, multi-mine operations and some may have closed during or since 2019.
- The majority of Australian Ore Reserves and Mineral Resources are reported in compliance with the JORC Code, however there are a number of companies that report to foreign stock exchanges using other reporting codes, which are largely equivalent. In addition, Geoscience Australia may hold confidential information for some commodities. NB: Not all operating mines report Ore Reserves. Ore Reserves are as at 31 December 2019.
- Measured and Indicated Mineral Resources are inclusive of the Ore Reserves. NB: Not all operating mines report Mineral Resources. Mineral Resources are as at 31 December 2019.
- Inferred Mineral Resources are as at 31 December 2019. NB: Not all operating mines report Mineral Resources.
- Mining production from Resources and Energy Quarterly, September 2020, published by the Office of the Chief Economist, Department of Industry, Innovation and Science unless otherwise stated. Production data often have a higher level of certainty than reserve and resource estimates and, thus, may be presented with more significant figures.
- Antimony production from company reports (Mandalay Resources Ltd).
- Measured, Indicated and Inferred Mineral Resources for black coal are presented on a recoverable basis (these are Geoscience Australia estimates unless provided by the company).
- Mine production refers to raw coal.
- Lithium production data (tonnes of spodumene concentrates) from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file. Production of lithium calculated assuming 6% Li₂O in spodumene concentrates.
- Australian manganese production from company reports and total reported production from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
- Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y₂O₃).
- Rare earths production is based on Western Australian production of concentrates from Mount Weld (17,613 t) and from trial mining and processing at Browns Range (45.66 t).
- Major silver producing mines only; many gold and copper mines also produce silver as a by-product but these are not counted here.
- The Office of the Chief Economist reports tin production of 7.74 kt in 2019. Renison, Australia's only significant tin mine, reports 7.6 kt. Additional production is as by-product from other operations such as Greenbushes, where tin production data (0.82 t) is from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file.

Ore Reserves at other mines and deposits

Australia's Identified Mineral Resources covers 36 mineral commodities, of which 30 have estimated Ore Reserves and 26 were actually in production in 2019 (Table 2).

For many commodities (e.g. bauxite, copper and lead) the majority of Ore Reserves are associated with operating mines but Ore Reserves are also attributable to mines on

care and maintenance, mines under development and, in some cases, undeveloped deposits (Figure 1). Australia's graphite, potash and scandium sectors, for example, do not yet have operating mines so Ore Reserves are predominantly attributable to developing mines.

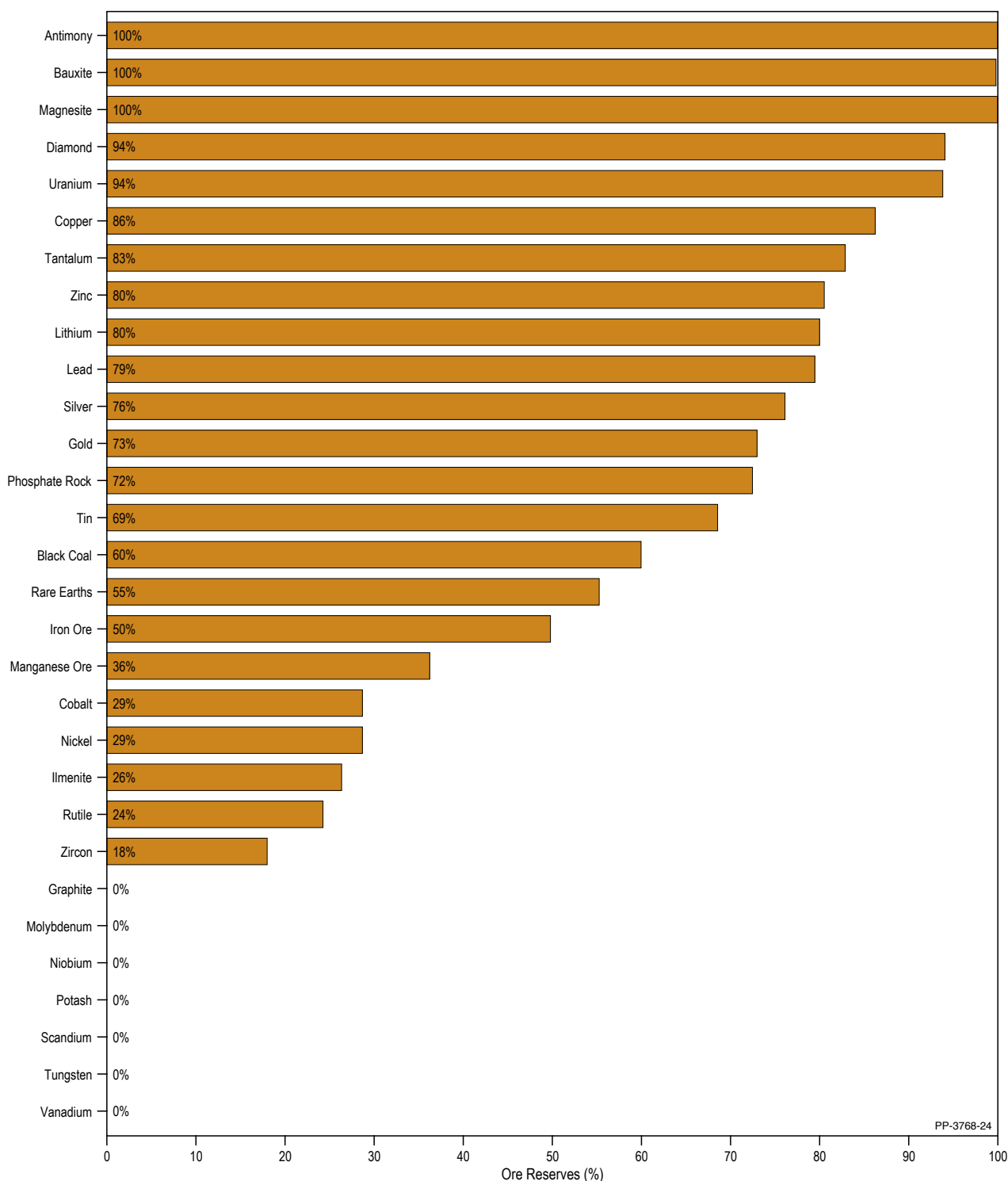


Figure 1 Ore Reserves attributable to operating mines as a percentage of total Australian Ore Reserves, 2019.

Table 2 Australia's Estimated Ore Reserves⁽¹⁾ as at December 2019.

Commodity	Unit	Proved Ore Reserves	Probable Ore Reserves	Proved & Probable Ore Reserves ⁽²⁾	Total Ore Reserves	Mine Production ⁽³⁾	Reserve Life (years)
Antimony	kt Sb	5.5	12.2	0	17.7	2.03 ⁽⁴⁾	9
Bauxite	Mt	952	1,093	0	2,045	105.5	19
Black Coal	Mt	7,866	9,316	2,277	19,458	588 ⁽⁵⁾	33
Brown Coal	Mt	n.a.	n.a.	n.a.	n.a.	43 ⁽⁶⁾	n.a.
Chromium	kt Cr	0	0	0	0	0	0
Cobalt	kt Co	205	350	2	557	5.7 ⁽⁷⁾	98
Copper	Mt Cu	6.70	15.51	0.78	22.99	0.93	25
Diamond	Mc	0	10.30	0	10.30	12.99	1
Fluorine	kt F	0	0	0	0.0	0	0
Gold	t Au	911	3,132	27	4,069	326	12
Graphite	Mt	0.1	4.7	0	4.8	0	0
Iron							
Iron ore	Mt	7,951	15,763	0	23,714	919	26
Contained iron	Mt Fe	3,842	6,942	0	10,784	569	19
Lead	Mt Pb	6.58	4.94	0	11.52	0.509	23
Lithium	kt Li	553	3,209	0	3,761	45 ⁽⁸⁾	84
Magnesite	Mt MgCO ₃	10	3	24	37	<1 ⁽⁹⁾	187
Manganese Ore	Mt	45	30	17	91	7.5 ⁽¹⁰⁾	12
Mineral Sands							
Ilmenite	Mt	27.9	35.7	0	63.6	1.0 ⁽¹¹⁾	64
Rutile	Mt	5.2	4.7	0	9.9	0.2 ⁽¹¹⁾	54
Zircon	Mt	11.8	13.1	0	24.9	0.5 ⁽¹¹⁾	50
Molybdenum	kt Mo	0	4	0	4	0	0
Nickel	Mt Ni	3.3	5.0	<1	8.3	0.16	54
Niobium	kt Nb	58	0	0	58	n.a. ⁽¹²⁾	n.a.
Oil Shale	GL	0	0	0	0	0	0
PGE (Pt, Pd, Os, Ir, Ru, Rh)	t metal	0	0	0	0	0.483 ⁽¹³⁾	n.a.
Phosphate							
Phosphate rock ⁽¹⁴⁾	Mt	12	21	81	113	1.0 ⁽¹⁵⁾	116
Contained P ₂ O ₅	Mt P ₂ O ₅	3	6	20	28	n.a.	n.a.
Potash	Mt K ₂ O	1	4	0	5	0	n.a.
Rare Earths ⁽¹⁶⁾	Mt	1.66	1.36	0	3.02	0.018 ⁽¹⁷⁾	167
Scandium	kt Sc	5.57	7.11	0	12.68	0	n.a.
Silver	kt Ag	14.86	10.22	0	25.08	1.33	21
Tantalum	kt Ta	7.0	32.2	0	39.2	0.096 ⁽¹⁸⁾	408
Thorium	kt Th	0	0	0	0	0	0
Tin	kt Sn	35	128	98	261	7.6	34
Tungsten	kt W	21	194	0	215	<1 ⁽¹⁹⁾	>1000
Uranium	kt U	108	174	1	284	6.613	43
Vanadium	kt V	707	847	0	1,554	0	0
Zinc	Mt Zn	14.33	10.04	0	24.37	1.337	18

Abbreviations

t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats); GL = gigalitre (1,000,000,000 L); n.a. = not available; PGE = platinum group elements (Pt, Pd, Os, Ir, Ru, Rh).

Where an element symbol follows the unit it refers to contained metal content.

Notes

Reserve Life = Ore Reserves ÷ Production.

Figures are rounded so Proved, Probable and Proven & Probable Ore Reserves may not add up to Total Ore Reserves exactly.

1. The majority of Australian Ore Reserves are reported in compliance with the JORC Code, however there are a number of companies that report to foreign stock exchanges using other reporting codes, which are largely equivalent. In addition, Geoscience Australia may hold confidential information for some commodities.
2. 'Proven & Probable Ore Reserves' is a distinct reporting category that is no longer supported by the JORC Code. Some overseas reporting codes still use this category and some historical resources fall into this category.
3. Mining production from Resources and Energy Quarterly, September 2020 published by the Office of the Chief Economist, Department of Industry, Innovation and Science unless otherwise stated. Production data often have a higher level of certainty than reserve and resource estimates and, thus, may be presented with more significant figures.
4. Antimony production from company reports (Mandalay Resources Ltd).
5. Black coal production refers to raw coal.
6. Australian production of brown coal is a Geoscience Australia estimate from company reports.
7. Cobalt production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file.
8. Lithium production data (tonnes of spodumene concentrates) from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file. Production of Lithium calculated assuming 6% Li₂O in spodumene concentrates.
9. The Department of State Development, South Australia (Report Book 2020/00010) reported magnesite production of 5,511 t in 2019. The Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2018–19) reported magnesite production of 407,761 t in 2018–19.
10. Australian manganese production from company reports and total reported production from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
11. Minerals sands production from company reports.
12. There are no mines producing niobium as a primary product in Australia but it is likely produced as a by-product at some lithium/tantalum operations, but these data have not been reported.
13. Platinum and palladium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file.
14. Phosphate rock is reported as being economic at grades ranging from 8.7% to 30.2% P₂O₅.
15. Geoscience Australia estimate based on reported mining production of 259,835 t from Christmas Island in 2019; 462 t from South Australia in 2019 (Report Book 2020/00010), and 720,186 t from Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2018–19).
16. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y₂O₃).
17. Australian rare earths production is based on Western Australian production of concentrates from Mount Weld (17,613 t) and from trial mining and processing at Browns Range (45.66 t).
18. Tantalum production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file. Production represents a maximum as no correction has been made for actual tantalite concentration in reported concentrates.
19. Tungsten production from company correspondence (Tasmania Mines Pty Ltd). There is a small amount of additional unreported production from the December 2019 commencement of concentrate production at Mount Carbine in Queensland.

National Classification System

The following terminology and definitions are used in Australia's National Classification System for Identified Mineral Resources.

Resource: A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust and in such form that its economic extraction is presently or potentially (within a 20–25 year timeframe) feasible.

Identified Resource: A specific body of mineral-bearing material whose location, quantity and quality are known from specific measurements or estimates from geological evidence for which economic extraction is presently or potentially (within a 20–25 year timeframe) feasible.

To reflect degrees of geological assurance, Identified Resources can be divided into Measured Resources, Indicated Resources and Inferred Resources where Measured Resources have the most geological confidence and Inferred Resources the least. The National Classification System's definitions for Measured, Indicated and Inferred Resources are consistent with those of the JORC Code.

Under the JORC Code, with the application of Modifying Factors and mine planning, Measured Resources can be converted into Proved Ore Reserves or Probable Ore Reserves and Indicated Resources can be converted into Probable Ore Reserves.

Demonstrated Resource: A collective term for the sum of Measured and Indicated Resources, including Proved and Probable Ore Reserves.

Economic: This term implies that, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Economic Demonstrated Resource (EDR):

A Demonstrated Resource that is regarded as economic under the definition above. The EDR category provides a long-term view of what is likely to be available for mining (potential supply). It does not include Inferred Resources which do not have enough geological confidence to support mine planning. For shorter-term, commercial viewpoints of the economic category see Table 1 (Ore Reserves and Mineral Resources at Operating Mines) and Table 2 (Australia's Ore Reserves).

Subeconomic: This term refers to those resources that are geologically demonstrated but which do not meet the criteria of Economic at the time of determination. Subeconomic Resources include paramarginal and submarginal categories:

- **Paramarginal:** That part of Subeconomic Resources which, at the time of determination, could be produced given postulated limited increases in commodity prices or cost-reducing advances in technology. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria of economic.
- **Submarginal:** That part of Subeconomic Resources that would require a substantially higher commodity price or major cost-reducing advance in technology to render them economic.

Accessible Economic Demonstrated Resource (AEDR):

Some resources have enough geological confidence to be considered a Demonstrated Resource and, in normal circumstances, would also be regarded as economic but they are not currently available for development because of legal and/or land-use restrictions. They are included in EDR but not in AEDR.

3. Australia's Identified Mineral Resources

The National Classification System for Identified Mineral Resources has been used by the Australian Government since 1975 for classifying mineral resources for regional and national assessments. It provides a long-term view on what is likely to be available for mining.

The National Classification System uses two general criteria for classifying Australia's national inventory of mineral resources:

1. the geological certainty of the existence of the mineral resource, and
2. the economic feasibility of its extraction over the long term.

The National Classification System uses reports on mineral resources published by companies using the JORC Code (or equivalent foreign codes) and, to a lesser extent, confidential information, to compile national totals for the resource classification categories set out in Table 3 (see page 8 for terminology and definitions). Both the National Classification System and the JORC Code are based on the McKelvey resource classification system used by the USGS. Thus Australia's national system is compatible with the JORC Code and remains comparable to the USGS system, as published in the annual USGS Mineral Commodity Summaries.

Economic Demonstrated Resources (EDR) is the category used for the national totals of economic resources and provides a basis for meaningful comparisons of Australia's economic resources with those of other nations. For major commodities, Section 8 presents long-term trends in EDR, Ore Reserves, total resources, production and resource life, with accompanying notes on significant changes.

Estimating the total amount of each mineral commodity likely to be available for mining over the long term (EDR) is not a precise science. The long-term perspectives presented herein take account of the following:

- Ore Reserves reported in compliance with the JORC Code (or equivalent foreign codes) will all be mined, but they only provide a short-term view on what is likely to be available for mining.
- Most current Measured and Indicated Resources reported in compliance with the JORC Code are also likely to be mined.

- Some current Inferred Resources will be transferred to Measured and Indicated Resources and Ore Reserves.
- New discoveries will add to the resource inventory.

In addition, some resources that, all being equal, would normally be considered EDR are not accessible because of environmental, legal or military land-use restrictions. Thus Table 3 also lists Accessible Economic Demonstrated Resources (AEDR). Of the 36 mineral commodities assessed in this publication, only black coal, brown coal, gold, mineral sands, platinum group elements and uranium have EDR that is considered inaccessible.

Over time, all of Australia's current EDR of gold, silver, tin, zinc, lead and any number of other commodities will be mined. At first glance, this statement might seem somewhat paradoxical because, obviously, not every deposit that contributes to EDR will have all of that EDR brought into production. Indeed, some deposits currently contributing to EDR will never produce any metal. However, the National Classification System is not designed to be used for individual mine assessments but, instead, is a way of estimating regional and national totals. So, from an aggregated point of view, it is a reasonable proposition that, eventually, all of the current EDR (and more) will be mined. Gold, for example, had an EDR of 5,018 t in 1999; since then Australian mines have produced 5,685 t of gold.

Australia is yet to run out of EDR because, to use JORC Code terminology, as individual Ore Reserves are depleted, Measured and Indicated Resources are reassessed into Proved and Probable categories, Inferred Resources are worked on to bring them to Measured and Indicated status and new drilling at existing mines as well as new greenfield discoveries add to the resource inventory. In addition, extractive technologies improve over time and if a commodity becomes rare then the laws of supply and demand result in previously subeconomic deposits becoming profitable. Thus EDR fundamentally differs from Ore Reserves under the JORC Code because it is not meant to provide a picture of what is currently commercial to mine but rather an outlook on what is likely to be available for mining over the long term, i.e., of opportunity for supply at regional and national scales.

Table 3 Australia's Identified Mineral Resources as at December 2019.

Commodity	Unit	Australia						World	
		Demonstrated Resources			Inferred Resources ⁽²⁾	Accessible EDR ⁽³⁾	Mine Production ⁽⁴⁾	Economic Resources ⁽⁵⁾	Mine Production ⁽⁶⁾
		Economic (EDR) ⁽¹⁾	Subeconomic						
	Paramarginal		Submarginal						
Antimony	kt Sb	100.5	8.8	0	37.2	100.5	2.03 ⁽⁷⁾	1,150	160
Bauxite	Mt	5,292	30	1,429	3,170	5,292	105.5	29,700	372
Black Coal									
In situ	Mt	89,707	2,524	4,314	105,772				
Recoverable	Mt	75,428	1,934	3,856	84,097	68,546	588 ⁽⁸⁾	749,167 ⁽⁹⁾	7,182 ⁽¹⁰⁾
Brown Coal									
In situ	Mt	85,634	44,399	234,825	124,496				
Recoverable	Mt	73,865	40,314	215,449	103,732	63,796	43 ⁽¹¹⁾	320,469 ⁽¹²⁾	739 ⁽¹³⁾
Chromium	kt Cr	0.5	302.0	0	6583.6	0.5	0	570,000 ⁽¹⁴⁾	44,000 ⁽¹⁴⁾
Cobalt	kt Co	1,399	268	5	1,179	1,399	5.7 ⁽¹⁵⁾	7,200	144
Copper	Mt Cu	93.36	1.27	0.62	45.44	93.36	0.93	877	20.3
Diamond	Mc	10.97	0	0	20.30	10.97	12.99 ⁽¹⁶⁾	1,100 ⁽¹⁷⁾	147
Fluorine	kt F	343	721	6	2,543	343	0	153,000	3,400 ⁽¹⁸⁾
Gold	t Au	10,795	148	208	4,822	10,768	326	51,100	3,300
Graphite	Mt	7.97	0.10	0	7.32	7.97	0	308	1.1
Iron									
Iron ore	Mt	50,593	8,858	1,582	91,059	50,593	919	171,000	2,500
Contained iron	Mt Fe	24,508	2,690	426	42,071	24,508	569	83,000	1,500
Lead	Mt Pb	37.31	1.35	0.14	25.06	37.31	0.509	91.7	4.60
Lithium	kt Li	5,702	0	<1	1,594	5,702	45 ⁽¹⁹⁾	19,500	80
Magnesite	Mt MgCO ₃	285	75	35	992	285	<1 ⁽²⁰⁾	8,500	28 ⁽²¹⁾
Manganese Ore	Mt	272	3	190	396	272	7.5 ⁽²²⁾	826 ⁽²³⁾	19 ⁽²³⁾
Mineral Sands									
Ilmenite	Mt	274.7	16.3	10.9	255.5	264.8	1.0 ⁽²⁴⁾	1,260	13
Rutile	Mt	35.4	0.1	3.1	35.9	32.9	0.2 ⁽²⁴⁾	55	1
Zircon	Mt	79.7	0.3	4.7	57.8	77.1	0.5 ⁽²⁴⁾	110	2
Molybdenum	kt Mo	248	366	<1	1,737	248	0	18,000	290
Nickel	Mt Ni	21.2	2.5	<1	19.5	21.2	0.155	90	2.7
Niobium	kt Nb	216	15	0	397	216	n.a. ⁽²⁵⁾	>13,000	74
Oil Shale (recoverable)	GL	0	213	2,074	1,472	0	0	961,873 ⁽²⁶⁾	n.a.
PGE	t metal	37.6	134.4	0	107.2	35.6	0.483 ⁽²⁷⁾	69,000	394 ⁽²⁸⁾
Phosphate									
Phosphate rock ⁽²⁹⁾	Mt	1,091	498	0	2,364	1,091	1.0 ⁽³⁰⁾	70,000	240
Contained P ₂ O ₅	Mt P ₂ O ₅	178	90	0	389	178	n.a.	n.a.	n.a.
Potash	Mt K ₂ O	35	11	<1	148	35	0	>3,600	41
Rare Earths⁽³¹⁾	Mt oxide	4.03	4.29	35.88	26.62	4.03	0.018 ⁽³²⁾	115	0.210
Scandium	kt Sc	26.91	8.10	0.00	19.59	26.91	0	n.a.	n.a.
Silver	kt Ag	90.26	1.86	0.48	45.37	90.26	1.325	560	27.0
Tantalum	kt Ta	93.5	1.4	0.2	35.9	93.5	0.096 ⁽³³⁾	>127	1.9
Thorium	kt Th	0	16	543	707	0	0	n.a.	n.a.
Tin	kt Sn	561	63	32	301	561	7.6	4,880	312
Tungsten	kt W	403	0	5	322	403	<1 ⁽³⁴⁾	3,200	82
Uranium	kt U	1,147	56	27	722	1,091	6.613	3,792 ⁽³⁵⁾	54.7 ⁽³⁶⁾
Vanadium	kt V	6,019	196	1376	22,838	6,019	0	24,000	73
Zinc	Mt Zn	68.92	0.43	0.75	46.12	68.92	1.337	251	13

Abbreviations

t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats); GL = gigalitre (1,000,000,000 L); n.a. = not available; PGE = platinum group elements (Pt, Pd, Os, Ir, Ru, Rh).

Where an element symbol follows the unit it refers to contained metal content

Notes

1. Economic Demonstrated Resources (EDR) predominantly comprise Ore Reserves and most Measured and Indicated Mineral Resources that have been reported in compliance with the Joint Ore Reserves Committee (JORC) Code to the Australian Securities Exchange (ASX). In addition, some reserves and resources have been reported using other reporting codes to foreign stock exchanges and Geoscience Australia may hold confidential data for some commodities.
2. Total Inferred Resources in economic, subeconomic and undifferentiated categories.
3. Accessible Economic Demonstrated Resources (AEDR) is the portion of total EDR that is accessible for mining. AEDR does not include resources that are inaccessible for mining because of environmental restrictions, government policies or military lands.
4. Australian mine production from Resources and Energy Quarterly, September 2020 published by the Office of the Chief Economist, Department of Industry, Science, Energy and Resources unless otherwise stated. Production data often have a higher level of certainty than reserve and resource estimates and, thus, may be presented with more significant figures.
5. World economic resources from Mineral Commodity Summaries 2020 published by the USGS and adjusted with Geoscience Australia data, unless otherwise stated.
6. World production from Mineral Commodity Summaries 2020 published by the USGS and adjusted with Geoscience Australia data, unless otherwise stated.
7. Australian antimony production from company reports (Mandalay Resources Ltd).
8. Australian black coal production refers to raw coal.
9. World economic resources of black coal derived from BP Statistical Review of World Energy June 2020.
10. World mine production of black coal derived from International Energy Agency, Coal Information 2020 Overview.
11. Australian production of brown coal is supplied by International Energy Agency 2019.
12. World economic resources of brown coal derived from BP Statistical Review of World Energy June 2020.
13. World mine production of brown coal from International Energy Agency (Coal Information 2020 Overview).
14. World economic resources and mine production are presented as chromite ore.
15. Australian cobalt production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file.
16. Australian diamond production from Rio Tinto Ltd annual report 2019.
17. World resource figures are for industrial diamonds only, no data provided for resources of gem diamonds.
18. World mine production of fluorine excludes the USA.
19. Australian lithium production data (tonnes of spodumene concentrates) from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file. Production of Lithium calculated assuming 6% Li₂O in spodumene concentrates.
20. The Department of State Development, South Australia (Report Book 2020/00010) reported magnesite production of 5,511t in 2019. The Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2018–19) reported magnesite production of 407,761 t in 2018–19.
21. World mine production excludes the USA.
22. Australian manganese production from company reports and total reported production from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
23. World economic resources and mine production are presented as manganese content, not manganese ore.
24. Australian mineral sands production from company reports.
25. There are no mines producing niobium as a primary product in Australia. It is likely that niobium is produced as a by-product at some lithium/tantalum operations, but these data have not been reported.
26. World resources of oil shale from World Energy Council, World Energy Resources 2016.
27. Australian platinum and palladium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file.
28. World mine production is platinum and palladium only.
29. Phosphate rock is reported as being economic at grades ranging from 8.7% to 30.2% P₂O₅.
30. Geoscience Australia estimate based on reported mining production of 259,835 t from Christmas Island in 2019, 462 t from South Australia in 2019 (Report Book 2020/00010), and 720,186 t from Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2018–19).
31. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y₂O₃).
32. Australian rare earths production is based on Western Australian production of concentrates from Mount Weld (17,613 t) and from trial mining and processing at Browns Range (45.66 t).
33. Australian tantalum production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2019 Major commodities resources file. Production represents a maximum as no correction has been made for actual tantalite concentration in reported concentrates.
34. Australian tungsten production from company correspondence (Tasmania Mines Pty Ltd).
35. World economic resources from the International Atomic Energy Agency estimate for Reasonably Assured Resources recoverable at costs of less than US\$130/kg U published in Uranium 2020: Resources, Production and Demand (the Red Book).
36. World production of uranium in 2019 from World Nuclear Organisation (World Uranium Mining Production, September 2020 update).

Trends in EDR

Australia's EDR of the following mineral commodities increased significantly (>5%) during 2019: copper, gold, graphite, manganese ore, molybdenum, nickel, platinum group elements, potash, tantalum, tin and vanadium (Table 4). The EDR of five commodities decreased significantly in 2019: antimony, brown coal, diamond, magnesite and uranium (Table 4). All other mineral EDR stayed within 5% of the previous year's estimates (Table 4).

Trends in EDR for Australia's major mineral commodities have undergone significant and sometimes dramatic changes over the period 1975 to 2019 (see Section 8). These changes can be attributed to one, or a combination, of the following factors:

- Increases in resources resulting from discoveries of new deposits and delineation of extensions at known deposits.
- Depletion of resources as a result of mine production.
- Advances in mining and metallurgical technologies, e.g. carbon-based processing technologies for gold have enabled economic extraction from low-grade deposits that were previously uneconomic.
- Adoption of the JORC Code for resource classification and reporting by the Australian minerals industry and the subsequent impacts on re-estimation of Ore Reserves and Mineral Resources to comply with the requirements of the JORC Code. The impacts of the JORC Code on EDR occurred at differing times for each of the major commodities.
- Significant changes in the prices of mineral commodities driven largely by both escalating and cooling demand from China over the past two decades.



Gold is poured into bars for easy transport. In 2019, Australia produced 326 tonnes of gold from mining, a new national record.

Table 4 Changes in Australia's EDR from 2018 to 2019.

Commodity	Unit	EDR		
		2018	2019	Change (%)
Antimony	kt Sb	142.7	100.5	▼ -30%
Bauxite	Mt	5,118	5,292	▲ 3%
Black Coal				
In situ	Mt	88,085	89,707	▲ 2%
Recoverable	Mt	73,719	75,428	▲ 2%
Brown Coal				
In situ	Mt	92,244	85,634	▼ -7%
Recoverable	Mt	76,951	73,865	▼ -4%
Cobalt	kt Co	1,353	1,399	▲ 3%
Copper	Mt Cu	88.17	93.36	▲ 6%
Chromium	kt Cr	0.0	0.5	
Diamond	Mc	25.48	10.97	▼ -57%
Fluorine	kt F	343	343	0%
Gold	t Au	10,165	10,795	▲ 6%
Graphite	Mt	7.25	7.97	▲ 10%
Iron				
Iron Ore	Mt	49,604	50,593	▲ 2%
Contained iron	Mt Fe	24,122	24,508	▲ 2%
Lead	Mt Pb	35.78	37.31	▲ 4%
Lithium	kt Li	5,437 ⁽¹⁾	5,702	▲ 5%
Magnesite	Mt MgCO ₃	316	285	▼ -10%
Manganese Ore	Mt	232	272	▲ 17%
Mineral Sands				
Ilmenite	Mt	276.3	274.7	▼ -1%
Rutile	Mt	35.4	35.4	0
Zircon	Mt	79.9	79.7	0
Molybdenum	kt Mo	171	248	▲ 45%
Nickel	Mt Ni	19.7	21.2	▲ 8%
Niobium	kt Nb	216	216	0%
PGE	t metal	31.5	37.6	▲ 19%
Phosphate				
Phosphate rock	Mt	1,091	1,091	0%
Contained phosphate	Mt P ₂ O ₅	178	178	0%
Potash	Mt K ₂ O	30 ⁽²⁾	35	▲ 17%
Rare Earths⁽³⁾	Mt oxide	4.12	4.03	▼ -2%
Scandium	kt Sc	26.05	26.91	▲ 3%
Silver	kt Ag	88.36	90.26	▲ 2%
Tantalum	kt Ta	88.6	93.5	▲ 5%
Tin	kt Sn	430	561	▲ 30%
Tungsten	kt W	394	403	▲ 2%
Uranium	kt U	1,325	1,147	▼ -13%
Vanadium	kt V	4,646	6,019	▲ 30%
Zinc	Mt Zn	66.96	68.92	▲ 3%

Abbreviations

t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats); PGE = platinum group elements (Pt, Pd, Os, Ir, Ru, Rh). Where an element symbol follows the unit it refers to contained metal content.
EDR = Economic Demonstrated Resources.

Notes

- Geoscience Australia published an EDR of lithium amounting to 4,718 kt in Australia's Identified Mineral Resources 2019. New information has become available, resulting a re-evaluation of Australia's lithium inventory for that period.
- Geoscience Australia published an EDR of potash amounting to 72 Mt in Australia's Identified Mineral Resources 2019. New information has become available, particularly around the drainable recovery from some deposits, resulting a re-evaluation of Australia's potash inventory to 30 Mt for 2018.
- Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y₂O₃).

Mine inventories as a proportion of EDR

While the national inventory is an aggregation of individual resources, it is useful to compare the EDR attributable to currently operating mines with all mines and the national total as shown in Table 5. In many cases, operating mines dominate the minerals inventory. With the exception of mineral sands, black coal and nickel, operating mines of most major commodities contain more than 50% of Australia's EDR (Table 5). When all mines are considered (operating + care and maintenance + developing), only the mineral sand commodities of ilmenite, rutile and zircon have more than 50% of EDR associated with undeveloped deposits. For copper, diamond and uranium, Australian operating mines account for 80% or more of EDR (Table 5).

The high proportion of the national EDR attributed to operating mines is not unexpected as most resource delineation occurs at, and in the vicinity of, existing operations. However, this concentration of EDR at operating mines results in a number of potential supply vulnerabilities in the minerals sector. Many commodities have large EDR (e.g. manganese ore, bauxite, uranium and mineral sands; Table 3) but relatively few operating mines (Table 1). Price shocks or other circumstances leading to the permanent closure of one or more of these mines would dramatically impact Australia's potential to supply these minerals. If there is no foreseeable possibility of a mine reopening, then the deposit is removed from EDR. Economic Demonstrated Resources will only be replaced from new deposits if mining and exploration companies can attract the capital necessary for exploration, drilling and development.

Other commodities with large EDR, such as gold, black coal and iron ore, have many mines (Table 1). Thus, Australia's EDR of these commodities and ability to supply appear unlikely to be significantly impacted by the fortunes of individual mines. Black coal, for example, has 263 deposits contributing to the national EDR, but the 96 operating mines comprise only 41% of that EDR (Table 5). If even a sizeable proportion of coal mines were inaccessible in the future, a large resource could potentially still be exploited.

However, this is not necessarily the case for gold. Australia has the largest EDR of gold in the world (Table 8) but most of it is associated with large, low-grade, multi-commodity deposits such as Olympic Dam (South Australia) and Cadia (New South Wales). The majority of production, however, comes from lode-gold deposits which produced 67% of Australia's gold in 2019. At 2019 rates of production, 685 gold deposits have a potential resource life of 35 years based on AEDR (Table 9), but the operations mining lode gold only have a comparable resource life of 10 years. With depletion of these high-grade mines, it is unlikely

that production at the other types of deposit could make up the shortfall in the same period, thus Australia's gold production, and associated export income, would inevitably decline. This circumstance is, of course, based on the very unlikely scenario that three things will happen: (1) future rates of production are unchanged from those of 2019, (2) deposits currently assessed as economic/sub-economic remain so in the future and (3) companies do not replace depleted gold resources. More probably, the EDR from depleted lode-gold deposits will be replaced by successful mineral exploration. Advances in extractive technologies or substantial price rises could also contribute to future EDR.

Mineral exploration will occur in and around existing mines (brownfield exploration) but the most important contributions to Australia's future EDR of gold and other commodities is more likely to come from successful exploration in new and under-explored areas of the continent (greenfield exploration). It is through the discovery of large, globally significant mineral deposits such as Broken Hill, Mount Isa, Olympic Dam and the Kalgoorlie goldfields, that Australia has become a mining world leader. If Australia is to remain globally competitive, then new discoveries are essential as only the very best deposits will attract the investment necessary for development in an internationally competitive investment environment.

Ore Reserves as a proportion of EDR and AEDR

The National Classification System's category of EDR captures those Demonstrated Resources that are considered to be economic under current conditions or those of the foreseeable future: EDR indicate potential supply. However, just because a deposit could be exploited profitably does not mean that it will be. The EDR category does not capture modifying factors (such as metallurgical, engineering, processing, infrastructure, environmental, social and regulatory considerations) and commercial considerations (e.g. costs and internal rates of return) that mining companies must consider for individual deposits to determine an Ore Reserve and mine plan. Table 6 compares the short-term outlook provided by Ore Reserves to the long-term outlook of EDR.

In addition, some resources that would normally meet the criteria to be considered EDR are not accessible because of environmental, legal or military land-use restrictions. Only five mineral commodities are currently affected by land-use restrictions: 9% of black coal EDR, 14% of brown coal EDR, <1% of gold EDR, around 5% of mineral sands EDR, 7% of platinum group elements EDR and 5% of uranium EDR (see Table 3 for comparisons of EDR and AEDR). Thus, it is more applicable to compare Ore Reserves to AEDR for these commodities (Table 6).

Table 5 Comparisons of EDR of major commodities at Australian mines to total EDR as at December 2019.

Commodity	Unit	EDR	Number of			Percentage of EDR		
			Deposits with EDR	Operating Mines	All Mines	Operating Mines	All Mines	Other Deposits
Bauxite	Mt	5,292	20	10	15	63%	72%	28%
Black Coal – Recoverable	Mt	75,428	263	96	119	41%	51%	49%
Copper	Mt Cu	93.36	181	43	55	83%	84%	16%
Diamond	Mc	10.97	3	1	3	95%	100%	0%
Gold	t Au	10,795	685	150	243	70%	72%	28%
Iron Ore	Mt	50,593	80	36	54	56%	65%	35%
Lead	Mt Pb	37.31	77	19	27	64%	89%	11%
Lithium	kt Li	5,702	11	7	7	71%	71%	29%
Manganese Ore	Mt	272	6	3	4	74%	74%	26%
Mineral Sands								
Ilmenite	Mt	274.7	79	12	18	18%	45%	55%
Rutile	Mt	35.4	58	10	15	15%	29%	71%
Zircon	Mt	79.7	80	10	16	15%	47%	53%
Nickel	Mt Ni	21.2	95	10	21	36%	54%	46%
Silver	kt Ag	90.26	133	31	42	64%	79%	22%
Uranium	kt U	1,147	33	3	4	80%	81%	19%
Zinc	Mt Zn	68.79	84	20	26	79%	89%	11%

Abbreviations

t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats).
Where an element symbol follows the unit it refers to contained metal content.

Notes

All Mines = mines that are currently operating, placed on care and maintenance or under development.
'Deposits with EDR' is inclusive of the mines.

Table 6 Comparisons of Ore Reserves of major commodities to total EDR and AEDR as at December 2019.

Commodity (unit)	Unit	Ore Reserves	EDR	AEDR	Ore Reserves/ EDR(%)	Ore Reserves/ AEDR (%)
Bauxite	Mt	2,045	5,292	5,292	39%	39%
Black Coal – Recoverable	Mt	19,459	75,428	68,546	26%	28%
Copper	Mt Cu	22.99	93.36	93.36	25%	25%
Diamond	Mc	10.30	10.97	10.97	94%	94%
Gold	t Au	4,069	10,795	10,768	38%	38%
Iron Ore	Mt	23,714	50,593	50,593	47%	47%
Lead	Mt Pb	11.52	37.31	37.31	31%	31%
Lithium	kt Li	3,761	5,702	5,702	66%	66%
Manganese Ore	Mt	91	272	272	34%	34%
Mineral Sands						
Ilmenite	Mt	63.6	274.7	264.8	23%	24%
Rutile	Mt	9.9	35.4	32.9	28%	30%
Zircon	Mt	24.9	79.7	77.1	31%	32%
Nickel	Mt Ni	8.3	21.2	21.2	39%	39%
Silver	kt Ag	25.08	90.26	90.26	28%	28%
Uranium	kt U	284	1,147	1,091	25%	26%
Zinc	Mt Zn	24.37	68.92	68.92	35%	35%

Abbreviations

t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats).
Where an element symbol follows the unit it refers to contained metal content.
EDR = Economic Demonstrated Resources.
AEDR = Accessible Economic Demonstrated Resources.

