Mineral resources

Australia's more significant mineral deposits as known by late 1984 are presented on the two 1:5 million scale maps 'Fuels' and 'Minerals other than Fuels'. The maps depict the type, location and size of mineral deposits, their state of exploitation, associated mineral processing facilities, and the larger mineral movements between mines and treatment plants or points of consumption.

As a general rule small deposits which are not being mined are not shown on these two maps though in some instances such deposits have been included as possible indicators of more widespread mineralisation.

The size class for each mineral deposit (small, medium or large) is based on an international classification developed by the Circum-Pacific Council for Energy and Mineral Resources but adapted and expanded to suit Australian circumstances by the Bureau of Mineral Resources, Geology and Geophysics. The limits of each class are given in Table 1.

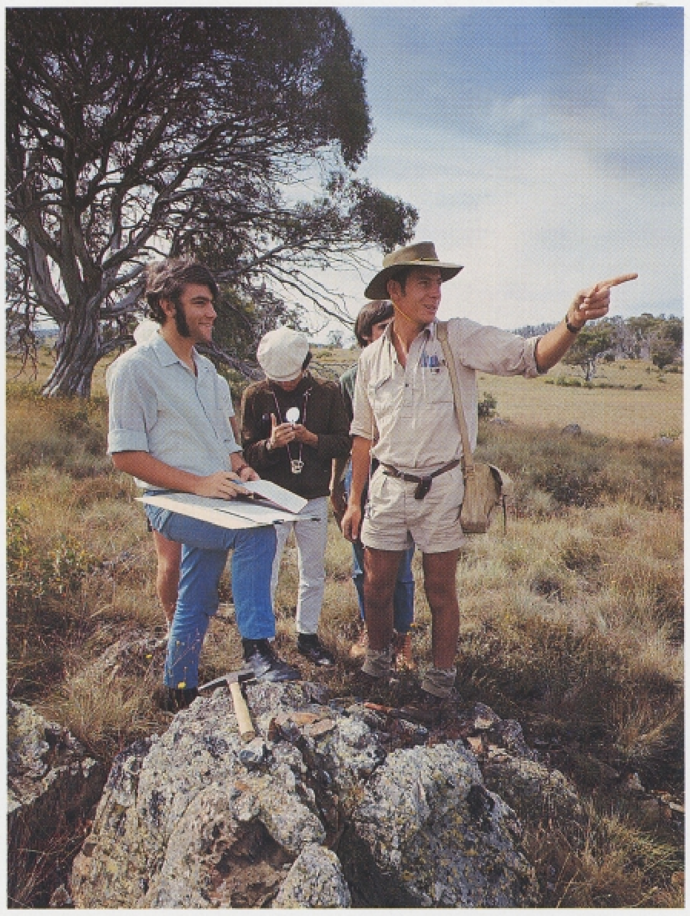
The distribution of Australia's mineral deposits is closely related to the underlying geological structure. The two major kinds of structural units which make up the continent— cratons and craton covers— are shown as background information on the 1:5 million minerals maps: exposed cratons and Early Proterozoic sedimentary basins (craton covers) on 'Minerals other than Fuels' and sedimentary basins younger than Early Proterozoic on 'Fuels'. Their names are distinguished in the following text by the use of italic capitals, for example *YILGARN BLOCK*.

Continents evolve through time by a process of craton formation and subsequent deposition of sedimentary cover. Metallogenic evolution parallels such tectonic evolution.

In broad terms Australia grew from west to east. Nickel, gold and uranium are concentrated in the oldest westerly cratons and iron in the associated craton cover. The major base metal deposits are associated with the somewhat younger central cratonic blocks. Eastern Australia is younger still and is host to tin, tungsten, tantalum and particular types of base metal and gold deposits.

