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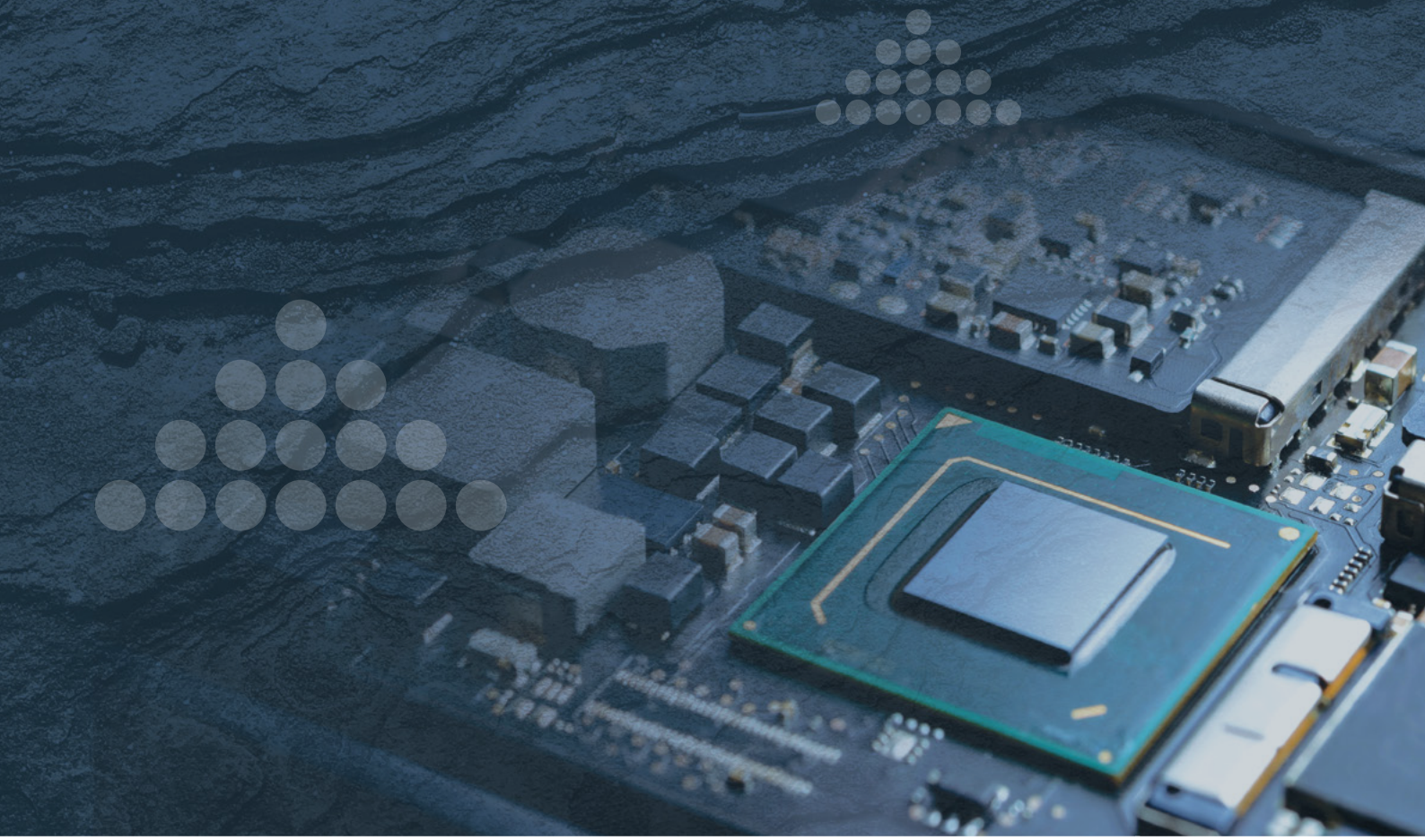
Australia's Identified Mineral Resources 2019



Australia's Identified Mineral Resources 2019

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AIMR 2019 at a Glance

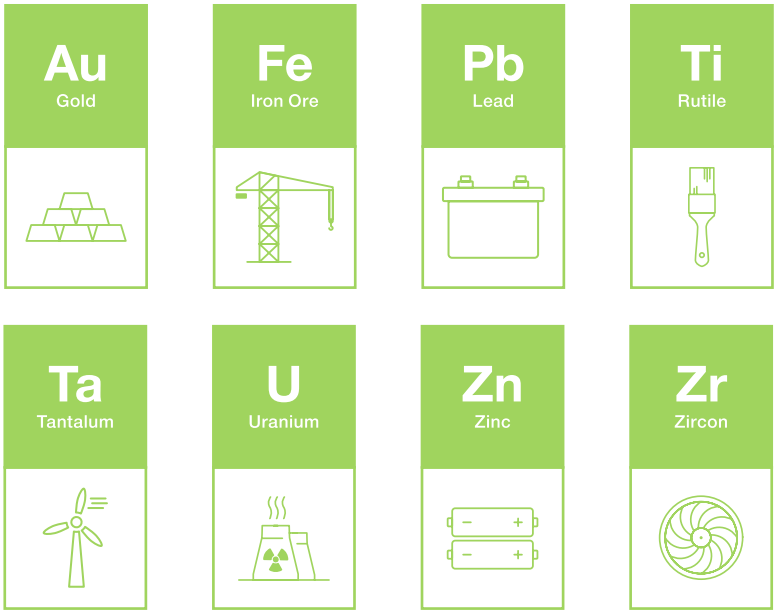
Minerals account for nearly two thirds of all export merchandise.

Mineral exports added $201 billion to Australia's economy in 2018.

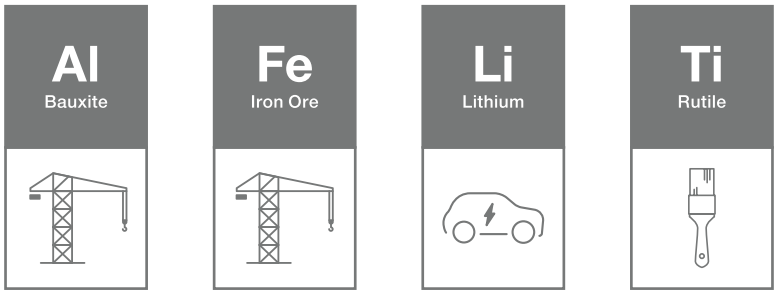
58%
of all Australian export merchandise is mineral commodities

18%
Iron Ore accounts for eighteen percent of these exports

Australia has the world's largest economic resources of these minerals.



Australia is the largest global producer of these minerals.



Top Movers in 2018

- Tantalum ▲ 79%
- Lithium ▲ 68%
- Platinum Group Elements ▲ 26%
- Rare Earths ▲ 26%
- Potash ▲ 24%
- Vanadium ▲ 17%
- Cobalt ▲ 11%

Australia is richly endowed with the critical minerals needed for modern technologies.

These top movers reflect increased exploration and resource discovery in response to growing demand.

$2184 million AUD

25%

2018 Exploration Expenditure

Investment in Australian exploration has increased 25% in the last year, showing confidence in our resource sector.

100+ years	50–100 years	<50 years
Black Coal, Brown Coal, Cobalt, Mineral Sands, Nickel, Rare Earths, Tantalum, Uranium	Bauxite, Copper, Iron Ore, Lead, Lithium, PGE, Silver, Tin, Zinc	Antimony, Diamond, Gold, Manganese Ore

Determined at 2018 rates of production.

Resource Life

Australia has an abundant supply of the mineral resources the world needs.

Notes: Economic Demonstrated Resources and production rankings as at 31 December 2018. Changes are from 31 December 2017 to 31 December 2018. Resource life for each mineral commodity is calculated by dividing the inventory (EDR) 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.

Acronyms, Abbreviations and Symbols

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

1. Introduction

Australia has a robust and world-leading mining industry evidenced by a top five position as a producer for some 16 commodities including gold, bauxite, iron ore, rare earths, mineral sands, zinc, nickel and coal. In 2018, Australia's mineral exports (excluding petroleum products) amounted to $201 billion which was 58% of all export merchandise and 46% of all exported goods and services[1]. In 2018, mining accounted for 8.4% of gross domestic product[2]. In addition, the mining industry employed some 241 000 people in 2018, with many more employed by related industries[3].

The major commodities of iron ore, black coal, gold, aluminium and copper contributed some $174 billion to Australia's export income in 2018[1]. Australia is also richly endowed with many other minerals, particularly those that are regarded as critical, 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.

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 more than 40 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. 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 2019 of Australia's Ore Reserves and Mineral Resources are as at 31 December 2018. 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 former Department of Industry, Innovation and Science, 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, Resources and Energy Quarterly, December 2019, Table 17. Department of Industry, Innovation and Science.
2. Australian Bureau of Statistics (ABS), Australian National Accounts, National Income, Expenditure and Product, cat. no. 5206.0, Figure of 8.4% calculated by dividing Mining (B) Table 45 by Gross Domestic Product Current Table 1.
3. Australian Bureau of Statistics. Labour Force, Australia, Detailed, Quarterly, cat. no. 6291.055.003, August 2019 Table 4.

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

There are 2192 companies and securities listed on the Australian Securities Exchange (ASX) of which 852 (39%) are 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 has 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 other parts of the world and the code is compatible with the international CRIRSCO[4] and United Nations Framework Classification for Resources templates.

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 2018, 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 8.4% to Australia's gross domestic product in 2018[5] and 46% 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 2018 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.

4. CRIRSCO is the Committee for Mineral Reserves International Reporting Standards.
5. See Footnote 2.

Table 1 Australia's Ore Reserves and Mineral Resources of selected commodities at operating mines in 2018.

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[a] (years)	Resource Life 1[b] (years)	Resource Life 2[c] (years)
Antimony	kt Sb	1	17.3	40.9	15.4	3.57[6]	5	11	16
Bauxite	Mt	10	1956	3202	3646	96.5	20	33	71
Black Coal	Mt	95	12 592	26 030[7]	13 141[7]	578[8]	22	45	68
Copper	Mt Cu	36	19.13	72.32	30.97	0.920	21	79	112
Diamond	Mc	2	24.81	24.94	19.23	14.01	2	2	3
Gold	t Au	141	2872	6689	2458	315	9	21	29
Iron Ore	Mt	34	11 610	25 538	40 111	899	13	28	73
Lead	Mt Pb	15	10.61	24.25	4.42	0.469	23	52	61
Lithium	kt Li	7	2680	3295	1200	57[9]	47	58	79
Manganese Ore	Mt	3	92	196	29	7.0[10]	13	32	37
Mineral Sands									
Ilmenite	Mt	12	15.3	56.1	14.8	1.4[11]	11	40	51
Rutile	Mt	10	2.1	7.6	2.1	0.2[11]	11	38	49
Zircon	Mt	10	4.5	13.4	2.9	0.5[11]	9	27	33
Nickel	Mt Ni	12	1.1	5.5	1.1	0.148	7	37	45
Rare Earths[12]	Mt	2	1.71	2.12	1.37	0.019[13]	90	112	184
Silver	kt Ag	23[14]	19.64	53.30	12.27	1.220	16	44	54
Tin	kt Sn	1	167	224	97	6.9[15]	24	32	47
Uranium	kt U	3	258	1425	752	5.872	44	243	371
Zinc	Mt Zn	16	22.44	49.46	11.86	1.112	20	44	55

Abbreviations

t = tonne; kt = kilotonnes (1000 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

a. Reserve Life = Ore Reserves ÷ Production.
b. Resource Life 1 = Measured and Indicated Resources ÷ Production.
c. Resource Life 2 = Measured, Indicated and Inferred Resources ÷ Production.

1. The number of operating mines counts individual mines that operated during 2018 and thus contributed to production. Some of these mines may belong to larger, multi-mine operations and some may have closed during or since 2018.
2. 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 2018.
3. 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 2018.
4. Inferred Mineral Resources are as at 31 December 2018. NB: Not all operating mines report Mineral Resources.
5. Mining production from Resources and Energy Quarterly, June 2019, 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.
6. Antimony production from company reports (Mandalay Resources Ltd).
7. 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).
8. Mine production refers to raw coal.
9. Lithium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
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. Mineral sands production from company reports.
12. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y_2O_3).
13. Rare earths production is based on Western Australian production of concentrates from Mount Weld (18 556 t) and from trial mining and processing at Browns Range (2.6 t).
14. Major silver producing mines only; many gold and copper mines also produce silver as a by-product but these are not counted here.
15. The Office of the Chief Economist reports tin production of 6.9 kt in 2018 but Renison, Australia's only tin mine, reports 6.6 kt. Additional unreported production is as by-product from other operations such as Greenbushes.

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 2018 (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.

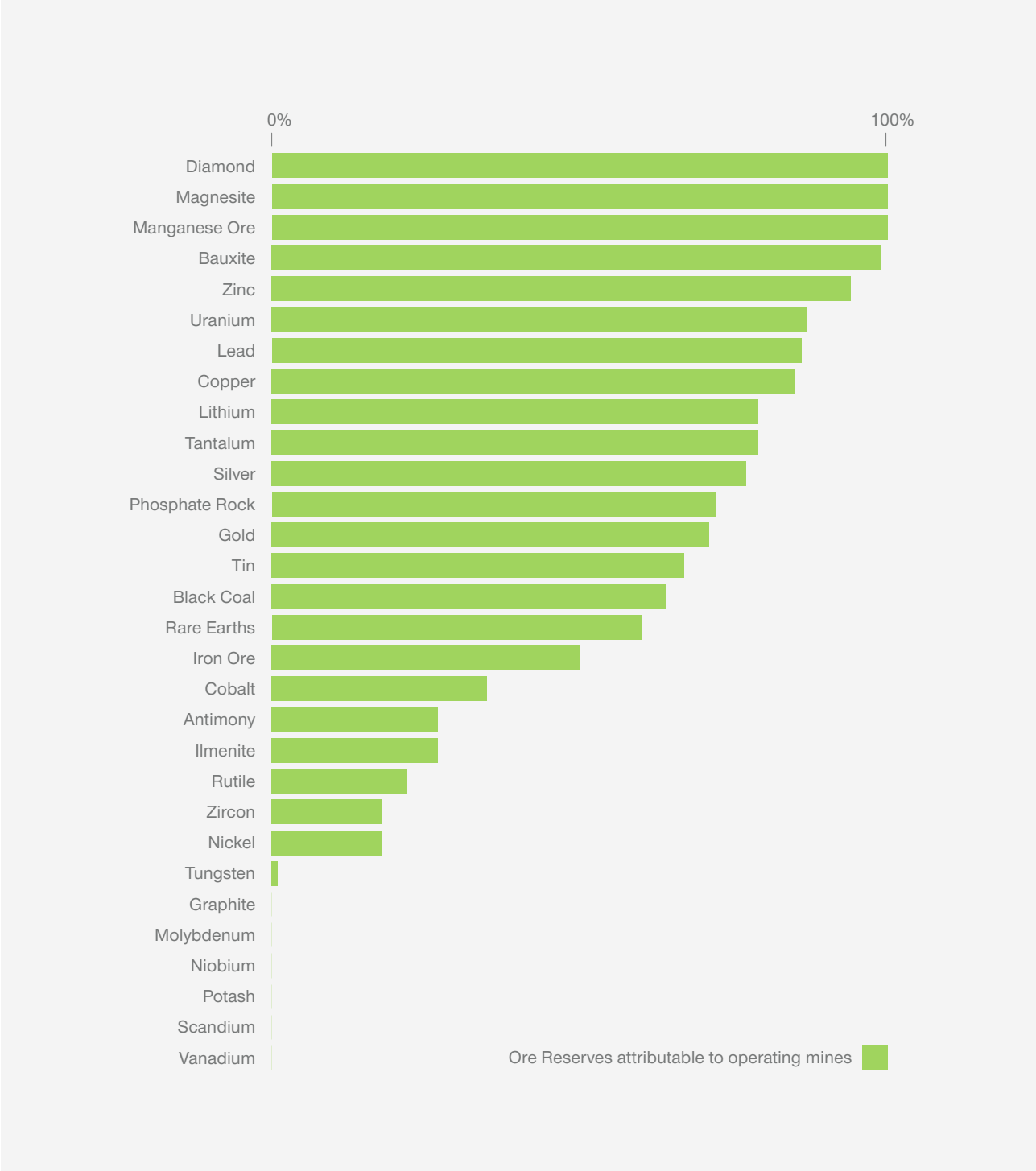


Figure 1 Ore Reserves attributable to operating mines as a percentage of total Australian Ore Reserves 2018.

Table 2 Australia's Estimated Ore Reserves[1] as at December 2018.

Commodity	Unit	Ore Reserves				Mine Production[3]	Reserve Life
		Proved (A)	Probable (B)	Proven & Probable[2] (C)	Total (A + B + C)		
Antimony	kt Sb	12.3	52.3	0	**64.6**	3.57[4]	18
Bauxite	Mt	1007	955	0	**1962**	96.5	20
Black Coal	Mt	8467	9354	1894	**19715**	578[5]	34
Brown Coal	Mt	n.a.	n.a.	n.a.	**n.a.**	48[6]	n.a.
Chromium	kt Cr	0	0	0	**0**	0	0
Cobalt	kt Co	196	437	1	**635**	4.9[7]	130
Copper	Mt Cu	6.13	15.47	0.77	**22.38**	0.920	24
Diamond	Mc	0	24.81	0	**24.81**	14.01	2
Fluorine	kt F	0	0	0	**0**	0	0
Gold	t Au	888	3100	29	**4018**	315	13
Graphite	Mt	0.28	4.89	0	**5.17**	0	0
Iron							
Iron ore	Mt	5677	12690	2	**23106**	899	26
Contained iron	Mt Fe	2442	5669	1	**10540**	557	19
Lead	Mt Pb	6.20	6.17	0	**12.37**	0.469	26
Lithium	kt Li	601	2788	0	**3389**	57[8]	59
Magnesite	Mt $MgCO_3$	10	3	24	**37**	<1[9]	187
Manganese Ore	Mt	46	30	17	**92**	7.0[10]	13
Mineral Sands							
Ilmenite	Mt	27.7	32.7	0	**60.3**	1.4[11]	43
Rutile	Mt	4.5	4.1	0	**8.7**	0.2[11]	44
Zircon	Mt	11.0	11.1	0	**22.1**	0.5[11]	44
Molybdenum	kt Mo	0	4.2	0	**4.2**	0	0
Nickel	Mt Ni	2.1	4.1	<1	**6.2**	0.148	42
Niobium	kt Nb	58	0	0	**58**	n.a.[12]	n.a.
Oil Shale	GL	0	0	0	**0**	0	0
PGE	t metal	0	0	0	**0**	0.541[13]	n.a.
Phosphate							
Phosphate rock[14]	Mt	12	21	81	**113**	1.4[15]	81
Contained P_2O_5	Mt P_2O_5	2	7	20	**29**	n.a.	n.a.
Potash	Mt K_2O	1	2	0	**3**	0	0
Rare Earths[16]	Mt	1.65	1.19	0	**2.84**	0.019[17]	149
Scandium	kt Sc	5.52	6.61	0	**12.14**	0	n.a.
Silver	kt Ag	13.56	11.84	0	**25.40**	1.220	21
Tantalum	kt Ta	12.5	32.0	0	**44.4**	0.06[18]	740
Thorium	kt Th	0	0	0	**0**	0	0
Tin	kt Sn	35	214	0	**249**	6.9	36
Tungsten	kt W	21	195	0	**216**	<1[19]	>10000
Uranium	kt U	90	203	3	**296**	5.872	50
Vanadium	kt V	740	442	0	**1182**	0	0
Zinc	Mt Zn	11.23	12.71	0	**23.94**	1.112	22

Abbreviations

t = tonne; kt = kilotonnes (1000 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, June 2019 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. Brown coal production a Geoscience Australia estimate from company reports.
7. Cobalt production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
8. Lithium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
9. The Department of State Development, South Australia (Report Book 2019/00009) reported magnesite production of 4587 t in 2018. The Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2017–18) reported magnesite production of 258 859 t in 2017–18.
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, 2018–2019 Major commodities resources file.
14. Phosphate rock is reported as being economic at grades ranging from 8.7% to 30.2% P_2O_5.
15. Geoscience Australia estimate based on reported mining production of 555 358 t from Christmas Island in 2018; 1040 t from South Australia in 2018 (Report Book 2019/00009); and 849 927 t from Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2017–18).
16. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y_2O_3).
17. Rare earths production is based on Western Australian production of concentrates from Mount Weld (18 556 t) and from trial mining and processing at Browns Range (2.6 t).
18. Tantalum production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
19. Tungsten production from company correspondence (Tasmania Mines Pty Ltd).

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 Identified 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 7 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, iron and any number of other commodities will be mined. At first glance, this statement might seem somewhat astonishing 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 material. 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, people will mine all of the current EDR (and more). Gold, for example, had an EDR of 4263 t in 1995; since then Australian miners have produced 6523 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 2018.

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	142.7	8.8	0	61.1	142.7	3.57[7]	1500	140
Bauxite	Mt	5118	30	1429	3172	5118	96.5	30 000	317
Black Coal									
In situ	Mt	88 085	2462	3986	105 094				
Recoverable	Mt	73 719	1937	3640	82 206	67 533	578[8]	737 562[9]	7010[10]
Brown Coal									
In situ	Mt	92 244	44 069	234 987	124 496				
Recoverable	Mt	76 951	41 112	215 449	103 732	66 882	48[11]	320 322[12]	803[13]
Chromium	kt Cr	0	302	0	6584	0	0	560 000[14]	36 000[14]
Cobalt	kt Co	1353	265	8	1282	1353	4.9[15]	6900	140
Copper	Mt Cu	88.17	1.27	0.63	46.82	88.17	0.920	826	20.6
Diamond	Mc	25.48	0	0	20.30	25.48	14.01	1200[16]	101
Fluorine	kt F	343	721	6	2543	343	0	153 000	2900[17]
Gold	t Au	10 165	157	200	5268	10 135	315	54 000	3260
Graphite	Mt	7.25	0.06	0	6.98	7.25	0	300	0.9
Iron									
Iron ore	Mt	49 604	10 382	1319	94 100	49 604	899	173 104	2491
Contained iron	Mt Fe	24 122	3137	443	43 021	24 122	557	83 852	1546
Lead	Mt Pb	35.78	2.70	0.14	25.20	35.78	0.469	95	4.45
Lithium	kt Li	4718	0	<1	1404	4718	57[18]	14 000	93
Magnesite	Mt $MgCO_3$	316	73	35	943	316	<1[19]	8500	29[20]
Manganese Ore	Mt	232	3	190	354	232	7.0[21]	760[22]	18[22]
Mineral Sands									
Ilmenite	Mt	276.3	16.3	0	264.6	245.0	1.4[23]	1330	9
Rutile	Mt	35.4	0.1	0.1	35.8	31.5	0.2[23]	70	1
Zircon	Mt	79.9	0.3	0.1	62.9	73.4	0.5[23]	121	2
Molybdenum	kt Mo	171	366	<1	1233	171	0	17 500	300
Nickel	Mt Ni	19.7	2.5	<1	19.1	19.7	0.148	89	2.3
Niobium	kt Nb	216	15	0	397	216	n.a.[24]	>9100	68
Oil Shale	GL	0	213	2074	1472	0	0	961 873[25]	n.a.
PGE	t metal	31.5	136.7	0	16.2	28.9	0.541[26]	69 000	370[27]
Phosphate									
Phosphate rock[28]	Mt	1091	312	0	2363	1091	1.4[29]	70 000	270
Contained P_2O_5	Mt P_2O_5	178	57	0	387	178	n.a.	n.a.	n.a.
Potash	Mt K_2O	72	8	0	124	72	0	5800	42
Rare Earths[30]	Mt oxide	4.12	0.43	33.56	26.15	4.12	0.019[31]	120	0.170
Scandium	kt Sc	26.05	7.64	0.00	19.49	26.05	0	n.a.	n.a.
Silver	kt Ag	88.36	2.26	0.49	44.14	88.36	1.220	560	27.0
Tantalum	kt Ta	99.3	1.2	0.2	42.8	99.3	0.06[32]	>110	1.8
Thorium	kt Th	0	110	17	648	0	0	n.a.	n.a.
Tin	kt Sn	430	63	32	363	430	6.9	4760	310
Tungsten	kt W	394	0	5	236	394	<1[33]	3739	82
Uranium	kt U	1325	85	21	1016	1268	5.872	3865[34]	53.5[35]
Vanadium	kt V	4646	708	1376	18 013	4646	0	22 821	73
Zinc	Mt Zn	66.96	0.45	0.75	42.17	66.96	1.112	230	13

Abbreviations

t = tonne; kt = kilotonnes (1000 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, June 2019 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.
5. World economic resources from Mineral Commodity Summaries 2019 published by the USGS and adjusted with Geoscience Australia data, unless otherwise stated.
6. World production from Mineral Commodity Summaries 2019 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 BGR Energy Study 2018 and adjusted with Australian data.
10. World mine production of black coal derived from BP Statistical Review of World Energy 2019 with lignite production removed (see International Energy Agency, Coal Information 2019 Overview) and adjusted with Australian data.
11. Australian production of brown coal a Geoscience Australia estimate from company reports.
12. World economic resources of brown coal derived from BGR Energy Study 2018 and adjusted with Australian data.
13. World mine production of brown coal from International Energy Agency (Coal Information 2019 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, 2018–2019 Major commodities resources file.
16. World resource figures are for industrial diamonds only, no data provided for resources of gem diamonds.
17. World mine production of fluorine excludes the USA.
18. Australian lithium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
19. The Department of State Development, South Australia (Report Book 2019/00009) reported magnesite production of 4587 t in 2018. The Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2017–18) reported magnesite production of 258 859 t in 2017–18.
20. World mine production excludes the USA.
21. 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.
22. World economic resources and mine production are presented as manganese content, not manganese ore.
23. Australian mineral sands production from company reports.
24. 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.
25. World resources of oil shale from World Energy Council (World Energy Resources 2016).
26. Australian platinum and palladium production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
27. World mine production is platinum and palladium only.
28. Phosphate rock is reported as being economic at grades ranging from 8.7% to 30.2% P_2O_5.
29. Geoscience Australia estimate based on reported mining production of 555 358 t from Christmas Island in 2018; 1040 t from Department of State Development, South Australia (Report Book 2019/00009); and 849 927 t from Queensland Department of Natural Resources and Mines (Queensland Annual Mineral Summary 2017–18).
30. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y_2O_3).
31. Australian rare earths production is based on Western Australian production of concentrates from Mount Weld (18 556 t) and from trial mining and processing at Browns Range (2.6 t).
32. Australian tantalum production data from Department of Mines, Industry Regulation and Safety, Western Australian Government, 2018–2019 Major commodities resources file.
33. Australian tungsten production from company correspondence (Tasmania Mines Pty Ltd).
34. 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 2018: Resources, Production and Demand (the Red Book).
35. World production of uranium in 2018 from World Nuclear Organisation (World Uranium Mining Production, August 2019 update).

Trends in EDR

Australia's EDR of the following nine mineral commodities increased significantly during 2018: cobalt, lithium, rutile, molybdenum, platinum group elements, potash, rare earths, tantalum and vanadium (Table 4). In addition, 26.05 kt of scandium resources were classified as EDR for the first time (Table 3). The EDR of three commodities decreased significantly in 2018: bauxite, diamond and phosphate in the form of phosphate rock and contained phosphate (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 2018 (see Section 7). 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.

Investment in exploration drilling expenditure totalling $2184 million in 2018, an increase of 25% from the previous year, contributed to the growth in Australia's resource base. Interestingly, as much as 80% of Australia still remains under-explored. Government initiatives such as the $100.5 million *Exploring for the Future* program support industry to make new discoveries that will help ensure Australia's prosperity into the future.

Table 4 Changes in EDR from 2017 to 2018.

Commodity	Unit	EDR		
		2017	2018	Change (%)
Antimony	kt Sb	138.2	142.7	▲ 3%
Bauxite	Mt	6015	5118	▼ -15%
Black Coal				
In situ	Mt	87 490	88 085	▲ <1%
Recoverable	Mt	72 571	73 719	▲ 2%
Brown Coal				
In situ	Mt	92 887	92 244	▼ <1%
Recoverable	Mt	76 508	76 951	▲ <1%
Cobalt	kt Co	1222	1353	▲ 11%
Copper	Mt Cu	87.47	88.17	▲ <1%
Diamond	Mc	39.68	25.48	▼ -36%
Fluorine	kt F	343	343	0%
Gold	t Au	10 070	10 165	▲ 1%
Graphite	Mt	7.14	7.25	▲ 2
Iron				
Iron Ore	Mt	47 987	49 604	▲ 3%
Contained iron	Mt Fe	23 251	24 122	▲ 4%
Lead	Mt Pb	36.42	35.78	▼ -2%
Lithium	kt Li	2803	4718	▲ 68%
Magnesite	Mt $MgCO_3$	316	316	0%
Manganese Ore	Mt	231	232	▲ <1%
Mineral Sands				
Ilmenite	Mt	276.5	276.3	0%
Rutile	Mt	32.9	35.4	▲ 8%
Zircon	Mt	78.3	79.9	▲ 2%
Molybdenum	kt Mo	160	171	▲ 7%
Nickel	Mt Ni	19.7	19.7	0%
Niobium	kt Nb	216	216	0%
PGE	t metal	24.9	31.5	▲ 26%
Phosphate				
Phosphate rock	Mt	1170	1091	▼ -7%
Contained phosphate	Mt P_2O_5	198	178	▼ -10%
Potash	Mt K_2O	58	72	▲ 24%
Rare Earths[1]	Mt oxide	3.27	4.12	▲ 26%
Silver	kt Ag	90.31	88.36	▼ -2%
Tantalum	kt Ta	55.4	99.3	▲ 79%
Tin	kt Sn	415	430	▲ 4%
Tungsten	kt W	386	394	▲ 2%
Uranium	kt U	1290	1325	▲ 3%
Vanadium	kt V	3965	4646	▲ 17%
Zinc	Mt Zn	67.52	66.96	▼ -1%

Abbreviations
t = tonne; kt = kilotonnes (1000 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.

