Other metals

Antimony–gold ore mining at Hillgrove (N.S.W.)
Hillgrove (above) is the only producer of antimony ore and concentrate in Australia. Following separation of the co-product gold, antimony concentrates are produced from the ore for export.

Exposed manganese orebody, Groote Eylandt (N.T.)
Groote Eylandt contains one of the world's largest manganese deposits. Much of the orebody consists of natural pellets or 'pisolites' (lower right). These pisolites have resulted from current and wave action on manganese oxides precipitated from seawater under special temperature and chemical conditions in shallow tidal areas during the Cretaceous. Subsequently the pisolites have been agglomerated by erosion and cementation (right).

Antimony

Antimony metal is not produced in Australia though about 30 000 t of antimonial lead, containing nearly 1000 t of antimony, are produced each year as a by-product of lead refining at **Port Pirie.** A small amount of antimony concentrate, all of which is exported, is produced at **Hillgrove** in the New England area of north-eastern New South Wales.

Bismuth

In recent years Australia has been the world's largest mine producer of bismuth, accounting for some 25% of world output. Bismuth production is almost entirely a by-product of copper–gold ore treatment at the **Warrego** mine (N.T.) and amounts to an estimated 700 t per annum.

The bismuth concentrates are treated in a first-stage bismuth plant which produces copper sulphate, gold bullion and bismuth-rich residues. The residues are stockpiled, as is bismuth recovered from lead refining at Port Pirie. Occasionally some of the Warrego residue is upgraded and sold.

Cadmium

Cadmium is found in small quantities in most base metal concentrates produced in Australia. Recovery as a by-product from zinc refining at **Risdon** and **Cockle Creek** accounts for the bulk of Australia's production of about 1000 t of refined cadmium annually. Minor amounts of cadmium are also recovered as a by-product of lead refining at **Port Pirie.**

Cobalt

With an annual output of around 3000 t Australia is the world's fourth largest mine producer of cobalt, a major by-product of nickel mining at **Greenvale** (Qld) and **Kambalda** (W.A.). However, there is no domestic production of cobalt metal, all requirements being met by imports.

All of the nickel–cobalt sulphide (13–20% cobalt) produced at the **Yabulu** (Qld) and **Kwinana** nickel refineries is exported to Japan and Canada for further treatment. Most of the minor by-product cobalt oxide recovered from the refining of **Broken Hill** zinc concentrates at **Risdon** is also exported.

Manganese

Australia is a major producer of manganese ore, with production in recent years having averaged about 1.75 Mt.

During the 1940s manganese from small deposits in several states was used in the production of ferroalloys at Newcastle to ensure a supply to Australian steelworks during the Second World War. In 1960 a major deposit was discovered on **Groote Eylandt** in the Gulf of Carpentaria and an opencut mine, town and port facilities were subsequently established. Today Groote Eylandt is the only producer of manganese ore in Australia although small quantities of manganese dioxide are recovered during zinc refining operations at **Risdon**.

Much of the manganese consumed domestically is used in the production of manganese alloys at **Bell Bay**. The plant, commissioned in 1960, now has the capacity to produce up to 190 000 t per annum of alloys (mainly ferromanganese, used in steel making to improve the hardness, toughness and tensile strength of the finished product, and silicomanganese). The Bell Bay site was chosen because of the availability of hydro-electric power and port facilities, and its convenient location between the steelworks in New South Wales and South Australia.

Australia is a leading exporter of manganese, shipping 75% of its ore production to steel plants in South-East Asia (notably Japan) and Europe. Much of the ferromanganese and silicomanganese produced at Bell Bay is also exported.

Platinum and palladium

Platinum and palladium are contained in nickel concentrate produced in Western Australia. Some is recovered overseas during refining of nickel matte produced at the **Kalgoorlie** nickel smelter, and some in Australia during the treatment of copper sulphide residue from the **Kwinana** nickel refinery at the **Port Kembla** copper refinery.

Silver

Australia is the world's fifth largest mine producer of silver, almost all of which is a by-product of base metal mining and smelting. By far the largest mine producers of silver are **Mount Isa** and **Broken Hill**. Of a total mine production of just over 1 million kg in 1986, 74% was from lead concentrates, 10% from zinc concentrates and 12% from copper concentrates. Only 1.4% was a by-product of gold mining, mainly at Kidston (Qld) and mines throughout Western Australia.

Production of refined silver is in excess of 300 000 kg annually. Most is recovered at the **Port Pirie** lead refinery, though some silver is also recovered at the copper refinery at **Port Kembla** and from the refining of gold bullion and scrap at the **Perth** Mint.

The silver content of lead bullion produced at **Mount Isa** and **Cockle Creek** is not recovered in Australia. A considerable quantity of silver is also contained in exported base metal concentrates.

Tantalum and lithium

Australia is a substantial producer of tantalum, a co-product of tin mining. **Greenbushes** (W.A.) is Australia's largest producer of tantalum, a metal used in the manufacture of electronic components and corrosion-resistant alloys. Smaller amounts of tantalum are mined at **Moolyella** (W.A.) and **Bynoe Harbour** (N.T.).

In 1983 production of lithium began at Greenbushes from one of the world's highest grade and largest known deposits of spodumene, a major source of lithium. The deposit occurs on the margin of the tin–tantalum orebody. By 1986 production of high grade spodumene concentrate, which is mostly exported, amounted to 12 700 t.

Tungsten and molybdenum

Australia is one of the Western world's major producers of tungsten, ranking fourth after South Korea, Canada and Bolivia. This position has been maintained even though continuing weak demand and low prices over the last few years have resulted in production falling to about half of its 1980 peak of over 3500 t.

