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# Characteristics of Mining in Australia

by

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**Abstract**

This paper provides an overview of the general characteristics of the mining industry in Australia, with particular emphasis on minerals that are important exports. It includes a description of the minerals, the methods of their extraction, and the activities of federal and state governments related to mining.

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# CHARACTERISTICS OF MINING IN AUSTRALIA


by

Marco Bini and Peter J. Wilcoxen[1]


## 1. INTRODUCTION

In this paper we provide an overview of the Australian mining industry with particular emphasis on minerals that are important exports. Subsequent sections include a description of the minerals, a brief discussion of mining methods, and a summary of government activities related to mining. In the remainder of this section, we present a summary of our most important findings.

Australia's most important mineral exports are black coal, alumina, aluminium, gold and iron ore, which together earned in excess of 11 billion dollars in 1987. With the exception of gold, the supply of these minerals is relatively abundant. In the most extreme case, black coal, Australia possesses enough known reserves to support current rates of production for well over three hundred years.

Most domestic mining industries are dominated by a handful of firms. For example, three companies control almost ninety per cent of Australian iron ore production, and four control all of domestic bauxite mining. The principal exceptions to this rule are gold and black coal, both of which have scores of producers. Lead, silver and zinc mining (the three are usually found together) also has a large number of firms, but it is dominated by Mount Isa, one of the world's largest base metal mines.


1. The authors would like to thank Robert McDougall, Alan Powell, and Simon Wear for many helpful comments on earlier drafts of this paper.

Finally, although Australia is a major world mineral producer, it is not as important in mineral processing: many minerals are exported raw or in partially processed form. Iron ore, for example, is merely crushed and sized before shipping. Similarly, most tin is exported in the form of concentrate. One important exception is bauxite, almost all of which is processed at least to the intermediate stage of alumina before export. In addition, three minerals are exported principally in metallic form: gold, copper and nickel.

## 2. DESCRIPTION OF MINERALS

Table 1 presents a summary of 1987 data on thirteen of Australia's most important mineral industries.[2] Each row gives statistics for a particular mineral in a particular form. The figures shown in the columns are as follows. Column one gives the unit in which quantities of each mineral are measured: tonnes (t), kilotonnes (Kt), or megatonnes (Mt). Column two gives the quantity of domestic output. With the exception of bauxite and alumina, for ores and intermediate products the value shown is the weight of the contained mineral, not the weight of the ore or product itself. Column three gives the Bureau of Mineral Resources (BMR) estimate of "demonstrated economic" reserves of the mineral. The BMR classifies a given deposit as "demonstrated" when it is well established that the deposit actually exists. Of demonstrated reserves, the deposits that the BMR believes might be worth mining at current prices and wages are said to be "economic".[3] Column four gives the number of years that the

2. The statistics in Table 1, as well as any others in this section not specifically attributed to another source, come from the Bureau of Mineral Resources' *Australian Mineral Industry Review 1987*, which was published in 1989.
3. To be specific, the BMR classifies a deposit as "economic" if it appears that at current prices, a hypothetical firm mining the deposit using current technology would be able to cover its variable costs. For a complete description of the BMR's classification scheme, see Bureau of Mineral Resources (1983).



## 5. SUMMARY

As discussed above, many minerals are mined in Australia and a wide variety of mining techniques are used. However, only a few minerals are important exports, namely gold, iron ore, bauxite, and coal. The principal methods used to mine these minerals are highly capital-intensive, involving expensive specialized machinery. The government plays an active part in the mining industry through the imposition of taxes and royalties, but does not, on the whole, involve itself with actual mineral production. The only notable exception to this is the production of brown coal in Victoria.

the rock in which the miner will work, and the infrastructure surrounding the mine. Little mining equipment can be bought "off the shelf". This, in turn, means that there is a minimum lead time of 2-3 months between placing an order for a miner and receiving the machine. Larger and more specialized machinery may have a lead time of up to 3 years. Mining contracts usually allow for mobilization periods to account for delays involved obtaining machinery. Mining companies which need to expand quickly can look to the second-hand market, although there is not a lot of second hand machinery available.[85]

In spite of mechanization, underground mining only recovers around 50 per cent, and at best 85 per cent, of a mineral seam. In contrast, open-cut mining results in almost complete extraction of a mineral deposit. Underground mining is limited by two factors: the need to leave some of the ore in place for structural support, and the difficulty of following ore seams underground.

### 4.3 Dredging

Mineral sands, since they are often located in waterways, are usually mined by dredging. There are three principal types of dredge: suction-cutters, draglines and bucketlines. A suction-cutter dredge has a cutting arm which digs into the deposit and sucks up the sand. Dragline dredges work much like dragline excavators. Bucketline dredges are somewhat similar to bucket wheel excavators: buckets on the cutting arm pick up the sand and carry it directly to the barge. In all cases, the dredge moves slowly through the mining area collecting minerals from the sand.[86]

85. Conversation with Dr W. Bamford, Engineering Faculty, University of Melbourne.
86. Woodcock (1980).



**Table 1: Statistics on Selected Minerals for 1987**

| Mineral *Condition* | Quantity Unit | Output (Q) | Economic Reserves | Years of Supply | Export (Q) | Export (M$) | World Share (%) |
|---|---|---|---|---|---|---|---|
| Aluminium (a) | | | | | | | |
| *Bauxite* | Mt | 32 | 2854 | 88 | 4 | na | 36 |
| *Alumina* | Kt | 9423 | -- | -- | 7687 | 1427 | 28 |
| *Aluminium* | Kt | 882 | -- | -- | 580 | 975 | 6 |
| Coal | | | | | | | |
| *Black* | Mt | 144 | 49540 | 343 | 102 | 5045 | 4 |
| *Brown* | Mt | 44 | 41900 | 963 | 0 | 0 | 4 |
| Copper | | | | | | | |
| *Ore (b)* | Kt | 233 | 16940 | 73 | 41 | 69 | 4 |
| *Other* | Kt | 352 | -- | -- | 85 | 198 | na |
| Gold | | | | | | | |
| *Ore* | t | 111 | 1274 | 12 | 1 | (c) | 6 |
| *Bullion* | t | 160 | -- | -- | 85 | 1694 | na |
| Iron | | | | | | | |
| *Ore* | Mt | 102 | 14930 | 147 | 78 | 1686 | 11 |
| Lead | | | | | | | |
| *Ore* | Kt | 489 | 15550 | 32 | 69 | 79 | 20 |
| *Refined* | Kt | 398 | -- | -- | 311 | 433 | na |
| Nickel | | | | | | | |
| *Ore* | Kt | 75 | 1100 | 15 | 0 | 0 | 10 |
| *Smelted* | Kt | 49 | -- | -- | na | 241 | na |
| *Refined* | Kt | 44 | -- | -- | na | 149 | 6 |
| Silver | | | | | | | |
| *Ore* | t | 1119 | 32830 | 29 | 733 | (d) | 8 |
| *Refined* | t | 362 | -- | -- | 178 | 59 | na |
| Tin | | | | | | | |
| *Ore* | Kt | 8 | 185 | 24 | 7 | 59 | 6 |
| Titanium | | | | | | | |
| *Rutile* | Kt | 246 | 9120 | 37 | 257 | 150 | 53 |
| *Ilmenite* | Kt | 1349 | 49890 | 37 | 1046 | 61 | 24 |
| *Leucoxene* | Kt | 12 | (e) | (e) | 11 | 4 | na |
| Uranium (f) | | | | | | | |
| *Ore* | Kt | 4 | 470 | 124 | 4 | 342 | 10 |
| Zinc | | | | | | | |
| *Ore* | Kt | 712 | 23990 | 34 | 411 | 219 | 13 |
| *Refined* | Kt | 310 | -- | -- | 241 | 305 | na |
| Zircon | | | | | | | |
| *Ore* | Kt | 457 | 13620 | 30 | 465 | 108 | 55 |

(a) Data are for 1986.
(b) For all minerals, ore includes concentrates.
(c) Exported in concentrates of other minerals.
(d) Most exported silver is contained in concentrates of lead and other minerals.
(e) Included in ilmenite reserves.
(f) Quantities shown are tonnes of contained uranium.

demonstrated economic reserves of the mineral would last at current rates of extraction. Column five gives the quantity of exports; comparing this to total production shows the proportion of the mineral that is exported. Column six gives the value of exports in millions of dollars at f.o.b. prices. Finally, column seven shows Australian output as a per cent of world production.