Note
1. Rare earths comprise rare earth oxides (REO) and yttrium oxide (Y_2O_3)

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 ilmenite, rutile, zircon, 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 ilmenite, rutile and nickel have more than 50% of EDR associated with undeveloped deposits. For bauxite, copper, diamond, lead, manganese ore, uranium and zinc, Australian mines account for more than 80% 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 278 deposits contributing the national EDR, but the 95 operating mines comprise only 42% 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 69% of Australia's gold in 2018. At 2018 rates of production, 744 gold deposits have a potential resource life of 32 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 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 2018, (2) deposits currently assessed as economic/subeconomic 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 wishes 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: 8% of black coal EDR, 13% of brown coal, <1% of gold EDR, around 10% of mineral sands EDR, 8% of platinum group elements EDR and 4% of uranium EDR (Table 3). 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 2018.

Commodity (unit)	EDR	Number of			Percentage of EDR		
		Deposits with EDR	Operating Mines	All Mines	Operating Mines	All Mines	Other Deposits
Bauxite	5118 Mt	20	10	14	57%	85%	15%
Black Coal, recoverable	73 719 Mt	278	95	121	42%	55%	45%
Copper	88.17 Mt Cu	172	36	46	84%	84%	16%
Diamond	25.48 Mc	3	2	3	95%	100%	0%
Gold	10 165 t Au	744	141	187	66%	71%	29%
Iron Ore	49 604 Mt	80	34	50	57%	64%	36%
Lead	35.78 Mt Pb	71	15	20	84%	92%	8%
Lithium	4718 kt Li	10	7	9	71%	97%	3%
Manganese Ore	234 Mt	5	3	3	88%	88%	12%
Mineral Sands							
Ilmenite	276 Mt	80	12	15	22%	49%	51%
Rutile	35 Mt	59	10	11	23%	38%	62%
Zircon	80 Mt	82	10	13	18%	53%	47%
Nickel	19.7 Mt Ni	84	12	27	28%	42%	58%
Silver	88.36 kt Ag	127	23	32	75%	77%	23%
Uranium	1325 kt U	37	3	8	80%	83%	17%
Zinc	66.96 Mt Zn	80	16	19	85%	87%	13%

Abbreviations
t = tonne; kt = kilotonnes (1000 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 2018.

Commodity (unit)	Ore Reserves	EDR	AEDR	Ore Reserves/ EDR (%)	Ore Reserves/ AEDR (%)
Bauxite (Mt)	1962	5118	5118	38%	38%
Black Coal, recoverable (Mt)	19 715	73 719	67 533	27%	29%
Copper (Mt Cu)	22.38	88.17	88.17	25%	25%
Diamond (Mc)	24.81	25.48	25.48	97%	97%
Gold (t Au)	4018	10 165	10 135	40%	40%
Iron Ore (Mt)	23 106	49 604	49 604	47%	47%
Lead (Mt Pb)	12.37	35.78	35.78	35%	35%
Lithium (kt Li)	3389	4718	4718	72%	72%
Manganese Ore (Mt)	92	232	232	40%	40%
Mineral Sands (Mt)					
Ilmenite	60.3	276.3	245.0	22%	25%
Rutile	8.7	35.4	31.5	25%	28%
Zircon	22.1	79.9	73.4	28%	30%
Nickel (Mt Ni)	6.2	19.7	19.7	31%	31%
Silver (kt Ag)	25.40	88.36	88.36	29%	29%
Uranium (kt U)	296	1325	1268	22%	23%
Zinc (Mt Zn)	23.94	66.96	66.96	36%	36%

Abbreviations
t = tonne; kt = kilotonnes (1000 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 744 deposits with an EDR, account for 60% of all gold EDR (Table 7). For black coal, the top 20 deposits (7% of 278 deposits with an EDR) account for 41% 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 2018 with the 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 (68–93%; Table 7).

Table 7 Distribution of EDR of major commodities in Australia as at December 2018

Commodity (unit)	EDR	Number of		Percentage of EDR in largest	
		Deposits	Deposits with EDR	10 deposits	20 deposits
Bauxite	5118 Mt	40	20 (50%)	99	100
Black Coal, recoverable	73 719 Mt	413	278 (67%)	29	41
Copper	88.17 Mt Cu	392	172 (44%)	83	90
Diamond	25.48 Mc	12	3 (25%)	100	100
Gold	10 165 t Au	1832	744 (41%)	51	60
Iron Ore	49 604 Mt	353	80 (23%)	64	84
Lead	35.78 Mt Pb	164	71 (43%)	91	96
Lithium	4718 kt Li	14	10 (71%)	100	100
Manganese Ore	232 Mt	44	5 (11%)	100	100
Mineral Sands					
Ilmenite	276.3 Mt	225	80 (36%)	68	82
Rutile	35.4 Mt	202	59 (29%)	71	87
Zircon	79.9 Mt	225	82 (36%)	79	90
Nickel	19.7 Mt Ni	233	84 (36%)	68	90
Silver	88.36 kt Ag	264	127 (48%)	78	88
Uranium	1325 kt U	112	37 (33%)	93	98
Zinc	66.96 Mt Zn	180	80 (44%)	89	94

Abbreviations
t = tonne; kt = kilotonnes (1000 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.

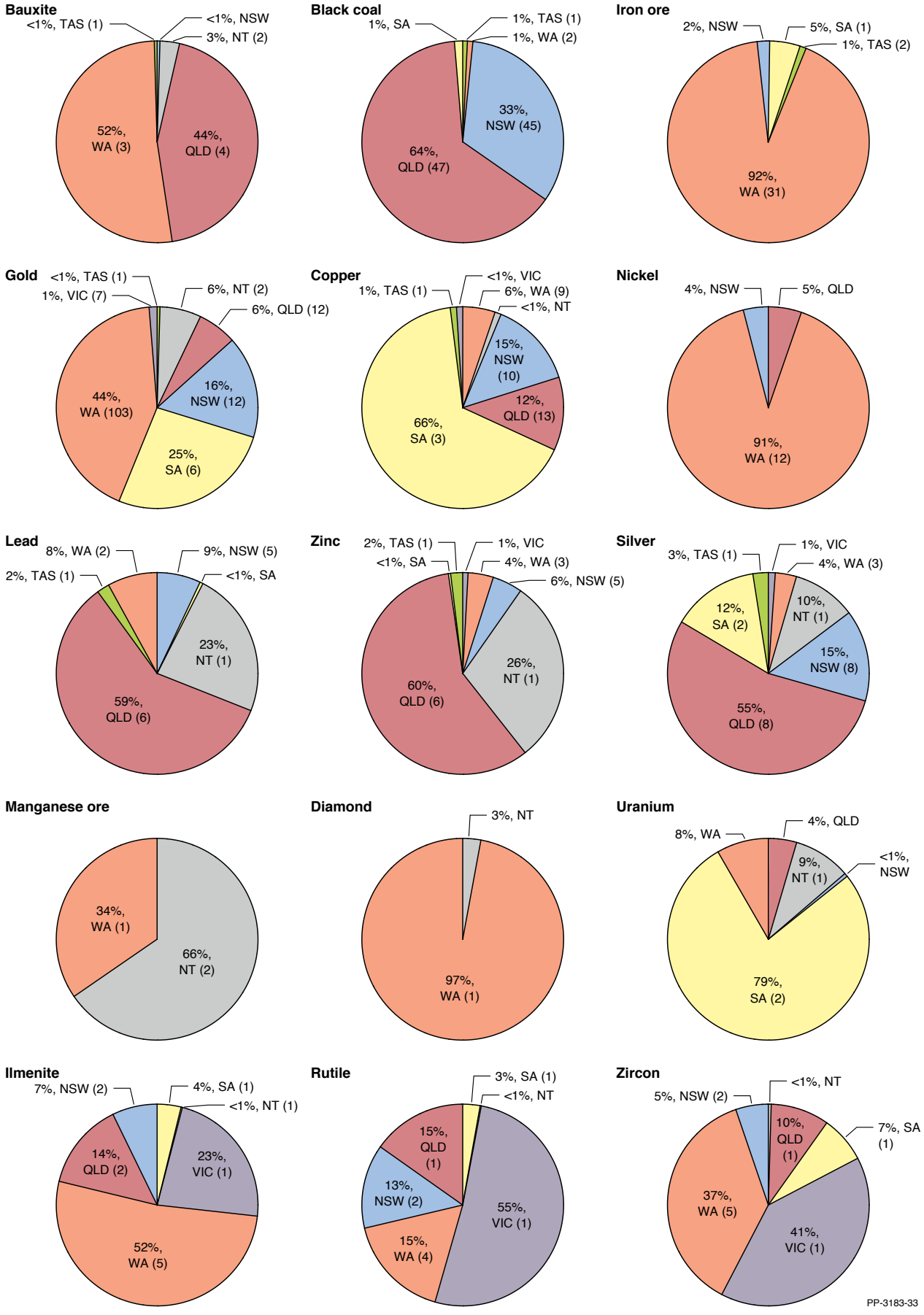


Figure 2 Distribution of EDR of major commodities by Australian jurisdiction as at December 2018. Where applicable, the number of mines in each jurisdiction is in brackets after the percentage of EDR.

In 2018, Australia's EDR of lithium increased by 68%, ranking Australia number two in the world. In terms of global production, Australia is ranked number one. Increasing lithium production has been largely driven by demand for its use in rechargeable batteries that power a range of electronic devices and electric vehicles. Australia is well placed to continue its significant contribution of lithium to global supply chains well into the future.

Photo: lithium batteries of assorted sizes.

4. World Rankings

Australia's EDR of gold, iron ore, lead, rutile, tantalum, uranium, zinc and zircon were the world's largest in 2018 (Table 8). Another 16 commodities ranked in the top five for world economic resources: antimony, bauxite, black coal, brown coal, cobalt, copper, diamond, ilmenite, lithium, manganese ore, nickel, niobium, silver, tin, tungsten and vanadium (Table 8). Australia's ranking for economic resources of lithium went from third in the world in 2017 to second in 2018, but Australia's rankings for nickel, magnesite and silver resources fell one position each in 2018 to second, sixth and third, respectively. In addition, it should be noted that 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.

In 2018, 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 gold, lead, rare earths and zircon; the third largest producer of cobalt, diamond, ilmenite, manganese ore and zinc; and the fourth largest producer of antimony, black coal and uranium in 2018 (Table 8).

Table 8 World rankings for Australia's mineral resources (EDR) and production as at December 2018.

Commodity	World Ranking for Resources	Share of World Resources	World Ranking for Production	Share of World Production
Antimony	4	9%	4	3%
Bauxite	2	17%	1	30%
Black Coal (recoverable)	4	10%	4	8%
Brown Coal (recoverable)	2	24%	6	6%
Chromium	n.a.	n.a.	0	0%
Cobalt	2	19%	3	5%
Copper	2	11%	6	4%
Diamond	5	2%	3	23%
Fluorine	minor	minor	0	0%
Gold	1	19%	2	10%
Graphite	8	2%	0	0%
Ilmenite	2	19%	3	15%
Iron Ore	1	29%	1	36%
Lead	1	38%	2	11%
Lithium	2	30%	1	63%
Magnesite	6	4%	minor	minor
Manganese Ore	5	13%	3	15%
Molybdenum	8	1%	0	0%
Nickel	2	23%	6	6%
Niobium	3	4%	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	3%	2	11%
Rutile	1	50%	1	27%
Scandium	unknown	unknown	0	0%
Silver	3	16%	6	5%
Tantalum	1	67%	7	3%
Thorium	n.a.	n.a.	0	0%
Tin	4	9%	8	2%
Tungsten	2	11%	minor	minor
Uranium	1	34%	3	12%
Vanadium	3	20%	0	0%
Zinc	1	29%	3	9%
Zircon	1	63%	2	25%

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

Australia is a leading producer of many minerals used in a vast array of modern technologies, including critical minerals. Critical minerals are vital for the economic well-being of the world's major and emerging economies but supply can be threatened by scarcity and/or geopolitical issues. Australia has significant resources of many of these technology minerals, including the lithium, rare earths and cobalt needed for the electric vehicle industry. Australia's large mineral resources mean that it is well placed to meet growing global demand.

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 2018 reserve and resource estimates to 2018 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 estimates 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 2018.

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	20	33	71	20	55	100
Black Coal	22	45	68	34	115	280
Copper	21	79	112	24	95	150
Diamond	2	2	3	2	<5	<5
Gold	9	21	29	13	30	50
Ilmenite	11	40	51	43	165	400
Iron Ore	13	28	73	26	55	175
Lead	23	52	61	26	75	135
Lithium	47	58	79	59	85	105
Manganese Ore	13	32	37	13	35	110
Nickel	7	37	45	42	135	280
Rutile	11	38	49	44	160	355
Silver	16	44	54	21	70	110
Tin	24	32	47	36	60	130
Uranium	44	243	371	50	225	415
Zinc	20	44	55	22	60	100
Zircon	9	27	33	44	145	285

Notes

Reserve and resource life for each mineral commodity is 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.

1. Operating mines includes all mines that operated during 2018 and thus contributed to production (see Table 1).
2. Ore Reserves as reported in compliance with the JORC Code, plus non-JORC Code equivalents (see Table 1).
3. 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).
4. 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).
5. Ore Reserves as reported in compliance with the JORC Code, plus non-JORC Code equivalents (see Table 2).
6. AEDR = Accessible Economic Demonstrated Resources (see Table 3). Figures rounded to nearest five years.
7. All Resources for All Deposits includes EDR, Subeconomic Demonstrated Resources and Inferred Resources (see Table 3). Figures rounded to nearest five years.

Energy generated from wind and solar has become a larger proportion of the energy mix over the last decade and is expected to continue growing to meet future demand for clean energy sources. A wide range of minerals, including many critical minerals, are used in the production of renewable energy technologies and Australia is well placed to provide the world with reliable and responsible supply.

Photo: windfarm at Albany, Western Australia.

6. Value of Australian Mineral Exports

In 2018, Australian mineral exports (excluding petroleum products) amounted to approximately $201 billion, which was more than 58% of all export merchandise and 46% of all exported goods and services (Table 10). Domestically, mining industries accounted 8.4% of gross domestic product in the 2018 calendar year. Table 10 also shows that mineral export earnings in 2018 were up 12% on 2017, continuing the gains seen since 2016. Prior to this, the Australian economy was subject to large price falls for many mineral commodities, particularly for iron ore and coal, following the 2008 global financial crisis.

Quarterly reports published by the Office of the Chief Economist show that the main mineral export earners in 2018 were iron ore (31.5% of total mineral export earnings), black coal (33.2%), gold (9.4%), copper (4.6%), bauxite-alumina-aluminium (7.9%), nickel (2.1%) and zinc (2.0%; Table 11). These same minerals were the main income earners in the previous year (Table 12).

Significant increases in export earnings were recorded in 2018 by alumina, aluminium, bauxite, black coal, copper, gold, steel, iron scrap, unrefined lead, nickel and unrefined zinc (Table 12). The increased export earnings for gold, steel and unrefined lead and zinc generally correlated with increased export volumes (Table 12). In contrast, increased export earnings for alumina in 2018 (up 38%) was the result of higher prices as there was no significant change in export volume. Other significant prices rises in 2018 were seen for aluminium, black coal, copper, scrap iron, unsorted diamonds and nickel, which all had prices increases of 10% or more compared to 2017 (Table 12).

The nickel sector experienced the most significant gains in 2018 with refined and intermediate nickel showing a 31% increase in export volume and a massive 83% increase in export earnings owing to a 39% increase in value (Table 12). Bauxite, aluminium, black coal, copper, gold and zinc also recorded increased volumes outpaced by increased export earnings due to price rises (Table 12). For example, zinc ore and concentrate was up 30% by volume compared to 2017 but had a 38% increase in export earnings. In contrast, gem-quality diamonds saw prices reduced by 56% in 2018 and it was only a massive 145% increase in export volume that prevented export earnings from decreasing compared to 2017 (Table 12).

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 2018, for example, was worth $42/t whereas alumina was worth $580/t (Table 11). This is a 14-fold increase on the price of alumina; 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 $2976/t in 2018 (Table 11). This is a fivefold increase on the price of alumina and a massive 70-fold increase on the price of bauxite. Similar value adding is seen in the copper, iron 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 2018.

Category	2011	2012	2013	2014	2015	2016	2017	2018
Total Mineral Exports	167 867	149 879	162 572	158 312	140 885	150 186	178 999	201 512
Total Resources and Energy Exports	194 607	179 007	190 323	190 859	166 131	175 645	213 046	257 607
Total Merchandise Exports	263 222	249 678	263 456	266 739	250 334	259 071	301 998	345 468
Total Goods and Services Exports	319 539	306 237	323 442	332 120	323 136	336 894	386 677	438 345

Note: Total mineral exports includes: metallic minerals, energy minerals (coal and uranium), gemstones, mineral sands and refined minerals (concentrates, bullion, ingot metals).
Source: Office of the Chief Economist (Resources and Energy Quarterly December 2019).

Table 11 Australian export volumes and values of mineral and metal commodities 2018.

Commodity	Export volume	Unit	Export earnings ($million)	Value ($/t or $/c)	Percentage of total mineral export earnings
Aluminium—Bauxite	31512	kt	1308	42	0.6%
Aluminium—Alumina	17868	kt	10357	580	5.1%
Aluminium—Ingot Metal	1437	kt	4277	2976	2.1%
Black Coal—Metallurgical	178853	kt	41244	231	20.5%
Black Coal—Thermal	207654	kt	25605	123	12.7%
Copper—Ore and Concentrates	2072	kt	6119	2953	3.0%
Copper—Refined	354	kt	3155	8912	1.6%
Diamonds—Unsorted	14736000	c	255	17	0.1%
Diamonds—Sorted Gem	169000	c	302	1787	0.1%
Gold—Refined	341	t	18856	55296188	9.4%
Iron—Ore	834553	kt	63339	76	31.4%
Iron—Crude Steel	1209	kt	1044	864	0.5%
Iron—Scrap	2048	kt	1002	489	0.5%
Lead—Concentrates	243	kt	590	2428	0.3%
Lead—Refined	192	kt	587	3057	0.3%
Lead—Bullion	109	kt	383	3514	0.2%
Nickel—Ore and Concentrates	164	kt	259	1579	0.1%
Nickel—Refined and Intermediate	234	kt	4027	17205	2.0%
Silver—Refined	286	t	194	678322	0.1%
Tin—metal content	6911	t	168	24309	0.1%
Uranium—Oxide (U_3O_8)	7272	t	635	87321	0.3%
Zinc—Ore and Concentrates	2017	kt	2477	1228	1.2%
Zinc—Refined	418	kt	1675	4007	0.8%

Note: Total mineral export earnings in 2018 were $201208 million (see Table 10).
Source: Office of the Chief Economist (Resource and Energy Quarterly December 2019).

Table 12 Changes in Australian minerals and metal export volumes, earnings and values from 2017 to 2018, along with percentage share of export earnings in 2017 and 2018.

Commodity	Export Volume (%)	Export Earnings (%)	Value (%)	Percentage of total mineral export earnings 2017	Percentage of total mineral export earnings 2018
Aluminium—Bauxite	▲ 16%	▲ 19%	▲ 3%	0.6%	0.6%
Aluminium—Alumina	0%	▲ 38%	▲ 38%	4.2%	5.1%
Aluminium—Ingot Metal	▲ 10%	▲ 27%	▲ 15%	1.9%	2.1%
Black Coal—Metallurgical	▲ 4%	▲ 14%	▲ 10%	20.3%	20.5%
Black Coal—Thermal	▲ 4%	▲ 23%	▲ 19%	11.6%	12.7%
Copper—Ore and Concentrates	▲ 17%	▲ 28%	▲ 9%	2.7%	3.0%
Copper—Refined	0%	▲ 11%	▲ 11%	1.6%	1.6%
Diamonds—Unsorted	▼ -9%	▲ 1%	▲ 11%	0.1%	0.1%
Diamonds—Sorted Gem	▲ 145%	▲ 7%	▼ -56%	0.2%	0.1%
Gold—Refined	▲ 7%	▲ 12%	▲ 4%	9.4%	9.4%
Iron—Ore	▲ 1%	0%	▼ -1%	35.3%	31.4%
Iron—Crude Steel	▲ 25%	▲ 13%	▼ -9%	0.5%	0.5%
Iron—Scrap	▲ 5%	▲ 22%	▲ 17%	0.5%	0.5%
Lead—Concentrates	▲ 57%	▲ 33%	▼ -15%	0.2%	0.3%
Lead—Refined	▼ -12%	▼ -11%	▲ 1%	0.4%	0.3%
Lead—Bullion	▼ -14%	▼ -22%	▼ -9%	0.3%	0.2%
Nickel—Ore and Concentrates	▼ -5%	▼ -6%	▼ -1%	0.2%	0.1%
Nickel—Refined and Intermediate	▼ -31%	▼ -83%	▼ -39%	1.2%	2.0%
Silver—Refined	▼ -44%	▼ -47%	▼ -6%	0.2%	0.1%
Tin—metal content	▼ -1%	▲ 1%	▲ 2%	0.1%	0.1%
Uranium—Oxide (U_3O_8)	▼ -2%	▲ 7%	▲ 9%	0.3%	0.3%
Zinc—Ore and Concentrates	▲ 30%	▲ 38%	▲ 6%	1.0%	1.2%
Zinc—Refined	▼ -4%	▲ 3%	▲ 7%	0.9%	0.8%

Note: See Table 10 for total mineral export earnings in 2017 and 2018. Value refers to $/unit of product, i.e. $/c for diamonds and $/t for all other commodities.
Source: Office of the Chief Economist (Resource and Energy Quarterly December 2019).

7. Commodity Summaries

Bauxite

Australia's EDR of bauxite fell from 6015 Mt in 2017 to 5118 Mt in 2018 (Table 3), a 15% drop (Table 4). Subeconomic resources remained unchanged over the year at 1459 Mt, but Inferred Resources increased 53% from 2079 Mt in 2017 to 3172 Mt on the back of new resource estimates at Weipa and Amrun (South of Embley).

Production increased from 87.9 Mt in 2017 to 96.5 Mt in 2018 (Table 1). This 10% increase was offset by a 10% fall in Ore Reserves. Ore Reserves in 2018 were 1962 Mt (Table 2), reduced from 2170 Mt in 2017. Consequently, Australia's reserve life for bauxite fell from 25 years to 20 years (Table 2). Resource life (based on AEDR) fell from 70 years to 53 years (Table 9). Major deposits are shown in Figure 3 on a total resource basis.

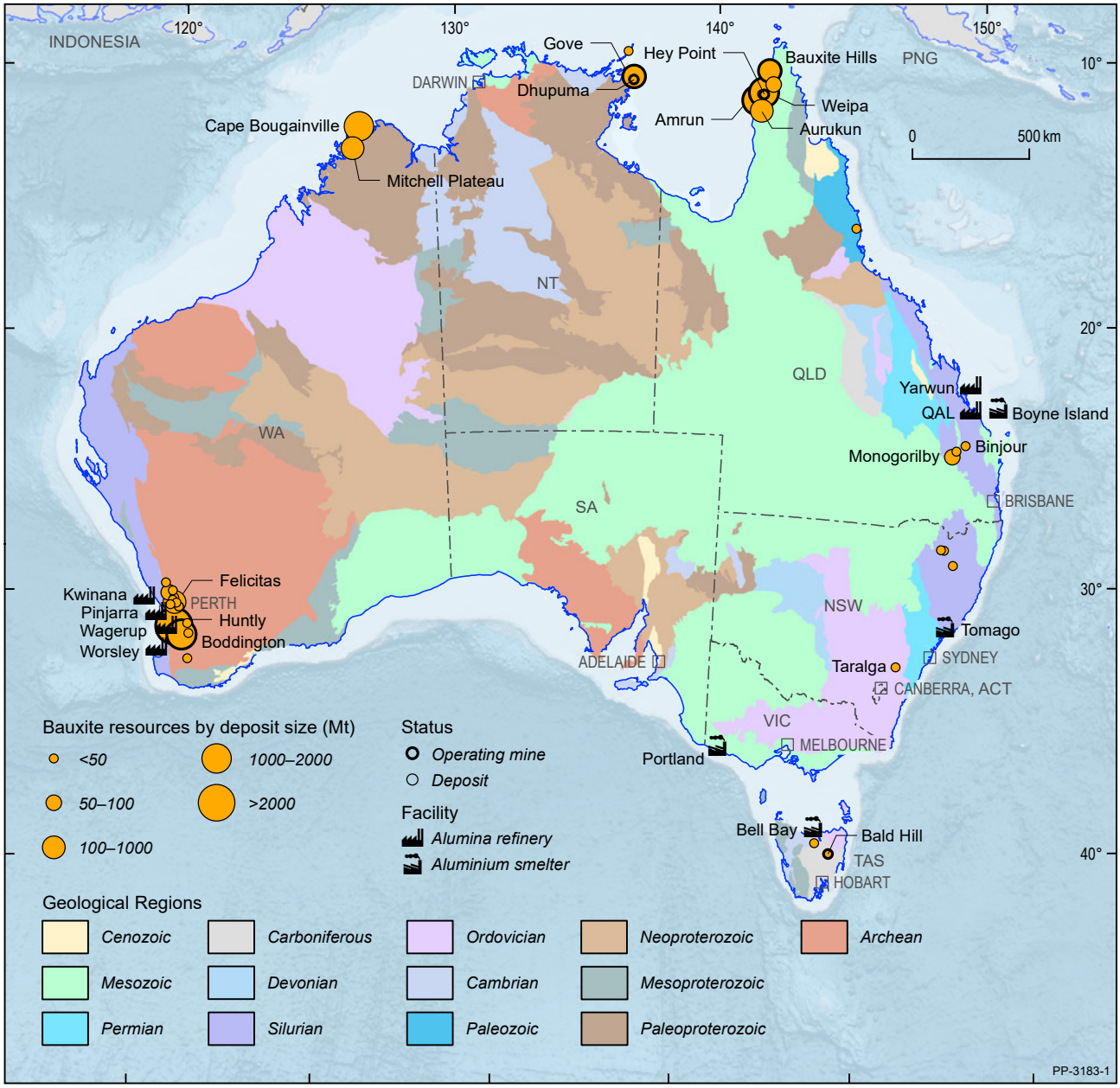


Figure 3 Australian bauxite deposits, operating mines, alumina refineries and aluminium smelters 2018.

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

Figure 4 shows that since 1975 bauxite production has increased more rapidly than the bauxite inventory. In 1975, bauxite production was 21 Mt which rose to 96.5 Mt in 2018, an increase of 360%. Bauxite EDR has increased 71% in the same time period (3000 Mt in 1975 to 5118 Mt in 2018) and total resources of bauxite (EDR + Subeconomic + Inferred) have increased from 6678 Mt in 1976 to 9749 Mt in 2018, an increase of 46%.

In addition to increased production, the number of active mines has also increased (Table 1) with new mines in Queensland and the Northern Territory. Rio Tinto Ltd's major Amrun mine, located south of Weipa on the western side of the Cape York Peninsula in Queensland, came on line in late 2018 and is the second largest in Australia. Also in this region, Bauxite Hills, owned by Metro Mines Ltd, began producing in April 2018 and, in the Northern Territory, the Dhumpuma (Gulkula Mining Company Pty Ltd) mine sent its first production to Rio Tinto's Gove operation.

In Tasmania, Australian Bauxite Ltd produced from its Bald Hill operation and the company continues to progress its Binjour deposit in Queensland with the announcement of a three-party memorandum of understanding for supply with Tianshan Aluminium Co Ltd and Rawmin Mining and Industries Pty Ltd.

Australia remains the world's largest producer of bauxite accounting for 30% of global production (Table 8). Australia is also the world's second largest producer of alumina, after China, with 26% of production, and is ranked sixth in the world for aluminium production (3%). Australia's resources of bauxite are the second largest in the world with only Guinea holding more, 25% compared to Australia's 17% (Table 8).

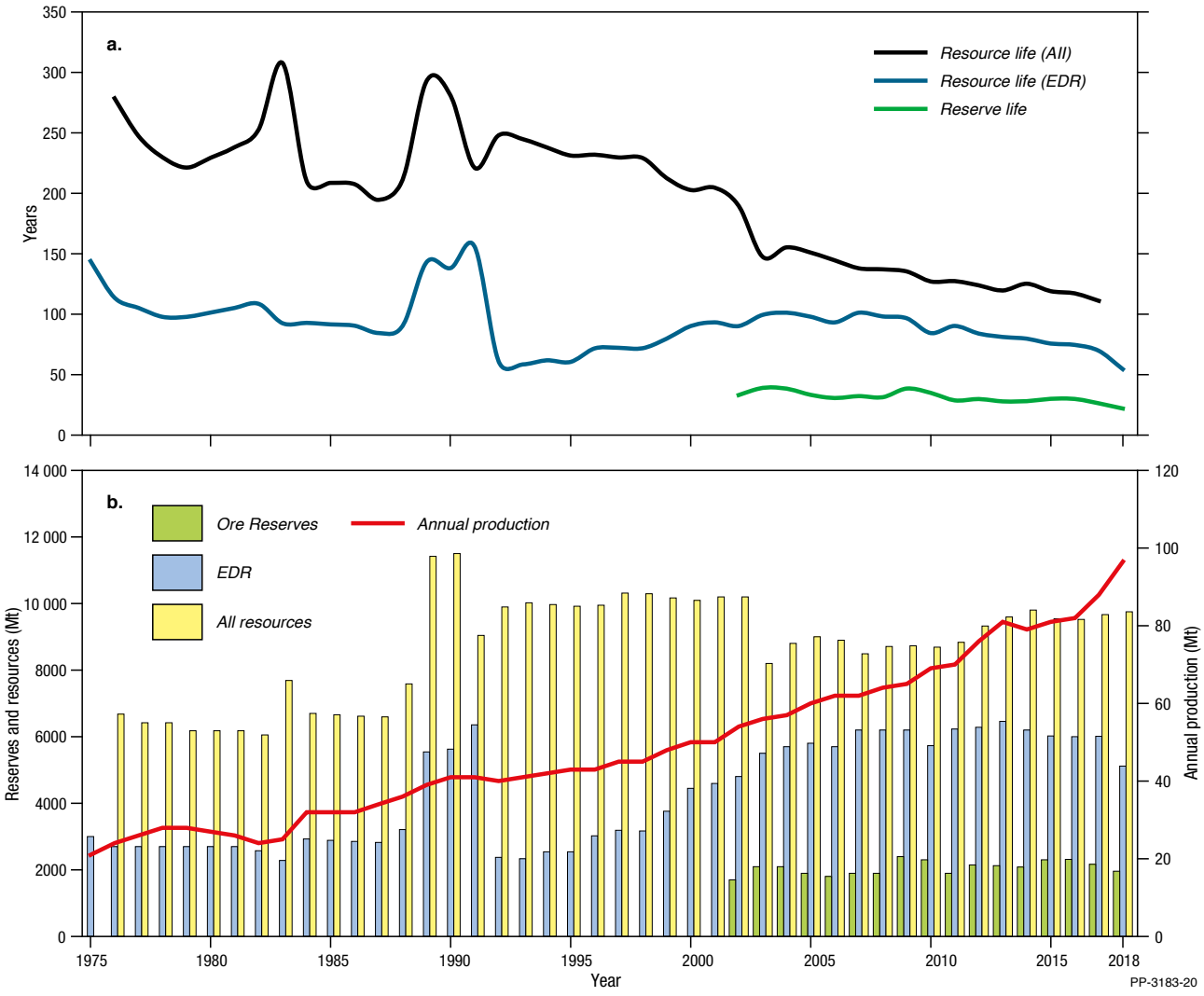


Figure 4 (a) Trends in bauxite reserve and resource life. These ratios are derived from (b) bauxite Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Black Coal

At the end of December 2018, EDR of recoverable black coal were 73 719 Mt (Table 3), a small increase (1%) from 72 571 Mt the previous year (Table 4). Most of Australia's black coal EDR is in Queensland (64%) and New South Wales (33%), the remainder is in South Australia, Western Australia and Tasmania (Figure 2). Major deposits are shown in Figure 5 on a total resource basis.