Contribution of largest deposits to EDR

Most of Australia's EDR of major commodities are skewed heavily toward a small number of relatively large deposits. Table 7 shows that more than 80% of all EDR lies in the top 20 deposits for most commodities. The two exceptions are gold and black coal, both of which have the greatest number of deposits of all mineral commodities in Australia, as well as the greatest number of deposits that contribute to EDR. Even so, the top 20 deposits of gold, which make up less than 3% of the 710 deposits with an EDR, account for 63% of all gold EDR (Table 7). For black coal, the top 20 deposits (8% of 263 deposits with an EDR) account for 42% of EDR.

Geographical distribution of EDR

Most bauxite EDR are attributable to Queensland and Western Australia (Figure 2) where the giant deposits in Cape York and the Darling Range, respectively, dominate. Similarly, Australia's enormous iron ore EDR are geographically concentrated in the Pilbara region of Western Australia. Western Australia also holds almost all of nickel and diamond EDR, though the latter has fallen dramatically in 2020 with the imminent closure of the Argyle mine (Table 4). Manganese ore EDR are found in Western Australia and the Northern Territory. On the other side of the country, almost all black coal EDR are located in Queensland and New South Wales (Figure 2). Silver, lead, zinc, copper, uranium and mineral sands are more dispersed across the country (Figure 2), but the top ten deposits for each of these minerals dominate EDR (66–94%; Table 7).

Table 7 Distribution of EDR of major commodities in Australia as at December 2019.

Commodity	Unit	EDR	Number of		Percentage of EDR in largest	
			Deposits	Deposits with EDR	10 deposits	20 deposits
Bauxite	Mt	5,292	40	20 (50%)	99	100
Black Coal – Recoverable	Mt	75,428	416	263 (63%)	28	42
Copper	Mt Cu	93.36	404	181 (45%)	84	90
Diamond	Mc	10.97	12	3 (25%)	100	100
Gold	t Au	10,795	1,880	710 (38%)	52	63
Iron Ore	Mt	50,593	353	80 (23%)	63	84
Lead	Mt Pb	37.31	169	77 (46%)	89	96
Lithium	kt Li	5,702	15	11 (73%)	100	100
Manganese Ore	Mt	272	44	6 (14%)	100	100
Mineral Sands						
Ilmenite	Mt	274.7	227	79 (35%)	66	81
Rutile	Mt	35.4	204	58 (28%)	69	88
Zircon	Mt	79.7	227	80 (35%)	76	89
Nickel	Mt Ni	21.2	239	95 (36%)	68	87
Silver	kt Ag	90.26	271	133 (49%)	76	87
Uranium	kt U	1,147	112	33 (30%)	94	99
Zinc	Mt Zn	68.92	186	84 (46%)	87	93

Abbreviations

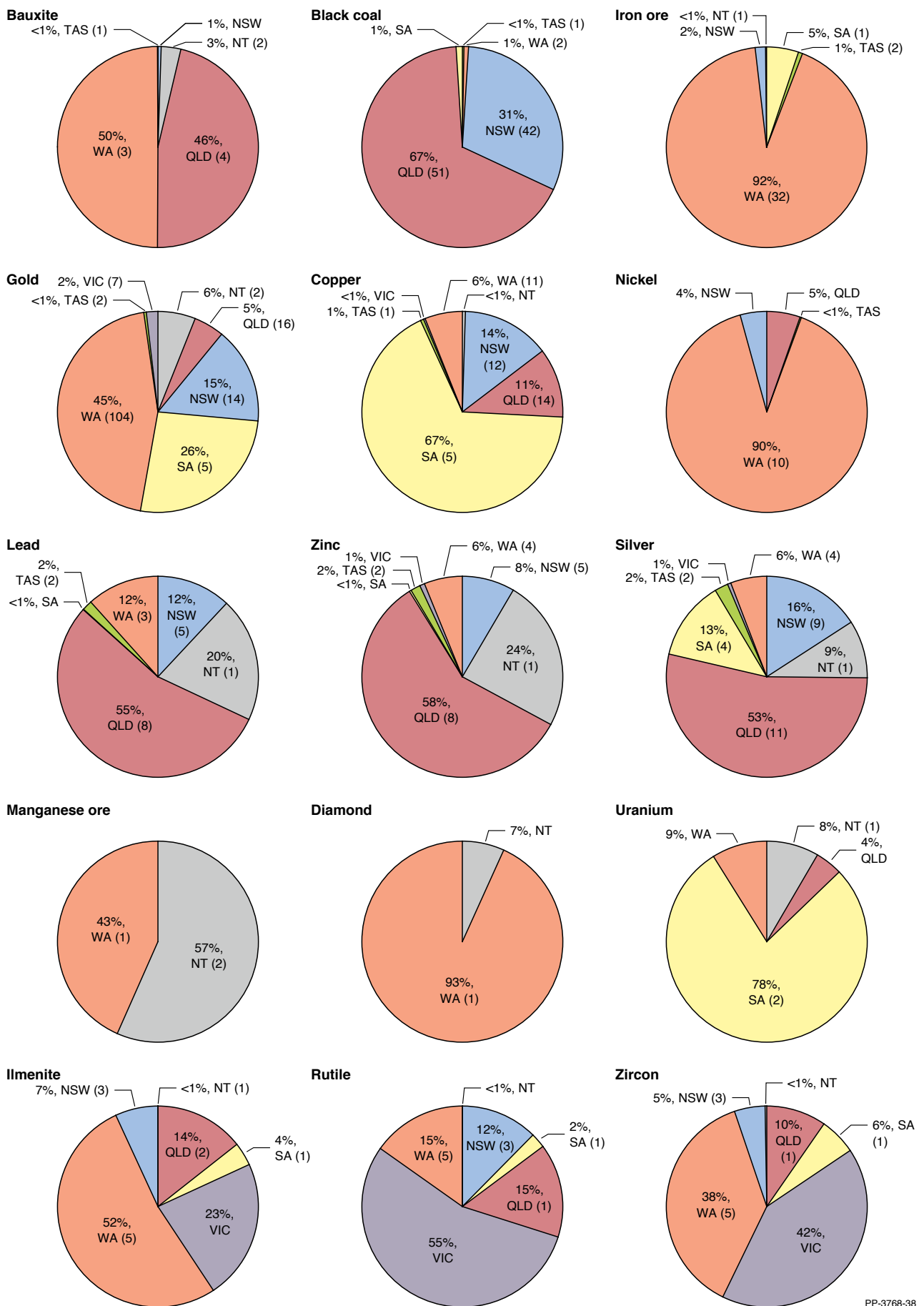
t = tonne; kt = kilotonnes (1,000 t); Mt = million tonnes (1,000,000 t); Mc = million carats (1,000,000 carats).

Where an element symbol follows the unit it refers to contained metal content.

EDR = Economic Demonstrated Resources.

Note

For classification as a mineral deposit there must be, at a minimum, an Inferred Resource compliant with the JORC Code (or equivalent) or, in some cases, a historical (pre-JORC) resource estimate.



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Figure 2 Distribution of EDR of major commodities by Australian jurisdiction as at December 2019. Where applicable, the number of mines in each jurisdiction is in brackets after the percentage of EDR.



Iron ore pellets are used in steel production. Australia is the world's largest producer of iron ore, meeting over one third of global demand in 2019.

4. World Rankings

Australia's EDR of gold, iron ore, lead, nickel, rutile, tantalum*, uranium, zinc and zircon were the world's largest in 2019 (Table 8). Another 15 commodities ranked in the top five for world economic resources: antimony, bauxite, black coal, brown coal, cobalt, copper, diamond, ilmenite, lithium, manganese ore, niobium*, silver, tin, tungsten and vanadium (Table 8). Australia's ranking for economic resources of nickel went from second in the world in 2018 to first in 2019. Australia's rankings for manganese ore, molybdenum and vanadium resources

all increased by one position in 2019 to fourth, seventh and second, respectively.

In 2019, Australia was the top global producer for bauxite, iron ore and rutile (all bulk commodities), as well as lithium which is becoming increasingly important for battery storage technologies. Australia was the second largest producer of diamond, gold, lead, manganese ore and zircon; the third largest producer of cobalt, uranium and zinc; the fourth largest producer of ilmenite and rare earths; and the fifth largest producer of black coal (Table 8).

Table 8 World ranking for Australia's mineral resources (EDR) and production as at December 2019.

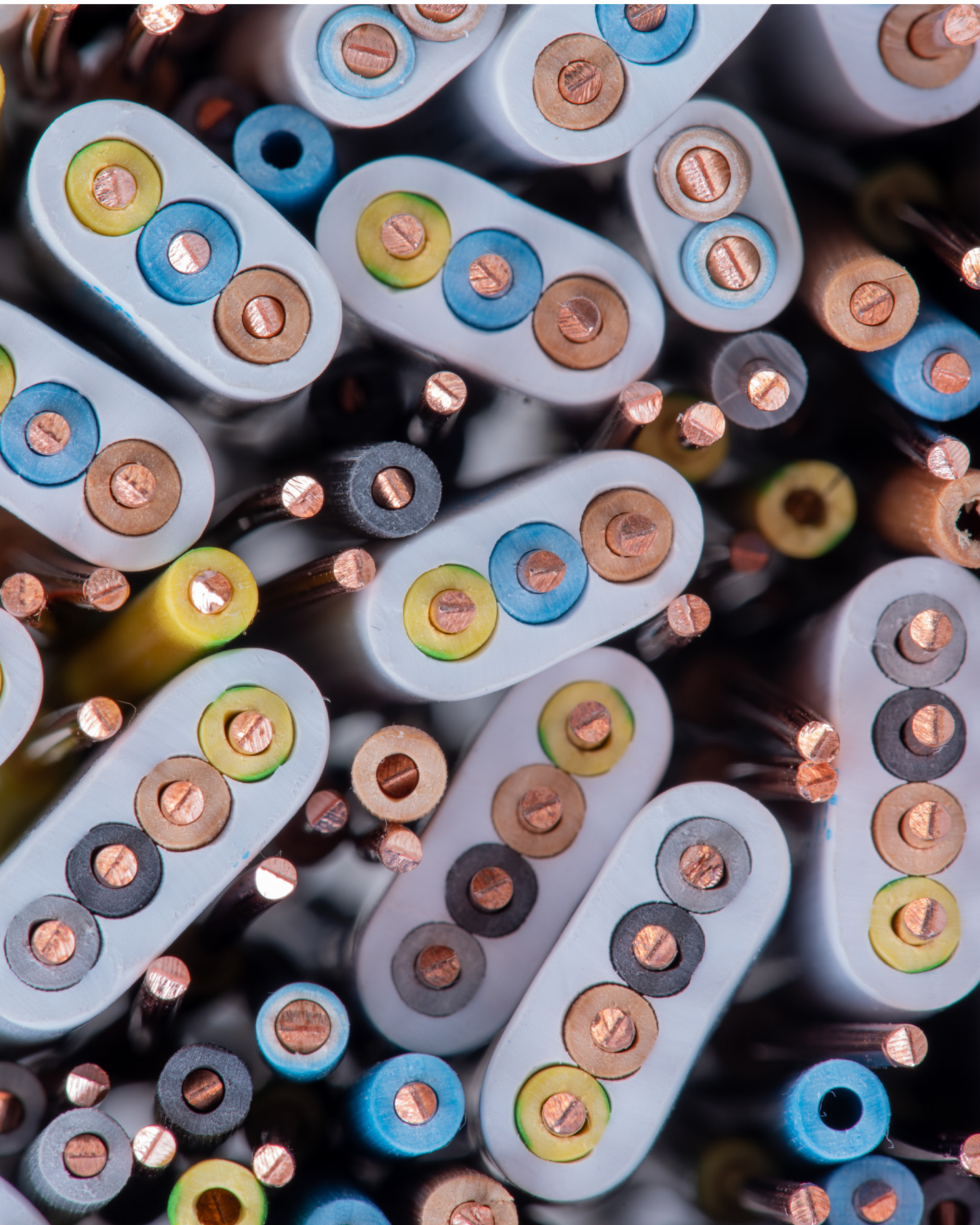
Commodity	World Ranking for Resources	Share of World Resources	World Ranking for Production	Share of World Production
Antimony	4	7%	7	1%
Bauxite	2	18%	1	28%
Black Coal – Recoverable	4	10%	5	6%
Brown Coal – Recoverable	2	24%	7	6%
Chromium	n.a.	n.a.	0	0%
Cobalt	2	19%	3	4%
Copper	2	11%	6	5%
Diamond	5	1%	2	23%
Fluorine	minor	minor	0	0%
Gold	1	21%	2	10%
Graphite	7	3%	0	0%
Ilmenite	2	24%	4	9%
Iron Ore	1	30%	1	36%
Lead	1	41%	2	11%
Lithium	2	29%	1	56%
Magnesite	6	3%	9	1%
Manganese Ore	4	14%	2	17%
Molybdenum	7	1%	0	0%
Nickel	1	24%	6	7%
Niobium	3*	2%	unknown	unknown
Oil Shale	n.a.	n.a.	0	0%
Phosphate	9	2%	minor	minor
PGEs	minor	minor	minor	minor
Potash	11	1%	0	0%
Rare Earths	6	4%	4	8%
Rutile	1	65%	1	29%
Scandium	unknown	unknown	0	0%
Silver	3	16%	7	5%
Tantalum	1*	73%	6	5%
Thorium	n.a.	n.a.	0	0%
Tin	4	11%	8	2%
Tungsten	2	11%	minor	minor
Uranium	1	31%	3	12%
Vanadium	2	25%	0	0%
Zinc	1	27%	3	10%
Zircon	1	72%	2	29%

Abbreviations n.a. = not applicable because Australia has no Economic Demonstrated Resources of that particular commodity.

Notes Minor = <1% of global economic resources and/or production, therefore Australia's ranking unable to be determined. Unknown = production is likely to have occurred during the year but quantities are not publically available. World rankings determined by comparing Australia's EDR and production to economic resources and production reported for other countries, see sources below. Undocumented resources and production are not used in the comparisons.

Sources USGS (Mineral Commodity Summaries 2020), OECD Nuclear Energy Agency/International Atomic Energy Agency (The Red Book 2018), World Nuclear Association (World Uranium Mining Production, September 2020 update), BP Statistical Review of World Energy 2019, International Energy Agency (Coal Information 2019 Overview) and Geoscience Australia.

* Australia's high rankings for niobium and tantalum are based on published estimates of economic resources and, therefore, do not consider the large, but undocumented, resources of the Congo.



Copper cables and wires are used in electronics and electricity distribution. Demand is expected to increase with the decarbonisation of global economies.

5. Summary of Reserve and Resource Life

Australia has vast resources of many of the 36 major and minor mineral commodities covered in this report, as well as unquantified resources of many other minerals, some of which are considered critical for modern and emerging technologies and by trading partners.

It is not possible to state with any certainty how long Australia's resources will last because production rates vary, the economic viability of deposits may change in the future and the rate of new resource delineation rarely matches resource depletion. However, a general impression of the range of possibilities can be gained by deriving the ratio of the various 2019 reserve and resource estimates

to 2019 production figures (Table 9). Operating mines have provided the production rates for each commodity and the resulting ratios are an average mine life that assumes the unlikely scenario that no new mines are ever developed, no mines are closed or, if so, other mines make up the shortfall in production.

The reserve and resource life estimations for 'all deposits' (Table 9) indicate the potential for longer-term mineral supply in Australia. Using the AEDR/production ratio as the best proxy for a long-term outlook, it is only diamond, gold and manganese ore that have resource lives of less than 50 years (Table 9).

Table 9 Average reserve life and resource life (years) for selected commodities as at December 2019.

Commodity	Operating Mines ⁽¹⁾			All Deposits		
	Ore Reserves ⁽²⁾	Demonstrated Mineral Resources ⁽³⁾	All Resources ⁽⁴⁾	Ore Reserves ⁽⁵⁾	AEDR ⁽⁶⁾	All Resources ⁽⁷⁾
Bauxite	19	15	50	19	50	95
Black Coal	20	52	76	33	120	280
Copper	21	90	118	25	100	150
Diamond	1	0	0	1	<5	<5
Gold	9	20	29	12	35	50
Ilmenite	17	51	62	65	270	525
Iron Ore	13	33	77	26	55	165
Lead	18	45	54	23	75	125
Lithium	69	90	119	84	130	160
Manganese Ore	4	6	7	12	35	115
Nickel	15	49	56	54	135	280
Rutile	13	28	32	55	180	375
Silver	14	41	51	21	70	100
Tin	24	46	51	35	85	125
Uranium	40	224	333	43	165	295
Zinc	15	36	45	18	50	90
Zircon	8	22	25	45	145	250

Notes

Reserve and resource life for each mineral commodity are calculated by dividing the inventory by production. The resulting ratio is a snapshot in time that can only be used for general impressions because it is an average and it assumes (1) that production rates in the future will remain the same as those used in the calculation, (2) deposits deemed economic/uneconomic remain so in the future and (3) that depleted resources are never replaced.

- Operating mines includes all mines that operated during 2018 and thus contributed to production (see Table 1).
- Ore Reserves as reported in compliance with the JORC Code, plus non-JORC Code equivalents (see Table 1).
- Measured and Indicated Mineral Resources, inclusive of Ore Reserves, as reported in compliance with the JORC Code, plus non-JORC Code-equivalents (see Table 1).
- All Resources for Operating Mines includes Measured, Indicated and Inferred Mineral Resources, inclusive of Ore Reserves, as reported in compliance with the JORC Code, plus non-JORC Code-equivalents (see Table 1).
- Ore Reserves as reported in compliance with the JORC Code, plus non-JORC Code equivalents (see Table 2).
- AEDR = Accessible Economic Demonstrated Resources (see Table 3). Figures rounded to nearest five years.
- All Resources for All Deposits includes EDR, Subeconomic Demonstrated Resources and Inferred Resources (see Table 3). Figures rounded to nearest five years.



Australia's mineral resources are exported throughout the world. Mineral exports comprised 47% of Australia's export income in 2019.

6. Value of Australian Mineral Exports

In 2019, Australian mineral exports (excluding petroleum products) amounted to approximately \$234 billion, which was slightly less than 60% of all export merchandise and 47% of all exported goods and services (Table 10). Domestically, mining industries accounted for 12% of gross domestic product in the 2019 calendar year. Table 10 also shows that mineral export earnings in 2019 were up 16% on 2018, continuing the gains seen since the low of 2015. Prior to this, the Australian economy was subject to large price falls for many mineral commodities, particularly iron ore and coal, following the global financial crisis.

Quarterly reports published by the Office of the Chief Economist show that the main mineral export earners in 2019 were iron ore (41.1% of total mineral export earnings), black coal (27.4%), gold (10.0%), copper (4.3%), bauxite-alumina-aluminium (6.0%), nickel (1.8%) and zinc (1.6%; Table 11). These same minerals were the main income earners in the previous year (Table 12).

Significant increases in export earnings of greater than 20% were recorded in 2019 by bauxite, copper (refined), diamonds (gem), gold, iron ore, lead (concentrates) and nickel (ore and concentrates) (Table 12). The increased export earnings for bauxite, copper (refined) and nickel (ore and concentrates) generally correlated with increased export volumes (Table 12). In contrast, increased export earnings for diamonds (gem), gold and iron ore in 2019 were the result of higher prices as there were no significant changes in export volume for gold and iron ore and diamond exports actually fell more than 50% from 2018 levels.

The lead (concentrates) and nickel (ore and concentrates) sectors experienced the most significant gains in 2019 with lead concentrates showing a 70% increase in export

volume and a massive 63% increase in export earnings despite the unit value falling 4% (Table 12). Nickel ores and concentrates had a 57% increase in export volume for an overall 72% increase in export earning on the back of a 10% increase in unit value (Table 12).

Copper, gold, nickel and uranium also recorded increased volumes and increased export earnings due to price rises (Table 12). For example, refined copper was up 15% by volume compared to 2018 but also had a 22% increase in export earnings. In contrast, tin prices in 2019 were down by 47% and it was only a massive 110% increase in export volume that prevented export earnings from decreasing compared to 2018 (Table 12). Iron ore export volume was virtually unchanged from 2018 but had a 52% increase in export earning thanks to a matching increase in unit, value from \$76/t in 2018 to \$115/t in 2019.

Comparing export earnings to export volume, it is clear that processed mineral commodities are worth more per unit than raw minerals or concentrates, often significantly so. Bauxite in 2019, for example, was worth \$40/t whereas alumina was worth \$478/t (Table 11). This is a 12-fold increase on the price of bauxite; bearing in mind it takes two-to-three tonnes of bauxite to make one tonne of alumina. Further, it takes two tonnes of alumina to make one tonne of aluminium metal which was worth \$2,699/t in 2019 (Table 11). This is a 6-fold increase on the price of alumina and a massive 67-fold increase on the price of bauxite. Similar value adding is seen in the copper, iron, nickel and zinc sector and, to a lesser extent, in the lead sector. Thus any appraisal of the strength of Australia's minerals industry must also include domestic downstream processes, such as refining and smelting, in addition to mineral discovery, mining and raw material exports.

Table 10 Export value (\$million) of mineral commodities, resources and energy, merchandise and goods and services, 2011 to 2019.

Category	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total Mineral Exports	167,867	149,879	162,572	158,312	140,885	150,186	178,999	201,208	233,772
Total Resources and Energy Exports	194,607	179,007	190,323	190,859	166,131	175,645	213,046	257,304	296,859
Total Merchandise Exports	26,222	249,678	263,456	266,739	250,334	259,071	301,998	345,468	390,579
Total Goods and Services Exports	319,539	306,237	323,442	33,120	323,136	336,894	386,677	438,284	492,684

Note

Total mineral exports includes: metallic minerals, energy minerals (coal and uranium), gemstones, mineral sands and refined minerals (concentrates, bullion, ingot metals).

Sources

Office of the Chief Economist (Resources and Energy Quarterly September 2020).

Table 11 Australian export volumes and values of mineral and metal commodities 2019.

Commodity	Export volume	Unit	Export earnings (\$million)	Value (\$/t or \$/c)	Percentage of total mineral export earnings
Aluminium					
Bauxite	39,149	kt	1,577	40	0.7%
Alumina	17,764	kt	8,488	478	3.6%
Ingot Metal	1,445	kt	3,900	2,699	1.7%
Black Coal					
Metallurgical	184,355	kt	41,280	224	17.7%
Thermal	212,275	kt	22,660	107	9.7%
Copper					
Ore and Concentrates	1,895	kt	6,265	3,306	2.7%
Refined	407	kt	3,839	9,436	1.6%
Diamonds					
Unsorted	13,148,886	c	234	18	0.1%
Sorted Gem	71,315	c	379	5,318	0.2%
Gold – Refined	362	t	23,372	64,652,504	10.0%
Iron					
Ore	835,546	kt	96,183	115	41.1%
Crude Steel	1,148	kt	1,230	1,072	0.5%
Scrap	2,224	kt	1,031	464	0.4%
Lead					
Concentrates	414	kt	962	2,322	0.4%
Refined	117	kt	332	2,827	0.1%
Bullion	119	kt	386	3,246	0.2%
Nickel					
Ore and Concentrates	258	kt	446	1,733	0.2%
Refined and Intermediate	241	kt	3,679	15,235	1.6%
Silver – Refined	140	t	125	893,432	0.1%
Tin – concentrate	14,520	t	188	12,963	0.1%
Uranium – Oxide (U₃O₈)	8,159	t	747	91,516	0.3%
Zinc					
Ore and Concentrates	2,310	kt	2,401	1,039	1.0%
Refined	379	kt	1,426	3,757	0.6%

Note

Total mineral exports earnings in 2019 were \$233,772 million (see Table 10).

Table 12 Changes in Australian mineral and metal export volumes, earnings and values from 2018 to 2019, along with percentage share of export earnings in 2018 and 2019.

Commodity	Export Volume (%)	Export Earnings (%)	Value (%)	Percentage of total mineral export earnings 2018	Percentage of total mineral export earnings 2019
Aluminium					
Bauxite	▲ 24%	▲ 21%	▼ -3%	0.7%	0.7%
Alumina	▼ -1%	▼ -18%	▼ -18%	5.1%	3.6%
Ingot Metal	▲ 1%	▼ -9%	▼ -9%	2.1%	1.7%
Black Coal					
Metallurgical	▲ 3%	0%	▼ -3%	20.5%	17.7%
Thermal	▲ 2%	▼ -12%	▼ -13%	12.7%	9.7%
Copper					
Ore and Concentrates	▼ -9%	▲ 2%	▲ 12%	3.0%	2.7%
Refined	▲ 15%	▲ 22%	▲ 6%	1.6%	1.6%
Diamonds					
Unsorted	▼ -11%	▼ -8%	▲ 3%	0.1%	0.1%
Sorted Gem	▼ -58%	▲ 26%	▲ 198%	0.2%	0.2%
Gold – Refined	▲ 6%	▲ 24%	▲ 17%	9.4%	10.0%
Iron					
Ore	0%	▲ 52%	▲ 52%	31.5%	41.1%
Crude Steel	▼ -5%	▲ 18%	▲ 24%	0.5%	0.5%
Scrap	▲ 9%	▲ 3%	▼ -5%	0.5%	0.4%
Lead					
Concentrates	▲ 70%	▲ 63%	▼ -4%	0.3%	0.4%
Refined	▼ -39%	▼ -43%	▼ -8%	0.2%	0.1%
Bullion	▲ 9%	▲ 1%	▼ -8%	0.3%	0.2%
Nickel					
Ore and Concentrates	▲ 57%	▲ 72%	▲ 10%	0.1%	0.2%
Refined and Intermediate	▲ 3%	▼ -9%	▼ -11%	2.0%	1.6%
Silver - Refined	▼ -51%	▼ -36%	▲ 32%	0.1%	0.1%
Tin – metal content	▲ 110%	▲ 12%	▼ -47%	0.1%	0.1%
Uranium – Oxide (U₃O₈)	▲ 12%	▲ 18%	▲ 5%	0.3%	0.3%
Zinc					
Ore and Concentrates	▲ 15%	▼ -3%	▼ -15%	1.2%	1.0%
Refined	▼ -9%	▼ -15%	▼ -6%	0.8%	0.6%



The mining sector employed some 243,000 people in 2019, with many more employed in related industries. Exploration initiatives such as the Australian Government's Exploring for the Future program contribute to Australia's future prosperity by supporting regional development and helping industry make new discoveries.

7. Mineral Exploration

Quarterly reports published by the Australian Bureau of Statistics Mineral Exploration data¹¹ highlighted that mineral exploration in Australia remained strong in 2019 with total mineral exploration expenditure for the calendar year up 21% to \$2,648 million compared to the 2018 calendar year, which had expenditure of \$2,184 million (Figure 3).

In the search for new mineral deposits, exploration expenditure and drilling in greenfield tenements was up 32% from \$800 million in 2018 to \$1,057 million in 2019 and metres drilled up 3% to from 3,594,500 m in 2018 to 3,712,200 m. Likewise, 2019 expenditure and drilling around existing deposits (brownfields) was up 15% to \$1,591.7 million on 2018 (\$1,384 million) and metres up 7% to 6,678,800 compared from 6,246,700 m in 2018 (Figure 4).

All states apart from Tasmania, which was down 26% (from \$22 million to \$16 million), showed increases in mineral exploration expenditure from 2018 to 2019. Exploration expenditure in New South Wales and Victoria was at the highest level ever recorded with New South Wales recording \$296 million in exploration, up 20% from 2018 (\$247 million), and Victoria recording \$113 million, up 21% from its previous high in 2008 of \$93 million (Figure 5).

Western Australia attracted \$1,648 million in exploration expenditure in 2019, accounting for 62% of the national expenditure. Queensland ranked second as an exploration destination, recording an expenditure of \$354 million.

Gold is the most explored for commodity and accounted for 40% of all mineral exploration expenditure in 2019. Over the past five years, the high price of the precious metal has resulted in a new 'gold rush' with exploration expenditure for this commodity reaching a new record of \$1,068 million in 2019 (Figure 6). As well as record prices and exploration expenditure, the sustained interest in gold over the past five years has led to large tonnages of resources being upgraded.

Copper had the biggest expenditure increase of 60% from \$261 million in 2018 to \$415 million in 2019, slightly higher than the previous high of \$414 million in 2012. Copper was the second most explored for commodity in 2019, ahead of iron ore which was up 16.2% from \$301 million in 2018 to \$350 million.

Compared to 2018, there were also falls in 2019 exploration expenditure. This was seen for base metals (silver, lead and zinc; -18%), uranium (-17%), and diamonds (-17%). Diamond exploration expenditure continued to fall in the early quarters of 2020 as the Argyle mine in Western Australia closed in November 2020.

11. ABS, Quarterly Statistics, Mineral and Petroleum Exploration Australia September 2020. See <https://www.abs.gov.au/statistics/industry/mining/mineral-and-petroleum-exploration-australia/latest-release#data-download> (accessed 18 December 2020).

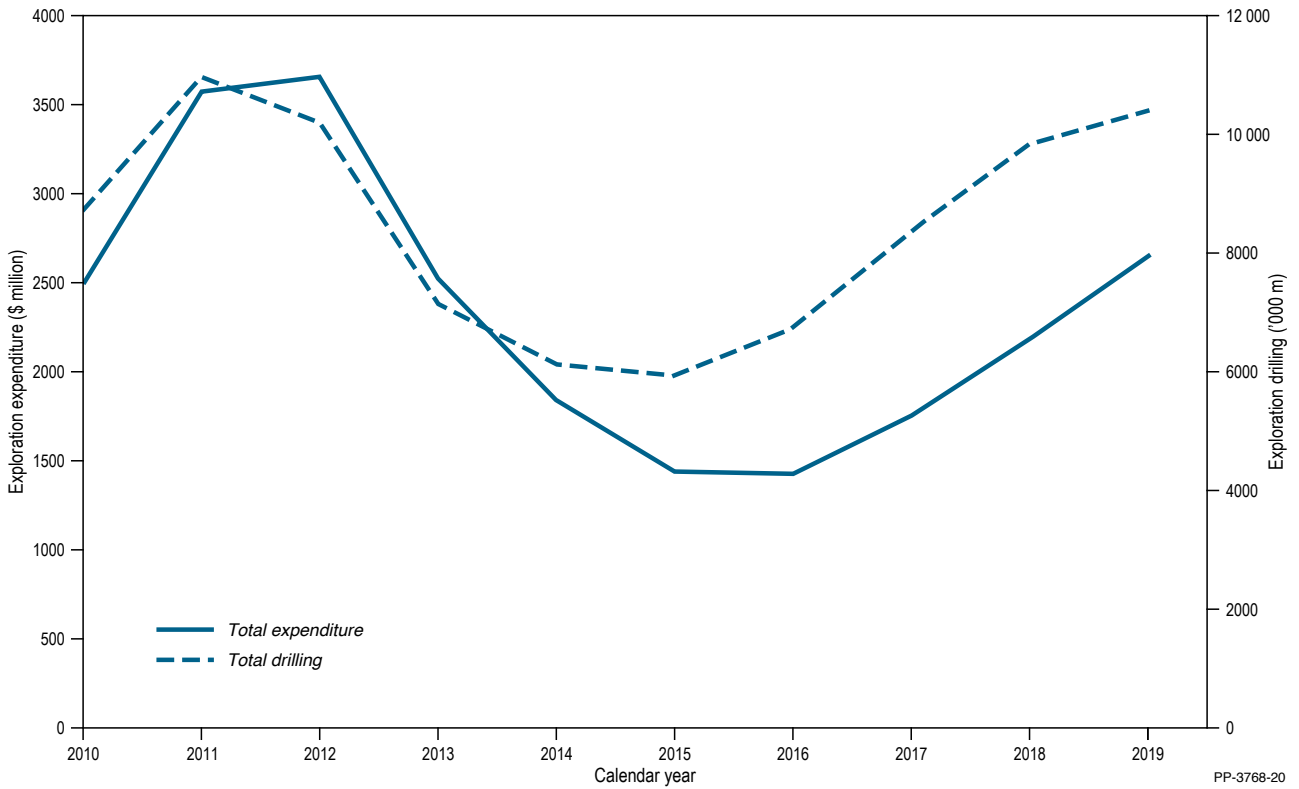


Figure 3 Total mineral exploration expenditure and drilling, 2010–2019.

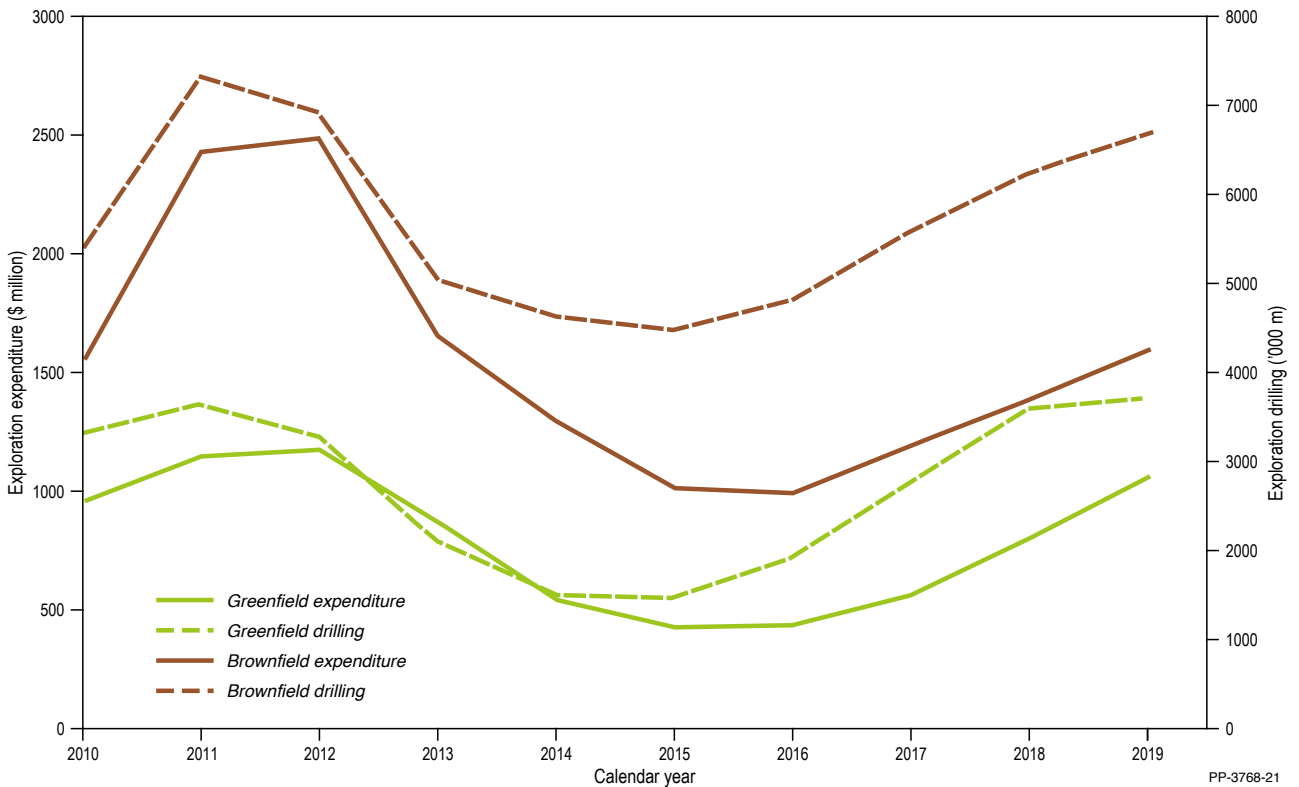


Figure 4 Greenfield and brownfield mineral exploration expenditure and drilling, 2010–2019.

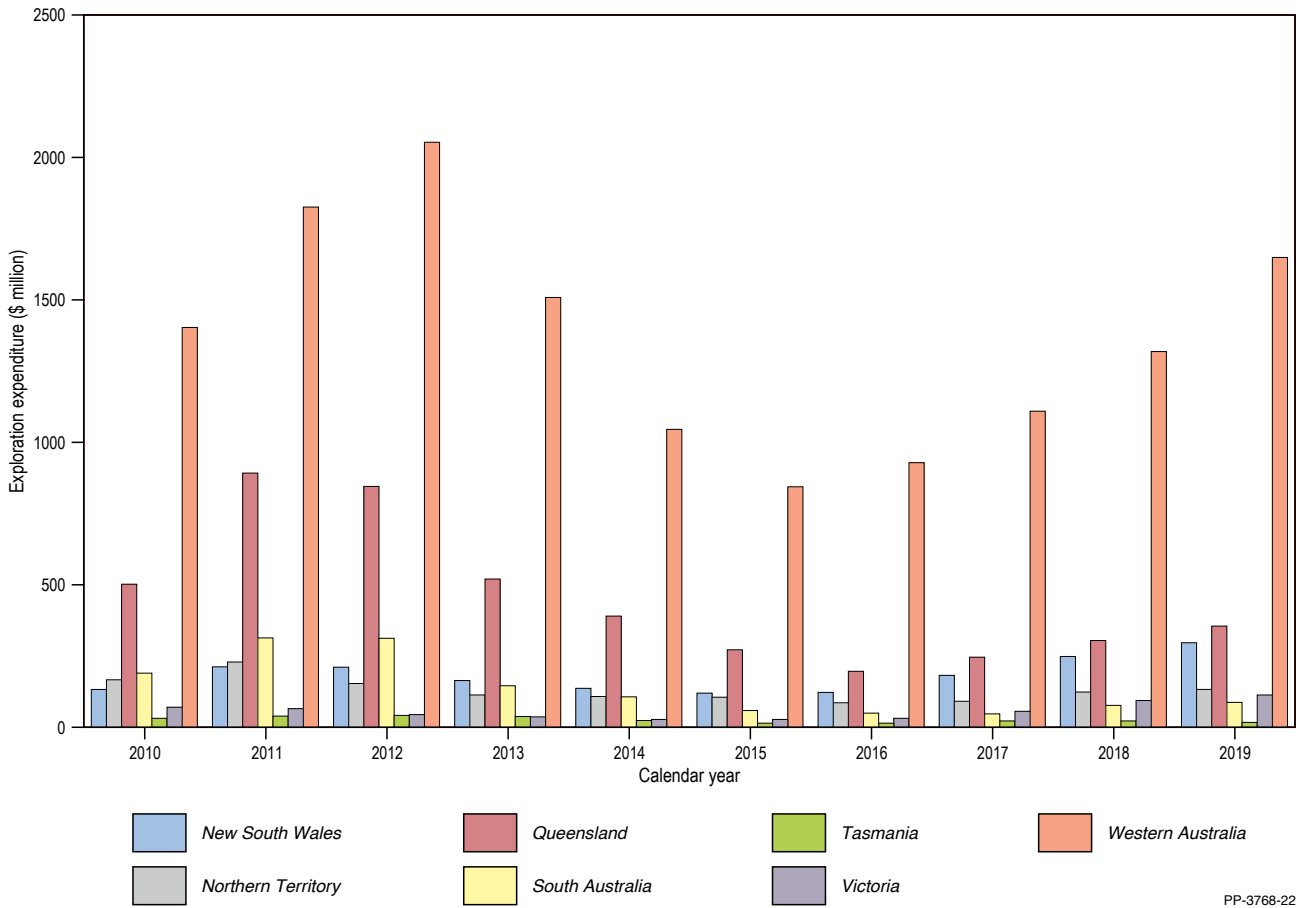


Figure 5 Mineral exploration expenditure by jurisdiction, 2010–2019.

