Australian Government
Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2013

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Department of Industry

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Panorama of the Ensham Coal Mine near Emerald, Queensland.

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Acronyms, Abbreviations and Symbols

g	gram
kg	kilogram
t	tonne
kt	kilotonne (thousand tonnes)
Mt	million tonnes
ℓ	litre
Gℓ	gigalitre (thousand million litres)
c	carat
Mc	million carats
oz	ounce
Moz	million ounces
lb	pound
m	metre
km	kilometre
ha	hectare
MWe	megawatt electric
GWe	gigawatt electric
%	per cent
wt%	weight per cent
°C	degrees Celsius
tpa	tonnes per annum
ktpa	kilotonnes per annum
Mtpa	million tonnes per annum
g/t	grams per tonne
kg/t	kilograms per tonne
ℓ/t	litre per tonne
ppm	parts per million
ppb	parts per billion

ACT	Australian Capital Territory
NSW	New South Wales
NT	Northern Territory
Qld	Queensland
SA	South Australia
Tas	Tasmania
WA	Western Australia
USA	United States of America

BREE	Bureau of Resources and Energy Economics
CSIRO	Commonwealth Scientific and Industrial Research Organisation
IAEA	International Atomic Energy Agency
OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
USGS	United States Geological Survey

EDR	Economic Demonstrated Resources
AEDR	Accessible Economic Demonstrated Resources
RAR	Reasonably Assured Resources
JORC	Joint Ore Reserve Committee – Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves

$	dollar (Australian)
US$	United States of America dollar
Pty	Proprietary
Ltd	Limited
NL	No Liability (company)
plc	Public Limited Company
Co	Company
Inc	Incorporated

Ag	silver
Al	aluminium
Au	gold
Be	beryllium
Bi	bismuth
C	carbon

Ca	calcium
Ce	cerium
Cl	chlorine
Co	cobalt
Cr	chromium
Cu	copper
Dy	dysprosium
Er	erbium
Eu	europium
F	fluorine
Fe	iron
Gd	gadolinium
H	hydrogen
Hf	hafnium
Hg	mercury
Ho	holmium
I	iodine
In	indium
Ir	iridium
K	potassium
La	lanthanum
Li	lithium
Lu	lutetium
Mg	magnesium
Mn	manganese
Mo	molybdenum
N	nitrogen
Na	sodium
Nb	niobium
Nd	neodymium
Ni	nickel
O	oxygen
Os	osmium
P	phosphorus
Pb	lead
Pd	palladium
Pm	promethium
Pr	praseodymium
Pt	platinum
Re	rhenium
Rh	rhodium
Ru	ruthenium
S	sulfur
Sc	scandium
Se	selenium
Si	silicon
Sm	samarium
Sn	tin
Ta	tantalum
Tb	terbium
Te	tellurium
Th	thorium
Ti	titanium
Tm	thulium
U	uranium
V	vanadium
W	tungsten
Y	yttrium
Yb	ytterbium
Zn	zinc
Zr	zirconium
DSO	direct shipping ore
PGE	platinum-group elements
REE	rare earth elements
REO	rare earth oxides
TREO	total rare earth oxides

Executive Summary

Australia's Identified Mineral Resources is an annual national assessment that takes a long-term view of mineral resources likely to be available for mining. The highest category in the national inventory is Economic Demonstrated Resources (EDR) which, in essence, combines the Joint Ore Reserve Committee (JORC) Code categories of Ore Reserves and most of the JORC Code Measured and Indicated Resources. JORC Code Ore Reserves of commodities are included for comparison, which provides a short- to medium-term view of mineral stocks. The assessment also includes evaluations of long-term trends in mineral resources, world rankings, summaries of significant exploration results and brief reviews of mining industry developments.

Australia's EDR for the following 13 mineral commodities increased during 2012: antimony, bauxite, black coal, copper, gold, iron ore, lithium, molybdenum, rare earth oxides, tin, tungsten, vanadium and zircon. EDR for chromium, fluorine, magnesite, niobium, shale oil and thorium remained at levels similar to those reported in 2011. However, during the same period there was a decrease in the EDR of 13 commodities: brown coal, cobalt, diamonds, ilmenite, lead, manganese, nickel, phosphate rock, rutile, silver, tantalum, uranium and zinc.

Australia's EDR of gold, iron ore, lead, rutile, zircon, nickel, uranium and zinc are the world's largest, while bauxite, black coal, recoverable brown coal, cobalt, copper, ilmenite, lithium, magnesite, manganese, niobium, silver, tantalum, tungsten and vanadium all rank in the top six worldwide.

Australia's EDR of **bauxite** were estimated to be 6281 Mt in 2012 (slightly up from 5665 Mt in 2011), ranking second in the world behind the Republic of Guinea and ahead of Brazil, Vietnam, Jamaica and Indonesia. Australia was the world's leading producer of bauxite in 2012, the second largest producer of alumina and the fifth largest producer of aluminium. Australia's aluminium industry continues to be a highly integrated sector of mining, refining, smelting and semi-fabrication and is of major economic importance nationally and globally. Australia's aluminium industry is underpinned by vast resources of bauxite at Cape York in Queensland, Gove in the Northern Territory and in the Darling Range southeast of Perth in Western Australia. In recent years, however, processing costs have made some operations unviable, leading to the closure of the Kurri Kurri aluminium smelter, New South Wales in 2012 and the imminent closure of the Gove alumina refinery in 2014, along with the necessity for government assistance for smelters at Point Henry in Victoria and Bell Bay in Tasmania.

In 2012, the estimate of Australia's recoverable **black coal** EDR was revised upwards to 61 082 Mt, an increase of 6% on the previous year. The resource constitutes 6% of the world's recoverable black coal EDR. Globally, Australia is ranked fifth behind the United States, Russia, China and India in terms of recoverable economic coal resources. Most of Australia's black coal EDR is located in Queensland (59%) and NSW (37%). The Bowen Basin in Queensland and the Sydney Basin in NSW dominate black coal production in Australia and contain 61% of the nation's recoverable black coal EDR. Significant black coal resources are found also in the Surat, Clarence-Moreton and Galilee Basins (Qld) and in the Gunnedah Basin (NSW). At 2012 rates of production, Australia's black coal EDR will support 122 years of production.

The estimate of Australia's recoverable **brown coal** EDR (44 164 Mt) changed little between 2011 and 2012. Approximately 19% of the world's recoverable brown coal resources are located in Australia, with the nation ranked second behind Germany in terms of brown coal reserves. All of Australia's recoverable brown coal EDR is located in Victoria with approximately 93% in the Latrobe Valley. During 2012, brown coal production in Australia was estimated at 66.7 Mt. Brown coal mined in Australia is used almost exclusively for domestic electricity generation and at current rates of extraction the resource base will support 662 years of production.

Australia's EDR of **copper** rose by 4 Mt in 2012 to 91.1 Mt, an increase of 5%. Australia has the second largest economic resources of copper at 13% after Chile's 28%. South Australia has 68% of the national total of EDR, mainly in the Olympic Dam deposit, followed by NSW with 13% and Queensland with 12%. In 2012, mine production of copper fell by 5% and exports totalled $8.1 billion, down 6%. Spending on copper exploration rose by 4% with expenditure in SA accounting for 35% and Queensland a further 31%. Commercial production commenced at the new $400 million DeGrussa mine (WA), at the $2 billion Cadia East project (NSW) and at Mount Margaret (Qld). Studies into three major expansions were suspended or remained on hold at Olympic Dam (SA), the Mount Isa open pit (Qld) and the Northparkes step change project (NSW). Two significant copper mines were acquired by foreign entities during the year, Northparkes (NSW) and Osborne (Qld).

Diamond production from the Argyle and Ellendale mines in WA increased to 8.6 Mc during 2012, 1.1 Mc more than in 2011. Australia's EDR of total diamond resources decreased by 2% in 2012 to 268 Mc. Diamond EDR and production are dominated by the Argyle diamond mine.

Australia's EDR of **gold** rose 8% or about 750 t in 2012 to 9909 t. Australia continued to hold the world's largest resources of the commodity by country, with about 18% of the estimated total and South Africa and Russia holding the second and third largest shares respectively. EDR rose in most states and the Northern Territory but declined in Victoria (down 18 t) and Tasmania (down 9 t). Western Australia continued to dominate the national gold resource inventory with EDR of 4295 t, or 43% of the total, an increase of about 240 t from 2011. South Australia with 2752 t and NSW with 1766 t maintained their second and third placings, respectively. Mine production of gold declined by 7 t in 2012 to 251 t and export of refined gold fell by 26 t to 282 t. Exploration expenditure continued to rise totalling $741 million for the year despite a softening of the gold price of about US$100/oz to around US$1650/oz by the end of 2012.

Because of major changes in Australia's **iron ore** mining industry and the development of large magnetite deposits in Australia, Geoscience Australia has estimated national resources of iron in two categories:

- Iron ore (t), and
- Contained iron (t).

Australia's EDR of iron ore increased by 18% to 44 650 Mt during 2012 with the EDR of contained iron estimated to be 20 638 Mt. Western Australia has the largest share of these resources with 91% of Australia's EDR, the majority of which is in the Pilbara region. Australia has the world's largest EDR with 25% of the world's iron ore followed by Brazil with 17%. Western Australia produced 505 Mt or 97% of Australia's total production of iron ore in 2012. Iron ore exploration expenditure in Australia during 2012 totalled $1138.2 million, a 26% increase on the $905.3 million spent in 2011. Exploration for iron ore in 2012 accounted for 31% of Australia's total mineral exploration expenditure.

Australia's EDR of **lithium** increased by 50% to 1538 kt in 2012, ranking it third largest globally, behind Chile and China, with 11.4% of the world's economic resources. All of Australia's EDR of lithium occur within hard rock pegmatite deposits in WA. The bulk of the increase in Australia's EDR of lithium reflects a large addition to resources at the Greenbushes (WA) deposit, which is the world's largest and highest grade spodumene deposit.

Australia's EDR of **magnesite** totalled 330 Mt, representing about 4% of the world's economic resources of magnesite. South Australia has the largest share of these resources with 71% followed by Queensland with 19%. The Kunwarara deposit in Queensland is the world's largest known resource of ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

Australia's EDR of **manganese** decreased by 5% to 187 Mt in 2012, ranking Australia's resources as the world's fifth largest. All of the EDR occur in the NT and WA. Australia's mine production of manganese ore reached record levels of 7.2 Mt in 2012, ranked third behind China and South Africa.

The regions containing the major proportion of Australia's **mineral sands** resources (**ilmenite**, **rutile** and **zircon**) are the Perth Basin north of Perth (WA), the Murray Basin (NSW, Vic and SA) and in the Eucla Basin (WA and SA). In 2012, an initial JORC Code compliant resource was published for the Thunderbird deposit in the emerging heavy mineral sand province in the Canning Basin in WA. EDR increased by 1.7% to 47.4 Mt for zircon, decreased by 1.0% to 187 Mt for ilmenite, and decreased by 2.2% to 26.6 Mt for rutile. Australia's economic resources of rutile and zircon are the largest in the world, while ilmenite resources are the second largest worldwide behind China.

Australia's EDR of **molybdenum** increased by 21.5% to 203 kt in 2012, ranking it eighth globally with 1.7% of the world's economic resources. Most of this growth is the result of a large increase in resources at Dart Mining NL's Unicorn deposit in Victoria. Resource figures for Australia's EDR do not include 220 kt of resources at Australia's largest molybdenum deposit at Spinifex Ridge in WA, which the owner, Moly Mines Ltd, has indicated is currently uneconomic.

Australia's EDR of **niobium** remained stable at 205 kt in 2012, ranking Australia's resource as the second largest in the world behind Brazil. The bulk of the EDR are associated with the Toongi deposit, 20 km south of Dubbo in NSW.

Australia's EDR of **nickel** decreased by 13.2% from 20.4 Mt in 2011 to 17.7 Mt in 2012. Despite the reduction, Australia continues to contain the world's largest economic resources with 24.4%. Western Australia remains the largest holder of nickel resources with 96.0% of total Australian EDR made up of both sulphide and lateritic deposits. Nickel production ceased in 2013 at the Leinster Perseverance, Maggie Hays, Cosmos and Sinclair deposits, partly because of a prolonged period of low nickel prices.

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 was 869 Mt in 2012, slightly down from the 2011 figure following reassessment of some phosphate resources. Contained P_2O_5 EDR remained unchanged at 148 Mt. The phosphorites of the Georgina Basin (Qld and NT) account for almost all of Australia's EDR of phosphate rock and 91% of Australia's EDR of contained P_2O_5. The remaining phosphate rock occurs at Christmas Island and the Mount Weld (WA) and Nolans Bore (NT) rare earth deposits also have EDR of contained P_2O_5. Australia has about 1% of the world's economic resources of phosphate rock.

Potash is a generic term covering a variety of potassium-bearing ores, minerals and refined products. Potash is not mined in Australia, which has only modest resources by world standards. Australia's fertiliser requirements are met through phosphate rock production and imports of potassium fertiliser. Ongoing exploration in recent years has led to recent published resources for some deposits such as Lake Disappointment, Lake Chandler and Dandaragan Trough/Dinner Hill deposits in WA, in the WA/NT portion of Lake Mackay and in the Karinga Creek Salt Lakes area in the southern NT. Project investigations are ongoing at the Lake Disappointment, Karinga Creek Salt Lakes and the Dandaragan greensand deposits. A new type of potash deposit hosted in ultrapotassic microsyenite lava flows was reported at Oxley in in the northern Moora Basin, WA, in 2013.

Australia's EDR of **rare earth oxides** (REO) in 2012 were 3.19 Mt which increased from 2.03 Mt in 2011 and currently account for 2.8% of the world's economic resources of REO. Significant resources of rare earths are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Currently, extraction of rare earths from monazite is not viable because of the cost involved with the disposal of thorium and uranium present in the monazite. However, scoping studies at the Charlie Creek alluvial heavy mineral deposit in the NT suggest that extraction of REO from xenotime and monazite would be viable. Commissioning of the Lynas advanced materials plant in Malaysia, which is processing REO concentrates from Mount Weld in WA, commenced in 2012. By early June 2013, the plant had achieved nameplate production capacity (11 000 tpa REO capacity) in the cracking and leaching units of phase 1.

Shale oil resources predominantly occur in a series of sedimentary basins around Gladstone, Mackay and Proserpine in central Queensland. Australia currently has no EDR of shale oil, with all resources being assessed as subeconomic. Exploration activity in the sector has returned with the lifting of Queensland's moratorium on shale oil development. Queensland Energy Resources Ltd's Paraho II™ shale oil technology demonstration plant at the Stuart deposit, near Gladstone, produced its first crude oil in September 2011 and operated successfully for two years.

Australia's EDR of **tantalum** remained stable at 62 kt in 2012, ranking Australia the second largest in the world behind Brazil. More than 94% of the EDR are located in WA and are associated with the Greenbushes and Wodgina deposits.

Australia's EDR of **tin** increased by 14% to 277 kt in 2012, ranking Australia's resources as the world's seventh largest. Just under 75% of Australia's EDR of tin are contained in the Renison Bell deposit in Tasmania.

Australia's EDR of **tungsten** in 2012 increased marginally (4%) to 391 kt to have 11.2% of the world's economic resources and ranking it the second largest behind China. Half of Australia's EDR is contained within the O'Callaghans multi-commodity deposit in WA. In early 2012 tungsten production commenced at both Wolfram Camp and Mount Carbine in north Queensland.

Australia's Reasonably Assured Resources (RAR) of **uranium** that can be produced at costs of less than US$130/kg of uranium at December 2012 were estimated to be 1174 kt, a decrease of 2% on the estimate for December 2011. Australia's RAR of uranium is the world's largest, accounting for over 30% of the global estimate. Market prices for uranium have progressively decreased from early 2011 through to mid-2013. During 2012 and 2013, spot prices remained below the level required to encourage investment in new mines. This resulted in mining and exploration companies in Australia delaying uranium projects that had become uneconomic. Companies decided to focus investment on advancing only those projects that would result in highest return on capital investments. Australia's mine production for 2012 was 7009 t of uranium (8 265 t U_3O_8), which was 17% more than production in 2011.

Australia's **vanadium** EDR increased by 11% during 2012 to 1684 kt. This represents approximately 2.7% of estimated global vanadium resources, ranking Australia fourth in the world. The economic impacts of volatile prices and the nature of the vanadium market, which is supplied largely from secondary sources, has a significant impact on Australia's vanadium EDR and the development of Australian vanadium projects. The bulk of Australia's vanadium is located in WA at Windimurra, approximately 600 km north of Perth, which reopened in 2011. It is the only vanadium mine in production.

Australia's EDR of **zinc**, **lead** and **silver** declined by around 5% in 2012 because of production and resource revisions. Zinc EDR declined by 6% to 64 Mt, lead by 4% to 34 Mt and silver by 3% to 85 kt in 2012. Australia's economic resources for both zinc and lead are the world's largest holdings at 27% for zinc and 40% for lead. Queensland has 55% of the national total of EDR for zinc and lead, mainly in the Mount Isa region, followed by the NT with 28%, almost all of which is at the McArthur River mine. Exploration expenditure for zinc-lead in 2012 was $83 million, the same as in 2011. There were three major mine developments in 2012, all in Queensland, with first ore produced from both the Lady Loretta mine and from the expansion of the George Fisher underground mine, while the Dugald River mine was approved for construction.

Resources to production ratios

Ratios of Accessible Economic Demonstrated Resources (AEDR) to current mine production provide indicative estimates of the resource life. AEDR of most of Australia's major commodities can sustain current rates of mine production for many decades. Resource life based on JORC Code compliant ore reserves is lower, reflecting a shorter term commercial outlook.

Prior to 2008, there had been a significant trend towards lower AEDR/production ratios for coal and iron ore which was a result of major increases in production and reassessment of resources. The decline in iron ore prior to 2008 has been increasingly offset in the past few years by the development of large magnetite iron ore deposits in the Pilbara and mid-west regions of WA. These magnetite resources, which were previously considered to be subeconomic, have been reassessed as economic.

Commodities with resource life duration of less than 50 years are manganese ore (about 15 years at current rates of production), diamond (35 years), gold (40 years) and zinc (40 years).

The severe world financial crisis in late 2008 highlighted the fact that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly competitive and globalised commodity market, multinational mining companies are continuously seeking mineral deposits that will provide attractive returns on their investment. Such returns are influenced by the quality of the resources (grade and tonnage) as well as environmental, social and political factors, land access and the location and scale of competitor projects. Individual mine projects in Australia will be ranked by multinational companies against the investment returns from other deposits worldwide.

Australia's continuing position as a premier mineral producer is dependent on continuing investment in exploration to locate high quality resources and/or upgrade known deposits to make them competitive on the world market, as well as investment in beneficiation processes to improve metallurgical recoveries.

Introduction

Geoscience Australia and its predecessors have prepared annual assessments of Australia's mineral resources since 1975. The resource data and related information from Australia's Identified Mineral Resources provide input into Australian Government policy decisions and programs associated with the minerals sector and sustainable development of resources.

Australia's Identified Mineral Resources 2013 presents estimates of Australia's mineral resources at end of December 2012 for all major and several minor mineral commodities (Table 1). This national minerals inventory is based on published company reports of Ore Reserves and Mineral Resources. The national resource estimates provide a long-term view of what is likely to be mined. National total for the Joint Ore Reserve Committee (JORC) Code Ore Reserves are compiled for each commodity, which provides the industry view of what is likely to be mined in the short to medium term. Mine production data are based on figures from the Bureau of Resources and Energy Economics (BREE). World rankings of Australia's mineral resources have been calculated mainly from information in publications of the United States Geological Survey (USGS). A summary of significant industry developments also is presented.

National Resource Classification System

The mineral resource classification system used for Australia's national inventory is based on two general criteria:

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

For a full description of the system see Appendix 1 'Australia's National Classification System for Identified Mineral Resources'.

The description of the National Classification System shows how mineral resources reported by companies under the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (referred to as the JORC Code) are used when compiling national total resources. The classification category Economic Demonstrated Resources (EDR) is used for national totals of economic resources and provides a basis for meaningful comparisons of Australia's economic resources with those of other nations. Long-term trends in EDR for bauxite, black coal (recoverable), iron ore, gold, copper, lead, zinc, nickel, mineral sands and uranium (recoverable) are presented in Figure 1 and the reasons for significant changes in resource trends are noted.

Accessible Resources

Some mineral deposits are not accessible for mining currently because of government policies or various environmental and land access restrictions such as location within National and State parks and conservation zones, military training areas or environmental protection areas, as well as areas over which mining approval has not been granted by traditional owners. Accessible Economic Demonstrated Resources (AEDR), as shown in Table 1, represent the resources within the EDR category that are accessible for mining.

Table 1: Australia's resources of major minerals and world figures as at December 2012.

Commodity	Units	Australia							World	
		JORC Reserves (a) (% of Accessible EDR)	Demonstrated Resources			Inferred Resources (c)	Accessible EDR (d)	Mine Production 2012 (e)	Economic Resources 2012 (f)	Mine Production 2012 (g)
			Economic (EDR) (b)	Subeconomic						
				Para-marginal	Sub-marginal					
Antimony	kt Sb	55 (51%)	107	9	0	203	107	3.9	1800	180
Bauxite	Mt	2145 (34%)	6281	144	1429	1474	6281	76.3	28 000	263
Black coal										
in situ	Mt		77 589	1613	5341	89 194				
recoverable	Mt	20 662 (38%)	61 082	1134	3984	64 184	54 200	489 (h)	665 000 (i)	6637 (j)(k)
Brown coal										
in situ	Mt		49 035	37 465	16 873	123 240				
recoverable	Mt	n.a. (l)	44 164	33 402	15 185	102 502	34 095	66.73 (m)	195 000 (i)	1041 (k)
Cobalt	kt Co	519 (51%)	1021	294	37	1209	1021	5.88 (n)	7273	110.48
Copper	Mt Cu	25.2 (28%)	91.1	1.4	0.4	43.9	91.1	0.91	690	16.6
Chromium	kt Cr	0	0	0	0	3657	0	127.7 (o)	>460 000	24 000 (p)
Diamond	Mc	146.1 (55%)	268.0	0	0	42.7	268.0	8.6	600 (q)	150
Fluorine	Mt F	0	0	0.5	0	0.4	0	0	117 (r)	3.34 (r)
Gold	t Au	4119 (42%)	9909	372	122	4571	9879	251	54 300	2660
Iron										
iron ore	Mt	15 305 (34%)	44 650	566	1365	73 570	44 650	520	175 650	2959
iron (contained Fe)	Mt Fe	7931 (38%)	20 638	224	473	33 827	20 638	n.a.	83 688	n.a.
Lead	Mt Pb	15.4 (45%)	34.4	3.4	0.2	20.2	34.4	0.62	89	5.2
Lithium	kt Li	854 (55%)	1538	0	0.1	139	1538	12.7 (s)	13 538	37 (r)
Magnesite	Mt $MgCO_3$	37.5 (11%)	330	22	35	836	330	0.644 (t)	8300	21.16 (r)
Manganese ore	Mt	135.4 (72%)	186.8	23.1	167	324.1	186.8	7.208	1635	48
Mineral sands										
Ilmenite	Mt	43.2 (28%)	187.0	30.2	0.03	219.9	156.4	1.344	1233.57	11.30
Rutile	Mt	7.1 (31%)	26.6	0.3	0.06	42.2	22.8	0.439	50.68	0.79
Zircon	Mt	14.9 (36%)	47.4	1.1	0.07	68.3	41.0	0.605	88.62	1.41
Molybdenum	kt Mo	79.5 (39%)	203	1220	0.5	572	203	0 (u)	11 203	252
Nickel	Mt Ni	7.5 (42%)	17.7	4.2	0.2	17.8	17.7	0.244	72.6	2.14
Niobium	kt Nb	115 (56%)	205	82	0	418	205	(v)	4300	0
Phosphate										
phosphate rock (w)	Mt	289 (33%)	869	312	0	2089	869	3.09	67 500	210
contained P_2O_5	Mt	51 (34%)	148	65	0	354	148	n.a.	n.a.	n.a.
PGE (Pt, Pd, Os, Ir, Ru, Rh)	t metal	0	4.7	139.0	1.4	131.0	0.3	0.706	66 000	379
Potash	Mt K_2O	0	0	20.7	0	11.5	0	0	9500	34
Rare earths (REO & Y_2O_3)	Mt	2.15 (67%)	3.19	0.42	31.14	22.33	3.19	0	115	0.106
Shale oil	GL	0	0	213	2074	1272 (x)	0	0	763 139 (i)	1.165 (i)
Silver	kt Ag	30.4 (36%)	85.2	3.5	0.5	36.0	85.2	1.76	556	23.8
Tantalum	kt Ta	29 (48%)	60	18	0.2	21	60	(y)	156	0.77
Thorium	kt Th	0	0	91 (z)	0	444 (z)	0	0	n.a.	n.a.
Tin	kt Sn	170 (61%)	277	65	31	262	277	5.8 (aa)	4947	228
Tungsten	kt W	201 (51%)	391	11.1	5	102	391	0.29 (ab)	3488	73.3
Uranium	kt U	373 (34%)	1174	34	0	590	1104	7.009	3472 (ac)	58.394 (ad)
Vanadium	kt V	1305 (77%)	1684	14 640	1759	16 591	1684	0.07 (ae)	16 000	63
Zinc	Mt Zn	32.1 (50%)	64.1	1.1	0.8	25.8	64.1	1.54	247	13.1

Abbreviations

t = tonne; **L** = litre; **kt** = kilotonnes (1000 t); **Mt** = million tonnes (1000 000 t); **Mc** = million carats (1000 000 c); **GL** = gigalitre (1000 000 000 L); **n.a.** = not available.

Notes

a. Joint Ore Reserves Committee (JORC) Proved and Probable Ore Reserves as stated in company annual reports and reports to Australian Securities Exchange.

b. Economic Demonstrated Resources (EDR) includes Joint Ore Reserves Committee (JORC) Reserves, Measured and Indicated Mineral Resources.

c. Total Inferred Resources in economic, sub-economic and undifferentiated categories.

d. Accessible Economic Demonstrated Resources (AEDR) is the portion of total EDR that is accessible for mining. AEDR does not include resources which are inaccessible for mining because of environmental restrictions, government policies or military lands.

e. Source: Bureau of Resources and Energy Economics (BREE).

f. Sources: Geoscience Australia for Australian figures, United States Geological Survey (USGS) *Mineral Commodities Summaries* for other countries.

g. World mine production for 2012, mostly United States Geological Survey (USGS) estimates.

h. Raw coal.

i. Source: World Energy Council (WEC). Survey of Energy Resources 2010.

j. Saleable coal.

k. Source: World Coal Association, 2012.

l. There are no JORC code ore reserve estimates available for brown coal.

m. Source: Victoria's Minerals, Petroleum & Extractive Industries 2010–11 Statistical Review. Victorian Department of Primary Industries.

n. Source: Western Australian Department of Mines and Petroleum.

o. 186 635 t of chromite expressed as Cr_2O_3 (Source: Western Australian Department of Mines and Petroleum).

p. World production of 24 Mt of 'marketable chromite ore' as reported by United States Geological Survey (USGS).

q. Source: USGS Commodity Summaries 2012. Note—world resource figures are for industrial diamonds only. No data provided for resources of gem diamonds.

r. Excludes USA.

s. Calculated assuming a grade of 6% Li_2O in spodumere concentrates.

t. Production for 2010–11 (Source: Queensland Government. Department of Natural Resources and Mines).

u. Some molybdenum was produced as a by-product of tungsten at the Wolfram Camp mine. Amount produced is not known but is believed to be minor.

v. Not reported by mining companies.

w. Phosphate rock is reported as economic at grades ranging from 8.7% to 30.2% P_2O_5.

x. Total Inferred Resource excludes a 'total potential' shale oil resource of the Toolebuc Formation, Queensland of 245 000 GL that was estimated by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and CSIRO in 1983.

y. Department of Mines and Petroleum, Government of Western Australia reported a combined production in dollar values of tin, tantalum and lithium of $200 844 824.

z. Thorium resources reduced by 10 per cent to account for mining and processing losses.

aa. For all states except WA where actual figures not available.

ab. Estimated from production figures for tungsten (WO_3) concentrate.

ac. Source: Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) (2011). Compiled from the most recent data for resources recoverable at costs of less than US$130/kg U.

ad. Source: World Nuclear Association.

ae. For 2012 the Windimurra Vanadium project has produced 87 t of FeV, containing 70 t of vanadium.

Trends in Australia's Economic Demonstrated Resources of Major Mineral Commodities

The trends in Economic Demonstrated Resources (EDR) for Australia's major mineral commodities have undergone significant and sometimes dramatic changes over the period 1975–2012 (Figure 1). These changes for each commodity 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 of 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 Joint Ore Reserve Committee (JORC) Code[1] 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. Many companies re-estimated their mineral resources to comply with the JORC Code. The impacts of the JORC Code on EDR occurred at differing times for each of the major commodities; and
- increases in prices of mineral commodities driven largely by the escalating demand from China over the past decade.

Past trends and changes in EDR for a number of Australia's major mineral commodities are discussed below.

Bauxite

EDR of bauxite increased in 1989 as a result of the delineation of additional resources in deposits on Cape York Peninsula in northern Queensland ('a' in Figure 1). Decreases in bauxite EDR in 1992 resulted from reclassification of some resources within deposits on Cape York Peninsula to comply with requirements for the JORC Code ('b').

Black Coal

A major reassessment of New South Wales (NSW) coal resources during 1986 by the NSW Department of Mineral Resources and the Joint Coal Board resulted in a large increase in black coal EDR as reported in 1987 ('c').

EDR for black coal has declined since 1998 because of the combined impact of increased rates of mine production and mining companies re-estimating ore reserves and mineral resources more conservatively to comply with requirements of the JORC Code. From 2008 onwards, black coal EDR increased significantly mainly because of the discovery and delineation of additional resources as a result of high levels of exploration and through reclassification of resources.

Iron Ore

Australia's EDR of iron ore declined from 1994 through 2003 due to the combined impacts of increased rates of mine production and mining companies re-estimating reserves and resources to comply with the requirements of the JORC Code. Post 2003, EDR increased rapidly due to large increases in magnetite resources (including reclassification of some magnetite deposits to economic categories), and increases in hematite resources, mainly at known deposits. Mine production increased rapidly from 168 Mt in 2000 to 520 Mt in 2012.

Gold

Gold EDR has increased steadily since 1975 with a clear increase in the rate of growth since 1983. Much of the increase can be attributed to the successful introduction of carbon-based processing technology that allowed the profitable processing of relatively low-grade ore deposits. In addition, the higher than previous prevailing gold prices (denominated in US$) supported high levels of exploration for gold to the extent that gold accounted for more than half of the total mineral exploration expenditure in Australia for many years. Increased exploration contributed to the increases in EDR.

1 In 1988, the Australian mineral industry adopted the Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves (JORC Code). Many companies first used this code for reporting their mineral resources in 1989. The requirements of the Code differed significantly from the resource classification schemes used by companies prior to 1989.

Copper

Following the adoption of the JORC Code by the Australian mineral industry, many companies first used this code in 1989 for reporting their copper resources. These companies re-estimated mineral resources to comply with the JORC Code which resulted in a sharp fall in Australia's copper EDR in 1989 ('d').

The sharp increase in copper EDR in 1993 resulted mainly from an increase in company announced resources for the Olympic Dam deposit in South Australia (SA). Additional resources were reported also for Ernest Henry in Queensland (Qld), Northparkes (NSW) and other smaller deposits ('e').

Reassessments of copper resources by Geoscience Australia in 2002 and 2003 resulted in further transfers (reclassification) of Olympic Dam resources into EDR ('f'). In 2007 and 2008, copper resources again increased sharply, mainly because of a large increase in resources for Olympic Dam where drilling outlined large resources in the southeastern part of the deposit ('g'). Since 2008, successful exploration has continued to yield new discoveries and to delineate new resources, resulting in a steady increase of copper EDR, including the Carrapateena, Rocklands, DeGrussa, Hillside and Cadia East deposits.

Lead, Zinc

The adoption of the JORC Code in 1988 by the Australian mineral industry led to a re-estimation of mineral resources by many companies to align with the JORC Code, and some reassessments of resource data for other deposits by Geoscience Australia's predecessor, the Bureau of Mineral Resources. This resulted in a sharp fall in Australia's lead and zinc EDR in 1989 ('h').

Increases in EDR for lead and zinc in 1993 resulted from the reclassification of paramarginal demonstrated resources into EDR for McArthur River in the Northern Territory (NT) and George Fisher deposits (Qld). Additional resources were reported also for Century and Cannington deposits (Qld) ('i').

Increases in 2008 and 2009 were associated with reassessment of resources at the McArthur River mine, where an expansion from underground to open-cut mining was approved, reassessment of the Dugald River deposit (Qld) for which a new and increased resource estimate was released and reporting of additional resources for George Fisher in Qld ('j').

Nickel

The EDR for nickel increased during the period 1995 to 2001 by 18.2 Mt. This resulted mainly because of progressive increases in resources of lateritic deposits at Bulong, Cawse, Murrin Murrin, Mount Margaret, Ravensthorpe, all in Western Australia (WA), Marlborough (Qld), Syerston and Young (NSW). Australia's EDR of nickel doubled in 2000 (compared to the level at the end of 1999) – this dramatic increase was due to further large increases in resources at the Mount Margaret and Ravensthorpe deposits, and other lateritic deposits in the Kalgoorlie region (WA). In addition, during the period 1995 to 2001 there were increases in resources of sulphide deposits at Yakabindie, and the discoveries of the Silver Swan and Cosmos high-grade sulphide deposits (all in WA).

From 2001 onwards, the sharp rises in market prices for nickel led to increased expenditure on exploration and on evaluation drilling at many known deposits. This contributed to further increases in total EDR for sulphide deposits at Perseverance, Savannah, Maggie Hays, Anomaly 1, Honeymoon Well, deposits in the Forrestania area, as well as new deposits at Prospero and Tapinos in WA, Avebury in Tasmania and remnant resources at several sulphide deposits in the Kambalda (WA) region including Otter-Juan and Lanfranchi groups of deposits.

From 2001 onwards, EDR increased at a slower rate because of the absence of further discoveries of lateritic nickel deposits and as a result of increases in resources for some deposits being offset by companies reclassifying their lateritic nickel resources to lower resource categories pending more detailed drilling and resource assessments. Decreases in nickel EDR from 2009 onwards reflect reclassification of nickel resources in response to the very sharp falls in nickel prices following the 2008–09 global financial crisis followed by only a partial recovery in nickel prices from 2009 onwards.

Mineral Sands

Increases in EDR of ilmenite from 1996 to 2003 resulted from discovery and subsequent evaluation drilling of heavy mineral sands deposits in the Murray Basin which include the Gingko and Snapper deposits (NSW), Douglas-Bondi and Woornack deposits in Victoria, and the Mindarie project (SA). In addition, from 1998 onwards there were progressive increases in resources at mineral sands deposits at Jacinth-Ambrosia and Cyclone in the Eucla Basin embracing parts of SA and WA, in the North Swan Coastal Plain area north of Perth, WA, and the Blackwood Plateau region in WA. The EDR of ilmenite declined after 2007 owing to reclassification of resources to lower resource categories.

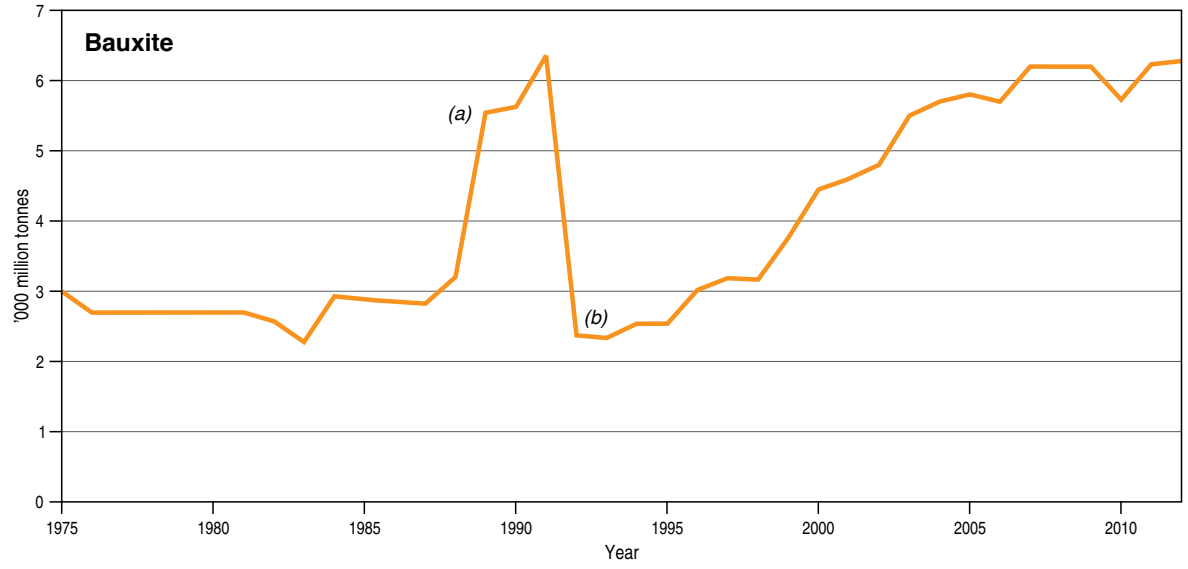
Uranium

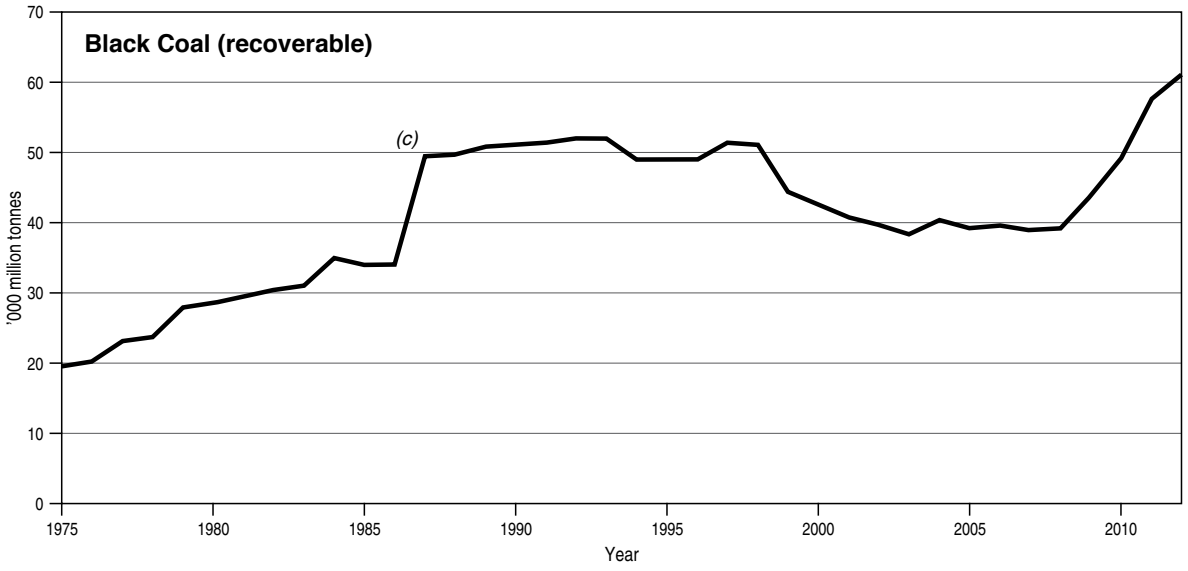
The majority of Australia's uranium deposits were discovered between 1969 and 1975 when approximately 50 deposits, including 15 with significant resource estimates, were discovered. Since 1975, only another five deposits have been discovered and of these, only three deposits (Kintyre in the Paterson Province of WA, Junnagunna in Queensland and Four Mile in SA) have Reasonably Assured Resources recoverable at less than US$130/kg U (equates with EDR). As a result, the progressive increases in Australia's EDR for uranium from 1975 to the present were largely because of the ongoing delineation of resources at known deposits.

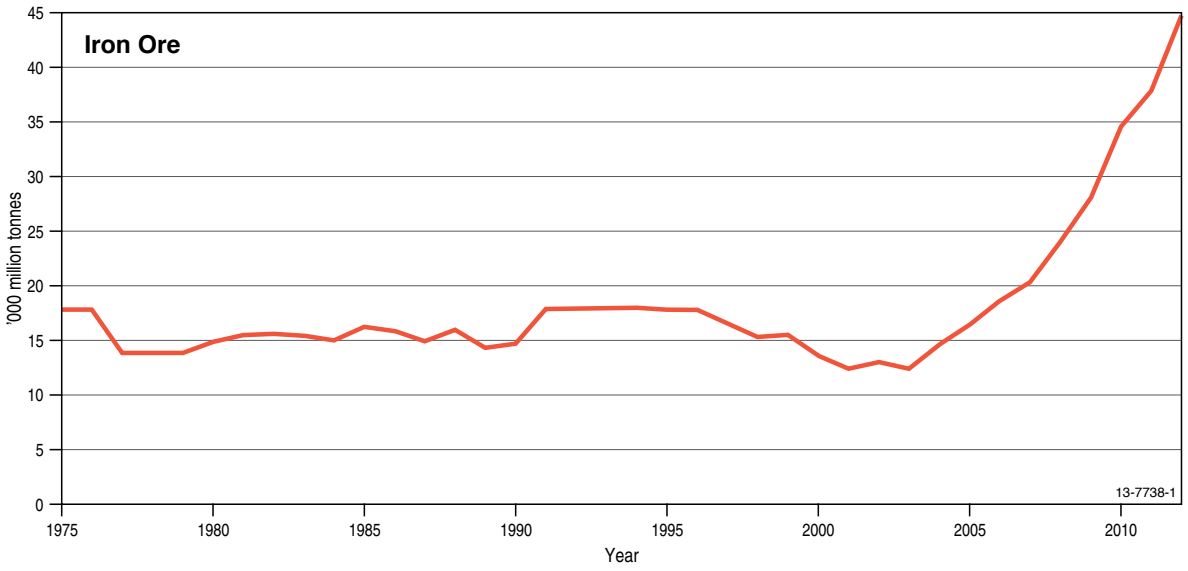
From 1983 onwards, the Olympic Dam deposit has been the major contributor to increases in Australia's EDR. The large increases shown on Figure 1 occurred:

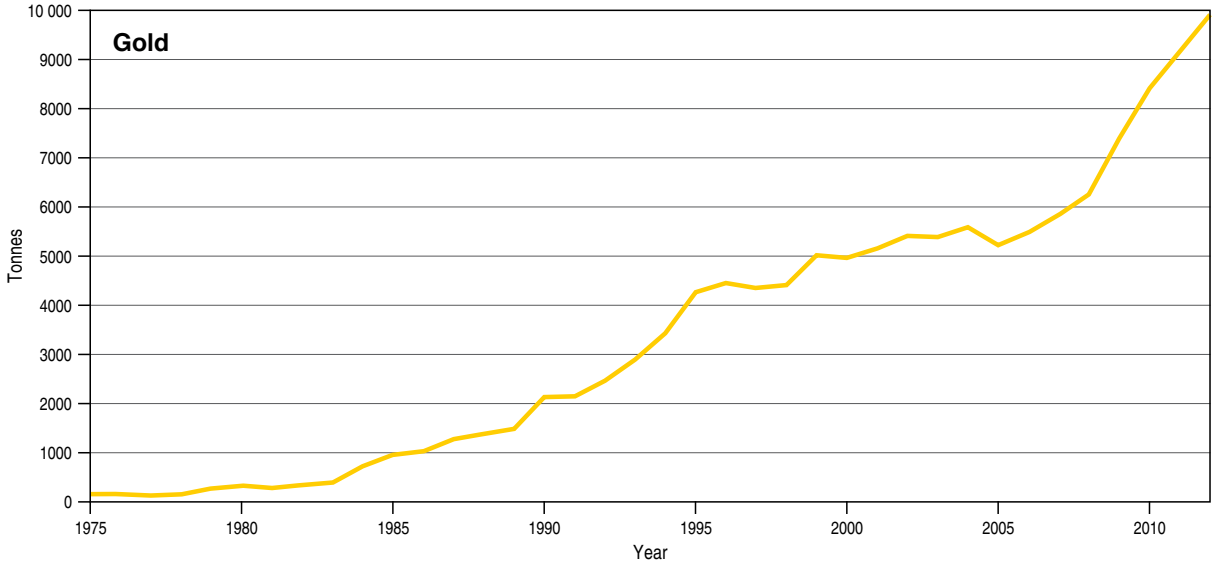
- in 1983, when initial resource estimates for Olympic Dam and Ranger No. 3 Orebody (NT) were made by the former Australian Atomic Energy Commission ('k');
- in 1993, when further increases in EDR for Olympic Dam and first assessment of resources for the Kintyre deposit were made by Geoscience Australia's predecessor, the Bureau of Mineral Resources ('l');
- in 2000, when increases were due to continuing additions to the Olympic Dam resources; and
- from 2007 to 2009 when a major increase in EDR for Olympic Dam was made after drilling outlined major extensions to the southeast part of the deposit.

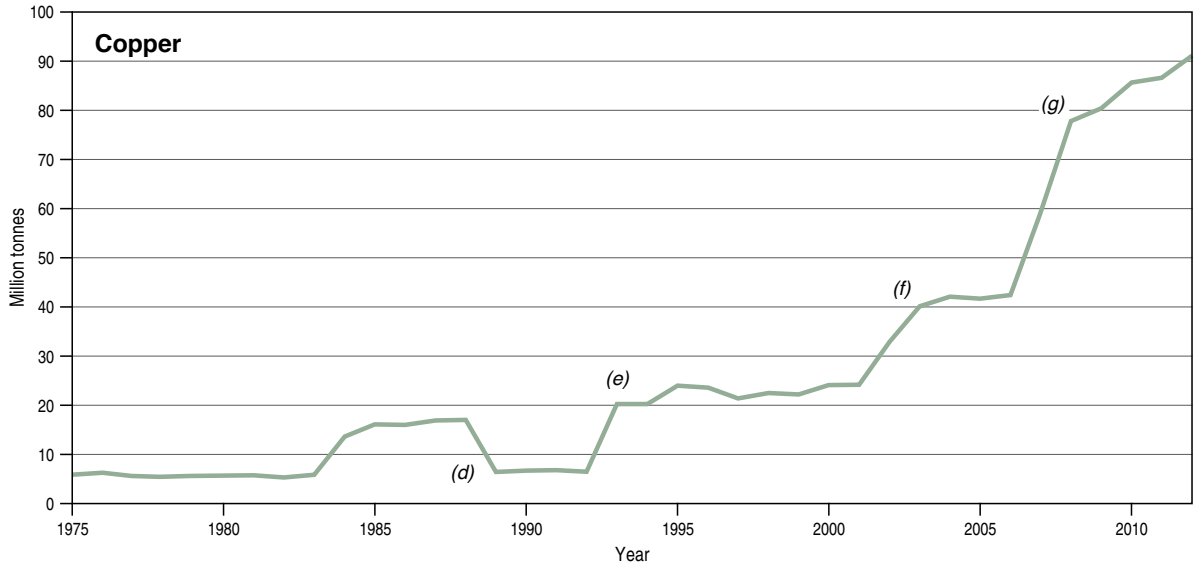
Economic resources have decreased since 2010 because of higher costs of mining and milling uranium ores. Resources in some deposits were reassigned to higher cost categories than in previous years. In previous years, resources in the cost category of less than US$80/kg uranium were considered to be economic. As a result of increases in costs and uranium market prices, economic resources since 2009 were extended to include resources within the cost category of less than US$130/kg uranium.

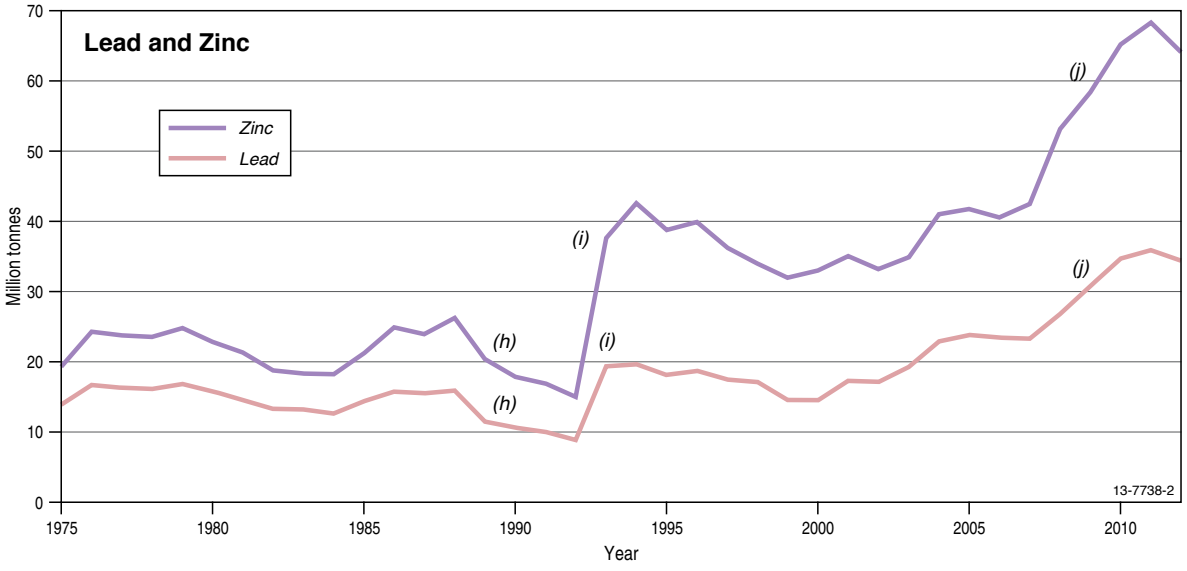

Bauxite
'000 million tonnes
Year
(a)
(b)
0
1
2
3
4
5
6
7
1975
1980
1985
1990
1995
2000
2005
2010


Black Coal (recoverable)
'000 million tonnes
Year
(c)
0
10
20
30
40
50
60
70
1975
1980
1985
1990
1995
2000
2005
2010


Iron Ore
'000 million tonnes
Year
13-7738-1
0
5
10
15
20
25
30
35
40
45
1975
1980
1985
1990
1995
2000
2005
2010


Gold
Tonnes
10 000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1975
1980
1985
1990
1995
2000
2005
2010
Year


Copper
Million tonnes
100
90
80
70
60
50
40
30
20
10
0
(d)
(e)
(f)
(g)
1975
1980
1985
1990
1995
2000
2005
2010
Year


Lead and Zinc
Zinc
Lead
Million tonnes
70
60
50
40
30
20
10
0
(h)
(h)
(i)
(i)
(j)
(j)
13-7738-2
1975
1980
1985
1990
1995
2000
2005
2010
Year

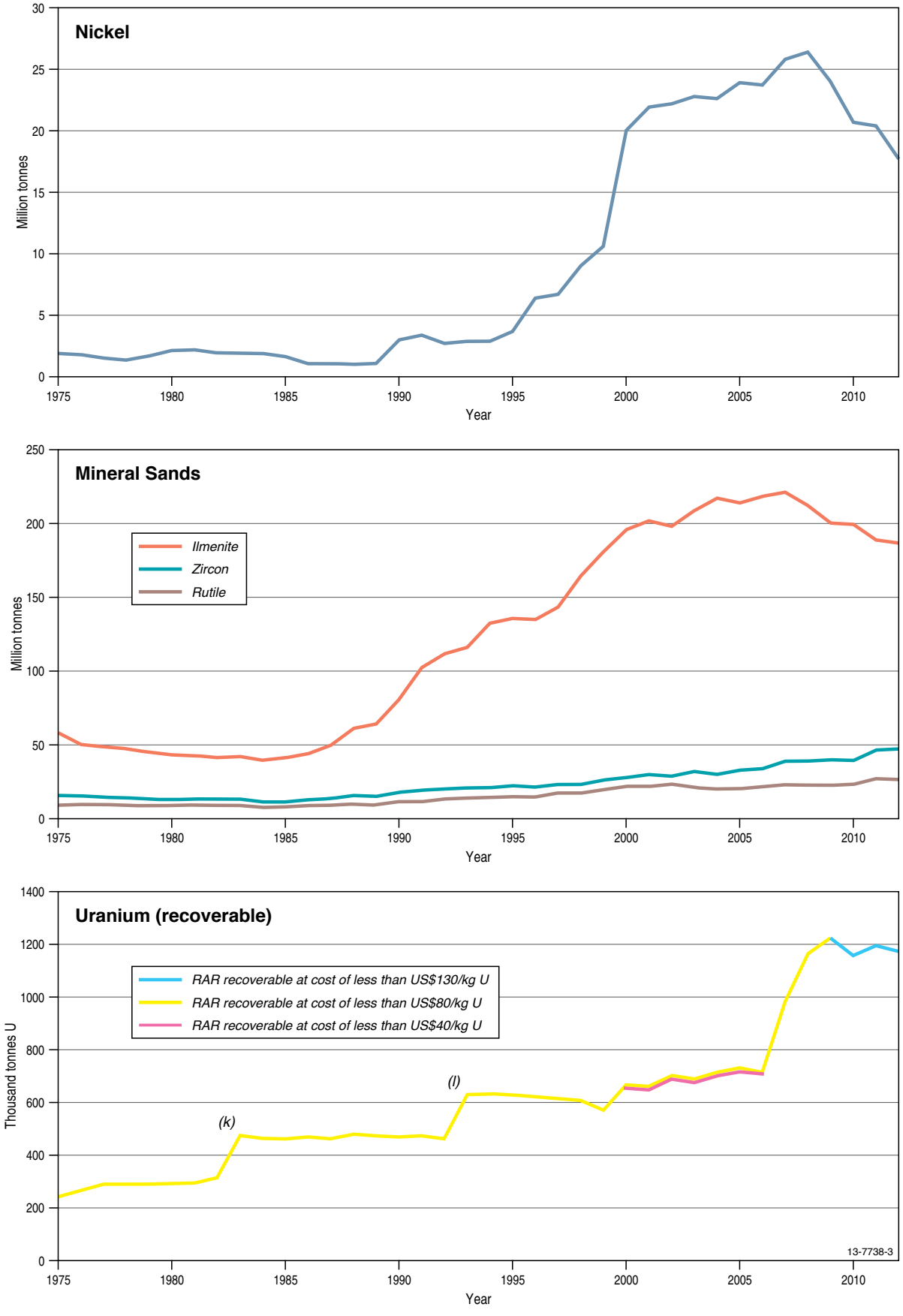


Figure 1: Trends in Economic Demonstrated Resources of major commodities since 1975.

Resources to Production Ratios

The continuing contribution of mineral resources to Australia's economic performance in the medium and longer term will depend on the discovery and development of new, good quality resources. To assist with an assessment of the future long-term supply capability of identified resources, an indicator of long-term resource life using ratios of Accessible Economic Demonstrated Resources (AEDR) to current mine production are compiled in Table 2. It is important to note that these indicators can change rapidly with significant variations in rates of production in response to demand as well as major changes to resources.

Table 2 presents the AEDR/production ratios from 1998 to 2012 and Reserves/production ratios are provided for 2003, 2008 and 2012 for comparison with the longer term AEDR/production ratios. The AEDR/production ratios differ for various commodities over this 15 year period:

- In 2012, the AEDR/production ratios (resource life at current rates of production) ranged between 15 years (manganese ore) and 510 years (brown coal).
- The commodities with the longest resource life based on AEDR/production ratios in 2012 are brown coal (510 years at current rates of production), uranium (160 years), ilmenite (115 years) and black coal (110 years).
- Commodities with a resource life of less than 50 years at current rates of production are manganese ore (about 15 years), diamond (35 years) and gold and zinc (40 years).
- Long-term decline between 1998 and 2012 for black coal, rutile and nickel reflect major increases in production and downgrading of resources.
- The decline in iron ore prior to 2008 has been partly offset by the development of large magnetite iron ore deposits in the Pilbara and mid-west regions of Western Australia. These magnetite resources, which were previously considered to be subeconomic, are becoming increasingly more viable.
- Long-term increases in AEDR/production ratios are evident for copper, diamond and gold.
- Increases in the AEDR/production ratios between 2011 and 2012 were recorded for copper, gold and iron ore as a result of increases in resources.
- Reductions in AEDR/production ratios during 2012 were recorded for lead, ilmenite, nickel, uranium and zinc. For lead, nickel and zinc the reductions were the result of decreases in resources while increases in production levels accounted for the drop in AEDR/production ratios for ilmenite and uranium.

Ratios of Ore Reserves to production are generally more indicative of changes of ratios in the shorter term where mining companies replenish depleted Reserves by upgrading Measured and Indicated Resources to maintain a steady supply of mineable ore for anticipated short to medium-term mine production. Reserve/production ratios for the period 2003 to 2012 show that:

- In 2012, the Reserve/production ratios (Reserve life in years at current rates of production) ranged between 10 years for manganese ore and 55 years for uranium with 13 out of 15 commodities (excluding brown coal) having a ratio of 10 to 30 years.
- Reserve/production ratios fall within a narrower bandwidth than the AEDR/production ratios and have not changed much during the 10 year period between 2003 and 2012 with the shortest Reserve/production ratio of 5 years for diamonds in 2003 (15 years in 2012) and the longest at 55 years for uranium in 2003 and again in 2012.
- These figures indicate that as Reserves are depleted by mining these are replenished by upgrading Measured and Indicated Resources to Reserves as required.

Table 2: Years of Accessible Economic Demonstrated Resources (AEDR) at the production level for each year (rounded to the nearest 5 years). Years of JORC Code compliant Reserves at the production level for each year shown in brackets for 2003, 2008 and 2012 (also rounded to the nearest 5 years).

Commodity	1998	2003	2008	2010	2011	2012
Bauxite	70	90 (35)	85 (30)	80	80	80 (30)
Black Coal	180	110 (40)	90 (30)	90	110	110 (40)
Brown Coal	630	440 (30)	490 (75)	495	510	510
Copper	40	50 (25)	85 (20)	100	90	100 (30)
Diamond	3	5 (5)	10 (10)	30	35	35 (15)
Gold	15	20 (10)	30 (15)	30	35	40[1] (15)
Iron Ore	100	60 (20)	70 (30)	80	75	85 (30)
Lead	30	30 (15)	40 (15)	50	60	55 (25)
Manganese Ore[2]	na	na	20 (15)	15	15	15 (10)
Mineral Sands						
Ilmenite	70	85 (20)	85 (20)	125	120	115 (30)
Rutile	75	90 (20)	55 (15)	45	50	50 (15)
Zircon	60	50 (10)	55 (20)	60	50	70 (25)
Nickel	65	120 (35)	130 (35)	120	95	70 (30)
Silver	30	25 (15)	30 (15)	40	50	50 (15)
Uranium	105	80 (55)	125 (30)	175	180	160 (55)
Zinc	30	25 (15)	35 (15)	45	45	40 (20)

1. Average AEDR/production ratio for gold (40 years) is strongly influenced by low-grade copper-gold deposits with a ratio of over 79 at current rates of mine production, whereas lode-gold deposits have AEDR/production ratio of less than 23 years.
2. AEDR/production ratios for manganese allow for losses that occur in beneficiating (upgrading) manganese ores.
na: data not available

It is important to note that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly globalised and competitive commodity market, multinational mining companies are continuously searching for mineral deposits that offer the most attractive returns on investment. Such returns are influenced by both the quality of the resources (grade and tonnage) and by the environmental, social and political factors as well as land access, infrastructure and the location and scale of the mining operations owned by the company.

The world financial crisis in 2008 exacerbated these factors and forced many companies to reassess their options for both existing and planned operations in Australia. In the case of black coal and iron ore, the initial impact of the world financial crisis caused some mining operations to scale back production while others delayed plans for expansion and some mines closed at the end of 2008. By mid-2009, recovery in mining operations and development plans were well underway but this trend was less pronounced in 2012 because of volatile commodity prices, including for iron ore and coal.

During 2011, the international spot price for thermal and metallurgical coal peaked at more than $140/t and $330/t, respectively. During 2012, however, an oversupply of both thermal and coking coal emerged in the international market and prices declined significantly. In response to the subdued prices, Australian coal producers sought to extract greater efficiencies from their mining operations, placed several uneconomic mines under care and maintenance and deferred the expansion of several existing coal mines and the development of several proposed mines. However, export volumes of both thermal and coking coal, continued at near record levels as many producers remained committed to take or pay contracts negotiated as part of export terminal expansions.

Reserves and production of iron are expected to increase as magnetite operations, such as Sino Iron and Karara Magnetite, continue to progress and ramp-up their production. BREE has projected strong growth in Australia's iron ore production as the three large producers, Rio Tinto Ltd, BHP Billiton Ltd and Fortescue Metals Group Ltd, increase their capacity.

During 2009 and 2010, some multinational companies closed sulphide and lateritic nickel mines in Western Australia and Tasmania and consolidated their operations at larger, low-cost mining operations, although not necessarily in Australia. A number of these nickel mines resumed production by 2011 and the large Ravensthorpe lateritic nickel mine restarted operations during the second half of 2011after being refurbished during 2010–11. Persistent low nickel prices during 2012 and 2013 have returned some of the sulphide nickel mines to care and maintenance pending improved nickel prices. Continuing low prices have resulted in ongoing downgrading of resources and are partly responsible for declining AEDR/production ratios.

The AEDR/production ratio for copper rose by 11% in 2012 with AEDR increasing by 5% and production decreasing by 5%. The two most significant production declines in 2012 were associated with Ernest Henry transitioning to underground mining and Olympic Dam processing lower grade ore and mining at reduced rates. Over the previous 14 years, with the exception of 2011, the AEDR/production ratio for copper has increased progressively as a result of increasing resources, particularly at Olympic Dam.

AEDR/production ratios for zinc, lead and silver decreased by an average of 5% in 2012 in line with decreases in AEDR while production remained at similar levels to 2011. However, AEDR/production ratios for zinc, lead and silver over the past 14 years have generally increased slowly. Mine production and resources of zinc, lead and silver also increased over the 14 year period.

AEDR for gold increased by 756 t or about 8% in 2012 while JORC Code Reserves declined by 12 t or 0.3%. Production for the year was 251 t or 7 t less than in 2011. These figures resulted in an increase in the AEDR/production ratio to about 40 years (about 35 years in 2011) while the Reserve/production ratio remained much the same at about 16 years. The figures provide a generalised overview that masks significant differences between contributing parts of the industry. The gold resources and mining industry in Australia may be subdivided into two major components (and other lesser ones) based on deposit type:

- lode-gold deposits, which contribute the largest share of production (64% in 2012), and
- relatively low-grade copper-gold deposits, which contain the greatest share of resources (58% in 2012).

AEDR for both the lode-gold deposits and copper-gold deposits increased by more than 300 t each in 2012, while production dropped by about 10 t and 8 t, respectively. The resulting AEDR/production ratios for 2012 increased for both deposit types but that for lode deposits increased by just 4 years to about 23 years. In contrast, the copper-gold deposits increased by 11 years to about 79 years. The positive trend for the industry was the continued growth in AEDR for the lode-gold deposits, despite the fact that these deposits contributed the largest share of Australia's annual mine production of gold.

For heavy mineral sands operations, some producers closed down low-grade ilmenite deposits in 2008 to concentrate on deposits that have higher zircon content or are more readily amenable to beneficiation. However, sharply lower levels of production of ilmenite, rutile and zircon in 2009 resulting from the flow-on effects of the global financial crisis in late 2008 and early 2009 led to increases in resource life in 2010. However, in 2012, an increase in ilmenite production to 1.344 Mt continued to decrease the AEDR/production ratio for ilmenite.

For uranium, AEDR/production ratios have increased progressively since 2003. For the period 2003 to 2009, this increase was the result of increases in Australia's uranium resources, mostly from ongoing evaluation of the Olympic Dam deposit. From 2009 onwards, increases in this ratio resulted from lower uranium production caused by operational problems at each of the three uranium mines (damage to a haulage shaft at Olympic Dam, flooding of the Ranger 3 pit and operating problems at Beverley). By 2012, these problems had been rectified and production increased, resulting in a slightly lower ratio. Increases in mining and processing costs have limited the growth of Australia's AEDR over recent years. An additional factor influencing Australia's AEDR/production ratio for uranium was a large (one-off) increase in AEDR of uranium resulting from the Queensland State Government lifting its ban on uranium mining. Otherwise, the AEDR/production ratio for uranium would have decreased further in 2012.

Market prices for uranium have progressively decreased from early 2011 to mid-2013. During 2012 and 2013, spot prices remained below the level required to encourage investment in new mines. This resulted in mining and exploration companies in Australia delaying uranium projects that had become uneconomic. Companies decided to focus investment on advancing only those uranium projects that would result in highest return on capital investments.

Commodity Reviews

Photo: Bauxite operations at Andoom, Weipa, Queensland.

Bauxite

Allison Britt (allison.britt@ga.gov.au)

Bauxite is the main raw material used in the commercial production of alumina (Al_2O_3) and aluminium metal, although some clays and other materials can be utilised to produce alumina. Bauxite is a heterogeneous, naturally occurring material of varying composition that is relatively rich in aluminium. The principal minerals in bauxite are gibbsite ($Al_2O_3.3H_2O$), boehmite ($Al_2O_3.H_2O$) and diaspore, which has the same composition as boehmite, but is denser and harder.

Australia is the world's largest producer of bauxite, representing 30% of global production in 2012. The large bauxite resources at Weipa with more than 3000 Mt in Queensland and Gove (>200 Mt) in the Northern Territory have average grades between 49 and 53% Al_2O_3 and are amongst the world's highest grade deposits. Other large deposits (each >500 Mt) are located in Western Australia in the Darling Range, the Mitchell Plateau and at Cape Bougainville, of which the latter two have not been developed. The bauxite mines in the Darling Range have the world's lowest grade bauxite mined on a commercial scale (around 27–30% Al_2O_3). Despite the low grade, the mines accounted for 23% of global alumina production as they also have low reactive silica, making the bauxite relatively easy to refine. Bauxite resources also occur in New South Wales and Tasmania but these are small (<25 Mt).

More than 85% of the bauxite mined globally is converted to alumina for the production of aluminium metal. An additional 10% goes to non-metal uses in various forms of specialty alumina, while the remainder is used for non-metallurgical bauxite applications. In most commercial operations, alumina is extracted (refined) from bauxite by a wet chemical caustic leach process known as the Bayer process. Alumina is smelted using the energy-intensive Hall-Heroult process to produce aluminium metal by electrolytic reduction in a molten bath of natural or synthetic cryolite ($NaAlF_6$).

Australia's aluminium industry is a highly integrated sector of mining, refining, smelting and semi-fabrication centres and is of major economic importance nationally and globally. The industry is becoming less vertically integrated, however, largely because of the rise of independent smelters, particularly in China.

In 2012, the Australian industry consisted of:

- Five long-term bauxite mines at Weipa; Gove; Huntly, Boddington and Willowdale (Figure 2);
- Seven alumina refineries at Gove, Yarwun; QAL, Kwinana, Pinjarra; Wagerup and Worsley (Figure 2);
- Five primary aluminium smelters (previously six before the 2012 closure of Kurri Kurri, NSW) at Bell Bay, Boyne Island, Tomago, Portland and Point Henry (Figure 2);
- Twelve extrusion mills located in NSW, Victoria, South Australia, Qld and WA; and
- Two rolled product plants producing aluminium sheet, plate and foil in Victoria.

The industry in Australia is geared to serve world demand for alumina and aluminium with more than 80% of production exported. Transport, packaging, building and construction provide much of the demand for the metal in Australia.

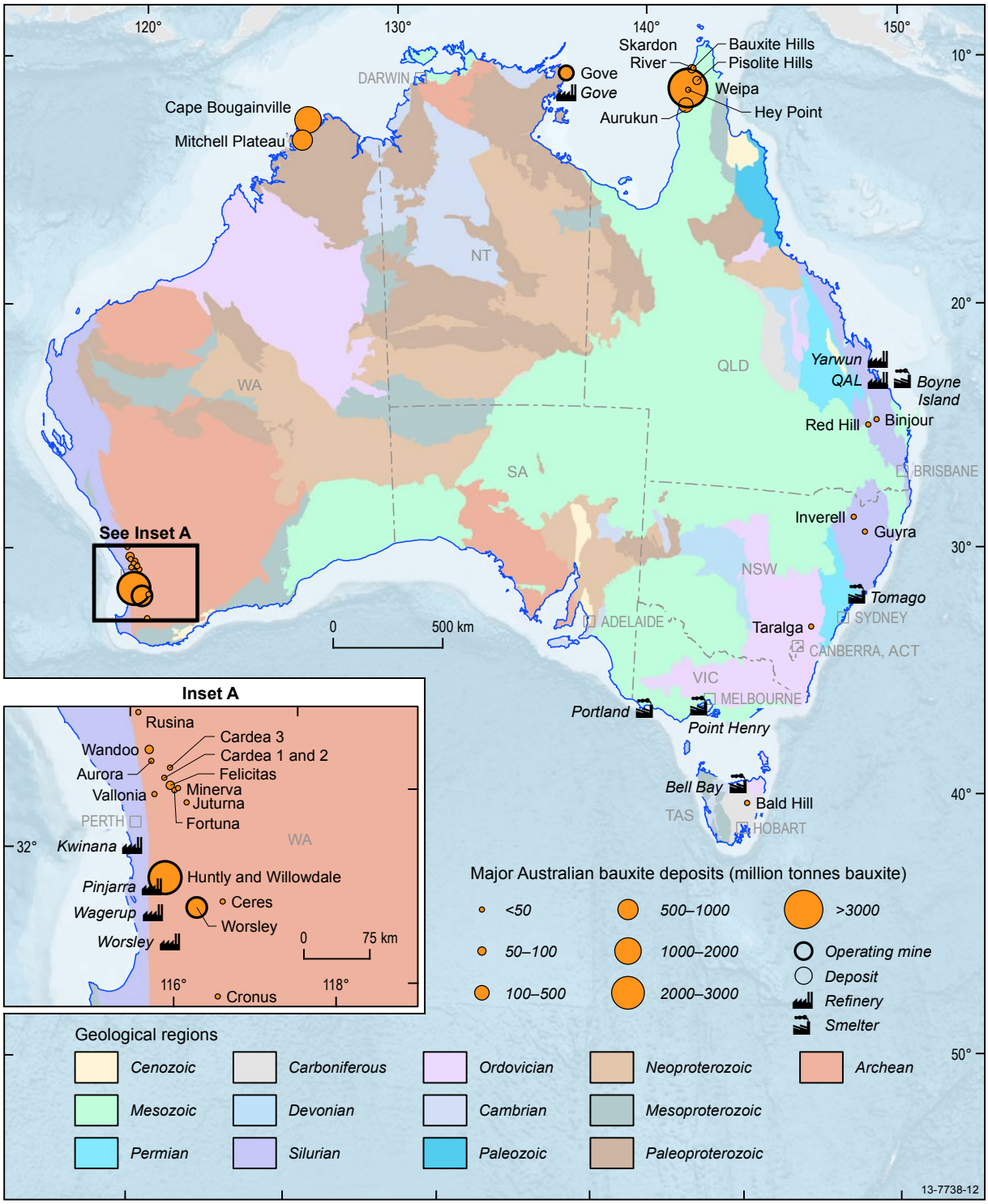


Figure 2: Australia's bauxite deposits, alumina refineries and aluminium smelters.

Resources

Economic Demonstrated Resources (EDR) of bauxite were 6281 Mt at December 2012, up from 5665 Mt in 2011. Queensland holds 61% of EDR, WA 35% and the Northern Territory 4%.

Australia's subeconomic resources of bauxite totalled 1573 Mt, down from 2055 Mt in 2011, and Inferred Resources totalled 1474 Mt, up from 1120 Mt in 2011.

Accessible EDR

About 95% of Australia's EDR of bauxite is accessible for mining. Some areas within Darling Range mining leases in WA are not available for environmental reasons.

JORC Reserves

By end of December 2012, JORC Code Reserves in the Proved and Probable Reserve categories comprised 2145 Mt of bauxite, accounting for approximately one third of AEDR with the remainder defined as Measured and Indicated Resources. These proportions are almost unchanged from 2011.

Exploration

Data on exploration expenditure for bauxite are not available in published statistics. The bulk of drilling is associated with brownfield occurrences close to existing infrastructure. However, smaller exploration projects away from the big five mines are scattered through the Darling Range in WA and along the east coast of Australia.

Australian Bauxite Ltd has exploration projects in Queensland, NSW and Tasmania with the bulk of recent efforts directed towards the Tasmania Project where the company continued its drilling program in 2013, with particular focus on mine boundary definition and the identification of new targets.

On the west coast, Bauxite Australia Ltd upgraded its Fortuna deposit in WA with an exploration program comprised of 302 vertical holes totalling 2857 m across an area of approximately 385 ha on a nominal 160 x 80 m drill pattern. The company completed an additional 220 vacuum drill holes at Fortuna in June and July 2013. It also scheduled a drilling program for its Felicitas deposit comprising 6029 holes for a total of 28 662 m. The program covered some 3300 ha on an 80 x 80 m spacing and two upgraded resources were announced in May 2013.

In Queensland, Gulf Alumina Ltd further explored the Skardon River deposit with a drilling program in late 2012 comprising 128 holes for a total of 484 m. About 111 holes were drilled through bauxite into clays and 1602 samples were screened and assayed with an upgraded resource announced in March 2013.

Production

Australia was the leading producer of bauxite (Table 3) globally in 2012, the second largest producer of alumina and the fifth largest producer of aluminium. Indonesia was the largest exporter of bauxite because the majority of Australian bauxite is processed within Australia to alumina and aluminium.

Table 3: World production for bauxite.

Rank	Country	Bauxite (Mt)	Percentage of world total
1	Australia	76	30%
2	China	48	19%
3	Brazil	34	13%
4	Indonesia	30	12%
5	India	20	8%
6	Guinea	19	7%
7	Jamaica	10	4%
8	Russia	6	2%
9	Kazakhstan	5	2%
10	Venezuela	5	2%
	Others	4	2%
	Total	**257**	

Source: United States Geological Survey and the Bureau of Resources and Energy Economics; Percentages are rounded so might not add up to 100% exactly.

Based on data from BREE, bauxite production totalled 76.281 Mt in 2012 (up from 70.231 Mt in 2011; Figure 3), alumina production totalled 21.357 Mt (up from 19.399 Mt in 2011; Figure 4) and aluminium production totalled 1.864 Mt (down from 1.95 Mt in 2011; Figure 5). The closure of the Kurri Kurri smelter in NSW in 2012 removed around 180 000 t of aluminium from Australia's production capacity.

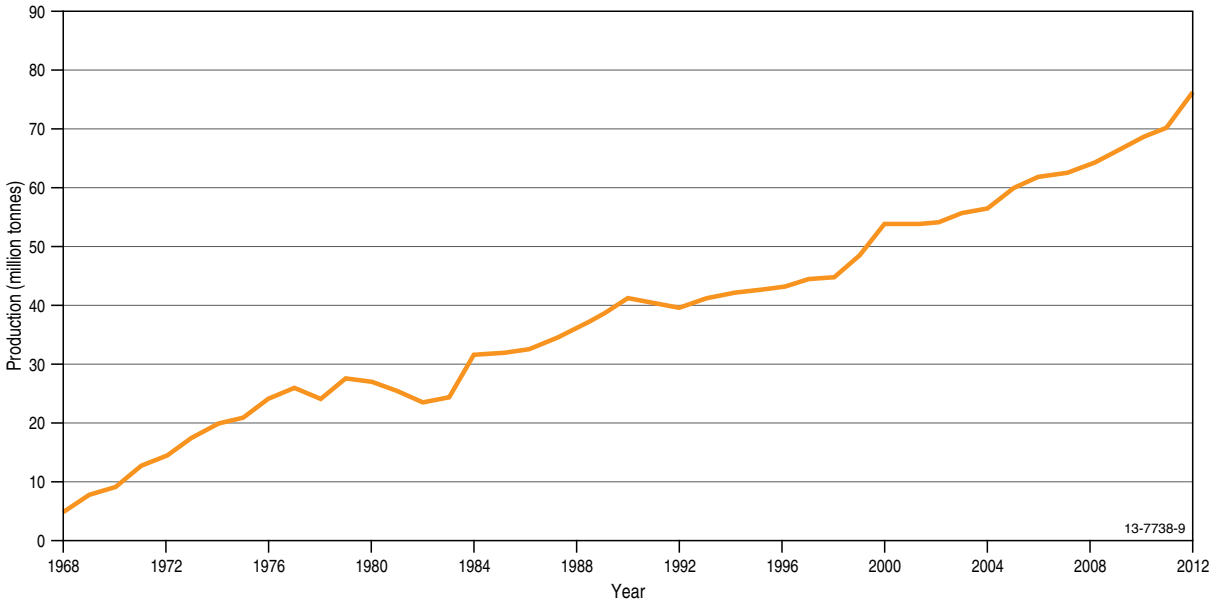


Figure 3: Australian bauxite production from 1968 to 2012. Source: Bureau of Resources and Energy Economics.

In 2012, 18.271 Mt of alumina was exported for a value of $5.152 billion. The average price was $282.00/t which was significantly lower than the 2011 price of $332.90/t.