Australia holds an estimated 10% of world economic resources of black coal and ranks fourth in the world (Table 8), behind the United States (30%), China (18%) and India (13%). In 2018, Australian black coal production was 578 Mt (Table 1), up by 3% from 559 Mt in 2017, representing 8% of world production.

In 2018, the Newcastle benchmark thermal coal spot price averaged US$105/t, compared to US$87/t in 2017, and the premium hard coking coal spot price averaged US$207/t, compared to US$186/t in 2017. The value of Australia's exports of coal totalled $66.8 billion, up 17% on $57.1 billion in 2017.

As at December 2018, total Ore Reserves of black coal reported in compliance with the JORC Code amounted to 19 715 Mt (Table 2) of which 12 592 Mt (64%) was attributable to 95 operating mines (Table 1, Figure 1). In 2018, total Ore Reserves increased by 6% from 18 536 Mt to 19 715 Mt, whilst the Ore Reserves at operating mines decreased by almost 1% from 12 713 Mt to 12 592 Mt.

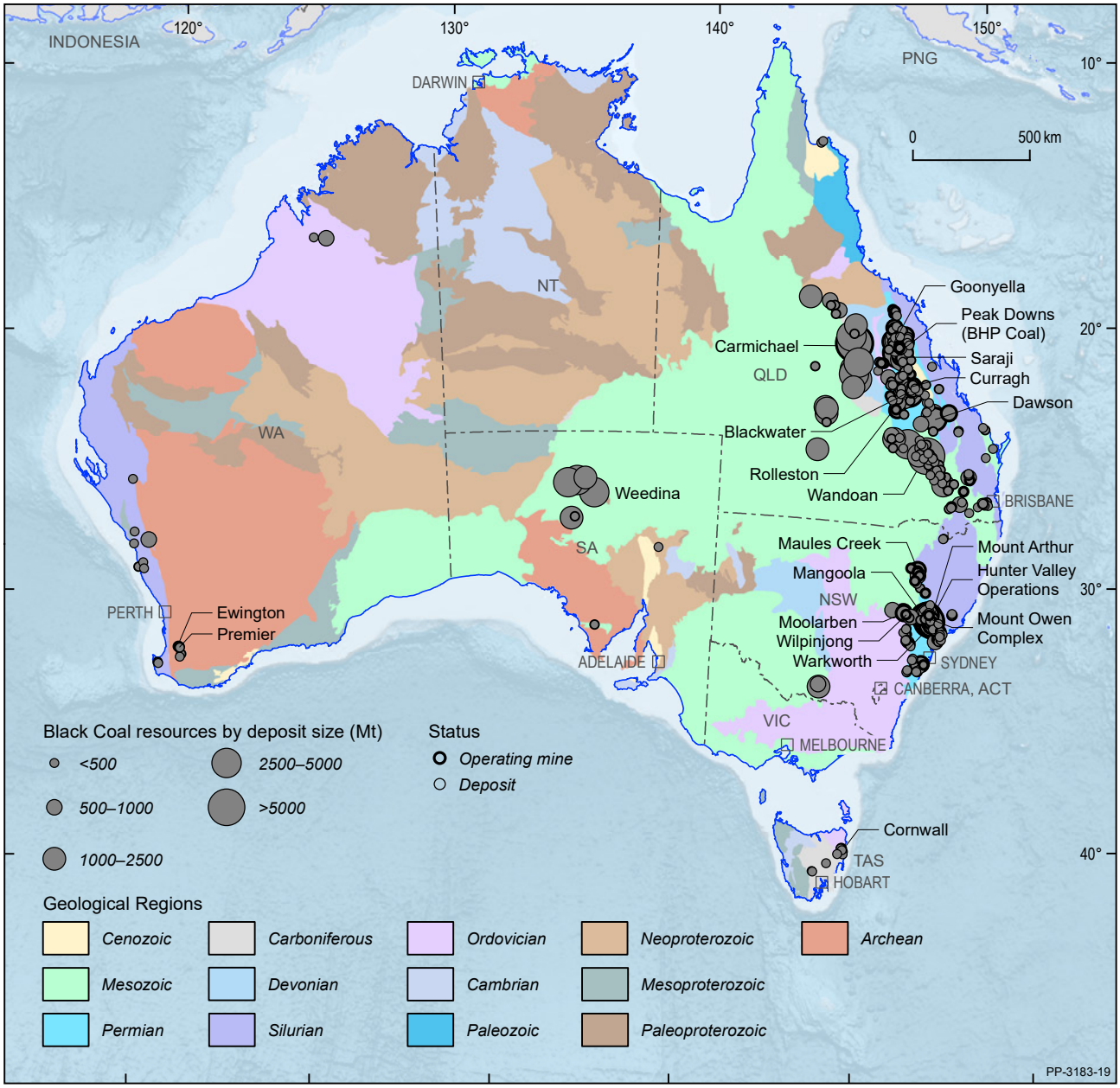


Figure 5 Australian black coal deposits and operating mines 2018.

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

At 2018 production levels, the average reserve life at operating mines for black coal is potentially 22 years (Table 1, Figure 6), a modest change from 23 years in 2017. The Measured and Indicated Mineral Resource life at operating mines is 45 years and the Measured, Indicated and Inferred Mineral Resource life at operating mines is 68 years (Table 1).

Resource life is a snapshot in time derived by taking a reserve or resource number and dividing it by a production number. 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 6).

Spending on coal exploration in 2018 was $173 million, a 40% increase on 2017 ($124 million) with most of the exploration expenditure occurring Queensland. In 2017, the New South Wales Department of Planning and Environment, and the New South Wales Planning Assessment Commission, rejected the Rocky Hill Coal Project near Gloucester. New operations did, however, commence in 2018 at the following locations: Isaac Plains East, a satellite of the Isaac Plains mine near Moranbah in Queensland; Meteor Downs South, near Emerald in Queensland; and Mount Pleasant in New South Wales. In 2019, the New South Wales Independent Planning Commission refused development consent to the Bylong Coal Project on environmental grounds, whilst the United Wambo project in the Hunter Valley (also New South Wales) gained conditional approval.

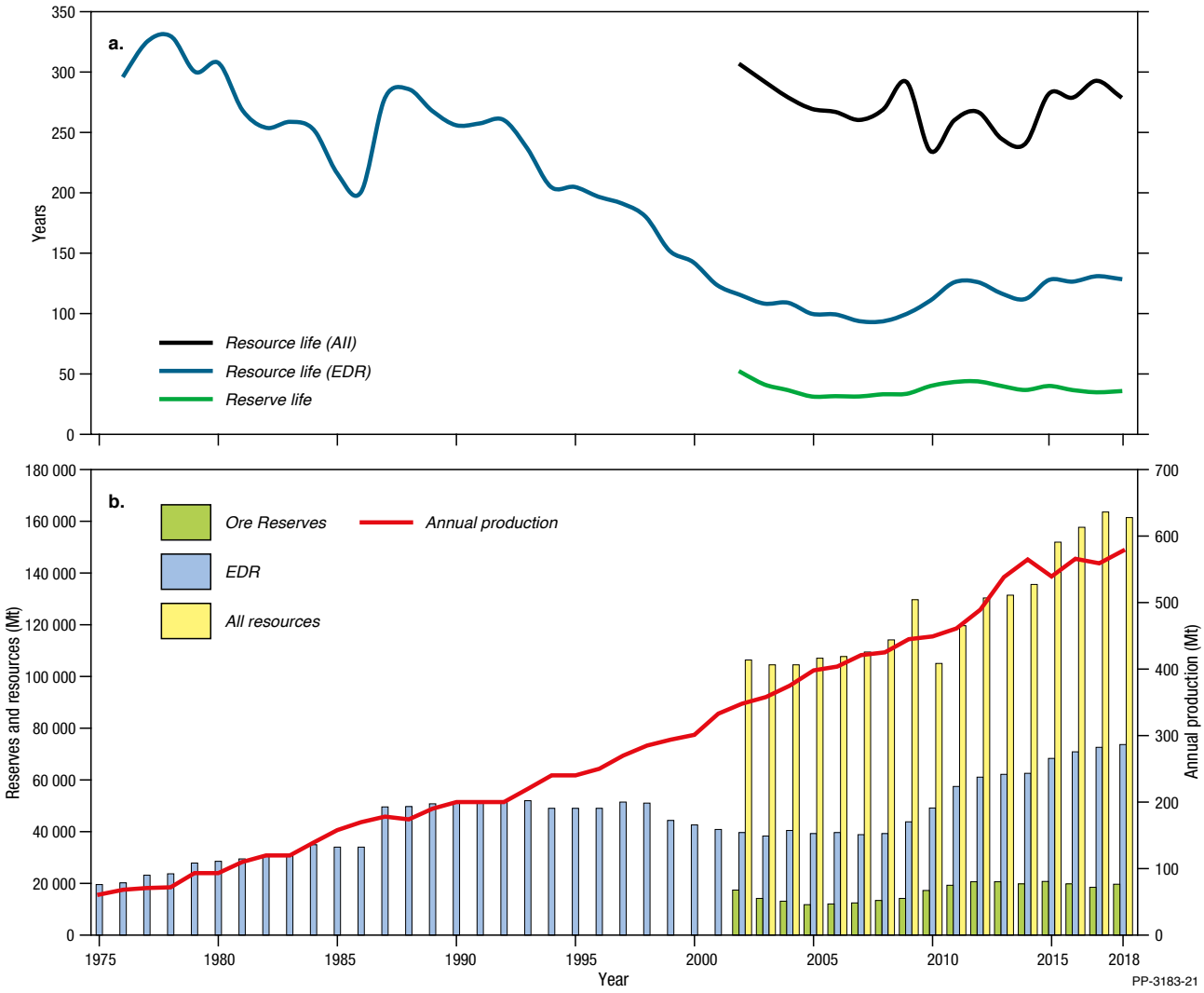


Figure 6 (a) Trends in recoverable black coal reserve and resource life. These ratios are derived from (b) recoverable black coal Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Brown Coal

The 2018 estimate of Australia's recoverable brown coal EDR is 76 951 Mt (Table 3), a modest increase from 76 508 Mt in 2017. Nearly all of Australia's recoverable brown coal is located in Victoria with more than 93% 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% and Australia ranks second (Table 8), behind Russia (28%) and followed by Germany (11%) and the USA (9%).

The estimate of Australian brown coal production for 2018 is 48 Mt, ranking Australia sixth in the world (Table 8) behind Germany, Russia, Turkey, the USA and Poland. Brown coal mined in Australia is used almost exclusively for domestic electricity generation in Victoria, although a small mine at Maddingley, 50 km northwest of Melbourne, uses brown coal to produce agricultural products. At 2018 rates of extraction, the accessible resource base (66 882 Mt; Table 3) will support over 1000 years of production.

Recent years have seen the ongoing closure of brown coal-fired power stations and an associated reduction in brown coal production and consumption. The most recent closure, in March 2017, was the Hazelwood mine and power station. However, the Loy Yang A, Loy Yang B and Yallourn Valley power stations, all located in the Latrobe Valley, remain operational and continue to contribute to the national electricity market.

Cobalt

Australia's EDR and Ore Reserves of cobalt significantly increased in 2018. Cobalt EDR were 1353 kt (Table 3), an increase of 11% from the 2017 estimate of 1222 kt (Table 4), and total Ore Reserves were 635 kt (Table 2), up 52% from 307 kt in 2017. Most cobalt deposits in Australia occur in Western Australia (Figure 7), which hosts the largest proportion of cobalt EDR (70%). Queensland has the second largest EDR (15%) followed by New South Wales (14%) and South Australia (1%). Major deposits are shown in Figure 7 on a total resource basis.

In world rankings, Congo dominates the global economic resources of cobalt with an estimate of 3400 kt which is equivalent to 49% of the global inventory. Australia follows with 20% of global economic resources with Cuba third (7%). In 2018, Australia produced 4.9 kt of cobalt (Table 3) ranking third globally (Table 8), behind Congo and Russia.

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 minerals[6].

Coal is most commonly used as a source of fuel for generating electricity and provides approximately 60% of Australia's annual electricity requirements. High-grade black coal can be used, not only as a fuel source, but to make coke. Coke is an essential raw material needed for making steel, which is used in millions of applications worldwide such as in cars, buildings, bridges and electrical appliances.

Photo: Moranbah Mine in central Queensland.

6. United States Government Federal Register, 2018. Final List of Critical Minerals 2018. A Notice by the Interior Department on 05/18/2018. Document 83 FR 23295.
7. United States Geological Survey, 2019. Mineral Commodity Summaries, Cobalt.

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 USGS notes the 2018 average cobalt price was higher than that of 2017, owing to strong demand from consumers in the rechargeable battery and aerospace industries and to limited availability of cobalt metal[7]. However, by the end of 2018, the cobalt price was down 66% from its peak value of $55/lb, reached in April 2018. The high price of cobalt had caused a widespread push by battery and car makers to reduce the amount of cobalt needed in batteries, negatively impacting demand. Despite the fallen price, the long-term outlook for cobalt is still strong with predicted growth in demand and a tightening in supply.

Recent activity in Australia has seen CuDeco Ltd, a copper producer, partnering with Cobalt Blue Holdings Ltd to assess the potential of recovering cobalt from the tailings of the Rocklands mine in Queensland. Cobalt Blue has also partnered with Broken Hill Prospecting Ltd in the Thackaringa cobalt project that includes the Railway and Pyrite Hill deposits in New South Wales.

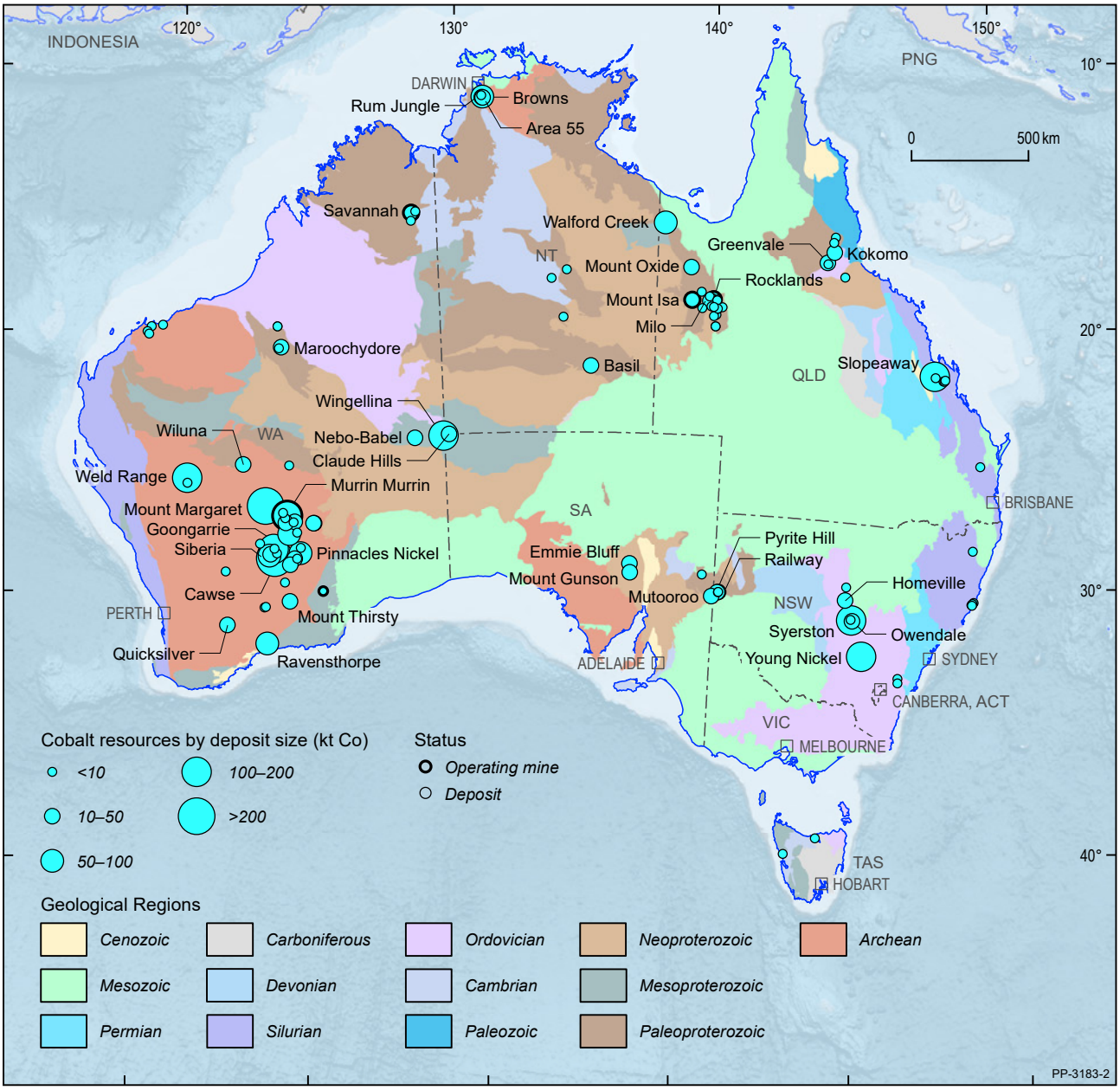


Figure 7 Australian cobalt deposits and operating mines 2018.

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

Copper

Australia's EDR of copper were 88.17 Mt at the end of December 2018 (Table 3), a modest increase from 87.47 Mt in 2017 (Table 4). South Australia holds 66% of Australia's copper EDR, followed by New South Wales (15%), Queensland (12%), Western Australia (6%) and Tasmania (1%), with minor (<1%) EDR each held by the Northern Territory and Victoria (Figure 2).

As at December 2018, total Ore Reserves of copper reported in compliance with the JORC Code amounted to 22.38 Mt (Table 2) of which 19.13 Mt (85%) was attributable to 36 operating mines (Figure 1, Table 1). Ore Reserves at operating mines decreased by nearly 5% from 20.08 Mt in 2017 to 19.13 Mt in 2018 as a result of increased production, which totalled 0.920 Mt (Table 1), up 7% on 2017 levels and accounting for 4% of global supply (Table 8). At 2018 production levels, the reserve life at operating mines for copper was potentially 21 years. Total Ore Reserves at all deposits also decreased in 2018, from 23.03 Mt in 2017 to 22.38 Mt (Table 2). At 2018 production levels, the Measured and Indicated Mineral Resource life at operating mines is 79 years and the Measured, Indicated and Inferred Mineral Resource life at operating mines is 112 years. Operating mines and deposits are shown in Figure 8 on a total resource basis.

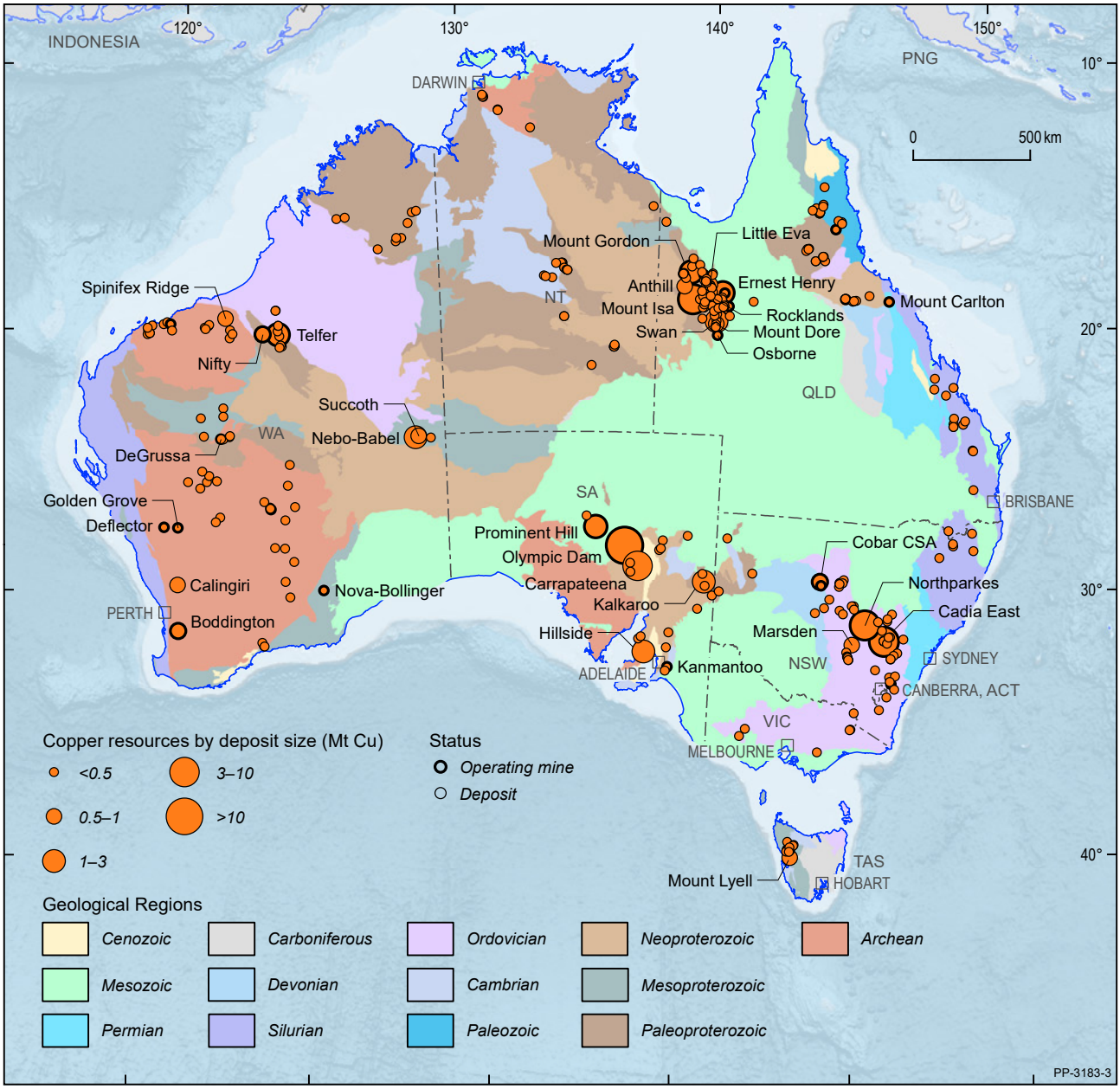


Figure 8 Australian copper deposits and operating mines 2018.

Deposit size is based on total 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. While copper reserve life has been broadly constant (Figure 9), 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 9). Since 2009, resource life (EDR) has ranged between 90 and 100 years reflecting a congruency between production and resource replacement (Figure 9).

Spending on copper exploration in 2018 was $260 million, a 70% increase on 2017 ($155 million) with increases in copper exploration expenditure occurring over the last two years still not reaching the levels seen in 2012 ($414 million). Exploration activity in 2018 included drilling at Rio Tinto Ltd's tenements in the Yeneena Basin of the Paterson Province (Western Australia), resulting in the discovery of copper-gold mineralisation at the Winu project. Talisman Mining Ltd was granted two exploration licenses in the Boona project area (New South Wales) and, as of October 2019, exploration drilling continues. In 2018, Hammer Metals Ltd reported a maiden Inferred Resource at the Jubilee copper-gold deposit in the Mount Isa region of Queensland and Thor Mining PLC also reported a maiden Inferred Resource at the Bonya copper project in the Northern Territory.

Australia hosts 11% of the world's copper resources (Table 8), second only to Chile and ahead of Peru. 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 concentrates and refined copper in 2018 totalled $9.3 billion (Table 11), up 22% on $7.6 billion in 2017. In 2018, the London Metal Exchange cash price averaged US$6525/t, an increase from US$6164/t in 2017.

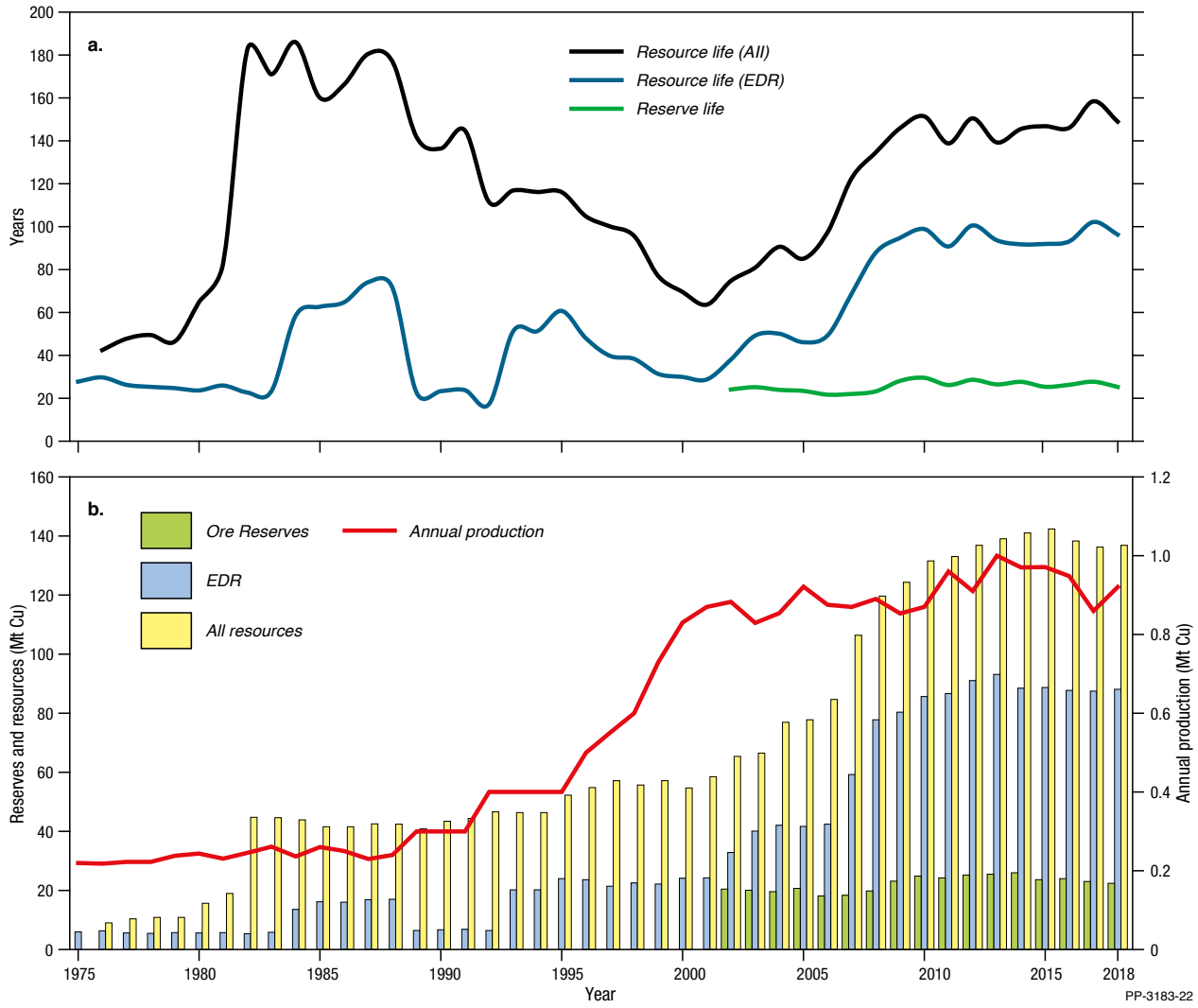


Figure 9 (a) Trends in copper reserve and resource life. These ratios are derived from (b) copper Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Diamond

In 2018, Australia's total EDR of diamond were 25.48 Mc (Table 3), down 36% from 39.68 Mc in 2017 (Table 4). This is largely owing to resources at Argyle being depleted by mining. Despite a 145% increase in export volume of sorted gem diamonds (Table 12), total production also decreased, from 17.14 Mc in 2017 to 14.07 Mc in 2018 (Table 3). This combination of declining resources and mine production has resulted in an Australian diamond resource life of only two years or less (Table 9).

The Argyle lamproite pipe in the east Kimberley region of Western Australia was responsible for almost all diamond production in Australia, with small-scale mining at the Merlin mine in the Northern Territory contributing a small quantity of diamonds. Operating mines and deposits for diamond are shown in Figure 10 on a total resource basis.

