

Western Australia

# Mineral and Petroleum Exploration and Development



1997-98



DEPARTMENT OF  
MINERALS AND ENERGY  
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**GEOLOGICAL SURVEY OF WESTERN AUSTRALIA**

**WESTERN AUSTRALIA  
MINERAL AND PETROLEUM  
EXPLORATION AND DEVELOPMENT  
1997–98**

**by**

**D. J. Flint, P. B. Abeyasinghe, Gao Mai, D. B. Townsend  
and R. H. Bruce**

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# Western Australia mineral and petroleum exploration development 1997–98

by

D. J. Flint, P. B. Abeyasinghe, Gao Mai, D. B. Townsend, and R. H. Bruce

The geological setting of Western Australia has provided a rich endowment of mineral wealth covering a variety of mineral types and mineralization styles. In 1997–98, the value of mineral production (including petroleum) amounted to \$17.8 billion. Western Australia continues to be a very significant producer of gold, iron ore, bauxite–alumina, nickel, diamond, heavy-mineral sand products, salt, tantalite, spodumene (lithium), and liquefied natural gas (LNG) in a world market context.

The minerals sector continues to dominate current and planned economic development in Western Australia. Although the limelight is often focused on value-adding by downstream processing of minerals, particularly in the iron-ore industry, such operations rely on the availability of suitable minerals in the ground and their improved economic viability after extraction. Advances in process technology, gas-price deregulation in Western Australia and, very significantly for Eastern Goldfields gold and nickel producers, wider gas distribution with the opening of the Goldfields Gas Transmission Line, are having a significant impact on project economics and are changing in some respects the focus of exploration effort. Mineral discoveries are critical to the continuance of project developments, although a number of evaluations and developments currently taking place are on deposits first identified over 30 years ago. Mineralization that perhaps was not contemplated as having significant development potential a few years ago is now attracting major exploration effort.

This article is compiled from public information, and relies heavily on company reports to the Australian Stock Exchange. Unless otherwise stated, data on mineral exploration expenditure is obtained from the Australian Bureau of Statistics, Catalogue 8412, *Actual and expected private mineral exploration*. The geological context and most of the localities mentioned in this report can be found in the *Western Australia atlas of mineral deposits and petroleum fields 1999*, published by the Geological Survey of Western Australia. Information on estimated mineral resources (excluding petroleum), as well as discoveries since 1995, is maintained within the Department's MINEDEX database. A digital subset of MINEDEX is available, with the latest data extracted in August 1998 (Townsend, 1996). Formal names of the

various greenstone belts in the Yilgarn Craton used in this article are as defined by Griffin (1990a,b). Details of mineral production are from data supplied by producers, under requirements of the *Mining Act 1978* and *Petroleum Act 1967*, to the Department of Minerals and Energy, or from company reports to the Australian Stock Exchange. More information on production in Western Australia is available in the Department's *Statistics Digest*, published every six months.

## Exploration overview

Western Australia's acknowledged prospectivity is reflected by the continuing high level of exploration expenditure throughout the State. In 1997–98, mineral exploration expenditure (excluding petroleum) in the State was \$660.4 million, a decrease of \$31.3 million or 4.5% on the record previous year. This is the first decline in total exploration expenditure after seven successive years of growth (Fig. 1), and the decline is not as much as might have been anticipated from market sentiment and earlier predictions.

The continued high levels of exploration activity in Western Australia have helped to maintain Australia's

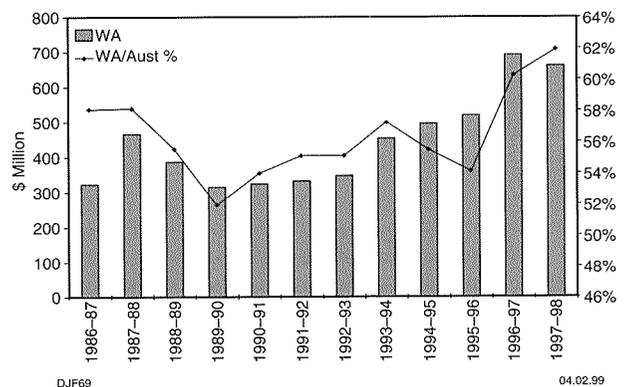


Figure 1. Mineral exploration expenditure in Western Australia (dollars of the day)

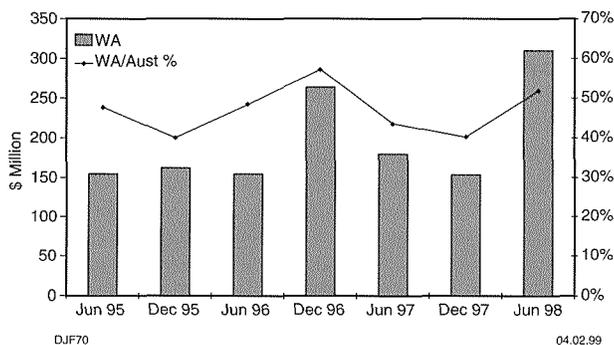


Figure 2. Petroleum exploration expenditure in Western Australia (dollars of the day)

total annual exploration expenditure (excluding petroleum) above the \$1000 million mark for the second time — reaching \$1066.8 million (original figures) for 1997–98. This is, however, a 7.1% decline from the previous year, but the decline in Western Australia was only 4.5%. Western Australia now attracts 61.9% (60.2% previously) of all Australian exploration expenditure, the highest proportion since at least 1986–87 (Fig. 1). In the last eight years, Western Australia has increased its share of Australian mineral exploration expenditure (excluding petroleum) on seven occasions.

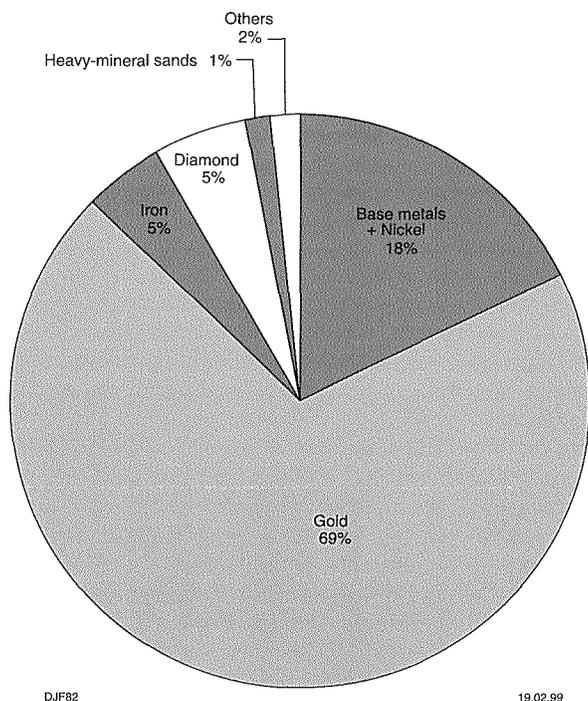


Figure 3. Mineral exploration expenditure in Western Australia for 1997–98, by commodity

In 1997–98, petroleum exploration expenditure in the State set a new record for the second year in a row, totalling \$463.9 million, following a very strong performance in the second half of the year (Fig. 2). This is an increase of \$19.8 million or 4.6% on the previous year, and it extends a significant period of increasing petroleum exploration in Western Australia, which now attracts around 48% of all Australian petroleum exploration expenditure.

The weakness in the gold sector during 1997–98 is readily apparent, with gold exploration accounting for only 69% (previously 76%) of the total exploration expenditure in the State (Fig. 3). But the strong push to develop lateritic nickel deposits has seen exploration for base metals and Ni–Co (undifferentiated) rise from 13 to 18% of the total exploration expenditure in the State. The dramatic decrease of \$72.4 million in gold exploration expenditure has only been partly offset by the net increase of \$29 million in exploration for Ni–Co and base metals (Fig. 4). Other commodities are relatively unchanged, with diamond and iron at 5% each, and heavy-mineral sands and ‘other minerals’ both at 1–2% of the total spent in the State.

Western Australia attracts the major part of the Australian exploration dollar for iron ore (99%), gold (70.8%), diamond (73.4%), and heavy-mineral sands (62.9%). Western Australia now attracts 51.6% of the Australian exploration dollar for base metals (Cu–Pb–Zn–Ni–Co), and this is the first time since at least 1984–85 that the proportion in Western Australia has exceeded 50%. The percentage for Ni–Co is presumed to be higher, but data sourced from the Australian Bureau of Statistics do not show Ni–Co separately. All proportions except gold are higher than for the previous year.

Despite the strong pessimism in many parts of the gold sector, the State’s inventory of measured and indicated gold resources increased during 1997–98, though reserves would have decreased as a result of the lower gold price and hence higher cut-off grades. Some significant discoveries and resource upgrades were announced during the year, but mostly failed to generate enthusiasm or optimism within the gold sector and the investing public. Undoubtedly, 1997–98 was a turning

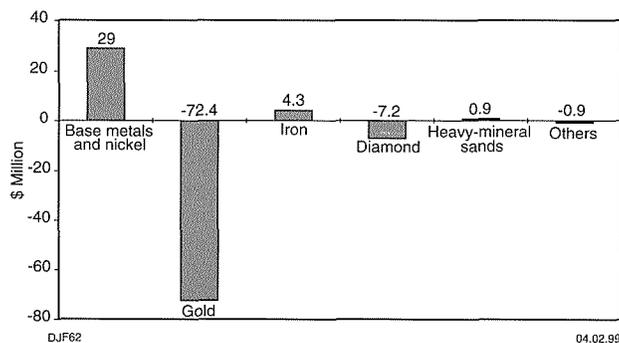


Figure 4. Change in mineral exploration expenditure in Western Australia from 1996–97 to 1997–98, by commodity

point in the gold industry with gold exploration expenditure falling by 13.6%, and with some expectations emerging that the downturn may be more than just short-lived.

The development of mines at the lateritic nickel deposits of Murrin Murrin, Cawse, and Bulong was a feature of 1997–98, though none had been commissioned at the end of the financial year. The strong focus on establishing resources at the numerous lateritic nickel deposits led to a 56% increase in the measured and indicated resources in lateritic nickel deposits. Under optimistic scenarios, WA’s output could be around 450 000 t of nickel (as nickel metal or as nickel in concentrates) by 2005. This would represent about one third of the predicted world production of 1.3 Mt. However, the low nickel price may lead to a sharp reversal in the current focus on nickel, and, already, three high-cost underground mines at Kambalda have closed.

For iron ore, increases were recorded in exploration expenditure and the estimated resources (measured and indicated categories). The strongly positive development for the year was Hamersley’s commencement of mine construction at Yandicoogina. However, the year was also marked by time delays and cost over-runs of BHP’s hot-briquetted iron plant at Port Hedland, and delays in developing An Feng Kingstream’s Mid West project.

Another highlight for the year was the continued emergence of the Lennard Shelf into one of the world’s major zinc-producing provinces. With Pillara in full production, the Lennard Shelf region will be the seventh largest zinc-mining region in the world.

The high levels of exploration expenditure in Western Australia over the last few years have resulted in an increase of measured and indicated resources for many commodities. These include (with the percentage increase during 1997–98 shown in brackets) gold (12.2%), iron ore (2.6%), bauxite (0.8%), heavy-mineral sands (26.8%), and nickel (25.0%). However, estimated resources of diamond declined by 6.3% due to production from Argyle.

## Precious metals

### Gold

In 1997–98, gold exploration expenditure in Western Australia fell sharply, decreasing by 13.6% over the previous year and falling from the record of \$531.7 million to \$459.3 million, but it is still at very high levels historically (Fig. 5). Western Australia continues to lead the way, attracting 70.8% of all gold exploration expenditure in Australia during 1997–98. This is slightly down on the record of the previous year (73%), but is still the second highest recorded. Despite some pessimism in the gold sector, Western Australia undoubtedly continues to be recognized by industry as the best place to explore for gold in Australia.

In 1997, gold discoveries and upgrades of resource categories added about 367 t (313 t previously) of

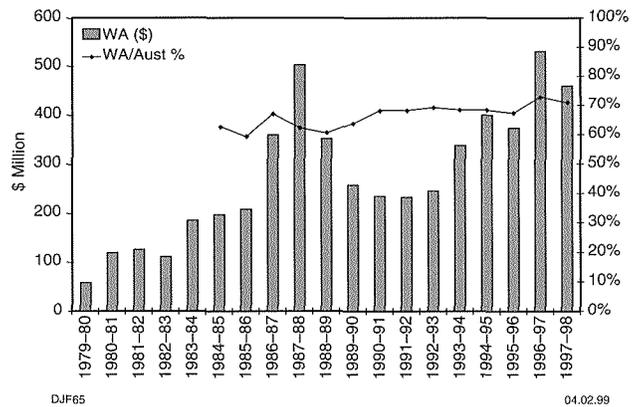


Figure 5. Gold exploration expenditure in Western Australia (1997–98 dollars)

contained in-ground gold resources to the measured and indicated inventory, from about 3009 t (1996) to 3376 t at the end of 1997 (Fig. 6). This translates, after allowing for production, to an average discovery cost of around \$A26/oz for 1997 — unchanged from 1996 and maintaining the pattern since 1993 of average discovery costs in Western Australia being within the range of \$A21–28/oz. It should be noted that this applies to measured and indicated resources only (including any reclassified as reserves); no allowance is made for inferred resources.

Gold production in Western Australia continued to increase, by 5.8% from 228.0 t in 1996–97 to 241.3 t — representing yet another record. The rise in value of gold production to \$3496 million was, however, a more modest 2.5%, caused by a lower average \$US gold price but assisted by a lower \$A/\$US exchange rate.

Approximately 13% of the gross value of gold production is returned as exploration funds (15% previously) — a level that is markedly higher than for other commodities in Western Australia. This level is likely to continue to fall, and levels of 5–9% are considered more sustainable in the longer term. One way

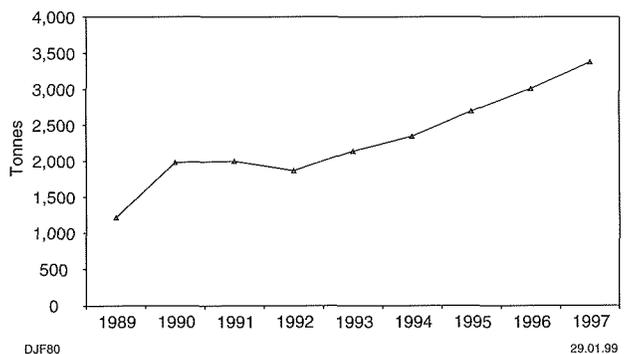


Figure 6. Western Australia’s gold resources (total measured and indicated) for 1989–97

**Table 1. Western Australian gold exploration costs per ounce of production**

Year	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Exploration dollars per ounce of production	38	50	63	56	72	59

to illustrate this point is to examine the trend in the estimate of exploration expenditure per ounce of production, as this is widely used as a component of total costs of production. Table 1 illustrates that State-wide exploration expenditure per ounce of production has been generally rising in Western Australia since 1992-93, with a peak of \$A72 in 1996-97, but is now declining. At a time of low commodity prices and a squeeze on cash margins, it is obvious that many companies view such high rates of capitalized exploration expenditure as imprudent.

During April 1998, legislation to introduce a gold royalty in Western Australia passed through Parliament and came into effect from 1 July 1998. The rate is 1.25% of the realized value of gold metal produced during the period from 1 July 1998 to 30 June 2000, whereupon the rate lifts to 2.5%. Royalty relief is available for small producers.

During 1997-98, negative sentiment prevailed within the gold sector. The \$US gold price fell throughout 1997, and it stayed at what is considered to be depressed levels during the first half of 1998. The gold sector was very much out of favour with investors, the Australian Stock Exchange gold index falling by around 30% over the 12 months. This placed serious constraints on the ability of companies to raise working capital. However, thanks to a falling \$US/\$A exchange rate, the \$A gold price rose by about 7% during 1997-98 — from \$A450 in June 1997 to \$A483 in June 1998 (Perth Mint average monthly price).

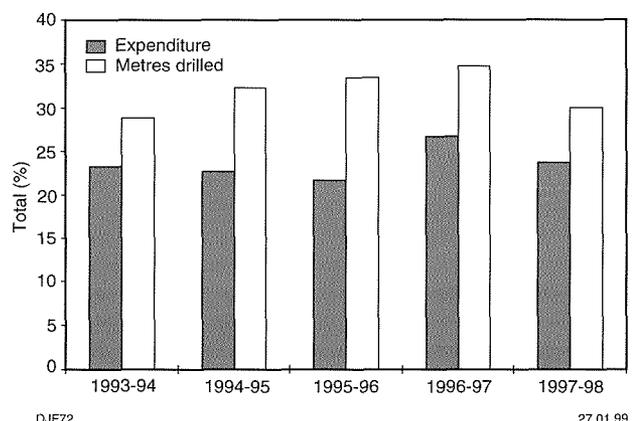
The low gold price and medium-term gloomy economic outlook for world growth and commodity prices resulted in, amongst other things: the closure of unprofitable high-cost mines; a drive to reduce operating costs and improve cash margins; downgrading of estimates of reserves; revised mine plans; a squeeze on junior companies with limited working capital; greatly reduced profits for service companies (particularly drilling and analytical companies); reduced exploration budgets; lay-offs in staff (both in exploration and operating mines); bargain hunting by local and overseas companies with strong balance sheets; and massive abnormal write-offs and write-downs in the assessed market value of mines, plant and equipment, stockpiles, and capitalized exploration expenditure. It was a gloomy year for many, but not for those with healthy margins and strong cash positions.

Anecdotal evidence and the stated exploration philosophy of some companies (e.g. Sons of Gwalia Ltd) suggest that most of the exploration effort is concentrated

on extending known orebodies and finding deeper, buried deposits around current mines, i.e. the so-called 'brownfields' exploration. That trend is supported by studies by Placer Dome Inc which indicate that the cheapest way to acquire additional resources is to expand those at existing mining operations, at an estimated cost of only \$US2/oz. This compares most favourably with costs from project acquisition (\$US25/oz) and grass-roots exploration (\$US100/oz).

However, data from the Australian Bureau of Statistics (applying to Australia as a whole and for all commodities) indicate that the exploration metres drilled and exploration expenditure on production leases as a proportion of the total actually fell by 3-5% during 1997-98, rather than the anticipated rise (Fig. 7). The fall during 1997-98 reverses the rising trends of the previous year and the broad four-year rising trend (particularly in metres drilled), but the reason for this is not immediately apparent. The falling trend could be a result of severe cost savings around existing gold operations or result from a change in accounting policy where exploration costs on production leases are partially re-assigned to development costs. Interestingly, Australian petroleum exploration expenditure shows the same trend, but the fall during 1997-98 is even greater.

Perhaps the most dramatic example of cutbacks in exploration budgets is Mount Isa Mine Ltd's closure of its Western Australian office — ending a 25-year presence in Western Australia. MIM cut its Australian exploration budget by 50% and staffing by 33%. In addition, WMC Ltd decided in March 1998 to reduce its exploration budget and staff (worldwide) by 20%.



**Figure 7. Australian mineral exploration on production leases (expenditure and metres drilled as % of total)**

Newcrest Mining Ltd also cut its worldwide budget by 24%, from \$79.7 million in 1996–97 to \$60.6 million in 1997–98. A smaller decrease of around 3% is estimated for 1998–99. Another company to cut its exploration budget was BHP Ltd, with a cut of around 10%. An example of a 1998–99 exploration budget with a sizeable decrease is that of Aberfoyle Ltd, with a planned 30% decrease in exploration expenditure in Australia.

The changing face of the gold industry in Western Australia was exemplified by numerous significant corporate changes during 1997–98. The most noticeable were those involving Great Central Mines Ltd. Control of the Yandal and Wiluna greenstone belts was consolidated when Great Central Mines Ltd completed its takeover of Eagle Mining Corporation NL and Wiluna Mines Ltd, and took a major shareholding in Australian Resources Ltd. In turn though, Normandy Mining Ltd has acquired a significant stake (27.5%) in Great Central Mines Ltd. Another sign of the times was the amalgamation of Plutonic Resources Ltd with Homestake Mining Company. Other amalgamations included Kilkenny Gold NL with Kalmet Resources NL, and Cove Mining NL with Golden Valley Mines NL. Severe financial hardship fell upon several public companies, including St Barbara Mines Ltd, Australian Gold Fields NL, and Consolidated Gold NL.

