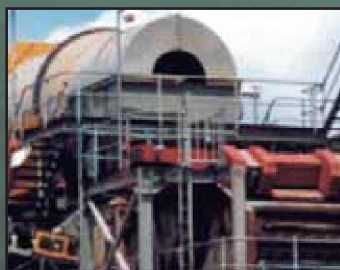
AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 1999



AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 1999

Department of Industry, Science & Resources

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ISSN 1327-1466

Australian Geological Survey Organisation (1999)

Australia's identified mineral resources 1999.

Australian Geological Survey Organisation, Canberra.

Design by Lindsay Davidson, Australian Geological Survey Organisation

Cover photograph:
Processing plant to recover diamonds at Ashton-s Merlin project, Northern Territory
Photograph courtesy of Ashton Mining Limited

Cover page for ìContentsî
MIM's Townsville copper refinery
Photograph courtesy of MIM Holdings Ltd

Foreword

In late 1998, the Australian Geological Survey Organisation (AGSO) was incorporated into the new Department of Industry, Science & Resources. This represented an amalgamation of the Department of Industry, Science & Tourism with the Resources & Energy functions of the former Department of Primary Industries & Energy. It resulted in the transfer of the Minerals & Energy and Petroleum Resources Branches from the former Bureau of Resource Sciences to AGSO. Before 1992, these branches were part of AGSO's predecessor — the Bureau of Mineral Resources, Geology and Geophysics.

AGSO's geological survey and research roles in minerals are now complemented by an important resource assessment and scientific advice and analysis role that supports informed decision-making and policy development in relation to minerals and metals issues, land use, energy, and sustainable development.

To ensure that policy makers, the mining industry, the investment sector and the general community are well informed on Australia's mineral endowment, AGSO will continue to draw on data and information from mineral exploration and mining companies to:

- provide independent advice and analysis on Australia's inventory of identified mineral resources, their rate of development, and the level of exploration activity; and
- publish key statistics and developments in 'Australia's Identified Mineral Resources'.

The MINRES database supports AGSO's resource assessment work. MINRES contains information on the locations of and resource tonnages, grades and elements in around 3000 mineral deposits; a commercially available version contains non-confidential entries for over 1500 of these deposits. MINRES is currently being redeveloped with the aims of improving both the efficiency of maintaining a high quality dataset and the ease of use of the system. During 1998 MINRES was redeveloped as an Internet-based system. During 1999, issues associated with granting easier and wider public access to MINRES will be addressed.

AGSO also underpins Government resource policy and management decisions by appraising the mineral resource potential of areas being considered for restricted land use; advising on environmental issues in relation to exploration, mining, rehabilitation, and mineral processing; and providing advice on offshore exploration and mining issues.

Neil Williams
Chief Executive Officer
Australian Geological Survey Organisation

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Plate 3 Ground vibrators at work during a deep seismic reflection survey across the northeast margin of the Broken Hill Block, as part of a study by the Australian Geological Survey Organisation and the NSW Department of Mineral Resources of the resource potential of the Bancannia Trough and Koonenbury region. (Photo courtesy of the Australian National Seismic Imaging Resource - ANSIR).

COMMODITIES REVIEW

Summary

In 1998, Australia's economic demonstrated resources (EDR) of cobalt, copper, magnesite, gold, ilmenite, nickel, platinum group metals, tantalum and vanadium increased while those of diamond, iron ore, lead, manganese ore, lithium, silver, uranium, tin and zinc diminished. The reductions in EDR were due mainly to ongoing high levels of production; commodity prices were a subsidiary factor. EDR of all other commodities remained essentially unchanged.

EDR of nickel and tantalum reached record levels in 1998. Gold increased slightly and maintained a flattening-off trend in EDR that has been evident since the mid-1990s. Black coal and bauxite EDR remained around levels established in the late 1980s and mid-1990s respectively. A decrease of almost 8% in iron ore EDR is attributable to production and a comprehensive review of resources information that became available during the year.

Australia continues to rank highly as one of the world's leading mineral resource nations. It has the world's largest EDR of lead, mineral sands (ilmenite, rutile, and zircon), nickel, silver, tantalum, uranium and zinc. In addition, its EDR is in the top six worldwide for bauxite, black coal, brown coal, copper, cobalt, gold, iron ore, lithium, manganese ore, rare earth oxides, industrial diamond and vanadium.

Mineral exploration expenditure decreased by 7% from $1148.5 million in 1996–97 to $1066.8 million in 1997–98. The biggest reductions were recorded in Tasmania (20%), Queensland (17%), Victoria (17%) and the Northern Territory (15%). Expenditure on gold was down slightly from the previous period, but still accounted for over 60% of total mineral exploration expenditure. Total expenditure on greenfields leases was 76%, which was slightly higher than in 1996–97. The decline in Australia's aggregate minerals exploration expenditure is expected to continue over the next two years, and remain at relatively subdued levels over the period to 2003–04.

Australia's mineral resources sector continued to underpin the standard of living of all Australians in 1998. As the nation's largest export earner, the minerals industry is vital to the well-being of the economy. In addition to its nationally important export performance, mining contributes significantly to the regional economies and the social well-being of communities in many parts of Australia.

In 1997–98 Australia's mineral and energy exports increased to a record of $41.2 billion, a rise of 13% over the previous fiscal year, as a result of increased production. The Australian Bureau of Agriculture and Resource Economics (ABARE) forecast export earnings to fall by just under 2% in 1998–99.

Introduction

This report presents the first annual assessment of Australia's identified mineral resources by the Australian Geological Survey Organisation (AGSO). It continues a series of national mineral resource assessments that have been published by the Australian Government since 1988.

The assessment is undertaken as input into Government policy decisions relating to the sustainable development of mineral resources. The report examines trends in resources of all major and some minor mineral commodities, and comments on Australia's world ranking as a resource nation. In addition, it comments on exploration expenditure (in current dollars) in 1997-98 and the previous five fiscal years. The current level of expenditure is put into perspective by comparing it in real terms to expenditure over the preceding 28 years.

Estimates of Australia's identified resources of all major and several minor mineral commodities are reported for 1998 (Table 1). The estimates are based on published and unpublished data available to AGSO up to the end of December 1998. The Petroleum Resources Program of AGSO provided data on petroleum resources. World data have been obtained or calculated from data in various sources, but mainly in publications of the United States Geological Survey (USGS).

The mineral resource classification used in this report reflects both the geological certainty of existence of the mineral resource and the economic feasibility of its extraction (see 'National classification system for identified mineral resources' at the end of this report). The classification category, economic demonstrated resources (EDR), is used instead of 'reserves' for national totals of economic resources because the term 'reserve' has specific meanings for individual mineral deposits under the criteria of the Joint Ore Reserves Committee (JORC) code used by industry for reporting reserves and resources. EDR also provide a basis for meaningful international comparisons of the economic resources of other nations. With few exceptions, ore is mined from resources in the EDR category. EDR are therefore depleted by mining and increased by new discoveries, and by technical and economic changes that can allow formerly subeconomic deposits to be reclassified as economic.

AGSO has prepared estimates of Australia's uranium resources within categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA; OECD/NEA & IAEA 1998). In this publication these estimates are reported under the corresponding resource categories of the national classification scheme. A correlation of the national and OECD/NEA schemes is given in the review of uranium resources.

Long-term trends in EDR for bauxite, black coal, iron ore, gold, copper, lead, zinc, nickel, and mineral sands are shown in Figure 1. EDR for these commodities have generally increased or at least been maintained since 1975 despite substantial levels of production. Much of the success in maintaining EDR can be attributed to the sustained exploration activity that Australia has enjoyed over the period and to the highly prospective nature of the continent.

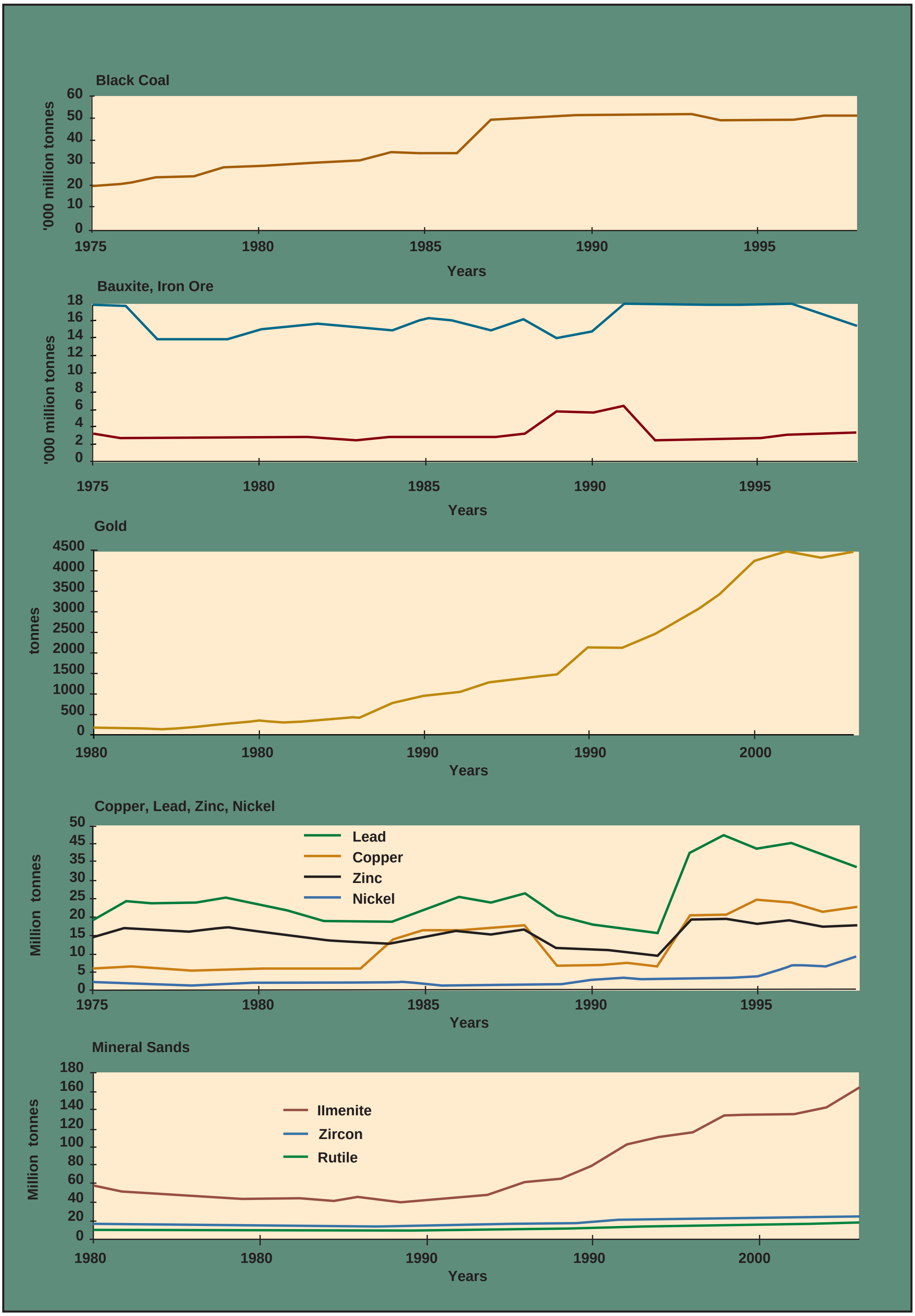
Table 1 Australia's resources of major minerals and fuels, and world figures for 1998

COMMODITY	UNITS	AUSTRALIA							WORLD	
		Demonstrated			Inferred			Mine Production	Economic Demonstrated Resources(1)	Mine production(a)
		Economic	Sub economic: Para-marginal	Sub economic: Sub-marginal	Econo-mic	Sub eco-nomic	Undifferent-iated			
Antimony	kt Sb	88.7	9.2	61.4	10.8	14.8	25.7	1.8	2100	140
Asbestos										
Chrystal Ore	Mt	—	46.24	—	—	—	75.18	—	large	
Crocidolite fibre	Mt	3169	3793	1729	—	—	2.12	—	large	1.95(k)
Bauxite	Mt	3169	3793	1729	—	—	1598	44.7	25000	125(k)
Black coal										
in situ	Gt	70.9	0.7	5.6	—	—	very large			
recoverable	Gt	51.1	0.4	3.4	—	—	very large	0.285(c)	698(0)	3.9(d)(o)
Brown coal										
in situ	Gt	45.6	1.0	2.3	—	—	184.4			
recoverable	Gt	41.1	0.9	2.1	—	—	166.0	0.065	310(0)	0.9(o)
Cadmium	kt Cd	112.6	9.5	25.5	24.4	1.5	—	na	600	19.9
Chromium	kt Cr							—		
Cobalt	kt Co	676	46.5	194.6	—	—	975.8	1.5	4,300	30.9
Copper	Mt Cu	22.5	17.4	1.1	1.2	3	10.5	0.6	356	11.9
Diamond										
gem & near gem	Mc	68	203.3	0.1	1.4	33.8	1.1 }	40.8	—	53
industrial	Mc	70.4	209.7	0.3	0.1	49.5	0.4 }		580	59
Flourine	Mt F	—	24.34	9.81	—	—	2.14	—	107(i)	2.21
Gold	t Au	4,404	1,202	124	—	—	2,470	311	45,404	2,400
iron ore	Gt	15.3	4.9	0.4	—	—	11.4	0.153	140.0	1.02
Lead	Mt Pb	17.2	4	10.7	5	15.2	0.8	0.62	66.0	3.1
Lithium	kt Li	158	79	3	—	—	7	na	3,400	16(b)
Magnesite	Mt $MgCO_3$	201.9	40	343.7	—	—	325.3	0.36	8,600	11.5(b)
Manganese ore	Mt	109.7	27.0	167.0	70	93.8	—	1.5	1952	22.1
Mineral sands										
Ilmenite	Mt	164.3	65.7	0.2	—	—	103.7	2.4	632	6.7(b)
Rutile	Mt	17.5	36.3	0.3	—	—	31.5	0.24	44.87	0.48(b)
Zircon	Mt	23.2	26.6	0.4	—	—	25.5	0.40	64.6	0.81(b)
Molybdenum	kt Mo	—	6.3	3.2	—	—	859.5	—	5,500	136
Nickel	Mt Ni	9.0	1.8	2.8	—	—	12.8	0.14	45.3	1.17
Niobium	kt Nb	10	67.6	—	—	—	1,994	—	3,500	20.4
Petroleum (recoverable)(e)										
Crude oil	GL	240	—	30	—	—	—	21.1		
Natural (sales) gas	$10^9 m^3$	1360	—	984	—	—	—	28.8		
Condensate	GL	193	—	54	—	—	—	7.7		
LPG naturally occur	GL	174	—	77	—	—	—	3.8		
Phosphate rock	Mt	88	981	—	—	—	3,739		12,000	141
PGM (Pt, Pd, Os, Ir, Ru, Rh)	t metal	36.1	13.3	28.4	3.5	94.6	3.9	na	71,000	280(1)
Rare earths										
REO & Y_2O_3	Mt	1	3.5	10.7	—	—	4.4	—	100	0.07
Shale oil	GL	—	461	3,345	—	—	41,425		na	na
Silver	kt Ag	40.6	9.2	16.1	9.5	13.3	1.6	1.5	280	16.2
Tantalum	kt Ta	18.0	5.9	0.17	—	—	72.58	na	26.02	0.44
Tin	kt Sn	100.9	19.1	182.2	—	298.0	73.4	10.2	7,700	216
Tungsten	kt W	0.98	34.22	27.99	2.47	177.61	—	—	2,000	33.5
Uranium(g)	kt U	607	—	109	147	47	—	5.790(n)	2325(h)	33.9(m)
Vanadium	kt V	190	1423	8425	700	2595	—	—	10.000	35.0(b)
Zinc	Mt Zn	34.0	10.5	18.1	10.1	10.1	0.7	1.06	190	7.8

Abbreviations: t=tonne; m^3=cubic metre; L=litre; kt= 10^3t; Mc=10^6carat; Mt=10^6t;Gt=10^9t;Gl=10^9L;na=not available.

(a) World mine production for 1998 are mostly USGS estimates.
(b) Excludes USA.
(c) Raw coal.
(d) Saleable coal.
(e) Source: Petroleum Resources Branch, AGSO(as at 31 December 1996).
(f) Source: ABARE
(g) Refer to text for comparison of resource categories in the national scheme with those of the international scheme for classifying uranium resources.
(h) Compiled from most recent resources data published by OECD/NEA and IAEA.
(i) Excludes Morocco and Brazil.
(j) Platinum and palladium only.
(k) Includes cricidolite production.
(l) Based on AGSO,USGS and other sources.
(m) Source: Ux Weekly, 8 March 1999.

Figure 1 Trends in economic demonstrated resources (EDR) for major commodities since 1975



Commodity reviews

All mining operations and most of the mineral deposits referred to in this section are shown in the 1998 edition of the 1 to 10 million-scale map of 'Australian mining operations and significant mineral deposits', which is reproduced with this report.

Bauxite

When exports of bauxite, alumina, aluminium, and semi-fabricated products are taken into account, the aluminium industry is Australia's second largest merchandise exporter, accounting for exports valued at around $6 billion in 1997–98. This is now second only to coal.

The bauxite, alumina and/or aluminium sectors are particularly important in terms of development and employment in regions such as north Queensland, southwest Western Australia, the Northern Territory, north Tasmania, the Hunter Valley, and southwest Victoria.

Resources

Vast resources of bauxite, located in the Weipa and Gove regions adjacent to the Gulf of Carpentaria and in the Darling Ranges south of Perth, underpin the long-term future of Australia's world-class alumina and aluminium industries. Deposits in these regions continue to rank among the world's largest identified resources in terms of extractable alumina content. Bauxite deposits at Mitchell Plateau and Cape Bougainville, in the north of Western Australia, are uneconomic to develop, but represent a significant, potentially viable future resource.

EDR remained unchanged in 1998, accounting for just over 30% of identified resources. Demonstrated subeconomic and inferred resources were also unchanged from levels reported in 1997. Ongoing exploration programs at and near to existing sites of production were successful in upgrading resources from inferred to demonstrated. Similarly, the addition to inferred resources occurred at a rate equal to or greater than the rate of production.

Exploration

Data relating to exploration for bauxite specifically are not available nationally.

Production

In 1997–98 Australia produced 44.9 Mt of bauxite, 13.5 Mt of alumina, and 1.6 Mt of primary aluminium.

World ranking

Based on USGS and AGSO data, Australia's demonstrated bauxite resources of 8.7 Gt rank second in the world behind Guinea and ahead of Brazil, India, and Jamaica. Australia is the largest producer and second largest exporter of bauxite, the largest producer and exporter of alumina, and the fifth largest producer and third largest exporter of aluminium.