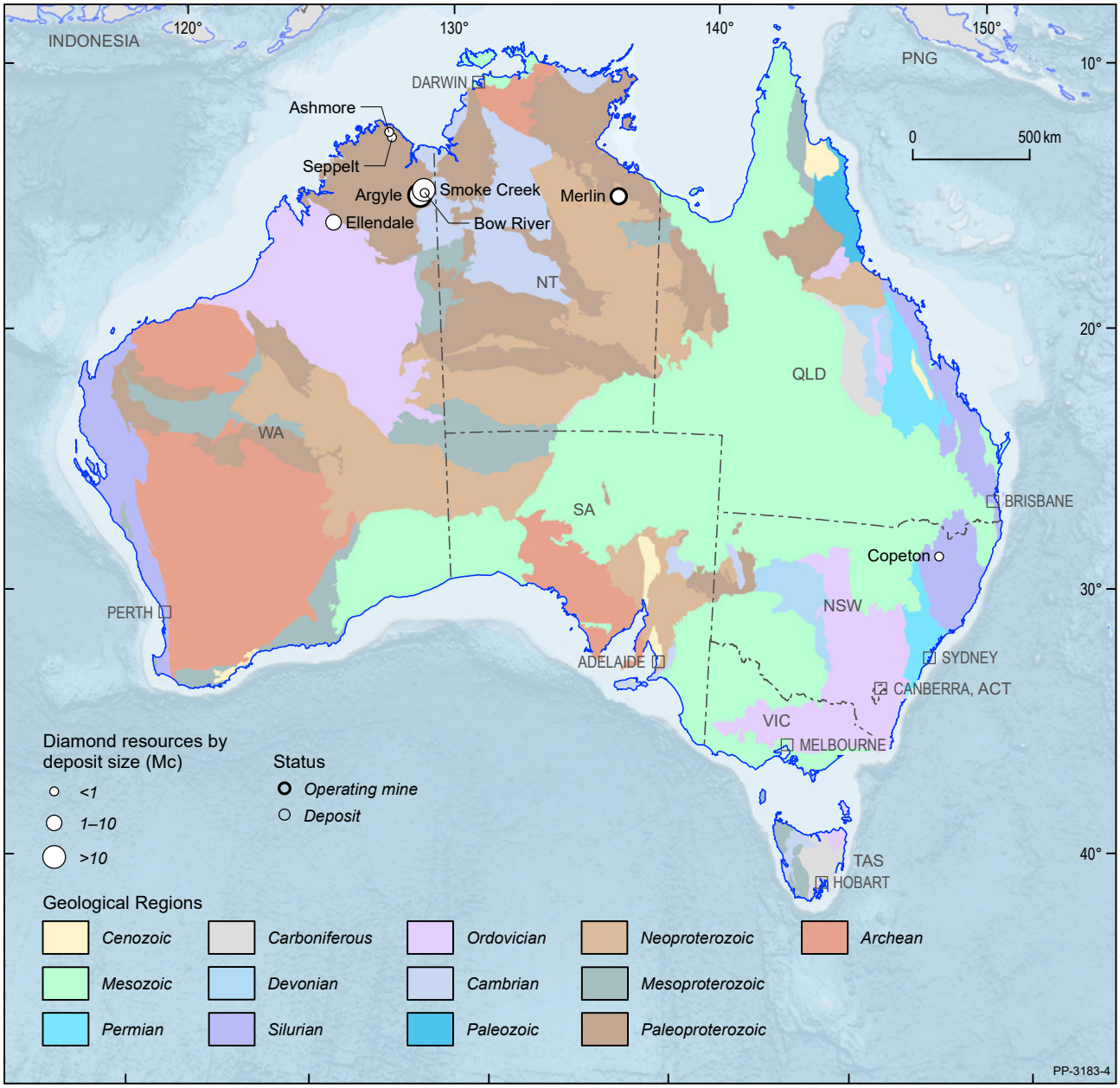


Figure 10 Australian diamond deposits and operating mines 2018.

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

Graphite

Demand for graphite by manufacturers of electric vehicles and battery storage technology is increasing. Graphite mining occurs globally, with China the leading producer in 2018 accounting for 68% of world supply, followed by Brazil (10%). Economic resources of graphite have shown notable increases since 2013, with Turkey hosting the largest graphite inventory (30%) in 2018, followed by China and Brazil (both 24%).

Australia's EDR of graphite in 2018 were approximately 7.25 Mt (Table 3), a 2% increase from the previous year's estimate (Table 4). In contrast, Australia's total graphite Ore Reserve in 2018 was estimated to be 5.17 Mt (Table 2), a 393% increase since 2017. Inferred Resources of graphite were estimated at 6.98 Mt, up 15% from 6.05 Mt in 2017.

Graphite deposits occur across Queensland, Western Australia and South Australia. South Australia hosts 65% of graphite EDR, followed by Queensland (18%) and Western Australia (17%). 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 11).

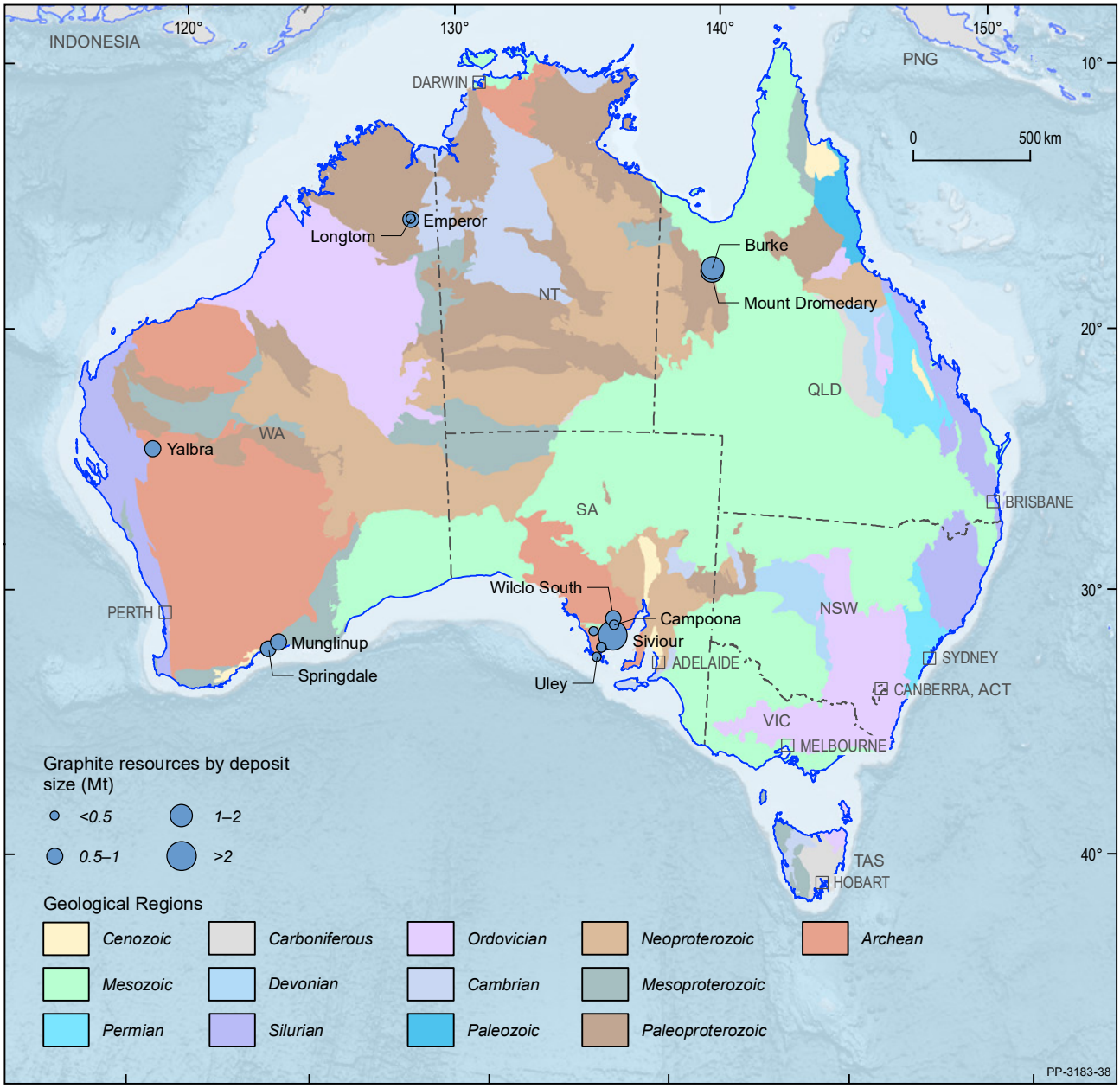


Figure 11 Australian graphite deposits 2018.

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

Gold

Australia's gold resources occur in all states and the Northern Territory (Figure 12). In 2018, EDR of gold increased 95 t to 10 165 t (Table 3), up by 1% from 2017 (Table 4). Western Australia has the largest share of EDR (44%), followed by South Australia (25%) and New South Wales (16%): collectively, these three states hold slightly less than 86% of the national EDR (Figure 2). Based on estimates provided by the USGS and adjusted for Australia by Geoscience Australia, world economic resources of gold in 2018 were 54 000 t (Table 3). Australia, with EDR of 10 165 t, or slightly less than 19% of world resources (Table 8), has the largest share ahead South Africa with 6000 t (11%), Russia with 5300 t (10%) and the United States with 3000 t (6%).

Paramarginal Resources of gold declined by 28 t to 157 t in 2018. Submarginal Resources increased by 138 t in 2018 to 200 t. Inferred Mineral Resources of gold in Australia had an increase of 641 t, or 14%, to total 5268 t (Table 3). Western Australia's Inferred Mineral Resources remain the largest of any state or territory at 2615 t, followed by South Australia with 1206 t and Queensland with 710 t.

Total Ore Reserves reported in compliance with the JORC Code increased by 149 t in 2018 to 4018 t (Table 2) and comprised 40% of EDR (Table 6). Ore Reserves at operating mines, based on 2018 production rates, have a reserve life of 9 years, which extends to 13 years when reserves at other deposits are included.

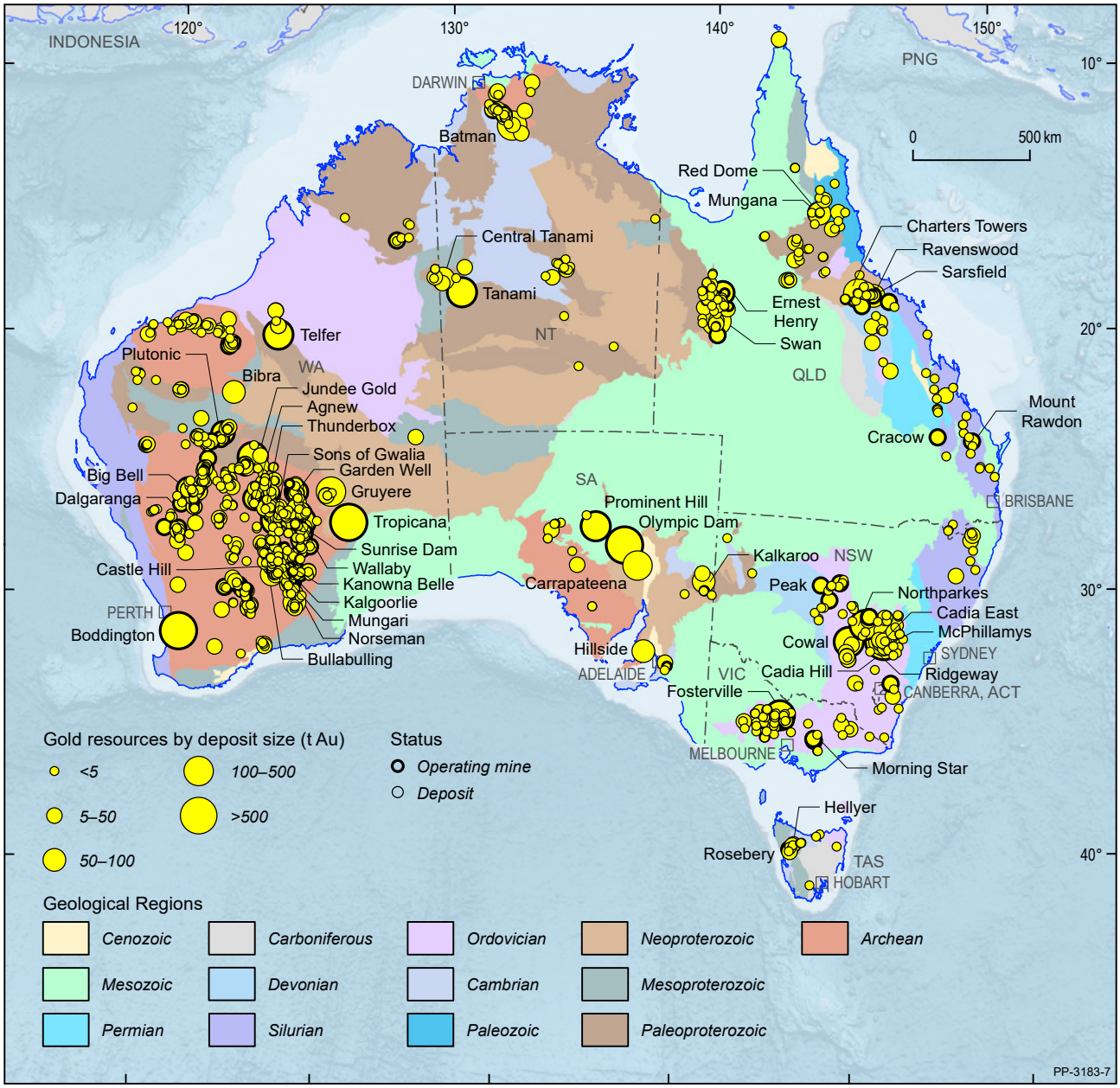


Figure 12 Australian gold deposits and operating mines 2018.

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

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 13). It then declined rapidly as gold production surged 800% from 27 t in 1982 to 243 t in 1990. Since 1990, resource life for gold has generally trended upward 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 13).

Exploration drilling expenditure for gold reached an all-time high in 2018 increasing by 19% from 2017 ($892.1 million). This is higher than the previous peak of $740.9 million in 2012. Gold had the highest exploration expenditure of all commodities in 2018, ahead of iron ore ($300.9 million) and copper ($260.8 million) reflecting the strong price of gold in Australian dollars, which had a monthly average price of $1697/oz in 2018, $56/oz higher than in 2017.

Domestic mine production increased by 23 t in 2018 to 315 t (Table 1). Western Australia maintained the highest output of gold at 211 t. New South Wales gold production retained second position at 39 t and Queensland had the third highest production at 18 t. As a percentage, Western Australia's share of production was 67% followed by New South Wales (12%) and Queensland (6%). According to the USGS, the world produced 3260 t of gold from mining in 2018 (Table 3). Thus, Australia's mine production of 315 t accounts for 10% of world production (Table 8) and was second to that of China (12%), but ahead of the Russia (9%) and the USA (6%). In 2018, Australia exported 341 t gold valued at $18 856 million (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 2018, lode-gold deposits (e.g, Kalgoorlie Super Pit) yielded 216 t or 69% 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 2018 from these deposits amounted to 77 t or 24% of national production. Production for the year from polymetallic and other deposits, including epithermal and antimony-gold deposits totalled 22 t (7% of national production).

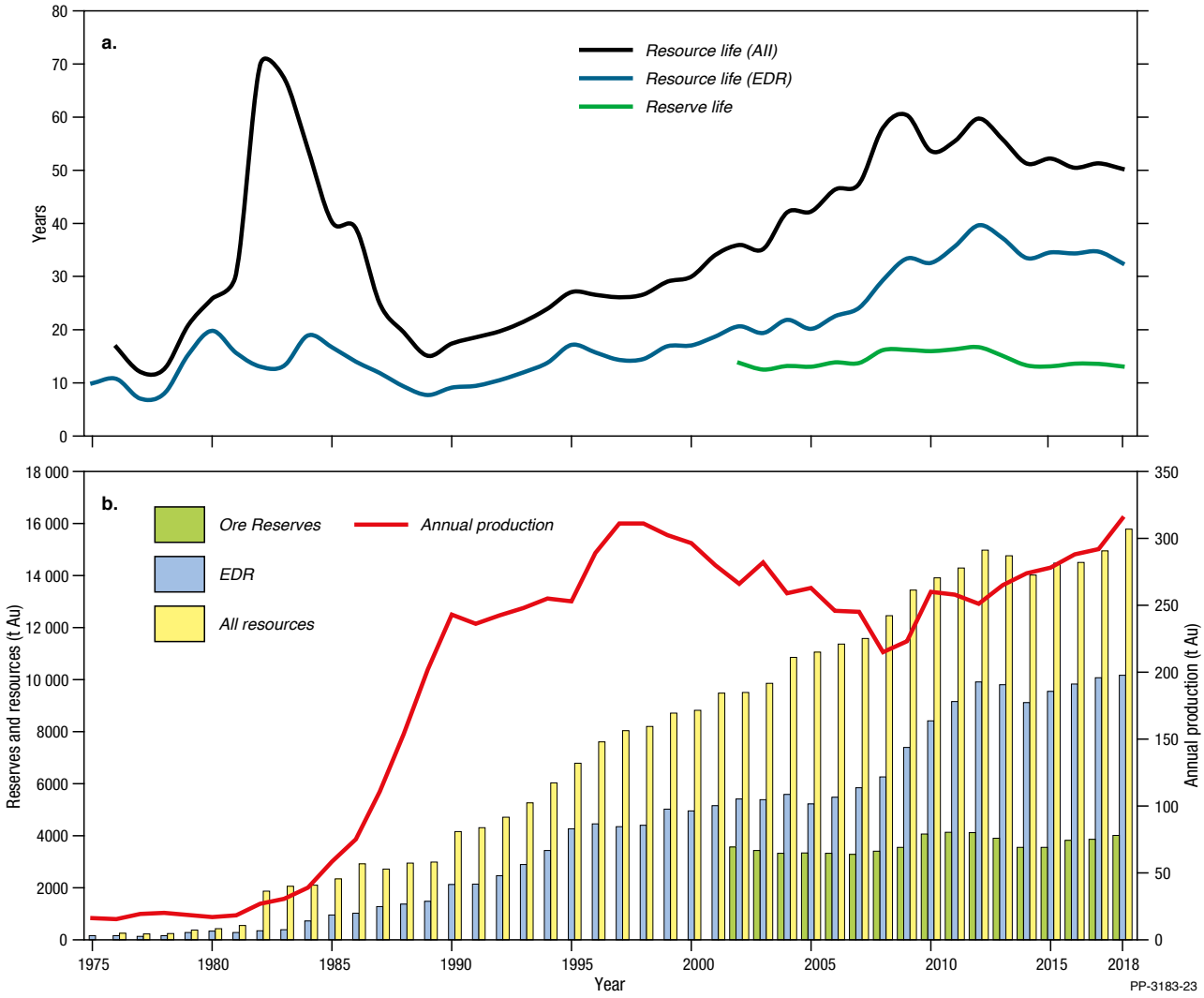


Figure 13 (a) Trends in gold reserve and resource life. These ratios are derived from (b) gold Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Iron Ore

Australia's EDR of iron ore increased by 3% to 49 604 Mt during 2018 (Table 4) with the EDR of contained iron estimated to be 24 122 Mt (Table 3). Of this, 92% of EDR occurs in the Pilbara region of Western Australia. Major deposits are shown in Figure 14 on a total resource basis. The slight increase in iron ore resources in the Pilbara was the upshot of regional project expansion and developments by Australia's major producers—BHP Ltd, Rio Tinto Ltd and Fortescue Metals Group Ltd.

The market price of iron ore recovered marginally during late 2018 and, although remaining volatile, it was enough to encourage project owners to embark on expansions and new developments. For instance, a US$2.9 billion development of the South Flank project was announced by BHP in June 2018. Product output from this project will replace the 80 million tonnes per annum (Mtpa) production at the company's depleting Yandi mine. Another project approval during the period was Fortescue's US$1.275 billion Eliwana project. Output from the Eliwana operation will ensure Fortescue maintains its minimum production rate of 170 Mtpa. Also adding to the new mine developments in the region is Rio Tinto's Koodaideri iron ore mine. The projected capacity at Koodaideri is around 43 Mtpa with production expected in late 2021. The previously halted Koolan Island mine by Mount Gibson Ltd has also re-started with the operation's first ore sale reported in early 2018. The main pit at Koolan Island has a JORC-compliant Ore Reserve of 21 Mt at a grade of 65.5% Fe and it is expected to be mined over the next five and half years.

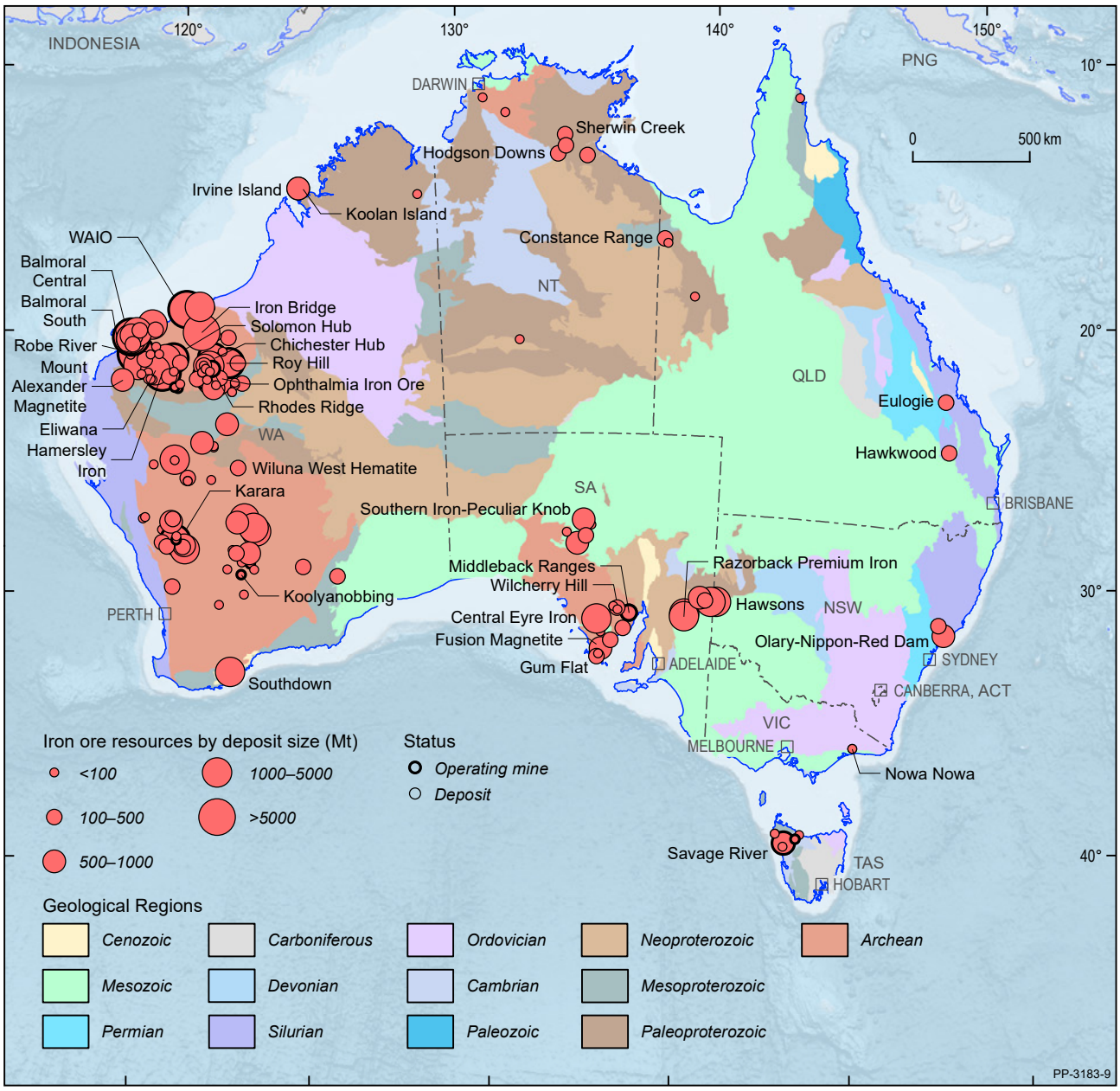


Figure 14 Australian iron ore deposits and operating mines 2018.

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

At end of December 2018, Australia's identified magnetite resource was 18 356 Mt, representing 37% of the national iron ore EDR. Not unexpectedly, most of the magnetite EDR also occurs in Western Australia (80%), followed by South Australia (13%), with the remaining resource occurring in Tasmania, New South Wales and Victoria. Australia's JORC Inferred Resources have also increased marginally (2%) to 94 100 Mt. Correlative to the EDR, the Inferred Resource increases were generated from resource drilling at brownfield projects rather than from greenfield exploration.

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 15). It is only since 2003 that exploration drilling has added to the resource base enabling resources to keep pace with rising production.

In 2018, total Australian production of iron ore was 899 Mt (Table 1) with Western Australia producing 897 Mt, or 99%. Iron ore expenditure in Australia during 2018 was $300.9 million, accounting for 14% of Australia's total mineral exploration expenditure.

Australia has the world's largest EDR of iron ore (29%; Table 8), followed by Brazil (18%). Australia also ranks first for global production of iron ore, accounting for 36% in 2018, followed by Brazil (20%) and China (14%) (Table 8).

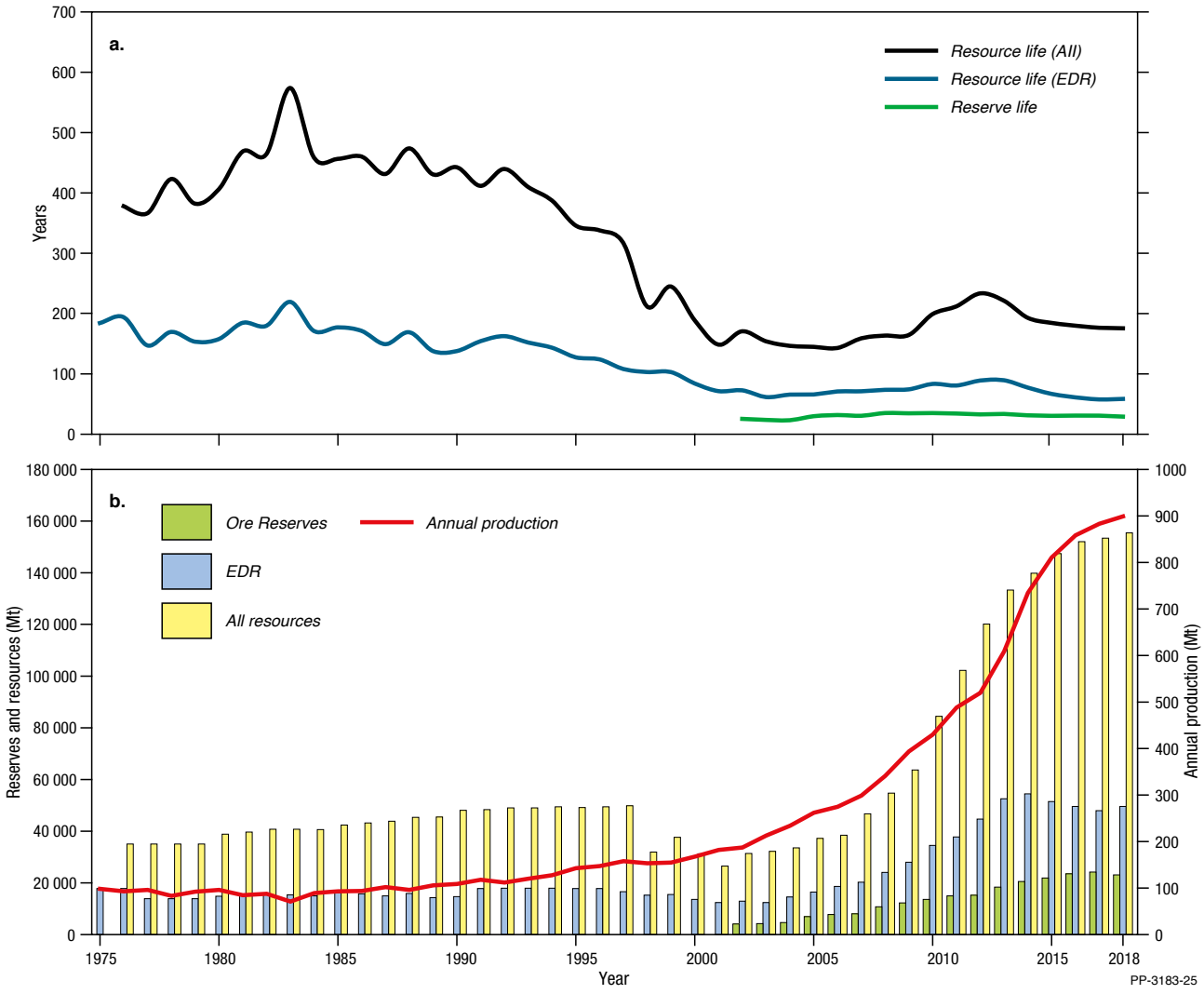


Figure 15 (a) Trends in iron ore reserve and resource life. These ratios are derived from (b) iron Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Lead, Zinc and Silver

Australia's EDR of lead were 35.78 Mt in 2018 (Table 3), down 2% from 36.42 Mt in 2017 (Table 4). Australia ranks first globally with 38% of the world's economic resources (Table 8), and second for production (11%; Table 8), behind China (47%).

Australia's EDR of zinc were 66.96 Mt in 2018 (Table 3), down 1% from 67.52 Mt in 2017 (Table 4). Australia ranks first globally with 29% of the world's economic resources (Table 8), and third for production (9%; Table 8), behind China (33%) and Peru (12%).

Australia's EDR of silver were 88.36 kt in 2018 (Table 3), down 2% from 90.31 kt in 2017 (Table 4). Australia ranks third globally with 16% of the world's economic resources (8), behind Chile and Poland, and sixth for production (5%; Table 8), behind Mexico (23%), Peru (16%), China (13%), Chile (5%) and Poland (5%).