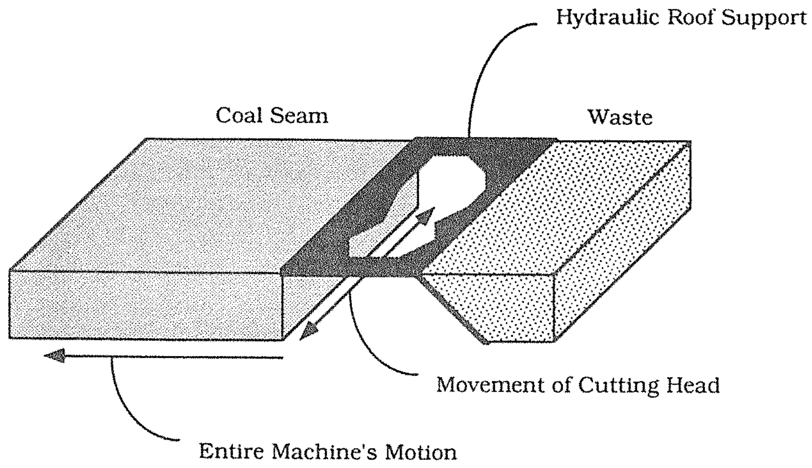
Several interesting facts are apparent from the table. First, Australia has enormous reserves of several minerals. Bauxite, black and brown coal, copper, iron ore and uranium are all in sufficient supply to support current production for many decades. A number of other minerals are also relatively abundant: lead, silver, tin, rutile and ilmenite, zinc and zircon all have known supplies that will last thirty years or more at current prices and technology. Moreover, new discoveries, improvements in mining methods, and changes in mineral prices are likely to keep most of these industries operating for many years beyond what is shown in the table.

The second important fact shown in the table is that for a few minerals Australia is one of the world's largest producers. Over a third of the world's bauxite comes from Australia, as well as half the world's rutile and zircon, and a quarter of its ilmenite. In addition, Australia produces a fifth of the world's supply of lead.

Finally, an additional fact evident from the table is that four of the minerals are particularly important exports: alumina/aluminium, black coal, gold and iron ore each account for well over a billion dollars of foreign trade. The remainder of this section presents detailed descriptions of each of those industries, followed by somewhat shorter descriptions of the other nine major mining sectors.



**Figure 5: Longwall Mining**



entire machine, including the hydraulic roof supports, moves forward. The roof behind the machine (where coal has been extracted) is allowed to collapse. The cutting head then moves back the way it came. Figure 5 is a schematic diagram of longwall mining.

Longwall mining produces a continuous flow of coal. Moreover, unlike the room and pillar method, no shuttle cars are required. However, longwall machines must run at all times to avoid being crushed by rock pressures.[81] Longwall mining recovers around 90 per cent of a coal seam, compared with the 40-60 per cent obtained with room and pillar mining. However, longwall methods can only be used where roof conditions are appropriate.

The heavy mechanisation of coal mining operations has caused several problems, namely the appearance of bottlenecks between the coal face and processing operations, and the difficulty in keeping face development[82] up to the pace of mechanized extraction methods. Mechanization has tripled coal production over the past 15 years, and the NSW Coal Association predicts further large increases from the increased use of longwall methods.[83]

Continuous miners are very expensive and highly specialized machines. In 1987, they varied in cost between $500 thousand and $5 million. Moreover, the larger machines can require up to a megawatt of power to operate, and have high maintenance requirements.[84] Machines of all sizes are highly specialized and are usually built to order, taking into consideration the type of mining being undertaken, the strength of

81. The collapse of the roof behind the machine is needed to release stress in the rock.
82. Such as the extension of conveyors, electrical and ventilation systems.
83. *Jobson's Mining Yearbook.*
84. *Jobson's Mining Yearbook*, p. 29.



**2.1 Coal**

Coal is formed from peat (partially decomposed organic matter) subjected to great pressure over millions of years. As the peat ages, its chemical composition changes and its water content falls. Eventually it becomes lignite, the lowest grade of coal. Further pressure removes more water and produces useful chemical changes in the lignite, gradually converting it into higher grades of coal.[4]

Today, coal is classified according to its moisture content (and hence its age) as either lignite (youngest and most moist), sub-bituminous coal, bituminous coal, or anthracite (oldest and least moist). Anthracite is not found in Australia, but the other varieties occur in large quantity. Lignite is often called "brown" coal, while sub-bituminous and bituminous coals are collectively known as "black" coal.

For most purposes, brown and black coal are not very close substitutes. Many grades of black coal can be used for making iron and steel, and all can be burned to produce heat or to generate electricity. Brown coal, however, cannot be used in iron and steel and produces much less heat per kilogram when burned.[5] In fact, it is used almost exclusively for generating electricity. Black coal is Australia's most important mineral export (by value), while brown coal is virtually not exported. Each type of coal is discussed in more detail below.

4. As water content decreases across grades of coal, heating value increases. At the same time, higher grades of coal also contain fewer volatile hydrocarbons, so they are harder to ignite, burn more slowly and produce more intense heat. See Deans (1983), pp. 14-15.
5. Four times as much brown coal is needed to produce the heating value of a given amount of black coal. See Holmes (1980), pp. 842.

### 2.1.1 Black Coal

Australia is the world's largest exporter of black coal, accounting for 30 per cent of world trade. The second largest exporter is the United States, which supplies 21 per cent of total trade, while South Africa ranks third with 12 per cent. Many countries, including China, the United States and the Soviet Union, produce vast amounts of black coal for domestic use, so in terms of production (rather than exports) Australia ranks only seventh and accounts for but 4 per cent of world output. Exported Australian black coal is used both for coking (in iron and steelmaking) and for steaming (power and heat generation). Coking coal made up 54 per cent of exports in 1987, while steaming coal accounted for the remaining 46 per cent. About half of total exports are sent to Japan. Seventy-one per cent of domestic coal production is exported; the remainder is used for power generation (22 per cent), iron and steel making (4 per cent), and other purposes (3 per cent).

Virtually all Australian black coal (and all of the exports of it) is produced in Queensland or New South Wales. In 1987, Queensland produced 88.1 megatonnes (Mt) of raw black coal (49 per cent of the total) of which 5.2 Mt came from underground mines. New South Wales produced another 83.6 Mt (47 per cent), of which 49.6 Mt came from underground mines and 34.0 Mt came from open-cut operations. Thus, in Queensland and New South Wales together, 32 per cent of the black coal produced came from underground mining while 68 per cent of it came from open-cut. South Australia and Western Australia together produced about 4 per cent of total coal output and used it almost entirely for generating electric power. A very small amount of black coal was produced in Tasmania and used in cement and paper production.

Coal mining methods have changed dramatically in the last thirty years. Most noticeably, there has been enormous growth in open-cut mining. In 1960, open-cut



A typical continuous miner is electrically powered, mounted on caterpillar tracks, weighs about 65 tonnes, and is 11 metres long and 4 metres wide.[78] Once extracted, the coal is transferred to the rear of the machine where it is loaded into an electric shuttle car. The shuttle then carries the coal to a nearby conveyor belt which takes it out of the mine. It is usual for 2 such shuttlecars to be used in this type of operation.