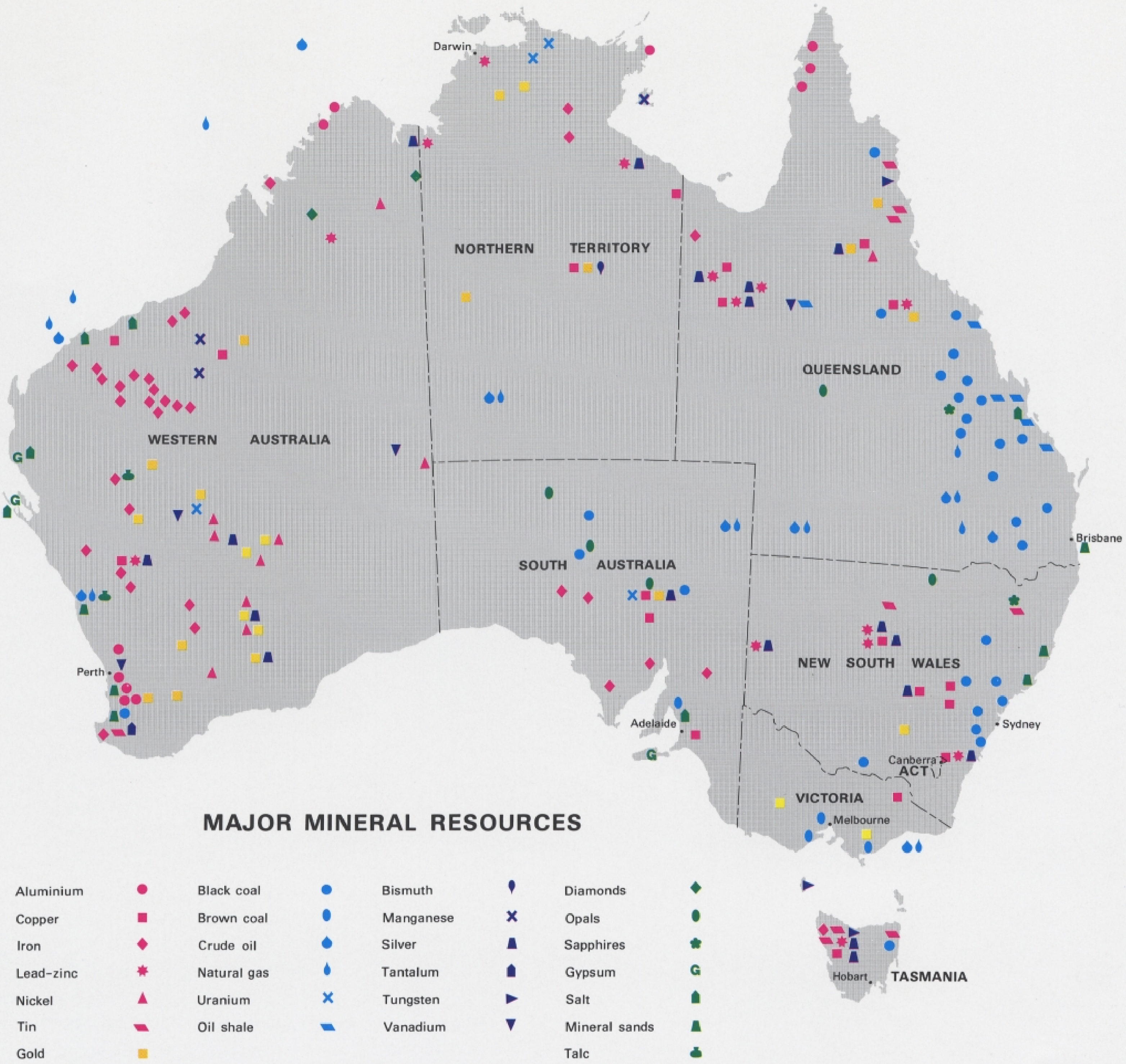
In general the distribution of non-metallic (or industrial) minerals cannot be as closely correlated with structural units as can the metallic minerals because of the significant influence of non-geological factors. For example, the location of surficial deposits such as mineral sands, silica, opal and the various clays reflects weathering and geomorphological controls, while the formation of salt and gypsum is strongly climate-dependent.

Hydrocarbons are most developed in young (but not the youngest) sedimentary basins that formed relatively late in the evolution of the continent.