Industry developments

During 1998, Comalco completed a major upgrade of plant at the Weipa bauxite mine. The upgrade involved replacing the haulage truck fleet, refurbishing the beneficiation plant and upgrading the Andoom mine loadout station. Under the terms of an agreement with Alcan, covering the Ely bauxite resource, Comalco commenced an exploration drilling program of this resource. The results will enable Ely bauxite to be integrated within Comalco's long range mine plan.

Comalco continues to study the feasibility of a greenfield refinery based on Weipa bauxite. Two sites are being evaluated — one near Gladstone, Queensland, and the other near Bintulu in Sarawak, Malaysia.

Nabalco Pty Ltd, manager of the Gove bauxite/ alumina joint venture in the Northern Territory, reported that the year ended 31 March the bauxite mine produced a record 6.6 Mt.

Plate 4 Roof bolting in preparation for longwall mining at Oaky Creek's second underground mine, Queensland
Photograph courtesy of MIM Holdings Ltd

Alcoa's Jarrahdale operation, the oldest bauxite mine in Western Australia, closed at the end of 1998 as a consequence of dwindling reserves and uneconomic haulage distances. Over its 35-year life, Jarrahdale produced 168 Mt of bauxite. Rehabilitation of the Jarradale mine site will be completed over the next two years.

The Huntly and Willowdale mines continue to feed Alcoa's three refineries (Kwinana, Pinjarra, and Wagerup) south of Perth. To maintain throughput at Kwinana, Huntly has been developed into a 19-Mt-a-year bauxite mine, the largest in the world. Both Huntly and Willowdale have been equipped with 'walking' crusher units, which can walk small distances over a number of days when trucking distances become too great.

Black coal

The black coal mining industry employs over 20 000 people, mostly in Queensland and New South Wales, and provides locally significant employment in Western Australia, South Australia, and Tasmania. By far the greatest use of black coal in Australia is for electricity generation. Other uses include coke-making for the iron and steel industry, and as a source of heat in the manufacture of cement.

Resources

Australia has substantial resources of both metallurgical and thermal coals with production for export being based on coal deposits in Queensland and New South Wales. In-situ EDR remained at 71 Gt in 1998. Queensland (50%) and New South Wales (47%) dominate the in-situ EDR. Black coal amenable to open-cut mining represents about 40% of in-situ EDR. About 14 Gt, or 27% of the recoverable EDR of 51 Gt, occurs at currently operating coal mines.

Subeconomic resources of black coal remained unchanged in 1998. Inferred resources are very large but not quantified for Queensland and New South Wales. An in-situ total of about 20 Gt occurs in Western Australia and South Australia.

Exploration

Exploration expenditure on coal in 1997–98 totalled $64.8 million, down from $70.5 million in 1996–97. Expenditure in Queensland and New South Wales was $32.6 million and $28.3 million respectively. The level of expenditure continued at relatively high levels, compared to the early 1990s, owing to the Queensland and New South Wales governments lifting restrictions on tendering for prospective areas, and companies planning expansion of mine capacity.

Production

In 1998, Australia produced 285 Mt of raw coal (271 Mt in 1997), which yielded 225 Mt of saleable coal (217 Mt in 1997). Exports of black coal during 1998 were 83 Mt of metallurgical coal and 84 Mt of steaming coal. In 1998, 71% of Australia's raw coal production came from open-cut mines.

ABARE forecasts Australian thermal coal exports to grow at an average annual rate of 3.5% over the next five years, up from 85.5 Mt in 1998–99 to around 101 Mt in 2003–04. Metallurgical coal exports are projected to grow at an average annual rate of 1.7%, up from 84.9 Mt to 92 Mt over the same period.

World ranking

In 1998, Australia accounted for 7% of the world's recoverable EDR of black coal and ranked sixth behind the USA (29%), the former USSR (20%), China (13%), India (10%) and South Africa (8%). Australia produced about 6% of the world's saleable black coal output in 1998 and was ranked fifth after China (35%), USA (23%), India (8%) and the former USSR (8%).

Industry developments

In New South Wales, open-cut mining of thermal coal started at the Bengalla mine near Muswellbrook, and development of a new longwall operation commenced at Wambo. The Clarence Colliery, near Lithgow, reopened as an underground bord and pillar operation, and longwall mining recommenced at the Ellalong Colliery, near Cessnock. Approvals were granted for extensions to the Cooranbong Colliery, near Lake Macquarie, and the Lemington Mine, near Singleton.

Approvals being sought for extensions to existing operations or new mines include: the Tahmoor North underground longwall mine, which will extend mining at Tahmoor for at least 20 years; the proposed Donaldson (Maitland) and Kayuga (Muswellbrook) open-cut thermal coal mines; and the Mount Pleasant and Mount Arthur North deposits, near Muswellbrook. The Mount Owen mine is evaluating the potential to expand capacity to 5 Mtpa, and the Saddlers Creek deposit is being evaluated to extend the life of the Drayton open-cut.

Queensland's newest mine is at Coppabella, near Nebo, in the northern Bowen Basin. Coal from this operation serves the pulverised coal injection market. A longwall installed at Moranbah North, also in the northern Bowen Basin, is scheduled to reach its design capacity of over 3.5 Mtpa in 1999. The Ensham open-cut and Newlands and Oaky North longwall mines are all in an expansion phase.

Feasibility studies in progress include: the Kerlong underground project, at Burton, which is examining the possibility of hydraulic mining of coal to a depth of 400m; and the Pisces thermal coal deposit, north of Blackwater in the Bowen Basin. Other feasibility studies involve the possible development of mine-mouth power stations at the Wandoan, Millmerran, Acland, and Kogan Creek thermal coal deposits, in the Surat Basin.

In Western Australia, a 300-megawatt coal-fired power station at Collie is under construction and is scheduled to be commissioned in the first half of 1999.

Infrastructure developments include the new third berth at the Koorangang Island Coal Loader expansion project, in Newcastle. The expansion has been completed, and is designed to boost the port's coal-exporting capacity by an additional 9 Mtpa to 75 Mtpa. In Queensland, the Surat Rail and Port Infrastructure Development Project has identified several rail-link options for the transport of coal from mines in the Surat Basin. They include a rail connection to the port of Gladstone or a new coal-export terminal at Coonarr, south of Bundaberg, with a rail line to Chincilla.

Technological developments and new approaches to mining include Australia's first contract punch longwall mining development at the Alliance Colliery (Oaky Creek). This mine is using conventional equipment to mine longwall coal from blocks developed directly from an open-cut final highwall. At the Norwich Park open-cut, in central Queensland, cast-blasting followed by dozing has been introduced to optimise coal uncovering and minimise rehandling. This approach is replacing some of the draglines as the major stripping method for a 12–15-m parting.

Plate 5 Copper anode casting wheel at MIM's Mount Isa smelter operation Photograph courtesy of MIM Holdings Ltd

Brown coal

Brown coal occurs in Victoria, South Australia, Western Australia and Tasmania. It is only mined in Victoria, however, where extensive resources are utilised mainly for electricity generation.

Resources

Australia's in-situ EDR (46 Gt) and inferred resources (184 Gt) remained unchanged in 1998. Victoria accounted for 94% of Australia's in-situ EDR, most of which is located in the La Trobe Valley.

Production

In 1998, Australian brown coal production was about 65 Mt, up from 61 MT in 1997. Australia produced over 7% of the world's brown coal in 1998, and was the fourth largest producer after Germany (21%), USA (17%), and former USSR (10%).

World ranking

Australia has about 14% of the world's recoverable brown coal EDR, and was ranked third behind the former USSR (32%) and Germany (14%).

Industry developments

Planning by Yallourn Energy Pty Ltd to develop a brown coal mine at Maryvale by 2004 to replace the depleted Township Field mine continues. At Loy Yang advance long-term planning aims to extend the mine from 2028 to 2048. Details of these projects were presented in BRS (1998).

Copper

Some of Australia's earliest major mines were based on rich secondary copper ores. Mines like Burra, Kapunda, Moonta, and Wallaroo, in South Australia, were major producers during the mid- and late 1800s. Australia has become a world-class copper-producing nation again over the past decade, with the discovery of major new resources. At the end of 1998, there were 15 copper mines in Australia — five in New South Wales, nine in Queensland, two in Western Australia and one each in Tasmania, South Australia, and the Northern Territory.

Resources

In 1998, EDR increased by 5% to 22.5 Mt. Reassessments of resources at several major deposits, particularly the Northparkes copper–gold mine and at Tritton near Girilambone (both in central NSW), more than compensated for production. However, total identified resources of copper decreased by 1.3 Mt or around 2%.

Exploration expenditure

Exploration expenditure for copper is not recorded separately but is aggregated with expenditure for base metals (made up copper–lead–zinc plus silver, nickel, and cobalt). During 1997–98, expenditure on base metals went against the overall downward trend, increasing by $20 million (10%). Base metals

accounted for 21% of the total exploration expenditure, amounting to $227 million. However, in the six months to December 1998, base metal exploration expenditure decreased in both the September and December quarters.

Production

In 1998, Australia's mine production was 604 000 t of contained copper, 11% higher than in 1997. Production was boosted by the start-up of the Reward open-pit, near Charters Towers (central Queensland), in July and Cadia, near Orange (central New South Wales), in August, and also by increased output from the Mount Gordon operations (formerly Gunpowder) and the Ernest Henry mine (both in north Queensland), and Nifty, in the east Pilbara (Western Australia).

Exports of copper, amounting to about 490 000 t of contained metal, contributed a little over $1.3 billion to the Australian economy in calendar 1998, and represent about 3% of all export earnings from minerals.

World ranking

Australia has the world's third largest EDR of copper (6%), after Chile (25%) and USA (16%). As a copper producer, Australia ranks fifth in the world after Chile, USA, Indonesia, and Canada.

Industry developments

At Mount Isa, expansion and upgrade of the Mount Isa copper smelter to more than 250 000 t per year was near completion at the end of the year. This will accommodate mine production from MIM's 51%-owned Ernest Henry mine as well as production from Mount Isa. The development of the 1800-m-deep Enterprise operation at Mount Isa was more than 50% complete at the end of the year. Enterprise will provide continuity of sources of ore grading about 4% copper for ten years, and the development should be fully operational by early calendar 2000.

By the end of August 1998, the Ernest Henry copper–gold mine had completed its first 12 months of operation; commercial production was declared in May 1998, following its commissioning phase. Ernest Henry will produce about 95 000 t of copper per annum at full capacity.

In October 1998, Western Metals Limited completed a takeover of Aberfoyle Limited, and acquired that company's business interests, including the Mount Gordon copper project (formerly known as Gunpowder), in northwest Queensland. Western Metals announced the discovery of the new Mammoth No. 2 lens, which has an inferred resource of 1.1 Mt of chalcocite ore grading 5.8% copper. The combined measured, indicated, and inferred resources of the Mount Gordon district were put at 15.4 Mt at a grade of 4.9% copper as at the end of December 1998. Production increased strongly in the December quarter; output was made up of 10 000 t of direct shipping chalcocitic ore grading 30.1% copper, and a further 100 500 t of ore grading 10.8% copper. About 4250 t of copper cathode was produced at the electro-winning plant.

At the Reward open-pit mine near Charters Towers, mining of 0.45 Mt supergene- enriched copper ore averaging 10.8% copper commenced in mid-July, and treatment and production of copper concentrates began at the nearby Thalanga mill a few days later. Production at year end was running at around 5000 t of contained copper per month, and mining of this ore is expected to be completed by May 1999.

When completed in early 1999, the $1.94 billion Olympic Dam (South Australia) expansion project of WMC Limited will triple annual production capacity to over 9 Mt of ore, which will yield 200 000 t of copper to be refined at the Olympic Dam plant. These production levels should be achieved by late 1999.

In Western Australia, Straits Resources Limited completed the acquisition of Nifty Copper operations from WMC Resources Limited in November 1998. Overall, reassessment of the resource inventory by Straits resulted in an increase in inferred resources of about half a million tonnes of contained copper. Leachable copper resources at Nifty in the measured, indicated, and inferred categories aggregated 20.5 Mt grading 1.43%

copper, while measured, indicated, and inferred resources of primary sulphide ore totalled 73.5Mt at 1.75% copper, for a combined grand total resource of about 94 Mt at an average grade of 1.68% copper.

In October, Normandy Mining Limited reported that reserves and resources at the Gecko mine, near Tennant Creek (Northern Territory), were expected to be depleted in late 1998.

In early December 1998, the directors of the Mount Lyell Mining Company Limited announced that they had appointed an Administrator of its affairs and those of its wholly owned subsidiary Copper Mines of Tasmania Pty Ltd. An announcement to the Australian Stock Exchange on 11 December by Macmahon Holdings Limited stated that the mining contract for the underground mining of copper at Mount Lyell was due to expire on 31 January 1999, and that Macmahon Holdings had been asked by the Administrator to continue for the time being under its current mining contract.

Plate 6 Open pits developed to access ore at the Merlin diamond project, Northern Territory
Photograph courtesy of Ashton Mining Limited

Diamonds

Resources

In 1998, EDR decreased by 2.3 Mc (3%) to 68 Mc for gem/near gem diamond and 1.2 Mc (2%) to 70.4 Mc for industrial diamond compared with 1997. However, total identified resources for gem/near gem and industrial diamond increased by 2 Mc (1%) to 307.7 Mc and by 4.3 Mc (1%) to 330.4 Mc respectively. Production and delineation of additional resources at Argyle in Western Australia accounted for most of these changes.

Exploration

Data relating to exploration for diamond specifically are not available nationally.

World resources and production

Australia's EDR are the world's third largest for industrial diamond, after the Republic of Congo and Botswana. Detailed data are not available on world resources of gem/near gem diamond, but Australia has one of the largest stocks for this category. Australia's diamond production is the largest in the world for both gem/near gem and natural industrial diamond categories. Production, mostly from the Argyle open-pit, is bolstered by a minor contribution from the nearby Argyle alluvials operation. Copeton (NSW) also recorded minor production.

Industry developments

The Argyle mine AK1 Stage One open-pit expansion, in northwestern Western Australia, commenced in late 1998, and further pit expansions are planned. A new deep drilling program is scheduled for 1999, and studies are continuing on sublevel underground mining, which may be implemented late in the next decade. Alluvial diamond production at Argyle is scheduled to wind down toward the end of 1999, although additional alluvial sources are being investigated.

Mining operations at the Merlin project in the Northern Territory started in November 1998 and the first diamond concentrate was produced at the end of January 1999. Of the 3306 c of diamond produced, a large selection of the stones is greater than one carat, including a 14.76-c white gem-quality stone. Pits have been developed on the southern cluster of pipes including Sacramore, Launfal, Palomides and Excalibur. Processing of 1.5 Mt of ore over 2.5 years from seven of the 12 Merlin pipes will facilitate decisions on increasing the processing plant size, underground mining, and viability of mining other Merlin pipes.

Gold

Resources

Australia's gold resources are mined in all States and the Northern Territory. In 1998, resources increased in all categories except demonstrated submarginal, which remained unchanged. The increases, however, were modest with total resources increasing by 164 tonnes (2%). Maintaining gold resources at such levels in the future may be thwarted by falling exploration expenditure.

Australia's EDR of gold rose by 52 t (1%) to 4404 t in 1998. Despite the increase, EDR remained below the record level of 4454 t established in 1996. EDR is a combination of resources from the JORC Code reserves categories and those resources from the JORC measured and indicated resources categories assessed by AGSO as being economic. In 1998, 62% (2709 t) of EDR was derived from the JORC Code reserves categories. This compares with almost 58% in 1996.

Western Australia increased its dominance to 58% of Australia's total EDR (up from 55% in the previous year — an increase of 147 t to 2547 t). South Australia maintained its position as the State with the second largest EDR, but it remained almost unchanged in 1998. New South Wales further consolidated its standing as the third largest EDR; its increase of 79 t to 461 t represented a growth of 17%. Despite a 10% reduction in its stock of EDR, Queensland surpassed the Northern Territory as holder of the fourth largest EDR stock, and in 1998 held 243 t (268 t in 1997). EDR in the Northern Territory fell to 161 t, mainly as a result of the reclassification of Mount Todd resources into a lower category. Developments since the end of 1998 have raised expectations that mining may be resumed at this site. Victoria's EDR was unchanged at 72 t, and that for Tasmania fell by 34% to 50 t.

Subeconomic demonstrated resources remained at 16% of total identified resources. They totalled 1326 t in 1998; 1308 t in 1997. Of the 1998 total, 1202 t was in the paramarginal category and 124 t in the submarginal category.

As in 1997, paramarginal resources were dominated by Western Australia (813 t). Small increases (less than 10 t) were recorded in the Northern Territory, South Australia, Tasmania, Victoria, and New South Wales. In Queensland, paramarginal resources fell by 4 t.

Submarginal resources were unchanged in total at 124 t in 1998. Increases totalling 5 t in Queensland, New South Wales, and Victoria were evenly balanced by reductions totalling 5 t in Western Australia and the Northern Territory. South Australia and Tasmania remained unchanged.

Overall, Australia's inferred resources rose by 94 t (4%) to 2470 t in 1998. Increases in Western Australia, South Australia, and Tasmania were offset by reductions in New South Wales, Victoria, and the Northern Territory. The growth in Western Australia resulted from many minor variations and significant resources at new deposits such as Wallaby and Just in Case. In New South Wales, the reduction was due mainly to the reclassification of resources from the inferred to the demonstrated category (e.g., at the Ridgeway deposit, Cadia).

Exploration expenditure

According to four quarterly figures published by ABS, Australia's total mineral exploration expenditure in 1998 was $958.5 million. Of this, $561.8million (58.6%) was attributed to the search for gold. Expenditure on gold exploration was down by $174.8 million compared with 1997, and also held a smaller share of the overall exploration expenditure at 58.6% compared with the 1997 level of 63%.

Western Australia dominated gold exploration expenditure by contributing almost $410 million (73% of the Australian total). Expenditure in the other States was: Northern Territory, $39.7 million (7.1%); Queensland, $36.3 million (6.5%); Victoria, $29.9 million (5.3%); New South Wales, $24.2 million (4.3%); South Australia, $17.9 million (3.2%); and Tasmania, $3.9 million (0.7%).

Production

Preliminary production data from ABARE show Australian gold output to be unchanged in 1998 at 312 t. Western Australia remained the dominant producer with an output of some 234 t (75% of total production), slightly lower than in 1997. Ranking of the other States and the Northern Territory remained unchanged in 1998. Queensland was the second largest producer with an estimated 32 t, followed by the Northern Territory (20 t), New South Wales (15 t), Victoria (5 t), Tasmania (4 t), and South Australia (1 t).

Production in New South Wales rose by about 30% due mainly to the Cadia project coming on stream during the year and producing in excess of 100 000 ounces. About 5% of Australia's gold production came from operations at which gold was not the primary commodity recovered.

ABARE has forecast that gold production will be 308 t for the 1998–99 financial year, 313 t in 1999–2000, and after a steady reduction, 294 t in 2003–2004.

World ranking

World resources and production rankings remained unchanged in 1998. South Africa, the USA, and Australia occupied the first three positions in both EDR and production.