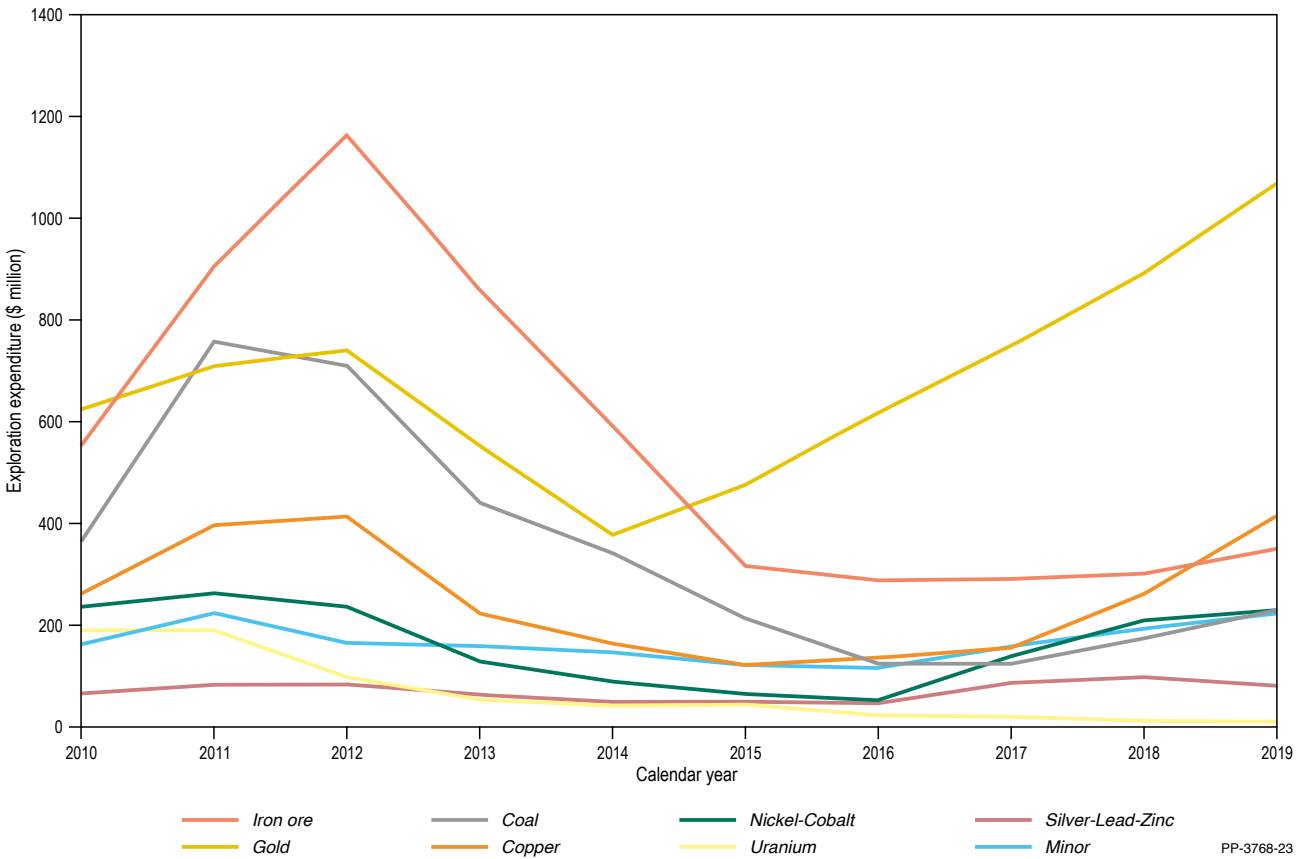


Figure 6 Mineral exploration expenditure by commodity, 2010–2019.



Electronic devices contain a wide range of mineral commodities, including precious metals and rare earth elements.

8. Commodity Summaries

Antimony

Antimony is a silvery, lustrous grey metal that exhibits poor heat and electrical conductivity. It is relatively soft, measuring only 3.25 on Moh's scale of mineral hardness. Antimony is commonly found in association with gold mineralisation but it also occurs with some silver-lead-zinc deposits. Its average abundance in the Earth's crust ranges from 0.2 to 0.5 ppm, which is 10 times that of silver.

It is most commonly used with other metals to form antimony alloys or combined with oxygen to form antimony trioxide (ATO; Sb_2O_3). Metallic antimony is used as a hardening agent for lead and its use in lead storage batteries accounts for around one third of global use. Antimony alloys are also used for manufacturing solder, sheet and pipe metal, ammunition, bearings, castings and pewter.

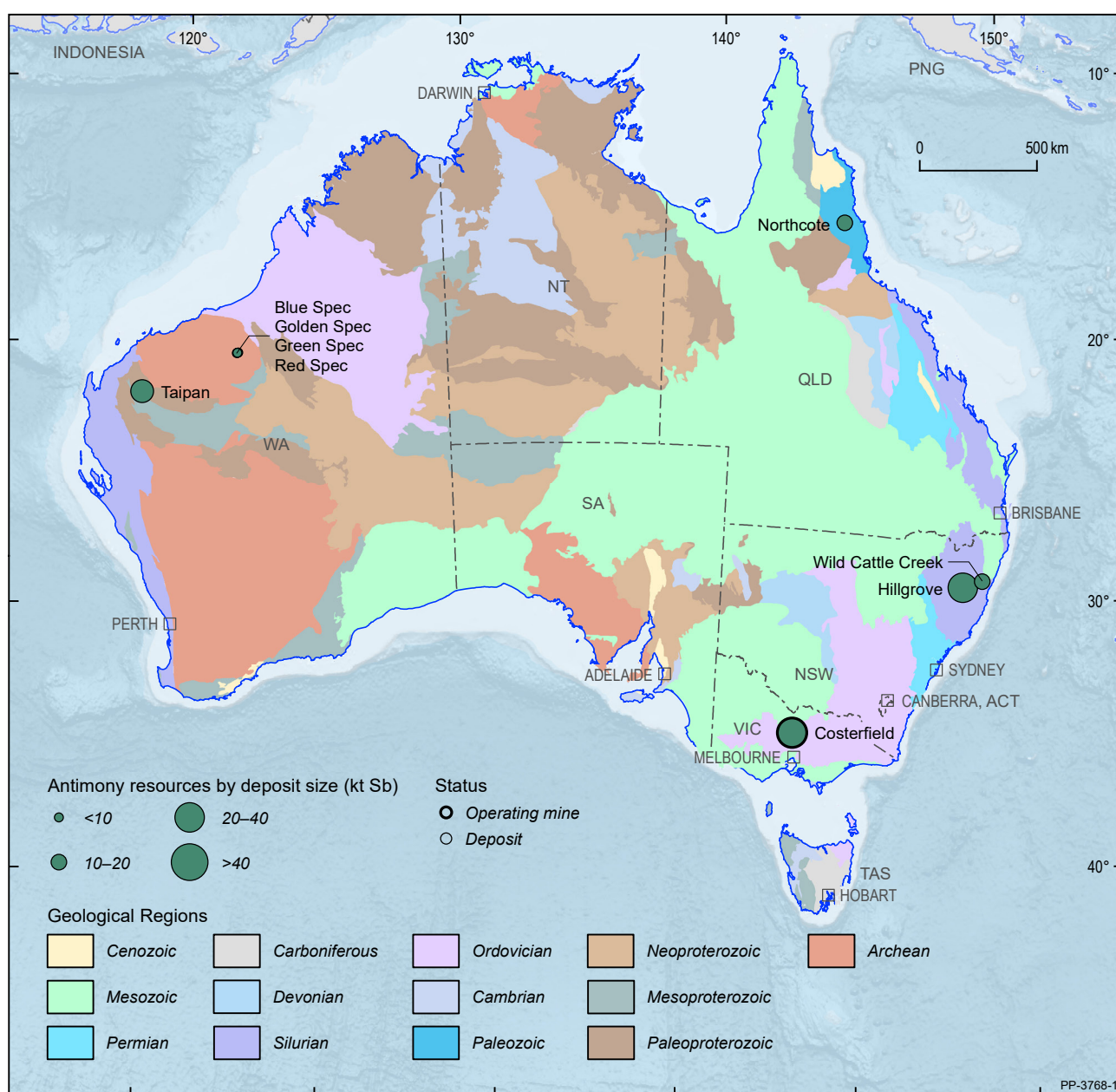


Figure 7 Australian antimony deposits and operating mines, 2019.

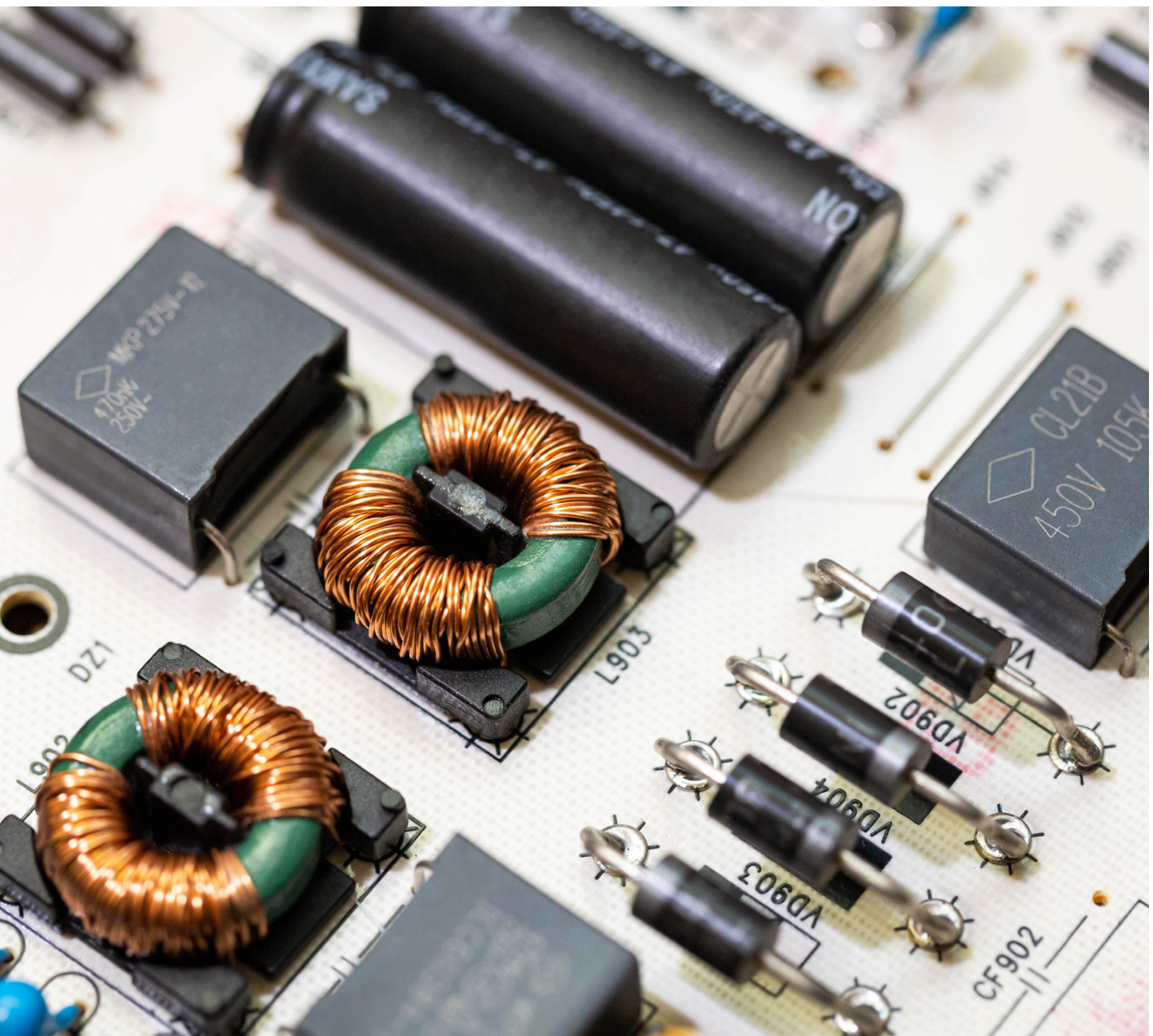
Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred).

ATO is used in non-metallic products such as paint (pigment and fire retardant), ceramics (opacifier), enamels (fire retardant), rubber (fire retardant), glass (de-gassing), paper (fire retardant), plastics (fire retardant) and textiles (fire retardant). ATO's use as a fire retardant also accounts for about one third of global antimony use. In its purest forms, antimony is used in semiconductor technology, infrared detectors and diodes. Antimony is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*¹².

Australia's EDR of antimony in 2019 were 100.5 kt (Table 3), a decrease from 142.7 kt in 2018, or 30%

(Table 4). This ranks Australia's resources as the world's fourth largest (Table 8) behind China, Russia and Bolivia. Antimony deposits that contribute to Australia's EDR occur in New South Wales, Victoria and Western Australia; a minor deposit also occurs in Queensland (Figure 7). Australia's only antimony producing mine is Costerfield in Victoria. In 2019, the mine produced 2.03 kt of antimony, a decrease of 1.54 kt compared to 2018 (3.57 kt). Australia is ranked seventh in the world for antimony production and accounts for only 1% of global production (Table 8). Antimony production is dominated by China (63%) and Russia (19%).

¹². See above n 7.



Antimony is used as a flame retardant and is an important component of circuit boards.

Bauxite

Australia's EDR of bauxite had a small rise in 2019, up 3% from 5,118 Mt in 2018 to 5,292 Mt in 2019 (Table 3, Table 4). Subeconomic resources remain unchanged in 2019 at 1,459 Mt and Inferred Resources of bauxite fell slightly in 2018, by 2 Mt to 3,170 Mt in 2019.

Bauxite production increased from 96.5 Mt in 2018 to 105.5 Mt in 2019 (Table 1), an increase of 9%. Ore Reserves of bauxite in 2019 were 2,045 Mt (Table 2), up 4% from 1,962 Mt in 2018. This small increase in Ore Reserves is in line with increased production, thus Australia's reserve life for bauxite remained similar to the previous year, falling from 20 years to 19 years (Table 2).

Resource life (based on AEDR) fell from 55 years to 50 years (Table 9). Australia's bauxite deposits are shown in Figure 8 on a total resource basis along with alumina refineries and aluminium smelters.

Figure 9 shows that, since 1975, bauxite production has increased more rapidly than the bauxite inventory. In 1975, bauxite production was 21 Mt which rose to 105.5 Mt in 2019, an increase of 402%. Bauxite EDR have increased 76% over the same period (3,000 Mt in 1975 to 5,292 Mt in 2019) and total resources of bauxite (EDR + Subeconomic + Inferred) have increased from 6,678 Mt in 1976 to 9,921 Mt in 2019, an increase of 49%.

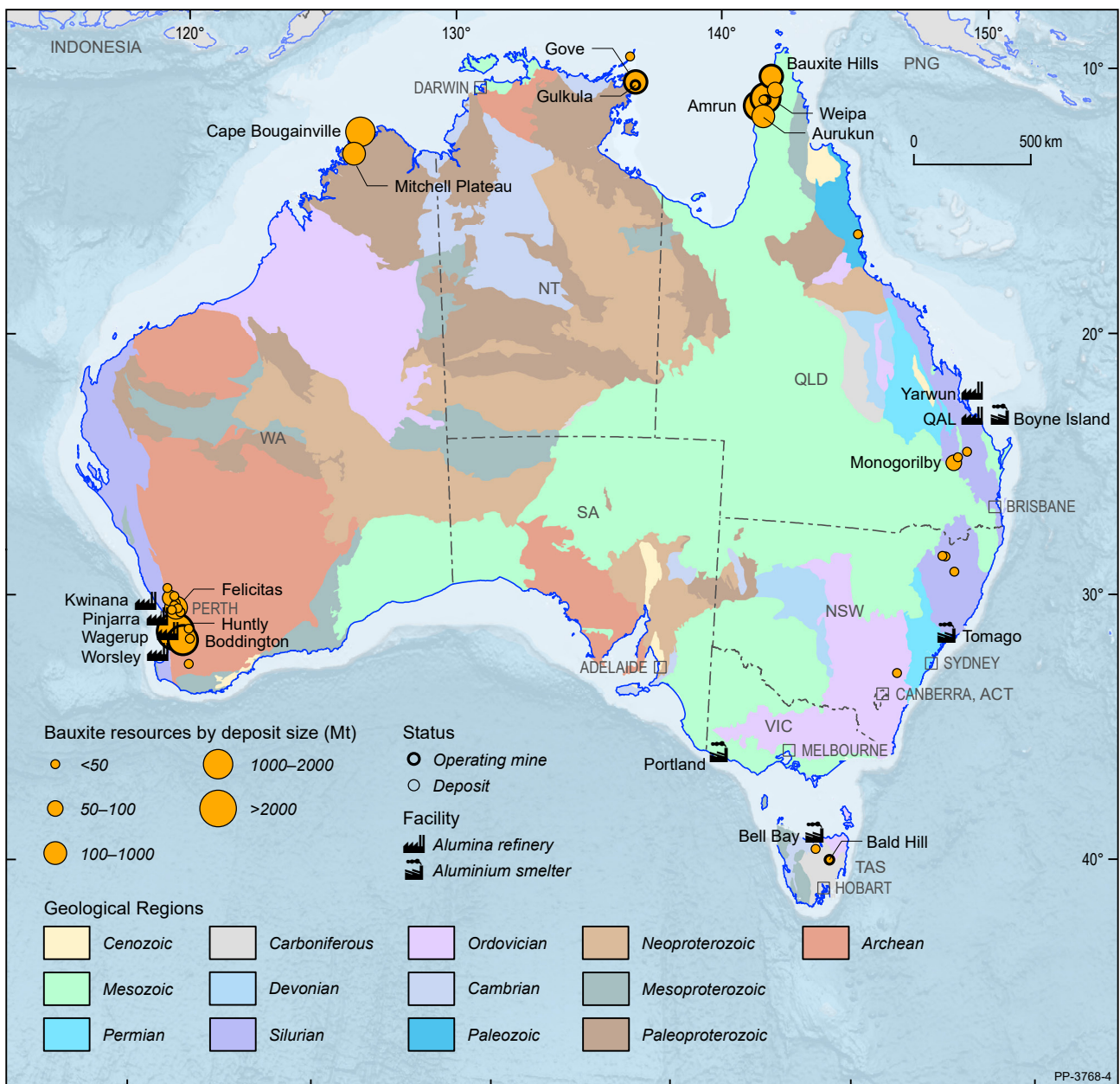


Figure 8 Australian bauxite deposits, operating mines, alumina refineries and aluminium smelters, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Australia had ten operating bauxite mines in 2019. The large mines of Huntly and Boddington continued to operate in the Darling Range of Western Australia, supplying the alumina refineries of Pinjarra, Kwinana, Wagerup (Huntly) and Worsley (Boddington). The Huntly operation also includes the Willowdale deposit which is being moved to a different part of the mining lease to ensure grades are maintained and haulage costs contained. Other activity in Western Australia includes an early-stage proposal to mine 6 Mtpa of bauxite from the Wuudagu deposit in the Kimberly of Western Australia.

In the Northern Territory, the major bauxite mine is Gove, run by Rio Tinto Ltd near the town of Nhulunbuy. Gumatj Corporation Ltd also produces bauxite from the Gulkula mine near Gove. It is Australia's first 100%-indigenous owned and operated bauxite mine. In December 2019, Rio Tinto announced that it had signed a new sales agreement to continue purchasing bauxite from Gulkula for another two years.

In Queensland, Rio Tinto operates major mines at Weipa and Amrun on the western side of the Cape York Peninsula. In 2019, Rio Tinto opened a new Bauxite Integrated Operations Centre in Brisbane that enables mining and product dispatch to be managed remotely. It also provides ore information downstream to the refineries and smelters, enabling them to adapt their processing operations with minimal disruption.

Also in Cape York, Bauxite Hills, owned by Metro Mines Ltd, produced 3.5 Mt of ore in 2019 and received a Loan Facility of up to \$47 million from the Northern Australia Infrastructure Facility for its Stage 2 Expansion to take production to 6 Mtpa. Unfortunately, in September 2020, when the mine had produced almost 2.5 Mt that year, it was put onto care and maintenance ahead of its planned wet-season shutdown, owing to the impacts of the COVID-19 pandemic on sales to China. The company plans to re-open in April 2021 at the end of the wet season.

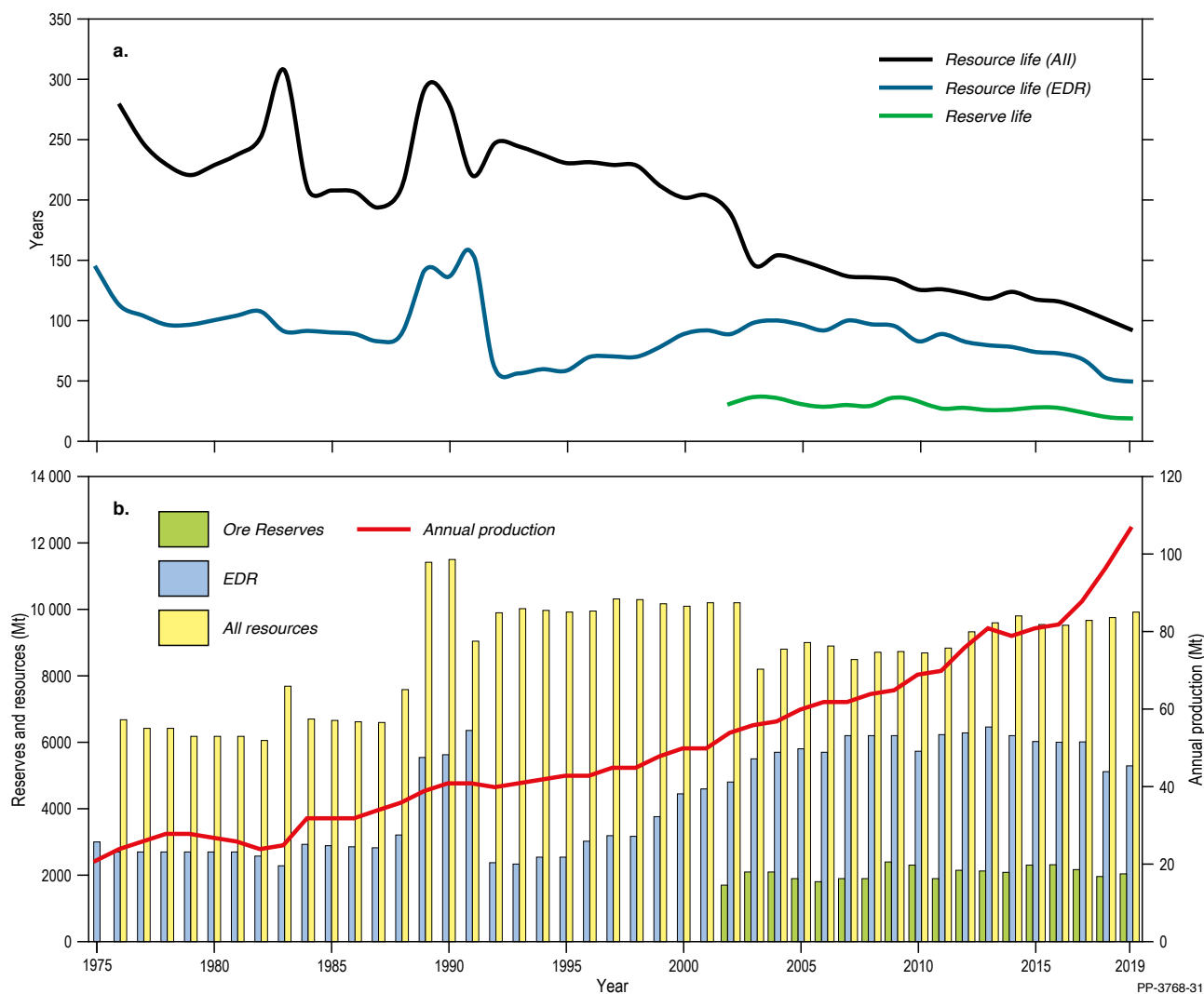


Figure 9 (a) Trends in bauxite reserve and resource life. These ratios are derived from (b) bauxite Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

The Binjour project in southeast Queensland was also impacted by COVID-19. Australian Bauxite Ltd and its partner, Rawmin Mining and Industries of India, plan to supply a new low-temperature alumina refinery in southern China from this deposit but some aspects of the development have been put on hold until the effects of the pandemic become clearer. Positively, Australian Bauxite continued to produce bauxite from its Bald Hill operation in Tasmania for cement and fertiliser applications.

Australia remains the world's largest producer of bauxite accounting for 28% of global production (Table 8). Australia is also the world's second largest producer of alumina (15%), after China, and the largest exporter, and is ranked sixth in the world for aluminum production (2%). Australia's resources of bauxite are the second largest in the world with only Guinea holding more, 25% compared to Australia's 18% (Table 8).

Black Coal

Most of Australia's recoverable EDR of black coal are in Queensland (67%) and New South Wales (31%) within four coal-bearing sedimentary basins (Bowen, Sydney, Surat and Galilee); the remainder is in South Australia, Western Australia and Tasmania (Figure 2). Major deposits are shown in Figure 10 on a total resource basis. In the twelve months to December 2019, Australia produced 588 Mt of raw coal (Table 1). Of this total, Queensland produced 322 Mt (55%) and New South Wales 258 Mt (44%); the remainder was produced in Western Australia and Tasmania.



Aluminium ingots are smelted from alumina, which is refined from bauxite. Australia is the world's largest producer of bauxite and makes aluminium at smelters in Tomago (NSW), Bell Bay (Tasmania), Portland (Victoria) and Boyne Island (Queensland).

From 2018 to 2019, the estimate of Australia's recoverable EDR of black coal increased by 2% to 75,428 Mt (Table 3, Table 4), and the estimate of in situ EDR also increased during this period by 2% to 89,707 Mt. Australia is thought to hold approximately 10% of world economic resources of black coal and ranks fourth (Table 8), behind the United States (29%), China (18%) and India (13%).

Over the same period, Paramarginal Demonstrated Resources of recoverable black coal decreased by 3 Mt to 1,934 Mt, whilst Submarginal Demonstrated Resources and Inferred Resources increased by 216 Mt to 3,856 Mt and by 1,891 Mt to 84,097 Mt, respectively.

Queensland holds the majority of Inferred Resources at 59,555 Mt (71%), followed by New South Wales at 13,522 Mt (16%) and South Australia at 9,307 Mt (11%), with the remainder in Tasmania and Western Australia.

Total Ore Reserves of black coal reported in compliance with the JORC Code amounted to 19,458 Mt in 2019 (Table 2), of which 11,670 Mt (60%) was attributable to 96 operating mines (Table 1, Figure 1). Total Ore Reserves saw a modest decrease of 1% from 19,715 Mt in 2018 to 19,458 Mt in 2019, whilst the Ore Reserves at operating mines saw a larger decrease of 7% from 12,592 Mt to 11,670 Mt.

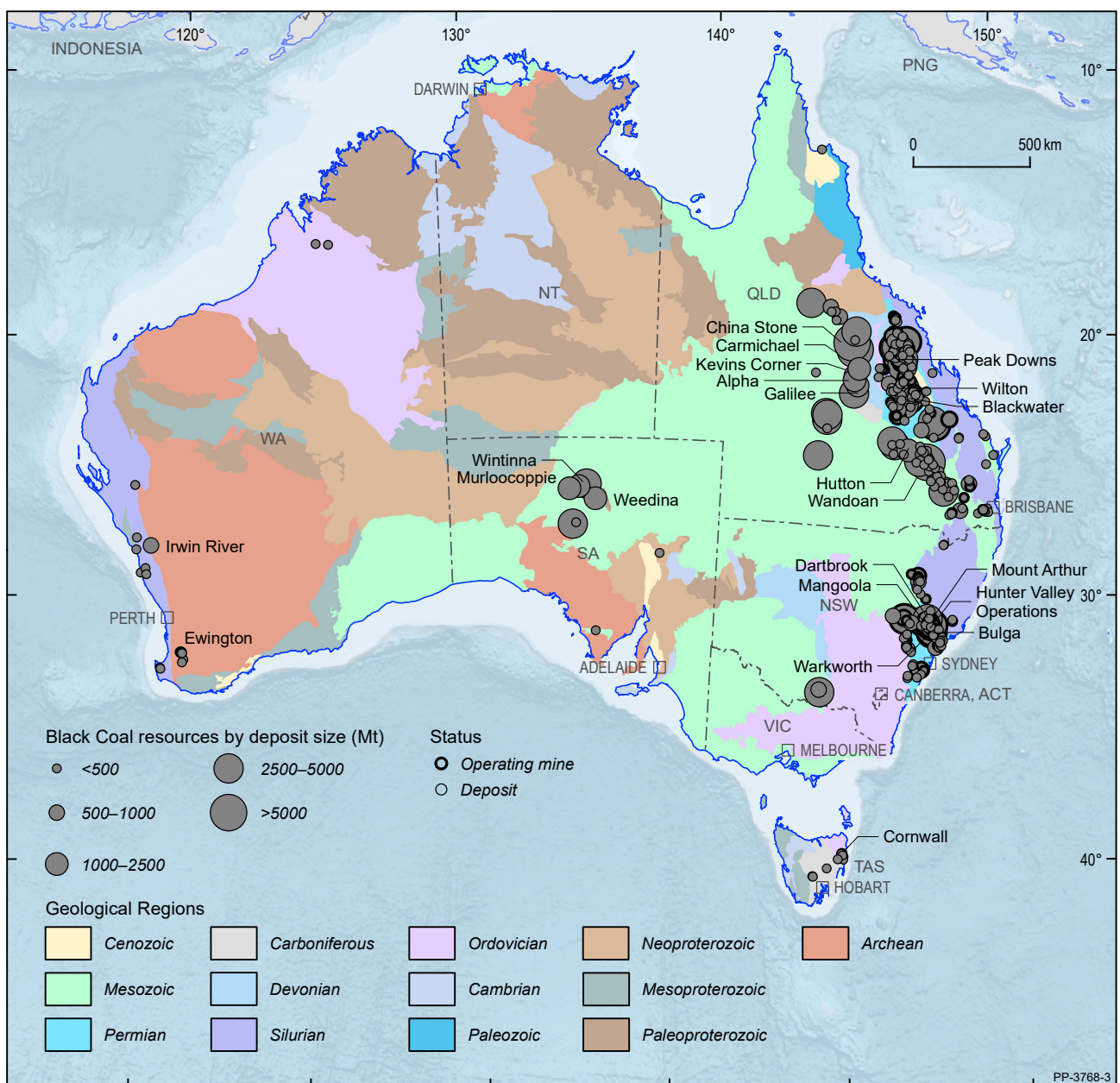


Figure 10 Australian black coal deposits and operating mines, 2019.

Deposit size is based on total recoverable resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. At 2019 production levels, the reserve life at operating mines for black coal is potentially 20 years (Table 1, Figure 11), and the resource life, when all resource categories are included, is an estimated 76 years (Table 1).

Last century, resource life (based on EDR) for black coal declined rapidly from more than 300 years in the late 1970s to less than half that by the year 2000 as rapidly increasing production was not matched by new resource delineation. Since the turn of the century, however, the reserve/production and resource/production ratios for recoverable black coal have been generally steady because companies have been demarcating new Ore Reserves and Mineral Resources at approximately the same rate that they have been increasing production (Figure 11).

The majority of Australian black coal production is exported. During the 2019 calendar year, 184 Mt of metallurgical coal (coal used in steel-making), and valued at \$41.28 billion (Table 11), was exported primarily to India, China, Japan, South Korea and Taiwan. During the same period, 212 Mt of thermal coal (used in electricity generation), valued at \$22.61 billion (Table 11), was exported primarily to Japan, China, South Korea, Taiwan and India.

Exploration expenditure for black coal during 2019 was \$229.3 million, an increase of 32% since 2018 (\$55.7 million). In 2019, the Bluff coal project in Queensland commenced operations and began shipping pulverised injection coal for use in steel production. Bluff is owned by Carabella Resources Pty Ltd and has the potential to produce up to 1.2 Mtpa of coal.

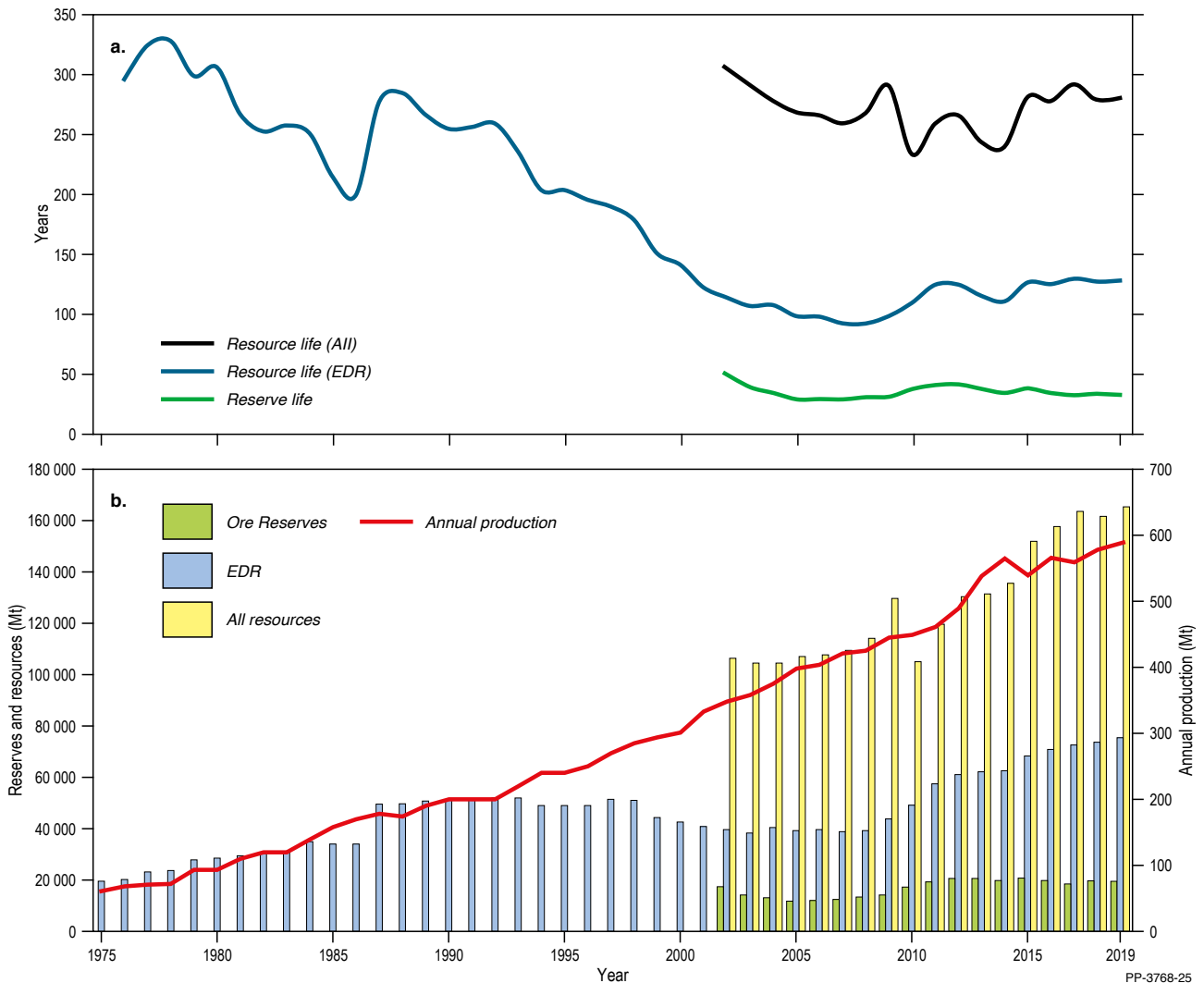


Figure 11 (a) Trends in recoverable black coal reserve and resource life. These ratios are derived from (b) recoverable black coal Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

Brown Coal

Australia's substantial brown coal, or lignite, resources are principally hosted in the Gippsland Basin of Victoria (Figure 12). Australian brown coal is mined at three open-cut operations in Victoria where it is used mainly as a feedstock for power stations. Mines at Loy Yang and Yallourn provide coal to power stations in the Latrobe Valley, and a small mine at Maddingley, 50 km northwest of Melbourne, uses brown coal to produce agricultural products.

During 2019, Australia's three brown coal mines produced an estimated 43 Mt and, at 2019 rates of extraction, AEDR (63,796 Mt; Table 3) will support over 1,000 years of production. Australia is ranked seventh

in the world for brown coal production (Table 8) behind Germany, Turkey, Russia, Poland the USA and India.

Australia's 2019 recoverable brown coal EDR were estimated to be 73,865 Mt (Table 3), a decrease from 76,951 Mt in 2018. Nearly all of Australia's recoverable brown coal is located in Victoria with more than 90% of EDR in the Latrobe Valley alone. Australia's share of the world's economic resources of brown coal is in the order of 24%, ranking Australia second in the world (Table 8) behind Russia (28%) and followed by Germany (11%) and the USA (9%).