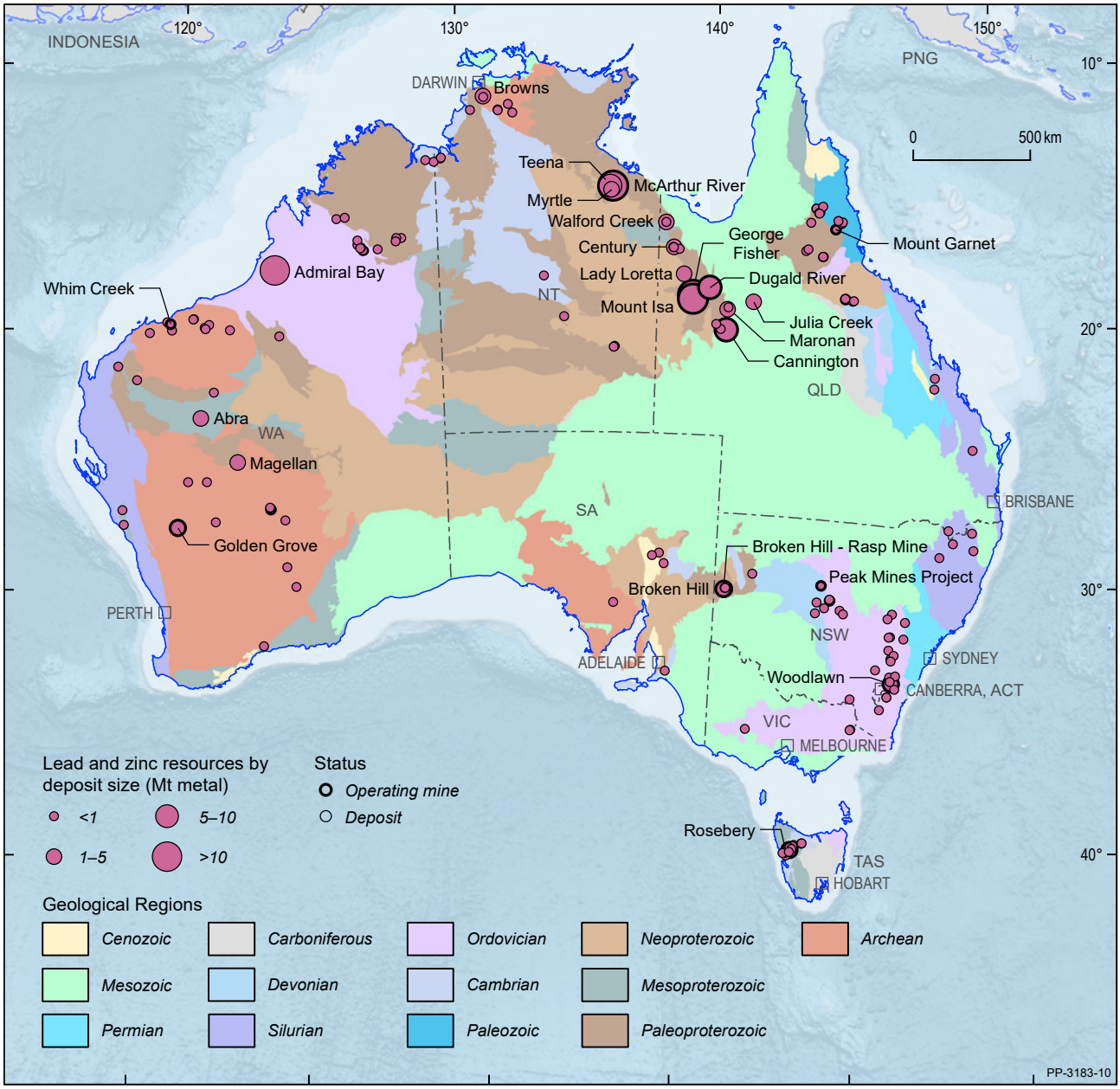


Figure 16 Australian lead and zinc deposits and operating mines 2018.

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 16 and silver in Figure 17, 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 mid-2018.

Exploration spend has increased over the last two years since the trough in expenditure from 2014 to 2016. 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

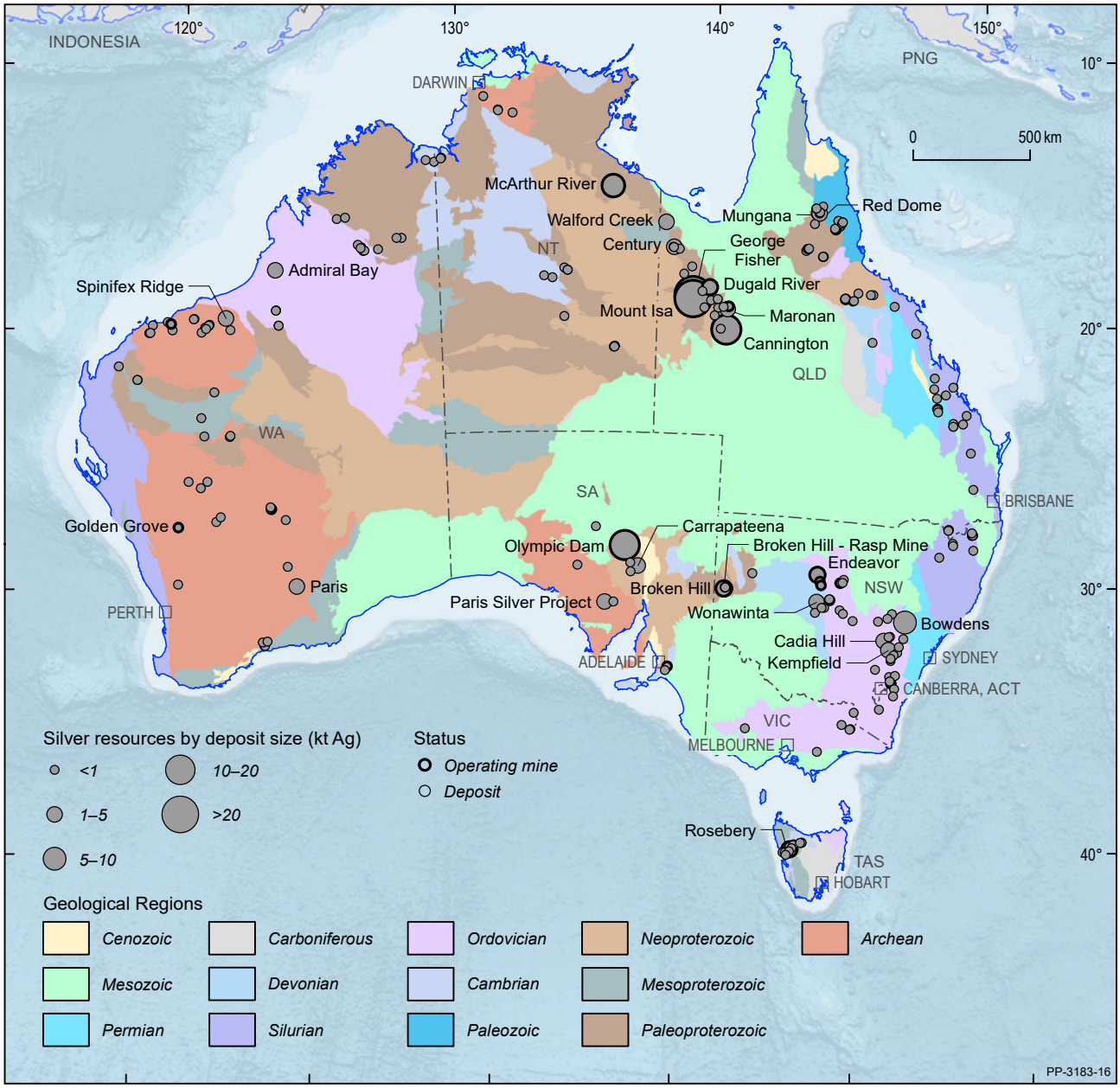


Figure 17 Australian silver deposits and operating mines 2018.

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

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, the Woodlawn and Hera zinc-lead-silver mines have (re)opened since 2012, and 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 18, Figure 19, Figure 20). Reserve life, the ratio of reserves to production, was 22, 26 and 21 years for zinc, lead and silver, respectively (Table 9). The 2018 reserve life for zinc is significantly lower than that of 2017 and reverses a trend of increasing reserve life since 2015 (Figure 19). This is due mostly to increased production, but also to the minor fall in Ore Reserves. For lead, the reserve life is similar to 2016 and 2017: changes in production and reserves were small and offsetting (Figure 18). For silver, 2018 reserve life (21 years) is similar to 2017 (22 years), and follows a broad trend of increasing reserve life since 2005 (Figure 20). The overall increase in reserve life for all three metals since 2015 is largely owing to the decision to decrease production by Glencore at that time.

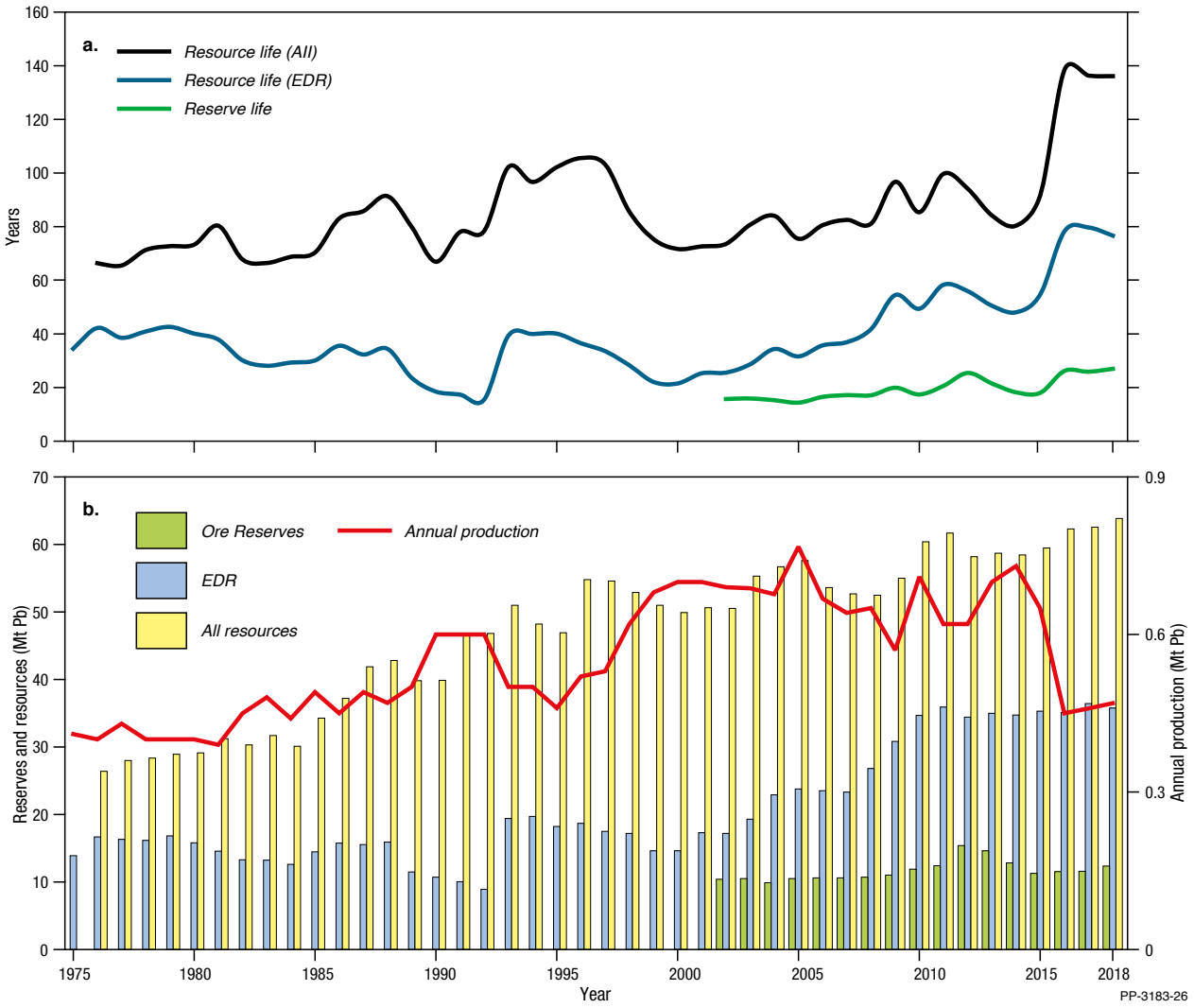


Figure 18 (a) Trends in lead reserve and resource life. These ratios are derived from (b) lead Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

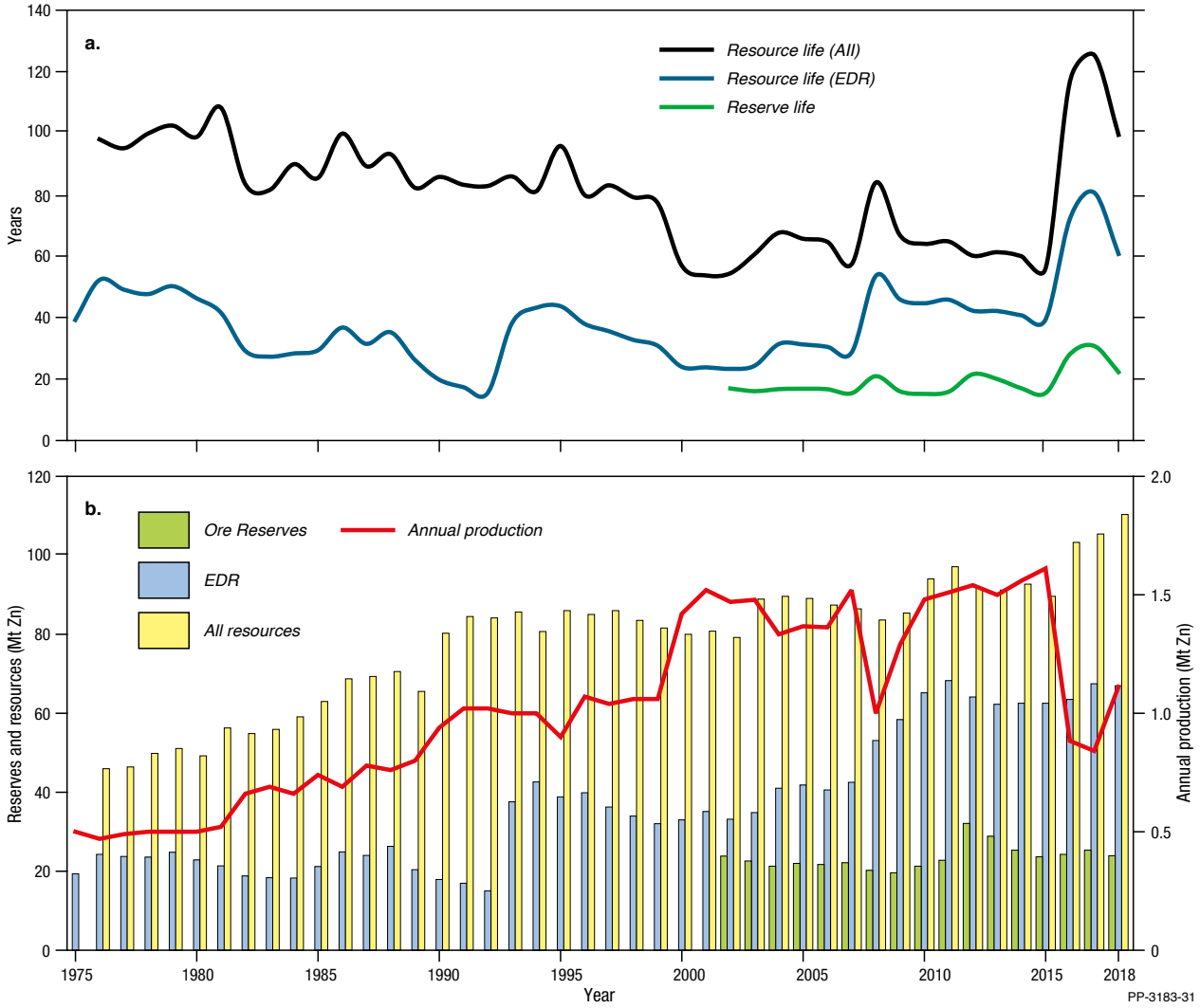


Figure 19 (a) Trends in zinc reserve and resource life. These ratios are derived from (b) zinc Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Australia's world-class lead-zinc-silver mines such as Broken Hill, Mount Isa, Dugald River, George Fisher and McArthur River have helped shaped the nation's economy. They are an important source of employment for regional areas and bring significant export income into the country.

Photo: Mount Isa smelter in north-west Queensland.

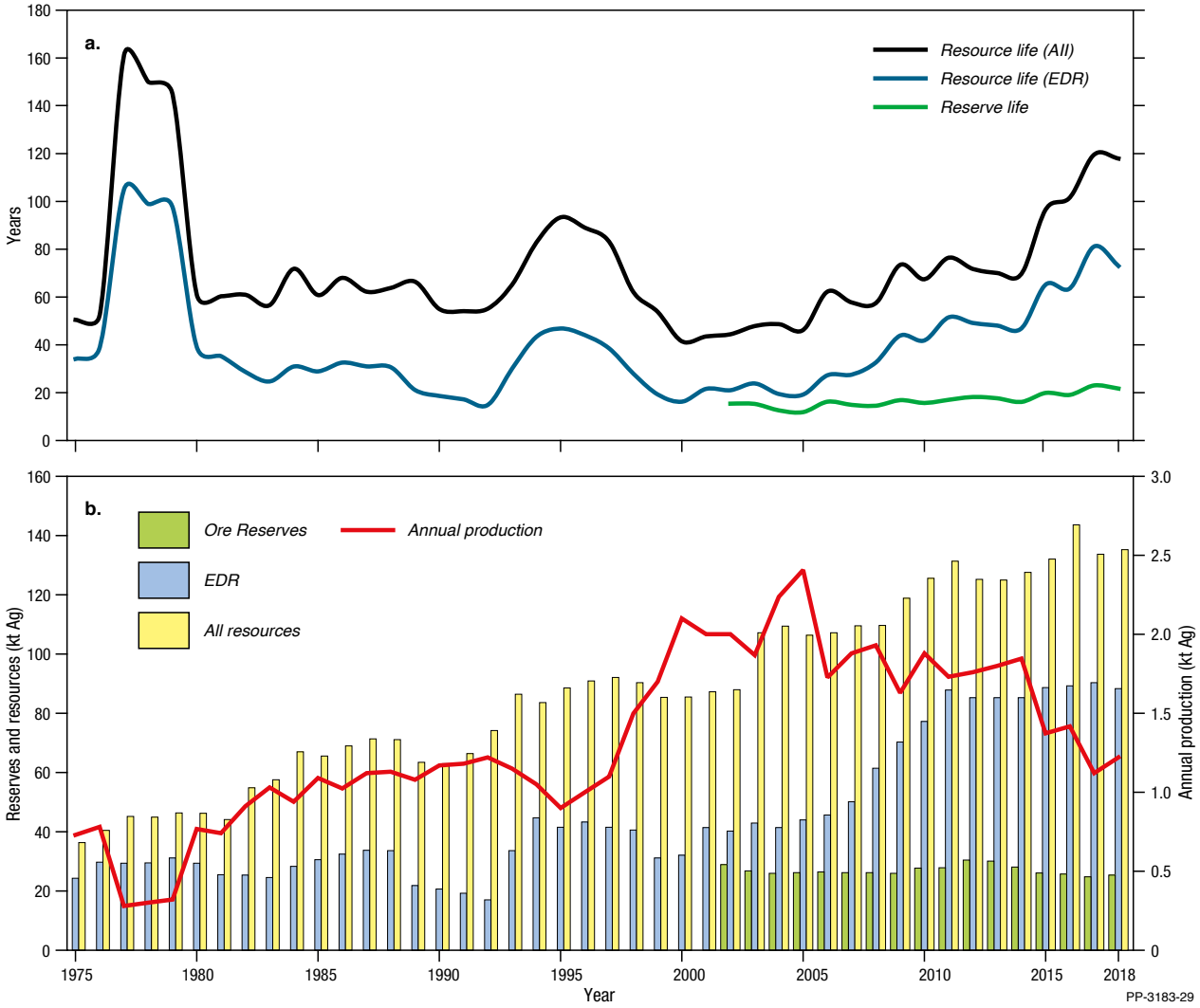


Figure 20 (a) Trends in silver reserve and resource life. These ratios are derived from (b) silver Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Jewellery remains one of the most popular uses for silver, along with photographic paper and film, electronics, tableware, mirror coatings and biocides. Australia has the world's third largest resources of silver, which is associated with both lead-zinc and gold deposits.

Lithium, Tantalum and Niobium

Australia's EDR of lithium were 4718 kt in 2018 (Table 3), up 68% from 2803 kt in 2017 (Table 4). Australia ranks second globally with 30% of the world's economic resources (Table 8), behind Chile, and first for production (63%; Table 8). All of Australia's EDR of lithium occur within hardrock pegmatite deposits and most deposits occur in Western Australia. Over 85% of Australia's lithium EDR is 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 21 on a total resource basis.

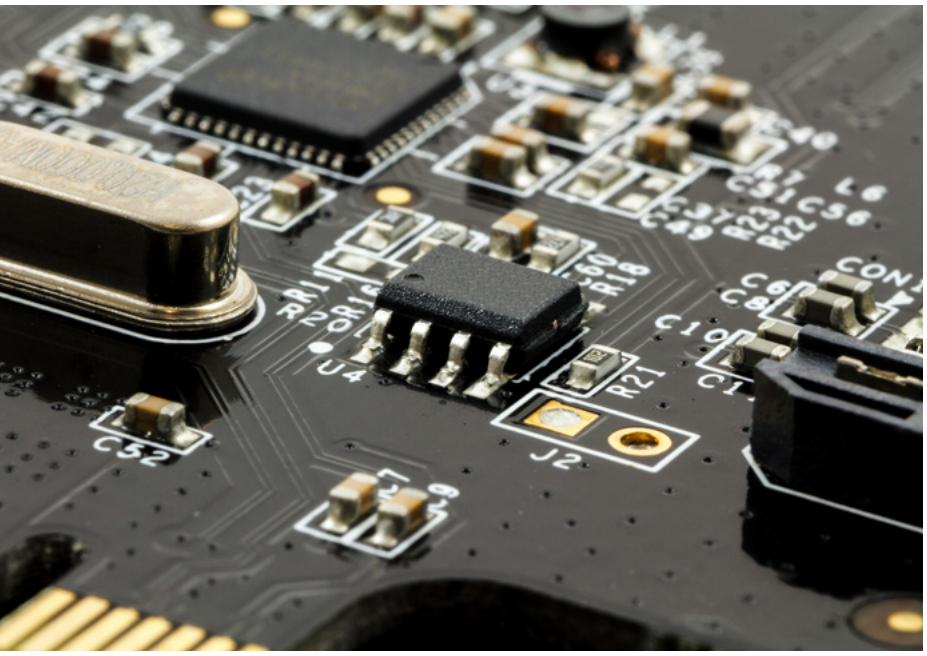
Over the last five years, there has been heightened activity in the Australian lithium industry with significant increases in resources as well as the commencement of production from a number of deposits in Western Australia: Wodgina, Pilgangoora (both deposits), Mount Cattlin, Mount Marion and Bald Hill, in addition to continuing production at Greenbushes. Both Chengdu Tianqi Industry Group Co and Albemarle Corp (owners of the Greenbushes deposit) are in the process of building processing plants in Western Australia, utilising their respective shares of the lithium concentrate from the Greenbushes deposit to produce (higher value) battery-grade lithium hydroxide.

The relatively rapid growth in lithium in Australia is also evidenced by the large increases in total resources (>1000%) over the last ten years, for which total Ore Reserves have increased by more than 2000% and EDR by more than 800%. Increases in annual production have also been significant, up 20% since 2017[8], and over nine times as much as a decade ago. Ore Reserves at operating mines, based on 2018 production rates, have a reserve life of 47 years which extends to 59 years when Ore Reserves at other deposits are included (Table 9).

Softer demand and lower prices for lithium in 2019 has seen both production decreases and revised infrastructure timetables at a number of Australian deposits. This downturn is also expected to affect tantalum production as the majority of Australia's EDR of tantalum occurs within the same hard-rock pegmatite deposits.

Australia's EDR of tantalum were 99.3 kt in 2018 (Table 3) up from 55.4 kt in 2017 (Table 4) and 75.7 kt in 2016[9]. Australia ranks first globally with 67% of the world's documented economic resources (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 seventh for tantalum production with 3% of the total world production (Table 8).

Western Australia hosts 88% 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 and the Pilgangoora deposits (all in



In 2018, EDR of tantalum in Australia increased by 79% along with lithium which was up 68%. The surge in interest is mostly attributed to increased lithium exploration for use in battery storage technology. However, tantalum has important uses in electronic components such as capacitors in mobile phones and other portable electronic devices. Due to their strength and high resistance to corrosion, tantalum alloys are also used in the aerospace industry and electricity-generating industries.

8. Based on spodumene production figures within The Western Australia Department of Mines, Industry Regulation and Safety, 2018-19 Major commodities resource file.
9. 2016 figures are used because the 2017 figures were atypical, reflecting a temporary reclassification of EDR as Inferred Resources at the Wodgina deposit that year.
10. Based on tantalite production figures within The Western Australia Department of Mines, Industry Regulation and Safety, 2018-19 Major commodities resource file.

Western Australia), and at the Dubbo (Toongi) zirconium-hafnium-niobium-yttrium-rare earth deposit in New South Wales (Figure 21). Over the last two years, Australia's tantalum Ore Reserves have increased 21% from 36.7 kt in 2016 to 44.4 kt in 2018. Similarly, tantalum production in Australia has increased by 121% over this period to 60 t in 2018[10]. Increases in tantalum resources, reserves and production are largely a by-product of the heightened activity in the Australian lithium industry over the last five years.

Australia's EDR of niobium were 216 kt in 2018 (Table 3), unchanged from 2017 figures (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 21).

Although Australia ranks third in the world for economic resources of niobium, it only holds 4% (Table 8), as world resources are overwhelmingly dominated by Brazil. Australia's total Ore Reserves of niobium, as of 2018, were 58 kt (Table 2), all from the Dubbo deposit. This is unchanged from 2017 but is a significant decrease from 116 kt of Ore Reserves in 2016. This decrease reflects a reappraisal of the Dubbo deposit, including a shift to a 20-year mine life. Annual production figures for Australia are not known but are not considered to be significant.

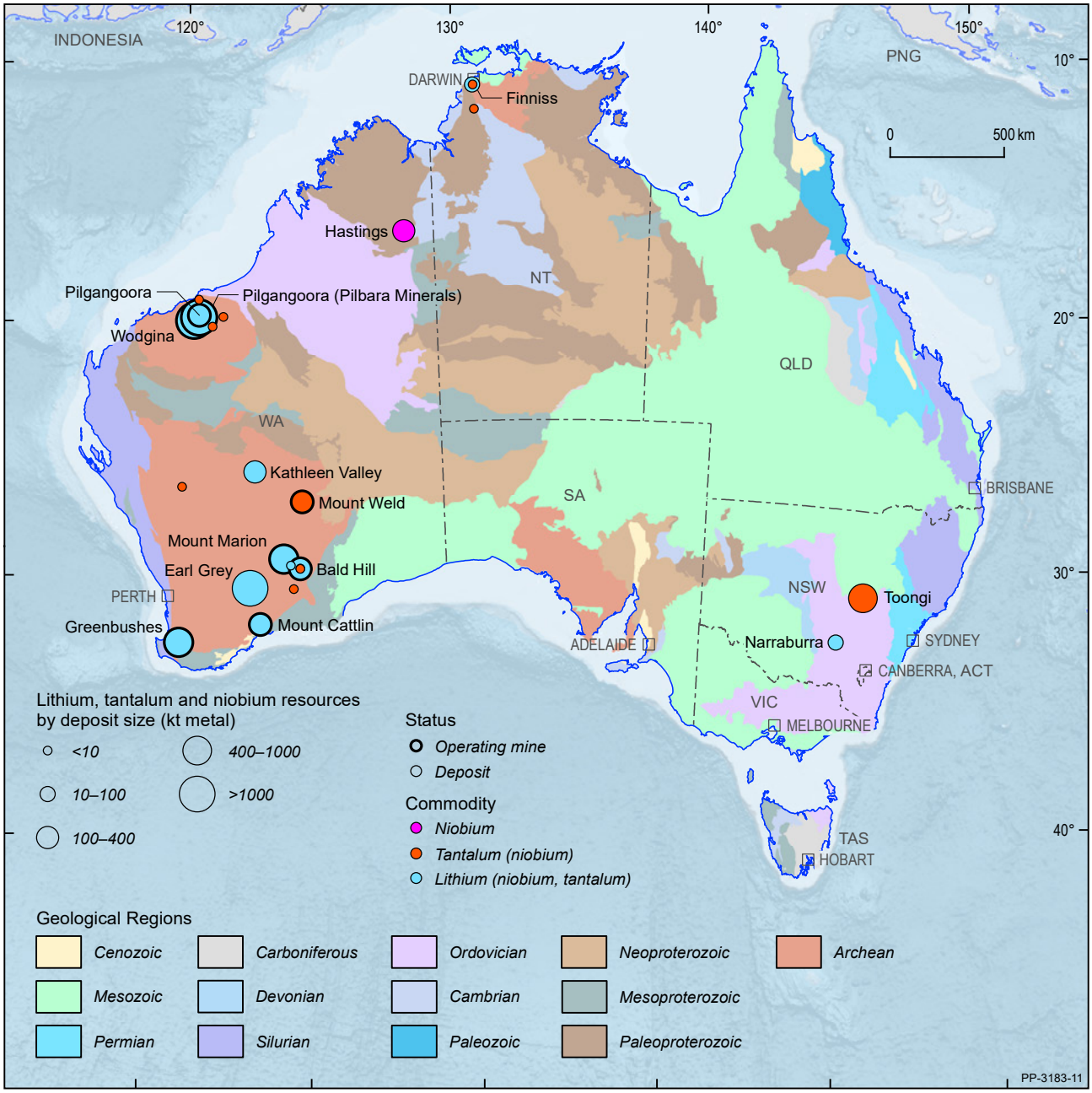


Figure 21 Australian lithium, tantalum and niobium deposits and operating mines 2018.

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

Magnesite

In 2018, Australia's EDR of magnesite were 316 Mt (Table 3), unchanged from the previous year (Table 4), representing approximately 4% of the world total (Table 8). The Department of Premier and Cabinet South Australia reported magnesite production of 4587 t in 2018, significantly up (42%) from 3241 t in 2017.

The Queensland Department of Natural Resources Mines and Energy reported magnesite production of 258 859 t in 2017–18, also up (25%) from 207 859 t in 2016–17. Apart from South Australia and Queensland, magnesite EDR also occur in New South Wales, Western Australia and the Northern Territory (Figure 22).