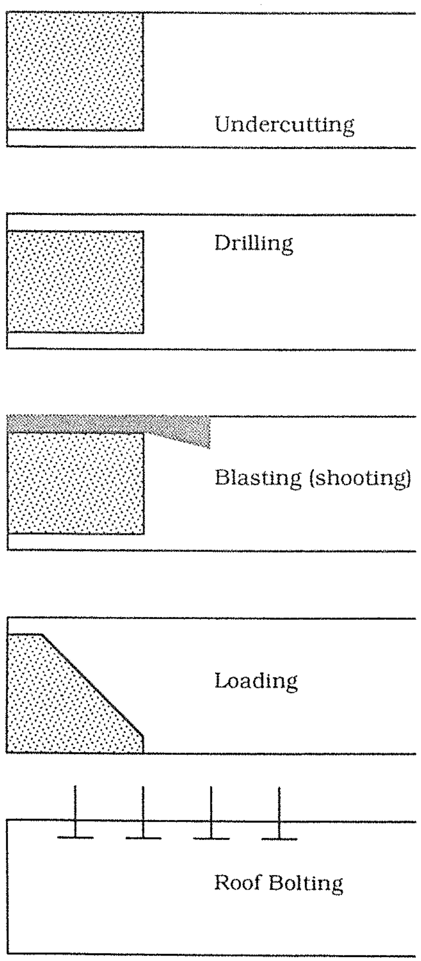
In general, operating these machines requires a crew of seven: two men to drive the shuttlecars, two to operate the mining machinery, two assistants, and one man to handle miscellaneous tasks.[79] In any given shift (6-8 hours), a crew can produce up to 500 tonnes of coal. Other persons such as an electrician, a mechanical fitter and the mine supervisor may be required from time to time. A typical mine may operate seven or more crews per shift. Usually, one of the crews is assigned to roof support, since continuous miners eliminate the need for drilling and shooting, but not for supporting the roof.

Increasingly, however, longwall mining is being used for underground coal extraction. In longwall mining, a long narrow tunnel is dug along the side of the seam to be extracted.[80] A second tunnel, perpendicular to the first and much shorter, is dug into the seam at the far end. Then, a special longwall mining machine is installed in the transverse tunnel. Longwall machines have two key features: a cutting head that moves back and forth along the transverse tunnel, and a set of hydraulic supports which hold up the tunnel's roof. The cutting head moves down the transverse tunnel ripping the coal from the seam. The extracted coal falls onto a conveyor which carries it from the mine. When the cutting head reaches the end of the transverse tunnel, the

78. See, for example, *Western Australia School of Mines: 85 Years*, pp. 27-36.
79. This paragraph is based on a telephone conversation with Richard Pinchen of the Great Greta Mine in the Hunter Valley, New South Wales.
80. These tunnels can be up to two kilometres long.

**Figure 4: Drilling and Shooting**

(Adapted from Marovelli and Karnhak (1982), p. 68)






mines accounted for 10 per cent of black coal production, while in 1987-88 they accounted for 70 per cent. Interestingly, this was not due to a contraction in underground mining but rather to explosive growth in open-cut mining: underground output has doubled since 1960, from 21 Mt to 50 Mt, while open-cut production has gone from 2 Mt to 117 Mt.[6] The expansion of open-cut mining has probably come about because open cut mines produce more than twice as much saleable coal per employee-year as underground mines.[7] In 1987-88, for example, open cut mines produced 6.7 Kt of coal per employee while underground mines produced only 2.8 Kt. Put in terms of coal produced per employee-shift, this comes to 14.3 tonnes and 35.9 tonnes for underground and open cut mines, respectively.[8]

Despite this, underground mining is likely to remain important because 60 per cent of the black coal reserves in both Queensland and New South Wales can only be mined by underground methods. Moreover, the methods used continue to evolve. Over the last ten years there has been enormous growth in the use of longwall techniques (described in detail in section 4). In 1978-79, longwall mining produced about 4 per cent of underground coal (1.6 Mt), while in 1987-88 it accounted for 37 per cent.[9] Longwall units continue to be installed at a high rate, and a number of new units are planned for Queensland and New South Wales.[10]

Finally, port facilities do not currently constrain exports of coal: the total capacity of existing coal loading facilities is 140 Mt per year. In 1987, total exports were 102

6. Joint Coal Board (1989), p. 15.
7. Raw coal contains debris which must be removed before the coal is sold, so coal production statistics are often quoted in terms of saleable, rather than raw, coal.
8. Joint Coal Board (1989), p. 74-75.
9. Joint Coal Board (1989), p. 15.
10. Joint Coal Board (1989), p. 1 and *Australian Mineral Industry Review 1987*, p. 75.

Mt, so the loading facilities were operating at 72 per cent of rated capacity.[11]

### 2.1.2 Brown Coal

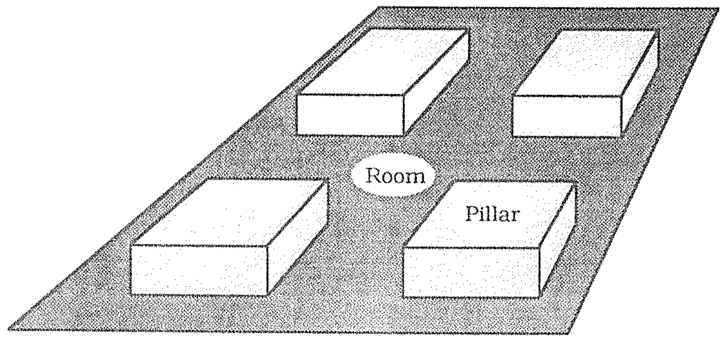
Brown coal is inferior to black coal in several respects. It has a relatively high moisture content and produces less heat per kilogram when burned than black coal.[12] In addition, it is high in volatile hydrocarbons, so it deteriorates rapidly and can ignite spontaneously. Thus, inventories must be kept to a minimum.[13] All of Australia's known *economic* reserves of brown coal occur in Victoria's Latrobe Valley. There, however, the seams are quite thick (60-125 metres) and are overlain by only a thin layer of sandy clay (10-15 metres).[14]

In spite of its disadvantages, a large amount of brown coal is mined in Victoria and used to fuel electric power stations. To overcome the problem of volatility, the coal is moved by conveyor directly from the mines to nearby power stations for immediate use.[15] Since each power station must receive a continuous supply of coal at all times, the State Electricity Commission of Victoria itself operates the mines. In 1987, it accounted for 97 per cent of all domestic brown coal production (42.22 Mt). Most of the remaining brown coal was produced by Alcoa, which has a small mine (1.25 Mt) at Anglesea which it uses to fuel an aluminium smelter at Point Henry. AMCOR Ltd operates the only other mine, a very small one (.04 Mt) near Baccus Marsh which fuels a steam plant. All of these mines are open-cut.

11. Joint Coal Board (1989), p. 108.
12. Holmes (1980), p. 835.
13. *Australian Mineral Industry Review 1987*, p. 80.
14. Holmes (1980), pp. 836-838.
15. Holmes (1980), p. 835.



Figure 3: Room and Pillar Mining



stopes must be used and rock bolts must be installed in the roof of the stope after blasting to prevent it from collapsing.[74]

Somewhat different methods are used for black coal, one of the most important minerals mined underground. There are two basic extraction techniques for underground coal: "room and pillar" mining and "longwall" mining.[75] In the room and pillar method, mining creates open areas, or "rooms", alternating with unmined areas, or "pillars", as shown in Figure 3.

Until the early 1950's, the conventional method of creating rooms was "drilling and shooting", a five stage cyclic process much like ordinary stoping, as shown in Figure 4. Initially, a slot was cut at the bottom of the coal face and a row of holes drilled in the top. The holes were filled with explosives and the coal face was "shot" (blasted apart). The resulting rubble was collected and transported out of the mine. Once the new room had been created, its roof was reinforced by timbers or roof bolts.

Today, however, drilling and shooting is not often used. Instead, rooms are created using continuous mining machines and other forms of mechanization.[76] For example, in the NSW black coal industry during 1973-74, 92 per cent of the industry's output was produced using continuous miners, 2.5 per cent by mechanised longwall units, and 5 per cent through other mechanization.[77] Continuous miners are large machines with rotating cutting heads which chip coal from the seam as the heads turn.

74. In certain kinds of rock, it is possible to support the roof of a tunnel by driving a number of large bolts into it. This is known as "roof bolting", and is usually accomplished using a special machine.
75. See Marovelli and Karnhak (1982) for a detailed discussion of modern coal mining methods.
76. Ritchie (1989).
77. Smith (1975), p. 135.