The \$US gold price briefly touched \$US275 in August 1998 — the lowest in 18 years, but it has since recovered slightly. When this is combined with the \$A strengthening against the \$US, then the outlook for 1998–99 seems no better than for 1997–98. On the supply side, there are plans to end the backing of the Swiss franc with gold, which may lead to the Swiss central bank selling up to 1300 t of gold (50% of its reserves). On the demand side, there is obviously weaker demand throughout Asia, and the Indian government has raised the import duty on gold.

The possibility of three new large openpits, as well as an expansion of the current superpit at Kalgoorlie, was canvassed during the year. These were at Sunrise Dam (Acacia Resources), Jundee–Nimary (Great Central Mines Ltd), and St Ives–Leviathan (WMC Ltd). The Leviathan project, if it proceeds, may produce gold at the rate of 1 Moz per year. Homestake Gold and Normandy Mining were also considering a three-fold expansion of the Fimiston mill (currently treating about 10 Mtpa), which treats ore from the Super Pit and the Mount Charlotte underground mine. Development scenarios being considered included mining very low grade resources at the Super Pit with a waste-to-ore ratio of 5:1.

Although the market sentiment has been decidedly negative during 1997–98, there are numerous highlights for the year, some of which struggled to receive much market attention. Selected highlights during 1997–98 include:

- Homestake Mining Company is reviewing development options for Darlot Centenary, with its 2.1 Moz of gold in resources.
- Discovery of broad, high-grade gold on the eastern flank of the Tarmoola pit. Results include 90 m at 6.7 g/t Au from 150 m depth.
- Continued exploration success at Nimary Deeps. Nimary Deeps is estimated to contain 1.1 Moz of gold, within resources averaging an impressive 12.6 g/t Au (pre-dilution).
- The Cleo resource at Sunrise Dam is estimated to contain 2.9 Moz, and additional exploration drilling includes an intercept of 156 m at 9.0 g/t Au.
- Discovery of the adjacent Wallaby and Just in Case deposits on the edge of Lake Carey. The initial resource estimate for Wallaby is at least 1.3 Moz of gold.
- Discovery of deposits along the Chatterbox shear zone. Inferred resources in several deposits (Whisper, Innuendo, and Rumour) total 640 000 oz of gold (oxide zone only).
- Establishing inferred resources of 1.0 Moz at Carosue Dam (Khartoum project), with similar style mineralization nearby at Whirling Dervish.
- Discovery of mineralization at Aphrodite and Leilani, 45 km and 10 km northwest of Paddington respectively. Results include 16 m at 10.9 g/t Au, but from a depth of 432 m.
- Discovery of the Bullant deposit, 1 km north of the Zuleika openpit. Drilling results include 27 m at 12.4 g/t Au.
- Expansion of the total estimated resources at the Golden Cities project — from 260 000 oz to 824 000 oz.
- Upgrading of resources at White Foil — measured and indicated resources are estimated to contain 510 000 oz of gold.
- Promising intersections in the King Bore area of the Menzies – Broad Arrow greenstone belt, including 6 m at 72.8 g/t Au.
- Underground mining to commence at Ghost Crab (Mount Marion), where 570 000 oz of gold are contained in resources averaging 5.1 g/t Au.
- Discovery of the Axehandle deposit, 6 km along strike from Cornishman.
- Deep drilling of the Hill 50 main lode at Mount Magnet, with an intersection of 21 m at 6.2 g/t Au from a depth of 1478 m. If developed to 1500 m, the mine would become the deepest in Australia.
- Discovery of Au–Cu–Ag mineralization, apparently of Telfer style, at Magnum prospect in the northern part of the Paterson Orogen.
- Development of a mine at Mount Olympus (Ashburton Basin).

- Discovery of significant gold mineralization at the old Paulsen workings (Wyloo Dome).
- Enhancement of the gold potential of the Mallina Shear Zone in the West Pilbara (Indee project), with drilling confirming significant deposits at Withnell and Camel 1 and 2.

Further details on these are provided in the following section. The geological units used within this article are shown on Figure 8, whereas the numerous place names mentioned in the following text are shown either in Figure 9 or in the *Western Australia atlas of mineral deposits and petroleum fields 1999*, published by the Geological Survey of Western Australia.

Homestake Mining Company is reviewing development at Darlot and Darlot Centenary, 120 km north of Leonora, after the take-over of Plutonic Resources Ltd. Homestake Mining Company is considering expanding the treatment plant from 700 000 tpa to 1 Mtpa, and reviewing the mining methods to be applied to the Darlot Centenary orebody where development ore was extracted in late 1997, only one year after discovery. Total identified resources at Darlot Centenary are estimated at 8.4 Mt at 7.7 g/t Au, containing 2.1 Moz of gold.

At Tarmoola, 30 km northwest of Leonora, Pacific Mining Corporation Ltd (incorporating Camelot Resources NL) has announced the discovery of broad, high-grade intersections on the eastern flank of the current Tarmoola pit. Results include 90 m at 6.7 g/t Au from 150 m, 29 m at 24.4 g/t Au from 81 m, 10 m at 35.1 g/t Au from 156 m, and 16 m at 12.2 g/t Au from 54 m. Mineralization is within 200 m of the surface and is apparently in a series of dilational, gently dipping, sheeted veins along the contact zone of granite with silicified and brecciated basalt. The discovery has the potential to significantly expand the Tarmoola resource and improve the mine economics.

Mining and exploration in the Yandal and Wiluna greenstone belts were largely consolidated under Great Central Mines Ltd after the takeover of Wiluna Mines Ltd and Eagle Mining Corporation NL. Exploration success continued with further high-grade intercepts at depth at Nimary (Nimary Deeps) including 14 m at 14.7 g/t Au from 244 m, 21 m at 6.4 g/t Au from 212 m, and 2.5 m at 47.4 g/t Au from 259.5 m. Inferred resources for Nimary Deeps are estimated at 2.7 Mt at 12.6 g/t Au, containing 1.1 Moz. Great Central Mines Ltd is considering the feasibility of creating one new superpit at the neighbouring Jundee and Nimary mines — potentially producing a mine 4 km long, 1 km wide and up to 300 m deep. This could see production at Jundee–Nimary increase to about 500 000 oz per year from treatment of 10–11 Mtpa of ore.

At Mount McClure, 50 km northeast of Leinster, Australian Resources Ltd continued to obtain high-grade intercepts below the existing Cockburn openpit and its planned base (290 m below the surface). Preliminary modelling shows the potential for an economic underground deposit. Inferred resources are estimated at

2.5 Mt at 8.2 g/t Au, using a cut-off of 2.0 g/t Au, for 650 000 oz of contained gold.

During 1997–98, there was renewed interest in the relatively underexplored Mount Eureka greenstone belt, east of and parallel to the Yandal greenstone belt. Delta Gold NL is earning a 75% interest through exploration on tenements covering 330 km<sup>2</sup>. The belt contains the abandoned Mount Fisher gold mine, but no sites with currently defined resources.

Further east, the Duketon greenstone belt continues to attract significant exploration activity because of the outstanding exploration and mining success at Sunrise Dam. The openpit mine commenced in March 1997 and is one of the lowest cost gold mines in Australia. Average cash costs in 1997 were \$169/oz, and are forecast to be less than \$200/oz for 1998. Two resources have been outlined at Cleo and Golden Delicious (7 km northeast of Cleo). The Cleo resource is 22.2 Mt at 4.1 g/t Au, at a 1 g/t Au cut-off, containing 2.9 Moz of gold. Indicated and inferred resources at Golden Delicious contain a total of about 215 000 oz of gold. Exploration at Cleo in 1997 increased the resource by 1.7 Moz. Openpit reserves are 6.1 Mt at 4.6 g/t Au, including oxide and transition ore estimated at 2.6 Mt at 4.3 g/t Au. For the current mining of the weathered ore, up to 60% of the gold is recovered in the gravity circuit. In mid-1998, exploration success continued in deep drilling of the Western Deeps mineralization at Cleo, with an intersection of 156 m at 9.0 g/t Au, including 80 m at 16 g/t Au, in drillhole CD244. Acacia Resources is spending \$7–8 million per year at and around Sunrise Dam, with feasibility studies commencing into underground mining or vastly expanding the openpit to a depth of about 400 m.

At Granny Smith, reserves as at the end of June 1998 were greater than 12 months previously, despite the production of 550 000 oz of gold. Delta Gold NL has discovered significant mineralization at Wallaby, located on the edge of Lake Carey and 11 km west-southwest from Granny Smith. Between 15 and 70 m of lake sediments cover the deposit, which consists of at least three subparallel, flat-lying, mineralized zones. Significant intersections from RC and diamond drilling include 21 m at 5.5 g/t Au from 170m, 10 m at 12.9 g/t Au from 60 m, and 7 m at 20.8 g/t Au from 90 m. Early predictions of a substantial resource were confirmed when Delta Gold NL announced in October 1998 the initial resource estimate for Wallaby — inferred resources of 9.3 Mt at 4.4 g/t Au, for 1.3 Moz of contained gold. The deposit is immediately adjacent to the Just-in-Case discovery, which is apparently part of the same mineralized system but is being explored by a joint venture of Abednego Nickel Ltd and Homestake Mining Company.

Development of the Red October deposit, 70 km south of Laverton, moved one step closer after settlement in mid-1998 of a two-year native title dispute. The deposit is jointly owned by Sons of Gwalia Ltd and Mount Burgess Gold Mining Company NL, and lies beneath sediments in Lake Carey. Indicated resources are estimated at 1.586 Mt at 5.8 g/t Au, containing 295 000 oz of gold. Work is proceeding on further

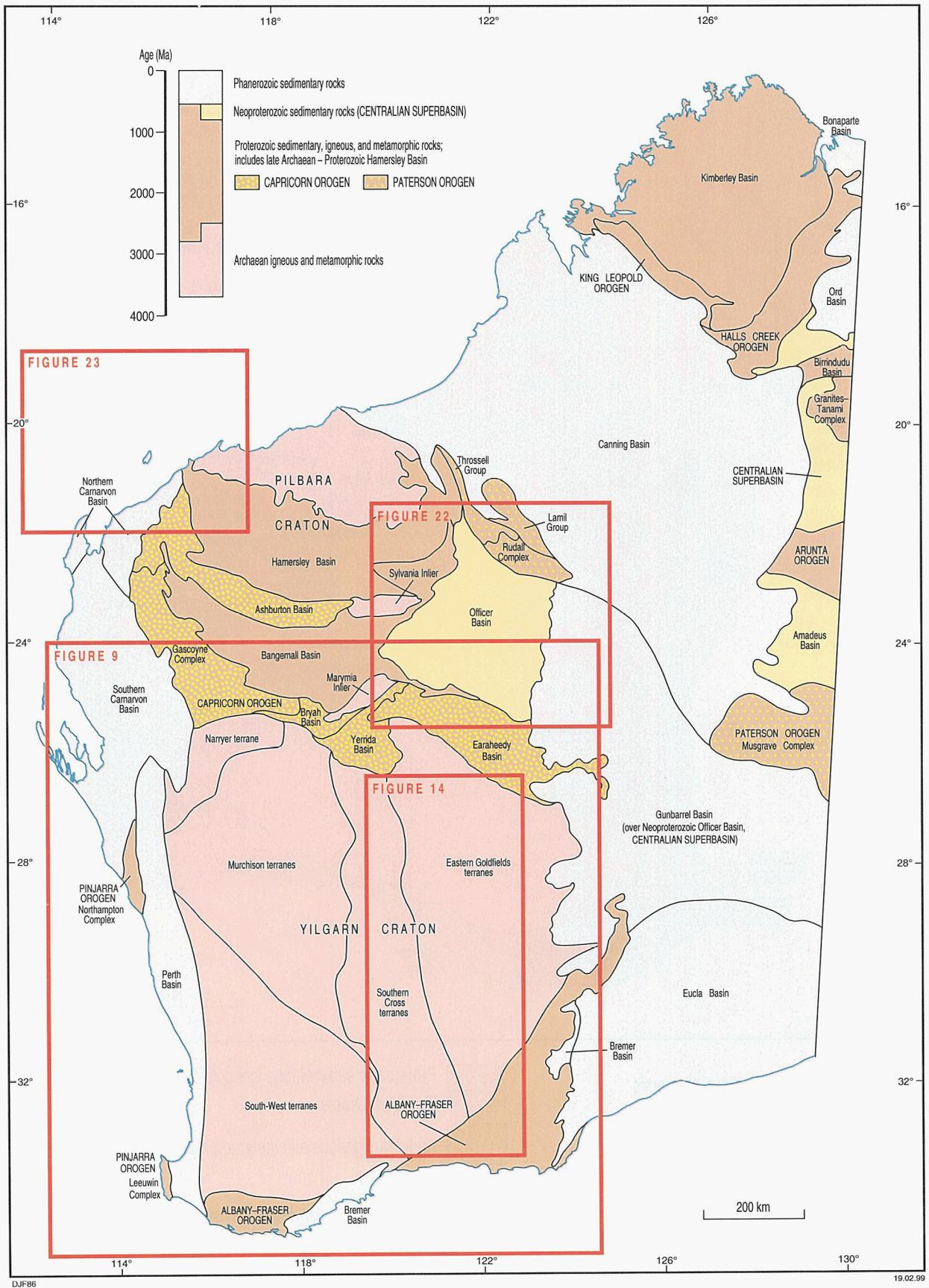


Figure 8. Main geological subdivisions of Western Australia

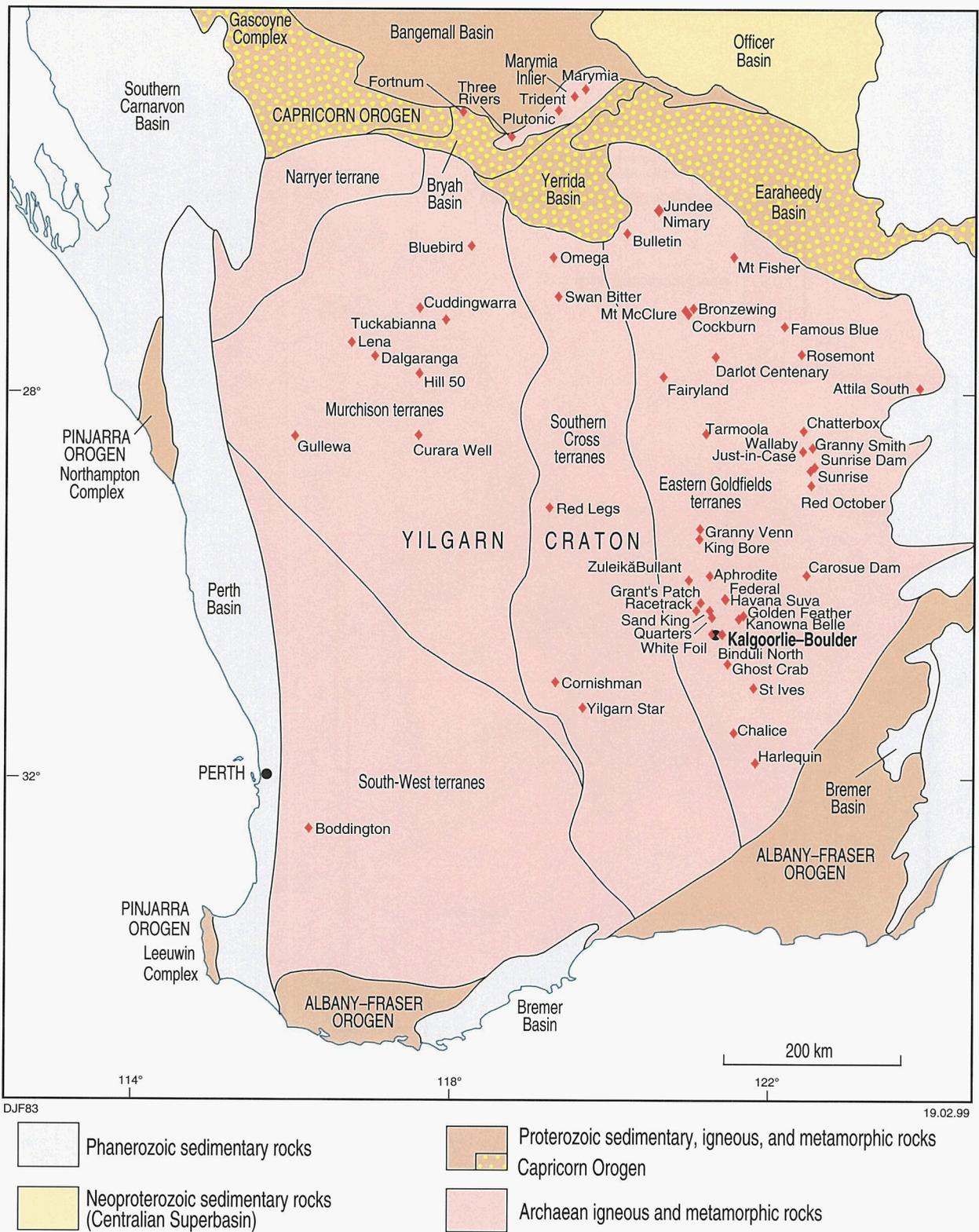


Figure 9. Gold localities of significance in the Yilgarn Craton and adjacent areas during 1997–98. See Figure 8 for location

feasibility studies, including close-spaced infill drilling and a detailed mine plan. Development may proceed in 1999. Meanwhile, the Laverton treatment plant is on care-and-maintenance.

The mineral potential of Rosemont, 90 km north of Laverton and discovered by Johnson's Well Mining NL in mid-1997, was advanced during 1997–98. Mineralization is within a stockwork of steeply dipping quartz–carbonate veins hosted by dolerite. Indicated resources are estimated at 5.13 Mt at 2.4 g/t Au, for 393 000 oz of contained gold. Inferred resources are estimated at 6.94 Mt at 3.7 g/t Au, for 820 000 oz of contained gold. Cut-off grades vary with depth, from 1 g/t Au above 150 m to 2 g/t Au below 180 m. Preliminary metallurgical studies indicate high recoveries (around 95%) and pre-feasibility studies indicate the possibility of mining from an openpit up to 1500 m long, which would engulf the existing Christmas Well openpit. Feasibility studies are continuing.

Gold mineralization along the Chatterbox Shear was found in 1997 by Metex Resources NL only 8 km from Laverton, illustrating that significant discoveries are still being made in highly explored areas. This discovery is on the soil-covered Chatterbox Shear — an apparently fundamental structure that had not previously been recognized, but was found by use of high-resolution airborne magnetic data and ground-based gravity data. Numerous sites of localized supergene enrichment have been identified along the 11-km strike length of anomalous gold, including Whisper, Innuendo, and Rumour. The total inferred oxide resources at all sites along the Chatterbox Shear are estimated at 5.55 Mt at 3.6 g/t Au, using a 1.0 g/t Au cut-off, for 640 000 oz of contained gold. Within the three main prospects (Whisper, Innuendo, and Rumour), estimated inferred resources are 3.6 Mt at 4.3 g/t Au, using a 1.0 g/t Au cut-off, for 497 000 oz of contained gold. Metex Resources NL and Delta Gold NL are proceeding with a pre-feasibility study, including infill drilling and metallurgical testing.

In 1997, Aberfoyle Ltd discovered gold mineralization at Carosue Dam (Khartoum project) in the Pinjin greenstone belt, 110 km northeast of Kalgoorlie, and inferred resources are now estimated at 10.8 Mt at 2.9 g/t Au, containing 1.0 Moz of gold. At the nearby Whirling Dervish prospect, 2–3 km to the north, RC drilling indicates mineralization of similar dimensions and grade, but drillhole density is insufficient for a resource estimate.

Mining has commenced at Delta Gold NL's Golden Feather deposit, 22 km northeast of Kalgoorlie and 3 km east of Kanowna Belle, with ore to be processed through Goldfields Kalgoorlie Ltd's Paddington plant. Production of at least 200 000 oz of gold is expected over the first 18 months from treating 1.5 Mt of ore; total resources contain about 1 Moz of gold.

Along the Bardoc Tectonic Zone, Goldfields Ltd announced discovery of mineralization at the Aphrodite prospect, approximately 45 km northwest of Paddington, from follow-up on earlier drilling that had revealed erratic

supergene gold. Follow-up drilling yielded intercepts including 16 m at 10.9 g/t Au from 432 m, and 19 m at 6.5 g/t Au from 385 m. Drilling is continuing, targeting the high-grade intercepts at depths greater than 380 m below surface. The gold-bearing alteration system at Aphrodite has a strike length of over 1 km. Elsewhere in the Bardoc Tectonic Zone, Goldfields Ltd also announced discovery of mineralization at the Leilani prospect, 10 km northwest of Paddington. Supergene and primary gold have been intersected within a porphyry host. Results include 5 m at 14.6 g/t Au from 29 m, and 11 m at 7.7 g/t Au from 13 m.