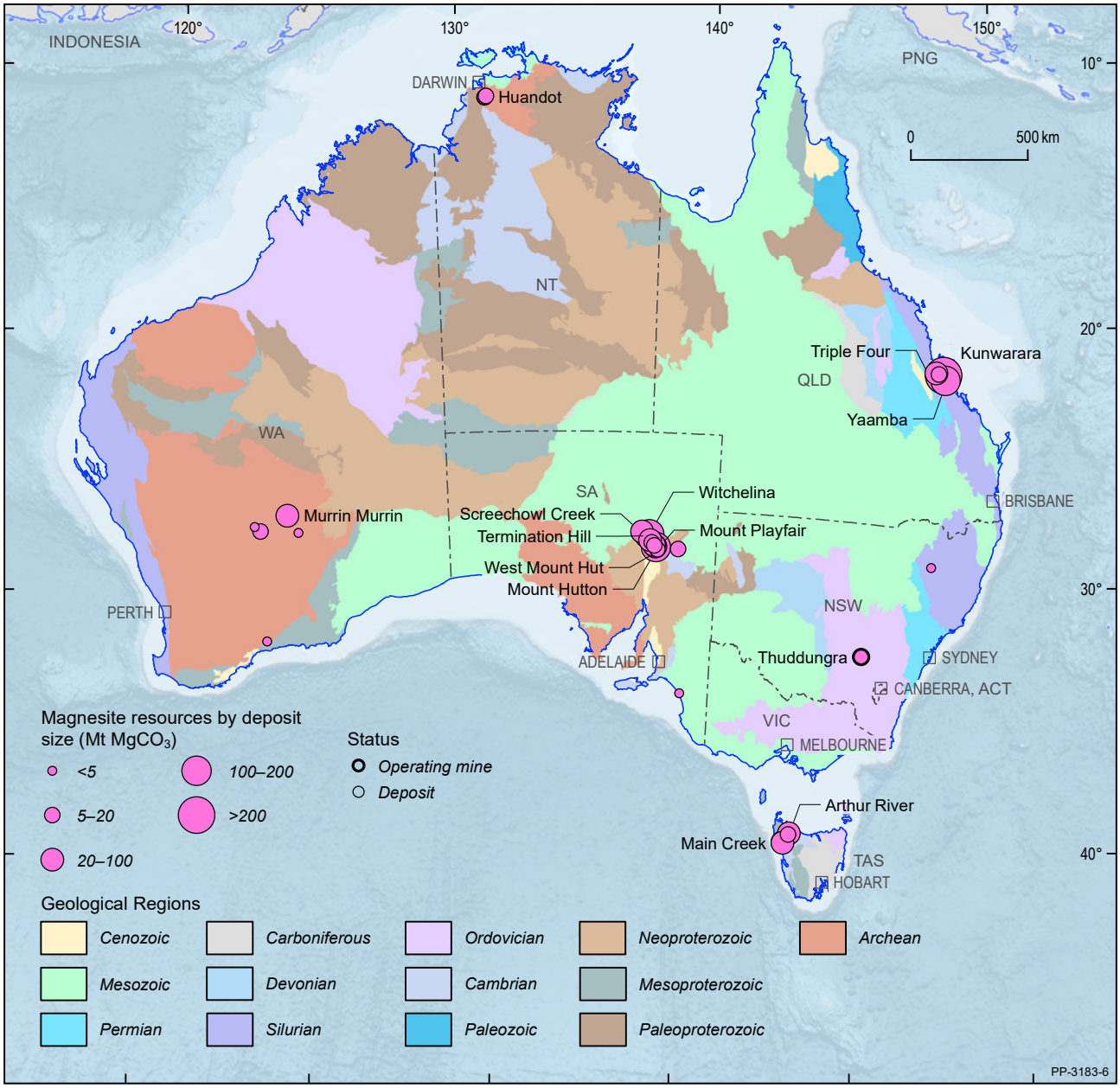


Figure 22 Australian magnesite deposits and operating mines 2018.

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

Manganese

Australia's EDR of manganese remained steady in 2018 at 232 Mt (Table 3), a small increase of 1 Mt over 2017 (Table 4). This ranks Australia's resources as the world's fifth largest (Table 8) behind South Africa, Ukraine, Brazil and China. All EDR of manganese ore occur in the Northern Territory and Western Australia (Figure 2), although minor deposits also occur in other Australian states (Figure 23). Australia's mine production of manganese ore increased to 7.0 Mt in 2018, a 25% increase over the previous year's production estimates, due to 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 is ranked third (Table 8) behind China and South Africa.

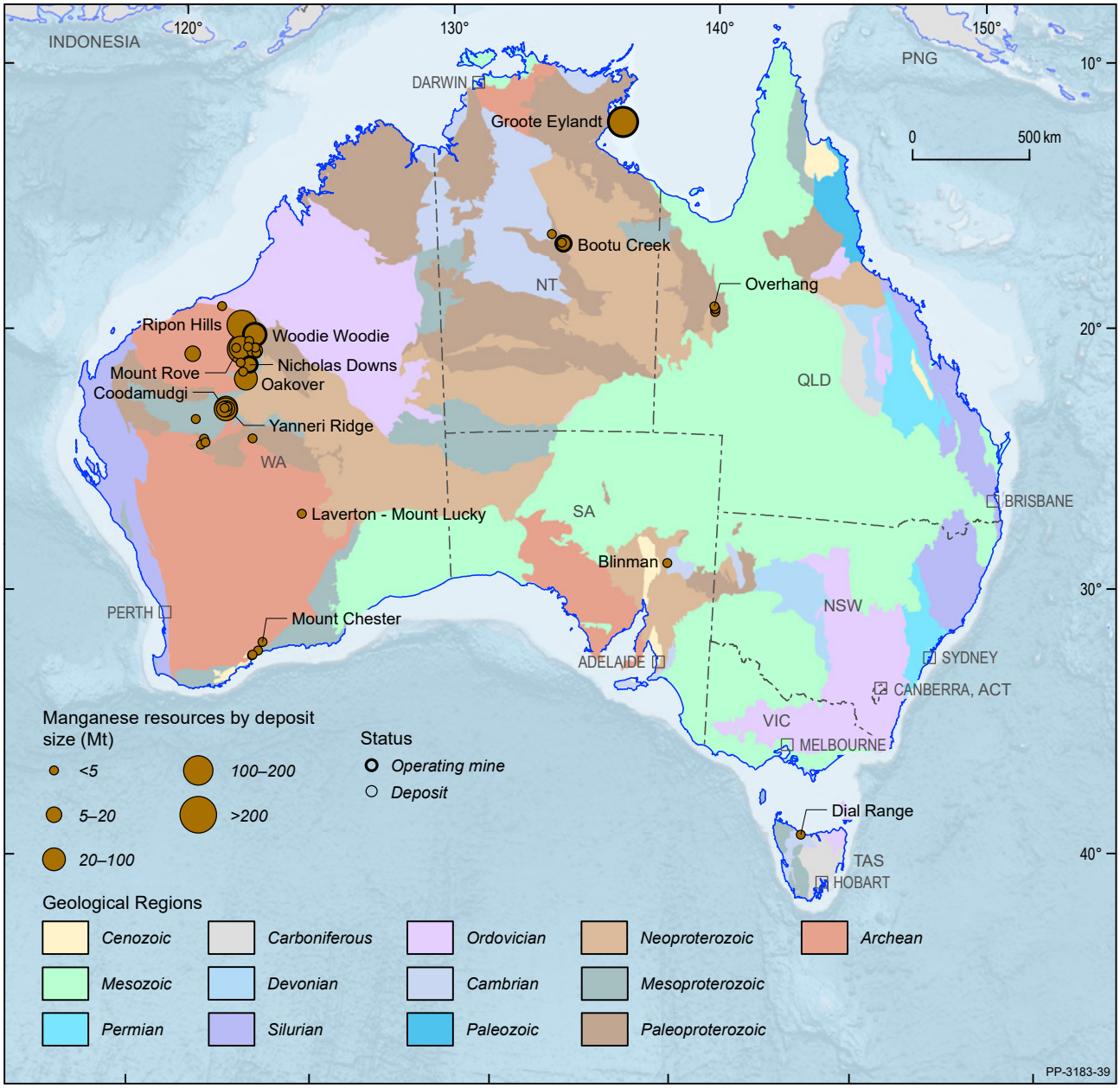


Figure 23 Australian manganese deposits and operating mines 2018.

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. 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 but are not currently exploited. 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.

In 2018, Australia's mineral sand EDR were estimated to be 276.3 Mt of ilmenite, 35.4 Mt of rutile and 79.9 Mt of zircon (Table 3). Compared to 2017, these estimates are largely unchanged for ilmenite and up for rutile and zircon (Table 4). These resources represent:

- the world's second largest economic resources of ilmenite (19% of the global economic resource; (Table 8) after China (29%) and ahead of India (11%);
- the largest economic resource of rutile in the world (50%; Table 8) followed by Kenya (20%), South Africa (12%) and India (11%); and
- and the largest economic resource of zircon in the world (63%; Table 8) followed by South Africa (17%).

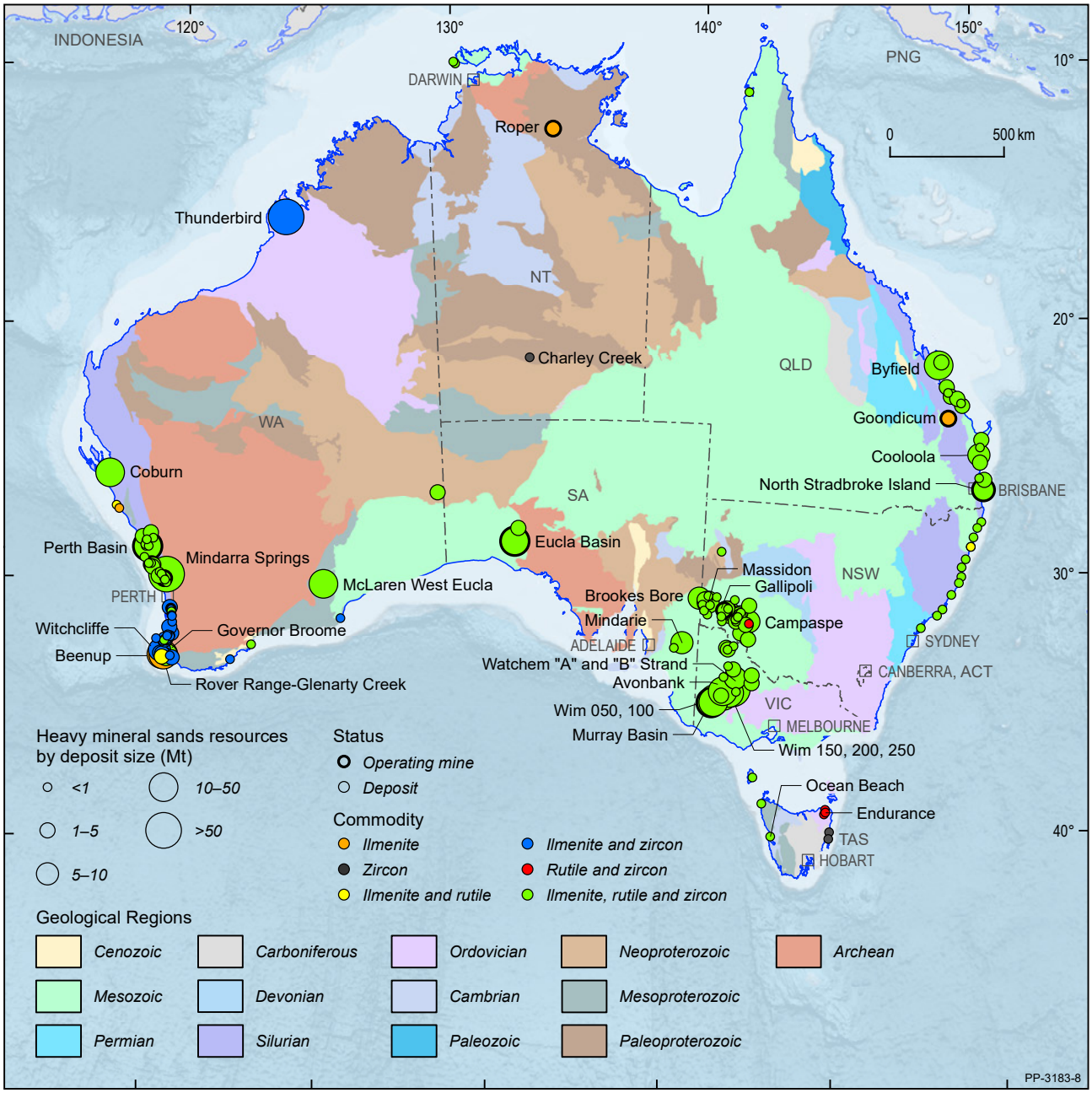


Figure 24 Australian heavy mineral sands deposits and operating mines 2018.

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

Australia also had Inferred Resources of 264.6 Mt of ilmenite, 35.8 Mt of rutile and 62.9 Mt of zircon plus smaller amounts regarded as subeconomic (Table 3). Heavy mineral sand deposits and operating mines are shown in Figure 24 on a total resource basis.

In terms of total Ore Reserves, Australia had an estimated 60.3 Mt of ilmenite, 8.7 Mt of rutile and 22.1 Mt of zircon in 2018 (Table 2). Twelve operating mines produced a total of 1.4 Mt of ilmenite, 10 mines produced 0.2 Mt of rutile and 10 produced 0.5 Mt of zircon (Table 1), largely unchanged from 2017 production. Ore Reserves at these mines accounted for 27%, 22% 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 25, Figure 26, Figure 27). Initially, ilmenite production almost kept pace with the new discoveries so resource life only increased gradually (Figure 25). 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 combining with dramatically decreased production from 2014 (Figure 25).

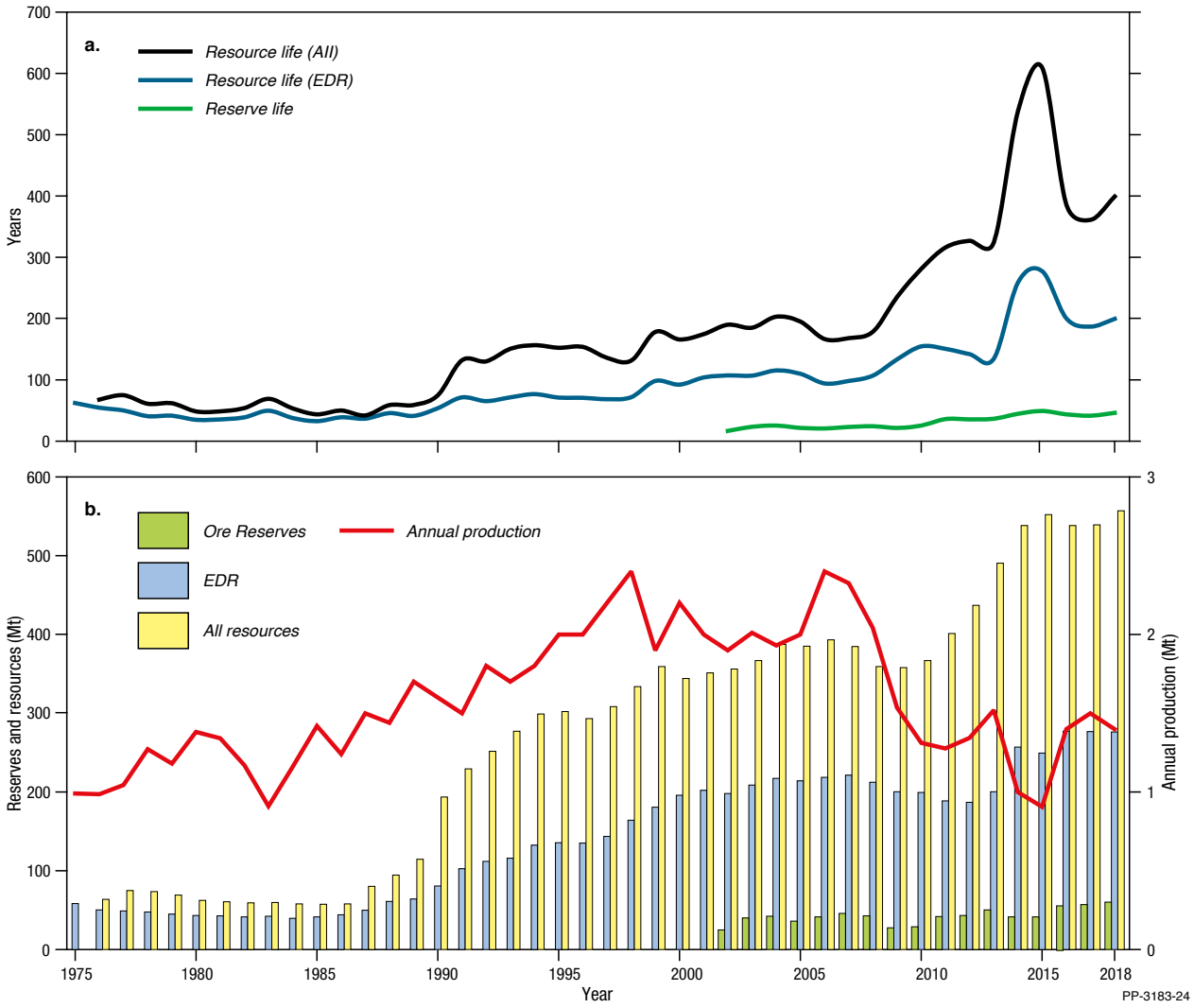


Figure 25 (a) Trends in ilmenite reserve and resource life. These ratios are derived from (b) ilmenite Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

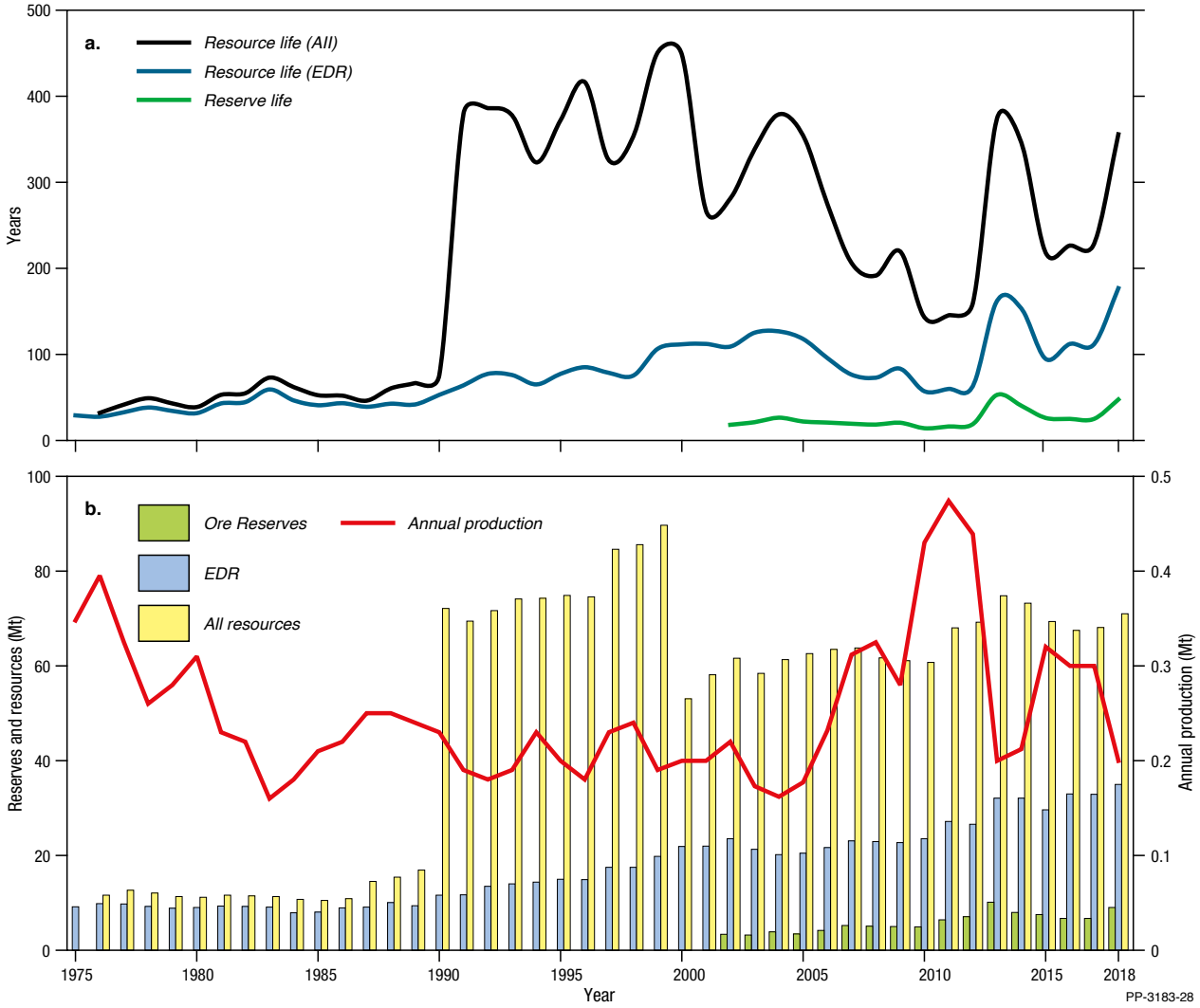


Figure 26 (a) Trends in rutile reserves and resource life. These ratios are derived from (b) rutile Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

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 26 and Figure 27). As a result, the significant increases in resources estimates from around 1990 caused dramatic increases in resource life (Figure 26 and Figure 27). Since 1990, the resource life for rutile and zircon has increased and decreased conspicuously in response to variable production rates (Figure 26 and Figure 27). Increased zircon resource delineation since 2011 has also contributed to the most recent increase in resource life (Figure 27).

Exploration expenditure for mineral sand exploration during 2018 was approximately $34.5 million, an increase of almost 66% since 2017 ($20.8 million). In 2018, an estimated 804 kt of ilmenite concentrate, 312 kt of rutile concentrate and 617 kt of zircon concentrate were exported from Australia, down 17%, up 9% and up 9%, respectively, on 2017 export figures.

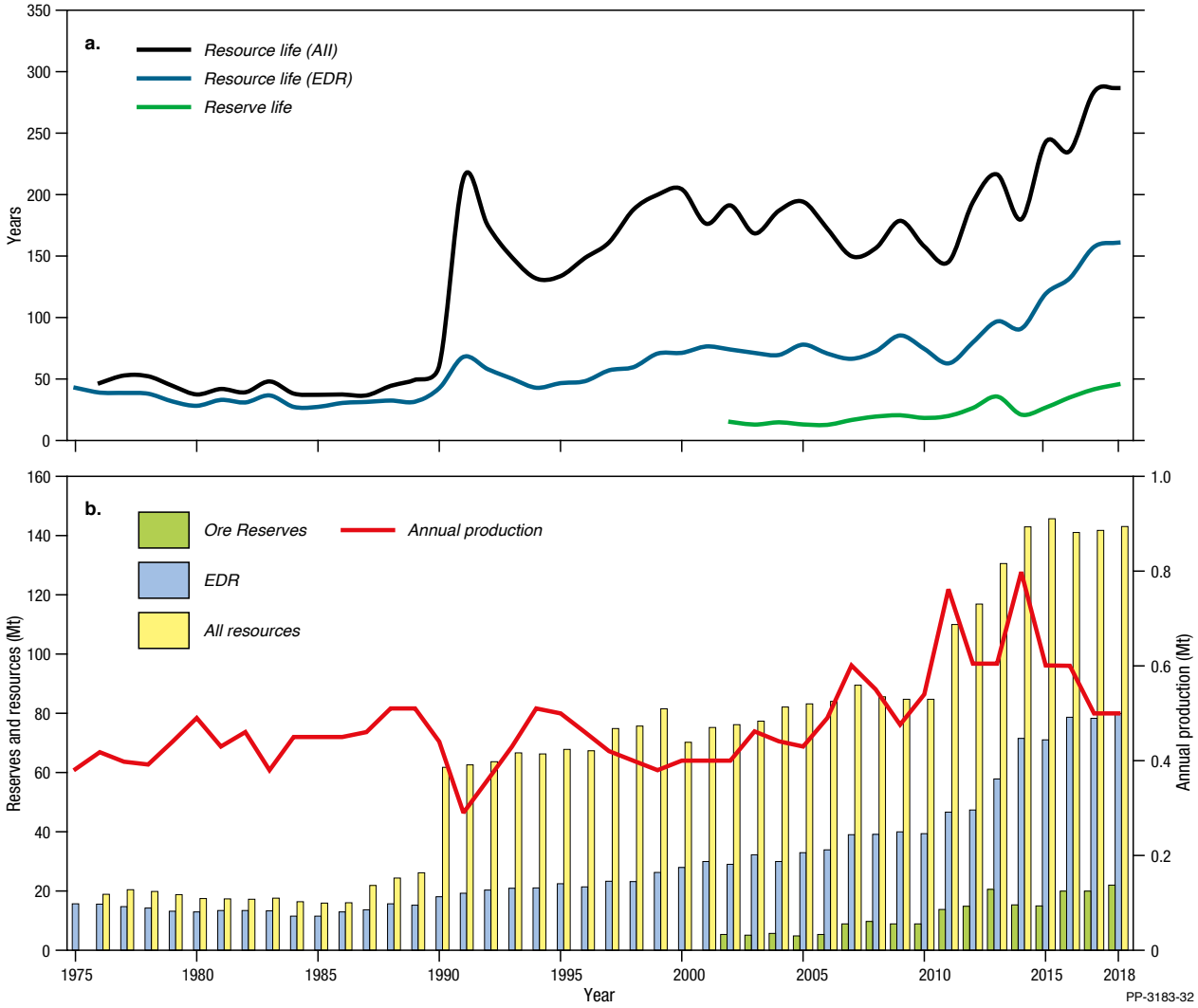


Figure 27 (a) Trends in zircon reserves and resource life. These ratios are derived from (b) zircon Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

Titanium from mineral sands is one of a number of critical minerals used as alloying agents because they can create high-strength, lightweight metals for use in industrial applications such as aircraft engines. Critical mineral alloys also tend to improve the workability of some metals, improve resistance to corrosion and, when alloyed with other critical minerals, create permanent magnets that can be used in electric vehicle motors, electric storage systems and wind turbine generators.

Molybdenum

Australia's EDR of molybdenum in 2018 were 171 kt (Table 3), a 7% increase from 160 kt in 2017 (Table 4). Australia ranks eighth globally for economic molybdenum resources but only hosts approximately 1% of world resources (Table 8), which are dominated by China, the USA, Peru and Chile. The bulk of Australia's EDR of molybdenum occurs in Queensland (89%), followed by Western Australia (7%) and the Northern Territory (3%; Figure 28). In 2018, Inferred Resources of molybdenum in Australia totalled 1233 kt and another 366 kt of molybdenum were categorised as paramarginal (Table 3).

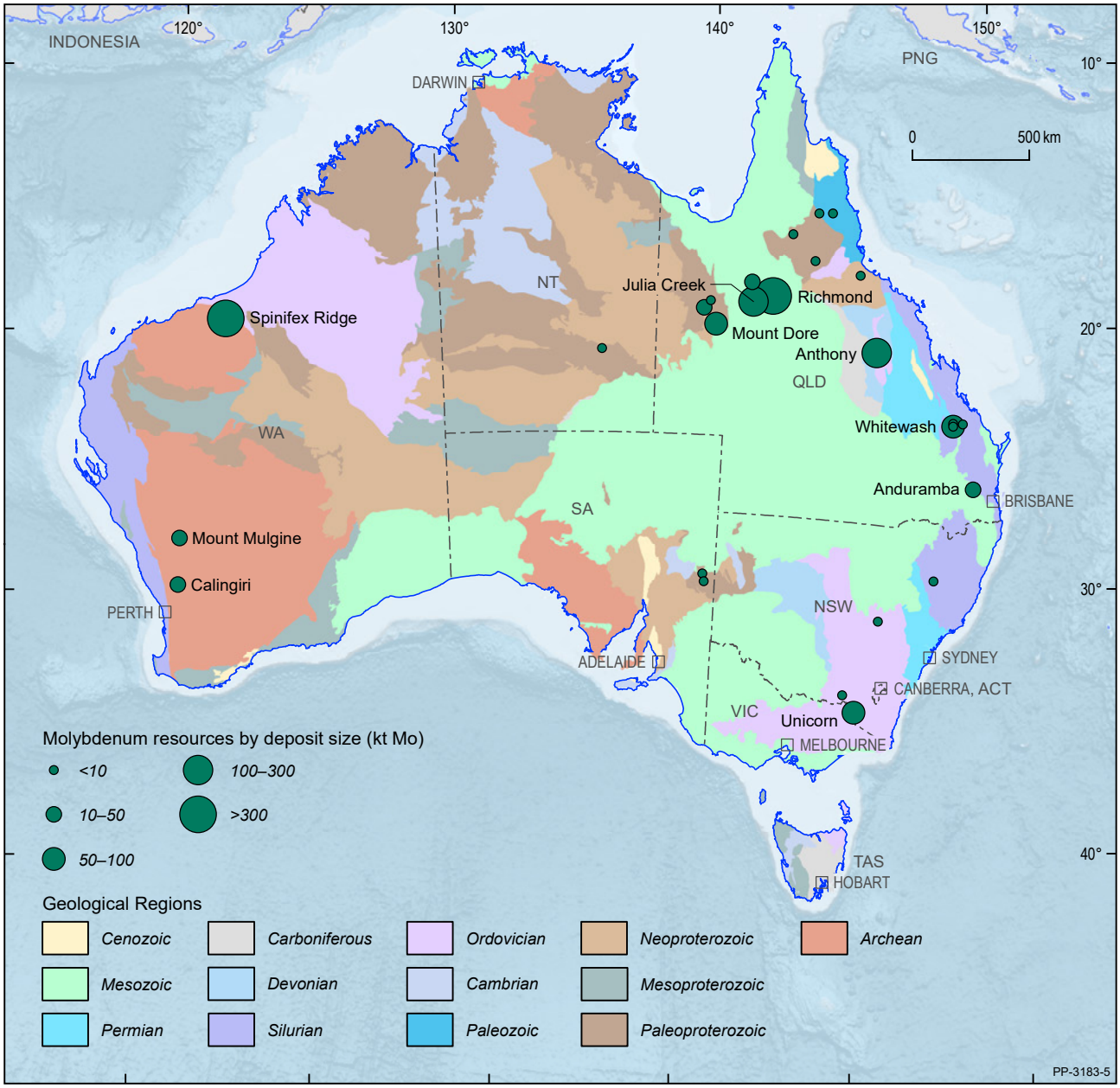


Figure 28 Australian molybdenum deposits 2018.