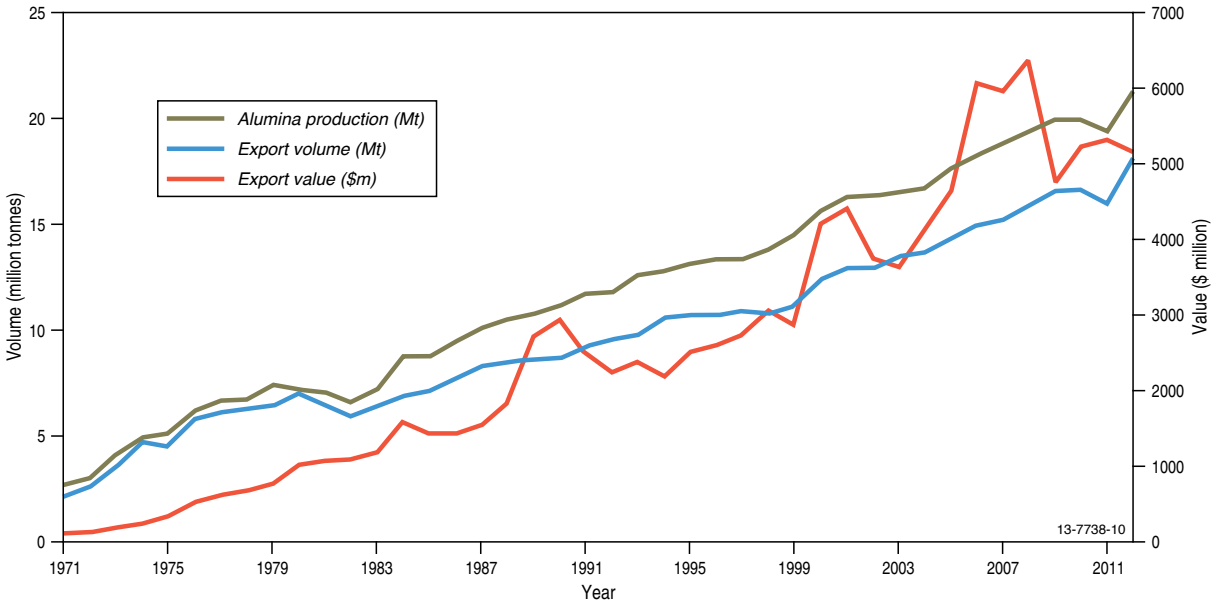


Figure 4: Australian alumina production and export volumes (Mt, left axis) as well as value ($million, right axis) from 1971 to 2012. Source: Bureau of Resources and Energy Economics.

As well as primary production, aluminium primary consumption and exports also declined in 2012 (Figure 5). In 2012, Australia consumed 233 216 t of aluminium (down from 276 309 t in 2011), and exported 1650 kt (down from 1681 kt in 2011) for a value of $3.460 billion (down from $4.099 billion in 2011). Like alumina, the average price of aluminium declined significantly in 2012 to $2097.50/t from the 2011 average price of $2439.00/t.

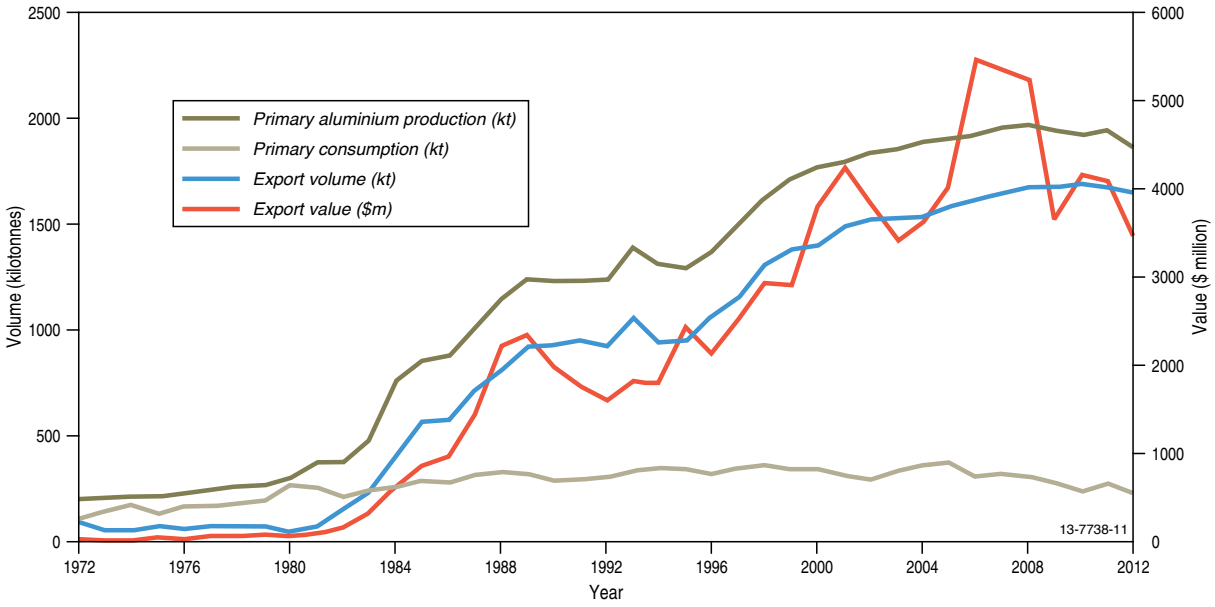


Figure 5: Australian primary aluminium production, consumption and export volumes (kt, left axis) as well as export value ($million, right axis) from 1972 to 2012. Source: Bureau of Resources and Energy Economics.

World Ranking

World bauxite resources are estimated at approximately 28 280 Mt with Australia holding the second highest amount after Guinea (Table 4). Brazil, Vietnam and Jamaica also hold significant resources (more than 2000 Mt) with Indonesia, India, Guyana, China and Greece making up the remainder of the top 10 countries.

Table 4: World economic resources for bauxite.

Rank	Country	Bauxite (Mt)	Percentage of world total
1	Guinea	7400	26%
2	Australia	6280	22%
3	Brazil	2600	9%
4	Vietnam	2100	7%
5	Jamaica	2000	7%
6	Indonesia	1000	4%
7	India	900	3%
8	Guyana	850	3%
9	China	830	3%
10	Greece	600	2%
	Others	3720	13%
	Total	**28 280**	

Source: United States Geological Survey and Geoscience Australia; Figures are rounded to nearest ten million tonnes; Percentages are rounded so might not add up to 100% exactly.

Industry Developments

The bauxite market appears to be undergoing structural change. Traditionally, Australia has had an integrated bauxite-alumina-aluminium industry but the rise of Chinese alumina refineries and aluminium smelters, along with industry changes in Indonesia, has created new market opportunities for direct export of the raw commodity.

Indonesia is the largest exporter of bauxite in the world but it is moving towards its own integrated bauxite-alumina-aluminium industry, including the construction of new alumina refineries to supply the growing aluminium smelter industry. In May 2012, the Indonesian Government implemented export quotas and a 20% export tax on raw commodities, including bauxite. In January 2014, the tax rate on commodity exports rose to 50% along with a further reduction in export quotas. Indonesian bauxite is usually sold to Chinese low-temperature refineries and, with the potential reduction in supply, Australian and African bauxite producers (and emerging producers) are expected to fill any shortfall along with supplying new capacity.

While the market for bauxite is looking positive, the Australian alumina market is undergoing significant changes. The Gove alumina refinery in the NT is facing a bleak future. Rio Tinto announced in November 2013 its intention to close the refinery, reducing Australia's alumina capacity by up to 3.8 Mtpa. The company will continue to operate the bauxite mine.

This loss of alumina capacity is partly offset by increases in alumina production at the Yarwun (Qld) and Worsley (WA) refineries. Stage 2 of Rio Tinto Alcan's Yarwun refinery near Gladstone was commissioned in 2012 and will add up to 2 Mt to Australia's alumina production and the expansion of BHP Billiton's Worsley refinery in WA will add an additional 1.1 Mt.

Aluminium production in Australia also faces significant upheavals. The Kurri Kurri smelter in the Hunter Valley of NSW ceased aluminium production in October 2012. The smelter had operated since 1969 but Norsk Hydro announced in June 2012 that the plant would close because the high Australian dollar and low aluminium prices made it unprofitable. About 180 000 tonnes of aluminium was lost from Australian capacity.

The aging and high-cost Point Henry aluminium smelter at Geelong in Victoria is also facing an uncertain future. The owner, Alcoa Inc, is consolidating its business with a strategy of closing high-cost plants and boosting production at low-cost plants. Point Henry was thrown a lifeline by the Victorian and Federal governments in 2012 with a $44 million assistance package designed to help keep the plant running until June 2014. The results of the Alcoa review of operations are expected in March 2014.

More positively, the Bell Bay aluminium smelter in Tasmania was the beneficiary of a power deal between Pacific Aluminium and the Tasmanian Government in 2012. The Bell Bay smelter was established in 1955 and is the oldest aluminium smelter in Australia (and the first in the southern hemisphere). It produces around 180 000 tpa of aluminium. The power deal will provide the iconic smelter with lower energy costs until 2025.

Northern Territory

Gove: The Gove bauxite mine and alumina refinery are located by the Arafura Sea in northeast Arnhem Land, some 650 km east of Darwin. Operated by Pacific Aluminium, a Rio Tinto subsidiary, the Gove operation is the largest private employer in the NT with approximately 1400 employees and contractors. Current reserves (Proven and Probable) are 155 Mt of bauxite with additional resources (Measured and Indicated) of 45 Mt. Alumina grades are typically 49–50% Al_2O_3.

In 2012, Rio Tinto raised concerns about the ongoing viability of the Gove alumina refinery owing to the high cost of producing electricity from diesel generators. The company proposed a long-term gas supply arrangement via a 600 km-long gas pipeline which the Australian Government agreed to support. In February 2013, the Northern Territory Government agreed to guarantee the supply of gas for 10 years and the company initially indicated that the Gove refinery would remain open. However, in November 2013, Rio Tinto decided not to proceed and announced it would suspend production at the refinery in February 2014 with a ramp down likely to be completed by July 2014. It is estimated that more than 1100 people will lose their jobs with the closure of the refinery but Rio Tinto will continue to operate the bauxite mine with the remaining 300 employees. The mine produced 7.943 Mt of bauxite in 2012.

Queensland

Weipa: Weipa, on the western side of the Cape York Peninsula, is run by Rio Tinto Alcan Inc and is the only operating bauxite mine in Queensland. As at December 2012, the deposit has Proven and Probable Reserves totalling 1534 Mt bauxite, a Measured Resource of 116 Mt, an Indicated Resource of 1351 Mt and an Inferred Resource of 455 Mt. Average aluminium grade is typically around 50–53% Al_2O_3. Currently, operations take in the **East Weipa**, **Ely** and **Andoom** bauxite deposits. About one third of production is shipped directly to China with the remainder sent to the Yarwun and Queensland Alumina Ltd refineries at Gladstone. Weipa produced 23.257 Mt in 2012.

Approximately 45 km southwest of Weipa, Rio Tinto continues with the development of the **South of Embley** project. In May 2012, the Queensland Coordinator General approved the project and in May 2013, the Australian Government gave environmental approval. In addition to a bauxite mine, the South of Embley project will comprise processing facilities and a port with barge and ferry terminals. Production will be up to 50 Mtpa of dry product, although initially it will be much less and ramp up in stages. The project is expected to extend operations at Weipa for another 40 years and underpin the continued operation of the Gladstone refineries.

Aurukun: In November 2012, the Queensland Government announced that it was seeking expressions of interest for the development of the Aurukun bauxite deposit, about 70 km south of Weipa on the western side of the Cape York Peninsula. Aurukun is the largest undeveloped bauxite deposit in Queensland with a historical (i.e., not compliant with the JORC Code) resource estimated to be 614.8 Mt. Another three deposits just north of the Aurukun area were estimated in 1973 to contain an additional 73.2 Mt of bauxite.

Potential developers needed to be able to demonstrate experience in developing and managing mines and associated infrastructure, as well as experience in working with indigenous communities and traditional owners. Five companies were initially shortlisted for consideration: Aluminium Corporation of China Ltd, Australian Indigenous Resources Pty Ltd, Cape Alumina Consortium, Glencore International AG and Rio Tinto Aluminium Ltd. By September 2013, only Glencore and Australian Indigenous Resources remained in contention.

Pisolite Hills: In October 2012, the newly elected Queensland Government declared the Pisolite Hills project on the western side of Cape York to be a 'significant project for which an Environmental Impact Statement is required'. As a result, Cape Alumina Ltd restarted the technical and environmental studies that were suspended in 2010 when the area was affected by the previous government's Wild Rivers Legislation.

In July 2013, the company released the results of a prefeasibility study for the Pisolite Hills project that confirmed the technical and economic feasibility of the project based on a potential yield of 7.5 Mtpa dry product over a mine life of 14 years. The Pisolite Hills resource is estimated at 134.6 Mt of bauxite.

In September 2013, Cape Alumina Ltd agreed to merge with MetroCoal Ltd to establish a multi bulk-commodity company with an initial focus on progressing the Pisolite Hills operation, including the establishment of a port at Mapoon. However, in November 2013, the Queensland Government announced that it would ban mining over the Steve Irwin Wildlife Reserve, which overlies a significant part of the Pisolite Hills deposit. As a result, the planned merger between MetroCoal and Cape Alumina was shelved and Cape Alumina announced that it had suspended work on the Pisolite Hills mine and port project. Pisolite Hills was to have been Cape Alumina's flagship project enabling the company to establish an independent bauxite supply business to feed the growing alumina and aluminium market in China.

Bauxite Hills: The Bauxite Hills deposit is located approximately 50 km north of Pisolite Hills and 95 km north of Weipa. In December 2012, Cape Alumina released a prefeasibility study that confirmed the technical and economic feasibility of a mine producing 5 Mtpa of bauxite over 10 years. Bauxite Hills has an Inferred Resource of 64 Mt and is planned to be a mine and port project.

The company had planned to develop Bauxite Hills in conjunction with Pisolite Hills but following the suspension of activities at Pisolite Hills, the company has redirected its efforts to Bauxite Hills. Cape Alumina is also in discussions with the Queensland Government regarding the draft Cape York Regional Plan, which will have an impact on some of the company's tenements.

Hey Point: Hey Point is adjacent to Rio Tinto Alcan's South of Embley project and is unaffected by the draft Cape York Regional Plan. Hey Point has an Inferred Resource of 3.8 Mt of bauxite and potential as a small-scale direct-shipping operation. In November 2012, Cape Alumina announced that it was in the process of selling its Hey Point tenements to Racle Resources PL.

Skardon River: In March 2013, Gulf Alumina Ltd announced a resource update for its bauxite deposit at Skardon River 80 km north of Weipa. Skardon River now has a total resource of 71 Mt bauxite comprising a 29.9 Mt Measured Resource, a 32.1 Mt Indicated Resource and an 8.1 Mt Inferred Resource using a 17% SiO_2 cut-off. The bauxite grade is around 50.3% Al_2O_3 with a 61.7% recovery rate.

In May 2013, the company announced that it had reached in-principle agreement with the traditional owners regarding proposed bauxite activity on the site.

Binjour: In June 2012, Australian Bauxite Ltd published an increased resource of 24.5 Mt comprising an Indicated Resource of 15.5 Mt and an Inferred Resource of 9.0 Mt for the Binjour bauxite deposit located 100 km southwest of Bundaberg. Average yield is 61% when the bauxite is sieved at 0.26 mm. The company claims this resource is based on less than 25% of the known extent of the bauxite. The deposit contains thick zones of premium gibbsite-rich bauxite, referred to as 'brown sugar', which is used as feedstock for sweetener circuits in alumina refineries. However, parts of the bauxite deposit are affected by veins of silica gel and the company is conducting tests with a view to removing the silica by simple screening. If successful, this would reduce the strip ratio for mining and increase the resource base significantly.

About 40 km southwest of the main Binjour exploration tenements, near Mundubbera, Australian Bauxite has also been engaged in exploring privately held Mining Lease 80126 (**Red Hill**) with a view to acquisition. In December 2012, the company released a maiden Inferred Resource for this bauxite deposit of 3.5 Mt raw tonnage with a 67% yield when sieved at 0.26 mm. The deposit comprises a gibbsite-rich layer of bauxite from 1 to 7 m thick with approximately half being suitable for direct shipping.

New South Wales

Taralga: In May 2012, Australian Bauxite released an increased bauxite resource for the Taralga-Mount Rae deposit located about 45 km north of Goulburn. The new resource totals 37.9 Mt with a 63% yield when sieved at 0.26 mm. Of this total, 17.5 Mt is an Inferred Resource and 20.4 Mt is an Indicated Resource, with 53% of the resource suitable for direct shipping. This includes the occurrence of a 38 m-thick continuous bauxite intersection at Mount Rae.

Inverell: In May 2012, Australian Bauxite released a resource upgrade for the Inverell bauxite deposit of 38 Mt with a 61% yield when sieved at 0.26 mm. This is comprised of a 20.5 Mt Indicated Resource and a 17.5 Mt Inferred Resource. The company claims that the bauxite is medium-quality, low-silica, gibbsite-rich bauxite that is suitable for low-temperature alumina refineries.

Tasmania

Tasmania Project: In early 2012, Australian Bauxite began a drilling program exploring bauxite occurrences in central northern Tasmania. In November 2012, the company released a maiden Inferred Resource of 5.7 Mt of bauxite with a 55% yield when sieved at 0.26 mm. This resource includes a raw unsieved Inferred Resource of 3.0 Mt that is suitable for direct shipping and, in March 2013, the company announced a memorandum of understanding with the Tasmanian Ports Corporation for access to Bell Bay Port in northern Tasmania.

In April 2013, Australian Bauxite began negotiations with potential offtake partner Xinfa Group, a large Chinese aluminium company. And in May 2013, the company lodged a Mining Lease Application and announced that its first bauxite mine in Tasmania will be known as **Bald Hill** with mining planned to commence in the second half of 2014.

The company continued its drilling program in 2013, particularly focussing on mine boundary definition and identifying new targets such as the **Fingal Rail** prospect, 11 km north of Bald Hill. During the September 2013 quarter, five large pits at Bald Hill and Fingal Rail were excavated and trial mined with four of the pits rehabilitated. Four 50-tonne bulk samples were collected from four of the pits for dry-screening trials and analysis.

Western Australia

Aurora: The Aurora deposit, approximately 70 km northeast of Perth near Bindoon, is the subject of a joint venture between Yankuang Group (China) and Bauxite Resources Ltd. In 2010, the joint venture lodged a referral with the Environmental Protection Authority (EPA) of Western Australia for a mining operation producing up to 2 Mtpa of bauxite over five years. The EPA determined that a public environmental assessment (PER) was the appropriate level of review and the joint venture began a number of baseline studies as part of the PER process. In October 2013, the joint venture announced that it had withdrawn its referral to the EPA in order to concentrate on other, larger, bauxite resources in the Darling Range.

Ceres: During 2011, Bauxite Resources, in a joint venture with Shandong Provincial Bureau of Geology and Mineral Resources, carried out a drilling program comprising 3017 vertical holes for 7924 m over an area of approximately 3500 ha near the town of Williams, 150 km southeast of Perth. In July 2012, the company released a maiden Inferred Resource for the Ceres bauxite deposit of 15.0 Mt with a total Al_2O_3 content of 40.9% with 3.0% reactive silica.

Cronus: During the September 2012 quarter, Bauxite Resources published a maiden Inferred Resource for the Cronus deposit, which is approximately 220 km southeast of Perth. The new deposit totals 2.8 Mt of bauxite at 39.3% Al_2O_3 with 2.8% reactive silica.

Felicitas: In June 2012, the bauxite resource at Felicitas, approximately 60 km northeast of Perth in the Darling Range, stood at 73.3 Mt. Bauxite Resources scheduled an extensional drilling campaign to run until June 2013 that would comprise 6029 holes on an 80 x 80 m spacing for a total of 28 662 m covering some 3300 ha of mostly cleared farmland.

In early May 2013, Bauxite Resources upgraded the Felicitas bauxite resource to 33.1 Mt Measured, 49.1 Mt Indicated and 45.3 Mt Inferred for a total of 127.5 Mt. In late May 2013, the company published another upgrade for the Felicitas deposit of 35.3 Mt Measured, 65.3 Mt Indicated and 47.3 Mt Inferred for a total of 147.9 Mt of bauxite. The bauxite at Felicitas has a total Al_2O_3 grade of 39.4% and reactive silica grades at 1.9%.

Fortuna: In the first half of 2013, Bauxite Resources carried out a drilling campaign at the Fortuna deposit, which is adjacent to the Felicitas bauxite deposit. In May 2013, the company announced a maiden Inferred Resource for the Fortuna deposit of 26.8 Mt of bauxite and in September 2013, the company published a new Inferred Resource of 39.5 Mt. The resource is largely gibbsitic and has low amounts of reactive silica (total silica content is 5.2%).

Wandoo: In August 2012, Iron Mountain Mining Ltd sold the Wandoo bauxite deposits, approximately 100 km northeast of Perth, to private company Alpha Bauxite Pty Ltd for $4 million. As at December 2011, the total Inferred Resource for the Wandoo deposit was 89.3 Mt at 41.75% Al_2O_3 and 4.43% reactive silica.

Worsley: The Worsley mine (Boddington/Mount Saddleback) is located approximately 100 km southeast of Perth and operated by BHP Billiton Ltd as a joint venture with Japan Alumina Associates (Australia) Pty Ltd and Sojitz Corporation. As at June 2013, the Worsley bauxite deposit had a Measured Resource of 339 Mt including a Proved Reserve of 250 Mt, an Indicated Resource of 584 Mt including a Probable Reserve of 51 Mt and an Inferred Resource of 50 Mt. Average Al_2O_3 and reactive silica grades for the Worsley bauxite are 31.9% and 2.3%, respectively.

Ore is crushed at the mine and transported overland via a 50 km-long conveyor belt to the Worsley refinery. The refinery produced 3.729 Mt of alumina in 2012 (3.295 Mt in 2011).

Huntly and Willowdale: Alcoa of Australia Ltd operates the Huntly and Willowdale mines as well as the associated refineries at Kwinana, Pinjarra and Wagerup. Combined, these three refineries are the world's single biggest source of alumina, supplying 9.2 Mt of alumina in 2012. The alumina is either used in the company's aluminium smelters at Portland and Point Henry in Victoria or exported to Southeast Asia, North America, South Africa, the Middle East, Russia, China and South America.

The Huntly mine (70 km south-southwest of Perth) opened in 1976 and is the world's largest bauxite mine with a mining rate exceeding 23 Mtpa. The Willowdale mine (100 km south of Perth) commenced operations in 1983 and supplies the Wagerup alumina refinery. The combined mining rate of the two mines in 2011 was 34.3 Mt.

Probable Reserves for the Huntly and Willowdale mines combined are 34.7 Mt and Proven Reserves are 109.0 Mt. Available alumina averages 32.9% and reactive silica is less than 1%. To date, the company has not published resources.

Black Coal

Steve Cadman (steve.cadman@ga.gov.au)

Coal is a combustible sedimentary rock formed predominantly from plant material that has been deposited in ancient marshy environments. Through burial over long periods of geological time, the plant material is transformed by microbial action, pressure and heat into coal. This process is commonly referred to as "coalification". In Australia, the term "black coal" includes anthracite, bituminous coal and sub-bituminous coal. The higher rank (greater degree of coalification) black coals are predominantly used in either electricity generation (thermal coals) or to produce coke for the iron and steel making industry (metallurgical or coking coals). Black coal is also used in cement manufacturing, alumina refining, paper manufacturing and several other industrial applications.

Black coal occurs in all states and the Northern Territory. Most of Australia's Identified Resources of black coal occur in Queensland (62%) and New South Wales (24%). Australian coal production is dominated by Queensland and NSW. In the twelve months to 31 December 2012, Australia produced 501 Mt of raw coal. Of this total, Queensland produced 256 Mt (51%) and NSW produced 235 Mt (47%). During this period, approximately 79% of black coal production came from open-cut mining operations. There are locally important coal mines at Collie in Western Australia, Leigh Creek in South Australia and in the Fingal Valley and at Kimbolton in Tasmania.

See Figure 6 for the location of Australia's major black and brown coal basins and operating mines.

Resources

Between December 2011 and December 2012, the estimate of Australia's Recoverable EDR of black coal increased by 6% to 61 082 Mt (Table 5). The estimate of in situ EDR also increased during this period (by 9%) to 77 589 Mt. Most of Australia's Recoverable EDR is located in Queensland (59%) and NSW (37%) within four coal-bearing, sedimentary basins (Bowen, Sydney, Surat and Galilee Basins). Approximately 31% of Recoverable EDR is located in the Sydney Basin (NSW), 31% in the Bowen Basin (Qld), 13% in the Surat Basin (Qld) and 10% in the Galilee Basin (Qld).

Table 5: Recoverable resources of black coal in Australian states and the Northern Territory at December 2012.

Jurisdiction	**JORC Reserves** (Mt) (% of AEDR)	**Demonstrated Economic** (Mt)	**Demonstrated Paramarginal** (Mt)	**Demonstrated Submarginal** (Mt)	**Inferred** (Mt)
New South Wales	7749	22 963	169	26	8739
Northern Territory	0	0	0	0	0
Queensland	12 677	36 855	872	3	43 729
South Australia	0	758	40	3930	9788
Tasmania	0	520	3	0	303
Victoria	0	0	0	0	0
Western Australia	236	986	50	25	1625
Total Australia	**20 662** (38%)	**61 082**	**1134**	**3984**	**64 184**

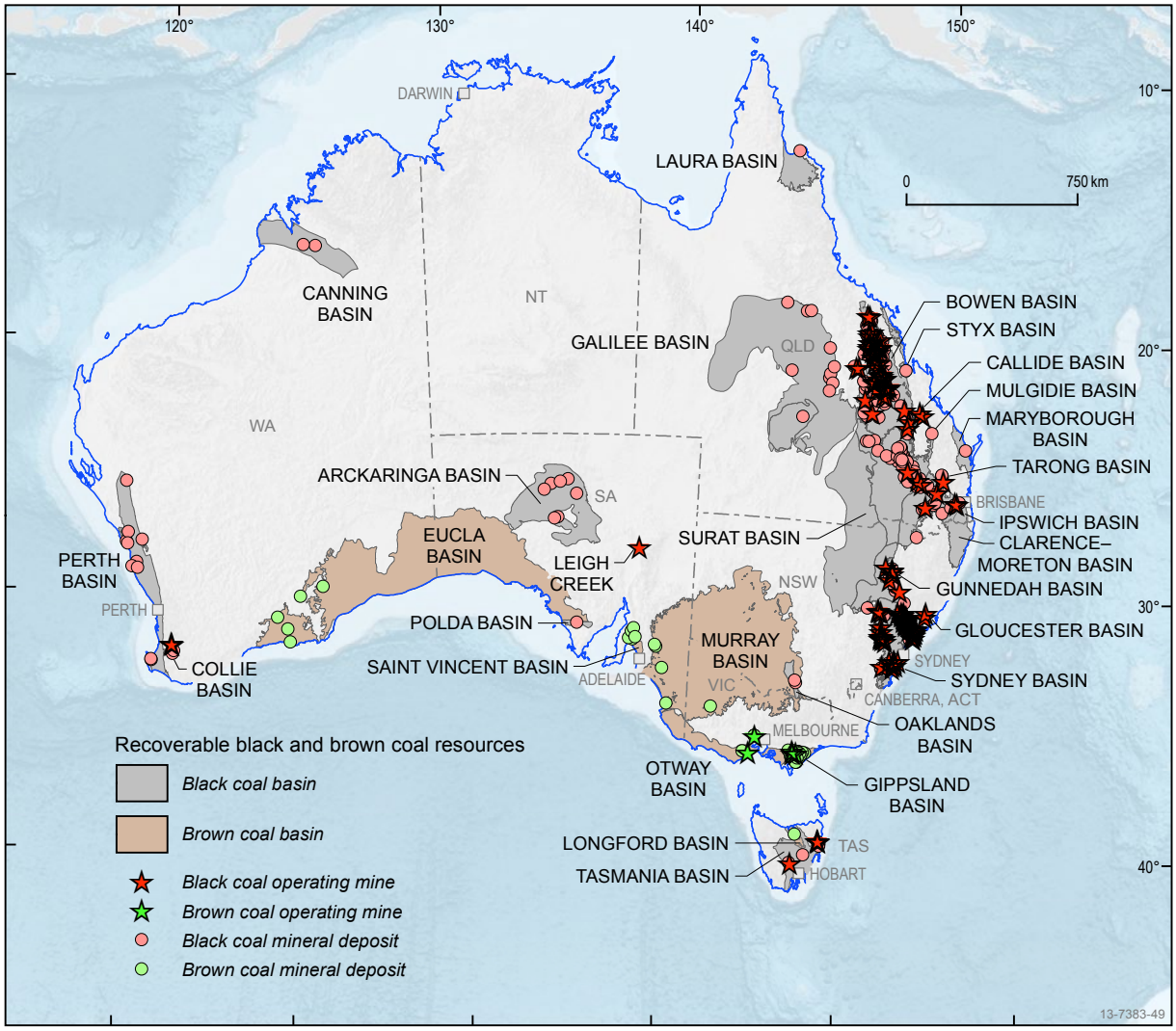


Figure 6: Australia's operating black and brown coal mines as at December 2012.

Accessible EDR

Nearly all black coal EDR is accessible. A relatively small tonnage of EDR is quarantined within State Reserves at Hill River in WA.

JORC Reserves

Australia's JORC Code reserves are estimated at 20 662 Mt or 38% of Accessible EDR. Included in this tonnage are estimates by Geoscience Australia of reserves associated with operating mines for which reserves were not reported by the mining companies. The estimated resource life of the JORC Code Reserves at the 2012 rate of production is approximately 41 years.

Exploration

Data published by the Australian Bureau of Statistics for coal indicate that exploration expenditure during 2012 declined 6% from the previous year to $709 million. Most of the decline occurred in Queensland where expenditure fell 7% to $611 million. In NSW, exploration expenditure fell by 3% to $87 million. (Exploration expenditure data for South Australia, Western Australia, Tasmania and Victoria are not available). In 2012, 19.4% of total expenditure on mineral exploration in Australia was attributable to coal exploration. While this represents a 1.8% fall from the previous year, it is substantially higher than the 14.5% recorded in 2010.

Production and Trade

In 2012, Australian production of raw black coal increased to a record 501 Mt. Due to lower contract and spot prices for both metallurgical and thermal coal during the latter half of 2012, however, the value of Australian coal exports declined from $47 013 million in 2011 to $41 563 million in 2012.

Of the 501 Mt of raw coal produced during 2012, 379 Mt comprised saleable coal. Queensland and New South Wales dominate Australian black coal production and in 2012 accounted for 51% and 47%, respectively, of total raw coal and saleable coal production. During 2012, small quantities of black coal were produced for the domestic market in Western Australia (5 Mt raw), South Australia (3.8 Mt raw) and Tasmania (0.64 Mt raw).

During 2012, Australia exported 145 Mt of metallurgical coal and 171 Mt of thermal coal – an increase in export volumes over the previous year of 9% and 16%, respectively. While Japan remains the primary destination for Australia's coal exports, most of the additional export volumes reported for 2012 were exported to the People's Republic of China. (In 2012, imports of thermal coal into China increased by 59% due to increasing electricity demand and the relatively low cost of imported coal.)

In 2012, Australian coal exports were valued at $41 226 million. The Bureau of Resources and Energy Economics forecasts that between 2012 and 2018, Australia's exports of thermal coal will rise at an average rate of 8% per annum to 271 Mt.

World Ranking

Data on world coal resources are compiled and aggregated under two classification systems. In Australia, the term 'black coal' includes anthracite, bituminous and sub-bituminous coal and the term 'brown coal' refers to lignite. Under the international system, only anthracite and bituminous coal are included in the 'black coal' category and sub-bituminous coal is included with lignite and referred to as 'brown coal'.

Under the international classification system, at the end of 2012, Australia was estimated to have 9.2% of the world's proven reserves of black coal and ranked fifth in the world behind the United States of America (26.8%), China (15.4%), India (13.9%) and Russia (12.1%). Under the Australian classification system, it is estimated that Australia has approximately 9.2% of the world's economic recoverable black coal resources.

In 2012, total world coal production of black and brown coal reached record levels and Australia was ranked fifth in the world behind China, the United States of America, India and Indonesia in terms of total coal production. Australia exported 319 Mt of black coal during this period and was the world's largest exporter of metallurgical coal and the world's second largest exporter of thermal coal (behind Indonesia).

Industry Developments

New South Wales

In March 2012, Yancoal Australia Ltd received approval to proceed with the Stage 3 Modification to the **Austar** underground mine located 12 km southwest of Cessnock. The modification involves removal of an existing longwall and the re-alignment of other longwalls with the direction of principal stress.

In June 2012, BHP Billiton Ltd approved US$845 million of expenditure to sustain operations at Illawarra Coal by establishing a mine replacement area at the **Appin** coal mine. Known as Appin Area 9, the new area will be operational in 2016 and replace production at the **West Cliff** mine.

In July 2012, Cockatoo Coal Ltd announced a JORC resource upgrade for the **Hume** Project. Located approximately 160 km from Sydney in the southwest portion of the Southern Coalfield, Identified Resources at Hume were upgraded to 451 Mt (an increase of 58%).

In September 2012, Nucoal Resources Ltd executed an agreement with Mitsui Matsushima International Pty Ltd to develop the **Doyles Creek** Underground Coal Project and training facility in the Hunter Valley.

In December 2012, Pacific National Coal Pty Ltd launched a $110 million train support facility at Greta in New South Wales. It is anticipated that the facility will increase the efficiency of services in the Hunter Valley and provide significant capacity benefits to the Hunter Valley coal chain.

In December 2012, Gujarat NRE Coking Coal Ltd received approval to continue mining a new longwall block and to construct associated surface infrastructure at the **NRE No.1 Colliery** located 8 km north of Wollongong.

Idemitsu Kosan Co. Ltd is proceeding with its expansion of the **Boggabri** coal mine 17 km northwest of the town of Boggabri. The Boggabri Project involves a brownfield expansion of the existing 1.5 Mtpa open-cut mine to 4.3 Mtpa by 2013–14. By 2016, Idemitsu Kosan plans to increase production at Boggabri to be in the range 6.6 to 7.0 Mtpa.

During 2012, the expansion of underground mining operations at the **Metropolitan** colliery 30 km north of Wollongong continued. Peabody Energy Corp is extending longwall mining operations to the north of the existing mine to increase production of saleable hard coking and semi-hard coking coal from 1.5 Mtpa to 2.8 Mtpa. In 2012, the mine produced 2.1 Mt of saleable coal.

Xstrata Coal Pty Ltd continued construction of the **Ravensworth North** Project during 2012. Located near Singleton in the Hunter Valley, the project is a large open-cut mine that will produce up to 8 Mtpa of saleable semi-soft and thermal coal. Construction on the project was scheduled for completion in the fourth quarter of 2013.

Xstrata Coal is proceeding with the installation of a second longwall mining operation at the **Ulan West** mine located 42 km north-northeast of Mudgee. Production from the new longwall mine is scheduled to commence in 2014. When completed, Ulan West will produce 6.7 Mtpa of thermal coal for the export market.

Queensland

During 2012, either maiden JORC resource estimates or JORC resource upgrades were announced for seventeen coal projects and deposits in Queensland. Of these, six are located in the Bowen Basin (**Comet Ridge**, **Baralaba**, **Moorlands**, **Rockwood**, **T9 Block** (Tiaro) and **Tennyson**), seven are located in the Surat Basin (**Back Creek**, **Thorn Hill**, **Bushranger**, **Krugers**, **Davies Road**, **Columboola** and **The Range**), two are located in the Galilee Basin (**Hughenden** and **Galilee Project** (Tiaro)) and two are located in the Clarence-Moreton Basin (**Amberley** and **Bremer View**).

In June 2012, Cockatoo Coal Ltd (as part of the North Surat Joint Venture) announced that it had been selected as a 4.2 Mtpa user of the Wiggins Island Coal Export Terminal (WICET) Stage 1 Expansion in Gladstone. The North Surat Joint Venture will commence supplying coal from the **Collingwood**, **Taroom** and **Woori** thermal coal projects to the terminal in 2016. Capacity commitments were also confirmed with Cockatoo Coal Ltd, Stanmore Coal Ltd and Xstrata Coal for their share of the 32.2 Mtpa capacity needed to support the WICET Stage 2 Expansion.

In August 2012, Cougar Energy Ltd announced that it planned to sell its Queensland coal assets and focus on underground coal gasification in Asia.

In response to falling coal prices and oversupply, in September 2012, Anglo American plc announced plans to cut production and staffing levels at its operations around **Moranbah**. The company stated, however, that it remained committed to tripling production of coking coal from its Moranbah operations by 2020.

In December 2012, the Adani Group plc formalised an agreement to develop the **Carmichael** Coal Project in the Galilee Basin. The project is one of the largest in the world. The Adani Group proposes to build a 400 km rail link from the Galilee Basin to the Abbot Point Coal terminal near Bowen. The Adani Group acquired the Abbot Point Coal terminal in 2011 and plans to increase its capacity from 50 Mtpa to 120 Mtpa. When operational, output from both underground and open-cut mining operations at Carmichael is projected to rise to 60 Mtpa.

Elsewhere in the Galilee Basin, the Hancock-GVK Joint Venture received approval for its 30 Mtpa **Alpha** Coal Project and the proposed development of the Abbot Point coal terminal. The joint venture also submitted an Environmental Impact Statement for the proposed **Kevins Corner** Project – a large deposit of thermal coal located immediately to the north and adjacent to the Alpha Project.

During 2012, owing to shrinking profit margins, the closure of 12 coal mines was mooted. In Queensland, closures include the **Gregory** open-cut mine operated by Xstrata Coal (although underground mining operations at the associated **Crinum** mine continue), the **New Oakleigh** mine near Ipswich operated by New Hope Corporation Ltd,

Norwich Park operated by the BHP Billiton Mitsubishi Alliance and the **Blair Athol** mine operated by Rio Tinto Ltd. Many other mines continued to operate despite negative cash margins due to transport and port contracts (known as "take-or-pay" contracts). Some companies (Yancoal Australia and the BHP Billiton Mitsubishi Alliance) shelved plans for selected mine expansions.

The BHP Billiton Mitsubishi Alliance continued with its expansion of the **Broadmeadow** mine and the development of new mines at **Daunia** and **Caval Ridge**. The three mines are located in the Bowen Basin near the town of Moranbah. When completed in 2013–14, Daunia and Caval Ridge will have the combined capacity to produce 10 Mtpa of coking coal for the export market.

During 2012, the development of a further two new mines located near the town of Moranbah (**Eagle Downs** and **Grosvenor Underground**) proceeded. Eagle Downs (operated by Aquila Resources Ltd and Vale SA) will be a hard-coking coal, longwall mine adjacent to the BHP Billiton Mitsubishi Alliance's **Peak Downs** operation. Eagle Downs is expected to have a 47-year mine life with a peak production rate of 5.9 Mtpa. The Grosvenor Project (operated by Anglo American) is a greenfields, underground coal mine which will produce up to 7 Mtpa run-of-mine coking coal for the export market.

Approximately 50 km northeast of the town of Emerald, Rio Tinto Energy continued its expansion of underground operations at the **Kestrel** mine. Scheduled for completion in 2013, the extension will add 20 years to the life of the mine and increase production of hard coking coal to around 6 Mtpa.

Also near Emerald, Ensham Resources Pty Ltd continued the transition to increased underground mining operations at the **Ensham** coal mine. Known as the Ensham Central Project, the operator is undertaking bord and pillar underground mining operations within the footprint of the existing open-cut mine.

In 2011, the Jellinbah Group Pty Ltd commenced the expansion of open-cut mining operations at the **Lake Vermont** mine located 20 km north of Dysart. As part of the expansion, a second Coal Handling and Processing Plant was constructed. In 2013, production of hard coking and PCI coal from the mine is expected to increase to 6 Mtpa.

Millennium is an open-cut mine located 160 km south-southwest of the town of Mackay and operated by Peabody Energy. The mine produces coking and PCI coal for the export market. Peabody Energy plans to expand open-cut operations at the mine into two new mining leases and increase production at Millennium by 1.4 Mtpa.

Northwest of Rolleston in the Bowen Basin, a joint venture led by Glencore Xstrata plc is seeking approval to extend the life of the existing **Rolleston** coal mine by expanding open-cut mining operations into adjacent mining leases. The Rolleston Coal Expansion Project has the potential to extend the life of the Rolleston mine by 30 years and increase total production capacity at the mine to 14 Mtpa. Rolleston produces thermal coal for both the domestic and international market.

South Australia

In August 2012, Altona Energy plc announced that the Altona-CNOOC Joint Venture had all the necessary regulatory approvals in place to allow it to commence a drilling program designed to gather further technical data for its **Arckaringa** CTL Project. The joint venture holds interests in three exploration licences that cover a combined area of 2500 square kilometres in the Permian Arckaringa Basin and is evaluating the potential of the northern part of the basin for a coal-to-liquids project.

Western Australia

During 2012, Rey Resources Ltd continued its environmental evaluation and stakeholder consultation for the proposed **Duchess Paradise** mine located in the Canning Basin. The project will include a slot/high wall mine and a Coal Handling and Processing Plant. Rey Resources proposes to truck coal from the Duchess Paradise mine to the port of Derby where it will be loaded onto barges for transhipment to export vessels.

In July 2012, TPL Corporation Ltd announced a maiden coal intercept from its drilling program at the **Lightjack Hill** Coal Project in the Canning Basin. In August 2012, the company announced a second coal intercept (2 m thick at a depth of 103–105 m) at Lightjack Hill. TPL has several targets in the Canning Basin based on the location of the subcrop of the Permian Lightjack Formation (Liveringa Group) within its 14 exploration licences.

Brown Coal

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Australian brown coal or lignite is a low-rank, low-ash, high-moisture content coal. In Australia, brown coal is currently considered unsuitable for export and is used primarily to generate electricity in domestic power stations. Deposits of brown coal in Australia are exclusively Cenozoic in age and occur in all states. The largest deposits of brown coal are located in the Gippsland Basin in Victoria where thick (up to 100 m) seams of brown coal were deposited in a relatively short (as little as 30 million years) geological time span.

Victoria is the only state in which brown coal is mined. Open-cut mines at Anglesea, Loy Yang, Yallourn and Hazelwood supply coal to nearby power stations. Small quantities of brown coal are also mined at Maddingley to produce soil conditioners and fertilisers. Briquettes for industrial and domestic use and low-ash and low-sulphur char products are also produced from Victoria's brown coal.

See Figure 6 in the black coal chapter for the location of Australia's major black and brown coal basins and operating mines.

Resources

Estimates of Australia's Recoverable EDR and total Identified Resource of brown coal (Table 6) changed little between 2011 and 2012. Approximately 99% of Australia's brown coal EDR and 97% of its total Identified Resource of brown coal are located in Victoria predominantly in the Latrobe Valley.

Table 6: Recoverable resources of brown coal in Australian states and the Northern Territory at December 2012.

Jurisdiction	**JORC Reserves** (Mt) (% of AEDR)	**Demonstrated Economic** (Mt)	**Demonstrated Paramarginal** (Mt)	**Demonstrated Submarginal** (Mt)	**Inferred** (Mt)
New South Wales	0	0	0	0	0
Northern Territory	0	0	0	0	0
Queensland	0	0	0	0	0
South Australia	0	0	2820	246	776
Tasmania	0	0	106	0	0
Victoria	0	43 651	30 111	14 939	99 980
Western Australia	0	513	365	0	1746
Total Australia	**0**	**44 164**	**33 402**	**15 185**	**102 502**

Accessible EDR

Approximately 78% of brown coal EDR is accessible. Quarantined resources include the coal beneath the APM Mill site (which had a 50-year mining ban applied in 1980), the town of Morwell and the Holey Plains State Park. The resource life of the accessible EDR (estimated at 34 095 Mt) at the 2012 rate of production is 510 years.

JORC Reserves

There are no publicly reported brown coal reserves that comply with the Joint Ore Reserve Committee (JORC) Code.

Exploration

BREE does not report exploration expenditure data for brown coal. The Victorian Department of Primary Industries (VDPI) reported, however, that in 20102011, $7.9 million had been spent on brown coal exploration and a further $221.8 million on brown-coal mining within Victoria. More recent data are not available.

Production

In 2010–11, VDPI reported Victorian brown coal production at 66.7 Mt. Production of brown coal in Victoria has remained relatively constant during the last decade. It is likely, therefore, that production of brown coal during 2012 continued at a level similar to that reported for 2011.

World Ranking

Data on world coal resources are compiled and aggregated under two classification systems. In Australia, the term 'black coal' includes anthracite, bituminous and sub-bituminous coal and the term 'brown coal' refers to lignite. Under the international system, only anthracite and bituminous coal are included in the 'black coal' category and sub-bituminous coal is included with lignite and referred to as 'brown coal'.

Under the international classification system, Australia is estimated to hold 8.6% of the world's proven reserves of sub-bituminous coal and lignite and ranks fifth in the world behind the United States of America (28.2%), the Russian Federation (23.7%), China (11.5%) and Germany (8.9%).

Under the Australian classification system, it is estimated that Australia holds approximately 22.6% of the world's recoverable EDR of brown coal.

During 2012, Australia produced approximately 7% of the world's brown coal and is ranked as the third largest producer of brown coal after Germany (17.7%) and Russia (7.5%).

Industry Developments

In 2012, the Commonwealth Government and the Victorian Government sought proposals from parties interested in developing pre-commercial demonstration-scale, coal-upgrading processes for raw lignite. Up to $90 million in funding was available to support projects assessed by the Commonwealth and Victorian governments as addressing the program objectives. To be eligible for funding, the pre-commercial technologies must include coal-upgrading processes such as drying, dewatering, char production and separation and may include liquefaction, combustion and gasification. Successful projects are expected to be announced during 2013.

During 2012, the Victorian Government conducted an initial market assessment to gauge local and international interest in developing Victoria's unallocated brown coal resources. This process will continue into 2013 and could lead to a decision to tender and ultimately allocate further brown coal resources in the state.

Mantle Mining Corporation Ltd completed a 15-hole drilling program at **Bacchus Marsh** and reported a JORC Code compliant Inferred Resource of 1600 Mt. Mantle Mining also executed a joint venture agreement with Exergen Pty Ltd. The joint venture plans to construct a $50 million demonstration project to transform the high-moisture brown coals at Bacchus Marsh into low-moisture briquettes.

Copper

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Copper is a ductile, coloured metal that has very high thermal and electrical conductivity. Copper was the first metal to be used by man (probably as early as 7000 BC) and was used as a substitute for stone; its malleability enabled tools to be easily shaped by beating. In the modern era, increasing use of copper is linked to the increasing use of electricity. In addition to being an excellent electrical conductor, copper is ductile enough to be drawn into wire and beaten into sheets without fracturing. It is therefore used to produce electrical cables and electrical equipment. Copper and its alloys are also widely used in plumbing components, building construction as well as industrial machinery. An average car contains more than 20 kg of copper and suburban homes have around 200 kg of copper. Demand for copper is often viewed as a leading indicator of global economic health.

Australia is a major copper (Cu) producer with mining and smelting operations at Olympic Dam in South Australia and Mount Isa in Queensland (Figure 7). Other significant copper producing operations are at Prominent Hill (SA), Northparkes, Cadia-Ridgeway, Cobar and Tritton (NSW), Nifty, DeGrussa, Boddington, Telfer and Golden Grove (WA), Ernest Henry, Lady Annie and Mount Gordon (Qld), and Mount Lyell (Tas).

Most of the copper ore produced in Australia comes from underground mines. At a few Australian mines, copper is leached from a copper oxide ore to produce a copper-rich solution that is then treated by solvent extraction and electrowinning to recover the copper metal. At most Australian mines the traditional method used involves copper sulphide ore being ground finely before the copper-bearing sulphide minerals are concentrated by a flotation process that separates the grains of ore mineral from the waste material. Depending on the type of copper-bearing minerals in the ore and the treatment processes used, the concentrate contains copper from around 25% for chalcopyrite ($CuFeS_2$) ores, increasing to over 50% for bornite (Cu_5FeS_4) and chalcocite (Cu_2S) ores. The concentrate is then smelted to float off as slag the iron oxides and iron sulphides. Air then blown through the molten copper matte drives off the sulphur. The copper blister produced by smelting is around 98% purity. Subsequent refining in an anode furnace uses natural gas to drive off the oxygen and finally, electrolysis produces copper at around 99.99% purity.

Resources

Australia's total Demonstrated Resources of copper rose by 4 Mt in 2012 to 137 Mt, with SA, NSW and Queensland contributing most of the increase.

Similarly, Australia's EDR of copper rose by 4 Mt to 91.1 Mt, an increase of 5% on the EDR in 2011. South Australia has the largest EDR at 62.4 Mt, which is 68% of the national total. Almost all of the EDR in SA are associated with BHP Billiton Ltd's Olympic Dam deposit, where EDR of 55.9 Mt are slightly higher than in 2011. New South Wales has 13% of Australia's copper EDR, which is nearly all in the Lachlan Fold Belt and largely at Cadia. Queensland has 12%, predominantly in the Mount Isa region. The balance of Australia's copper EDR is principally in WA which has 5% of the national total.

Inferred Resources were little changed at 43.9 Mt in 2012. South Australia holds 62% of Australia's Inferred Resources, most of which is at Olympic Dam, followed by Queensland with 18%, NSW with 10% and WA with 8%.

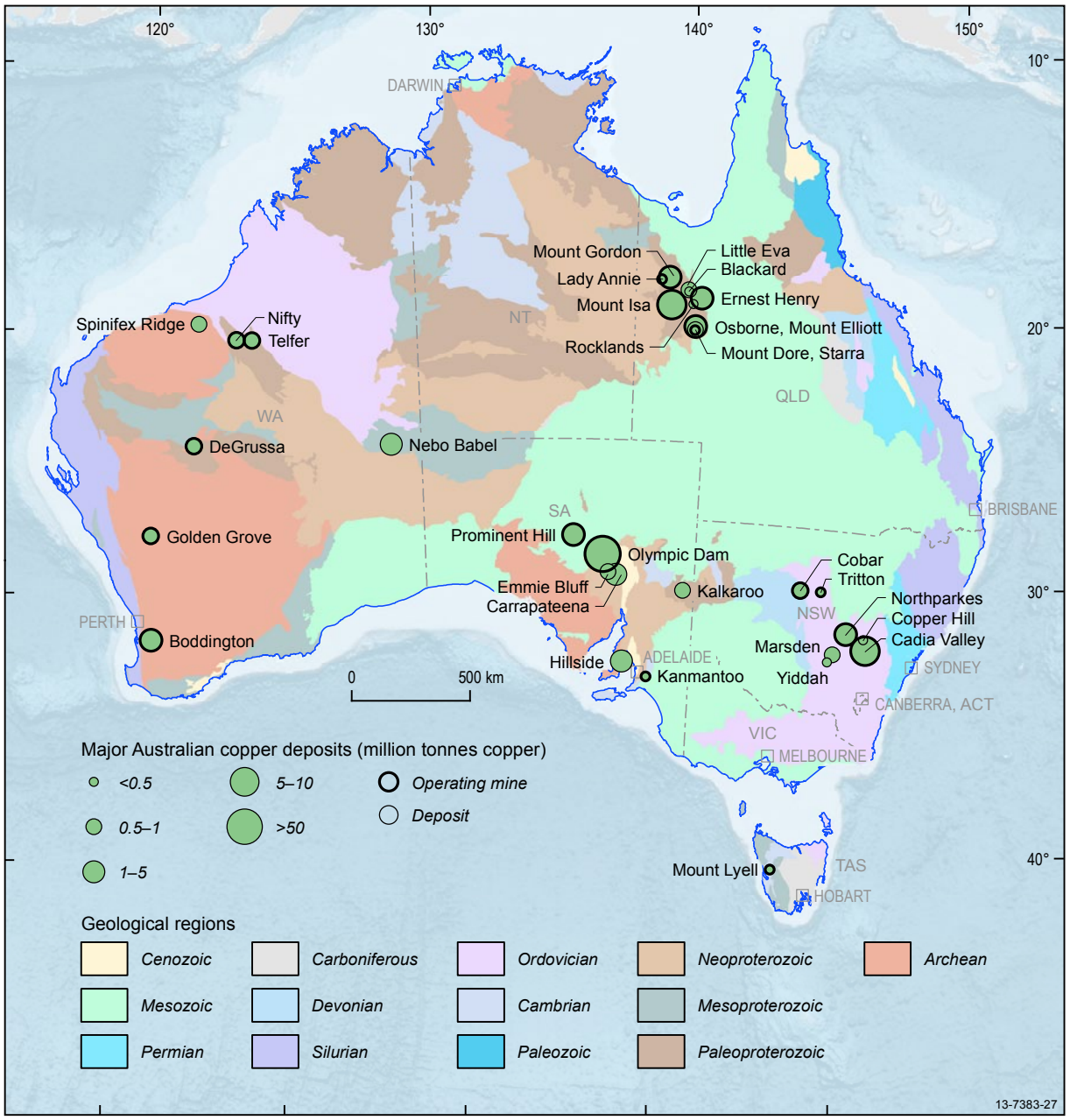

Figure 7: Australia's major copper deposits based on total Identified Resources.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

JORC Code reserves account for around 28% of AEDR. The remaining AEDR comprise those Measured and Indicated Resources reported by mining companies that Geoscience Australia considers will be economic over the long term. The copper resource life using national AEDR divided by annual production is 100 years, but using the ore reserve and dividing by annual production gives a resource life of around 30 years.

Exploration

Spending on exploration for copper rose by 4% in 2012 to $414 million. Expenditure in SA of $146 million was 35% of all copper exploration. Expenditure in Queensland of $127 million represented a further 31%. The main areas of expenditure in Queensland were the Mount Isa and Cloncurry districts. In SA, expenditure was in the search for further Olympic Dam style mineralisation in the Gawler Craton. Western Australia had 23% of spending on copper exploration across a range of projects, largely focused on seeking volcanogenic massive sulphide ore deposits. New South Wales is estimated to be about 7%, the Northern Territory had 3% and both Victoria and Tasmania are estimated at 1% each. Expenditure on exploration for copper made up 11% of all of Australia's mineral exploration expenditure.

Production

In 2012, Australia's mine production of copper totalled 914 kt of contained copper, 5% lower than in 2011 (961 kt). In 2012, SA surpassed Queensland for a second year as the top copper producer with a total of 285 kt, which was 9% less than in 2012 and represented 31% of all Australian production. The Olympic Dam and Prominent Hill mines produced almost all of SA's output, contributing 18% and 11% respectively of national production. In 2012, Queensland produced 247 kt (27%) of Australian copper, largely from Mount Isa and Ernest Henry and down 19% on 2011. For a fourth year, Queensland production was significantly down on the historic average of around 400 ktpa for the years 2000 to 2008. New South Wales produced 163 kt (18%) in 2012, down 8% on 2011, largely from Northparkes, CSA Cobar, Ridgeway, Tritton and Cadia Hill. Western Australia produced 191 kt (21%), up 36% on 2011, mainly from Nifty, the newly commissioned DeGrussa mine, Boddington, Telfer and Golden Grove. Tasmania produced 28 kt, up 3% on 2011, mostly from Mount Lyell, but with some from Rosebery.

The value of Australia's exports of copper concentrates and refined copper totalled $8.1 billion in 2012, down 6% on the $8.6 billion in 2011, but holding at 3% of the value of total merchandise exports. The Australian-dollar average copper price for 2012 fell 11% to $7672/t compared to the average of $8584/t in 2011. The average copper price in the December quarter of 2012 was $7611, 3% higher than in the corresponding quarter of 2011. Copper exports in 2012 increased 5% to 946 kt.

World Ranking

Based on USGS data for other countries, Australia has the world's second largest economic resources of copper (13%) after Chile (28%) and ahead of Peru (11%), the USA (6%), Mexico (6%), and China, Russia, Indonesia and Poland with 4% each. As a producer, Australia ranks fifth in the world, with 5% of world copper production after Chile (32%), China (9%), Peru and the USA (both 7%).

Industry Developments

Queensland

Mount Isa and Ernest Henry: Copper-in-concentrate production in 2012 from Glencore Xstrata plc's Mount Isa and Ernest Henry operations totalled 177 kt, a reduction of 29% on 2011. This reduction stemmed mainly from Ernest Henry as the operation transitioned to underground mining, initially at a lower mining rate and at lower grades. At Mount Isa, production was 143 kt of copper in concentrate, a decrease of 4% on the previous year as a result of a 9% reduction in grades, offset by an 8% increase to the volumes of ore mined.

Ernest Henry copper-in-concentrate production decreased 66% to 34 kt for 2012. Ernest Henry open pit operations had closed by the end of 2011 as mining operations reached the final high-grade ore zone of the open pit. The new underground mine at Ernest Henry commenced production in December 2011. The $589 million transformation of the open-pit mine to a long-term underground mine included the construction of a magnetite processing facility. The magnetite plant was commissioned in 2011 and sold a total of 296 kt of contained magnetite (Fe_3O_4) in 2012. For 2011, Xstrata reported cost savings of $49 million at Ernest Henry as a result of improved by-product credits from the 2011 production of 259 kt of magnetite. During 2012, Ernest Henry's underground mine continued to ramp up to mining rates of 3 Mtpa and the satellite **Mount Margaret** project commenced production in September 2012.

Mount Margaret was acquired in June 2011 from Exco Resources for $175 million as two mining tenements with completed feasibility studies; E1 with 48.1 Mt of ore, located 8 km east of Ernest Henry, and Monakoff which is 21 km south. Xstrata then spent $124 million to develop the Mount Margaret mining operation, which comprises a series of small open pits with a combined resource of 52.1 Mt grading 0.77% Cu and 0.23 g/t Au, representing 40 kt of contained copper and 384 000 oz of gold. Over its five-year life, Mount Margaret will produce around 140 kt of copper, 83 000 oz of gold and 560 kt of magnetite in concentrate, at a rate of around 30 ktpa of copper. In total, Ernest Henry will produce an average of approximately 70 ktpa of copper in concentrate from the combined Ernest Henry underground and Mount Margaret open pit operations.

The **Mount Isa** smelter produced 173 kt of copper anode, a 27% decrease on 2011, mainly due to lower concentrate production at Ernest Henry. The Townsville refinery produced 267 kt of copper cathode, a decrease of 4% on 2011, as reduced north Queensland mined production was largely offset by the processing of Altonorte anode from Xstrata's Altonorte smelter in Chile.

The merger of Xstrata plc and Glencore International plc was completed in May 2013. By mid-2013, plans for the Mount Isa Open Pit (MIOP) were placed on hold by Glencore Xstrata. Investigations had been progressing into the viability of a large, multi-commodity open pit mine at Mt Isa. If proven viable, the MIOP would extend operations by 20–30 years beyond the current life of mine of 2032. Without the MIOP, copper mining operations will cease in 2021. The work followed a review of a $3 million, eight-month concept study, from which Xstrata Mount Isa Mines had announced in May 2011 that it would expand existing mines, potentially develop new mines, but phase out its Mount Isa copper smelting and Townsville refining operations by 2016 and export concentrates. This would require increased rail and port capacity.

Findings from the study indicated the potential to mine and process at least 340 Mt of zinc-lead ore and 130 Mt of copper ore by large-scale open-pit mining at Mount Isa. In August 2011, Xstrata had commenced a $47 million prefeasibility study into the development of the large open-pit zinc-lead-copper mine, potentially extending the life of the combined operations to beyond 2060. The prefeasibility study was due for completion early 2013. Subject to the prefeasibility study being approved, Xstrata planned to progress to a feasibility stage in 2013. However, by mid-2013, plans for the MIOP were suspended.

Mount Gordon: Production for 2012 was 20 kt of copper in concentrate up from 8 kt in 2011 as the Mount Gordon mine returned to full production. The Mount Gordon operation currently has the capacity to mine 1.2 Mtpa of ore with a production rate of approximately 20 ktpa of copper. Aditya Birla Minerals Ltd had resumed production at Mount Gordon in 2011 after two years on care and maintenance since 2009 because of low copper prices. Mt Gordon again returned to care and maintenance in April 2013 because of economic factors. The Mineral Resource as at October 2013 had almost doubled to 185 Mt at 1.26% Cu, compared to last year. Based on this new resource, a scoping study in 2013 estimated the potential for the mine to produce at a rate of 4 Mtpa from six deposits (**Mammoth Surrounds**, **Mammoth Deeps**, **Mammoth North**, **Esperanza-Pluto**, **Esperanza South** and **Greenstone**) using sub-level caving for a 17-year mine life, with a capital expenditure of $340 million.

Lady Annie: Hong Kong listed CST Mining Group Ltd reported production of 22 kt of copper for 2012 from the Lady Annie project, located approximately 120 km northwest of Mount Isa. This was up 24% on 2011 with CST completing, in July 2012, the final ramp-up at the solvent-extraction and electrowinning cathode production plant, and in August 2012, a conveyor belt that extends across the entire leach pad area. Drilling in 2012 of 28 000 m at **Anthill** and 16 000 m at **Lady Brenda** increased total project resources by around 7 Mt over the July 2012 total Lady Annie project figure of 71.9 Mt at 0.67% Cu.

Osborne, Kulthor, Starra Line etc: Underground mine development work recommenced in March 2011 at **Osborne and Kulthor** following purchase by Ivanhoe Australia Ltd from Barrick Gold Corp for $17.4 million in 2010. Copper production from the Osborne processing complex began in February 2012 and by end 2012 reached 12 kt of copper contained in copper-gold concentrate. The Osborne complex is doubling 2012 processing to around 1.5 Mtpa through 2013 to 2014 from ore grading 1.3% to 1.5% Cu and 0.8 to 1 g/t Au.

Closed since 2003, development recommenced at the **Starra 276** deposit in early 2012 and mine ramp up was complete by mid-2013 with ore being processed through the Osborne processing complex.

Ivanhoe released a feasibility study for **Merlin,** the world's highest grade molybdenum and rhenium vein deposit in April 2012. The study projected 15-year life, a throughput rate of 0.5 Mtpa, average annual production of 5100 t Mo and 7.3 t Re for first seven years, and initial capital expenditure to first production of $345 million. Merlin has Measured and Indicated Resources totalling 6.7 Mt at 1.4% Mo and 23 g/t Re.

In early 2012, Ivanhoe completed a scoping study on the **Mount Elliott** project, a 570 Mt, low-grade copper-gold deposit. The study found that the original Mount Elliott underground mine could potentially be mined via an open pit and processed at the Osborne complex and the SWAN higher-grade area of the deposit could potentially be progressed to a large-scale 12 Mtpa underground block cave mine.

Ivanhoe Australia reported, for December 2012, total Measured and Indicated Resources for the Osborne, Kulthor, Mount Elliott, Starra 276, Starra 222 and Mount Dore deposits of 300 Mt at 0.58% Cu and 0.31 g/t Au as well as Inferred Resources of 410 Mt at 0.43% Cu and 0.24 g/t Au. In May 2013 Ivanhoe was renamed to Inova Resources. In September 2013 China's Shanxi Donghui Coal Coking & Chemicals Group Co made an off-market takeover offer for Inova. By mid-November, Shangxi had accumulated over 95% of Inova and was able to proceed to compulsory acquisition.

Rocklands: Located 15 km west of Cloncurry, the deposit was discovered in 2006 with initial drill intersections of 67 m at 1.08% Cu and 71 m at 2.38% Cu. In April 2012, environmental approval was given to build a 3 Mtpa processing plant to produce 480 ktpa of copper-gold-cobalt concentrate. In October 2013, CuDeco entered into a $100 million agreement with Minsheng Banking Corporation that will fund completion of mine development through to commencement of production at Rocklands. Commissioning is due mid-2014. CuDeco has signed contracts with Sinosteel (one of China's largest State-owned corporations) to supply the $300 million processing plant and procure and hand over a 28 megawatt power station to be constructed by Cummins Australia. In November 2013, CuDeco Ltd reported a Measured, Indicated and Inferred Resource totalling 272 Mt at 0.19% Cu, 0.08 g/t Au and 214 ppm Co.

South Australia

Olympic Dam (SA): BHP Billiton Ltd reported that 168 kt of copper cathode was produced from its Olympic Dam mine during 2012. This was below the installed capacity of 200 ktpa and 15% less than in 2011 due to mining a lower tonnage and grade of ore and decreased smelter availability. Olympic Dam has a ratio of Ore Reserves to production of 56 years.

In August 2012, BHP Billiton announced it will not proceed, in the interim, with the $28 billion open-pit expansion of Olympic Dam and will investigate a less capital-intensive design involving new technologies to substantially improve the economics of the project. The South Australian and Federal Governments had approved, in 2011, the Environmental Impact Statement for the proposal which would create one of the world's largest mines. BHP has until 2016 to decide whether or not to proceed with the expansion under a four-year extension of the Indenture Agreement granted by the South Australian government. The expansion would be a progressive development, requiring construction activity over 11 years, generating up to 6000 new jobs during the construction phase, as well as a further 4000 full-time positions and an estimated 15 000 new indirect jobs. It would lift ore production six-fold to produce 0.75 Mtpa of refined copper from a total resource of almost 80 Mt of contained copper. Measured Resources at the mine at June 2013 were estimated at 1470 Mt grading 1.02% Cu, 0.30 kg/t U_3O_8, 0.35 g/t Au and 2 g/t Ag for the sulphide ore. The sulphide Indicated Resources stood at 4840 Mt grading 0.84% Cu, 0.27 kg/t U_3O_8, 0.34 g/t Au and 1 g/t Ag.

Prominent Hill: Located 130 km southeast of Coober Pedy in the Gawler Craton, OZ Minerals Ltd's Prominent Hill mine produced 102 kt of copper and 140 746 oz of gold in 2012, the fifth year of operations. This was around 6% less copper than in 2011.

Construction of a $148 million underground mine to access the **Ankata** deposit was completed in 2012. Located 800 m from the **Malu** open pit, Ankata reached full production rates by the end of 2012 and is expected to annually contribute 25 kt copper for a current mine life to around 2019.

OZ Minerals is currently developing the $201 million Malu underground mine with the objective of reaching first ore from stoping in 2014. Malu underground is expected to contribute up to 20 ktpa of copper to production until at least 2024. In 2012 and 2013 significant volumes of waste were moved from the Malu open pit to give access in 2014 onwards to ore in the later stages of the pit.

Copper production from the existing operations, Malu Open Pit and Ankata Underground, for 2015 to 2018 is expected to be at least 95 ktpa. At June 2013, Prominent Hill mineral resources were 186 Mt grading 1.1% Cu, 0.7 g/t Au for 2 Mt of contained copper and 3.9 Moz of contained gold.

The **Kalaya** mineralisation, located between the Malu and Ankata deposits, is yet to be developed.

Carrapateena: Located 130 km north of Port Augusta and approximately 75 km from the Stuart Highway, the top of the Carrapateena deposit is 470 m below the surface and mineralisation extends down a further 1000 m vertically. A prefeasibility study is currently underway and a decision to mine is expected by 2015.

In early 2014, OZ Minerals will be taking delivery of a tunnel-boring machine to develop a 6.5 km $110 million exploration decline to the resource. The decline will include geotechnical and exploration access to areas at 625 m and 1000 m below the surface. In May 2013 OZ reported it would not award any contract for the decline until the prefeasibility study and further metallurgical testing were complete so as to reduce risk and expense. In November 2013, OZ Minerals announced an increase in resources to 800 Mt grading 0.8% Cu, 0.3 g/t Au for 6.3 Mt contained copper and 8.4 Moz of contained gold. OZ Minerals has estimated total operating costs, inclusive of mining, processing and other site expenses of $23/t, assuming the deposit fractures suitably for block caving – a lower cost mining method that uses gravity to feed ore through underground draw points.

In October 2013, OZ reported that regional exploration at the **Khamsin** prospect, located 10 km northwest of the Carrapateena deposit, intersected 414 m at 1.06% Cu and 0.29 g/t Au from 894 m, including 126 m at 1.95% Cu and 0.65 g/t Au.

Kanmantoo: The deposit was discovered in 1967 and mined previously from 1970 until 1976. In 2012, Hillgrove Resources Ltd completed its first full year of production at Kanmantoo copper mine located 55 km east of Adelaide. Twelve kilotonnes of copper in concentrate were produced in 2012. A new crusher circuit lifted processing capacity of the mill to 2.8 Mtpa. Kanmantoo is forecast to reach annual production by 2014 of 20 kt of copper, 10 000 oz of gold and 180 000 oz of silver for a ten-year mine life from reserves grading 0.7% Cu and 0.18 g/t Au.

Hillside: An updated mine plan was released for Hillside in July 2013, 10 months on from the prefeasibility study. The improved plan is for an annual production of 75 kt of copper and 60 000 oz of gold for the first 12 years from 180 Mt of reserves at 0.52% Cu and 0.13 g/t Au. The June 2013 Hillside resource was 337 Mt at 0.6% Cu, 0.14 g/t Au and 15.7% Fe. Preproduction capital costs are estimated at $900 million. Rex Minerals Ltd expects a bankable feasibility study to be completed by early 2014 and to have Hillside financed by mid-2014, with construction to commence shortly after, leading to commissioning in late 2015 and first production in 2016.

New South Wales

Cadia-Ridgeway: Newcrest Mining Ltd's Cadia Valley operations are located 250 km west of Sydney and consist of three gold-copper mines, Cadia Hill, Ridgeway and Cadia East. **Cadia Hill**, discovered by Newcrest in 1992, had copper-in-concentrate production for 2012 of 13 kt, a reduction of 7 kt on 2011, as the mining of the Cadia Hill open pit concluded in June 2012. Three kilometres northwest of the Cadia Hill open pit and beginning 500 m below the surface is the **Ridgeway** underground gold-copper mine, discovered in 1996. Ridgeway copper production for 2012 was 32 kt, an increase of 6 kt on 2011 reflecting post-commissioning production at Ridgeway Deeps block cave beneath the original sub-level cave.

Adjacent to the eastern edge of the Cadia Hill orebody is the **Cadia East** deposit which is a porphyry zone of gold-copper mineralisation, extending up to 2.5 km east and up to 1.9 km below the surface. The $2 billion Cadia East project commenced in April 2010. Cadia East is one of the world's largest gold deposits, comprising a mineral resource of 2800 Mt grading 0.41 g/t Au and 0.26% Cu containing 37.6 Moz of gold and 7.5 Mt of copper. Cadia East underground mine produced 2 kt of copper in concentrate in 2012 in conjunction with development. Commercial production at Cadia East commenced in January 2013 following the completion of the undercut and extraction levels for the initial panel cave and completion of the plant expansion to 26 Mtpa with new materials handling systems. Annual production from Cadia Valley operations is expected to increase to around 90 kt of copper and 0.8 Moz of gold in coming years. A second panel cave is to follow in 2014. The Cadia East panel cave mine will be Australia's largest underground mine and will underpin production from Cadia Valley for at least the next 30 years.

Northparkes: Located 27 km north of Parkes, Northparkes mine produced 54 kt of copper and 72 200 oz of gold in 2012, up 7% on 2011, in line with a recovery in ore grades. Rio Tinto Ltd reported resources for 2012 of 288 Mt with 0.57% Cu and 0.26 g/t Au, with additional reserves of 74.2 Mt with 0.76% Cu and 0.28 g/t Au. A prefeasibility study, named the Step Change Project, was underway in 2011 and 2012. It sought to evaluate the potential for further underground mining and processing operations based on a series of large-tonnage, low-grade areas of mineralisation within the existing mine leases. The $115 million study considered a five-fold increase in production and a mine life until 2041. However, early in 2013, Rio announced a change in direction, advising that thousands of modelled scenarios found that the best way was to focus on mine life extensions that do not depend on large additional water use or a construction camp as needed by a significant expansion of the mining operations. Exploration work carried out by Northparkes as part of the study will be 'banked' for further investigation if lower ore grades become economic.

In August 2012, the Rio Tinto Block Cave Knowledge Centre officially opened at the Northparkes mine, providing employees from across the Group with technical and safety training for underground block caving operations. In October 2012, Northparkes began commissioning a new tunnel-boring technology. This technology will reduce up-front capital costs and decrease construction time for underground operations. Initial tests have demonstrated a 40% increase in the speed at which tunnelling occurs. In July 2013, Rio sold its 80% stake in Northparkes to China Molybdenum Co Ltd for $US820 million advising that although Northparkes was a successful business, it was not of sufficient size to be a good fit with the Rio strategy. Japanese based Sumitomo Metal Mining Co Ltd holds the remaining 20% interest.

Mineral Hill: Previously mined by Triako Resources Ltd, from 1987 to 2005, the 2011 restart of the Mineral Hill operation in central western NSW by KBL Mining Ltd (then Kimberley Metals) is based on an initial 10-year mine life plan. Following completion of the $8 million refurbishment of the copper-gold processing plant and a $4 million modernisation of the underground infrastructure at Mineral Hill, KBL produced an initial 700 t of copper in 2011 and 4032 t in 2012, KBL's first full year of production. By November 2013 resources were increased slightly to 5.7 Mt containing 66 kt of copper, 82 kt of lead, 45 kt of zinc, 5.8 Moz of silver and 246 531 oz of gold. Having completed the **Parkers Hill** copper lodes, KBL began mining the newly discovered high-grade **Red Terror** copper-gold lodes which greatly improved metal recoveries to over 90% and alleviated elevated lead and talc processing issues experienced during September to November 2012.

Western Australia

DeGrussa: Located 900 km north of Perth and 150 km northeast of Meekatharra, DeGrussa has progressed from discovery in 2009 to production in 2012—a relatively short period of time. Early-stage, open-pit mining began in February 2012 from a high-grade chalcocite part of the resource that begins 55 m below surface and totalled 143 kt of direct shipping ore (DSO) grading 25.6% Cu and 2.5 g/t Au, containing 37 kt of copper. The ship loading and sale of the first DSO from the open-pit mine, containing roughly 30% copper, occurred in May 2012.

By late 2012 Sandfire Resources NL was commissioning the concentrator and was finalising mining from the Stage 1 pit with 40 kt of contained copper produced. The bulk of the ore now comes from underground using long-hole open stoping with haulage by 50–60 t trucks. Sandfire expects to mine 10.2 Mt of ore grading 6.55% copper over the initial seven-year mine life.

Construction at the mine has included a $65 million, 1.5 Mtpa processing plant, a 1920 m on-site airstrip and a permanent 400-person camp. To process the oxide resource of 1.04 Mt at 2.3% Cu, Sandfire is working on designs and approvals for a $15–17 million oxide plant. A $20 million exploration program is underway with an at-depth on-site focus and by mid-2013 this had delivered an extension to the mine life to late 2020.

In March 2013, Sandfire Resources reported a total Mineral Resource for DeGrussa of 13.4 Mt at 4.7% Cu and 1.9 g/t Au, containing 634 kt copper and 795 000 oz gold. With the ramp-up of production at DeGrussa largely complete by late 2013, Sandfire were targeting 65–75 000 t of copper and 35–45 000 oz of gold for 2013–14.

Nifty: Production at Nifty for 2012 was 50 kt of copper in concentrate from processing 2.3 Mt of sulphide ore grading 2.4% Cu. Aditya Birla Minerals Ltd's Nifty mine has a processing capacity of 2.3 Mtpa and the concentrator plant has a capacity of 2.5 Mtpa. Concentrate produced is trucked to Port Hedland for shipping to parent Hindalco Industries Ltd's Dahej smelting and refining facility in India. Underground drilling identified new ore to replace production and the Nifty resource was reported in March 2013 as 30.6 Mt at 2.5% Cu using a 1.2% Cu cut-off.

Thaduna/Green Dragon: Ventnor Resources Ltd has completed over 50 000 m of drilling since April 2011 to underpin an Indicated and Inferred Resource of 7.9 Mt grading 1.8% Cu and 3.7 g/t Ag for 142 kt of contained copper and 945 000 oz of contained silver. The resource comprises oxide, secondary sulphide and deeper sulphide mineralisation. The project was mined historically until 1971.

A Scoping Study completed by Ventnor in February 2013 outlined a potential production profile of 15 ktpa of copper over an anticipated mine life of 10 years with an estimated $70 million capital cost for a stand-alone operation. In October 2013, Sandfire Resources announced a farm-in and joint venture with Ventnor, with an up-front payment of $3 million for an immediate 35% interest and the option to increase to 80% by sole funding a further $6 million on exploration and studies. The sulphide material is potentially amenable for processing through the existing DeGrussa concentrator 40 km west and the oxide material will be considered for processing as part of the DeGrussa oxide copper project feasibility study. Ventnor's drilling has returned sulphide intersections at depth, indicating the potential to extend the sulphide component.

Diamond

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Diamond is composed of carbon and is the hardest known natural substance, although it can be shattered with a sharp blow. It also has the highest thermal conductivity at room temperature of any known material. Diamonds form 150 to 200 km below the Earth's surface at high temperatures (between 1050 °C and 1200 °C) and pressures (from 45 to 55 kilobars). They are carried to the surface within kimberlite and lamproite magmas which intrude through the Earth's crust. These intrusions generally form narrow cylindrical bodies called pipes, but only a very small proportion have significant diamond content. When the pipes are eroded, liberated diamonds can accumulate in alluvial deposits and may be found far from their source. This is because their hardness allows them to survive multiples episodes of erosion and deposition.