For the Siberia project of Gilt-Edged Mining NL, a new resource estimate has been determined following pit optimization studies at Sand King and Missouri, 75 km northwest of Kalgoorlie. Measured resources at both sites total 2.677 Mt at 3.1 g/t Au, using a 1 g/t Au cut-off, for 266 000 oz of contained gold. Infill and extension drilling is continuing, including targeting depth extensions of high-grade mineralization at Missouri where previous intersections include 5 m at 42.9 g/t Au from 84 m, and 6 m at 19.4 g/t Au from 67 m.

Centaur Mining and Exploration Ltd is targeting Kalgoorlie-style and size deposits in the Mount Pleasant – Ora Banda area (northwest of Kalgoorlie), but particularly at Grants Patch, Zuleika–Bullant and Racetrack. Centaur Mining and Exploration announced the discovery of the Bullant prospect, 1 km north of the Zuleika openpit. Initial drilling over a strike length of 600 m has yielded results including 27 m at 12.4 g/t Au from 182 m, 17 m at 4.5 g/t Au from 201 m, 6 m at 15.3 g/t Au from 14 m, and 12 m at 6.1 g/t Au from 48 m. At Quarters prospect, 500 m from the Mount Pleasant gold-processing facility, resource drilling has extended the known mineralization. Results include 6 m at 29.4 g/t Au from 147 m and 7 m at 23.0 g/t Au from 131 m. Mineralization is beneath 35 m of cover, with a depleted supergene zone.

At the Golden Cities project, about 30 km north of Kalgoorlie, AMX Resources NL has continued to expand the known resources at the Havana–Suva and Jakarta deposits, with total resources (indicated and inferred) increasing from 260 000 oz to 824 000 oz of contained gold. Total indicated and inferred resources at Havana–Suva are estimated at 7.602 Mt at 3.1 g/t Au, using a cut-off of 1.0 g/t Au, for 760 000 oz of contained gold. Mineralization at Havana–Suva and Jakarta is hosted by granite of the Scotia–Kanowna Granitoid complex. Preliminary mining studies have commenced.

The potential of the White Foil prospect, 23 km southwest of Kalgoorlie, continues to be upgraded by drilling by Mineral Commodities NL and Mines and Resources Australia Pty Ltd. The best drilling result for 1996–97 was a spectacular 227 m at 2.55 g/t Au from 76 m. During 1997–98, some of the initial inferred resources were upgraded — measured and indicated resources now total 7.12 Mt at 2.23 g/t Au, using a 1 g/t Au cut-off, for a total of 510 000 oz of contained gold. A pre-feasibility study is continuing. Deep drilling beneath the conceptual openpit indicates potential for underground mining with deep intercepts of

21 m at 3.17 g/t Au, 2 m at 14.3 g/t Au, and 4 m at 10.2 g/t Au.

The possible closure of Australia's largest and deepest gold mine, Mount Charlotte, was flagged by Kalgoorlie Consolidated Gold Mines Pty Ltd due to a combination of low grades and ground-stability problems, which affected production and cash operating costs. If the mine's performance does not improve over the next year then this historic mine, which has operated continuously since 1962, may be closed.

In the Menzies – Broad Arrow greenstone belt, Golden State Resources NL has promising intersections at several prospects within its King Bore project, 10 km southeast of Menzies. These include a promising 6 m at 72.8 g/t Au from 14 m at Cigar prospect, and broader low-grade intercepts from the King Bore – Down and Out prospect, which include 16 m at 2.61 g/t Au from 65 m, and 16 m at 2.27 g/t Au from 56 m.

During 1996–97, WMC Ltd delayed the planned \$157 million expansion and doubling of capacity to 5 Mtpa of ore at St Ives (25 km southeast of Kambalda), instead opting for a plant refurbishment costing \$30 million. During 1997–98, the Leviathan project was revised, with feasibility studies continuing into the possibility of creating a large openpit, up to 300 m deep, which would engulf some of the closed-down Britannia, Sirius, and North Orchin mines. Early estimates are of production at about 1 Moz per year, with cash costs of around \$300/oz. Ore from the Leviathan project, if it goes ahead, would be processed at the St Ives mill.

At the Ghost Crab openpit mine, 39 km south of Kalgoorlie, Newcrest Mining Ltd has approved underground mining. Resources at Ghost Crab total 3.5 Mt at an average grade of 5.1 g/t Au, for 570 000 oz of contained gold. Underground mining is expected to be at the rate of 500 000 tpa, producing gold with cash costs of production around \$350/oz, with production commencing in mid-1999. The underground mine will be known as Mount Marion, and production from Ghost Crab–Mount Marion is anticipated to underpin the long-term future of the nearby New Celebration mine.

In the Southern Cross terranes, Savage Resources Ltd announced in mid-1998 the discovery of significant gold mineralization (Red Legs prospect) in banded iron-formation at the northern end of the Johnston Well greenstone belt, about 200 km north of Southern Cross. Shallow RAB and RC drilling within the oxidized zone returned intercepts of 16 m at 2.2 g/t Au from the surface and 3 m at 22.3 g/t Au from 18 m, and the potential for sulfide mineralization was indicated by an intercept of 7 m at 7.2 g/t Au from 40 m.

Only 12 km southeast of Southern Cross, Sons of Gwalia Ltd has discovered a new zone of mineralization (Axehandle prospect) beneath 30–40 m of transported cover. Mineralization is hosted in the same stratigraphy and is of the same style as Cornishman, 6 km along strike to the north. Drill intercepts include 14 m at 6.7 g/t Au from 90 m, 4 m at 21.9 g/t Au from 148 m, and 11 m at 5.4 g/t Au from 71 m. Nearby at the New Zealand Gully

prospect, 2 km southwest of Southern Cross, drilling by Sons of Gwalia Ltd has led to estimation of an inferred resource of 810 000 t at 2.73 g/t Au, using a cut-off of 0.5 g/t Au, for 71 000 oz of contained gold. Pit optimization studies have commenced. In early 1998, Sons of Gwalia Ltd and Troy Resources NL announced agreement to redevelop the Cornishman mine, with ore to be milled at Bullfinch. The initial reserves are estimated at 942 000 t at 5.15 g/t Au, for 156 000 oz of contained gold. Pre-development work commenced in mid-1998.

In the Gum Creek greenstone belt at Gidgee, 65 km southeast of Meekatharra, Australian Resources Ltd decided to commence underground mining beneath the existing Swan Bitter openpit. At Omega mine, 40 km north of Gidgee, Australian Resources Ltd has obtained high-grade intercepts at depth beneath the openpit. Results include 7 m at 11.6 g/t Au, 13 m at 7.3 g/t Au, and 10 m at 12.9 g/t Au.

Meanwhile at Meekatharra, St Barbara Mines Ltd had a troubled year — closing its flagship mine (Bluebird) but continuing to process low-grade stockpiles, running at an operating loss of \$20.2 million for 1997–98, and incurring large abnormal write-offs to the value of \$73.7 million. One bright spot for the year was the sale of St Barbara's tenements at Cuddingwarra to Normandy Mining Ltd.

In the southwest Yilgarn, the Boddington partners in early 1998 completed studies to extend the oxide mining operations at Boddington, and a pilot operation to study the efficiency of hydraulic mining commenced. Hydraulic mining has the potential to increase the oxide mine life by up to six years.

The Boddington partners also completed a feasibility study for the Wandoo gold–copper hardrock resource located beneath the existing pits from which oxide ore is mined. The feasibility study used a resource of 311 Mt at 0.89 g/t Au and 0.10% Cu (based on drilling to May 1996), containing 8.9 Moz of gold, but with a forecast milled tonnage of 164 Mt containing 5.35 Moz of gold. Average forecast gold production was 320 000 oz per year, with average cash costs over the 14-year mine life of \$330/oz (after copper credits). A number of opportunities to improve the project's economic viability were also studied. The Boddington partners have executed a Heads of Agreement with Alcoa of Australia Ltd and Hedges Gold Pty Ltd to acquire all the mineral rights over the adjacent Hedges gold mine, which will enhance the potential of mining the two hardrock resources jointly. Meanwhile, drilling of the hardrock resource continues at Wandoo, with drilling in early 1998 confirming and extending the Wandoo South zone. Intersections include 101.5 m at 2.45 g/t Au and 0.21% Cu, and 234 m at 1.34 g/t Au and 0.43% Cu.

Exploration in the Murchison terranes should receive a boost during 1998–99 and beyond following an agreement between Acacia Resources Ltd and Gullewa Gold NL to explore Gullewa Gold's large tenement holdings in the Gullewa greenstone belt. The belt lies approximately 150 km west-southwest of Mount Magnet.

Gullewa Gold NL has also accepted a cash offer from Western Districts Corporation for the sale of its Gullewa mine.

Mining and exploration at Mount Magnet is now consolidated with Hill 50 Gold NL (formerly Wattle Gully Gold Mines) and its 100% subsidiary Mount Magnet Gold NL. Hill 50 Gold NL acquired the Mount Magnet gold assets of WMC Ltd and has rejuvenated activity in the region. During the first year after floating, Hill 50 Gold NL produced 112 000 oz at a cash cost of only \$293/oz. In openpit and underground deposits at Mount Magnet, Hill 50 Gold NL has measured resources estimated at 7.31 Mt at 1.4 g/t Au (containing 334 000 oz) and indicated resources estimated at 8.93 Mt at 4.5 g/t Au (containing 1.291 Moz). Deep drilling of the Hill 50 main lode at Mount Magnet has struck success, with an impressive intersection of 21 m at 6.2 g/t Au, but from a depth of 1478 metres. The program of deep drilling indicates, however, that the stratigraphy and mineralized structures continue to depths below previous mining and exploration data. If developed to 1500 m, the mine would become the deepest in Australia. As well as exploring for depth extensions to mineralization at Hill 50 mine, the company has also advanced Franks Tower to a mining project and discovered an openpit resource at Bartus South (immediately adjacent to the existing Bartus openpit where reserves will be exhausted in late 1998).

In the Murchison terranes, the likelihood of longer term mining at and near Dalgara mine (70 km northeast of Yalgoo) was enhanced following an agreement in principle between Equigold NL and Western Reefs Ltd to allow WMC Resources Ltd to acquire the tenements in the Western Queen project, about 37 km northwest of Dalgara. Inferred resources at Western Queen are estimated at 450 000 t at 11 g/t Au, for 158 000 oz of contained gold.

The Marymia mine had been originally scheduled to close in November 1996 but continued in production until early 1998. Exploration continues on nearby targets, particularly at Trident.

In the Bryah Basin, formerly part of the Nabberu Basin, Perilya Mines NL completed pre-feasibility studies on underground mining of the Starlight and Twilight orebodies at Fortnum Mine, 140 km north of Meekatharra. The two orebodies contain 565 000 t at 5.5 g/t Au (100 000 oz of contained gold), with forecast cash costs of production of \$300/oz, and have the potential to expand the mine-life of Fortnum by two years. Perilya Mines NL is proceeding with a final feasibility study.

Interest in the Paterson Orogen will undoubtedly increase during 1998–99 following an announcement in mid-1998 by Croesus Mining NL and Gindalbie Gold NL of mineralization at the Magnum prospect, 100 km north of Telfer and 120 km east of Nifty. A significant gold–copper mineralized system has been found (along with anomalous silver, bismuth, and tungsten), which has the potential to host a substantial resource. Mineralized zones contain massive sulfide (chalcopyrite, pyrrhotite,

and pyrite) and quartz. Alteration and mineralization are within a 240 m-thick interval, but the main mineralization is over a 44 m-thick interval. Drill results include 30 m at 1.4 g/t Au, 1.6% Cu and 5.5 g/t Ag from a depth of 264 m, including 8 m at 3.5 g/t Au, 4.4% Cu and 15.1 g/t Ag. Down-hole electromagnetic (EM) surveys indicate that the original EM anomaly found by BHP Minerals Pty Ltd has still not yet been intersected by drilling. Country rocks are metasedimentary successions of the Yeneena Supergroup, part of the Proterozoic Paterson Orogen that also hosts the Telfer gold deposit and the copper deposits at Nifty and Maroochydore. Numerous large exploration licences were pegged at the time of the announcement and BHP has the right to clawback to 70% interest, should a BHP-size resource (plus 2 Moz of gold) be identified, by reimbursing the other joint venture partners 300% of their exploration expenditure.

Grass-roots exploration by Glengarry Resources NL and Tanami Gold NL in the Western Australian portion of the Granites–Tanami Complex continued during 1997–98, with work directed at expanding the resource at Kookaburra and establishing resources at Sandpiper and Albatross. An inferred resource of 1.7 Mt at 2.1 g/t Au, for 115 000 oz of contained gold, has been defined at the Kookaburra prospect. Previous high-grade intersections at Sandpiper include 59 m at 5.49 g/t Au from 170 m, 15 m at 4.37 g/t Au from 120 m, and 17 m at 7.7 g/t Au from 8 m.

Exploration along the southern margin of the Hamersley Basin has been given a real boost by the very rapid discovery-to-development of the Mount Olympus mine (located 35 km southeast of Paraburdoo in Palaeoproterozoic sedimentary rocks of the Ashburton Basin) and the discovery of significant mineralization at the old workings at Paulsen (105 km south of Pannawonica in Archaean sedimentary rocks of the Fortescue Group in the Wyloo Dome).

BP Minerals discovered Mount Olympus in 1988 by stream-sediment sampling, but the full significance was not realized until Sipa Resources International NL commenced drilling in 1996. In mid-1998, a feasibility study was completed and the decision made to proceed with mine development. A joint venture of Lynas Gold NL, Sipa Resources International NL, and Arcadia Minerals NL is developing the resource within oxide and transition ore. The carbon-in-leach treatment plant from the closed Lynas Find mine near Port Hedland is being relocated to Mount Olympus to treat the oxide and transition ore. The base of total oxidation extends to about 30 m below the surface at West Olympus and 100 m depth at Mount Olympus. The ore reserve for oxide and transition ore at Mount Olympus and West Olympus is estimated at 1.94 Mt at 3.2 g/t Au, with 175 000 oz of recoverable gold. The mill throughput is planned for 600 000 tpa, producing 60 000 oz of gold over a mine life of three years. Gold production is forecast to commence in early 1999, with estimated cash costs of production at \$250/oz. Lynas Gold NL has already commenced a forward sales program — 20 000 oz at \$A472 (spot deferred). Sipa Resources

International NL (and its subsidiary Arcadia Minerals NL) retains ownership of the underlying refractory sulfide mineralization, which is estimated to contain an additional 580 000 oz of gold.

Taipan Resources NL has made an exciting discovery at the old workings at Paulsen mine, 105 km south of Pannawonica. Paulsen was previously explored by CRA Exploration Pty Ltd (now part of Rio Tinto Ltd). The host rocks are sedimentary rocks of the Archaean Fortescue Group within the Wylloo Dome on the southern margin of the Hamersley Basin, with quartz and massive pyrite mineralization in a large dilational zone. Previous work by CRA Exploration Pty Ltd suggests that the gold is essentially free milling, with recoveries from both oxide and sulfide ores of above 90%. Drilling by Taipan Resources NL during 1997–98 obtained numerous high-grade intersections, including 8 m at 74.65 g/t Au from 126 m, 8 m at 25.07 g/t Au from 145 m, 24 m at 13.20 g/t Au from 146 m, and 9 m at 22.5 g/t Au from 25 m. These have led to a significant upward revision of the resources. Measured and indicated resources are estimated to total 1.128 Mt averaging 6.3 g/t Au, using a 1 g/t Au cut-off, for 229 000 oz of contained gold. Inferred resources are substantial and estimated at 1.690 Mt averaging 9.1 g/t Au, for an additional 496 000 oz of contained gold. A pre-feasibility study is underway. The deposit is well situated for infrastructure, being located only 8 km east of the sealed Nanutarra–Paraburdoo road and the Goldfields Gas Pipeline. However, CRA Exploration Pty Ltd retains the right to acquire a 60% interest in the mining lease (M08/99) if Taipan Resources NL discovers indicated mineral resources containing more than 500 000 oz of gold.

In the north Pilbara about 80 km southwest of Port Hedland, Resolute Resources Ltd has revealed an extensive area containing several new prospects and largely untested gold anomalies (Indee project), which apparently relate to the Mallina Shear Zone. Drilling has confirmed significant deposits at Withnell, Camel 1 and 2, Calvert, and Mount Berghaus, whereas first-pass reconnaissance drilling produced encouraging results at Geemas, Mirdawari, and Charity. Drill results at Withnell include intercepts of 14 m at 5.8 g/t Au from 149 m, and 18 m at 5.0 g/t Au from 27 m, while RC drilling at Camel 1 has yielded 15 m at 9.0 g/t Au from 74 m. Numerous high-grade shoots have been found, many of which are not fully tested. In addition, broad-spaced aircore drilling along the Camel–Withnell shear-zone trend suggests the potential for a number of new openpits.

## Silver

The price of silver climbed 35% during 1997–98, rising from \$A211/kg in June 1997 to \$A288/kg in June 1998 (ABARE, monthly average prices). The price peaked even higher in February 1998, at \$A333/kg, representing a nine-year high, but the price rise had no immediate impact on exploration — the pessimism in the gold sector prevailed.

The Elizabeth Hill high-grade silver deposit, 35 km south of Karratha in the West Pilbara, received attention during the year when a 100 t bulk sample averaged 1% silver. East Coast Minerals NL (70%) and Legend Mining NL (30%) have sunk a shaft to a depth of 85 m in order to collect bulk samples of the mineralization, and now plan to deepen the shaft to 105 m and collect another 5000 t. Visible native silver has been exposed by the shaft development in 1997–98, and 150 kg of silver was sold to the Perth Mint. The metallic silver is in thin veins 3–10 mm thick within altered peridotite (Dingo Intrusion). Further trial mining is planned, including the introduction of a gravity-separation circuit estimated to recover at least 90% of the silver. The mineralization, as currently known, is of limited extent with indicated resources estimated at 28 000 t averaging 1% Ag, for about 9 Moz of contained silver. The conceptual target is about 300 000 t at a similar grade.

The Nimbus silver deposit, 15 km southeast of Kalgoorlie, consists of two shallow high-grade silver oxide deposits. These overlie primary massive and breccia-hosted stringer sulfides locally containing high grades of zinc, lead, and silver. During 1997, drilling was directed towards finding extensions of three known primary sulfide zones (Discovery, Eastern, and Western Zones) and two RC and two diamond drillholes were completed. The best assay result reported was 24 m grading 1.63 g/t gold (including 4 m at 5 g/t gold). Two RC drillholes intersected maximum values of 62 g/t silver and 1.55% lead, but no visible mineralization was noted. However, the drilling discovered the presence of previously unknown felsic lithologies (?volcanic rocks) beneath apparently subhorizontal mafic volcanic rocks. Measured and indicated resources at Nimbus remain at 891 000 t at an average grade of 282 g/t Ag, for an estimated 8.1 Moz (251 t) of contained silver.

## Major metals

### Iron ore

Iron-ore exploration expenditure in Western Australia for 1997–98 was \$29.8 million. This marks a 16% increase from 1996–97 and is the third year in a row in which exploration expenditure has increased. In terms of 1997–98 dollars, the level of exploration expenditure is at, or close to, previous boom periods of iron-ore exploration in the very early 1980s and in 1991–92 (Fig. 10). Exploration resulted in an increase in the State's resource inventory of high-grade iron ore in the measured and indicated categories — increasing by 2.6% from 21 960 Mt to 22 539 Mt (Fig. 11). High-grade iron ore is classified as containing more than 60% iron if the deposit is hosted by the Brockman or Marra Mamba iron formations, or is within iron formations of granite–greenstone terrains. But the grade limit is 55% iron if the deposit is a channel iron deposit (CID) or scree and detrital deposit. Levels of phosphorous, silica, or alumina are not considered. The decrease in high-grade, measured and indicated resources during 1995 and 1996 (Fig. 11) was due to the combination of increased production and a gradual re-assessment of resources to conform with the

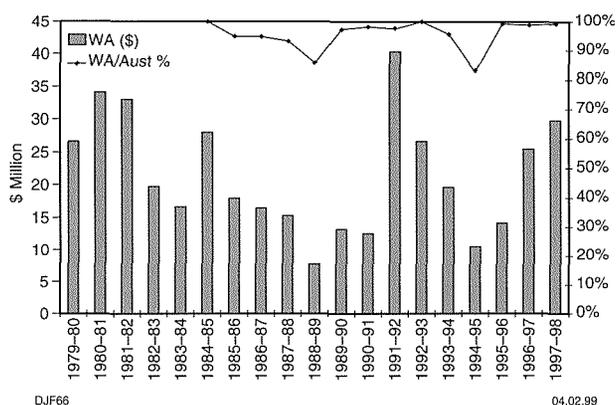


Figure 10. Iron-ore exploration expenditure in Western Australia (1997–98 dollars)

JORC (1996) code. In many instances, portions of the resources were downgraded to the inferred category. Inferred resources of high-grade iron ore, determined on the same basis, are estimated at 10 381 Mt as at mid-1998.