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

Nickel

Australia's EDR of nickel were 19.7 Mt in 2018 (Table 3), unchanged from 2017 (Table 4). Australia ranks second globally with 23% of the world's economic resources, and sixth for production (6%; Table 8). Australia's nickel deposits and operating mines are shown in Figure 29 on a total resource basis.

Australia's total Ore Reserves of nickel were 6.2 Mt in 2018 (Table 2), up 15% from 5.4 Mt in 2017. Twelve operating mines (Table 1) produced 0.148 Mt of nickel in 2018 (Table 1), down 17% from 0.179 Mt in 2017. The USGS notes that, in recent years, production of refined nickel decreased as stainless steel producers preferred lower cost nickel pig iron[11]. At the same time, production of nickel chemicals has increased, particularly nickel sulphate used in the production of batteries. Industry analysts project a significant increase in global nickel consumption in batteries for energy storage and electric vehicles.

In 2018, exports of nickel ore and concentrates (0.164 Mt) and intermediate and refined nickel (0.234 Mt) had a combined export value of $4285 million (Table 11), significantly up from $2445 million in 2017 owing to improved nickel prices, despite lower production (Table 12).

At 2018 rates of nickel production, the average reserve life at operating mines is seven years and demonstrated resource life (Measured and Indicated categories) is 37 years (Table 1).

11. United States Geological Survey, 2019. Mineral Commodity Summaries, Nickel.

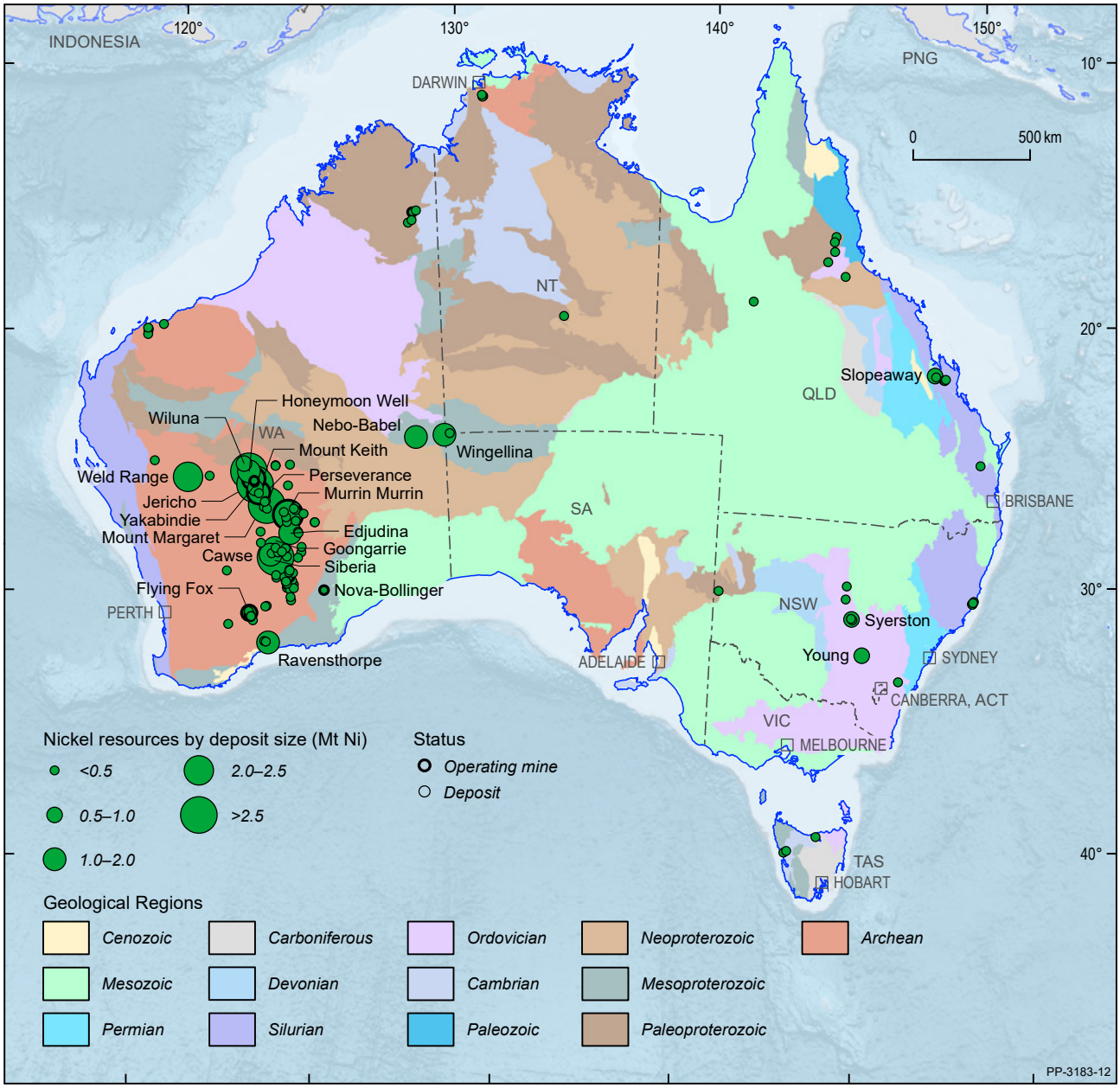


Figure 29 Australian nickel deposits and operating mines 2018.

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

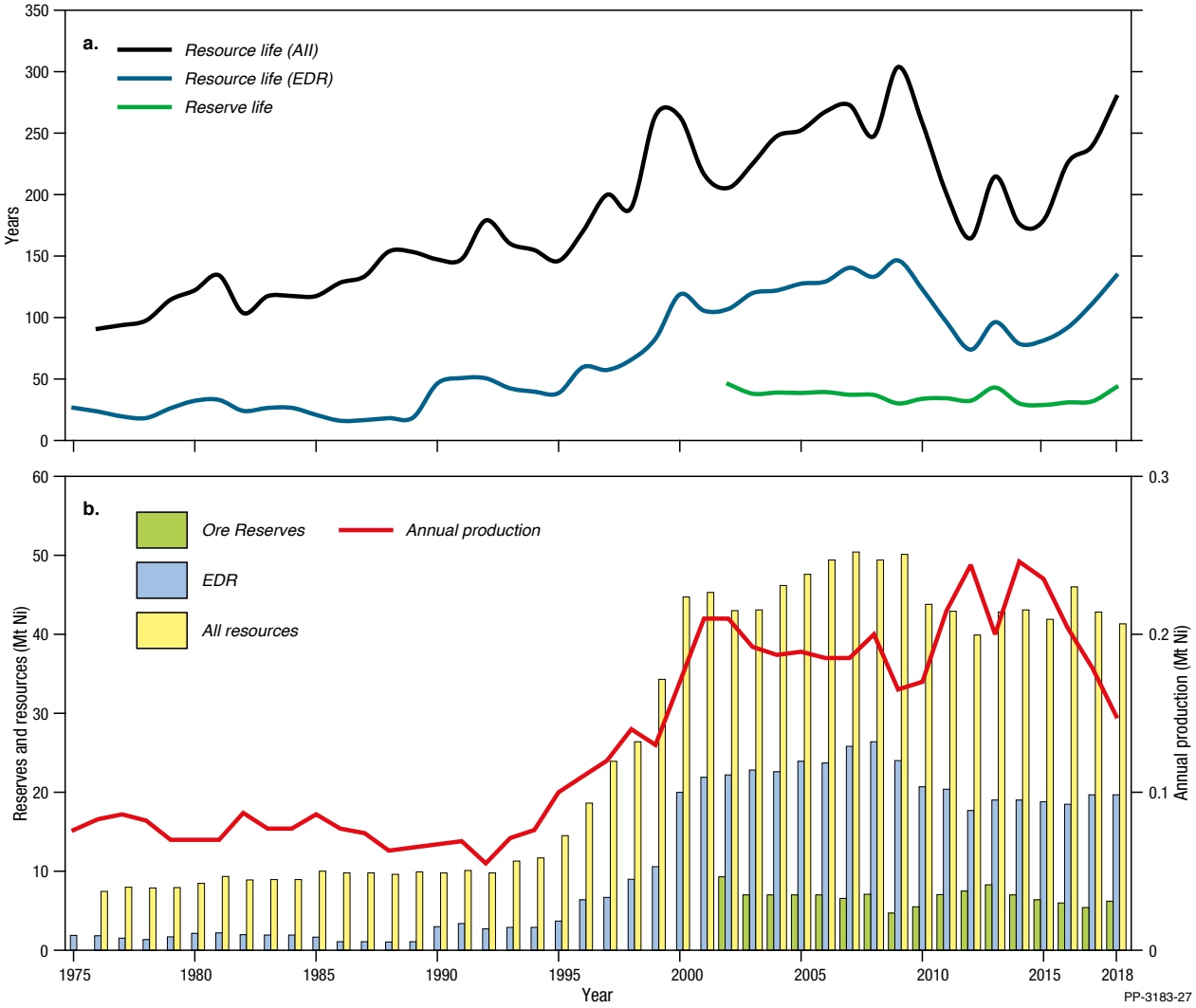


Figure 30 (a) Trends in nickel reserves and resource life. These ratios are derived from (b) nickel Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR + Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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

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 42 years (Table 2) and if accessible EDR is used as an indication of long-term potential supply, then Australia's nickel resources could last 133 years at 2018 rates of production (Table 9). At 2018 rates of production, and even with increased rates of production, Australia has the potential to produce nickel for many decades into the future.

Reserve life for nickel shows a general decline since 2002 because companies have been replacing Ore Reserves at a slower rate than production has been depleting them (Figure 30). Resource life for nickel gradually rose from 1990 to 2009 because companies delineated new resources faster than they increased production (Figure 30). Since the 2009 peak, resource life has declined but has begun to increase again in recent years owing to falling production (Figure 30).

In second half of 2018, Panoramic Resources Ltd restarted production at its Savannah nickel-copper-cobalt mine in Western Australia. A number of other companies are developing projects for cobalt production that should become operational in the next two to three years (e.g. the Australian Mines Ltd Sconi battery metals project in Queensland; the Clean TeQ Holdings Ltd Sunrise nickel-cobalt project in New South Wales). In 2018, Carnavale Resources Ltd acquired the Grey Dam nickel-cobalt project in Western Australia and is evaluating the potential for a shallow, low strip-ratio open pit.

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 2287 GL (14 385 million barrels), and Inferred (prospective) resources were estimated at 1472 GL (9261 million barrels) in 2018 (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.

Phosphate

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. Australia's EDR of phosphate rock were 1091 Mt in 2018 (Table 3), down 7% from 1170 Mt in 2017 (Table 4). Contained P_2O_5 EDR in 2017 decreased 10% to 178 Mt (Table 3) from 198 Mt the previous year (Table 4). The phosphorites of the Georgina Basin (encompassing parts of Queensland and the Northern Territory; Figure 31) 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.

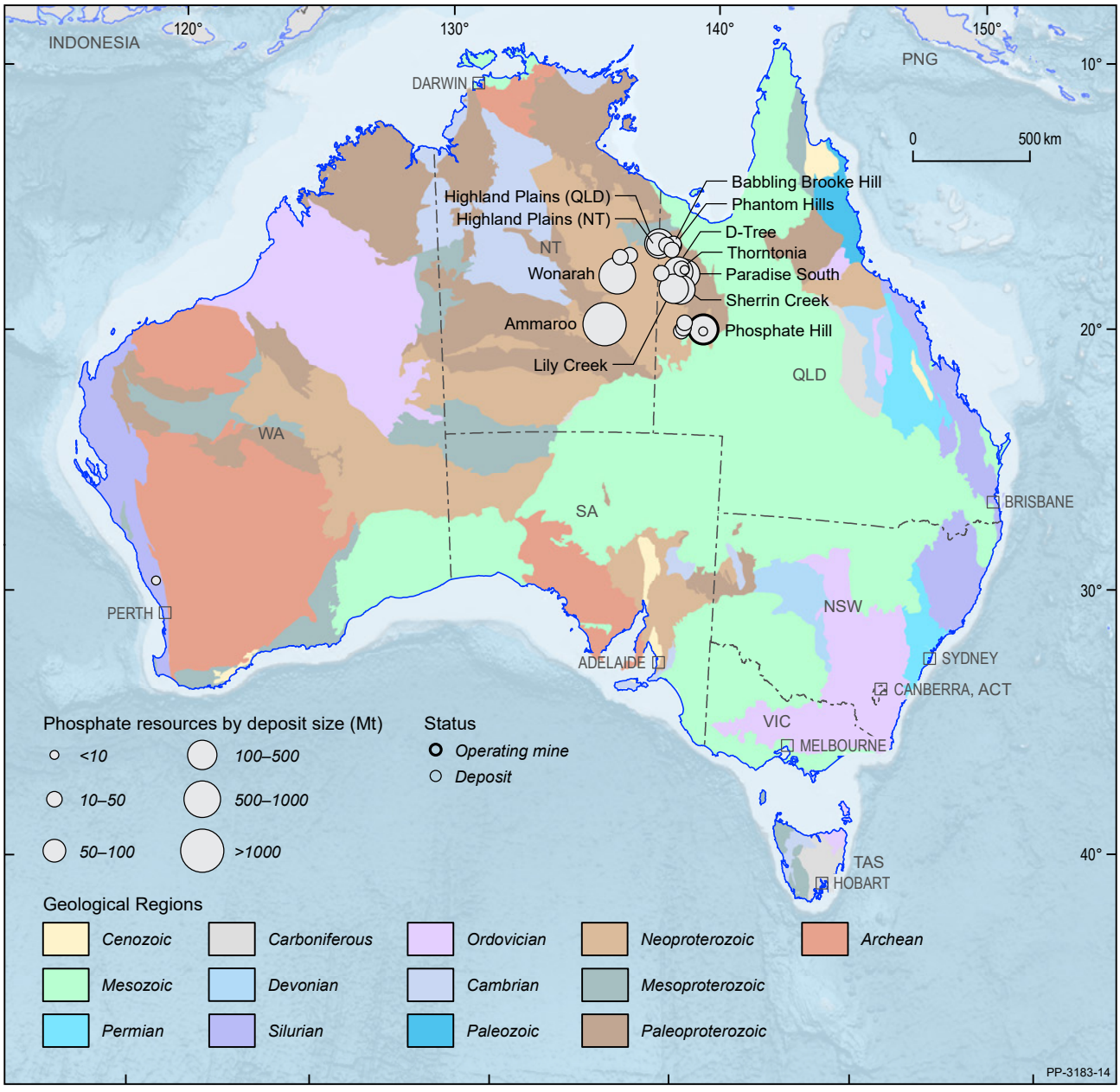


Figure 31 Australian phosphate operating mines and deposits 2018.

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

Australia's EDR of platinum group elements (PGE) increased 26% (6.6 t) from 24.9 t in 2017 to 31.5 t in 2018 (Table 4). Australian EDR represents a minor portion of the world total of 69 000 t (Table 3). Australia also has Inferred Resources of 16.2 t and another 136.7 t categorised as paramarginal (Table 3). In addition to public PGE resource reports, Australian mineral deposits may contain unreported resources that are recovered as by-products to the primary commodity being mined (usually from nickel sulphide ores). The Western Australian Department of Mines and Petroleum reported that 541 kg of platinum and palladium was produced during 2018 (Table 3), a decrease from 765 kg in 2017. The bulk (71%) of Australia's EDR of PGE occur in Western Australia (Figure 32).

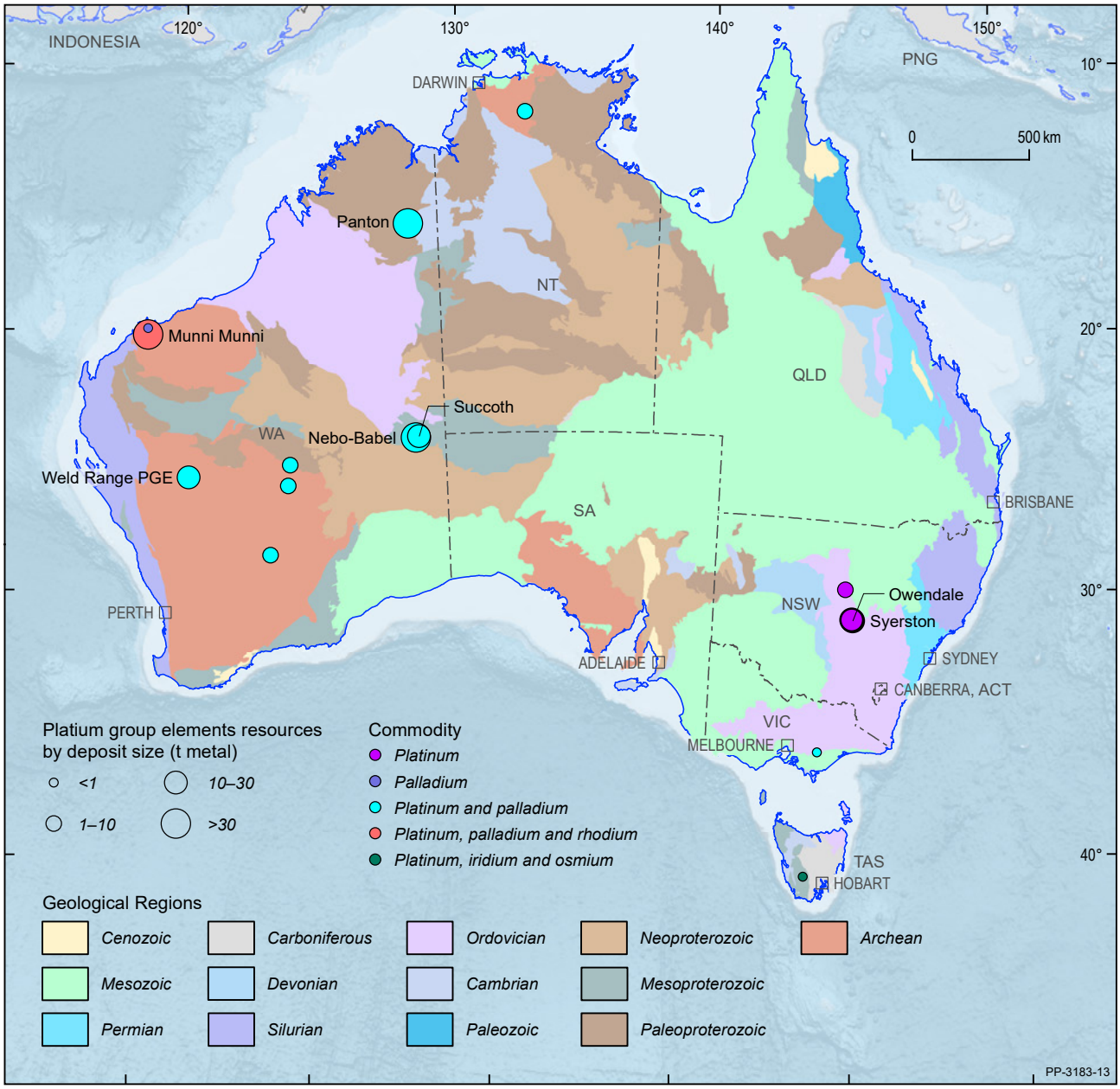


Figure 32 Australian platinum group elements deposits 2018.

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

Potash

In 2018, Australia's EDR of potash increased by 24% to 72 Mt, up from 58 Mt in 2017 (Table 4). The increase reflects significant industry and exploration activity, boosted by rising potash prices over the past three years, leading to the development of promising projects with potential to bring high-grade sulphate of potash (SOP) products online.

Several projects are on track to commence potash production starting in 2020 with the Beyondie SOP project currently in development by Kalium Lakes Ltd. The project is expected to produce 90 000 tonnes per annum (tpa) and eventually ramp up to 180 000 tpa. Additional projects are set to come online soon after, including Agrimin Ltd's Lake Mackay SOP project which is expected to commence commercial production in 2022 and eventually ramp up to 426 000 tpa. Salt Lake Potash Ltd is building a 50 000 tpa demonstration plant to provide a template for a very large-scale future operation as part of its Goldfields Salt Lakes Project, which includes the Lake Wells deposit in Western Australia.

Nearly all (95%) 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 resources also delineated at Kalium Lakes, Lake Chandler, Lake Disappointment, Lake Hopkins and Lake Wells (Figure 33).

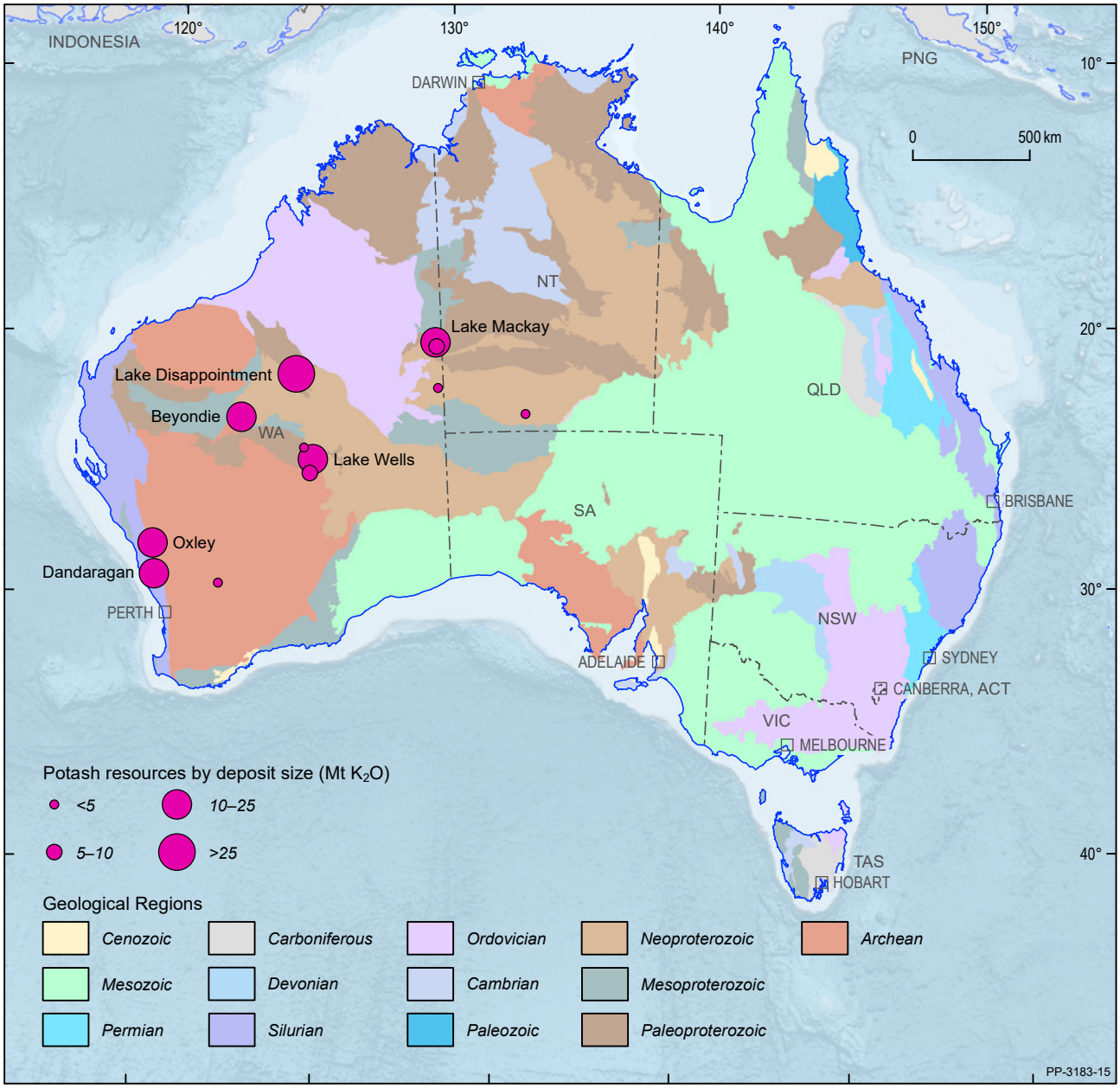


Figure 33 Australian potash deposits 2018.

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

Historically, Australia produced potash in the 1950s but, since then, has predominately imported potash and potassic fertilisers. Potash is imported principally from Canada, the USA and Germany, while, over the last five years, other potassic fertilisers (besides potash) have been principally imported from Belgium, South Korea and Israel. In 2018, Australia imported over 796 Mt of potash and potassic fertilisers worth $244 million.

Australia's potash resources remain small (1%) by world standards (Table 8). The countries with the largest economic resources of potash (K_2O) in 2018 were Russia (2000 Mt), Canada (1200 Mt) and Belarus (750 Mt), together representing 68% of the world's total K_2O-equivalent resources. Australia is ranked 11th in the world for resources but did not produce potash in 2018 (Table 8).

Potash is important for agriculture as it promotes plant growth and health. It is used for improving the quality and yield of fruit, vegetable, nut, tea, coffee and tobacco crops. Historically, Australia has been dependent on imports for its potash requirements but, with many new projects under development, could become increasingly self-sufficient in coming years.

Photo: citrus orchards in South Australia.

Rare Earth Elements

The rare earth elements (REE) are a group of metals comprising the 15 elements of the lanthanide series[12]. 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) and Geoscience Australia incorporates yttrium when determining these resource estimates but assesses scandium separately.

As at December 2018, total Ore Reserves of REO, including yttrium but not scandium, reported in compliance with the JORC Code amounted to 2.84 Mt (Table 2) an increase of 48% over 2017. This estimate does not include approximately 17 kt of REO that have been reported in Ore Reserves of heavy mineral sands. Ore Reserves accounted for 69% of Australia's Economic Demonstrated Resources of REO.

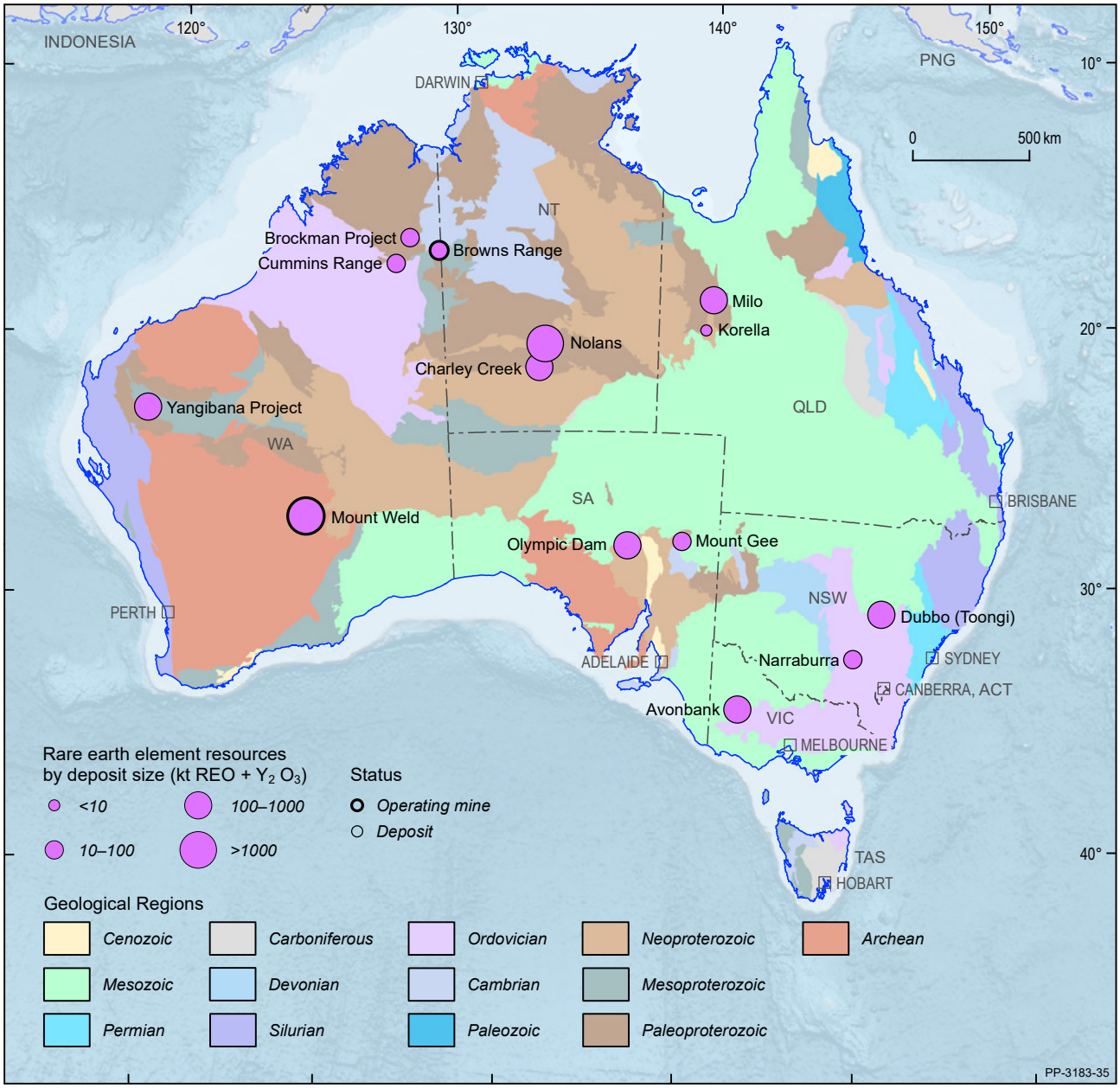


Figure 34 Australian rare earth element deposits and operating mines 2018.

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

12. 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).

Economic Demonstrated Resources of REO were 4.12 Mt at the end of December 2018 (Table 3), up by 26% from 3.27 Mt in 2017 (Table 4). Australia also had 33.99 Mt of REO resources considered to be subeconomic at the end of 2018 (Table 3), an increase of 11% from the 30.56 Mt recorded at the end of 2017. Similarly, 26.15 Mt of Inferred Resources of REO in 2018 (Table 3), were 5% higher than the 24.81 Mt at the end of 2017. Rare earths deposits and operating mines are shown in Figure 34 on a total resource basis.

World production of rare earths, based on USGS data and modified for Australian production, was estimated to be 0.170 Mt of REO in 2018. Australia was the world's second largest producer, providing 11% of global supply (Table 8). Australian production of REO in 2018 was 0.019 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. In addition, 2.6 t of rare earth carbonate was 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.