Current uses for diamond include jewellery, mining and resource exploration, stone cutting and polishing, computer chip manufacturing, machinery manufacturing, construction and transportation services. A large proportion of industrial diamond is manufactured and it is possible to produce synthetic diamonds of gem quality.

Resources

In the past, natural diamond quality was subdivided into gem, near-gem and industrial categories, however recent developments within the diamond industry has resulted in almost all natural diamonds being used for jewellery. The USGS reports that only 3% of industrial diamonds are non-synthetic. As a result, only total carats are reported here.

Australia's EDR of total diamond resources decreased by 2% in 2012 to 268 Mc.

Accessible EDR

All diamond EDR is accessible for mining.

JORC Reserves

JORC Code Reserves account for 55% of AEDR. The remaining AEDR comprise those Measured and Indicated Resources reported by mining companies, which Geoscience Australia has assessed as being economic in the long term.

Production

Australia produced 8.6 Mc of diamond in 2012, 1.1 Mc more than in 2011. Production during 2012 was almost entirely from Rio Tinto Ltd's Argyle mine, which produced 8.5 Mc. Production at Australia's two currently operating diamond mines, Argyle and Ellendale, both increased in 2012.

World Ranking

As a result of the changes in the reporting of Australia's diamonds described above, it is not possible to compare Australia's EDR for diamonds with the rest of the world based on USGS figures. In terms of overall production, Australia ranks as the world's sixth largest producer of diamonds by weight, up from seventh largest in 2011.

Industry Developments

Argyle (WA): Production continued at Rio Tinto's Argyle open-cut operation in 2012, yielding 8.5 Mc of diamonds, including valuable rare pink diamonds. Production figures for 2012 were higher than for 2011 when the company's open-cut operation yielded 7.4 Mc. In March 2012, Rio Tinto announced that it had commenced a strategic review into its diamond business, including exploring options for divestment of its diamond interests. Following the review, it was announced in June 2013 that Rio Tinto would retain its diamond businesses. In April 2013, Rio Tinto officially opened the Argyle underground mine. Production from Argyle is expected to transition from open-pit to underground mining by 2015. Development of the underground operation is expected to extend the life of the mine until at least 2020.

Ellendale (WA): Production at Ellendale in 2012 took place from the E9 pipe, with the E4 pipe remaining on care and maintenance. A total of 0.16 Mc was produced, representing an increase from 0.12 Mc in 2011. During 2012, diamonds produced from Ellendale achieved an average price of US$720 per carat. The Ellendale mine produces rare fancy yellow diamonds which achieved an average price of US$4393 per carat in 2012 and contributed 78% of revenue. The Ellendale diamond mine was acquired by Goodrich Resources Ltd (now Kimberley Diamonds Ltd) in December 2012. Kimberley Diamonds has begun an extensive exploration program at Ellendale aimed at increasing the life of mine, with the E4 Satellite and E6 pipes prioritised for exploration.

Venus Smoke Creek (WA): Venus Metals Corporation Ltd undertook a bulk sampling program during 2012 following an announcement in 2011 of an initial Inferred Resource of 6 Mc, which was based on historical exploration data. The bulk sampling program yielded 552 diamonds for a total of 39.72 c, with a highest nominal grade of 3.22 carats per hundred tonnes. These results were below expectations and prompted an independent audit to assess the suitability of the modular diamond-processing plant and investigate possible reasons for diamond losses during processing. Some modifications to the diamond-processing plant were suggested to improve efficiency and diamond recovery. Further bulk sampling is planned for the future.

Webb (WA): Meteoric Resources NL, in joint venture with GeoCrystal Ltd, has identified more than 80 magnetic anomalies in the Arunta Region of WA with characteristics similar to known kimberlite and lamproite bodies. Seven of these targets were drilled in June 2013, of which five holes intersected weathered olivine-bearing ultramafic volcanic rocks with geochemical and petrographic characteristics consistent with kimberlite magmas. A number of diamond indicator minerals were recovered, although, at this stage, no diamonds have been recorded. Additional drilling of a further 15 to 20 magnetic anomalies commenced in September 2013. Regional sampling of surface material for diamond indicator minerals is also planned.

Merlin (NT): Exploration at Merlin continued throughout 2012 and into 2013, with the focus on drilling, geophysical surveys and stream gravel sampling. In September 2013, Merlin Diamonds Ltd announced that it had begun trial mining at Merlin. Trial mining took place for approximately one month using hydraulic borehole mining techniques. Follow-up investigation is focussed on engineering work aimed at increasing the rate of production. A processing plant was commissioned at Merlin also, and achieved a capacity of 75 tonnes per hour.

Gold

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The principal uses for gold (Au) are as an investment instrument for governments, central banks and private investors, and as jewellery, which accounts for most of its annual usage. The main industrial use for gold is in the electronics industry, taking advantage of its high conductivity and corrosion-resistance properties. Small amounts of gold are present in most modern electronic devices. Gold is used in dentistry also because gold alloys are strong, resistant to tarnishing and easy to work.

According to the World Gold Council, trade in physical gold during 2012 amounted to 4452 t. This is almost 1800 t more than world mine production for the year as estimated by the USGS (2660 t; adjusted for actual Australian production). World Gold Council data shows jewellery consumed 1908 t, bullion and coins 1582 t and technology applications 428 t. Central Banks were again net purchasers of gold during 2012.

The monthly price of gold started 2012 at US$1744/oz and ended the year at US$1664/oz having bottomed at US$1558 in May and reaching a maximum of US$1776/oz in September (Figure 8). For most of the year, the exchange rate between the Australian and United States dollars varied between 1.03 and 1.06, yielding slightly lower gold prices expressed in the local currency. In Australian dollars, the price of gold started the year at $1675/oz and followed a similar price fall, rise and fall course to that expressed in United States dollars, ending the year on $1600/oz. In general, the Australian gold price throughout 2012 was about $50/oz lower than the second half of 2011, but more than $150/oz higher than the first half of the same year (Figure 8). In April 2013, the gold price in US dollars dropped about 25% to US$1200 and subsequently rebounded to around US$1320/oz. Despite being partially offset by a corresponding fall in the Australian/US dollar exchange rate to about 0.93, in Australian currency terms, the price of gold fell by about 12.5% to between $1380 and $1450/oz by mid-2013, or similar to values seen throughout 2010. Allowing for inflation, and expressing the gold price in constant 2012 Australian dollars, the current purchasing power of the commodity remains about double that seen between 2000 and 2005. The main impact of the recent, rapid downward correction has been the closure of some high-cost mines and an increase in difficulty for companies to raise market capital. Given the continuing demand for gold, observers have suggested that the recent price drop has been driven by a shift in the equities market towards other areas of investment.

Resources

Australia's gold resources occur in all states and the Northern Territory (Figure 9). In 2012, newly identified gold in total JORC Code resources (all categories) amounted to 937 t, a 47 % increase over that delineated during 2011. Total JORC Code resources of gold at December 2012, nett of that lost to mining, rose 686 t to 14 974 t, an increase of almost 5% on the previous year. The largest gains were in South Australia, which rose by 240 t, largely because of increases at Olympic Dam (203 t). Other states to enjoy increases were New South Wales with an increase of 238 t, mainly because of increases at the Cadia group of deposits (172 t), and in Western Australia by 200 t spread over a much larger group of deposits. Queensland also experienced a modest rise of 67 t in total JORC Code resources. In contrast, in Victoria total JORC Code resources reduced by 48 t, Tasmania by 11 t and the Northern Territory by 1 t.

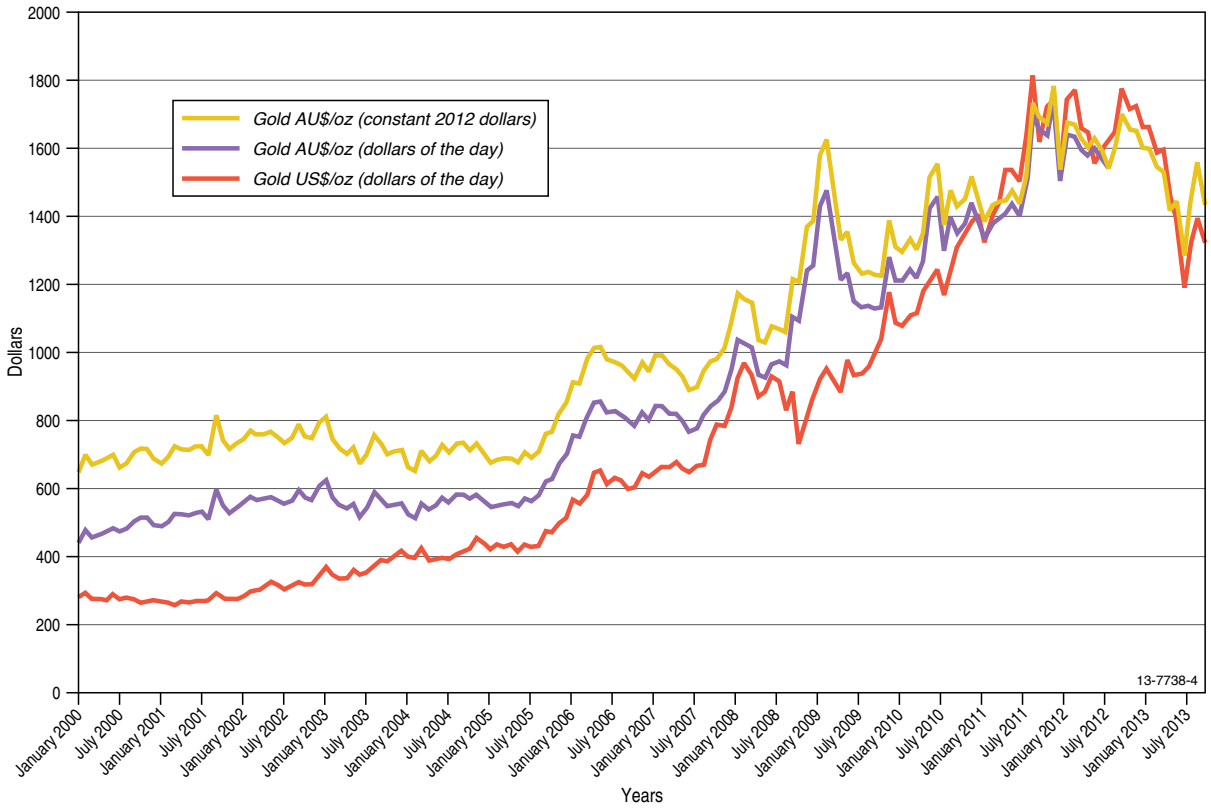

Figure 8: Monthly gold price in US$, AU$ (dollars of the day) and constant 2012 AU$ for the period January 2000 to September 2013. The gold price time series in US$ was derived from Bank of England data, the exchange rate from WM/Reuters, and deflation factors from the Reserve Bank of Australia.

In 2012 Australia's EDR of gold increased 756 t to 9909 t (Figure 10), up by 8% on 2011. In contrast to 2011, when the reclassification of Paramarginal Resources resulting from higher gold prices made the largest contribution to growth in EDR, more than 80% of growth in 2012 was derived from additions to resources in the contributing JORC Code categories. The largest growth in EDR by state occurred in SA (381 t), followed by WA (237 t) and NSW (121 t). Only two states, Victoria (18 t) and Tasmania (9 t) saw reductions in their EDR. Western Australia continued to hold the largest share of EDR (4295 t or 43% of total EDR), followed by SA (2752 t) and NSW (1766 t). Collectively, these three states hold slightly less than 90% of national EDR.

The 40 largest contributing deposits in 2012 accounted for 75% of national EDR with just over 50% of national EDR derived from the five largest of these deposits — Olympic Dam in SA and Cadia East in NSW, as well as Boddington, Telfer and the Superpit at Kalgoorlie in WA.

Paramarginal Resources of gold declined by 115 t, or 24%, to 372 t in 2012. This reduction was less than 25% of that in 2011, but again, was largely attributed to the sustained relative high price of gold throughout the year. The greatest reduction in the category occurred in WA (by 100 t to 240 t), although the state retained the largest share of this resource category. Queensland held the second largest share of Paramarginal Resources, about 43 t.

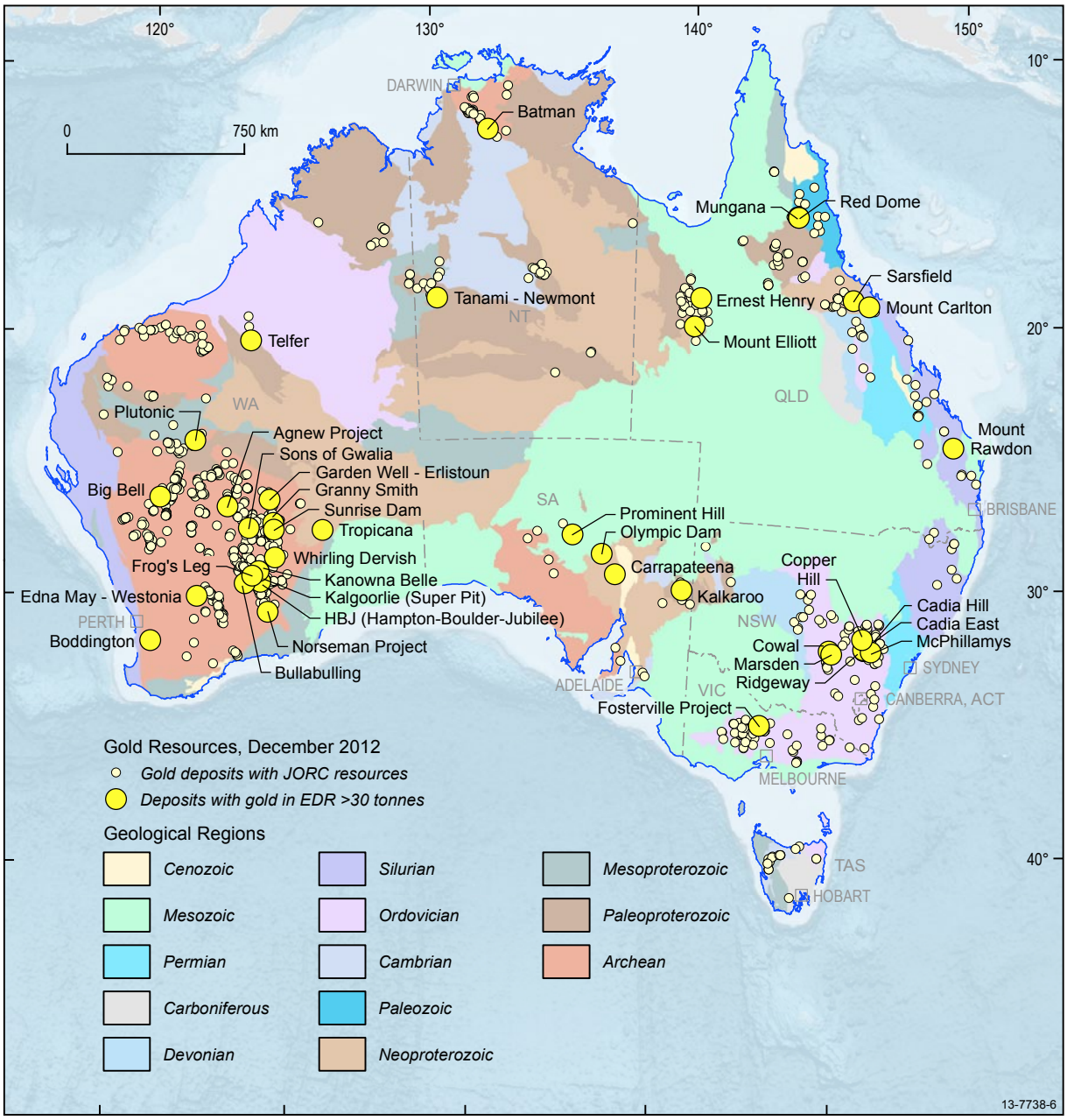

Figure 9: Gold deposits with JORC compliant resources highlighting those with more than 30 t of contained gold.

Submarginal Resources declined only 13 t in 2012 to 122 t but remained about 2 t higher than the totals for the category in 2009 and 2010. Western Australia experienced a small drop of 8 t to 86 t while Queensland's total increased by about 5 t to slightly less than 20 t. Together, Paramarginal and Submarginal Resources total about 500 t or 5% of resource categories that contribute to EDR. Gold in Paramarginal and Submarginal Resources has declined by about 1100 t since 2009.

Australia's Inferred Mineral Resources of gold rose marginally by 58 t to 4571 t in 2012 and account for 30% of gold in all JORC Code categories. Increases in the category were achieved in NSW (130 t), WA (71 t) and Queensland (51 t) while SA incurred the most significant loss of 140 t. Western Australia's Inferred Mineral Resources remain the largest by state or territory at 1854 t followed by SA with 1018 t and Queensland with 691 t. Since an abrupt increase of about 1100 t in 2004, due mainly to a substantial increase at Olympic Dam, the amount of gold in this category has remained relatively constant. In general, the trends in the data over recent years indicate an equilibrium between defining new resources and converting existing Inferred Mineral Resources to those with higher geological certainty.

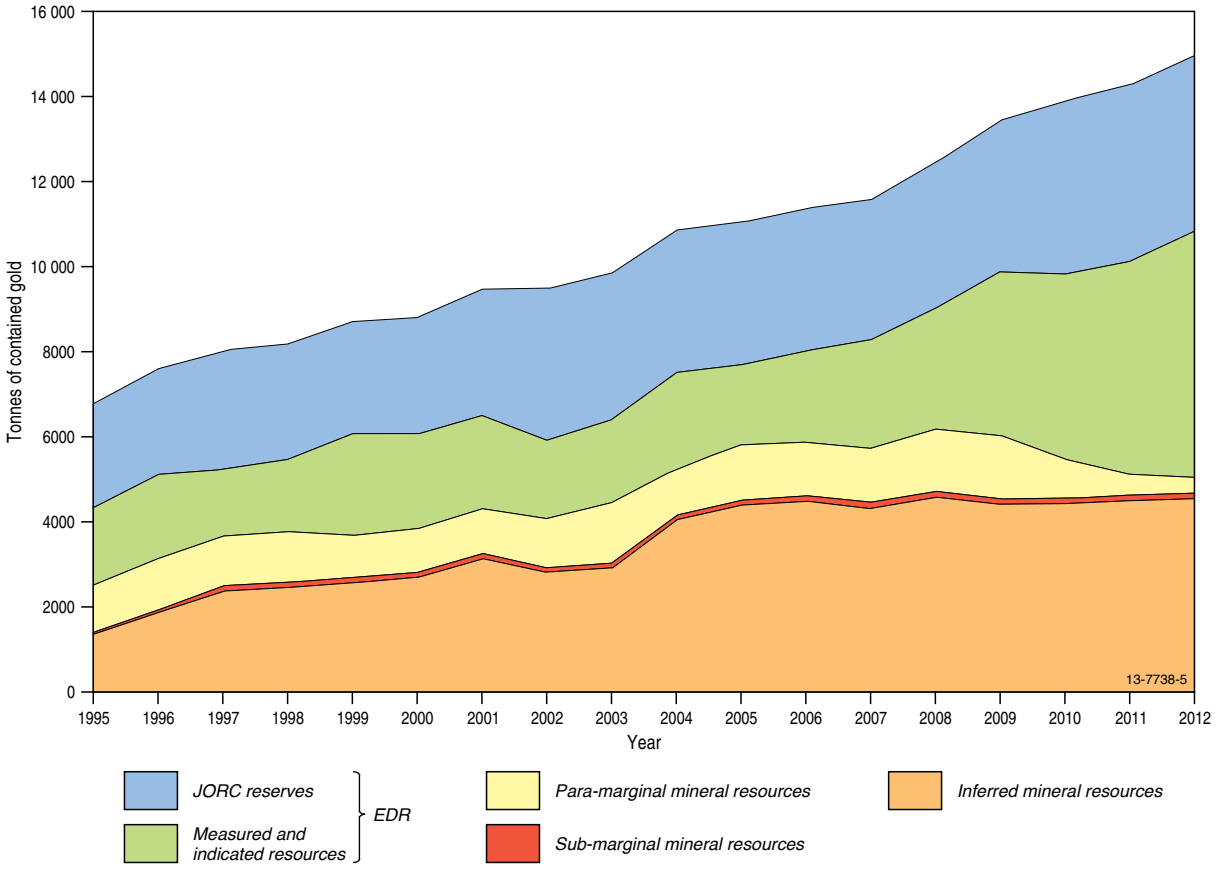

Figure 10: Contained gold in the various Geoscience Australia groupings of JORC Code categories through time from 1995 to 2012. Economic Demonstrated Resources (EDR) consisting of total JORC Ore Reserves (blue) and Measured and Indicated Mineral Resources deemed to be economic (green); Paramarginal Resources (yellow); Submarginal Resources (red); and Inferred Mineral Resources (orange). The EDR of gold for 2012 constitutes 66% of total JORC Code resources.

Accessible EDR

Australia's EDR for gold are essentially unencumbered with around 30 tonnes, or less than 1%, currently unavailable for exploitation. Deposits which contain gold resources that are unavailable for mining include Jabiluka, Koongarra, and Coronation Hill, which are all located in the NT.

JORC Reserves

JORC Code reserves comprise total resources in Proven and Probable Ore Reserves as defined in the JORC Code. In 2012, national JORC Code reserves declined minimally by 12 t to 4119 t and amounted to 42% of EDR and 28% of total JORC Code resources. The most significant change in JORC Code reserves occurred in the NT with a loss of 137 t, or 56%, to just 107 t. This loss was offset by gains of 65 t in NSW, 47 t in SA and 20 t in Queensland. Changes to JORC Code Reserves in other states were not significant.

Exploration

Total mineral exploration expenditure, as reported by the Australian Bureau of Statistics, increased by $82.5 million, or 2.3%, to $3656 million in 2012. Exploration expenditure on gold showed a greater percentage increase (4.5%) over the previous year to total $741 million, second only to that spent on iron ore ($1163 million). In contrast to 2011, more money was spent on gold exploration in 2012 than on coal ($709 million) or combined base metals ($733 million; lead-zinc-silver and nickel and cobalt).

During the past decade, exploration expenditure on gold has remained relatively constant, between $500–750 million expressed in terms of constant 2012 Australian dollars. However, because of the growth in expenditure on other commodities, the percentage spent on gold has fallen from about 50% in 2002 to just over 20% in 2012. In contrast, expenditure on iron ore over the same time period has risen from 6% to 32% and that on coal from 9% to 19% of total mineral exploration expenditure.

On a state-by-state basis, the greatest increase in expenditure on gold exploration was in WA with a $42 million, or an 8.4%, rise to $541 million. The largest percentage increase in expenditure was in Queensland with a rise of 40%, or $18.8 million, to a total of $65 million. All other states and the NT experienced lower expenditures on gold exploration with the most significant reductions in the NT and Victoria, both decreasing by about $13 million to $60 million and $21 million, respectively.

There is no differentiation in available statistics for gold exploration expenditure in greenfields regions and at existing deposits. Total drilling kilometres for all commodities declined by about 7%, or 780 km, in 2012 to 10 190 km. The reduction was split proportionally between greenfields and brownfields with greenfields attracting only 32% of all drilling.

Production

The Perth Mint in WA is the sole refiner of gold in Australia. The mint acquires raw material from domestic mine production, recycled materials and from sources overseas. Total refined gold for 2012 amounted to 309 t, of which 282 t, worth an estimated $15.2 billion was exported. The exported volume was 25 t less than in 2011.

Domestic mine production fell by 7 t in 2012 to 251 t, which was 11 t less than the recent maximum of 261 t in 2010 and about 60 t lower than Australia's highest annual yield of about 310 t in the late 1990s. By state, WA maintained the highest output of gold at 180 t, the same as in 2011. However, its share of production rose 2% to 72% as a result of reduced production in other states (Table 7). The NT was the only jurisdiction in 2012 to see an increase in gold output, up by just 1 t to 10 t. New South Wales gold production retained second position at 26 t, despite dropping by 4 t on the levels in 2011. Queensland had the third highest production at 15 t.

Table 7: Gold production by state/territory (rounded to the nearest tonne) since 2006. The NT was the only jurisdiction to achieve an increase in output while WA continued to dominate production. Sources: Australian Bureau of Statistics and the Bureau of Resources and Energy Economics.

Jurisdiction	**2006** (t)	**2007** (t)	**2008** (t)	**2009** (t)	**2010** (t)	**2011** (t)	**2012** (t)
Queensland	22	23	18	16	15	16	15
New South Wales	27	35	31	25	30	30	26
Victoria	6	6	5	8	7	5	4
Tasmania	5	4	5	4	4	4	3
South Australia	7	7	7	8	13	14	12
Northern Territory	14	17	15	10	10	9	10
Western Australia	165	156	134	152	181	180	180
Australia	**246**	**248**	**215**	**223**	**260**	**258**	**251**

Gold was a primary commodity output of about 75 mining and processing activities during 2012, with both open-pit and underground operations. As in 2011, about 20 operations also produced gold as by-product from processing other commodities, such as at Olympic Dam and the Nystar NV Port Pirrie smelter in SA, at Rosebery in Tasmania, at Northparkes in NSW and at Golden Grove in WA. During 2012, about six operations were placed on care and maintenance or closed, including two in WA: Stone Resources Australia Ltd's Brightstar plant near Laverton and Norseman Gold plc's operations at Norseman. At the end of 2012, more than 20 gold plants were idle, although, many of these have not operated for several years. With the sustained relatively high price of gold, at least 15 operations commenced or recommenced production, including Evolution Mining Ltd's Mount Carlton project and Ivanhoe Australia Ltd/Inova Resources Ltd's Osborne mine in Queensland, along with Doray Minerals Ltd's Andy Well project and Silver Lake Resources Ltd's Murchison (Tuckabianna) project in WA. A further three plants were undergoing construction or refurbishment, including AngloGold Ashanti Ltd/Independence Group NL's Tropicana project east of Laverton in WA.

Gold deposits can be grouped into a number of geological or metal association types with differing contributions to production and resources (Table 8). In 2012, lode-gold deposits of Archean age yielded 136 t or 54% of Australian mine production, more than double the next largest producing type, copper-gold deposits. Output in the year from all lode-gold types amounted to 161 t or 64% of mine production. In contrast, their contribution to EDR amounted to 3643 t or just 37% of the national total. Copper-gold deposits including porphyries produced the next highest quantity of gold at 63 t or about 25% of national mine production. Together with the iron oxide-copper-gold deposits (e.g., Olympic Dam), gold output in 2012 from copper-associated deposits amounted to 72 t or 29% of national production while their combined contribution to EDR was 5789 t or 58% of the national total. Production for the year from polymetallic (5 t) and other deposits, including epithermal and antimony-gold deposits, was relatively minor, totalling only 11 t. Polymetallic and other deposit's contribution to EDR was also proportionally small at only 4% or about 415 t.

Since 2010, the total gold production from all lode-gold deposits has amounted to about 530 t while the contribution to EDR from lode-gold deposits has grown by 880 t. During the same time period, iron oxide-copper-gold and other copper-gold deposits, including porphyries, have yielded just 214 t to total gold production. The growth of 400 t in the contribution to EDR from these types of deposits since 2010 was also less than the contribution from lode-gold deposits. However, it should be noted that there are significantly fewer copper-gold deposits (of all types) than lode-gold deposits, and the former types are dominated by several large examples, including Olympic Dam (SA), Boddington (WA) and the Cadia group (NSW). In the past, episodic substantial resource reviews at these large operations have caused more notable jumps in contribution to EDR in contrast to the more consistent year-on-year increases attributed to lode-gold deposits.

Table 8: Economic Demonstrated Resources, Inferred Resources and mine production of gold (in tonnes) for 2012 categorised by deposit type. Also shown are category percentages for respective total resource types and mine production. Lode gold deposits of Archaean age dominate current mine production, but lower grade copper-gold deposits of various styles comprise the majority of Australia's current resources. Other copper-gold/gold-copper deposits include Telfer and Boddington in WA and the porphyry-related mineralisation at Northparkes and Cadia in NSW. Data for the mine production figures were provided by Surbiton Associates Pty Ltd.

Deposit Type	EDR		Inferred Resources		Mine Production	
	Tonnes	%	Tonnes	(%)	Tonnes	%
Lode Au Archean	2668	26.9	1579	34.6	136	54.3
Lode Au Proterozoic	788	8.0	411	9.0	13	5.3
Lode Au Phanerozoic	187	1.9	610	13.3	12	5.0
Iron Oxide Cu-Au	2871	29.0	1127	24.7	10	3.9
Cu-Au (Other)	2918	29.4	567	12.4	63	25.2
Polymetallic base metals	258	2.6	145	3.2	5	2.0
Other	167	1.7	103	2.2	11	4.5

World Ranking

Based on estimates provided by the USGS and adjusted for Australian figures by Geoscience Australia, world economic resources of gold increased by approximately 1300 t or 3% in 2012 to 54 300 t. Australia, with EDR of 9909 t, or slightly more than 18% of world resources, has the largest share ahead of South Africa with 6000 t (11%), Russia with 5000 t (9%), and Chile with 2900 t (7%). Based on USGS figures, the world produced 2660 t of gold from mining in 2012, equating to about 5% of current resources. Australia's mine production of 251 t, or 9.4% of world production, was second to that of China with 370 t, but ahead of the USA with 230 t, Russia with 205 t and South Africa with 170 t. Over the past decade, world mine production has varied between 2260 t in 2008 and 2700 t in 2011. Over the same period, consistent increases in China's output from 185 t in 2001 to 370 t in 2012 have been offset by declining production in South Africa, which fell from 402 t to 170 t, Canada from 160 t to 102 t and the USA, which dropped from 335 t to 230 t. Estimated production rates for other countries over the same period are more irregular.

Industry Developments

Marginally increased mineral exploration expenditure and a largely sustained and elevated gold price maintained heightened activity in the gold industry throughout 2012. The following selected announcements provide a snapshot of industry activities in 2012.

Queensland

Altona Mining Ltd announced the results of a positive feasibility study for the **Little Eva** deposit in the **Roseby** project (copper-gold) northeast of Mount Isa. The company also stated that Xstrata plc intended to acquire a 51% interest in the project.

CuDecco Ltd obtained state government approval for development of the **Rocklands** project 15 km west of Cloncurry. The company also released an intersection of 20 m at 3.1 g/t Au and 76.7 g/t Ag from the **Wilgar** prospect within Rocklands.

Evolution Mining Ltd advised that it had begun commissioning of its 800 000 tpa processing plant at **Mount Carlton** east of Charters Towers.

Ivanhoe Australia Ltd (now Inova Resources Ltd) recommenced production of copper-gold concentrate and poured its first gold at **Osborne** south of Cloncurry. The company also announced the results of scoping studies of the **Mount Elliott** and **Swan** copper-gold deposits north of Osborne.

Malachite Resources Ltd and BCD Resources NL announced a joint development plan for the **Lorena** deposit east of Cloncurry.

Resolute Mining Ltd completed a feasibility study for re-opening of its **Sarsfield** open pit at Ravenswood.

Xstrata advised that mining had commenced at its **E1** and **Monakoff** copper-gold deposits at its **Mount Margaret** mining project northeast of Cloncurry.

New South Wales

Cortona Resources Ltd (now merged with Unity Mining Ltd) received final regulatory approvals for the development of **Dargues Reef** gold mine south of Braidwood.

Polymetals Mining Ltd stated that it had received development consent for its **Mount Boppy** gold mine at Canbelego east of Cobar.

Regis Resources Ltd acquired the **McPhillamys** gold deposit southeast of Orange from Alkane Resources Ltd and Newmont Exploration Ltd.

Resource Base Ltd commenced production of gold from the **Broulia King** gold mine southwest of Cowra.

TriAusMin Ltd announced that the retreatment of tailings at the **Woodlawn** mine south of Goulburn would proceed.

White Rock Minerals Ltd released the results of a scoping study for the **Mount Carrington** silver-gold deposits near Drake.

YTC Resources Ltd advised that it had completed a $155 million funding arrangement with Glencore International for the construction of the **Hera** and **Nymagee** projects southeast of Cobar.

Victoria

Crocodile Gold Corporation acquired from AuRico Gold Inc the **Fosterville** and **Stawell** gold mines, northeast of Bendigo and two kilometres from Stawell respectively.

GBM Gold Ltd placed its **Inglewood** plant in central Victoria on care and maintenance.

Morning Star Gold NL produced its first gold from the **Morning Star** mine at Woods Point.

Octagonal Resources Ltd commenced mining of the **Black Reef** open pit at Wehla and began reprocessing tailings from Unity Mining Ltd's **Kangaroo Flat** mine in Bendigo.

Tasmania

Bass Metals Ltd placed the **Hellyer** operation southeast of Waratah on care and maintenance.

BCD Resources NL recovered the final parcel of ore from the **Tasmania** mine, Beaconsfield, and commenced reprocessing tailings from the **Lefroy** mine north of Launceston.

Frontier Resources Ltd intersected 7.7 m at 5.39 g/t Au and 0.19% Bi at **Stormont** southwest of Devonport.

Unity Mining intersected 3.15 m at 268.7 g/t Au from the Read Zone at **Henty** gold mine south of Rosebery.

Northern Territory

ABM Resources NL released the results of a scoping study of **Old Pirate** southwest of Tanami. The company also announced intersections including 42 m at 44.2 g/t Au and 20 m at 10.59 g/t Au from the adjacent **Golden Hind** prospect.

Crocodile Gold Corporation completed mining of the **West Howley** pit and commenced mining of the **North Point** pit northwest of Pine Creek. The company also received approval for the redevelopment of the **International** pit at Pine Creek.

Tanami Gold NL substantially upgraded the resource at **Groundrush** northeast of Tanami to just over 1 Moz of contained gold at an average grade of 4.2 g/t Au.

South Australia

Mungana Goldmines Ltd purchased the **Tunkillia** gold mine south of Tarcoola from Minotaur Exploration Ltd. The company also announced a drill intersection of 20 m at 134.1 g/t Au from the deposit.

Exco Resources Ltd and Polymetals Mining Ltd advised that the **Vertigo** project northeast of Olary would be developed and that mining had ended at the adjacent **White Dam** deposit.

Rex Minerals Ltd completed a prefeasibility study of the **Hillside** deposit on Yorke Peninsula.

Trafford Resources Ltd announced an intersection of 93 m at 1.59 g/t Au at the **Weednanna** prospect in its **Wilcherry Hill** project north of Kimba.

Western Australia

Barra Resources Ltd commenced mining at its **Newminster** deposit northwest of Coolgardie.

Doray Minerals Ltd commenced mining at its **Andy Well** project north of Meekatharra.

Integra Mining Ltd announced that trial mining was to commence at **Cock-eyed Bob** southeast of Kalgoorlie and first ore was produced from the adjacent **Maxwells** open cut.

Metals X Ltd acquired Westgold Resources Ltd and released the results of a feasibility study on its **Central Murchison** project.

Mutiny Gold Ltd completed a feasibility study on its **Deflector** deposit southwest of Yalgoo.

Nex Metals Explorations Ltd commenced mining at its **Butterfly** open pit at the company's **Kookynie** gold project 200 km north of Kalgoorlie.

Northern Star Resources Ltd advised that it had increased plant capacity to 450 000 tpa at its **Paulsens** gold mine in the Ashburton.

Phoenix Gold Ltd commenced mining at **Catherwood** north of Coolgardie.

Ramelius Resources Ltd completed mining at **Wattle Dam** northwest of Widgiemooltha.

Reed Resources Ltd commenced commissioning of its **Bluebird** plant at Meekatharra.

Regis Resources Ltd completed a feasibility study and announced plans to develop the **Rosemont** deposit north of Laverton.

Saracen Mineral Holdings Ltd commenced mining at **Red October** south of Laverton.

Silver Lake Resources Ltd completed the expansion of its **Lakewood** plant south of Kalgoorlie to 900 000 tpa and commenced mining at its **Murchison** project.

First gold was poured by Kentor Gold Ltd at **Burnakura** in the Murchison, Millennium Minerals Ltd at **Nullagine**, Ramelius Resources Ltd at **Mount Magnet** and Regis Resources Ltd at **Garden Well** northeast of Laverton.

Kalgoorlie Mining Company Ltd suspended mining at its **Bullant** mine north of Coolgardie.

Norseman Gold plc entered voluntary administration and ceased operations at **Norseman**.

Stone Resources Ltd advised that its **Brightstar** plant southeast of Laverton had been placed on care and maintenance.

Iron Ore

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Iron (Fe) is a metallic element which constitutes about 5% of the Earth's crust and is the fourth most abundant element in the crust. Iron ores are rocks from which metallic iron can be economically extracted. The principal iron ores are hematite (Fe_2O_3) and magnetite (Fe_3O_4).

Hematite is an iron oxide mineral. It is non-magnetic and has colour variations ranging from steel-silver to reddish brown. Pure hematite mineral contains 69.9% iron. It has been the dominant iron ore mined in Australia since the early 1960s. Approximately 96% of Australia's iron ore exports are high-grade hematite, most of which has been mined from deposits in the Hamersley province in Western Australia. The Brockman Iron Formation in the Hamersley province is a significant example of high grade hematite iron ore deposits.

Magnetite is an iron oxide mineral which is generally black and highly magnetic, the latter property aiding in the beneficiation of magnetite ores. Magnetite mineral contains 72.4% iron, which is higher than hematite but the presence of impurities results in lower ore grade, making it more costly to produce the concentrates that are used in steel smelters. Magnetite mining is an emerging industry in Australia with large deposits being developed in the Pilbara region of WA.

At the end of 2012, the two major magnetite projects, the Sino Iron and Karara projects were commissioned, with the Karara project officially opened in April 2013. The Karara project is in the ramp-up stage to achieve a target capacity of 8 Mtpa.

Mining and processing hematite and magnetite ores

High-grade hematite ore is referred to as direct shipping ore (DSO) because it is mined and the ores go through a relatively simple crushing and screening process before being exported for use in steel-making. Australia's hematite DSO from the Hamersley region averages from 56% to 62% iron. Like hematite ores, magnetite ores require initial crushing and screening, but undergo a second stage of processing which relies on the magnetic properties of the ore and involves magnetic separators to extract the magnetite and produce a concentrate.

Further processing involves the agglomeration[2] and thermal treatment of the concentrate to produce pellets that can be used directly in blast furnaces, or in direct-reduction steel-making plants. The pellets contain 65% to 70% iron, which is a higher iron grade than hematite DSO currently being exported from the Hamersley region. Additionally, when compared to hematite DSO, the magnetite pellets contain lower levels of impurities, such as phosphorous, sulphur and aluminium. These magnetite pellets are premium products that attract higher prices from steel makers, offsetting the higher costs of production.

Worldwide production trends

Hematite ores dominate the world production of iron ores and are sourced mainly in Australia and Brazil. Magnetite ore has established its presence in world production and contributes to the increase in Australia's EDR mainly as a result of the commissioning of large magnetite projects in WA, as well as numerous magnetite developments in South Australia. More than 90% of SA's iron ore is magnetite. The world's production of iron ore for 2012 was dominated by Australia with 27% or 520 Mt, followed by Brazil with 19% or 375 Mt and China with around 14% or 281 Mt.

Resources

Australia's iron ore reserves and resources are in both hematite and magnetite ores. Because of the high average grades (% Fe) of hematite ores when compared to the average grades for magnetite ores, it is necessary to report national resources in terms of contained iron. The national resource estimate for iron ore are reported in two categories namely:

- Tonnes of iron ore, and
- Tonnes of contained iron.

2 Agglomeration is the process in which magnetite grains are aggregated into pellets using a chemical binding reagent. Pellets are produced in a pelletising plant.

This form of reporting is mainly because of an increase in magnetite resources resulting from ongoing exploration and assessment of known and new magnetite deposits.

Economic Demonstrated Resources of iron ore in 2012 increased by 18% to 44 650 Mt. The Pilbara EDR had a 3% increase during the 2012 period. The volatility of the iron ore price during 2012 resulted in deferrals of ongoing exploration and development for some major iron ore projects in the Pilbara region. Based on GA's assessment, a 17% increase in Pilbara Inferred Resources indicates that, in this current economic environment, exploration activities were confined to minimal exploration drilling aimed at defining Inferred Resources at new deposits. During 2012 in the Yilgarn region of Western Australia, EDR increased by approximately 23% compared with 2011 indicating more resource definition and development activities in the region.

During the same period, South Australia has increased its EDR by 79% from 2011 contributing to the overall increase in Australia's iron ore EDR (SA's EDR which is mostly magnetite ore amounts to approximately 8% of Australia's iron ore EDR for 2012). The national EDR for magnetite is approximately 19 282 Mt. Australia's iron ore AEDR has a resource life of 86 years.

Contained Iron: As at December 2012, Australia's EDR of contained iron was estimated to be 20 638 Mt while Paramarginal Resources were 224 Mt and Inferred Resources were 33 851 Mt.

Figure 11 shows major Australian hematite iron ore deposits. Figure 12. Detailed maps with total resources of Australia's hematite and magnetite deposits are also available as free downloads at:

- https://www.ga.gov.au/image_cache/GA21217.pdf
- https://www.ga.gov.au/image_cache/GA21218.pdf

Accessible EDR

Australia has AEDR of iron ore totalling 44 650 Mt, of which 91% occurs in WA.

JORC Reserves

The total JORC Code reserves of iron ore were estimated to be 15 305 Mt, representing 34% of AEDR. The JORC Reserve of contained iron is 7931 Mt, or 38% of the EDR for contained iron. However, unreported reserves and resources are not included. Based on the data which is publicly available, JORC Code reserves are sufficient for approximately 29 years at the current rate of mine production.

The increase in EDR during 2012 is mainly the result of an increase and reclassification of resources at iron ore projects being developed. Initial resources from new deposits also contributed to the EDR. These include the Jimblebar mine project by BHP Billiton Ltd, which reported an increase of approximately 499 Mt on its Brockman ore reserves. Macarthur Minerals Ltd's Lake Giles hematite project deposits, Banjo, Snark, Central DSO and Drabble Downs, all reported an increase and upgrade of resources to JORC Code reserves. Atlas Iron Ltd's Mount Webber and Abydos project deposits also reported an increase in EDR for 2012. Rocklea deposit owned by Dragon Energy Ltd also increased and upgraded its Inferred Resource to Indicated. Fortescue Metals Group Ltd's Christmas Creek and Cloudbreak has also reported an increase of its EDR to approximately 347 Mt for 2012. There were new resources for Red Dragon project's Iron Peak (Indicated Resource of 213 Mt at 21% Fe) and an increase in resources for Razorback Ridges (Indicated Resource of 980 Mt at 21.6% Fe) deposits during 2012.

Exploration Expenditure

Australian Bureau of Statistics data indicates that mineral exploration expenditure in Australia for 2012 totalled $3655.8 million, a 2% increase on the $3573.3 million spent in 2011. About $1040.8 million was spent on iron ore exploration in WA, which represented 91% of Australia's total iron ore exploration expenditure. Western Australia also accounted for 56% of total mineral exploration expenditure in Australia during 2012 of around $2052 million. Iron ore exploration expenditure in SA was $79.7 million, the Northern Territory $10.4 million and Tasmania $6.8 million.

Production

Australia's total production of iron ore for 2012 was 520 Mt with WA producing 505 Mt, or 97% of overall production. South Australia had a slight increase in its iron ore production from approximately 10 Mt in 2011 to 10.7 Mt in 2012, representing 2% of Australia's total iron ore production. South Australia's iron ore resource is small when compared to WA, but it is emerging to become Australia's second major iron ore producing state.

The Bureau of Resources and Energy Economics reported Australia's iron ore exports during 2012 to be 494 Mt, a 13% increase on 2011 figure of approximately 439 Mt. BREE has forecast an increase in iron ore exports to approximately 571 Mt or 16% in 2013 with project expansions by companies such as Rio Tinto, BHP Billiton and Fortescue Metals Group supporting the projected increase. Major consumers of Australia's iron ore exports are developing countries such as China and India. BREE forecasts an increase in steel consumption in China of 4% to 725 Mt coinciding with development of the Chinese Government's infrastructure program.

World Ranking

Australia has the world's largest iron ore EDR with 25%, followed by Brazil with 17%, Russia with 14% and China with 13%. In terms of contained iron, Australia has 25% of world EDR while Brazil has the second largest EDR with 19%.

Industry Developments

Western Australia

Rio Tinto Ltd: The company reported an increase of 4% or 239 Mt in production at its Pilbara mine operations in 2012. The increasing production is likely to continue as new mines, such as the new operation at **Hope Downs 4** are commissioned. Mines that were included in the expansion are **Marandoo** mine, which is expected produce 15 Mtpa for an extended mine life of approximately 16 years and **Yandicoogina** mine which will increase capacity to 56 Mtpa by 2021.

BHP Billiton Ltd: The company's WA Iron Ore Rapid Growth 5 project is among six major projects approved during 2012 achieved its first production in the same year. Included with the approved projects is **Orebody 24**, which commenced production in late 2012. Budget capital expenditure for the Orebody 24 project is US$698 million with the project production maintaining the company's Newman joint venture output.

Fortescue Metals Group Ltd (FMG): FMG has reported the resumption of the **Kings Deposit** development to become the company's second mine at its **Solomon Hub** operation. Kings mine will produce approximately 40 Mtpa, contributing to the company's production capacity target of 155 Mtpa by the end of 2013. The most recent estimate (2011) of Kings Deposit reserves was 257.9 Mt at 55.8% Fe.

Atlas Iron Ltd: The company has announced significant increases in reserves from its three projects, **McPhee Creek**, **Abydos** and **Mount Dove**. The increase also included an upgrade of resources for **Mount Webber**. The increase was the result of infill and extension drilling to some of the project's deposits, including **Main Range** (at McPhee Creek), **Mettams**, **Mullaloo**, **Scarborough** and **Leightons** at the Abydos Project. Similarly, an upgrade to the Mount Webber Project resource was generated through an increase in resource from the project's **Dalton**s deposit. Atlas and its joint venture partner, Altura Mining Ltd, have announced the development of the Mount Webber mine, which is to become Atlas Iron's fifth DSO mine in the Pilbara. Other Mount Webber DSO deposits include **Ibanez**, **Fender** and **Gibson**.

Gindalbie Metals Ltd: The first magnetite concentrate from the company's **Karara** magnetite project was produced in late 2012 and approximately 55 000 t was shipped in early January 2013. The company stated that the commissioning and the ramping up of production will continue to progress over the coming months, with the aim of achieving a production target of 8 Mtpa.

For project development, Gindalbie has announced the commencement of feasibility studies for its **Hinge** and **Shine** DSO deposits. The Hinge deposit is 11 km north of the company's direct shipping hematite ore mining of the **Terapod** deposits.

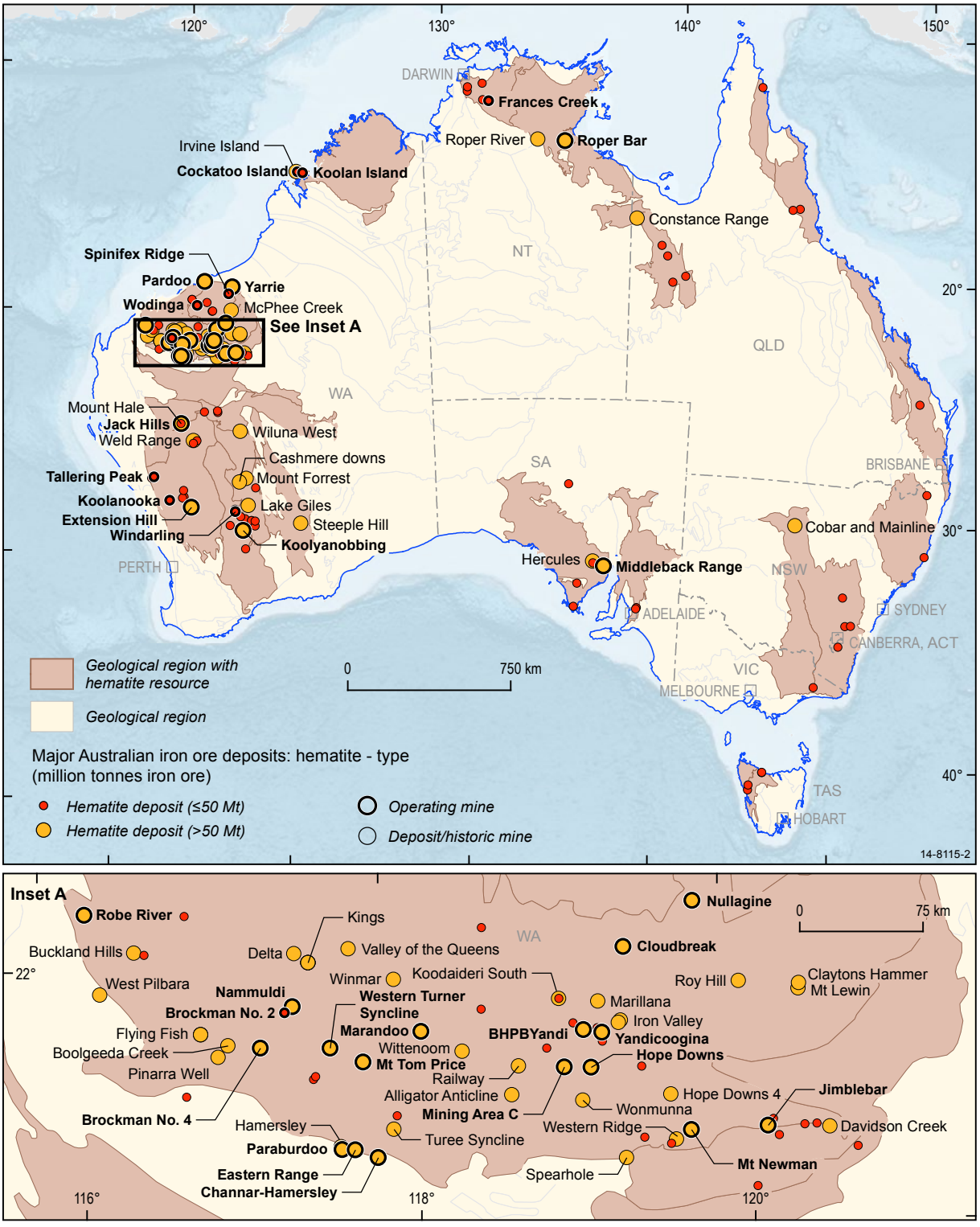

Figure 11: Major Australian hematite iron ore deposits.

Figure 12: Major Australian magnetite iron ore deposits.

Brockman Resources Ltd: The company reported a series of initial resources for its **Opthalmia** iron project at the Kalgan Creek, Siruis and Coondiner tenements and the Palla and Castor deposits. The total mineral resource at the Ophthalmia iron project is approximately 290 Mt at 59.10% Fe. The company stated that there is great potential for an increase in resources for the Ophthalmia project resulting from the consolidation of its newly acquired tenements at Coondiner area. Importantly, Brockman Resources says that Ophthalmia's increased resource tonnages will warrant the company's proposed independent railway. The Ophthalmia project is approximately 80 km southeast of the company's **Marillana** iron project.

Mindax Ltd: The company reported that its **Mount Forrest** Project phase 2 drilling program had reportedly identified four areas of detrital mineralisation. The project is located in Yilgarn region about 650 km from the Port of Esperance. As previously reported, one of the project's potential products is the beneficiated hematite DSO. It also reported an aggregated regolith (goethite-hematite-martite-magnetite) JORC Code Indicated Resource of approximately 12.3 Mt at 45.5% Fe for Mount Forrest.

Iron Ore Holdings Ltd: An initial Ore Reserve of 134 Mt at 58.5% Fe was reported for the company's **Iron Valley** project. The reported reserve is part of the total JORC Code mineral resources of approximately 259.1 Mt at 58.3% Fe. The project has successfully obtained a mining approval from the WA Department of Mines and Petroleum. An early mine development of the Iron Valley deposits has been indicated by Iron Ore Holdings Post Mine Gate Agreement with Mineral Resources Ltd.

Pluton Resources Ltd: An initial shipment of iron ore from its **Cockatoo Island** mine operation in late 2012 has been reported. Cockatoo Island stage 4 has a global resource of 10.8 Mt exclusive of a JORC Code Probable Ore Reserve of 1.2 Mt at 68% Fe. Progress on development work for the company's **Irvine Island** iron project continues with announced project JORC Code reserves of approximately 143 Mt at 28% Fe.

BC Iron Ltd: An increase of reserves to 10 Mt and resources of around 108.7 Mt were reported for the company's **Nullagine** Joint Venture Outcome 1 & 2 deposits in the Pilbara during 2012. The production capacity target rate of 5 Mtpa was achieved and exported in 2012.

Jupiter Mines Ltd: Feasibility studies at the company's **Mount Mason** DSO hematite deposit are in progress for development into a DSO mine. The initial scoping study for Mount Mason project envisages production of 1.5 Mtpa for an approximate four-year mine life.

Aquila Resources Ltd: The company has reported maiden Inferred Resources for its **Kumina Creek** deposit of 102 Mt at 57.3% Fe and its **Headon** deposit with 97 Mt at 53.9% Fe which both occur within the company's West Pilbara Iron Ore Project. A resource update for the company's **Hardy Bedded** iron deposit has resulted in an increase in the Measured Resource during 2012. The Hardy Bedded deposit forms part of the company's proposed Stage 2 development of the West Pilbara Iron Ore Project.

Dragon Energy Ltd: The mining lease approval for the company's Pilbara Iron Project was announced in May 2013. Dragon Energy states that the mining lease covers **Rocklea's** "North" and "Central" channel iron deposits. North and Central deposits have a combined JORC Code compliant resource of approximately 93.6 Mt at an average grade of 52% Fe. The resource is inclusive of Inferred Resources of 14.66 Mt at 51.24% Fe.

Mount Gibson Iron Ltd: The **T1** deposit with an estimated Reserve of 801 000 t at 61% Fe was reported, with project commencement of production in September 2013. The deposit is located 1 km east of the company's **Tallering Peak** iron ore mine. Mining at Tallering Peak is scheduled to cease in the middle of 2014 and mining of T1 is expected to conclude later in the same year. Tallering Peak Iron Ore mine operation is 260 km east of Geraldton, WA.

Radar Iron Ltd: The company's primary focus is to define the hematite resource at its Johnston Range Iron Ore Project in the Yilgarn region. An initial JORC Code Inferred Resource for the project's **Muldoon** prospect of 2.1 Mt at 57.6% Fe with a cut-off of 55% was announced in 2012. Radar Iron states that the Johnson range area has the potential to host numerous hematite enriched deposits.

South Australia

Royal Resources Ltd: An increase in Inferred Resources was reported at the company's **Ironback Hill** prospect to 1187 Mt at 21% Fe. Ironback Hill prospect is located within the company's Red Dragon Venture. The company said that the resource increase had brought the total resources for Red Dragon Venture to three billion tonnes and included the **Razorback** Premium Iron Project Indicated and Inferred Resource of 1815 Mt at 21% Fe. Prefeasibility study works were conducted for the company's Razorback Premium Iron Project during 2012.

Iron Road Ltd: The Definitive Feasibility Study for the company's Central Eyre Iron Project (CEIP) is progressing. A major part of the study is to extract 110 Mtpa of magnetite ore for a potential mine life of more than 30 years. The drilling program in 2012 at the CEIP's **Rob Roy** prospect has increased the CEIP mineral resource of magnetite gneiss to 2597 Mt at 16% Fe.

Arrium Ltd: The company reported the sale of 12 Mtpa iron ore from its **Southern Iron** and **Middleback Ranges** mine operations and said it aimed to maintain the sales capacity for at least 10 years. In support of the company's objectives, increased exploration drilling is being conducted for resource definition at existing mine operations, including at **Iron Princess**, **Iron Monarch** and **Iron Chieftain North** prospects at the northern end and south of the Middleback Ranges. In addition, at the company's Southern Iron Project, resource definition drilling is being conducted at Hawks Nest Buzzard and **Tui** deposits. As at 30 June 2013, Middleback Ranges Hematite has reported total Reserves of 42.2 Mt at 58.3% Fe. Magnetite Ore Reserves for Middleback Ranges is approximately 66.3 Mt at 38.9% Fe. Southern Iron project has also reported total hematite reserves of approximately 24.5 Mt at 62% Fe, consisting of reserves for Hawks Nest deposits (Buzzard and Tui) and for **Peculiar Knob** deposits.

Centrex Metals Ltd: The company's joint venture Bungalow Magnetite project has reported an upgrade of resources amounting to a combined JORC Code Measured, Indicated and Inferred Resource of approximately 338 Mt at 31% Fe. The combined JORC Code mineral resource consists of **Minbrie** deposit's Inferred Resource of 99 Mt at 27% Fe and **Bangalow** deposit's Measured Resource of 22.3 Mt at 29.1% Fe, Indicated Resource of 163.5 Mt at 30.5% Fe and Inferred Resource of 53.3 Mt at 31.9% Fe. The project's prefeasibility study is progressing and is due to be completed sometime in 2013.

The company's Fusion Magnetite joint venture project has also reported an increase in resources from its **Koppio**, **Brennand** and **Kapperna** (KBK) deposits to a combined total of 652.7 Mt at 24.7% iron. Centrex reports that mining and project studies are currently being conducted at these deposits. They are planned to become the start-up mines for the Fusion project.

IronClad Mining Ltd: The drilling program commenced at the company's **Hercules** prospect approximately 15 km southeast of its **Wilcherry Hill** iron ore project. The program aims to intersect near-surface, low strip ratio mineralisation with the grade being suitable as DSO or for upgrade through simple beneficiation products. The development of the Hercules deposits is part of the company's overall three-stage mining development plan which involves stage 1 mining and shipping of DSO and stage 2 processing and shipping of non-DSO from the company's Wilcherry Hill project.

Apollo Minerals Ltd: The scoping study result for the company's Commonwealth Hill Iron Project's **Sequoia** deposit has reportedly confirmed the economic potential for development. Apollo Minerals reports that the study was based on the Sequoia deposit JORC Code compliant mineral resource of 72 Mt at 25.9% Fe. The study assumed a production capacity of 2.5 Mtpa for a proposed mine life of approximately 17 years.

New South Wales

Carpentaria Exploration Ltd: A small-scale processing pilot-plant study for the company's **Hawsons** Iron Project was initiated during 2012 with positive test results being quantified for the coming launch of a Bankable Feasibility Study and full-scale pilot-plant test studies. The Hawsons Iron Project, which is located 60 km south-west of Broken Hill, has an Inferred magnetite resource of approximately 1400 Mt at Davis Tube Recovery (DTR[3]) rate of 15.5% using a 12% cut-off. This represents 220 Mt of high-grade iron concentrate averaging 69.9% Fe.

An additional highlight for the company is the declaration by the NSW Government that the Hawsons Iron Project is a "State Significant Development" project, which represents a significant initial step toward granting a mining lease.

Tasmania

Grange Resources Ltd: The company's **Savage River** magnetite mineral resource was reported at 30 June 2012 to be 343.7 Mt at 51.3% DTR. In the company's 2012 annual report, it stated that the increase resulted from the inclusion of estimated minerals resource of 48.8 Mt at 44.6% DTR for its **Long Plains** deposit approximately 10 km south of Savage River. The company anticipates an extended mine life for Savage River of three to five years.

Shree Minerals Ltd: The company has received approval from the Circular Head Council and Environmental Protection Authority to develop its **Nelson Bay River** Iron Project. A mining lease was granted also by Mineral Resources Tasmania during the September quarter of 2012. The project mine plan includes mining DSO iron ore through two separate open-cut mines during the first two years of operation. The company has reported DSO reserves of 0.33 Mt at 57.4% Fe. Mining of the magnetite ore which underlies the oxide cap (DSO) will be conducted at stage 3 of the mine development plan. On 29 February 2012, the company announced that its Nelson Bay River Iron Project had estimated magnetite resources of approximately 7.8 Mt at 38% DTR using a 20% cut off.

Northern Territory

Sherwin Iron Ltd: The company's **Roper River** Iron Ore Project was progressively working towards production during 2012. In addition to the lodgement of the mining lease for deposit C within the **Sherwin Creek** prospect, the company reached agreement with the Northern Land Council in regard to mining at the Roper River Iron Ore project, which also was awarded a major project status by the Northern Territory Government. As at 30 June 2013, the Roper River Iron Ore Project had an overall mineral resource of approximately 488 Mt at 41.7% Fe, inclusive of Inferred Resources of approximately 432.4 Mt at an average grade of 31.4% Fe. The project is located approximately 120 km east of Mataranka and 475 km southeast of Darwin.

Western Desert Resources Ltd: The company reported that during 2012, regulatory requirements, including the Environmental Impact Statement, were granted by the Federal Minister for Environment for its **Roper Bar** Iron Ore project. The company has also reported an upgrade to some deposits, bringing a current overall resource total of approximately 611 Mt at an average grade of 40.3% Fe, inclusive of DSO resource for **Area F** of 30.8 Mt at 59% Fe and **Area E** of 16.6 Mt at 54.2% Fe.

Victoria

Eastern Iron Ltd: The company has reported the completion of scoping studies at its **Nowa Nowa** Iron Project with results indicating the project has potential for development. The project has several deposits of hematite and magnetite including the **Five Mile** and **Seven Mile** deposits which, as at September 2012, had a combined mineral resource of 6.8 Mt at 50.4% Fe. The Nowa Nowa project is approximately 270 km east of Melbourne.

3 Davies Tube Recovery (DTR) testing is a laboratory technique that uses a Davis Tube to recover magnetic particles from an ore sample. The per cent mass recovery of magnetic material is determined from the mass of sample recovered compared to the mass of the initial sample. The recovered magnetic and non-magnetic portions can be analysed for chemical composition.

Lithium

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Lithium (Li) is recovered from both mineral deposits, largely from the mineral spodumene ($Li_2O.Al_2O_3.4SiO_2$) and from salts, largely from lithium-rich brines in salt lakes. Lithium has a range of uses in both chemical and technical applications.

Lithium in various forms, such as lithium carbonate, lithium hydroxide and lithium chloride, is used in lubricant greases, pharmaceuticals, catalysts, air treatment and particularly in batteries both non-rechargeable (primary) lithium batteries and rechargeable (secondary) Li-ion batteries. Demand for lithium has expanded significantly in recent years as a result of its increasing use in rechargeable batteries for portable electronic devices, such as mobile phones, computers and rechargeable power tools, as well as in batteries and electric motors for electric bikes, hybrid and electric passenger cars, and other vehicles.

The major technical application for lithium is for production of ceramics and glasses, including heat-resistant glass and ceramics such as those used in oven wear and cook tops. It is also used in fluxes and glazes. Lithium is also used in alloys to increase strength to weight ratios, taking advantage of lithium's strength and light weight (low-density) characteristics. Aluminium-lithium alloys, for example, are used in the aerospace and motorsport industries.

For location of lithium deposits refer to Figure 20 in the tin chapter.

Resources

Australia's EDR of lithium in 2012 were estimated to be 1538 kt, which represents a 50% increase on the 1006 kt of lithium in 2011. All EDR occur within hard-rock pegmatite deposits. Most of Australia's lithium resources are in the Greenbushes Lithium Operations spodumene deposit, 250 km south of Perth in Western Australia, and the bulk of the growth in Australia's EDR of lithium reflect a large increase of resources at this deposit. The Greenbushes Lithium Operations is the world's largest and highest grade spodumene deposit. Other EDR of lithium occur at Mount Marion about 40 km southwest of Kalgoorlie, Mount Cattlin, about 2 km north of Ravensthorpe, and Pilgangoora, 120 km south of Port Hedland, all in WA. Resources at Mount Marion amount to about 45 kt while resources at the Mount Cattlin are around 70 kt and resources at the Pilgangoora deposit total approximately 100 kt.

In 2012, Subeconomic Resources of lithium, all in the submarginal category and all in WA, total less than 1 kt.

Inferred Resources of lithium total about 139 kt, a slight increase from the 131 kt in 2011. All the Inferred Resources are associated with the Greenbushes, Mount Cattlin, Mount Marion and Pilgangoora pegmatite deposits, except for 4 kt in the Narraburra rare earth and rare metals project, 12 km northeast of Temora in New South Wales.

Accessible EDR

All of Australia's EDR of lithium is accessible.

JORC Reserves

JORC Code reserves comprise total lithium in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC code reserves of 854 kt accounted for about 55% of Australia's AEDR This compares with JORC Code reserves of 506 kt in 2011. At Australia's 2012 rate of spodumene production, lithium reserves in the JORC Code categories are adequate for more than 65 years.

Exploration

There are only a few companies exploring for lithium, mainly in WA, but no statistics are available on exploration expenditure.

Production

Production figures based on company reports indicate 2012 production of spodumene concentrates was about 452 kt, an increase of approximately 7% on 2011. Assuming a 6% Li_2O grade (true value between 4.8% and 7.5%), the 2012 production equates to about 12.7 kt of contained lithium.

World Resources

According to estimates by the USGS, which have been modified by Geoscience Australia for Australia's resources, world lithium resources in 2012 totalled about 13 538 kt. The resource data does not include Canada. Chile holds approximately 7500 kt, or about 56% of the total world resources, followed by China with 3500 kt (about 26%), Australia with 1538 kt (11.4%), and Argentina with 850 kt (6.3%).

Lithium resources occur in two distinct categories, lithium minerals and lithium-rich brines. Canada, China and Australia have significant resources of lithium minerals, while lithium brine is produced predominantly in Chile, followed by Argentina, China and the USA. Lithium brines are the dominant feedstock for lithium carbonate production. All Australia's current resources and production are from lithium minerals.

World production in 2012 was estimated by the USGS to be 37 kt of contained lithium, excluding the USA production (commercial reasons). Chile produced about 13 kt (35.4%) to remain the world's largest producer in 2012 followed closely by Australia (34.6%), China (16.4%) and Argentina (7.4%).

Industry Developments

According to various industries reports, the estimated global demand for lithium in 2012 was expected to be between 137 000 and 150 000 t of lithium carbonate equivalent, approximately 10% more than the previous year. The primary growth in demand was in lithium batteries, glass and ceramics. Within the lithium battery sector, growth areas were in batteries for laptops, mobile phones and other personal electronic devices. Demand for lithium in the electric vehicles segment is forecast to grow exponentially from 2014 onwards as major global car manufacturers launch new models to secure market share. The subsidies provided by some governments, including various legislations on fuel emissions to promote less reliance on fossil fuels and a cleaner environment, is expected to encourage consumers to gradually move into hybrid, plugin-hybrid or fully electric vehicles.

In Australia, Talison Lithium Ltd, the world's largest producer of hard-rock spodumene, produces two categories of lithium concentrates at the **Greenbushes** Lithium Operations in WA:

- Technical-grade lithium concentrates with low iron contents, primarily for feedstock for the glass and ceramic industries
- High-yielding chemical-grade lithium concentrate used to produce lithium chemicals.

In early 2011, Talison announced an expansion to 740 000 tpa lithium concentrate at the Greenbushes Lithium Operations involving a new purpose-built chemical-grade production facility at a cost of about $70 million. This plant was commissioned in mid-2012 and officially opened in August 2012. Talison is also evaluating the construction of a 20 000 tpa lithium-carbonate conversion plant in Australia to produce battery-grade lithium carbonate from lithium concentrates produced at their Greenbushes operations. Preliminary studies into the proposed plant were completed in 2011 with Kwinana, WA, chosen as the preferred location.

In September 2012, the company reported a large increase in combined Measured and Indicated Resources of 118.4 million tonnes (Mt) grading 2.4% Li_2O, containing Proven and Probable lithium reserves of 61.5 Mt grading 2.8% Li_2O.

In early 2013, Talison was acquired by the Chinese privately-owned company Chengdu Tianqi Industry (Group) Co Ltd (Tianqi) through its Australian incorporated, wholly-owned subsidiary, Windfield Holdings Pty Ltd. Tianqi's subsidiaries include Sichuan Tianqi Lithium Industries, the world's largest lithium chemical producer from spodumene, and Sichuan Tianqi Industry Co Ltd, which distributes technical grade lithium concentrates and is the sole distributor for Talison's technical grade lithium concentrate in China. The successful action by Tianqi followed the termination in late 2012 of a prior takeover agreement Talison had entered in August 2012 with Rockwood Holdings, a US-based specialty chemicals and advanced materials company, which includes Rookwood Lithium, a lithium producer from brines at operations in Chile and in Nevada (USA).

In March 2013, Galaxy Resources Ltd signed a three year agreement with Talison for supply of spodumene feedstock to Galaxy's wholly-owned Lithium Carbonate Plant in the Jiangsu Province in China. Under this agreement, from July 2013, Galaxy will purchase spodumene feedstock from Talison, rather than producing the feedstock itself from its **Mount Cattlin** lithium-tantalum mine (hard-rock spodumene) near Ravensthorpe in WA. Operations, which were temporarily stopped at Mount Cattlin in July 2012 (the mine had a year's supply of spodumene feedstock stockpiled for Jiangsu operations), will remain suspended until further notice.

In February 2011, the Mount Cattlin deposit had a reported JORC Code compliant resource of 18 188 kt at an average grade of 1.08% Li_2O and 156 g/t tantalum pentoxide (Ta_2O_5), containing an estimated 197 kt of Li_2O and 2845 t of Ta_2O_5, based on a cut-off grade of 0.4% Li_2O. These figures include (at December 2011) JORC Code compliant Proven Reserves of 2803 kt at 1.09% Li_2O and 136 g/t Ta_2O_5 and Probable Reserves of 7933 kt at 1.03% Li_2O and 150 g/t Ta_2O_5.

Prior to suspending operations, the Mount Cattlin deposit had mined 616 714 t of ore grading 1.11% Li_2O for 63 863 t of spodumene grading 6.18% Li_2O. The company had also produced 464 t of tantalum concentrate grading 3.3% contained Ta_2O_5. In full production, the Mount Cattlin project will produce 137 000 tpa of 6% Li_2O spodumene concentrate and about 25 t of tantalite concentrate for an expected mine life of 16 years. The company has commenced preliminary equipment design to reduce mica content in the spodumene end-product and to produce a saleable mica by-product. It has shipped a 10 t trial shipment of mica from its Mount Cattlin operation.

Reed Industrial Minerals Pty Ltd, which is 70% owned by Reed Resources Ltd and 30% by Mineral Resources Ltd, continues to advance the **Mount Marion** lithium project, 40 km southwest of Kalgoorlie, WA. Both companies have received approval for the final mining proposal from the Western Australian Department of Mines and Petroleum, allowing construction of the minerals processing plant at Mount Marion. Mine production is expected at an initial rate of 200 000 tpa of 6% Li_2O chemical-grade spodumene concentrate, containing about 12 000 t of Li_2O. It is envisaged that the mining will also produce 60 000 tpa of muscovite and 30 tpa of tantalite concentrate.

The joint venture partners are evaluating the economics of producing by-product high-grade mica and have been in discussions with distributors and users of mica products. The Mount Marion deposit consists of a series of shallow-dipping, parallel sheets of spodumene-bearing pegmatites within mafic-ultramafic volcanic rocks. The pegmatite sheets are more than 20 m thick. The deposit has total contained resources of 14 867 kt at 1.3% Li_2O for a contained Li_2O resource of 200.5 kt, of which 48% are Measured Resources (13.6%) or Indicated Resources (33%).

The decision on when mining operations will commence at Mount Marion is under review, having been delayed because of economic and financial market conditions, and the decision by Talison Lithium to significantly expand lithium production at the nearby Greenbushes Lithium Operations mine. As part of the 30% ownership agreement, project development at the Mount Marion project is being fully funded by Mineral Resources. Proof of technology test work is underway, looking at the production of battery-grade lithium carbonate (Li_2CO_3) and a high-purity lithium hydroxide product from spodumene concentrates produced at the Mount Marion lithium deposit. This is expected to be completed in the second half of 2013.

Altura Mining Ltd completed a positive project scoping study in late 2012 of its wholly owned **Pilgangoora** Lithium Project, 120 km south of Port Hedland in the Pilbara region of WA. At October 2012, the project had total resources of 25 157 kt at 1.23% Li_2O for 310 kt of contained Li_2O, of which 17 288 kt at 1.25% Li_2O for 219 kt of Li_2O are Indicated Resources.

Lithium at Pilgangoora is within spodumene in 12 outcropping to shallow spodumene-bearing pegmatites. Scoping study parameters included 830 000 tpa of ore mined producing up to 150 000 tpa of spodumene concentrate at greater than 6.0% Li_2O. Altura undertook diamond drilling in the first half of 2013 for secondary process testing. Additional drilling is focussing on resource extension. The company is also undertaking a prefeasibility study and is actively seeking an off-take partner to progress development of the Pilgangoora project.

Altura commenced exploratory drilling in April 2013 to test lithium, tin and tantalum for potential of pegmatites at its Smithfield project, about 260 km south of Perth and approximately 15 km south to Talison's Greenbushes Lithium Operations mine.

Magnesite

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Magnesite (magnesium carbonate $MgCO_3$) is marketed in three main forms:

- Crude magnesite, primarily for use in chemicals and agriculture;
- Dead-burned magnesia, a durable refractory used in the cement, glass, steel and metallurgical industries; and
- Caustic calcined magnesia, for use in making oxychloride and oxysulphate cements for flooring and wallboards, mouldings and acoustic tiles as well as various environmental and chemical applications.

Resources

EDR of magnesite remained unchanged in 2012 at 330 Mt. South Australia continued to have Australia's largest holding of EDR with 235 Mt, which is unchanged from 2006. The bulk of these resources occur as interbeds of sedimentary magnesite within the Skillogalee Dolomite at the Witchelina and Mount Hutton deposits, up to 30 km northwest of Leigh Creek in SA. The average magnesite grade is 40% magnesium oxide (MgO).

Queensland has Australia's second largest inventory with 63 Mt of magnesite EDR. The bulk of this resource occurs at Kunwarara, 70 km northwest of Rockhampton, where Queensland Magnesia Pty Ltd has global resources of 1200 Mt of magnesite-bearing material. Within this global resource, which has an Inferred Resource of 500 Mt of magnesite, several high-grade magnesite zones have been classified as EDR. The Kunwarara deposit occurs as sheet-like lenses of magnesite with an average thickness of 7.6 m extending over about 63 square kilometres. It contains four high-grade zones of very high-density bone-type, low-iron ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

The third largest inventory of EDR is in Tasmania where the Arthur River deposit has a Measured Resource of 13.2 Mt with an average magnesite grade of 43.4% magnesium oxide (MgO). The resource is part of a much larger global resource of 195 Mt in Tasmania's Arthur-Lyons River area, about 53 km south of Burnie. The remainder of Australia's EDR occurs in the Winchester deposit 70 km south of Darwin in the Northern Territory, at Thuddungra 80 km northwest of Young in NSW and at Bandalup 20 km east of Ravensthorpe in Western Australia.

Subeconomic Demonstrated Resources of 57 Mt of magnesite remained unchanged from 2011. All of these resources occur at Triple Four in central Queensland at Main Creek in northwest Tasmania.

Inferred Resources of magnesite remained unchanged in 2012 at 836 Mt with Qld accounting for 56%, followed by SA with 35% and Tasmania with 5%. The remaining resources are in NSW, the NT and WA.

Accessible EDR

All magnesite EDR is accessible for mining.

JORC Reserves

JORC Code reserves comprise total magnesite in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC Code reserves of 37.5 Mt (unchanged from 2011) accounted for approximately 11% of AEDR. At Australia's 2012–13 rate of production, magnesite resources in the JORC Code reserves categories are adequate for almost 64 years.

Exploration

Data associated with exploration expenditure for magnesite are not published by the Australian Bureau of Statistics.

Production

The bulk of Australia's magnesite production was by Queensland Magnesia Pty Ltd which supplied high-grade electrofused and dead-burned magnesia to the global refractory market, as well as calcined magnesia for a wide range of applications. In 201213, the company produced a total of 587 688 t of magnesite (644 325 t in 201112). About 3595 t of magnesite was produced from the Myrtle Springs region in SA in the six months to 30 June 2012.

World Ranking

According to Geoscience Australia and USGS data, Australia has about 4% of the world's EDR of magnesite, which totals 8300 Mt. Russia, China and North Korea jointly account for almost 67% of the world's EDR. The Kunwarara deposit in Queensland is the world's largest known resource of ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

According to USGS data, estimated world production of magnesite totalled 21.16 Mt (20.65 Mt in 2011). The world's largest producers of magnesite in 2012 were China (70%), Russia (6%), Turkey (5%) and Austria (4%).

Industry Developments

Korab Resources Ltd had entered into an agreement to sell the **Winchester** magnesite deposit located in the NT for up to $33.2 million in cash and royalties to Augur Investments Oü, a diversified Estonian investment company with interests in mining, infrastructure and commercial property development. The company negotiated a sale price of $2/t of JORC Code compliant magnesite resource. The current resource base consists of an Indicated Resource of 12.2 Mt at 43.1% MgO and an Inferred Resource of 4.4 Mt at 43.6% MgO. On completion of the sale, $16.6 million ($1/t of resource) was payable and an additional $1/t of resource was payable as a royalty on each tonne of magnesite mined from the deposit. The amount of royalties was capped at $16.6 million. The agreement was subject to Korab Resources obtaining all regulatory and other approvals necessary for the sale of the assets, including the consent of the relevant Minister under the Northern Territory Mineral Titles Act. It was also dependant on Augur Investments completing a due diligence in relation to the transaction, but in May 2013, Augur advised that it would not proceed with the purchase of the Winchester deposit.