The downturn in demand and the collapse of steel prices in 1998 in Japan and South East Asia, will inevitably lead to a fall in exploration expenditure during 1998–99 or at least until the Asian economic crisis is over. The cost overruns and time delays in establishing BHP’s hot-briquetted iron plant at Port Hedland, along with speculated losses when it does operate, will also have a dampening effect on exploration and development.

The issue of sharing existing rail and port infrastructure is becoming an increasingly important factor in any future development of known iron-ore deposits, and is already a factor in the potential development of Hope Downs and West Angelas. Rail construction costs are about \$1.5 million per kilometre. No agreements have yet been reached, and, in the case of the West Angelas deposit, Robe River Iron Associates has used provisions of the Trade Practices Act and approached the Australian and Competition Consumer Commission. The immediate objective is to get a ruling requiring Hamersley Iron to negotiate terms and conditions for access to part of Hamersley Iron’s rail network. Robe River is seeking to improve project economics for the West Angelas deposit by limiting rail development in the mine area to only a 65-km spur line from Hamersley Iron’s Marandoo–Yandicoogina line.

Highlights during the year include commencement of construction of Hamersley’s Yandicoogina deposit; release of BHP’s environmental management plan for mining of Mining Area C; continued scoping and feasibility studies by North Ltd on the West Angelas deposits; involvement of Iscor Ltd with Hancock Prospecting Pty Ltd to jointly undertake a feasibility study of the Hope Downs project; and the takeover of the AUSI direct-reduced iron project near Cape Lambert by Kvaerner Pty Ltd Co. In addition, there was success on the research and development front by Rio Tinto Ltd

(HISMELT process) and Westralian Sands (converting waste from the manufacture of synthetic rutile at Capel into pig iron).

In late 1997, Rio Tinto Ltd announced its decision to proceed with the \$700 million Yandicoogina iron-ore project, 150 km east of its main mine at Tom Price. The Yandicoogina deposits contain over 3000 Mt of pisolitic iron ore (in resources of all types). On-site crushing and screening is expected to produce a fines product that is low in alumina. Project construction has commenced, with Fluor Daniel awarded the engineer–procure–construct–manage (EPCM) contract. Production and first shipments are scheduled for mid-1999, with an initial production rate of 5 Mtpa increasing to 15 Mtpa as market demand grows. The mine has an anticipated 30-year lifespan. Yandicoogina will be connected to the existing Hamersley Iron railway system via a 147-km rail line to Marandoo. Under the Hamersley Agreement Act, Hamersley Iron is obliged to process the Yandicoogina iron ore into products such as direct-reduced iron, but the downstream processing requirement is not triggered until Hamersley Iron has mined for 10 years or produced 150 Mt of iron ore.

Hamersley Iron has received approval from the Western Australian Government for the Brockman mine extension, allowing optimal utilization of Hamersley’s existing resource base, particularly the Tom Price and Paraburdoo orebodies. The mining at Brockman extension will add approximately 4 Mtpa to production.

BHP is proposing to mine deposits within the northern portion of Mining Area C, 100 km northwest of Newman. To date, 14 deposits containing over 1200 Mt of iron ore have been identified. The environmental management plan was released for public review in early 1998. The mine plan requires construction of only 35 km of new railway, which would connect with BHP’s existing line from Newman to Port Hedland.

Scoping and feasibility studies by North Ltd on the West Angelas iron-ore deposit continued during 1997–98. West Angelas contains resources of about 900 Mt of iron ore that would take 2–3 years to develop and involve capital costs of about \$1000 million. North

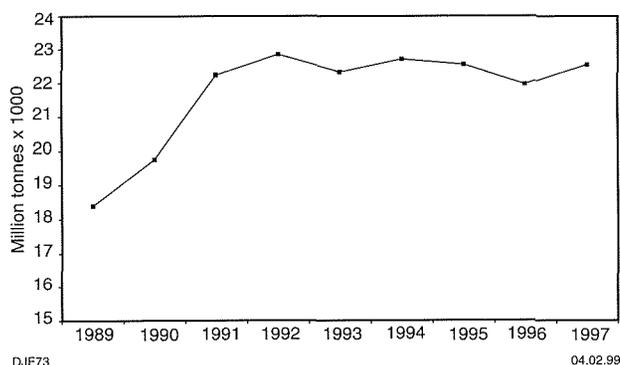


Figure 11. High-grade iron-ore resources in Western Australia (total measured and indicated) for 1989–97

had planned to commence production in about 2001 at a rate of about 20 Mtpa, but the Asian economic crisis may impact on the long-term development plans.

Development of An Feng Kingstream's Mid West Iron and Steel project continued, but not without incident, including adverse findings from the Australian Competition and Consumer Commission on the agreement between AlintaGas and Epic Energy Inc. to transport gas to the project. In addition, An Feng Kingstream was forced to start fresh construction and finance negotiations after failing to reach agreement on completion guarantees with the consortium including the world's biggest mill builder, Mannesmann Demag. A new Heads of Agreement was signed with Mitsui-Danieli-Lurgi, which included \$80 million bridging finance until project finance is arranged. Under that agreement, the cost of the Oakajee plant increased from \$1500 million to \$1775 million, but with a lift in annual capacity to 2.6 Mt of steel slab. Proposed production would be split between An Feng Kingstream's Taiwanese partner (2 Mtpa) and Mitsui (0.6 Mtpa). In August 1998, the Asian economic crisis hit hard with An Feng Kingstream being forced to stop site works at Oakajee following funding problems with An Feng Kingstream's Taiwanese subsidiaries and the need for restructuring of \$900 million of debt. A final contract with Mitsui-Danieli-Lurgi has not yet been signed, and Mitsui-Danieli-Lurgi apparently requires further site works and drilling before final commitment.

Hancock Prospecting Pty Ltd and the South African mining giant Iscor Ltd announced that they would jointly undertake a feasibility study of the large deposits of the Hope Downs project. The two-year feasibility study was expected to cost about \$20 million, with Iscor Ltd providing 80% of the funds and earning 49% interest in the project. Capital costs are of the order of \$1000 million, and project economics would be greatly improved if rail and port infrastructure were shared on a sensible and commercial basis with one of the existing iron-ore producers. The Marra Mamba Formation hosts deposits at Hope Downs, and marketing of iron ore from such deposits has been a problem in the past. The Hope Downs deposit has been extensively explored, including 100 000 m of RC drilling, 3200 m of 85 mm diamond drilling, a 100-m decline, and 12 winzes. Resources are estimated at over 800 Mt. The iron ore contains more hematite and goethite, and less limonite, than many other deposits hosted by the Marra Mamba Formation. Hence, crushing yields a product with about 40% lump ore (within the range 6–30 mm) and less ultrafines (only 25% of the total fines are less than 0.15 mm). Lump ore contains 62.14% iron, 2.7% silica, and 1.22% alumina, whereas fines grade 61.43% iron, 3.4% silica, and 1.83% alumina.

The Koolyanobbing iron-ore project, a joint venture between Portman Mining and a China-based consortium, is located 50 km north of Southern Cross and there are plans to expand the mine production from 1.5 Mtpa to 2 Mtpa. Mineable reserves are estimated at 15.1 Mt at 63.2% iron. Plans were also announced to switch the port of export from Esperance to Fremantle, and the

plan has been referred to the Environmental Protection Authority.

The proposed \$2000 million AUSI direct-reduced iron project near Cape Lambert received a slight boost during 1997–98. The proposal is to convert about 6.5 Mt of high-grade fines, supplied by Hamersley Iron, into iron pellets for export to electric-arc furnace steel producers in South East Asia. The new owner of AUSI, the British-based international engineering company Kvaerner Pty Ltd Co., has had the AUSI project rated as one of national significance, i.e. it qualifies for special Commonwealth investment allowances. Kvaerner Pty Ltd Co. is seeking State and Federal government support in terms of investment incentives and infrastructure. A memorandum of understanding has already been signed between the Australian Prime Minister and Chinese steel mills, with the latter expected to be the major customers for the pellets.

Rio Tinto Ltd's 17-year and \$30 million research and development program into the metallurgical HISMELT process passed a milestone during 1997–98, and Rio Tinto moved closer into becoming an iron-ore processor as well as exporter. Rio Tinto announced a major technological breakthrough, with alumina and silica retained in slag during steel production. The test plant at Kwinana had demonstrated that the process worked at an annual treatment rate of 50 000 tpa, and plans were announced for an intermediate-scale project with an annual capacity of 200 000–300 000 tpa. The intermediate-scale plant, estimated to cost \$100 million, may be built at a steel mill overseas rather than at Kwinana or Dampier. Rio Tinto are looking for a partner for the project, most likely an existing steel producer who can bring knowledge and expertise to the project. The intermediate-scale plant is likely to be in production between 2002 and 2005. A full commercial-scale plant is expected to process about 2.5–3 Mtpa, cost about \$1000 million, and would be built in the Pilbara.

Another research and development project advanced during 1997–98 with Westralian Sands announcing plans to build an \$18.5 million prototype plant at Capel to process waste from its synthetic-rutile operations into high-quality pig iron. Construction will commence in late 1999. Commissioning of an upgraded prototype plant, capable of producing 100 000 tpa of pig iron, is expected in mid-2000.

## Bauxite and alumina

Worsley Alumina Ltd currently mines bauxite in the Boddington–Saddleback area, and transports it via a 51-km two-flight conveyor to a refinery at Worsley, near Collie. In September 1997, Worsley Alumina Ltd announced that it would proceed with the planned \$800 million expansion of its Mount Saddleback bauxite operations and Worsley alumina refinery. This represents the biggest resource development in the southwest of Western Australia during the last ten years. The expansion has been on hold since 1994, but will increase Worsley's

annual capacity from 1.7 Mt to 3.1 Mt of alumina — confirming Worsley as one of the world's leading alumina producers. Project approval coincided with an industrial relations agreement between the West Australia Trades and Labor Council, and various unions and contractors. Project expansion commenced in October 1997 and is scheduled for completion in mid-2000. The gas-fired co-generation facility, at 120 megawatts, will be the biggest in Australia.

Alcoa of Australia operates mines at Jarrahdale (scheduled to close at the end of 1998), Huntley, and Willowdale to supply alumina refineries at Kwinana, Pinjarra, and Wagerup, respectively. During the year, the company announced plans that it would expand mine production in 1999 to supply both the Pinjarra and Kwinana refineries, and the capacity of the Wagerup alumina refinery would be expanded by 0.44 Mtpa. Currently, Alcoa's total capacity of 6.4 Mtpa of alumina (Kwinana 1.7 Mt, Pinjarra 3.0 Mt, Wagerup 1.7 Mt) is about 15% of the international market.

On-going exploration at and near existing sites of production has been successful in upgrading resources from inferred to that of measured or indicated status. This upgrading of resources has been at a rate equal to, or faster than, the production rate for the last eight years (Fig. 12). During 1997, bauxite resources (total measured and indicated) increased by 0.8% from 3359 Mt to 3386 Mt.

## Copper-lead-zinc

In 1997–98, the combined exploration effort on base metals and nickel-cobalt was \$117.1 million, an increase of \$29 million or 32.9% on the previous year. However, it is estimated that the search for nickel-cobalt made up the major proportion of this increase.

Falling base-metal prices during 1997–98 will mean that base-metal exploration in Western Australia during 1998–99 will remain depressed. The falls in copper, lead and zinc prices from June 1997 to June 1998 were 23%, 14% and 25% respectively (London Metal Exchange \$US/t prices), with copper trading at a 12-year low point. Already, Mount Isa Mines Ltd has closed its Western Australian office — ending a 25-year presence in Western Australia. Mount Isa Mines Ltd had been exploring the Ryansville base-metal project, including the Glenview prospect, located in the Weld Range 50 km northwest of Cue.

Exploration for base metals has concentrated on the major projects on the Lennard Shelf of the Canning Basin, the Nifty–Maroochydore area of the Paterson Orogen, the Golden Grove area of the Murchison Province, and the Albany–Fraser Orogen along the southern margin of the Yilgarn Craton.

Western Metals Ltd is developing the Lennard Shelf into one of the world's major zinc-producing provinces. With Pillara in full production, the Lennard Shelf region will be the seventh largest zinc-mining region in the world with an annual production of 2.4 Mt milled ore,

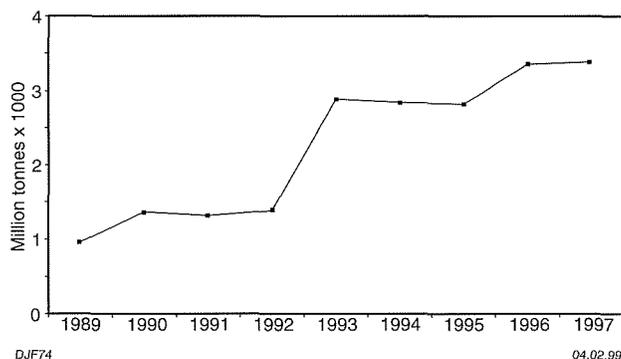


Figure 12. Bauxite resources in Western Australia (total measured and indicated) for 1989–97

yielding 170 000 t of zinc and 65 000 t of lead in concentrates. The company has a life-of-mine agreement, binding for five years, to supply 150 000 tpa of zinc concentrate to Korea Zinc Co Ltd's smelters in Townsville (under construction), South Korea and the United States. The measured and indicated resources of Western Metals on the Lennard Shelf are estimated to total 15.958 Mt averaging 9.063% Pb and 3.638% Zn. These equate to 6–7 years of mine life at the current production rate. Inferred resources are estimated to total 11.616 Mt averaging 6.925% Pb and 2.903% Zn. Western Metals Ltd has extensive tenement holdings on the Lennard Shelf, with tenements covering about 2500 km<sup>2</sup> and containing six advanced exploration projects. During 1997–98, new high-grade mineralization was discovered at Prices Creek, midway between Kapok and Goongewa mines.

Homestake Gold of Australia Ltd and Tectonic Resources NL discovered the polymetallic Trilogy prospect, with Cu–Au and Ag–Pb–Zn mineralization, in the Ravensthorpe area in late 1997. The deposit was found from a combination of conceptual modelling, airborne magnetic data and mobile metal ion geochemistry (MMI). Intercepts included 37 m at 0.58 g/t Au, 1.10% Cu, 5.82% Pb, 4.09% Zn and 71 g/t Ag. The country rocks form part of the Neoproterozoic Mount Barren Group within the Albany–Fraser Orogen, along the southern margin of the Yilgarn Craton. Previously, only the Archaean Ravensthorpe greenstone belt had been regarded as prospective, but the Trilogy discovery opens up a much larger area as prospective. The controls to mineralization are not known at this stage, but mineralization may relate to a southwest-trending structural corridor that extends into the Fitzgerald River National Park. Two mines, Copper King and Last Venture, located along the northeastern boundary of the national park, were worked in 1908–09 and have recorded copper and gold production. Pan Australian Resources NL believes its Steere River project may contain a strike extension of the polymetallic Trilogy prospect. Geochemical soil sampling by Pan Australian Resources, 500 m southwest of Trilogy, has yielded results similar to anomalies that led to the Homestake/Tectonic find.

The Maroochydore copper deposit in the Paterson Orogen is located 92 km south of the Telfer gold mine and 100 km southeast of the Nifty copper mine. The deposit comprises stratabound oxide and secondary chalcocite copper mineralization. Indicated resources are estimated at 61 Mt at 0.66% Cu, and inferred resources are estimated at 77 Mt at 0.50% Cu. These represent Australia's biggest undeveloped low-grade copper resource. Additional resource studies are now being conducted prior to the commencement of formal feasibility studies in 1999. The development potential of the project has been enhanced during 1997–98 following acquisition by Straits Resources Ltd of the Nifty copper mine. The Maroochydore project could conceivably deliver 30 000 to 40 000 t of London Metal Exchange (LME) Grade-A copper cathode for a period in excess of ten years.

During 1997–98, the Nifty copper mine was sold by WMC Ltd to Straits Resources Ltd. Current annual production is approximately 16 500 t of copper, which Straits Resources plans to sustain for at least eight years. In addition to the current oxide heap leach, Straits Resources is planning to introduce bacterial heap leaching of the chalcocite and native copper, using proven methods developed at the Girilambone copper mine in New South Wales. Nifty also has a large primary sulfide resource, which is estimated at 23 Mt (indicated resources) at 3.4% Cu using a 1% Cu cut-off. Development of the primary sulfide resources could conceivably lift the production rate to about 40 000 tpa.

The Whim Creek – Mons Cupri copper project, located in the Pilbara 100 km east of Karratha, is still in the pre-development stage. Total measured and indicated resources are 21.360 Mt with 0.89% Cu, using a 0.2% Cu cut-off. A feasibility study, which was completed in 1996, estimated the leachable copper reserve as 6.621 Mt containing a total of 64 490 t of copper metal. Regional exploration is directed at defining the multi-element signature and haloes of known deposits, and generating targets which are completely concealed.

## Ferro-alloy metals

### Nickel and cobalt

Exploration expenditure for Ni–Co and base metals (combined) increased by 32.9% (\$29 million) during 1997–98 (Fig. 13). The major proportion of both the increase and the total exploration expenditure is attributable to nickel–cobalt, rather than base metals; base-metal expenditures most likely decreased during 1997–98. The increase is expected to have been within both greenfield and brownfield areas, though specific data are not available.

The London Metal Exchange average monthly nickel price dropped 35% over the year, from \$US6838/t (\$US3.10/pound) in July 1997 to \$US4479/t (\$US2.03/pound) in June 1998, and has caused some of the major producers (including WMC Ltd) to close mines with high operating costs. Cobalt prices remained steady throughout

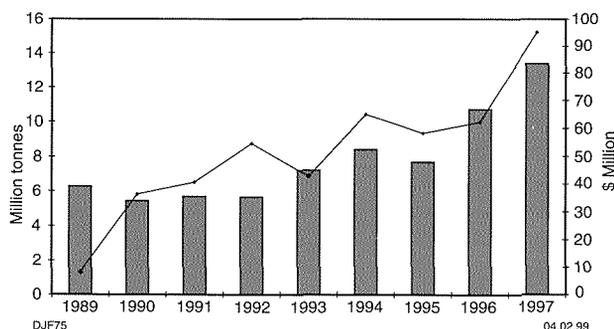


Figure 13. Western Australia's contained nickel in measured and indicated resources, and exploration expenditure for Cu–Pb–Zn–Ni–Co (dollars of the day)

1997–98, with monthly averages between \$US48/kg (\$US22/pound) and \$US55/kg (\$US25/pound). This, along with the slide in the value of the Australian currency, has made cobalt an economically important byproduct.

Early in the year, the perception was that rapid development of the huge Voisey's Bay deposit (138 Mt at 2.09% Ni, 1.24% Cu, and 0.99% Co) might flood the market with a low-cost product. However, the depressed nickel market and breakdowns in negotiating agreements with the Labrador government and the traditional landowners have led to long delays in developing Voisey's Bay. Voisey's Bay is now not expected to be commissioned before 2003, and therefore the pressure on potential Australian producers to gain an early foothold in the nickel market has eased.

The falling nickel price has not had an immediate impact on exploration, with many companies committed to evaluating the feasibility of mining their deposit(s). The proving up of lateritic nickel ore reserves still dominates exploration expenditure. However, the exploration success and potentially low development costs of recent discoveries at Silver Swan, Cosmos, and Emily Ann have kept many players interested in sulfide nickel, which may be sufficient for nickel sulfide exploration to maintain its share of the total nickel exploration expenditure.