Brown coal does occur in other states. South and Western Australia both have substantial deposits of low-grade brown coal which are not presently exploited. Studies are underway to discover whether it is feasible to use the South Australian deposits for power generation.

Finally, although brown coal is used extensively in East Germany and other eastern European nations (and to a lesser extent in West Germany), no Australian brown coal is presently exported. In the near future, however, a small amount will be sent to Yugoslavia in the form of briquettes. The instability of brown coal remains a formidable barrier to exports.

## 2.2 Aluminium

Aluminium is the most common metal in the earth's crust, but unlike other metals it never occurs in metallic form – it is always found combined with other elements.[16] Many minerals contain substantial amounts of aluminium, but the easiest ore to extract aluminium from is bauxite. Bauxite is composed mostly of hydrates of aluminium oxide ($Al_2O_3{\cdot}H_2O$ and $Al_2O_3{\cdot}3H_2O$), although impurities such as silicates or iron compounds are present in varying amounts. It occurs in large deposits at or near the surface and is naturally friable, so it is easy to mine.[17] In fact, bauxite mining is the simplest stage of aluminium production and requires the least capital investment.

After mining, bauxite is refined to alumina (aluminium oxide, $Al_2O_3$) by a method known as the Bayer process, which uses heat, pressure and caustic soda to

16. Most of this paragraph is based on Brubaker (1967), pp. 83-86.
17. Webb (1980), p. 366.

remove impurities and water from the bauxite.[18] Then, metallic aluminium is produced from alumina by electrolytic smelting. In this step, a carbon anode is used to feed electric current (DC) through vats of molten alumina. The oxygen in the alumina combines with carbon in the anode to produce carbon monoxide and carbon dioxide. What remains is pure aluminium, which settles to the bottom of the vat and is drawn off periodically. An enormous amount of electricity is used -- typically 15-20 kwh per kg of aluminium.[19] Refining alumina and producing aluminium are very capital intensive, with capital costs per tonne of capacity ranging from three to seven times that required for steel making.[20]

Australia is by far the world's leading producer of bauxite, accounting for 37 per cent of world output in 1987. The second largest producer, Guinea, supplies about 16 per cent of world output, while the third largest producer, Jamaica, generates only 8 per cent. Sixty-one per cent of Australian bauxite comes from the Darling Range in Western Australia (near Perth), where it is mined by two companies, Alcoa of Australia Ltd and Worsley Alumina Pty Ltd. Another 23 per cent comes from Weipa, at the north end of Cape York in Queensland, where it is mined by Comalco Ltd. The remaining 16 per cent is produced by Nabalco Pty Ltd at Gove in northeastern Arnhem Land in the Northern Territory.

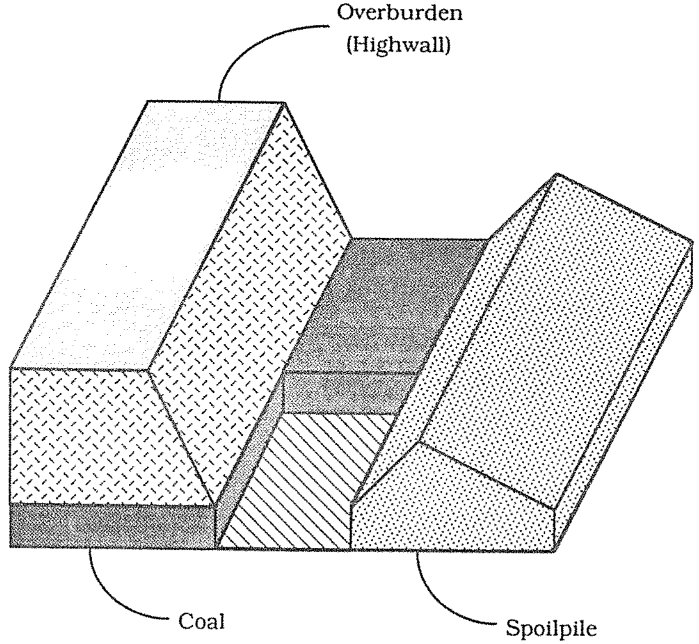
Most bauxite mined in Australia is refined at least to the stage of alumina before exporting.[21] This is largely due to transportation costs: it takes two or three tonnes of

18. A complete description of the Bayer process is given in Brubaker (1967).
19. A single smelting pot uses 70,000 to 100,000 amps of current at 5 volts. A complete smelter will have 150 or more of these pots connected in series. For a detailed description of aluminium smelting, see Brubaker (1967), pp. 90-94.
20. Brubaker (1967), p. 98.
21. In 1987, for example, alumina accounted for 84 per cent of the total bauxite used to produce exports. In the same year, primary aluminium accounted for 14 per cent, while shipments of raw bauxite accounted for only 2 per cent.



**Figure 2: Deep Stripping**

(Adapted from Radmanovitch (1975), p. 130)



area. The other side, called the spoilpile, is used for rock waste. These features are shown in Figure 2, a diagram of a deep stripping operation. The use of deep stripping is limited by highwall and spoilpile stability. In addition, it requires the use of more machinery to transport the mineral and waste upwards.

Open cut mining is least expensive when the terrain is flat and the mineral seam is generally horizontal. When the deposit is actually at the surface (that is, when there is little or no overburden), the method is sometimes known as quarrying.

### 4.2 Underground

With the exception of coal, most minerals mined underground are extracted using a cyclic process of drilling, blasting, loading and filling. This process is known as "stoping", and usually proceeds as follows. First, numerous holes are drilled in the face being mined. The holes are then filled with explosives and blasted. The resulting rubble is collected by special loading vehicles and transported to lifts or conveyors for removal from the mine. Finally, once the mineral seam in a particular area has been exhausted, the area is filled with sand or gravel.

The details of stoping vary from mine to mine. In some mines the face is a metre or two high, while in other mines it can be hundreds of metres in height. At Mount Isa, for example, copper ore is mined in stopes that are 40 m wide, 50-100 m long and up to 245 m high.[73] The ore body is blasted away in huge slices of up to 50000 tonnes of rock. This particular technique is known as open stoping, and can be used where the surrounding rock is very strong. Where the rock is weaker, smaller

73. See Mount Isa Mines Ltd (1980), pp. 281.



bauxite to produce one tonne of alumina, so shipping alumina is much less expensive. Converting alumina to primary aluminium reduces the weight in half again but does not lower shipping costs much because aluminium ingots are more difficult to handle than alumina (alumina is a bulk material).[22] Moreover, the enormous amounts of electricity used in aluminium smelting force the production of primary aluminium to take place where cheap power is available. Thus, most bauxite mined for export is refined to alumina, but is not smelted to produce primary aluminium. However, the world price per tonne of primary aluminium is much higher than alumina, so the values of alumina and aluminium exports are about the same. Alumina is exported principally to North America and the Middle East, while most aluminium exports go to Japan and southeast Asia.

In 1987 there were six alumina refineries in Australia, and all were operating at or above rated capacity. The world's largest alumina refinery is located at Gladstone, Queensland, and processes bauxite from Weipa. In 1987 it produced 2.8 Mt of alumina, which was above its rated capacity of 2.7 Mt. There are four alumina refineries in Western Australia: one each at Kwinana, Pinjarra, Wagerup and Worsley. During 1987, the Kwinana and Pinjarra refineries operated at rated capacity, while those at Wagerup and Worsley operated above capacity. Finally, there is a single refinery in the Northern Territory, located at Gove. It has operated at or above capacity for several years.

There are also six aluminium smelters in Australia: one in Queensland, two in New South Wales, two in Victoria, and one in Tasmania. The two Victorian smelters process alumina refined at Kwinana and Pinjarra in Western Australia, while the other

22. Brubaker (1967), p. 156.

four smelters process alumina from Gove and Gladstone. Unlike the alumina refineries, these smelters generally have some excess capacity.