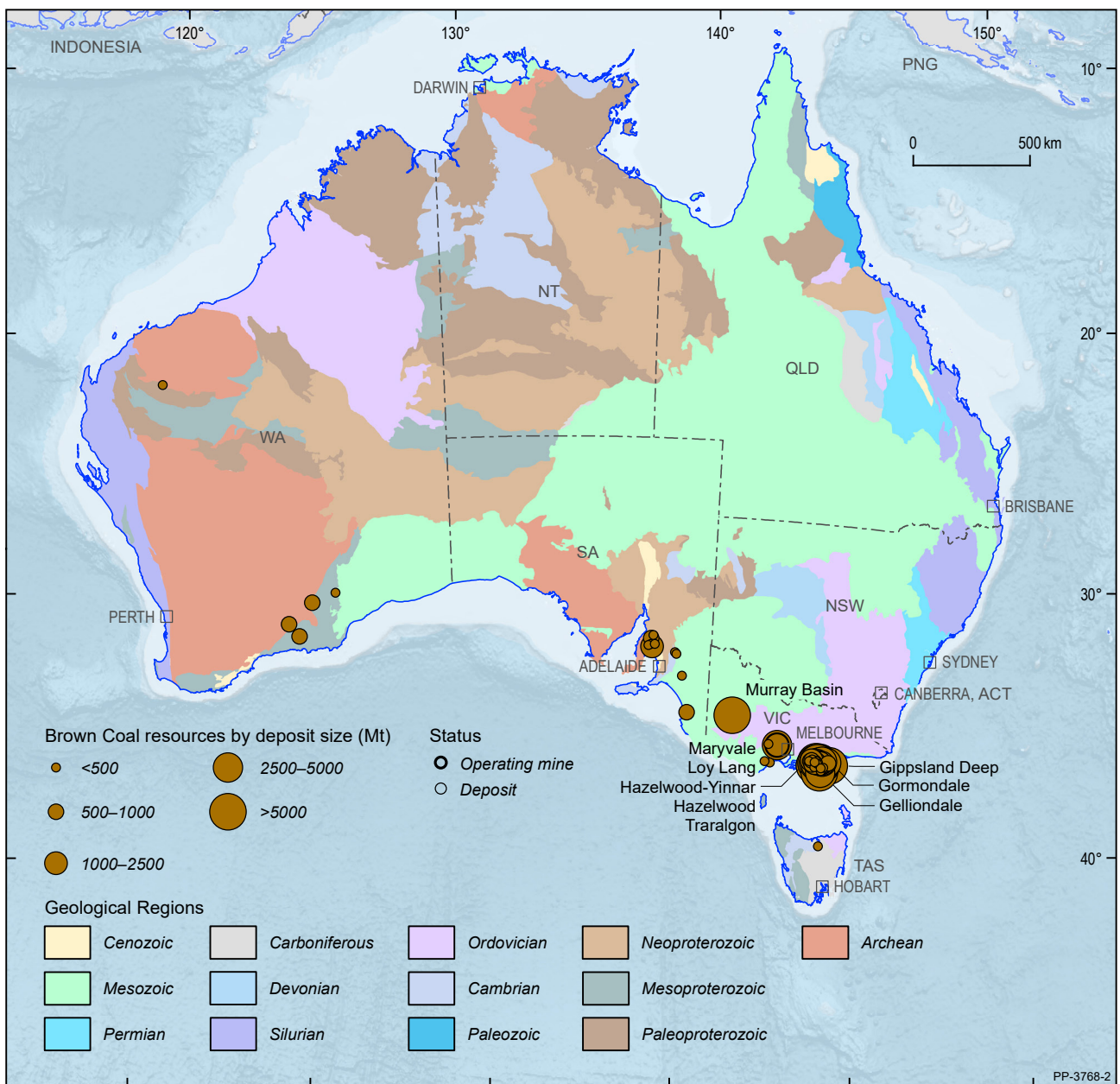


Figure 12 Australian brown coal deposits and operating mines, 2019.

Deposit size is based on total recoverable resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Cobalt

The Hydrogen Energy Supply Chain pilot project commenced construction in 2019 and, with the achievement of major project milestones, a one-year pilot project will demonstrate the production and supply of hydrogen gas from coal from 2021. The pilot project is a Japanese-Australian collaboration, whereby brown coal from Loy Yang mine will be used to make hydrogen at a trial plant at AGL's Loy Yang complex. The hydrogen will be liquefied at a facility at the Port of Hastings, loaded on to a specialised marine carrier and shipped to Japan where it will be used in hydrogen fuel cell vehicles and residences.

Australia's EDR of cobalt were 1,399 kt (Table 3) in 2019, an increase of 3% from the 2018 estimate of 1,353 kt (Table 4). Total Ore Reserves were 556.8 kt (Table 2), down 12% from 635 kt in 2018. Most cobalt deposits in Australia occur in Western Australia (Figure 13), which hosts the largest proportion of cobalt EDR (69%). Queensland has the second largest EDR of cobalt (16%) followed by New South Wales (13%) and South Australia (1%). Major deposits are shown in Figure 13 on a total resource basis.

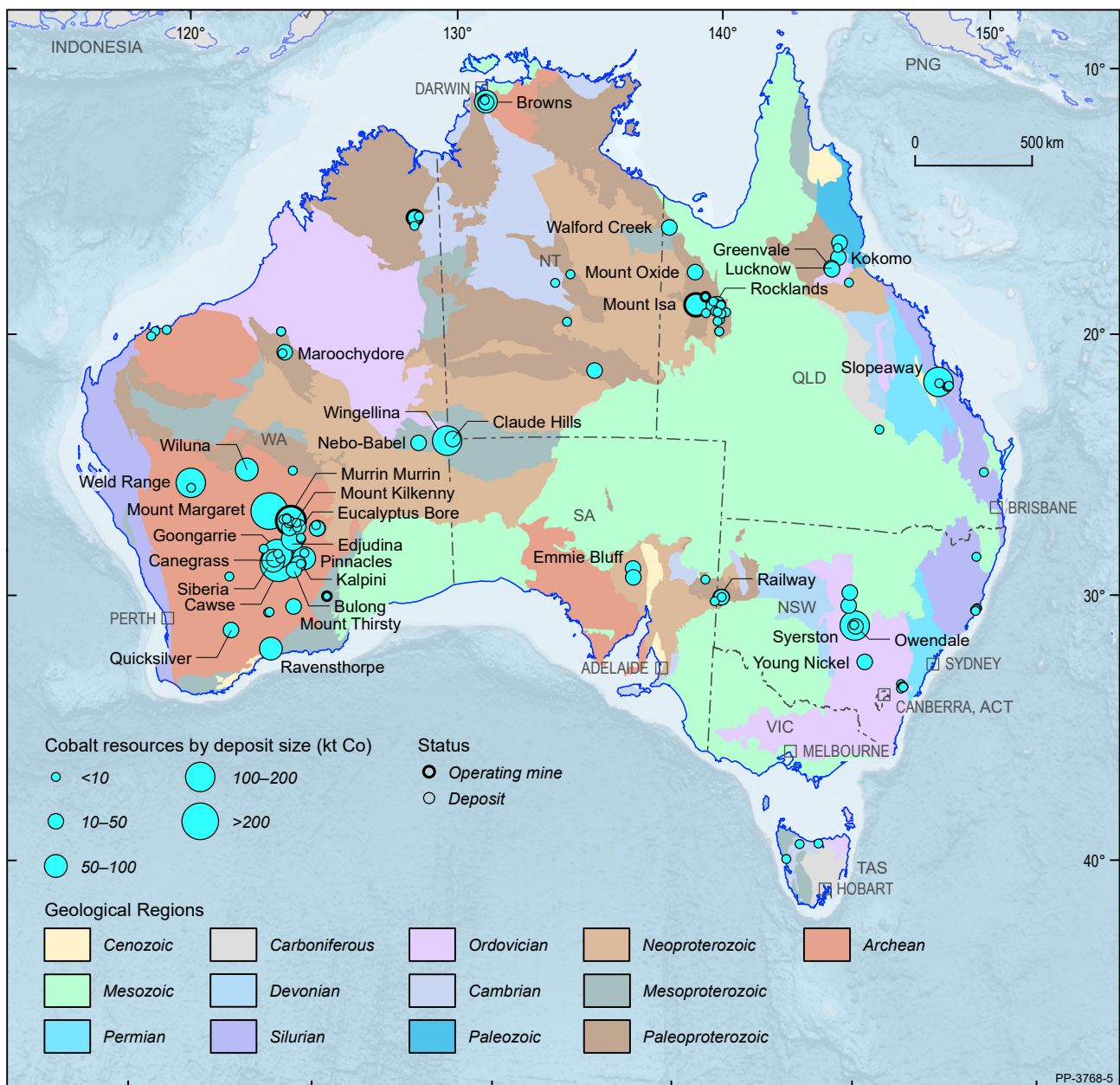


Figure 13 Australian cobalt deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

In world rankings, Congo dominates the global economic resources of cobalt with an estimated 3,600 kt which is equivalent to 50% of the global inventory. Australia follows with 19% of global economic resources of cobalt with Cuba third (7%). In 2019, Australia produced 5.7 kt of cobalt (Table 3) ranking third globally (4%; Table 8), behind Congo (100 kt; 70%) and Russia (6.1 kt; 4%).

Cobalt is used as a metal in numerous diverse commercial, industrial and military applications, many of which are strategic and critical. Its main use is in rechargeable battery electrodes. Cobalt is also used in superalloys for gas engine components, as a catalyst for the petroleum and chemical industries, in alloys for tools and in many industrial products such as paints, magnets and tyres. The United States Department of the Interior included cobalt in its published list of 35 critical minerals¹³, and is listed in *Australia's Critical Minerals Strategy 2019*¹⁴.

The present upward trend of electric vehicle production has increased the interest in cobalt mineral exploration and project development. Commonly, cobalt minerals occur as accessories to nickel and copper, thus it is usually produced as a by-product of nickel and copper mining. However, as the electric car battery industry grows globally, it has been accompanied by increased development activity at deposits where cobalt is regarded as the primary resource.

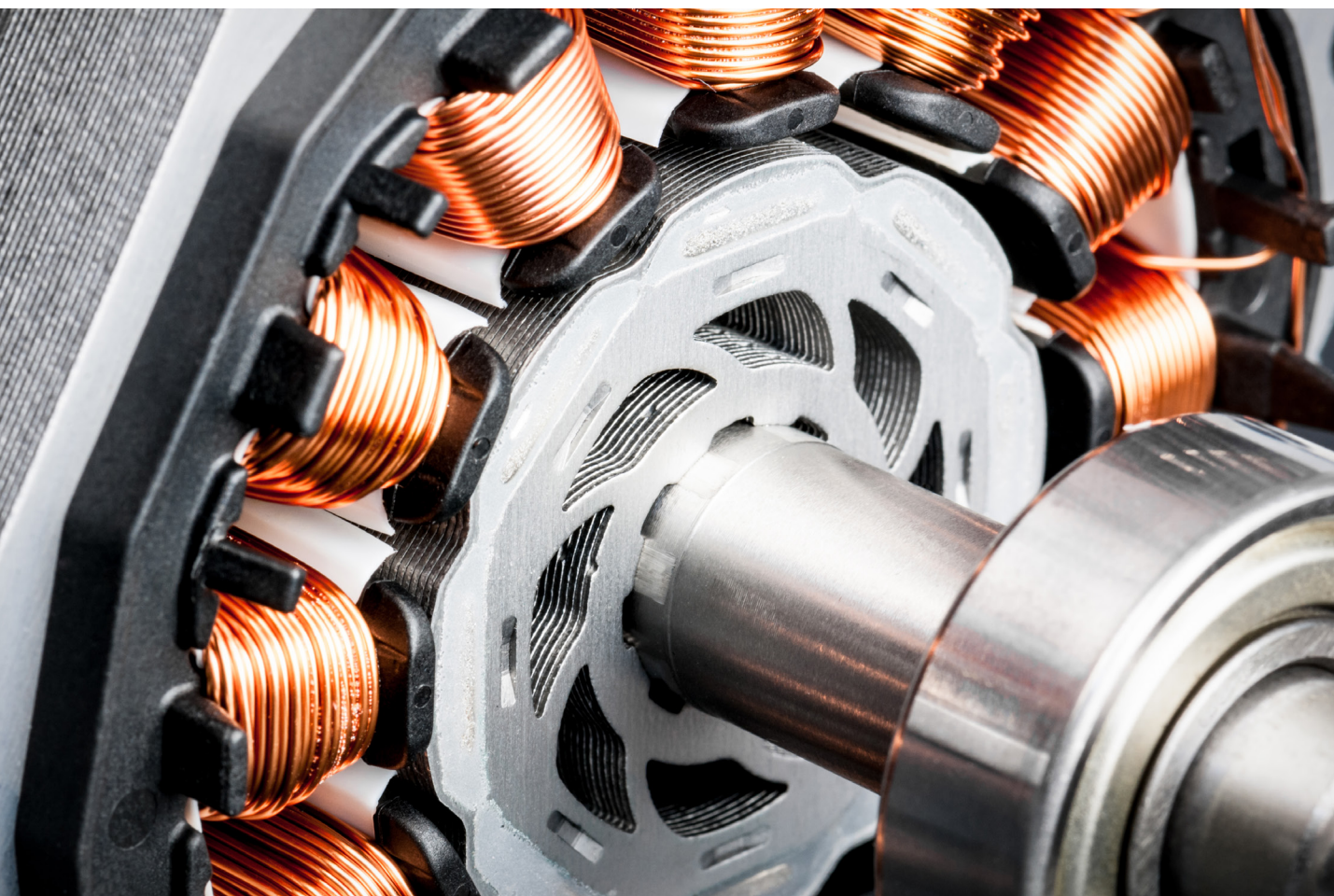
The average price for cobalt in 2019 was approximately \$33,000 per tonne down from \$55,000 per tonne in 2018¹⁵. The USGS notes the average cobalt price trended downward during the first seven months of 2019 owing to oversupply, consumer destocking and announcements by major battery companies about the use of less cobalt in batteries in the future. However, by August, prices began to slightly increase again¹⁶.

13. United States Government Federal Register, Final List of Critical Minerals 2018, Document 83 FR 23295 (Interior Department Notice, 18 May 2018). See <https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018> (accessed 18 December 2020).

14. See above n 7.

15. S&P Global, Cobalt Price Chart. See <https://platform.marketintelligence.spglobal.com/web/client?auth=inherit#industry/priceChart> (accessed 18 December 2020).

16. United States Geological Survey (USGS), Mineral Commodity Summaries 2020, Cobalt. See <https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-cobalt.pdf> (accessed 18 December 2020).



Permanent magnets in many home appliances contain copper coils and cobalt. Australia has the world's second largest resources of both.

Copper

Australia's EDR of copper were 93.36 Mt at the end of December 2019 (Table 3), a significant increase of 6% from 88.17 Mt in 2018 (Table 4). South Australia holds 67% of Australia's copper EDR, New South Wales (14%), Queensland (11%), Western Australia (6%), with minor (<1%) EDR each held by Tasmania, Northern Territory and Victoria (Figure 2). Major operating mines and deposits are shown in Figure 14 on a total resource basis.

As at December 2019, total Ore Reserves of copper reported in compliance with the JORC Code amounted to 22.99 Mt (Table 2) of which 19.8 Mt (86%) was attributable to 43 operating mines (Figure 1, Table 1). Ore Reserves at operating mines increased by nearly 4% from 19.13 Mt

of copper in 2018 to 19.8 Mt in 2019. Total Ore Reserves at all deposits increased in 2019, from 22.38 Mt in 2018, to 22.99 Mt (Table 2). Copper production totalled 0.93 Mt (Table 1), a small increase of 2% on 2018 levels and accounting for 5% of global supply (Table 8).

Resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. At 2019 production levels, the reserve life at operating mines for copper is potentially 21 years (Table 1). At 2019 production levels, the Measured and Indicated Mineral Resource life at operating mines is 90 years and the Measured, Indicated and Inferred Mineral Resource life at operating mines is 118 years.

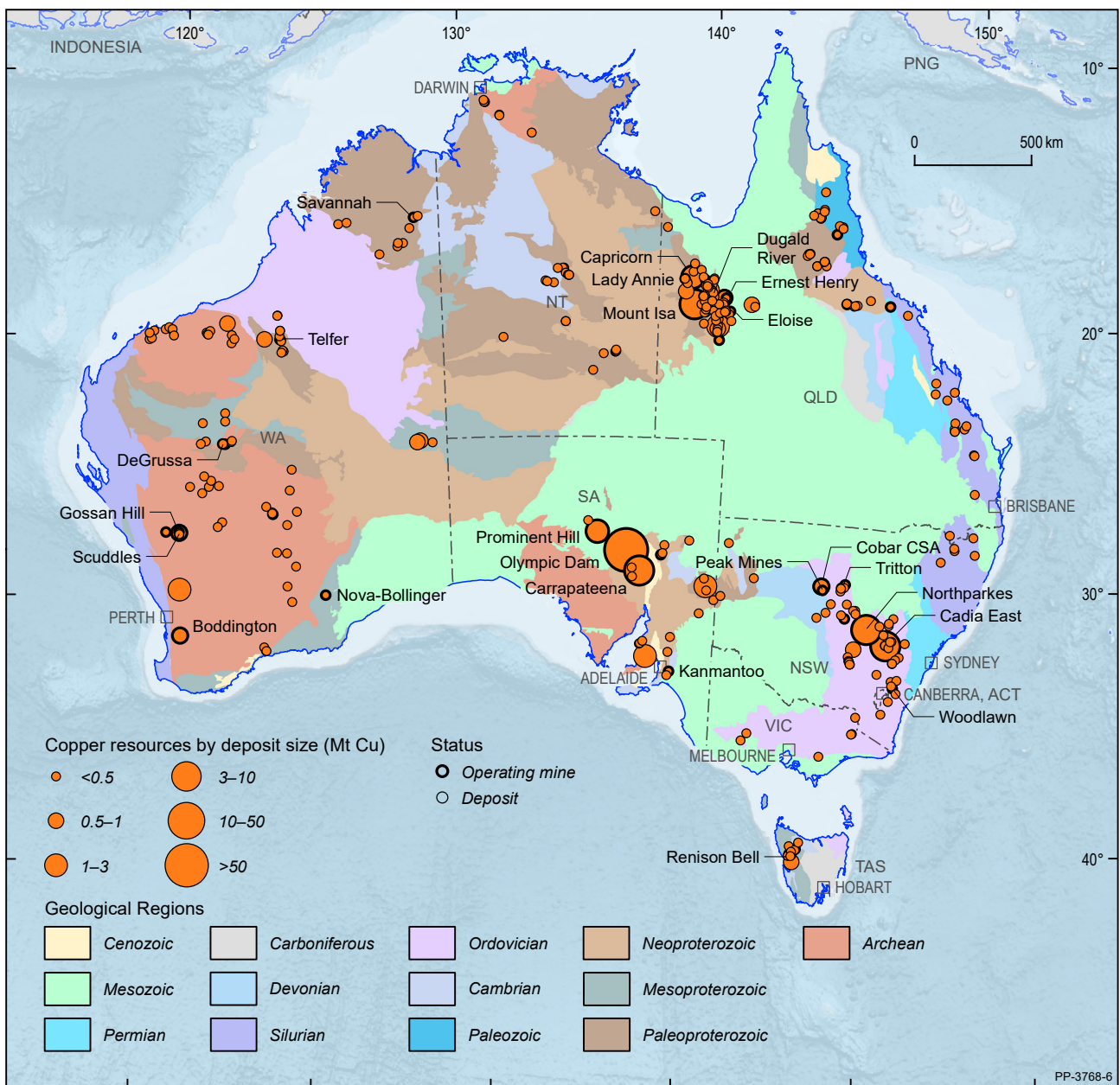


Figure 14 Australian copper deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

While copper reserve life has been broadly constant (Figure 15), resource life (EDR) increased rapidly from 30 years in 2001 to 100 years in 2009 as new resources were added to the inventory but were not matched by increasing production rates (Figure 15). Since 2009, resource life (EDR) has ranged between 90 and 100 years reflecting a congruency between production and resource replacement (Figure 15).

Spending on copper exploration in 2019 was \$414.9 million, a 59% increase on 2018 (\$260.8 million; Figure 6). With increases in copper exploration expenditure occurring over the last three years, expenditure has now exceeded the levels seen in 2012 (\$413.7 million). Exploration activity in 2019 included drilling at Rio Tinto tenements

in the Yeneena Basin of the Paterson Province (Western Australia), at the Winu project. In 2019, Canterbury Resources Ltd reported a maiden Inferred Resource at the Briggs porphyry-style copper deposit in the New England Orogen of Queensland.

Australia hosts 11% of the world's copper resources (Table 8), second only to Chile (23%) and ahead of Peru (10%). For global production, Australia ranks sixth (Table 8), behind Chile, Peru, China, the United States and Congo. The value of Australia's exports of copper ore and concentrates and refined copper in 2019 totalled \$10.1 billion (Table 11), up 9% on \$9.3 billion in 2018. In 2019, the London Metal Exchange cash price averaged US\$6,005/t, a decrease from US\$6,525/t in 2018.

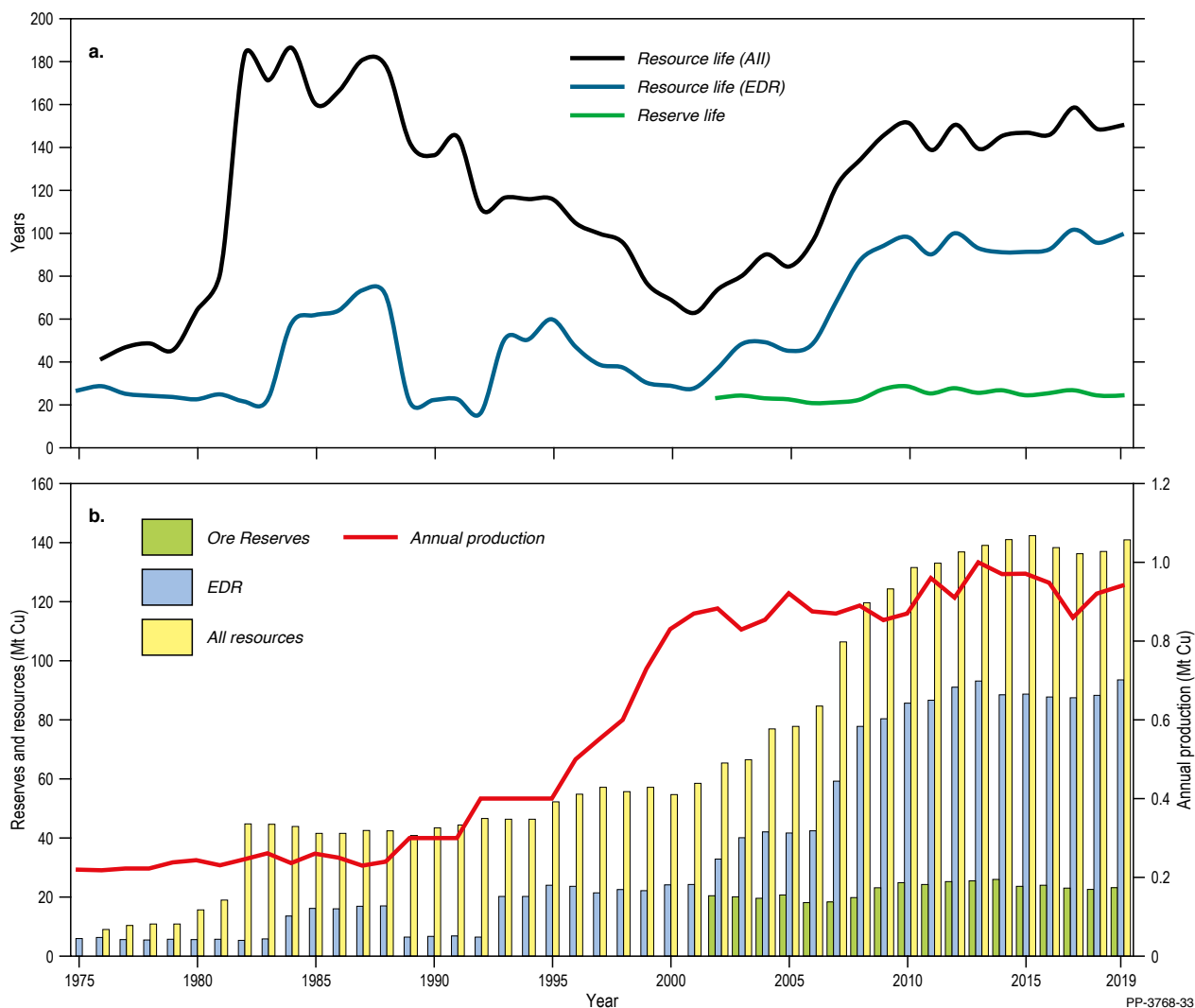


Figure 15 (a) Trends in copper reserve and resource life. These ratios are derived from (b) copper Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt Cu = million tonnes of contained copper. Prior to 2002, Ore Reserves were not recorded.

Diamond

In 2019, Australia's total EDR of diamond were 10.97 Mc (Table 3), down 57% from 25.48 Mc in 2018 (Table 4). This is largely owing to resources at Argyle being depleted by mining and lower grades. Despite a 58% decrease in export volume of sorted gem diamonds, export earnings went up 26% due to a massive increase of 198% in value (Table 12). Total production also decreased, from 14.01 Mc in 2018 to 12.99 Mc in 2019 (Table 3). This combination of declining resources and mine production

has resulted in an Australian diamond reserve life of only one year (Table 9).

The Argyle lamproite pipe in the east Kimberley region of Western Australia was responsible for all diamond production in Australia. The Argyle mine is scheduled to cease operation by the end of 2020. Operating mines and deposits for diamond are shown in Figure 16 on a total resource basis.

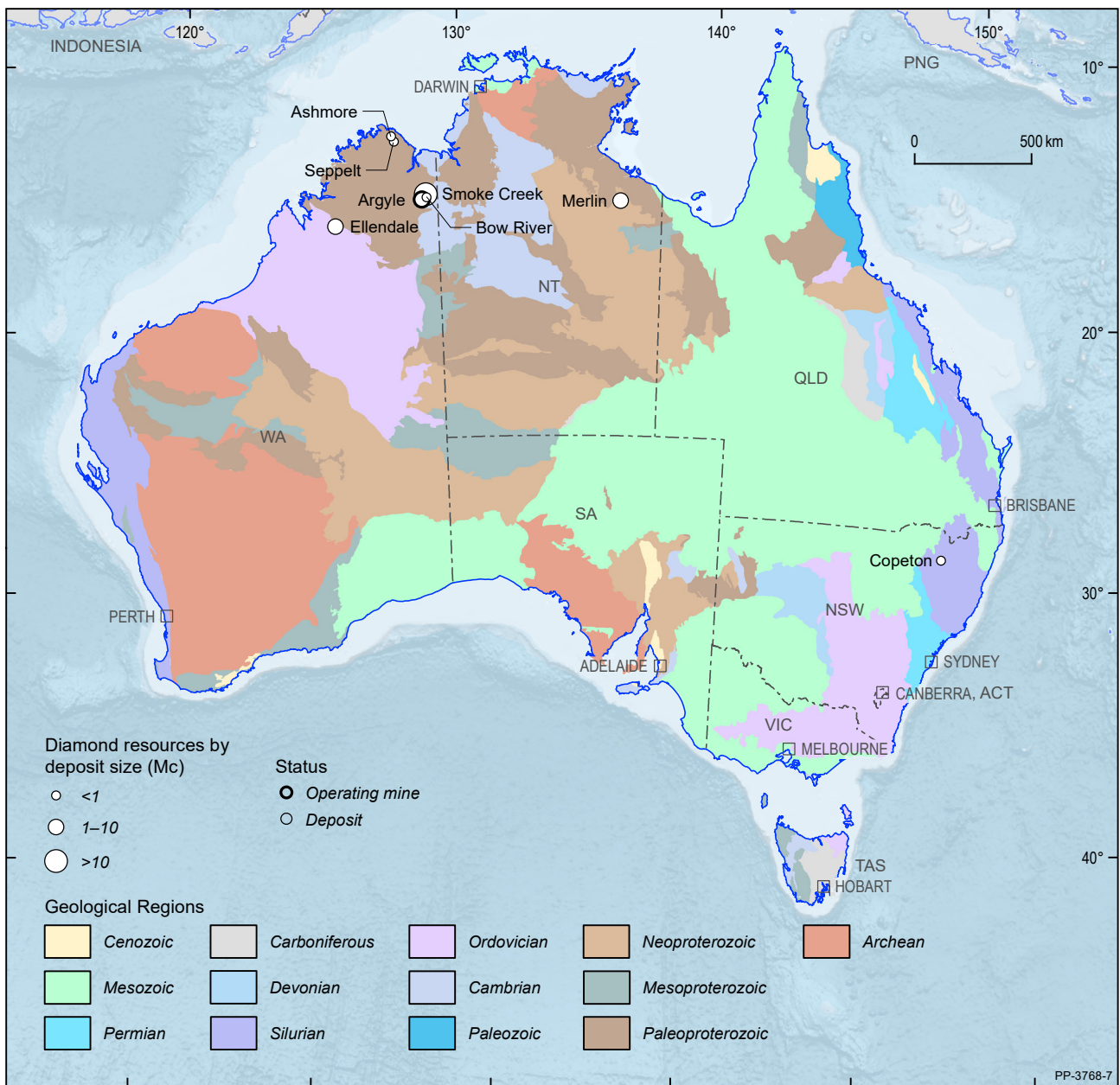


Figure 16 Australian diamond deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred).

Gold

Australia's gold resources occur in all states and the Northern Territory (Figure 17). In 2019, EDR of gold increased 630 t (6%) to 10,795 t (Table 3) from 10,165 t in 2018 (Table 4). Western Australia has the largest share of EDR (45%), followed by South Australia (26%) and New South Wales (16%): collectively, these three states hold slightly less than 87% of national EDR (Figure 2).

Based on estimates provided by the USGS and adjusted for Australia by Geoscience Australia, world economic resources of gold in 2019 were 51,100 t (Table 3). Australia, with EDR of 10,795 t, or slightly more than 21% of world gold resources (Table 8), has the largest share

ahead of Russia with 5,300 t (10%), South Africa with 3,200 t (6%), and the United States with 3,000 t (6%).

From 2018 to 2019, Paramarginal Demonstrated Resources of gold declined by 9 t to 148 t and Submarginal Demonstrated Resources increased by 8 t to 208 t. Over the same period, Inferred Mineral Resources of gold in Australia decreased 446 t, or 8%, from 5,268 t to 4,822 t (Table 3). Western Australia's Inferred Mineral Resources of gold remain the largest of any state or territory at 2,203 t (46%), followed by South Australia with 1,092 t (23%) and Queensland with 713 t (15%).

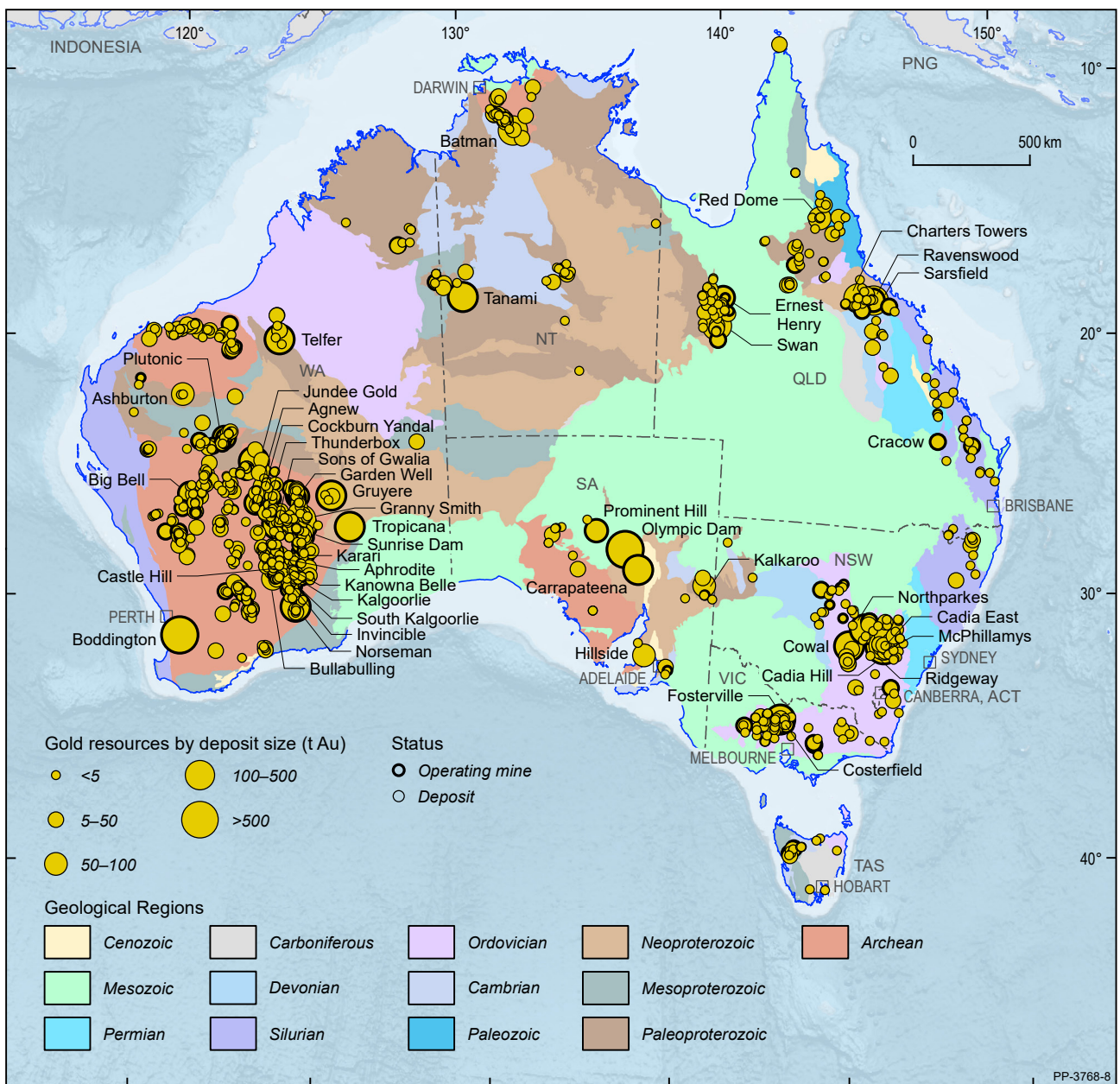


Figure 17 Australian gold deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Total Ore Reserves of gold reported in compliance with the JORC Code increased by 51 t from 4,018 t in 2018 to 4,069 t in 2019 (Table 2) and comprised 38% of EDR (Table 6). Ore Reserves of gold at operating mines, based on 2019 production rates, have a reserve life of 9 years, which extends to 12 years when reserves at other deposits are included (Table 9).

Reserve/resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. Resource life for Australian gold dramatically increased, briefly, during the early 1980s as the introduction of new gold extraction technologies stimulated exploration (Figure 18). Resource life then declined rapidly as gold production surged 800% from 27 t in 1982 to 243 t in 1990 (Figure 18). Since 1990,

resource life for gold has generally trended upward (Figure 18) as new resource delineation has outpaced increases in production. It is only since 2012 that gold resource life has decreased owing to favourable exchange rates stimulating increased production but with slower increases in new resource delineation (Figure 18).

Exploration expenditure for gold reached an all-time high in 2019 increasing by 20% on the previous year from \$892 million to \$1,068 million¹⁷ (Figure 6). Gold had the highest exploration expenditure of all commodities in 2019, accounting for 40% of all mineral exploration expenditure (\$2,648 million). This reflects the strong price of gold in Australian dollars, which had a monthly average price of \$2,007/oz in 2019. This was \$309/oz higher than in 2018¹⁸.

17. See above n 11.
18. See above n 1, Table 27.

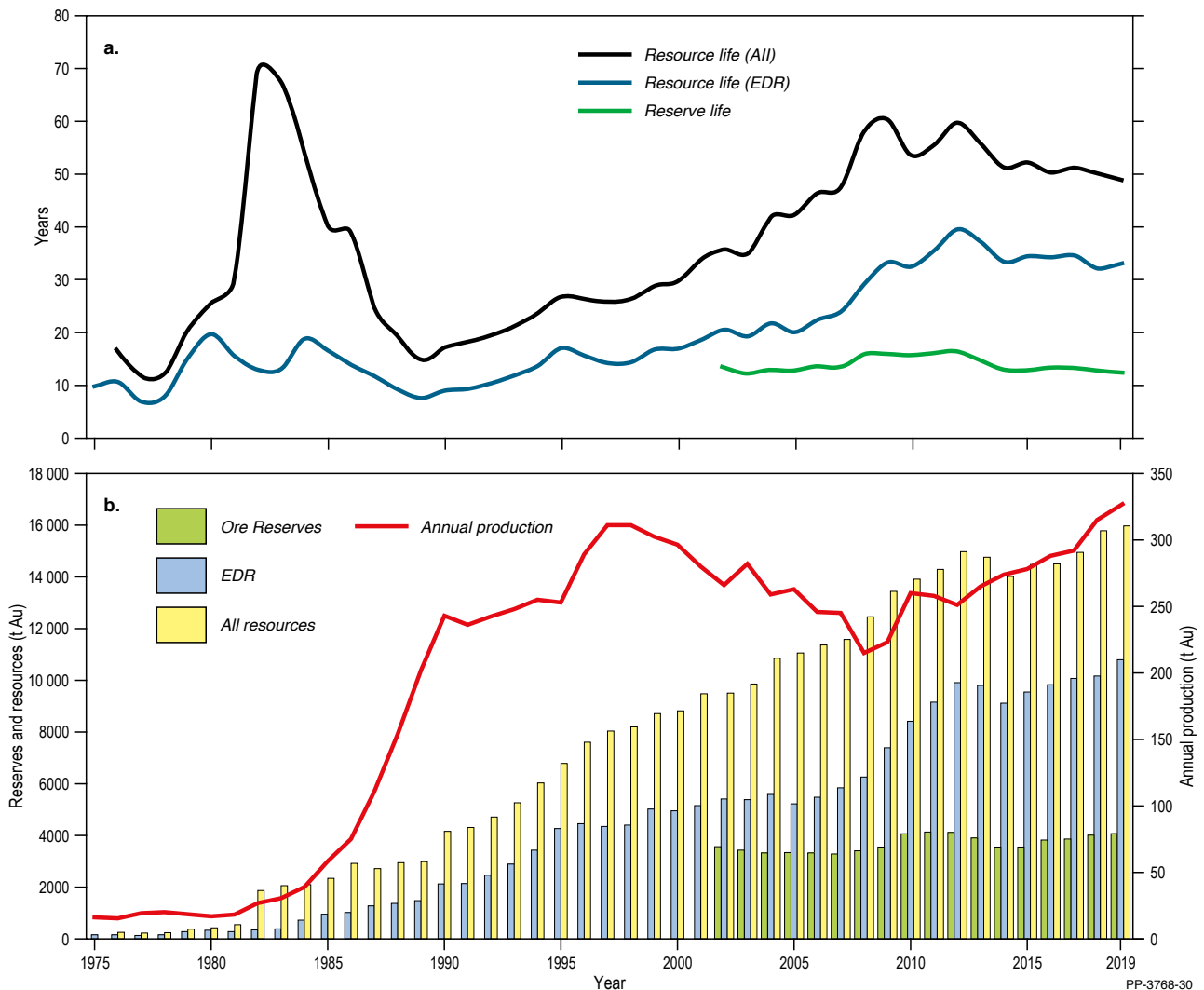


Figure 18 (a) Trends in gold reserve and resource life. These ratios are derived from (b) gold Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: t Au = tonnes of contained gold. Prior to 2002, Ore Reserves were not recorded.