Exploration success is reflected in the 25% increase in measured plus indicated resources of nickel in Western Australia during 1997–98, rising to 13.14 Mt of contained nickel (10.73 Mt in 1996–97) (Fig. 13). Total measured and indicated resources of lateritic nickel increased by 2.1 Mt (56%) to 5.8 Mt of contained nickel. For sulfide nickel deposits, total measured and indicated resources increased by only 0.6 Mt (8%) to 7.6 Mt of contained nickel (production of 0.135 Mt was not taken into account). Measured and indicated resources within lateritic nickel deposits are now around 43% of Western Australia's total demonstrated resources. The rapid and substantial rise in lateritic nickel resources is a result of many factors including that they have been the new focus in exploration, that many of the lateritic deposits have been known for many years (some were discovered

twenty years ago), the shallow nature of the deposits, and cheap exploration costs relative to sulfide nickel.

Other factors influencing decisions on where exploration expenditure is directed are mining operating costs and potential capital costs. Mining operating costs for deeply buried sulfide deposits are generally high. However, the capital expenditure required to produce a saleable product (nickel concentrate) is much less than that required for lateritic ore, where the saleable product is nickel metal.

### Lateritic Ni and Co deposits

During 1997–98, construction of the high-pressure acid leach (HPAL), and solvent extraction and electrowinning (SX–EW) circuits for Murrin Murrin, Bulong, and Cawse lateritic nickel projects continued — all three are scheduled to be in production in late 1998 or early 1999. The first cathode nickel is likely to be produced in late 1998 from either Bulong or Cawse. The early success of these operations could see up to five more new developments, and rapid upgrades of existing facilities. The expected low treatment cost of less than \$US2200/t (\$US1.00/pound), after cobalt credits, is about half that of low-cost sulfide production by WMC Ltd from Kambalda, Mount Keith, and Leinster for the first half of 1998 (around \$US4400/t or \$US2.00/pound). However, the future of mining Australian nickel laterites depends on the successful application of the high-pressure acid leach and solvent extraction technology.

At Cawse, 55 km northwest of Kalgoorlie (Fig. 14), construction of the mine and processing facilities continued throughout the year. The capital costs are estimated at \$265 million for a mine producing 130 000 tpa of ore, with the first nickel metal product due in late 1998 or early 1999. The planned initial production is 4800 t of LME-grade cathode nickel and 1200 t of contained cobalt (the latter as a sulfide) for each of the first two years. Production will then be upgraded to 8500 tpa of nickel and 1900 tpa of contained cobalt. Operating costs are estimated at \$US3960/t of nickel produced (\$US1.80/pound) or around \$US1210/t of nickel (\$US0.55/pound) after cobalt credits, assuming a cobalt price of \$US26.4/kg (\$US12.0/pound). If the cobalt price of July 1997 is taken into account, i.e. around \$US46.2/kg (\$US21.0/pound), then overall operating costs would fall to only about \$US0.20/kg (\$US0.09/pound). The strong current price of cobalt, and a reasonable outlook for the cobalt market, has led Centaur Mining and Exploration Ltd to consider the feasibility of constructing a \$35 million cobalt refinery to produce cobalt metal. The current anticipated mine life is 23 years, based on proven and probable reserves of 30 Mt at 1.0% Ni and 0.06% Co. Upgrading of the 154 Mt of inferred resources to reserves will either extend the mine life or allow for substantial expansion of the processing facilities.

Development of Bulong has proceeded along similar lines to that of Cawse, with construction of the SX–EW plant at Bulong beginning in 1997–98, and the first nickel

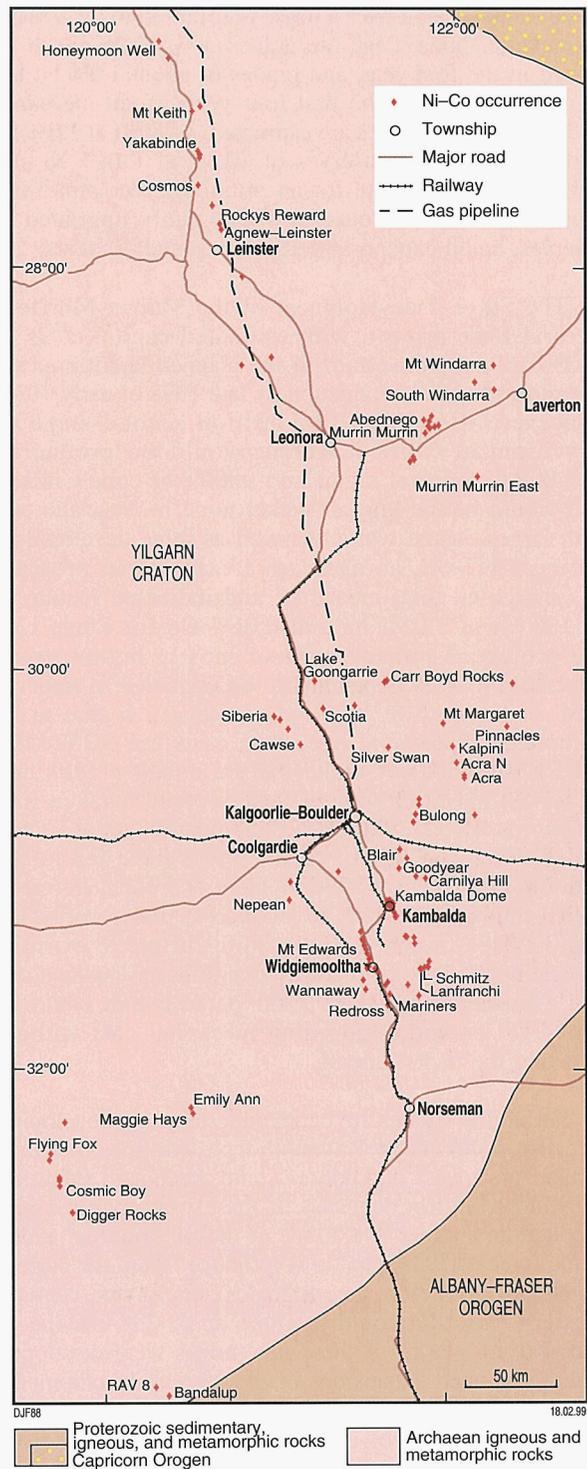


Figure 14. Nickel deposits of the Eastern Goldfields region. See Figure 8 for location

production planned for late 1998 or early 1999. However, the lower nickel price and more buoyant cobalt prices forced a slight change in the mining/processing strategy, with a switch to initially treat cobalt-rich ore. This slight change in focus, and the sale of the project to Preston Resources NL for \$312 million, seems to be delaying the project's first nickel output. Initial production rates are forecast at 9000 tpa of nickel cathode and 700 tpa of

cobalt metal, rising over a three-year period to 22 200 tpa of nickel cathode. Peak ore grades of 1.9% Ni are to be mined in the first year, and grades of about 1.5% Ni are to be mined during the first four years. Total measured and indicated resources are estimated at 78 Mt at 1.0% Ni and 0.1% Co, with reserves of 40 Mt at 1.14% Ni and 0.09% Co — adequate for an initial 26-year mine life. However, known resources, if eventually upgraded to reserves, could expand mine life to around 40 years.

The Stage 1 development of the Murrin Murrin – Central Bore project, with estimated capital costs of \$1030 million, is the third of the planned lateritic nickel operations to be in production by late 1998 or early 1999. However, after the \$1000 million second stage of development Murrin Murrin would be producing 115 000 t of nickel metal and 9000 t of cobalt metal, and would be the biggest nickel mine in Australia and fifth largest in the world. As well as mine development during 1997–98, an aggressive exploration program has increased total measured and indicated resources to 130 Mt at 1.01% Ni and 0.06% Co for Stage 1 of the project. Another 90 Mt of mostly higher grade inferred resources is planned to be upgraded to reserves prior to the end of 2000, when Stage 2 is due to be completed. Estimated operating costs are \$US2420/t (\$US1.10/pound) of nickel before cobalt credits and \$US770/t (\$US0.35/pound) after cobalt is taken into account at \$US27.5/kg (\$US12.50/pound). As at Cawse and Bulong, the steady cobalt prices have led to the addition of a Stage 1 SX–EW plant and cobalt refinery, with a combined capacity to produce 45 000 tpa of nickel and 3000 tpa of cobalt. Extra infrastructure to expedite expanding the cobalt-processing facilities has been added, and a further capacity of 2000 tpa of cobalt could be added for around \$15 million in capital cost without affecting the nickel circuit.

Feasibility studies are being undertaken on developing lateritic deposits at Ravensthorpe, Mount Margaret (70 km northwest of Leonora), and Abednego (abutting the Murrin Murrin deposits). If these were to come into production, another 90 000 tpa of nickel would be added to the forecast 59 000 tpa to be produced from the current developments (before any upgrades). Early next century, Western Australia could produce up to 238 000 tpa of nickel from laterites if these new mines were developed and the planned expansions of the current developments were to take place. This would be 100 000 t more than the contained nickel currently being produced from Western Australia's nickel sulfide mines. The Murrin Murrin partners, Anaconda Nickel Ltd (60%) and Glencore International AG (40%), have the potential to produce 182 000 tpa of nickel or around 70% of Western Australia's projected lateritic nickel output if they were to complete the takeover of Abednego Nickel Ltd (owners of the Abednego deposits).

Exploration for nickel laterites continued at other deposits in the Eastern Goldfields, including Siberia (Ora Banda greenstone belt), Pinnacles (Pinnacles greenstone belt), Waite Kauri and Mertondale (Murrin greenstone belt), Irwin Hills (Irwin Hills greenstone belt), Gindalbie (Gindalbie greenstone belt), and Kalpini (Kurnalpi

greenstone belt). In the Murchison terranes, nickel exploration continued at Weld Range (Weld Range greenstone belt).

## Sulfide Ni–Cu–Co

Exploration for nickel sulfide deposits is likely to have increased in 1997–98, with the re-opening of the Radio Hill mine near Karratha, and pre-feasibility studies undertaken at Cosmos, Emily Ann, and RAV 8 (Fig. 14).

The small, but high-grade Silver Swan deposit, 45 km northeast of Kalgoorlie, celebrated its first year of production. Proven and probable ore reserves are estimated at 700 000 t at 9.3% Ni. The mine is designed to produce 12 000 tpa of nickel in concentrates, grading around 20% Ni, for about five years. Mine life could be extended by accessing resources below the current mine plan and/or developing the adjacent Cygnet and Black Swan deposits. Cygnet has the potential to add another 6000 tpa of nickel in concentrates, and is accessible from the same decline used for Silver Swan. At current nickel prices, it is unlikely that there would be any expansion of the milling facilities to accommodate the lower grade ore. The sale in September 1998 of the 50% interest in the Silver Swan project by Mining Project Investors Pty Ltd to partner Outokumpu Oy indicates Outokumpu's confidence in the project's medium-term profitability.

Separate pre-feasibility studies, completed in September 1998, indicated that mining of the Cosmos and Emily Ann deposits would not be profitable at the current nickel prices below \$US4400/t (\$US2.00/pound). However, at nickel prices at or above \$US4400/t both could be profitable because of low development costs of around \$50 million for each project, and grades greater than 3% Ni. Cosmos, with measured and indicated resources of massive sulfide estimated at 250 000 t at 11.2% Ni, 0.47% Cu, and 0.16% Co, is most likely to be developed first if the nickel price shows improvement. Emily Ann, with higher tonnage (1.6 Mt) but a lower grade of 3.6% Ni, would soon follow if the nickel market had a strong outlook.

The low nickel price has forced WMC Ltd to close three, high-cost, underground mines at Kambalda, and subsequently reduce output by around 10 000 t of contained nickel to 108 000 tpa. For the six months to June 1998, operating costs for all WMC's operations (Kambalda, Mount Keith, and Leinster) were reduced to \$US4510/t (\$US2.05/pound) of nickel produced, which was still higher than the September 1998 nickel price of \$US4106/t (\$US1.87/pound). If the low nickel prices continue, WMC will have to consider more mine closures, or develop higher grade ore zones in order to reduce production costs. An active exploration program at Kambalda has been successful in locating potential ore-grade (>3.0% Ni) prospects at Skinner (Schmitz Extension), North Miitel, Grimsby (near Stockwell) and Durkin North.

Operations at Mount Keith and Leinster continued at near capacity levels, producing 37 000 t and 38 000 t of

contained nickel in concentrates, respectively. In April 1998, WMC announced it was undertaking studies into reducing costs at Mount Keith by increasing output 50% to 60 000 tpa of contained nickel. This would increase WMC's total output capacity to 135 000 tpa of contained nickel. Drilling at Leinster, designed to locate more high-grade deposits to replace the soon to be depleted Rockys Reward mine, has intersected zones containing more than 3% Ni in three areas — Harmony (north of Rockys Reward), Spinifex Park, and McCarthy Bore. Drilling at Mount Keith intersected thin, high-grade ore shoots to the northeast of the main orebody.

Mining at Outokumpu Oy's first Australian nickel mine at Forrestania, 130 km north of Ravensthorpe, continued but at a reduced rate. For the year ending December 1997, production was 0.4 Mt of ore, yielding 7900 t of contained nickel in concentrate — down from the previous year where 0.7 Mt of ore was mined for 9500 t of contained nickel. All concentrates produced from Forrestania, along with all of Silver Swan's product and 50% of the concentrates from Mount Keith, are trucked to Esperance for export to Outokumpu's Harjavalta smelter in Finland. Forrestania's proven and probable reserves at December 1997 were 1.1 Mt at 2.1% Ni, which should sustain the operation for another 2–3 years. This could be extended by upgrading some of the total identified resources of 5.9 Mt at 1.85% Ni to reserves.

In April 1998, nickel mining restarted at Radio Hill in the west Pilbara after Titan Resources NL purchased the deposit in November 1997 and upgraded the plant to treat 200 000 tpa of ore. All the concentrates are being transported by road to the Kalgoorlie nickel smelter. Cash operating costs of \$US3080/t (\$US1.40/pound) after copper and cobalt credits makes it one of the lowest cost nickel sulfide mines in the world. Palladium and platinum average 4.02 g/t and 0.7 g/t respectively in the concentrate. Exploration to extend the known mineralization has been successful, with drill intersections up to 3.65% Ni, 2.1% Cu, and 5.23 g/t Pd in separate drillholes. More drilling is required to upgrade the total measured and indicated resources of 976 500 t at 2.58% Ni, 1.82% Cu, and 0.11% Co.

At Spargoville, 20 km southwest of Kambalda, 41 000 t at 2.14% Ni were extracted and stockpiled from an openpit in the 5A deposit. The owners, Amalg Resources NL, are trying to find a market for this ore. The decline in the 5B deposit was dewatered for underground drilling and metallurgical sampling. Indicated resources are 117 000 t at 1.95% Ni for sulfide in the 5B deposit, and 14 000 t at 4.84% Ni for sulfide below the pit in the 5A deposit. In the early 1990s, underground mining of 64 000 t at 2.08% Ni of sulfide ore from the 1A deposit yielded 1114 t of contained nickel in concentrate. However, the operation was unprofitable because of high levels of contaminants, particularly arsenic, in the concentrate that led to financial penalties. It is likely that ore from the other deposits (3, 5A, 5B, and 5D) will suffer from similar high contaminant levels, and therefore they may be very difficult to sell.

Another deposit in the development spotlight is RAV 8, about 25 km east-southeast of Ravensthorpe, where a mining feasibility study began in early 1998. The total measured and indicated resources are now estimated at 187 000 t at 5.92% Ni, which contains probable reserves of 144 000 t at 5.12% Ni. Resources may be adequate for a small-scale mining operation that would last about two years. If this proves successful, other sulfide deposits in the area, Ravensthorpe 1, 4, and 5 (currently being explored by Outokumpu), may become viable if they use the RAV 8 infrastructure.

In May 1998, Yakabindie, one of the world's largest nickel sulfide deposits with total resources of 293 Mt at 0.525% Ni, was sold to North Ltd for \$18 million. For North Ltd, this acquisition is a long-term investment and Yakabindie will remain undeveloped until a marked improvement in the nickel market is forecast. Feasibility studies by the previous owner, Dominion Mining Ltd, indicated that staged development using the concentrate-to-metal Activox process would be the best option. The first stage, costing \$40 million, was expected to produce about 3000 tpa of nickel metal and 63 tpa of cobalt. Stage 2 development would cost \$340 million, with construction of the main treatment facility capable of producing 13 300 tpa of nickel metal and 370 tpa of cobalt metal. The third stage would lift output to 32 000 tpa of nickel metal and 900 tpa of cobalt metal.

Exploration of the massive sulfide prospects at Goodyear (Hampton East Location 45, 35 km southeast of Kalgoorlie) and Lake Goongarrie (15 km north of the old Scotia mine) continued to yield good results during 1997–98. At Goodyear, intersections of up to 0.88 m at 14.2% Ni were reported; however, more work is still required before resources can be calculated. At Lake Goongarrie, exploration continued to locate potential targets outside the previously discovered St Patricks and St Andrews prospects. These prospects still remain the main focus of exploration with reported intersections of 3.2 m at 5.2% Ni at St Patricks, and 1.18 m at 2.24% Ni at St Andrews.

Anomalous results were reported for many other nickel sulfide prospects. These include Four Corners (60 km northwest of Menzies), Mount Goode (the southerly extension of Cosmo), Sampson Dam (45 km northeast of Kalgoorlie), Nepean nickel mine (near Coolgardie), and Queen Victoria Rocks (50 km southwest of Coolgardie). In the Pilbara, further exploration is planned in the Radio Hill and Mount Sholl areas, and further work is underway in the Sherlock Bay area with Outokumpu earning a 75% interest in this nickel project (currently owned by Dragon Mining NL) by spending \$0.6 million on exploration over four years. The Sherlock Bay deposit has inferred resources of 16 Mt at 0.75% Ni and 0.09% Cu.

## The future

The short- and medium-term future of the Western Australian nickel industry will be known by the end of 1998–99, when the three laterite operations (Cawse, Bulong, and Murrin Murrin) have been in production for

about six months. Their success or failure to meet forecast production rates, costs, and product quality could lead to a boom or bust situation, especially while nickel prices are low.

Assuming that the high-pressure acid leach technology used to recover nickel from lateritic deposits is successful, and the planned new mines and all proposed production upgrades go ahead, then by 2005, WA's output could be around 450 000 t of nickel (as nickel metal or as nickel in concentrates). This would represent about one-third of the predicted world production of 1.3 Mt. The distribution of production from lateritic and sulfide deposits is predicted to be almost even, with the laterites edging slightly ahead by yielding about 240 000 t of nickel metal. The sulfide deposits are expected to contribute a little less, with around 210 000 t of contained metal in the form of concentrates, nickel matte, and nickel metal. Current total measured and indicated resources of 13.4 Mt of contained nickel (in all deposit types) could sustain these production levels for about 30 years. Judging from the past, resources are likely to increase with increasing exploration expenditure (Fig. 13), hence continued elevated levels of exploration is one requirement for the long-term future of the nickel mining industry in Western Australia.

## Manganese

During the year, Sovereign Resources (Australia) NL moved closer to the development of the Ant Hill deposit (previously known as Balfour Downs), 150 km east of Mount Newman. Ant Hill contains low-grade and ferruginous manganese ore, with indicated resources estimated at 1.42 Mt at 25% Mn, along with stockpiled ore from previous mining. The mineralization is not suitable for direct shipping for ferro-alloy production, but is amenable to leaching to produce manganese sulfate, which is used as a fertilizer and animal feed supplement. The operation will be the first manganese sulfate plant in Australia, and will produce about 20 000 tpa of manganese sulfate. A cashflow model by Grant Thornton Corporate Services (WA) Pty Ltd forecasts an annual after-tax operating cashflow of \$4 million on sales of \$10.4 million, with an internal rate of return of 36%. Capital is being raised for the project and completion of a bankable feasibility study, and strategic alliances formed with BHP Engineering Pty Ltd, Hatch Africa Pty Ltd, and the Frank and Schulte Group. Invest Australia, a Federal government agency jointly operated by Austrade and the Department of Industry, Science and Tourism, has entered into an agreement to promote Sovereign's manganese sulfate project to foreign investors.

Mining and exploration at the Woodie Woodie deposit in the East Pilbara ceased in September 1997. Valiant Consolidated Ltd experienced financial problems including a drop in the market for manganese over the period 1995–97; cyclonic rains in 1996–97 that caused cessation of mining and delayed expected revenues in early 1997; significant trading losses from mining at Mike mine and intercompany investments and loans;

overreliance on debt; cashflow problems when Standard Chartered Bank of Australia Ltd enforced its security over Valiant's manganese stockpiles at Port Hedland; and lack of support from existing creditors. Valiant has remained in voluntary administration since October 1997, and various attempts to inject fresh capital since then have failed. Meanwhile, Main Roads WA is pressing ahead with upgrading the Ripon Hills Road, but without the support of Valiant, Newcrest, and WMC.