Tungsten occurs principally in two ore minerals—wolframite and scheelite. Both have been mined to a greater or lesser extent in Australia since tungsten first gained commercial importance in the early 1900s. Much production in the past has been in association with tin mining, particularly in Tasmania and Queensland.

The bulk of Australian tungsten now comes from two deposits—**King Island** in Bass Strait (scheelite), one of the largest tungsten mines in the world, and **Mount Carbine** in Queensland (wolframite 75%, scheelite 25%). Following recent closures of a number of mines, the only other significant producing mine is **Kara** in Tasmania.

Almost all production is exported in the form of concentrates, mainly to West Germany, U.S.A. and U.S.S.R. Small amounts of concentrates are processed domestically and used mainly in the manufacture of tungsten carbide-tipped tools.

In the early 1900s Australia was the world's leading producer of molybdenum but now produces only minor amounts, all as a by-product of tungsten mining at **King Island**.

Vanadium

Australia's demonstrated resources of vanadium total almost 10 Mt, or approximately 15% of reported world resources, but almost all are at present classified as sub-economic. Vanadium is not currently mined in Australia though a small quantity was produced at Cloates near **Wundowie** (W.A.) in 1980 and 1981. Its main use is to strengthen and toughen steel.

Most of Australia's vanadium resources are contained in oil shale deposits in the **Julia Creek** area of north-western Queensland. Substantial resources are also contained in titaniferous magnetite deposits in Western Australia including **Barrambie**, **Wundowie** and **Jameson Range**.

Tungsten mining on King Island, Bass Strait (Tas.)
Although tungsten has been mined in various parts of Australia since late last century, most production in recent years has come from the King Island scheelite deposit (above). Annual output now averages around 1200 t of scheelite concentrates and 12 t of molybdenum concentrates.

Opencut tin–tantalum mining at Greenbushes (W.A.)
Tin has been mined at Greenbushes since 1888 though commercial production of tantalum did not begin until the 1920s. Since 1983 lithium has also been produced at Greenbushes. The combined output of tin–tantalum and lithium ore has averaged 1.5 Mt in recent years.

From mine to metal

Most minerals undergo several stages of processing between mine and market or point of manufacture. Each step involves successively smaller tonneages and higher grade or purer end-product.

Primary processing, or concentration, generally involves only physical processes. The ore is first crushed and ground to release the mineral particles from the waste rock and then concentrated by utilising physical or chemical differences to separate the mineral ore and the unwanted material.

With generally large tonneages of ore to be processed the concentration plants are usually located as close as possible to the mines, a far more economical arrangement than transporting the ore elsewhere for treatment.

Secondary processing, which involves smelting and/or refining, is usually carried out away from the mine. The importance of proximity to energy, water and other raw materials (such as coke and limestone in the case of iron and steel plants) and to industrial and transportation facilities are paramount in determining the location of secondary plants.

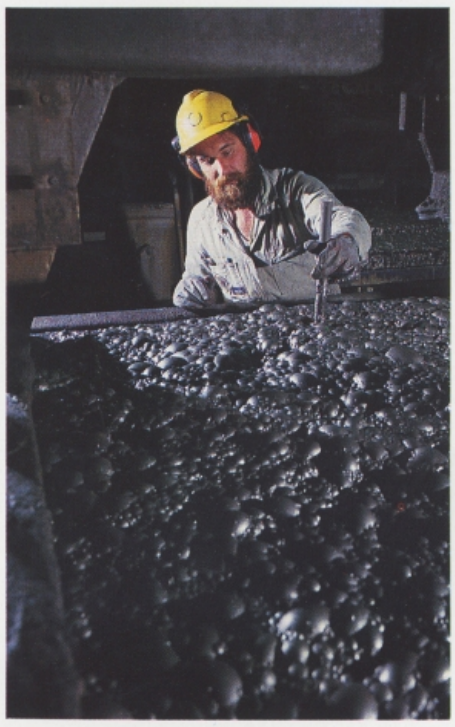
Smelting breaks the chemical bonds in the concentrated ore compound, thereby reducing the mineral to metal. For example, galena (lead sulphide) is roasted and smelted to separate lead from sulphur. Iron ore, largely hematite (iron oxide), is smelted to separate iron from oxygen. The very high temperatures required to break the chemical bonds mean that processing costs are much higher than at the primary stage. Oxide bonds are more difficult to break than sulphide bonds hence the treatment of oxide ores, such as bauxite, requires a greater amount of energy.

Refining removes the small amounts of other metals which may have chemically followed the main metal in the smelting process. Refining is also a costly process, requiring precise control to produce the desired highly pure mineral.

Concentration and refining both involve the removal of impurities. For most metals concentration refers to the initial ore upgrading while refining refers to the final metal purification. In aluminium processing, however, ore upgrading is actually refining because all impurities are removed at this stage, leaving only alumina (aluminium oxide). The process, both chemically complex and energy intensive, is part of the secondary processing stage. Consequently, alumina refineries are usually located in industrial or port areas with ready access to large quantities of power.

In contrast, many industrial or non-metallic minerals are frequently used for their physical properties alone and processing generally does not go beyond beneficiation. Indeed, for many purposes these minerals require only crushing and sizing.

Although many deposits in Australia are found inland the coast is directly accessible with no major obstacles in the form of physical or political boundaries. Thus ore can be concentrated at the mine and then transported overland to the coast for further processing and/or shipment from specialised ports. Sea transport is used not only for exporting minerals but also for much domestic mineral traffic, especially the more bulky, lower value commodities.



Testing the depth of froth in a nickel flotation cell at the Kambalda nickel concentrator (W.A.)