Beacon Hill Resources plc, through its subsidiary Tasmania Magnesite NL, holds mineral tenure over two large, high-grade magnesite deposits at **Arthur River** and **Lyons River** in northwest Tasmania. The company announced the results of a preliminary scoping study into the Arthur River project in the June quarter 2012. The study demonstrated a pre-tax nett present value of $42 million based on a mine life of 17 years and a 292 000 dry tpa operation producing on average 100 000 tpa of caustic-calcined magnesia with an average grade of 95% MgO. The study was based on an Inferred Resource of 25 Mt of magnesite grading 42.4% MgO, 4.8% SiO_2, 1.4% Fe_2O_3 and 2.6% CaO to a maximum depth of 100 m below the surface at a cut-off grade of 40% MgO. Initial capital cost is estimated at $155 million with an average life-of-mine operating cost, including both mining and processing costs, of approximately $250/t free-on-board.

The company plans to move towards a full feasibility study, which would include the submission of a development proposal and environmental management plan to secure mining approval, the completion of the approved drilling program to upgrade resources and the securing of a joint venture and/or off-take partner to fund the future development of the project.

Archer Exploration Ltd is planning to develop a 150 000 tpa caustic-calcined magnesia operation based on magnesite resources that occur on two Exploration Licences, one covering the **Mount Hutton**, **Mount Playfair**, **Termination Hill** and **Pug Hill** deposits, and the other covering the **Witchelina** deposit. These licences were granted to Archer Exploration through its wholly-owned subsidiary, Leigh Creek Magnesite Pty Ltd, in late 2010/early 2011. These deposits, formerly owned by SAMAG Ltd, to supply magnesite to its proposed magnesium metal plant at Port Pirie, SA, contain a combined JORC Code compliant resource of 413 Mt with an average grade of 41.3% MgO. SAMAG failed to raise the necessary capital to develop the magnesium metal plant and the plan was abandoned. Archer Exploration is seeking joint venture partners with technical and marketing expertise in magnesia industry to assist in the development of deposits.

In April 2012, the global industrial minerals group SCR-Sibelco NV acquired QMAG Ltd from Resource Capital Funds, a private equity company with a mining focus. The acquisition included the magnesite resource at Kunwarara, the mining, beneficiation and the production of dead-burned, electrofused and calcined magnesia products at its mine and production facilities in Rockhampton. Sibelco, with over 200 production sites in 41 countries, operates a network of 45 mines, plants, and distribution warehouses in Australia and New Zealand. The company supplies products to the glass, mining, agriculture, construction, and manufacturing industries.

Foyson Resources Ltd, formerly known as Magnesium International Ltd (MIL), has sold its Myrtle Springs magnesite tenements comprising two mining leases and two mining purpose leases located 20 km west-northwest of Leigh Creek in SA to Calix Ltd and its wholly-owned subsidiary MS Minerals Pty Ltd for $1 million (excluding the goods and services tax). The magnesite tenements were part of Magnesium International's magnesium smelter project (SAMAG project) proposed for Port Pirie in the early 2000s. The combined Measured, Indicated and Inferred Resources of magnesite of Foyson Resources' tenements formed part of the total 579 Mt grading on average 42% MgO associated with the SAMAG project. Calix is an Australian mineral processing and carbon capture technology company which operates a large-scale calciner at Bacchus Marsh, 40 km northwest of Melbourne in Victoria.

Manganese Ore

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Manganese (Mn) is the twelfth most abundant element in the Earth's crust. Of approximately 300 minerals containing manganese, only about a dozen are of economic significance. The two main manganese minerals are pyrolusite (MnO_2) and rhodochrosite ($MnCO_3$). Manganese is the fourth most used metal in terms of tonnage after iron, aluminium and copper and 90% of all manganese consumed annually goes into steel as an alloying agent. No satisfactory substitute for manganese has been identified that combines a relatively low price with its outstanding technical benefits, such as the ability to combine with sulphur and its powerful de-oxidation capacity. After steel, the second most important market for manganese, in the form of electrolytic manganese dioxide (EMD), is that of dry cell batteries. Manganese is also an important alloying element in aluminium and copper and is also used in plant fertilisers and animal feeds and is a colorant.

In Australia, there are three operating mines and one tailings re-treatment plant. The Woodie Woodie mine is located about 400 km south east of Port Hedland in Western Australia (WA). A manganese tailings processing plant also operates near the Woodie Woodie mine. The Northern Territory has two manganese mines with one being located on Groote Eylandt in the Gulf of Carpentaria and the other located at Bootu Creek 110 km north of Tennant Creek.

Australia's sole manganese ore processing plant is operated by TEMCO at Bell Bay in Tasmania.

Resources

In 2012, Australia's EDR of manganese ore decreased by 5% to 187 Mt (Table 9), mainly because of a fall in EDR at Groote Eylandt and Bootu Creek. Paramarginal Resources remained unchanged at 23.1 Mt and Submarginal Resources also remained unchanged at 167 Mt (Table 9). Inferred Resources increased by 3.6% to 324 Mt (Table 9), due to the announcement of an Inferred Resource at the Contact deposit in Western Australia.

Table 9: Resources of manganese ore in Australian states and the Northern Territory (Mt).

Jurisdiction	Demonstrated Economic	Demonstrated Paramarginal	Demonstrated Submarginal	Inferred Undifferentiated
Queensland	0	0	0	0.2
Western Australia	46.1	23.1	167.0	273.9
Northern Territory	140.7	0	0	50.0
Australia	186.8	23.1	167.0	324.1

Accessible EDR

All manganese ore EDR (186.8 Mt) is accessible. The resource life (resource to production ratio) is about 13 years at current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore JORC Code reserves are 135.4 Mt (72% of accessible EDR). The resource life based on JORC reserves, and at the current rate of production of beneficiated manganese ore, is about 9 years.

Exploration Expenditure

Data associated with exploration expenditure for manganese are not published by the Australian Bureau of Statistics on either a state or national basis.

Production

The Bureau of Resources and Energy Economics reported that Australia produced 7.2 Mt of beneficiated manganese ore in 2012 (7.0 Mt 2011). The total tonnage of manganese ore mined is approximately twice the tonnage of beneficiated manganese ore produced because of yields of around 50% after beneficiation. Exports of manganese ores for 2012 totalled 6.7 Mt valued at $1204 million compared to 6.9 Mt valued at $1369 million in 2011.

World Ranking

Australia has 11% of the world's EDR of manganese ore and is ranked fifth behind the Ukraine (25%), South Africa (20%), Brazil (15%) and China (14%). Australia produces 15% of the world's manganese ore and is ranked third behind China (31%) and South Africa (16%).

Industry Developments

Northern Territory

GEMCO (Groote Eylandt Mining Company Ltd): The US$279 million GEMCO Expansion Phase 2 was approved in July 2011 and commenced in 2012. This will increase the beneficiated manganese capacity at **Groote Eylandt** to 4.8 Mtpa from 4.2 Mtpa. The expansion will also create 1.1 Mtpa additional capacity for future expansions by addressing infrastructure constraints by increasing road and port capacity.

OM Holdings Ltd: The company's **Bootu Creek** plant has the capacity to produce 1 Mtpa annually, and 2012 resulted in the production of 738 kt which represents a decrease of 18% on 2011. The fall in production was caused by a transition of operations and rail service disruptions.

Tasmania

TEMCO (Tasmanian Electro Metallurgical Company Pty Ltd): In February 2012, BHP Billiton Ltd announced a 90-day suspension of operations at its manganese alloy smelter in Bell Bay. The plant reopened in May and was back to full production by the end of August.

Western Australia

Consolidated Minerals Ltd: The **Woodie Woodie** manganese mine is located approximately 400 km southeast of Port Hedland in the Pilbara region of Western Australia. The Woodie Woodie product has high manganese content and very low phosphorus, while having very low degradation and high thermal stability.

Mesa Minerals Ltd: The **Ant Hill** and **Sunday Hill** projects are located 400 km south of Port Hedland. Both mines remained on care and maintenance throughout 2012.

Montezuma Mining Company Ltd: The **Butcherbird** manganese project is located 120 km south of Newman. A scoping study was conducted into the development of a mine with capacity to produce up to 1 Mtpa with a mine life of at least 10 years. The study showed excellent potential for the commercial development of the Butcherbird manganese project.

Mineral Sands

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The principal components of heavy mineral sands are rutile (TiO_2), ilmenite ($FeTiO_3$), zircon ($ZrSiO_4$) and monazite ($[Ce,La,Th]PO_4$). Minor amounts of xenotime (YPO_4) a yttrium-bearing phosphate hosting 54 to 65% rare earth oxides (REO), and comprising other rare earth elements (REE) such as erbium and cerium, and thorium. Rutile, ilmenite, leucoxene (an alteration product of ilmenite) are used predominantly in the production of titanium dioxide pigment. The titanium-bearing minerals rutile and leucoxene are sometimes blended to produce HiTi (High grade titanium with a TiO_2 content of 70% to 95%) which is used as a feedstock to produce titanium dioxide, make titanium metals for the aerospace industry and in the manufacture of welding rods. Less than 4% of total titanium mineral production, typically rutile, is used in making titanium sponge metal. Zircon is used as an opacifier for glazes on ceramic tiles, in refractories and for the foundry industry. Recently there has been renewed interest in monazite as a source of thorium for possible use to generate electricity in thorium nuclear reactors.

Resources

EDR of ilmenite decreased by 1.0% to 187.0 Mt in 2012, down from 188.9 Mt in 2011. About 45.0% of Australia's EDR of ilmenite is in Western Australia and 19.3% is in Queensland with Victoria containing 21.8%, New South Wales 10.3% and South Australia 3.6%.

EDR of rutile, which includes some leucoxene in WA, decreased by 2.2% from 27.2 Mt in 2011 to 26.6 Mt in 2012. Victoria has the largest share of Australia's rutile EDR with 42.8% followed by Queensland (20.0%), WA (17.6%), NSW (16.5%) and SA (2.5%).

EDR of zircon increased from 46.6 Mt in 2011 to 47.4 Mt in 2012 with Vic (34.5%), WA (29.3%) and Queensland (16.2%) accounting for most of Australia's zircon EDR. The balance was in SA (11.7%) and NSW (7.7%).

Australia's Subeconomic Demonstrated Resources of ilmenite, rutile and zircon in 2012 amounted to 30.2 Mt of ilmenite, with marginal decrease from 30.3 Mt in 2011, a decrease to 0.36 Mt of rutile from 0.56 Mt in previous year, and 1.17 Mt of zircon, compared to 1.27 Mt in 2011.

Inferred Resources of ilmenite increased by 20.8% in 2012 to 219.9 Mt. Victoria has the largest proportion of inferred ilmenite resources with 40.6% of the Australian total followed by WA (31.7%), NSW (12.6%) and Queensland (7.2%).

Inferred Resources of rutile increased in 2012 to 42.2 Mt from 40.2 Mt in 2011. Victoria has the largest share of Australia's Inferred Resources of rutile with 63.3% of the total followed by NSW (21.6%), WA (5.8%), Queensland (4.6%) and SA (4.6%).

Inferred Resources of zircon increased in 2012 to 68.3 Mt from 62.1 Mt in 2011. Victoria is the main holder of zircon Inferred Resources with 70.4% of the Australian total, followed by WA (10.7%), NSW (9.7%) and Queensland (4.4%).

Accessible EDR

A significant portion of mineral sands EDR is in areas quarantined from mining because they are largely incorporated in national parks and other areas with restricted access to mining. Geoscience Australia estimates that around 16% of ilmenite, 14% of rutile and 14% of zircon EDR is unavailable for mining.

Deposits in this category include Moreton Island, Bribie Island and Fraser Island, the Cooloola sand mass, the Byfield sand mass and the Shoalwater Bay area in Qld as well as the Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in NSW.

JORC Reserves

About 28% of Australia's ilmenite AEDR, 31% of rutile AEDR and 36% of zircon AEDR comprise Reserves as defined under the JORC Code.

Duration of Resources

At the rate of production in 2012, Australia's AEDR of ilmenite, rutile and zircon is sufficient for an average of 116 years for ilmenite (122 years in 2011), 52 years for rutile (50 years in 2011) and 68 years for zircon (53 years in 2011). However, resources in the JORC Code reserves categories are adequate for only 32 years for ilmenite (33 years in 2011), 16 years for rutile (14 years in 2011), and 25 years for zircon (18 years in 2011). Variations in resource life of the three commodities are based on the AEDR and are the result of changing levels of production as well as changes in AEDR. For example, lower production in response to a fall in demand may create the impression of an increase in resource life, but is not necessarily indicative of an increase in resources. Such trends may be reversed with resumption of demand and, as a consequence, represent snapshots of the resource life at that time.

Exploration

Full expenditure on exploration for mineral sands has not been available since 2010. The available exploration figures for mineral sands for the March, September and December quarters in 2012 totalled $31.2 million. The exploration figure for the June quarter in 2012 was not available.

Production

In 2012, Australia produced 1.344 Mt of ilmenite, 439 000 t of rutile, 228 000 t of leucoxene and 605 000 t of zircon compared with 1.277 Mt of ilmenite, 474 000 t of rutile, 225 000 t of leucoxene and 762 000 t of zircon in 2011. About 2.023 Mt of ilmenite, 342 000 t of rutile and 680 000 t of zircon was exported in 2012, with exports exceeding production for ilmenite in 2012. Australia also produced 480 000 t of synthetic rutile in 2012 compared with 503 000 t in 2011.

According to Iluka Resources Ltd[4] the global zircon demand remained weak throughout 2012. The demand for high grade titanium dioxide was high in the first quarter in 2012 but softened in the second half of the year.

World Ranking

According to Geoscience Australia and USGS data, Australia's EDR of rutile and zircon in 2012 was the world's largest economic resources with 52%, and 53%, respectively. Australia also has the second largest share of the world's ilmenite with 15%, behind China, which has 31%. Other major country rankings include India (13%), South Africa (10%) and Brazil (7%) for ilmenite, South Africa (16%) and India (15%) for rutile and South Africa (24%) and India (6%) for zircon.

During 2012, world production of ilmenite increased by 2.9% to 11.30 Mt and rutile increased by 2.9% to 790 000 t while world production of zircon decreased by 2.8% to 1.41 Mt. Australia is the largest producer of rutile with 55.9% of the world production followed by South Africa with 16.7% and Sierra Leone with 12.7%. Australia is the second largest producer of ilmenite with 11.9% after South Africa with 17.3%, followed by Canada and China with 11.8% each, and is the largest producer of zircon with 42.9% followed by South Africa with 28.4% and China with 10.6%.

Industry Developments

Companies that produced heavy mineral sands during 2012 were Iluka Resources Ltd, Cristal Mining Australia Ltd (formerly Bemax Resources Ltd), Tronox Ltd and Doral Mineral Sands Pty Ltd, all in WA, and Sibelco Australia Ltd in Queensland. Iluka and Cristal Mining also produced heavy minerals in the Murray Basin in Victoria and NSW and Murray Zircon Pty Ltd in SA. MZI Resources Ltd continued mining of heavy mineral sand deposits on the Tiwi Islands off the Northern Territory.

Iluka's heavy mineral sand operations in WA are located in two regions, the mid-west region about 150 km north of Perth and in the State's southwest region south of Perth.

The coastal mid-west region comprises the main mines of **Eneabba** (two wet concentrators, five mining units). The region includes the company's Narngulu facility at Geraldton comprising mineral separation, zircon finishing and two synthetic rutile kilns (SR kilns 3 and 4) as well as port operations and storage facilities at Geraldton. Iluka's Narngulu plant processes the heavy mineral concentrates (HMC) from local mines in WA as well as its **Jacinth-Ambrosia** mine in the Eucla Basin in SA.

4 Iluka Resources Ltd, 2012. Iluka Review 2012, 64pp.

Another mineral separation plant, as well as SR kilns 1 and 2, is located at North Capel in the southwest region of WA, which also hosts Iluka's heavy minerals mine at **South Tutunup**.

According to Iluka's review of operations in 2012, coincident cyclic weakness in both zircon and high grade titanium dioxide demand led to a deterioration of demand in 2012 which was worse than that experienced at the height of the global financial crisis in 2009[5].

Mining at Eneabba continued throughout 2012, after recommencing in December 2011, with processing of Eneabba sourced heavy mineral concentrate at the Narngulu mineral separation plant commencing from the first quarter of 2012. The Narngulu mineral separation plant was upgraded to accommodate an additional 300 000 t of Eneabba heavy mineral concentrate. Mining operations at Tutunup South in southwest Western Australian continued during 2012. Tutunup South is an ilmenite feed source for synthetic rutile kiln 2. Iluka operated its main kiln, synthetic rutile kiln 2 at a reduced feed rate of approximately 60% of capacity in response to lower demand in the second half of the year. Iluka also deferred its planned recommencement of its synthetic rutile kiln 1 from the fourth quarter of 2012. A trial parcel of Virginia ilmenite from USA was processed through synthetic rutile kiln 3. Preliminary results indicate a high titanium-dioxide grade is achievable along with other favourable product characteristics.

Iluka is undertaking a prefeasibility study for the **Cataby** mineral sands deposit north of Perth. Cataby is a high-quality chloride ilmenite deposit which is expected to also produce zircon during its initial years. The prefeasibility study is expected to be complete by mid-2013.

In 2012, production of heavy mineral sand commodities from Iluka's mining and processing activities from the Perth Basin in WA and the Eucla Basin in SA amounted to 86 600 t of saleable ilmenite, 204 000 t of upgradeable ilmenite (upgradeable to synthetic rutile), 248 300 t of synthetic rutile and 158 200 t of zircon.

Iluka reported in 2013 March quarterly report that, because of persisting low demand, it was planning to idle Eneabba and the Tutunup South mines, the synthetic rutile kiln 2, and the Narngulu separation Plant 2.

In the Eucla Basin in SA, Iluka operates the Jacinth-Ambrosia mine and owns the nearby satellite deposits of **Tripitaka**, **Typhoon**, **Atacama** and the **Sonoran**. The heavy-mineral concentrates from the Jacinth-Ambrosia mine are transported 270 km by road to the Port of Thevenard near Ceduna, before being sent about 2500 km by sea to Geraldton in WA for mineral separation at Iluka's upgraded Narngulu Plant 2 in the mid-west region. The Sonoran deposit is similar to Atacama, but differs from the Jacinth-Ambrosia deposit in that it contains a zircon component in the heavy-mineral concentrate of around 15% which compares with around 50% for the Jacinth-Ambrosia deposit. Iluka announced in its March 2013 quarterly report[6] that it has undertaken a scoping study on the Sonoran, Atacama and Typhoon satellite deposits adjacent to the Jacinth-Ambrosia operation. Chloride ilmenite from these deposits is expected to be suitable as a feed source to Iluka's synthetic rutile kilns or for direct sale. The deposits would also produce associated zircon. The company plans to progress the potential development of one or more of these deposits through a prefeasibility study.

Iluka operates a mineral separation plant at Hamilton in Victoria to produce the final specification rutile and zircon. The mineral separation plant processes feedstock from the **Douglas** project near Horsham in western Victoria and from the Murray Basin Stage 2 development at **Kulwin**, 30 km west of Ouyen in northwest Victoria. Iluka reported in its annual review for 2012 that mining and concentration operations at Douglas were completed in the first half of 2012. Mining at the first of the northern Murray Basin deposits, Kulwin, also ceased in mid-February as planned, with the mining and processing equipment relocated to the **Woornack**, **Rownack** and **Pirro** group of deposits.

Commissioning of Woornack, Rownack and Pirro commenced in mid-April, with heavy mineral concentrate production in early May. Plant alterations and installation of additional equipment at the end of 2012 allowed Iluka to produce a combination of sulphate and chloride ilmenite for sale or for use in synthetic rutile upgrading. This represents the commercialisation of a significant quantity of ilmenite within the deposit which previously was considered to have no commercial value.

5 Iluka Resources Ltd, 2012. 2012 Full Year Results. Presentation slide pack, 58pp.

6 Iluka Resources Ltd, 2013. Iluka March 2013 Quarterly Production Report,12pp.

Another group of deposits are located at Euston in NSW named **Castaway**, **Kerribee**, **Earl**, **Dispersion** and **Koolaman**.

Production from Iluka's Murray Basin operations in 2012 totalled 170 300 t of rutile, 96 500 t of saleable ilmenite, 72 300 t of upgradeable ilmenite and 135 600 t of zircon.

Balranald and **Nepean** are two rutile-rich deposits in the northern Murray Basin in NSW. During the March 2013 quarter, a prefeasibility study for the potential development of the Balranald and Nepean deposits was completed. The deposits provide the potential for approximately eight years of rutile and associated zircon production. In light of weak market conditions, the planned definitive feasibility study for these deposits will be deferred. In its March 2013 quarterly report, Iluka stated that it will proceed with all necessary regulatory approvals and mine design work but defer the commencement of the definitive feasibility study for at least 12 months (until 2014).

The heavy mineral resources/reserves held by Cristal Mining Australia (formerly Bemax Resources) are located in old shorelines in two provinces, the Murray Basin in Vic and NSW, and the southwest region of WA.

The company's operations in the Murray Basin include the **Ginkgo** and **Snapper** mines and a mineral separation plant at Broken Hill in western NSW.

The heavy mineral sand resources in the Murray Basin were last reported by Bemax Resources in 2009 (95.1 Mt of contained heavy mineral). Bemax no longer publishes its resources for individual deposits and regions. The resources for either the Murray Basin or the southwest region (WA) in 2012 are not known.

Production from Cristal Mining Ginkgo and Snapper mines in 2012 totalled 151 336 t of ilmenite, 107 179 t of other titanium minerals (sulphate ilmenite, secondary ilmenite and leucoxene), 46 677 t of zircon, and 80 399 tonnes of rutile[7]. Cristal Mining reported that resource drilling at **Atlas-Campaspe** and **Crayfish** deposits was completed in 2011.

Cristal Mining reported in its March 2013 quarterly report[8] that construction of a new 400 000 tpa ilmenite upgrade plant located at Broken Hill commenced in July 2012. The commissioning on ore feed stock commenced in January 2013 and completion is expected in second half of 2013.

The feasibility study on the Crayfish deposit was completed in 2012 and an Environmental Impact Statement was submitted in December 2012 with the company aiming to complete the process by the end of 2013. The Environmental Impact Statement for the proposed mining of the Atlas-Campaspe deposits was also submitted to regulators in mid-February and Cristal Mining aims to complete the process by the end of 2013.

In its December 2012 and March 2013 quarterly reports, Cristal Mining advised that heavy mineral sand mining in the southwest region of WA at the **Gwindinup** mine had ended on 31 October 2012 and rehabilitation work had commenced. Development at the **Wonnerup** mine continued with production expected to commence mid-2013.

Heavy mineral production from Cristal Mining operations in the southwest region in 2012 amounted to 52 521 t of sulphate and secondary ilmenite and leucoxene and 6223 t of zircon.

The heavy mineral sand mines on **North Stradbroke** island, are owned by Sibelco Australia Ltd. There has been no published information on the production of heavy minerals or resources of heavy minerals since 2008.

Tronox Ltd now owns and operates an integrated titanium dioxide project in WA incorporating a dredging and dry-mining heavy mineral sands operation at **Cooljarloo**, dry separation and synthetic rutile plants at Chandala and a titanium dioxide pigment plant at Kwinana. Tronox does not appear to have published mine production figures for 2012. However, its website states that production rates vary but approximately 750 000 t of HMC from about 20 Mt of ore at Cooljarloo are transported around 100 km south via truck to the Chandala mineral separation plant/synthetic rutile metallurgical complex at Muchea where the HMC is separated into ilmenite, natural rutile, leucoxene and zircon.

Mining of the MZI Resources Ltd's **Leithbridge South** deposit, on the Tiwi Islands (NT) was completed on 14 January 2013. MZI Resources is planning to complete further drilling and commence feasibility studies in 2013 on its **Kilimiraka** heavy mineral sand deposit in the southeast of Bathurst Island which has an Inferred Resource of over 890 000 t of HMC. Meanwhile, MZI Resources announced in its March 2013 quarterly report[9] that its **Keysbrook** deposit in

7 Cristal Mining Australia Ltd, 2013. December 2012 Quarterly Report, 4pp.

8 Cristal Mining Australia Ltd, 2013. March 2013 Quarterly Report, 5pp.

9 MZI Resources Ltd, 2013. Quarterly activities report for the period ending 31 March 2013, 7pp.

southwest WA had a 60% increase in Measured, Indicated and Inferred Resources totalling 8.8 Mt at 2.4% heavy minerals. MZI Resources has executed an agreement with Doral Pty Ltd for toll treatment and capital works program to process the heavy mineral concentrate (HMC) from the Keysbrook deposit. MZI Resources is planning to commence production from the Keysbrook deposit in the first half of 2014 and anticipates the mine life will exceed 15 years.

Murray Zircon Pty Ltd completed redevelopment of **Mindarie** heavy mineral sand project in the fourth quarter of 2012. The company restarted mining at Mindarie C West deposit in October 2012 and started ore processing in December 2012. In May 2013, the project was still in commissioning phase with production being ramped up to the project's design capacity of 500 t an hour ore feed to the primary concentrator plant (pers. Comm. Patrick Mutz, Chief Executive Officer Murray Zircon Pty Ltd, 30 May 2013).

Gunson Resources Ltd released a revised project study in on 26 February 2013 on its **Coburn** heavy mineral sand deposits south of Geraldton in WA[10]. The study envisaged a mine life of 19 years with increased annual production rates of 49 500 t of zircon, 109 000 t of ilmenite, and 23 500 t of high titanium (HiTi) products. The study indicated a net present value for the project of $330 million. Gunson Resources announced on 28 March 2013 that its negotiations for a joint agreement with POSCO had been terminated as a result of difficulties in reaching agreement on commercial and financial conditions because of deterioration in the zircon market.

Image Resources NL holds heavy mineral sand resources in the North Perth Basin and in the Eucla Basin, WA. On 16 July 2013, Image released the results of a feasibility study for the **Boonanarring** and **Atlas** deposits, which form part of the company's North Perth Basin mineral sand resources. The study indicated a pre-tax net present value of $145 million. Boonanarring and Atlas hold a total resource of 32.3 Mt at 8.1% heavy minerals and plans a mining rate of 3.3 Mtpa over a projected 10-year mine life. Annual production from the mine is expected to average 89 000 t of ilmenite, 5400 t of leucoxene, 9000 t of rutile and 32 400 t of zircon[11].

The Company announced its intention to dispose of the **Cyclone Extended** deposit in the Eucla basin, subject to obtaining an adequate return on historical expenditure but does not intend to pursue the disposal for the time being[12]. The Cyclone Extended deposit forms a southeast extension of the **Cyclone** deposit.

In March 2012, Diatreme Resources Ltd released results of a prefeasibility study on its Cyclone heavy minerals deposit in the Eucla Basin together with a prefeasibility-study pit design that enclosed a Probable Ore Reserve of 97 Mt containing 2.4 Mt heavy minerals, including 770 000 t of zircon at 2.5% heavy mineral cut-off. The prefeasibility study indicated a potential to mine 10 Mtpa of ore yielding approximately 147 000 t of HMC producing 65 000 t of zircon, 10 000 t of HiTi87 (86.6% TiO_2) and 46 000 t of HiTi67 (67.3% TiO_2). The Ore Reserve is contained within a Measured and Indicated Resource of 136 Mt of ore at 2.3% heavy minerals containing 3.1 Mt of heavy minerals grading 31% zircon, 3% rutile, 6% leucoxene (85–95% TiO_2), 21% HiTi (70–85% TiO_2) and 23% altered ilmenite (<70% TiO_2)[13]. Diatreme announced its December 2012 quarterly report[14] that it was continuing with a definitive feasibility study for the Cyclone deposit and anticipated the study will be completed in first half of 2014, with construction and development during 20142015 and commissioning and production to commence in 2015. The company was also conducting environmental studies for three road options from the Cyclone deposit to the trans-Australian railway about 270 km to the south.

Astron Ltd's Donald project in the Murray Basin in Victoria comprises the **Donald** (WIM 250) and **Jackson** (WIM 200) deposits located 240 km west-northwest of Melbourne. On 1 December 2011, the company announced Measured, Indicated and Inferred Resource for the deposits totalling 2630 Mt grading at 5.3% heavy minerals. The heavy mineral concentrate was reported to grade at 19% zircon, 33% ilmenite, 7% rutile and 12% leucoxene. Astron Ltd reported that the zircon content amounted to about 37 Mt. These resources are located within a larger resource totalling Measured, Indicated and Inferred Resources at 4040 Mt grading at 4.8% heavy minerals[15].

In June 2012, Astron Ltd announced Proved and Probable Reserves within the Donald project totalling 461 Mt at 5.9% heavy minerals, which equates to about 27.199 Mt of heavy minerals at about 18.6% zircon, 33.9% ilmenite,

10 Gunson Resources Ltd, 2013. Optimisation study results – Coburn Zircon Project, 3pp.

11 Image Resources NL, 2013. Robust project economics for Boonanarring and Atlas, 53pp.

12 Image Resources NL, 2013. Quarterly report for the quarter ended 31 December 2012, 13pp.

13 Diatreme Resources Ltd. 2012. Exploration activities report. Quarter ended 31 March 2012. Australian Securities Exchange release, 8pp.

14 Diatreme Resources NL, 2013. Exploration activities report. Quarter ended 31 December 2012. Australian Securities Exchange release, 10pp.

15 Astron Ltd. 2011. Donald mineral sands project – resource update. Australian Securities Exchange release 1 December 2011, 3pp.

18.6% leucoxene and 6.8% rutile[16]. Astron also reported that it engaged an independent technical consultant to conduct a review of the company's proposed hot acid-leaching process designed to reduce the level of uranium and thorium in its Donald zircon product from around 1000 ppm to around 500 ppm and minimize impurities such as iron, titanium, aluminium and phosphorus. The project is planned to be a 7.5 Mtpa mining operation producing 0.5 Mtpa of heavy mineral concentrate for export to China. Astron reported in its March quarterly report for 2013 that work continued on a definitive feasibility study, including further work on more accurately defining operating and capital expenditure. Cost studies are being undertaken for a potential alternative plan with some plant located in China.

On 28 August 2012, Sheffield Resources Ltd announced that its **West Mine**, **Yandanooka**, **Durack** and **Ellengail** deposits in the Eneabba region north of Perth in WA had Measured, Indicated and Inferred Resources totalling 226 Mt grading at 2.3% heavy minerals amounting to 5.29 Mt of heavy minerals[17]. The heavy mineral concentrate is estimated to grade at 11% zircon, 6.7% rutile, 6.4% leucoxene and 63.5% ilmenite.

On 18 December 2012 Sheffield Resources also announced a resource for its **Thunderbird** mineral sand deposit near Derby in the Kimberley Region of WA. The Indicated and Inferred Resources total 1370 Mt at 6.1% heavy minerals (at a cut-off of 2% heavy minerals) containing 5.7 Mt of zircon, 1.3 Mt rutile, 3.6 Mt leucoxene and 24 Mt ilmenite.

The deposit occurs over the Canning Basin and represents a new unexplored heavy mineral province. Other companies exploring the area include Iluka Resources Ltd and Diatreme Resources Ltd.

On 15 May 2012, Crossland Uranium Mines Ltd announced resources for an inland placer deposit, the **Charley Creek** deposit, containing zircon, monazite and xenotime (YPO_4). The company reported that the deposit is an alluvial outwash which comprises an Indicated Resource of 387 Mt containing 27 000 t of xenotime, 161 000 t of monazite and 196 000 t of zircon. The xenotime and monazite were stated to contain about 14 000 t of total REOs. In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 t of REOs in about 31 000 t of xenotime and 167 000 t of monazite, as well as 220 000 t of zircon[18]. An earlier report by Crossland, dated 5 April 2012, stated that the equivalent monazite in the HMC (calculated from chemical analyses) is 87 372 g/t and equivalent xenotime is 8310 g/t while the HMC in the alluvium was 2.54%[19]. On 15 April 2013, the company released the results of a scoping study which estimated a net present value for the project of $302 million and a capex of $156 million. Crossland reported that it was working towards a production date of 2016[20].

Metallica Minerals Ltd reported that it was progressing its **Urquhart Point** heavy mineral sands project in far north Queensland towards its planned development, subject to granting of a mining lease, obtaining zircon-rutile product off-take agreements and adequate project funding. The Urquhart Point mining lease is expected to be granted towards the end of 2013[21]. The Urquhart Point deposits are approximately 5 km southwest of Weipa on the Gulf of Carpentaria in Queensland. The zircon and rutile deposit has an Indicated Resource of 2.8 Mt at 7% heavy mineral sands to a maximum depth of 3 m. On 26 April 2012, Metallica also announced an Inferred Resource for its **Glenaladale-Stockdale** deposit in east Gippsland (Vic) amounting to 1700 Mt of ore grading 2.2% heavy minerals with a heavy mineral content of 38 Mt. An Inferred Resource of 360 Mt within the larger resource was reported as grading 2.7% heavy minerals containing 9.7 Mt heavy minerals, including 1.42 Mt zircon, 0.4 Mt rutile, 4.76 Mt combined titanium minerals and 60 000 t monazite[22]. The company announced on 17 December 2012 that it had decided not to renew its option to acquire the Glenaladale-Stockdale deposit[23].

Australian Mineral Resources Pty Ltd has reported resources on their website at http://ilmenite.com.au/bmc-project.html for a residual ilmenite deposits in the Roper River area about 80 km east of Mataranka in the NT. The resources have been released for two deposits, the **Buka** deposit with 2 298 957 t at 6.05% ilmenite, and the **BMC** deposit with 2 123 354 t at 4.7% ilmenite with both resources calculated at a cut-off of 2.5% ilmenite.

16 Astron Ltd. 2012. Donald mineral sands project – review of uranium/thorium wash process and proved ore reserve update. Australian Securities Exchange release 18 June 2012, 4pp.

17 Sheffield Resources Ltd. 2012. Eneabba project resource inventory exceeds 5Mt heavy mineral. Australian Securities Exchange release, 28 August 2012, 11pp.

18 Crossland Uranium Resources Ltd. 2012. Announcement to the Australian Securities Exchange 15 May 2012. Initial Indicated Resource of 387 Mt containing xenotime/monazite REE mineralization at Charley Creek project, 7pp.

19 Crossland Uranium Resources Ltd. 2012. Announcement to the Australian Securities Exchange 5 April 2012, 3pp.

20 Crossland Uranium Resources Ltd. 2013. Announcement to the Australian Securities Exchange 15 April 2013. Charley Creek Rare Earth project scoping study results, 54pp.

21 Metallica Minerals Ltd, 2013. Company update. Announcement to the Australian Securities Exchange, 8 July, 2013, 1pp.

22 Metallica Minerals Ltd, 2012. Maiden heavy mineral sands (HMS) resource Gippsland zircon-rutile HMS project update. Announcement to the Australian Securities Exchange, 26 April, 2012, 9pp.

23 Metallica Minerals Ltd, 2012. Gippsland option lapses. Announcement to the Australian Securities Exchange, 17 December, 2012, 1pp.

Molybdenum

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Molybdenum (Mo) is used mostly in steels and superalloys to enhance strength, toughness, thermal and corrosion resistance, and to reduce brittleness. Applications include high-speed steels, stainless steels (especially to increase corrosion resistance), high-temperature steels and in cast iron. It is used also in nickel-, titanium- and molybdenum-base alloys for applications requiring high strength and stability at high temperatures such as heating elements, radiation shields, glass-melting equipment and in jet and rocket engines. Other uses include catalysts, lubricants and pigments, as well as applications in the electronics industry and as trace nutrients in fertilisers. The main commercial source of molybdenum is the mineral molybdenite (MoS_2) but it is found also in minerals such as wulfenite ($PbMoO_4$) and powellite ($CaMoO_4$). Molybdenum is mined as a principal ore but is more commonly recovered as a by-product or co-product from copper and tungsten mining.

Resources

Australia's EDR of molybdenum increased from 167 kt in 2011 to 203 kt in 2012. The rise results from a large increase in resources at Dart Mining NL's Unicorn deposit in Victoria. Resource figures for Australia's EDR do not include 220 kt Mo of reserves at the Spinifex Ridge Molybdenum-Copper Project deposit in Western Australia which the owner, Moly Mines Ltd, indicates is currently uneconomic and, as a consequence, has been reclassified as Paramarginal. Spinifex Ridge is Australia's largest molybdenum deposit. The majority of Australia's EDR is in Queensland with 70.5%, followed by Victoria with about 25%. If the Spinifex Ridge resources are included in the EDR, the overall resources would be 52% in WA, followed by Queensland (34%) and Victoria (12%).

Australia's Subeconomic Demonstrated Resources accounted for about 86% of the total Demonstrated Resources, with 75% of Subeconomic Demonstrated Resources in Queensland and the remainder in WA. In 2012, Paramarginal Resources and Submarginal Resources stood at 1220 kt and 0.5 kt respectively, which is unchanged from 2011.

Inferred Resources of molybdenum increased only slightly from 562 kt in 2011 to 572 kt in 2012. Queensland and WA account for 66% and 28% of Inferred Resources respectively.

Accessible EDR

All of Australia's EDR of molybdenum is accessible.

JORC Reserves

JORC Code reserves comprise total molybdenum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC Code reserves of 79.5 kt accounted for approximately 39% of AEDR. Nearly all these reserves (about 77.4 kt) are from Inova Resources Ltd's Merlin Project in northwest Queensland. The 2012 figures do not include 220 kt Mo of reserves from the Spinifex Ridge Molybdenum-Copper Project deposit in WA which, as reported by Moly Mines, are uneconomic at current molybdenum prices.

Exploration

Data on exploration expenditure for molybdenum are not available nationally.

Production

There was no recorded molybdenum production in Australia in 2012.

World Ranking

According to USGS data, updated by Geoscience Australia for Australia's resources, world economic resources of molybdenum in 2012 are estimated to be about 11 200 kt with China holding about 38% of the resources followed by the USA with 24% and Chile with 21%. Australia accounts for around 1.8% of the world's economic resources of molybdenum.

The USGS estimates that world molybdenum production in 2012 amounted to 252 kt, slightly lower than its revised 2011 figures of 264 kt. China, the USA, Chile and Peru accounted for about 87% of global outputs in 2012 with China producing 105 kt, followed by the USA with 57 kt, Chile with 35 kt and Peru with 19.5 kt.

Industry Developments

World molybdenum prices soared in 2007, reaching a high of US$38/lb in September 2008 from a low of about US$5/lb in 2001. After the global financial crises in October 2008, the average price declined sharply to US$8/lb and continued at that level through the first half of 2009. This led to a tightening of global supplies as many companies ceased operation. However, increased demand from China, Japan and Korea resulted in prices increasing, with the average price for the second half of 2009 to mid-2011, fluctuating from US$14/lb to US$18/lb. Prices have steadily declined since mid-2011 to around US$10/lb in June 2013.

Inova Resources (previously Ivanhoe Australia Ltd) has progressed its **Merlin** molybdenum-rhenium deposit, located approximately 100 km south of Cloncurry in northwest Queensland, through scoping, prefeasibility and feasibility studies. Completed in April 2012, the feasibility study included a mine life of 15 years with a throughput rate of 500 kt a year (with the processing plant located at the nearby Osborne Mine) and average production of 5100 t of molybdenum and 7300 kg of rhenium per year for the first seven years. The feasibility study was based on an April 2012 upgrade of Probable Reserves to 7.1 Mt at 1.1% Mo and 18.1 g/t Re for a contained 78 kt Mo and 129 t Re. Indicated Resources are 6.7 Mt at 1.39% Mo and 23.4 g/t Re with contained 93 kt Mo and 157 t Re. Probable Reserves are included in the Indicated Resources.

Inova commenced a value engineering program in August 2012 reviewing the outcomes of the feasibility study with the aim of reducing risk and enhancing economics. Initial results suggested the potential for a 10% increase in production rates. The Merlin deposit consists of high-grade molybdenite mineralisation within the faulted basal metasediments of the Kuridala Formation in the Mount Isa Eastern Succession. The molybdenum mineralisation is overlain by discrete copper- and zinc-rich polymetallic sulphide zones of the Mount Dore ore body. The Merlin deposit is the world's highest grade molybdenum and rhenium deposit with very high-grade molybdenum mineralisation close to the surface at its southern end in the **Little Wizard** deposit. The company reported an Indicated Resource for Little Wizard of 15 000 t grading 6.49% Mo, 83.9 ppm Re, 2.3% Cu and 25 g/t Ag. The Little Wizard resource is included in the Merlin Reserve figures.

Inova commenced construction of a decline at Merlin in late 2010 and reported that phase 1 was completed in early 2012. Phase 2 of the decline development is awaiting project approval. Inova has reported molybdenum drill core intersections both north and south of Merlin and has suggested the region may represent a new molybdenum-rhenium province. Inova has been investigating strategic partnership options to secure the long-term funding needed to progress the development of Merlin and its other projects in the Cloncurry area. In mid-August 2013, Shanxi Donghui Coal Coking and Chemicals Group Company Ltd announced it intended to make an off-market takeover offer for Inova.

In early 2013, Syndicated Metals Ltd withdrew from the Kalman Joint Venture with Mt Dockerell Mining Pty Ltd (a 100% owned subsidiary of Cerro Resources NL). Under the joint venture, agreed to in May 2011, Syndicated had a controlling interest and management of the **Kalman** molybdenum-rhenium-copper-gold project, with rights to earn an 80% interest. Syndicated and Mt Dockerell have reverted to a previously agreed joint venture, the Pelican joint venture, which includes approximately half of the Kalman deposit. Mt Dockerell has 51% interest in this joint venture with a right to earn up to 70%. The Kalman project is hosted by calc-silicate rocks of the Corella Formation within the eastern succession of the Mount Isa Inlier, around 60 km southeast of Mount Isa in northwest Qld. The deposit has Inferred Resources of 60.8 Mt at 0.05% Mo, 1.19 g/t Re, 0.32% Cu and 0.15 g/t Au, with a contained 30.4 kt of Mo. A total of 27.3 kt Mo occurs within an identified internal molybdenum domain of 24.9 Mt at 0.11% Mo and 2.78 g/t Re. Syndicated undertook drilling in late 2011 as part of a planned update of the Kalman resource model which will be used as a basis for an economic evaluation of the deposit. In the second half of 2012 and early 2013 Syndicated completed a large soil geochemistry survey immediately west of the Kalman deposit which delineated two long linear zones with anomalous gold, copper and molybdenum.

Aeon Metals Ltd (formerly Aussie Q Resources Ltd) continued exploration for porphyry copper-molybdenum mineralisation in its Rawbelle tenements near Monto, Qld. Focus was on both the advanced Greater Whitewash Project, comprising the **Whitewash**, **Gordon's**, **Whitewash South** and **Windmill Hill** molybdenum-copper deposits, and the company's copper-molybdenum exploration projects **John Hill** and **Kiwi Carpet**.

The deposits of the Greater Whitewash Project occur within a 5 km corridor along strike of each other. The deposits have a total JORC Code compliant resource of 242 Mt grading 258 ppm Mo, 1173 ppm Cu and 1.54 ppm Ag, including Indicated Resources of 185 Mt grading 263 ppm Mo, 1189 ppm Cu and 1.55 ppm Ag with a contained 48.5 kt Mo. Mineralisation in these deposits occurs as veins within a molybdenum-copper porphyry system confined within granodiorite.

In December 2012 a mineral development licence was granted to Aeon for the Greater Whitewash Project. Conceptual modelling undertaken by the company suggested potential for an open-pit mine with 13-year mine life and an estimated annual production of 45 000 tpa of Mo, in addition to 20 000 tpa Cu and 800 000 oz per annum of Ag. The company has undertaken favourable metallurgical testing with good recoveries of molybdenum, copper and silver.

The John Hill and Kiwi Carpet copper-molybdenum targets are approximately 10 km along strike from the Greater Whitewash Project. Drilling by Aeon has demonstrated that mineralisation at John Hill extends into the Kiwi Carpet area. Aeon considers the two form part of one large system in what it calls the Ben Hur Project. Indications from the company are that the system is copper-dominated. Drilling results from the first half of 2013 include 287 m at 0.22% Cu, 161 ppm Mo and 1.2 g/t Ag and 77 m at 0.38% Cu, 290 ppm Mo and 1.8 g/t Ag, consistent with 2012 results. Aeon is continuing drilling aimed at defining a JORC resource for this system.

Aeon also reported favourable results for drilling at other exploration prospects in the general region, including for the **Kildare** Project, 22 km south of the Greater Whitewash Project. The Kildare Project is owned by joint venture company SLW Queensland Pty Ltd (Aeon 35%, and Hong Kong based SLW Minerals Corporation Pty Ltd 65%) and the **Brigalow** prospect, just north of the Greater Whitewash Project.

In February 2011, Zamia Metals Ltd reported an upgraded JORC Code complaint Inferred Resource of 173 Mt grading 0.43% Mo at a cut-off grade of 200 ppm Mo, for 163 million pounds of contained Mo, for its **Anthony** molybdenum deposit, approximately 60 km north-northwest of Clermont, Qld. The deposit is a porphyry molybdenum system associated with the Dead Horse Bore intrusive complex in which the molybdenite occurs in stockwork quartz veins and breccia zones within intrusive rocks as well as in surrounding schists of the Anakie Inlier. The deposit is oxidised to a depth of 60 to 80 m. In June 2011 and March 2012, the Inferred Resources were upgraded to include the Oxide Resource and the Transitional Resource respectively, with total resources of 260 Mt at 400 ppm Mo, at a cut-off grade of 200 ppm Mo, for 230 million pounds of contained Mo. Recent work has focused on regions adjacent to the Anthony deposit. Zamia is currently developing a geological model of the Anthony system in and around the Anthony deposit, to better understand the deposit and potential for copper and gold mineralisation.

Intermin Resources Ltd's wholly owned **Julia Creek** Vanadium-Molybdenum Project has a total resource of 5308 Mt grading 0.375% vanadium oxide (V_2O_5) and 312 g/t molybdenum trioxide (MoO_3), within the **St Elmo**, **Alisona** and **Lilyvale** deposits, spread between Julia Creek and Richmond, in northwest Queensland. Just over 80% or 4332 Mt of the total resource comprises Indicated Resources with contained molybdenum of slightly more than 900 kt. The resource includes Measured Resources of 204 Mt at 0.4% V_2O_5 and 300 g/t MoO_3.

Intermin's tenements are located within the Cretaceous Toolebuc Formation of the Eromanga Basin, where vanadium and molybdenum, as well as nickel and copper, occur within weathered and fresh oil-shale horizons. The delineated resources are within the oxidised portions. In late May 2013, Intermin announced it had reached agreement with energy company Global Oil Shale Group (GOS) plc for GOS to acquire full ownership of tenements in the Julia Creek region. Intermin has indicated it will keep the rights to recover metals from oil shales and any tailings and residues from oil shale mining by GOS. Intermin is also keeping control of those tenements in the Richmond region, which include the Lilyvale and Alisona deposits. Intermin has previously reported that the Lilyvale resource includes higher grade Indicated Resources of 87.7 Mt at 0.55% V_2O_5 and 384 g/t MoO_3.

In 2011, Metallic Minerals Ltd completed the sale of its wholly-owned subsidiary Wolfram Camp Mining Pty Ltd to the German mining company Deutsche Rohstoff AG (DRAG) to give DRAG an 85% stake in the **Wolfram Camp** tungsten-molybdenum project, 90 km west of Cairns in Queensland. In November 2011, DRAG announced it had acquired full ownership of Tropical Metals Pty Ltd, which had held the remaining 15% of the Wolfram Camp Mine project, as well as all of the **Bamford Hill** tungsten-molybdenum deposit 25 km south of Wolfram Camp. This gave DRAG full control over both deposits.

The most up-to-date resource estimate for Wolfram Camp was released by Planet Metals Ltd in May 2010 and reported 1.42 Mt grading 0.6% tungsten trioxide (WO_3) and 0.12% Mo, comprising 0.78 Mt at 0.56% WO_3 and 0.13% Mo in Indicated Resources and 0.64 Mt at 0.65% WO_3 and 0.11% Mo in Inferred Resources.

DRAG delivered its first WO_3 concentrate from Wolfram Camp in February 2012. In June 2012, production was reported to be about 1.5 t of concentrates per day and increased to between 3 t and 4 t of tungsten concentrates per day (plus by-product molybdenum concentrate) in February 2013 following upgrading of the treatment plant and commissioning of a new X-ray sorter. DRAG has forecast that the Wolfram Camp mine will produce approximately 7000 t of WO_3 concentrates and 800 t of Mo concentrates during the next four years. The company also announced a planned exploration program at both Wolfram Camp and Bamford Hill.

Thor Mining PLC reported in January 2012 that its **Molyhil** tungsten-molybdenum project 250 km northeast of Alice Springs in the Northern Territory had Indicated Resources of 3.8 Mt at 0.29% WO_3 and 0.22% molybdenum disulphide (MoS_2) and Inferred Resources of 0.9 Mt at 0.25% WO_3 and 0.25% MoS_2. Resource figures include Probable Reserves in open cut at April 2012 of 1.64 Mt at 0.42% WO_3 and 0.13% MoS_2.

Potential development of the project was hampered by the global financial crisis and a decline in international metal prices, resulting in the company scaling back activities. Thor had signed an off-take agreement with one of China's largest state-owned companies, CITIC Australia Trading Ltd, committing it to take all molybdenum and tungsten concentrates produced from the project, but that agreement lapsed. However, the recent increase in tungsten prices has resulted in renewed interest and, in mid-2012, Thor completed a positive definitive feasibility study of the deposit, with a mine life of four years based on current reserves. Since mid-2012 Thor has been holding discussions with potential customers. Additional test work was undertaken by Thor to successively decrease molybdenum, uranium and thorium levels in scheelite concentrates to acceptable market levels. The company was also evaluating tungsten targets within the general region of the deposit and has undertaken geochemical surveys.

Moly Mines Ltd's Spinifex Ridge Molybdenum-Copper Project, containing the **Spinifex Ridge** deposit is located in the Pilbara region about 50 km northeast of Marble Bar. The Spinifex Ridge deposit has a Measured and Indicated Resource of 206.8 Mt at 0.06% Mo, 0.1% Cu and 1.5 g/t Ag and 445.5 Mt at 0.04% Mo, 0.07% Cu and 1.1 g/t Ag, respectively (2008 figures, reissued in 2012). The total resource of 652 Mt contains 294.5 kt Mo, 5.2 kt Cu and 26.4 Moz Ag. Mineralisation at Spinifex Ridge occurs as vein-hosted molybdenite and chalcopyrite associated with an Archean granodiorite which has intruded mafic and felsic volcanic rocks.

The Spinifex Ridge Molybdenum-Copper Project has all the necessary permits and is ready for immediate development. The deposit underwent a feasibility study and, prior to the global financial crisis, was scheduled to become Australia's only molybdenum producer. Development of the deposit was deferred in December 2011. As indicated by Moly Mines, the deposit is subeconomic at current metal prices and is on care and maintenance until markets improve. Prior to the downgrade by Moly Mines, which resulted in reclassification of 220 kt of reserves to Paramarginal, the deposit contained more than 75% of Australia's EDR of molybdenum.

Caravel Minerals Ltd (previously Silver Swan Group Ltd) released a maiden exploration target of 60 to 100 Mt grading 0.33–0.38% Cu with associated Mo, Au and Ag, for its **Dasher** copper- molybdenum prospect, which is part of its **Calingiri** copper- molybdenum project, 120 km northeast of Perth. Caravel acquired the Calingiri project from Kingsgate Consolidated Ltd in early 2013, with Kingsgate becoming the major shareholder in Caravel.

The Dasher prospect occurs within a recently identified 30 km belt of Cu-Mo-Au mineralisation. Other prospects, identified by Induced Polarisation surveys include **Edmunds**, **Cavel** and **Kurrali** prospects, about 3 km, 2.5 km and 5 km, respectively, south of the Dasher prospect, as well as previously recognised **Ninan North**, **Ninan South**, and **Bartel** (renamed **Bindi** by Caravel) prospects, all north of Dasher, and the **Chapman** (renamed **Opie** by Caravel) prospect, about 7.5 km southeast of Dasher. Mineralisation largely comprises chalcopyrite and associated molybdenite as well as gold and silver. Best intercepts at Dasher include 233 m at 0.44% copper equivalents and 122 m at 0.46% copper equivalent. Reported molybdenum grades range from 100 ppm up to 300 ppm and higher. Metallurgical test work at Dasher has indicated recoveries of up to about 96% for copper and around 98% for molybdenum. Planning is currently underway for drilling programs to test identified prospects.

Peel Exploration Ltd released a resource estimate in April 2008 of 1.29 Mt at 0.61% WO_3 and 0.05% Mo, for the **Attunga** deposit 20 km north of Tamworth in New South Wales. Mineralisation at the deposit occurs within skarns developed at the contact of a lime-rich sequence with the Inlet Monzonite. In 2010–11, Peel undertook a study to investigate development options, which revealed conditions were favourable for a low capital expenditure operation. There was no field activity in 2011–12. In April 2012, Peel indicated it had begun a review of the Attunga tungsten deposit. The company has indicated it is seeking potential joint venture/off-take partners.

In March 2012, Straits Resources Ltd announced a significant resource upgrade for its **Temora** copper-gold project southeast of West Wyalong in southern NSW. Total resources are 279 Mt at 0.5% Cu, 0.2 g/t Au and 30 g/t Mo, of which 26 Mt at 0.3% Cu, 0.5 g/t Au and 30 g/t Mo are Indicated Resources with the remainder being Inferred Resources. The resource occurs within the **Yiddah**, **Mandamah**, **Culingerai**, **Estoril** and **Dam** prospects. Additional work since then involved drilling in the first half of 2012 aimed at expanding the resource envelope and identifying higher grade zones. Minimal work has been undertaken since.

In 2011, Zodiac Resources Pty Ltd, which is 58.7% owned by Goodrich Resources Pty Ltd, entered a farm-in agreement with Augur Resources Ltd that allowed Zodiac to acquire a 75% interest in Augur's **Yeoval** Project, about 85 km north of Orange in NSW. Augur previously released an Inferred JORC Code resource estimate for the Yeoval Porphyry deposit of 12.9 Mt at 0.38% Cu, 0.14 g/t Au, 120.1 g/t Mo, and 2.2 g/t Ag. Zodiac completed an Induced Polarisation survey around the Yeoval deposit and its environs in 2012 that suggested that the known mineralisation was part of a larger mineralised system. Drilling in late 2012 intersected potentially economic higher gold and copper grades on the eastern side of the resource, which is the focus of further exploration.

Dart Mining NL released upgraded figures in September 2012 for its **Unicorn** Project 20 km south of Corryong in northeast Victoria that show the deposit has total resources of 203 Mt at 355 ppm Mo, 480 ppm Cu and 2.97 ppm Ag. These include Measured Resources of 102 Mt at 367 ppm Mo, 599 ppm Cu and 3.58 ppm Ag for a contained 37.4 kt Mo, and Indicated Resources of 35 Mt at 362 ppm Mo, 414 ppm Cu and 2.75 ppm Ag for a contained 12.7 kt Mo.

Molybdenite (MoS_2) mineralisation at Unicorn is associated with rhyolitic intrusives and occurs within stockwork veins in the rhyolites, surrounding metasediments and breccia zones. It is disseminated also throughout the rhyolites. Dart Mining completed a favourable scoping study into the deposit in October 2012 which suggested an initial open-pit mine life of 14 years with annual production of 10 Mtpa. Metallurgical testing demonstrated molybdenum recoveries of more than 90%. A prefeasibility study is underway.

In late 2012, Dart Mining announced a deep drilling program at Unicorn to test depth extensions of mineralisation. Two holes were completed by the middle of 2013, the deepest of which extended to 1194 m, ending in mineralised porphyry. The drilling intersected a number of mineralised zones that Dart Mining interpreted to indicate a similarity to the Climax-style porphyry model of stacked mineralised zones.

Havilah Resources NL reported a combined JORC Code compliant Indicated and Inferred Resource of 11.3 Mt grading 0.89% Cu, 0.64 g/t Au and 500 ppm Mo for 5.68 kt of contained Mo for its wholly owned **North Portia** deposit 30 km north of its **Kalkaroo** deposit in South Australia. The vein and breccia style of mineralisation at the North Portia deposit is hosted in a 150 m sequence of carbonate-rich siltstones and shales. Resources occur in both supergene and sulphide mineralisation. Havilah also identified a standalone supergene molybdenum resource with Indicated Resources of 7.7 Mt at 340 ppm Mo for a contained 2.6 kt of Mo.

Havilah indicate that a mining lease has been granted for North Portia and that metallurgy and mining studies are in progress, particularly with regards to the copper-gold-molybdenum in the oxidised ore. Current planning suggests North Portia ore, once mined, will be treated at the Kalkaroo Plant. Operations at the Kalkaroo copper-gold project are expected to begin in late 2015.

Nickel

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More than 80% of nickel production is used in alloys. When alloyed with other elements, nickel imparts toughness, strength, resistance to corrosion and various electrical, magnetic and heat resistant properties. About 65% of world nickel output is consumed in the manufacture of stainless steel, which is used widely in the chemical industry, motor vehicles, the construction industry and in consumer products such as sinks, cooking utensils, cutlery and white-goods.

Resources

Australia's EDR of nickel decreased by 13.2% from 20.4 Mt to 17.7 Mt in 2012 as a result of mining companies revising their resources. About 88% of Australia's EDR is in 15 deposits. Australia's EDR of nickel can be subdivided as follows:

- About 42.4% of Australia's EDR comprise Reserves as defined under the JORC Code.
- About 57.6% is made up of published JORC Code compliant Measured and Indicated Resources.

Western Australia retains the largest nickel resources with 96.0% of total Australian EDR. Queensland is the second largest with 3.8%, followed by Tasmania with 0.2%. The EDR in Western Australia comprises both sulphide and lateritic deposits, while EDR in Queensland is associated with laterite deposits.

Subeconomic Demonstrated Resources (Paramarginal plus Submarginal Demonstrated Resources) account for about 11.0% of total Identified Resources in 2012. Paramarginal Resources increased from 3.5 Mt to 4.2 Mt, while the Submarginal Resources decreased from 0.6 Mt to 0.2 Mt. A total of 75.0% of the subeconomic nickel resources are in WA.

Inferred Resources decreased from 18.4 Mt to 17.8 Mt in 2012 with WA maintaining its dominance with 87.6% of the total followed by NSW with 5.7%.

The ratio of Inferred Resources to EDR in 2012 was 1:1.

See Figure 13 for the locations of Australia's major nickel deposits based on total Identified Resources.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2012, AEDR of nickel is sufficient for about 73 years.

JORC Reserves

About 42% of AEDR is made up of JORC Code Reserves. The remaining 58% of AEDR represents resources assessed by Geoscience Australia from the Measured and Indicated categories of industry reported mineral resources as defined under the JORC Code and other classification systems used by companies not listed on the Australian Securities Exchange.

Total JORC Code Reserves of nickel are adequate for 31 years at current rates of production.

Exploration

Expenditure on nickel-cobalt exploration for 2012 as reported by the Australian Bureau of Statistics was $235.7 million, a decrease of 10.1% on 2011. WA attracted most of this expenditure with $228.4 million.

Production

All of Australia's nickel production in 2012 was from WA and amounted to 244 kt, up from 215 kt in 2011, as reported by BREE. The value of all nickel products exported was $4.005 billion and was Australia's eight most valuable mineral and petroleum export commodity. Australia was the world's fourth-largest nickel producer behind Philippines, Indonesia and Russia accounting for 11.4% of estimated world mine production.

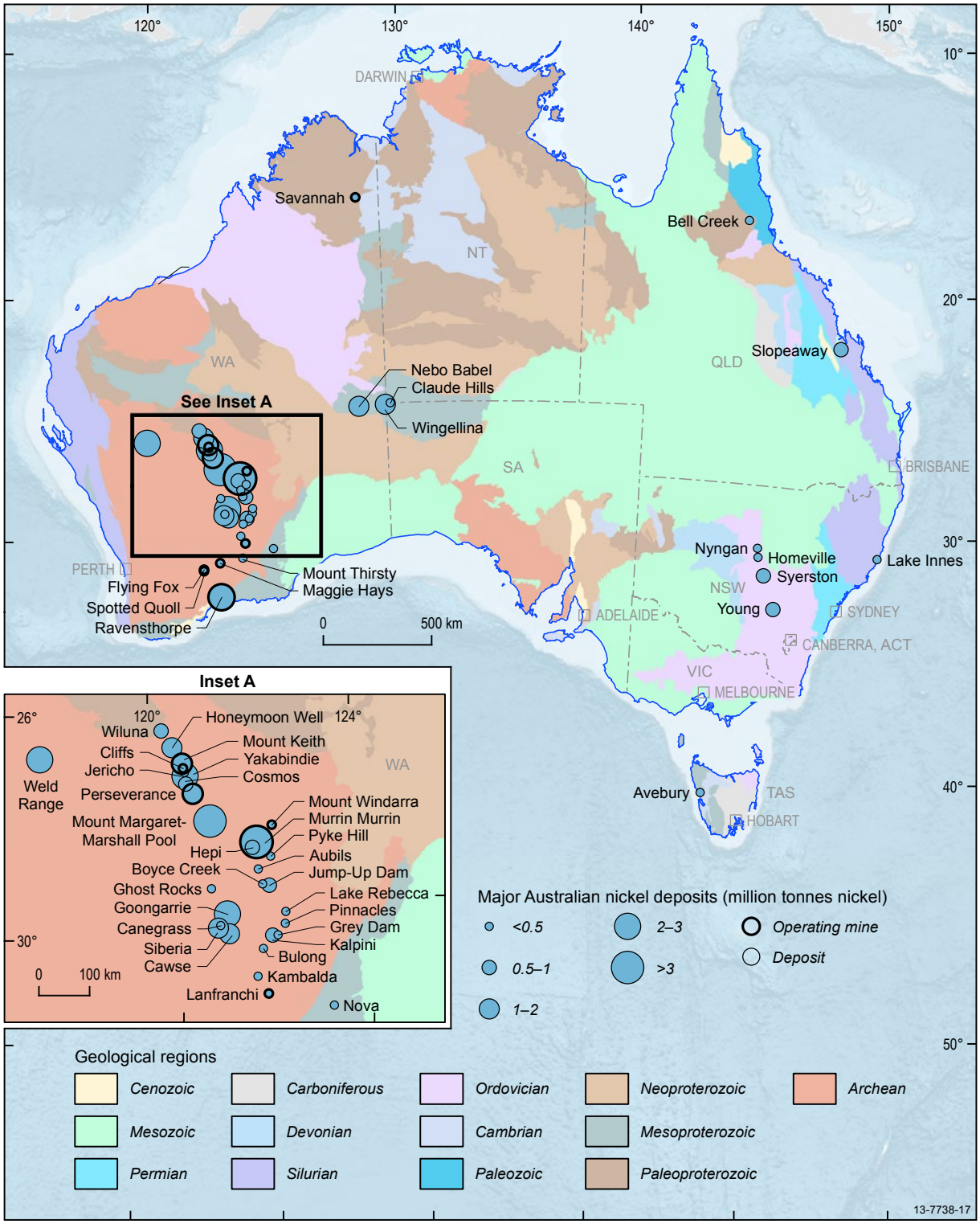

Figure 13: Australia's major nickel deposits based on total Identified Resources.

World Ranking

Based on figures published by the USGS and the latest Australian resource figures, world economic resources of nickel decreased to 72.6 Mt in 2012 from 76.0 Mt in 2011. Australia's share of world economic resources of nickel was 24.4% in 2012. It remained the largest holder of economic resources followed by New Caledonia (16.5%), Brazil (10.3%), Russia (8.4%) and Cuba (7.6%).

Russia was the largest producer with 330 kt (15.4%), followed by Indonesia with 320 kt (14.9%), Philippines with 270 kt (12.6%) and Australia with 244 kt (11.4%).

Industry Developments

In its September Resources and Energy Quarterly 2013, BREE reported the nominal average price for nickel in 2012 was about US$17 504/t, a decrease from about US$22 854/t in 2011. The average spot price of nickel in 2013 is forecast to decrease by 14% to US$15 103/t, relative to 2012. In the longer term, however, nickel spot prices are projected to increase over the period 2014 to 2018 and average US$16 250/t in 2018 (in 2013 US$).

The major sulphide nickel mines, which are owned by BHP Billiton Nickel West Pty Ltd, continued operating at Leinster, Mount Keith and Cliffs north of Kalgoorlie in WA. Smaller sulphide nickel mines in WA continued to be operated by Mincor Resources NL, Panoramic Resources Ltd, Western Areas Ltd and Independence Gold NL. Glencore Xstrata plc closed down its sulphide nickel operations at Cosmos in 2012 but continued its small nickel mine at Sinclair, WA. Glencore Xstrata's Murrin Murrin lateritic nickel mine continued to operate in 2012 and First Quantum Minerals Australia Nickel Pty Ltd continued production of nickel mixed hydroxide precipitate from its lateritic nickel operation at Ravensthorpe in 2012.

Nickel sulphide deposits

BHP Billiton reported that its WA operations produced 104 200 t of nickel during 2012 sourced from the **Mount Keith**, **Leinster (Perseverance)** and **Cliffs** mines. Production was down from 109 000 t in 2012. BHP Billiton Nickel West also operate the Kambalda concentrator south of Kalgoorlie, where ore is sourced through tolling and concentrate purchase arrangements with third parties in the Kambalda region. Leinster and Mt Keith have reserve lives of eight and twelve years, respectively; both have options for further expansion. Cliffs is a high-grade underground mine with a reserve life of four years. The reduction in nickel production during 2012 due to planned maintenance at the Nickel West Kalgoorlie smelter and Kwinana refinery.

Ore from Mt Keith mine is concentrated at Mt Keith and then transported by road approximately 110 km to Leinster for drying. Ore from Cliffs and Leinster mines is concentrated and dried at Leinster. Dry nickel concentrate is then transported via road and rail approximately 375 km to BHP Billiton Nickel West's Kalgoorlie smelter. Concentrate from Kambalda is transported via rail approximately 60 km to the Kalgoorlie smelter. Small volumes of concentrate are sold into the external market; however, the majority of volumes are processed into nickel matte, containing approximately 68% nickel. In 2012–2013, approximately 34% of the nickel matte production was exported. The remaining nickel matte is transported, principally by rail, to Nickel West's Kwinana nickel refinery, a distance of approximately 650 km. The nickel matte is processed into nickel metal in the form of London Metal Exchange-grade briquettes and nickel powder, together with a range of saleable by-products.

The Kwinana nickel refinery has a capacity of 65 000 tpa of nickel metal. BHP Billiton reported that a new hydrogen plant at its Kwinana refinery was successfully commissioned in the first half of 2012.

BHP Billiton announced on 17 December 2013 that due to a seismic event on about 31 October 2013, production at the Leinster Perseverance underground mine had ceased due ongoing safety concerns.

OJSC MMC Norilsk Nickel owns the **Lake Johnston** operations 500 km east of Perth, WA, and includes the **Maggie Hays** mine which was placed on care and maintenance in April 2013. The ore for the concentrator is sourced from the Maggie Hays mine and the total nickel production in 2012 amounted to 8975 t. The company investigated options for adapting existing nickel processing facilities at **Cawse** for the use of new hydrometallurgical technology. The plant was expected to be re-oriented towards the processing of sulphide feedstock from Norilsk's Australian sulphide nickel deposits. Norilsk is planning to produce a nickel hydroxide with a nickel content of about 50%, which bypasses smelting by directly refining the semi-product. The use of this technology is expected to reduce the costs of refined metal.

Xstrata Nickel Australasia Pty Ltd operates the **Cosmos** nickel project in WA which is made up of a concentrator at Cosmos and mines at **Tapinos** and **Prospero**. Another operation, the **Sinclair Mine**, which has its own concentrator, is about 100 km southeast of the Cosmos operations. In September, Xstrata announced the suspension of operations at Cosmos project and introduction of a care and maintenance schedule in response to adverse market conditions, including a prolonged period of low nickel prices and a strong Australian dollar. Evaluation of the newly-discovered **Odysseus**, **Odysseus North** and **Odysseus Massive** deposits at Cosmos was continued, with a view to completing a feasibility study by the first quarter of 2014 to enable an investment decision, which would depend on market conditions. Mining operations ceased at Sinclair in May 2013 as resources were exhausted but stockpiled ore will continue to be processed.

Xstrata announced that metal in concentrates produced in 2012 from the Cosmos and Sinclair operations, amounted to 11 674 t of nickel, 573 t of copper and 322 t of cobalt[24]. The concentrate is transported by truck to the coastal town of Esperance in southwest WA and shipped to the Xstrata nickel smelter in Sudbury, Ontario.

Western Areas Ltd nickel mine at the **Flying Fox** deposit in WA mined 18 884 t of nickel in 2012. Underground mining at the company's **Spotted Quoll** deposit produced 8169 t of nickel and an additional 2280 t of nickel in concentrate was produced from the open-cut operation at Spotted Quoll. All ore mined at Flying Fox and Spotted Quoll is treated at the Cosmic Boy concentrator. The Cosmic Boy concentrator also treated the ore from the **Lounge Lizard** deposit. In March 2012, Kagara Ltd announced that it had completed the sale of its Lounge Lizard deposit to Western Areas. The nickel concentrate from the Cosmic Boy plant is delivered under off-take contracts to BHP Billiton in Kalgoorlie and to the Jinchuan Group in China.

As reported in Western Areas Ltd's 2013 annual report, total high-grade Measured, Indicated and Inferred Resources at 30 June 2013 for the Flying Fox and Lounge Lizard deposits amounted to 1 676 487 t at 5.7% Ni and an additional low-grade disseminated Measured, Indicated and Inferred Resources of 4 983 000 t at 0.8% Ni. The Spotted Quoll deposit has Indicated and Inferred Resources of 2 919 200 t of ore at 5.9% Ni. The company also reported, in their September 2013 quarterly report, an initial Indicated Resource of 113 000 t at 9.3% Ni and Inferred Resources of 22 000 t at 11.0% Ni for their **Spotted Quoll North** deposit. Western Areas noted in their annual report for 2013 that the annual cash cost of nickel in concentrate was $2.68/lb which puts Western Areas as the lowest cost nickel miner in Australia.

Western Areas is also developing its 'BioHeap' high-pH leaching microbial culture. The company reported in its 2013 annual report that testwork on a process stream from the Cosmic Boy concentrator (CBC) was completed and the encouraging results are being used to conduct a preliminary engineering study. The testwork on the process stream from CBC has verified the capability of BioHeap's high-pH microbial cultures. The company claimed that this study has the potential for BioHeap to provide unique solutions to concentrators around the world for process streams that world normally be rejected from final concentrates.

During 2012, Panoramic Resources Ltd's underground mine operation at **Savannah** in WA produced 7360 t of nickel, 4438 t of copper, and 401 t of cobalt. Nickel concentrates produced at the Savannah plant are contracted for sale to the Jinchuan Group in China. Panoramic continued to explore for extensions of the Savannah deposit below the 900 m structure and on 17 September 2012 reported drill intersections in two holes of:

- 9.7 m at 2.55% Ni, 0.52% Cu and 0.16% Co, and
- 8.5 m at 2.2% Ni, 0.51% Cu and 0.12% Co.

In 2012, Panoramic produced 11 897 t of nickel and 1014 t of copper from **Lanfranchi**, WA. The ore from the Lanfranchi operation is processed at the Kambalda nickel concentrator owned by BHP Billiton.

On 12 April 2012, the company reported that drilling from the new hanging-wall drill drive, testing the down-plunge extension of the Lanfranchi orebody, intersected broad zones of strong matrix and massive sulphide mineralisation including best intersections in three holes of:

- 13.66 m at 9.31% Ni,
- 12.59 m at 7.6% Ni, and
- 9.32 m at 6.3% Ni.

24 Xstrata plc, 2013. Production report for the 12 months ended 31 December 2012, 13pp.

On 27 November 2013[25], Panoramic reported that drilling east of its **Deacon** deposit in the Lanfranchi group showed that the combination of channel facies lithologies, a strong off-hole conductor and mineralisation all suggests there could be another mineralised channel east of Deacon.

Mincor Resources NL's nickel production for 2012 was reported under two groups of operations in WA. The **North Kambalda** operation is made up of the **Otter Juan** and **McMahon** mines and Mincor's 70% interest in the **Carnilya Hill** mine. These operations yielded a combined production in 2012 of 3500 t of nickel, 283 t of copper and 62 t of cobalt. The **Southern Kambalda** operations produced 5564 t of nickel, 537 t of copper and 105 t of cobalt, from the **Mariners** and **Miitel** operations. The Carnilya Hill mine was closed in March 2012. The ore body was discovered by Mincor in 2006 and mining commenced in early 2008. A total of 339 849 t of ore at 3.18% Ni was produced, at a life-of-mine cash cost of $4.96/lb payable nickel. Mincor reported in their September 2013 quarterly report that both McMahon and Otter Juan are likely to close before the end of 2013.

Independence Group NL reported total production for 2012 of 11 094 t of nickel and 840 t of copper from its **McLeay**, **Victor South**, **Moran** and **Long** mines in WA. The company noted in its September 2013 quarterly report that it was continuing exploration drilling at the **Long North** and **Moran South** deposits. Independence also reported in their 2013 annual report that payable cash costs for the 2012–2013 financial year, including royalties, was $4.34/lb Ni. The nickel ore produced from the Long operation is treated at the BHP Billiton Nickel West Pty Ltd Kambalda nickel concentrator.

Poseidon Nickel Ltd announced on 12 November 2012 that the WA Minister for State Development had given conditional approval to resume nickel mining at the **Mount Windarra** site in the north eastern goldfields of WA. The proposal for the resumption of mining and processing operations at the Mount Windarra site includes:

- Resumption of nickel mining at the Mount Windarra underground mine;
- Commencement of nickel mining at the new **Cerberus** ore body;
- Construction of a nickel flotation concentrator plant capable of minimum throughput of 700 000 tpa;
- Construction of a gold tailings retreatment facility; and
- Installation of in-pit tailings deposition via a slurry pipeline to **South Windarra**.

Poseidon reported in their September 2013 quarterly report that the permitting process has been completed but the company is waiting for improvement in demand for nickel before seeking financing for the project. The company also reported additional new mineralised zones of nickel close to existing mine with true zone widths as follows:

- 8.68 m at 2.36% Ni,
- 17.53 m at 3.52% Ni, and
- 3.57 m at 2.77% Ni.

25 Panoramic Resources Ltd, 2013. Company Update - November 2013. Announcement to the Australian Securities Exchange, 27 November 2013, 6pp.

Sirius Resources NL announced that on 21 July 2012 it had discovered the **Nova** nickel-copper-cobalt deposit in the Fraser Range, WA. The discovery followed drilling the southern end of a 1.2 km-long electromagnetic conductor. By September 2012, Sirius had drilled approximately 70 holes over the southern half of this conductor and delineated thick, continuous mineralisation over an area measuring approximately 500 m down plunge and up to 400 m down dip. The mineralisation forms a thick lenticular slab which is up to 60 m thick in the central part. On 28 February 2013, Sirius announced another discovery east of Nova named the **Bollinger** deposit. These discoveries were followed by mineral resource assessments released on 15 July 2013 stating that the combined Indicated and Inferred Resources for Nova-Bollinger totalled 14.6 Mt at 2.2% Ni, 0.9% Cu and 0.08% Co for 325 000 t of nickel, 134 000 t of copper and 11 000 t of cobalt (at a 0.6% nickel-equivalent lower cut-off). Results of a scoping study for the Nova-Bollinger project was released on 18 September, 2013 which included the following:

- Production of separate nickel and copper concentrates planned to commence in mid-2016 with an initial mine life of 10 years;
- Projected life-of-mine nickel revenue of $4.6 billion;
- Projected net cash flow of $2.8 billion (including capital);
- Estimated cash operating cost of $1.75/lb Ni in concentrate (after by-product credits);
- Estimated capital cost to first concentrate production of $471 million including $51 million of contingency;
- 1.5 Mtpa throughput plant resulting in average annual production of 28 000 t of nickel and 11 000 t of copper in concentrate;
- Mining inventory of 13.9 Mt grading 2.0% Ni, 0.82% Cu and 0.07% Co for a contained 276 000 t of nickel, 114 000 t of copper and 9300 t of cobalt; and
- Definitive feasibility study on track to be completed by mid-2014 enabling underground development and on-site construction to start in the third quarter of 2014.

Lateritic nickel deposits

The annual production for 2012 from the **Murrin Murrin** lateritic nickel plant in WA operated by Glencore Xstrata plc was a record 33 400 t of nickel and 2400 t of cobalt.

First Quantum Minerals Australia Nickel Pty Ltd acquired the **Ravensthorpe** lateritic nickel operation in WA from BHP Billiton in February 2010. In a media release on 3 November 2011, First Quantum reported:

- The plant is performing well and ramping up as planned towards commercial operations before the end of 2011;
- First production of nickel contained in mixed hydroxide was achieved on 4 October 2011;
- Reconstructed plants consistently achieving design throughputs; and
- Both Atmospheric Leach and Pressure Acid Leach plants have been brought on line.

First Quantum Minerals is planning to produce 39 000 tpa of nickel metal for the first five years and 28 000 tpa for the remainder mine life of about 30 years.