## Tantalum

The total production of tantalite in the State during 1997–98 was 818 055 pounds, valued at \$41.9 million. All the production was by Sons of Gwalia Ltd from its mines at Wodgina (110 km south of Port Hedland) and Greenbushes (250 km south of Perth). Sons of Gwalia Ltd remains the world's biggest producer of tantalum, accounting for about 25% of global primary production. All production from Greenbushes and Wodgina has been pre-sold to Cabot Corporation (USA) and HC Starck of the Bayer Group (Germany). Forward sales extend through to 2003, and underpin planned capital expenditure over the next few years to lift production by 15–20% over the next two years. This would include almost doubling the capacity of Wodgina, from about 160 000 pounds to 300 000 pounds per annum in 1999–2000. During 1997–98, the estimated resources at Wodgina increased and now are estimated at 2.979 million pounds of contained Ta<sub>2</sub>O<sub>5</sub> in reserves and an additional 2.522 million pounds of contained Ta<sub>2</sub>O<sub>5</sub> in indicated and inferred resources. At Greenbushes, reserves are estimated at 4.0 million pounds of contained Ta<sub>2</sub>O<sub>5</sub>, whereas measured and indicated resources contain an additional 3.4 million pounds of contained Ta<sub>2</sub>O<sub>5</sub>.

## Vanadium

One of the world's biggest vanadium deposits, Windimurra, is rapidly developing into Australia's only vanadium mine. Windimurra is located 75 km east-southeast of Mount Magnet, and is a magmatic Fe–Ti–V deposit with vanadium in magnetite and ilmenite. The following factors have all combined to give this project a big boost: recent advances in processing technology; availability of cheap clean energy from the Dampier–Bunbury gas pipeline; and establishing a substantial resource of oxidized magnetite.

Precious Metals Australia Ltd and Glencore International AG have completed a bankable feasibility study, which included laboratory and pilot-scale metallurgical testing. The projected cash operating costs of production are \$US1.60 per pound of V<sub>2</sub>O<sub>5</sub>, i.e. within the lower quartile of world production. Design engineering has commenced and the contract for the rotary kiln (which will be the largest rotary kiln in the world) has been let to the Danish company FFE Minerals. A joint venture of Western Power Corporation and AGL Gas Trading Pty Ltd will construct a Mid West Gas Pipeline, with the Windimurra project being the foundation customer. With all government approvals

granted, on-site construction commenced in mid-1998, with commissioning anticipated in late 1999. Total capital costs of the project are estimated at \$A110 million. At a production level of 16 million pounds of  $V_2O_5$  per year, the Windimurra project will supply about 10% of world production.

Drilling during 1997–98 has led to revised estimates for the measured oxidized resources — now 69.8 Mt at 0.46%  $V_2O_5$ , using a cut-off of 0.2%  $V_2O_5$ , of which 98% has been converted to reserves. The measured oxidized resources are considered adequate for a mine life of 21 years, but with a mine life of 30 years based on proven and probable reserves. Total resources (measured and indicated) for oxidized and unoxidized mineralization are estimated at 111.4 Mt at 0.46%  $V_2O_5$ , using a cut-off of 0.2%  $V_2O_5$ .

Developments at Windimurra should encourage further exploration and a reassessment of other vanadium deposits in the Yilgarn and Pilbara Cratons.

## Heavy-mineral sands

Western Australia continues to remain the major focus of exploration expenditure in Australia for heavy-mineral sands. During 1997–98, \$8.8 million was spent (\$7.9 million previously), an increase of 11.4%. This is the highest exploration expenditure on heavy-mineral sands during the last decade when expressed in dollars of the day, but is below the peak activity of 1988–89 to 1990–91 when expressed in 1997–98 dollars (Fig. 15). However, the proportion of Australian exploration expenditure for heavy-mineral sands, spent in Western Australia, has been generally rising over the last 15 years and was 62.9% of the total during 1997–98, the second highest on record (Fig. 15). Despite the surge in exploration for heavy minerals within the Murray Basin in the last few years, Western Australia is holding its premier position.

The strong phase of exploration for heavy minerals in 1988–89 to 1990–91 has underpinned a steadily rising

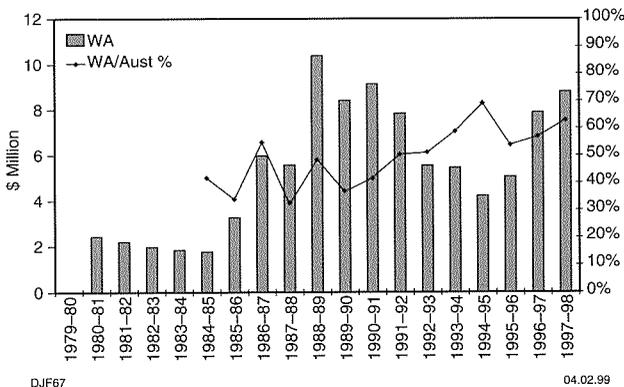


Figure 15. Heavy-mineral sands exploration expenditure in Western Australia (1997–98 dollars)

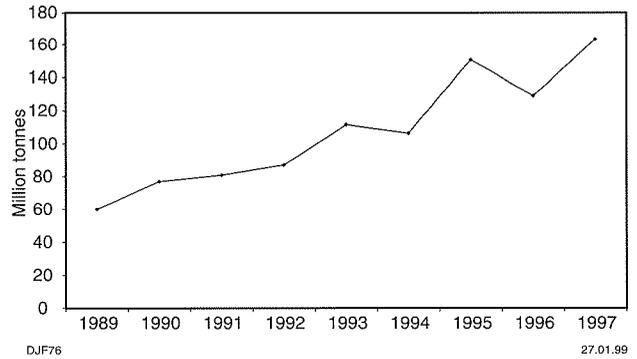


Figure 16. Western Australia's heavy-mineral sands resources (total measured and indicated) for 1989–97

resource inventory since then, despite expanded production (Fig. 16). The sharp increase in exploration expenditure for heavy minerals since 1994–95 has led to the identification of more measured and indicated resources of heavy minerals. During 1997, the total contained heavy minerals in deposits throughout the State increased by 26% from 128.9 Mt to 163.4 Mt. The fall in heavy-mineral resources during 1996 followed introduction of the JORC (1996) code and a reassessment of resources within the MINEDEX database, with substantial resources being reconsidered as inferred resources.

RGC Ltd and Westralian Sands Ltd have announced plans to merge, forming one of the world's major producers of titanium minerals and feedstock for the manufacture of titanium dioxide pigment. While the merger will reduce the number of non-integrated suppliers of titanium dioxide feedstocks to domestic pigment manufacturers to only one, the merger was not opposed by the Australian Competition and Consumer Commission. This is on the basis that the merged firm will compete in a world market against strong competition, and that potential import competition in titanium dioxide feedstocks and zircon should provide effective constraints on the merged entity.

RGC Ltd has operations at Eneabba (70 km south-southeast of Geraldton) and at Capel. Mining at Eneabba West experienced difficult operating conditions with a high slimes content in the feed, and a review of Eneabba West's mine plan is likely to see a switch to mining, in the early part of 2000, to the Pharaohs Flat area (north of Eneabba North). The declining quality of ore from Eneabba North will result in the plant being moved during 1998–99 to an area known as 'IPL'. Productivity has increased and costs have been reduced at Capel, but the mine is still scheduled for closure in mid-2000.

The new synthetic-rutile plant in Capel, owned by Westralian Sands Ltd, was officially opened in February 1998. In developing the new plant, the company focused on reducing water consumption and creating an ilmenite-blending facility, which carefully blends the ilmenite

purchased from Cable Sands with its own supply. The production from both plants will now be around 250 000 tpa, with an expected plant life of at least 20 years.

About 50% of the exploration by Westralian Sands Ltd during 1997–98 was directed at production drill-outs of current and future mine sites, e.g. Yoganup Extended. The remainder was directed at greenfield exploration targets including Hill River, Metricup, and Scott River.

Development of the world-class ilmenite–zircon deposit at Beenup, 280 km south of Perth, had a troubled year after attempts to overcome technical problems at the Augusta project failed. The Beenup project has so far cost BHP close to \$260 million to develop (against an original estimate of \$233 million), with the floating dredge one of the largest in the world. The target sands are about 45 m below surface and among the deepest to be mined by conventional dredges anywhere in the world. Design faults and production problems have dogged the operation since production started in January 1997. These include wear on the teeth of the dredge, dredge throughput, and tailings deposition and consolidation. Although the scheduled production was 600 000 tpa of ilmenite and 20 000 tpa of zircon, the Beenup operation was only producing at about 40% of its capacity in mid-1998 and full production is now not expected to be reached until 2000.

At the Cooljarloo operations of the Tiwest Joint Venture, drilling during 1997–98 increased resources by 47.9 Mt — a net increase of 35.6 Mt after allowing for 1997–98 production. Total measured and indicated resources (including reserves) at Tiwest are estimated at 458.6 Mt at an average of 3.515% heavy minerals. The synthetic-rutile plant was shut down in July 1998 for three months to undertake planned kiln relines. This was the first refractory reline in almost eight years of operation. The pigment plant is continuing to expand its capacity through incremental improvements in the process. The plan for a major expansion of capacity to 180 000 tpa remains under consideration, with implementation subject to market conditions for pigment.

## Diamond

Expenditure on diamond exploration in Western Australia in 1997–98 totalled \$31.4 million, a decrease of \$7.2 million or 20.2% from 1996–97 (Fig. 17). This decrease is probably attributable to the combination of at least the following: poor equity market conditions and difficulty in raising fresh venture capital; uncertainty over the future of mining at Argyle; lack of any announcement about diamondiferous kimberlite within the Yilgarn Craton during the last year; emphasis by Ashton Mining Ltd on developing the Merlin deposits in the Northern Territory (to be commissioned in early 1999); corporate activity involving Striker Resources NL that has impacted negatively on activities at the highly promising Beta Creek project in the northern Kimberley Basin; and the continued trend to increase exploration overseas. The weak Japanese market and the broader economic problems in the Asian region continue to put diamond

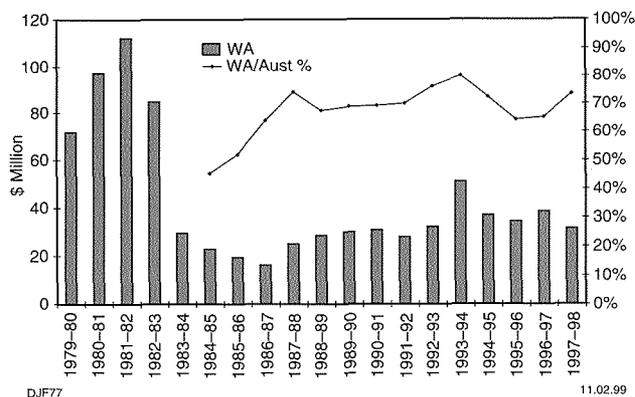


Figure 17. Diamond exploration expenditure in Western Australia (1997–98 dollars)

prices under pressure and do not provide incentives for diamond exploration activities.

The diamond exploration boom in the late 1970s and early 1980s (Fig. 17) followed the significant discoveries at Big Spring near Fitzroy Crossing in 1976, Ellendale field in 1977, and Argyle in 1979. However, the lack of commercial discoveries, other than at Argyle and Bow River, led to a rapid fall in exploration expenditure, with on-going exploration at subdued levels (Fig. 17). The extra activity in 1993–94 was mostly from the expensive offshore exploration by Cambridge Gulf Exploration NL. Subdued diamond exploration is likely to continue until there is some exploration success, the prospects improve for raising additional venture capital, or trial mining by Striker Resources at Beta Creek indicates viability.

Over the last decade, Western Australia's proportion of Australia's total diamond exploration has varied within the range 64 to 80%. Although exploration for diamond in Western Australia fell (in dollar terms) during 1997–98, Western Australia's proportion of Australia's total diamond exploration has actually increased — from 65.1% to 73.4% (Fig. 17). This is obviously a reflection of larger falls in diamond exploration in the other States, highlighting the greater perceived prospectivity for diamond in Western Australia.

Highlights for 1997–98 include discoveries of diamondiferous kimberlite at the Beta Creek project (Ashmore 4 and possibly Ashmore 5) and Blina project (Kimberley 1 and 2), recovery of macrodiamonds from the Walgidee Hills lamproite (Canning Basin) and Jewill prospect (Earaheedy Basin), and discovery of a kimberlitic dyke near Marble Bar in the Pilbara. The largest diamond recovered was from the Jewill prospect in the Earraheedy Basin and weighed 1.7 carats. There are at least 240 diamond prospects in Western Australia, with 136 companies having an active interest in tenements containing diamond prospects. Locations of places mentioned in this article are shown on Figure 18.

Striker Resources NL moved closer to mining of the Ashmore and Seppelt pipes in the north Kimberley Basin, but were restricted by intense corporate activity involving

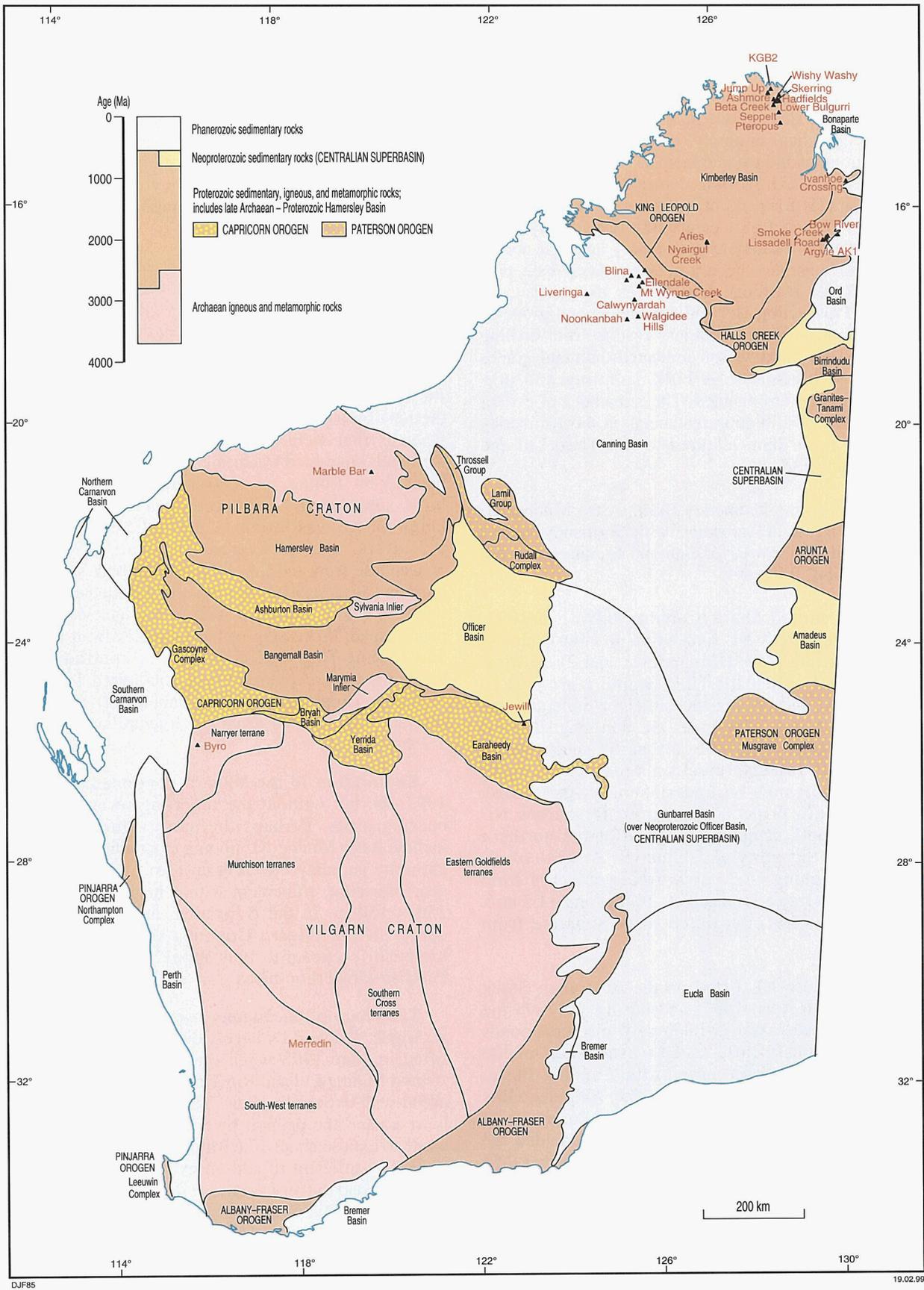


Figure 18. Diamond deposits and significant occurrences in Western Australia

Australian Gold Fields NL going into receivership and a take-over attempt of Striker Resources NL by Diamond Rose NL. However, pre-feasibility studies of mining the Ashmore 1 and 2 and Seppelt pipes continued. Drilling of Ashmore 3 confirmed it as diamondiferous, whereas diamonds were discovered in the Ashmore 4 pipe. A nearby geophysical anomaly, coincident with surface concentrations of indicator minerals, is suggestive of an additional pipe (A5). Drilling during 1997 indicated the following grades for parts of the Ashmore 1–4 pipes — 8.6, 47.3, 127.6, and 65.1 carats/100t respectively. Note however that the results are preliminary and that not all the size fractions have been processed. At Seppelt pipe (Forrest River project), which was discovered by Stockdale Prospecting Ltd and has a diamond grade of about 50 carats/100t, preliminary results from drilling during the 1997 field season indicated diamond grades of only 8.0 carats/100t. A bulk sampling and pre-feasibility mining are planned. The remainder of Striker Resources NL's exploration tenements in the Kimberley Basin have been joint ventured to Rio Tinto Ltd and Ashton Mining Ltd.

Elsewhere in the Kimberley Basin, Astro Mining NL has signed a Heads of Agreement with Normandy Mining Ltd to acquire the Bow River diamond operation (closed) and exploration properties.

On the Lennard Shelf (Canning Basin) in 1997, Kimberley Resources NL found two previously undiscovered lamproite pipes (Kimberley 1 and 2) at Blina, following their systematic bulk sampling program of alluvial gravel and tracing the indicator-mineral trails back to their source. The pipes are non-magnetic and gravity surveys have proved only partly successful in defining drill targets; electromagnetic surveying (DIGHEM) will now be undertaken. At the nearby Ellendale South project, Kimberley Resources NL undertook a bulk sampling program of the northern extension of the alluvial J-channel. A total of 68 diamonds weighing 17.3 carats were recovered from about 150 t of sample screened at -10 mm and +1.5 mm. The source is now interpreted to be separate from Ellendale 4.

Diamond Rose NL listed on the Australian Stock Exchange on 16 April 1997, and during 1997–98 the company was successful in finding 10 macrodiamonds from the previously little-tested western half of the Walgidee Hills lamproite pipe in the Canning Basin, about 160 km southeast of Derby. The Walgidee Hills lamproite is broadly circular and about 2.5 km across. A bulk sample of 423 t of -25 mm lamproite yielded ten macrodiamonds in the range 0.8–1.5 mm, weighing 0.54 carats in total. Six of the diamonds are colourless, three are minor brown and one is yellow in colour. The diamonds are well shaped (octahedral and dodecahedral), step layered, frosted and with rare inclusions. Detailed magnetic surveying suggests the lamproite intrusion is multiphased, rather than a single zoned intrusive as previously interpreted, and with a previously unknown satellite lamproite. The target is now diamond-bearing pyroclastic deposits associated with explosive emplacement of one of the early phases of lamproite.

In the Marble Bar area of the Pilbara, Haoma Mining NL announced the discovery of a kimberlitic dyke system with an interpreted strike length of 8 km. Drilling of 100 holes has intersected kimberlite at six locations along the system. Preliminary results, from the first two holes only, indicated no diamonds in the -4 mm to +0.3 mm fraction, but abundant kimberlitic spinel and garnet. The finer fractions are being processed for the presence of microdiamonds. As a consequence, Haoma Mining NL has applied for exploration licences covering extensive areas near Marble Bar.