Domestic mine production increased by 11 t of gold in 2019 to 326 t (Table 1)¹⁹. By jurisdiction, Western Australia maintained the highest output of gold at 218 t (67%), New South Wales gold production retained second position at 41 t (13%) and Queensland had the third highest production at 23 t (7%). According to the USGS, the world produced 3,300 t of gold from mining in 2019 (Table 3). Thus, Australia's mine production of 326 t accounts for 10% of world production (Table 8) and was second to that of China (13%), but ahead of the Russia (9%) and the USA (6%). In 2019, Australia exported 362 t of gold valued at \$23,372 million with a value of \$64.7 million/tonne (Table 11). Gold accounted for 10% of total mineral export earnings in 2019 (Table 11).

Australian gold deposits can be grouped into a number of geological or metal-association types with differing contributions to production and resources. In 2019, lode-gold deposits (e.g. Kalgoorlie Super Pit) yielded 219 t or 67% of Australian mine production, more than double the next largest producing type—copper-gold deposits. Copper-gold deposits include porphyries (e.g. Cadia) and the iron oxide-copper-gold deposits (e.g. Olympic Dam). Gold output in 2019 from these deposits amounted to 91 t or 28% of national production. The remaining 5% of national gold production for the year came from polymetallic and other deposits, including epithermal and antimony-gold deposits, totalled 16 t.

Significant industry activity includes the start of construction at PYBAR Mining Services Pty Ltd's Dargues gold mine in New South Wales in 2019, which is expected to produce 50,000 oz of gold per annum. In Western Australia, RNC Minerals Corporation (now Karora Minerals Inc) announced high-grade drill results from the Father's Day vein discovery of 2 m at 1,017.3 g/t Au in January 2019.

Graphite

Graphite is a good electrical conductor and has a high fusion point and good lubricating properties. It is used as an anode in batteries, as a refractory material in industries producing molten metal for crucibles and blast furnace linings, and to replace asbestos in brake shoes for heavier vehicles. Graphite is also used in pencils. Because of its use in low-carbon technologies, graphite demand is projected to rise significantly (383%) by 2050²⁰. Graphite is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*²¹.

19. *ibid.*
20. See above n 6.
21. See above n 7.



Gold is used as an investment tool, in electronics and for jewellery. The jewellery sector accounts for almost half of the world's gold demand.

In Australia, graphite deposits occur across Queensland, Western Australia and South Australia. South Australia hosts 65% of graphite EDR, followed by Queensland (17%) and Western Australia (18%). Graphite deposits include: Uley, Oakdale, Siviour, Kookaburra Gully, Wilclo South, Koppio and Campoona in South Australia; Mount Dromedary and Burke in Queensland; and Springdale, Emperor, Longtom, Munglinup and Yalbra in Western Australia (Figure 19).

Australia's EDR of graphite in 2019 were approximately 7.97 Mt (Table 3), a 10% increase from the previous year's

estimate of 7.25 Mt (Table 4). In 2019, there were no significant changes from the previous year to Australia's total graphite Ore Reserve estimate at 4.77 Mt (Table 2). Inferred Resources of graphite were estimated at 7.32 Mt in 2019, a nominal increase from 6.98 Mt in 2018.

Graphite mining occurs globally, with China remaining the leading producer in 2019, accounting for 62% of world supply, followed by Mozambique (9%). Economic resources of graphite have shown notable increases since 2013, with Turkey hosting the largest graphite inventory (29%) in 2019, followed by China (24%) and Brazil (23%).

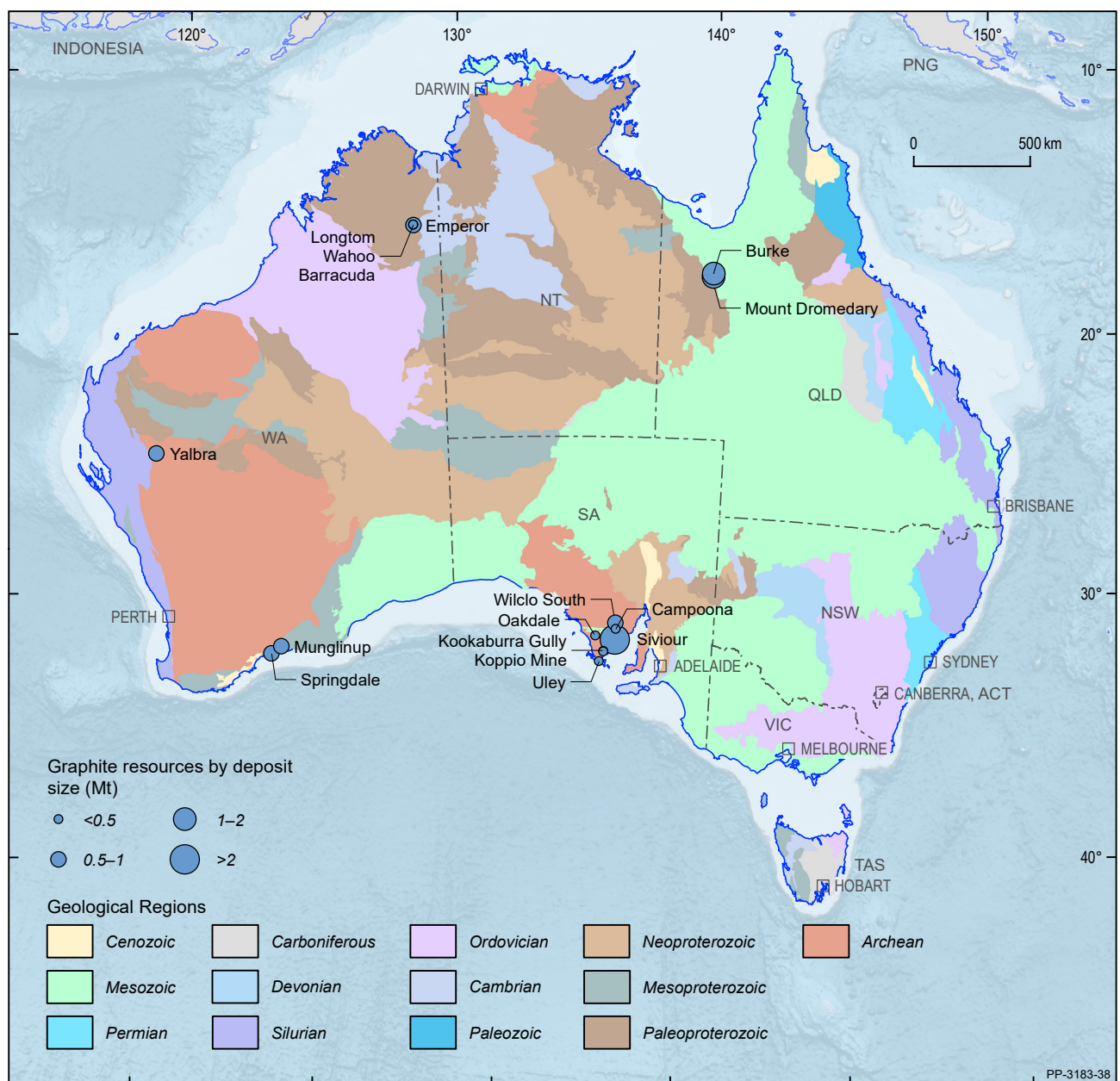


Figure 19 Australian graphite deposits, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Iron Ore

Australia's EDR of iron ore increased by 2% to 50,593 Mt during 2019 (Table 4), with the EDR of contained iron estimated to be 24,508 Mt (Table 3). Of this, 83% of EDR occur in the Pilbara region of Western Australia. Major deposits and operating mines are shown in Figure 20 on a total resource basis. The slight increase in iron ore EDR was the upshot of regional project expansion and developments by Australia's major producers—BHP Ltd, Rio Tinto and Fortescue Metals Group Ltd. Australia has the world's largest economic resources of iron ore (30%; Table 8), followed by Brazil (17%). Australia also ranks first for global production of iron ore, accounting for 36% in 2019 (Table 8), followed by Brazil (19%) and China (14%).

The market view is that the unexpected, but welcome, price spike of iron ore during 2019 and through most of 2020 was influenced by the anticipated shortfall in supply owing to the collapse of the Brumadinho tailings dam in Brazil and from the effects of Cyclone Veronica on Australia's major producers in the Pilbara region^{22,23,24}. This latter disruption cost about 3% of Australia's annual production, according to the Reserve Bank of Australia²⁵, although production of iron ore still increased from 899 Mt in 2018 to 919 Mt in 2019 (Table 3), with Western Australia producing 910 Mt or 99%.

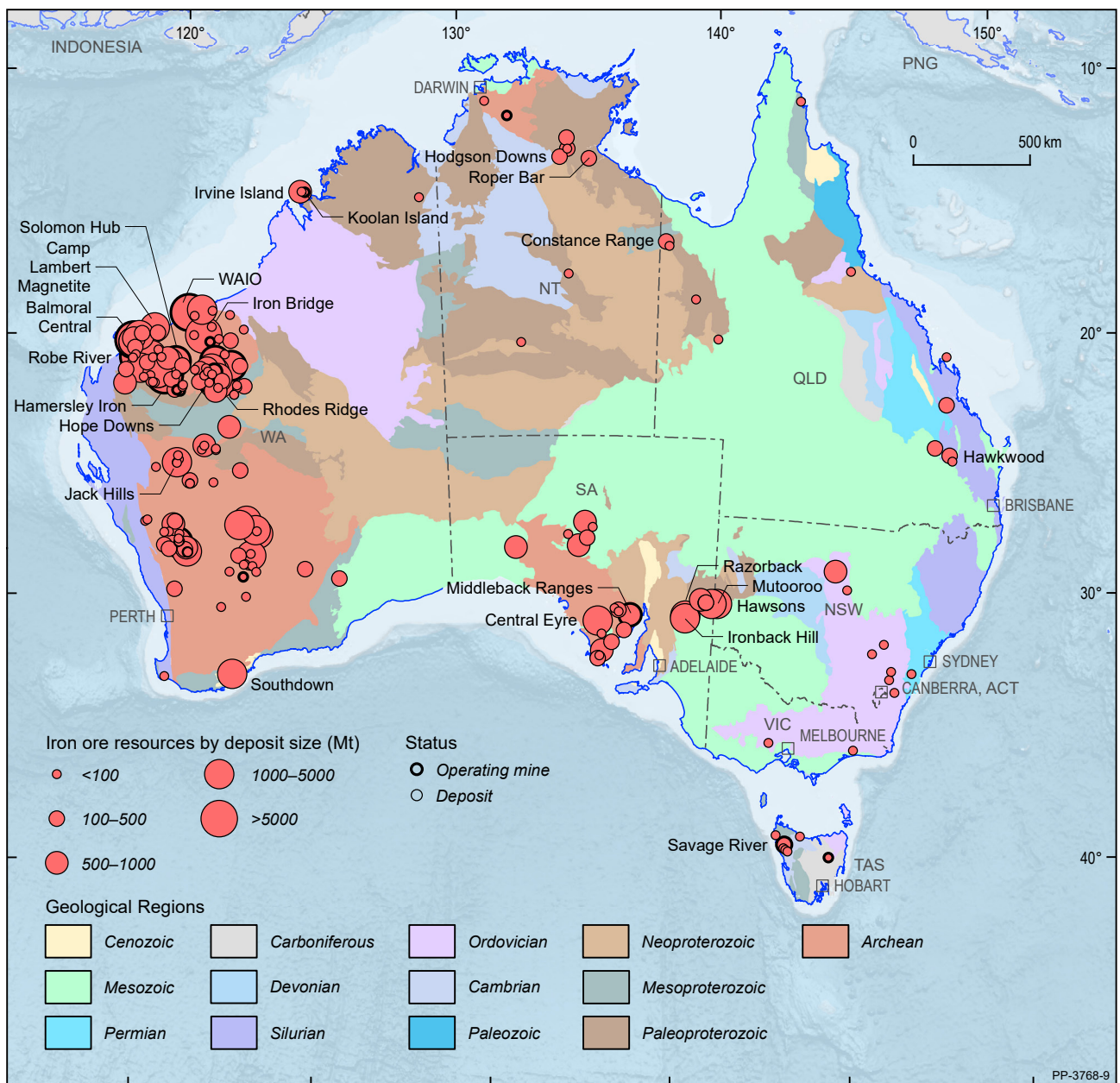


Figure 20 Australian iron ore deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Australian iron ore production growth is expected to continue as output from new operations comes on line. Developing projects include Eliwana²⁶, which is scheduled to be completed in late 2020, followed by South Flank²⁷ and Koodaideri²⁸, where both are anticipated to start in mid to late 2021. Another potential project that will support Australia's production growth is the developing Iron Ridge DSO project, which also aims for its first shipment of ore in early 2021²⁹.

Existing operations will also support Australia's continuing growth in iron ore production, through expansion projects from existing operations, such as the West Angelas C&D and the Robe Valley Mesa B, C and H mines, expected to come online in 2021³⁰. This supports the 15% production growth for iron ore projected by the Office of the Chief Economist for their outlook period³¹.

22. Office of the Chief Economist (Department of Industry, Science, Energy and Resources), Resources and Energy Quarterly, March 2020. See <https://publications.industry.gov.au/publications/resourcesandenergyquarterlymarch2020/documents/Resources-and-Energy-Quarterly-March-2020-Iron-Ore.pdf> (accessed 18 December 2020).
23. Reserve Bank of Australia, The Recent Increase in Iron Ore Prices and Implications for the Australian Economy (Report, August 2019). See <https://www.rba.gov.au/publications/smp/2019/aug/pdf/box-b-the-recent-increase-in-iron-ore-prices-and-implications-for-the-australian-economy.pdf> (accessed 18 December 2020).
24. Barrera, Priscila, Iron Outlook 2020: Prices to Stabilize Following Supply Shock (Investing News Article, 1 January 2020). See <http://investingnews.com/daily/resource-investing/base-metals-investing/iron-investing/iron-outlook/> (accessed 18 December 2020).
25. See above n 23.
26. Fortescue Metals Group, Eliwana Project Announcement (ASX Announcement, 28 May 2018). See https://www.fmg.com.au/docs/default-source/announcements/eliwana-project-announcement.pdf?sfvrsn=b23b5e83_6 (accessed 18 December 2020).
27. BHP, BHP Operational Review for the Year Ended 30 June 2020 (ASX Announcement, 21 July 2020). See <https://www.asx.com.au/asxpdf/20200721/pdf/44kpkd8gc3s6l1.pdf> (accessed 18 December 2020).
28. Rio Tinto, Rio Tinto approves \$2.6 billion investment in Koodaideri iron ore mine (ASX Announcement, 29 November 2018). See <https://www.asx.com.au/asxpdf/20181129/pdf/440rjgj4h0jind.pdf> (accessed 18 December 2020).
29. Fenix Resources Ltd, Iron Ridge Project Site Works Commence (ASX Announcement, 21 September 2020). See <https://www.asx.com.au/asxpdf/20200921/pdf/44mtbz47b2qx4t.pdf> (accessed 18 December 2020).
30. Rio Tinto, Interim Results 2020 (ASX Announcement, 29 July 2020). See <https://www.asx.com.au/asxpdf/20200729/pdf/44kypftdntvqscx.pdf> (accessed 18 December 2020).
31. See above n 22.



Mineral exploration in the Pilbara region of Western Australia. Australia has the largest share of the world's economic resources of iron ore and the Pilbara region of Western Australia hosts 83% of Australia's economic inventory.

At the end of December 2019, Australia's identified magnetite resource was 19,437 Mt, representing 38% of the national EDR of iron ore. Not unexpectedly, most of the magnetite EDR also occur in Western Australia (81%), while South Australia's magnetite EDR remain the same at 13%, with the remaining resource occurring in Tasmania, New South Wales and Victoria. A review of the status of Australia's iron ore deposits has reduced Australia's Inferred Resources by 3% from 94,100 Mt in 2018 to 91,059 Mt in 2019.

Reserve or resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. Resource life for iron ore is expected to fluctuate as mine production responds to market demand.

This is clearly seen with the falling resource life for iron ore from the 1980s to around the turn of this century as new resource discoveries were outpaced by rising production (Figure 21). It is only since 2003 that exploration drilling has added to the resource base, enabling resources to keep pace with rising production.

Iron ore exploration in Australia remained strong in 2019, increasing by 16% to \$349.6 million (Figure 6), accounting for 13% of Australia's total mineral exploration expenditure. Not unexpectedly, the bulk of the exploration expenditure and activities were centred in Western Australia where most of Australia's iron ore deposits occur. Around 96% (\$336.5 million) of iron ore exploration expenditure was spent in Western Australia, with 2% in South Australia.

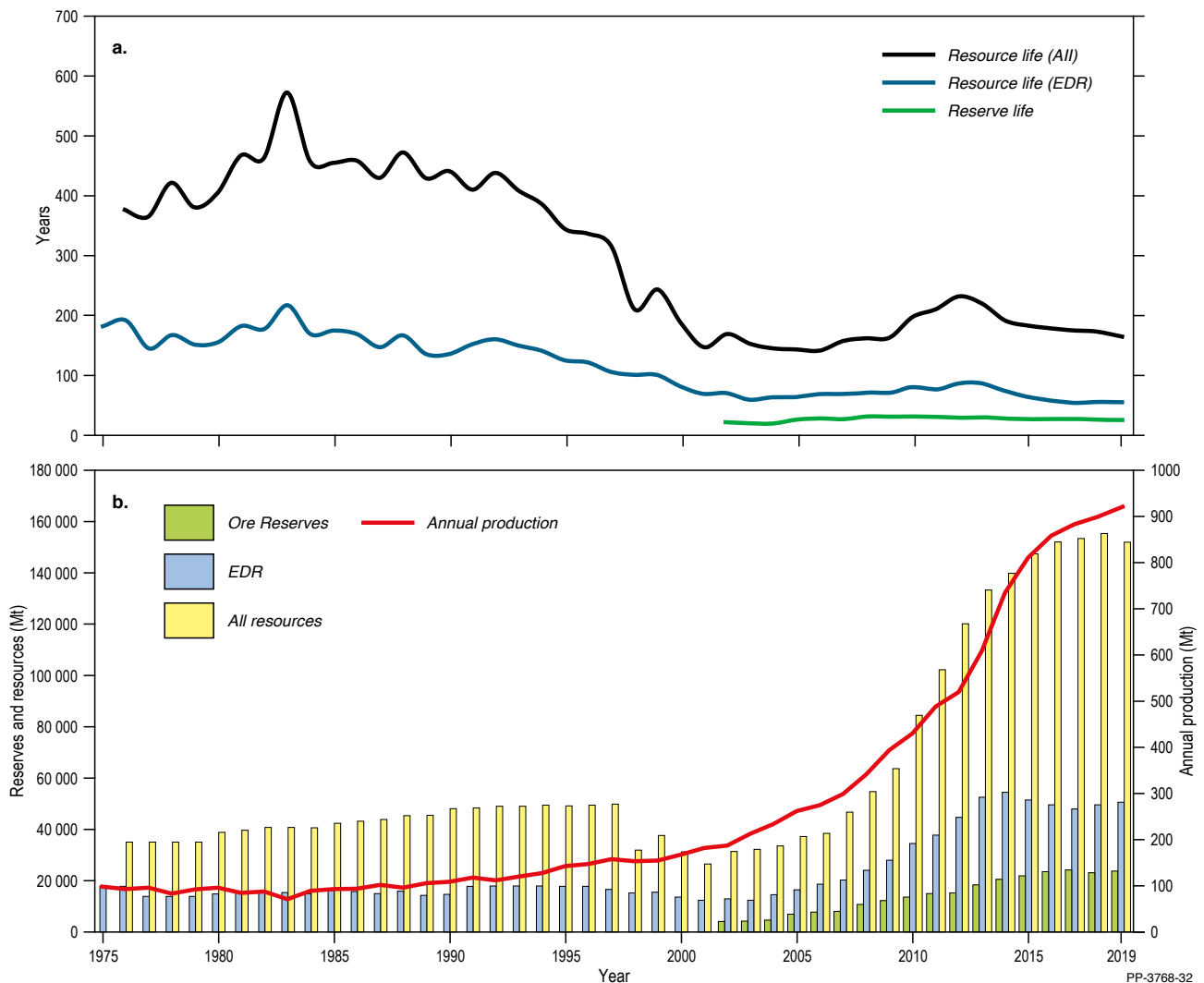


Figure 21 (a) Trends in iron ore reserve and resource life. These ratios are derived from (b) iron Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

Lead, Zinc and Silver

Australia's EDR of lead were 37.31 Mt in 2019 (Table 3), up 4% from 35.78 Mt in 2018 (Table 4). Australia ranks first globally with 41% of the world's economic resources (Table 8), and second for production (11%; Table 8), behind China (47%).

Australia's EDR of zinc were 68.92 Mt in 2019 (Table 3), up 3% from 66.96 Mt in 2018 (Table 4). Australia ranks first globally with 27% of the world's economic resources (Table 8), and third for production (10%; Table 8), behind China (34%) and Peru (11%).

Australia's EDR of silver were 90.26 kt in 2019 (Table 3), up 2% from 88.36 kt in 2018 (Table 4). Australia ranks third globally with 16% of the world's economic resources (Table 8), behind Peru and Poland, and seventh for production (5%; Table 8), behind Mexico (23%), Peru (14%), China (13%), Russia (8%), Poland (6%) and Chile (5%).

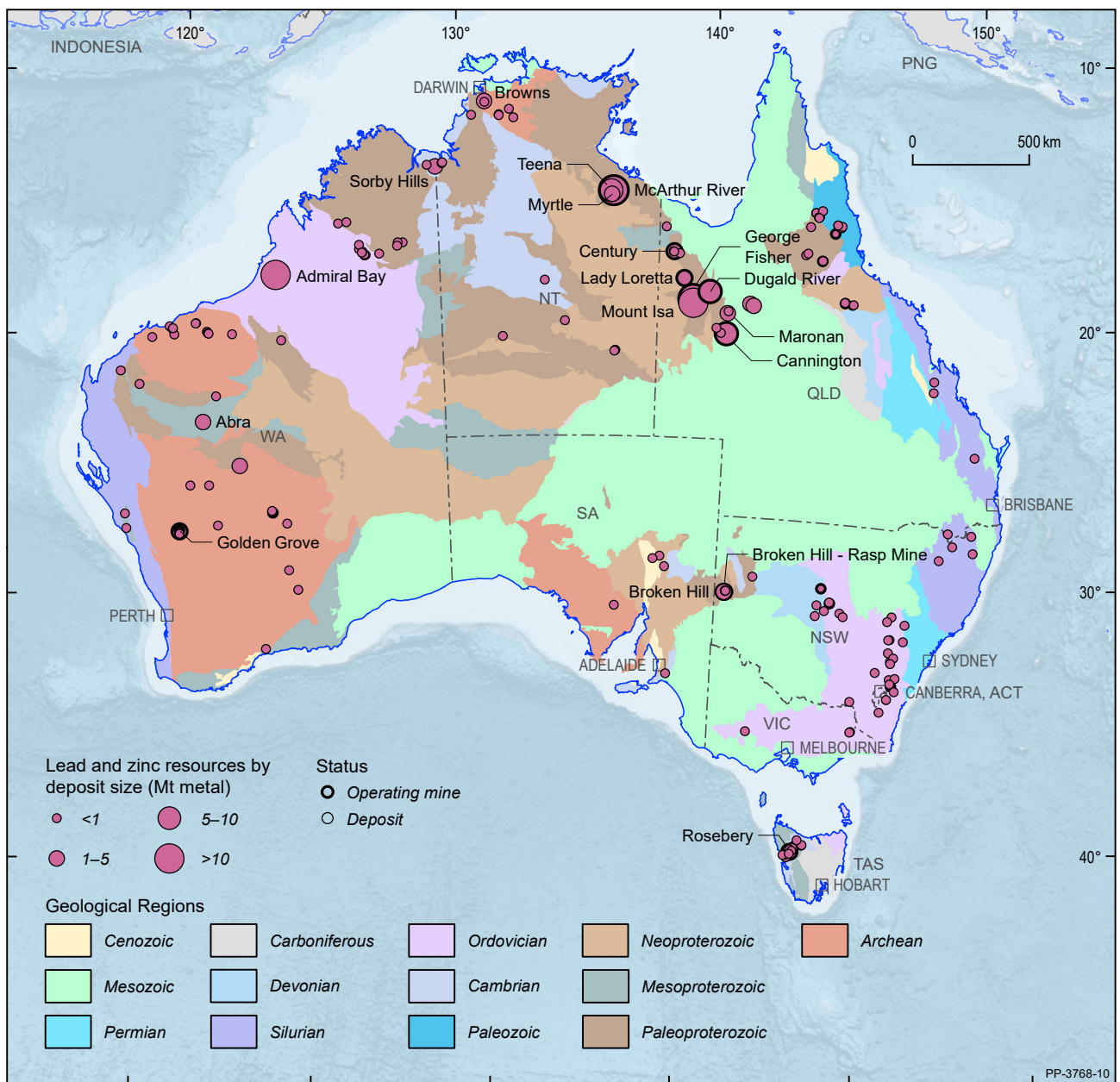


Figure 22 Australian lead and zinc deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Operating mines and deposits for lead and zinc are shown in Figure 22 and silver in Figure 23, on a total resource basis. Virtually all of Australia's EDR of zinc, lead and silver occur within hard-rock sulphide deposits, with resources in all states and the Northern Territory, but with the largest proportion of EDR for all three metals in Queensland (Figure 2). The Carpentaria Zinc Belt, which extends from northwest Queensland into the northeast Northern Territory is the largest repository of zinc-lead-silver deposits in Australia, including the major George Fisher-Hilton and McArthur River mines as well as some smaller, but still globally significant, deposits.

Between 2012 and 2016, five major global zinc deposits, including the Century and Black Star (Mount Isa) deposits in Queensland, closed. In 2015, Glencore Pty Ltd decreased its global zinc production by one third, partly from deposits in northern Australia. The closures and decreased zinc (and lead) production initially resulted in increasing zinc and lead prices until February-March 2018, followed by a broad trend of decreasing prices to the end of 2019.

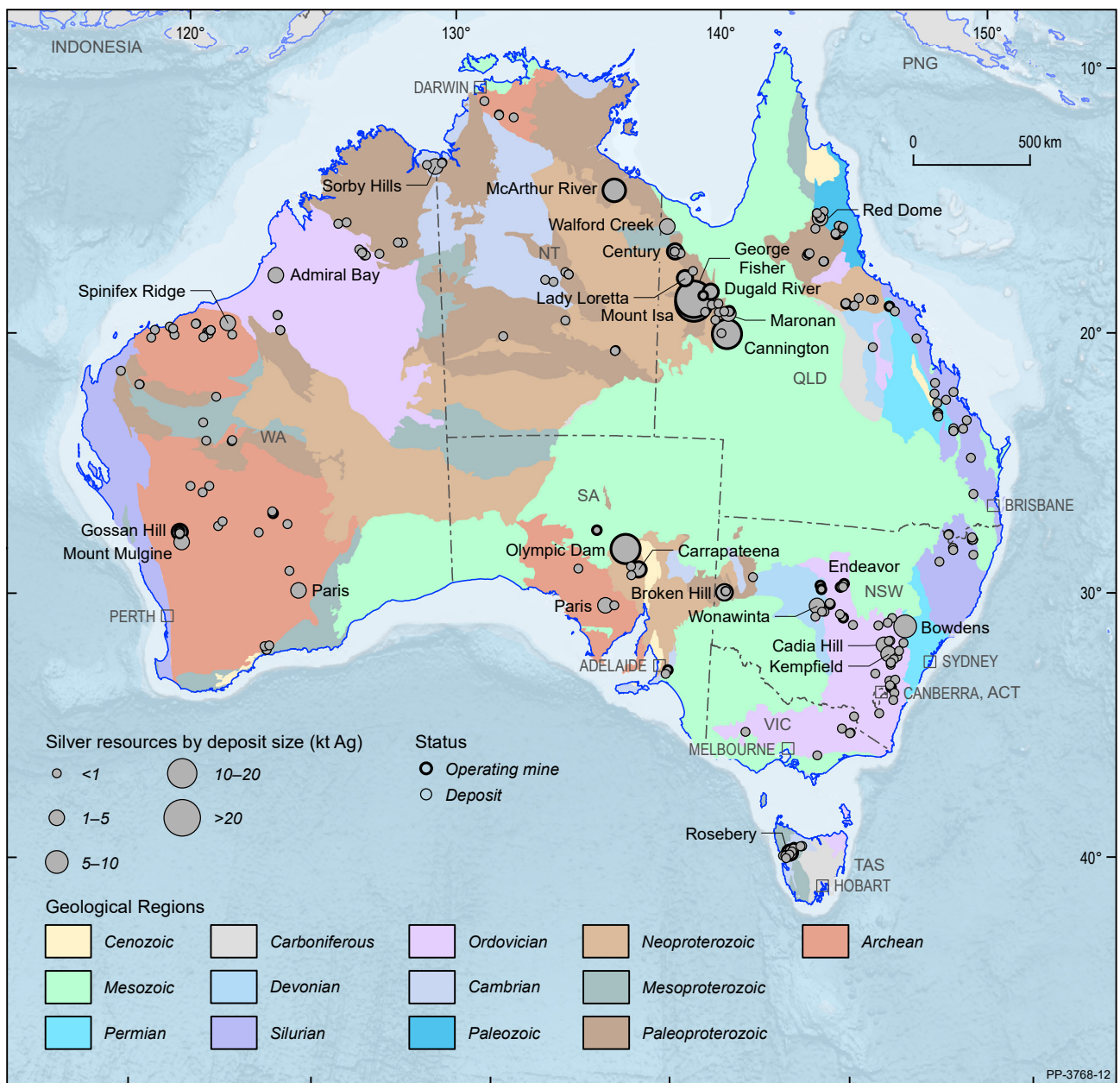


Figure 23 Australian silver deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

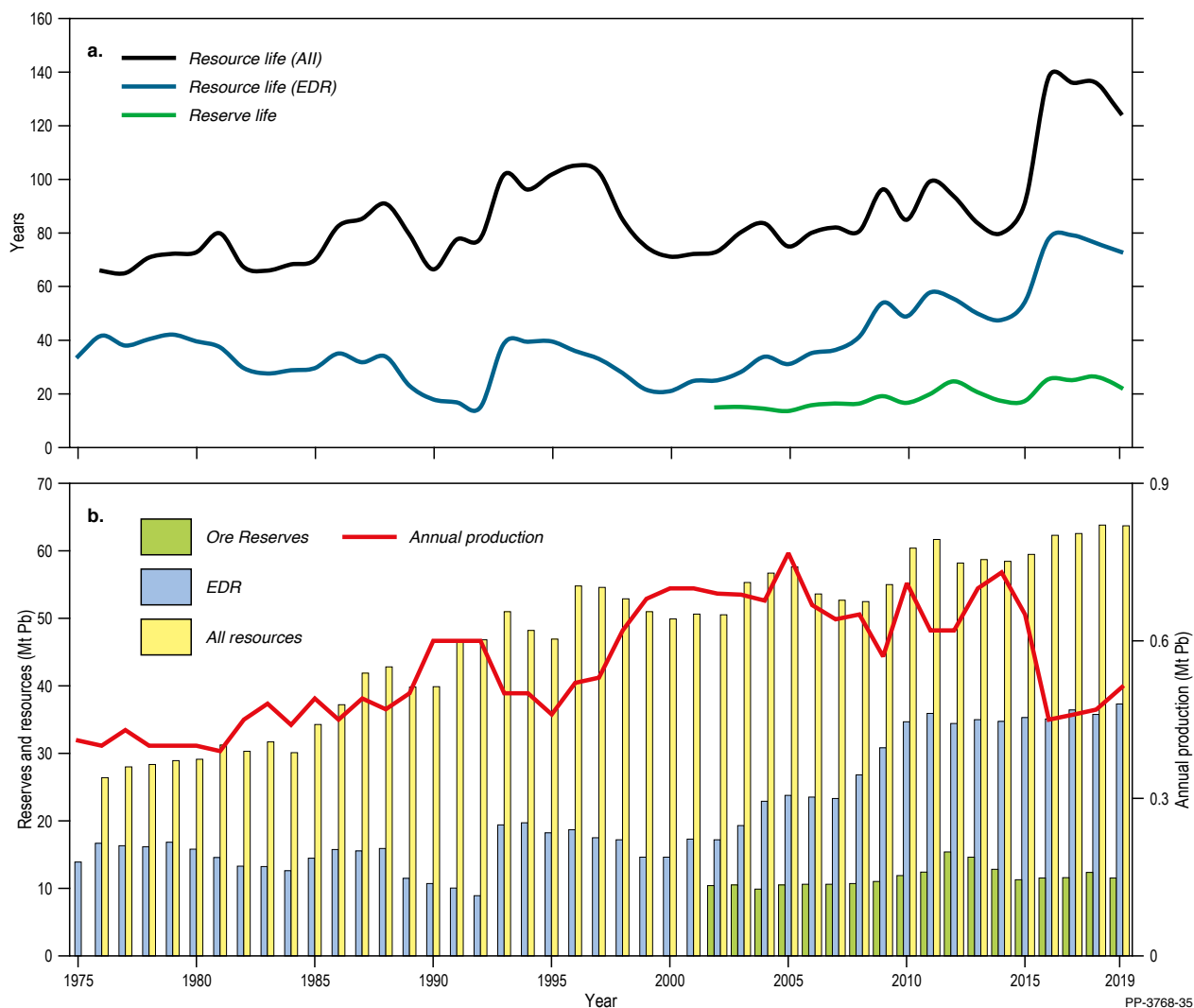


Figure 24 (a) Trends in lead reserve and resource life. These ratios are derived from (b) lead Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt Pb = million tonnes of contained lead. Prior to 2002, Ore Reserves were not recorded.

Exploration spend for lead-zinc-silver decreased 18% in 2019 to \$80.5 million after an increase in 2018 (\$98.4 million; Figure 6). Exploration for zinc, lead and silver deposits in Australia since 2012 has been geographically targeted, with much of the exploration concentrated in the Carpentaria Zinc Belt. Other areas that have produced significant results include other parts of the Northern Territory, western and central New South Wales and northeastern Queensland.

The most significant discovery in the last decade was the Teena deposit near McArthur River, discovered in 2013. The Walford Creek deposit has also seen significant exploration and an upgrade to resources, which include copper and cobalt in addition to zinc, lead and silver.

In New South Wales, exploration in the Cobar region has seen some significant discoveries and the Hera and Woodlawn mines have (re)opened since 2012; although the latter has been affected by the COVID-19 pandemic and was placed in care and maintenance in 2020. Exploration in the Cobar region has seen some significant discoveries.

Ore reserves of zinc, lead and silver (Table 2) have remained relatively constant over recent years (Figure 24, Figure 25 and Figure 26). Reserve life, the ratio of reserves to production, was 18, 23 and 21 years for zinc, lead and silver, respectively (Table 9). The 2019 reserve life for zinc (18 years) is lower than that of 2018 (22 years) and continues the trend of decreasing reserve life seen in 2018 (Figure 25). This is due mostly to increased production. For lead, reserve life in 2019 (23 years) is also lower than 2018 (26 years) but silver (21 years) is unchanged.

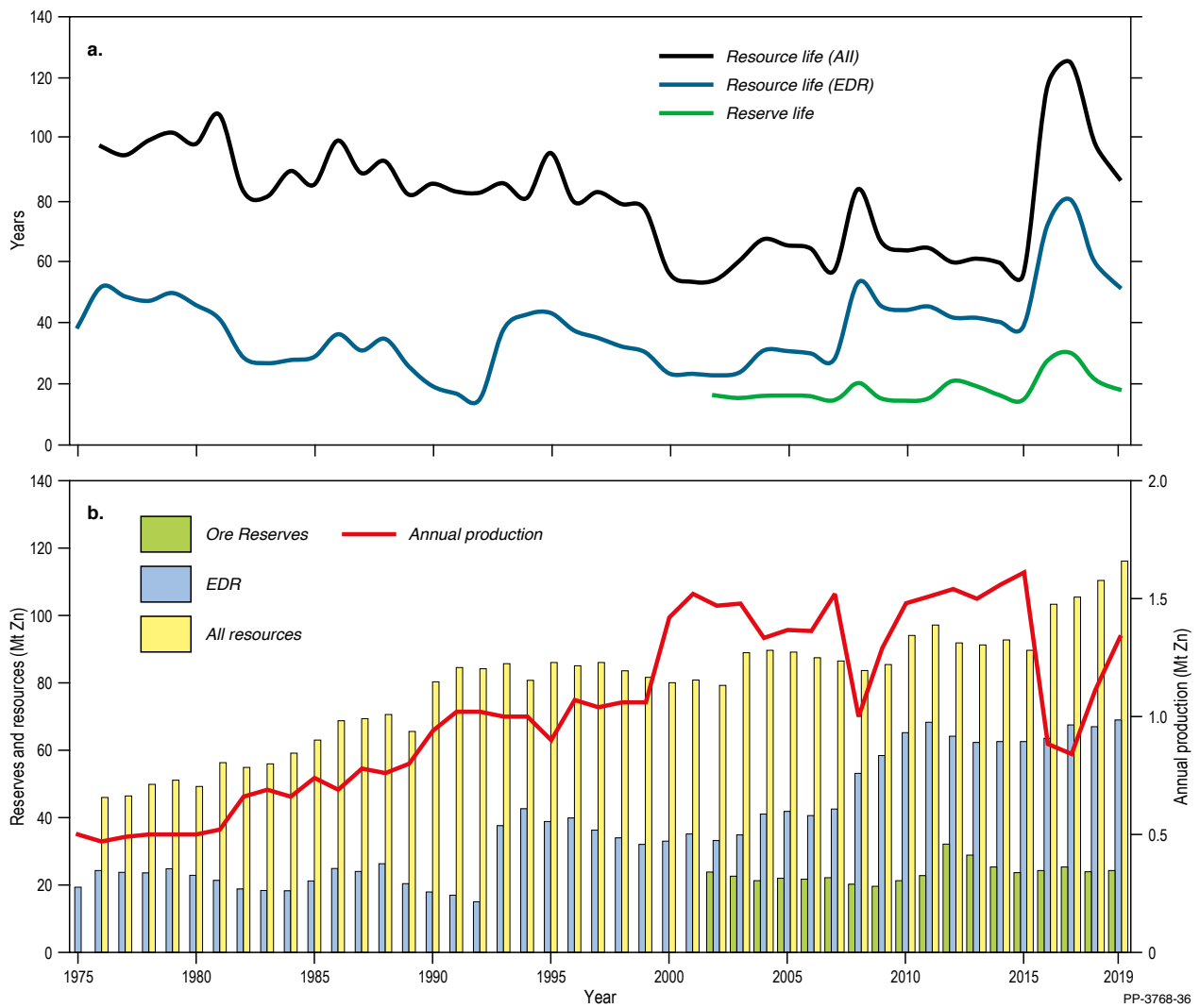


Figure 25 (a) Trends in zinc reserve and resource life. These ratios are derived from (b) zinc Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt Zn = million tonnes of contained zinc. Prior to 2002, Ore Reserves were not recorded.