Finally, it is important to realize that the world aluminium market is dominated by only six firms: Alcan (Canadian), Alcoa (US), Reynolds (US), Kaiser (US), Pechiney Ugine Kuhlmann (French) and Alusuisse (Swiss).[23] Before World War II, the aluminium industry was definitely not competitive, but that is less evident today.[24]

### 2.3 Gold

Gold is Australia's third most important mineral export, following black coal and alumina/aluminium. In 1987, it generated over $1600 million in export earnings. About 78 per cent of Australian gold production is exported, almost all of it in the form of refined bullion.[25]

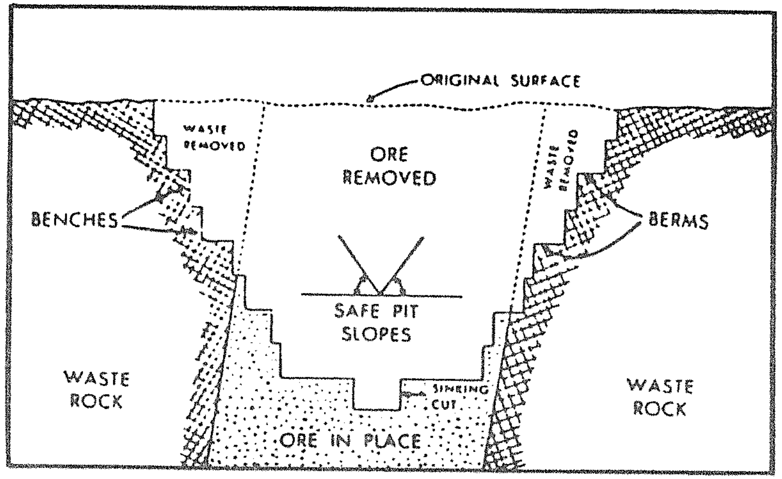
Over the last decade, the Australian gold industry has boomed. In 1987 alone, production rose 47 per cent and 29 new mines were commissioned. Increases of that magnitude have not been unusual: production rose by 45 per cent in 1985 and 29 per cent in 1986. In fact, total production has increased sixfold since 1981. During the 1960's and early 1970's, however, the industry shrank by about thirty per cent.[26] Currently, there are nearly 200 gold mines operating in Australia, with at least a few in every state. Western Australia, however, accounts for about 70 per cent of total gold production.

23. Brubaker (1967), pp. 99-108.
24. Brubaker (1967), p. 114.
25. Refined bullion is at least 99.95 per cent pure.
26. Brodie-Hall (1980), p. 460.



**Figure 1: Sketch of an Open Cut Mine**

(From Macleod (1981), p. 14)



## 4.1 Open Cut

Open cut mining (also known as strip mining) is used where mineral deposits are close to the surface. The first step is the removal of rock, soil, sand and shale – the overburden – from above the mineral seam. Where possible, this is done by heavy equipment such as bulldozers, scrapers, excavators or draglines.[71] Usually, however, the final layer of rock must be blasted apart with explosives. Removal of the overburden is one of the major costs of open-cut mining.[72] Once the overburden has been removed, mining typically follows a three step cycle: holes are drilled in the mineral seam, explosives are used to blast the seam apart, the rubble is collected and loaded into trucks using front-end loaders or electric shovels, and drilling begins again.

For brown coal, however, the drill-blast-load cycle has been replaced by the use of bucket-wheel excavators which scoop up and load the coal directly. A bucket-wheel excavator is an enormous crane (weighing up to 4200 tonnes) with a rotating wheel at the end of its boom. Buckets attached to the wheel scoop up coal as the wheel turns. The buckets then dump the coal onto a conveyor which transports it out of the mine. Since brown coal is used almost exclusively to fire electric power plants, a bucket-wheel excavator's ability to supply a continuous stream of coal is essential.

For a typical open-cut mine, as mining proceeds the pit becomes both wider and deeper. A diagram of such a mine is shown in Figure 1. For particularly deep and narrow deposits, a slightly different method is used. Instead of a circular pit, long narrow trenches are used. One side of the trench, called the highwall, is the unmined

71. A dragline is a huge crane with enormous bucket at the end of its boom. Draglines are used primarily for removing overburden. See Woodcock (1980).
72. Conversation with Richard Pinchen concerning coal mining methods used in the Hunter Valley, New South Wales.



Unlike bauxite and iron ore mining, gold mining is not dominated by a handful of large producers. The largest mine in Australia (Telfer in Western Australia) produces only 4 per cent of total output. This lack of concentration does not carry over to gold refining, however. Almost all Australian gold is refined by the Perth Mint, although there are a handful of other refiners also capable of producing gold to international standards of purity.

Worldwide, the principal use of new gold is jewellery making, which accounted for 72 per cent of world industrial gold consumption in 1987.[27] Official coins minted by various countries used another 13 per cent, while the electronics industry used 8 per cent. The remaining industrial gold was used for dentistry and various other purposes.

## 2.4 Iron Ore

Australia is the world's second largest iron ore exporter (after Brazil), accounting for 21 per cent of world trade in 1987. It is the fourth largest iron ore producer, trailing the Soviet Union, China, and Brazil. Seventy-seven per cent of Australian iron ore is exported, with 40 per cent going to Japan alone. The fortunes of the industry are closely tied to the state of the world steel market, and to the condition of the Japanese steel industry in particular.[28]

Australian iron ore mining is centered in the Pilbara region of northwest Western Australia, where high-grade ore occurs in vast surface deposits as mesas or mountains.[29] In 1987, 88 per cent of the entire national output of iron ore was produced by

27. Although governments hold vast reserves of gold bullion, they do not buy much additional gold except that needed to mint official gold coins.
28. Madigan (1980).
29. Deans (1983), p. 39, and Robinson (1980), p. 62.

three companies in the Pilbara: Hamersley Iron (38 per cent), Mount Newman Joint Venture (34 per cent), and Robe River Iron Associates (16 per cent). All three firms operate in remote areas and must transport their ore hundreds of kilometres by rail to reach the nearest port. The remaining 12 per cent of total iron ore production came from much smaller mines in Western Australia, South Australia and Tasmania. All iron ore mines, including those of the three largest producers, use the conventional drill/blast/load open-cut mining method.[30] Virtually all of the ore is treated to some extent before being exported or sold to domestic customers. At a minimum, it is crushed and sorted by size.[31] In addition, a small amount of ore is made into pellets, and some low-grade ores are concentrated.[32] All Western Australian ore, and virtually all of that mined elsewhere, is ultimately used for making iron or steel. Iron oxide produced for other purposes is less than 0.1 per cent of total output.

### 2.5 Copper

The world's largest copper producers are Chile and the United States, which together account for 41 per cent of total output. Australia is the world's seventh largest producer of copper, but it produces less than 4 per cent of the world's output. About three quarters of all Australian copper comes from Mount Isa in Queensland.[33] Another 12 per cent comes from Tasmania, mostly from the Mount Lyell mine operated by Renison Goldfields. Two mines in New South Wales and one in Western Australia produce most of the remainder, although a number of other mines produce

30. Robinson (1980), Cornelius and Simpson (1980), Grieve (1980) and several other articles from Woodcock (1980). See section 4 for a complete description of open-cut mining.
31. This process is known as "screening".
32. Madigan (1980), p. 59.
33. The ore deposit at Mount Isa is enormous: the mine has been in operation for more than 40 years and has enough reserves to continue operating for another 40 at current rates of production. Deans (1983), p. 24.



the High Court and include, among other things, refining.[68] Other deductions available under Section 122 of the act include expenditure on plant, and the costs of accommodation of employees. Section 23 (o) and 23C prohibit taxes on gold, but have sunset clauses expiring on 1 January 1991.

Division 10AAA deals with transportation of minerals, and allows deductions for the costs of railroads, pipelines and other methods of transport. Division 10AA deals with the mining of petroleum and allows similar deductions to those in Division 10.[69] Finally, mining is subject to capital gains tax and there are also specific anti-avoidance provisions relating to the carrying out of prescribed mining activities.[70]

## 4. EXTRACTION METHODS

The mineral industry uses a wide variety of extraction techniques, even for a single mineral such as black coal. Roughly speaking, however, most methods can be classified according to two important characteristics: whether they are used on the surface or underground, and whether they are continuous or cyclical. The following subsections describe the principal features of surface and underground mining and highlight the difference between continuous and cyclical techniques. A final section briefly discusses dredging, which is used for mining mineral sands.