Diamond exploration in the Earaeedy Basin (part of the former Nabberu Basin) has been intermittent since 1986, but Livingstone Resources NL has significantly upgraded the prospectivity of the eight known kimberlite/ultramafic lamprophyre intrusives. During 1997–98, ten diamonds were recovered from the -1 mm to +0.25 mm fraction after processing of about 5 t of drill cuttings from the Jewill prospect. Six were macrodiamonds (> 0.4 mm) whereas four were microdiamonds (<0.4 mm). As the diamonds suggested fracturing of larger stones during the hammer-bit drilling, the coarser fraction of a new 1000 t bulk sample of weathered kimberlite/ultramafic lamprophyre was tested. A macrodiamond, weighing 1.7 carats, was recovered from the 4–7 mm pan concentrate from the first 80 kg of the bulk sample. The diamond is described as a resorbed dodecahedra. It is white in colour, clear but with minor inclusions, and is pear shaped. Processing of bulk samples from the Jewill and Mount Throssell prospects is continuing. The diamond was recovered from weathered kimberlite/ultramafic lamprophyre (olivine lamproite?), which forms discrete bodies along a narrow fracture system at least 1.3 km long.

Exploration in the Yilgarn continued throughout 1997–98, but without the reporting of any diamond-bearing pipes. Perhaps the more significant results include Astro Mining NL finding a potentially kimberlitic chromite anomaly covering an area of 15 km by 6 km near Merredin, coincident with a magnetic anomaly of 250 × 150 m. In the Byro area, on the northwestern corner of the Yilgarn Craton, Astro Mining NL has kimberlitic chromite that appears to indicate post-Permian kimberlitic pipes.

The cloud of uncertainty over the future of mining at Argyle, the world's largest diamond mine, was partly lifted in June 1998 when the Argyle joint venturers, Ashton Mining Ltd and Rio Tinto Ltd, announced the go-ahead with expansion plans. The \$100 million first stage is to expand the openpit by removing about 100 Mt of waste to expose about 17.6 Mt of ore grading 2.58 carats/tonne — sufficient to add an extra 18 months of mine life. A second, larger cutback of the openpit is also under consideration, as is a third-stage move to underground mining with targeting of high-grade parts to the orebody.

The total measured and indicated resources of gem-quality and industrial-quality diamond in Western Australia as at the end of 1997 was 546 million carats. Figure 19 illustrates the steady decline in resources over the last six years as production at Argyle has progressed, combined with unsuccessful exploration generally.

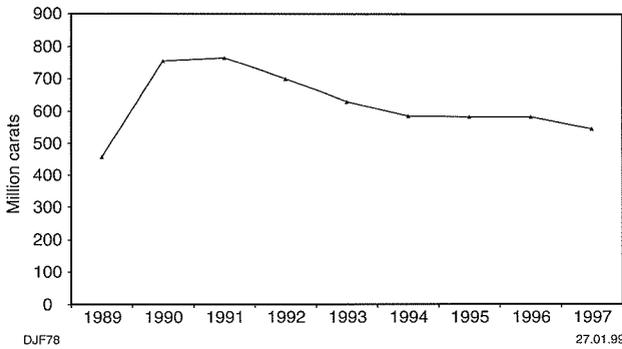


Figure 19. Western Australia's diamond resources (total measured and indicated) for 1989–97

## Energy resources

### Petroleum

Offshore Western Australia, and the North West Shelf in particular, is now recognized internationally as a premier place for new ventures because of the combination of favourable prospectivity, success rates, legislative and taxation regime, and political stability.

In 1997–98, the value of petroleum production amounted to \$4933.9 million (\$5037.8 million previously) — 27.7% of the State's total mineral output (30.7% previously). The petroleum sector (by value) became the dominant sector of Western Australia's mining industry in 1994–95, and has continued to dominate since then (Fig. 20). The value of petroleum production currently (1997–98) exceeds its nearest competitor, iron ore, by about \$1000 million. Western Australia, after increasing its share of production in recent years, now leads the nation in both gas and liquid petroleum production.

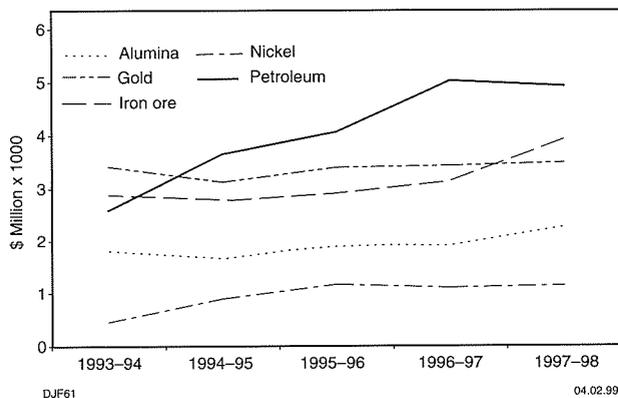


Figure 20. Comparative value of petroleum and mineral production in Western Australia

During 1997–98, petroleum exploration expenditure in Western Australia set a new record — reaching \$463.9 million (\$444.1 million previously), an increase of 4.5%. Western Australia currently attracts around 50% of Australia's total petroleum exploration (Fig. 2). This has been steadily increasing over the last decade, and was only around 30% in 1987. Western Australia is perceived to be one of the most attractive exploration areas in the world and this has been reflected in the number of new international companies applying for acreage and the high levels of work programs proposed.

Exploration, a leading indicator for upstream petroleum-industry activity, continued to grow, particularly offshore. Geophysical activity was at or near record highs, and Australia's first multiclient 3D seismic survey, the Panaeus survey, was carried out in Western Australia. This 3D survey was instrumental in the discovery of the Reindeer and Caribou gasfields and in the appraisal of the Legendre oilfield. In addition, the largest non-exclusive 2D seismic survey ever conducted in Australia, the Beagle Deep survey, was completed during the year. Extensive aeromagnetic surveys were conducted onshore. A record high number of offshore new-field wildcat holes were drilled.

Although exploration drilling onshore was relatively active, with the number of holes drilled increasing for the second year in a row, the current level of activity is broadly unchanged to that five years ago (Fig. 21) and there are signs that the interest of industry towards onshore exploration is starting to wane. No applications were received for the Quarterly State Acreage Release that closed in March 1998. A major factor in the waning interest is Native Title, with its lengthy Right-to-Negotiate process and the accompanying uncertain outcomes.

A second Special Prospecting Authority with an Acreage Option (SPA AO) was granted in the onshore Canning Basin. Shell has been awarded a six-month SPA AO over a 190-block area and the work commitment includes 5000 line km of aeromagnetic surveying and an extensive correlation study of existing data.

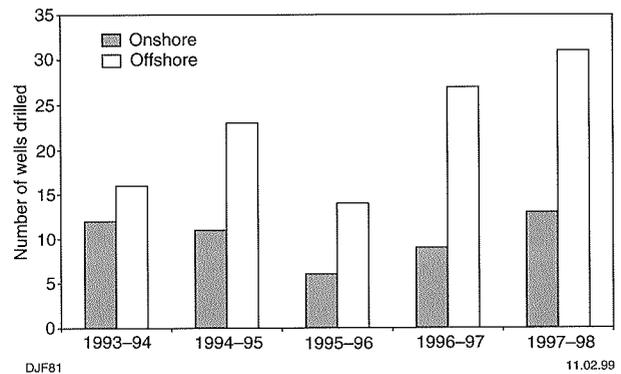


Figure 21. Petroleum exploration wells drilled in Western Australia

Three exploration/stratigraphic coreholes were drilled by industry in the frontier Savory Sub-basin (Officer Basin) — Mundadjini 1, Boondawari 1 and Akubra 1 (Fig. 22). The first petroleum exploration well to be drilled in Western Australia's Savory Sub-basin struck a minor oil show at the top of the target formation. Amadeus Petroleum NL said that Mundadjini 1 indicated that oil had been generated in the basin and that it had migrated into porous reservoirs. Boondawari 1 also had a minor oil show. As well, the Geological Survey drilled a stratigraphic hole, Empress 1/1A, in the Officer Basin, providing continuous stratigraphy from the Permian to the base of the Officer Basin succession.

Western Australia achieved a petroleum milestone in January 1998 when the cumulative total of oil produced reached 100 million kilolitres. Oil and gas production continued to rise with a significant increase in oil production coming from Goodwyn condensate and three new oil developments starting up — Lambert Hermes, Agincourt, and Stag (Fig. 23). Western Australia continued to lead Australia with 57% of the nation's oil production and 51% of gas production.

Planning and evaluation was accelerated for four major developments:

- North West Shelf Project LNG expansion by using Perseus field gas;
- Gorgon field development for an LNG project;
- Cornea field oil development; and
- Scott Reef field development for an LNG project.
- All of these petroleum industry exploration and development activities have an impact on Western Australia's economy and have the potential to have an even larger impact in the future.

The locations of all exploration and appraisal wells spudded since January 1997 in the Carnarvon Basin are shown in Figure 23.

During the year, the AlintaGas Dampier–Bunbury natural gas pipeline was privatized and sold for \$2407 million to Epic Energy Australia and brought under the jurisdiction of the Petroleum Pipelines Act. This required issue of a new title, as well as ongoing safety and environmental monitoring. A joint venture of Western Power and the Australian Gas Light Company announced that it would construct a pipeline from the Dampier–Bunbury pipeline to Mount Magnet to service the Windimurra vanadium project, 85 km southeast of Mount Magnet. A proposed second stage would extend the line to Cue and Meekatharra.

## Coal

During 1997–98, the decision on the State's new base-load power station was made with Wesfarmers Coal Ltd signing a seven-year contract to supply 1.2 Mtpa of coal to Western Power's new, 300-megawatt power station at Collie. Measured resources at the Premier mine are

estimated at 235 Mt, of which 200 Mt is recoverable. Production will commence in July 1999, and increase the company's total production to about 4 Mtpa.

## Uranium

Several factors combined to keep exploration activity for uranium in Australia at subdued levels. These included continued depressed uranium prices; the 'no new mine' policy of the Australian Labor Party (adopted on 20 January 1998); general uncertainty prior to the federal election held on 3 October 1998; and continued controversy concerning opening of Australia's 'third' mine, Jabiluka, in the Northern Territory. These eroded confidence in the uranium sector, and the poor immediate outlook for uranium spot prices reduces the prospect for development of the larger deposits in Western Australia, i.e. Yeelirrie (calcrete style) and Kintyre (Proterozoic unconformity-related mineralization).

A positive point for the industry was commencement of trial mining in situ at Beverley, South Australia by Heathgate Resources Pty Ltd. In addition, Acclaim Uranium NL was successful in raising \$5.7 million and floating on the Australian Stock Exchange in November 1997.

1997–98 was characterized by the emergence of Paladin Resources NL and Acclaim Uranium NL, with their consolidation of numerous deposits within their portfolios. Emphasis was placed on deposits where exploration is relatively advanced and that could be developed quickly, particularly by leaching in situ.

Paladin Resources acquired the Manyingee deposit, 85 km south of Onslow, from Afmeco Mining and Exploration Pty Ltd and Urangesellschaft Australia Pty Ltd. Manyingee, a roll-front deposit in Cretaceous sandstone within a palaeochannel, contains indicated and inferred resources estimated at 7860 t of  $U_3O_8$  at a grade of 0.12%. Infill drilling to upgrade the quality of the resource estimate is planned, as well as extension drilling to define the overall resources. Previous trial leach tests ten years ago did not achieve the economic objectives at the time, but the deposit is viewed by Paladin Resources as the best known advanced in situ leach project in Australia (after Beverley and Honeymoon in South Australia), with considerable potential for rapid development.

Acclaim Uranium, after its successful listing in November 1997, has undertaken an extensive program of compiling historical data for its numerous projects, most of which are calcrete-style deposits developed in surficial sediments on the Yilgarn Craton. Aircore drilling at the Nowthanna deposit (Quinns Lake), 55 km southeast of Meekatharra, has led to an initial estimate of inferred resources of 8.7 Mt at 0.42 kg/t  $U_3O_8$  (3658 t of contained  $U_3O_8$ ) with a cut-off grade of 0.2 kg/t  $U_3O_8$ . In addition, Acclaim Uranium has also acquired the Abercromby prospect, which is adjacent to the Millipede–Centipede deposits on the margin of Lake Way, 30 km south of Wiluna.

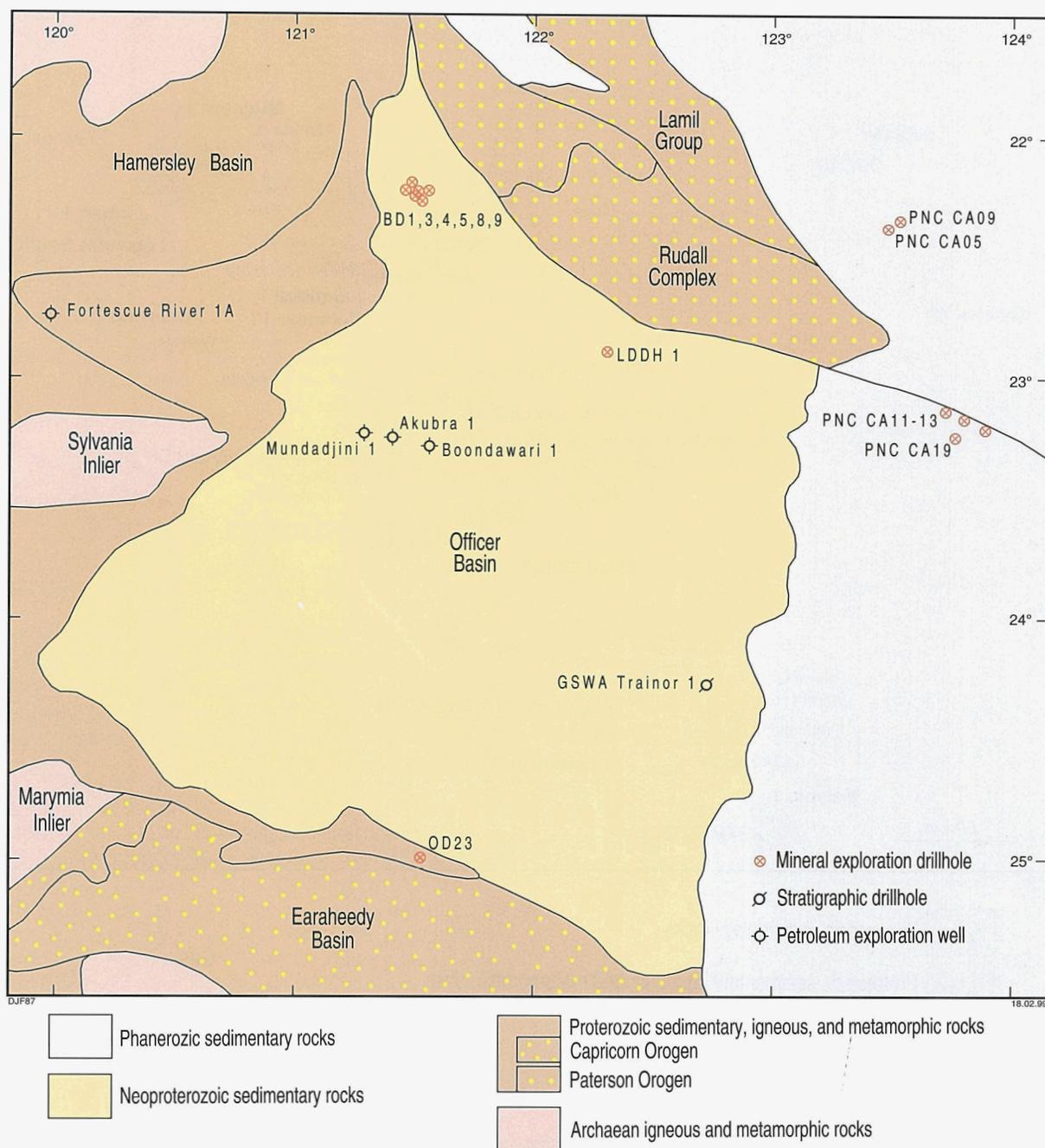


Figure 22. Petroleum exploration, stratigraphic, and mineral exploration drillholes in the Savory Sub-basin. See Figure 8 for location

The activity of Paladin Resources and Acclaim Uranium has seen exploration expenditure for uranium total \$2.4 million during 1997–98, but this only continues the minimal levels of uranium exploration seen in Western Australia for the last twenty years (Fig. 24). Exploration expenditure for uranium during 1979–88 had previously been at levels of \$10–14 million annually. Western Australia’s portion of Australia’s exploration expenditure for uranium has steadily fallen from a level of over 60% in 1986–87 to the current levels of about 10% (Fig. 24).

## Industrial minerals

### Alunite

The Lake Chandler deposit, 42 km north of Merredin, is estimated to contain a resource of 4.7 Mt grading 6.1% potash, and includes salina mud up to 2 m thick containing 50–80% alunite. During 1997–98, Lycopodium Pty Ltd carried out an economic evaluation of the Lake Chandler alunite project for Welcome

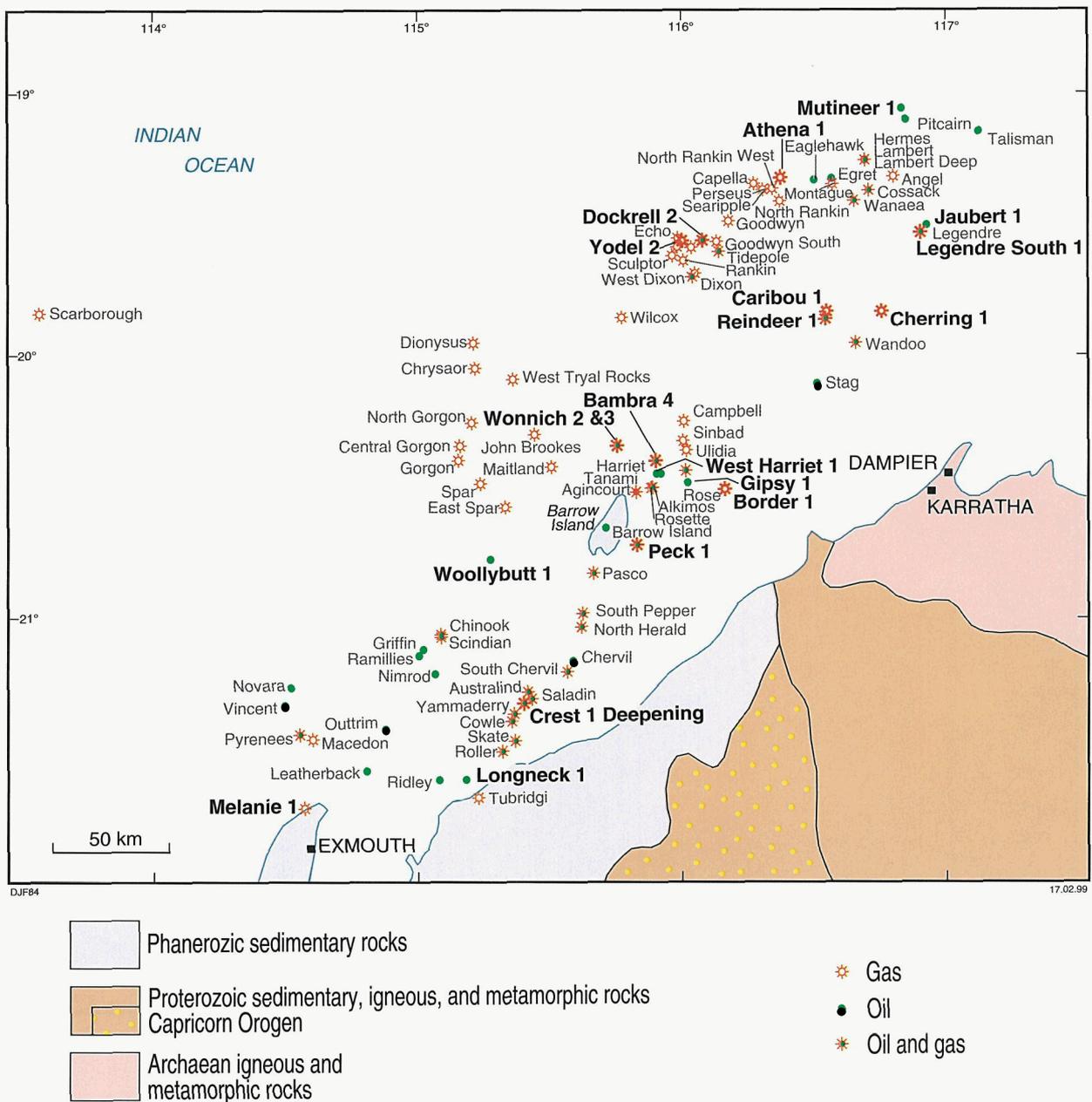


Figure 23. Petroleum exploration and appraisal wells drilled in the Carnarvon Basin since January 1997 (in bold). See Figure 8 for location

Stranger Mining NL. However, the study revealed the proposed acid-process route to be uneconomic, with high capital and operating costs.