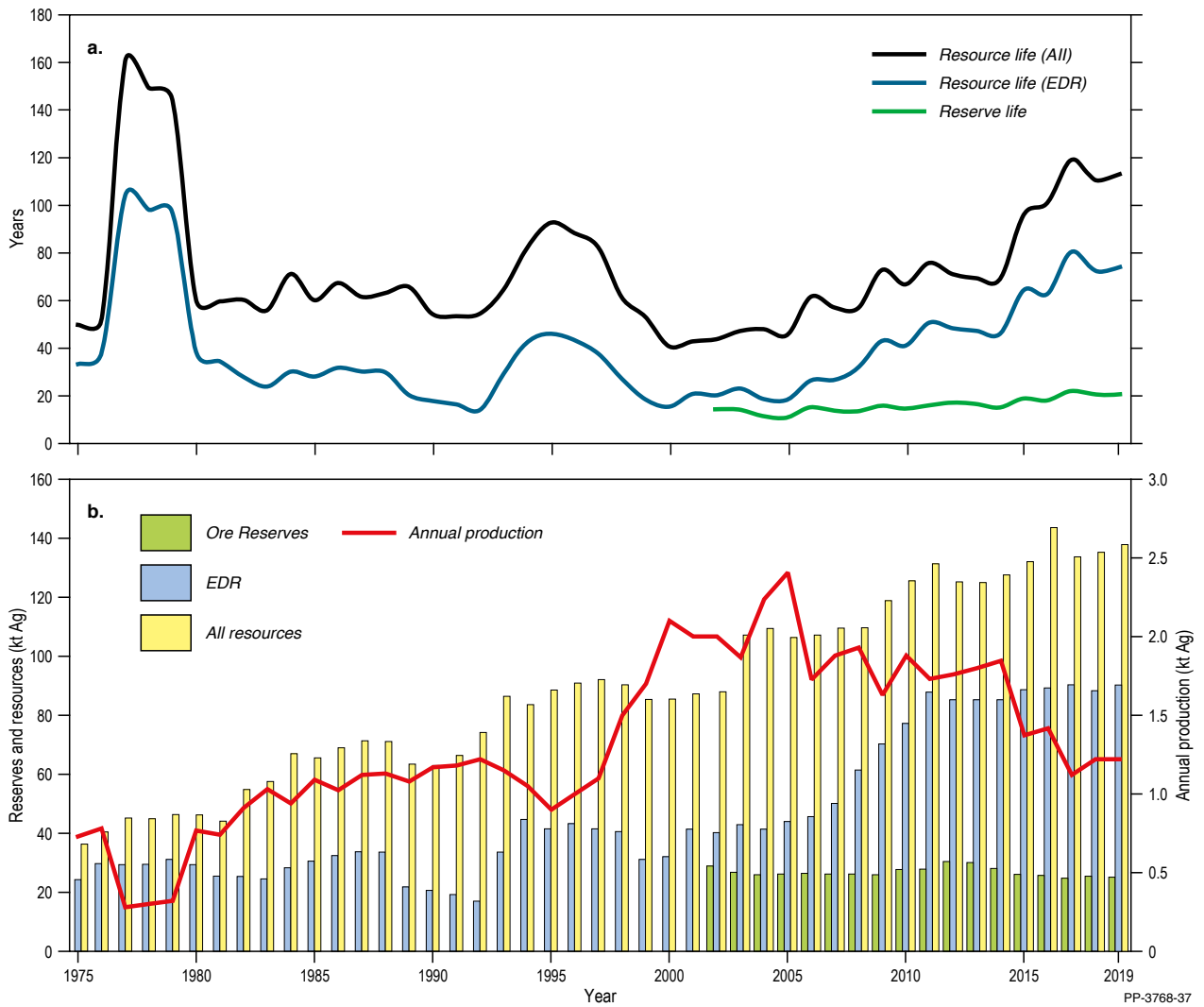


Figure 26 (a) Trends in silver reserve and resource life. These ratios are derived from (b) silver Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: kt Ag = thousand tonnes of contained silver. Prior to 2002, Ore Reserves were not recorded.

Lithium, Tantalum and Niobium

Lithium, tantalum and niobium are chemically associated and are mostly hosted together in hard rock pegmatite deposits, mainly occurring in Western Australia. Lithium, tantalum and niobium are all regarded as a critical minerals by many advanced economies, and are listed in *Australia's Critical Minerals Strategy 2019*³².

Australia's EDR of lithium were 5,702 kt in 2019 (Table 3), up 5% from 5,437 kt in 2018 (Table 4). Australia ranks second globally with 29% of the world's economic resources (Table 8), behind Chile (44%), and first for production (56%; Table 8). All of Australia's EDR of lithium occur within hard rock pegmatite deposits.

Over 84% of Australia's lithium EDR are hosted by four deposits: Greenbushes, Wodgina, Pilgangoora (Pilbara Minerals Ltd) and Earl Grey. Other resources occur at Mount Cattlin, Mount Marion, Bald Hill and Kathleen Valley in the Yilgarn region of Western Australia; at Wodgina and Pilgangoora (Altura Ltd) in the Pilbara region of Western Australia; and at the Grants deposit (Finniss Project) in the Northern Territory. Operating mines and deposits are shown in Figure 27 on a total resource basis.

Lithium prices since 2019 have decreased, driven largely by both softening demand (due to slower growth in electric vehicle uptake) and oversupply. As a result, Australian producers have delayed planned mine expansions (e.g. at Greenbushes) and also reduced production rates (e.g. Pilgangoora (Pilbara Minerals)). Two mines—Bald Hill and Wodgina—ceased production in the second half of 2019 and are now on care and maintenance. The decrease in price and demand follows five years of heightened activity in the Australian lithium industry which had seen significant increases in resources and the number of operating mines (seven operating mines at the height of production).

In 2019, Tianqi Lithium Australia Pty Ltd commenced production of lithium hydroxide at their processing plant in Kwinana, Western Australia, using ore from their Greenbushes deposit. Once fully operational, the plant will produce 24 ktpa of battery-grade lithium hydroxide. The stage two expansion (to 48 ktpa of lithium hydroxide) has been placed on hold.

In 2019, Albemarle Corporation commenced construction of a lithium hydroxide processing plant at Kemerton, Western Australia. Albemarle announced a downgrade in processing capacity of the plant in mid-2019, reducing production trains from seven to two. The company indicated an initial production capacity of about 50 ktpa of lithium hydroxide from the two trains. The company announced further spending cuts to the plant in 2020, with commissioning expected in 2021.

Prior to the recent downturn, there was a rapid growth in lithium resource delineation in Australia from 2016, evidenced by large increases in EDR (>800%) and total resources (>1,000%) of lithium. In the same period, total Ore Reserves increased by more than 2,000%. Increases in annual production were also significant, up over nine times as much as a decade ago. Ore Reserves at operating mines, based on 2019 production rates, have a reserve life of 69 years which extends to 84 years when Ore Reserves at other deposits are included (Table 9).

Australia's EDR of tantalum were 93.5 kt in 2019 (Table 3), up from 88.6 kt³³ in 2018 (Table 4). Australia holds 73% of the world's documented economic resources, ranking first on this basis (Table 8). However, it should be noted that the USGS figures, on which the ranking is based, do not include resource data for Rwanda, Congo, Nigeria, Brazil or China, all significant tantalum producers. Australia ranks sixth for tantalum production with 5% of the total world production (Table 8).

Western Australia hosts 89% of Australia's EDR of tantalum, with over 61% occurring at the Greenbushes and Wodgina deposits. Other resources include the lithium pegmatites at Pilgangoora, Kathleen Valley, Mount Cattlin, Bald Hill (all in Western Australia), and at the Dubbo (Toongi) zirconium-hafnium-niobium-yttrium-rare earth deposit in New South Wales (Figure 27).

Over the last year, Australia's tantalum Ore Reserves have slightly decreased from 39.6 kt in 2018 to 39.2 kt in 2019. Tantalum production in Australia has increased from 60 t in 2018 to 96 t in 2019. Increases in production have largely been a by-product of the heightened activity in the Australian lithium industry in this period.

³². See above n 7.

³³. Geoscience Australia revised down the 2018 tantalum EDR from 99.3 kt (reported in Australia's Identified Mineral Resources 2019) to 88.6 kt. New information has become available resulting a re-evaluation of Australia's tantalum inventory for that period.

Australia's EDR of Niobium were 216 kt in 2019 (Table 3), unchanged from 2018 (Table 4). Niobium commonly occurs within lithium-tantalum pegmatite deposits, but all of Australia's EDR of niobium occur at two (per)alkaline deposits: the Brockman rare earth-niobium-zirconium project (also known as Hastings) in Western Australia; and the Dubbo deposit in New South Wales (Figure 27).

Although Australia ranks third in the world for economic resources of niobium, it only holds 2% (Table 8), as world resources are overwhelmingly dominated by Brazil (84%). Australia's total Ore Reserves of niobium, as of 2019, were 58 kt (Table 2), all from the Dubbo deposit. This is unchanged from 2018. Annual production figures for Australia are not known but are not considered to be significant.

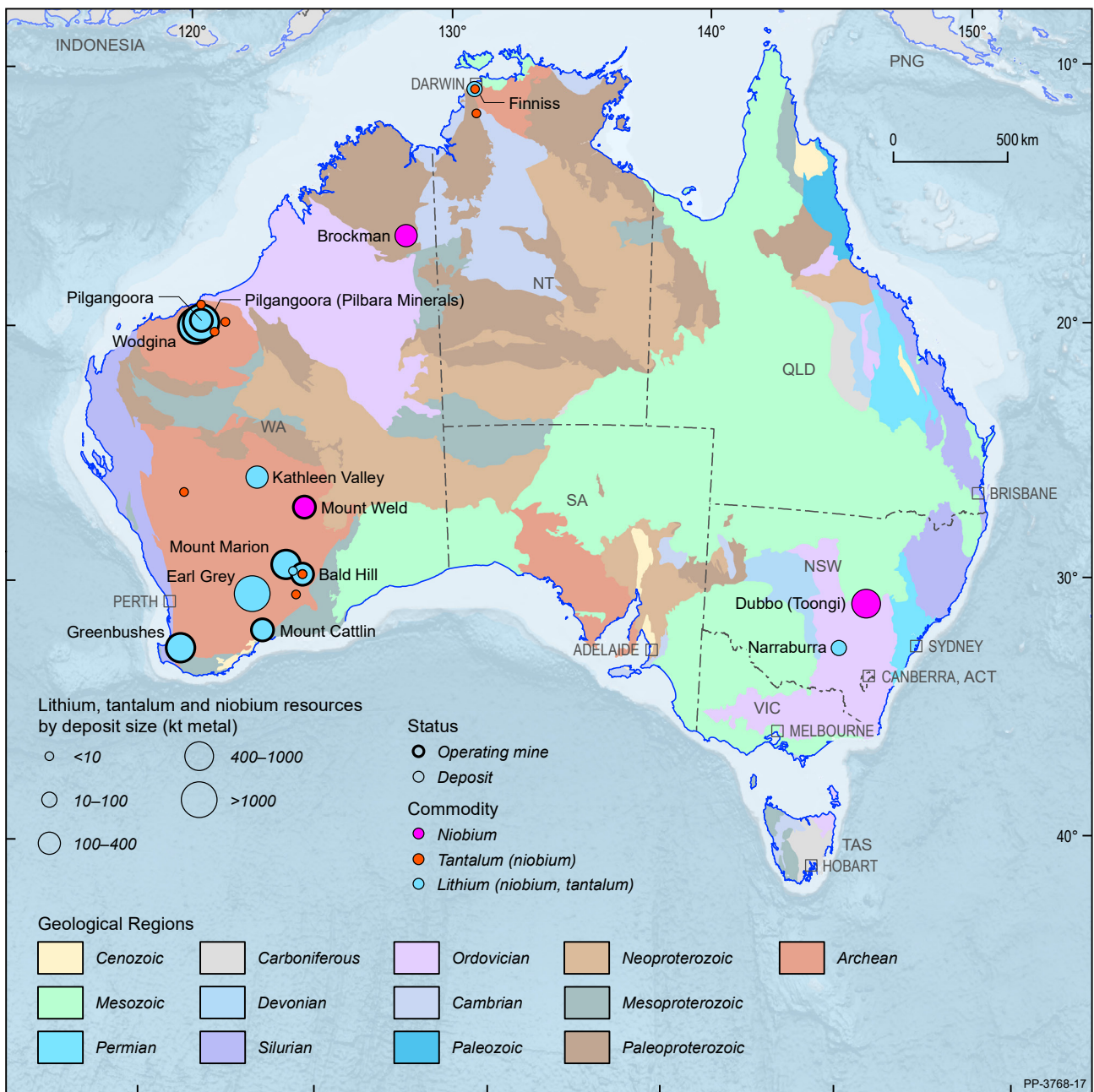


Figure 27 Australian lithium, tantalum and niobium deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic + Inferred). For clarity, only major or significant deposits are labelled.

Magnesite

In 2019, Australia's EDR of magnesite were 285 Mt (Table 3), a decrease of 31 Mt when compared to 2018 (Table 4), representing approximately 3% of the world total (Table 8). The South Australia Department of Premier and Cabinet reported magnesite production of 5,111 t in 2019, up (11%) from 4,587 t in 2018. The Queensland Department of Natural Resources Mines and Energy reported magnesite production of 407,761 t in 2018–19, also up (58%) from 258,859 t in 2017–18. Apart from South Australia and Queensland, magnesite EDR also occur in New South Wales, Western Australia and the Northern Territory (Figure 28).

Australia's magnesite EDR comprises approximately 3% of total world economic resources and Australia is a minor producer (1%; Table 8). The world's largest resources are found in North Korea (27%), followed by Russia (27%) and China (12%). Production is led by China (69%), Turkey (7%) and Brazil (6%).

Magnesium compounds are used for agriculture, chemical, construction, environmental and industrial applications. They also used for refractories in the form of dead-burned magnesia. Magnesium is regarded as a critical mineral by many advanced economies, including Australia which lists it in *Australia's Critical Minerals Strategy 2019*³⁴.

34. See above n 7.

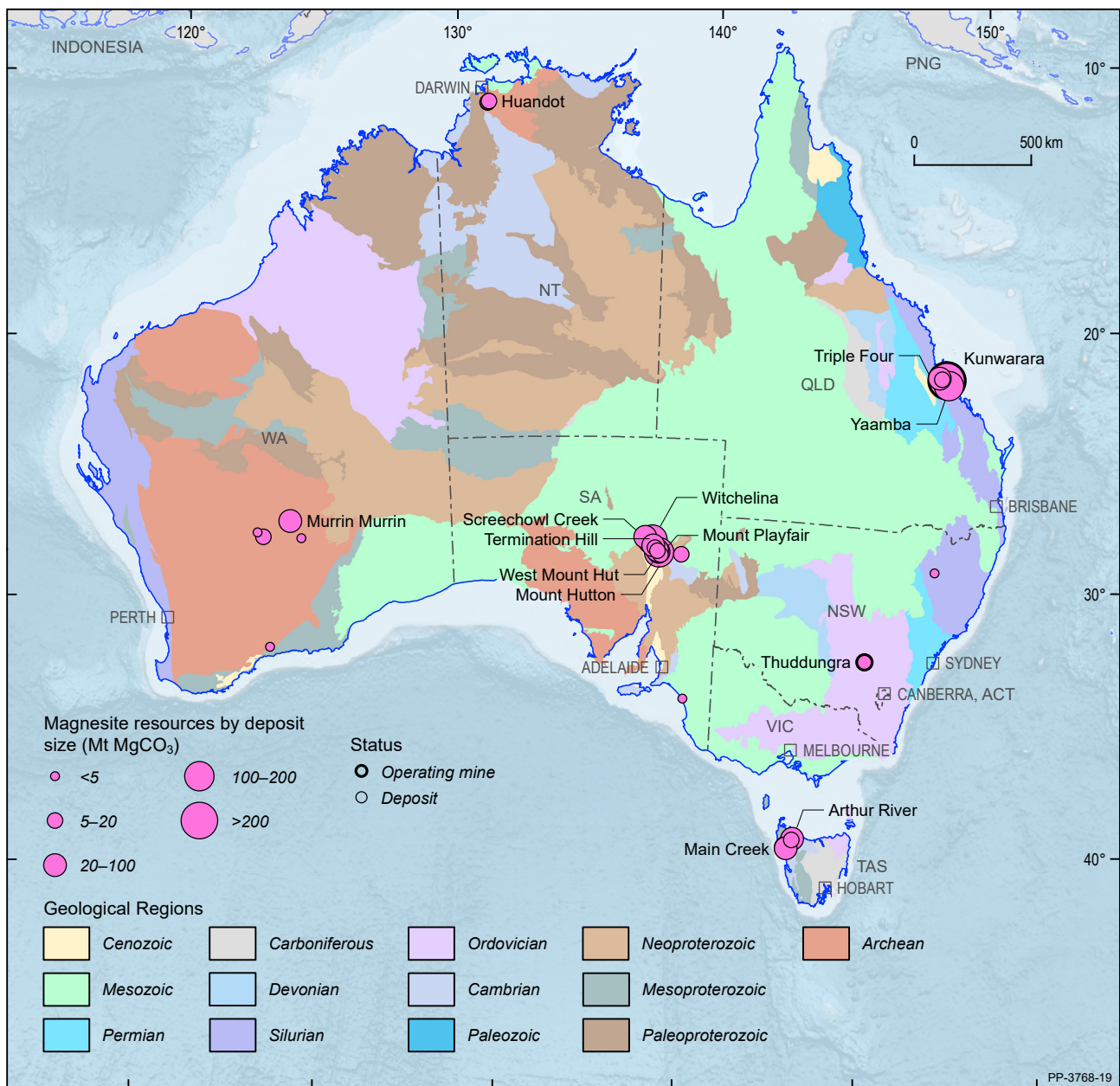


Figure 28 Australian magnesite deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Manganese Ore

Australia's EDR of manganese ore went up 40 Mt in 2019 to 272 Mt (Table 3), a 17% increase, compared to 2018 (Table 4). This ranks Australia's resources as the world's fourth largest, accounting for 14% of global manganese resources (Table 8) behind South Africa (31%), Brazil (17%) and Ukraine (17%). All of Australia's EDR of manganese ore occur in the Northern Territory and Western Australia (Figure 2), although minor deposits also occur in other Australian states (Figure 29).

Australia's mine production of manganese ore increased to 7.5 Mt in 2019, a 7% increase over the previous year's production (7 Mt), reflecting increased production at all three of Australia's operating manganese mines—Groote Eylandt, Woodie Woodie and Bootu Creek (Table 1). Australia's manganese ore production accounts for 17% of world production, ranking second (Table 8) behind South Africa (29%). Manganese is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*³⁵.

35. See above n 7.

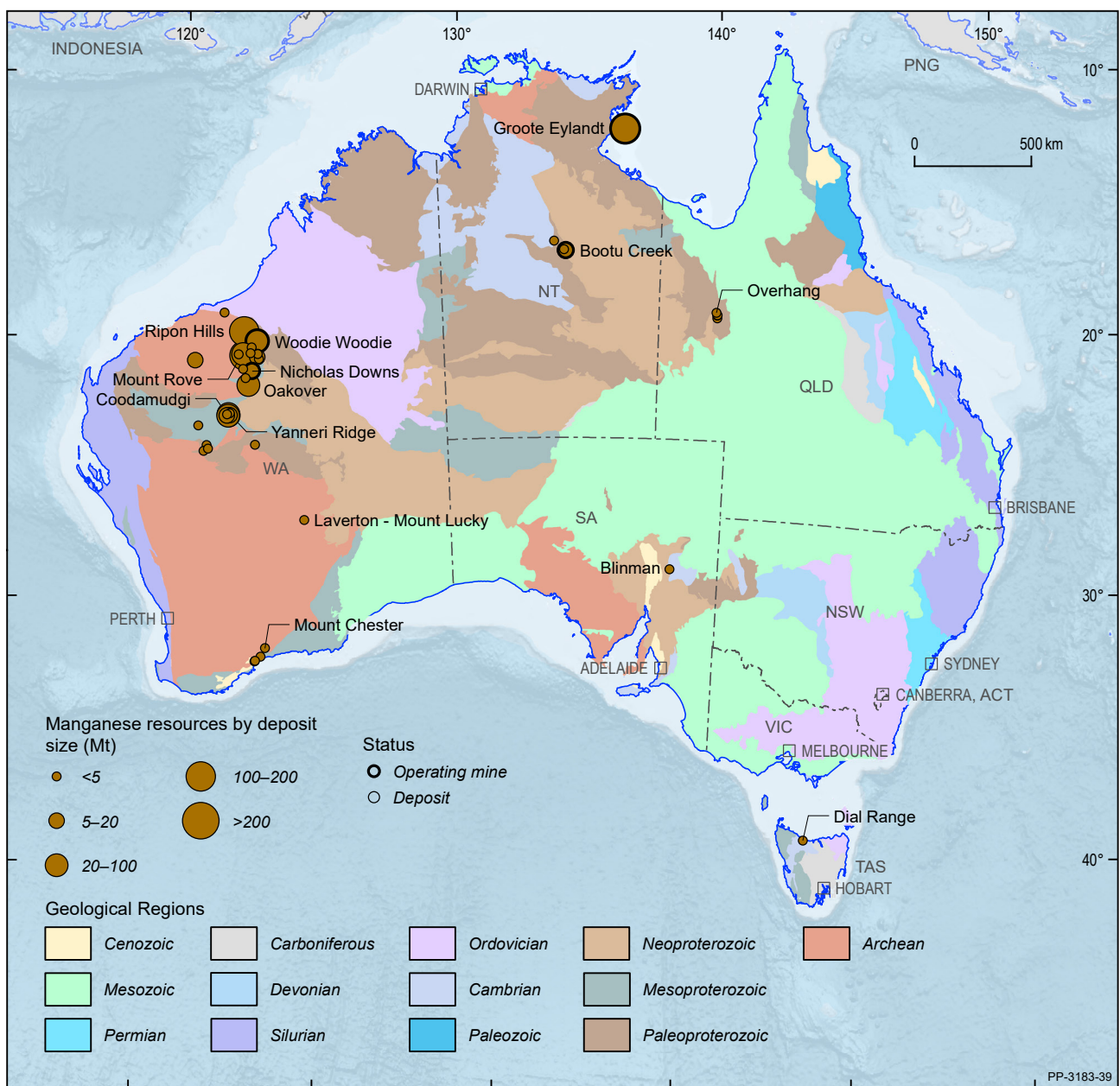


Figure 29 Australian manganese deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Mineral Sands

Every Australian state and the Northern Territory hosts heavy mineral sand deposits (Figure 30). The deposits contain a variety of minerals depending on their original source rock and the natural processes they have undergone during their formation. The main minerals of commercial interest are zircon and the titanium-bearing minerals ilmenite, rutile and leucoxene. Minor amounts of other minerals such as monazite and xenotime may also be present. Monazite commonly contains rare earth elements

and thorium. Neither has been recently produced from Australian mineral sand operations; however, growing demand for rare earths is prompting some operators to begin including them in their production plans. The majority of Australia's mineral sand resources are in the Murray Basin, encompassing parts of Victoria, New South Wales and South Australia; the Eucla Basin, in South Australia and Western Australia; and the Perth and Canning basins in Western Australia.

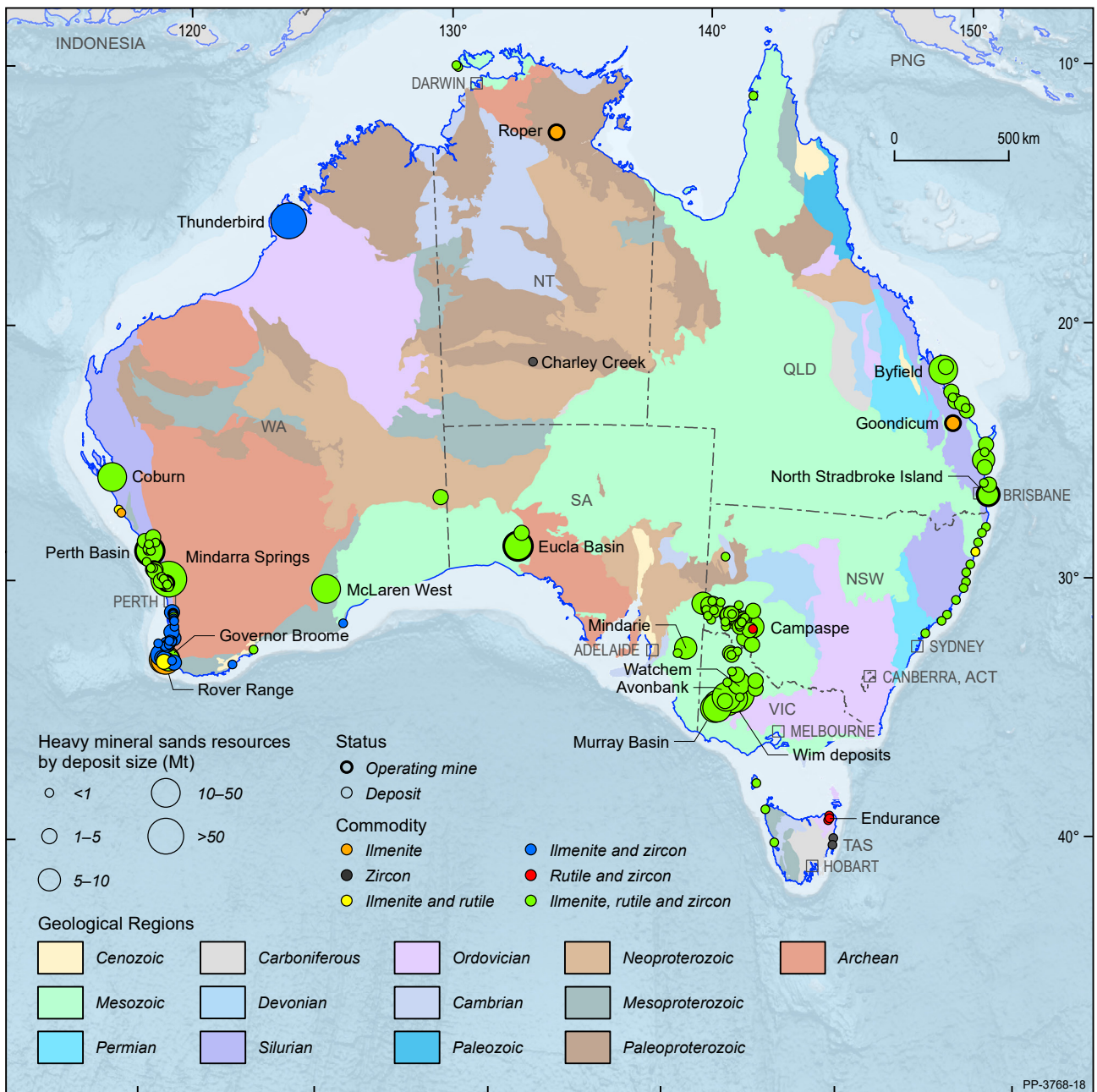


Figure 30 Australian heavy mineral sands deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

In 2019, Australia's mineral sand EDR were estimated to be 274.7 Mt of ilmenite, 35.4 Mt of rutile and 79.7 Mt of zircon (Table 3). These estimates are largely unchanged from 2018 (Table 4). They represent the world's:

- second largest economic resources of ilmenite (24% of global economic resources, Table 8) after China (34%) and ahead of India (12%);
- largest economic resources of rutile (65%; Table 8) followed by India (14%) and South Africa (12%); and

- largest economic resources of zircon (72%; Table 8) followed by South Africa (9%) and Mozambique (2%).

Australia also had Inferred Resources of 255.5 Mt of ilmenite, 35.9 Mt of rutile and 57.8 Mt of zircon plus smaller amounts regarded as subeconomic (Table 3). Heavy mineral sand deposits and operating mines are shown in (Figure 30) on a total resource basis.

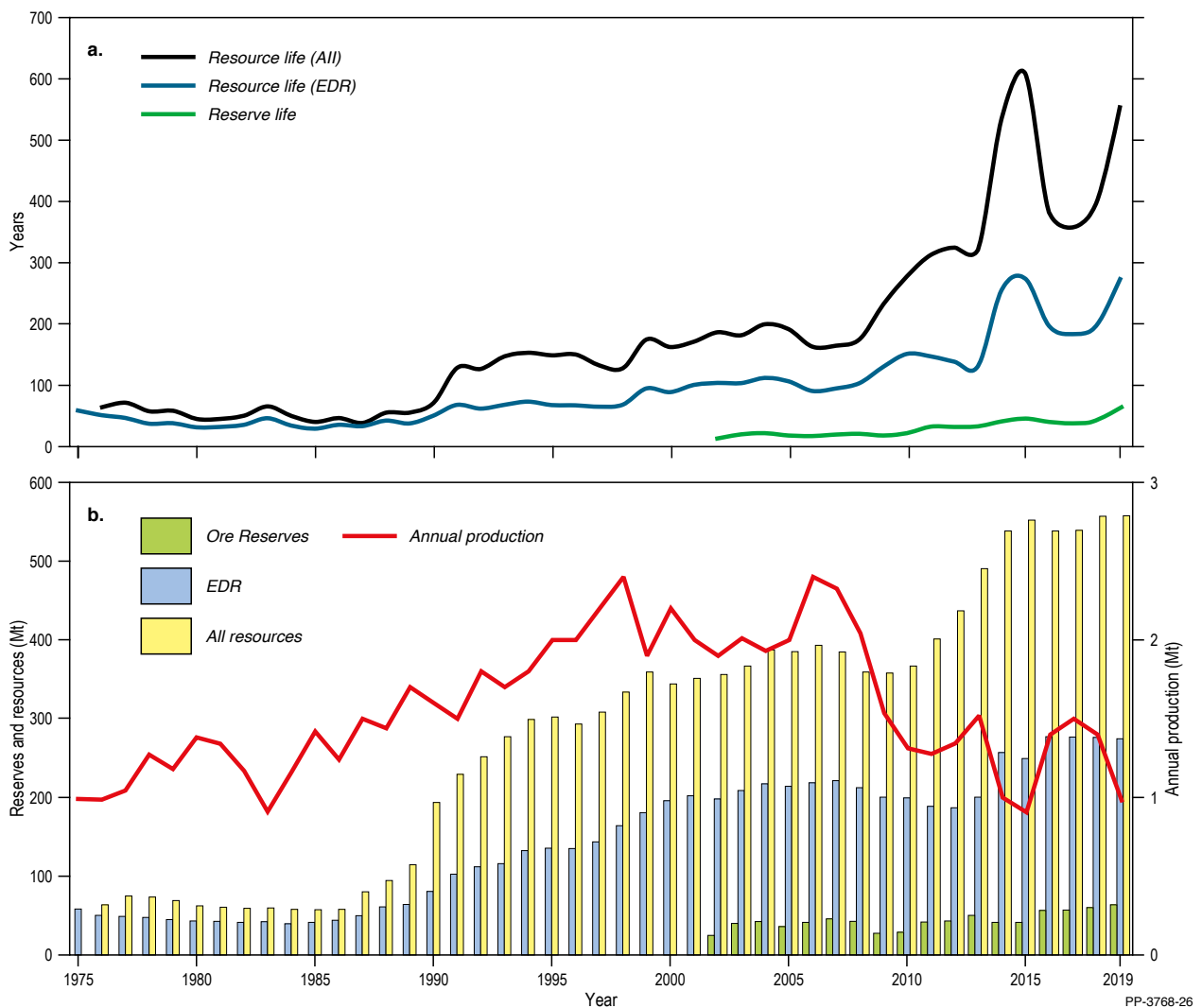


Figure 31 (a) Trends in ilmenite reserve and resource life. These ratios are derived from (b) ilmenite Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

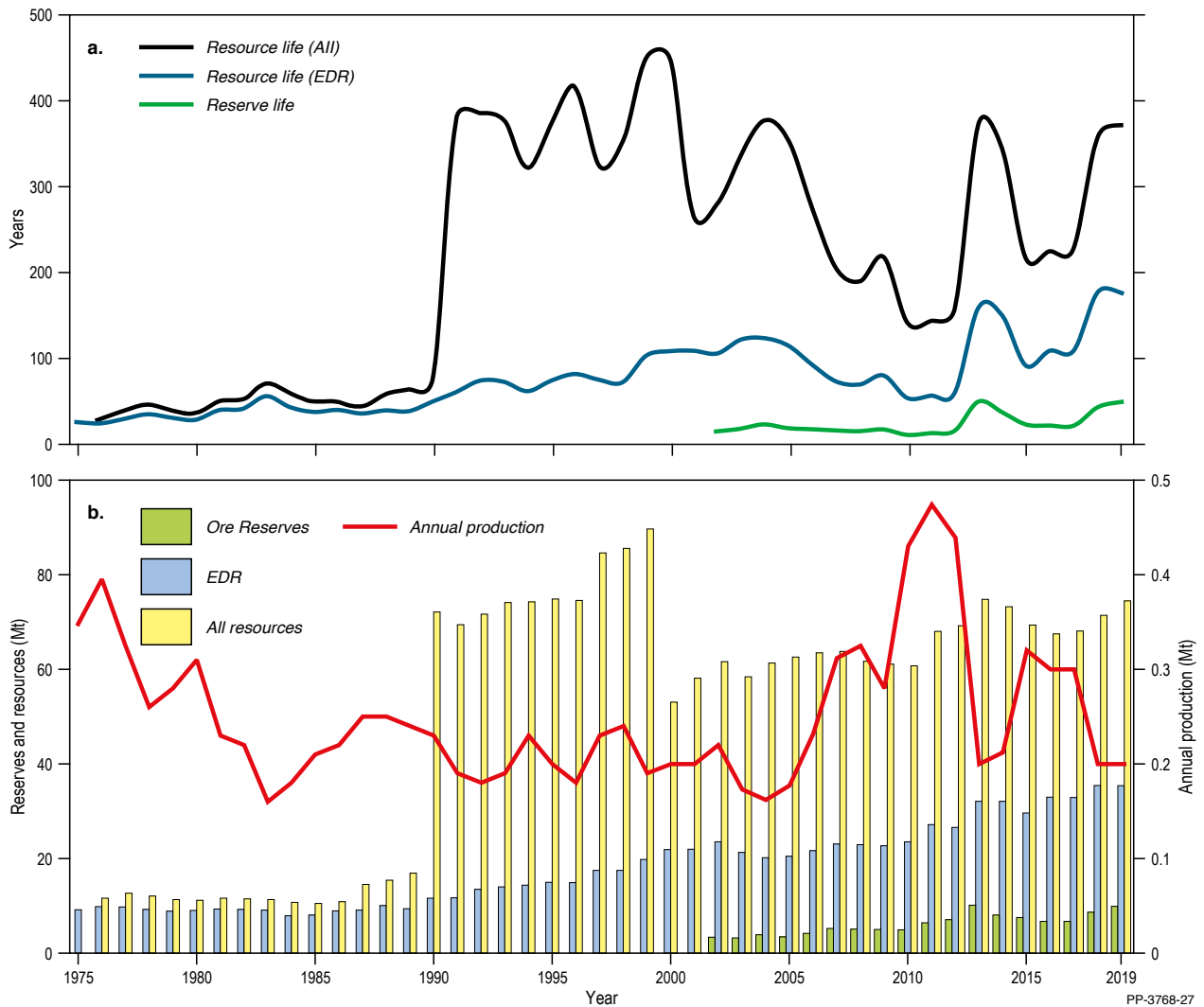


Figure 32 (a) Trends in rutile reserves and resource life. These ratios are derived from (b) rutile Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

In terms of total Ore Reserves, Australia had an estimated 63.6 Mt of ilmenite, 9.9 Mt of rutile and 24.9 Mt of zircon in 2019 (Table 2). Twelve operating mines produced a total of 1.0 Mt of ilmenite, 10 mines produced 0.2 Mt of rutile and 10 produced 0.5 Mt of zircon (Table 1), largely unchanged from 2018 production. Ore Reserves at these mines accounted for 26%, 24% and 18% of Australia's ilmenite, rutile and zircon Ore Reserves, respectively (Figure 1).

From 1990 onward, new mineral sand discoveries resulted in significant increases in mineral resource estimates (Figure 31, Figure 32, Figure 33). Initially, ilmenite production almost kept pace with the new discoveries so resource life only increased gradually (Figure 31). In the 2000s, however, lower than average production rates resulted in larger increases to resource life and, since 2011, ilmenite resource life has again been boosted with new resource delineation combined with dramatically decreased production from 2014 (Figure 31).

Unlike ilmenite, production rates for rutile and zircon from around 1987 to 2006 decreased slightly or were steady, although these minerals also had increased resource estimates (Figure 32 and Figure 33). As a result, the significant increases in resources estimates from around 1990 caused dramatic increases in resource life (Figure 32 and Figure 33). Since 1990, the resource life for rutile and zircon have increased and decreased conspicuously in response to variable production rates (Figure 32 and Figure 33). Increased zircon resource delineation since 2011 has also contributed to the most recent increase in resource life (Figure 33).

Expenditure for mineral sand exploration during 2019 was approximately \$34.7 million, largely unchanged since 2018 (\$34.5 million). In 2019, an estimated 0.676 Mt of ilmenite concentrate, 0.312 Mt of rutile concentrate and 0.710 Mt of zircon concentrate were exported from Australia, down 16%, no change and up 15%, respectively, on 2018 export figures.