According to AGSO and USGS data, world EDR of gold in 1998 was 45 404 t. Australia had the third largest EDR with 10%. South Africa was ranked first with 41% followed by the USA with 12%. Both the share of resources and rankings of these countries remained unchanged from 1997. Russia had the fourth largest EDR with 7%.

USGS estimate of world gold production in 1998 was 2400 t. South Africa remained the world's leading producer with an output estimated by the USGS at 465 t (19.4% of the world total compared with 21.2% in 1997). The USA retained its ranking as the world's second largest producer with 350 t (14.6% of the total) and Australia was again ranked third with 312 t (13% of the total). Canada, with 155 t (6.5%) was the fourth largest producer.

Industry developments

Although gold prices in Australian dollar terms were slightly better in 1998 than in 1997, they remain low. Despite this situation there has been considerable activity in the industry during the year.

Delta Gold NL commenced mining at its Golden Feather project, near Kalgoorlie (WA), during the year. Production started after an agreement was reached with Goldfields Kalgoorlie Limited to process Golden Feather ore at Goldfields' Paddington CIL plant. Delta announced that it planned to produce at least 200 000 ounces of gold from 1.5 Mt of ore in campaigns starting in December. Under the agreement, Delta is to pay an access fee, meet all plant operating costs, and spend $2 million upgrading the Paddington plant to handle the higher grade ore from Golden Feather.

Mining also commenced at the Cornishman project, 4 km south of Southern Cross (WA), during the year. The first gold was poured in the December quarter at the Bullfinch plant, and just over 16 000 ounces were poured in that quarter. Cornishman is a joint venture between Sons of Gwalia Limited (51%; project manager) and Troy Resources NL (49%).

Operations at the Mount Olympus mine, near Paraburdoo in the Ashburton region (WA), began late in the year, and the first gold was poured on 31 December 1998. The operation is using the plant relocated from the former Lynas Find operation. It is expected that the mine will yield some 175 000 ounces of gold over three years at an average cash cost of A$250/ounce. Ownership of the project is Sipa Resources International NL (45.5%), Lynas Gold NL (35%), and Arcadia Minerals NL (19.5%). Lynas Gold is the production manager for the operation.

In a major development at the Boddington mine, south of Perth, the Boddington Gold Mine Joint Venture partners agreed with Alcoa of Australia Limited and Hedges Gold Pty Ltd to acquire for $15 million all mineral rights over the Hedges gold mine's worked areas and some of an adjoining

exploration licence. An important consequence is that a comprehensive evaluation of basement mineralisation at Hedges can now be undertaken with a view to it being part of a fully integrated development of the Wandoo resource. During the December quarter approval was given for an updated feasibility study on the Wandoo project at a cost of $4.6 million. The study is to be completed by the end of 1999, and a decision on the project will be taken soon after. The Boddington Gold Mine Joint Venture partners are Normandy Mining Limited (44.44%), Acacia Resources Limited (33.33%) and Newcrest Mining Limited (22.22%).

Newcrest Mining Limited's Cadia operation (NSW), came into production during the year. The first gold was poured in the June quarter. A decline being developed to access the Ridgeway deposit at Cadia was well advanced at the end of the year, and should intersect the first ore in 1999.

In an interesting development at its McKinnons mine (NSW), Burdekin Resources NL completed trial milling of stockpiled material which had been classified as mineralised waste and excluded from its resource inventory. About 850 000 t of oxide material is in the stockpile. By the end of the year the company had successfully treated some 360 000 t of this material, and had completed a revised estimate which showed that the stockpile had 545 000 t of oxide and 50 000 t of sulphide ore.

Successful exploration continued in all States and the Northern Territory. Mineralisation and/or resources were extended at many sites — including for example: Fosterville, Vic. (Perseverance Corporation Limited); Peak Hill, NSW (Alkane Exploration NL); Gympie, Qld (Gympie Gold Limited); Tanami joint venture, NT (Acacia Resources Limited and Otter Gold Mines Limited); Sunrise Dam, WA (Acacia Resources Limited); Challenger, SA (Dominion Mining Limited and Resolute Limited); and Henty, Tas. (Goldfields Limited).

Separate tenement applications have been lodged by Mt. Kersey Mining NL and Johnson's Well Mining NL over large areas of land in central Australia. Mt. Kersey's application covers some 39 000 km2 and Johnson's Well's covers 24 000 km2. The companies plan to explore for gold in sedimentary basins they believe are similar to the Witwatersrand Basin, in South Africa.

Iron ore

Iron ore is the raw material for the production of iron that is mostly further processed to produce steel. Although the production of iron and steel accounts for most of the iron ore consumed in Australia and the rest of the world, small tonnages are used in a variety of applications — including pigment manufacture, coal washeries, and cement manufacture.

A major review of Australia's iron ore resources by AGSO during 1998, resulted in a significant reduction in the level of resources in all categories except the submarginal resource classification, which showed a small increase. Just over 93% of all Australian iron ore resources occur in Western Australia, mostly in the Hamersley Basin in the Pilbara region.

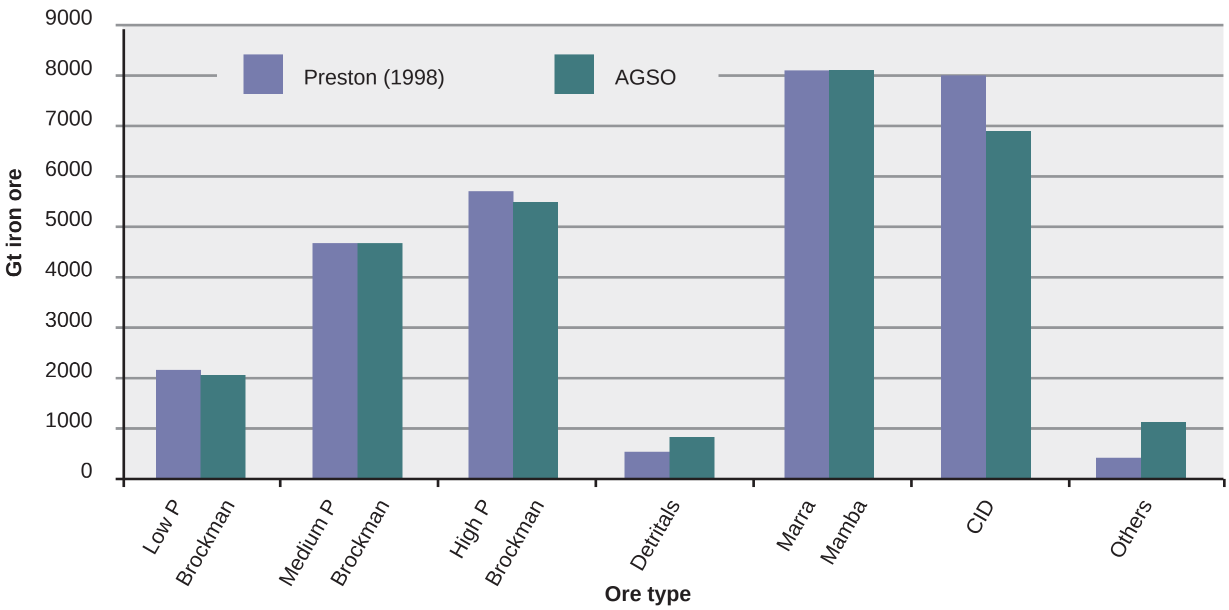
AGSO's review of Western Australian resources confirms the results published by Preston (1998). A comparison of the two reviews is shown in Figure 2. Several important points should be noted about the information portrayed in this figure.

The first is that it represents total resources, including inferred resources. Therefore, there will be a need for ongoing delineation of inferred resources by the industry in order to upgrade them to higher categories necessary to support classification as reserves, and of course not all resources will be upgraded. Secondly, the high phosphorus Brockman Iron Formation ores are currently not a saleable product. Without significant advances in technology at either the ore preparation or iron- and steel-making processes, these ores are likely to be used only in very small quantities in blended products at best. Thirdly, the 'others' category is small, and includes resources outside the Hamersley Basin. Although these resources are important to local communities and to the nation, they are too small to have a major impact on the long-term future of the industry. Not included in the 'others' category are some 650 Mt of resources in titanomagnetite deposits. Owing to the limited levels of low phosphorus Brockman ore, the source of most high-grade lump ore for export, the detritals (a source of lump ore), will be an important resource in the future. Even so, they are too small to impact substantially on the industry's long term outlook.

The future of the industry then is linked to four major groups — low- and medium- phosphorus Brockman Iron Formation ores (e.g., Mount Whaleback, Mount Tom Price, and Paraburdoo), Marra Mamba Iron Formation ores (e.g., Orebody 29, West Angelas, Hope Downs, and Marandoo), and Channel Iron Deposits (CID; e.g., Robe River, Yandi, and HI Yandi). The low phosphorus Brockman resources are the source of the premium high-grade lump ore that has been the backbone of the iron ore export industry in Western Australia since the late 1960s. Clearly, however, these resources have a limited life if production is maintained at current rates. Medium-phosphorus Brockman ores have traditionally been used as blending ores with the low-phosphorus ores. This situation is likely to continue.

From this resource base, it is apparent that the Marra Mamba and CID ores will provide the long-term base for the industry. They are two quite different ore types. The Marra Mamba ore is a hematite and goethite mix capable of producing limited lump ore that may partly substitute for the premium Brockman lump ore, but does not have equivalent chemical or physical properties. A large proportion of Marra Mamba ore will be in the form of fines, which are generally lower in alumina than fines generated from the Brockman ores.

Figure 2 Western Australian iron ore resources 1998



CIDs have been exploited at the Robe River operations for many years, and in recent years successful marketing has seen the BHP and Hamersley Iron Yandi mines come on stream. These resources are used principally as sinter feed. The origins of CIDs would suggest that composition may not be as consistent as with the Brockman of Marra Mamba ores across deposits, but internally deposits are reasonably consistent. The substantial stock of CID resources should ensure that they will be an important component of Western Australia's iron ore exports over the long term.

Over the next two to three decades, there will be a significant change in the composition of Western Australian iron ore production that will reflect the depletion of the premium ores and the growing importance of Marra Mamba and CID ores.

Resources

Australia's EDR fell by almost 8% in 1998. Although production accounts for some of this reduction, a comprehensive review generated many revised estimates of resources. In 1998, virtually all of Australia's EDR were in Western Australia. Small tonnages occur in South Australia, Tasmania, and New South Wales. Most of the reduction in EDR occurred in Western Australia (down by 7.6%), and resulted from a loss of resources to production and new resource estimates being made available to AGSO. Tasmanian EDR remained steady. South Australian EDR more than halved, but this was due to new data becoming available rather than a major downgrading of resources. South Australia has the potential to see EDR delineated in areas outside of the Middleback Ranges as work continues on the South Australian Steel and Energy project (SASE). To date, however, all published data for deposits being investigated as part of SASE are classified as inferred resources, and thus are ineligible for inclusion in EDR or any other category of demonstrated resources.

Australia's subeconomic demonstrated resources (SDR) fell by 63% in 1998. Much of the fall was due to companies reclassifying resources from the demonstrated to the inferred category, and some was due to SDR being upgraded to EDR by AGSO. Almost all the reduction in SDR occurred in Western Australian deposits. Small variations occurred in all other states except Tasmania.

Inferred resources fell by almost 40% to just under 11.4 Gt, due mainly to a reduction of over 6 Gt in Western Australia. The reductions were a consequence of new information becoming available to AGSO.

Exploration expenditure

According to quarterly ABS figures, expenditure on iron ore exploration in 1998 was $45 million. This represented an increase of 68% over the previous year. As in past years, comprehensive State-by-State data are not published by ABS, but, most of the expenditure was in Western Australia.

Production

Australian iron ore production in 1998 is reported by ABARE as 155.7 Mt, a reduction of 1% over 1997. Of the total, 148.9 Mt (95.6%) was won in Western Australia, 2.5% in Tasmania, and 1.9% percent in South Australia. Minor production of iron ore for non-steel industry use occurred in New South Wales and Queensland.

World ranking

According to USGS estimates modified by AGSO to account for revised Australian estimates, Australia has some 11% of world EDR of iron ore. This is slightly higher than the 1997 estimate of 10%. Australia has the world's fourth largest EDR after China, Ukraine, and Russia. In terms of iron contained in the EDR, Australia has some 12% of the world's EDR and is ranked third after the Ukraine and slightly behind Russia. China is ranked fourth, a position, which reflects the lower grade of its resources.

Industry developments

The depressed state of the Asian steel sector hindered development within the Australian iron ore industry during the year under review. BHP decided not to proceed with the development of its Orebody 18 in the Newman district. The company is keeping the project under review, but a restart will depend on improved market conditions. The Mid West iron and steel project's on-site preparation work at Oakajee, near Geraldton, also ceased as a consequence of the Asian financial crisis.

Sharing infrastructure is an issue that has important implications for many potential developments in the industry. In a first test, to facilitate development of its West Angelas deposits, Robe River Iron Associates is seeking access to a railway line owned by Hamersley Iron Pty Ltd. Robe made application to the National Competition Council for it to recommend to the Commonwealth Treasurer the declaration of a bulk iron ore track transportation service. If successful, Robe would have access to parts of Hamersley's rail facilities to support the West Angelas project.

BHP completed the under-harbour tunnel link between its Nelson Point and Finucane Island facilities at Port Hedland in March 1998. The tunnel will be used to transport ore from Nelson Point to the Finucane Island ship-loading facilities and the company's hot briquetted iron (HBI) plant. Work on the HBI plant continued during the year, and, by year's end, production of the first metal was expected in early 1999.

A South African company, Iscor Ltd, has joined Hancock Prospecting Pty Ltd to investigate the possible development of the Hope Downs deposit, in the Pilbara district. It is expected that a two-year feasibility study will cost in the order of $20 million with ISCOR meeting 80% of the cost to earn 49% interest in the project. Hope Downs is one of several Marra Mamba Iron Formation deposits currently under consideration for development by various companies. The project has three deposits — Hope Downs 1, 2, and 3 — which all have Marra Mamba ore. Hope Downs 3 also has Brockman Iron Formation ore. Hancock Prospecting have noted that the Marra Mamba ore in Hope Downs 1 has low impurities, low stripping ratios, and about 40% lump fraction; tests have indicated the lump ore would perform well in blast furnaces.

BHP continued work on its Mining Area C deposits to the west of Newman. An environmental management plan for the project was released for comment during the year. Heritage surveys of both the proposed mining and access areas have been completed and the company reported that it is studying a number of mining, processing, and ore-handling options.

The Western Australian Government approved extended mining operations at Hamersley Iron's Brockman mine, in the State's Pilbara region. The mine is located some 50 km northwest of the company's Mount Tom Price mine. The extended operation will be mining in-situ bedded ore from an area adjacent to the Brockman No. 2 detritals orebody. Production will be at the rate of 4 Mt of ore per year. Hamersley will operate the mine with it's own employees rather than contractors.

In February 1998, Rio Tinto Ltd announced that research had resulted in an important breakthrough in the HIsmelt iron-making process. The breakthrough came from the replacement of a horizontal vessel with a new water-cooled vertical vessel, which simplified engineering issues, increased the life on the refractory bricks lining the vessel, and overall increased reliability of the process. Rio Tinto stated that the process would allow the use of Pilbara iron ores that previously were difficult to use because of the high levels of undesirable constituents, namely silica, alumina, and phosphorus. HIsmelt allows silica and alumina to be contained in slag and thus separated from the liquid iron. Following successful demonstration of the process, it is planned to build an intermediate-sized plant at an international site to be determined.

In an interesting development Westralian Sands announced plans to build a prototype plant at its Capel mineral sands operation to produce high-quality pig iron from wastes from its synthetic rutile plant. Construction of the plant is expected to begin during 1999.

Lithium

Resources

All of Australia's lithium resources occur in Western Australia, and all EDR occur in the Greenbushes deposit at the town of Greenbushes in the State's southwest. EDR fell by almost 3% to just over 158 000 t in 1998, due mainly to loss of resource to production. Greenbushes is the world's largest and highest-grade spodumene ($Li_2O.Al_2O_3.4SiO_2$) resource.

SDR and inferred resources were unchanged in 1998.

Exploration expenditure

There are no statistics available on exploration expenditure for lithium in 1998. In view of the current world oversupply of lithium resources, particularly in the form of lithium rich brines, it is unlikely that there will be substantial exploration expenditure in Australia in the near future.

Production

Sons of Gwalia Limited remained the world's largest producer of lithium minerals in 1998. Production for the year was 68 666 t, about 22% less than in 1997. The reduction in output was in response to a significant oversupply in the world lithium carbonate market resulting from production at brine operations in Chile and Argentina.

World ranking

According to estimates published by the USGS, Chile holds about 88% of the world's lithium resources, followed by Canada with just over 5% and Australia with just under 5%. Resource data, however, are not available for some important producing countries including — Argentina, China, and Russia. Lithium resources occur in two distinct categories — lithium minerals and lithium-rich brines. Lithium brine resources, now the dominant feedstock for lithium carbonate production, are dominated by Chile. Canada and Australia dominate resources of lithium minerals.

World production of lithium in 1998 was estimated by the USGS to have been 16 000 t of contained lithium. This was an increase of 2000 t over the 1997 estimate. For both these statistics, USA production is withheld by the USGS for commercial reasons. Most of the world increase is due to growth in output in Argentina (up by 992 t to 1000 t) and Chile (up by 400 t to 4500 t). Chile (with 28%) remained the world's largest producer, followed by China (18%), Australia (13%) and Russia (12.5%).

Industry developments

No significant developments occurred in the Australian lithium industry in 1998. Faced by a substantial world oversupply, Sons of Gwalia reduced production, but reported that in the 1997–98 financial year its lithium operation at Greenbushes remained profitable and cashflow was positive.

Magnesite

Resources

EDR of magnesite increased by about 6% to 202 Mt in 1998. The bulk of this increase occurred in South Australia, where Pima Resources NL has identified in excess of 120 Mt of magnesite in the Willouran Ranges, northwest of Leigh Creek.

The largest Australian EDR of magnesite occur at Kunwarara, 70 km northwest of Rockhampton (Qld). Although some 2.4 Mt of ore was mined in 1998, further infill drilling and reclassification of resources resulted in EDR increasing by about 2%. The Kunwarara deposit contains substantial accumulations of very high-density 'bone-type' magnesite, which is characterised by a nodular and cryptocrystalline structure and low iron content.

The Thuddungra mine, 80 km northwest of Young (NSW), did not operate in 1998. Magnesite from this mine, which typically contains 98–99% $MgCO_3$, is processed at Young.

The second largest EDR of magnesite are in Tasmania, where the Arthur River deposit contains an indicated resource of 29 Mt of magnesite. The magnesite has a grade of 42.8% MgO and is part of a much larger resource of 180 Mt in the Arthur–

Lyons River area, about 53 km south of Burnie. A small EDR of magnesite occurs in the Ravensthorpe area in southeast Western Australia

SDR, which account for around 42% of total identified resources, rose by 34 Mt during the year. All the increase was in the paramarginal category and recorded in South Australia and Tasmania. Submarginal demonstrated resources in 1998 totalled in excess of 340 Mt, unchanged from the previous year. All these resources are located in Queensland.