68. Cyprus Mines v FCT 9 ATR 33.
69. See Section 124AA.
70. Section 160ZZE, Section 160 ZZF, Section 160 ZZG. These provisions attempt to prevent avoidance of tax by mining companies in particular.

Nickel is subject to *ad valorem* royalties in all states except Queensland, where royalties are levied per tonne of ore. The treatment of bauxite is similar: most states levy *ad valorem* royalties, except for New South Wales, which imposes royalties per tonne, and Queensland, whose rate varies according to where the mineral is mined and consumed.

The treatment of coal is less uniform. Victoria, the Northern Territory and South Australia levy *ad valorem* royalties, Tasmania and New South Wales charge royalties per tonne, and Queensland and Western Australia impose a combination of both according to the method of mining, the place of consumption, and whether the coal is exported or not. Royalties on iron ore have a roughly similar pattern. Victoria, Northern Territory, Tasmania and South Australia levy *ad valorem* royalties, while Queensland, and New South Wales levy flat rates per tonne. Western Australia operates a complex system of *ad valorem* and flat royalties according to the grade of the ore. Royalties are levied on uranium by the federal government in the Northern Territory on an *ad valorem* basis according to specific mines. South Australia and Western Australia levy a general *ad valorem* royalty.

The federal government also influences mining through the income tax system. In particular, three divisions of the Income Tax Assessment Act (Commonwealth) 1936 as amended, provide mining interests with special deductions which reduce their taxable incomes. In particular, divisions 10, 10AA and 10AAA of the act deal with general mining, mining transport, and petroleum prospecting and mining, respectively.[66] Under division 10, a deduction is allowed for the carrying out of "prescribed mining activities".[67] Prescribed mining activities have been very broadly construed by

66. See *Taxation Law in Australia.*
67. Section 122.



small amounts of copper as byproducts of other activities.

About 75 per cent of copper exports are in the form of primary copper.[34] Primary copper is produced in two steps. First, copper ore is smelted to produce an intermediate product, blister copper, which is somewhat impure. Then, the blister copper is refined to produce primary copper.[35] Mount Isa and its subsidiaries account for almost 90 per cent of both blister and primary copper production. Virtually all of the remainder is produced by the CRA smelter at Port Kembla in New South Wales.[36]

The Olympic Dam project in South Australia is a major new producer of copper, gold and uranium.[37] Actual production statistics are not available yet, but the project's planned annual output is 30 kilotonnes (Kt) of refined copper, 2800 kg of gold and 2 Kt of uranium oxide. Together, Olympic Dam and Mount Isa contain more than 90 per cent of Australia's demonstrated economic reserves of copper. Furthermore, the Olympic Dam deposit is believed to contain vast additional reserves of lower grade copper ore not presently worth mining.

### 2.6 Lead

Australia is the world's leading mine producer of lead, accounting for 19 per cent of world output. It is also the leading lead exporter, supplying about one-quarter of total world trade. However, most of the lead is exported as concentrate or bullion, not

34. Based on tonnes of copper contained in exported products.
35. Some primary copper is also made from copper matte, which is an impure form produced as a byproduct from smelting other metals.
36. Actually, the Port Kembla smelter is owned by Australian Mining and Smelting Ltd (AMS), a subsidiary of CRA. See Deans (1983), pp. 140-142.
37. Olympic Dam is owned by Western Mining Corporation and British Petroleum of Australia. It began full-scale production in 1988. See Deans (1983), p. 27.

as refined metal.[38] Thus, Australia is only the seventh largest producer of primary refined lead. By value, lead exports are 62 per cent bullion, 15 per cent ore and concentrate, and 23 per cent refined lead.

The single largest Australian producer of lead is Mount Isa, which accounts for 42 per cent of domestic output.[39] Another 31 per cent is contributed by three mines at Broken Hill, while the remainder comes from a number of smaller mines in New South Wales, the Northern Territory and Tasmania. Almost all of Australia's lead reserves are contained in zinc-lead-silver sulphide deposits. The Mount Isa and Broken Hill areas contain about three-quarters of domestic demonstrated economic reserves.

Lead bullion is produced by two smelters: one at Mount Isa, and the other at Cockle Creek, New South Wales.[40] All output of both plants is exported. The only domestic producer of primary refined lead is the Broken Hill Associated Smelters (BHAS) plant at Port Pirie, South Australia.[41] About 75 per cent of the lead produced by Port Pirie is exported. Of the remainder, over half is used to produce lead-acid batteries.[42]

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38. Lead bullion is less pure than primary refined lead and contains substantial amounts of silver and other minerals.
39. Mount Isa is among the largest lead producers in the world (see Deans (1983), p. 43). Lead, silver and zinc usually occur together, so mines producing one of them often produce the others as well. This is certainly true of Mount Isa–it is also Australia's leading producer of silver and zinc.
40. The Cockle Creek plant is subsidiary of CRA; see Deans (1983), p. 141.
41. The BHAS plant is also a subsidiary of CRA; see Deans (1983), pp. 174-175.
42. The importance of batteries to the lead industry cannot be overstated. In the United States, the world's largest consumer of lead, automobile batteries account for almost 80 per cent of all lead consumption. With the increased use of engines designed to run on unleaded fuel, the use of lead as an additive to petrol has declined.



High Court at present is that an excise duty is a tax on goods at any stage of production, manufacture, sale or distribution.[61] Thus, the states can only impose royalties on mineral production, since a royalty is not a tax but rather a payment for the right to enter land for the purpose of extracting a mineral. Royalties are, however, calculated according to the quantity or value of the mineral removed.[62]

The fact that mineral reserves generally fall under state jurisdiction means royalty rates are not uniform throughout the country. Moreover, the basis on which royalties are charged also varies from state to state: some states impose flat fees per tonne, while others impose *ad valorem* charges. Roughly speaking, however, most states use *ad valorem* royalties in the range of 2-5 per cent for most minerals.[63] Tin, rutile and ilmenite, for example, are subject to *ad valorem* royalties in all states and the Northern Territory. Similarly, silver, lead and zinc also have *ad valorem* royalties levied in all states, although some mines in New South Wales and Queensland receive special treatment.[64] Copper bears an *ad valorem* royalty in all states except Queensland, which again treats some mines in a special way.[65] In addition, gold is generally subject to an *ad valorem* charge, although no royalties are charged in Western Australia or Victoria.

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61. Matthews v Chicory Marketing Board 1938 60 CLR 623, Haematite Petroleum v Victoria 1983 151 CLR 599.
62. Stanton v Federal Commissioner for Taxation 1955 92 CLR 630. A royalty involves some sort of property right, whereas a tax does not. Unfortunately, these distinctions are somewhat arbitrary.
63. The tax rates in this section come from a very detailed description in the *Australian Mineral Industry Review 1987*, pp. 301-309.
64. New South Wales uses special formulae to calculate the royalty rate charged for mines at Broken Hill. These formulae depend on the grade and depth of the ore. All other mines are subject to a 4 per cent *ad valorem* fee. In Queensland, mines at Mount Isa are charged special royalties that depend on the ratio of current production to that of 1973-74. See the *Australian Mining Industry Review 1987*, p. 302.
65. In particular, copper mined at Mount Isa is treated in the same way as silver, lead and zinc.

The third type of licence is the mining lease. There are two basic forms of mining lease available in Victoria. A "development" lease is granted to allow research on an ore body to determine the feasibility of establishing a mine. Development leases are granted for a maximum of five years and may be renewed for a period not exceeding an additional five years. Commercial mining is not permitted under a development lease. As at January 1990 a development lease cost $5 per hectare per annum.