The **SCONI** (previously NORNICO) project in Queensland is owned by Metallica Minerals Ltd and includes five nickel-cobalt laterite deposits at **Greenvale**, **Lucknow**, **Kokomo**, **Minnamoolka** and **Bell Creek**. There has been significant interest in the company's potential to become a scandium producer. On 21 October 2013 Metallica announced[26] that SCONI's combined resource base of Measured, Indicated and Inferred Resources for the southern deposits of Lucknow, Greenvale and Kokomo stood at 89.1 Mt at 0.58% Ni, 0.06% Co, 48 g/t Sc using a 0.7% Ni equivalent cut-off grade (Ni equivalent is calculated using Ni + 1.5Co + 0.01Sc using commodity prices of US$10/lb Ni, US$15/lb Co, and US$1500/kg Sc_2O_3). Metallica also reported a Measured, Indicated and Inferred Resource of scandium totalling 20 Mt at 162 g/t Sc, 0.3% Ni and 0.06% Co.

26 Metallica Minerals Ltd 2013. Greenvale mineral resource update & Sconi JORC Code 2012 statement. Announcement to the Australian Securities Exchange, 21 October 2013, 40pp.

Metallica has entered into a Heads Of Agreement with Bloom Energy to supply up to 30 000 kg of scandium oxide (Sc_2O_3) per annum (based on production output and Bloom Energy's global usage) with provision to increase supply up to 60 000 kg scandium oxide per annum (at Bloom's election) over the term of the agreement. Metallica also has entered into a non-binding Memorandum Of Understanding (MOU) with KBM Affilips BV, Europe's leading producer of master alloys. Under the MOU, KBM Affilips will assist Metallica with its ongoing feasibility studies and in developing relationships with key aerospace and component manufacturing companies in procuring funding for the development of the SCONI project and enter into commercial negotiations with respect to an offtake agreement governing the sale of scandium from the SCONI project. Based on ongoing discussions with potential scandium oxide end users, Metallica has revised its potential estimates for future scandium oxide demand from SCONI. Metallica announced an updated mine plan and a scoping study, for the SCONI project to allow production of approximately 90 tpa of scandium oxide over not less than 20 years based on a processing rate of 750 000 tpa of ore. The revised mining plan, which is designed to increase the scandium oxide production level, results in an increased pre-tax net present value of $870 million for the SCONI project (up from $402 million) and increased average annual operating margin of $213 million (up from $179 million).

Metals X Ltd owns the **Wingellina** lateritic nickel deposit in WA, which has a published a Probable Reserve of 167.47 Mt at 0.98% Ni and 0.08% Co on 6 September 2012[27]. In July 2010, Metals X signed a Mining Agreement with the Ngaanyatjarra Land Council for the Wingellina project. The agreement is subject to regulatory approvals and a mining lease being granted. Environmental approvals are expected to be finalised in 2013[28]. On 20 April 2011, Metals X through its wholly owned subsidiaries Austral Nickel Pty Ltd and Hinckley Range Pty Ltd entered into a Heads of Agreement with China's largest nickel producer, Jinchuan Group Ltd (Jinchuan) to sell to Jinchuan a 20% direct interest in the company's globally significant Wingellina Nickel-Cobalt Project as part of the project's advancement toward future production. In 2012 Metals X signed a non-binding MOU with Samsung C&T Corporation which is to complete an updated bankable feasibility study, provide technical expertise in engineering and assist with the financing and development proposals for the project. The company reported in their 2013 annual report that, in response to falling nickel and cobalt prices and depressed nickel market outlook, a decision was made in June 2013 to defer the expenditure on the updated feasibility for a period of up to 12 months.

The **Barnes Hill** project in Tasmania is a joint venture between Metals Finance and Proto Resources & Investments Ltd which owns the tenements. The project is based on a lateritic nickel deposit located in northeast Tasmania and has an Indicated Resource of 5.674 Mt of ore grading at 0.82% Ni and 0.06% Co. The Indicated Resource includes a Probable Reserve of 3.956 Mt at 0.84% Ni and 0.06% Co. In addition, the Barnes Hill deposit has an Inferred Resource of 933 000 t at 0.77% Ni and 0.059% Co. Proto Resources released results of an updated feasibility study on 26 March 2013[29] that estimated construction capital for the project of $78.4 million, operating costs of $5.16/lb (nickel equivalent with cobalt credits) in the first 5 years, $5.75/lb over the first 10 years and a net present value of $143.6 million (12.5% discount rate). The feasibility study is based on commodity pricing of $10/lb Ni and $13/lb Co with foreign exchange parity.

27 Westgold Resources Ltd and Metals X Ltd, 2012. Announcement to the Australian Securities Exchange 6 September, 2012, 31pp.

28 Metals X Ltd, 2013. Presentation to the annual general meeting 2013, 32pp.

29 Proto Resources & Investments Ltd, 2013. Barnes Hill optimised feasibility study completed. Announcement to the Australian Securities Exchange, 7pp.

The combined Measured, Indicated and Inferred Resources for GME Resources Ltd's **NiWest** nickel laterite project comprising the **Mount Kilkenny**, **Hepi**, **Waite Kauri**, **Murrin North**, **Mertondale**, **Wanbanna**, **Macey Hill** and **Eucalyptus** nickel-cobalt laterite deposits at a cut-off grade of 0.8% Ni amount to 75.73 Mt at 1.01% Ni and 0.06% Co. The deposits are located about 50 km east of the Leonora township in WA and are adjacent to Glencore's Murrin Murrin lateritic nickel-cobalt mine. The area is well serviced with infrastructure, including a gas pipeline, an open access rail line linked directly to ports and a sealed road running through the project area and linked to established mining townships on either side. The company released the results of a scoping study on 11 December 2013[30] which included the following:

- Optimum start-up project at 1.5 Mtpa combined heap leach- direct solvent extraction and electrowinning process plant;
- Defined resources support minimum 20-year operation with potential to extend further or scale up production;
- Annual production rate of 14 000 t nickel cathode and 540 t cobalt;
- Figures based on a nickel price of US$10/lb and an exchange rate of US$1.00 to $0.85;
- Operating Cost at US$5.68/lb Ni (includes royalties);
- Capital Cost of $460 million (includes contingency of $103 million);
- Operating surplus of $2.8 billion pre-tax (includes capital payback);
- Net present value of $934 million pre-tax (10% discount);
- Internal rate of return of 37%;
- Pay back on capital in 2 years; and
- Capital intensity at US$12.75/lb annual nickel production.

Heron Resources Ltd announced on 18 December 2013[31] that it has entered into a strategic partnership with the Simulus Group LLC to co-fund the development of an atmospheric leach process together with the acid recovery and recycling for Heron's lateritic nickel deposits. Heron stated that the process has the potential to reduce the capital and operating costs associated with development of its lateritic nickel deposits compared with the high pressure acid leach (HPAL) process employed in the 2009 and 2010 **KNP (Kalgoorlie Nickel Project)** prefeasibility studies. Simulus has now commenced testwork on Heron's **Siberia** limonite ore, and the production of a scoping study to assess the capital and operating costs for a commercial-scale nickel laterite processing operation based on atmospheric leaching and reagent recovery within a fairly standardised mixed hydroxide product flowsheet.

Heron's total Measured, Indicated and Inferred Resources of its lateritic nickel and cobalt deposits on 18 October 2013[32] amounted to 655.4 Mt at 0.693% Ni and 0.047% Co.

30 GME Resources Ltd 2013. NiWest nickel laterite project: scoping study results. Announcement to the Australian Securities Exchange, 11 December 2013, 9pp.

31 Heron Resources Ltd 2013. Kalgoorlie Nickel Project update - exclusive partnership with Simulus. Announcement to the Australian Securities Exchange, 18 December 2013, 2pp.

32 Heron Resources Ltd 2013. Kalgoorlie Nickel Project updated mineral resource estimate. Announcement to the Australian Securities Exchange, 18 October 2013, 23pp.

Niobium

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Niobium (Nb) and tantalum are often found together in the same ores, namely columbite ((Fe, Mn)Nb_2O_6) and tantalite ((Fe,Mn)Ta_2O_6), because of their very similar chemical properties. Niobium is used with iron and other elements in stainless steel alloys. Niobium-titanium alloy wire is used in the medical sector for magnetic resonance imaging. Niobium alloys are strong and are often used in pipeline construction. The metal is used in superalloys for jet engines and heat-resistant equipment. At cryogenic temperatures (minus 150 °C), niobium is a superconductor.

For location of niobium deposits refer to Figure 20 in the tin chapter.

Resources

In 2012, Australia's EDR of niobium remained unchanged at 205 kt. The bulk of the EDR of niobium is associated with the Toongi deposit (Dubbo Zirconia Project), 20 km south of Dubbo in New South Wales. This deposit is a sub-volcanic intrusive trachyte body (vertical) with dimensions of approximately 900 m x 600 m which has been drilled out to a depth of 55 m to provide a Measured Resource (reported in December 2012) of 35.7 Mt grading 0.46% Nb_2O_5, and between 55 and 100 m for an Inferred Resource of 37.5 Mt grading 0.46% Nb_2O_5[33].

The other source of niobium EDR is the Brockman-Hastings deposit located 18 km southeast of Halls Creek in Western Australia. This deposit, which is owned by Augustus Minerals Ltd, is hosted by a fine-grained volcaniclastic unit informally known as the Niobium Tuff within a sequence of thick volcano-sedimentary rocks. The Niobium Tuff can be traced over a strike length of 3.5 km and varies in width up to 35 m. In September 2011, the company reported a JORC Code compliant resource of 36.2 Mt grading 0.89% ZrO_2, 0.36% Nb_2O_5 and 0.018% Ta_2O_5 which included an Indicated Resource of 27.1 Mt grading 0.36% Nb_2O_5 and an Inferred Resource of 9.1 Mt grading 0.36% Nb_2O_5[34]. These resources are based on a 1500 parts per million (ppm) Nb_2O_5 cut-off grade.

Since January 2010, the niobium and tantalum zone in the Mount Weld deposits in WA is defined as the separate Crown Polymetallic deposit. In January 2010, Lynas reported a JORC Code compliant resource of 37.7 Mt grading 1.07% Nb_2O_5 and 0.024% Ta_2O_5 that included an Indicated Resource of 1.5 Mt grading 1.4% Nb_2O_5 and 0.037% Ta_2O_5 and an Inferred Resource of 36.2 Mt grading 1.06% Nb_2O_5 and 0.024% Ta_2O_5[35].

Paramarginal Resources totalling 82 kt are unchanged from 2011 and account for all the Subeconomic Demonstrated Resources. They occur in the Hastings (also known as Brockman-Hastings; 67 kt) in the Halls Creek Orogen and in the Crown Polymetallic (15 kt) deposit in the eastern goldfields in WA.

No changes in the Inferred Resources (418 kt) have been recorded in 2012. Western Australia is the largest holder of Inferred Resources with 70% associated with the Mount Weld and the Hastings deposit, while NSW holds the remaining 30% in the Toongi deposit.

Accessible EDR

All of Australia's EDR of niobium is accessible.

JORC Reserves

JORC Code reserves comprise total niobium in Proved and Probable Ore Reserves as defined in the JORC Code. No changes in reserves of niobium (115 kt) have been reported in 2012. All are contained in the Toongi deposit.

33 Alkane Resources Ltd, 2012. Annual report 2012.

34 Hastings Rare Metals Ltd, 2011. Announcement to the Australian Securities Exchange 8 September 2011.

35 Lynas Corporation Ltd, 2010. Investor presentation January 2010. Presentation at http://www.lynascorp.com/Presentations/2010/Investor_Presentation_March_10_823534.pdf accessed on 8 October 2013.

Exploration

Exploration for niobium is occurring in WA and NSW, but there are no statistics available on exploration expenditure for niobium. Alkane Resources Ltd has reported the presence of mineralisation at the neighbouring Railway prospect (4 km northwest of the Toongi ore body), where reverse circulation drilling in the trachyte body intersected a zone containing grades ranging from 0.85% to 0.99% ZrO_2, 0.21% to 0.23% HfO_2, 0.21% to 0.26% Nb_2O_5, 0.013% to 0.15% Ta_2O_5 and 0.43% to 0.48% TREO (Y_2O_3 + REO)[36]. The report notes that there has been insufficient exploration of the Railway trachyte to define a mineral resource and it is uncertain that further exploration will result in the determination of a mineral resource.

During 2011, Hastings Rare Metals Ltd completed a 51-hole drilling program at the Hastings deposit and reported numerous significant intersections of ZrO_2, niobium and rare-earth elements. In November 2012, Hastings announced the acquisition of additional tenements in the Hastings deposit area to focus on the exploration of rare-earth element mineralisation[37].

Production

Currently there is no production of niobium in Australia. However, in previous years niobium concentrates were recovered as a by-product of tantalum mining.

World Ranking

Based on incomplete world estimates published by the USGS for 2012, the largest holders of the world's niobium resources are Brazil with 4100 kt and Canada with 200 kt[38]. USGS data also estimates that world production of niobium in 2012 was 68.7 kt, which represents an increase of 9% on 2011 production of 63.4 kt. The production was dominated by Brazil with 63 kt and Canada with 5 kt.

Industry Developments

Historically, Global Advanced Metals (GAM) Pty Ltd (formerly Talison Minerals) **Greenbushes** mine in WA produced tantalite-columbite concentrate for export. Columbite $Fe(Nb,Ta)_2O_6$ is the main niobium ore mineral. The company's primary tantalum plant at Greenbushes has been under care and maintenance since 2008 while its secondary processing plant treats primary tantalum concentrates from the **Wodgina** mine in the Pilbara region of WA. In January 2011, GAM announced it would resume operations at the Greenbushes and Wodgina mines but closed them again in early 2012 following softening of demand for tantalum. In 2011, GAM established an agreement with its neighbour, Atlas Iron Ltd, allowing it to use the infrastructure at the mine to support its iron ore production[39].

Alkane Resources Ltd is in advanced process of developing a Memorandum of Understanding with a niobium consumer to form a joint venture to produce ferro-niobium from niobium concentrate for specialised alloy markets from the Dubbo Zirconia Project based on the **Toongi** deposit. In May 2011, the company signed an Memorandum of Understanding with a European company committing to the joint venture all of the niobium produced. The company expects to convert the Memorandum of Understanding to an off-take/joint venture agreement in early 2013[40].

36 Alkane Resources Ltd, 2012. Annual Report 2012.

37 Hastings Rare Metals Ltd, 2012. Announcement to the Australian Securities Exchange 28 November 2012.

38 Niobium, 2013. United States Geological Survey, Minerals Commodity Summaries, January 2013.

39 Global Advanced Metals, 2011. World's largest tantalum producer resumes operation, 17 January 2012. Article at www.globaladvancedmetals.com/news/announcements/2011.aspx accessed on 8 October 2013.

40 Alkane Resources Ltd, 2012. Annual Report 2012.

Phosphate

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

Phosphate rock is a general term referring to rock with high concentrations of phosphate minerals. Phosphate rock is primarily mined to produce chemical fertilisers for the agriculture sector, with 90% of production going towards this purpose. Phosphorous is also used in animal-feed supplements, food preservatives, baking flour, pharmaceuticals, anticorrosion agents, cosmetics, fungicides, insecticides, detergents, ceramics, water treatment and metallurgy.

The most common source of phosphate rock is phosphorite, which is a marine sedimentary deposit. The other source is guano, an accumulation of bird or bat excrement. The most common phosphate minerals belong to the apatite group, $Ca_5(F,Cl,OH)(PO_4)_3$, with main minerals being collophane, francolite and dahlite.

Australia has two main phosphate mines. The larger is in northwest Queensland at Phosphate Hill, 140 km southeast of Mount Isa, and the other is on the remote offshore territory of Christmas Island in the Indian Ocean. Phosphate Hill is a world-class phosphorite resource that is close to the surface and easy to access and mine. The rock is ideal for the manufacture of high analysis mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) fertilisers for domestic and international use.

Christmas Island produces quality rock phosphate from guano deposits comprised of a sought-after combination of fluorohydroxyapatite, calcium, iron and aluminium. Christmas Island phosphate is exported to the Asia-Pacific region with products used widely as direct application fertiliser in the palm oil sector. In addition, Christmas Island phosphate is used in the manufacture of various fertilisers. Its relatively high phosphorus pentoxide (P_2O_5) grade improves many straight and compound fertilisers and its iron and aluminium content betters the granule strength of a range of acidulated fertilisers. In addition, its reactive characteristics enhance compacted fertilisers that do not undergo chemical processes.

DAP and MAP fertilisers have different ratios of phosphorous and nitrogen and have slightly different applications. Both products are generally produced as granules with a diameter of between 2–4 mm. DAP (20% P and 18% N) is used for broad-acre products such as cereals, legumes, fodder and horticultural crops, as well as for dairy and newly established pastures. MAP (22% P and 10% N) assists with early crop growth and enhances phosphorous uptake in broad-acre crops. Ideally, phosphate rock for fertiliser production will contain approximately 30% P_2O_5, around 5% calcium carbonate and less than 4% iron and aluminium oxides.

Resources

Australia's EDR of phosphate rock in 2012 was 869 Mt. This is slightly changed from the 2011 EDR of 945 Mt because some deposits have been reassessed owing to their geology and phosphate content. For example, Nolans Bore in the Northern Territory has an average P_2O_5 content of 12% but is primarily regarded as a rare earths deposit. Any phosphate produced would most likely be as a co-product or by-product rather than as a bulk commodity. As a result, Geoscience Australia has not regarded this kind of phosphate deposit as phosphate rock. However, the phosphate in this kind of deposit is included in the EDR of contained P_2O_5.

Australia's EDR of phosphate has rapidly increased from about 2009 (Figure 14). From 2007 to 2008, there was a significant price spike for phosphorous (Figure 15 and Figure 16), triggering increased interest and exploration, which has flowed through in subsequent years to increased resource definition. EDR of contained P_2O_5 in 2012 was unchanged from 2011 at 148 Mt.

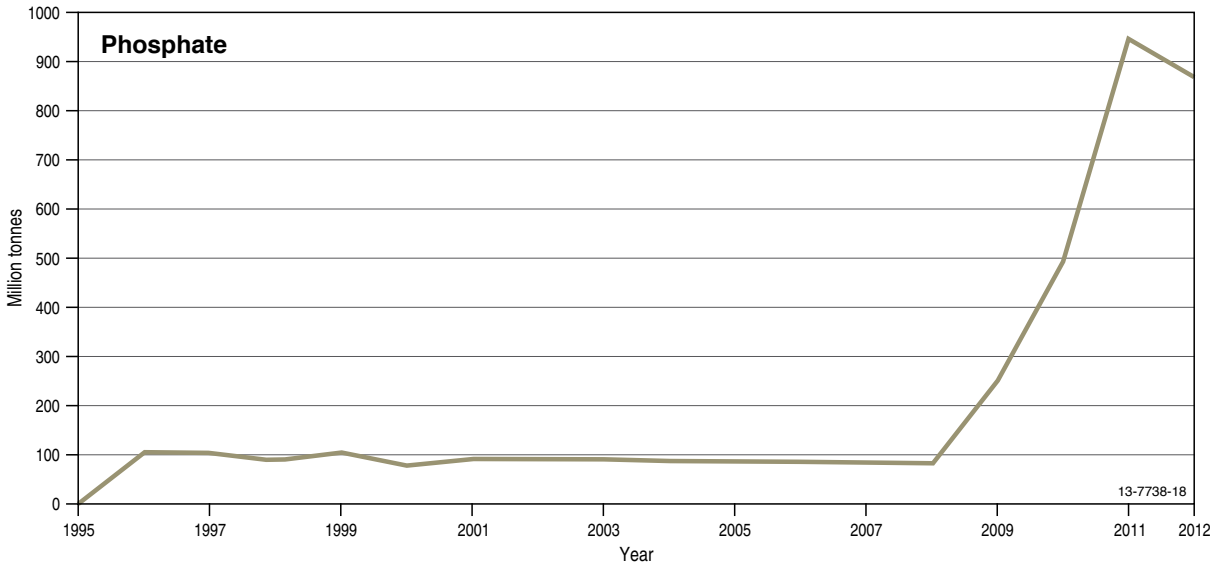

Figure 14: Australia's Economic Demonstrated Resources of phosphate from 1995 to 2012.

Australia's total demonstrated resource of rock phosphate is 1181 Mt, of which 312 Mt (26%) is classified as Paramarginal. Australia's total demonstrated resource of contained P_2O_5 is 213 Mt, of which 65 Mt (31%) is classified as Paramarginal. All of the demonstrated phosphate occurrences in Queensland and the Northern Territory, with the exception of Nolans Bore (NT), occur as phosphorites in the Georgina Basin, accounting for almost all of Australia's demonstrated resources of phosphate rock and 91% of Australia's demonstrated resources of contained P_2O_5. The remaining demonstrated resources occur at Christmas Island, Nolans Bore and the deposits of Mount Weld, Balla Balla, Dandaragan and Cummins Range in Western Australia (Table 10).

About 99% of Australia's Inferred Resources of phosphate rock (2068 Mt of a total of 2089 Mt) and 93% of Australia's Inferred Resources of contained P_2O_5 (329 Mt of a total 354 Mt) also occurs in the Georgina Basin phosphorites.

Table 10: Australia's EDR of phosphate at December 2012.

Deposit	Location	Ore Type	EDR (Mt)	Average Grade of P_2O_5 (%)	P_2O_5 (Mt)
Phosphate Hill	Queensland	Phosphorite	168.6 (a)	25.5 (a)	41.38 (a)
Paradise South	Queensland	Phosphorite	380.2	9.6	36.57
Paradise North	Queensland	Phosphorite	3.34	28.4	0.95
Wonarah	Northern Territory	Phosphorite	300.0	18.3	54.96
Nolans Bore	Northern Territory	Fluorapatite	25.3	12.0	3.04
Ammaroo	Northern Territory	Phosphorite	13.0	16.4	2.13
Mount Weld	Western Australia	Carbonatite	56.3	14.34	8.07
Christmas Island	Indian Ocean	Guano	(b)	(b)	(b)

(a) Incitec Pivot has not published updated resource figures since acquiring Phosphate Hill in 2006.
(b) Figures not publically available.

While Table 10 shows average P_2O_5 grades for Australian phosphate deposits with an EDR, published grades actually range from 8.7% P_2O_5 (Paradise South) to 30.0% P_2O_5 (Wonarah). Traditionally, phosphate rock needs to have an average grade of around 30% P_2O_5 for direct shipping. However, as the availability of high-grade resources is diminishing and demand is projected to increase, companies are increasingly evaluating projects in which lower grade phosphate resources could be mined and then beneficiated through processes such as washing, flotation and calcining. Similarly, milling operations in which phosphate products are produced as a by- or co-product are potentially economic at low grades.

Phosphate prices, as sourced from the World Bank, are expressed in the amount of US$ paid per metric tonne for free-alongside-ship (f.a.s.) Moroccan phosphate (70% bone phosphate of lime (BPL)). The long-term annual price chart for phosphate rock (Figure 15) shows that, for the most part, phosphate prices are generally flat but subject to price spikes from time to time. The price spike in 1974–75 was caused by the Moroccan Office Cherifien des Phosphates radically increasing the price for phosphate, followed quickly by Nauru and North American producers. Phosphate demand, however, slumped and prices gradually returned to the long-term average. The price spike in 2007–08 was a result of two economic factors combined with an already overheated market: The first was real increased fertiliser demand for food in developing regions (particularly Asia) and, importantly, for the emerging biofuel industry. The second factor was the resulting speculation about this increased demand and its implications for food security. The fact that prices have not yet returned to the long-term real dollar trend is possibly a truer reflection of the increased demand for fertilisers in Asia and other developing regions.

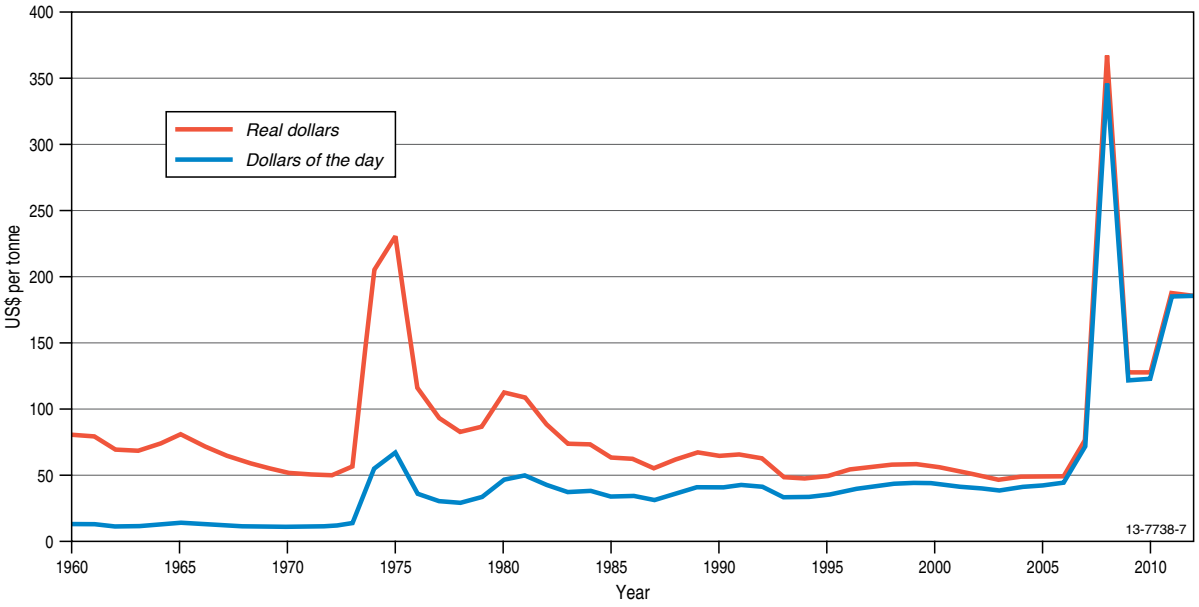

Figure 15: Long-term phosphate prices since 1960 for phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca. Source: World Bank.

Starting in 2007, Figure 16 shows the monthly price chart for phosphate, including the peak phosphate price of US$430/t in 2008 before the crash of the global financial crisis (GFC) took prices to lows of US$90/t in mid to late 2009. By 2011, prices had recovered from the lows of the GFC and steadily climbed to US$202/t by November. They fell in 2012, dipping to US$175/t in May and June, recovered by August 2012 to US$185/t, but have again fallen away since January 2013 to be just US$120/t in October 2013.

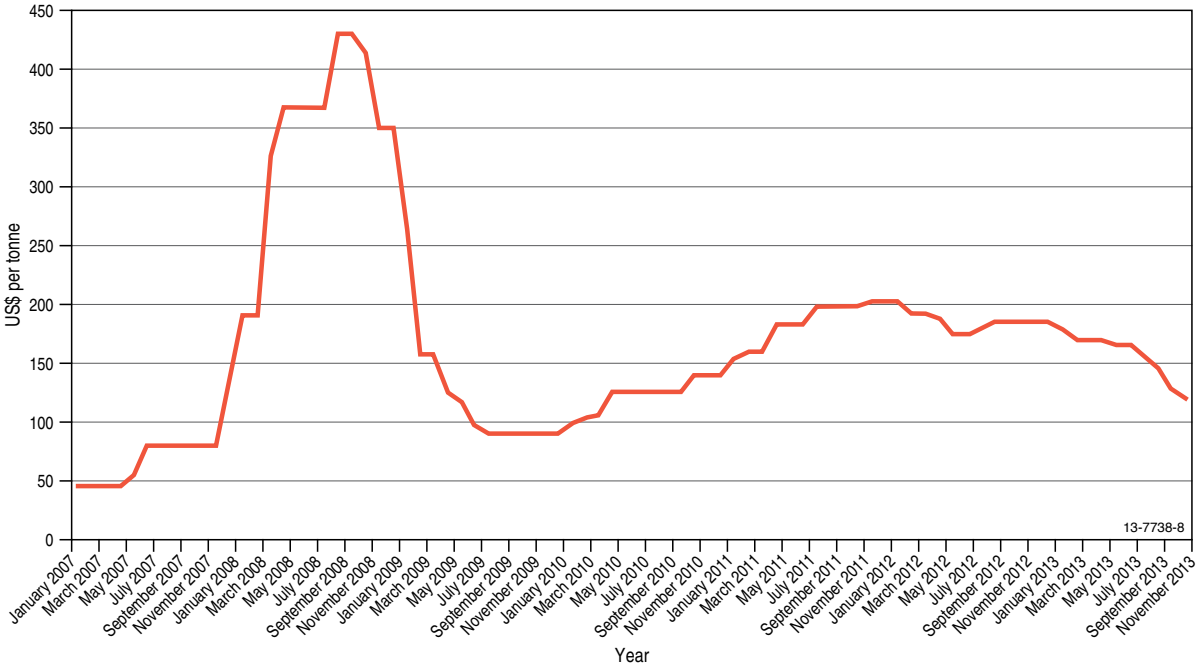

Figure 16: Monthly phosphate prices since 2007 for phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca. Source: World Bank GEM Commodities Database.

Accessible EDR

Virtually all of Australia's EDR of phosphate are accessible. A small resource on Christmas Island is inaccessible because of environmental restrictions.

JORC Reserves

By end of December 2012, JORC Code reserves in the Proved and Probable Reserve categories comprised 289.3 Mt of phosphate rock and 50.9 Mt of contained P_2O_5, accounting for approximately one third of accessible EDR with the remainder defined as Measured and Indicated Resources. This is a slight increase from the 280 Mt of phosphate rock and 45 Mt of contained P_2O_5 of the year before.

Exploration

Data on exploration expenditure for phosphate are not available in published statistics. However, exploration for phosphate is reduced from previous years with the bulk of activity occurring at advanced projects.

The Arganara (Central Australian Phosphate Ltd) and Ammarroo 1/Barrow Creek 1 (Rum Jungle Resources Ltd) phosphate projects in central Australia have seen the most exploration activity. These two projects are contiguous and upcoming exploration work will concentrate on assessing the mineralised corridor between them with some 300 holes for more than 10 000 m planned to be completed by the end of 2013.

During 2012, Rum Jungle drilled 1192 reverse circulation (RC) holes totalling 35 094 m on a closely spaced grid of 100x100 m at Barrow Creek 1 and, by October 2013, the company had completed infill and extensional resource drilling with 69 diamond drill holes for 2091 m as well as 214 RC/air core drill holes for 4849 m. In addition, Rum Jungle completed 130 holes for 1262 m at Ammaroo 1 and another 131 air core holes for 6442 m at the nearby Murray Downs prospect.

In WA, Potash West NL has been exploring the Dandaragan Trough north of Perth for greensand deposits containing both potash and phosphate. In June 2012, to enable resource estimation, the company completed an air core drilling program of 83 vertical NQ diameter holes for 3215 m over 10 square kilometres. In August 2012, the company completed four diamond drill holes for 148 m for greensand bulk density determinations.

Production

There are two main locations for the production of phosphate rock in Australia: Phosphate Hill in northwest Queensland and Christmas Island in the Indian Ocean. In 2012, Incitec Pivot Ltd produced 2.38 Mt of phosphate rock from Phosphate Hill (down from 2.49 Mt in 2011) and Phosphate Resources Ltd mined 662 632 dry tonnes of phosphate and shipped 716 600 dry tonnes of bulk rock phosphate and 44 070 dry tonnes of bagged phosphate dust from Christmas Island. Bagged phosphate dust was lower than in 2011 because shipments were affected by the port closure following the Tycoon Incident in early January 2012 in which the general cargo vessel MV Tycoon broke its mooring and foundered in severe weather spilling oil and phosphate close to shore.

Several small operations in South Australia produced 1863 t of phosphate rock in 2012, which is slightly up on the 1650 t produced in 2011. The main South Australian producer (around 1000 tpa) is Catford's Cut, located about 4 km east of the small settlement of Tarcowie. The phosphate is low grade (around 6%) but it is used locally as an agricultural fertiliser as it contains desirable levels of trace elements.

World Ranking

Figures from Geoscience Australia and the USGS indicate that total world resources of phosphate rock are approximately 67 500 Mt. Australia's EDR of phosphate rock comprises about 1% of the world's resources. Morocco and Western Sahara jointly hold about 75%, followed by China with 6% and Algeria and Syria with 3%. South Africa, Jordan, Russia and the USA each hold around 2% of the world's phosphate resources.

The USGS estimates that world production of phosphate rock in 2012 totalled 210 Mt (198 Mt in 2011), with China producing 89 Mt, the USA 29.2 Mt, Morocco/Western Sahara 28 Mt and Russia 11.3 Mt, all slightly up from 2011. Australia produced approximately 3 Mt of phosphate rock in 2012, ranking 10th in the world.

Industry Developments

Christmas Island

Phosphate Resources Ltd mined 662 632 dry tonnes of phosphate in 2012 on Christmas Island and shipped 716 600 dry tonnes of bulk rock phosphate along with 44 070 dry tonnes of bagged phosphate dust in 2012. The most recent figures are for the 2012–13 financial year and state that the company shipped 672 000 t of phosphate product.

In June 2013, the mining lease for Christmas Island was extended for another 21 years by the Commonwealth, covering some 1755 ha. Mining is now permitted until 2034 but Phosphate Resources continues to have problems gaining clearance permits over the mining lease.

The company has a program of capital works and recently installed the first phase of a cascade loading system which is expected to increase loading rates and improve environmental outcomes. The company is also continuing a major structural upgrade of the plant and facilities, including the fuel farm. There are plans also to upgrade the burner systems in the dryers and finalise the cantilever loading improvements.

Northern Territory

Arganara: In August 2012, Nupower Resources Ltd (now Central Australian Phosphate Ltd) released a maiden Inferred Resource for the Arganara deposit of 310 Mt at 15% P_2O_5 using a 10% cut off. The estimates were based on an X-ray fluorescence (XRF) analysis of 387 RC drill holes for 14 480 m of drilling. In March 2013, the company applied to the Northern Territory Department of Resources for a mineral lease over the prospect.

In February 2013, Central Australian Phosphate received a hostile takeover bid by Rum Jungle Resources Ltd and in November 2013 Rum Jungle announced it had acquired more than 90% of Central Australian Phosphate and was moving to compulsory acquisition of the remaining shares as per the *Corporations Act 2001*.

Meanwhile, Central Australian Phosphate, as a controlled subsidiary of Rum Jungle, has continued with its exploration program aimed at assessing the contiguous mineralised corridor between Arganara and the Barrow Creek 1 deposit. Based on limited drilling, a potential phosphate resource is conceptualised to lie between the two known deposits. The companies received a Clearing Certificate from the Central Land Council in the Northern Territory and work began in October 2013 with a plan to drill in excess of 300 holes for more than 10 000 m by the end of 2013.

Ammaroo 1/Barrow Creek 1: Rum Jungle Resources Ltd's Ammaroo Phosphate Project covers a number of exploration tenements over 175 km of strike of phosphorite in the Georgina Basin, approximately 280 km northeast of Alice Springs.

In December 2011, Rum Jungle Resources released a resource upgrade for Barrow Creek 1 comprising an Indicated Resource of 13 Mt at 16.4% P_2O_5 and an Inferred Resource of 240 Mt at 15% P_2O_5. The company followed up with resource infill and extensional drilling during 2012 drilling 1192 RC holes for 35 094 m on a closely spaced grid of 100x100 m. Additionally, the company completed southern extensional drilling at Ammaroo 1 (30 holes for 1262 m) and exploration drilling at nearby Murray Downs (131 air core holes for 6442 m).

In January 2013, the company announced a further upgrade at Barrow Creek 1 to a Measured Resource of 136 Mt at 15.7% P_2O_5, an Indicated Resource of 42 Mt at 14.9% P_2O_5 and an Inferred Resource of 60 Mt at 12.0% P_2O_5 using a 10% P_2O_5 cut-off. As at October 2013, the company had completed infill and extensional resource drilling with 69 diamond drill holes at Barrow Creek 1 for 2091 m as well as 214 RC/air core drill holes for 4849 m.

Rum Jungle also completed a scoping study on the Barrow Creek 1 deposit that identified three options for the economic development of the deposit accounting for capital and operating costs, production and transport:

- Starting as a Direct Shipping Ore (DSO) operation, ramping up to 1.8 Mtpa, switching to beneficiation by floatation when grade drops below traditional DSO levels.
- Beneficiation through flotation from the start, ramping up to 1.8 Mtpa of 30–32% P_2O_5.
- Production of 540 000 tpa of merchant-grade phosphoric acid.

All three options were found to be viable for the development of the deposit as a stand-alone operation with an operating life in excess of 25 years.

Rum Jungle is in the process of taking over Central Australian Phosphate which owns the nearby Arganara phosphate deposit. Combined, the Arganara and Barrow Creek 1 deposits have a resource of approximately 550 Mt of phosphate. The company has engaged WorselyParsons Ltd to lead a prefeasibility study for the combined Arganara-Barrow Creek 1 project, with results expected during the first half of 2014.

The company has also commenced a detailed program of metallurgical, mineralogical and beneficiation testwork. Chemical analyses of the phosphate ore indicates that it is low in uranium and cadmium but has higher than normal levels of lead compared to the Moroccan benchmark standard, which is typical for Georgina Basin phosphates.

Finally, the company has initiated good-faith negotiations with the NT Central Land Council to reach an agreement under the Native Title Act that will facilitate acquisition of a mineral lease, as well as tenure for a transport corridor.

Nolans Bore: Arafura Resources Ltd published a resource upgrade in March 2012 of 46 Mt at 11% P_2O_5, 2.5% rare earth oxides (REO) and 0.41% U_3O_8. This total resource is comprised of a 4.3 Mt Measured Resource (12% P_2O_5, 3.4% REO and 0.61% U_3O_8), a 21 Mt Indicated Resource (12% P_2O_5, 2.5% REO and 0.41% U_3O_8) and a 21 Mt Inferred Resource (10%P_2O_5, 2.3% REO and 0.37% U_3O_8).

In December 2012, the company published a maiden Probable Reserve of 24 Mt at 12% P_2O_5, 2.8% REO and 0.45% U_3O_8. Based on an open-cut mining method and a maximum beneficiation throughput of 1.1 Mtpa, these figures support a 22-year mine life with 95% of Measured and Indicated Resources converted to Reserves.

The company has continued work at Nolans Bore with activities such as proving up the beneficiation circuit, commissioning a sulphation demonstration plant, baseline environmental studies, technical reviews and optimisation programs. The recent depressed rare earths market has seen the company's main focus shift to boosting the project economics with targeted cuts of up to $1 billion, which includes the option of moving the chemical processing plant from Whyalla (SA) to close to the mine site in the Northern Territory. Arafura is preparing a definitive feasibility study and in September 2013, it announced a memorandum of understanding with Shenghe Resources Holding Co Ltd with a view to forming a strategic partnership.

Wonarah: Minemakers Ltd describes Wonarah as the largest known phosphate deposit in Australia, with only 15% of known mineralisation having been sufficiently drilled to enable a resource estimate to be defined. The deposit has a Measured Resource of 78 Mt at 20.8% P_2O_5, an Indicated Resource of 222 Mt at 17.5% P_2O_5 and an Inferred Resource of 542 Mt at 18.0% P_2O_5. The Northern Territory Government has designated Wonarah as a major project and the company has reached a life-of-mine Mining Agreement with the Traditional Owners that covers mining, processing and fertiliser production.

In June 2013, the Northern Territory Environmental Protection Authority granted approval for the company's proposed phosphate processing method – 'improved hard process' (IHP), which is a thermal technology that improves efficiency of superphosphoric acid production from rock phosphate. In November 2013, the company announced that its IHP demonstration plant had begun phosphate agglomeration feed to its kiln with expectation that production would begin in the near future.

Geolsec: The Geolsec phosphate resource is located near Rum Jungle, 65 km south of Darwin in the sedimentary Geolsec Formation deposited around the Waterhouse Dome. Korab Resources Ltd plans to supply the agricultural sector with finely ground rock phosphate to be used for direct application for pastoralists around Darwin, mango growers in the Ord River (WA) and Pine Creek (NT) regions and as an organic fertiliser in WA and the eastern states of Australia.

The company aims to develop a simple quarrying operation with no processing other than grinding and bagging. In December 2011, Korab received authorisation from the Northern Territory Department of Resources to conduct mining activities at the mineral lease covering the Geolsec project but owing to the presence of uranium in some parts of the deposit, not all of the required authorisations for quarrying have been obtained.

No exploration work has been reported for the deposit during 2012, but in September 2013 the company announced that it had engaged consultants with a view to obtaining the necessary quarrying permits. The company believes that the elevated uranium levels occur in small areas that can easily be defined and isolated. Results show that uranium oxide levels are generally low, mostly ranging between 40 and 120 ppm, which compares well to the typical global range of 30 to 250 ppm uranium oxide for phosphate rock. The company also announced that it had received approvals for a drilling program at Geolsec, which will help define long-term development plans.

The company claims that Geolsec has the best logistics of any phosphate rock project in Australia, being located near a major highway, rail, gas pipeline and power. There are no figures compliant with the JORC Code published for the Geolsec phosphate resource but there is a historical pre-JORC Code resource of 1.3 Mt at 12% P_2O_5.

Highland Plains: The NT portion of the Highland Plains phosphate deposit is owned by Phosphate Australia Ltd. In 2009, the company released a maiden Inferred Resource of 56 Mt at 16% P_2O_5 but has since corrected this to 53 Mt at 16% P_2O_5. In 2011 and 2012, the company had been investigating the potential for beneficiating the resource through froth flotation to a grade of around 34% P_2O_5 and transporting the slurry by pipeline to a barging facility in the Gulf of Carpentaria. However, in March 2013, Phosphate Australia reported that the project camp had been demobilised and sold, and all outstanding rehabilitation requirements closed out with a view to the possible sale of the project.

The company also has exploration permits for the geologically along-strike **Alexandria**, **Alroy** and **Buchanan Dam** prospects (some 130–170 km distant from Highland Plains) from which historical phosphate occurrences have been recorded.

Queensland

Highland Plains: The Queensland portion of the Highland Plains phosphate deposit is owned by Legend International Holdings Inc and was included in the withdrawn 2012 float of Paradise Phosphate Ltd on the Australian Stock Exchange. As part of the 2012 exploration program, Legend collected 552 samples from Highland Plains for assaying following a drilling program in 2011. The company also collected 454 samples from the nearby **Lily Creek- Sherrin Creek** phosphate deposit and 446 samples from the **Quita Creek** phosphate deposit. To date, no further drilling has been announced and resources remain at a historical, pre-JORC Code estimation of 84 Mt at 13.4% P_2O_5.

Paradise North, Paradise South, D-Tree: The Paradise North and South deposits were previously known as the **Lady Jane** and **Lady Annie** deposits, respectively. These deposits, as well as D-Tree, are part of the Paradise Phosphate Project owned by Legend International Holdings and were included in the withdrawn 2012 float of Paradise Phosphate on the Australian Securities Exchange. The company stated that it was in advanced negotiations with a potential strategic partner and that this course of action would provide greater shareholder returns.

Legend states that its initial focus is on developing the Paradise North project to mine and deliver phosphate DSO to potential Australasian and South Asian customers. The company has already shipped DSO to Ballance Agri-Nutrients Ltd's single superphosphate plant in New Zealand for trial production.

Legend's longer-term aim is to develop a beneficiation plant for the Paradise South deposit and, during 2012, the company completed a tendering process for the plant's design and construction. The tender packages cover the beneficiation plant, electrical power transmission, water supply and a tailings dam. In addition, the company received a patent for the beneficiation plant that describes a methodology for capturing ultrafine particles of phosphate that would otherwise be discarded as waste.

The company also lodged a Supplementary Environmental Impact Statement and Environmental Management Plan with the Queensland Government Department of Environment and Heritage Protection (DEHP) for the Paradise South project. In Oct 2012, the DEHP issued an Environmental Authority stipulating the environmental limits for an operation of up to 7.5 Mtpa of ore for 30 years. In addition, the DEHP accepted the Plan of Operations for Paradise North which approves the commencement of mining activity in 2013.

Phosphate Hill: Incitec Pivot Ltd, a publically listed company on the Australian Securities Exchange, does not publish resource figures. The last publically available resource compliant with the JORC Code for Phosphate Hill dates from BHP Billiton's Annual Report 2006 and quotes a Proven Reserve of 29 Mt at 24.6% P_2O_5 and a Probable Reserve of 52 Mt at 24.3% P_2O_5.

Incitec Pivot continues to work the Phosphate Hill deposit, mining some 2.38 Mt in 2012. The phosphate rock feeds into the Phosphate Hill fertiliser plant, the company's largest, which has a current (reduced) annual capacity of 763 000 t. The plant's capacity is reduced owing to production problems at the company's Mount Isa sulphuric acid plant. The sulphuric acid is used at Phosphate Hill, along with ammonia, to produce ammonium phosphates. Incitec Pivot also produces superphosphates at its Geelong and Portland plants.

Corella Bore: The **Korella** prospect at Corella Bore occurs immediately to the south of Phosphate Hill and also contains a rare earth (yttrium) resource occurring in the phosphate mineral xenotime (YPO_4). In June 2012, Krucible Metals Ltd received an Environmental Authority for level 1 mining activity on its lease over the Korella prospect and, in August 2012, the company was granted the Korella Phosphate Mining Lease for a quarry-style trial mining operation of the phosphate ore.

Corporate activities resulted in Krucible Metals signing a Heads of Agreement in August 2012 with Getax International Pte Ltd, a Singaporean company, with a view to forming a joint venture for mining and trading the phosphate from the Korella project. However, the agreement was terminated in January 2013 and Krucible announced that they proposed to sell their phosphate tenements, including the Korella mining lease, to Australia New Agribusiness and Chemical Group Ltd (formerly Daton Group Australia Ltd) for $12.371 million. The Sale and Purchase Agreement between the two companies was executed in May 2013, with a plan for completion no later than 31 January 2014.

Current resources at the Korella prospect are reported as an Inferred Resource of 8.3 Mt at 27.3% P_2O_5 and 13.72 Mt at 0.70 kg/t Y_2O_3.

Western Australia

Cummins Range: In 2011, Kimberley Rare Earths Ltd (now Anova Metals Ltd) acquired 25% of the Cummins Range REO-uranium-phosphate deposit, 130 km southwest of Halls Creek as part of a joint venture with Navigator Resources Ltd. They completed a 77-hole RC drilling program for 4230 m. However, in October 2012, the company terminated the joint venture agreement and relinquished its interest in Cummins Range, returning it to Navigator.

In September 2012, Navigator Resources announced a 17% increase in the Inferred Resource for Cummins Range to 4.9 Mt at 11.2% P_2O_5, 145 ppm U_3O_8, 1.74% REO and 48 ppm Th. Navigator also completed a pit optimisation study and a conceptual mine schedule in order to develop a preliminary evaluation study.

The future of Cummins Range is unknown because Navigator Resources went into voluntary administration in March 2013.

Balla Balla: The Balla Balla deposit is primarily a vanadium-titanium-magnetite (V-Ti-Fe) project but also contains a phosphate resource of 89.7 Mt at 3.74% P_2O_5. During 2012, the Balla Balla project was purchased by Forge Resources Ltd from Atlas Iron Ltd with the view to developing the V-Ti-Fe project. The company has no current plans to exploit the phosphate resource, but will be stockpiling the gabbro-host as it accesses the underlying tintanomagnetite ore zone, with a view to possibly processing the phosphate-rich gabbro in the future.

Dandaragan Trough: Potash West NL is principally exploring for potash in the greensand deposits of the Dandaragan Trough, 100 km north of Perth. In addition to potash, the company also has an Indicated Resource of 90 Mt at 2.65% P_2O_5 at its **Dinner Hill** deposit. In September 2013, Potash West released the results of a scoping study that examined the production of superphosphate from the greensands at Dinner Hill. Results showed that the phosphate was easily concentrated with recoveries in excess of 30% P_2O_5.

Mount Weld: Mined by Lynas Corporation Ltd, Mount Weld is one of the world's richest deposits of rare earth elements. It also contains a significant phosphate resource at the **Swan**, **Coors** and **Crown** deposits, with a total resource of 213 Mt at 13.9% P_2O_5. In March 2011, Lynas entered into an agreement with Forge Resources to sub-lease designated areas of the orebody for the exploitation of niobium oxide at the Crown deposit and phosphate at the Swan deposit. However, in May 2011, the agreement was terminated by Lynas, citing shareholders' wishes that it focus its energy on the rare earths project.

Platinum Group Elements

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The platinum group elements (PGE) comprise platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru). The elements of most commercial significance are platinum, palladium and, to a lesser degree, rhodium. The properties of PGEs which have commercial importance include their resistance to corrosion and oxidation, high-melting points, electrical conductivity and catalytic activity in the chemical, electrical, electronic, glass and motor vehicle industries. The emerging commercial importance of PGEs is in applications associated with the motor vehicle industry resulting from increasing global emission controls, development of lead-free petrol and efforts to improve fuel efficiency. Other applications include the use of platinum-rhodium alloys to oxidise ammonia to nitric acid in the production of fertilisers, while platinum is used extensively in jewellery.

According to figures published by Matthey (2013)[41], gross demand for platinum fell marginally in 2012 to 8.05 Moz with higher jewellery demand offset by sharply lower industrial buying. Demand for platinum in auto-catalyst applications rose slightly in 2012 to 3.24 Moz. The demand for platinum in jewellery increased by 305 000 oz to 1.57 Moz while the gross industrial demand for platinum fell by 405 000 oz in 2012. Net identifiable physical demand for platinum in the investment sector reached 455 000 oz in 2012, about 5000 oz lower than in 2011.

Gross demand for palladium increased by 16% to 9.90 Moz in 2012. Gross demand for palladium from the auto-catalyst sector in 2012 reached an all-time high level of 6.62 Moz as a result of greater use of palladium in light duty gasoline vehicles in China and another rise in the ratio of palladium to platinum in autoclasts for European diesel vehicles. Demand for palladium in industrial applications fell by 100 000 oz to 2.365 Moz, while demand for jewellery fell by 60 000 oz to 445 000 oz but net physical investment demand switched from a negative of 565 000 to a positive of 470 000 or an increase of more than 1 Moz to 470 000 oz in 2012.

Resources

Australia's EDR of PGEs remained unchanged at 4.7 t in 2012.

Western Australia and the Northern Territory hold all of Australia's EDR but additional EDR in other States may be established if deposits currently being assessed are confirmed to be viable. However, the EDR of PGEs in individual deposits within State and Territory jurisdictions is often unrecorded, resulting in the overall distribution of the PGE EDR being unknown.

In 2012, Paramarginal Resources increased from 135.3 t to 139.0 t while the Submarginal Resources declined from 35.3 t to 1.4 t in 2012. The Paramarginal Resources are shared mostly between WA (86.3%) and New South Wales (13.6%), while the Submarginal Resources are in WA.

Inferred Resources decreased from 148.2 t to 131.0 t in 2012 with WA having most (87.1%) followed by NSW (12.2%).

Total Identified Resources of PGEs, which represents EDR plus Paramarginal, Submarginal and Inferred Resources, total about 276 t. Of this amount, deposits that have only PGE resources account for about 51% of the total resources, although all of Australia's production is as a by-product from PGE resources associated with nickel sulphide deposits in WA.

Accessible EDR

Currently, 400 kg of the published PGE EDR is accessible for mining while the balance of 4.3 t occurs within national parks. The reason for the low AEDR figure for PGEs is that PGE resources are generally not reported by nickel-cobalt producers where PGEs are a by-product of nickel mining.

JORC Reserves

Currently there are no PGE resources in the AEDR of PGEs which have been reported as JORC Code Reserves. The reason for the absence of a published Reserve figure is that companies don't report the PGE content in nickel Reserves.

41 Mathey, J., 2013. Platinum 2013. http://www.platinum.matthey.com/media/1614079/platinum_2013.pdf

Exploration

Expenditure for PGEs is not reported separately and much of the PGE resource is associated with nickel deposits. Areas of activity in 2012 where PGEs were a significant component of exploration targets included regions of the Yilgarn in WA's eastern goldfields, the East Kimberley and West Pilbara as well as the West Musgrave in the border region of Western Australia, the Northern Territory and South Australia. Platina Resources Ltd was in the process of delineating platinum and scandium resources within their Owendale project in the Fifield area in NSW.

Production

Australia's PGE production (platinum and palladium) in 2012 amounted to 706 kg, which was very minor by world standards. The production was exclusively from nickel sulphide deposits hosted by Archean mafic/ultramafic rocks in WA.

World Ranking

Based on figures published by the USGS and the latest Australian resource figures, world economic resources of PGEs in 2012 remained unchanged at 66 000 t. Australia's share of world EDR was less than 0.1% in 2012. South Africa has most of the world's EDR with 63 000 t (95%), followed by Russia with 1100 t (1.7%) and the USA with 900 t (1.4%).

The world's supply of PGEs in 2012 was dominated by South Africa (70% Pt, 36% Pd) and Russia (10% Pt, 41% Pd), with minor contributions from Zimbabwe, Canada, the USA and Colombia.

Industry Developments

Platinum Group Elements as the major commodity

About half of Australia's Identified Resources of PGEs are in the following deposits, which have PGEs as the major commodity.

Western Australia

Munni Munni: Published Measured, Indicated and Inferred Resources of 23.6 Mt at 1.5 g/t Pd, 1.1 g/t Pt, 0.1 g/t Rh, 0.2 g/t Au, 0.09% Ni and 0.15% Cu. In its 2012 Annual Report, the owner of the deposit, Platina Resources Ltd, reported that the project was on hold.

Panton: Measured, Indicated and Inferred Resources total 14.3 Mt at 2.19 g/t Pt, 2.39 g/t Pd, 0.31 g/t Au, 0.27% Ni, and 0.07% Cu. On 20 March 2012, Platinum Australia Ltd announced the results of a review of the Panton project, reporting that it would generate a net present value (NPV) on base case assumptions of US$15 million with an initial capital cost of US$172 million. The operating costs was estimated to be US$830/oz of Pt+Pd+Au concentrate produced with an average annual production rate of 83 000 oz. On 21 May 2012, Panoramic Resources Ltd announced that it had purchased the Panton PGE deposit from Platinum Australia Ltd. Panoramic reported in its quarterly report for June 2013 that it was in the process of assessing the 2012 bankable feasibility study[42].

Weld Range – Parks Reef: A published Inferred Resource amounted to 14.76 Mt at 1.1 g/t Pt+Pd+Au and occurs in a truncated lateritic profile overlying low-grade primary PGE mineralisation in ultramafic rocks[43]. The Weld Range PGE deposit is adjacent to the very large Weld Range lateritic nickel-cobalt deposit which has an Inferred Resource of 330 Mt at 0.75% Ni and 0.06% Co. An Inferred Resource of 63.5 Mt at 5.2% Cr, 38% Fe and 0.38% Ni at a cut-off grade of 4% Cr also occurs within the Weld Range nickel-cobalt deposit. A scoping study was released by Weld Range Metals Ltd (WRM) in August 2010 which concluded that Stage 1 of the project is technically and economically feasible using processing equipment and technology currently used by the steel industry. Dragon Mining Ltd noted in its 2012 Annual Report that WRM continued to work with the Wajarri Yamatji people to develop these resources. In 2012, WRM and the Native Title Claimants entering into an Indigenous Land Use Agreement and Mining Agreement to allow exploration, mining and related activities to proceed within and adjacent to the tenements of WRM. The Indigenous Land Use Agreement has been submitted to the National Native Title Tribunal for registration.

42 Panoramic Resources Ltd 2013. Quarterly report for the period ending 30 June 2013, 24pp.

43 Parks, J, 1998. Weld Range platinum group element deposit. In: Geology of Australian and Papua New Guinean Mineral Deposits (eds: Berkman, D.A. & Mackenzie, D.H.), The Australasian Institute of Mining and Metallurgy: Melbourne, 279–286.

New South Wales

Fifield: Platina Resources Ltd[44] announced Indicated and Inferred Resources totalling 12.7 Mt at 0.7 g/t Pt for its Owendale North, Cincinnati and Milverton deposits at Fifield. The company also published a scandium (Sc) resource of 10.1 Mt at 340 g/t Sc. Historical production from Fifield amounts to about 640 kg of PGEs. On 11 September 2012[45], Platina Resources announced results of a scoping study which indicated the economic and technical viability of a combined platinum and scandium mining operation supporting an average mining rate of 6.9 Mtpa for three years. After three years the scandium-bearing stockpile laterite will continue to be processed to produce:

- 0.9 tpa of platinum for three years,
- 40 tpa of scandium oxide for 41 years.

For the scoping study, capital expenditure was estimated to be $222 million and annual operating costs $62 million for the first three years, reverting to approximately $42 million once platinum processing ceased.

Platina also reported that exploratory drilling in 2013 delineated new zones of fresh rock platinum mineralisation at Cincinatti and Milverton with the highest single platinum assay to date of 1 m at 24 g/t Pt from a drill hole depth of 26 m (Platina Resources Ltd, 2013a)[46].

Platinum Group Elements as the minor commodity

PGE resources are present also in deposits where other commodities are dominant, mainly komatiitic nickel-cobalt sulphide deposits as well as lateritic nickel deposits. They include the following deposits below.

Western Australia

Rosie: South Boulder Mines Ltd announced an updated total Indicated and Inferred Resource of 1.94 Mt at 1.7% Ni, 0.4% Cu, 0.8 g/t Pt and 1.1 g/t Pd[47].

Radio Hill nickel mine: Fox Resources Ltd reported that remaining Indicated and Inferred Resources of palladium amounted to 1.275 Mt at 0.493 g/t. In mid-2010, the company announced updated Indicated and Inferred Resources of 4.22 Mt at 0.65% Ni and 0.76% Cu for its Radio Hill mine. An Indicated and Inferred Resource of 5.78 Mt at 0.54% Ni and 0.67% Cu was reported also for the nearby Sholl B2 deposit, but no details were given for palladium content. The mine is on care and maintenance while the company is investigating options for heap leaching nickel and copper. On 15 November 2011, the company announced it had signed a non-binding Memorandum of Understanding (MOU) with Jiangxi Jiangli Sci-Tech Co. Ltd regarding the development of the Radio Hill and Sholl nickel-copper bacterial heap leaching project in the Pilbara region of WA. On 20 July 2012, Fox Resources reported that the MOU with Jianghi Jiangli had been suspended because of continuing low commodity prices for nickel and copper[48].

Waterloo nickel mine: The resources for this deposit were last reported in 2004 as 653 000 t at 2.795% Ni, 0.194% Cu and 0.858 g/t PGE. Recorded production amounts to 185 000 t of ore at 2.76% Ni in 2007 and 57 818 t of ore at 3.085% Ni in 2006, but there are no details on production of PGEs. The mine's owner, OJSC MMC Norilsk Nickel, placed the mine on care and maintenance in November 2008 because of prevailing low nickel prices and reduced world demand at the time.

44 Platina Resources Ltd, 2012. Project update: Owendale platinum and scandium resource, NSW, Australia. Announcement to the Australian Securities Exchange, 26 April, 2012, 12pp.

45 Platina Resources Ltd, 2012. Platina Resources delivers positive scoping study for Owendale project. Announcement to the Australian Securities Exchange, 6pp.

46 Platina Resources Ltd, 2013a. Significant platinum and scandium assay results at Owendale project NSW: Highest single platinum assay to date. Announcement to the Australian Securities Exchange, 16 July, 2013, 10pp.

47 South Boulder Mines Ltd, 2012. September Quarter operations report, 30pp.

48 Fox Resources Ltd, 2012. MOU with Jiangxi Jiangli Suspended. Announcement to the Australian Securities Exchange 20 July 2012, 1pp.

Horn nickel sulphide deposit: In April 2008, Breakaway Resources Ltd reported a small Inferred Resource for Horn nickel deposit of 600 000 t at 1.39% Ni, 0.3% Cu and 0.5 g/t Pd+Pt. In early 2009, the company reported that massive and matrix nickel sulphide mineralisation at the Horn deposit had been drilled over a 500 m strike length and remained open along strike. Geological mapping undertaken during the March quarter of 2009 confirmed the presence of nickeliferous gossans within a structurally bound, high magnesium oxide (MgO) ultramafic unit immediately south of the known mineralisation. The Revolution prospect[49], located immediately north of Breakaway's Horn nickel deposit includes PGE-bearing disseminated nickel mineralisation (12 m at 0.96% Ni, 311 ppm Cu and 424 ppb Pt+Pd from 192 m and 4 m at 1.14% Ni, 1003 ppm Cu and 749 ppb Pt+Pd from 209 m in drill hole LWDD0809).

Yarawindah Brook: An Inferred Resource of 2.9 Mt at 0.79 g/t PGE was announced by Washington Resources Ltd in March 2006. The deposit was acquired by Northern Minerals Ltd in 2010.

Bamboo Creek tailings: Haoma Mining NL announced on 5 October 2012 that assay results of samples of trial concentrates produced from its recently designed Bamboo Creek pilot plant by the Elazac Process showed they were suitable for commercial extraction of gold and PGEs (platinum and palladium). The company reported that commercial production was planned to commence in the near future. The company reported in its June 2013 quarterly report that test work was continuing to develop a commercial process to extract gold and platinum group metals from both Bamboo Creek Tailings and Mt Webber ores[50].

Binti Gossan and Binti South (Emu Lake): Emu Nickel NL reported in its 2011 Annual Report that a drilling program at Binti Gossan and Binti South had intersected significant nickel, cobalt and PGE values, with some of the best downhole intersections including 0.30 m at 7.55% Ni, 0.35% Co, 1015 ppb Pt and 1726 ppb Pd.

Jack's Hills: Victory Mines Ltd reported on 12 November 2012[51] that gossan samples collected at the Jack's Hills prospect returned analytical results of up to 13.9% Cu, 87.1 ppm Ag, 0.77% Ni, 0.24 ppm Au, 1.12 ppm Pt and 1.20 ppm Pd. Historical drill hole samples from a drilling program in 2007 returned values of up to 3.7% Cu, 1.14 g/t Au, 0.48% Ni, 0.73 g/t Pt and 14.4 g/t Ag[52].

Nebo-Babel nickel-copper-PGE deposit: The Nebo-Babel Ni-Cu-PGE deposit discovered by Western Mining Corporation Ltd in mid-2000 has a preliminary resource of 393 Mt grading 0.3% Ni, 0.3% Cu and 0.18 g/t PGE. The deposit was later acquired by BHP Billiton Ltd as a result of its takeover of Western Mining Corporation in mid-2005[53].

New South Wales

Nyngan lateritic nickel-cobalt-scandium-platinum deposit: In its 2004 annual report Jervois Mining Ltd reported a resource of 16 Mt at 0.87% Ni and 0.06% Co of which there is 3 Mt at 290 ppm Sc and 0.22 g/t Pt. The scandium-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718 Mt at 274 ppm Sc and Indicated Resources of 9.294 Mt at 258 ppm Sc.

Syerston lateritic nickel-cobalt-platinum deposit: In April 2000, Black Range NL announced a total platinum resource of Measured, Indicated and Inferred Resources of 108.3 Mt at 0.21 g/t Pt which occurs partly within the Syerston nickel-cobalt deposit. The platinum resource was calculated using a 0.6% nickel equivalent cut-off grade. In a preliminary prospectus, Ivanplats Ltd announced on 10 September 2012 that an internal study in 2005 indicated that, because of increasing capital and operating costs, development of the Syerston deposit was not economically attractive. However, Ivanplats announced that it was monitoring technological advances which could make Syerston commercially viable.

49 Breakaway Resources Ltd, 2011. Activity report for the quarter ended 31 December 2010. ASX Release 28 January 2011, 12pp.

50 Haoma Mining NL, 2013. Activities report for the quarter ended June 30, 2013, 18pp.

51 Victory Mines Ltd, 2012. Clara Hills rock chip sampling and RC drilling program completed. Announcement to the Australian Securities Exchange, 12 November 2012, 2pp.

52 Victory Mines Ltd, 2012. Prospectus, 144pp.

53 Seat Z., Beresford S.W., Gee M.A.M., Grguric B.A., Groves D.I., Hronsky J.M.A., Mathison C.I., and Waugh R. 2005. Geological and geochemical architecture of the Nebo and Babel Ni-Cu-PGE deposit, West Musgrave, Western Australia. Editors: Tormanen, T. O., Alapieti, Tuomo T. Source: Geological Survey of Finland, Espoo, Finland, 227–230, 10th international platinum symposium; Platinum-group elements; from genesis to beneficiation and environmental impact; extended abstracts, 2005.

Syerston Project Exploration Licence 7805, drill hole Sy10A: Exploration Licence 7805 is held by Jervois Mining Ltd which reported analyses from a drill hole in its June 2013 quarterly report[54] that revealed up to 2197 ppm Co, 0.35 ppm Pt, 352 ppm Sc, 909 ppm V and 42.5% Fe. The company reported that it was planning to commence a 14-hole aircore drilling program to test the occurrence.

Victoria

Thomson River: In 1981, CRA Exploration Pty Ltd estimated resources as 40 000 t averaging 3.2 g/t Pt, 3.6 g/t Pd, 2.7% Cu, 9.5 g/t Ag and 2.5 g/t Au. Intermittent mining since the discovery of the deposit in about 1864 produced around 13 200 t of ore, from which only about 10 kg of platinum was extracted.

Coopers Creek dyke prospect, East Walhalla, Maynards Gully: Orion Gold NL in its June 2013 report released assay results of samples from a historical drill hole showing 36 m from a drill hole depth of 303 m assaying at 1.75% Cu, 0.2% Ni, 0.78 g/t Pt, 1.08 g/t Pd, 0.39 g/t Au and 8.8 g/t Ag. Chip sampling of surface outcrops yielded elevated Cu-Ni-PGE values associated with pyroxenite. The company is planning drilling to test the extent of the mineralisation. Trial geochemical surveys are also being planned to cover Coopers Creek, East Walhalla and Maynards Gully and a trial geophysical survey over Coopers Creek is being designed to develop appropriate methods of exploration for this unique style of mineralisation.

Northern Territory

Coronation Hill: It was reported in 1994 (Economic Geology. Vol 89, p1053–1073) that the Coronation Hill deposit had an Indicated Resource of 3.49 Mt at 5.12 g/t Au, 0.21 g/t Pt and 0.56 g/t Pd with a further Inferred Resource of 2.87 Mt at 7.25 g/t Au, 0.35 g/t Pt and 1.31 g/t Pd. The deposit occurs within the Kakadu National Park and is inaccessible for mining.

Tasmania

Adamsfield[55]: The deposit it is located 70 km west of Hobart within the Franklin-Gordon Wild Rivers National Park. A small near surface Inferred Resource amounts to 14 500 t of ore at 6.5 g/t Ir, 7.3 g/t Os and 0.13 g/t Pt using a cut-off grade of 1 g/t Os+Ir.

54 Jervois Resources Ltd, 2013. Quarterly report to 30 June 2013. Announcement to the Australian Securities Exchange, 12pp.

55 Shree Minerals Ltd, 2009. Shree Minerals Ltd Prospectus, 160pp.

Potash

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The term potash refers to potassic fertilisers, which are potassium chloride (KCl or sylvite), potassium sulphate (K_2SO_4 or sulphate of potash (SOP), which is usually a manufactured product), and potassium-magnesium sulphate ($K_2SO_4 \bullet 2MgSO_4$ or either langbeinite or double sulphate of potash magnesia (SOPM or K-Mag)). Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride (halite) for fertiliser use, which includes minor amounts of other nontoxic minerals from the mined ore and is neither the crude ore sylvinite nor pure sylvite.

Resources

Historically Australia has always been deficient for known resources of potash but ongoing exploration has led to published resources in recent years for some deposits such as Lake Disappointment, Lake Chandler and the Dandaragan Trough/Dinner Hill deposit in Western Australia, in the WA/NT portion of Lake Mackay, and in the Karinga Creek Salt Lakes area in the southern Northern Territory.

JORC Reserves

Currently there are no JORC Code reserves for potash resources.

Exploration

Interest in exploration for potash in 2012 was largely restricted to areas with known deposits in WA and NT.

Production

Potassium chloride is the main fertiliser product, containing an average 61% of K_2O equivalent. In 2012, the main producers of potash were Canada with 9.0 Mt followed by Russia (6.5 Mt) and Belarus (5.65 Mt). The three accounted for about 62% of the world production of 34 Mt, which was down from 36.4 Mt in 2011.

In Australia, some minor historic production of potash include an operation at Buladelah Mountain, New South Wales, where alunite $KAl_3(SO_4)_2(OH)_6$, was mined between 1890 and 1926 and again from 1935 to 1952, for a total production of 75 000 t. Crude potash in form of soluble salt glaserite $(K,Na)_2SO_4$, was produced from Lake Chandler (WA) during 1943 to 1950 for a total of 9218 t of glaserite.

In 1973, Geoscience Australia's predecessor, the Bureau of Mineral Resources, reported that Texada Mines Pty Ltd was working towards becoming Australia's first local potash producer in the form of langbeinite $K_2Mg_2(SO_4)_3$ at Lake Macleod in northwest WA. The planned capacity of the proposed plant was variously reported to be from 80 000 to 200 000 tpa. There is no record of production of potash from the proposed operation.

Australia imports all its potash requirements and according to BREE[56], the imports of potassium fertiliser amounted to 298 kt in 2010–11 and 290 kt in 2011–12.

World Ranking

According to the USGS, the countries with the largest economic resources of potash (K_2O) in 2012 were Canada 4400 Mt, which represents about 46% of the total world resource, followed by Russia with 3300 Mt (35%) and Belarus with 750 Mt (8%).

56 Bureau of Resources and Energy Economics, 2012. Resource and energy statistics, annual 2012, 173pp.

Industry Developments

Western Australia

Lake Disappointment: Located in the Gibson Desert of WA about 320 km east of Newman, Lake Disappointment is a modern playa lake covering approximately 1600 square kilometres. Potash mineralisation occurs in lacustrine sediments of the lake and in the entrained brine.

On 13 March 2007, Reward Minerals Ltd published a lower estimate of 7705 Mt Indicated Resource at 3.17 kg/t K_2SO_4 containing 24 Mt K_2SO_4 and an upper estimate of 8635 Mt at 3.17 kg/t K_2SO_4 containing 27.37 Mt K_2SO_4. The difference between the upper and lower figure is the result of assumptions about the depth and area for the lake margins. On 30 October 2012, Reward Minerals lodged the Lake Disappointment Project Mining and Indigenous Land Use Agreement with the Native Title Tribunal for registration as an indigenous land use agreement between the Martu representative body Western Desert Lands Aboriginal Corporation (Jamukurnu-Yapalikunu), Holocene Pty Ltd and Reward Minerals Ltd. Reward Minerals has been granted a Mining Lease and a Miscellaneous Licence and advanced to the next phase of the project through exploration and feasibility stages.

On 9 April 2013, Reward Minerals released preliminary results from a 10 000 litre pilot evaporation trial over 180 days carried at Sylvania Station where the harvest grade/recovery figures were:

- Product A 3.44% K - Potash Recovery 47.5% (63.5% NaCl),
- Product B 8.80% K - Potash Recovery 40.0% (29.8% NaCl), and
- Composite 4.80% K - Potash Recovery 87.5% (57.0% NaCl).

The potash minerals breakdown in the combined potash harvest was:

- Leonite, K_2SO_4 $MgSO_4$ $4H_2O$: 48.0%,
- Kainite, KCl $MgSO_4$ $3H_2O$: 37.4%,
- Carnallite, $KMgCl_3$ $6H_2O$: 8.8%, and
- Sylvite, KCl: 5.7%.

The trial location at Sylvania Station near Newman, WA is 350 km west of and on similar latitude to Lake Disappointment to provide for evaporation conditions comparable to Lake Disappointment.

The pilot-scale evaporation trial at Sylvania was followed by a laboratory/pilot-scale evaporation trial in Perth in late June/early July 2013. The trial achieved a potassium recovery of 80.2% in a harvest grading 8.06% K. The potassium yield was increased to 91.9% with a fourth evaporation stage leading to an overall harvest product grading 6.97% K for a four-stage process. The low sodium chloride (NaCl) content of the harvest products at 11.5% and 9.95% NaCl, respectively, was considered to be important. A NaCl content of less than 20% has the potential to eliminate the flotation stage from the currently proposed flowsheet and lead to a significant reduction in the capital and operating costs for the project.

Dandaragan Greensands Project: Potash West NL is exploring the potential for producing potash from greensand deposits in the Perth Basin which are located between 50 and 230 km north of Perth. The company is investigating the possibility of using conventional magnetic separation techniques to separate glauconite from greensands and is conducting field trials and laboratory scale testing to produce marketable potash products from glauconite concentrate[57]. On 11 October 2012, Potash West reported an initial Indicated and Inferred Resource of 244 Mt at 3% K_2O and 1.6% P_2O_5 for the **Dinner Hill** deposit containing the Molecap Greensand and the Poison Hill Greensand stratigraphic greensand units. Results of a scoping study were released by Potash West on 10 January 2013[58] that, according to the company, confirmed technical and financial viability for a potash production facility based at the Dandaragan Trough Project. Potash West also reported that consistently higher grades of phosphate averaging 3% P_2O_5 were present in the northern 30% of the Dinner Hill potash resource area and preliminary test work and economic modelling suggested that a saleable phosphate rock could be concentrated from the greensands by

57 Potash West NL, 2012. Potash West succeeds in producing potash from WA glauconite deposits. Announcement to the Australian Securities Exchange, 23 January 2012, 3pp.

58 Potash West NL, 2013. Dandaragan project scoping study produces positive results. Announcement to the Australian Securities Exchange, 10 January 2013, 14pp.

conventional processing steps to produce single superphosphate (SSP). The phosphate component in the samples was identified as nodular fluorapatite. The company released results of another scoping study on 19 September 2013[59] that suggested that a SSP production facility may be viable with a capacity for 340 000 tpa of SSP over 20 years. On 23 September 2013, Potash West released an updated resource figure for the phosphate-rich northern portion of the Dinner Hill deposit amounting to 90 Mt of Indicated Resource at 2.65% P_2O_5, 3.6% K_2O and 4.5% CaO.

Lake Chandler: On 29 January 2009, ActivEX Ltd announced a JORC Code compliant Inferred Resource of 5 779 025 t at 5.73% K_2O at its Lake Chandler potash deposit 45 km north of Merredin and 300 km east of Perth in WA. The company stated in its 2010 annual report that it carried out a scoping study on a nominal throughput of 200 000 tpa to give the project a mine life of 25 years. The company concluded that the study showed that, with the softness of the potash market, the project would be only marginal under current economic conditions.

Oxley Potash Prospect: On 24 April 2013, Sheffield Resources Ltd reported that they had located the Oxley potash prospect about 120 km northwest of Geraldton, WA. The Oxley potash prospect is an unconventional, hard rock style of mineralisation, hosted by a unique series of ultrapotassic microsyenite lava flows that contain over 90% sanidine (potash) feldspar. Sheffield pegged about 32 km strike extent of this prospective horizon within the northern portion of the Moora Basin. In their September 2013 quarterly report, the company released assay results of diamond drill samples as follows:

- 17 m @ 8.76% K_2O from 19 to 36 m, including 10 m @ 10.8% K_2O from 25 m, and
- 14 m @ 7.12% K_2O from 71 to 85 m.

Western Australia – Northern Territory

Lake MacKay: Situated in the Gibson Desert and straddling the WA/NT border 50 km north of the Tropic of Capricorn, Lake MacKay is a modern playa lake with a surface area of more than 2250 square kilometres. Reward Minerals reported in its 2009 annual report that it has delineated a JORC Code compliant Inferred Resource at Lake MacKay of 4780.4 million bench cubic metres (BCM) at 4.3 kg of K_2SO_4 (SOP) per BCM for a total of 20.56 Mt of K_2SO_4.

The resource estimate was calculated on the basis of lake bed sediment volume of BCM to a depth of two metres and the water soluble potassium sulphate content of the sediments that lie within the company's tenement holdings.

The company reported in its annual report for 2012 that the next stage of development at Lake MacKay will involve infill drilling, construction of pilot ponds and pump testing as well as flow sheet development for the preparation of a project feasibility study.

Prior to committing to this phase, the company has engaged in discussions with the Tjamu Tjamu people and other traditional owner groups aimed at reaching agreement on terms that would be acceptable for development to proceed at Lake MacKay in the event feasibility analysis proved favourable[60].

Northern Territory

Karinga Creek Project: Rum Jungle Resources Ltd, in a joint venture with Reward Minerals Ltd, was analysing potassium, magnesium and sulphate levels in aquifers surrounding Karinga Creek Lakes, about 225 km southwest of Alice Springs in the NT. On 9 April 2013, Rum Jungle Resources reported an Inferred Resource estimate of between 2.4 and 5.5 Mt of sulphate of potash at the Karinga Creek Salt Lake Potash Project, equating to a schoenite (potassium magnesium sulphate) resource of between 5.6 and 13 Mt (on a 100% basis)[61]. The resource is an Inferred Brine Resource estimate based on estimated upper, middle and lower ranges of porosity for known rock and sediment types. No porosity measurements have yet been taken on the sediments to accurately determine total and drainable porosity. On 18 December 2013, Rum Jungle announced that it had signed an agreement with Chinese International Chemical Consulting Corporation (CICCC) for the completion of a prefeasibility study on the Karinga Lakes Potash Project[62].

59 Potash West NL, 2010. Revision to phosphate scoping study announcement. Announcement to the Australian Securities Exchange, 19 September 2013, 17pp.