Inferred resources rose by 67% to a record level of 325 Mt in 1998. South Australia and Tasmania recorded the largest increases as a result of recent discoveries. South Australia with 39% has the largest inferred resource followed by Queensland (31%) and Tasmania (25%).

Exploration

Data relating to exploration for magnesite specifically are not available nationally.

Production

During 1998, Queensland Metals Corporation Limited mined 2.4 Mt of crude magnesite ore at Kunwarara, which was beneficiated to produce about 345 000 t of magnesite. This material was used to produce 102 000 t of deadburned magnesia, about 17 500 t of calcined magnesia, and 27 300 t of electrofused magnesia. These products are used for the manufacture of high-quality refractory bricks, which are for lining heat-containment vessels in the steel, cement, non-ferrous, and chemical industries.

World ranking

According to USGS estimates, Australia has about 2% of the world's EDR of magnesite. China, Russia, and North Korea together account for over 70% of the world's EDR of magnesite. The Kunwarara deposit, however, is the world's largest known resource of cryptocrystalline, nodular magnesite, a high-quality ore by world standards.

Australia accounted for 3% of the world's production in 1998. Turkey (with 19%) was the world's largest producer, followed by China (18%) and North Korea (14%).

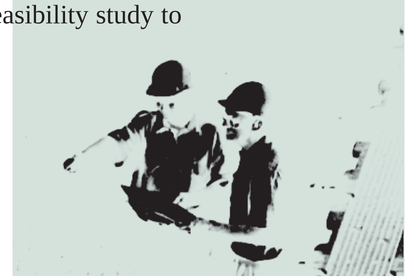
Industry developments

With an increasing trend towards lightweight automobiles and hence an increase in the usage of magnesium metal in automobile parts, the demand for magnesium metal is forecast to rise. This has resulted in an abundance of new project proposals to produce magnesium metal.

In the second half of 1998, Australian Magnesium Corporation (AMC), jointly owned by Normandy Mining Limited and Queensland Metals Corporation, commenced operation of a 1500 tpa demonstration plant at Gladstone (Qld). The purpose of the plant is to trial the magnesium technology developed by CSIRO, to develop design criteria, and to validate all environmental operating parameters for a proposed commercial plant. AMC expects to commit to the construction of a commercial plant at Rockhampton during the third quarter of 1999. Magnesium metal production from the plant is anticipated to start in late 2002; full production should be achieved by late 2004.

In Tasmania, Crest Magnesium NL (formerly Crest Resources Australia NL) is continuing with its evaluation of the Arthur River magnesite project. The first stage involves mining 300 000 tpa of raw magnesite ore which will be upgraded by a single-stage beneficiation process to 45% MgO. The second stage involves production of magnesium metal. The company has negotiated an option to acquire a license to use proven magnesium metal production technology from the Ukrainian National Research and Design Titanium Institute in Zaporozhie. Crest Magnesium has also entered into an agreement with Multiplex Constructions to construct a 95 000 tpa metal plant in the Bell Bay region, in northeast Tasmania.

Golden Triangle Resources NL has commenced a scoping study of a $700 million 80 000 tpa magnesium plant based on magnesite deposits at Main Creek and Bowry Creek, south of Burnie. The company is also carrying out a feasibility study to



produce magnesium metal from the Woodsreefs serpentinite tailings, in northern New South Wales.

In the Northern Territory, Mount Grace Resources NL is undertaking a prefeasibility study of a proposed magnesium project based on their Batchelor magnesite deposit, located about 80 km south of Darwin.

Magnesium Developments Ltd plans to complete a feasibility study by mid-1999 into a proposed magnesium plant with a potential capacity of 52 500 tpa of magnesium or magnesium alloys. This project is based on the magnesite resource in the Willouran Ranges, northwest of Leigh Creek (SA).

Manganese ore

Australia's resources of manganese ore are the basis of a major mineral export sector, as well as a significant domestic ferromanganese, silicomanganese, and manganese dioxide processing industry. The value of exports of manganese ore decreased by about 20% in 1998 to around $166 million.

Resources

In 1998, Australia's EDR of manganese ore decreased by about 3% from 112.9 Mt to 109.7 Mt. This was mainly due to the depletion of resources as a result of mining at Groote Eylandt (NT). During the period there were no significant changes to either SDR or inferred resources.

Exploration

Data relating to exploration for manganese specifically are not available nationally.

Production

Lower production from Groote Eylandt, coupled with the absence of manganese ore production from the east Pilbara district (WA), resulted in manganese ore production falling by about 35% to 1.5 Mt with a grade of about 49% manganese.

World ranking

According to combined USGS and AGSO data, Australia has an estimated 11% of world EDR of manganese ore, and is ranked third after South Africa and the Ukraine. Australia is the world's sixth largest producer of manganese ore after China, South Africa, Ukraine, Gabon, and Brazil. In 1998, Australia produced an estimated 10% of world output.

Industry developments

With the closure of the mining and processing operations at Woodie Woodie in the east Pilbara district in October 1997, Australia's only operating manganese mine is on Groote Eylandt. This deposit, discovered in 1961, is a world-class resource from which manganese ore is mined for both domestic use and export. To date, the mine has produced about 47 Mt of high-grade (49% Mn) ore.

In late1998, BHP announced the sale of its manganese mining operations on Groote Eylandt to Billiton Plc. The sale also included BHP's share in the Tasmanian Electro Metallurgical Co. Pty Ltd ('TEMCO').

Mineral sands

The principal components of mineral sands are the titanium minerals — rutile and ilmenite, — and zircon. Rutile and ilmenite are mainly used in the production of titanium dioxide pigment; a small portion, less than 4% of total titanium mineral production — typically rutile — is used in making titanium sponge metal. Zircon is consumed as an opacifier for glazes on ceramic tiles, in refractories, and for foundry industry.

Resources

EDR of ilmenite increased substantially during 1998, up from 143.5 Mt in 1997 to 164.3 Mt, an increase of 14.5%. The bulk of the increase (96%) is accounted for in Western Australia, where Australia's largest ilmenite resources occur. Apart from some minor increases in the northern and southern Swan Coastal Plain resulting from infill drilling, most of the Western Australian increase occurred in the Blackwood Plateau/Scott Coastal Plain in the southern part of the State.

Continuing successful exploration in the Murray Basin in northern Victoria and New South Wales resulted in the ilmenite EDR increasing by 19% in Victoria and by 27% in New South Wales.

EDR of rutile (which includes leucoxene in WA) decreased by about 30 000 t to 17.5 Mt in 1998. The largest decrease occurred in Western Australia, notably in the Southern Swan Coastal Plain and Blackwood Plateau / Scott Coastal Plain regions, where leucoxene is more abundant than rutile. Western Australia and Queensland together hold 86% of Australia’s EDR of rutile.

EDR of rutile in Victoria and New South Wales increased by 21% and 13% respectively. All of the increase occurred in the Murray Basin.

EDR of zircon decreased marginally by about 40 000 t to 23.22 Mt in 1998. Increases in EDR in Victoria and New South Wales failed to compensate for decreases in Western Australia and Queensland, which together have 92% of Australia’s EDR of zircon. EDR of zircon in Victoria and New South Wales increased by 17% and 7% respectively; all of this increase occurred in the Murray Basin.

Some 19%, 26% and 31% of Australia’s EDR of ilmenite, rutile, and zircon respectively are unavailable for mining. Areas quarantined from mining and now largely incorporated into national parks include: Moreton, Bribie, and Fraser Islands (Qld); Cooloola sand mass north of Noosa (Qld); Byfield sand mass and Shoalwater Bay area (Qld); and Yuraygir, Bundjalung, Hat Head, and Myall Lakes National Parks (NSW).

SDR of ilmenite, rutile, and zircon declined by 1.8%, 1.4%, and 1.2% respectively to 66.95 Mt, 36.35 Mt, and 26.91 Mt in 1998. The bulk of the decrease occurred in the Murray Basin in southwest New South Wales after further drilling upgraded deposits from this category to EDR.

Inferred resources of ilmenite increased by just over 6% to 103.7 Mt in 1998. Increases occurred in Queensland, New South Wales, Victoria and South Australia. Victoria has the largest inferred ilmenite resource with 37% of the Australian total. Western Australia with 29% is ranked second followed by Queensland with 23%.

Inferred resources of rutile and zircon increased marginally by 4.3% and 5%, respectively. Most of the increase occurred in New South Wales, Victoria, and South Australia; a small increase occurred in Western Australia. Victoria, the main holder of rutile and zircon, has inferred resources of 77% and 64% respectively of the total. Queensland with 8% (rutile) and 16% (zircon) is the second largest holder of resources in this category.

Exploration

Following successful initial exploration for coarse-grained heavy mineral strandlines by companies such as BeMax Resources NL, Aberfoyle Resources Limited, RZM Ltd, and RGC Limited, most the Murray Basin area in New South Wales, Victoria, and South Australia is now under active exploration.

Production

In 1998, Australia produced 2.4 Mt of ilmenite, 240 000 t of rutile, and 400 000 t of zircon. The bulk of Australia’s rutile and zircon production is exported, and about 55% of the ilmenite is exported. The remaining ilmenite production is upgraded to synthetic rutile, which contains about 92–93% TiO_2.

World ranking

According to AGSO and USGS data, Australia has the world’s largest EDR of ilmenite, rutile and zircon with 26%, 39%, and 36% respectively. Other significant rankings are: South Africa (19%) and Norway (12%) for ilmenite; South Africa (19%) and India (15%) for rutile; and South Africa (35%) and Ukraine (10%) for zircon.

In 1998, world production of ilmenite increased by 8% to 6.73 Mt; rutile increased by 3% to 476 000 t; and zircon decreased by 13% to 807 000 t. Australia produced about 36%, 50%, and 50% each of world production of ilmenite, rutile and zircon respectively.

Australia is the world's leading producer and largest exporter of all three minerals. South Africa (from dune sands) and Canada (from hard rock) mine similar quantities of ilmenite to Australia, and upgrade it to titanium slag before exporting it.

Industry developments

Production from the first heavy-mineral sand mine in the Murray Basin is expected to commence in early 2000. The Wemen project, owned by RZM Ltd (70%) and Western Metals (30%), plans to treat 9.9 Mt of ore over almost four years. Annual production will average 9600 t of zircon and 23 600 t of rutile. The deposit will be mined by dredge, and the wet concentrates trucked to RZM's dry plant at Tomago, near Newcastle (NSW).

RGC Limited is progressing a detailed feasibility study into a number of high-grade deposits referred to as Kulwin, Woornack, and Rownack, east of Ouyen (Vic.). The grade of heavy mineral within these deposits varies from 9 to 25%.

Rio Tinto has relinquished a number of its exploration areas covering the fine-grained WIM200 and WIM250 deposits near Horsham, central Victoria. Areas covering the WIM150 and WIM100 deposits have been retained.

Nickel

Resources

Nickel resources occur in all States except Victoria. Australia's total identified resources of nickel increased by 2.19 Mt (9.2%) in 1998.

EDR of nickel increased by 33.7% over 1997, from 6.72 Mt to a record 8.97 Mt, and represented 34% of total identified resources. EDR increased in all states as a result of company reassessments at either existing mines or new projects nearing production.

Western Australia has the nation's largest resources of nickel with 88% of EDR. While proven and probable reserves at WMC Ltd's Mount Keith operations declined, measured and indicated resources increased by over 40%. Reserves at WMC's other operations, Kambalda and Leinster, decreased as a result of production and the lower nickel prices that prevailed throughout the year. Substantial increases in resources were reported at the Ravensthorpe and Abednego laterite projects, and smaller increases at Cawse and Murrin Murrin.

In Queensland, further drilling and reassessment of Preston Resources Ltd's Marlborough deposits resulted in a significant increase in EDR. Exploration at the Syerston project in New South Wales delineated resources that have also been classified as EDR, the first so classified in that State.

SDR, which accounted for about 18% of total identified resources, decreased by 2.54 Mt during the year. The largest decrease, in Western Australia, more than offset the small increases in Queensland, New South Wales, and the Northern Territory.

Inferred resources increased by about 28% to a record level of 12.82 Mt. Western Australia recorded strong growth, up by about 3.5 Mt (45%) over 1997. Increases in inferred resources also occurred at the Murrin Murrin, Mount Margaret, and Eucalyptus deposits and at WMC Ltd's Mount Keith operation.

Exploration

Data relating to exploration for nickel are not available nationally.

Production

In 1998, production increased by 15%, to a record level of 933 000 t of nickel concentrates containing an estimated 142 000 t of nickel. All the production was from Western Australia.

World ranking

According to AGSO and USGS data, world EDR of nickel increased by 5.4% (43 Mt in 1997 to 45.3 Mt in 1998). Australia's share of world EDR increased to 19.8%, up from 15.6% in 1997, making it the largest holder of EDR, followed by Russia (14.5%), Cuba (12.1%), and Canada (11.7%).

Australia accounted for about 12% of estimated world nickel output of 1.17 Mt in 1998, and was the third largest producer after Russia (22.7%) and Canada (19%).

Industry developments

Australia has six nickel mines currently in operation: WMC Ltd's Kambalda, Leinster, and Mount Keith; Outokumpu Oy's Silver Swan and Forrestania; and Titan Resources' Radio Hill. A nickel smelter operates at Kalgoorlie (WA), and there are two nickel refineries — one at Yabulu (Qld), and the other at Kwinana (WA). Billiton Plc took over QNI Limited in early 1999 and now operates the Yabulu refinery, which produced 227 000 t of nickel in 1997–98. The refinery's principal output is nickel rondelles produced from lateritic ore imported from Indonesia, New Caledonia, and the Philippines.

During late 1998 and early 1999, WMC Ltd's Wannaway, Blair and Otter/Juan mines (all within the Kambalda region) were put on care-and-maintenance as a result of continuing low nickel prices.

Three lateritic nickel projects in Western Australia, Murrin Murrin, Cawse, and Bulong commenced production during late 1998 and early 1999. Each operation utilises pressure acid leaching to process the laterite ore, which is then refined on site. Murrin Murrin (Anaconda Nickel), the largest of the three mines, uses Sherritt technology to produce a nickel–cobalt mixed sulphide concentrate, which is refined by releaching. Cobalt is removed by solvent extraction, and nickel and cobalt metal are precipitated by hydrogen reduction.

At the Cawse mine (Centaur Mining and Exploration Ltd) ore processing involves pressure acid leaching to produce a mixed hydroxide intermediate product that is releached and refined by solvent extraction and electrowinning. Nickel production commenced in late January 1999, and annual production is expected to be 10 000 tpa.

Bulong (Preston Resources Ltd) utilises pressure acid leaching, solvent extraction, and electrowinning, without producing an intermediate product. When fully operational, Bulong nickel capacity will be 9000 tpa. When fully operational, these relatively low cost mines will provide an additional 64 000 tpa of nickel to world supply.

Other potential laterite projects are either at feasibility or prefeasibilty stages of evaluation. They include Mount Margaret and Ravensthorpe (WA), Marlborough (Qld), and Syerston (NSW). Potential new mines based on nickel sulphide ore are Yakabindie, Maggie Hays, and Emily (WA).

Phosphate

Apart from a small amount used for direct fertiliser application, there is no phosphate rock mined in Australia for the manufacture of phosphoric acid, an essential component in the production of high-analysis fertilisers. Towards the end of 1999, this situation is expected to change with the expected commissioning of Queensland Fertiliser Project's Phosphate Hill mine in Queensland.

Australia's Indian Ocean Territory of Christmas Island is a source of quality rock phosphate, which is exported to the Asia–Pacific and south east Asian region. Christmas Island rock phosphate products are used widely in the palm oil sector of this region, and increasing sales of higher-grade phosphate are being made to Australian manufacturers of Single Superphosphate.

Resources

Since a reclassification of resources by WMC Fertilizers Ltd, Australia's EDR of phosphate rock declined by about 15% in 1998 to 88 Mt. All these resources are located at Phosphate Hill, 70 km south of Duchess, in northwest Queensland. They occur as sedimentary phosphate rock deposits (phosphorites), at the southeastern margin of the Georgina Basin, and have an average grade of 23.4% P_2O_5.

Most of Australia's demonstrated resources of phosphate occur in the Georgina Basin and are classified as paramarginal. Two deposits, Swan and

Emu, occur within carbonatite at Mount Weld, 26 km southeast of Laverton (WA), where a phosphate-rich zone has formed by the solution and weathering of a primary carbonatite.

The bulk of Australia's inferred phosphate resources are in phosphorites in the Georgina Basin, and these are evenly distributed between Queensland and the Northern Territory. A small part of the Mount Weld resource is classified as inferred.

There are no publicly available data on current phosphate resources on Christmas Island.

Exploration

Data relating to exploration for phosphate are not available nationally.

Production

In mainland Australia, less than 5000 t of phosphate rock is mined annually from small deposits in South Australia. This phosphate rock is high in aluminium and iron, and is not suitable for manufacturing superphosphate. It is used as a direct-application fertiliser or for making organic fertiliser for horticultural applications.

In 1997–98, Phosphate Resources Ltd (PRL) shipped 587 000 t of phosphate rock from Christmas Island, an increase of 5.2% over 1996–97. Of this amount, about 360 000 t of phosphate were shipped to Malaysia and about 140 000 t to Australia. PRL mines more than 470 000 t of rock phosphate and 71 000 t of phosphate dust annually.

World ranking

Australia's EDR of phosphate rock comprises less than 1% of the world's total EDR of 12 000 Mt, which occurs principally as sedimentary marine phosphorites.

Industry developments

Mining at Phosphate Hill–Duchess deposit (Qld) has been on care-and-maintenance since 1983. After an announcement that natural gas would be piped into the Mount Isa region, WMC Fertilizers Ltd announced in late 1996 that they would develop an integrated fertiliser manufacturing facility in the region.The components of this chemical processing operation consist of a mine, phosphoric acid facility, ammonia plant, and granulation plant at Phosphate Hill, and a sulphuric acid plant at Mount Isa.

The acid plant at Mount Isa will convert sulphur dioxide from Mount Isa Mine's copper smelter into sulphuric acid, which will be transported by rail to Phosphate Hill. The conversion plant will remove 97% of the sulphur-bearing gases currently being emitted by the copper smelter, and overall stack emissions of sulphur dioxide at Mount Isa will be reduced by about 80%. About 4000 t of sulphuric acid will be produced each day.

The mined phosphate rock will be crushed and combined with sulphuric acid to produce 1500 t per day of phosphoric acid. A 600 t per day ammonia plant will utilise, as feedstock, natural gas sourced from the Cooper Basin.

The granulation plant will combine phosphoric acid and ammonia to produce one million tonnes per year of diammonium phosphate and monoammonium phosphate fertiliser. Construction of the various plants at Phosphate Hill and Mount Isa began in early 1998, and commissioning is expected in late 1999.