A "mining" lease, on the other hand, allows commercial mining and is usually obtained after the existence of an ore body has been established. This type of lease is granted for periods up to 15 years and may be renewed. The rent payable is the same as for a development lease. Both mining and development leases are subject to a variety of regulations covering marking out and inspection of the area, provision of a bond repayable on satisfactory restoration of the land, compensation for private landowners and minimum expenditure requirements. Land under planning schemes is not available for such a lease.[60]

An interesting point to note is that under all these licences, the compensation paid to private landowners is a fixed sum. Thus, the private landowner gains no return from the value of the minerals produced under his land.

### 3.4 Taxation

The Commonwealth has the power to tax mineral production under section 51 ii) of the Constitution. The states, however, are impeded by section 90 of the Constitution, which prohibits states from imposing excise duties. The prevailing view in the

60. Local councils have the power to set aside land for certain purposes.



### 2.7 Nickel

Australia produces about 10 per cent of the world's mine output of nickel and about 6 per cent of the world's output of refined nickel.[43] There are four nickel mines in Australia: three in Western Australia and one in Queensland. The largest is the Kambalda complex owned jointly by BHP and Western Mining Corporation (WMC). It is located in Western Australia and accounts for about 53 per cent of domestic output. WMC also owns one of the other Western Australian mines, Windarra, which produces another 10 per cent of the total. The third Western Australian mine, Agnew, has been shut down until world nickel prices rise substantially.[44] The rest of domestic nickel output (36 per cent) comes from the Greenvale mine in Queensland.[45]

There is a single nickel smelter in Australia, located near Kalgoorlie, and it produces nickel matte, a somewhat impure intermediate product. There are also two refineries which produce metallic nickel: one at Kwinana near Perth and the other at Yabulu in Queensland. The smelter and one of the refineries are owned by WMC; the other refinery is owned by the parent company of the Greenvale mine.

Almost all nickel mined in Australia is eventually exported: domestic consumption accounts for only 4 per cent of total production. In value terms, about two-thirds of nickel exports were in the form of intermediate products such as nickel matte, and one-third in the form of refined nickel. The principal use of nickel is in the manufacture of alloyed steels, such as stainless steel.

43. Canada and the Soviet Union are the world's largest producers, together accounting for 47 per cent of total mine output.
44. Although it is closed, it has not been abandoned; in the terminology of the minerals industry it has been placed on "care and maintenance".
45. In 1987, a small amount of nickel was also contributed by the Nepean mine in Western Australia. Nepean, however, closed permanently in May of that year.

## 2.8 Silver

In Australia silver is produced almost exclusively as a byproduct of mining for other minerals. Most domestic silver comes from lead and zinc mining, but some comes from copper and gold mining as well. The largest domestic producer by far is Mount Isa, which produces almost half of all Australian silver. The remainder comes primarily from other major lead mines. Mount Isa's silver is contained in lead bullion, most of which is shipped to a subsidiary in the United Kingdom for refining.

Of total silver production, 19 per cent is consumed domestically, 65 per cent is exported in lead bullion or various concentrates, and 16 per cent is exported as refined silver.[46] Most of the refined silver (over 60 per cent) is produced by the BHAS smelter at Port Pirie. The remainder is produced by smaller smelters at Port Kembla and Hobart (Electrolytic Zinc's Risdon refinery), and by the Perth Mint. Worldwide, photographic film accounts for about half of the use of refined silver. Much of the remainder is used in minting commemorative coins.

## 2.9 Tin

Australia produces around 5 per cent of world tin output. Most of that (85 per cent) comes from Renison Bell, an underground mine in Tasmania owned by Renison Goldfields Consolidated. The remaining 15 per cent of domestic tin production comes from much smaller mines in Queensland and Western Australia.

All of Renison's output is exported to Malayasia in the form of concentrate. There are, however, two domestic tin smelters which process some of the output of the

46. These percentages are based on tonnes of silver contained in the different products.



To use Victoria as an example, under the Victorian Mines Act and regulations made by the minister, three major types of licence are available: exploration licences, mining leases, and miner's claims.[59] Each of these confers various rights upon its holder. They differ in the tenure and size of mining operations permitted, and according to how much is known about the mineral seam.

Exploration licences authorize exploration for crown-owned minerals and permit feasibility studies to determine whether commercial mining is viable. These licences are subject to a number of restrictions, including a minimum annual expenditure per square kilometre of land leased which increases the longer the licence is held. In addition, a bond must be posted to ensure that the area is satisfactorily restored. Licences are issued for one or two years, with the possibility of extensions up to a total of five years.

A miner's claim, which is best suited to small mining operations, entitles the owner to a number of exclusive rights. The most important of these is the right to possession of any minerals found. A claim also grants other rights, including the right of residence, the right to erect buildings, and the right to use machinery and explosives on the claim. The initial term of a claim is five years, but it can be renewed. In January 1990, the cost of a claim was $20. In addition, a bond of up to $500 was required, although the bond would be returned upon satisfactory restoration of the mining claim after working.

59. See the publications issued by the Victorian Department of Industry, Technology and Resources listed in the Reference section.

The defence power fluctuates in potency depending on whether it is exercised in times of peace or war. In wartime, it can be used to impose rationing and price regulation, or to take control of the nation's resources in order to mobilize for war.[58] It could also be used to channel particular mineral resources into specified industries or sectors of the economy. For example, the total production of iron could be channelled into the manufacture of armaments. In peacetime, however, the power is construed far more narrowly and only has relevance to national security issues. The power is relevant to uranium, however, since the legislation establishing the federal regulatory body dealing with uranium, the Atomic Energy Commission, relies to some extent on the defence power.

The external affairs power includes domestic implementation of international treaty obligations. Various treaties affect mining; for example, there is an international agreement on safeguards for uranium export.

### 3.3 Regulation

The crown, in its capacity as owner of mineral resources, usually leaves the exploitation of those resources to individuals, under the control of a licensing system. Licences, leases and claims to mine are available in different forms in different states. The licences impose conditions on mining companies such as restoration of the land after mining is complete and the submission of reports on the activity's progress to the relevant minister.

58. Farey v Burvett 1916 21 CLR 433.



smaller producers. Both run well below capacity: there is so little smelting to be done that neither plant operates for more than one week out of every four. The principal domestic use of tin is the manufacture of tinplate. Australia has a single tinplate producer: BHP's plant at Port Kembla. It has an annual capacity of 500 Kt of tinplate, but in 1987 it produced only 287 Kt. About 16 per cent of Port Kembla's output is exported.

For many years the Australian tin industry has been heavily influenced by the activities of the International Tin Council (ITC).[47] The ITC, an organization of tin producing and consuming countries, was formed after World War II with the goal of stabilizing world tin prices. For decades it bought and sold tin from its own buffer stock in order to keep prices within a target range. From time to time it also imposed export controls on producing countries when adjustments to the buffer stock were not enough to maintain a desired price.

In 1980, however, tin prices began a secular decline. The ITC tried to keep the price up by buying tin for its stockpile, but was eventually forced to impose export controls in 1982. It continued buying up surplus tin until October 1985, when its financial resources were exhausted. On 24 October 1985, it ceased buffer stock operations entirely and world tin prices plummeted. All of the major world tin exchanges closed within the next two days and most have never reopened. Since 1986 the ITC has confined its activities to collecting and publishing industry statistics, and to settling litigation arising from the suspension of buffer stock operations.

47. The following discussion is based on material from *Australian Mineral Industry Review* for years 1978-1987, and on Deans (1983), p. 79.

The ITC's price control efforts have largely been taken over by a newer organization, the Association of Tin Producing Countries (ATPC). The ATPC was formed in 1983 with essentially the goal of a textbook cartel: achieving high earnings for its members. Together, members of the ATPC control over 65 per cent of world tin production. Two major producers, Brazil and China, are not members but cooperate with the ATPC to some extent. Including them brings the ATPC share of world tin production to 90 per cent.

Following the collapse of tin prices in 1985, the ATPC decided to restrict production and exports of tin beginning in 1987 in order to reduce world inventories. These inventories were considerable: the United States Government alone had stocks exceeding a year's worth of total world tin production. Australia implemented the ATPC export restrictions by issuing production quotas to producers.[48] In addition, the federal and various state governments adopted programs intended to encourage small producers (those with annual production under 100 t) to leave the industry. These programs, together with the fall in tin prices, have reduced the number of tin mining companies in Australia from 106 in 1983 to 15 in 1987.