60 Reward Minerals Ltd, 2012. Reward Minerals Ltd Annual Report 2012, 64pp.

61 Rum Jungle Resources Ltd, 2013. Lodgement of supplementary bidder's statement in connection with takeover bid for Central Australian Phosphate Ltd. Announcement to the Australian Securities Exchange 9 April, 2013, 4pp.

62 Rum Jungle Resources Ltd, Rum Jungle Resources Ltd signs on with Chinese International Chemical Consulting Corporation (CICCC) for the completion of a prefeasibility study on Karinga Lakes Potash Project, 1pp.

Rare Earths

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The rare earth elements (REEs) are a group of 17 metals that comprise the lanthanide series of elements lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu) in addition to scandium (Sc) and yttrium (Y), which show similar physical and chemical properties to the lanthanides. The REEs have unique catalytic, metallurgical, nuclear, electrical, magnetic and luminescent properties. Their strategic importance is indicated by their use in emerging and diverse technologies that are becoming increasingly more significant in today's society. Applications (Table 11 and Table 12) range from routine (e.g., lighter flints, glass polishing mediums, car alternators) to high technology (lasers, magnets, batteries, fibre-optic telecommunication cables) and those with futuristic purposes (high-temperature superconductivity, safe storage and transport of hydrogen for a post-hydrocarbon economy, environmental global warming and energy efficiency issues). Over the past two decades, the global demand for REEs has increased significantly in line with their expansion into high-end technological, environmental and economical environments[63].

During the past few years, Sc-bearing lateritic nickel-cobalt deposits have attracted increasing attention in response to anticipated rise in demand for Sc. Zirconia stabilised with Sc rather than Y as an electrolyte for Solid Oxide Fuel Cells (SOFCs) reduces the operating temperature of the fuel cell significantly, thereby providing a much longer life. SOFCs are expected to play a major role in the developing battery-powered, electric transportation industry (cars, trucks, trains, etc.) as well as in stationary applications such as electricity generation in the home or as a substitute for coal-fired power plants[64].

The group of REEs is variously, and inconsistently, reported by companies as light REEs consisting of La, Ce, Pr, Nd and, sometimes, Sm. Heavy REEs may start with Sm, followed by Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. However, the heavy REEs are sometimes subdivided further into middle REEs comprising Sm, Eu, Gd, Tb and Dy with the remainder of the group, Ho, Er, Tm, Yb and Lu, referred to as the heavy REEs. Because of inconsistent reporting, the component elements of light, medium and heavy REEs are best noted in each case. The resources of REEs are usually reported as rare earth oxides (REO). Kingsnorth[65] grouped La, Ce, Pr and Nd as light REEs, or Ceric, Sm, Eu and Gd as medium REEs and Tb, Dy, Ho, Er, Tm, Yb and Lu plus Y as heavy REEs, or Yttric.

The REEs are a relatively abundant group of elements that range in crustal abundance from Ce, which is the twenty-fifth most abundant element at 60 ppm, to Lu, the sixty-first most abundant at 0.5 ppm.

63 Hoatson, D.M., Jaireth, S. and Miezitis, Y., 2011. The major rare-earth-element deposits of Australia: geological setting, exploration, and resources. Geoscience Australia, 204pp.

64 EMC Metals Corporation of Canada in a press release on 8 February 2010 on the Toronto Stock Exchange.

65 Kingsnorth, K., 2010. The challenges of meeting 'Energy' rare earths demand. IEA Standing Committee on Long-Term Co-operation Paris, 17th May 2010.

Table 11: Distribution of types of REEs in selected deposits (Arafura Resources Ltd).

Rare Earth Oxide	Application	Nolans Bore (%)	Mount Weld (%)	Mountain Pass USA (%)	Baiyunebo China (%)
Lanthanum	Petroleum cracking catalysts, batteries (NiMH)	19.74	25.6	33.2	27.1
Cerium	Autocatalyst, glass, polishing	47.53	45.74	49.1	49.86
Praseodymium	Magnets, glass	5.82	5.42	4.34	5.15
Neodymium	Magnets (NdFeB)	21.2	18.62	12.0	15.4
Samarium	Magnets, (SmCo)	2.37	2.44	0.8	1.15
Europium	Phosphors, nuclear control applications	0.4	0.55	0.12	0.19
Gadolinium	Intravenous contrast agents, phosphors	1.0	0.97	0.17	0.4
Terbium	Phosphors	0.08	0.09		
Dysprosium	Magnets (NdFeB), lasers	0.33	0.16		0.3
Other Rare Earths (Ho, Er, Tm, Yb, Lu)		0.21	0.04	0.16	0.03
Other elements					
Yttrium	Phosphors, metal alloys	1.32	0.37	0.1	0.2

Table 12: Applications for REEs in the emerging technology areas.

Application	Examples	Rare Earth Elements
Light Weight Magnets	**Cars** Light weight magnets in motors for windows, windscreen wipers, starter motors, alternators, etc. **Electronics** Magnets in disc drives for computers, data storage, portable music players (e.g. iPods), video recorders, consoles, video cameras **Speakers** Wind turbine	Nd, Pr, Sm, Dy, Tb
Catalyst	Automotive catalyst Clean diesel Oil refining	La, Ce, Nd, Pr, Sc
Hybrid vehicles	Electric motors and generators Hybrid batteries	Nd, Pr, Dy, Tb, La, Nd, Ce
Compact fluorescent lights, energy saving lamps		Eu, Tb, Y, Sc
Polishing powders	**TV and computer screens** LCD, Plasma, CRT **Optical lenses** **Precision optical and electronic components**	Ce, La, Pr, Sc
Glass additives	**CRT screens** to stabilise glass from cathode ray **Small optical lenses** **Phosphors** TV and computer screens	Ce, Er, Gd, Tb, La, Nd, Yb, Pm, Sc
Ceramics		Dy, Er, Pr, Gd, Ho, Ce, La

Resources

Geoscience Australia's estimate of Australia's rare earths reported as REO on 31 December 2012, amounted to 3.19 Mt of EDR, 0.42 Mt Paramarginal and 31.14 Mt in the Submarginal Resource categories.

About 67% of Australia's Accessible EDR comprises Reserves as defined under the JORC Code.

About 33% of the EDR comprises published JORC Code compliant Measured and Indicated Resources in operating mines, deposits being developed for mining and in deposits which have published scoping/feasibility studies with positive results.

There is a further 16.13 Mt REO in the Inferred Resources category. A major proportion of REO (predominantly La and Ce) of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in South Australia (Figure 17). The REO at Olympic Dam are not recovered in current mining operations and finish up in the tailings storage facility at the mine site. About 10 250 t of Sc, mostly in the Subeconomic and Inferred categories was reported in 2012. In addition, about 56 140 t of Paramarginal and Inferred Resources was reported as REEs.

Significant resources of REEs are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content (Table 13). Monazite is a rare earth-thorium-phosphate mineral found within heavy mineral sand deposits in Australia. Using available information, Geoscience Australia estimates that Australia's monazite resources are around 7.8 Mt. Assuming that the REO content of monazite to be about 60%, the heavy mineral deposits could hold a resource of around 4.68 Mt contained REO. Currently, extraction of REEs from monazite is not viable because of the cost associated with the disposal of thorium and uranium present in the monazite.

Table 13: Distribution of types of REEs in monazite from different parts of the world (modified after Mukherjee 2007[66]).

REO	Guangdong China (weight%)	Taiwan (weight%)	Australia (weight%)	Florida,USA (weight%)	India (weight%)
La_2O_3	23	21	23.2	17.4	22
CeO_2	42.7	47.9	46.3	43.7	46
Pr_6O_{11}	4.1	5.4	4.9	4.9	5.5
Nd_2O_3	17	18.7	18.3	17.1	20
Sm_2O_3	3	3.3	2.5	4.9	2.5
Eu_2O_3	<0.1	0.54	0.04	0.16	0.016
Gd_2O_3	2	1.6	1.7	6.5	1.2
Tb_4O_7	0.7	0.19	0.22	0.26	0.06
Dy_2O_3	0.8	0.35	0.56	0.59	0.18
Ho_2O_3	0.12	0.03	0.08	0.11	0.02
Er_2O_3	<0.3	0.03	0.06	0.04	0.01
Tm_2O_3	Tr	-	-	0.03	Tr
Yb_2O_3	0.24	0.07	0.04	0.21	Tr
Lu_2O_3	<0.14	-	-	0.03	Tr
REO	55	48–62	58.5	-	58
Other elements					
Y_2O_3	2.4	0.19	1.57	3.18	0.45
ThO_2	4	0.41	6.4	-	9.5

Notes: Tr = trace.

66 Mukherjee, T.K., 2007. Thorium resources in India, its mining, separation and chemical processing. IAEA Technical meeting on Thorium based fuels and fuel cycle options for pressurized heavy water cooled reactors, light water reactors and high temperature gas-cooled reactors. 22 to 25 October, 2007. Istanbul, Turkey.

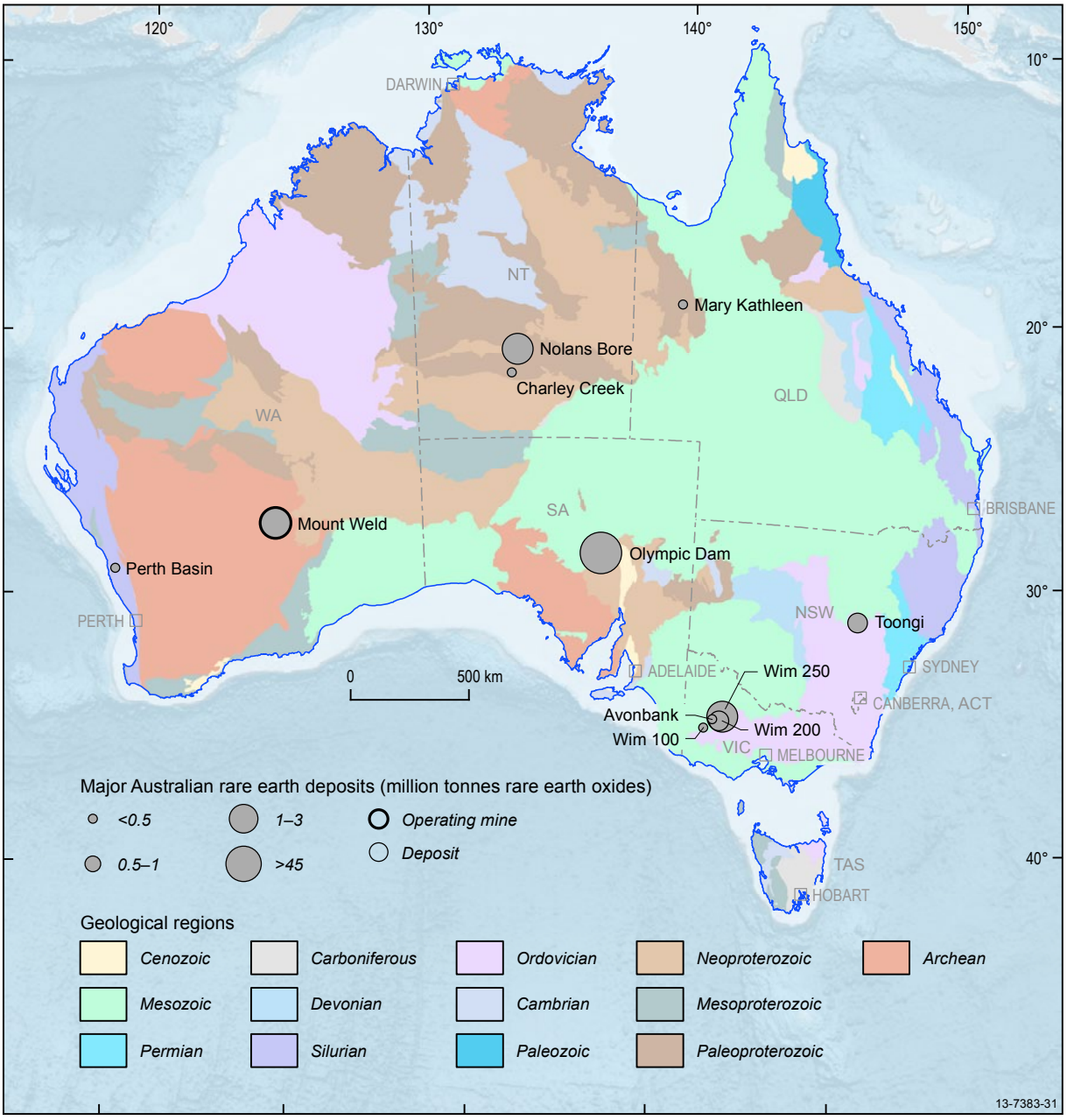

Figure 17: Australia's major rare earth deposits based in total Identified Resources.

Production

Historically, Australia has exported large quantities of monazite from heavy mineral sands mined in Western Australia, New South Wales and Queensland, for the extraction of both REEs and thorium. Between 1952 and 1995, Australia exported 265 kt of monazite with a real export value (2008 dollars) of $284 million[67].

Small-scale production of REEs has taken place in Australia but records on these activities are incomplete. The following information on historical attempts to establish a rare earth production industry in Australia is drawn from Cooper[68]. In the 1950s, Zircon Rutile Ltd at Byron Bay, NSW, processed a small quantity of monazite to produce cerium oxide for use in glass polishing. In 1969, Rare Earth Corporation of Australia Ltd, operating at Port Pirie, SA, began producing cerium, lanthanum, yttrium and thorium compounds from locally produced monazite. However, the plant ceased operations in mid-1972 because of a lack of working capital and the difficulty of breaking into world markets for processed rare earths.

67 Australian Bureau of Statistics, 2009. International trade, Cat. No.5465.0, Canberra.

68 Cooper W., 1990. Queensland mineral commodity report. Queensland Government Mining Journal, September 1990. Department of Resource Industries, 383–389.

In January 1987, it was announced that the French chemical company Rhone-Poulenc proposed to build a two-stage monazite processing plant at Pinjarra in WA to produce rare earths from monazite, but the project was suspended. In 1988, Deckhand Pty Ltd, a wholly owned subsidiary of Currumbin Minerals, was blocked on environmental grounds from establishing a rare earths processing plant at Lismore, NSW. SX Holdings Ltd was planning to establish a plant at Port Pirie (SA) to process monazite with a 2000 tpa cracking and separation plant but the project did not proceed.

Barrie (1965)[69] reported that a pegmatite deposit 6 km east of the Cooglegong crossing, WA, was worked in 1913 and 1930 and yielded about 2 t of gadolinite (yttrium iron beryllium silicate $(Ce,La,Nd,Y)_2FeBe_2Si_2O_{10}$). An analysis of Cooglegong gadolinite yielded 45.78% of yttrium trioxide (Y_2O_3) and 4.81% of other REO. Note that gadolinite does not contain more than trace amounts of gadolinium.

Globally, the production and resources of rare earths are dominated by China followed by India. China accounts for about 94% of the production but this is expected to fall to 70% by 2015[70] while India accounts for about 2%. These figures are only approximate because production for the Commonwealth of Independent States, which is made up of former members of the Soviet Union, is not available.

The main consumers of rare earths are China, the USA, Japan, Korea and Thailand with China reportedly accounting for about 70% of the world's consumption in 2011[70].

According to Roskill[70], all the growth in demand between 2005 and 2010 of 11% per year was from China while growth in the rest of the world fell by almost 4% per year. The reduction was largely the result of the global economic downturn in 2009 and a tightening of the Chinese export quota in 2010, which restricted availability. In the years to 2015, the main demand driver will be the use of rare earths in neodymium-iron-boron (NdFeB) magnets, which are forecast to grow between 11 and 13% per year as potential markets expand to include applications in permanent magnet motors for electric vehicles and wind turbines. It's anticipated that magnets could account for nearly one third of demand by 2015. Strong growth in demand is also forecast for rare earths in nickel-metal hydride (NiMH) batteries, phosphors, optical glass and ceramics.

Alkane Resources Ltd reported in November 2013[71], that consumption of rare earths of 115 000 t in 2012 is set to increase to about 162 000 t in 2016.

China has continued a nationwide crackdown on the illegal mining of rare earths. In addition, it has been reported that, on 6 August 2012, China's Ministry for Industry and Information Technology introduced new restrictions which are expected to reduce the existing 23 rare earth mines in China by one third and the 99 smelting and extracting operations by up to a half[72].

World Ranking

China holds 55 Mt (47.7%) of the world's economic resources for REO (including Y_2O_3), followed by the USA with 13 Mt (11.3%)[73]. Australia's EDR accounts for 2.8% of world's economic resources with 3.19 Mt REO.

The main types of REE deposits worldwide are REE-iron ores with bastnasite and monazite as the main REE bearing minerals and include deposits such as the Bayan Obo in China. The only production of REOs from a carbonatite has been the Mountain Pass deposit in California, which has 35.35 Mt of Measured, Indicated and Inferred Resources at 6.35% REO (2.24 Mt REO). Deposits associated with carbonatite laterites, include Araxa in Brazil, which has 28.29 Mt of Measured, Indicated and Inferred Resources at 3.754% REO (1.06 Mt REO) and Mount Weld in WA, which has 23.94 Mt at 7.867% REO (1.88 Mt REO). Other deposit categories with significant REO resources include a vein type at Nolans Bore in the Northern Territory and an alkaline trachyte deposit at Toongi in NSW, along with a peralkaline syenite deposit at Lovozero in Russia.

69 Barrie, J., 1965. Rare Earths, In: McLeod, I.R. (editor), Australian Mineral Industry: The Mineral Deposits. Bureau of Mineral Resources, Australia, Bulletin 72, 515–521.

70 http://www.roskill.com/reports/minor-and-light-metals/rare-earths (accessed August 2012).

71 Alkane Resources Ltd, 2013. Outlook for zirconium and rare earth materials until 2010. Hong Hong November 2013, 20pp.

72 Hastings Rare Metals Ltd, 2012. ASX Announcement 13 August 2012, 2pp.

73 Gambogi, J., 2012. Rare earths. In: Mineral commodity summaries 2013. United States Geological Survey, 128–129.

Industry Developments

Lynas Corporation Ltd: The **Mount Weld** deposit in WA occurs within a lateritic profile developed over an alkaline carbonatite complex. On 12 January 2012, Lynas reported Measured, Indicated and Inferred REO resources for the **Central Lanthanide** deposit at a cut-off of 2.5% REO of 14.949 Mt at 9.8% REO including Y_2O_3. An updated resource for the **Duncan** deposit in the weathered carbonatite complex stands at 8.992 Mt of Measured, Indicated and Inferred Resources at 4.8% REO including Y_2O_3. In another part of the carbonatite complex there are 37.7 Mt of mostly Inferred Resources grading 1.07% Nb_2O_5, total lanthanides at 1.16% and 0.09% Y_2O_3, 0.3% ZrO_2, 0.024% Ta_2O_5, 7.99% P_2O_5.

The company reported in its September 2013 quarterly report that ramp-up of the phase 2 concentration plant continued at the Mount Weld mine site and, at the end of the quarter, 18 425 t of concentrate containing 6724 t of REO were ready for export to its rare earth treatment plant, the Lynas Advanced Materials Plant in Malaysia. Lynas reported that, by early June 2013, the plant had achieved nameplate production capacity (11 000 tpa REO) in cracking and leaching units of phase 1. Total tonnes produced during the latter half of 2013 amounted to 397 t on an REO equivalent basis.

Arafura Resources Ltd: Nolans Bore rare earth-phosphate-uranium-thorium deposit is located 135 km northwest of Alice Springs in the NT. In June 2012, Arafura published a revised total Measured, Indicated and Inferred Resource figure of 47 Mt grading 2.6% REO, 11% P_2O_5 and 0.02% U_3O_8 down to a depth of 215 m. According to Arafura, the distribution of the light REEs currently being considered for extraction, (La, Ce, Pr, and Nd) amount to 95% while the heavy REEs (Sm, Eu, Gd, Tb, Dy) amount to 4.23%.

Because of much lower rare earth prices over the past year, Arafura has decided to reduce capital and operational costs by relocating its planned intermediate rare earth chemical processing plant from Whyalla in SA to a site near its Nolans Bore deposit[74] in the NT.

Arafura announced on 9 September 2013 that it had signed a memorandum of understanding with Shenghe Resources Holding Co Ltd to jointly fund development of the Nolans Bore Project and develop rare earth sales opportunities.

Alkane Resources Ltd: The company's Dubbo Zirconia Project, based on the **Toongi** deposit 30 km south of Dubbo in NSW has a reported Measured Resource of 35.7 Mt and 37.5 Mt of Inferred Resources grading 1.96% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, 0.745% total REO, 0.014% U_3O_8, and 0.0478% Th. On 16 November 2011, Alkane announced a Proved and Probable Reserve for the deposit of 35.93 Mt grading 1.93% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, and 0.74% total REO. In July 2012, Australian Zirconia Ltd, a wholly owned subsidiary of Alkane Resources Ltd, signed a memorandum of understanding with Japan's Shin-Etsu Chemical Co Ltd to produce a suite of separated heavy and light REEs using the rare earth concentrates from the Dubbo Zirconia Project.

In October 2012, Alkane announced in its annual report for 2012 that the company had engaged Credit Suisse (Australia) Ltd, Sumitomo Mitsui Banking Corporation and Petra Capital Pty Ltd to provide investment banking services, including the arrangement of project financing to fund the development of the Dubbo Zirconia Project. Securing the finance package of around $1 billion is expected to take up to 12 months and coincide with final project approvals, allowing the construction program for the Dubbo Zirconia Project to commence in 2014.

Crossland Strategic Metals Ltd: On 15 May 2012, the company reported resources for a new type of placer deposit, the **Charley Creek** deposit, containing zircon, monazite and xenotime. The company reported that the Charley Creek deposit is an alluvial outwash that comprises an Indicated Resource of 387 Mt containing 27 000 t of xenotime, 161 000 t of monazite and 196 000 t of zircon. The xenotime and monazite were stated to contain about 114 000 t of total REO (TREO). In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 t of REO in about 31 000 t of xenotime and 167 000 t of monazite as well as 220 000 t of zircon[75]. An earlier report by Crossland, dated 5 April 2012, stated that the average equivalent monazite in the heavy mineral concentrate (calculated from chemical analyses) is 87 372 g/t and equivalent xenotime is 8310 g/t while the heavy mineral concentrate in the alluvium was 2.54%[76].

A scoping study for the deposit was released by the company on 15 April 2013, which highlighted a low capital-cost requirement of $156 million based on a mine life of 20 years and projected an annual revenue of $154 million.

74 Arafura Resources Ltd, 2012. Australian uranium and rare earths conference 2013 16–17 July 2013, Fremantle, 15pp.

75 Crossland Uranium Resources Ltd. 2012. Quarterly report for period ended June 30, 2012, 5pp.

76 Crossland Uranium Resources Ltd. 2012. Announcement to the Australian Securities Exchange 5 April 2012, 3pp.

Crosslands reported in its September quarterly report for 2013[77] that a work program for the detailed feasibility drilling at the Charley Creek Project had been designed. Applications for all regulatory approvals required for this drilling have been submitted to the Northern Territory Department of Mines and Energy.

Hastings Rare Metals Ltd: The **Hastings** rare earth deposit (previously known as **Brockman**) is located about 16 km southeast of Halls Creek in WA. It is a large, low-grade zirconium-niobium-REE deposit hosted in altered trachytic tuff of Paleoproterozoic age. On 8 September 2011, Hastings reported 36.2 Mt of Indicated and Inferred Resources grading 8.86 ppm ZrO_2, 3.55 ppm Nb_2O_5, 182 ppm Ta_2O_5, 110 ppm Ga_2O_5, 318 ppm HfO_2, 186 ppm Dy_2O_5, 1120 ppm Y_2O_3, 2102 ppm TREO and 1802 ppm heavy REO.

In July 2013, the company announced the discovery of two new prospects, **Levon**, about 1.3 km south of the main deposit, and **Haig**, about 4.5 km to the southwest[78]. Nineteen rock chip samples from the Levon prospect averaged 2025 ppm TREO and 13 rock chip samples from the Haig prospect averaged 2485 ppm TREO.

Hastings Rare Metals is investigating toll-treatment partnerships in ore milling, extraction and separation, and in final product refining. The company considers that the benefit of taking the above functions off-shore reduces risks for the Hastings project, by reducing overall processing operating expenses and by making a significant reduction in capital cost while being able to access lower cost funding.

The **Yangibana** prospect, about 900 km north of Perth in WA, has a recorded historic resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse-grained monazite containing up to 20% Nd_2O_5 and 1600 ppm Eu_2O_3. Historic exploration records reported that the Yangibana ferrocarbonatite-magnetite-rare earth-bearing dykes (ironstones) form part of the Gifford Creek Complex in WA. The dykes occur as lenses and pods and are typically the last stage of carbonatite fractionation and are enriched in REEs fluorite and uranium-thorium mineralisation. On 11 November 2011, Hastings published results from 38 surface samples collected at six prospects located in the western portion of the Yangibana group. The samples indicated a distribution profile of REO as shown in Table 14.

Table 14: Distribution of types of REEs in the Yangibana deposits.

	Light Rare Earths					Heavy Rare Earths			
Oxide	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Y
% of TREO	18.6	42.9	5.9	25.5	4.0	0.8	1.4	0.3	0.6

The REO distribution of the Yangibana ironstones is biased towards the light REO (LREO) but the proportion of Nd in the rare earth mix is relatively high at 25%.

Navigator Resources Ltd (Holding Deed of Company Agreement): The company's **Cummins Range** carbonatite deposit occurs in the southeast part of the Kimberley region in WA. On 13 February 2012, Kimberley Rare Earths Ltd announced a revised Inferred Resource for the Cummins Range deposit of 4.9 Mt at 1.74% REO, 11.2% P_2O_5, 145 ppm U_3O_8 and 48 ppm Th. The resource was calculated at a cut-off grade of 1% REO. The total REO was subdivided into 95.6% light REO (La, Ce, Pr, Nd), 4.1% middle REO (Sm, Eu, Gd, Tb, Dy) and 0.3% heavy REO (Ho, Er, Tm, Yb, Lu). A mineralogical investigation of the Cummins Range deposit by the CSIRO Minerals Down Under Flagship was completed during the March 2010 quarter with the principal rare earth-bearing minerals being primary apatite and monazite. The investigation also showed that only subordinate amounts of secondary rare earth-bearing minerals were present.

In its December 2013 quarterly report, Navigator reported that Anova Metals Ltd (previously Kimberley Rare Earths Ltd) had agreed to terminate the Cummins Range joint venture and transfer Anova's 25% interest in Cummins Range back to Navigator. The appointed administrator to Navigator reported in May 2013[79]:

> *"Following a price peak in July 2011, light rare earth metals became oversupplied and prices fell by approximately 70%. As a result, Kimberley Rare Earths concluded that short-term commercial development of Cummins Range was not viable and that long-term development was dependent upon factors outside of their control."*

77 Crossland Strategic Metals Ltd, 2013. Quarterly report for period ended 30 September, 2013, 4pp.

78 Hastings Rare Metals Ltd, 2013. New high grade discoveries at the Hastings rare earths project. Announcement to the Australian Securities Exchange, 1 July 2013, 9pp.

79 Pitcher Partners, 2013. Navigator Resources Ltd (Administrator appointed) CAN 063 366 487, 125pp.

Capital Mining Ltd: Peralkaline granitic intrusions of the Narraburra Complex 177 km northwest of Canberra contain anomalous amounts of zirconium, REO and low concentrations of thorium (73.2 Mt at 1250 g/t ZrO_2, 146 g/t Y_2O_3, 327 g/t REO, 45 g/t HfO_2, 126 g/t NbO_2, 54 g/t Ga_2O_3, 118 g/t Li_2O and 61 g/t ThO_2)[80]. In the March quarterly report in 2010, Capital Mining reported that it was conducting metallurgical test to recover hafnium, thorium, tantalum, niobium, neodymium and cerium.

GBM Resources Ltd: On 9 August 2012, GBM announced an Inferred Resource of 187 Mt at 558 ppm TREO and 52 ppm Y_2O_3 for the **Milo** deposit located about 76 km east of Mount Isa and 22 km east of the Mary Kathleen uranium REO deposit. The Milo deposit is reported to be a polymetallic deposit with a range of metals including REEs, yttrium, copper, molybdenum and gold. On 22 November 2012, GBM reported that results of a scoping study suggested a long term base case for a project with a net cash flow of $701 million over a 11-year mine life[81].

Northern Minerals Ltd: On 15 October 2013, Northern Minerals announced that its **Browns Range** Project about 655 km northwest of Alice Springs in the NT has Indicated and Inferred Resources totalling 4.13 Mt at 0.68% TREO. These resources are shared between the **Area 5**, **Gambit** and **Gambit West** deposits while the **Wolverine** deposit has most of the Indicated and Inferred Resources totalling 2.14 Mt of ore grading at 0.86% total REO (which includes 4970 ppm Y_2O_3), 35 ppm U_3O_8, and 28 ppm ThO_2. The main ore mineral is xenotime which occurs within hydrothermal silicified and hematitic breccias. The resource has a well-defined, high-grade (less than 1% total REO) central zone.

BHP Billiton Ltd: A major proportion of REO (predominantly lanthanum and cerium) of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in South Australia. A research paper published in 2012 stated that Olympic Dam ore contains[82] about 0.17 wt% La and 0.25 wt % Ce. The REO at Olympic Dam are not recovered in mining operations and are contained in the tailings storage facility at the mine site.

Metallica Minerals Ltd: Metallica's scandium resources are located within its lateritic nickel-cobalt deposits near Greenvale about 190 km west-northwest of Townsville in northern Queensland. The company's **Kokomo** deposit is 50 km north-northeast of Greenvale and the **Lucknow** deposit is 2 km south of Greenvale.

On 21 October 2013, Metallica reported Measured, Indicated and Inferred Resources for the Lucknow deposit totalling 7.3 Mt grading at 176 g/t Sc, 0.23% Ni and 0.06% Co delineated at a cut-off-grade of 100 g/t Sc. The company's Measured, Indicated and Inferred Resource for the Kokomo deposit totals 4.7 Mt grading 140 g/t Sc, 0.40% Ni and 0.07% Co totalling 112.1 Mt at 0.30% Ni, 0.06% Co and 162 g/t Sc. The total Sc resource for the two deposits amounts to 15.1 Mt at 133 g/t Sc, 0.22% Ni, 0.04% Co. The contained scandium metal in the two deposits amounts to approximately 1950 t[83].

The Lucknow deposit includes a high-grade zone at a cut-off-grade of 120 g/t Sc measuring 4.12 Mt of Indicated and Inferred Resources at 206 g/t Sc, 0.21% Ni and 0.05% Co.

Metallica announced on 16 October 2012 that a revised scoping study indicated that, under an updated mine plan, there are sufficient Measured, Indicated and Inferred Mineral Resources at the SCONI project to allow production of approximately 90 tpa of scandium oxide over not less than 20 years based on a processing rate of 750 000 tpa of ore.

EMC Metals Corp: In June 2005, Jervois Mining Ltd reported that its **Nyngan** lateritic nickel-cobalt-scandium-platinum deposit in NSW had a resource of 16 Mt at 0.87% Ni and 0.06% Co. A scandium-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718 Mt at 274 ppm Sc and Indicated Resources of 9.294 Mt at 258 ppm Sc. Jervois formed a joint venture agreement with EMC Metals Corporation of Canada which conducted three-phased test-work to study the recovery of scandium from lateritic ores at Nyngan.

80 Capital Mining Ltd, 2011. Resource estimate update confirms rare earth potential Narraburra Project, NSW. ASX announcement, 9 November 2011, 4pp.

81 GBM Resources Ltd, 2012. Scoping study confirms strong commercial opportunity at GBM's Milo IOCG-REE Project. Announcement to the Australian Securities Exchange, 24pp.

82 Ehric, K., McPhie, J., and Kamenetsky V., 2012. Geology and mineralogical zonation of the Olympic Dam iron oxide Cu-U-Au-Ag deposit, South Australia. In Jeffrey W. Hedenquist, Michael Harris, and Francisco Camus, Editors: Geology and Genesis of Major Copper Deposits and Districts of the World: A Tribute to Richard H. Sillitoe.

83 Metallica Minerals Ltd, 2013. Sconi Project, North Queensland nickel-cobalt and scandium resource upgrade. Announcement to the Australian Securities Exchange, 21 October, 2013.

In 2013, EMC acquired full ownership of the Nyngan scandium project from Jervois Mining with Jervois receiving royalties on sales of product from the project in lieu of a cash payment. EMC reported on its website (http://www.emcmetals.com/new/Nyngan.asp) that processing and refining plant details are still being finalised. Previous pilot plant-scale metallurgical test work during 2011–2012 revealed that recoveries of more than 70% were achievable with conventional processing techniques on laterites, specifically acid leaching and solvent extraction. Subsequent bench-scale test work in 2013 explored several modified flow sheet approaches with the results indicating that improved recoveries, better product grades and lower acid consumption rates were possible, all of which would point to better economics and environmental outcomes.

Krucible Metals Ltd: Inferred REE resources for the **Korella** phosphate-yttrium deposit were reported to total 13.72 Mt at 0.70 kg/t Y_2O_3 and Nd and Dy are also reported to be present, but their resources have not been estimated[84]. Anomalous values of other valuable heavy REEs have also been intersected in drilling at Korella including 1 m at 831 ppm Nd and 336 ppm Sc from a hole depth of 13 m and 2 m at 294 ppm dysprosium from a hole depth of 19 m. Mineralogical investigations have indicated that yttrium is contained in the phosphate mineral xenotime (YPO_4), generally encapsulated within larger clay-silica-phosphate secondary minerals.

There is little published data associated with REEs in phosphorite in Australia. Total phosphate resources in the Georgina Basin in the NT and northwest Queensland are considered to be of the order of four billion tonnes[85], but total REE contents in the phosphorites are generally much less than 1000 ppm.

Chinalco Yunnan Copper Resources Ltd: REEs have been intersected in drill holes at the **Elaine 1** deposit, about 80 km south of the **Mary Kathleen** deposit in northwest Queensland. Chinalco has published resources for copper and gold for Elaine 1, but resources of REO have not been released for the deposit. Inferred Resources have been published for a small deposit near Elaine1 consisting of 83 000 t of ore grading 3236 ppm REO and 283 ppm U_3O_8. The historic uranium mine of Mary Kathleen is essentially a uranium-rare earths skarn deposit which has a remnant resource in tailings of about 5.5 Mt at 6.4% REO +Y. Commonly occurring REE minerals in the original deposit were stillwellite and allanite while other REE-bearing minerals included apatite, titanite and garnet.

Marathon Resources Ltd: In August 2005, the company reported that an Inferred Resource of 51 800 t of lanthanum and cerium is associated with its uranium deposit at **Mount Gee**, about 520 km north-northeast of Adelaide in South Australia. In July 2011, the South Australian Government established the Arkaroola Protection Area, reserving the area from operation under the South Australian Mining Act. It is proposed that, in due course, legislation will be enacted to protect the area and an application for World Heritage Listing will follow. As a consequence, future exploration and mining titles will not be granted in the Arkaroola Protection Area.

84 Krucible Metals Ltd, 2013. Annual Report 2013, 68pp.

85 Lottermoser, B.G., 1991. Rare earth element resources and exploration in Australia. The Australasian Institute of Mining and Metallurgy, Proceedings 296, Number 2, November 1991, 49–56.

Shale Oil

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Oil shale is organic-rich shale that yields substantial quantities of oil (normally referred to as shale oil) and combustible gas by heating (retorting) and distillation. The organic material in oil shale is called kerogen, which, under appropriate conditions in the Earth's crust, can be a precursor to conventional oil reservoirs. One tonne of commercial grade oil shale may yield from about 100 to 200 ℓ of oil.

Resources

The majority of oil shale resources of commercial interest are located in a series of narrow and deep extensional-basins near Gladstone and Mackay, and further north near Proserpine in central Queensland. These are thick Cenozoic lacustrine (lake-formed) deposits that are relatively easy to mine and process compared to carbonate-rich oil shales (marls) elsewhere in the world. The Permian Galilee and Bowen Basins in Queensland contain oil shale associated with coal measures. Oil shales occur in part of the Cretaceous Toolebuc Formation of the Eromanga Basin in northwest Queensland. Oil shale deposits of varying quality are located in the Sydney Basin, NSW, at the Latrobe tasmanite deposit in northern Tasmania, at Eyre Peninsular in SA and within an oil shale-heavy mineral sand deposit in southern WA.

Resource estimates were reviewed in 2011 to take into account the historic nature of the estimates and losses resulting from processing. Australia's shale oil resources estimates are for recoverable shale oil. Paramarginal and Submarginal Demonstrated Resources of shale oil as at the end of 2011 are 213 Gℓ (about 1340 million barrels) and 2074 Gℓ (about 13 050 million barrels) respectively. Both figures are unchanged from 2010.

An Inferred Resource as at the end of 2011 is estimated to be 1272 Gℓ (about 8000 million barrels), also unchanged from 2010. This figure excludes the total potential shale oil resources of the Toolebuc Formation which is estimated to be around 245 000 Gℓ. This estimate was made by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and the CSIRO in 1983[86]. The research project undertook detailed geological, petrophysical and geochemical examination of the oil shales of the Toolebuc Formation. The project was aimed at investigating the resource and developing methods to assist government and industry to assess the potential of the sedimentary sequence as a possible future source of oil shale. The research team also worked to develop an understanding of geological controls and the distribution of oil shale within the Toolebuc Formation. A resource assessment of around 245 000 Gℓ was based on productive oil shale covering an area of 484 000 square kilometres and ranging from 6.5 to 7 m thick with a specific gravity of 1.9 and yielding an average 37 ℓ of oil per tonne oil shale.

Exploration

With a 20-year moratorium on oil shale development in Queensland lifted, activity on exploration projects is slowly returning. Many new exploration leases have been obtained across the state, especially in the Julia Creek region in the Cretaceous Toolebuc Formation of the Eromanga Basin in northwest Queensland.

Axiom Mining Ltd announced three applications for exploration permits for minerals (EPM) covering an area of 980 square kilometres between Croydon and Julia Creek in north Queensland. The three applications target oil shale units hosted within the Toolebuc Formation. The tenements aggregate a total strike length of 105 km and cover from 10 to 30 km in the down-dip extent. The three tenement application areas, named Blackbull, Whitebull and Redbull, cover a specific area where the oil shale lies from 40 to 120 m below the surface.

JEMS Qld Pty Ltd has acquired 20 exploration tenements of over 6000 square kilometres over the Toolebuc Formation near Julia Creek in north Queensland. JEMS estimates that the deposits have an average thickness of 9.9 m with approximate oil yields of 55.6 ℓ/t. Depth to the top of the Toolebuc oil shales varies from 5.6 to 117.2 m from surface.

86 Ozimic, S. and Saxby, J.D., 1983. Oil Shale Methodology: An examination of the Toolebuc Formation and the laterally contiguous time equivalent units, Eromanga and Carpentaria Basins. Bureau of Mineral Resources and CSIRO research project.

Production

There was no oil extracted from oil shale in Australia between 2004 and September 2011. From 2000 to 2004, a demonstration processing plant at the Stuart deposit near Gladstone in central Queensland produced more than 1.5 million barrels of oil using a horizontal rotating kiln process (Alberta Taciuk Process). The facility has been dismantled and the site remediated.

In September 2011, Queensland Energy Resources Ltd (QER) produced its first crude oil from its demonstration Paraho IITM vertical shaft kiln processing plant at the Stuart deposit near Gladstone, central Queensland. The oil is being stored in secure tanks on-site, awaiting commissioning of the oil upgrading unit (refinery).

The QER demonstration plant achieved stable production capacity of 6000 t of shale per day and oil yield totalling 4500 barrels per stream day while maintaining product quality and adhering to Environment Protection Authority emissions limits. The oil products from the demonstration plant were Ultra Low Sulphur Naphtha (ULSN) 55% to 60% and Light Fuel Oil (LFO) 40% to 45%. The ULSN, which can be used to make petrol, diesel and jet fuel, has a sulphur content of less than 1 ppm. To put this into perspective, from 1 January 2008, the Fuel Standard (Petrol) Determination regulated that the maximum content of sulphur is 50 ppm in premium unleaded petrol.

World Ranking

The 2013 Survey of Energy Resources by the World Energy Council reported that total world in-place resources of shale oil are estimated to be 4.8 trillion barrels. The USA has the largest known deposit of 3 trillion barrels accounting for approximately 77% of world resources, followed by China with 3.5 billion barrels, the Russian Federation with 2.5 billion barrels, the Democratic Republic of Congo with 1 billion barrels and Brazil with 820 million barrels. Important oil shale deposits are also located in Italy, Israel, Morocco, Jorden and Estonia, as well as Australia. The USA, China, Estonia and Brazil are producing oil shale.

Industry Developments

Queensland Energy Resources Ltd: QER announced that it will conclude the technology demonstration program (Paraho IITM vertical shaft kiln processing plant) at the **Stuart** deposit near Gladstone in central Queensland in early 2014. The company is seeking partners to progress the development of a commercial oil shale project. QER stated that the technology demonstration plant had operated successfully for two years, and that sufficient data is available to support the case for a commercial project. QER produced its first crude oil in September 2011 and submitted a final report to the Queensland Government in September 2012 indicating there were no reportable environmental incidents at the plant during all phases of construction, commissioning and operations, and there were no community complaints about odour and noise.

Intermin Resources Ltd: The company announced the completion of a drilling program comprising 22 air-core holes for 1427 m at the **Lilyvale** prospect, which is part of the **Richmond Oil Shale** project about 50 km northwest of Richmond in north Queensland. Organic carbon results received from 18 holes confirm the historic oil grade and thickness of the Toolebuc oil shale over substantial areas of Intermin's tenements. Drilling has outlined an area with significantly higher organic carbon values than those previously recorded. Intermin also undertook Modified Fischer Assays on two of the drill holes (28 samples). These assay results established the fresh oil-shale horizon and recorded oil yields of 9 m at 73.2 ℓ/t and 7 m at 78.1 ℓ/t. Additional analytical work will be undertaken to determine metal values (vanadium, molybdenum, copper, nickel and silver) within the oil shale. Intermin aims to develop a pre-concentration process whereby the organics and the vanadium, molybdenum and nickel metals are concentrated prior to retorting for the oil recovery.

Greenvale Mining NL: Greenvale will progress exploration programs for its **Alpha**, **Lowmead** and **Nagoorin** projects. The company has release an updated JORC Code resource inventory for the Nagoorin and Lowmead projects with total estimated in-situ resource for Nagoorin (2445 million barrels of oil) and for Lowmead (706 million barrels of oil). Greenvale has advised that it has been approached by investors and technology providers interested in the company.

Boss Resources Ltd: Boss Resources has completed 3D modelling work from its drill-hole database on the **Latrobe** oil shale project in Tasmania.

Global Oil Shale Group: The company has prepared an exploration plan for its **Julia Creek** oil shale project comprising a 35 000 m reverse-circulation drilling program of 700 drill holes over an area of approximately 150 square kilometres. The company has prepared an extensive testing program also for the oil shale samples to evaluate oil concentration and thermal processing of the oil shale.

Linc Energy Ltd: Linc Energy announced that two separate commissioned and independent reports have confirmed a significant oil shale resource potential in three formations, the Stuart Range, Boorthanna and Pre-Permian, in the Arackaringa Basin near Coober Pedy in SA. Prospective resource estimates for unconventional reservoirs in the Arckaringa Basin range between 103 billion barrels and 233 billion barrels.

Tantalum

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The main use of tantalum (Ta) is in the manufacture of capacitors required for the electronics and telecommunications industries. Because they are small and have high reliability, these capacitors are used in miniaturised electronic circuits, mainly in mobile phones. Because of its anti-corrosive properties, tantalum metal is used in the chemical industry in applications such as tantalum carbide in tools for metal cutting and machining, as well as in metal alloys in the aerospace and electricity-generating industries. Overall, approximately 60% of annual world consumption of tantalum is used in the electronics industry, with more than half used in the manufacture of mobile phones.

Tantalum minerals have more than 70 different chemical compositions, of which tantalite ($(Fe,Mn)Ta_2O_6$), microlite ($CaTa_2O_6$), and wodginite ($Mn(Sn,Ta)(Ta,Nb)_2O_8$) are of greatest economic importance. It is common practice to name any mineral concentrate containing tantalum as tantalite.

Australia has historically been the world's largest producer of tantalum (as tantalite concentrates), providing approximately half of the world's mine output through mining operations at Greenbushes 250 km south of Perth, WA and at Wodgina 100 km south of Port Hedland, WA.

For location of tantalum deposits refer to Figure 20 in the tin chapter.

Resources

In WA, granitic rare-metal pegmatites are the dominant host rock for primary tantalum mineralisation. The only exceptions are the carbonatite-type deposit at Mount Weld in the eastern goldfields of WA and an unusual form of subalkaline granite–syenite mineralisation at the Hastings (also known as Brockman-Hastings) deposit, southeast of Halls Creek, WA. High-grade tantalum mineralisation is also found in a trachyte body at the Toongi deposit (also known as Dubbo Zirconia Project) in NSW.

Australia's EDR are estimated to be 60 kt of tantalum in 2012, a 3% decrease on 2011 resource of 62 kt. Of these, 85% are in WA and 15% in NSW. More than 94% of the EDR in WA are associated with Global Advanced Metals Pty Ltd's (formerly Talison Tantalum) Greenbushes and Wodgina deposits. The remaining EDR in WA occurs at the Mount Cattlin, Mount Deans, Dalgaranga, and Arthur River deposits. In NSW, all the EDR are associated with the Toongi deposit.

The Greenbushes pegmatite deposit is located approximately 250 km south of Perth, in southwest WA. The deposit is known to contain one of the world's largest hard rock tantalum resources. No new tantalum resources have been reported since October 2011. Hastings Rare Metals deposit (now known as Hastings Rare Earth, Zirconium, Niobium deposit), which is owned by Hastings Rare Metals Ltd, is located 18 km southeast of Halls Creek, WA. It is hosted by a fine-grained volcaniclastic unit (informally known as the Niobium Tuff) within a sequence of thick volcanic-sedimentary rocks. The Niobium Tuff can be traced over a strike length of 3.5 km and varies in width up to 35 m. The last update of a JORC Code compliant resource was reported in September 2011.

The Toongi deposit, 20 km south of Dubbo in NSW accounts for 15% of tantalum EDR. The deposit is a sub-volcanic intrusive trachyte body (vertical) with dimensions of approximately 900 m x 600 m and containing a Measured Resource of 35.7 Mt grading 0.03% Ta_2O_5, and an Inferred Resource of 37.5 Mt grading 0.03% Ta_2O_5[87].

Alkane Resources Ltd reported the presence of mineralisation at the neighbouring Railway prospect 4 km northwest of the Toongi orebody, where reverse circulation drilling in the trachyte body intersected a zone containing grades ranging from 0.85% to 0.99% ZrO_2, 0.21% to 0.23% HfO_2, 0.21% to 0.26% Nb_2O_5, 0.013% to 0.15% Ta_2O_5 and 0.43% to 0.48% TREO (Y_2O_3 + REO). The report notes that there has been insufficient exploration of the Railway trachyte to define a mineral resource and it is uncertain that further exploration will result in the determination of a mineral resource[88].

87 Alkane Resources Ltd, 2012. Annual Report 2012.

88 Alkane Resources Ltd, 2012. Annual Report 2012.

Subeconomic Demonstrated Resources account for about 31% of total Demonstrated Resources. The Paramarginal and Submarginal Resources amount to 18 kt, showing no increase on 2011. Western Australia is the largest holder of Paramarginal Resources with 61%, followed by NSW with 39%. All the Submarginal Resources occur in WA.

Inferred Resources totalled 21 kt and did not change from Inferred Resources reported for 2011. Western Australia and NSW account for 68% and 32% of Inferred Resources, respectively.

Accessible EDR

All of Australia's EDR of tantalum is accessible.

JORC Reserves

JORC Code Reserves comprise total tantalum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC Code reserves of 29 kt accounted for approximately 48% of AEDR.

Exploration

Data on exploration expenditure for tantalum are not available.

Production

The Western Australian Department of Mines and Petroleum did not report tantalum production figures for 2012. However, it announced a combined production in dollar values of tin, tantalum and lithium of $200 844 824.

World Resources and Production

Based on estimates published by the USGS and Geoscience Australia, the world resources of tantalum in 2012 totalled 156 kt. The world's largest holder of tantalum resource is Brazil with an estimated 88 kt, followed by Australia with 60 kt and Canada and Ethiopia with 4 kt each[89].

Using USGS data, Geoscience Australia estimated world production of tantalum in 2012 to be 765 t (767 t in 2011). Production in 2012 was dominated by Mozambique, with 260 t, which amounted to about 34% of world output. According to the USGS, other main producers were Brazil with 180 t, Congo (Kinshasa) with 95 t, Rwanda with 90 t and Nigeria with 50 t[90].

Industry Developments

Global Advanced Metals Pty Ltd (GAM) resumed operations at its Wodgina mine in January 2011 after it had been on care and maintenance since December 2008 as a result of the global financial crisis. Throughout 2009 and 2010, the company continued to process tantalum pentoxide (Ta_2O_5) from its ore stockpiles. Although the initial recommencement mining rate will be at 700 000 pounds per year, the Wodgina mine has a capacity to produce 1.4 million pounds of Ta_2O_5 per year from tantalum-bearing pegmatite ores at the Mount Cassiterite and South Tinstone open cut mines. The operations at the mine closed again in early 2012 following softening of demand for tantalum. In 2011, GAM established an agreement with its neighbour, Atlas Iron, allowing it to use the infrastructure at the mine to support the company's iron ore production[91].

89 Tantalum, 2013. United States Geological Survey, Minerals Commodity Summaries, January 2013.

90 Tantalum, 2013. United States Geological Survey, Minerals Commodity Summaries, January 2013.

91 Global Advanced Metals, 2011. World's largest tantalum producer resumes operation, 17 January 2012. Article at: http://www.globaladvancedmetals.com/news/announcements/2011/january/world's-largest-tantalum-producer-resumes-operations.aspx accessed on 8 October 2013.

GAM's Greenbushes operations includes an open-cut and an underground mine, primary and secondary tantalum processing plants, a tin smelter and a lithium plant. The company's primary tantalum plant remains on care and maintenance. Its secondary processing plant treats stockpiles of primary tantalum concentrates from the Wodgina mine. Processing of newly mined Wodgina ore commenced in mid 2011 but closed again in early 2012. The company's Greenbushes tin smelter is closed and its lithium operation produces various grades of spodumene products (see Lithium Chapter).

During the December quarter 2010, Galaxy Resources Ltd commenced production from the Dowling Pit at its Mount Cattlin lithium tantalum project (hard-rock spodumene) north-northeast of Ravensthorpe, WA. At full production, the project is expected to produce 137 000 tpa of spodumene concentrate grading 6% lithium oxide (Li_2O) and 56 000 pounds per year of contained Ta_2O_5 in concentrate. The company announce a temporary halt of operations in July 2012, which was extended in March 2013. According to the board of the company, Mount Cattlin was developed as a feedstock provider for the Jiangsu Lithium Carbonate Plant in China but the high Australian dollar placed pressure on the cost of production. The operations at Mount Cattlin will remain ready to restart in the event the company needs to resume production and to retain security of supply. Galaxy Resources has a five-year sales agreement with GAM under which it delivered the first shipment of tantalum concentrate from Mount Cattlin in March 2011. The shipment of 20 t had an average grade of 2.3% tantalum pentoxide[92].

Alkane Resources Ltd anticipates commissioning Toongi (Dubbo Zirconia Project) in late 2015 for the project to be in full production in 2016. However, tantalum is not currently considered in the output of the project, although the ore contains a significant concentration of tantalum. Preliminary testing for tantalum recovery by the company conducted in 2012 provides promising results, but the company emphasised the need for further testing at a much larger scale to consider commercial-scale production of tantalum. According to the company, a 30% tantalum recovery would produce 100 tpa of Ta_2O_5[93].

92 Galaxy Resource Ltd, 2013. Information on the Mt Cattlin operation. Accessed at http://www.galaxyresources.com.au/pro_raven_mt_cattlin.shtml on 8 October 2013.

93 Alkane Resources Ltd, 2012. Annual report 2012.

Thorium

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Thorium oxide (ThO_2) has one of the highest melting points of all oxides (3300 °C) and has been used in light bulb elements, lantern mantles, arc-light lamps and welding electrodes as well as in heat resistant ceramics.

Thorium can be used as a nuclear fuel through breeding to ^{233}U. There is no significant demand for thorium resources currently and any large-scale commercial demand is expected to be dependent on the future development of thorium-fuelled nuclear reactors. Several reactor concepts based on thorium fuel cycles are under consideration, but a considerable amount of development work is required before it can be commercialised.

India has been developing a long-term, three-stage nuclear fuel cycle to utilise its abundant thorium resources. The construction of a 500 megawatt electric (MWe) prototype fast breeder reactor at Kalpakkam, near Madras, was about 94% complete in February 2013. It will have a blanket with thorium and uranium to breed fissile ^{233}U and plutonium respectively. Six more such fast breeder reactors have been announced for construction and this project will take India's thorium program to stage 2.

In stage 3, Advanced Heavy Water Reactors (AHWRs) burn ^{233}U and plutonium with thorium to derive about 75% of the power from thorium. For each unit of energy produced, the amount of long-lived minor actinides generated is nearly half of that produced in current generation Light Water Reactors. In mid-2010, a pre-licensing safety appraisal had been completed by the Atomic Energy Regulatory Board and site selection was in progress. Construction of the AHWR is anticipated to commence in 2014, but full commercialisation of thorium reactors is not expected before 2030. The AHWR can be configured to accept a range of fuel types, including enriched U, U-Pu mixed oxide fuel (MOX), Th-Pu MOX, and 233U-Th MOX in full core.

In September 2009, India announced an export version of the AHWR, the AHWR- Low Enriched Uranium (LEU) version. This design will use LEU plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to ^{233}U). This version can meet the requirement also of medium sized reactors in countries with small grids along with the requirements of next generation systems[94,95].

It was also reported that design studies are proceeding in India for a 200 MWe Pressurised Heavy Water Reactor (PHWR) accelerator-driven system (ADS) fuelled by natural uranium and thorium[96].

In January 2011, the China Academy of Sciences launched a research and development program on Liquid Fluoride thorium reactor, known at the academy as the thorium-breeding molten-salt reactor (Th-MSR or TMSR). A 5 MWe MSR is believed to be under construction at Shanghai, with an operational target date of 2015 and a 2 MWe accelerator-driven sub-critical prototype has also been reported. The US Department of Energy is collaborating with the Academy on the program, which had a start-up budget of US$350 million.

94 World Nuclear Association, 2013. Nuclear Power in India. Country briefings, August 2013, 33pp.

95 Kakodkar A, 2009. Statement by Dr Anil Kakodkar, Chairman of the Atomic Energy Commission and leader of the Indian delegation, IAEA 53rd General Conference, Vienna, 16 September 2009.

96 World Nuclear Association, 2013. Nuclear Power in India. Country briefings, August 2013, 33pp.

In July 2009, Atomic Energy of Canada Ltd (AECL) signed a second phase agreement with four Chinese entities to develop and demonstrate the full-scale use of thorium fuel in the CANDU 6 reactors at Qinshan in China. This was supported in December 2009 by an expert panel appointed by China National Nuclear Corporation (CNNC) and comprising representatives from China's leading nuclear academic, government, industry and research and development organisations. The panel also recommended that China consider building two new CANDU units to take advantage of the design's unique capabilities in utilising alternative fuels[97]. It was reported by the World Nuclear Association that:

> *"In August 2012, a follow-on agreement among the parties (CANDU Energy having taken over from AECL) focused on undertaking a detailed conceptual design of the Advanced Fuel CANDU Reactor (AFCR), which is described as "a further evolution of the successful CANDU 6 and Generation III Enhanced CANDU 6, optimized for use of recycled uranium and thorium fuel." At the completion of the agreement in two years, the parties "expect to have the basis of a pre-project agreement for two AFCR units in China, including site allocation and the definition of the licensing basis." Phase one of the AECL agreement was a joint feasibility study to examine the economic feasibility of utilising thorium in the Qinshan Phase III PHWRs. (Geologically, China is better endowed with thorium than uranium.) This involved demonstration use of eight thorium oxide fuel pins in the middle of a Canflex fuel bundle with low-enriched uranium".*

A demonstration High Temperature Reactor-Pebble Modules of 210 MWe (two reactor modules) is being built at Shidaowan in Shandong province. A further 18 units of 210 MWe each are planned and followed by increases in the size of the 210 MWe unit modules including the introduction of thorium in fuels.

Resources

At the end of December 2012, Geoscience Australia estimated that Australia's total indicated and inferred in-situ resources of thorium amounted to about 595 000 t. Because there is no publicly available data on mining and processing for these resources, the recoverable resource of thorium is not known. However, assuming an arbitrary figure of 10% for mining and processing losses in the extraction of thorium, the recoverable resources of Australia's thorium could amount to about 535 500 t.

Because there is no established large-scale demand and associated costing information, there is insufficient information to determine how much of Australia's thorium resources are economically viable for electricity generation in thorium nuclear reactors.

There are no comprehensive detailed records on Australia's thorium resources because of the lack of large-scale commercial demand and a paucity of the required data.

Thorium resources in heavy mineral sand deposits

Most of the known thorium resources in Australia are in the rare earth-thorium phosphate mineral monazite within heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Prior to 1996, monazite was being produced from heavy mineral sand operations and exported for extraction of rare earth elements (REE). However, in current heavy mineral sand operations, the monazite is generally returned to the pit in dispersed form, as required by mining regulations. This dispersion is carried out to avoid a concentration of radioactivity when rehabilitating the mine site to an agreed land use. In doing so, the rare earths and thorium present in the monazite are negated as a resource because it would not be economic to recover the dispersed monazite for its rare earth and thorium content. The monazite content of heavy mineral resources is seldom recorded by mining companies in published reports. However, in June 2012, Astron Corporation Ltd noted in an investor presentation that it intends to export 10 000 t of monazite per year to China from its Donald heavy mineral sand deposit in Victoria[98]. In addition, monazite and xenotime resources were also published by Australian Zircon NL for the WIM 150 and by Crossland Uranium Mines Ltd for the Charley Creek deposit in the Northern Territory.

Most of the known resources of monazite are in Victoria and Western Australia. Heavy mineral sands are being mined in the Murray basin deposits at Ginkgo and Snapper in New South Wales and at Douglas in Victoria. In WA, mining of heavy minerals is taking place at Eneabba, Cooljarloo, Dardanup and Gwindinup.

97 World Nuclear Association, 2013. China Nuclear Fuel Cycle. Country briefings, 22 July 2013, 15pp.

98 Stockdale, H. and Nielsen, M., 2012. Astron Corporation Ltd investor presentation. June 2012, 35pp.

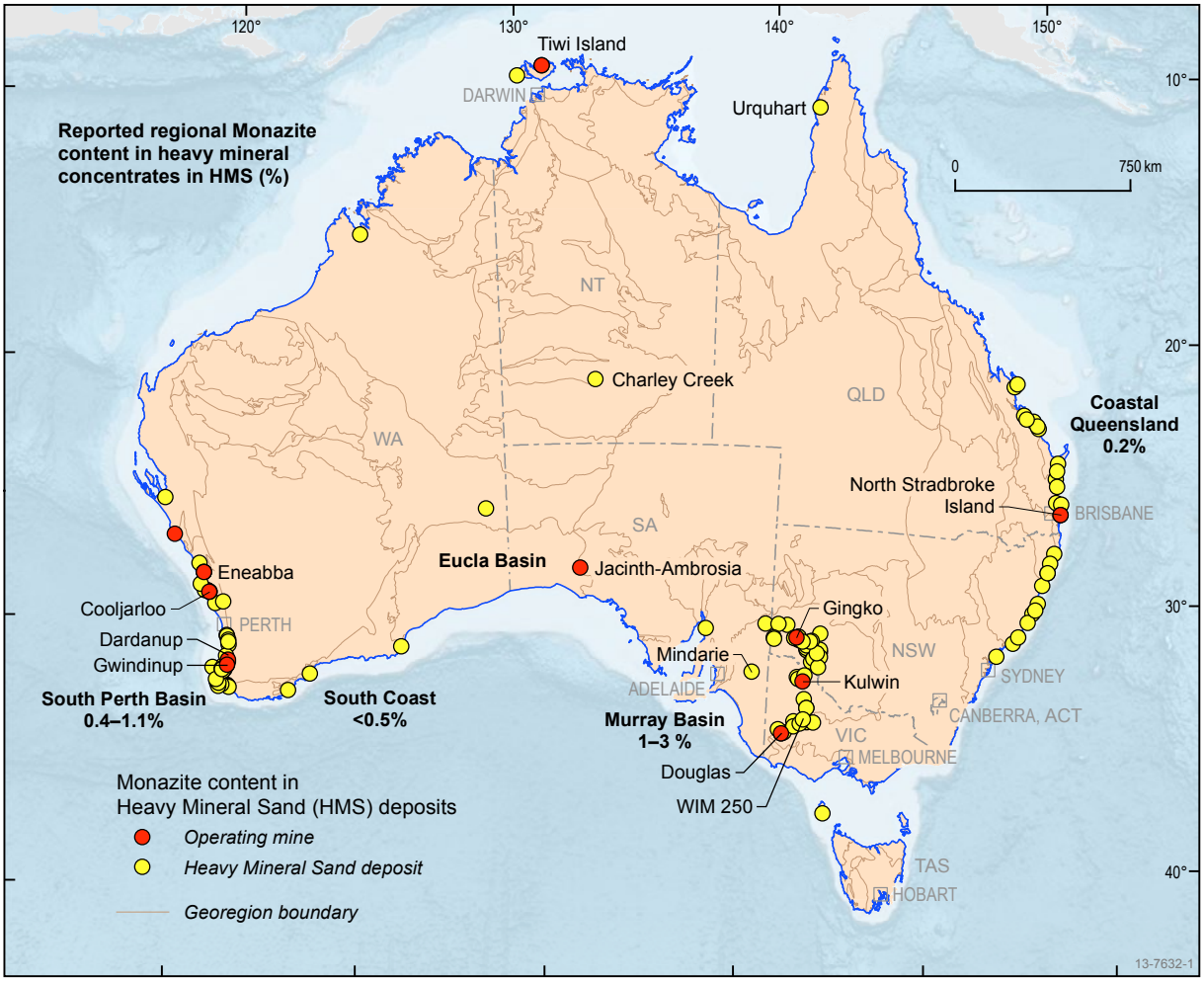

Figure 18: Reported regional monazite content in heavy mineral concentrates of heavy mineral sand deposits in Australia.

Using available data, Geoscience Australia estimates Australia's monazite resources in the heavy mineral deposits to be around 7.8 Mt. The data on monazite and the thorium content in the monazite in the mineral sand resources is very variable, but the available sources include:

- analyses for monazite and thorium in published and unpublished reports;
- published and unpublished analyses of thorium content in exported monazite concentrates; and
- monazite and thorium analyses on heavy mineral sand deposits in company reports on open file available at some State Geological Surveys.

Information from these sources was applied to resource data on individual heavy mineral sand deposits to estimate the thorium resources in these deposits. Where local data on the monazite and thorium were not available, regional data were applied to individual deposits to estimate their monazite and thorium resources. Using this information, Australia's inferred in situ thorium resources in the mineral sands were estimated to be around 388 800 t. The regional distribution of monazite in heavy mineral sands is shown in Figure 18 and the location of various types of deposits containing thorium and the regional distribution of estimated thorium resources is shown in Figure 19.

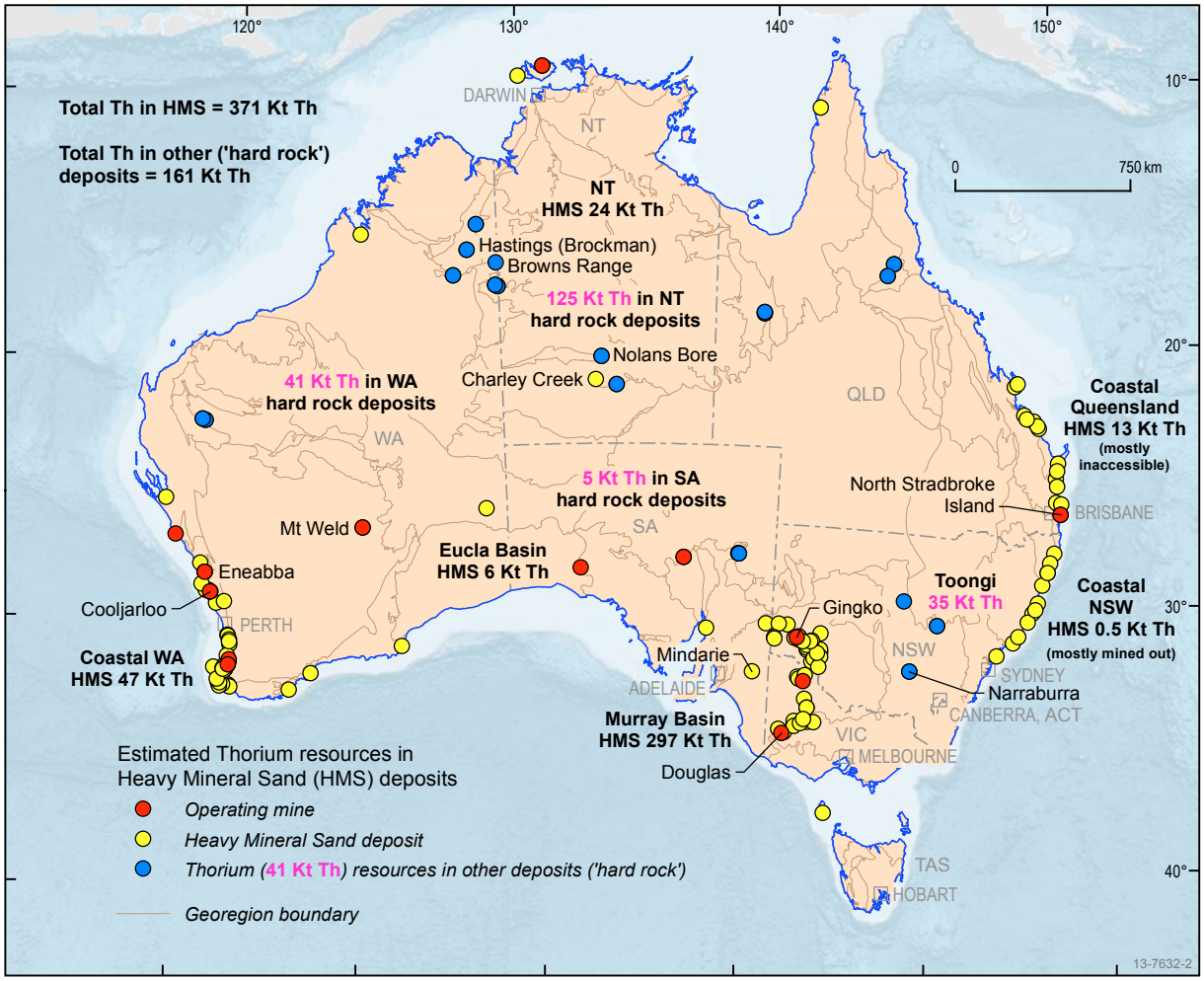

Figure 19: Distribution of thorium resources (in situ) in heavy mineral and other types of deposits.

In addition, monazite and xenotime were also reported by Australian Zircon NL to the Australian Stock Exchange on 18 July 2013 in an update of Proved and Probable Reserves totalling 24 Mt of in-situ heavy minerals at 11.7% rutile, 31.7% ilmenite, 5.9% leucoxene, 21.6% zircon, 2.3% monazite and 0.4% xenotime.

Resources for a new type of placer deposit, the Charley Creek deposit in the NT, containing zircon, monazite and xenotime was reported on 15 May 2012 by Crossland Uranium Mines Ltd. The Charley Creek deposit was reported by the company as an alluvial outwash which comprises an Indicated Resource of 387 Mt containing 27 000 t of xenotime, 161 000 t of monazite and 196 000 t of zircon. The xenotime and monazite were stated to contain about 114 000 t of total rare earth oxides (REO). In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 t of REO in about 31 000 t of xenotime and 167 000 t of monazite as well as 220 000 t of zircon. The thorium content in the xenotime and monazite was not stated. On 15 April 2013, Crossland released results of a scoping study which indicated a low capital-cost requirement of $156 million including contingency and project infrastructure with a payback of 2.5 years after commencing production. The project is based on a mine life of 20 years, with a drilled resource based on around 1% of the area with exploration potential. Average annual revenue of $154 million at 3645 t equivalent total REO production.

Apart from heavy mineral sand deposits, thorium can be present in other geological settings such as alkaline intrusions and complexes, including carbonatites, and in veins and dykes. In these deposits, thorium is usually associated with other commodities such as rare earths, zirconium, niobium, tantalum and other elements. The more significant deposits are described in the following sections.

Thorium resources in vein-type deposits

Arafura Resources Ltd: The **Nolans Bore** rare earth element-phosphate-uranium-thorium deposit is located 135 km northwest of Alice Springs in the Northern Territory. The mineralisation is hosted in fluorapatite veins and dykes. This deposit contains about 81 800 t of Th in 30.3 Mt of Measured, Indicated and Inferred Resources grading 2.8% REO, 12.9% P_2O_5, 0.02% U_3O_8 and 0.27% Th. Arafura is planning to establish an intermediate rare earth chemical processing plant near its Nolans Bore deposit[99]. In June 2012, Arafura published a revised total Measured, Indicated and Inferred Resource figure of 47 Mt grading 2.6% REO, 11% P_2O_5 and 0.02% U_3O_8[100]. The thorium grade was not published but assuming a similar thorium grade of 0.27% Th, the upgraded resource could contain thorium in the order of 120 000 t.

Northern Minerals Ltd: The **Wolverine** deposit of the Browns Range Rare Earth group is located about 150 km southeast of Halls Creek, WA. On 21 December 2012, Northern Minerals announced Indicated and Inferred Resources totalling 1.44 Mt of ore grading at 0.73% total REO (which includes 4153 ppm Y_2O_3), 26 ppm U_3O_8, and 28 ppm ThO_2. The main ore mineral is xenotime which occurs within hydrothermal silicified and hematitic breccias. Resource drilling has outlined mineralisation over a strike length of 250 m and a vertical depth of 250 m. The resource has a well-defined, high-grade (>1% total REO) central zone which is open at depth. At the cut-off grade of 0.15% total REO, the Indicated Resource has an average grade of 728 ppm Dy_2O_3 and 4739 ppm Y_2O_3[101].

Thorium resources in alkaline rock complexes

Alkane Resources Ltd: The **Toongi** zirconium-niobium-rare earth element deposit occurs within a sub-volcanic trachyte horizontal intrusive body approximately 900 m by 600 m about 30 km south of Dubbo in NSW[102]. The deposit has a Measured Resource of 35.7 Mt and 37.5 Mt of Inferred Resources grading 1.96% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, 0.745% total REO, 0.014% U_3O_8, and 0.0478% Th, giving a total of about 35 000 t contained Th. In November 2011, Alkane announced Proved and Probable Reserves for the deposit of 35.93 Mt grading 1.93% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, and 0.73% total REO. The company also released results of a definitive feasibility study for the project that excluded the production of thorium and uranium[103]. The financial analysis indicated a net present value for the project of $181 million at a processing rate of 400 ktpa and $1.207 billion at a processing rate of 1000 ktpa. In July 2012, Australian Zirconia Ltd, a wholly owned subsidiary of Alkane Resources Ltd, signed a Memorandum of Understanding with Japan's Shin-Etsu Chemical Co Ltd to produce a suite of separated heavy and light rare earths using the rare earth concentrates from the Dubbo Zircon Project.

Hastings Rare Metals Ltd: Other alkaline complexes with known rare earth and thorium mineralisation include **Brockman** (now renamed **Hastings**) in WA. It is a large, low-grade zirconium-niobium-rare earth element deposit hosted in altered trachytic tuff of Paleoproterozoic age. On 8 September 2011, Hastings reported 36.2 Mt of Indicated and Inferred Resources grading 8.86 ppm ZrO_2, 3.55 ppm Nb_2O_5, 182 ppm Ta_2O_5, 110 ppm Ga_2O_5, 318 ppm HfO_2, 186 ppm Dy_2O_5, 1120 ppm Y_2O_3, 2102 ppm total REO and 1802 ppm heavy REO. Historic company reports on open file on the Geological Survey of Western Australia's WAMEX database show analyses for thorium in six separate drill hole intersections (in tuffs) of 16 m to 28 m averaging from 259–371 ppm Th (WAMEX database report A 40991).

Capital Mining Ltd: The peralkaline granitic intrusions of the Narraburra Complex 177 km northwest of Canberra contain anomalous amounts of zirconium, REO and low concentrations of Th (73.2 Mt at 1250 g/t ZrO_2, 146 g/t Y_2O_3, 327 g/t REO, 45 g/t HfO_2, 126 g/t Nb_2O_5, and 61 g/t ThO_2; Capital Mining Ltd Prospectus 2006). The thorium oxide (ThO_2) content amounts to 4465 t (2420 t Th). In the March quarterly report in 2010, Capital Mining reported that it was conducting metallurgical test to recover hafnium, thorium, tantalum, niobium, neodymium and cerium.

99 Arafura Resources Ltd, 2012. Australian uranium and rare earths conference 2013, 16–17 July 2013, Fremantle, 15pp.

100 Arafura Resources Ltd, 2012. Upgrade in Nolans Bore JORC mineral resources. Announcement to the Australian Securities Exchange, 8 June 2012, 2pp.

101 Northern Minerals Ltd, 2012. Northern Minerals initial JORC compliant resource estimate. Announcement to the Australian Securities Exchange, 21 December 2012, 16pp.

102 Alkane Resources Ltd, 2013. Annual Report 2012, 74pp.

103 Alkane Resources Ltd, 2013. Definitive feasibility study confirms robust Dubbo zirconia project. Announcement to the Australian Securities Exchange, 11 April 2013, 9pp.

Thorium resources associated with carbonatite intrusions

Data on the thorium content of carbonatite intrusions in Australia is sparse. **Mount Weld** and **Cummins Range** in WA have the most significant rare earth resources reported for carbonatites in Australia, with both having some thorium content.

Lynas Corporation Ltd: The **Mount Weld** deposit in WA occurs within a lateritic profile developed over an alkaline carbonatite complex. On 18 January 2012, Lynas reported Measured, Indicated and Inferred REO resources for the Central Lanthanide deposit at a cut-off of 2.5% REO of 14.949 Mt at 9.8% REO including Y_2O_3. The ThO_2 content of the deposit is estimated to be 712 ppm, which equates to 626 ppm Th (personal communication B Shand, Lynas Corporation Ltd, 17 June 2009).

An updated resource for the **Duncan** deposit in the weathered carbonatite complex stands at 8.992 Mt of Measured, Indicated and Inferred Resources at 4.8% REO including Y_2O_3. The ThO_2 content is estimated to be 441 ppm (388 ppm Th). In another part of the carbonatite complex there are 37.7 Mt of mostly Inferred Resources grading 1.07% Nb_2O_5, total lanthanides at 1.16% and 0.09% Y_2O_3, 0.3% ZrO_2, 0.024% Ta_2O_5, 7.99% P_2O_5 and a ThO_2 content of 479 ppm (421 ppm Th).

Kimberley Rare Earths Ltd: On 13 February 2012, Kimberley Rare Earths Ltd announced a revised Inferred Resource for the **Cummins Range** in WA carbonatite deposit of 4.9 Mt at 1.74% REO, 11.2% P_2O_5 145 ppm U_3O_8 and 48 ppm Th. The resource was calculated at a cut-off grade of 1% REO. In other parts of the deposit, historic sample analyses recorded in open file report A16613 in the WAMEX database averaged about 500 ppm Th in the top 48 m of weathered zone in one drill hole. Thorium-rich zones of 200–400 ppm Th were intersected in two drill holes in fresh carbonatite and carbonated magnetite amphibolite to depths of 400 m.

Hastings Rare Metals Ltd: The **Yangibana** ferrocarbonatite-magnetite-REE-bearing dykes in WA (termed ironstones) crop out over an area of 500 square kilometres and form part of the Gifford Creek Complex. The dykes are part of a carbonatitic episode that intrudes the Proterozoic Bangemall Group. The ferrocarbonatite-magnetite-REE-bearing dykes occur as lenses and pods and are typically the last stage of carbonatite fractionation and are enriched in rare earth elements, fluorite and uranium-thorium mineralisation. The Yangibana prospect has a historic (1989) recorded resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse-grained monazite containing up to 20% Nd_2O_5 and 1600 ppm Eu_2O_3. Whole rock chemical analyses of 21 ironstone samples collected from five prospects in the Yangibana area recorded more than 1000 ppm Th for 10 of the samples (1062 ppm to 5230 ppm Th).

Exploration

There has been no widespread exploration for thorium in Australia. However, thorium is a significant component of some deposits being explored for in other commodities. Thorium is present in the Nolans Bore deposit in the NT and in the Toongi intrusives complex in NSW. In April 2011, Centius Gold Ltd reported that a low-altitude airborne survey detected thorium and uranium anomalies over the northern rim of its Bethungra Caldera prospect, which was claimed to resemble similar airborne radiometric anomalies over Alkane's Dubbo (Toongi) zirconium-rare earth project to the north. Drilling by Chinalco Yunnan Copper Resources Ltd at the Elaine deposit copper-cobalt-gold south of the Mary Kathleen deposit in Queensland has intersected up to 827 ppm ThO_2[104].