PRL was awarded the 1998 Australian Export Award for its effort in surviving the downturn in Asian markets in 1997. During 1997–98, it signed a new 21-year mining lease with the Australian Government. The lease has enabled the company to plan for expansion and growth with greater security. The company aims to improve its mine infrastructure and assist in the rehabilitation of previously mined phosphate areas.

Shale oil

Resources

AGSO assessed that in 1998 Australia had no shale oil resources in the EDR category. As reported last year, this situation may change significantly after the shale oil demonstration plant at Stuart (Qld) has

commenced operation. It is expected that the Stuart trials will begin in the first half of 1999.
Very little change occurred in the level of Australia's shale oil resources in 1998. Paramarginal demonstrated resources remained unchanged at 461 GL. There was an increase of 6% to 3158 GL in submarginal demonstrated resources as the result of a successful exploration program completed at Duaringa (Qld) during the year.

Resources in the Stuart deposit are classified as subeconomic paramarginal by AGSO. Should the demonstration plant prove that extraction of shale oil is commercially feasible, it is expected that the resources in that deposit will be upgraded to EDR.

Inferred resources were virtually unchanged in 1998.

Exploration

There was very little exploration for shale oil in 1998. Southern Pacific Petroleum / Central Pacific Minerals (SPP/CPM) completed the drilling program on the Duaringa deposit that resulted in the upgraded resource estimates referred to above.

Production

There was no production of shale oil in Australia in 1998.

World ranking

Information on world resources and production of shale oil is not available.

Industry developments

Considerable activity took place at the Stuart site over the year. In December, a contract to undertake mining was awarded to a joint venture between Macmahon Holdings Limited and Nghulin, which is a company formed by the local Aboriginal community. SPP/CPM reported that, by the end of December, 0.3 Mm^3 of overburden and topsoil had been mined. The overburden mined is being used by the Gladstone Port Authority in the development of its Bulk Liquids Handling Wharf on Gladstone harbour.

By the end of 1998, stage 1 of the Stuart plant was 95% completed and was both on schedule and budget. Overall site construction was 89% completed at the end of the year, and full completion is expected in the second quarter of 1999. If this target is achieved, the first shale oil production is expected by the end of 1999.

In October, a team of experts was formed to develop the Alberta Taciuk Process for stage 2 of the project. The task of this team is to develop a preliminary design for stage 2, into which the results of the stage 1 test program can be incorporated. Assuming stage 1 is successful, construction of stage 2 is expected to commence in 2001, and the first shale oil produced from it in 2003. Stage 2 would produce 15 000 barrels a day. If stage 2 proceeds it is expected to cost over $350 million.

Also in October, SPP/CPM and Suncor Energy announced that they would proceed with the development of several trial reafforestation projects. The companies announced that the trials would involve an investment of over $3.5 million over a four-year period to plant and maintain more than 180 000 native trees to capture carbon dioxide. They are aiming to achieve net levels of carbon dioxide emissions in commercial shale oil production equal to or less than those released in the production of conventional oil products.

During the year SPP/CPM joined with the Royal Melbourne Institute of Technology to develop techniques for the rapid analysis of oil shales. Should this project be successful, improved process control would be achieved, and this in turn would lead to higher levels of production from a given plant.

Tantalum

Rapid world-wide growth in the use of portable electronic devices — such as mobile phones, computers, and video cameras — has generated strong growth in demand for tantalum capacitors in recent years. Australia, through the operations of Sons of Gwalia Ltd, is the world's largest producer of tantalum in the form of tantalum concentrates. The company also controls the world's largest stock

of tantalum resources, principally in its holdings at Greenbushes and Wodgina (WA).

Resources

Australia's EDR is dominated by the very large Greenbushes deposit, in the southwest of Western Australia, and to a lesser extent the Wodgina deposit, in the State's Pilbara region. Successful exploration by Sons of Gwalia Ltd in the area south of its existing pit at Greenbushes led to an announcement, in November, that a substantial new resource occurred in a very large, low-grade, low-stripping-ratio deposit on the site. A measured and indicated resource for the existing and new Greenbushes deposits totalling 173 Mt at a grade of 200 g/t Ta_2O_5 was reported. Small tonnages of resources in the EDR category occur elsewhere in Western Australia and the Northern Territory.

Despite continued high levels of production Australia's EDR increased by 58% in 1998 to 18 020 t tantalum (Ta) largely because of the new resources at Greenbushes. In assessing EDR for the Greenbushes resources a recovery factor of 55%, the current metallurgical recovery reported for Greenbushes, was used.

A reduction of just over 2% in SDR (153 t Ta) occurred in 1998. The fall was caused by minor changes in resource estimates in Western Australia.

Inferred resources increased by 15% to 72 578 t Ta in 1998. This growth resulted from the discovery of a new deposit, Mount Cassiterite East, by Sons of Gwalia near its Wodgina mine. The company reported an inferred resource of 28 Mt at a grade of 415 g/t Ta_2O_5 in a deposit that is open at depth and in all directions. This resource occurs in flat-lying pegmatites 10 to 170 m thick and up to about 250 m deep.

Exploration

Data relating to exploration for tantalum are not available.

Production

In 1998, Sons of Gwalia produced 711 508 lbs of Ta_2O_5 from the Greenbushes operation and a further 165 447 lb from its Wodgina mine. The company reported that its Bynoe deposit in the Northern Territory is still being mined under a tribute arrangement, and that it purchases the output for processing at the Greenbushes mine. About 30 000 lb was produced from Bynoe in 1998.

World ranking

The discoveries at Greenbushes and Mount Cassiterite East consolidated Australia's position as the world's largest holder of tantalum resources. According to world estimates published by USGS and modified by AGSO to take account of recent discoveries, Australia has almost 70% of the world's EDR of tantalum. Nigeria has the second largest stock, and is followed equally by Canada and Congo.

World production in 1998, based on USGS estimates modified to account for later Australian data, was about 438 t Ta. Production was dominated by Australia, whose approximately. 330 t was responsible for about 75% of world output in 1998. Smaller tonnages were produced by Brazil and Canada (55 t each) and Nigeria (2 t) according to USGS.

Industry developments

An important development in 1998 was the decision to expand the capacity of the plant at Wodgina in order to meet the requirements of new sales contracts. Current capacity of 275 000 tpa is to be increased to 550 000 tpa. As a result of the increase, annual product output will rise from about 160 000 lb Ta_2O_5 to about 300 000 lb Ta_2O_5. By the end of the year, Sons of Gwalia reported that all design work had been completed and major equipment ordered. Construction was to commence in January 1999, and completion expected in July 1999.

Capacity at the Greenbushes plant is to be increased progressively over two years from 1.4 to 1.6 Mt per annum.

As part of its development strategy at Greenbushes, the company announced that it would access the large low-grade resources in the Central Lode, and blend the ore won with that from the open-cut

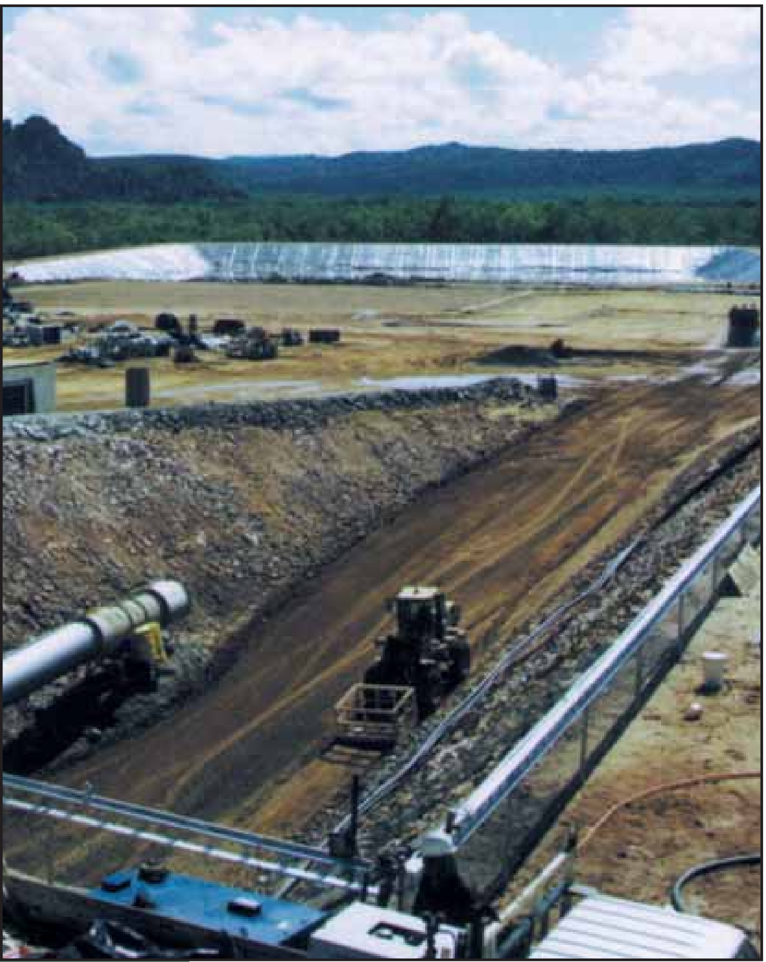


Plate 7 Entrance to the Jabiluka decline, Northern Territory
Photograph courtesy of Energy Resources of Australia Ltd

operation. Subsequently, in its December 1998 quarterly report, Sons of Gwalia noted that bulk-processing trials of this ore confirmed the metallurgical assumptions made in the feasibility study into the proposal. The resource is to be mined by bulk mining methods and processed at higher throughput rates.

Uranium

Resources

AGSO has prepared estimates of Australia's uranium resources within categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA; OECD/NEA & IAEA, 1998). In Table 1, these estimates are reported under the corresponding resource categories of the national classification scheme. The resource categories of both schemes are correlated as closely as possible in Table 2.

Australia has the world's largest resources of uranium in the low-cost RAR category, with 26% of world resources in this category. Other countries with large low-cost resources include Kazakhstan (19%), Canada (14%), South Africa (9%), Namibia (7%), Brazil (7%), Russian Federation (6%), and United States (5%).

About 95% of Australia's total uranium resources in the low cost RAR category are within the following six deposits (Fig. 3):

- Olympic Dam (SA);
- Ranger, Jabiluka, and Koongarra, in the Alligator Rivers region (NT);
- Kintyre and Yeelirrie (WA).

Exploration

After the exploration boom of the late 1970s, uranium exploration in Australia dropped from A$89.0 million in 1980 to an historic low of A$7.2 million in 1994 (expenditures in constant 1997 A$). Subsequently, exploration expenditure increased progressively to A$23.6 million in 1997. Australia is

Table 2 Comparison of resource classification schemes for uranium

National Scheme	OECD/NEA & IAEA Scheme
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US$80/ kg U (commonly referred to as low cost resources)
Subeconomic Demonstrated Resources	RAR recoverable at US$80-130/ kg U
Economic Inferred Resources	Estimated Additional Resources Category 1 (EAR-1) recoverable at less than US$80/ kg U
Subeconomic Inferred Resources	EAR-1 recoverable at US$80-130/ kg U

one of the few countries where exploration expenditure increased in recent years, a result of the abolition of the 'three mines' policy in 1996 and improved demand for uranium. Data for 1998 are yet to be finalised.

The main areas where exploration was carried out during 1997 and 1998 are:

- Arnhem Land (NT) — exploration for unconformity-related deposits in Palaeoproterozoic metasediments below a thick cover of Kombolgie Sandstone;
- Paterson Province (WA) — exploration for unconformity-related deposits in Palaeoproterozoic metasediments of the Rudall Metamorphic Complex, which hosts the Kintyre orebody;
- Westmoreland area (northwest Qld.) — exploration for sandstone-type deposits in Proterozoic strata of the McArthur Basin;
- Olympic Dam area — exploration drilling along the southern margin of the deposit.

Production

Uranium oxide is currently produced at two mining/milling operations — Ranger and Olympic Dam. Australia's total production for 1998 was 5790 t U_3O_8 (4910 t U; U=0.848 x U_3O_8), of which Ranger produced 4050 t U_3O_8 and Olympic Dam produced 1740 t U_3O_8. Total production for 1998 was 11% less than in 1997.

Industry developments

Ranger. Mining continued during the year at the Ranger No. 3 orebody, which commenced full-scale production in mid-1997 and has total proven plus probable reserves of 16.3 Mt ore with average grade 0.29% U_3O_8 (47 200 t of contained U_3O_8). No. 3 orebody is 1 km north of the mined-out No. 1 open-pit, which has been used as a repository for mill tailings since August 1996.

In August 1997, Energy Resources of Australia Ltd (ERA) completed the expansion of nominal milling capacity at Ranger to 5000 t U_3O_8 per annum. However, chemical problems within the mill resulted

Figure 3 Uranium deposits and prospects in Australia

in production only reaching 4050 t U_3O_8 in 1998. The plant returned to full capacity in June 1998 but ERA subsequently decided to temporarily shutdown the new ball mill from 8 January 1999 in view of depressed market conditions.

Olympic Dam. The Olympic Dam copper–uranium–gold–silver deposit is the world's largest deposit of low-cost uranium. Total proved plus probable reserves amounted to 336 000 t of contained U_3O_8 at December 1998 (WMC 1998). Uranium production is linked to copper production.

The Olympic Dam expansion project commenced in January 1997 and construction continued through 1998. The expansion will increase annual production capacity to 200 000 t of refined copper and 4600 t U_3O_8, which will triple current production levels. At this production rate the mill will process 9 Mt of ore per annum. The expansion, South Australia's largest development project, represents an estimated outlay of $1.94 billion.

Features of the expansion include:

- an automated electric rail haulage system and a new crusher station;
- a new autogenous mill incorporating the latest grinding technology;
- a new smelter;
- an enlarged hydrometallurgical plant;
- a third haulage shaft.

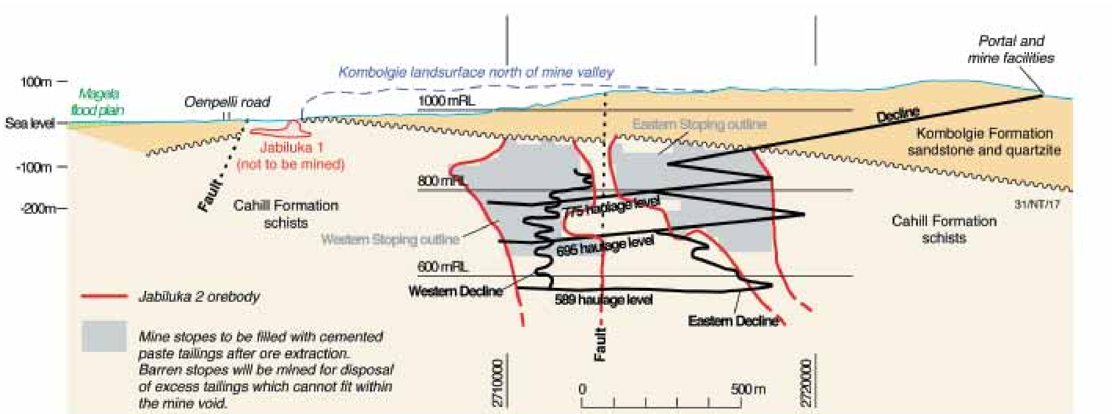
Jabiluka. ERA Ltd proposes to mine the Jabiluka orebody by underground mining methods (Fig. 4). Jabiluka has total proved and probable ore reserves of 19.5 Mt with average grade 0.46% U_3O_8 (90 400 t of contained U_3O_8).

ERA's preferred option is for an underground mining operation, and for the ore to be processed at the Ranger mill. The ore would be trucked 22 km to Ranger via a haul road entirely within the lease area, and the tailings would be disposed of into the open pits at Ranger (Shirvington 1997). This option is referred to as the Ranger Mill Alternative.
As an alternative option, ERA proposed in the environmental impact statement (EIS) that a mill be built adjacent to the Jabiluka mine, and that the ore be milled and processed within the Jabiluka Mineral Lease. This option is referred to as the Jabiluka Mill Alternative (JMA).

In August 1997, the Commonwealth Environment Minister recommended that there does not appear to be any environmental issue that would prevent the preferred Jabiluka proposal from proceeding. The Minister required that stringent regulatory and operating conditions be applied to ensure the protection of World Heritage values, flora, fauna, and cultural heritage (including Aboriginal sacred sites).

Subsequent to this approval, the traditional owners of the Jabiluka Mineral Lease area indicated that

Figure 4 Jabiluka – diagrammatic longitudinal section looking north



they were unwilling to consent to milling Jabiluka ore at Ranger. Consequently, it became necessary to submit the JMA to a detailed environmental assessment process to evaluate it as an acceptable option. In April 1998, the Commonwealth Environment Minister directed ERA to prepare a public environment report (PER) to assist the Commonwealth and Northern Territory Governments in assessing the environmental impacts of the JMA.

ERA Ltd proposed to use cemented paste-fill technology for disposing of tailings in the JMA. As much as possible of the cemented tailings would be disposed of underground in the mine stopes, and any excess tailings that could not be placed underground would be stored in two purpose-built surface pits.

In his assessment of the PER, the Commonwealth Environment Minister noted concerns about the nature and behaviour of cemented tailings paste in the pits, and concerns regarding the long-term security of the pits from a hydrological perspective.

After receiving an independent report on tailings management, the Minister announced in August 1998 that the milling of uranium ore at Jabiluka will be environmentally acceptable if 100% of the tailings are returned to the mine void underground. Acknowledging that there may be viable alternatives to disposing of all tailings underground, the Minister stated that the company must conduct an additional assessment that addresses the issues of concern before a decision could be made on any such option.

In August 1998, the Minister for Resources & Energy formally endorsed the recommendations made by the Environment Minister and cleared the way for the development of milling operations at Jabiluka. This decision completes the Commonwealth approvals process under the Environmental Protection (Impact of Proposals) Act for the Jabiluka mine and for the options

Plate 8 Ion exchange columns for in situ leach trials at the Beverley uranium project, South Australia
Photograph courtesy of Aden McKay, AGSO; published with the permission of Heathgate Resources Pty Ltd

to mill the ore either at Jabiluka or at Ranger. ERA considers that the option of milling the ore at Ranger is more environmentally beneficial than milling the ore at Jabiluka. The company is seeking to find common ground with the traditional owners, through their legal representatives (the Northern Lands Council), on where the ore should be processed. (ERA 1998).

Authorisation under the Northern Territory Uranium Mining (Environmental Controls) Act to construct the portal and access decline was issued in June 1998. Construction of the retention pond has been completed, and the mine portal is well advanced .

Beverley. Heathgate Resources Pty Ltd estimate that the Beverley uranium deposit has total resources of at least 10 600 t U_3O_8 recoverable by in-situ leach (ISL) mining.