## 2.10 Titanium

Three titanium-bearing minerals are mined in Australia: rutile, ilmenite and leucoxene. All three are obtained from deposits of mineral sands and are valued for the substantial amounts of titanium dioxide ($TiO_2$) they contain. Titanium dioxide is used principally as an ingredient in white pigment.

48. Quotas were also used to implement the export targets issued by the ITC in 1982. Thus, with the exception of a short gap in 1986, production quotas have been in effect in Australia since 1982.



The trade and commerce power gives the Commonwealth wide power to legislate with respect to exports, enabling it to prevent mining where major markets for a particular mineral are overseas. By refusing export licences, for example, the Commonwealth can render potential mineral production commercially non-viable. This power was used to prevent sand mining on Fraser Island in Queensland, which was thought by the federal government at the time to be an environmentally sensitive area. In this way, the Commonwealth may be able to regulate entire mineral industries by controlling a single phase of the production process.

The corporations power gives the Commonwealth the ability to control the activities of so-called "trading" corporations. A trading corporation has been held by the High Court to be any corporation in which trading constitutes a significant part of its overall activities.[54] Since bodies such as a football team, a state superannuation board, and even a shelf company have been held to be trading corporations, it is likely that any mining company would also be considered a trading corporation.[55] As far as the activities of a trading corporation are concerned, the Commonwealth can regulate trading activities and non-trading activities for the purpose of trade.[56] It is not clear whether the Commonwealth has control over *all* activities, although the latest case hints strongly that it has not.[57] For example, the Commonwealth does not have the power to incorporate companies itself.

54. Commonwealth v Tasmania (The Dams Case), 1983 46 ALR 625.
55. See R v Federal Court of Australia; *Ex Parte* WAFL 1979 143 CLR 190, State Superannuation Board v Trade Practices Commission 1982 150 CLR 282 and Fencott v Muller 1983 152 CLR 570. A shelf company is literally a company which can be bought "off the shelf" from a solicitor. It usually takes five weeks or more to comply with the formalities necessary to incorporate a company, so solicitors often create a stock of incorporated dummy companies. These can later be converted into real companies easily by changing the directors and shareholders.
56. Commonwealth v Tasmania (The Dams Case) *ibid.* For example, there was support in the High Court for the view that the building of a dam which would be used in the generation of electricity was a non-trading activity for the purpose of trade.
57. New South Wales v Commonwealth (The Corporations Case), 64 ALJR 157.

## 3. LEGAL ASPECTS OF MINING

There are four important legal aspects of mining: ownership (who actually owns mineral deposits), sovereignty (who controls how mineral deposits are used), regulation (what form does that control take) and taxation. All four are discussed in detail below.

### 3.1 Ownership

Under the Commonwealth Constitution, each state has sovereignty over the land within its borders. In practice, this has allowed state parliaments to pass legislation vesting all minerals in the state government. In Victoria, for example, the Mines Act (Vic.) 1958 grants all minerals to the Victorian government. Thus, most state governments own all minerals found on land within their state, although there is some variation between states. Overall, most mineral deposits are publicly owned.

### 3.2 Sovereignty

As mentioned above, minerals within a state *prima facie* fall under the jurisdiction of that state. However, under the Constitution the Commonwealth has a number of powers which it can use to affect state management of mineral resources. These powers include the trade and commerce power, the defence power, the corporations power, the race power, the external affairs power, the acquisition of property power, the incidental power and the resumption power.[53]

53. These powers are found in the Constitution under Sections 51 i), 51 vi), 51 xx), 51 xxvi), 51 xxix), 51 xxxi), 51 xxxix) and 85, respectively.



Rutile is produced by four mines in Australia: one in Queensland, one in Western Australia and two in New South Wales. Together they produce 53 per cent of all western world rutile. All but 1 per cent of domestic rutile production is exported, principally to the United States, the United Kingdom and the Netherlands. Australia also accounts for 24 per cent of western world ilmenite/leucoxene production.[49] Again, virtually all of this is exported, but about 20 per cent is first converted to synthetic rutile. There are four domestic producers of ilmenite, two of which are also large producers of rutile.

An important aspect of mineral sands mining is that the deposits often occur as beaches and dunes in environmentally sensitive areas.[50] About a third of all Australian ilmenite is found in areas that cannot be mined for environmental reasons.

### 2.11 Uranium

Australia possesses about a third of the world's known reserves of uranium. In addition, the Bureau of Mineral Resources (BMR) estimates that there is a 75 per cent chance that Australia has at least four times that much uranium in additional undiscovered reserves, and a 50 per cent chance of there being at least eight times that much.[51] However, because of regulations imposed for political reasons, Australia only produces about 10 per cent of western world uranium output. Nonetheless, it is the world's fourth largest producer and third largest exporter.[52] The largest producer by

49. Leucoxene is very closely related to ilmenite.
50. However, mineral sands deposits are also found in inland areas.
51. In 1987, known reserves were 470 Kt of uranium. The BMR's estimates of likely undiscovered reserves were 2.6 Mt (75 per cent chance) and 3.9 Mt (50 per cent chance). For comparison, total Australian uranium production was less than 4 Kt in 1987.
52. The United States produces more uranium, but it is also a net importer.

far is Canada, which alone accounts for about one-third of the world's output.

There are three uranium mines in Australia: Ranger, Nabarlek and Olympic Dam. Ranger and Nabarlek are both in Arnhem Land in the Northern Territory, while Olympic Dam is in South Australia. All three produce uranium oxide ($U_3O_8$), the principal form of uranium in world trade. Over 85 per cent of domestic uranium production is exported, mostly under long-term contracts negotiated with individual overseas utility companies (between 80 and 85 per cent of all world uranium production is sold under long-term contract). Uranium not exported is used domestically for medical and scientific purposes.

From 1965 to 1985, world uranium production exceeded consumption, resulting in large stockpiles. Since 1985, however, production has been below consumption.

### 2.12 Zinc

Australia is the world's second largest mine producer of zinc (13 per cent) and the fourth largest producer of refined metal (6 per cent). It is also the second largest exporter, after Canada, and supplies about 20 per cent of western world trade. About half of domestic zinc production is exported in the form of concentrate, while another third is refined to metallic zinc and then exported. The remaining sixth is used domestically, principally for galvanizing. Refined zinc is about 60 per cent of the value of total zinc exports.

Zinc and lead are usually found together and, as was the case with lead, Mount Isa is easily Australia's largest producer. Together with the small nearby Hilton mine, Mount Isa accounts for one-third of all Australian zinc production. Mines at Broken



Hill and adjacent areas of New South Wales contributed another 52 per cent of total output, while smaller mines in Tasmania, South Australia and the Northern Territory made up the remaining 16 per cent. Two-thirds of domestic demonstrated reserves of zinc are found at Mount Isa or Broken Hill. Most of the rest is in other parts of New South Wales or Tasmania.

Refined zinc is produced by three plants. Electrolytic Zinc's Risdon refinery in Tasmania accounts for about two-thirds of total output, a refinery at Cockle Creek in New South Wales produces another 23 per cent, and the remainder comes from the BHAS smelter at Port Pirie. The Risdon refinery is one of the largest in the world and uses concentrate from Mount Isa and Broken Hill, as well as from Tasmania.

### 2.13 Zircon

Zircon ($ZrSiO_4$) is a byproduct of mineral sands mining for rutile and ilmenite (see titanium). It is the principal commercial form of the element zirconium. Australia produces about 55 per cent of the world's supply of zircon, and has produced more than fifty per cent for many years. About 70 per cent of Australian zircon comes from Western Australia; the remainder comes from Queensland and New South Wales. Virtually all of it (96 per cent) is exported.

Zircon is used for a number of purposes and is not usually refined into metallic zirconium. Metallic zirconium, the principal use of which is in the construction of nuclear reactors, is not produced in Australia at all.