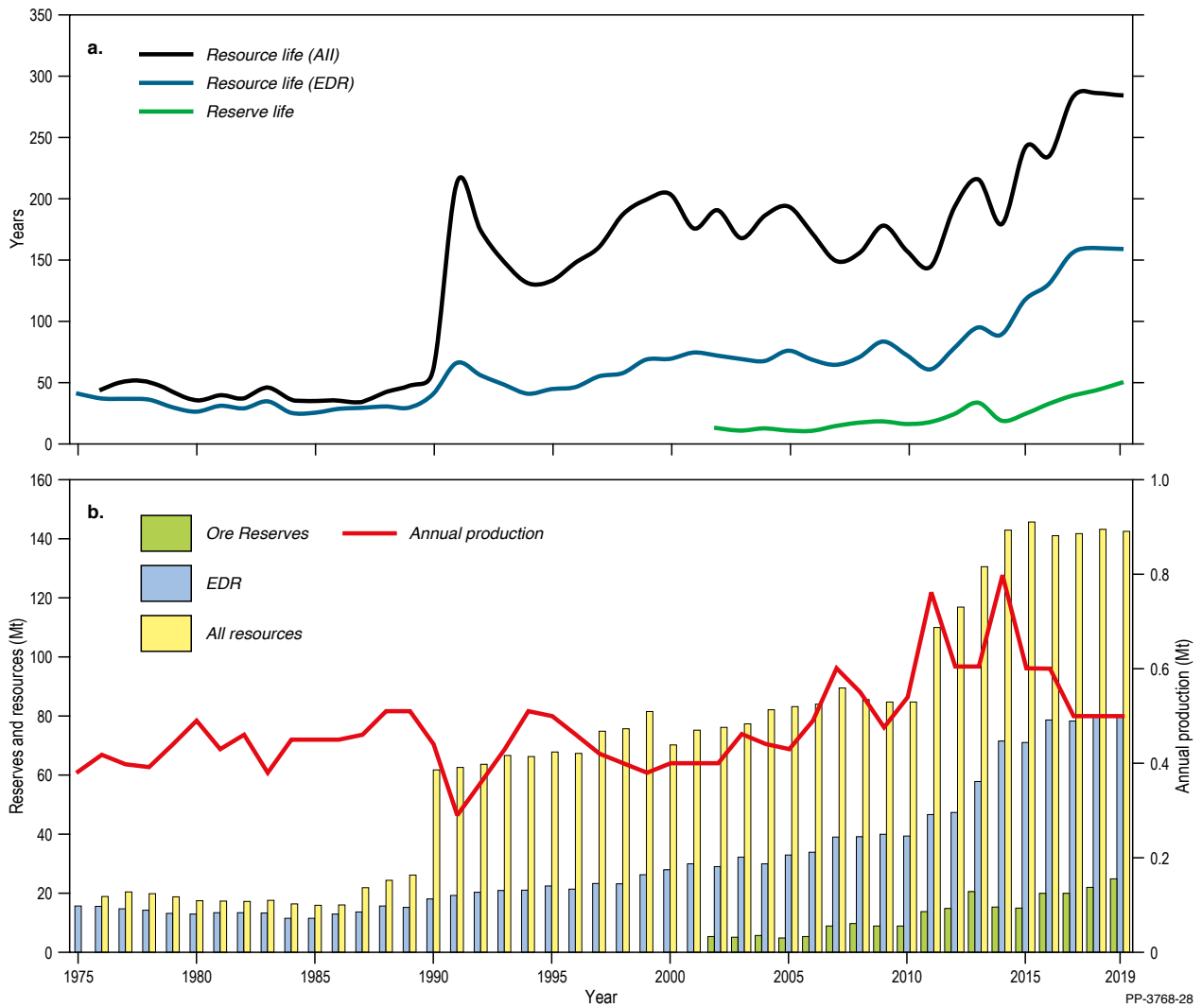


Figure 33 (a) Trends in zircon reserves and resource life. These ratios are derived from (b) zircon Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: Mt = million tonnes. Prior to 2002, Ore Reserves were not recorded.

Molybdenum

Australia's EDR of molybdenum in 2019 were 248 kt (Table 3), a 45% increase from 171 kt in 2018 (Table 4). Australia ranks seventh globally for economic molybdenum resources but only hosts approximately 1% of world resources (Table 8), which are dominated by China (46%), Peru (16%), the USA (15%) and Chile (8%). The bulk of Australia's EDR of molybdenum occur in Queensland (90%), followed by Western Australia

(7%) and the Northern Territory (2%; Figure 34). In 2019, Inferred Resources of molybdenum in Australia totalled 1,737 kt and another 366 kt of molybdenum were categorised as Paramarginal (Table 3).

Molybdenum is ductile, resistant to corrosion and has a high melting point. It is used in the production of alloys to increase strength, hardness and electrical conductivity.

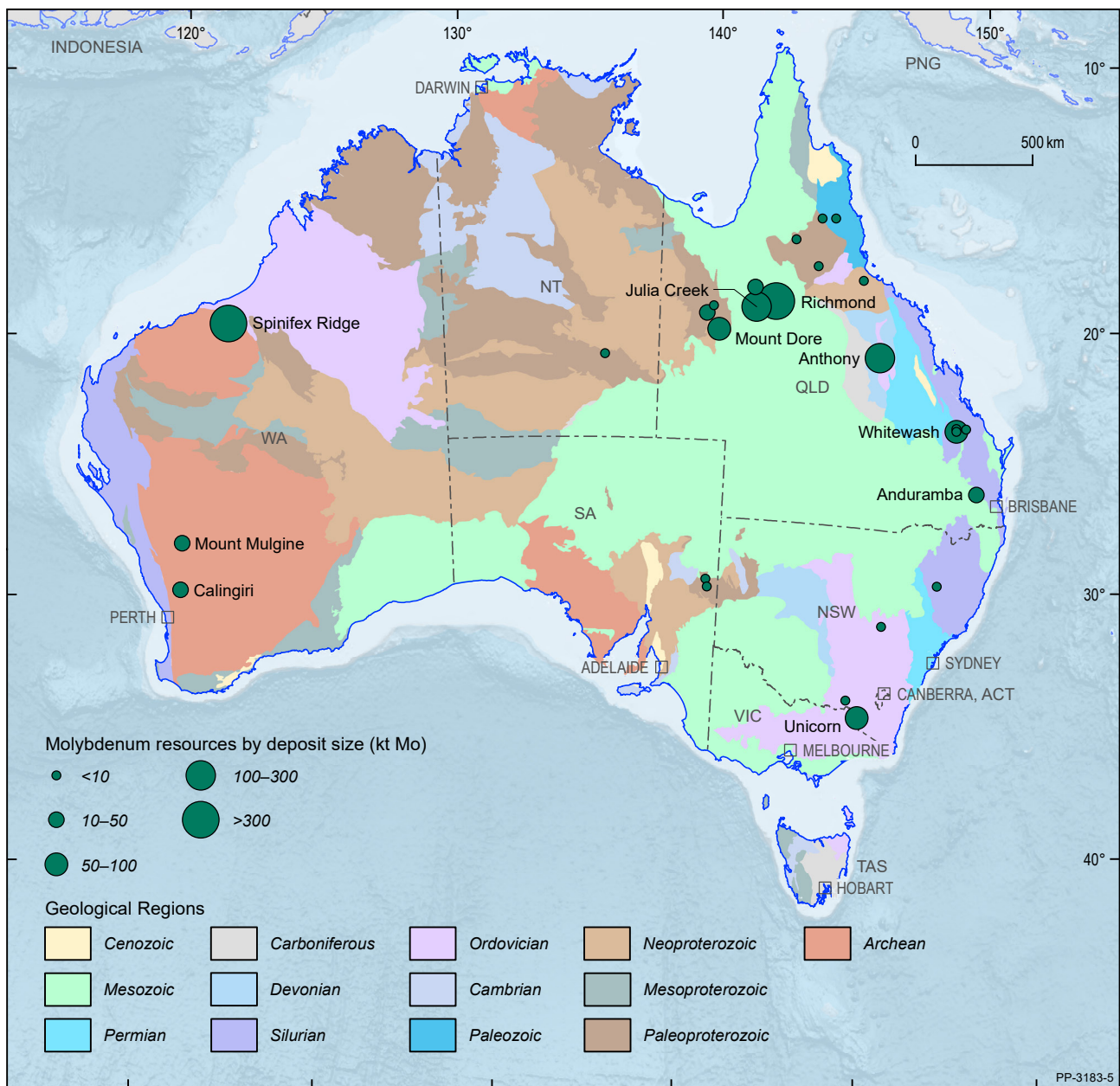


Figure 34 Australian molybdenum deposits, 2019.

Deposit size is based on total resources (EDR + Subeconomic + Inferred). For clarity, only major or significant deposits are labelled.

Nickel

Most nickel production is used in alloys. When alloyed with other elements, nickel imparts toughness, strength, resistance to corrosion and various electrical, magnetic and heat resistant properties. About 65% of world nickel output is consumed in the manufacture of stainless steel, which is used widely in the chemical industry, motor vehicles, the construction industry and in consumer products such as sinks, cooking utensils, cutlery and white goods.

Australia's EDR of nickel were 21.2 Mt in 2019 (Table 3), up 1.5 Mt (8%) from 19.7 Mt in 2018 (Table 4). Australia ranks first globally with 24% of the world's economic resources, and sixth for production (7%; Table 8).

Australia's nickel deposits and operating mines are shown in Figure 35 on a total resource basis.

Australia's total Ore Reserves of nickel were 8.3 Mt in 2019 (Table 2), up 34% from 6.2 Mt in 2018. Ten operating mines (Table 1) produced 0.16 Mt of nickel in 2019 (Table 1), up 7% from 0.15 Mt in 2018. The USGS notes that, in recent years, production of refined nickel decreased as stainless steel producers preferred lower-cost nickel pig iron. At the same time, production of nickel chemicals has increased, particularly nickel sulphate used in the production of batteries. Increased development and use of battery and electric vehicle technologies indicate a significant increase in global nickel consumption is likely.

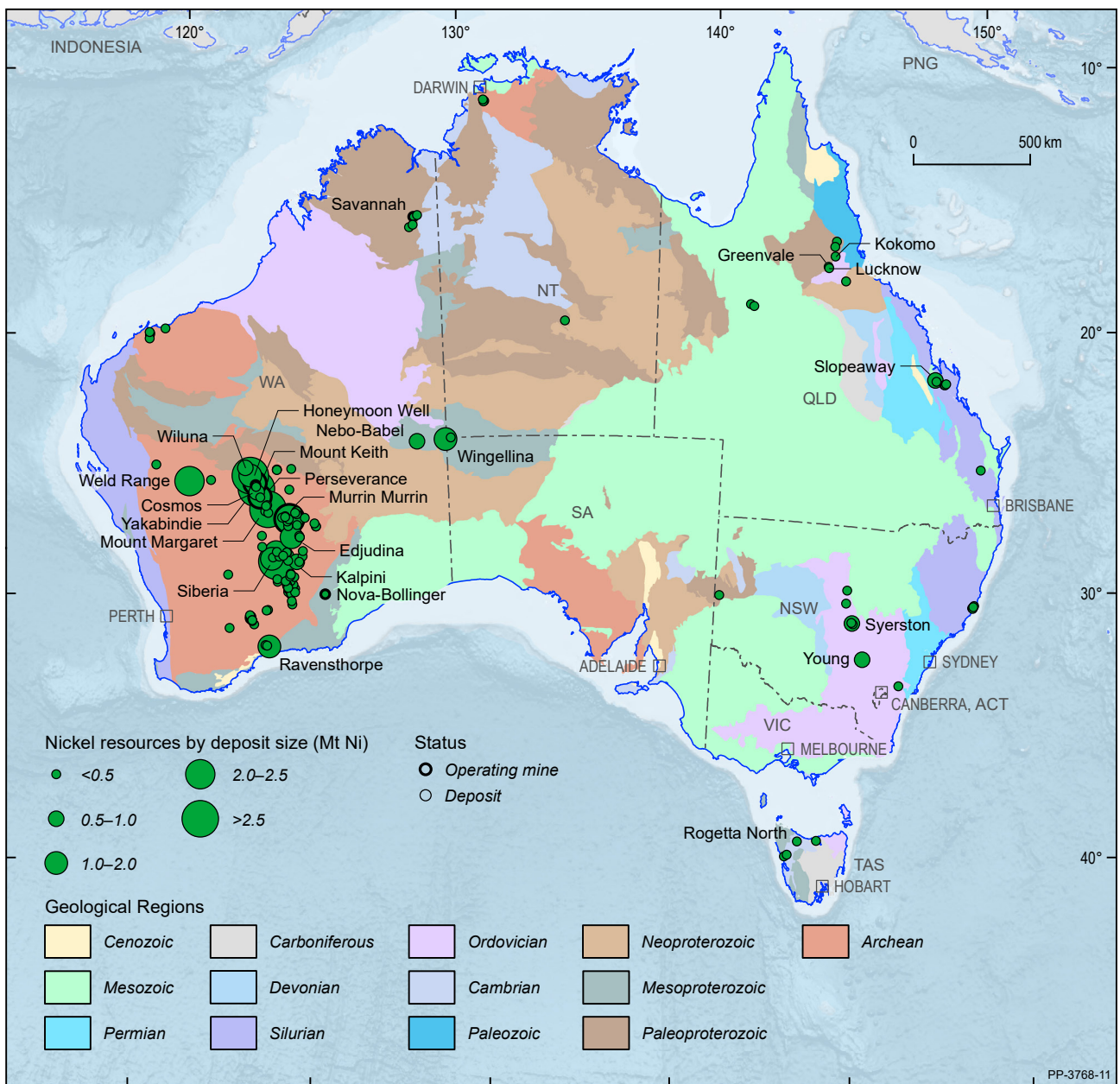


Figure 35 Australian nickel deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

In 2019, exports of nickel ore and concentrates (0.258 Mt) and intermediate and refined nickel (0.241 Mt) had a combined export value of \$4,126 million (Table 11), slightly down from \$4,286 million in 2018 owing to reduced value of refined nickel which fell 11.% to \$15,235/t (Table 12).

At 2019 rates of nickel production, the average reserve life at operating mines is 15 years and demonstrated resource life (Measured and Indicated categories) is 49 years (Table 1). If Ore Reserves at mines on care

and maintenance, developing mines and undeveloped deposits are also considered, the average reserve life of nickel is potentially 54 years (Table 9) and if accessible EDR is used as an indication of long-term potential supply, then Australia's nickel resources could last 135 years at 2019 rates of production (Table 9). At 2019 rates of production, and even with increased rates of production, Australia has the potential to produce nickel for many decades into the future and is well placed to provide reliable supply for use in decarbonising global economies.



Stainless steel contains nickel or chromium to prevent corrosion. Australia holds almost a quarter of the world's economic resources of nickel.

Long-term trends show that reserve life for nickel has generally declined since 2002 because companies have been replacing Ore Reserves at a slower rate than production has been depleting them (Figure 36). Resource life for nickel gradually rose from 1990 to 2009 because companies delineated new resources faster than they increased production (Figure 36). Since the 2009 peak, resource life has declined but has begun to increase again in recent years owing to falling production and the delineation of new reserves and resources (Figure 36).

Oil shale

Resources of oil shale predominantly occur in sedimentary basins around Gladstone, Mackay and Proserpine in central Queensland. Subeconomic (contingent) resources were estimated at 2,287 GL (14,385 million barrels), and Inferred (prospective) resources were estimated at 1,472 GL (9,261 million barrels) in 2019 (Table 3). Australia currently has no EDR of oil shale, with all resources being assessed as subeconomic. There is currently no production from oil shales in Australia.

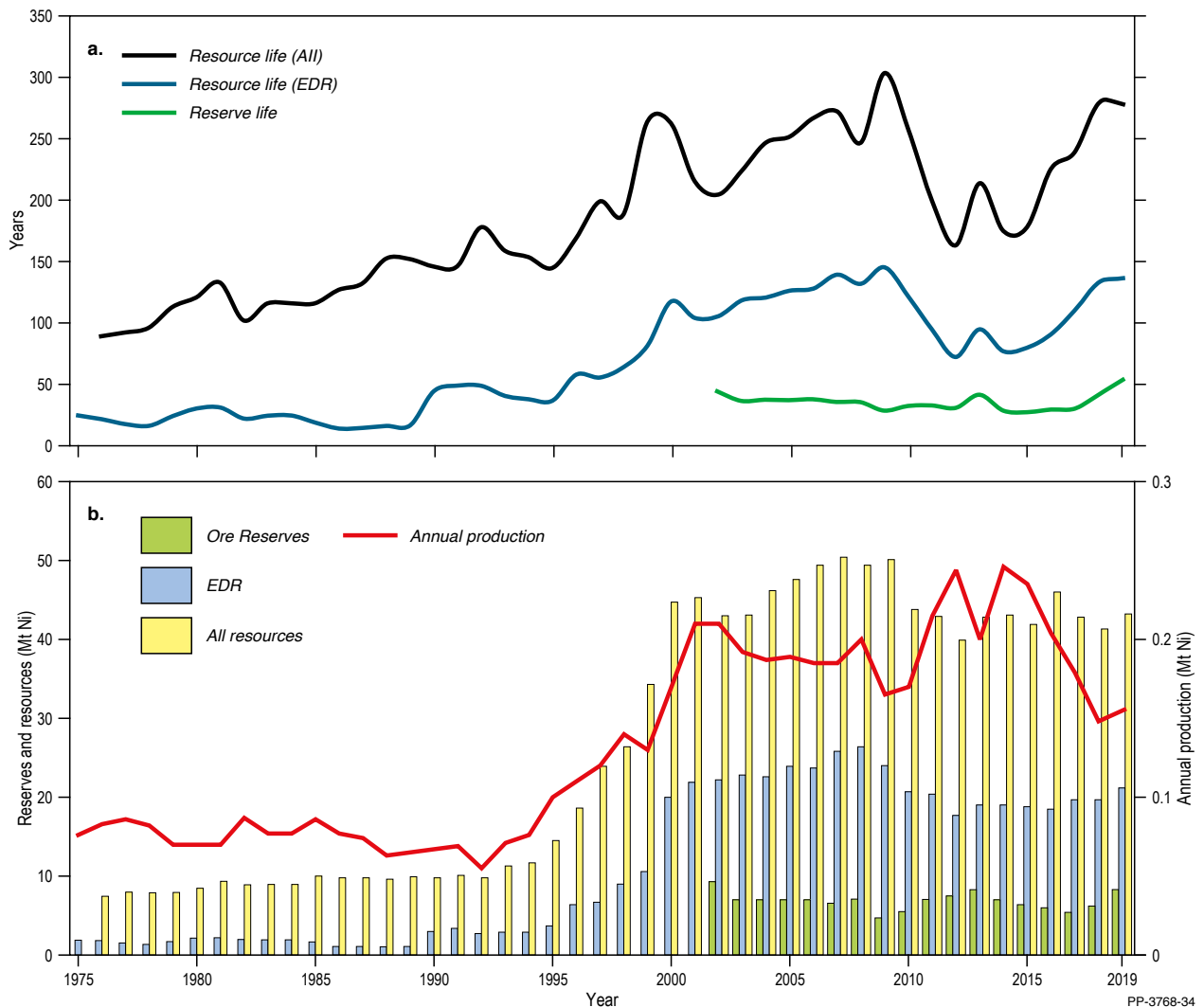


Figure 36 (a) Trends in nickel reserves and resource life. These ratios are derived from (b) nickel Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

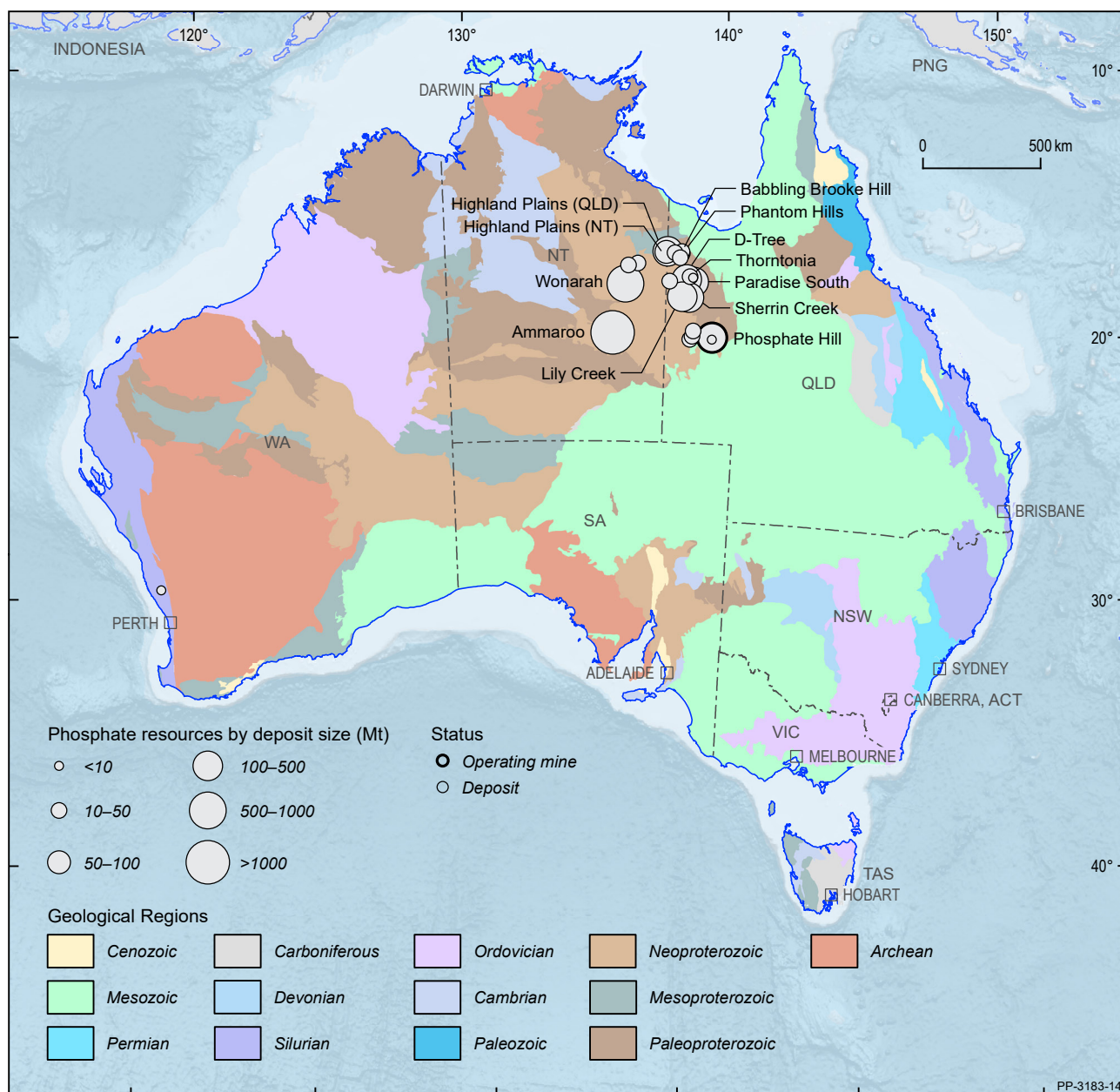
Notes: Mt Ni = million tonnes of contained nickel. Prior to 2002, Ore Reserves were not recorded.

Phosphate

Phosphate rock is the main source of phosphorus which is essential to all forms of life. It is a key component of DNA, it is used in the control of energy transfer and storage at the cellular level as well as playing an important role in metabolic processes. Plants require three major nutrients for life—nitrogen (N), potassium (K) and phosphorus (P). There is no substitute for phosphorus in agriculture.

Geoscience Australia assesses both phosphate rock (phosphorite and guano) and contained P_2O_5 which, as well as being a component of phosphate rock, can be found in other rock types in which alternative minerals are the primary target.

In 2019, Australia's EDR of phosphate rock and contained P_2O_5 were both unchanged compared to 2018 at 1,091 Mt and 178 Mt, respectively (Table 3, Table 4). The phosphorites of the Georgina Basin (encompassing parts of Queensland and the Northern Territory; Figure 37) account for almost all of Australia's EDR of phosphate rock and 93% of Australia's EDR of contained P_2O_5 . The remaining phosphate rock occurs at Christmas Island. The rare earth deposits at Mount Weld (Western Australia) and Nolans Bore (Northern Territory) also have EDR of contained P_2O_5 . Australia hosts less than 2% of the world's economic resources of phosphate rock (Table 8) with Christmas Island and Phosphate Hill (Queensland) the only significant producers.



Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled. Not shown: Christmas Island in the Indian Ocean.

Platinum Group Elements

The platinum group elements (PGE) comprise platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru). The elements of most commercial significance are platinum, palladium and, to a lesser degree, rhodium. The commercially important properties of PGEs include their resistance to corrosion and oxidation, high melting points, electrical conductivity and catalytic activity in the chemical, electrical, electronic, glass and motor vehicle industries. The emerging commercial importance of PGE is in applications associated with the

motor vehicle industry resulting from increasing global emission controls, development of lead-free petrol and efforts to improve fuel efficiency. Other applications include the use of platinum-rhodium alloys to oxidise ammonia to nitric acid in the production of fertilisers, while platinum is used extensively in jewellery. Due to their diverse uses, PGE are regarded as critical minerals by many advanced economies and are listed in *Australia's Critical Minerals Strategy 2019*³⁶.

³⁶. See above n 7.

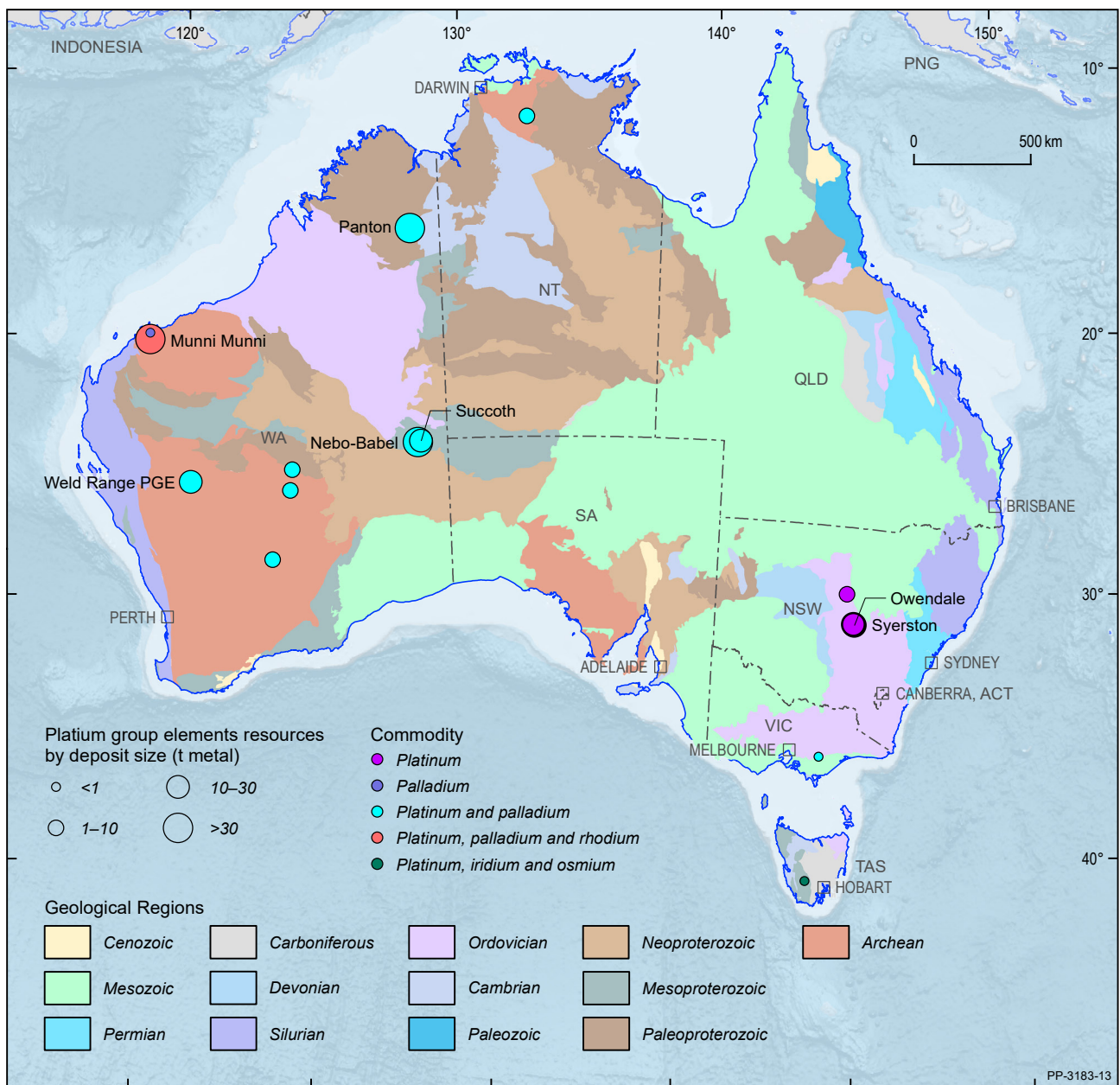


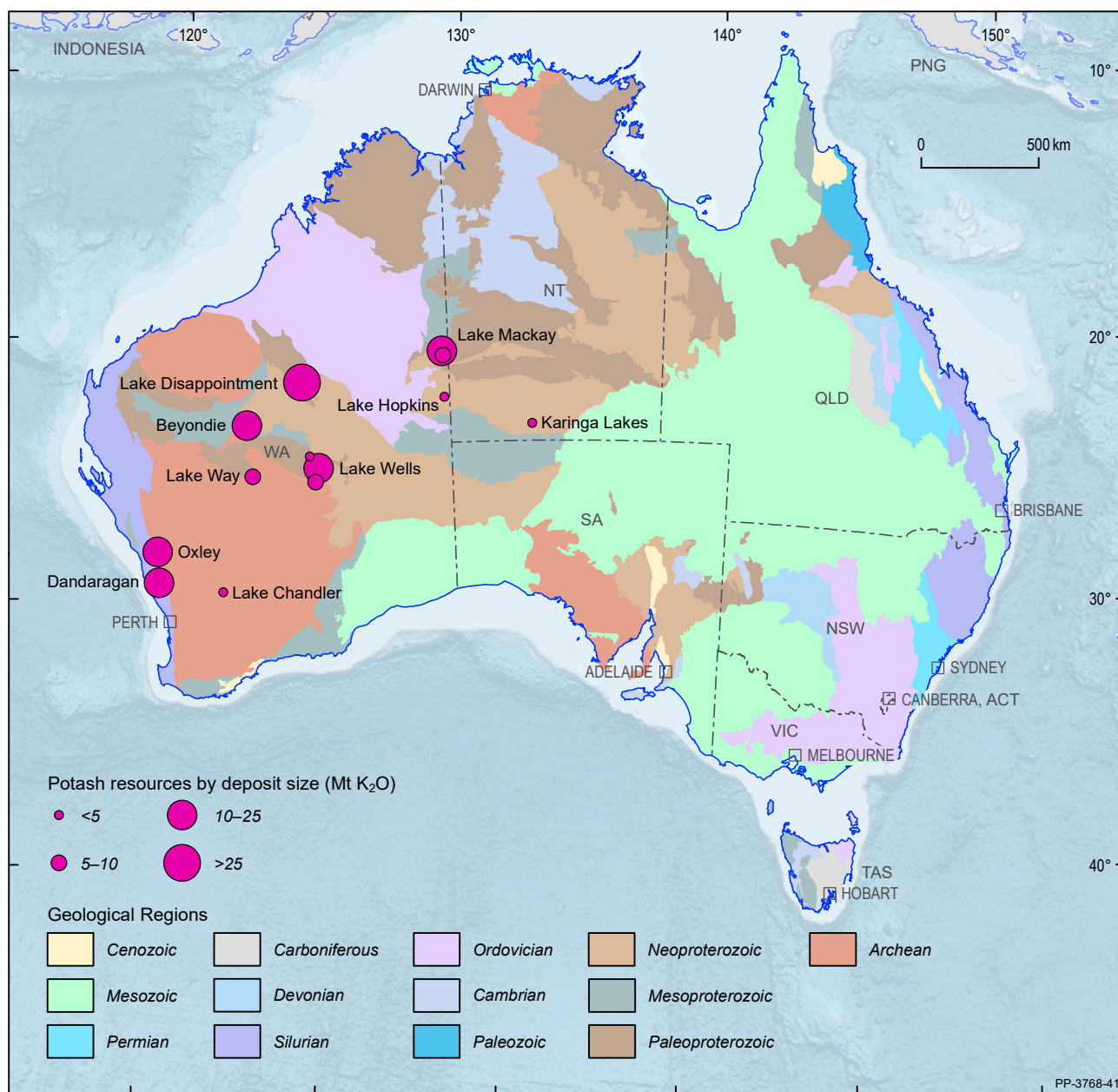
Figure 38 Australian platinum group elements deposits, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Australia's EDR of PGE increased 19% (6.1 t) from 31.5 t in 2018 to 37.6 t in 2019 (Table 4). Australian economic resources represent a minor portion of the world total of 69,000 t (Table 3). Australia also has Inferred Resources of PGE amounting to 107.2 t and another 134.4 t categorised as Paramarginal (Table 3). In addition to public resource reports, Australian mineral deposits may contain unreported resources of PGE that are recovered as by-products of the primary commodity being mined (usually from nickel sulphide ores). The Western Australian Department of Mines and Petroleum reported that 483 kg of platinum and palladium was produced during 2019 (Table 3), a decrease from 541 kg in 2018. The bulk (75%) of Australia's EDR of PGE occur in Western Australia (Figure 38).

Potash

In 2019, Australia's EDR of potash increased by 17% to 35 Mt, up from 30 Mt³⁷ in 2018 (Table 4). The increase reflects significant industry and exploration activity as projects matured and companies reported maiden Ore Reserves and upgrades to Mineral Resources. Nearly all (96%) of Australia's potash resources occur in Western Australia, with the exception of Karinga Lakes in the Northern Territory and Lake Mackay which occurs on the border between the two jurisdictions. In addition, nearly all Australian potash resources occur in lake brines with large resources also delineated at Kalium Lakes (Beyondie), Lake Disappointment, Lake Wells and Lake Way (Figure 39), with companies typically planning to produce sulphate of potash (SOP)³⁸.



Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

However, Australia's potash resources remain small (1%) by world standards (Table 8). The countries with the largest economic resources of potash (K_2O) in 2019 were Canada (1,000 Mt), Belarus (750 Mt) and Russia (600 Mt). The USGS estimates that Israel and Jordan also have large resources as the Dead Sea contains an estimated 2 billion tonnes of potassium chloride.

Australia did not produce potash commercially in 2019 (Table 8) but is on the verge of production just seven years after the publication of Geoscience Australia's review of Australian salt lakes and their potential for strategic resources³⁹. For example, Australian Potash Ltd published a definitive feasibility study in August 2019 that identified a 30-year mine life for their Lake Wells SOP project, 500 km northeast of Kalgoorlie. The project has a JORC (2012)-compliant Measured Mineral Resource of 18.1 Mt (SOP), the largest in Australia as at 31 December 2019.

Other advanced projects (all in Western Australia) include:

- Beyondie (Kalium Lakes Ltd) for which Australia's first bankable feasibility study for a potash project was completed in 2018. The company aims to produce 90 ktpa for 30–50 years.
- Lake Way (Salt Lake Potash Ltd) as part of the Goldfields Salt Lakes Project. The project owner released a bankable feasibility study for Lake Way in 2019 that showed the operation could produce 245 ktpa SOP over 20 years. The company has offtake partners for 224 ktpa and the project is expected to begin production in 2021.
- Lake Mackay Potash (Agrimin Ltd) for which a positive definitive feasibility study was completed. The project comprises the mine, processing plant, transport and a port facility at Wyndham. The company announced significant upgrades to its reserves and resources in 2020, including an Ore Reserve of 20 Mt SOP that will contribute to Australia's EDR in the next reporting period.
- Lake Disappointment (Reward Minerals Ltd) is promoted as the largest high-grade brine SOP resource in the world outside of China. The company completed a prefeasibility study in 2018 that indicated production of 400 ktpa SOP over 27 years was achievable. Most recently, it received both Commonwealth and Western Australia environmental approval in 2020.

BCI Minerals Ltd also plans to produce SOP, but from evaporated seawater, at its Mardi project located on the Pilbara coast of Western Australia. This project is primarily a high-purity salt ($NaCl$; table salt) operation that could produce up to 4.4 Mtpa but, in its 2020 definitive feasibility study, the company also included plans to abstract 120 ktpa SOP from the seawater.

Another industry action to note is adoption by the JORC Committee of brine guidelines that describe the unique technical considerations for reporting brine mineralisation, including a requirement for the Competent Person to consider brine composition and grade over time during its abstraction⁴⁰. The guidelines improve resources reporting for potash reserves and resources in compliance with the JORC Code and should lead to greater confidence for investors and other stakeholders.

³⁷. Geoscience Australia published an EDR of potash amounting to 72 Mt in Australia's Identified Mineral Resources 2019. New information has become available, particularly around the drainable recovery from some deposits, resulting a re-evaluation of Australia's potash inventory for that period.

³⁸. There are two major sources of potash for agriculture. The lower-value muriate of potash (MOP; potassium chloride— KCl) is a 'volume' business, and six companies occupy over 80% of the global market share. In comparison, sulphate of potash (SOP; potassium sulphate— K_2SO_4) is used for high-value, chloride-sensitive or chloride-intolerant crops and is therefore a 'value' business. It is a more bespoke product and global production is significantly lower than MOP.

³⁹. Mernagh, T.P. Bastrakov, E.N., Clarke, J.D.A., de Caritat, P., English, P.M., Howard, F.J.F., Jaireth, S., Magee, J.W., McPherson, A.A., Roach, I.C., Schroder, I.F., Thomas, M., Wilford, J.R. A Review of Australian Salt Lakes and Assessment of their Potential for Strategic Resources (Geoscience Australia Record 2013/039, 2013). See <http://pid.geoscience.gov.au/dataset/ga/76454> (accessed 18 December 2020).

⁴⁰. JORC, Guidelines for Resources and Reserve Estimation for Brines (JORC Guideline, 2019). See www.jorc.org/docs/Brine_Guideline_final.pdf (accessed 18 December 2020).

Rare Earth Elements

The rare earth elements (REE) are a group of metals comprising the 15 elements of the lanthanide series⁴¹. In addition, yttrium (Y) and scandium (Sc) are commonly considered part of the grouping because of their similar chemical properties. Resources of REE are reported as rare earth oxides (REO). Geoscience Australia incorporates yttrium when determining REO resource estimates but assesses scandium separately.

REE are used in renewable energy production; electric vehicles; military technologies; high-end technological applications, such as mobile phones and other electronics; lasers; speciality alloys; and batteries. REE are regarded as critical minerals by many advanced economies, and are listed in *Australia's Critical Minerals Strategy 2019*⁴².

As at December 2019, total Ore Reserves of REO, including yttrium but not scandium and reported in compliance with the JORC Code, amounted to 3.02 Mt (Table 2), an increase of 6.3% over 2018 (2.84 Mt). Ore Reserves accounted for 75% of Australia's EDR of REO for 2019. Economic Demonstrated Resources of REO were

4.03 Mt at the end of December 2019 (Table 3), down by 2% from 4.12 Mt in 2018 (Table 4). The fall in EDR was due to company reassessment of resource inventories.

Australia also had 40.17 Mt of REO resources considered to be subeconomic at the end of 2019 (Table 3), an increase of 18% from the 33.99 Mt recorded at the end of 2018. Similarly, 26.62 Mt of Inferred Resources of REO in 2019 (Table 3), were 1.8% higher than the 26.15 Mt at the end of 2018. Rare earths deposits and operating mines are shown in Figure 40 on a total resource basis.