The deposit occurs in uncemented, partly consolidated, fine- to medium-grained sand with interbedded clay and silt (upper Tertiary Namba Formation). It forms three lenticular zones, designated North, Central, and South ore lenses. The North and Central ore lenses are within the central of three palaeochannels, while the South ore lens is situated in the south palaeochannel (Fig. 5). The deposit occurs at an average depth below surface of 107 m, and the combined thickness of the mineralised sand is typically 20–30 m.

In January 1998, Heathgate commenced in-situ field leach trials to confirm the viability of ISL methods. On the basis of the success of these trials, it is proposed that the commercial operation, will use sulphuric acid and oxygen to dissolve the uranium in-situ, and resin-type ion-exchange techniques will be used to recover uranium in the processing plant.

Heathgate proposes that liquid wastes will be collected initially in the plant-holding ponds. Two options exist for disposing of these liquids:

- reinject the liquids into the Beverley aquifer in areas already mined out, or
- evaporate the water in surface ponds, and dispose of the resulting solids in an engineered disposal facility.

The company considers that reinjection into the mineralised aquifer is the best method of disposal from both environmental and operational perspectives because it:

- minimises the amount of material requiring near-surface disposal;
- significantly reduces the area needed for pondage;
- significantly reduces the release of radon to the atmosphere.

Groundwater in the mineralised zone is saline (total dissolved solids range from 3000 to 12 000 mg/l), and contains naturally occurring uranium and radium at concentrations well in excess of drinking water limits. It is unsuitable as potable water, for agriculture, or for stock-watering.

Discharge from the Beverley aquifer is believed to be virtually zero because (Heathgate 1998):

- the hydraulic gradient along the Beverley channel is virtually zero (i.e., no lateral flow),
- vertical hydraulic gradients are directed towards the Beverley aquifer from above and below, and
- the mineralised parts of the channel appear, from recent pumping test results, to be bounded to the north and south by low-permeability potential flow paths and to the east and west by similar restrictions.

The draft EIS for the proposed Beverley development was released in June 1998, and the supplement (response document) was released in September 1998. The EIS was assessed jointly by the South Australian and Commonwealth Governments. The Commonwealth Environment Minister announced in a press release of 23 December 1998 that, subject to the company carrying out further investigations to confirm that there is no hydraulic connection between the Beverley aquifer and other surrounding aquifers, '… the Beverley project is environmentally acceptable and there is no environmental reason which would prevent the granting of Commonwealth approvals.'

Plate 9 Solvent extraction demonstration plant at the Honeymoon uranium project, South Australia
Photograph courtesy of Aden McKay, AGSO; published with the permission of Southern Cross Resources Australia Pty Ltd

Honeymoon. The resources recoverable by ISL methods for Honeymoon and nearby deposits owned by Southern Cross are itemised in Table 3 (Ackland 1997; Southern Cross 1998a).

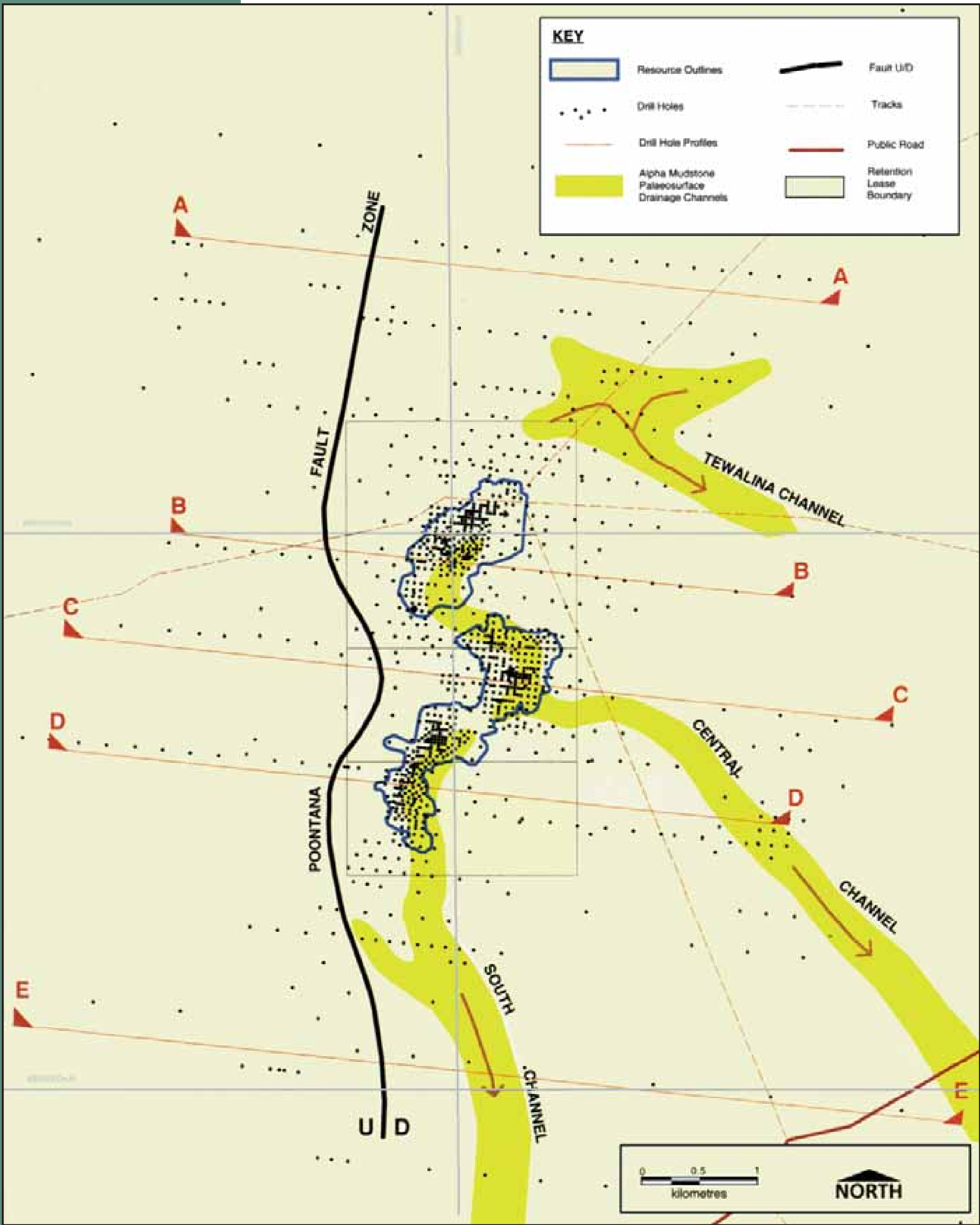
The deposit has a roll-front shape and occurs at an oxidation–reduction interface within coarse-grained Tertiary sand along the lateral margins of a bend in a palaeochannel. The deposit is between 100 and 120 m below the surface. Uranium is present mainly as coffinite; quartz and kaolinite are gangue minerals. The ore has a high pyrite content (average 7%), and total organic carbon averages 0.3%.

The mineralised palaeochannel provides the only significant groundwater occurrence in the area. It comprises three aquifers — upper, middle, and basal sand units — separated by semiconfining clay layers 2 to 4 m thick. The basal sand aquifer (which hosts the deposit) averages 12 m thick.

Table 3 Uranium resources for Honeymoon and nearby deposits

Deposit	Resource category	Resources (t U3O8)	Grade (% U3O8)
Honeymoon (including Honeymoon Extension)	Measured	3700	0.156
East Kalkaroo	Indicated	900	0.14
Goulds Dam	Inferred	18 000	0.098

Figure 5 Plan showing locations of ore lenses and palaeodrainage channel (from Beverley EIS, Heathgate 1998)



Groundwater quality in the mineralised sand is very poor; its total dissolved solids usually greater than 16 000 mg/litre (Southern Cross 1998b) make it unacceptable for human consumption, domestic use, irrigation supply and stock-watering. Minor stock-water supplies are being drawn from the upper aquifer.

In May 1996, the project was acquired by Southern Cross Resources Incorporated. Refurbishment of plant left on the site from previous testing commenced in the latter part of 1997. The plant was commissioned in early 1998.

In April 1998, approval was granted by the South Australian Department of Mines & Energy Resources for the company to carry out field leach trials. These used sulphuric acid and an oxidant to mobilise the uranium from the basal aquifer. The oxidants tested were oxygen gas, hydrogen peroxide, and ferric sulphate. Both solvent- extraction and ion-exchange (resin) techniques were investigated. The results obtained by solvent extraction were far superior. The extremely high chloride content of the groundwater prevented the ion exchange-process from working effectively.

A draft EIS for the project was in preparation at the end of 1998. The proposed commercial operation will produce 1000 t U_3O_8 per year. The company is considering three options for disposing of liquid waste:

- injection to a disposal well into the mineralised zone in an area where ISL operations have been completed,
- evaporation of the water and disposal of the resulting salts in an engineered solids disposal facility, and
- precipitation of the radioactive component (radium) and disposal of these salts in an engineered solids disposal facility, and reinjection of the water.

Senate Inquiry into uranium mining and milling

Australia's uranium mining sector was the subject of a review by the Senate Select Committee on Uranium Mining and Milling which tabled its report in the Senate in May 1997. The Committee's majority report found that the major finding of the 1977 Ranger Uranium Environmental Inquiry (the Fox Report) that — 'The hazards of mining and milling uranium, if these activities are properly regulated and controlled, are not such as to justify a decision not to develop Australian uranium mines' — remained valid as the foundation for policy on the mining and milling of uranium in Australia.

The Government tabled its response to the report in May 1998. It accepted most of the Committee's recommendations relating to environmental, health, and safety issues, but rejected a recommendation that a Commonwealth Uranium Authority be established to regulate uranium mining in Australia.

Vanadium

Vanadium is used in metal alloys, principally to strengthen steel.

Resources

During 1998, Australia's EDR of vanadium increased by 38 232 t (25%) as a result of increases in resources at the Windimurra deposit, 75 km east-southeast of Mount Magnet (WA). Proven reserves of oxidised ore reported by Precious Metals Australia Ltd for Windimurra are 55.4 Mt with average grade 0.497% V_2O_5.

Exploration

Exploration for vanadium increased in 1998 in response to higher market prices and increased demand. Exploration drilling at Interim Resources' Gabanintha/Yarrabubla project, 45 km southeast of Meekatharra, intersected zones of vanadium/titanium mineralisation within a titaniferous magnetite zone hosted by basic intrusive rocks.

Exploration and metallurgical testing of vanadium resources within the Julia Creek oil shale deposits, north Queensland, continued during the year.

Production

There was no production of vanadium in 1998.

Plate 10 Ore processing mill under construction at the Century zinc-lead-silver mine, Queensland Photograph courtesy of Pasminco Ltd

Industry developments

Windimurra is a world-class vanadium deposit and will be Australia's only vanadium mine when production commences. It is a magmatic Fe–Ti–V deposit in which the vanadium occurs in magnetite and ilmenite. The economic viability of the project has been enhanced by a number of recent developments including recent advances in processing technology, and the availability of energy from the Dampier to Bunbury gas pipeline.

Following the granting of government approvals, construction work at Windimurra commenced in mid-1998. Precious Metals Australia Ltd and Glencore International AG have completed a feasibility study that included pilot-scale metallurgical testing. The contract for the rotary kiln (which will be the world's largest) has been let to a Danish company. Total capital costs of the project are estimated at A$115 million. The scheduled full production of 16 million lb of V_2O_5 per year at Windimurra will represent about 10% of world production. Its proven ore reserve is considered adequate for a mine life of 21 years.

Zinc, lead, silver

Resources

EDR for zinc (34 Mt), lead (17.2 Mt), and silver (40.6 kt) decreased in 1998 by 6%, 1%, and 2% respectively as a result of production and reassessment of resources at major mines. Australia's total identified resources of zinc (83.5 Mt) and lead (53 Mt) each decreased by 3%, while silver (90.4 kt) decreased by 2% during 1998.

Exploration

Data relating to exploration for zinc, lead, and silver specifically were not assessed.

World resources and production

Australia has the world's largest EDR of zinc (18%), lead (26%), and silver (15%). According to USGS world production data for 1998, Australia ranks as the largest producer of lead, second of zinc, and fourth of silver. Production is mainly from mines at Cannington, George Fisher, Hilton, and Mount Isa (Qld); McArthur River (NT); Broken Hill and Elura (NSW); Hellyer and Rosebery (Tas.); and Scuddles, Gossan Hill and the Lennard Shelf deposits (WA). Australia's gold mines also contribute significantly to silver production.

Industry developments

Development of the large Century mine, in northwest Queensland, is ahead of schedule, and production is expected to commence in the final quarter of 1999. More than 1300 people are employed on the project, and over $600 million in goods and services has been sourced from Australian suppliers.

At the Mount Isa mine, a strategy to focus on higher mineral recovery at reduced mining rates is proving successful. Development of the new George Fisher mine has extended the operating life at Mount Isa and Hilton to about 2003. Thereafter, ore from the George Fisher mine will replace supply to the Mount Isa zinc and lead processing plant. The decision to develop two of George Fisher's eleven orebodies of 24 Mt was taken in April 1998, and the substantial remaining resources (70 Mt) could

extend the current 10-year mine life. The mine is scheduled to commence in mid-2000 and produce 2.5 million tpa of zinc–lead–silver ore.

At Elura, in western New South Wales, production was mainly from the newly developed Northern Orebodies. Production from the Main Orebody continued to be interrupted by the impacts of ground subsidence that occurred in 1996.

Ground failure also restricted access to high-grade areas at Rosebery, in western Tasmania, where deep exploration continued to identify new resources.

In Western Australia, underground mining commenced at the Pillara deposit (1.5 Mt of ore per year), in the Kimberley region, in mid-1998. A new mine was commissioned in late 1998 at Gossan Hill, east of Geraldton, which boosted ore feed to the nearby Scuddles mine processing plant.

At the Browns lead–copper–cobalt–nickel deposit (NT), a final feasibility study is to be completed in 1999, before proposed development of the mine in 2000. It is planned that 1.75 Mt of ore will be mined per year, and that sulphide concentrate be direct-smelted into lead bullion and a copper–cobalt–nickel matte. A further 300 000 t of oxide ore will be leached by sulphuric acid generated from smelter gases.

The Woodlawn mine (NSW) ceased operations in early March 1998, as a result of ground stability problems at depth and limited reserves.

Mining of the Thalanga base metal deposit, in central Queensland, ceased in June 1998. The mine's plant has been adapted to process ore from the Highway and Reward copper–gold deposits, 70 km southwest of Charters Towers.

Mineral industry performance & outlook

The Minerals Council of Australia's annual industry survey (MCA 1998) reported that overall mine production rose by 5.2% in 1997–98, following growth of 6.8% in the previous year. The report noted, however, that on all indicators of profitability the minerals industry performed poorly in the period under review. Over the past two years, net profit return on average shareholders' funds has seen the two lowest results recorded since the early 1980s (2.9% in 1996–97 and 1.8% in 1997–98). Australian mine production statistics for various commodities in 1998, provided by ABARE, are summarised in Table 1. Gross nominal value of mine production in 1997–98 was $39 775 million, an increase of 13.5% (10.9% in real terms, 1998–99 dollars) over 1996–97 (Waring & Hogan 1999). Overall, ABARE forecast production of metals and related minerals to increase by 14% in the five-year period to 2003–04. Substantial growth in mine output is projected to occur in the nickel industry (up by 65%), zinc (up by 39%), copper (up by 17%), and iron ore (up by 15%).

The nominal value of Australia's mineral and energy exports increased by 13% (over 11% in real terms) in 1997–98 to a record of $41.2 billion. Australia's total earnings from mineral and energy exports are forecast by ABARE to fall by 1.8% in 1998–99. Over the medium term, minerals and energy earnings are projected to fall by 10% to $36.3 billion (in real terms) between 1998–99 and 2000–01, before rising to around $37 billion in 2003–04. Details of production and exports of selected mineral commodities for 1997–98 are presented in Table 4.

Overall expenditure in all minerals and energy industries is expected to fall in 1998–99 (Waring & Hogan 1999). ABS survey data indicate a likely fall in capital expenditure of around 23% to $8.5 billion in that period, and a further decline of 18% to $7 billion in 1999–2000. Capital expenditure at these levels, while sharply down from 1997–98, remains relatively high by historic standards. Much of this expenditure, however, relates to major mining and processing developments at advanced stages of development. Recent corporate decisions are likely to result in further major declines in capital and exploration expenditure.