Production

There is no production of thorium in Australia, but it is present in monazite being mined with other minerals in heavy mineral beach sand deposits. Between 1952 and 1995, Australia exported 265 kt of monazite with a real export value of $284 million in 2008 dollars[105]. Most of the monazite was exported to France for rare earth element extraction, but the monazite plant in France was closed because its operators were unable to obtain a permit for the toxic and radioactive disposal site.

In current heavy mineral sand operations, the monazite fraction is returned to the mine site and dispersed to reduce radiation as stipulated in mining conditions. However, in June 2012, Astron Corporation Ltd indicated in an investor presentation that it intends to export 10 000 t of monazite per year to China from its Donald heavy mineral sand deposit. Astron also reported on 18 June that its zircon product from the Donald deposit contains about 1000 ppm U+Th which they intend to export to China where it will be leached to bring the U+Th content down to 500 ppm raising the possibility that this process could lead to some uranium and thorium by-product[106].

104 Chinalco Yunnan Copper Resources Ltd, 2012. Quarterly Report for the three months ending 30 June 2012, 14pp.

105 Australian Bureau of Statistics, 2009. International Trade, Cat. No.5465.0, Canberra.

106 Astron Corporation Ltd, 2012. Donald mineral sands project – review of uranium/thorium wash process and proved ore reserve update.

World Ranking

In 2012, the Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) revised estimates of thorium resources on a country-by-country basis. The OECD/NEA report notes that the estimates are subjective as a result of the variability in the quality of the data, much of which is old and incomplete. Table 15 has been derived by Geoscience Australia from information presented in the OECD/NEA analysis.

Table 15: Estimated thorium resources by region and country.

Region	Country	Identified Thorium Resources (In situ)*(kt)	Total thorium for regions and the world (kt)
Australia	Australia	595	
Australia	**Subtotal**		**595**
Americas	Brazil	606–1300	
Americas	United States of America	434	
Americas	Venezuela	300	
Americas	Canada	172	
Americas	Others	24.3	
Americas	**Subtotal**		**1536.3–2230.3**
Europe	Turkey	744–880	
Europe	Norway	320	
Europe	Greenland	86–93	
Europe	Others	166	
Europe	**Subtotal**		**1316–1459**
Asia	Commonwealth of Independent States (excluding Russian Federation European part but includes the CIS countries below)	1500	
Asia	- Kazakhstan	>50	
Asia	- Russian Federation Asian part	>100	
Asia	- Uzbekistan	5–10	
Asia	India	846	
Asia	China	>100	
Asia	Chinese Taipei	9	
Asia	Iran	30	
Asia	Others	58.5–66.5	
Asia	**Subtotal**		**2543.5–2551.5**
Africa	Egypt	380	
Africa	South Africa	148	
Africa	Morocco	30	
Africa	Nigeria	29	
Africa	Madagascar	22	
Africa	Others	40.5–50.5	
Africa	**Subtotal**		**649.5–659.5**
World	**TOTAL**		**6577.3–7432.3**

*Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries modified after OECD/NEA & IAEA, 2012: Resources, Production and Demand. OECD Nuclear Energy Agency & International Atomic Energy Agency.

OECD/NEA & IAEA (2012) has grouped thorium resources according to four main types of deposits as shown in Table 16. Thorium resources worldwide appear to be moderately concentrated in the carbonatite type deposits, accounting for about 30% of the total. The remaining thorium resources are more evenly spread across the other three deposit types in decreasing order of abundance in the placers, vein-type deposits and alkaline rocks. In Australia, a larger proportion of resources are located in placers where the heavy mineral sand deposits account for about 65% of the known thorium resources.

Table 16: In situ world and Australian thorium resources according to deposit type (modified after OECD/NEA & IAEA, 2012) with Australia's recoverable resources listed in the last column after an overall reduction of 10% for mining and milling losses.

Major deposit type	World Th Resources (kt)	World Th Resources (%)	Australian Th Resources (kt)	Australian Th Resources (%)	Recoverable Australian Th Resources (kt)
Carbonatite	1900	31.3	30.5	5.1	27.4
Placer deposits	1500	24.7	386.8	65	348.1
Vein-type deposits	1300	21.4	125	21	112.5
Alkaline rocks	1120	18.4	50.9	8.6	45.8
Other	258	4.2	2	0.3	1.8
Total	**6078**	**100.0**	**595.2**	**100.0**	**535.6**

Tin

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Tin (Sn) is used in solders for joining metals and pipes, as a coating for steel cans and in metal alloys. The largest single application for tin is in solders, which accounts for about half of current world consumption. Solders are used in light engineering applications such as plumbing and sheet metal work, in the motor vehicle industry and in cans for various uses. Another major application for tin is coating steel sheet in the manufacture of tinplate, which accounts for about 16% of world tin consumption. Tinplate is used for containers in the form of tin cans for food products, drinks, oils, paints, disinfectants and chemicals.

Resources

Australia's EDR of tin was 277 kt at December 2012, up from 243 kt in 2011. Increases in Australia's EDR were reported at both the Renison Bell and Mount Lindsay deposits in Tasmania.

Almost 75% of Australia's EDR of tin are contained in the Renison Bell deposit in western Tasmania. Others include the Mount Lindsay and Queen Hill deposits, also in western Tasmania. There are several occurrences also in north Queensland, including the Gillian and associated deposits, and the Mount Garnet and Baal Gammon deposits (Figure 20).

In 2012, Subeconomic Demonstrated Resources (comprising Paramarginal and Submarginal Resources) increased to 96 kt, largely because of reclassification of existing resources. Inferred Resources increased from 231 kt in 2011 to 262 kt in 2012. Tasmania accounts for 49% of Inferred Resources, followed by NSW with 24% and Queensland with 21%.

Accessible EDR

All of Australia's EDR for tin are accessible.

JORC Reserves

JORC Code reserves comprise total tin in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC Code reserves of 170 kt accounted for about 61% of AEDR. This compares with 119 kt of JORC Code reserves in 2011.

Exploration

Exploration continued in the historic tin mining areas of Herberton-Mount Garnet in north Queensland, in the New England and Bourke regions of NSW and in western Tasmania. Data on tin exploration expenditures are not reported by the Australian Bureau of Statistics.

Production

Australia's mine production in 2012 was 5800 t[107] of tin in concentrate, an increase from the 2011 production of 5000 t. There has been no production of refined tin in Australia since 2007 when the Greenbushes tin smelter in Western Australia closed. Total exports of tin for 2012 were 5706 t valued at $110 million[108]. This compares with 4992 t valued at $118 million exported in 2011.

107 Figures do not include tin production in Western Australia for which data is not available. Production in that state is not believed to be significant.

108 Export statistics from the Bureau of Resources and Energy Economics, 2013: Resources and Energy Quarterly September 2013.

Figure 20: Map showing location of tin (Sn), tungsten (W), tantalum (Ta), niobium (Nb) and lithium (Li) deposits and prospects discussed in commodity chapters.

World Ranking

World economic resources of tin in 2012 are estimated to be 4947 kt based on USGS data and updated by Geoscience Australia for Australia's resources. This compares with 4863 kt of tin resources in 2011. According to the USGS, China holds about 30% of the resources followed by Indonesia with about 16% and Brazil with about 14%. Based on the USGS figures and those updated by Geoscience Australia, Australia has a 5.6% share of world resources of tin.

Based on USGS data and updated with Australia's production data, world production of tin in 2012 is estimated to be 228 kt. These figures represent a decrease in production of 250 kt of tin in 2011. China was the major producer with about 44% of world production, followed by Indonesia with about 18% and Peru with about 13%. USA production was not recorded for confidential reasons. Australian production of 5.8 kt of tin was ranked number seven in the world.

Industry Developments

The price of tin on the London Metal Exchange had recovered significantly from the late 2008-early 2009 low point experienced during the global financial crisis (US$10 000/t or $14 400/t), reaching highs (US$33 000/t, or around $33 000/t) in the second half of the 2010–11 financial year. Since then the price has been through a couple of cycles, dropping to below US$18 000/t in August 2012, before rising to more than US$24 000/t in early 2013, and dropping again to around US$20 000/t in mid-2013. It has since recovered to around US$23 000/t.

Metals X Ltd: In September 2013, Metals X Ltd announced a 31% increase in JORC Code resources at the **Renison Bell** deposit, near Zeehan in western Tasmania. The resource includes Measured Resources of 1246 kt at 2.22% Sn, Indicated Resources of 6453 kt at 1.57% Sn and Inferred Resources of 3870 kt at 1.93% Sn, for a contained 204 kt of Sn. As at 30 June 2013, the resource includes Proved Reserves of 788 kt at 1.50% Sn and Probable Reserves of 3349 kt at 1.23% Sn for a contained 53 kt of Sn. Renison Bell also has total copper resources of 34 kt and total copper ore reserves of 11 kt.

The Renison Bell mine, along with the Renison Tin Concentrator, the Renison Expansion Project, **Rentails**, and the **Mount Bischoff** Tin Project, all form part of a group of Tasmanian tin assets. These assets are owned jointly (50:50) by Metals X and YT Parksong Australia Holding Pty Ltd, the latter of which is a partnership between Yunnan Tin Group, China's largest tin producer and the Hong Kong-based company, L'Sea Resources International Holdings Ltd (previously known as Goodtop Tin International Holdings Ltd). The assets are managed through the joint venture company Bluestone Mines Tasmania Joint Venture Pty Ltd. Current operations are at the Renison Bell underground mine with ore from the mine treated at the Renison concentrator.

Production for 2012 was 5848 t of tin metal and 336 t of copper metal. Renison is aiming for long-term production rates of between 7000 and 7500 tpa of tin in concentrate. A copper circuit was commissioned in December 2010, with production of around 500 tpa of copper in concentrate. Mining ceased at Mount Bischoff in July 2010 and the last ore was treated in late 2010. The company is carrying out both underground and surface exploration around the Renison deposit. The underground exploration has focussed on the Federal, Deep Huon, Huon North and North King ore zones, as well as delineation and further definition of the Central Federal Bassett zone, which is a recently discovered mineralised zone in the area between the southern and northern declines access.

In 2009, Metals X completed a feasibility study on proposals to recover tin from tailings produced by historic processing of tin ores from Rentails at the Renison Bell mine. Resources at Rentails to 30 June 2013 comprise Measured Resources of 20 598 kt averaging 0.45% Sn and 0.21% Cu, which represents 92 700 t of contained Sn and 43 200 t of contained Cu. The resource includes Probable Reserves of 19 757 kt at 0.45% Sn and 0.21% Cu. The recovery project proposes reclaiming tailings at a rate of 2 Mtpa to produce about 5300 t of tin and 2000 t copper in concentrate a year. Joint venture partners are still working on when the project will be brought into development.

Metals X's **Collingwood** mine, about 30 km south of Cooktown in north Queensland, has been under care and maintenance since its closure in mid-2008. The company has indicated that it will dispose of the property.

Venture Minerals Ltd: The **Mount Lindsay** tin-tungsten deposit is wholly owned by Venture Minerals Ltd. Located 15 km northwest of Renison Bell tin mine and 20 km west of Rosebery in western Tasmania, the prospect is in magnetite-rich skarns within the contact aureole of the Meredith granite, which is part of a suite of Devonian–Early Carboniferous granites that are the source rocks for a number of large tin, tungsten and magnetite deposits in western Tasmania and on King Island in Bass Strait.

The Mount Lindsay tin-tungsten deposit has, as of October 2012, combined resources of 45 Mt at 0.4% Sn equivalent (with a 0.2% cut-off, 73% of the resource is in the Measured and Indicated categories) or 13 Mt at 0.7% Sn equivalent at 0.45% cut-off. As of November 2012, reserves included Proven Reserves of 6.4 Mt at 0.2% Sn, 0.2% WO_3 and 0.1% Cu, and Probable Reserves of 7.3 Mt at 0.2% Sn, 0.1% WO_3 and 0.1% Cu, with a contained 30 000 t of Sn. The deposit also includes an iron resource.

In late 2012, Venture completed a bankable feasibility study (BFS) for Mount Lindsay, which highlighted the long-term potential of the deposit. Highlights of the BFS included a mine life of nine years, a plant capacity of 1.75 Mtpa, a payback period of four years and a capital cost of just under $200 million. The BFS assumed tin prices of US$23 800/t. The company also completed a pilot-scale metallurgical program in August 2012 that demonstrated recoveries of 72% Sn and 83% WO_3, as well as high-grade tungsten concentrate (more than 66% WO_3).

In August 2012, Venture announced favourable drill intersections from its first hole into the **Big Wilson** Project approximately 6 km northeast of the Mount Lindsay Project. Intersections include 35.4 m at 1.0% Sn, including 17.4 m at 2.0% Sn and 4.0 m at 5.6% Sn. The Big Wilson Prospect occurs in an area of historic alluvial tin workings with mineralisation including both skarn and greisen styles.

Stellar Resources Ltd: In January 2012, Stellar Resources Ltd took control of the **Heemskirk** Tin Project through acquisition of joint venture partner Gippsland Ltd's 40% share of the project. The Heemskirk project, located near Zeehan in western Tasmania, comprises the **Queen Hill**, **Montana** and **Severn** deposits. The deposits have a combined mineral resource of 6.28 Mt at 1.14% Sn (at February 2013), including Indicated Resources of 1.41 Mt at 1.26% Sn at the Queen Hill deposit. The majority of the resource is in the Severn deposit which has an Inferred Resource of 4.17 Mt at 0.9% Sn.

Stellar completed a favourable scoping study for the three deposits in July 2011 that highlighted the potential for an economic underground tin mine. The company completed a positive prefeasibility study in mid-2013 that indicated an initial mine life of seven years with an annual production of around 4300 t of tin in concentrate, and a head grade of 1.06% Sn. Metallurgical test work on the Heemskirk ores has suggested concentrate grades approaching 48% Sn with an overall tin recovery of 70%. The company has indicated that it is targeting additional drilling to expand the resource base and convert resources to reserves, as well as identify a potential tin industry partner to help with progression of the project through a definitive feasibility study.

Elementos Ltd: In mid-2013, the Australian based Elementos Ltd acquired the **Cleveland** Tin Project through a merger with the unlisted Rockwell Minerals Ltd, which previously controlled the project and owned 50% of the asset. The Cleveland project is located 60 km southwest of Burnie in Tasmania and includes the underground tin-copper Cleveland mine. The mine, which was mined by Aberfoyle Ltd between 1968 and 1986, produced about 23.5 kt of Sn and 9.7 kt of copper in concentrate. The mine closed as a result of low tin prices in the late 1980s. The Cleveland project also includes a large low-grade tin-copper tailings dam, as well as the **Foley Zone** tungsten deposit. The company has indicated it plans to undertake further drilling to test extensions of tin and tungsten mineralisation.

In late 2013, Elementos indicated it had initiated a prefeasibility study to assess the development potential of the hard rock and tailings dam tin-copper resources. The study, which is due for completion in the second quarter of 2014, will be based on a recently released (April 2013) JORC Code compliant total resource for the Cleveland mine of 6119 kt at 0.68% Sn and 0.25% Cu, containing 42 kt of Sn, of which 4239 kt at 0.70% Sn and 0.28% Cu (contained 30 kt of Sn) are Indicated Resources. Mineralisation at Cleveland is mainly hosted in vertical-dipping, semi-massive sulphide lenses replacing limestone. Mineralisation is thought to be related to the nearby Meredith Granite. Tin is present as cassiterite and minor stannite.

The tailings dam resource contains Inferred Resources of 3850 kt at 0.30% Sn and 0.13% Cu for a contained 11.6 kt of Sn. Rockwell previously completed an internal scoping study that reportedly demonstrated the reprocessing potential of the tailings. A JORC Code compliant Inferred Resource of 3980 kt at 0.30% WO_3, for a contained 12 kt of WO_3, has also been calculated for the Foley Zone tungsten deposit. The tungsten occurs as wolframite hosted within a quartz stock-work.

TNT Mines Ltd: In February and September 2011, TNT Mines Ltd applied for offshore exploration tenements in Ringarooma Bay as part of its **Ringarooma Bay** alluvial tin project in northeast Tasmania. The tenements cover parts of the old Ringarooma River channel. The project has an historic indicated resource of 16 million cubic metres at 227 grams of tin per cubic metre. TNT has undertaken work at its other Tasmanian properties, including initial metallurgical investigations at the undeveloped **Moina** fluorspar-tin-tungsten deposit which is a magnetite skarn with complex metallurgy in northwest Tasmania. In July 2013, Niuminco Group Ltd announced that it intended to make a takeover bid for TNT Mines.

Monto Minerals Ltd: In the third quarter of 2011, mining activities commenced at the Monto Minerals Ltd **Baal Gammon** polymetallic deposit, 7 km west of Herberton in north Queensland. Mining was being undertaken by Kagara Ltd which has a Minerals Rights Agreement with Monto Minerals. The ore was being processed at Kagara's Mount Garnet copper processing facility and just under 38 kt of ore with an average grade of 1.9% Cu and 41.5 g/t Ag had been milled prior to suspension of activities by Kagara in April 2012 before the company went into voluntary administration.

Prior to cessation of mining, Kagara undertook resource diamond drilling at the deposit and released an updated resource estimate with Indicated Resources of 2769 kt at 1.0% Cu, 40 g/t Ag, 0.2% Sn and 38 g/t In. Tin was not being extracted, but Monto Minerals and Kagara were assessing the technical and commercial feasibility of a tin extraction circuit.

In January 2013, Kagara announced it had completed the sale of the Kagara group's Central Region assets to Snow Peak Mining Pty Ltd, which is a subsidiary of Hong Kong investment group Snow Peak International Investment Pty Ltd, and the major shareholder of Consolidated Tin Mines Ltd. Assets included resources and the processing plant at Mount Garnet, as well as mining rights for the Baal Gammon mining area. Monto Minerals announced in October 2013 that Snow Peak had recommenced mining operations at Baal Gammon in the second half of 2013, with ore to be treated at the Mount Garnet processing plant, expected to begin in the first quarter of 2014.

In November 2011, Monto Minerals applied successfully for a mining lease over the **Confederation** copper-tin prospect, contiguous with the existing Baal Gammon Mining Leases and within 800 m of the Baal Gammon mine. Monto Minerals undertook drilling at the Confederation prospect in the first half of 2012. Intercepts included 6 m at 4.33% Cu, 1.25% Sn, 106 g/t Ag and 301 g/t In.

The Baal Gammon deposit forms part of Monto's larger **Herberton** tin project, centred on the historic tin mining region around, and to the west of, Herberton. A regional (188 square kilometres) soil geochemistry survey of the project area commenced in September 2012 and was about 30% complete by mid-2013. A number of anomalies have been identified. Monto Minerals also reported near-surface tin mineralisation from its May 2013 drilling program at its **Alexandra** and **Dargo** prospects at **Mount Ormonde** about 7 km southwest of Baal Gammon, including 6 m at 1.49% Sn and 5 m at 1.03% Sn. Follow-up drilling in June 2013 included 2 m at 2.61% Sn. Monto Minerals also reported interesting polymetallic anomalies including copper, lead, zinc, arsenic, bismuth, tellurium, tungsten, tin and gold in a deep drill hole at the **Zig Zag** prospect, also in the Mount Ormonde region.

Consolidated Tin Mines Ltd: In September 2013, Consolidated Tin Mines Ltd announced it had completed a positive prefeasibility study for the Mount Garnet tin project, 200 km southwest of Cairns in north Queensland. The Mount Garnet project includes the **Gillian** and **Windemere** tin deposits**,** 5 km southwest of and 25 km northeast of Mount Garnet, respectively, and prospects in the **Coolgarra** group area 15 km northeast of Mount Garnet. Highlights of the prefeasibility study included a minimum nine year mine life from a 1 Mtpa open-cut mine producing an average 2994 tpa of tin in concentrate, as well as iron and fluorine.

As part of the study, Consolidated released an updated minerals resource estimate in June 2013, with a total JORC Code resource of 13.118 Mt at 0.39% Sn and 22.87% Fe and 7.035 Mt at 5.8% F for its Mount Garnet project. Included within the total resource is a JORC Code Measured Resource for the Gillian deposit of 1.105 Mt at 0.73% Sn and 32.32% Fe. The majority of the tin resource (just over half) is contained within the **Pinnacles** deposit.

The Gillian, Pinnacles and Windemere deposits are in iron-rich skarns adjacent to granitic intrusions, while the Coolgarra area contains sediment-hosted and granite greisen mineralisation. The Mount Garnet skarn deposits contain fine cassiterite which is difficult to recover because of metallurgical problems. During 2011–12 Consolidated undertook metallurgical testing to separate the fine cassiterite from the ironstone skarn material. It also processed an 80 t sample from the Gillian Project at the Talison mine site at Greenbushes in WA. Results of the metallurgical testing were incorporated into the prefeasibility study.

In October 2013, major shareholder, Snow Peak International Pty Ltd indicated it would exercise its option to earn up to 50% interest in a joint venture with Consolidated to develop the Mount Garnet project. The option was based on a 2012 agreement between the two companies for Snow Peak to fund completion of the prefeasibility study. Consolidated has indicated it will use the funding raised from the joint venture options to complete a final phase of drilling at Gillian as part of its definitive feasibility study of the Mount Garnet project.

The company also announced in October 2011 that it had reached agreement with Friends Exploration Pty Ltd to purchase the **Jeannie River** prospect, 92 km northwest of Cooktown in north Queensland. On the basis of previous exploration results by Carpentaria Exploration Company Pty Ltd, Consolidated announced a JORC Code compliant Inferred Resource of 2240 kt at 0.60% Sn. The Jeannie River prospect comprises parallel cassiterite mineralised quartz veins.

MGT Mining Ltd: MGT Mining Ltd, formerly Xtreme Resources Ltd and an 86.5% owned subsidiary of MGT Resources Ltd, continued exploration around the historic tin mines in the immediate proximity of its Mount Veteran tin plant, including the **Dalcouth, Summer Hill,** and **Extended** prospects. All are located in the Mount Garnet district in north Queensland.

An upgrade of the tin plant was completed in 2011 resulting in a 70 000 tpa processing capacity. The company has indicated it is planning an upgrade to the plant to increase processing capacity to 250 000 tpa in 2013–2014, pending discovery of further tin resources. In September 2012, MGT successfully completed pilot runs of the mill.

A mining lease was granted in late 2011 for the **Heads or Tails** lease in the Smiths Creek area about 15 km from the mill and will use mine tailings as feed for the mill, but this has been delayed by environmental requirements. Metallurgical testing has indicated 75% recovery of tin is possible from the tailings.

MGT reported that 17 t of around 65% tin in concentrate was produced and shipped to an Asian smelter in the first quarter of 2013. Production was, in part, from stockpiles from historic mining but also included material purchased from local miners.

The Summer Hill mining lease, which surrounds the Mount Veteran processing plant and lease, was approved in January 2013 and the company has since undertaken three phases of drilling on the lease. Targets included the Dalcouth and Extended prospects. MGT reported favourable shallow tin intercepts from the first two phases of drilling, including 4 m at 2.24% Sn, and 8 m at 1.1% Sn.

Global Advanced Metals Pty Ltd: At **Greenbushes** mine in southwest WA production of tin ceased with the closure of the smelter in 2007. Tin resources for Greenbushes operations have not been publicly reported for more than a decade. Historical estimates of tin resources for Greenbushes have not been included in Australia's EDR since 2008. Global Advanced Metals (GAM) indicates that it has produced by-product tin from its tantalum deposit at **Wodgina** about 100 km southeast of Port Hedland in WA, but the amounts are not reported. Although production at Wodgina resumed in April 2011, with ore processed at GAM's Greenbushes facilities, the mine closed again early 2012 following softening of demand for tantalum.

Malachite Resources Ltd: In 2011–12, Malachite Resources Ltd shifted focus, concentrating on its **Lorena** gold project in northwest Queensland. As a result, minimal exploration has been undertaken by the company on its polymetallic **Conrad** silver project 25 km south of Inverell in northeast NSW. The current global resource figures for the Conrad project have Indicated Resources of 447 kt at 123.8 g/t Ag, 0.26% Cu, 1.3% Pb, 0.46% Zn, 0.28% Sn and 7.7 g/t In, as well as Inferred Resources of 1807 kt at 101.9 g/t Ag, 0.21% Cu, 1.22% Pb, 0.46% Zn, 0.22% Sn and 6.4 g/t In. Tin is present as stannite and cassiterite. A preliminary scoping study into the Conrad deposit highlighted the narrow width of ore zones (largely 0.6 m to 0.8 m) and the sensitivity of such to the economics of the deposit.

In 2012, Malachite granted an exclusive six-month option to Mancala Resources Pty Ltd, a privately-owned Australian mining contractor with narrow vein expertise and vertical mining technology. The option allowed Mancala to carry out an evaluation of the Conrad silver project and the right, if exercised, to enable it to take a 50% interest in the project by funding and completing a feasibility study. The option was extended by six months to March 2013, and in April 2013 Malachite announced that Mancala was not exercising the option. Based on Mancala's review of the project, Malachite indicated that it was considering an RC drilling program at the Princess shoot end of the field, testing for near surface mineralisation that, initially, could support a mining operation.

YTC Resources Ltd: In late 2012, YTC Resources Ltd (YTC) announced it had reached agreement with Straits Resources Ltd to acquire 100% of the **Doradilla** tin project. Prior to this, YTC had the right to earn 70% of the Doradilla project from Templar Resources Ltd, a wholly owned subsidiary of Straits, by spending $1.5 million over five years.

The Doradilla project, which is 55 km southeast of Bourke in NSW, contains the Doradilla, **Midway-East Midway** and **3KEL** tin deposits. These deposits occur within a linear skarn unit that can be traced for more than 17 km along strike. Mineralisation is thought to be genetically related to the mid-Triassic Midway Granite. The resource is limited to the weathered zone (laterite) where tin is hosted in stanniferous goethite, garnets, secondary cassiterite and minor primary cassiterite. The company has announced a combined Inferred Resource for the tin laterite (oxide) mineralisation of 7.81 Mt averaging 0.28% Sn at a cut-off grade of 0.1% Sn for 22.3 kt of contained tin.

During 2011, YTC undertook drilling to test the mineralised contact of an intrusion associated with copper-tungsten mineralisation at the historic **Doradilla Mine**. The company reported broad intervals of anomalous lead and zinc and occasional intervals of anomalous copper, tin and silver. Drilling at Doradilla in the second half of 2012 was undertaken to assess the largely untested oxide zone of the skarn above the Doradilla deposit. Drilling confirmed the presence of tin mineralisation, with the best intercept being 10 m at 1.09% Sn.

At its **Tallebung** tin-tungsten deposit 70 km northwest of Condobolin in central NSW, YTC has commenced a Right to Negotiate process under the Native Title Act to obtain access to undertake two deep drill holes to test targets from a previous resistivity survey below outcropping mineralisation and to assist in scoping of the Tallebung system for a potential large-tonnage, low-grade tin deposit. Negotiations were continuing as of November 2013.

AusNiCo Ltd: In the September quarter of 2011, YTC Resources Ltd completed a shares and options agreement with Taronga Mines Ltd and Australian Oriental Mines NL for its New England tin projects of **Pound Flat** and **Torrington**. Taronga Mines also controlled the adjacent lease over the large, low-grade **Taronga** tin deposit. AusNiCo Ltd acquired all of the shares in Taronga Mine in early 2013, including ownership of the Taronga deposit.

The company released a maiden JORC Code resource estimate for the deposit in August 2013. Indicated Resources, which include a larger northern zone (19.3 Mt) and a southern zone (7.6 Mt), are 26.9 Mt at 0.17% Sn for a contained 45 kt of Sn. The deposit also has an Inferred Resource of 9.4 Mt at 0.13% Sn for a contained 12.2 kt of Sn. The resource figures also include Inferred Resources of 36.3 Mt at 0.07% Cu and 3.8 g/t Ag, for a contained 26.4 kt of Cu and 4.4 Moz of Ag. Resource figures were calculated using a 0.1% Sn cut-off.

The mineralisation at Taronga, which is about 50 km north of Glen Innes in NSW, occurs as a sheeted vein system with two main zones (northern and southern) of mineralisation about 300 m apart. Tin occurs predominantly as cassiterite and is largely hosted within quartz vein boundaries.

AusNiCo is undertaking an updated prefeasibility study. A prior prefeasibility study for Taronga was completed by Newmont in 1982.

Havilah Resources NL: Further exploration at the **Prospect Hill** tin project in the northern Flinders Ranges of South Australia has been postponed indefinitely because of matters associated with Native Title. Havilah Resources NL, which has earned a 65% interest in the project, had planned further exploration in 2011–12, including drilling aimed at increasing the hard rock resource. The **South Ridge** prospect within the Prospect Hill project area has an old Inferred Resource of 172 000 t at 1.15% Sn.

Tungsten

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Tungsten (W) metal and its alloys are amongst the hardest of all metals and tungsten itself has the highest melting point of all pure metals. The combination of its hardness and high temperature capabilities makes it desirable for many commercial and industrial applications. Tungsten's range of properties also makes it difficult to substitute with other metals. It occurs as wolframite, which is an iron-manganese-tungstate mineral ($(Fe,Mg)WO_4$), and scheelite ($CaWO_4$). The major use for tungsten is within cemented carbides, which are also called hard metals. Tungsten carbide has a hardness approaching that of diamond and is used for cutting and in wear-resistant materials, primarily in the metalworking, mining, oil drilling and construction industries. Tungsten alloys are also used in electrodes, filaments (light bulbs), wires and components for electrical, heating, lighting and welding applications. Tungsten is used also in chemical applications, including as catalysts, as well as pigments for paints. Ferrotungsten (FeW) is a high value-added intermediate product and is used in steels and alloys where hardness and heat resistance are required. Tungsten is commonly supplied as mineral concentrates typically with 65% or more contained tungsten trioxide (WO_3). A number of secondary tungsten compounds are also important. These include ammonium paratungstate, tungsten trioxide (WO_3), ferrotungsten (FeW), tungsten carbide (WC), as well as tungsten metal.

Resources

Australia's total EDR of tungsten at December 2012 was 391 kt, a moderate increase from 376 kt in 2011. Increases in EDR were recorded in both Queensland and Tasmania. Australia's EDR are in deposits at Dolphin and Bold Head on King Island in Bass Strait off Tasmania, Kara and Mount Lindsay in Tasmania, at Watershed, Mount Carbine and Wolfram Camp in Queensland, O'Callaghans, Big Hill and Mount Mulgine in Western Australia and Molyhil in the Northern Territory. The majority of Australia's EDR of tungsten are in WA, accounting for about 61%, most of which is in the O'Callaghans deposit (about 50%). Other significant EDR are in Tasmania which has 21% and Queensland with 15.5%.

In 2012, Subeconomic Demonstrated Resources (comprising Paramarginal and Submarginal Resources) were 16 kt, which is equivalent to 4% of the total Demonstrated Resources. Inferred Resources decreased slightly from 107 kt in 2011 to 102 kt in 2012. Queensland accounts for 43% of Inferred Resources, followed by WA with 36%, Tasmania with 11% and NSW with 8%.

For location of tungsten deposits refer to Figure 20 in the Tin chapter.

Accessible EDR

All of Australia's EDR for tungsten are accessible.

JORC Reserves

JORC Code reserves comprise total tungsten in Proved and Probable Ore Reserves as defined in the JORC Code. In 2012, JORC Code reserves of 201 kt (up from 182 kt in 2011) accounted for approximately 51% of AEDR.

Exploration

Data on exploration expenditure for tungsten are not reported by the Australian Bureau of Statistics.

Production

During 2012, an estimated 290 t[109] of tungsten was produced as concentrates, a large increase over the 15 t produced in 2011, reflecting the start of tungsten production in early 2012 at Wolfram Camp and Mount Carbine in north Queensland.

109 Amount of tungsten produced estimated from daily production rates of concentrates and from an inferred 65% WO_3 content.

World Ranking

In 2012, world economic resources of tungsten are estimated to be around 3488 kt based on USGS data and updated by Geoscience Australia for Australia's resources. According to the USGS, China holds approximately 54.5% of the world economic resources followed by Australia with 11.2%, Russia with 7.2% and the USA with 4%.

The USGS estimates that world production of tungsten in 2012 amounted to 73 kt[110], which was similar to production in 2011. China was the major producer with approximately 84%, followed by Russia with 4.8%. Production for the USA was not recorded for reasons of confidentiality. Over the past few years, the Chinese Government has restricted the amount of its tungsten ores that can be offered on the world market by applying export quotas and taxes, favouring instead the export of value-added, downstream tungsten materials and products.

Industry Developments

The price of tungsten rose dramatically following the global financial crisis from a low of less than US$200 per metric tonne unit (MTU = 10 kilograms) of ammonium paratungstate in late 2008 to mid-2009 to reach new highs of US$480/MTU in mid-2011. This price increase reflected growth in demand and tightening of supply by China. Prices have since eased, to below US$350/MTU in early 2013, before recovering to around US$400/MTU in September 2013, which is still above the 2000–2010 long-term average levels. Price increases in the second half of 2013 have also coincided with a decrease in the value of the Australian dollar. There has been continued activity at a number of Australian projects, including production at Kara in Tasmania and Wolfram Camp and Mount Carbine in north Queensland.

Deutsche Rohstoff AG: In November 2011, the German mining company, Deutsche Rohstoff AG (DRAG) took full control of the **Wolfram Camp** tungsten-molybdenum project, 90 km west of Cairns in north Queensland, as well as the **Bamford Hill** tungsten-molybdenum deposit 25 km south of Wolfram Camp. In February 2012, DRAG delivered its first WO_3 concentrate from Wolfram Camp. The Wolfram Camp mine was discovered in the late 19th century and has a recorded production[111] of 5.4 kt of wolfram, 1.4 kt of tungsten and bismuth and 135 t of molybdenum. Tungsten-molybdenum-bismuth mineralisation occurs within quartz pipe-like bodies within the greisen-altered margin of the James Creek Granite in contact with metasediments of the Hodgkinson Province.

The Wolfram Camp mine was officially re-opened in July 2012. In December 2012, DRAG upgraded the treatment plant allowing greater throughput, and since February 2013 the company has been producing between three and four tonnes per day of tungsten concentrate, plus an unspecified amount of by-product molybdenum. Tungsten concentrates are handled by off-take partner USA-based Global Tungsten and Powders Corp. In November 2013, DRAG announced that the Wolfram Camp mine had officially commenced commercial operations with a planned 10-year mine life.

The most current resource estimate for Wolfram Camp, which was released by Planet Metals Ltd in May 2010, is 1.42 Mt grading 0.6% WO_3 and 0.12% Mo comprising 0.78 Mt grading 0.56% WO_3 and 0.13% Mo in Indicated Resources and 0.64 Mt grading 0.65% WO_3 and 0.11% Mo in Inferred Resources. In November 2013, DRAG released an updated non-JORC Code compliant, estimated inventory of about 3.8 Mt returning approximately 0.4% WO_3. Continued exploration is planned to further define the resource.

Vital Metals Ltd: Vital Metals Ltd's wholly owned **Watershed** scheelite project 150 km northwest of Cairns in north Queensland has, as of 30 June 2012, Measured Resources of 4.42 Mt at 0.25% WO_3, Indicated Resources of 11.51 Mt at an average grade of 0.24% WO_3, in addition to Inferred Resources of 4.73 Mt at 0.26% WO_3, using a cut-off grade of 0.10% WO_3, for a total of 50.7 kt contained WO_3.

In mid-2011, Vital entered into an earn-in agreement with Japan Oil, Gas and Metals National Corporation (JOGMEC), which has earned 30% of the Watershed project by co-funding a definitive feasibility study for the project. The JOGMEC interest will pass to a Japanese-owned corporation that, in partnership with Vital, will take the project into development and operation. Vital announced in July 2013 that it was extending its feasibility study to investigate tripling production rates to 3 Mtpa, partly in response to increasing wolfram prices. The company has indicated it expects the revised feasibility study to be completed by the first quarter in 2014.

110 Reassessed as 73 kt up from the previously reported 72 kt.

111 Historic production figures from Geological Survey of Queensland publications.

Environmental approvals for the project have been granted and mining leases are expected to be granted in the near future. The Watershed deposit, originally discovered by Utah Development Company Ltd in the early 1980s, consists predominantly of quartz-scheelite vein swarms within metasedimentary rocks of the Hodgkinson Province.

Carbine Tungsten Ltd: Carbine Tungsten Ltd's (formerly Icon Resources Ltd) **Mount Carbine** project, 120 km northwest of Cairns in north Queensland, contains the historic Mount Carbine deposit. The project includes a previous open-cut mine, tailings dams and low-grade stockpile, all of which are being targeted by Carbine Tungsten. The tailing dams are estimated to contain approximately 2 Mt at 0.1% WO_3. Carbine Tungsten opened a tailings re-treatment plant in March 2012, with an initial shipment of 1134 MTU of WO_3 concentrate in late June 2012. The company announced that the grade of concentrate produced greatly exceeded expectations from the tailings recovery feasibility study. The company is hoping for final production of 5000 MTU a month from the re-treatment plant with an envisaged project life of around two to three years. Carbine Tungsten has an off-take agreement with Mitsubishi RtM Corporation Japan Ltd.

Mount Carbine which was discovered late in the 19th century comprises wolframite and scheelite in sheeted quartz veins within metasedimentary rocks of the Hodgkinson Formation. Mineralisation is thought to be related to the nearby Permian Mount Carbine Granite. Recorded production[112] at the mine totals 16.6 kt of wolfram as wolframite and scheelite concentrates. Mining at the deposit stopped in the late 1980s as a consequence of low tungsten prices.

Carbine Tungsten completed a favourable feasibility study in July 2012 that investigated the economic viability of re-establishing the Mount Carbine tungsten mine. The study considered an open-cut, hard rock resource along with processing previously stockpiled low-grade material, which, together, would provide a 15-year project life. A result of this study was resource upgrades in June and August 2012, resulting in an Indicated Mineral Resource of 18.1 Mt at 0.14% WO_3 and an Inferred Resource of 29.3 Mt at 0.12% WO_3 using a 0.05% WO_3 cut-off for 48 kt of contained wolfram beneath and adjacent to the previous open-cut mine. Carbine Tungsten indicated that it considered the Indicated Resource is a Probable Reserve also, based on mining 3 Mtpa and receiving a price of US$290/MTU.

The company has indicated that hard-rock mining would only commence after processing of the low-grade stockpile had begun. In September 2012, Carbine Tungsten released an Indicated Resource of 12 Mt at 0.07% WO_3 for the low-grade stockpile. The company has reported a production target of 15 000 MTU of WO_3 in concentrate a month from the low-grade stockpile material, which it suggests will have an eight-year mine life.

King Island Scheelite Ltd: King Island Scheelite Ltd (KIS) is continuing to advance its wholly-owned Dolphin project, located in Bass Strait on King Island, Tasmania. The project contains the historic open-cut and underground **Dolphin** mine, the underground **Bold Head** mine and a low-grade tailings resource, all of which are being considered by KIS for development. The deposit was discovered in 1911, and comprises tungsten and minor molybdenum mineralisation within scheelite skarns replacing dolomitic metasedimentary units of the Grassy Group. Mineralisation is related to the spatially associated Early Carboniferous granites. Originally mined as an open pit, underground mining commenced at both Bold Head and Dolphin in the early 1970s. Previous mining ceased at both mines in 1990, because of low wolfram prices.

A pre-mining resource of approximately 17 Mt at 0.85% WO_3 has been determined for the resource[113]. In 2012, KIS completed a definitive feasibility study investigating both re-treatment of the tailings and re-opening the underground mines. Outcomes of the study include a planned 10-year mine life from both underground mining and re-treatment of tailings, producing 3500 tpa of contained WO_3 in concentrate.

A review of the definitive feasibility study completed in 2013 advocated shelving of the re-treatment of the tailings, and delaying underground production for several years by concentrating on an identified resource in the existing Dolphin mine open-pit floor and walls. A revised study is being undertaken and is due for completion in early 2014. KIS reported in May 2013 that Indicated Resources for the Dolphin open-pit remnant, Dolphin underground and the Bold Head Mine, are 0.91 Mt averaging 0.74% WO_3, 4.51 Mt averaging 1.28% WO_3, and 1.5 Mt averaging 0.93% WO_3, respectively, for a combined total of 78.4 kt of contained WO_3.

112 Historic production figures from Geological Survey of Queensland publications.

113 Figures from Brown, S. G., 1990. King Island scheelite deposits, in: Hughes, F. E. (ed.). Geology of the mineral deposits of Australia and Papua New Guinea. Monograph Serial Australasian Institute of Mining and Metallurgy 14:1175–1180.

Estimates of Probable Reserves for the Dolphin underground mine (excluding the open-pit remnant) were upgraded in August 2011 to 2.69 Mt averaging 1.04% WO_3 and containing approximately 28 kt of WO_3. In June 2011, the company reported Measured Resources for the tailings at the Dolphin Mine at a cut-off grade of 0.08% WO_3 as being 2.7 Mt averaging 0.17% WO_3. As a result of the feasibility study review, the tailings resource is considered marginal.

KIS announced in October 2013 that additional drilling at Dolphin and Bold Head to test previously recognised shallow wolfram mineralisation revealed that, potentially, it was amenable to open-cut mining.

Venture Minerals Ltd: The **Mount Lindsay** tin and tungsten deposit, which is wholly owned by Venture Minerals Ltd, is located 15 km northwest of Renison Bell tin mine and 20 km west of Rosebery in western Tasmania. The deposit is in magnetite (Fe_3O_4)-rich skarns within the contact aureole of the Meredith granite, which is part of a suite of Devonian-Early Carboniferous granites that are the source rocks for a number of large tin, tungsten and magnetite deposits in western Tasmania and on King Island in Bass Strait.

The Mount Lindsay tin-tungsten deposit has, as of October 2012, combined resources of 45 Mt at 0.4% Sn equivalent with a 0.2% cut-off, 73% of the resource is in the Measured and Indicated categories, or 13 Mt at 0.7% Sn equivalent at 0.45% cut-off. As of November 2012, reserves included Proven Reserves of 6.4 Mt at 0.2% Sn, 0.2% WO_3 and 0.1% Cu, and Probable Reserves of 7.3 Mt at 0.2% Sn, 0.1% WO_3, and 0.1% Cu, with a contained 30 000 t of Sn. The deposit also includes an iron resource.

In late 2012, Venture completed a bankable feasibility study for Mount Lindsay that highlighted the long-term potential of the deposit. Highlights of the study included a nine-year mine life, a plant capacity of 1.75 Mtpa, a payback period of four years and a capital cost of just under $200 million. The study assumed tin prices of US$23 800/t. The company also completed a pilot-scale metallurgical program in August 2012 that demonstrated recoveries of 72% Sn and 83% WO_3, as well as high-grade tungsten concentrate of more than 66% WO_3.

Elementos Ltd: In mid-2013, the Australian based Elementos Ltd acquired the **Cleveland** tin project through a merger with the unlisted Rockwell Minerals Ltd, which previously controlled the project and owned 50% of the asset. The Cleveland project is located 60 km southwest of Burnie in Tasmania and includes the underground tin-copper Cleveland mine. The mine, which was mined by Aberfoyle Ltd between 1968 and 1986, produced about 23.5 kt of Sn and 9.7 kt of copper in concentrate. The mine closed as a result of low tin prices in the late 1980s. The Cleveland project also includes a large low-grade tin-copper tailings dam, as well as the **Foley Zone** tungsten deposit. The company has indicated it plans to undertake further drilling to test extensions of tin and tungsten mineralisation.

In late 2013, Elementos indicated it had initiated a prefeasibility study to assess the development potential of the hard rock and tailings dam tin-copper resources. The study, which is due for completion in the second quarter of 2014, will be based on a recently released (April 2013) JORC Code compliant total resource for the Cleveland mine of 6119 kt at 0.68% Sn and 0.25% Cu, containing 42 kt of Sn, of which 4239 kt at 0.70% Sn and 0.28% Cu (contained 30 kt of Sn) are Indicated Resources. A JORC Code compliant Inferred Resource of 3980 kt at 0.30% WO_3, for a contained 12 kt of WO_3, has been calculated for the associated Foley Zone tungsten deposit. Tungsten occurs as wolframite hosted within a quartz stock-work.

Tasmania Mines Ltd: Tasmania Mines Ltd (Tasmines) continued production of by-product tungsten (approximately 35 t of WO_3 in 2012) at its **Kara** magnetite mine, 35 km south of Burnie in northwest Tasmania. The mine, which has been operating since 1977, produces magnetite and scheelite from skarn mineralisation that has replaced carbonates within Cambrian and Ordovician sediments close to the Devonian Housetop Granite.

In January 2013, Tasmines released updated resource figures for the mine, including, at **Kara No 1**, total resources of 16.58 Mt at 49% iron oxide (FeO) and 440 ppm WO_3, which includes Measured Resources of 10.21 Mt at 199 ppm WO_3, and Indicated Resources of 4.60 Mt at 714 ppm WO_3. In addition, updated resource figures for the **Eastern Ridge Magnetite Skarn**, are 6.50 Mt at 48.3% FeO and 0.10% WO_3, which includes Indicated Resources of 5.24 Mt at 0.12% WO_3 while at **Kara North 266** and the **Northern Magnetic Anomaly** there is a combined Inferred Resources of 14.55 Mt at 43.5% FeO and 462 ppm WO_3. Ore reserves, as of January 2013, for the Kara No 1 pit comprise Proven and Probable Reserves of 13.07 Mt at 45.4% FeO and 340 ppm WO_3 with 71% of the Reserves in the Proven category. Based on this reserve estimate, the company indicates a mine life of 18.4 years for the Kara No 1 pit.

Thor Mining plc: In January 2012, Thor Mining plc reported Indicated Resources of 3.8 Mt at 0.29% WO_3 and 0.22% molybdenum disulphide (MoS_2) and Inferred Resources of 0.9 Mt at 0.25% WO_3 and 0.25% MoS_2 for the company's **Molyhil** tungsten and molybdenum project, 220 km northeast of Alice Springs in the NT. Reserve figures for the deposit, reported in April 2012, include open-cut Probable Reserves of 1.64 Mt grading 0.42% WO_3 and 0.13% MoS_2.

Potential development of the project was hampered by the global financial crisis and a decline in international metal prices, which resulted in the company scaling back activities. Thor had signed an off-take agreement with one of China's largest State-owned companies, CITIC Australia Trading Ltd. The agreement was for CITIC to take all of the molybdenum and tungsten concentrates produced from the project, but that agreement has since lapsed.

The recent increase in tungsten prices has resulted in renewed interest and, in mid-2012, Thor completed a positive definitive feasibility study of the deposit, with a four-year mine life based on current reserves. Thor has been attempting to secure agreements for off-take of tungsten and molybdenum concentrates before beginning development of the deposit. The company announced in October 2013 that it had received a letter of intent from United States-based Global Tungsten and Powders Corp. to purchase between 70 and 75% of the annual production of scheelite concentrate from Molyhil. Discussions for the remaining tungsten and molybdenum concentrates are continuing. Thor Mining has indicated it is undertaking an upgrade of its feasibility study.

Hazelwood Resources Ltd: Hazelwood Resources Ltd released an initial ore reserve estimate for the **Big Hill** deposit of Proven Reserves of 18.78 Mt averaging 0.11% WO_3 and Probable Reserves of 6.43 Mt averaging 0.11% WO_3. The deposit's Measured Resources are 22.94 Mt averaging 0.11% WO_3, with Indicated Resources of 11.95 Mt grading 0.1% WO_3 and Inferred Resources of 12.54 Mt grading 0.08% WO_3 for a total resource of 47.43 Mt averaging 0.1% WO_3. All the estimates were at a cut-off grade of 0.05% WO_3. The deposit is part of the **Cookes Creek** tungsten project located 70 km from Nullagine in WA. Mineralisation occurs as scheelite veins thought to be related to the spatially-associated Mesoarchean Cookes Creek Monzogranite.

Hazelwood is undertaking a definitive feasibility study for the Big Hill deposit, including large-scale metallurgical test work on bulk ore samples, which has demonstrated the ability to produce high- purity tungsten concentrate. Hazelwood completed an integrated prefeasibility study in 2010, which incorporated its Big Hill tungsten deposit and its jointly-owned ferrotungsten project in Vietnam.

In June 2011, Asia Tungsten Products Company Ltd, which is 60%-owned by Hazelwood (increasing to 100%), completed construction of a ferrotungsten plant in the Vihn Bao district near the Port of Haiphong in northern Vietnam. The plant is expected to have a capacity of approximately 3000 tpa of contained tungsten in the form of 75%-grade ferrotungsten. Initial production commenced in April 2013 with 140 t of contained tungsten produced up to August 2013. Hazelwood has indicated it is targeting ferrotungsten production of 1500 tpa in 2014 and 2600 tpa in 2015. Current feedstock for the plant is being obtained from a variety of international sources. Hazelwood has indicated it plans to develop the Big Hill deposit to provide feedstock for the Vietnam ferrotungsten project.

The company also is evaluating its wholly-owned **Mulgine Hill** and **Trench** deposits of its Mount Mulgine project, 350 km north-northeast of Perth as a potential additional feedstock source. Hazelwood purchased Gindalbie Metal's 30% interest in the deposits in the second half of 2013 and commenced an engineering prefeasibility study in October 2013. Hazelwood released resource figures for Mulgine Hill in March 2011, which, based on a cut-off grade of 0.05% WO_3, included Indicated Resources of 10.16 Mt averaging 0.16% WO_3 and Inferred Resources of 5.35 Mt at 0.12% WO_3 for about 18 000 t of contained tungsten. Indicated Resources reduce to 2.23 Mt at 0.35% WO_3, using a cut-off grade of 0.2% WO_3. The company also indicated that 95% of the resource is within 100 m of the surface.

Recent drilling by Minjar Gold Pty Ltd, which has the gold rights for the Mount Mulgine project, resulted in significant tungsten intersections about 300 m from previous drilling at the Trench deposit. Intersections included 70 m at 0.167% WO_3 and 72 m at 0.134% WO_3. Mineralisation at Mount Mulgine, which includes molybdenum, is thought to represent an Archean porphyry tungsten-molybdenum system (Mulgine Hill) and associated skarn (Trench), related to the Neoarchean Mount Mulgine Granite.

Newcrest Mining Ltd: Newcrest Mining Ltd released updated reserve and revised resource figures in December 2012 for its **O'Callaghans** polymetallic tungsten-copper-zinc-lead skarn deposit about 10 km south of Telfer in WA. The company reported Probable Reserves of 59 Mt grading 0.28% WO_3, 0.29% Cu, 0.62% Zn and 0.3% Pb, with a contained 0.16 Mt of WO_3, all within Indicated Resources of 69 Mt grading 0.34% WO_3, 0.29% Cu, 0.55% Zn and 0.27% Pb, and Inferred Resources of 9 Mt grading 0.25% WO_3, 0.24% Cu, 0.15% Zn and 0.07% Pb. Mineralisation occurs within a sub-horizontal polymetallic skarn at the contact between the Neoproterozoic O'Callaghans granite and limestone of the Proterozoic Puntapunta Formation.

Newcrest has previously indicated it is undertaking a prefeasibility study into the deposit. Based on its 2011–2012 results, Newcrest was indicating potential development of the O'Callaghans deposit within the next five years, subject to board approval.

Tungsten Mining NL: In May 2013, Tungsten Mining NL announced a maiden JORC Code resource for its **Kilba** project, 320 km northeast of Carnarvon, in the Gascoyne region of WA. The company reported that the prospect has Indicated Resources of 1.3 Mt at 0.3% WO_3 and Inferred Resources of 3.7 Mt at 0.26% WO_3. Resources are from two zones (zone 8 and zone 11) with a total contained tungsten content of 10.8 kt. Tungsten mineralisation is present as scheelite associated with skarns and calc-silicate units within sediments that host the Paleoproterozoic Kilba Granite.

In June 2013, Tungsten Mining announced that it had completed a positive preliminary scoping study based on mineral resources not reserves, which led it to initiate a definitive feasibility study to upgrade the mineral resource estimate through infill drilling in zone 8 and zone 11. The study is due for completion by the second quarter of 2014.

Thomson Resources Ltd: In 2012–2013, Thomson Resources Ltd continued exploratory drilling of magnetic targets within the southern part of the undercover Thomson Orogen in northwest NSW. Drilling on the eastern flank of the company's F1 anomaly (**Falcon** project) in early 2013 intersected anomalous tungsten (best intercept of 0.3% W over 1 m), molybdenum and minor gold in what may be a zoned system. Previously, Thomson Resources reported on earlier drilling on other prospects in the Thomson Orogen that intersected evidence of mineralised hydrothermal systems. Two of these targets (**Cuttaburra** project) gave high-grade polymetallic intercepts, with grades up to 3.7 g/t Au and to 113 g/t Ag as well as to 0.4% Bi, to 0.5% Cu, to 1.8% Pb, to 0.8% Sn, to 0.6% W and to 4.25% Zn.

Mineralisation is reported to occur as sheeted and stockwork veins up to one metre wide within zones of altered basement rocks of the Thomson Orogen. On the basis of the polymetallic assemblages and the presence of granite, Thomson Resources has suggested an intrusion-related gold style of mineralisation for the mineral systems intersected so far. Tungsten, present as scheelite, appears to be a common feature of the majority of these mineral systems.

Thomson Resources announced in June 2013 that it had reached agreement with Cuttaburra project joint venture partner Raptor Minerals Ltd to acquire 100% of the project.

Peel Exploration Ltd: In April 2008, Peel Exploration Ltd released an Inferred Resource estimate of 1.29 Mt at 0.61% WO_3 and 0.05% Mo, at a cut-off of 0.2% WO_3 equivalent, for the **Attunga** deposit 20 km north of Tamworth in NSW. Peel followed this up, in 2010–2011, with a study investigating development options which indicated conditions were favourable for a low capital expenditure operation. Mineralisation at Attunga occurs within skarns developed at the contact of a lime-rich sequence with the Permian-Triassic Inlet Monzonite.

In late 2012, Peel indicated it had begun a review of the Attunga deposit and was seeking potential joint venture or off-take partners. In August 2013 Peel completed one diamond drill hole for metallurgical test-work.

Carpentaria Exploration Ltd: Carpentaria Exploration Ltd continued work at its **Broken Hill** tin and tungsten project in NSW, which contains the historical **Euriowie**, **Waukeroo** and **Kantappa** tin fields, and the **Yanco Glen** scheelite (tungsten) deposit 40 km north of Broken Hill. In 2012, Carpentaria undertook a drilling program at Yanco Glen to confirm the previous resource and test possible extensions. In October 2012 the company announced updated Inferred Resources of 3.4 Mt at 0.11% WO_3, using a 0.05% WO_3 cut-off, for a contained 3.95 kt of WO_3, doubling the previous amount of tungsten. At the Yanco Glen deposit, tungsten is present as scheelite and minor wolframite in stratabound mineralisation, occurring within high-grade gneiss (metavolcanic precursor?) and metasediments of the Paleoproterozoic Broken Hill Group. Carpentaria have been undertaking metallurgical test-work as well as a mining scoping study.

Cullen Resources Ltd: Cullen Resources Ltd has recently completed three exploration drill holes testing targets in the **Doyenwae** and **Trig Orr** prospects of its **Minter** project area about 50 km northwest of West Wyalong in central NSW. Target areas were based on previously identified wolfram (tin and arsenic) geochemistry anomalies from soil sampling and prior shallow drilling. The company is targeting tungsten stockwork and vein-type mineralisation associated with granite cupolas of the Silurian Kikoira Granite. Drilling in 2012 intersected multiple scheelite-bearing quartz veins in sediments. Higher grade intercepts included 1 m at 0.70% WO_3, 4.05 m at 0.58% WO_3 and 1.4 m at 136% WO_3. Cullen indicated in March 2013 that it was seeking a farm-in partner.

Uranium

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Major uses for uranium (U) are as fuel in nuclear power reactors for electricity generation, in the manufacture of radioisotopes for medical applications and in nuclear science research using neutron fluxes.

At the start of 2013, there were 435 operable commercial nuclear power reactors in 31 countries that produced approximately 11% of the world's electricity in 2012 (this number includes 48 plants in Japan that are still offline pending restart approvals by Japan's Nuclear Regulatory Authority). At the start of 2013, there were 65 reactors (with total generating capacity of 65 gigawatts) under construction in 14 countries. In addition, there were a total of 167 in the planned category, which, coupled with the 65 under construction, represents a higher number than immediately prior to the Fukushima incident in March 2011 (Source: World Nuclear Association).

China continues to lead growth with 29 reactors under construction. In late 2012, China resumed approval of new reactor constructions after completion of safety reviews. India, the Russian Federation and South Korea are expanding their nuclear generating capacity, and several non-nuclear countries are moving ahead with reactor construction programs, or are considering building nuclear power plants in the future. The United Arab Emirates recently commenced its first nuclear power plant. Saudi Arabia, Vietnam, Bangladesh, Poland, Turkey and Belarus are proposing to proceed with nuclear power development[114].

Although the Fukushima incident has affected nuclear power projects and policies in some countries, nuclear power remains a key part of the global electricity mix. The OECD/NEA and the IAEA in the latest edition of the Red Book[115] stated:

> *"By the year 2035, world nuclear capacity, taking into account the current understanding of policies announced by some countries (e.g. Belgium, Germany, Italy and Switzerland) following the Fukushima accident is projected to grow to between about 540 GWe nett in the low demand case and 746 GWe nett in the high demand case, increases of 44% and 99% respectively. Accordingly, world annual reactor related uranium requirements are projected to rise to between 97 600 and 136 400 tonnes a year by 2035."*

Uranium market prices

During 2010, spot market prices were bolstered by China's plans to expand its number of reactors. Prices peaked at US$72/lb U_3O_8 in January 2011. In March 2011, the impacts of the Fukushima incident caused spot market prices to fall. Continuing uncertainty in uranium markets resulted in spot prices falling to around US$35/lb by August 2013. During 2012, prices ranged from US$52/lb at the start of the year to US$44/lb by the end of December[116].

The spot market has been adversely affected by the sales of uranium inventories by Japanese nuclear power companies, which has been further exacerbated by an increase in sales of uranium inventory by the United States Department of Energy[117].

Resources

Geoscience Australia prepares estimates of Australia's uranium resources within categories defined by the OECD/NEA and the IAEA. The resource categories within this NEA/IAEA scheme reflect total costs of mining and milling uranium ore.

In recent years, the cost of mining and milling uranium ores has increased in Australia as a result of the mining boom. Capital costs have risen and labour costs have increased more quickly than the national average[118]. Because of increasing costs, some deposits/projects are now assigned to a higher cost category.

The estimates in each category are for resources of recoverable uranium after losses resulting from mining and milling have been deducted (Table 17 and Table 18).

114 Source: World Nuclear Association.

115 Source: Organisation for Economic Cooperation and Development Nuclear Energy Agency and International Atomic Energy Agency, 2012: Uranium 2011: Resources, Production and Demand. OECD Nuclear Energy Agency, Paris 2012.

116 Source: The Ux Consulting Company, http://www.uxc.com.

117 OECD Nuclear Energy Agency and International Atomic Energy Agency 2011. Uranium 2011: Resources Production and Demand, p433.

118 Port Jackson Partners, September 2012: 'Opportunity at Risk. Regaining our competitive edge in minerals resources'. Report prepared for the Minerals Council of Australia.

Table 17: Australia's uranium resources at December 2012 (reported under corresponding categories of NEA/IAEA and Australian national schemes).

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US$130/kg U	1 174 000
Paramarginal Demonstrated Resources	RAR recoverable at US$130–260/kg U	34 000
Submarginal Demonstrated Resources	RAR recoverable at greater than US$260/kg U	0
Inferred Resources	Inferred Resources recoverable at less than US$130/kg U	532 000
Inferred Resources	Inferred Resources recoverable at US$130–260/kg U	58 000

Table 18: Uranium resources in Australian states and the Northern Territory at December 2012.

Jurisdiction	RAR recoverable at <US$130/kg U (Tonnes U)	Inferred Resources recoverable at <US$130/kg U (Tonnes U)	Total Resources (Tonnes U)	Percentage of Australia's Total Resources (%)
South Australia	954 000	416 600	1 370 600	80%
Northern Territory	120 400	54 500	175 000	10%
Western Australia	63 300	40 700	103 900	6%
Queensland	36 200	20 300	56 500	4%
New South Wales	0	0	0	-
Victoria	0	0	0	-
Tasmania	0	0	0	-
Australia Total (rounded)	**1 173 900** (1 174 000)	**532 100** (532 000)	**1 706 000** (1 706 000)	**100%**

Australia's RAR of uranium which could be produced at costs of less than US$130/kg[119] at December 2012 were estimated to be 1174 kt, a decrease of 2% on the estimates for December 2011. Although there are 30 deposits with RAR of uranium recoverable at costs of less than US$130/kg, the vast majority of these resources are within the following four deposits:

- Olympic Dam, South Australia, which is the world's largest uranium deposit (Figure 21);
- Ranger and Jabiluka, in the Alligator Rivers region of the Northern Territory (Figure 21); and
- Yeelirrie in Western Australia (Figure 21).

Australia had an additional 532 000 t of uranium in Inferred Resources recoverable at costs of less than US$130/kg. These Inferred Resources are mainly in the southeast area of the Olympic Dam deposit.

Accessible EDR

Approximately 6% of uranium in RAR at less than US$130/kg is inaccessible for mining. In previous years, all uranium deposits in Queensland were inaccessible because state government policy at the time prohibited uranium mining, but in October 2012, the Queensland Government lifted its ban on uranium mining so that Queensland deposits became accessible. As a result, the level of inaccessible uranium resources has decreased markedly from 10% in 2011 to 6% at December 2012.

In the NT, inaccessible resources include the Jabiluka deposit, where the traditional Aboriginal land owners have not granted approval to mine the deposit, and the Koongarra deposit, which was added to the Kakadu World Heritage Area by the World Heritage Committee on 27 June 2011. In SA, the Mount Gee deposit is within the Arkaroola Protection Area, which was established by the state government in July 2011, prohibiting exploration and mining within this area.

119 US$130/kg U equates to US$50/lb U_3O_8.

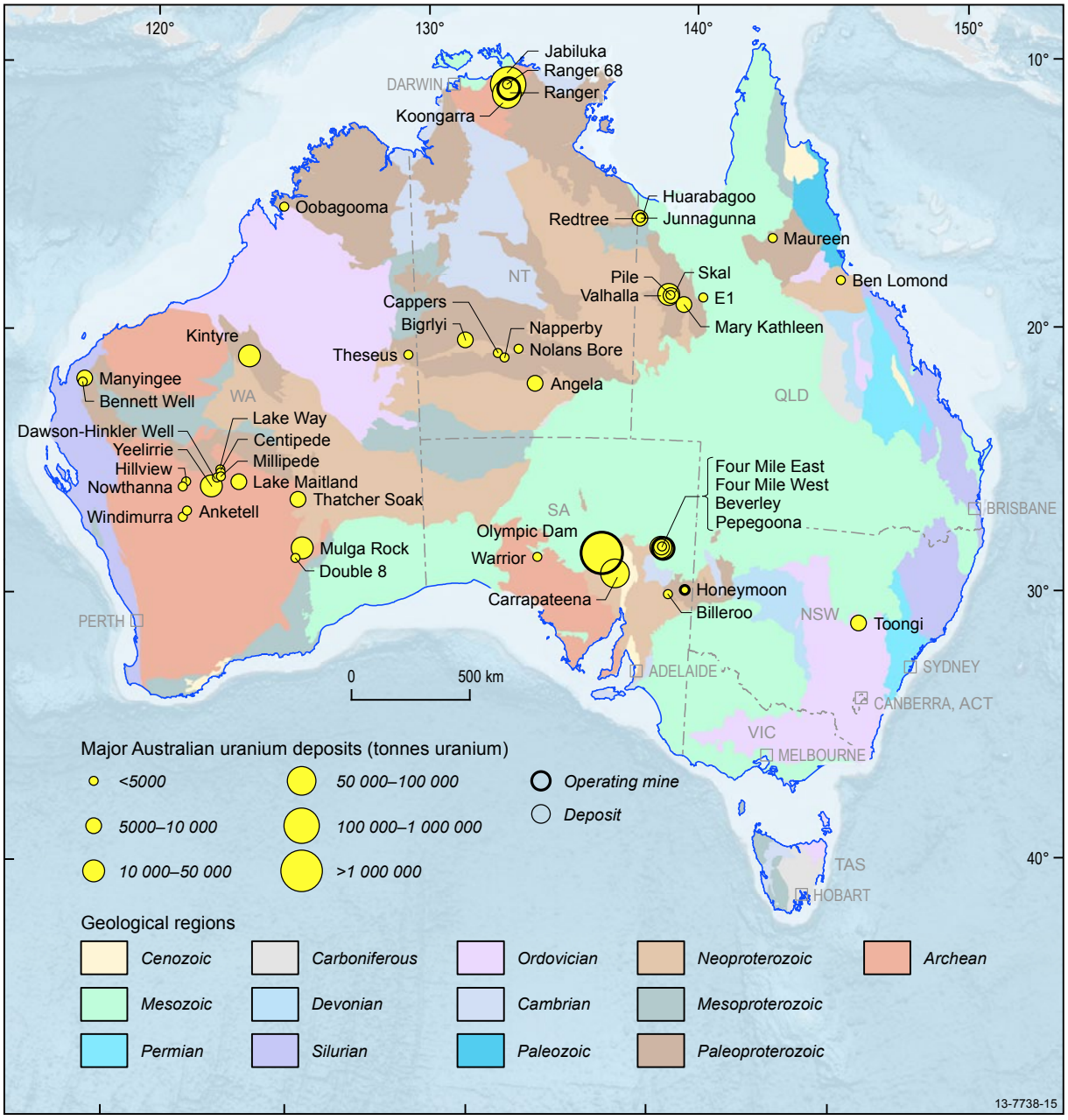

Figure 21: Australia's uranium deposits with significant resources.

JORC Reserves

JORC Code reserves comprise total uranium in Proved and Probable Ore Reserves as defined in the JORC Code. At December 2012, JORC Code reserves of 373 000 t recoverable uranium accounted for approximately 34% of accessible Reasonably Assured Resources.

World Ranking

Australia has the world's largest resources of uranium with an estimated 1174 kt in RAR recoverable at costs of less than US$130/kg. Based on the latest estimates[120] for other countries, this represents approximately 34% of world resources in this category. Other countries with large resources in this cost category include Niger with 10%, Canada 9%, Kazakhstan 9%, Namibia 7% and the United States of America 6%.

Australia's Inferred Resources of uranium recoverable at costs of less than US$130/kg are the world's largest resources in this category.

Exploration

Uranium exploration expenditure in 2012 was $98.3 million[121], which was almost 50% less than the expenditure in 2011 ($189.6 million). The majority of expenditure in 2012 was in WA (54%), followed by SA (approx. 17%), the NT (12%) and Queensland (more than 6%). The decline in exploration was the result of:

- the sharp fall in spot market prices for uranium in recent years; and
- small exploration companies with limited cash experiencing difficulties in raising further funds on the Australian Securities Exchange.

South Australia

In 2011, Geoscience Australia and the South Australian Department of Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) released the results of a regional airborne electromagnetic (AEM) survey over the Frome Embayment (SA) and northern portion of the Murray Basin[122]. The survey was one of the largest ever flown and covered an area of 95 000 square kilometres. The AEM data were used to map palaeochannels within the sedimentary succession which contained channel sands saturated by saline groundwaters. The release of these data has resulted in increased activity in uranium exploration over the Frome Embayment by several companies.

Quasar Resources Pty Ltd continued exploration for sandstone-hosted deposits in the Frome Embayment in the company's Beverley North mineral lease, north of the Beverley Mine. Pepegoona and Pannikan deposits, which are 10 and 8 km north of Beverley mine respectively, are within the Beverley North lease.

The Junction Dam project is 10 km east of the Honeymoon uranium mine and 50 km west of Broken Hill. The project covers the eastern extension of the Yarramba Palaeochannel which hosts the Honeymoon uranium deposit. Drilling programs were carried out in 2011 and 2012. Three zones of mineralisation (Saffron, Bridget and Yolanda prospects) have been outlined along approximately 15 km of palaeochannel.

Uranium mineralisation occurs in two sand layers within the Eyre Formation basal and upper layers. The basal layer averages 437 ppm eU_3O_8[123] and the upper layer averages 248 ppm eU_3O_8. The average thickness of mineralised intersections is 2.57 m for the basal and 1.07 m for the upper layers. Marmota has reported[124] an Inferred Resource for the Saffron deposit as being 1510 t of contained U_3O_8.

Cauldron Energy Ltd discovered uranium mineralisation in palaeochannel sands to the north of the Mount Babbage Inlier at the MacDonnell Creek prospect.

120 Latest estimates for other countries as reported in 'U 2011: Resources Production and Demand'. OECD Nuclear Energy Agency and International Atomic Energy Agency. Paris.

121 Australian Bureau of Statistics Mineral and Petroleum Exploration, December quarter 2012.

122 Roach, I (editor) 2012: The Frome electromagnetic survey, South Australia: implications for energy, minerals and regional geology. Record 2012/040 and Report Book 2012/00003. Geoscience Australia, Canberra; Dept. of Manufacturing, Innovation, Trade, Resources and Energy, South Australia, Adelaide.

123 eU_3O_8 – equivalent uranium grade measured using downhole gamma ray probe.

124 Marmota Energy Ltd Annual Report 2012.

Core Exploration Ltd intersected high-grade uranium-copper mineralisation at the Scott Lee prospect (Fitton project) SA. The prospect occurs in Radium Creek metamorphics (Proterozoic) within the northern portion of the Mount Painter Inlier. Mineralisation occurs in sheared doleritic schist within a broad shear zone in Proterozoic granite. Exploration drilling is in progress to test for continuations of the mineralisation along the structure and at greater depths.

Northern Territory

Western Arnhem Land was a focus for uranium exploration in the NT during 2012. Cameco Australia Pty Ltd continued exploration drilling at the Angularli prospect in western Arnhem Land (discovered in 2011). Unconformity-related uranium mineralisation was intersected in both the basement rocks and the overlying Kombolgie Sandstone[125]. The mineralisation is within a major breccia zone which post-dates the Kombolgie Sandstones. Basement rocks comprise metasediments and felsic to intermediate magmatic rocks of the Nimbuwah Domain. Uraninite and pitchblende form veins, stringers and breccia matrix infill. The best intersections at the Angularli prospect to date have been 12.2 m averaging 1.1% U_3O_8 followed by 20.2 m averaging 5.2% U_3O_8 within drill hole WRD0084.

Exploration drilling by Alligator Exploration Ltd intersected high-grade mineralisation at the Caramal and South Horn prospects within the Myra Inlier in western Arnhem Land. Uranium mineralisation is associated with intensely altered quartz-chlorite schists and breccias. The breccias are associated with a northeast-trending, northwest-dipping structural zone from South Horn to Caramel and beyond over a strike length of 10 km. Best intersections to date were 14 m averaging 7072 ppm U_3O_8, and 14 m averaging 6991 ppm U_3O_8[126].

During 2012, Energy Resources of Australia Ltd continued exploration drilling in the Ranger project area north of Ranger 3 open pit. Significant mineralisation was intersected at the Ranger 19 prospect. The company continued a major exploration drilling program at the Ranger 3 Deeps deposit located east of the open cut.

At Thunderball deposit near Hayes Creek 140 km southeast of Darwin, unconformity-related mineralisation occurs in sheared carbonaceous shales, cherts and tuffaceous siltstones of the Pine Creek Orogen. Thundelarra Ltd discovered new zones of uranium mineralisation near Thunderball from exploration programs in recent years but there was no exploration carried out in 2012 because of depressed prices for uranium.

Thundelarra completed a drilling program at Cliff South prospect, 30 km northeast of Pine Creek. Drill holes intersected significant uranium mineralisation in carbonaceous shales adjacent to the contact with Allamber granite[127].

Several companies explored the northern margins of the Ngalia Basin (Mount Eclipse Sandstone) including Energy Metals Ltd, which, in a joint venture with Paladin Energy Ltd, continued regional exploration in the northern portion of the basin between 180 km and 350 km northwest of Alice Springs. Bigrlyi is the main deposit in this area and other zones of mineralisation include Walbiri and Malawiri. Geophysical surveys were carried out and exploration drilling was undertaken in 2012 and 2013 to explore for extensions of the Bigrlyi deposit (Anomaly 15 and Anomaly 4) and the Camel Flat prospect in Mount Eclipse Sandstone 35 km southeast of Bigrlyi.

In 2012, Toro Energy Ltd completed an AEM survey in the Wiso Basin to explore for sandstone-hosted uranium mineralisation. The company reported that initial processing and analysis of the data showed a number of promising drill targets for uranium.

Queensland

Paladin Energy Ltd continued exploration in an area extending from 10 km to 110 km north of Mount Isa in northwest Queensland. Exploration tenements are held in a joint venture with Summit Resources Ltd (82% owned by Paladin Energy) and Fusion Resources Ltd. There are more than 14 uranium deposits within these tenements, 10 of which have significant resources. They are the Valhalla, Skal, Odin, Bikini, Andersons, Watta, Warwai, Mirioola, Duke-Batman and Honey Pot deposits. During 2012 and 2013, exploration drilling, evaluation of resources and metallurgical investigations continued at many of these deposits. The uranium resources for each are listed in Paladin Energy's 2013 annual report. The largest of these is the Valhalla deposit, which has total Measured+Indicated+Inferred Resources of 34 600 t U_3O_8 with an average grade of 800 ppm U_3O_8.

125 King, M., 2012. Exploration for unconformity-style uranium deposits: Geology and Mineralisation of the Angularli Prospect, Wellington Range Project, west Arnhem Land. AGES2012 Annual Geoscience Exploration Seminar. Northern Territory Geological Survey, March 2012.

126 Alligator Energy 2012 Annual Report.

127 Thundelarra Ltd Annual Report 2012.

Western Australia

During 2012, several companies continued exploration for sandstone-hosted uranium deposits in Cenozoic (Eocene) sands and lignite of the Gunbarrel Basin overlying the eastern margins of the Yilgarn Craton. Energy and Minerals Australia Ltd (EMA) continued exploration drilling in areas adjacent to its Mulga Rock deposit, 250 km east-northeast of Kalgoorlie. In mid-2012, EMA reported the discovery of a new uranium deposit, the Princess deposit, within the Mulga Rock project area. The Princess deposit is a tabular body 1.4 km long and ranges from 100 to 500 m wide. It contains mineralised intervals up to 8.22 m thick with the top of the mineralisation 40 m below the surface. The best intersection to date is 8.33 m averaging 1360 ppm U_3O_8 at a depth of 38.4 m. The mineralisation is hosted by carbonaceous sandstone, siltstone and minor peat layers, and is immediately below the boundary between oxidised and reduced sediments. This boundary corresponds approximately with the water table. The Mulga Rock project comprises four separate uranium deposits, including the Princess deposit, which have total Inferred Resources of 27 100 t of contained U_3O_8 with an average grade of 490 ppm U_3O_8.

Manhattan Corporation Ltd continued drilling at its Ponton project 180 km northeast of Kalgoorlie and 40 km southwest of Mulga Rock. The Double 8 deposit and the Stallion South, Highway South and Ponton prospects are within palaeochannel sands. The palaeochannel sands that host uranium deposits connect to the sands that host the Mulga Rock deposits to the northeast in the Gunbarrel Basin.

Toro Energy Ltd continued exploration at the Theseus prospect, in the Lake Mackay region in northeast WA adjacent to the NT border. Drilling intersected significant mineralisation in Cainozoic palaeochannel sands and silts about 100 to 120 m below the surface and adjacent to uranium-rich rocks of the Amadeus Basin. Theseus was discovered by Toro Energy in 2009 using reconnaissance air-core drilling. Significant uranium mineralisation was intersected in 2012 including 3.44 m at 0.13% eU_3O_8 from 111.4 m in hole LM00052.

Energy Metals Ltd continued exploration drilling and evaluation drilling at the Ankatell, Lake Mason and Mopoke Well calcrete-hosted deposits southwest of Wiluna.

Production

Australia's mine production for 2012 was 7009 t U (8265 t U_3O_8), which was 17% more than production in 2011. Australia had four operating uranium mines in 2012: Olympic Dam, Beverley/Beverley North and Honeymoon (all SA) and Ranger (NT).

Ranger produced 3146 t U (3710 t U_3O_8) in 2012, which was 40% more than for 2011. For 2012, ore was processed by the main metallurgical plant, which processed 2.4 Mt and the laterite treatment plant, which treated 0.24 Mt.

Olympic Dam production for 2012 was 3386 t U (3993 t U_3O_8) which was virtually unchanged from the previous year.

Production from Beverley/Beverley North in situ recovery (ISR) operation for 2012 was 358 t U (422 t U_3O_8) which was 2% higher than during 2011.

Pilot production at Honeymoon ISR mine commenced in September 2011 and commissioning of the plant continued through 2012. In its first full year of operation in 2012, Honeymoon produced 119 t U (140 t U_3O_8).

Total world production in 2012 was 58 394 t U (68 864 t U_3O_8), an increase of 9% on 2011[128]. Most of the increase in production in 2012 is attributable to growth in Kazakhstan's output, which rose 10% to 21 317 t U in 2012, and to increased production from Australia. The world's uranium requirement for nuclear electricity generation in 2012 was 67 990 t U[129], which exceeded production by more than 9596 t U.