On the subject of subeconomic resources, the REO content of heavy mineral sands is seldom publicly reported. However, in 2019, Geoscience Australia identified new information to that indicate REO content of some heavy mineral sands deposits, and which is now included in the 2019 assessment of Paramarginal Demonstrated Resources of REO. Because of this inclusion, Paramarginal REO increased 898% from 0.43 Mt in 2018 to 4.29 Mt in 2019.

⁴¹. The lanthanide series comprises 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).

⁴². See above n 7.



Electric vehicles utilise rare earth elements such as neodymium and dysprosium in powerful permanent magnets. Australia is one of the few producers of rare earth elements outside of China.

World production of rare earths, based on USGS data and modified for Australian production, was estimated to be 0.210 Mt of REO in 2019 (Table 3). Australia was the world's fourth largest producer, providing 8% of global supply (Table 8). Australian production of REO in 2019 was 0.018 Mt (Table 1) and came predominantly from Lynas Corporation Ltd's Mount Weld mine in Western Australia.

Concentrates from Mount Weld are processed at the Lynas Advanced Materials Plant in Malaysia to produce REO products. Under a deadline set by Malaysian

authorities to cease processing in Malaysia due to the low-level radioactive waste by-product, Lynas is planning to build a processing plant in Kalgoorlie, Western Australia, by mid-2023. Lynas also signed an agreement with the US Department of Defense to build a heavy rare earths separation plant in Texas.

In addition to Mount Weld, 45.66 t of rare earth carbonate were produced and exported to China by Northern Minerals Ltd from its pilot mining and processing operation at the Browns Range project in the Kimberley region of Western Australia.

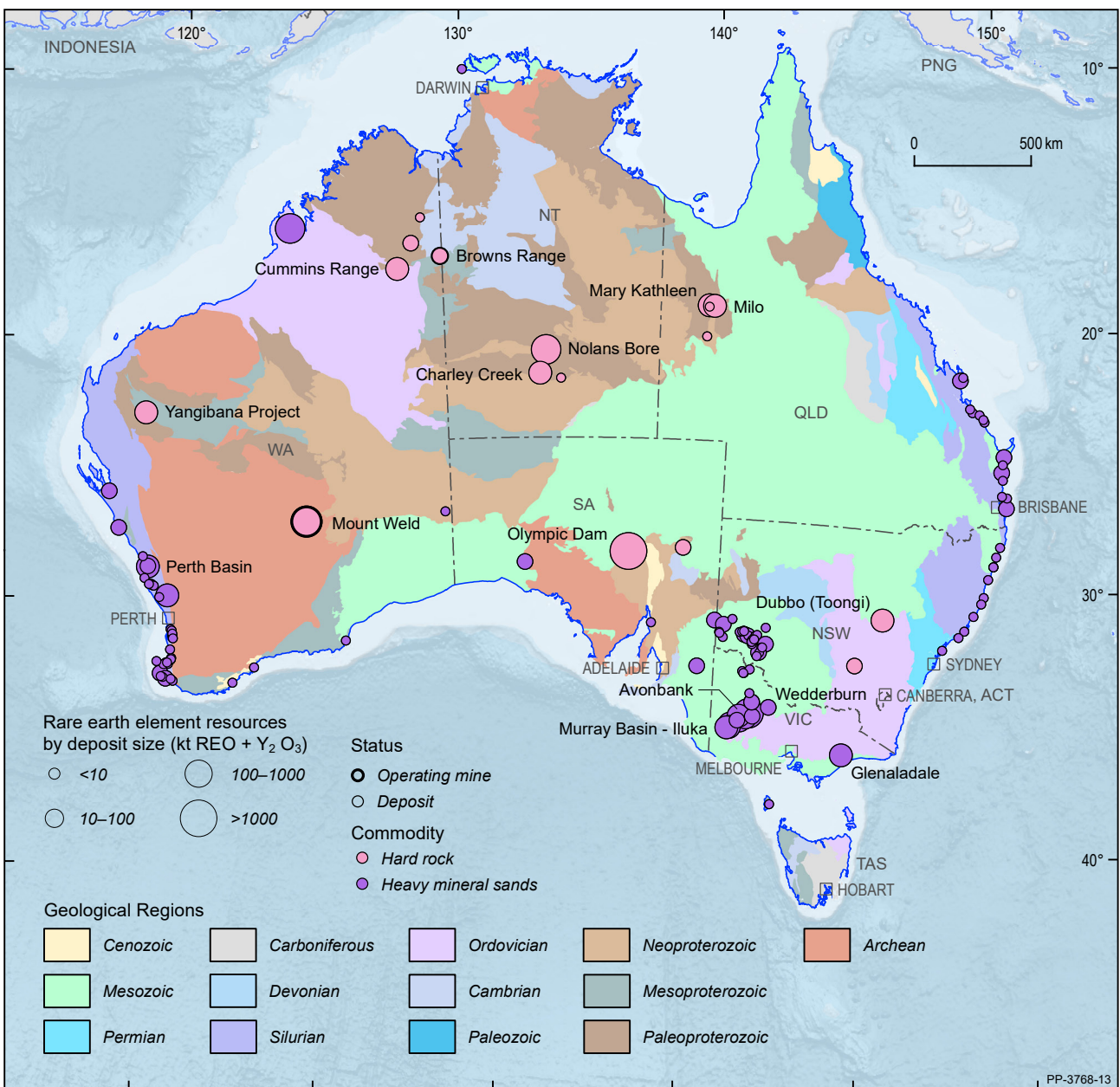


Figure 40 Australian rare earth element deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred).
 Note: The Inferred Resource at Mount Gee is not accessible.

Scandium

Scandium is used in the production of alloys for the aerospace industry. It is also used in solid-oxide fuel cells, in specialised lighting applications, ceramics, lasers, electronics and in aluminium alloys for sporting goods production. Scandium is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*⁴³.

Scandium is often grouped with the rare earths and yttrium. While not uncommon in the Earth's crust (averaging an abundance of around 25 ppm), scandium, like the rare earths, does not often occur in concentrations that can support commercial mining operations.

In Australia, known occurrences of scandium are mostly associated with lateritic nickel-cobalt mineralisation and are independent of rare earth deposits. Australian resources of scandium occur in Queensland, New South Wales and Western Australia but none are currently mined (Figure 41).

As at December 2019, total Ore Reserves of scandium, reported in compliance with the JORC Code, were 12.7 kt (Table 2). Ore Reserves accounted for 47% of Australia's EDR of scandium and have been reported from six projects. Scandium EDR were 26.91 kt in 2019 (Table 3) and Australia also had an estimated 8.10 kt of subeconomic scandium resources and Inferred Resources of 19.59 kt (Table 3).

43. See above n 7.

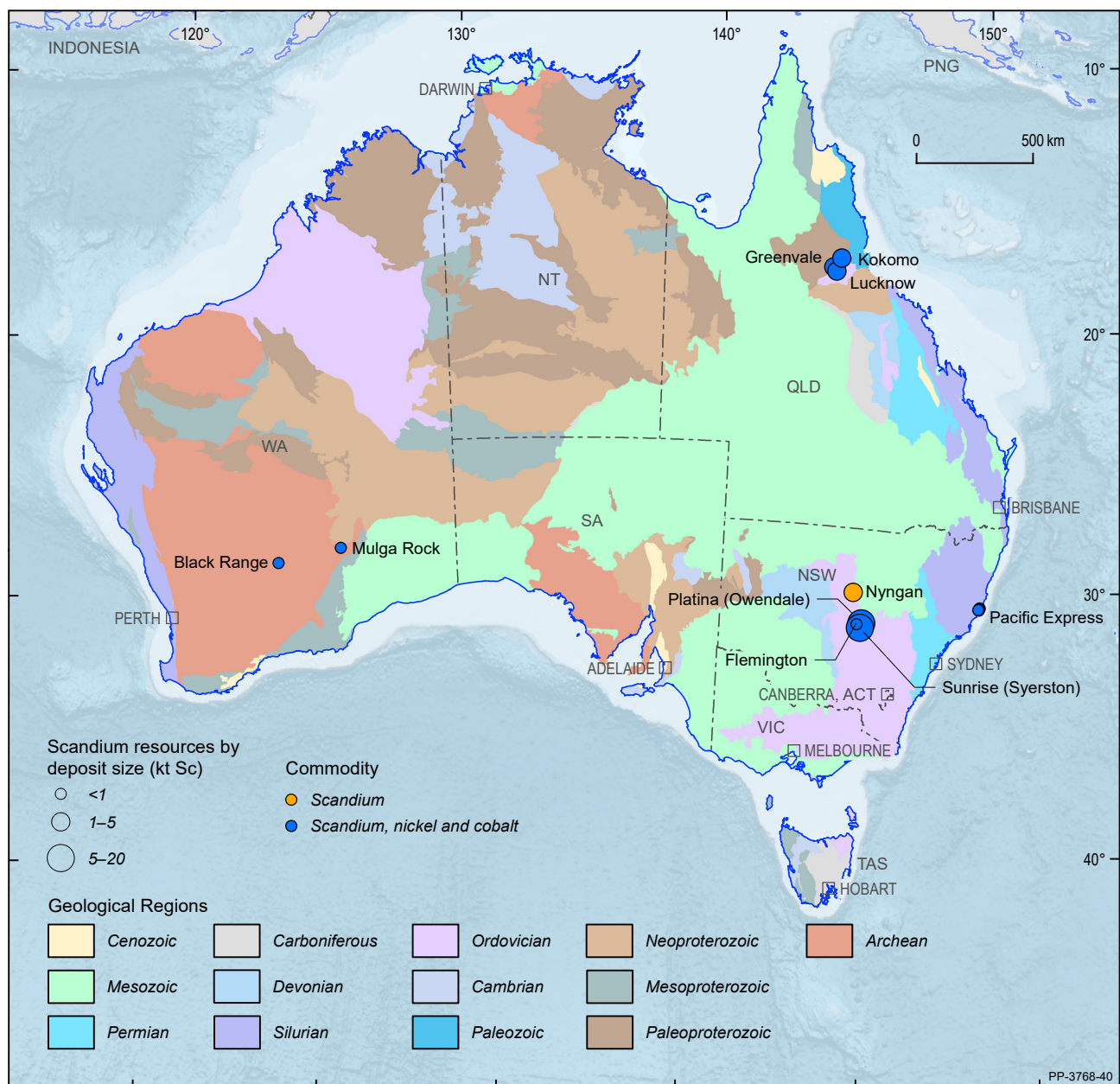


Figure 41 Australian scandium deposits, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred).

Tin

Australia's EDR of tin were 561 kt in 2019 (Table 3), up 30% from 430 kt in 2018 (Table 4). The increase reflects growth in EDR at the Renison deposit, Tasmania, which, in 2019, held 62% of Australia's EDR of tin. Other deposits with significant EDR (>10 kt) include Cleveland, Queen Hill, Severn, St Dizier and Mount Lindsay (all in Tasmania), Taronga (New South Wales), and Gillian and Pinnacles (both in Queensland). In 2019, Australia ranked fourth globally with 11% of the world's economic resources of tin (Table 8).

Annual production of tin for Australia in 2019 was 7.6 kt (Table 3), up from 6.9 kt in 2018. Nearly all of this

production was from the Renison deposit in Tasmania. Australian ranked eighth globally in 2019 with 2% of world production (Table 8).

Australia's total Ore Reserves of tin in 2019 were 261 kt (Table 2), of which the majority (68%) are within the Renison deposit (Figure 1). Other delineated Ore Reserves are reported at the Taronga, Cleveland and Mount Lindsay deposits (Figure 42). Based on the 2019 Ore Reserves to production ratio, Australian tin has 35 years of reserve life, reducing to 24 years when only operating mines are considered (Table 9).

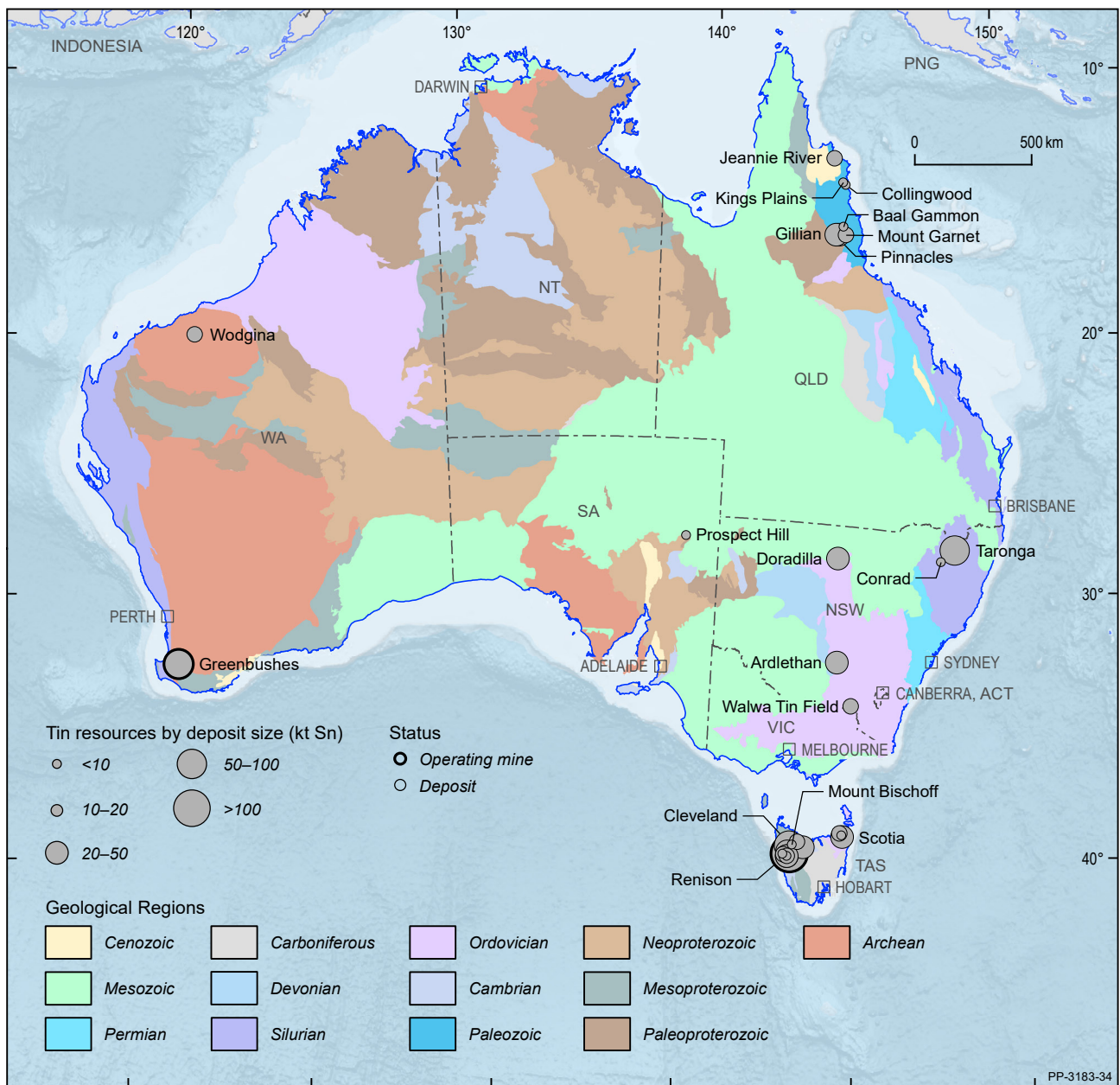


Figure 42 Australian tin deposits and operating mines, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled. Deposits not labelled in the Renison region include Queen Hill, Severn and St Dizier.

Tungsten

In 2019, the estimate of Australia's EDR of tungsten increased by 2% to 403 kt (Table 3) from 394 kt in 2018 (Table 4). Western Australia holds 53% of EDR, Tasmania 31% and Queensland 14%. Minor (<5%) EDR occur in the Northern Territory and New South Wales (Figure 43). Australia ranks second in the world with 11% of global world economic resources (Table 8), behind China (50%). Australian production, however, remains minor on the world scale (Table 8), with China responsible for more than 80% of global production. Tungsten is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*⁴⁴.

As at December 2019, total Ore Reserves of tungsten reported in compliance with the JORC Code amounted

to 215 kt (Table 2) of which 23 kt was attributable to Australia's two operating tungsten mines—Kara and Mount Carbine. In 2019, Ore Reserves had a small decrease of 1 kt to 215 kt from 216 kt in 2018 whilst production increased and, therefore, reserve life decreased. The large reserve life of more than 1,000 years (Table 2) is attributable to the relatively small production rate.

The Kara mine in Tasmania continued operations during 2019; it produced scheelite (calcium tungstate) concentrates as a by-product of magnetite processing. In December 2019, Mount Carbine in Queensland commenced tailings retreatment with planning for stockpile processing and open-cut mining ongoing.

44. See above n 7.



Tungsten-carbide is used in drill bits to increase their hardness and durability. Australia has the world's second largest resources of tungsten.

Other significant industry activity in 2019 included:

- Thor Mining PLC continued discussions with potential financiers and offtake partners for the Molyhil Tungsten and Molybdenum Project (Northern Territory), and by 2020 the project was awarded major project status by the Northern Territory government.
- Venture Minerals Ltd identified an additional tin-tungsten target in proximity to the Mount Lindsay Project (Tasmania).
- Vital Metals Ltd reported updated Ore Reserves and Resources for Watershed (Queensland).
- In December 2019, Tungsten Mining NL reported a significant increase to the Inferred tungsten-molybdenum resource, and a maiden resource for gold and silver, at the Mulgine Trench deposit (Western Australia).
- And at the Dolphin Project (Tasmania), King Island Scheelite Ltd entered into an offtake agreement for tungsten concentrate with Austrian-based Wolfram Bergbau und Hutton AG. During 2020, the company secured an additional offtake agreement with Asian-based Kalon Resources Ltd.

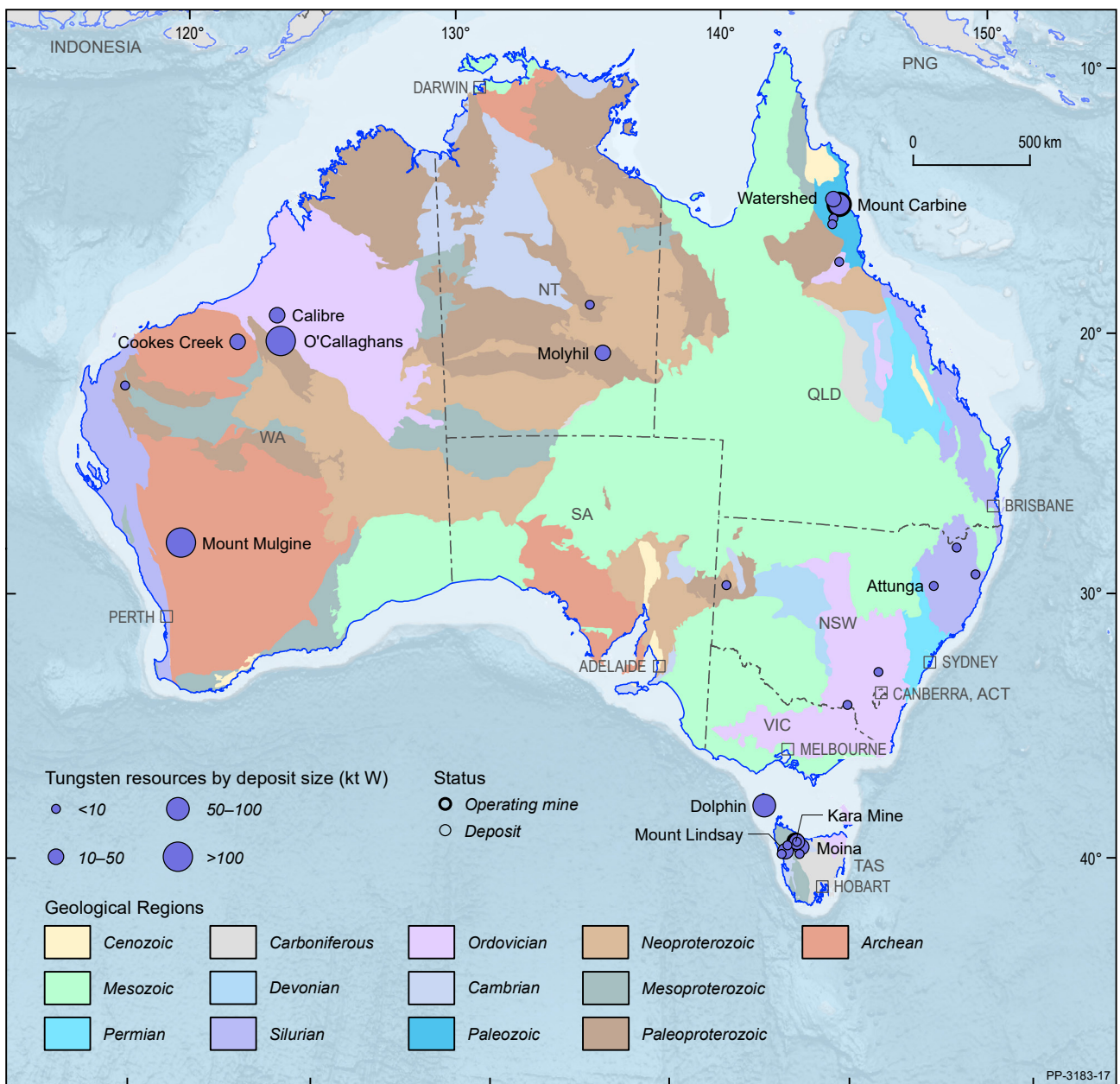


Figure 43 Australian tungsten deposits and operating mines, 2019.

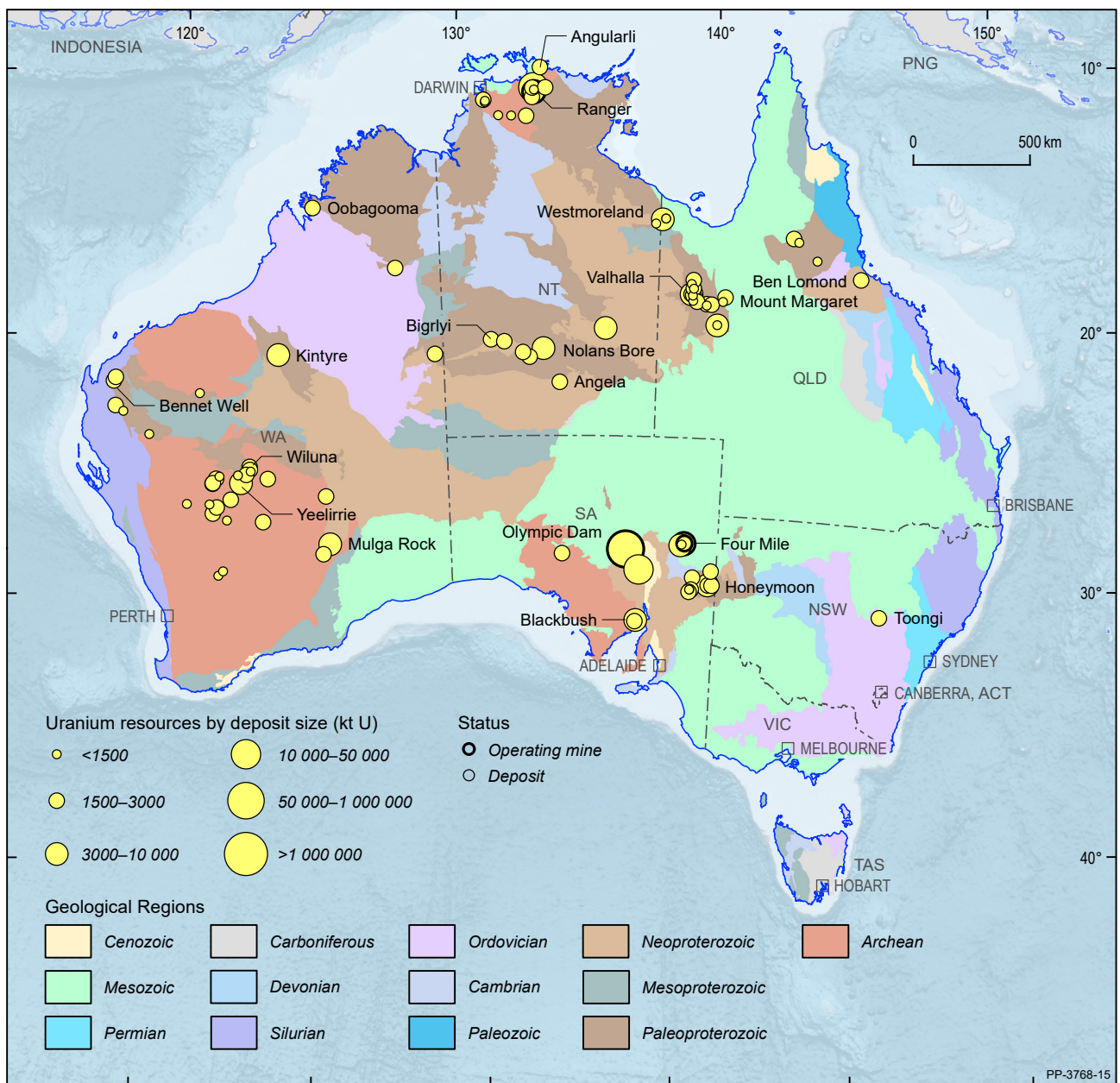
Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Uranium

Australia has the world's largest known resources of uranium, accounting for approximately 31% of the global inventory, and is the world's third largest uranium producer (12%; Table 8) after Kazakhstan (41%) and Canada (13%). As at December 2019, Australia had uranium EDR of 1,147 kt (Table 3). This is equivalent to the Organisation for Economic Co-operation and Development, Nuclear Energy Agency and the International Atomic Energy Agency (OECD-NEA/IAEA) category of Reasonably Assured Resources (RAR) of

uranium recoverable at costs of less than US\$130/kg U (RAR <\$130/kg U).

Ore Reserves of uranium in 2019 totalled 284 kt (Table 2), which was an approximately 4% decrease from 2018 (296 kt). Additionally, Australia has an estimated 722 kt of Inferred Resources of uranium and another 83 kt regarded as subeconomic (Table 3). Uranium deposits and operating mines are shown in Figure 44 on a total resource basis.



Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

Australia's uranium production in 2019 amounted to 6.613 kt (7.798 kt U₃O₈) and came from three operating mines—Olympic Dam and Four Mile in South Australia and Ranger in the Northern Territory (Table 1). This was a 13% increase on the previous year (5.872 kt). Uranium production is expected to decrease in the near future, however, as mining activities at the Ranger mine will cease in January 2021. In 2019, Australia exported 6.919 kt of uranium (8.159 kt U₃O₈) valued at \$747 million (Table 1).

Australia's uranium exploration expenditure has been in decline since the crash of the uranium price following the 2011 Fukushima Daiichi nuclear accident. Additionally, bans and uncertainties concerning uranium mining in some states has also have Australia's ability to attract uranium exploration investment. Exploration investment

in 2019 was \$10.2 million, a fall of 17% compared with the previous year and the lowest it has been since 2003.

Resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. After the flurry of discoveries in the 1970s, resource life (based on EDR) for uranium was more than 800 years in 1977 but this declined rapidly to around 100 years after uranium production increased in the 1980s (Figure 45). Resource life again ticked up in the early 1990s when the Kintyre and Olympic Dam resources were further delineated, and then decreased when production again rapidly increased from 1995. Since the turn of this century, resource life has again been increasing owing to a gradual increase in resources and a concurrent decline in production (Figure 45).

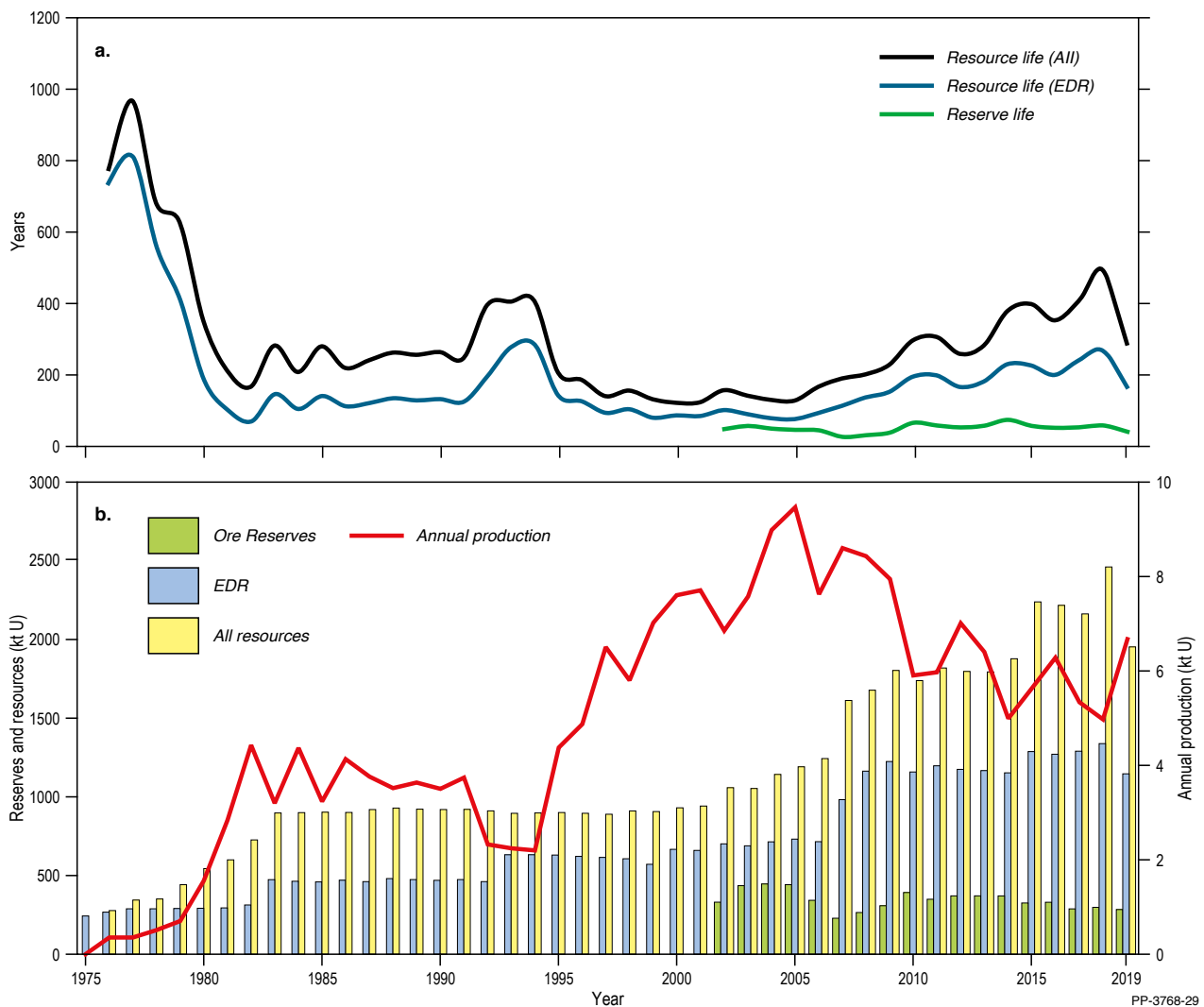


Figure 45 (a) Trends in uranium reserves and resource life. These ratios are derived from (b) uranium Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2019.

Notes: kt U = thousand tonnes of contained uranium. Prior to 2002, Ore Reserves were not recorded. EDR from 2009 onward is equivalent to Reasonably Assured Resources (RAR) recoverable at costs of less than US\$130/kg U. Prior to 2009, EDR is equivalent to RAR US\$80/kg U.

Following the closure of the Ranger uranium mine in January 2021, Australia will have two operating uranium production centres, Olympic Dam and Four Mile, both located in South Australia. Furthermore, because uranium at Olympic Dam is extracted as a by-product of copper mining (with gold and silver also recovered), Four Mile will stand as Australia's only dedicated uranium mine. Five other deposits, which have received environmental approval are awaiting better market conditions before proceeding with development. These are Honeymoon in South Australia (Boss Resources Ltd), and Kintyre (Cameco Australia Pty Ltd), Wiluna (Toro Energy Ltd) and Mulga Rock (Vimy Resources Ltd), all in Western Australia.

Australia currently has no plans for a domestic nuclear power industry. However, interest in the industry at the state level led to the South Australian Nuclear Fuel Cycle Royal Commission in 2015 and, more recently, the New South Wales Uranium Mining and Nuclear Facilities (Prohibitions) repeal Bill 2019 and the Victorian Inquiry into Nuclear Energy Prohibition (2020). Additionally, at the Federal level, an Inquiry into the Prerequisites for Nuclear Energy in Australia by the House of Representatives Standing Committee on the Environment and Energy was undertaken 2019.

Vanadium

Vanadium is a soft, ductile, silver-grey metal that is used primarily with iron to make metal alloys for high-strength steel production. High-strength steel has a wide range of applications, including for gas and oil pipelines, tool steel, jet engines, the manufacture of axles and crankshafts for motor vehicles, as well as for reinforcing bars in building and construction.

Vanadium is also used in the production of ceramics and electronics, textile dyes, fertilisers, synthetic rubber, in welding, as well as in alloys used in nuclear engineering and superconductors. Vanadium chemicals and catalysts are used in the manufacture of sulphuric acid, the desulphurisation of sour gas and oil, and in the development of fuel cells and low-charge-time lightweight batteries.

Increased steel production in China meant that demand for vanadium remained strong in 2019. Vanadium is regarded as a critical mineral by many advanced economies and is listed in *Australia's Critical Minerals Strategy 2019*⁴⁵.

⁴⁵. See above n 7.



Vanadium has a wide range of uses in modern and emerging technologies, for example, vanadium oxide is used in thermal imaging cameras. Australia holds one quarter of the world's economic resources of vanadium.

In Australia, there has been sustained momentum for developing vanadium projects, resulting in a 30% rise of vanadium EDR from 4,646 kt in 2018 to 6,019 kt in 2019 (Table 4). Vanadium EDR in Australia are mostly located in Western Australia at the developing deposits of Australian Vanadium, Balla Balla, Speewah, Barrambie and Gabanintha North, shown in Figure 46 on a total resource basis. Corresponding to the EDR, total Ore Reserves of vanadium reported in compliance with the JORC Code have also increased by 31% from 1,182 kt in 2018 to 1,554 kt in

2019 (Table 2). The Inferred Resource has also increased by 27% to 22,838 kt (Table 3), up from 18,013 kt in 2018.

In 2019, with 6,019 kt, Australia had the world's second largest economic resources of vanadium (25%; Table 8), behind China with 9,500 kt (39%), and ahead of Russia (5,000 kt; 21%) and South Africa (3,500 kt; 14%). China also led the global production of vanadium in 2019, producing 40 kt (54%) of the 73 kt total (Table 3), followed by Russia (18 kt; 25%) and South Africa (8 kt; 12%). Australia does not have any operating vanadium mines.

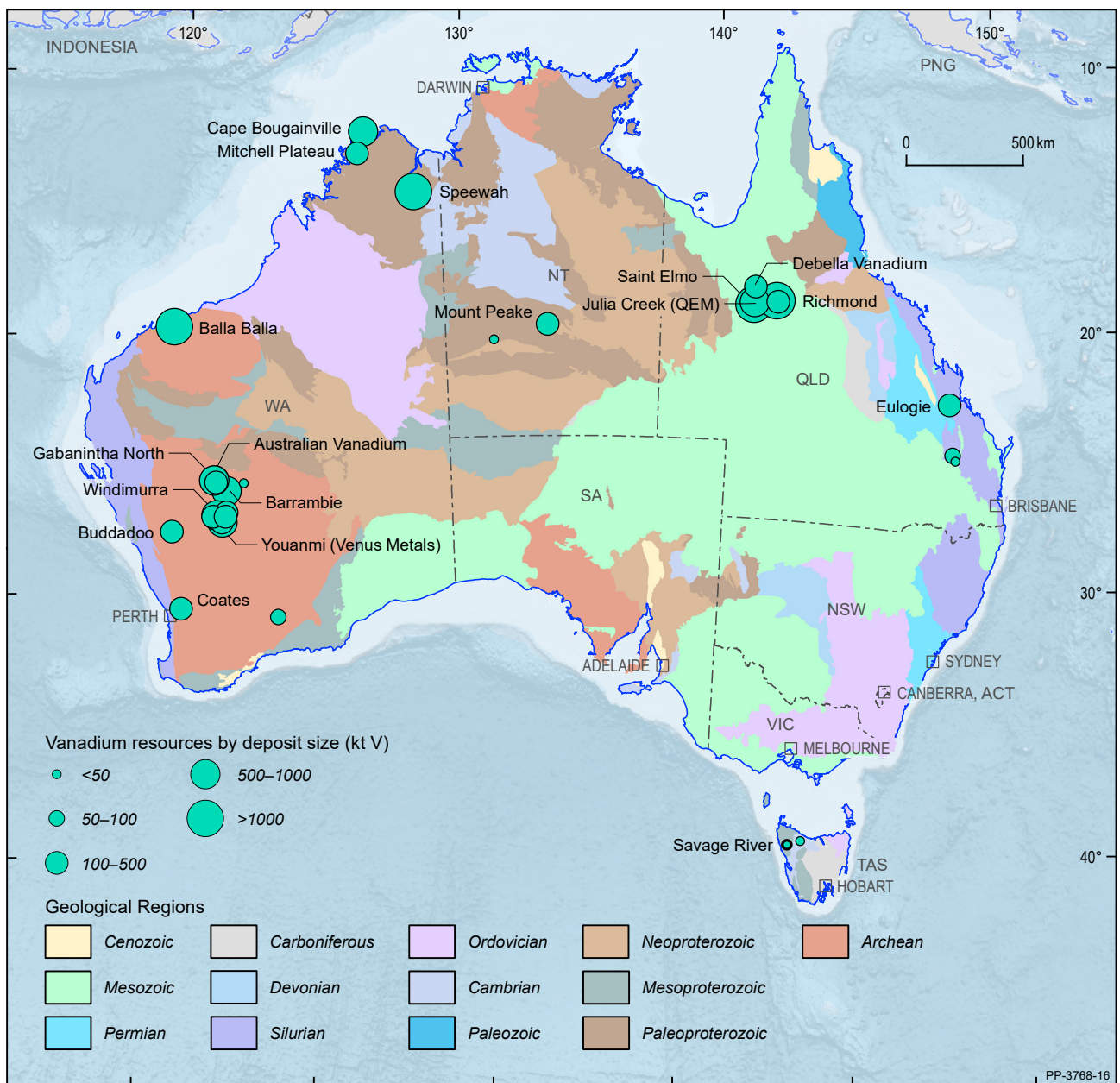


Figure 46 Australian vanadium deposits, 2019.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.