Table 4 Australian production and exports of selected mineral products 1997-98

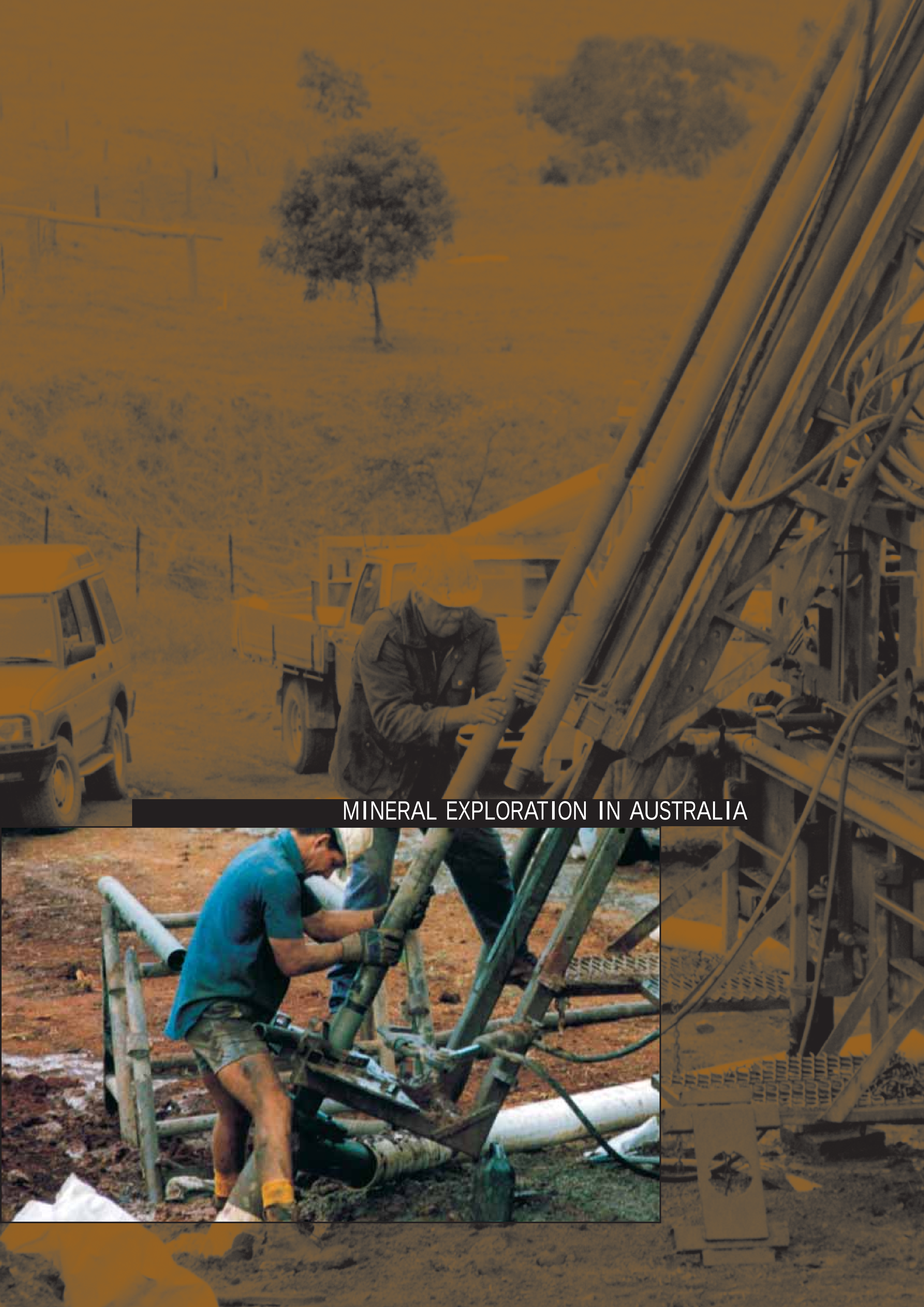
Commodity	Production	Exports	Export value million
Aluminium			
Bauxite (Mt)	44.878		141
Alumina (Mt)	13537	10.536	2,888
Aluminium (Mt)	1.589	1.236	2,836
Coal			
Black raw (Mt)	280.17		
Black seable (Mt)	222.45	163.08	9,557
Brown	65.60		
Copper			
Ores & concentrates (kt)	1,667	1097	822
Refined primary (kt)	284	127	372
Diamond (kc)	43,046	42,483	538
Gold			
Mine production (t)	316.15		
Refined (t)[(a)]	348.21	427.7	6242
Iron & Steel			
Ore & Pelets (Mt)	159.657	142.208	3,791
Iron & steel (Mt) [(b)]	16.971	3.347	1,608
Lead			
Ores & concentrates (kt)	838	253	140
Refined (kt)	185	177	180
Bullion (kt)	171	167	173
Manganese			
Ores & concentrates (Mt)	1,647	1,147	157
Mineral sands			
Ilmenite concentrates (kt)	2,352	1,304	139
Rutile concentrates (kt)	242	207	160
Synthetic rutile (kt)	688	501	286
Titanium dioxide pigment (kt)	162	136	346
Zircon concentrates (Kt)	427	396	231
Nickel			
Concentrate (kt)	871		
Refined (Kt)	182[(c)]	151	1,103[(d)]
Uranium (t U_3O_8)	5,797	6,415	288
Zinc			
Ores & concentrates (Kt)	1,947	1,450	581
Refined (Kt)	304	198	407

na=not available; t=tonnes; kt=10^2t; Mt= 10^6t; kc=10^3 carats

Source; Australian Commodity Statisics ,ABARE, December 1998

(a) Includes gold of Australian and overseas origin
(b) Includes 7,545 Mt pig iron and 8.427 Mt raw steel
(c) Sum of products in the Intermediate nickel, <99% Ni and >99% Ni categories
(d) Sum of all nickel product export values

Plate 11 Exploration drilling by Gympie Gold at Gympie, Queensland
Photograph courtesy of Gympie Gold Limited



MINERAL EXPLORATION IN AUSTRALIA

Mineral exploration in Australia

Exploration expenditure

Mineral exploration expenditure for a range of commodities is collected by ABS quarterly, and the following discussion and statistics are based on survey data for 1997–98 and the first two quarters of 1998–99. The differentiation of commodity groups before 1980 is based largely on a breakdown of ABS totals by AGSO.

Mineral exploration expenditure in Australia fell by 7% from $1148.5 million in 1996–97 to $1066.8 million in 1997–98 (Fig. 6). This was the first annual decrease for 7 years since the relative low point in 1990–91. Gold was responsible for the bulk of the decline (down by 11% or $80 million to $648 million), but decreases were also recorded by diamond ($17 million), coal ($6 million), and other ($12 million). Expenditure on base metals went against the trend, increasing by $20 million (10%), and iron ore expenditure rose $4 million (16%). Uranium exploration expenditure rose by $9 million (71%) to $22 million. There continued to be very little interest in tin or tungsten exploration with expenditure falling to an all time low of $0.1 million.

Exploration expenditure decreased in most States, except South Australia, where it was up by $10 million or 28%. Exploration expenditure fell most markedly in Tasmania (20%), Queensland (17%), Victoria (17%), and the Northern Territory (15%) in 1997–98. Western Australia, with 62% of the total, was again responsible for most of the expenditure, followed by Queensland (13%), New South Wales (8%), the Northern Territory (7%), South Australia (4%).

Gold accounted for 61% of total Australian exploration expenditure by commodity group in 1997–98, down from 63% in the previous year. It was followed by a group made up of the base metals (copper–lead–zinc) plus silver, nickel, and cobalt representing 21%, coal (6%), and diamond (4%), while uranium and mineral sands accounted for 2% and 1% respectively of the total exploration expenditure.

Expenditure on ‘production leases’ exploration fell by about $53 million or 17% in 1997–98. In contrast, exploration expenditure in ‘greenfields’ areas (areas outside production leases) decreased by only $29 million, or about 3%. Overall, about 24%,

Figure 6 Australian exploration expenditure since 1992-93

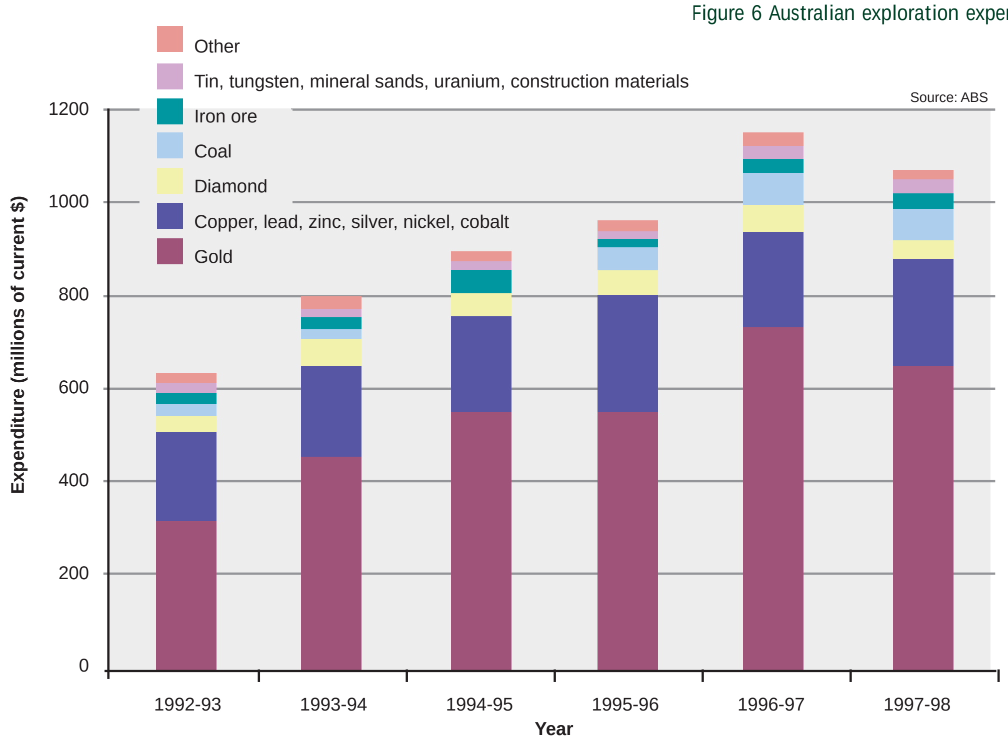
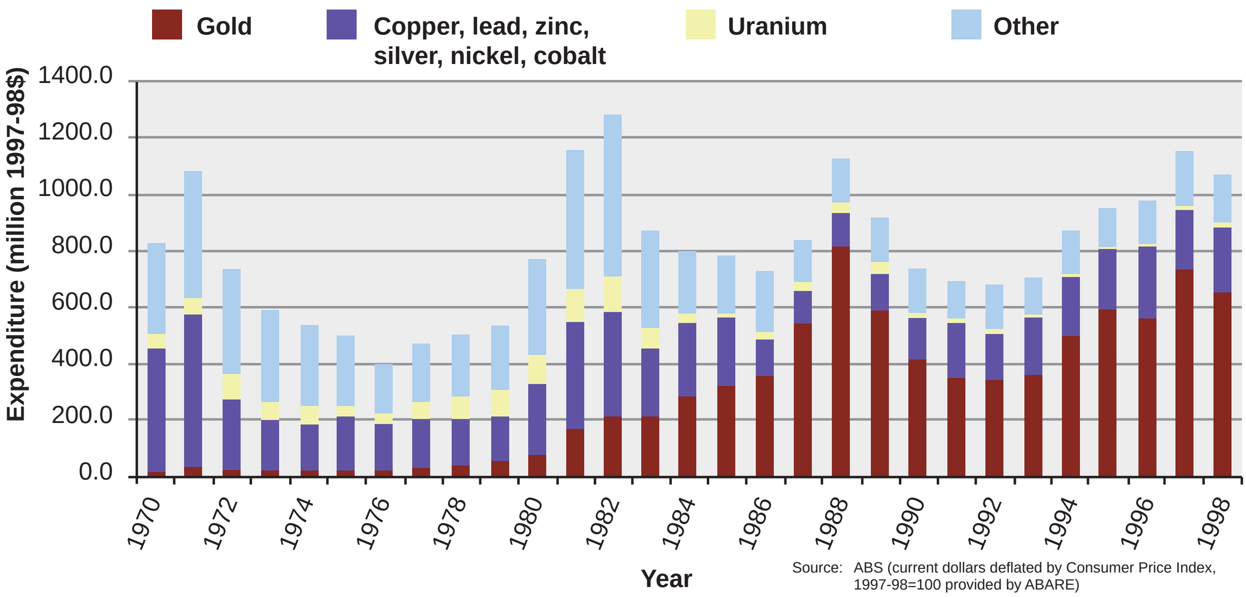


Figure 7 Australian exploration expenditure since 1969-70 expressed in 1997-98 dollars



or $253 million, was spent on 'production leases' in 1997–98, while 76% or $814 million was spent on 'greenfields' leases.

In constant 1997–98 dollar terms, the rise in exploration expenditure which began in 1992–93 peaked in 1996–97 (Fig. 7) and began to decline in 1997–98. The 'real' level of expenditure in 1996–97 did not reach the level of the all time high attained in 1981–82.

Exploration expenditure figures published by ABS for June to December 1998 show a 19% decrease in overall expenditure, compared with the corresponding period for 1996–97. Of all the States, Queensland with a reduction of $36 million (44%) experienced the largest relative fall in exploration expenditure in the September and December 1998 quarters combined compared with the corresponding 1997 quarters. Expenditure in New South Wales in the last six months of 1998 was also down by $17 million compared with the same six months in 1997, a 34% reduction. However, Western Australia's expenditure for the same period was down by only $34 million or 10%. The overall pattern over the last six quarters has been one of generally declining levels of expenditure, which appears to reflect the decreased demand for metals and lower commodity prices.

Outlook for exploration expenditure

Australia's aggregate minerals exploration expenditure is forecast by ABARE to decline sharply in 1998–99 and 1999–2000, and is expected to remain at relatively subdued levels over the medium-term to 2003–04 (Waring 1999).

Although the industry has demonstrated its ability to respond quickly and flexibly to many and varied factors in the past, there are lags (usually between 2 to 8 years) between resource discovery and minerals production. It is important therefore that governments and industry work cooperatively to ensure that mineral exploration is maintained at levels sufficient to allow continuing production and growth in the industry. Should ABARE's medium-term forecast be realised and a downward trend in expenditure continue beyond 2003–04, the cyclic periodicity of the last decade would be disrupted (Fig. 6). This could adversely affect the level of resource stocks for gold and base metals, where the links between expenditure and future production are critical because of the small resource base compared with current production rates. Levels of Australia's

EDR for major commodities like bauxite, iron ore, and coal are such that any downturn in exploration over the medium term would not manifest itself in terms of reduced production.

The Minerals Council of Australia's survey (MCA 1998) reveals that survey respondents (mostly the larger Australian mineral companies) are on average now spending 30 to 40% of their exploration budgets outside Australia — in 1997–98 respondents spent $450 million on overseas exploration activities and $699 million in Australia. Individual major Australian companies are spending up to at least 85% of their exploration budgets in other countries. This emphasises the global nature of the minerals industry and the importance of maintaining Australia's mineral prospectivity within a highly competitive investment climate.

Exploration drilling

In 1998, AGSO again commissioned ABS to undertake a survey of exploration and mining companies to ascertain the amount and type of exploration drilling carried out in Australia in 1997–98. The survey was undertaken on behalf of the Conference of Chief Government Geologists to enable a State-by-State comparison to be made of expenditure and metres drilled by type of drilling. A summary of the data was released by ABS on 22 December 1998 (ABS Catalogue No. 8412.0).

Figure 8 Proportion of Australian exploration expenditure spent on drilling in each State, 1997-98 Vs 1996-97

Table 5 Exploration expenditure and exploration drilling, 1997-98

State	**Total exploration expenditure** ($ million)	**Exploration Drilling** ($ million)	‘000 metres(a)
New South Wales	88.2	36.5	621.5
Victoria	43.1	9.374	200.6
Queensland	133.2	27.419	609.6
South Australia	45	13.528	452.7
Western Australia	660.4	259.88	8475.6
Tasmania	20.7	8.553	94.4
Northern Territory	75.9	23.434	604.8
Australia	1066.8	378.688	11059.1

Note: Totals and sums of components may vary because of rounding. (a) Statistics collected by Australian Bureau of Statistics for AGSO, on behalf of the Conference of Chief Government Geologists.

Figure 9 Exploration metres drilled in each state from 1993-94 to 1997-98

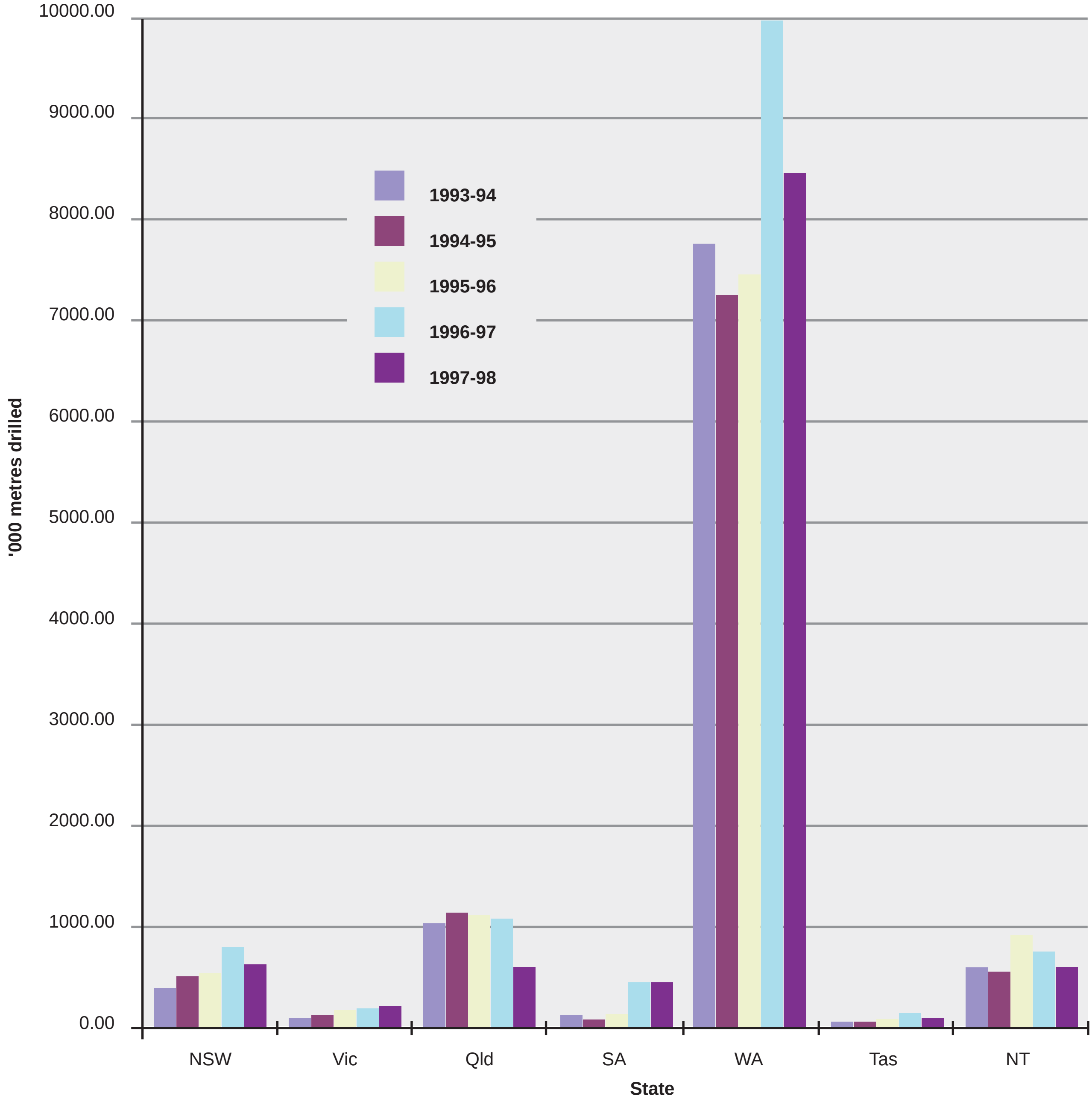
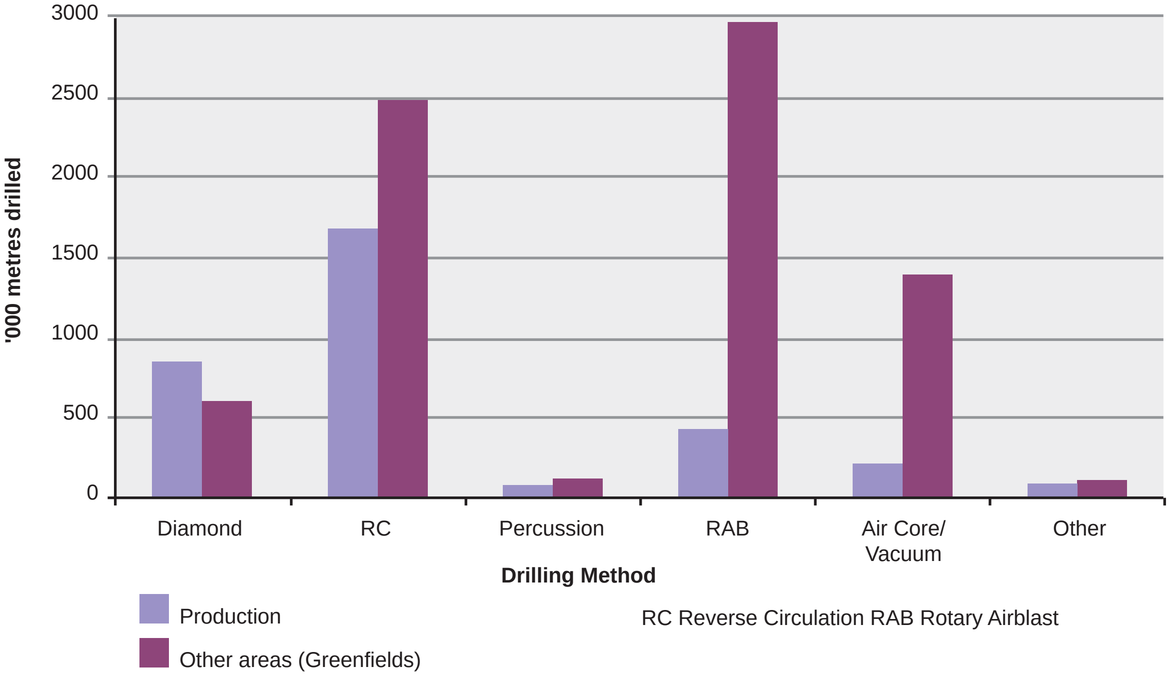