### Attapulgitite

Hudson Resources Ltd produced 24 023 t of attapulgitite in 1997–98 (17 173 t previously) from its Lake Nerramyne deposit, located approximately 165 km northeast of Geraldton. Currently, the clay is sold both domestically and overseas for the pet litter market, but the company is carrying out more research into the

suitability of the attapulgitite for various other applications in order to use this vast resource in a more productive manner.

### Diatomite

Hudson Resources Ltd, who owns the only known filter-grade diatomite deposits in Australia, is finalizing an agreement whereby Australian Diatomite Mining Pty Ltd will undertake all the company’s absorbent product operations in Australia. The Badgingarra deposit, 170 km north of Perth, is estimated to contain 232 000 t of

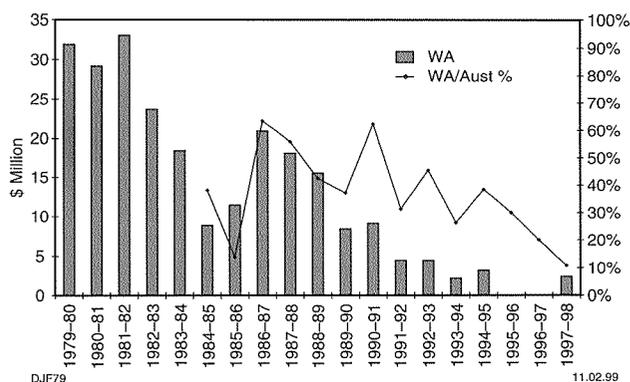


Figure 24. Uranium exploration expenditure in Western Australia (1997–98 dollars)

measured, 88 000 t of indicated and 240 000 t of inferred resources. Diatomite is a light-coloured, soft, friable, siliceous, sedimentary rock consisting of tiny fossilized skeletal diatoms. In the March 1998 quarter, 16 288 t of diatomite was mined from the Badgingarra deposit, but mining operations ceased with the deferment of plant construction.

## Fluorspar

Elmina NL is re-examining the economic viability of the Speewah fluorite (fluorspar) deposit, located in the Kimberley, 100 km southwest of Kununurra. The deposit has total measured, indicated, and inferred resources estimated at 3.87 Mt at 25% calcium fluoride. The reassessment includes further drilling, metallurgical test work, and engineering studies. Development of the deposit may commence in 1999, but depends on the outcome of this feasibility study.

Alichem Ltd has completed all feasibility studies and has been given all government approvals to build a proposed \$60 million aluminium fluoride plant at Kwinana. The construction of the plant, with a capacity of 40 000 tpa, is due to commence in late 1998. The process technology for the plant is being supplied by Kvaerner Buss CPS AG, the world's foremost designer of hydrofluoric acid, aluminium fluoride and other fluorine chemical plants. Two of the three main raw materials for the plant, sulfuric acid and aluminium hydrate, will be sourced within Western Australia. At this stage, the third raw material, acid-grade fluorspar, is planned to be imported from China or Africa. However, a long-term supply option is fluorspar from the Speewah deposit.

## Garnet

During 1997–98, Western Australia produced 116 037 t of garnet valued at \$9.4 million, and almost all the production was from Port Gregory, except for minor byproduct from the heavy-mineral sands industry.

GMA Garnet Pty Ltd, currently owned by Hancock & Gore Ltd (Australia) and Barton Mines Corporation (USA), is in the final stages of commissioning an additional garnet plant near Port Gregory, 80 km north-northwest of Geraldton. The plant will process ore from a palaeoshoreline. The company invested nearly \$4.5 million in the construction of the wet-separation plant, approximately 10 km north of the existing plant. The plant will use spirals and hydrosizers to produce an almandine concentrate, which will be processed to final product at GMA's dry plant at Geraldton. The capacity of the Geraldton plant is also being increased. These developments increase the total garnet production capacity of GMA to 200 000 tpa, representing a capacity 70% higher than the level of production for 1997–98.

## Gypsum

With the opening by Dampier Salt Pty Ltd in June 1997 of the gypsum operation at Lake MacLeod, 70 km north of Carnarvon, the export of gypsum from Western Australia resumed after a lapse of about 10 years. Gypsum is exported mostly to Japan for the wallboard and cement industries. The total production of gypsum in the State during 1997–98 was 826 639 t, substantially up on the 1996–97 production of 251 909 t.

## Kaolin

Rio Tinto Ltd has decided not to develop the Ockley kaolin deposit, 15 km east of Wickiepin. This deposit, also known as 'Sparks', is estimated to contain 29 Mt of high-quality kaolin suitable for paper coating and filler grades. The company is planning to sell the deposit, but as at mid-1998 there was no commitment from any prospective buyers. Rio Tinto Ltd has relinquished leases at Kerrigan (350 km east of Perth), which contain a substantial resource of high-quality kaolin. All these deposits and a number of others in the State have the potential for development under the right circumstances.

A feasibility study of the Jubuk kaolin project (180 km east-southeast of Perth) by Lycopodium Pty Ltd, for Summit Resources NL, indicated production of premium-grade kaolin could be commercially viable at an annual rate of around 100 000 t of calcined kaolin. The Guinness deposit of the Jubuk project is estimated to contain a measured resource of 8 Mt, within inferred resources initially estimated at 14.9 Mt. In addition, the adjacent Top Valley, South Guinness, and Homestead deposits contain inferred resources estimated at 3.5 Mt, 2.9 Mt, and 9.9 Mt respectively.

In 1998, Sons of Gwalia Ltd acquired a 15% stake in Australian Kaolin Ltd, which owns the Skardon River kaolin project in Queensland.

## Limestone

In 1997–98, the production of limestone and limesand in Western Australia, as reported to the Department of Minerals and Energy, was 2.4 Mt, valued at \$11.1 million.

In November 1997, Westlime (WA) began production of lime from its \$23 million quicklime plant 25 km south of Dongara. However, the company has experienced some unexpected production difficulties from the new plant, which has a design capacity of 120 000 t. Westlime (WA) is concentrating on markets in the Mid West region where its location gives transport advantages to the gold and base-metal industries of the Murchison and north Eastern Goldfields.

Cockburn Cement Ltd also began production of lime, in May 1998, from a new plant at Dongara, which has a design capacity of 100 000 tpa. This is in addition to the sixth kiln that was installed at Kwinana in 1997, which has a capacity of 400 000 tpa. The production from all six kilns at Kwinana amounts to a total of 1.4 Mt of cement clinker and lime. However, the change in demand for lime due to the lower price of gold, the Asian financial crisis, the growing threat of cheap Asian imports, and lower predictions of economic growth rates have dramatically altered the market outlook for cement clinker and lime.

In December 1997, Swan Cement (formerly Swan Portland Cement Ltd) closed its Rivervale cement and lime works, and relocated to Kwinana. Swan Cement has stopped manufacturing cement clinker, and instead imports clinker from its South Australian parent company (Adelaide Brighton Cement Ltd) for grinding at Kwinana. Currently, Swan Cement operates a 600 000 tpa cement-clinker grinding facility at Kwinana. In addition, a 100 000 tpa vertical-shaft lime kiln was constructed during 1997–98.

Exmouth Limestone Pty Ltd (51% owned by Adelaide Brighton Cement and 49% by Whitecrest Enterprises) commenced trial production of high-grade metallurgical limestone at Exmouth, in the Cape Range area.

In 1998, Amalg Resources NL acquired Loongana Lime Pty Ltd, including its assets and infrastructure at Loongana (540 km east of Kalgoorlie), Rawlinna mining leases (370 km east of Kalgoorlie), and associated facilities at Parkeston (5 km east of Kalgoorlie). Amalg Resources plans to increase the capacity of the combined plants from 55 000 tpa of quicklime to 80 000 tpa.

In 1997, BGC Cement commenced construction at Canning Vale of an additional clinker grinding mill, with a capacity of 300 000 tpa of cement. The cement clinker is obtained from Cockburn Cement Ltd. The new mill was commissioned in mid-1998, and BGC Cement now has a capacity to grind 600 000 tpa of cement clinker.

## Spodumene

The production of spodumene in the State during 1997–98 was 46 566 t, significantly less than the 1996–97 production of 114 934 t. All production is from the Greenbushes deposit, 250 km south of Perth and operated by Sons of Gwalia Ltd. Quantities, prices and profit margins for spodumene production suffered in 1997–98 as a result of the world market adjusting to the aggressive marketing of lithium carbonate produced in

Chile from crystallization of brines. However, Sons of Gwalia remains the world's largest producer of lithium minerals, and the Greenbushes pegmatite hosts the largest and highest grade resource of spodumene in the world. At June 1998, reserves were estimated at 8.53 Mt averaging 4.0% LiO<sub>2</sub>. Measured and indicated resources were estimated at an additional 4.90 Mt averaging 3.4% LiO<sub>2</sub>.

## Pigments

Imdex Ltd mined 1500 t of micaceous iron oxide (MIO) during March and May 1998 and the property was subsequently placed on a care-and-maintenance basis in June 1998. Total recorded production during 1997–98 was 6910 t. The MIO is used as a pigment in anti-corrosive paints for coating steel structures such as large bridges, industrial plants, and offshore oilrigs. Tests on the Mount Gould ore indicate that it contains greater than 90% Fe<sub>2</sub>O<sub>3</sub>, with a natural plate length of about 70 µm and thickness of around 5 µm, making it at least equal in quality to the world-standard material from Austria. The G6 MIO lens, which was partly mined in 1997–98, has indicated and inferred resources estimated at 117 000 t.

Imdex Ltd has diversified its markets because of less than anticipated purchases by Karntner Montanindustrie GmbH, the leading world dealer of MIO pigments. Imdex Ltd now sells the Mount Gould MIO under the trade name IMDOX, and markets have been secured in Australia, Japan, and USA.

## Salt

Western Australia currently accounts for more than 90% of the national production, and the State's production in 1997–98 was 8.2 Mt valued at \$189 million. The major producing centres are located at Port Hedland, Dampier, Lake Macleod, Useless Loop, and Lake Deborah.

Australia's largest salt producer, Dampier Salt Ltd, expanded its production capacity from 3 to 4 Mtpa during 1997–98. The planned expansion work included an additional salt production crystallizer, three extra brine concentration ponds, and six bitterns crystallizers.

Although Western Australia is already Australia's biggest producer of salt, the State's production capacity is set to jump by 25–30% with the current development of a new \$80 million solar salt project at Onslow. The project is a venture between Netherlands-based chemical producer Akzo Nobel, Hanwa Corporation of Korea, PT Sempurna Caturguna of Indonesia, and Gulf Holdings of Western Australia. The pumping of Indian Ocean water into the first of five evaporation ponds from a purpose-built pumping station at Beadon Creek commenced in November 1997, and by mid-March 1998 three of the ponds had been flooded to a depth of one metre. The pumping rate at mid-March was 12 000 litres per second. The planned production rate is 2.5 Mtpa of high-quality salt, with the first shipment of salt

anticipated for the year 2000 to destinations including South Korea and Indonesia.

## Silica

The total production of silica sand and quartz in Western Australia during 1997–98 was 784 310 t, valued at \$7.3 million. The major producing deposits of silica in the State are located at Kemerton (25 km north-northeast of Bunbury), Gnangarra and Jandakot (Perth Metropolitan Area), Mindijup (40 km northeast of Albany), and Mount Burgess (20 km north of Coolgardie).

Western Australia's major producer of high-quality silica sand is Kemerton Silica Sand Pty Ltd — a joint venture of Sons of Gwalia Ltd (70%) with Itochu Corporation and Tochu Company Ltd. The latter is one of the largest suppliers and distributors of silica sand in Japan. Mining at Kemerton commenced in April 1996 and has continuously exceeded feasibility study estimates, but the plant is currently running at full capacity. A total of 410 000 t of high-quality silica sand was produced in 1997–98 from Kemerton — over 50% of the State's total output of silica sand and quartz. Optimization work has indicated the potential to lift production to 500 000 tpa. The joint venturers have also been considering a major upgrade during 1998–99, to increase capacity to 700 000 tpa, but this has been deferred due to uncertainty in the principal markets of Japan and South East Asia. Resources at Kemerton total over 100 Mt of silica sand.

## Spongolite

A spongolite mine was opened in October 1997 at Woogenilup, 17 km northeast of Mount Barker. Spongolite is a lightweight, porous, sedimentary rock, composed principally of the remains of sponges. Spongolite produced at Woogenilup by Supersorb Minerals NL is used as an absorbent, fire retardant, and pet litter. Production of spongolite during 1997–98 was 2747 t.

## Talc

Production of talc in the State rose 8% to 191 297 t during 1997–98 (177 540 t previously), with all the production from Three Springs (150 km southeast of Geraldton) and Mount Seabrook (140 km northwest of Meekatharra).

Sons of Gwalia Ltd sold 50% of the Mount Seabrook deposit in 1996 to Industrial Mineraria Italiana Fabi Sri (Italy), and the remaining 50% was sold in 1998 to Commercial Minerals Ltd. Industrial Mineraria Italiana Fabi Sri has formed a talc joint venture with Zemex Industrial Minerals, through its subsidiary Suzorite Mineral Products Inc (SMP). The joint venture, Zemex Fabi-Benwood LLC, will process and market high-quality talc from the Mount Seabrook deposit. SMP (60% of the joint venture) will contribute and manage its processing facility in Benwood, West Virginia. The joint venture partners believe that they will be able to gain a market share in North America, especially for high-quality talc in polypropylene plastic.

WMC Ltd owns the Three Springs talc deposit. WMC and the Swiss Group Pluess–Staufer have merged their European talc interests with those of Finnminerals Oy, with the new entity named Mondo Minerals Oy. This arrangement resulted in the emergence of one of the most important talc suppliers in Europe, incorporating the activities of Norwegian Talc As (owned by Pluess–Staufer), Westmin Talc BV (owned by WMC) and Finnminerals (a 50:50 joint venture between the Swiss and Australian companies). The new entity, Mondo Minerals Oy, will obtain talc from Australia, Norway, Finland, China, and Egypt, with processing facilities located in Finland, Sweden, Norway, and the Netherlands. The combined processing capacity totals 600 000 tpa of dry talc.

## Other

A number of other industrial minerals continue to be evaluated in the State. These include a graphite deposit at Munglinup River (70 km east of Ravensthorpe); saponite deposits at Watheroo (40 km north of Moora); recently discovered bentonite deposits at Calwynyardah (55 km west of Fitzroy Crossing); and phosphate and rare-earth deposits at Mount Weld (250 km northeast of Kalgoorlie). There was no significant change in the feldspar and dimension stone industries in Western Australia during 1997–98.

The gallium-extraction plant at Pinjarra, owned by Rhône Poulenc and with a capital cost of development of \$50 million, is still under care-and-maintenance, but Rhône Poulenc intends to recommence production when market conditions improve. The extraction plant was placed on care-and-maintenance in June 1997, following the dumping of 50 t of gallium metal on the world market by Russia — the world market for gallium is about 50–70 tpa.

## Discussion

Another measure of mineral exploration activity in Western Australia is drilling statistics, but with these heavily biased towards activity in the gold sector. These provide another insight into trends in exploration activity generally and the gold sector specifically. The following data, extracted from the Department of Minerals and Energy's WAMEX database, relate to drilling statistics as compiled from mineral exploration reports received by the Department during the period, but may refer to work carried out up to one year earlier. These show that the downturn in drilling activity during 1997–98 was not uniform across the various types of drilling (Fig. 25). The fall in diamond and RC drilling over the 1997–98 year, of 12.6% and 1.9% respectively, is similar to the falls in exploration expenditure — both in overall spending (-4.5%) and in the gold sector specifically (-13.6%). However, RAB drilling declined sharply, by 38.7%, and is a sad but true indication of the severe cutback in grass-roots gold exploration.

The general state of the mineral exploration sector is also highlighted by the reductions in the number of

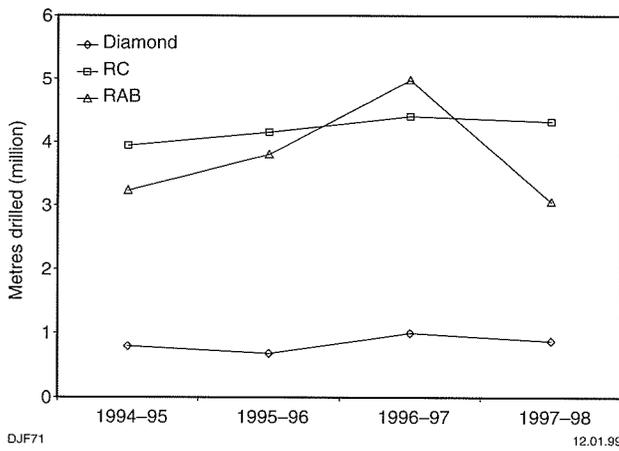


Figure 25. Mineral exploration drilling in Western Australia, by drilling type

tenements in force as at 30 June 1998 and the area held under tenure (by comparison with twelve months previously). For prospecting and exploration licences, the number of licences in force and the area held fell by 4–10% for both types, with the falls for prospecting licences greater than for exploration licences (Table 2). The number of mining leases remained constant.

Despite continuing high levels of mineral exploration expenditure, Native Title issues continue to cause frustration and delays to the planning of many exploration programs. Also, some successful exploration has defined mineralization that cannot be developed in the short term because of delays in granting mining leases when there are objections by Native Title claimants. Another issue affecting exploration and development is competing land-use, especially in the State’s southwest and in or near national parks.

Statistics highlighting the problems are the number of tenement applications yet to be granted as at 30 June 1998 (Table 2). These increased during 1997–98 for mining leases and prospecting licences by 44% and

16% respectively, whereas outstanding applications for exploration licences declined by 2%. Tenement applications, as a proportion of the total tenements granted and yet to be granted, are now 40% for mining leases, 31% for exploration licences, and 13% for prospecting licences. If the trend were to continue, then within two years there may be as many mining lease applications pending as there are existing mining leases. This is a sad indictment of delays predominantly caused by Native Title issues. The figures clearly show the magnitude of the problem, and solutions are urgently required for the future economic well-being of the State.

## Summary

Despite the strong pessimism in many parts of the gold sector, the State’s inventory of measured and indicated gold resources increased during 1997–98, and some significant discoveries were announced. The development of mines based on the lateritic nickel deposits of Murrin Murrin, Cawse, and Bulong was a feature of 1997–98, though none had been commissioned at the end of the year. The positive development for the year in the iron-ore sector was Hamersley’s commencement of mine construction at Yandicoogina. However, the year was also marked by time delays and cost over-runs of BHP’s hot-briquetted iron plant at Port Hedland, and delays in developing An Feng Kingstream’s Mid West project. The Lennard Shelf continued to emerge as one of the world’s major zinc-producing provinces. With Pillara in full production, the Lennard Shelf region will be the seventh largest zinc-mining region in the world. Australia’s only vanadium mine, Windimurra, was partly developed during the year.

The high levels of mineral exploration expenditure in Western Australia over the last few years have resulted in an increase of the measured and indicated resources for many commodities. These include gold, iron ore, bauxite, heavy-mineral sands, and nickel. However, estimated resources of diamond, reflecting production from Argyle, declined.

Table 2. Western Australian mineral tenements in force as at 30 June 1998

	1995-96		1996-97		1997-98	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
<b>Tenements in force as at 30 June 1998 (1978 Mining Act)</b>						
Prospecting Licence	8 111	1 098 339	8 212	1 099 671	7525	992 392
Exploration Licence	4 417	37 845 997	4 718	38 279 436	4505	35 992 499
Mining Lease and others	7 373	2 134 622	6 717	2 135 806	6717	2 238 301
<b>Tenements in force as at 30 June 1998 (1904 Mining Act)</b>						
Mineral claims and others	320	34 090	310	34 133	309	34 132
<b>Tenement applications yet to be granted as at 30 June 1998</b>						
Prospecting Licence	–	–	985	–	1 142	–
Exploration Licence	–	–	2 060	–	2 012	–
Mining Lease	1871	–	3 167	–	4 562	–
Others	–	–	357	–	1 493	–

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