128 World Nuclear Association http://www.world-nuclear.org/info/Facts-and-Figures/Uranium-production-figures/

129 Source: World Nuclear Association website.

Exports

Exports in 2012 were 6969 t U (8218 t U_3O_8) valued at $696 million[130]. Exports of Australian uranium are controlled by stringent nuclear safeguards with other countries. Those safeguards specify that Australian uranium must be used exclusively for peaceful purposes in civilian nuclear fuel cycles. The material is also protected in accordance with internationally agreed standards for physical security. These agreements ensure that countries to which Australia sells uranium are committed to IAEA safeguards and international nuclear security standards.

Australian mining companies supply uranium under long-term contracts to electricity utilities in the USA, Japan, China, South Korea and Canada as well as members of the European Union, including the United Kingdom, France, Germany, Spain, Sweden, Belgium and Finland.

In November 2010, the Australia-Russian Nuclear Cooperation Agreement came into force, allowing Australian uranium to be used in Russian civilian nuclear facilities. A trial shipment of uranium to Russia was successfully undertaken in September 2012.

In July 2012, a nuclear cooperation agreement between Australia and the United Arab Emirates was signed to provide for the supply of Australian uranium for use in the UAE's civil nuclear power program. The country plans for its first reactor to begin operation in 2017.

Australian uranium is exported to China and, in 2012, supplied around 22% of China's requirements.

Negotiations commenced with India in 2012 on a bilateral safeguards agreement. India represents an enormous market potential for Australian producers.

Industry Developments

The effects of the Fukushima incident and the shutdown of other nuclear power plants in Japan as well as the global economic slowdown resulted in downward pressure on uranium prices from early 2011 through to mid-2013. During 2012 and 2013, spot prices remained below the level required to encourage investment in new mines. These impacts resulted in uranium mining companies worldwide delaying or cancelling uranium projects that had become uneconomic[131]. Companies decided to focus investment on advancing only those uranium projects that would result in highest return on capital investments.

In Australia, there has been a decrease in uranium exploration activities and consolidation of ownership of uranium resources since early 2011. Examples of consolidation in the resources ownership include:

- BHP Billiton Ltd delayed development of the Olympic Dam Expansion and sold the Yeelirrie project (WA).
- Cameco Australia purchased both the Kintyre (from Rio Tinto Ltd) and Yeelirrie projects.
- Toro Energy progressively consolidated its resources in the Wiluna project and purchased other deposits in the general region of the Wiluna project, including Millipede, Nowthanna, Hinkler Well and Dawson Well deposits (to the west of Centipede deposit) and the Lake Maitland deposit 100 km southeast of Centipede.

South Australia

Olympic Dam: In August 2012, BHP Billiton announced[132] that it would delay the Olympic Dam Expansion project and investigate an alternative, less capital-intensive design of the open-pit expansion involving new technologies, which would substantially improve the economics of the project. As a result, the company stated it would not be ready to approve the expansion before the Indenture Agreement deadline of 15 December 2012. Heap leach and other technological solutions are being studied[133]. Market conditions, including subdued commodity prices and higher capital costs, led to the decision to delay the project.

130 Bureau of Resources and Energy Economics. Resources and Energy Quarterly - June Quarter 2013. BREE, Canberra, June 2013.

131 Cameco Corporation Ltd Annual report 2012 http://www.cameco.com/investors/financial_information/annual_reports/2012/

132 BHP Billiton Olympic Dam update 22 August 2012. Information release to shareholders.

133 Source: Base Metals briefing and Chilean site tour Non-ferrous overview. Andrew Mackenzie BHP Billiton. 30 September 2012. http://www.bhpbilliton.com/home/investors/news/Documents/2012/120930_BHPBillitonBaseMetalsBriefingSiteTour.pdf

In November 2012, the South Australian Government granted a four-year extension of the Indenture Agreement until 2016, which will allow the company to investigate the new designs for the expansion.

The proposed expansion has the potential to create one of the world's largest uranium mining operations with development to progressively increase output up to annual production of 19 000 t U_3O_8, 750 000 t copper and 800 000 oz of gold.

Beverley and Beverley North *in situ* recovery (ISR) mines: Heathgate Resources Pty Ltd operates the Beverley and Beverley North ISR mines between the North Flinders Ranges and Lake Frome, approximately 300 km northeast of Port Augusta.

ISR operations at the main Beverley deposit during 2012 continued to mine remnant resources. Over the past few years, production was partly from old well-fields that were re-opened after being shut down. The company continued exploration drilling within the Beverley leases during the year.

At Beverley North, satellite ISR operations commenced in 2011 at the **Pepegoona** deposit 12 km north of Beverley and at the **Pannikan** deposit 10 km northwest of Beverley. Uranium-bearing solutions from the well-fields are pumped to satellite ion-exchange plants at each site. Uranium is captured on resins within ion-exchange columns. The resin, which is loaded with uranium, is transferred to a road tanker and transported to the Beverley plant for elution and processing to recover the uranium.

Honeymoon ISR mine: Honeymoon mine is approximately 75 km northwest of Broken Hill. Uranium-bearing solutions are processed using solvent extraction technology at the processing facility. Initial production at Honeymoon commenced in September 2011 and commissioning of the plant will continue until production reaches the design capacity of 340 tpa U. In its first full year of operation in 2012, Honeymoon produced 119 t U (140 t U_3O_8). Drilling and installation of well-fields continued with four well-fields in operation by the end of 2012.

Four Mile ISR project: Four Mile comprises two large sandstone-hosted uranium deposits, Four Mile West and Four Mile East. The project is 75% owned by Quasar Resources Pty Ltd (affiliate of Heathgate Resources) and 25% owned by Alliance Resources Ltd.

On 26 April 2012, the joint venture was granted a 10-year mineral lease over the Four Mile project area by the South Australian Minister for Mineral Resources and Energy.

In October 2012, Alliance announced it would commence development of the Four Mile Project. The plan comprises:

- uranium capture at Heathgate's Pannikan satellite plant with elution, precipitation, drying and packing at Beverley processing plant; and
- ISR mining operations commencing at Four Mile East in 2013.

In August 2013, the South Australian Minister for Mineral Resources and Energy approved the joint venture's Program for Environmental Protection and Rehabilitation for mining at Four Mile East.

Four Mile East and Four Mile West have total Indicated and Inferred resources of 9.8 Mt averaging 0.33% U_3O_8 representing 32 000 t of contained U_3O_8[134].

Samphire project: UraniumSA Ltd continued evaluation drilling at the **Blackbush** and **Plumbush** sandstone-hosted uranium deposits 20 km southwest of Whyalla on the eastern Eyre Peninsula. In 2011, uranium mineralisation was discovered in granite basement below the sediment-hosted uranium mineralisation and the granite basement became the focus of new exploration drilling within the tenements.

In 2012, infill drilling programs were carried out within the western zone of the Blackbush deposit. High-grade mineralisation was intersected in a zone along the intersection between shallow east-dipping mineralised structures in Proterozoic granite (Hiltaba suite) and the subhorizontal unconformity surface[135].

An evaluation of mining methods to optimise the recovery of uranium from the resources continued. This included consideration of open-cut options in addition to an ongoing evaluation of *in situ* recovery methods.

134 http://www.ga.gov.au/products-services/publications/aimr/uranium.html

135 UraniumSA Ltd Annual Report 2012.

Northern Territory

Ranger mine: Pit 3 reached the end of its operational life in November 2012. This marked the completion of open-cut mining at Ranger after 31 years. In recent years, very high rainfall caused flooding of the pit and disruptions to mine production. However, in 2012, dewatering of the pit enabled access to the remaining ore in the bottom of the pit. Future production will be from existing stockpiles and a potential Ranger 3 Deeps underground mine.

Ranger 3 Deeps: In May 2012, development of an underground decline commenced in order to access the Ranger 3 Deeps orebody. By 31 December 2012, the decline reached a distance of 57 m and by June 2013 it was 1000 m long. Underground exploration drilling of the Ranger 3 orebody and adjacent areas commenced from the decline in May 2013. Energy Resources of Australia reported that the Ranger 3 Deeps mine feasibility study continued during 2012 and 2013 together with compilation of data for the environmental approvals process for the proposed underground mine.

In addition to the underground drilling of Ranger 3 Deeps, surface drilling in under-explored areas of the Ranger Project Area continued in 2012.

Bigrlyi deposit: Energy Metals Ltd completed a prefeasibility study at the Bigrlyi project 300 km northwest of Alice Springs that investigated using a combination of open-pit and underground mining. Results showed that the project would generate a positive cash flow for a mine life of eight years[136]. However, the study concluded that a substantial increase in resources is required to improve the economics for the project. Geophysical surveys and exploration drilling were carried out in 2012 and 2013 to explore for extensions of deposits under shallow cover at Bigrlyi and at Camel Flat 50 km southeast of Bigrlyi.

Western Australia

Yeelirrie project: The Yeelirrie deposit is 70 km southwest of Wiluna and is Australia's second largest undeveloped uranium deposit. It occurs in calcretes within a palaeochannel and is at shallow depths down to 15 m below the surface. In December 2012, Cameco Corporation purchased the Yeelirrie deposit from BHP Billiton for US$430 million. The latest estimates of mineral resources for the Yeelirrie deposit are in AIMR2012[137]. Cameco proposes to review the gamma logs and the grade-radiometry relationship and recalculate the resources during 2013.

Wiluna project: Operated by Toro Energy Ltd, the project comprises two shallow (less than 8 m deep) calcrete-hosted deposits, **Lake Way** and **Centipede**, which are 15 km south and 30 km south of Wiluna respectively. Toro also owns three other calcrete-hosted deposits in the Wiluna region, the **Millipede**, **Dawson Hinkler Well** and **Nowthanna** deposits. At August 2013, total Measured+Indicated+Inferred Resources for Lake Way, Centipede and three deposits in the region amounted to 55.2 Mt averaging 441 ppm U_3O_8 (24 300 t of contained U_3O_8).

In October 2012, Toro received environmental approval for the Wiluna project from the Western Australian Minister for Environment and, in April 2013, the Australian Government Minister for Environment formally granted environmental approval for the project. The company is completing detailed engineering design and commercial studies as part of a feasibility study for the project. The company proposes to produce uranium concentrates containing approximately 820 tpa U_3O_8.

Toro reported[138] that drilling carried out in 2013 resulted in the discovery of a second zone of mineralisation at depths of between 15 and 20 m below surface, well beneath the currently known resource. While the zone is commonly 0.5 to 1.0 m thick, and mainly of lower grade and less continuous than the overlying resource, in some areas, such as Dawson Hinkler, grades are greater than the mineralisation above.

Toro announced[139] that it had acquired the **Lake Maitland** project from Mega Uranium Ltd. It is anticipated that the Lake Maitland resource could be mined and transported to the proposed Wiluna mill for processing.

136 Energy Metals Ltd. Annual report 2012.

137 http://www.ga.gov.au/products-services/publications/aimr/uranium.html

138 Toro Energy Ltd, September 2013: High uranium grades at Toro's Lake Way and Millipede deposits, Wiluna WA. Report to ASX, 9 September 2013.

139 Toro Energy Ltd, August 2013: Australia's Leading Development Stage Uranium company. Lake Maitland Acquisition. Investor Presentation August 2013.

Lake Maitland project: This is a calcrete-hosted uranium deposit 100 km southeast of Wiluna. It occurs as a single horizontal layer one to three metres thick with the top of the mineralised zone one to two metres below the surface. Mega Uranium advanced its feasibility studies of the project and completed studies associated with two test pits which are each 34 m long by 19 m wide and 5 m deep.

Uranium mineralisation is flat-lying and thin, averaging around 1.7 m thick and lying beneath around 1.5 to 2.0 m of sand, silt and other evaporates. The deposit has a large areal extent approximately 5 km long (N-S) and 2 km wide (E-W).

Environmental Review and Management Programme for the Lake Maitland project is at an advanced stage of preparation and Toro propose to continue this process.

Kintyre project: A prefeasibility study of Kintyre was completed and, in July 2012, Cameco reported[140] that the study "...highlighted the project's challenging economics caused by low uranium prices and escalating costs in Western Australia". The prefeasibility study was based on a seven-year, open-pit mine to produce around 6 million pounds of U_3O_8 per year (2300 t U). The study found that, to break even, the project would need an average realised uranium price of US$67/lb or 62 million pounds (23 850 t U) of production over its seven-year life, as opposed to 40 million pounds (15 380 t U) in current resources.

The company plans to carry out further drilling aimed at discovering more resources at Kintyre and other projects in the region. Cameco stated that the project was unlikely to start construction in 2014 as previously envisaged.

Manyingee project: Manyingee deposit, located 85 km inland from the coastal town of Onslow, is a sandstone-hosted deposit which is amenable to ISR methods. It is in palaeochannel sands (Cretaceous age) of the Carnarvon Basin. The deposit has Indicated Resources of 8080 t of contained U_3O_8 at a grade of 0.1% U_3O_8 and Inferred Resources of 2810 t U_3O_8 at a grade of 0.05% U_3O_8. Paladin Energy Ltd carried out drilling in 2012 and completed 96 rotary mud drilling holes and a total of 242 m of cored drilling, which confirmed estimates by the previous owner. A total of 35 water bores were installed and monitoring of the chemical properties of the groundwater continued. Pumping tests revealed that permeability in the main aquifer was sufficient for an ISR operation[141]. Water sampling was undertaken to obtain baseline data and hydrogeological modelling commenced in support of a future application for field leach trials.

Other Developments

New South Wales Government lifts ban on uranium exploration

The NSW Government passed the *Mining Legislation Amendment (Uranium Exploration) Act 2012* on 4 April 2012 and it was proclaimed on 14 September 2012. This Act removes the ban on uranium exploration. The NSW Minister for Resources and Energy stated[142] that while the 26-year ban on uranium exploration has been overturned, the ban on uranium mining remained.

Exploration will enable an assessment to be made of the state's uranium resources, because there is very little knowledge currently about the extent and distribution of these resources in NSW.

The government called for Expressions of Interest (EOI) from interested parties wishing to explore for uranium and 39 were received. The government formed an evaluation panel made up of senior technical officers from within the Department of Trade and Investment and an independent from Geoscience Australia to assess the EOIs. The panel will make recommendations to the Government about whether exploration licences should be granted[143]. The evaluation process commenced in early 2013 and successful applicants will be invited by the Minister to apply for an Exploration Licence.

140 Kintyre uneconomic: Cameco. Press Release 30 July 2012. Cameco Corporation.

141 Paladin Energy Ltd. Annual report 2013.

142 Media release 15 September 2012 by NSW Minister for Resources and Energy.

143 Media release. Capital City Daily 21 Nov 2010.

Queensland Government lifts ban on uranium mining

The Queensland Government announced in October 2012 that uranium mining would be permitted and that an implementation committee to oversee the recommencement of mining had been established.

That committee considered, among other things, how to implement world's best practice environmental and safety standards, and delivered its report to the state government in March 2013.

Queensland's three most prospective uranium deposits are inland from Townsville, in the Mount Isa region, and in the Gulf of Carpentaria region near the Northern Territory border. These deposits have been studied and tested by various owners over a number of years.

Uranium mining has not occurred in Queensland since 1982 and has been effectively prohibited by the state government since 1989. However, exploration for uranium has not been subject to the prohibition and there has been significant interest from the industry in exploring for uranium in the state.

Vanadium

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

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

Vanadium is not found in its metallic form in nature but occurs in more than 60 minerals as a trace element in a number of different rock types. It occurs most commonly in titaniferous magnetite deposits and in uraniferous sandstone and siltstone, as well as bauxites and phosphorites. It also occurs in fossil fuel deposits such as crude oil, coal and tar sands. It is produced as both a primary product and co-product from mining and most commonly as co-products or by-products of steel making. It is also recovered from wastes such as fly ash, oil residues and waste solutions from the processing of uranium ores.

Nearly all of the world's vanadium is derived from mined ore as either direct mineral concentrates, usually vanadium- and titanium-rich magnetite, or as a by-product of steel-making slags. The USGS estimates that almost 70% of annual supply is recovered from slags and about 30% directly mined, with the remainder being acquired from other sources. Japan and the United States are thought to be the only countries to recover significant quantities of vanadium from petroleum residues.

Vanadium is sold as vanadium pentoxide (V_2O_5) and less commonly as vanadium trioxide (V_2O_3) for non-steel applications and as the alloy ferrovanadium (FeV) for steel making. The most common FeV alloy is FeV80, but FeV40, FeV50 and FeV60 are also sold. The numeric part of the symbol refers to the amount of contained vanadium; for example, FeV80 has approximately 80% contained vanadium.

Trade in vanadium products tends to be opaque with no central market recording prices. Various trade sheets such as the Metal Pages, Ryan's Notes and the London Metal Bulletin record propriety information for subscribers. The USGS[144], using Ryan's Notes, recorded that in 2012 there was a slight recovery of the FeV price for the United States domestic market with a price ranging from US$14.038/lb to US$15.728/lb, up from US$14.606/lb to US$15.004/lb of vanadium content in 2011. In contrast to the United States domestic FeV price, the European FeV annual average price has shown some decline with the price ranging from US$28.533/kg to US$29.273/kg in 2011 to US$24.786/kg to US$25.475/kg in 2012. As for the annual average price of V_2O_5, there was a slight decline in trend in the US domestic price, reaching a price of US$6.762/lb in 2012, compared with a peak price of US$6.960/lb in 2011.

Prices for vanadium have fluctuated over the past decade with sharp rises and equally sharp declines over short periods. For example, following the global financial crisis, FeV prices reached lows of US$16.30/kg and US$17.50/kg in May 2009 in North America and Europe, respectively, after reaching heights of about US$101.40/kg and US$93.00/kg, respectively, the previous year.

Resources

Australia's EDR of vanadium increased by 11% in 2012 to 1684 kt from 1519 kt in 2011.

Historically, Australia's EDR of vanadium have fluctuated because of the economic impacts of volatile prices and the nature of the vanadium market, which is supplied largely from secondary sources, particularly the reprocessing of slags from iron smelting. These secondary sources are able to rapidly increase or decrease output in response to price trends.

144 FeV and V_2O_5 prices were sourced from the United States Geological Survey Mineral Year Book 2012 report as noted from the Ryan's Notes published report.

Accessible EDR

All of Australia's EDR of vanadium are accessible.

JORC Reserves

In 2012, Proved and Probable Reserves compliant with the JORC Code comprised 1305 kt of vanadium compared with 1230 kt in 2011. This accounts for approximately 77% of AEDR. The remaining 23% of EDR comprises Measured and Indicated Resources.

World Ranking

The USGS estimates that world economic resources of vanadium are about 14 Mt but total world resources exceed 63 Mt. China and Russia each hold about 8% of the world's economic vanadium resources, followed by South Africa with 6%. Australia's EDR of 1.684 Mt represents approximately 2.7% of the world's economic vanadium resources. However, because vanadium can be recovered as a by-product or a co-product of steel slags, the estimated world resources are not fully indicative of available supply. At current usage, there are sufficient resources to meet the world's vanadium needs into the next century.

The USGS estimates that world production of vanadium from all sources in 2012 totalled 63 Mt compared to 62.4 Mt in 2011, with China producing 23 Mt, South Africa 22 Mt and Russia 16 Mt.

Exploration

Data on exploration expenditure for vanadium are not available in published statistics. However, during the last quarter of 2012, TNG Ltd completed two drilling programs aimed at upgrading the Mount Peake project's resource categories to Indicated and Measured Resources and providing information for metallurgical test works (iron-vanadium-titanium) in the Northern Territory. The Reverse Circulation drilling comprised 59 holes for 7189 m and 14 diamond drill holes for 1712 m. Geochemical and geophysical surveys were undertaken in WA at Gabanintha in 2011 and 2012. During the same period, exploration of the southern tenements at Windimurra in WA confirmed the potential for replenishing the mine reserves.

Production

In 2012, Atlantic Ltd's Windimurra vanadium project in WA produced 87 t of ferrovanadium, containing 70 t of vanadium. The company's Windimurra mine produces vanadium and high-titanium hematite fines (iron ore). Its first shipment of 7 t of ferrovanadium occurred in May 2012 and during the September quarter it transported another 36 t to the company's Perth warehouse.

Most of the world's reported mine production of vanadium during 2012 was in China (37%), South Africa (35%) and Russia (25%).

Industry Developments

Western Australia

Windimurra: The Windimurra mine, operated by Atlantic Ltd, is the only producing vanadium mine in Australia. It started producing in January 2012 and by the end of September the company had transported some 45 tonnes of ferrovanadium to its Perth warehouse. Improvements in the mine processing plant are expected to enable production to increase significantly with the company planning to produce 6300 tonnes per annum of vanadium once the mine and plant are fully operational. The projected mine life for Windimurra is approximately 28 years.

In July 2012, Atlantic published a Proven and Probable Reserve of 159.9 Mt at 0.47% V_2O_5 for the Windimurra vanadium project. The project's Measured, Indicated and Inferred Resource of 242.6 Mt at 0.48% V_2O_5, representing 652 600 t of contained vanadium, was published in April 2012.

The mine also has potential to produce hematite fines as a by-product of FeV processing. Significant stockpiles of hematite fines remain at the mine site, leftover from the previous Xstrata operation that ran for three years until the mine closed in 2004. Windimurra's iron ore fines also possess a high titanium grade, leading the company to successfully test for the optimal processing flow for separating the iron and titanium dioxide from the ore. This work was done in conjunction with the Changsha Research Institute of Mining and Metallurgy in China at both laboratory and process scale and confirmed that separation of the iron ore fines is a viable business opportunity for the Windimurra operation.

Speewah: During 2011, Speewah Metals Ltd (now King River Copper Ltd) drilled 266 holes for more than 18 000 m at the Speewah titanium-vanadium-iron deposit. The company completed hydrometallurgical testwork in February that confirmed a mixed chloride leaching process could be used to extract the titanium, vanadium and hematite. In March 2012, the company released a new JORC Code compliant resource for the deposit of 4712 Mt at 0.3% V_2O_5, 2.0% Ti and 14.7% Fe, an increase of 32% over the previous resource estimate. In April 2012, the company completed a scoping study and, in May 2012, signed a Memorandum of Understanding with the traditional owners of the land. In September 2012, the company suspended activities at Speewah, citing limited funding and an unfavourable outlook for financing.

Balla Balla: Forge Resources Ltd has commissioned the optimisation of the definitive feasibility study for the Balla Balla project which includes a review of the project's capital and operational costs as well as a proposed new export path for the project. The company stated that the 14 recommendations from the initial review have been approved for inclusion in the revised definitive feasibility study to be completed sometime in 2013. As reported for the company's December 2012 quarter, total resources for the project stand at 456 Mt at 45% Fe, 0.64% V_2O_5 and 13.7% TiO_2.

Barrambi: An evaluation by Reed Resources Ltd of hydrothermal technology for producing high-purity titanium has shown good laboratory-scale test work results, indicating it may be possible to precipitate high-purity titanium through a leaching process. The company aims to use the technology for Barrambie's Eastern Band iron-titanium-vanadium. The current estimated resource at Barrambie is 47.2 Mt at 0.63% V_2O_5, 46.70% Fe and 22.18% TiO_2 consisting of an Indicated Resource of 34.7 Mt and an Inferred Resource of 12.5 Mt.

Gabanintha: Yellow Rock Resources Ltd's 2012 annual report has stated a resource estimate for the Gabanintha titanium-vanadium-magnetite project of 125.8 Mt at 0.7% V_2O_5, 8.6% TiO_2 and 32% Fe. The resources consist of an Indicated Resource of 57 Mt at 0.59% V_2O_5, 7.59% TiO_2 and 28.1% Fe and an Inferred Resource of 68.8 Mt at 0.79% V_2O_5, 9.5% TiO_2 and 35.7% Fe. The Gabanintha vanadium-magnetite-titanium project is approximately 43 km south of Meekatharra, WA.

Canegrass: Flinders Mines Ltd's 2012 annual report has restated the previously reported Inferred Resource for the Canegrass magnetite project of 107 Mt at 0.6% V_2O_5, 5.8% TiO_2 and 29% Fe.

Unaly Hill: The 2012 annual report of Black Ridge Mining NL has re-announced the reported Inferred Resource for the Unaly Hill vanadium-titanium-magnetite project of 86.2 Mt at 0.4% V_2O_5, 4.5% TiO_2 and 24% Fe. The Unaly Hill project is located approximately 48 km south of Sandstone in WA.

Victory Bore: The previously reported Inferred Resource of 151 Mt at 0.4% V_2O_5, 6.7% TiO_2 and 25% Fe for Victory Bore has remained unchanged as at 30 June 2013 in the Quest Minerals Ltd quarterly report. Results from a metallurgical scoping study released in January 2012 indicate that the ore is amenable to standard processing with a high recovery of vanadium. However, results from the July 2012 mining scoping study show that capital costs are the major factor in determining the project economics.

Northern Territory

Mount Peake: The prefeasibility study results for TNG Ltd's Mount Peake iron-vanadium-titanium project was completed in 2012, demonstrating a strong economic outlook for the project over 20 years of operation. In March 2013, the company released an updated JORC Code Resources statement of 160 Mt at 0.28% V_2O_5, 5.3% TiO_2 and 23% Fe for the Mount Peake project.

Queensland

Hawkwood: Eastern Iron Ltd's 2012 annual report has stated that the Hawkwood iron project has an Inferred Resource of 103.7 Mt at 13.8% Fe, 1.83% TiO_2 and 0.05% V. The company also stated that future work and funding for the Hawkwood project will be subject to securing a joint venture partner.

Zinc, Lead, Silver

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Zinc (Zn) is the 23rd most abundant element in the Earth's crust and the 4th most common metal in use after iron, aluminium and copper. The construction, transport and appliance manufacturing industries use large amounts of zinc, mainly as anti-corrosion coatings (galvanising) on sheet steel, steel beams, vehicle panels, chain-link fencing, guard rails and light posts. Worldwide, galvanising accounted for 50% of the world's total consumption of zinc (consumption data from www.ilzsg.org). The widespread use of zinc as a protective coating is due mainly to its resistance to weathering as a consequence of an electrochemical reaction known as galvanic action. Zinc is more reactive than iron or steel and consequently attracts almost all local oxidation. A protective surface layer of oxide and carbonate forms as the zinc corrodes. Zinc is used also in brass (17% of zinc consumption), other alloys (17%), with the balance in other uses such as pigments, salts, oxide additives to rubber and agricultural chemicals (16%). Zinc metal is produced in Australia at Sun Metals Corporation's Townsville refinery in Queensland and at Nyrstar NV's Hobart refinery in Tasmania.

The widespread occurrence of **lead** (Pb), its relatively simple extraction and a combination of desirable properties have made it useful to humans since at least 5000 BC. In deposits mined today, lead, mainly in the form of galena (PbS), is usually associated with zinc, silver and sometimes copper and is extracted as a co-product of those metals. The largest use is in batteries for vehicles, which accounts for 80% of modern lead usage. The remaining 20% of applications include weights and ballast, underwater cable sheathing, solder, casting alloys, chemical compounds, including PVC plastics and pigments, ammunition, glassware and radiation protection. Uses for lead could increase in the future in large-storage batteries used for load-levelling of electrical power and in electric vehicles. The growing popularity of electric bikes, particularly in China, has led to an increase in demand for lead to make batteries for e-bikes. More than half of the lead currently used is from recycling rather than from mining. Of the 10.62 Mt produced in 2012, only 5.18 Mt was primary mine production[145]. Lead recycling plants jointly owned by Nyrstar NV and the Sims Group are in Melbourne, Victoria, and in Sydney, New South Wales. Nyrstar NV's Port Pirie smelter in South Australia is the world's largest primary lead smelting facility and a leading global silver producer.

The relative scarcity, attractive appearance and malleability of **silver** make it suitable for use in jewellery, ornaments and household silverware. Its extensive use in coins throughout history has declined over the past 50 years. In Australia, the 1966 50-cent piece was the last coin in general use to contain silver (80% Ag, 20% Cu). Silver is mined and produced mainly as a co-product of lead, zinc, copper and, to a lesser extent, gold. In 2012, the global supply totalled 32.6 kt of which 24.5 kt was mine production (75%) with the balance from scrap, de-hedging and government sales. Consumption was dominated by industrial applications (14.5 kt or 44%), followed by fabrication (10.1 kt or 31%: 5.8 kt for jewellery, 2.9 kt for coins and medals, and 1.4 kt for silverware), and photography (1.8 kt or 6%). The balance of consumption was de-hedging of 1.3 kt (4%) and nett investment of 5 kt (15%). The use of silver in the photographic industry has declined steadily since the development of digital photography, dropping from 6.3 kt in 2002 to 1.8 kt in 2012[146]. Industrial uses of silver are varied and include electronics such as batteries and solar panels, coatings for mirrors, catalysts, construction of high quality musical instruments, biocides in many different guises and many other applications. The use of silver as a biocide is growing and largely replacing the photographic industry as a major use. Silver can be used to prevent bacterial and fungal growth in plastic and textiles as well as being an antibacterial agent in topical gels, the treatment of wounds and in water treatment.

145 Source: www.ilzsg.org

146 Source of supply and demand data: www.silverinstitute.org

Resources

Australia's total resources of zinc, lead and silver declined by around 5% each in 2012. Total identified resources of zinc decreased to 92 Mt in 2012 from 97 Mt in 2011 while lead decreased by 3 Mt in 2012 to 58 Mt and silver decreased by 6 kt to 125 kt.

Zinc

Australia's EDR of zinc decreased by 3 Mt to 64 Mt in 2012 and accounted for around 27% of world economic resources which represents the world's largest holding. Queensland continued to hold the most resource with 35 Mt, or 54% of national EDR, predominantly at the George Fisher, Mount Isa, Dugald River and Century deposits. The Northern Territory had the second largest EDR with 19 Mt, or 30% of national EDR, almost all of which is at the McArthur River deposit. Following was NSW with 5 Mt EDR, mostly at the Broken Hill and Endeavor deposits, and Western Australia with 3 Mt, partly at the Golden Grove and Sulphur Springs deposits. Total inferred zinc resources decreased by 1 Mt to 26 Mt in 2012.

Lead

Australia's EDR of lead decreased by 2 Mt in 2012 to 34 Mt of contained lead and constituted 59% of Australia's total identified lead resources (58 Mt). Australia also accounted for the largest share of world economic resources for lead with 40%. Queensland retained the top ranking with its EDR of 19 Mt in 2012, representing a 55% share of national EDR, which is mostly at the Mount Isa, George Fisher and Cannington deposits. The NT's lead EDR ranks second with 8 Mt or 24% of the national total, almost all of which is at the McArthur River mine. Both NSW and WA have lead EDR of 3 Mt. Australia's Paramarginal Demonstrated Resources of lead remained at 3 Mt, which is 6% of total Identified Resources. Total Inferred Resources of lead decreased 2 Mt in 2012 to 20 Mt.

Silver

Australia's EDR for silver decreased by 3 kt in 2012 to 85 kt, which represents 16% of world economic resources. Queensland has 47 kt or 55% of Australian EDR, mainly in the Mount Isa, Cannington, George Fisher and Dugald River deposits. The other silver EDR occurs in SA (12 kt), NSW (11 kt), the NT (8 kt), WA (3 kt) and Tasmania (3 kt). In SA, most silver EDR is at Olympic Dam with some at Carrapateena and Prominent Hill, while in NSW it is mostly at Bowdens, Broken Hill and Endeavor. In the NT, silver EDR is nearly all at McArthur River, while in Tasmania it is largely at Rosebery.

Accessible EDR

All zinc, lead and silver EDR is accessible.

JORC Reserves

JORC Code Ore Reserves of zinc account for around 50% of AEDR. This rise to 50% from the 2011 proportion of 33% can be attributed to development of resources into reserves at two large deposits. These are the McArthur River mine, where an expansion is proposed, and Dugald River, where a new mine is under construction. The remaining AEDR is made up of those Measured and Indicated resources as reported by mining companies and which Geoscience Australia considers will be economic over the long term. The zinc resource life, using national AEDR divided by annual production, is 42 years, but using the Ore Reserve and dividing by annual production gives a resource life of 21 years.

Of Australia's AEDR of lead, 45% occurs in the JORC Code Ore Reserves categories. For lead, the national AEDR/production ratio is 55 years, but if the Ore Reserve/production ratio is used it is 25 years. For silver, JORC Code reserves account for around 36% of AEDR and resource life is 49 years for AEDR or 17 years for JORC Code Reserves.

Exploration

In 2012, exploration spending on zinc, lead and silver was $83 million, the same as in 2011. The 2012 expenditure was 11% of the total base metal expenditure of $733 million, which is slightly lower than the $741 million of expenditure in 2011. Expenditure on exploration for the three commodities made up only 2.3% of total mineral exploration expenditure of $3.7 billion (excluding petroleum), which compares closely to the 2.3% of $3.6 billion in 2011. New South Wales accounted for 36% of the total 2012 zinc, lead and silver exploration expenditure, which largely focussed on the Cobar and Broken Hill regions. Western Australia accounted for 19% of the exploration, which was spread across the state.

Production

According to BREE, 2012 Australian mine production of zinc, lead and silver was 1.54 Mt, 0.62 Mt and 1.73 kt, respectively. Compared to 2011, production in 2012 increased by 2% for zinc, but remained at the same levels for lead and silver. The majority of production was from Queensland, which contributed 1007 kt, or 65%, to national zinc production during 2012 along with 440 kt, or 71%, of lead and 1.39 kt, or 81%, of silver, all very similar amounts to 2011. Elsewhere, NSW produced 142 kt of zinc and 90 kt of lead while the NT produced 199 kt of zinc and 42 kt of lead and Tasmania produced 88 kt of zinc and 30 kt of lead. In NSW and the NT, production of zinc and lead increased from the levels of 2011. Western Australia produced 77 kt of zinc and 8 kt of lead with lead production remaining low in WA because of continued suspension of operations at the Magellan lead mine.

The Century zinc mine, which is located close to the Gulf of Carpentaria, about 250 km north of Mount Isa in northwest Queensland, ranks in the top few globally in zinc production. Century produced 515 kt of zinc and 21 kt of lead as metal in concentrate in 2012. The Cannington mine, also located in northwest Queensland, is the world's largest and lowest cost single mine producer of both silver and lead as well as a significant producer of zinc. Cannington produced 215 kt of lead, 1.00 kt of silver and 50 kt of zinc in 2012. Also in Queensland are Xstrata's Mount Isa operations which, in 2012, produced 390 kt of zinc, 300 kt of lead and 214 t of silver, including 31 t in silver from purchased concentrate.

The value of Australia's exports of zinc concentrates and refined zinc in 2012 totalled $2178 million, 10% less than the $2414 million in 2011 and 1% of the value of total merchandise exports. The amount of zinc exported increased by 1% to 1.56 Mt in 2012. The average price for zinc in 2012 was $1970/t, 16% lower than the average of $2350/t in 2011. The 2012 December quarter average price was 7% lower than for the December quarter in 2011.

Exports of lead totalled 688 kt in 2012, only slightly lower than in 2011. The value of the 2012 exports was 5% lower at $2080 million compared to $2181 million in 2011. The average price for lead was $2108/t in 2012, down 19% on 2011. However, lead prices were only 3% lower when comparing December quarters. For silver, the average price was 8% lower at $975/kg compared to the average of $1061/kg in 2011, with a 5% December on December increase. The value of Australia's mine production of silver was $1678 million in 2012, down 9% on 2011.

World Ranking

Based on USGS data for other countries, Australia has the world's largest economic resources of zinc (27%) and lead (40%) and ranks second for silver with 16% after Peru (22%). In terms of production, Australia ranks second for zinc and lead after China and fourth for silver after Mexico, China and Peru.

Industry Developments

Queensland

Mount Isa: Mount Isa zinc-lead operations commenced production in 1931 and were acquired by Xstrata plc in 2003. Operations currently comprise the **George Fisher** underground mine, the open cut mines of **Black Star** and **Handlebar Hill**, an 8 Mtpa-capacity zinc-lead concentrator, a lead smelter and a zinc filter plant. Following a major restructuring in 2009, there have been major increases in production in the Mount Isa operations, which continued into 2012. Mined volumes increased by 4% to 9.45 Mt, and ore treated increased by 1.5%, to 9.38 Mt in 2012. Higher head grades along with the increase in ore treated resulted in increases in production of zinc in concentrate to 390 kt from 357 kt in 2011 and lead with combined in-concentrate and bullion up to 300 kt from 269 kt in 2011. The production of silver in crude lead increased by 5% to 214 t (including 31 t from purchased concentrates) from 204 t (including 32 t in purchased concentrates) in 2011.

During 2012, Xstrata continued to expand its Mount Isa operations. The **Black Star Deeps** and Handlebar Hill expansions were completed in October and December 2011, respectively, and expansion of the George Fisher underground mine was begun. First production from this expansion was delivered during 2012. A decision was made in May 2011 to accelerate development of the **Lady Loretta** deposit northwest of Mount Isa. First ore production at Lady Loretta was achieved in September 2012, with ore trucked 140 km to the Mount Isa milling operations. Commercial-scale mining began in mid-2013, with production expected to ramp up to 1.6 Mtpa in 2016.

Century: The **Century** mine is one of the world's three largest zinc mines, producing 4% of global production. Minerals and Metals Group Ltd (MMG), a Chinese-owned corporation, acquired the **Century**, **Rosebery** and **Golden Grove** mines, among others, in early 2009. Zinc production at the Century mine in 2012 was similar to that in 2011, although lead and silver production was significantly lower. During 2012, production of zinc in concentrate increased slightly by 4% to 515 kt, while lead in concentrate decreased by 19% relative to 2011 to 21.4 kt. Total payable silver production was 1.5 t, a reduction of 61% relative to 2011 resulting from a decrease in grade. Mine life is expected to extend to 2016. The company is assessing possibilities to use existing mine infrastructure for phosphate production. The decrease in production associated with the anticipated closure of the Century Mine in 2016 will be replaced by development of the Dugald River deposit 220 km southeast of Century.

Cannington: The **Cannington** deposit in northwest Queensland was discovered in 1990 by BHP Billiton Ltd, with mining operations commencing in 1997. Mine production in 2012 increased marginally by 1% to 3.17 Mt on that achieved during 2011, while mill throughput was unchanged at 3.19 Mt. Silver production was virtually unchanged at 1.00 t, but lead in concentrate decreased by 8% to 215 kt, and zinc in concentrate decreased by 15% to 50.4 t.

Mount Garnet-Challagoe-Balcooma-Thalanga: On 30 April 2012, Kagara Ltd went into voluntary administration. At that time, Kagara's north Queensland zinc interests were centred on the Mount Garnet-Chillagoe region and included mines at **Mungana**, **Mount Garnet** and **Balcooma** and ore processing facilities at **Mount Garnet** (separate facilities for copper and polymetallic ores) and **Thalanga**. Limited mining and milling operations continued into the December quarter of 2012, with all operations subsequently on care and maintenance. Mill production during the March and June quarters in 2012 for all Kagara north Queensland operations totalled 3.32 kt of copper and 12.27 kt of zinc. Mill production in the September and December quarters totalled 1.82 kt copper concentrate, 5.06 kt zinc concentrate and 0.604 kt lead concentrate. Metal production was not reported for either of these two quarters.

Northern Territory

McArthur River: Underground mining at **McArthur River** began in 1995, with open-cut mining beginning in 2009. Xstrata plc acquired the McArthur River operations in 2003. The conversion to open-cut mining, combined with a concentrator expansion, increased production capacity to 2.5 Mtpa in 2009. Ore treated in 2012 was identical to 2011 at 2.34 Mt. Production of metals all increased. Because of higher head grades, zinc-in-concentrate production increased by 4% to 202 kt, production of lead in concentrate increased by 5% to 40.4 kt, and silver-in-concentrate production increased by 14% to 56.6 tonnes. In June 2013, the Northern Territory Government approved plans for the phase 3 expansion of the McArthur River mine. The expansion will extend mine life to 2036 and increase production from 2.5 Mtpa to 5.5 Mtpa from 2014, with concurrent increases in zinc and lead production. In May 2013, Glencore International plc and Xstrata plc merged to form Glencore Xstrata plc.

Western Australia

Golden Grove: MMG Ltd's **Golden Grove** operation consists of the **Scuddles** and **Gossan Hill** underground mines and the **Scuddles** processing plant. In 2012, a greater emphasis was placed on copper production, with an increase in copper in concentrate of 31% to 28.4 kt. Zinc-in-concentrate and lead-in-concentrate production decreased significantly by 47% and 29% to 37.4 kt and 5.3 kt, respectively. Payable silver and gold increased by 80% to 56.26 t (from 31.29 tonnes in 2011) and 78% to 965 kg (from 542 kg), respectively. In the first half of 2011, approval was granted for development of a copper oxide open pit at **Gossan Hill**. Development of this resource commenced in 2012, with first shipment of copper concentrate in 2013. Mining of this open cut resource will reduce the need for ore from underground operations.

Jaguar-Bentley: The **Jaguar** project consists of three high-grade deposits, **Jaguar**, **Teutonic Bore**, and **Bentley**, located approximately 300 km north of Kalgoorlie. Perth-based Jabiru Metals Ltd began operations at Jaguar in 2007 while production began at the Bentley deposit in June 2011 after it was discovered in 2008. Jabiru Metals was taken over by Independence Group NL in February 2011. Production in 2012 was 25.35 kt of zinc in concentrate, 6.19 kt of copper in concentrate and 26.1 t of silver in concentrate (in the copper concentrate) from 0.380 Mt of ore milled. As the tonnage milled and zinc grade were both higher in 2012 relative to 2011, zinc-in-concentrate production increased by 104%, although copper-in-concentrate production decreased by 12% because of lower grades.

Magellan: Toronto-listed Ivernia Inc, wholly owns the Paroo Station project, 30 km west of Wiluna in WA. Three deposits are known in this project, **Magellan**, **Cano** and **Pinzon**. Lead production at the Magellan deposit, which is the largest known carbonate lead deposit in the world, began in October 2005, with concentrates sold overseas and shipped initially from the Port of Esperance. However, because of lead contamination at the port, shipping was suspended and the mine was placed on care and maintenance in April 2007. Mine production recommenced in February 2010 following revision of concentrate transport procedures and with the concentrate being shipped through the Port of Freemantle. However, production ceased again in early January 2011 following a stop order on the transportation of lead carbonate and the mine was placed on care and maintenance once more. On 27 March 2013, the Western Australian Office of the Environmental Protection Authority provided final sign-off on preconditions and management plans to allow transport of concentrate to resume. Operations are ramping up, with nameplate production anticipated at the end of 2013.

South Australia

Angas: Operations began at Terramin Australia Ltd's underground **Angas** mine in July 2008. The mine reached nameplate production capacity of 0.4 Mtpa in the second half of 2009. In 2012, the mine produced 0.434 Mt of ore, 5% more than 2011, and the mill processed 0.441 Mt, 10% more than 2011. A total of 62 kt of zinc concentrate and 25 kt of lead concentrate was produced, which represented an increase of 41% over 2011 for each concentrate. The total amount of payable metal produced was 25.9 kt of zinc, 12.6 kt of lead, 145 t of copper, 11.6 t of silver and 167 kg of gold. In July 2013, Terramin announced that the Angas mine was to be closed on 30 September 2013.

Tasmania

Rosebery: In 2012, metals in concentrate produced at the **Rosebery** operations of MMG Ltd were 70.4 kt of zinc, 20.1 kt of lead and 1.59 kt of copper. In addition, payable silver and gold production were 73.3 t and 968 kg, respectively. Although total mine production was 10% higher than that achieved in 2011, lower grades resulted in production decreases of 13% for zinc in concentrate, 21% for lead in concentrate and 13% for copper in concentrate. However, payable silver and gold production increased by 37% and 25%, respectively. **Rosebery** currently has a mine life beyond 2020.

Hellyer-Fossey: Following cessation of Bass Metals Ltd's mining activities at its **Que River** mine in September 2010, the company concentrated on developing and mining the **Fossey** and **Fossey East** deposits, which were discovered adjacent to the historical **Hellyer** mine in 2007 and 2010, respectively. Work to develop a decline to access the Fossey deposit and refurbish the Hellyer mill began in January 2011. First ore production from Fossey was achieved in March 2012. Production at Fossey for 2012 was 0.188 Mt of ore for 15.04 kt of zinc in concentrate, 6.61 kt of lead in concentrate, 0.339 kt of copper in concentrate, 15.29 t of silver in concentrate, and 88.4 kg of gold in concentrate. Mining ceased at Fossey in May 2012.

New South Wales

Broken Hill: In 2012, Perilya Ltd slightly decreased ore production from its southern operations at **Broken Hill**, producing a total of 1.69 Mt, compared with 1.74 Mt in 2011. The decrease in ore production was offset by an increase in grade, resulting in increased production of produced metals. Relative to 2011, zinc-in-concentrate production increased by almost 10% to 76.9 kt and lead-in-concentrate production increased by 5% to 54.1 kt while contained silver production was 49.0 t, up by 7% from 44.8 t in 2011. Current reserves and resources provide for at least 10 years of production at the southern operations. The **Potosi-Silver Peaks** operation is in development, although slowed, and the historic **Broken Hill North** mine is the subject of a development study.

In 2010, CBH Resources Ltd continued to push towards production at its **Rasp** mine development, which had been placed on care and maintenance in June 2008. Approval from the New South Wales Department of Planning and Infrastructure for development was gained in January 2011 and development was approved by the Toho Board in February. Underground development began in April 2012 and the mine was opened in July 2012, with full-scale production achieved at the time of writing. On 1 July 2009, the mineral resource was 16.5 Mt at 6.6% Zn, 5.1% Pb and 89 g/t Ag. Annual production is planned to be 34 kt of zinc, 28 kt of lead and 34 t of silver for a minimum mine life of 15 years. In September 2010, CBH Resources was taken over by Toho Zinc Co Ltd of Japan.

Endeavor: In 2012, the **Endeavor** mine near Cobar in NSW and owned by CBH Resources, a wholly-owned subsidiary of Toho Zinc Co Ltd, produced 42.9 kt of zinc in concentrate, 20.9 kt lead in concentrate, and 20.5 t of silver[147]. Given these production rates, mine life is expected to be six years.

Other zinc-lead-silver developments

There are several zinc-lead-silver prospects at various stages of development that could come on line in the next decade. The most significant of the zinc-lead projects is the MMG-owned **Dugald River** deposit in Queensland. This deposit, the first zinc deposit discovered in the Mount Isa region, was the subject of a feasibility study in 2008, which was updated in 2010. The feasibility study indicated a mine life of 23 years based on a resource of 53 Mt grading 12.5% Zn, 1.9% Pb and 36 g/t Ag. Development approval was granted in December 2011 to bring the project to full environment approval, which was achieved in August 2012. The approval for construction was given in December 2012, with binding banking agreements signed in June 2013, and an engineering, procurement and construction contract let in May. However, in September 2013, this contract was terminated because geotechnical studies identified complexities in the orebody, which resulted in some surface construction being suspended.

After Dugald River, the most advanced project is YTC Resources Ltd's **Hera-Nymagee** project near Cobar in NSW. The **Hera** deposit has a global resource of 2.444 Mt grading 3.8% Zn, 2.8% Pb, 0.2% Cu, 16.7 g/t Ag and 4.1 g/t Au, and the nearby **Nymagee** prospect has a global resource of 8.096 Mt grading 1.2% Cu, 0.7% Zn, 0.3% Pb and 9 g/t Ag. A definitive feasibility study, completed in September 2011, indicated a financially and technically robust project with a minimum 7.3-year mine life. Financing facilities were agreed with Glencore International AG in November 2012, with surface construction and Hera decline development commenced in December. Full-scale ore production is anticipated in the September 2014 quarter, with full-scale mill production anticipated in the December 2014 quarter.

Another advanced project is the Independence Group's **Stockman** project in Victoria, which includes the **Wilga** and **Currawong** volcanic-hosted massive deposits with a combined (updated June 2012) resource of 13.986 Mt grading 4.3% Zn, 0.7% Pb, 2.1% Cu, 38 g/t Ag and 1.0 g/t Au. On 5 July 2013, Independence Group announced that exploration activities on the project had ceased and that the enhanced feasibility study had been curtailed. However, work is continuing on an environmental effects statement which is expected in December 2013.

Venturex Resources Ltd has consolidated many of the zinc-lead resources in the Pilbara region (WA) into its Pilbara volcanogenic massive sulphide-copper-zinc project. The project includes the **Whim Creek**, **Mons Cupri**, **Salt Creek**, **Evelyn, Kangaroo Caves** and **Sulphur Springs** deposits. Current resources for the consolidated project total 26.37 Mt grading 3.4% Zn, 0.3% Pb, 1.2% Cu, 18.9 g/t Ag and 0.1 g/t Au. A bankable feasibility study was released in December 2012 that covered the development of the Sulphur Springs, Whim Creek and Mons Cupri deposits, but not other deposits in the project (Salt Creek, Evelyn and Kangaroo Caves). No plans for further development of the project have been announced.

147 Cited production is from Earnest, D.F., 2013. Endeavor mine, Cobar, New South Wales, Australia, technical report. Unpublished report, Couer d'Alene, 95 p. (available at http://au.intierra.com/Reports/2013/Apr/02/CB537888.PDF#Page=1). The silver production is 10% lower than production data provided in the 2012 Couer d'Alene Annual Report (659 204 oz vs 734 008 oz).

The **Myrtle** deposit (NT) is located about 20 km south of the **McArthur River** deposit in the same host succession. This deposit and the **Teena** deposit, 10 km to the west of McArthur River, are the most significant prospects in the **Reward** project. The project, a joint venture between Rox Resources Ltd and Teck Australia Pty Ltd, is still at the exploration stage, but a total resource of 43.6 Mt grading 4.09% Zn and 0.95% Pb, with a higher grade resource of 15.3 Mt grading 5.45% Zn and 1.40% Pb, has been identified at Myrtle. Recent results at Teena, including 26.4 m grading 13.3% Zn+Pb, have encouraged Teck Australia to exercise its right to earn additional equity in the project.

At Kagara's **Admiral Bay** deposit in the Canning Basin (WA), a prefeasibility study identified mineral resources of 72 Mt grading 3.1% Zn, 2.9% Pb, 18 g/t Ag and 20% barite. However, this deposit is located more than a kilometre below the surface and requires a large financial investment to bring the project to bankable feasibility status. At the time of writing, this asset was to be retained by Kagara Ltd, which is currently in voluntary administration.

In July 2013, TriAusMin Ltd received final approval from the NSW government to proceed with development of the **Woodlawn** project. The **Woodlawn** mine, northeast of Canberra, produced 13.4 Mt of high-grade zinc-lead-copper ore between 1978 and 1998. The approval was for the re-treatment of tailings from the previous mining campaign, and redevelopment of underground operations. Global resources for the tailings re-treatment project total 11.65 Mt grading 2.29% Zn, 1.35% Pb, 0.50% Cu, 32 g/t Ag and 0.29 g/t Au, while the underground global resources total 10.10 Mt grading 10.15% Zn, 4.03% Pb, 1.78% Cu, 84 g/t Ag and 0.53 g/t Au. Subject to financing, TriAusMin plans to bring the Woodlawn project into production during the 2015–2016 financial year.

Kidman Resources Ltd reported a number of significant intersections at its **Home of Bullion** project, 25 km east of Barrow Creek in the NT. Historically, the Home of Bullion mine produced 8 kt of copper from the 1930s to the 1970s. Although dominantly a copper prospect, Home of Bullion also contains significant zinc, lead, silver and gold credits. For example, in October 2013, Kidman Resources reported a 9.7 m intersection grading 3.4% Cu, 2.0% Zn, 0.83% Pb, 40.7 g/t Ag and 0.47 g/t Au. At the time of writing, Kidman Resources is continuing with deep drilling at the project.

KBL Mining Pty Ltd has defined a JORC Code compliant resource of 16.7 Mt grading 4.5% Pb and 52 g/t Ag at the **Sorby Hills** project 50 km northeast of Kununurra in WA. The company completed a prefeasibility study on stage 1 development, which was granted approval by the Western Australian Environmental Protection Authority in October 2013, a ruling that has since been appealed. Construction of the project is planned for mid-2014, with operations 12 months later.

Other silver developments

The interest in deposits in which silver is the main, or only commodity has continued, with mining and processing commencing at Alcyone Resources Ltd's **Twin Hills** (Qld) mine in July 2011 and at Cobar Consolidated Resources Ltd's **Wonawinta** (NSW) mine in May 2012. A number of other projects are at various stages in the production pipeline, mostly in NSW and Queensland, but also in SA and WA.

At Alcyone Resources's **Texas Project**, the **Twin Hills** mine was recommissioned in February 2011 with production in 2012 totalling 24.5 t. The company also announced a resource for the **Mount Gunyan** deposit 4 km east of Twin Hills of 3.9 Mt grading 55 g/t Ag. The combined Twin Hills-Mount Gunyan resource has the potential for a 6- to 8-year mine life.

At the **Wonawinta** deposit, in the Cobar mineral field, Cobar Consolidated Resources treated the first batch of ore in May 2012, with pouring of the first silver in July and first shipment in August. The Wonawinta deposit produced 11.0 t of silver in doré in 2012.

Other silver projects in early stages of development in eastern Australia include Argent Minerals Ltd's **Kempfield** project and Kingsgate Consolidated Ltd's **Bowdens** project, both of which are in NSW and are the subject of feasibility studies. At Kempfield, updated resources released in April 2012 total 21.8 Mt grading 47 g/t Ag and 0.12 g/t Au with lead and zinc credits in primary ore. At Bowdens, an updated total resource of 88 Mt grading 47.4 g/t Ag, 0.39% Zn and 0.29% Pb was announced in December 2012. Other, less advanced, silver projects include Silver Mines Ltd's **Webbs** project in NSW and White Rock Minerals Ltd's **Mount Carrington** project in Queensland. The Webbs project currently has a total resource of 1.49 Mt grading 245 g/t Ag, 0.27% Cu, 0.71% Pb and 1.56% Zn. In July 2012, a scoping study on the Mount Carrington project using JORC Code compliant mineral resource data released in February 2012 indicated robust viability. This mineral resource was updated in July 2013 and stands at 12.21 Mt grading 58 g/t Ag and 0.2 g/t Au (silver-dominant) and 6.64 Mt grading 3.0 g/t Ag and 1.3 g/t Au.

Although silver exploration and development is occurring mostly in NSW and Queensland, particularly in the New England and Lachlan Orogens, silver exploration continues at MacPhersons Reward Gold Ltd's **Nimbus** project in WA and at Investigator Resources Ltd's **Paris** prospect in the **Peterlumbo** silver field in SA. At Nimbus, which produced 112 t of silver between 2003 and 2007, MacPhersons Reward has upgraded its total resource inventory to 4.876 Mt grading 79.3 g/t Ag, 0.29 g/t Au, 1.83% Zn, and 88 ppm Hg. In addition, the company has identified several massive sulfide zones that are not considered in the resource.

The Paris prospect in the southern Gawler Province continues to be advanced. This prospect, which was discovered in January 2011, consists of mainly sheet-like zones and sub-vertical veins in dolomite just below the unconformity with Gawler Range volcanics. The silver is interpreted to be epithermal in origin and has some similarities to manto-type deposits. A global resource comprising 5.9 Mt grading 110 g/t Ag and 0.6% Pb was announced in mid-October 2013.

Rocky roads

Financial difficulties for small to mid-tier producers continued from 2012 into 2013. Kagara Ltd went into voluntary administration on 30 April 2012 after suspending all operations in north Queensland earlier in the month. At the time of writing, the assets of Kagara had been partially sold. Kagara's former central operations, which included the **Surveyor** and **Mount Garnet** operations, were sold to Snow Peak Mining Pty Ltd. Consolidated Tin Pty Ltd, which manages and operates these assets, announced in October 2013 that mining had recommenced. Kagara's administrator, FTI Consulting (Australia) Pty Ltd, terminated an agreement for the sale of Kagara's southern (**Thalanga** and **Liontown/Waterloo**) and northern (**Chillagoe**) operations because of non-payment of deposits. These properties will be re-tendered. Although initially up for tender, the **Admiral Bay** assets in WA are being retained by Kagara.

Bass Metals Ltd ceased mining of the **Fossey** deposit in May 2012, with milling at the **Hellyer** mill finishing in June. The Hellyer mill operation was sold at the end of January 2013, providing funding for Bass Metals to clear debts and re-launch exploration.

Appendices

Photo: Underground gold mining at Stawell, Victoria.

Appendix 1

Australia's National Classification System for Identified Mineral Resources (2009 edition)

Introduction

Australia's mineral resources are an important component of its wealth, and a long-term perspective of what is likely to be available for mining is a prerequisite for formulating sound policies on resources and land access.

In 1975, Australia (through the Bureau of Mineral Resources, which has evolved to become Geoscience Australia) adopted, with minor changes, the McKelvey resource classification system used in the USA by the then Bureau of Mines and the United States Geological Survey (USGS). Australia's national system remains comparable with the current USGS system, as published in its Mineral Commodity Summaries.

Companies listed on the Australian Securities Exchange are required to report publicly on ore reserves and mineral resources under their control, using the Joint Ore Reserves Committee (JORC) Code (see http://www.jorc.org/). This has also evolved from the McKelvey system, so the national system and JORC Code are compatible. Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources.

Estimating the total amount of each commodity likely to be available for mining in the long term is not a precise science. For mineral commodities, the long-term perspective takes account of the following:

- JORC Code Reserves will all be mined, but they only provide a short term view of what is likely to be available for mining.
- Most current JORC Code Measured and Indicated Resources are also likely to be mined.
- Some current JORC Code Inferred Resources will also be transferred to Measured Resources and Indicated Resources and Reserves.
- New discoveries will add to the resource inventory.

Classification principles

The national system for classification of Australia's identified mineral resources is illustrated in Figure A1. It classifies Identified (known) Mineral Resources according to two parameters, the degree of geological assurance and the degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and grade while the latter takes account of economic factors such as commodity prices, operating costs, capital costs, and discount rates.

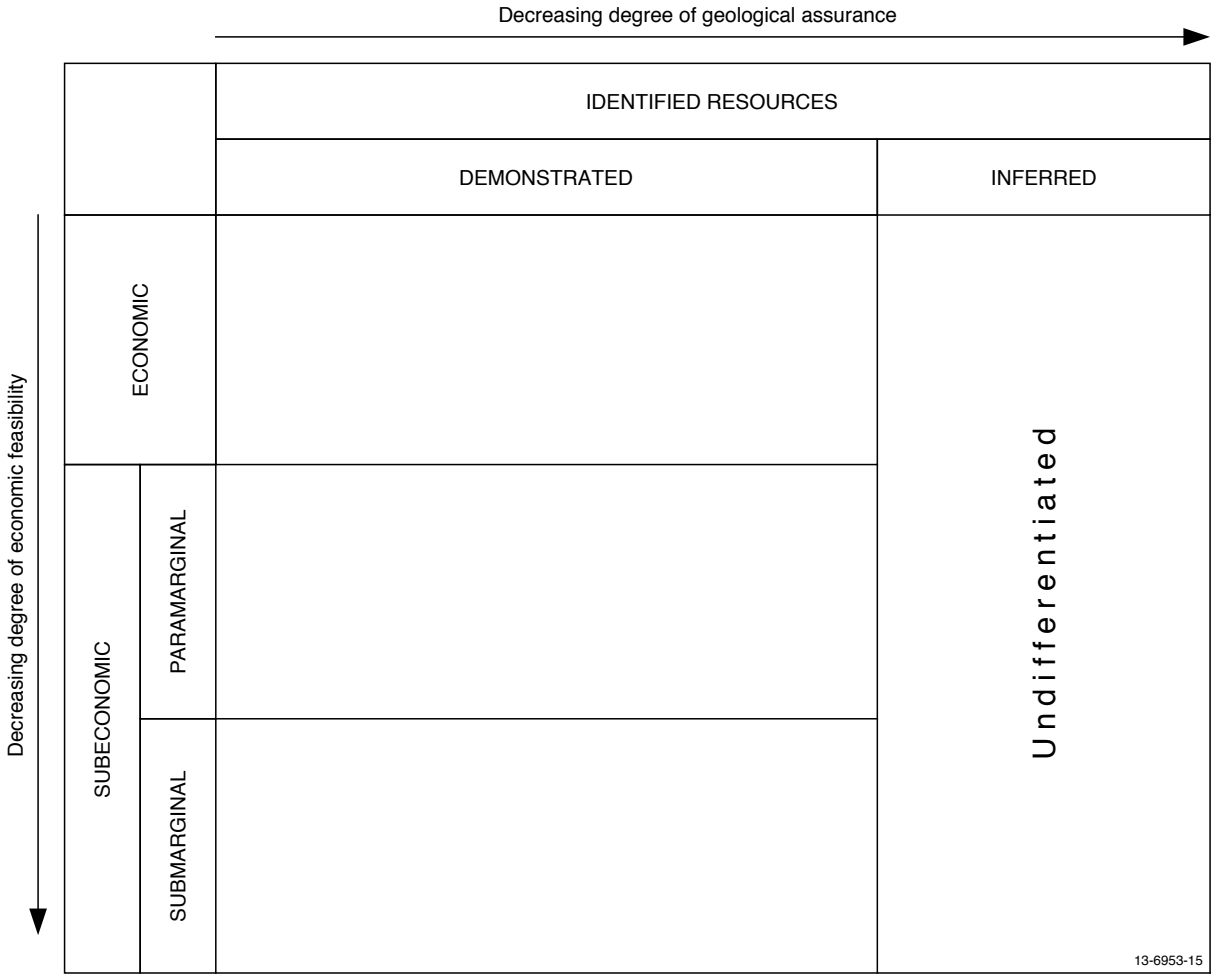

Figure A1: Australia's national classification system for mineral resources.

Resources are classified in accordance with economic circumstances at the time of estimation. Resources that are not available for development at the time of classification because of legal and/or land access factors are classified without regard to such factors, because circumstances could change in the future. However, wherever possible, the amount of resource affected by these factors is stated.

Because of its specific use in the JORC Code, the term 'Reserve' is not used in the national inventory, where the highest category is **'Economic Demonstrated Resources'** (EDR, Figure A1). In essence, EDR combines the JORC Code categories 'Proved Reserves', Probable Reserves', plus 'Measured Resources' and 'Indicated Resources' as shown in Figure A2. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term.

Terminology and definitions for Australia's national system

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

The definition does not intend to imply that exploitation of any such material will take place within that time span, but that exploitation might reasonably be considered. It should be applied also on a commodity by commodity basis to take account of prevailing and prospective technologies. The term includes, where appropriate, material such as tailings and slags. Mineralisation falling outside the definition of 'Resource' is referred to as an 'occurrence' and is not included in the national inventory.

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.

Categories based on degree of geological assurance of occurrence

To reflect degrees of geological assurance, Identified Resources are divided into Demonstrated Resources and Inferred Resources:

1. **Demonstrated Resource:** A collective term used in the national inventory for the sum of 'Measured Mineral Resources', 'Indicated Mineral Resources' 'Proved Ore Reserves' and 'Probable Ore Reserves' (see Figure A2), which are all defined according to the JORC Code:

   - 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.

   - 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.

   - 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.

     A Proved Ore Reserve represents the highest confidence category of reserve estimate and implies a high degree of confidence in geological and grade continuity, and the consideration of the Modifying Factors. It includes diluting materials and allowances for losses that may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.

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

  A Probable Ore Reserve has a lower level of confidence than a Proved Ore Reserve but is of sufficient quality to serve as the basis for a decision on the development of the deposit. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.

2. 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 Ore Reserves. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

   By definition, Inferred Mineral Resources are classified as such for want of adequate knowledge and therefore it may not be feasible to differentiate between economic and subeconomic Inferred Resources. Where the economics cannot be determined, these Inferred Resources are shown as 'undifferentiated'.

Categories based on economic feasibility

Identified resources include economic and subeconomic components.

3. **Economic:** 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.
4. **Subeconomic:** Refers to those resources which do not meet the criteria of economic; 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 for 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.

The definition of 'economic' is based on the important assumption that markets exist for the commodity concerned. All deposits that are judged to be exploitable economically at the time of assessment are included in the economic resources category irrespective of whether or not exploitation is commercially practical. It is also assumed that producers or potential producers will receive the 'going market price' for their production.

The information required to make assessments of the economic viability of a particular deposit is commercially sensitive. Geoscience Australia's assessment of what is likely to be economic over the long term must take account of postulated price and cost variations. Economic resources include resources in enterprises that are operating or are committed, plus undeveloped resources that are judged to be economic on the basis of a realistic financial analysis, or compare with similar types of deposits in operating mines.

How the national inventory is compiled

Virtually all of the mineral resource estimates compiled by Geoscience Australia's commodity specialists, including Subeconomic Resources, originate from published mining company sources reporting under the JORC Code. Given the common resource categories and definitions, the transfer of mineral resources from company reports into Australia's national mineral resource categories is quite straightforward, as summarised in Figure A2.

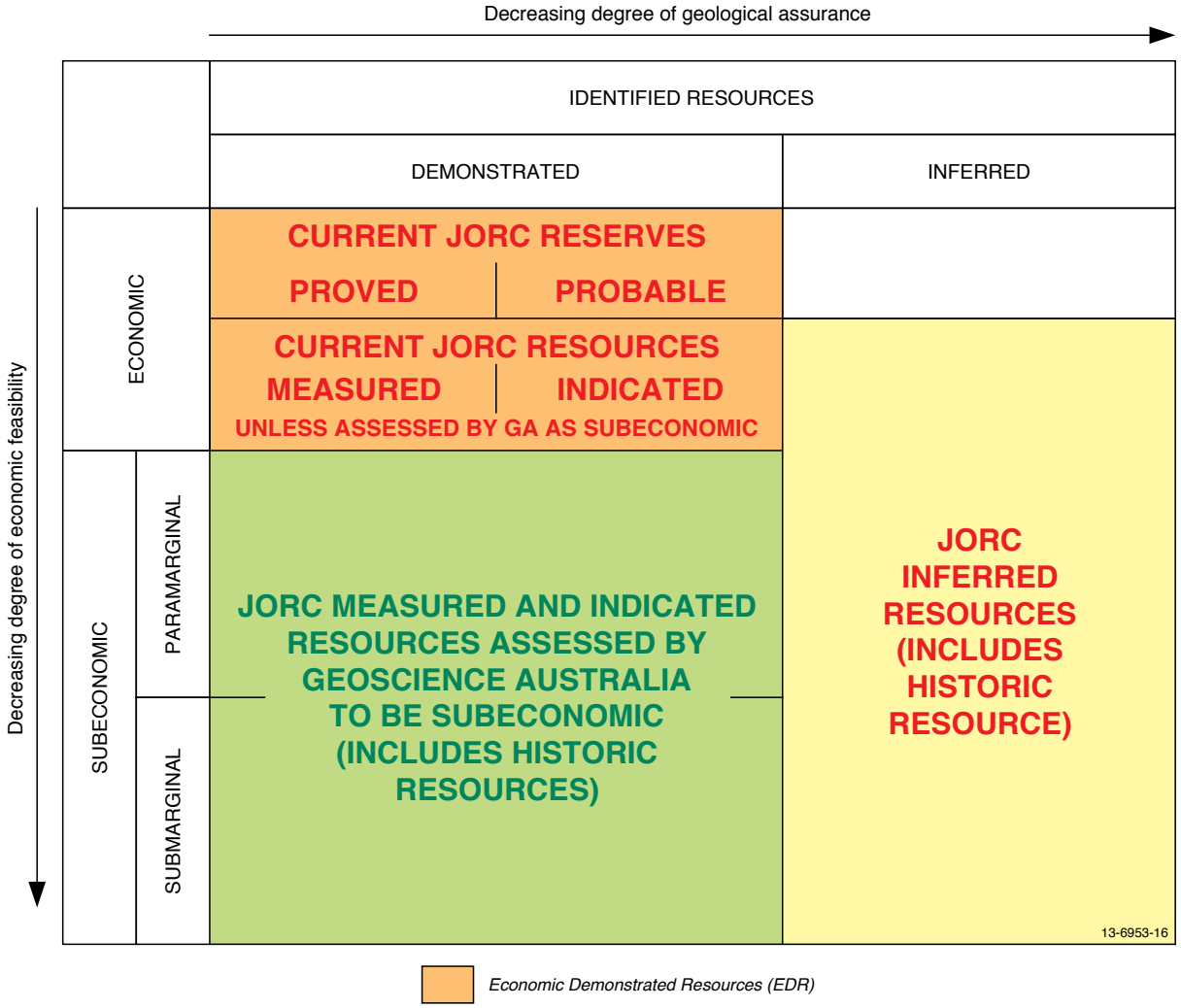

Figure A2: Correlation of JORC Code mineral resource categories with Australia's national mineral resource classification system.

Notes: (i) EDR comprise mainly current JORC Code reserves and resources, but minor proportions of EDR come from selected historic JORC Code and pre-JORC Code reserves and resources;
(ii) In some instances, where a deposit is reported as having Measured and/or Indicated Resources, particularly where there are no Reserves reported, a professional judgement is made by Geoscience Australia as to whether all or part of the reported Resources are included in EDR, or assessed as subeconomic; and
(iii) Subeconomic Resources are largely from historic company reports but are still the most recent estimates, and it also includes proportions of resources from current company reports which are JORC Code compliant but have been assessed by Geoscience Australia as subeconomic.

In essence, for the reasons outlined above, the national inventory is compiled by:

- Incorporating the JORC Code Proved and Probable Ore Reserves and Measured and Indicated Mineral Resources into EDR.
- Transferring JORC Code Inferred Resources to the national Inferred Resources category. There is commonly insufficient information to determine whether or not Inferred Resources are economic.

In addition, Geoscience Australia makes decisions on the transfer of historic JORC Code and pre-JORC Code estimates of ore reserves and mineral resources. Some of these old estimates are economically less attractive under current conditions, usually due to lower commodity prices and/or unforeseen technical problems. Some of these resources may be removed from EDR and transferred to Paramarginal or Submarginal Resources. However, if such resources cannot be reasonably expected to become economic within a time frame of 20 to 25 years, they are removed from the national mineral resources database.

Companies report grade and tonnage data for individual deposits. However, it is not meaningful to add up grades and tonnages from different deposits, so the national inventory reports only the aggregated total tonnage for each commodity – that is, the sum of the contained metal in individual deposits for each resource category, which has been derived from company reports.

Allowances for losses

Loss of resources resulting from mining and milling (metallurgical processing) are given for the reserve and resource categories of the JORC Code. The allowances for losses, which apply to all minerals except coal, uranium, thorium and oil shale, are summarised in Table A1.

Table A1: Allowance for mining and milling losses in the National and JORC Code systems.

National system	JORC Code system	Mining losses	Milling (metallurgical) losses
DEMONSTRATED RESOURCES	Proved Ore Reserves	Deducted	Not deducted - but are considered in assessing economic viability
	Probable Ore Reserves	Deducted	Not deducted - but are considered i n assessing economic viability
	Measured Mineral Resources	Not deducted	Not deducted
	Indicated Mineral Resources	Not deducted	Not deducted
INFERRED RESOURCES	Inferred Resources	Not deducted	Not deducted

Exceptions:
(i) For coal, the following resource categories are used – 'Recoverable coal resources' makes allowance for mining losses only. 'Saleable coal' makes allowance for mining as well as processing losses.
(ii) Uranium and thorium resources are reported with losses resulting from mining and milling deducted from all categories, consistent with the international uranium resource classification system of the OECD Nuclear Energy Agency and International Atomic Energy Agency.
(iii) Oil Shale resources are reported as recoverable oil.

Correlation of Australia's national classification system for mineral resources with United Nations Framework Classification system

In order to compare Australia's national inventory of mineral resources with those of other countries and estimate total global stocks, it is useful to map different systems onto a common international classification template.

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC 2009) is an internationally applicable generic principle-based system in which mineral resource categories are classified on the basis of the three fundamental criteria of:

- economic and social viability (E),
- project status and feasibility (F), and
- geological knowledge (G).
- Mineral resource 'classes' are defined by using a numerical coding xsystem ordered in a three-dimensional system along the three axes of E, F and G with '1' being the highest category in terms of quality and knowledge and 4 the lowest.
- A mineral resource class is defined by selecting from each of the three criteria a particular combination of a category or a sub-category.
- The codes are always quoted in the same sequence (e.g., E1; F1; G1),
  - The letters may be dropped and just the numbers retained, for example 111 at class level or 3.2; 2.2; 1,2 at sub-class level; and
  - These criteria may be further subdivided.

A full description of the UNFC system can be accessed at http://www.unece.org/energy/se/reserves.html

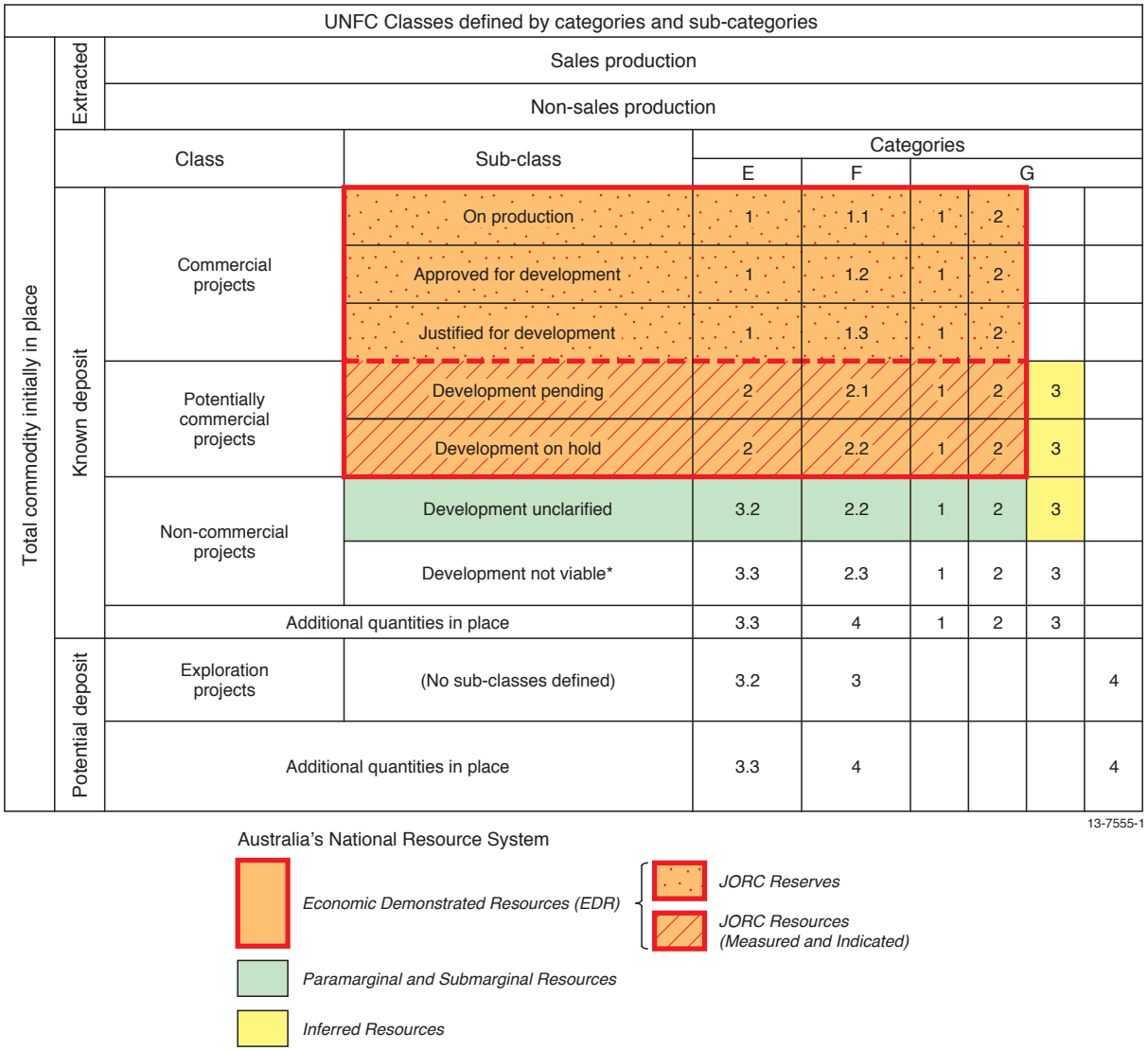

Figure A3: Correlation of Australia's national mineral resource classification system with the United Nations Framework Classification (UNFC) system.

As discussed previously (Figure A2), Geoscience Australia's EDR comprises JORC Reserves and JORC Resources where:

- the JORC Reserves component of EDR correlates with the UNFC's class of 'Commercial Projects' (as defined by mineral resource categories 111 and 112 in Figure A3); and
- the JORC Resources component correlates with 'Potentially Commercial Projects' (as defined by categories 221 and 222).
- Australia's national Subeconomic Resources (Paramarginal and Submarginal) correlate with a subclass of UNFC's 'Non-Commercial Projects' (categories 3.2; 2.3; 1,2).
- Geoscience Australia's Inferred Resources are identified by the UNFC geological criterion G3 and is defined by 223.

UNFC's mineral resource classes under 'Potential Deposits' comprise Exploration Results under the JORC Code and various types of quantitative estimates of undiscovered mineral resources which are not currently assessed under Geoscience Australia's national mineral resource system.

Appendix 2

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Credits

Photographs are from Peter Robey Photography and Geoscience Australia's Allison Britt, Alan Whitaker and Aden McKay.