Critical minerals are increasingly used in medical applications. For example, the rare earth element gadolinium has the strong magnetic properties needed for MRI machines. Other medical applications for critical minerals include use in X-Ray machines, medical tools, laboratory equipment and solid state lasers, which are used for optical surgery and cancer treatment.

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 often grouped with the rare earths and yttrium. While it is not uncommon in the Earth's crust (it has 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 35).

As at December 2018, total Ore Reserves of scandium, reported in compliance with the JORC Code, were 12.14 kt (Table 2). Ore Reserves accounted for 48% of Australia's EDR of scandium and have been reported from four projects—Nyngan, Owendale and Sunrise (Syerston) in New South Wales and Sconi in Queensland. Scandium EDR were 26.05 kt in 2018 (Table 3) and Australia also had an estimated 7.64 kt of subeconomic scandium resources and Inferred Resources of 19.49 kt (Table 3).

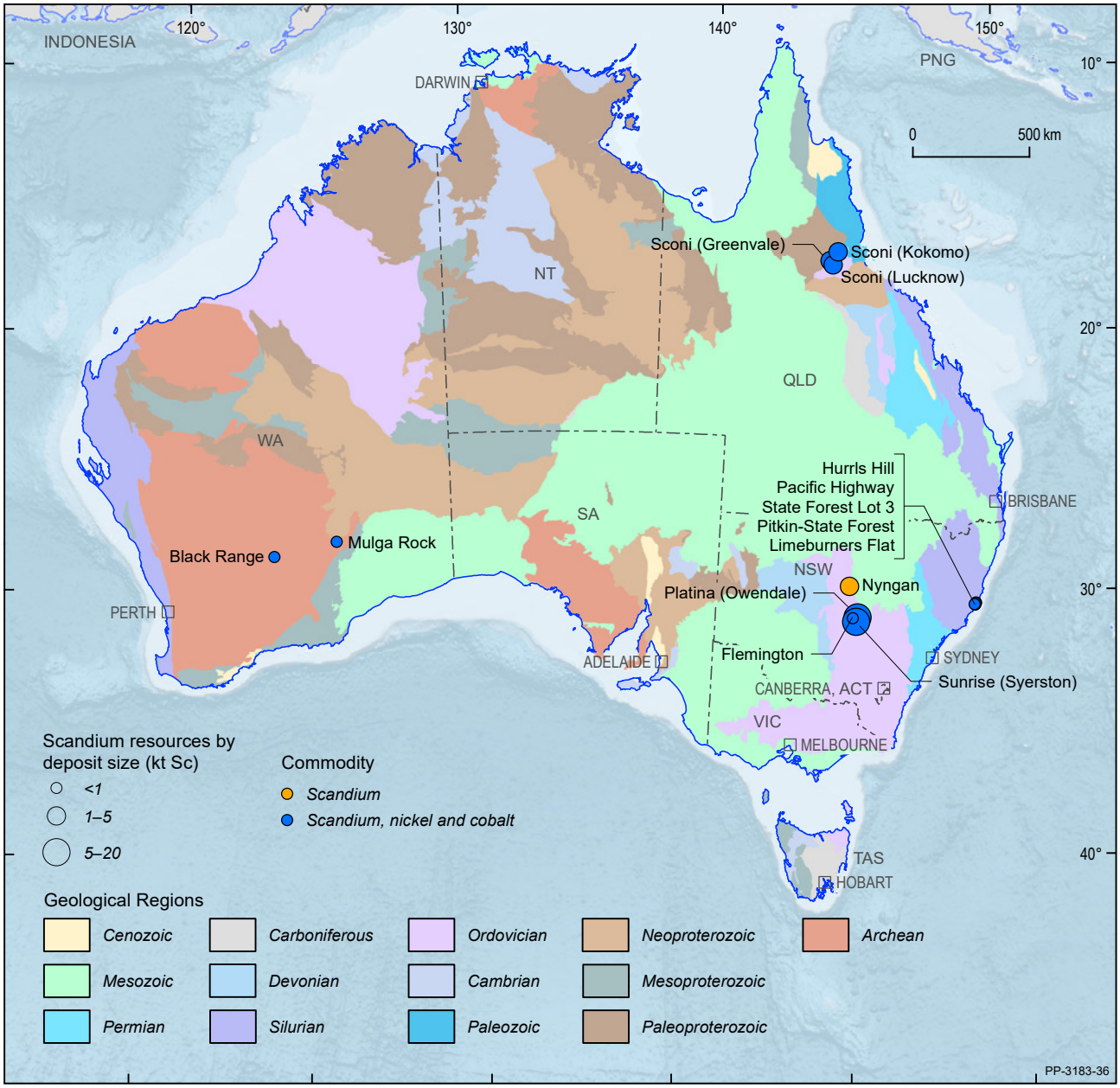


Figure 35 Australian scandium deposits 2018.

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

Tin

Australia's EDR of tin were 430 kt in 2018 (Table 3), up slightly (4%) from 415 kt in 2017 (Table 4). Just over half (52%) of Australia's EDR of tin occur within the Renison deposit, Tasmania. Other deposits with significant EDR include Cleveland, Queen Hill and Mount Lindsay (Tasmania), Taronga (New South Wales) and Gillian and Pinnacles (Queensland). Tin deposits and operating mines are shown in Figure 36 on a total resource basis. Total resources of tin in Australia are 888 kt (Table 3). In 2018, Australia ranked fourth globally with 9% of the world's economic resources of tin (Table 8).

Annual production of tin for Australia in 2018 was 6.9 kt (Table 3), down from 7.4 kt in 2017. Nearly all of this production was from the Renison deposit in Tasmania. Australia ranked eighth globally in 2018 with 2% of world production (Table 8).

Australia's total Ore Reserves of tin in 2018 were 249 kt (Table 2), of which the majority (67%) are within the Renison deposit (Figure 1). Other delineated Ore Reserves are reported at the Taronga, Cleveland and Mount Lindsay deposits. Based on the 2018 Ore Reserves to production ratio, Australian tin has 36 years of reserve life, reducing to 24 years when only operating mines are considered (Table 9).

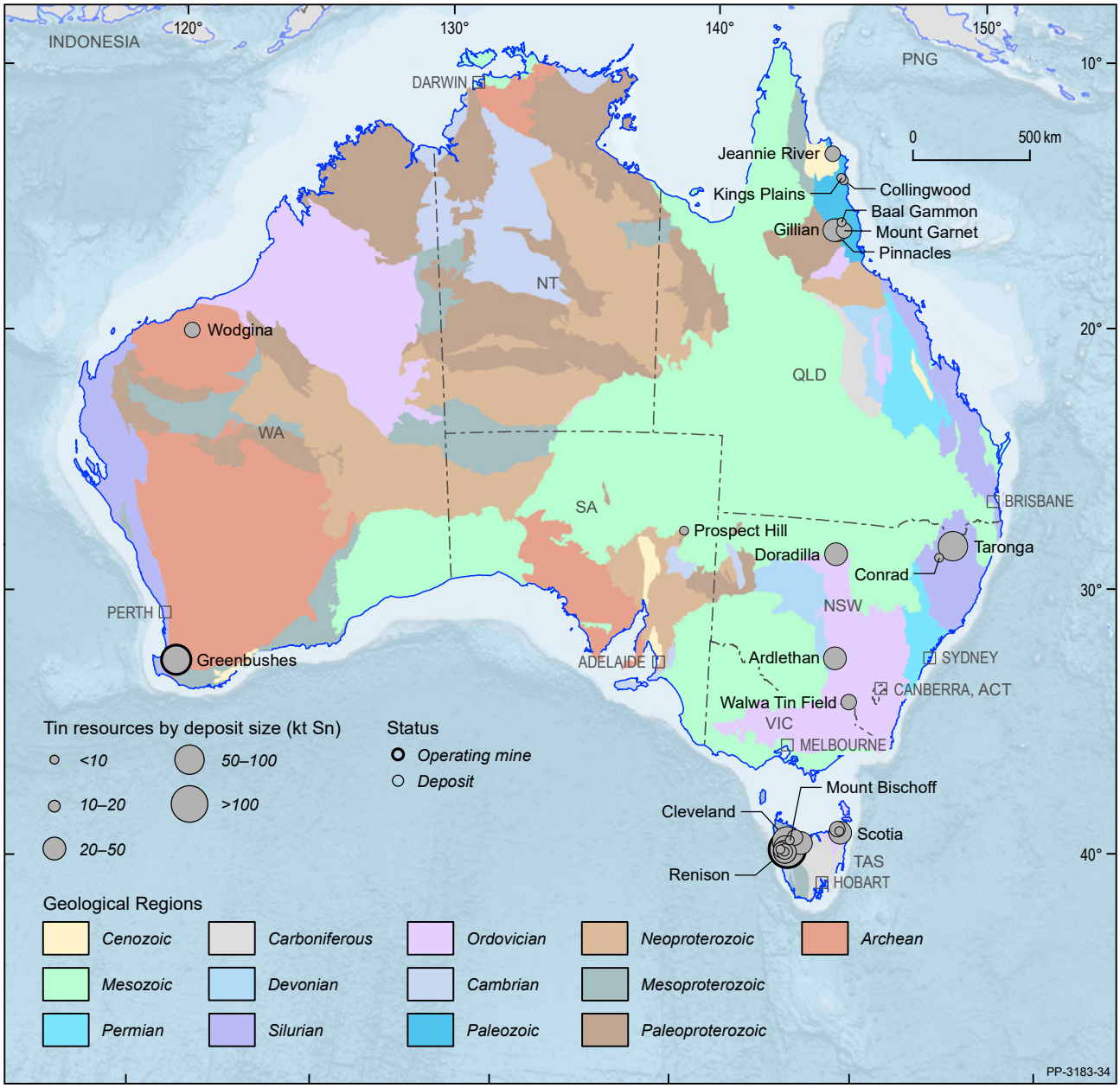


Figure 36 Australian tin deposits and operating mines 2018.

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

Tungsten

In 2018, EDR of tungsten were 394 kt (Table 3), up 2% (Table 4) from 386 kt the previous year. Western Australia holds 53% of EDR, Tasmania 26% and Queensland 18%. Minor EDR (<5%) occurs in the Northern Territory and New South Wales (Figure 37). Australia ranks second in the world (Table 8), behind China, with 11% of global world economic resources. Australian production, however, remains minor on the world scale (Table 8); China holds approximately 50% of world economic resources and is responsible for more than 80% of global production.

As at December 2018, total Ore Reserves of tungsten reported in compliance with the JORC Code amounted to 216.4 kt (Table 2) of which 2.9 kt was attributable to Australia's one operating tungsten mine. In 2018, Ore Reserves remained unchanged whilst production increased and, therefore, reserve life decreased: the very large reserve life, of more than 10 000 years (Table 2), is attributable to a relatively small production rate. In 2018, prices reached a peak of US$350/metric tonne unit (MTU) in June, by the end of the year, prices had dipped to approximately US$280/MTU.

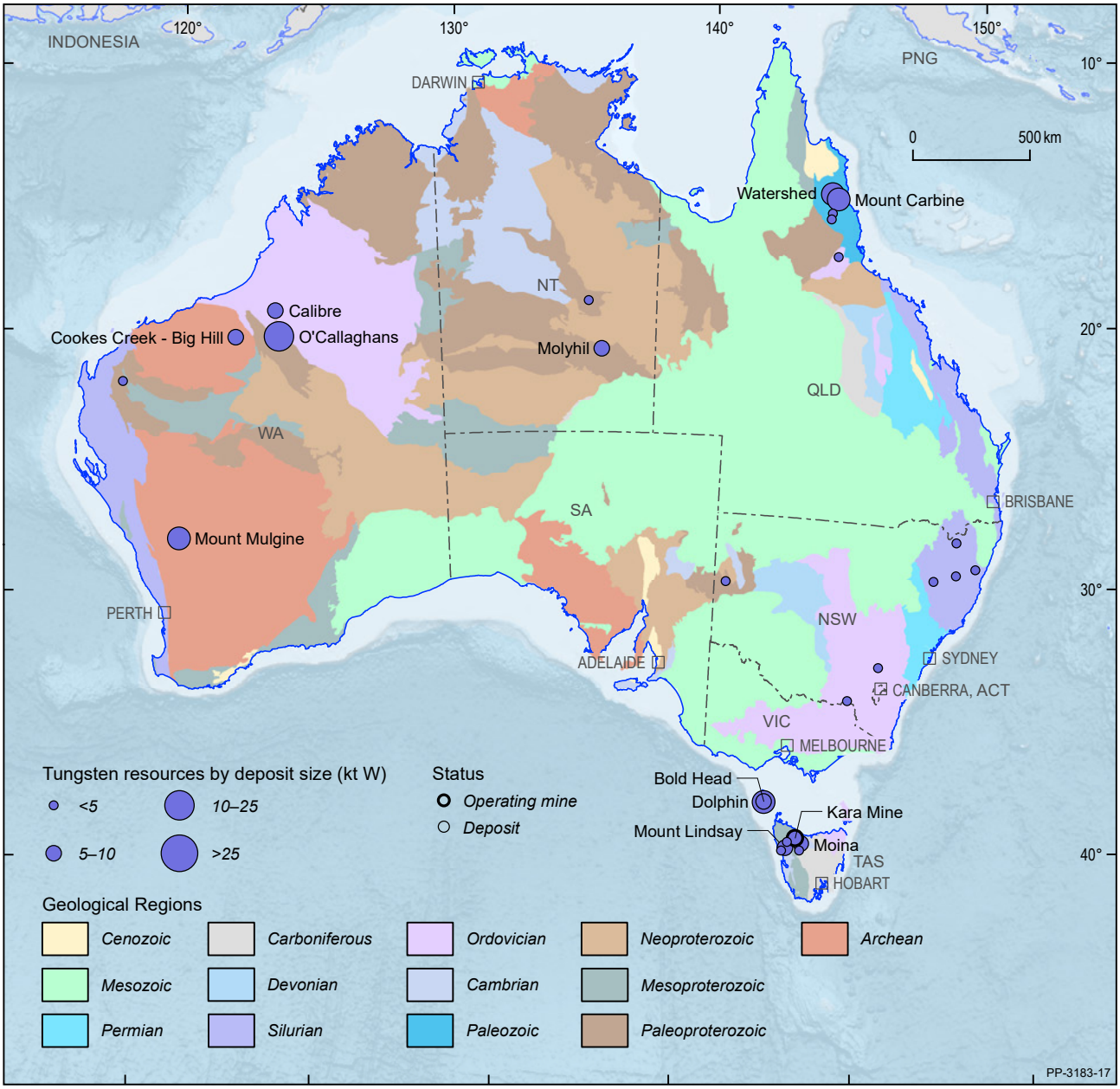


Figure 37 Australian tungsten deposits and operating mines 2018.

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

The Kara mine in Tasmania was Australia's only operating tungsten mine in 2018. It produces scheelite (calcium tungstate) concentrates as a by-product of magnetite processing. During 2018, Molyhil (Northern Territory), Mount Lindsay (Tasmania) and Watershed (Queensland) remained at various stages of development. During 2019, at the Dolphin Project (Tasmania), King Island Scheelite Ltd reportedly entered into an offtake agreement for tungsten concentrate with Austrian-based Wolfram Bergbau und Hutton AG pending the achievement of operational and financial milestones prior to 31 March 2021. In 2019, Specialty Minerals International Ltd reported the first delivery of equipment to the Mount Carbine site in Queensland and the engagement of sub-contractors for the installation of the newly arrived equipment. Specialty Minerals intended to commence tailings and stockpile retreatment at Mount Carbine in the final quarter of 2019.

Tungsten is used for a variety of high-temperature, high-strength applications due to its resistance to heat, corrosion and its high tensile strength. Because of these properties, tungsten is used extensively in drilling equipment for mining exploration projects.

Uranium

Australia has the world's largest known resources of uranium, accounting for more than 30% of the global inventory, and is the world's third largest uranium producer (Table 8) after Kazakhstan and Canada. As at December 2018, Australia had uranium EDR of 1325 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 and IAEA) category of Reasonably Assured Resources of uranium recoverable at costs of less than US$130/kg U (RAR <$130/kg U).

Ore Reserves of uranium in 2018 totalled 296 kt (Table 2), which was an approximately 4% increase from 2017.

Additionally, Australia has an estimated 1016 kt of Inferred Resources of uranium and another 106 kt regarded as subeconomic (Table 3). Uranium deposits and operating mines are shown in Figure 38 on a total resource basis.

Australia's uranium production in 2018 amounted to 5.872 kt (6.923 kt U_3O_8) 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 10% increase on the previous year. Uranium production is expected to decrease in the near future, however, as mining activities at the Ranger mine will cease in January 2021. In 2018, Australia exported 6.167 kt U (7.272 kt U_3O_8) valued at $635 million (Table 11).

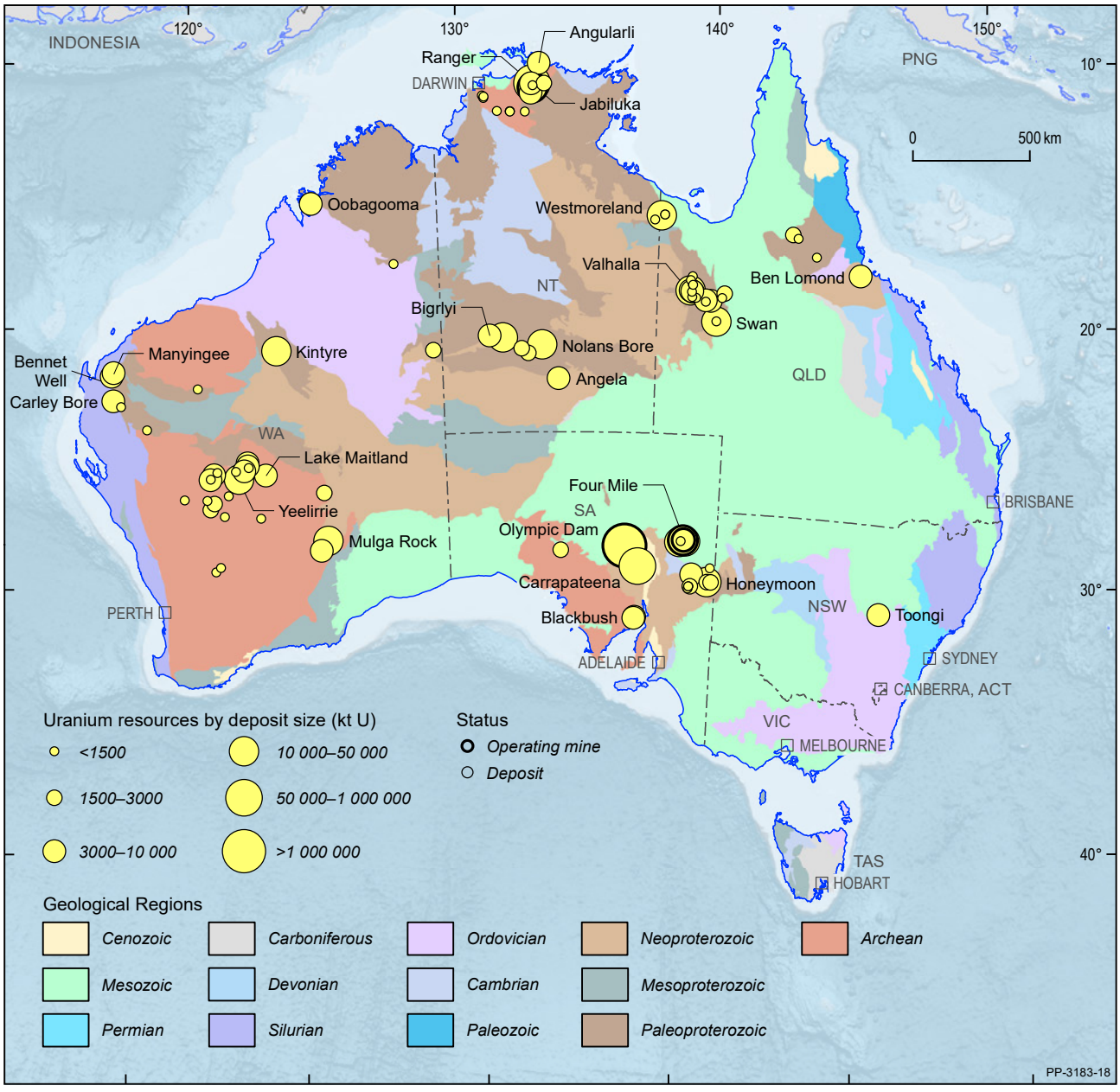


Figure 38 Australian uranium deposits and operating mines 2018.

Deposit size is based on total resources (EDR + Subeconomic Demonstrated Resources + Inferred). For clarity, only major or significant deposits are labelled.
Note: The Resources at Mount Gee, Jabiluka and Coronation Hill are not accessible.

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 39). 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 2000, resource life has again been increasing owing to a gradual increase in resources and a concurrent decline in production (Figure 39).

Australia exports all its uranium production to countries within its network of bilateral safeguards agreements, which now total 43. These agreements ensure that Australian uranium is used only for peaceful purposes and does not contribute to any military applications. Australian mining companies supply uranium under long-term contracts to electricity utilities in North America, Europe and Asia.

The Yeelirrie uranium deposit, wholly owned by Cameco Australia Pty Ltd, is located 70 km southwest of Wiluna in Western Australia and is one of the world's largest surficial uranium deposits. In April 2019, the Yeelirrie uranium project received environmental approval from the Australian Federal Department of Environment and Energy, which followed state government environmental approval in January 2017. The Yeelirrie project is one of five uranium projects that are awaiting better market conditions before proceeding with development. The other projects 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 (2019). 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 established in August 2019.

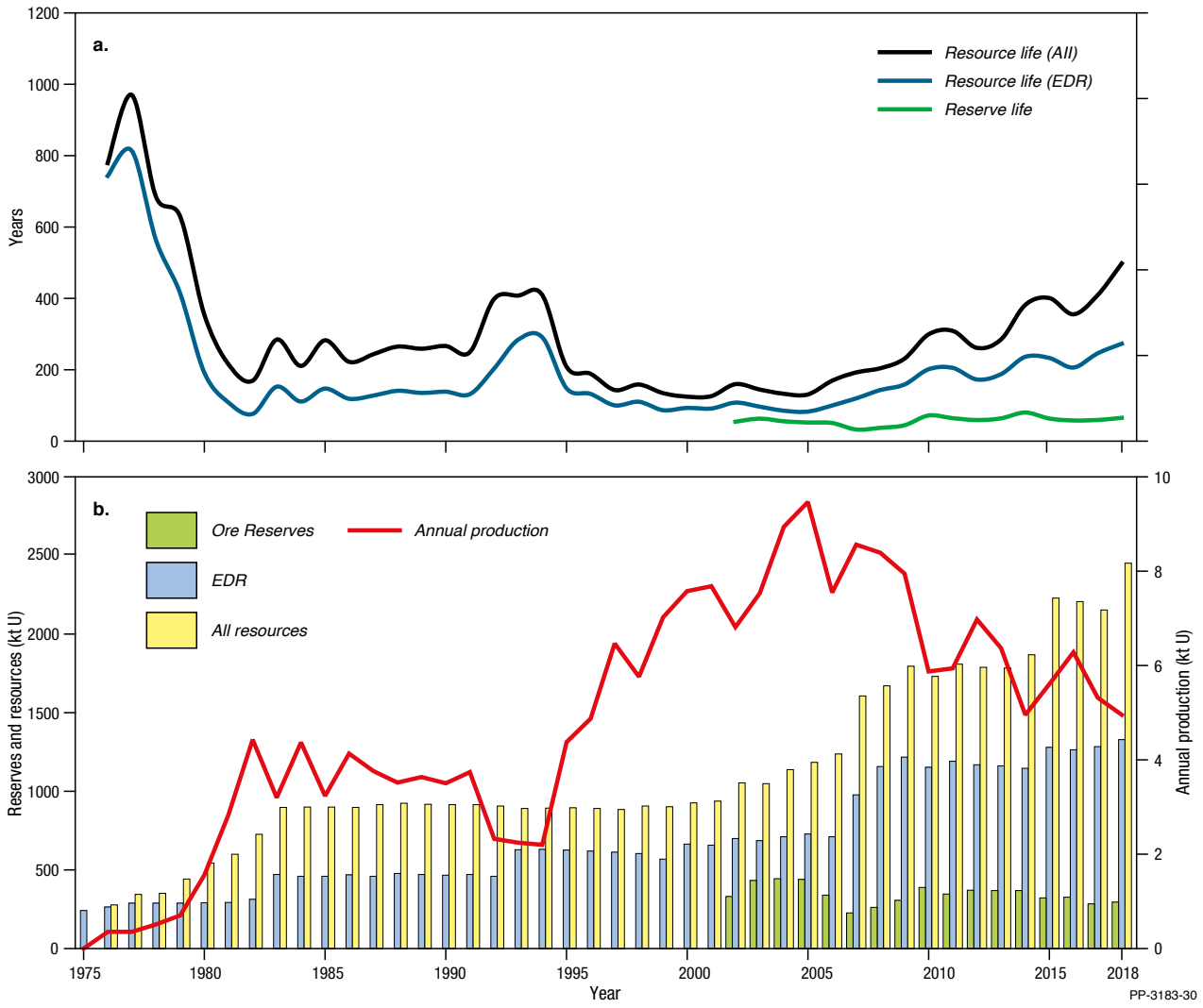


Figure 39 (a) Trends in uranium reserves and resource life. These ratios are derived from (b) uranium Ore Reserves, Economic Demonstrated Resources (EDR), all resources (EDR+Subeconomic Demonstrated Resources + Inferred) and annual production, 1975–2018.

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.

Vanadium

Vanadium has found favour with mineral explorers and developers in recent years owing to the global growth of renewable energy battery storage technologies. This is evident through the progressive increase of vanadium EDR, with a 17% increase to 4646 kt in 2018 (Table 3), up from 3965 kt in 2017 (Table 4). This EDR comprises approximately 20% of the global economic vanadium resources, ranking Australia third in the world (Table 8).

Australia's total vanadium Ore Reserve has correspondingly increased by around 10% to 1182 kt, amounting to approximately 25% of the EDR of vanadium.

Vanadium EDR in Australia are mostly located in Western Australia at developing deposits Balla Balla, Speewah, Barrambie and Gabanintha. The Windimurra vanadium mine (currently non-operational) in Western Australia has completed a study to recommence the operation in the near future. Windimurra was once Australia's sole vanadium producer but operations ceased in February 2014 following fire damage to the plant. Mount Peak in the Northern Territory is an advanced vanadium project with construction planned. Vanadium deposits are shown in Figure 40 on a total resource basis.

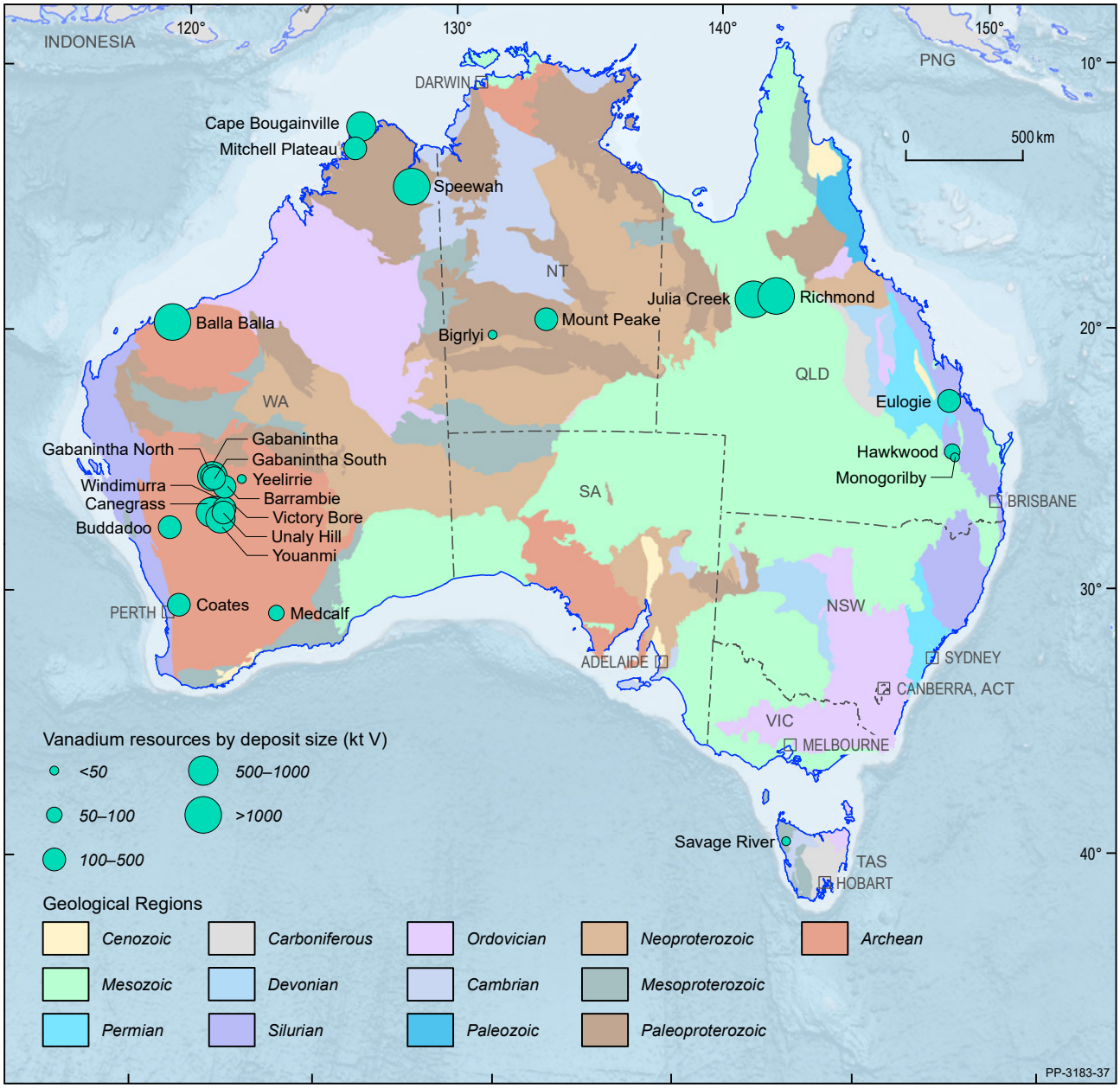


Figure 40 Australian vanadium deposits 2018.

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

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