Table 6 Methods of exploration drilling in Australia by type of area drilled, 1997-98

Drilling Method	Production Areas			Other Areas			Total		
	'000 Metres(a)	'000$(a)	Average $/M	'000 Metres(a)	'000$(a)	Average $/M	'000 Metres(a)	'000$(a)	Average $/M
Diamond	853.3	74422	87.22	615.1	58038	94.36	1468.4	132460	90.21
Reverse Circulation	1679.7	50240	29.91	2487.6	98313	39.52	4167.3	148553	35.65
Percussion	91.6	4528	49.43	118.8	4592	38.65	210.3	9120	43.37
Rotary Air Blast	439.5	4533	10.31	2971.1	37621	12.66	3410.6	42154	12.36
Air/Vacum	215.3	4114	19.11	1387.8	31332	22.58	1603.1	35446	22.11
Others	89.4	6684	74.77	110	4271	38.83	199.4	10955	54.94
Total	3368.8	144521	42.90	7690.4	234167	30.45	11059.1	378688	34.24

(a) Statistics collected by Australian Bureau of Statistics for AGSO, on behalf of the conferece of the Chief Government Geologists

Figure 10 Australian exploration drilling by drilling method and by type of exploration area during 1997-98



Of the $1066.8 million spent on exploration in Australia in 1997–98, about $378.7 million (36%) was spent on drilling, well down on the 42% of the previous year. A State-by-State breakdown of drilling expenditure is presented in Table 5. The highest and lowest proportions of exploration expenditure directed to drilling within the total expenditure recorded for each State in 1997–98 were 41.4% in New South Wales and 20.6% in Queensland (Fig. 8); the proportion in Queensland was almost half of the previous year. The proportion of exploration expenditure directed to drilling also decreased in Western Australia, New South Wales, and Tasmania.

About 11.06 million metres of exploration drilling was undertaken in 1997–98, 17% less than in 1996–97. In 1997–98, about 30% of the metres drilled was undertaken in production areas (Table 6), compared with 34% during the previous year. Drilling in Western Australia accounted for just under 8.5 million metres or 77% of total metres drilled (Fig. 9). In terms of drilling expenditure, Western Australia was responsible for 69% of the Australian total. Tasmania and Victoria were each below 3% in terms of both the proportion of total metres drilled and the proportion of the total expenditure spent on drilling, while South Australia increased its proportion to around 4% of the total for both expenditure and metres drilled in 1997–98.

Exploration drilling in greenfield areas decreased by 12% in 1997–98, to 7.69 million metres, at a cost of $234.2 million. This represented about 70% of all exploration metres drilled; in the previous year, the proportion of metres drilled in greenfield areas was lower, at around 66%. Drilling statistics by method of drilling and type of area are summarised in Table 6 and Figure 10.

Compared with 1996–97, drilling expenditure fell by 21.3% to $378.7 million, and metres drilled decreased by 17.2% from 13 361 to 11 059 million metres, in 1997–98. Average drilling costs per metre for all types of drilling combined fell by almost 5%. The 17% decrease in total metres drilled in 1997–98 reflected major reductions in all types of drilling both on production leases and on greenfields areas ("all other areas") as a result of cutbacks in expenditure by mining and exploration companies in response to lower metal prices.

Offshore mineral exploration in Commonwealth waters

Australia's Offshore Minerals Act 1994 regulates exploration for and mining of minerals, other than petroleum, over the continental shelf three nautical miles beyond the territorial baselines (generally the low-water mark) of the States and Territories.

Applications for a mineral exploration licence (MEL) are made to the designated authority (usually the relevant State or Territory minister responsible for mining) with an application fee of $3000. The application must be made in the approved manner and must specify details such as:

- block numbers (each block being ~ 4 km^2, and no more than 500 can be applied for with each application);
- proposed exploration program;
- amount of money allocated to each part of the program;
- technical qualifications of the applicant and employees;
- financial resources.

The initial term of a licence is 4 years and it may be renewed for three 2-year periods, subject to the licensee's satisfactory observance of the licence conditions. There is a mandatory reduction of 50% of the licence area on renewal of a MEL. However, it is possible to apply for an extension of term if activities have been significantly interrupted or stopped by circumstances beyond the control of the licensee.

As at 30 April 1999, a total of 64 offshore MEL applications had been received since February 1990. Currently there are eight active licences (Table 7), of which seven permit exploration for economic deposits of alluvial diamonds in offshore palaeochannels and tidal shoals in the Joseph Bonaparte Gulf (northwest Australia). Though no diamonds so far have been discovered in Commonwealth waters, gem-quality diamonds have been discovered adjacent to WA-1-MEL and WA-7-MEL in State waters.

Most offshore mineral exploration to date has been based on known distributions of diamonds, gold, heavy mineral sands, and tin in adjacent onshore areas. Other mineral commodities with offshore extensions from known onshore deposits include tungsten, coal, manganese, and iron ore. Phosphates and polymetallic manganese nodules (containing nickel, cobalt, and copper) occur in deep water and are of potential long-term interest.

Table 7 Active offshore exploration licences in Commonwealth waters

MEL	Date Granted	Location	Commodity
WA-1	29-Jul-90	120km north of Wyndham, (Ord Prospect)	Diamond
WA-4	22-Jun-92	120km northeast of Wyndham, (Victoria Prospect)	Diamond
WA-7	10-May-94	140km north northwest of Wyndham, (Berkeley Prospect)	Diamond
NT-1	17-Jan-92	170km northeast of Wyndham, (Victoria Prospect)	Diamond
NT-2	17-Jan-92	140km northeast of Wyndham (Victoria Prospect)	Diamond
NT-3	16-Apr-95	300km northeast of Wyndham (Daly River Prospect)	Diamond
NT-4	16-Apr-95	200km northeast of Wyndham (Daly River Prospect)	Diamond
T-1	30-Mar-98	Ringarooma Bay, Tasmania	Tin

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Appendix 1: Abbreviations and acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
BRS	Bureau of Resource Sciences
c	carat
CSIRO	Commonwealth Scientific & Industrial Research Organisation
EAR-1	estimated additional resources - category 1
EDR	economic demonstrated resources
GL	gigalitre
Gt	gigatonne
IAEA	International Atomic Energy Agency
kg	kilogram
km	kilometre
kt	kilotonne
L	litre
m	metre
m3	cubic metre
Mc	million carats
MEL	mineral exploration licence
mm	millimetre
MREB	Mineral Resources & Energy Branch
Mt	million tonnes
Mtpa	million tonnes per annum
MW	megawatt
na	not available
NSW	New South Wales
NT	Northern Territory
OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
PGM	platinum-group metals
Qld.	Queensland
RAB	rotary air blast
RAR	reasonably assured resources
RC	reverse circulation
$	dollar
SA	South Australia
SDR	Subeconomic demonstrated resources
t	tonne
Tas.	Tasmania
tpa	tonnes per annum
U	uranium
U_3O_8	uranium oxide
USA	United States of America
USGS	United States Geological Survey
US$	United States of America dollar
Vic.	Victoria
WA	Western Australia

Appendix 2: National classification system for identified mineral resources

Introduction

Australia's mineral resources are an important component of its wealth, and knowledge of the location, quantity and quality of such resources — including estimates of resources yet to be discovered — is an essential prerequisite of formulating sound policies on their use and conservation. Results of resource assessment can be used also to set priorities for mineral exploration and research to indicate mineral potential where alternative land uses are being considered.

In 1975, the then Bureau of Mineral Resources, Geology and Geophysics (BMR) adopted, with minor changes (BMR 1976), the McKelvey resource classification system used by the US Bureau of Mines and USGS (USBM/USGS 1980). Subsequently informal guidelines for using the system's definitions were developed and used by BMR for several years, until the whole system and its application was reviewed in the light of accumulated experience. The results of that review were published (BMR 1984) as the refined BMR mineral resource classification system for national resource assessment.

The principles of the McKelvey system, were retained, as were most of the definitions used by BMR in its original system, although minor changes were made to some. Guidelines on applying the system were established, and adopted. It was decided that the term 'reserves' would not be used for regional or national aggregates of resources, so as to avoid the confusion arising from its use with different meanings in other contexts.

The Bureau of Resource Sciences (BRS) was formed in 1992 by combining the Mineral and Petroleum Resource Assessment Branches of the BMR with the Bureau of Rural Resources. BRS used the modified McKelvey system in preparing its annual national assessments of Australia's identified mineral resources from 1992 to 1998 Following administrative changes in the Australian Government in late 1998, the Mineral and Petroleum Resource Assessment Branches of BRS were incorporated into AGSO within the newly created Commonwealth Department of Industry, Science & Resources. Estimates prepared by BRS and AGSO are therefore consistent with earlier estimates prepared by BMR, which means any analysis of trends is based on consistent datasets.

Several editions of an industry code for reporting resources in individual deposits have been published, the most recent being the 1996 edition entitled 'Australasian code for reporting identified mineral resources and ore reserves', commonly referred to as the JORC code. This was a report of a Joint Committee of the Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists, and the Minerals Council of Australia.

The modified McKelvey system and industry codes are compatible, and data reported for individual deposits under the industry code are used by AGSO in the preparation of its assessments of Australia's mineral resources.

Classification principles

AGSO classifies known (identified) mineral resources according to two parameters: degree of assurance of occurrence (degree of geological assurance) and degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and chemical composition (grade); the latter takes account of changing economic factors such as commodity prices, operating costs, capital costs, and discount rates.

Resources are classified in accordance with circumstances at the time of classification.

Resources which are not available for development at the time of classification because of legal and/or land-use factors are classified without regard to such factors; however, the amount of resource thus affected will, wherever possible, be stated for each classification category.

The classification framework is designed to accommodate all naturally occurring metals, non-metals, and fossil fuels, and to provide a means of comparing data on different resources which may have a similar end use (e.g., petroleum, coal, and uranium as energy sources).

The modified McKelvey system for classifying identified mineral resources is illustrated below.

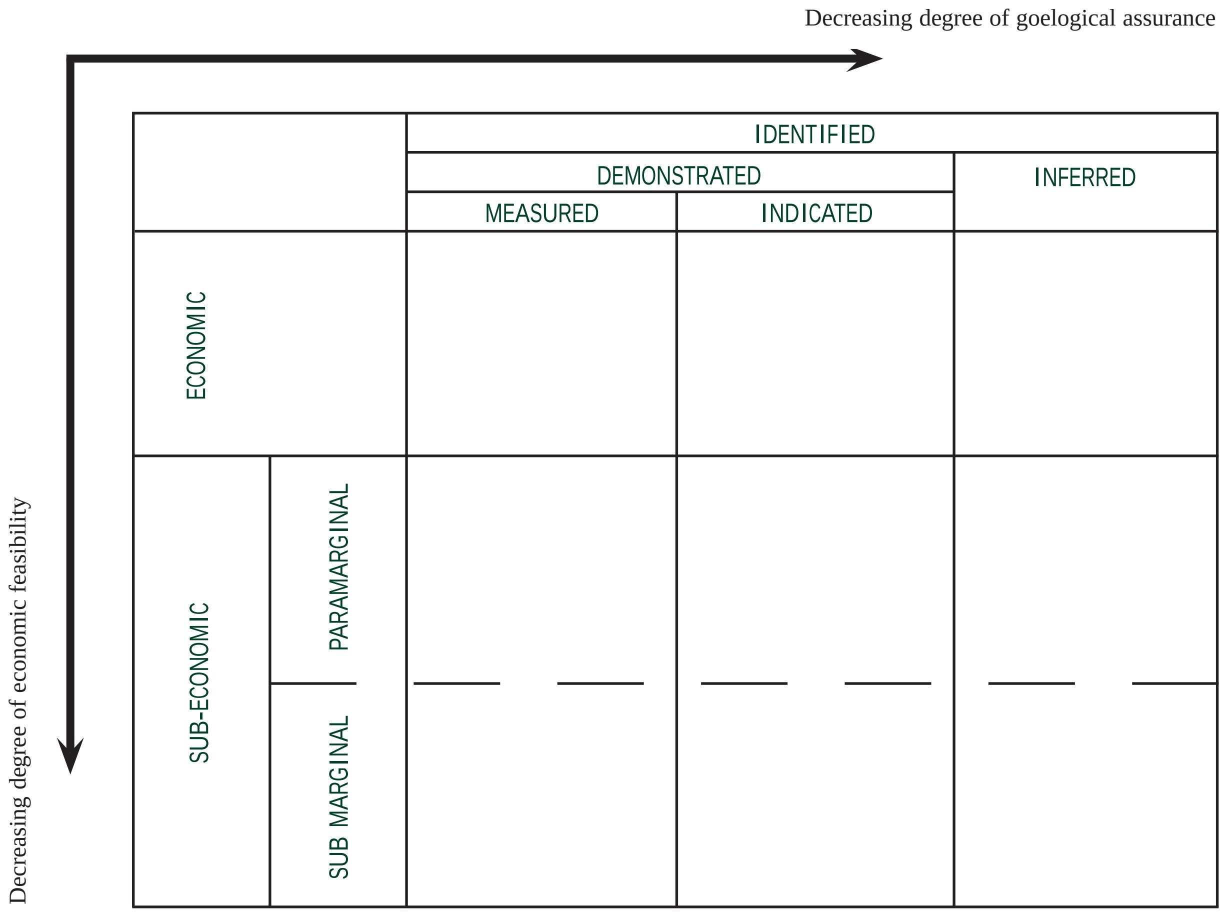
Terminology and definitions

RESOURCE — A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust and in such form that its economic extraction is presently or potentially (within a 20–25 year time frame) feasible (see guideline i).

Categories of resources based on degree of assurance of occurrence

IDENTIFIED RESOURCES — Specific bodies of mineral-bearing material whose location, quantity, and quality are known from specific measurements or estimates from geological evidence. Identified resources include economic and subeconomic components. To reflect degrees of geological assurance, identified resources can be divided into the following categories:

MEASURED — Resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drillholes, and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and



measurement are spaced so closely, and the geological character is so well defined, that size, shape, and mineral content are well established.

INDICATED — Resources for which tonnage and grade are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than for resources in the measured category, is high enough to assume continuity between points of observation.

DEMONSTRATED — A collective term for the sum of measured and indicated resources.

INFERRED — Resources for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is geological evidence. This evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geological evidence of their presence. Estimates of inferred resources should be stated separately and not combined in a single total with measured or indicated resources (see guideline ii).

Categories of resources based on economic considerations

ECONOMIC — This term implies that, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty (see guideline iii).

SUBECONOMIC — This term 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, almost satisfies the criteria for economic. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria which define economic. Included are resources which would be producible given postulated changes in economic or technologic factors.

SUBMARGINAL— That part of subeconomic resources that would require a substantially higher commodity price or some major cost-reducing advance in technology, to render them economic.

AGSO guidelines for classifying mineral resources

(i) Use of the term ‘resources’ is restricted to material, the extraction of which is generally judged to be potentially economically viable in an arbitrary time frame of about 20 to 25 years. The term includes, where appropriate, material such as tailings and slags. The definition does not intend to imply that exploitation of any such material will take place in that time span, but only that its possibility might reasonably be considered. This guideline attempts to establish a lower limit to what is worth assessing. It should be applied on a commodity by commodity basis to take account of prevailing and prospective technologies. Material falling outside the category of resource should be referred to as ‘occurrences’. Unless otherwise stated, the classification system refers to in-situ resources. However, it is possible and in fact desirable to also show recoverable quantities of resources in each category.

(ii) By definition, inferred 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 inferred resources are shown as ‘undifferentiated’, the amount known or judged to be economic may be indicated. Such judgements must take careful account of the commodity being assessed and its mode of occurrence as these factors will have a bearing on the reliability of estimates made. Specifically, grade estimates can be more reliably made for concordant sedimentary and biological deposits than for discordant epigenetic deposits (King et al. 1982, p. 8).

(iii) The definition of 'economic' is based on the important assumption that markets exist for the commodity concerned. All deposits which are judged to be exploitable economically at the time of assessment, whether or not exploitation is commercially practical, are included in the economic resources category. It is also assumed that producers or potential producers will receive the 'going market price' for their production. The classification is therefore based on the concept of what is judged to be economic rather than what is considered to be commercial at any particular time.

The information required to make detailed assessments of economic viability of a particular deposit is commercially sensitive (e.g., a company's costs and required internal rate of return), and these data may not be available to organisations such as BRS. Furthermore, as corporate strategies are likely to be different, individual companies will have different criteria for what is considered to be 'economic'. Thus to standardise the approach for national or regional resource assessments, the following mineral deposits/situations are accepted by AGSO, as a general guide, to be economic:

(a) the resources (published or unpublished) of operating enterprises, whether or not such operations are sustained by long- or short-term, direct or indirect, government subsidies;

(b) resources in a deposit which is being developed for production (i.e., where there is a corporate commitment to production);

(c) undeveloped resources which are judged to be economic on the basis of a financial analysis using actual, estimated, or assumed variables — viz., the tax rate, capital and operating costs, discount rate (such as reflects the long-term bond rate), commodity prices, and depreciation schedules; the values for the economic variables used in an assessment must be realistic for the circumstances prevailing at the time of the assessment;

(d) resources at mines on care-and-maintenance meeting the criteria outlines in (c) above.

(iv) The term 'recoverable' is considered to make allowance for mining as well as processing losses. Where a finer distinction needs to be made, mineable is used to take account of mining losses and metallurgically recoverable (saleable for coal) is used to take account of processing losses.

(v) Some minerals derive their economic viability from their co-product or by-product relationships with other minerals. Such relationships and assumptions must be clearly explained in footnotes or in accompanying text

(vi) National aggregates of resource estimates should be rounded to the appropriate last significant digit, so as not to create false impressions of accuracy.

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