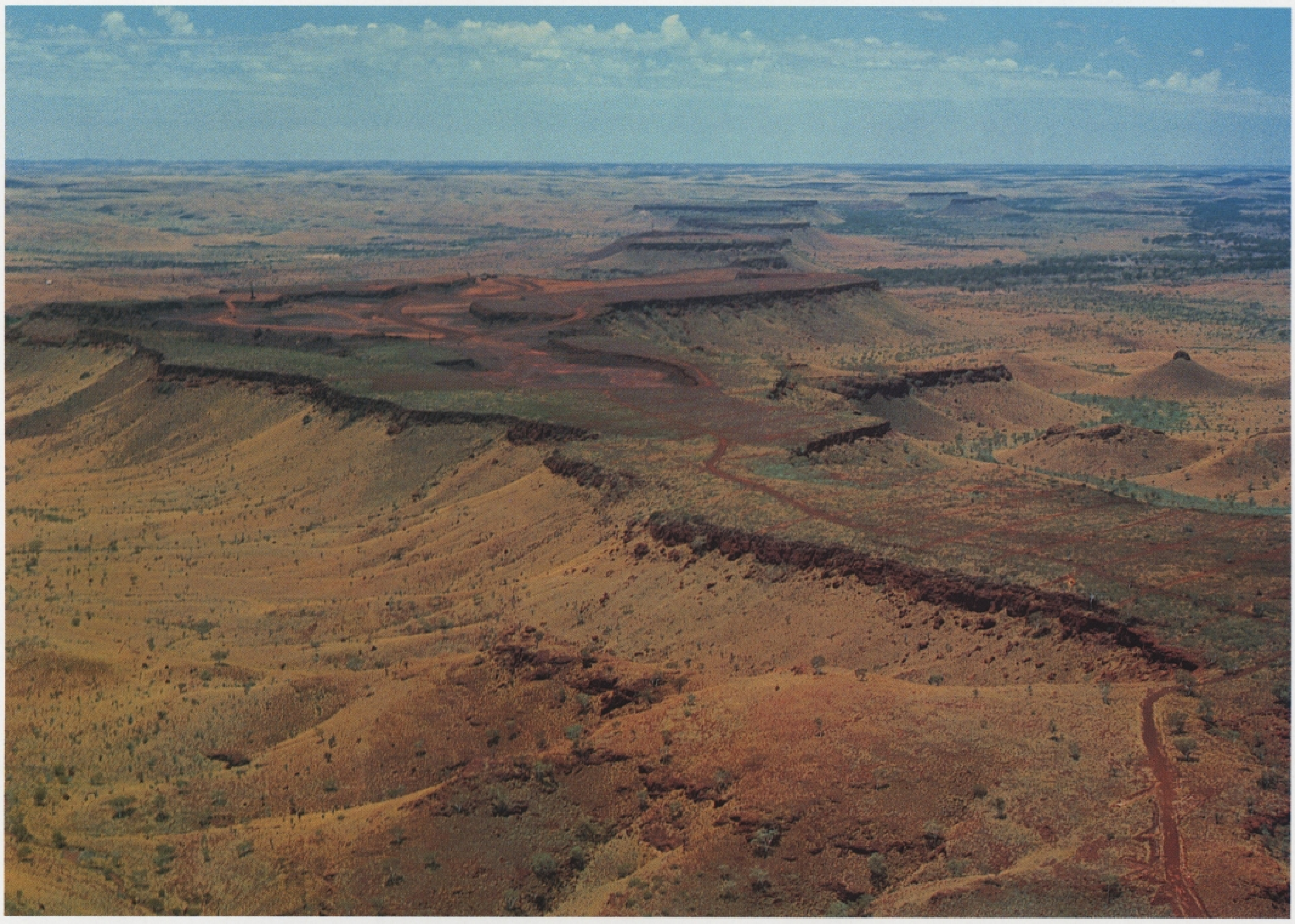
Prospecting in southern New South Wales

Australia's mineral industry is well established on a rich and diverse resource base. It provides raw materials to the manufacturing, construction, transport and power sectors. In fact, the mineral industry meets almost all domestic requirements for metals, industrial minerals and fuels used in the manufacture of a wide range of goods for consumption both in Australia and overseas. Additionally, as a major export earner minerals are responsible for around $A15 billion annually in foreign exchange earnings.



SCALE 1:20 000 000

SOURCE: Derived from the maps 'Fuels' and 'Minerals other than Fuels' in this volume.



Mesas with iron-rich cappings in the Robe River area (W.A.)
The cappings of pisolitic (pelletised) limonite—a form of iron ore—are the uplifted remnants of secondary iron deposits which filled ancient river channels draining the Hamersley area during the Tertiary. These 'rivers of ore' are generally about 30 m thick, average 57% iron and extend for more than 200 kms along the Robe River valley.

Mineral sufficiency

Australia's sufficiency in mineral resources is indicated below. The size class of each commodity is based on the ratio of known resources to the current annual rate of production. However, this figure does not necessarily represent the life of known resources because of possible future changes in production rates and further mineral discoveries. Some very small or low grade deposits which would not have a substantial impact on resource sufficiency have not been taken into account.

Large resources
(more than 30 years)

- Aluminium
- Chromium
- Coal, black
- Coal, brown
- Cobalt
- Copper
- Diamonds
- Dolomite
- Gypsum
- Iron
- Kaolin
- Lead
- Limestone
- Lithium
- Magnesite
- Manganese
- Monazite
- Natural gas
- Nickel
- Oil shale
- Opals
- Phosphate
- Pyrophyllite
- Salt
- Sapphires
- Silica
- Silver
- Sulphur (as metallic sulphides)
- Tantalum and columbium
- Tin
- Uranium
- Vanadium
- Zinc

Adequate resources
(15–30 years)

- Antimony
- Asbestos (short fibre)
- Barite
- Bentonite
- Bismuth
- Cadmium
- Corundum
- Diatomite
- Emery
- Felspar
- Fireclay
- Fluorspar
- Fullers earth
- Garnet
- Gold
- Mica
- Palladium
- Peat
- Platinum
- Pottery clay
- Siliceous abrasives
- Talc
- Titanium (as rutile, ilmenite)
- Tungsten

Small resources
(less than 15 years)

- Arsenic
- Asbestos (long fibre)
- Beryllium
- Crude oil
- Kyanite
- Mercury
- Molybdenum
- Potassium
- Sillimanite
- Vermiculite

Table 1. Definition of mineral deposit class sizes

Mineral	Deposit size: Large more than	Medium < >	Small less than
Major metals			
	tonnes of contained metal		
Aluminium‡	200 000 000		100 000 000
Copper	1 000 000		50 000
Iron	100 000 000		5 000 000
Lead	1 000 000		50 000
Nickel	500 000		25 000
Tin	100 000		5 000
Zinc	1 000 000		50 000
	kilograms of contained metal		
Gold	500 000		25 000
Other metals			
	tonnes of contained metal		
Antimony	50 000		5 000
Bismuth*			
Cadmium*			
Cobalt	20 000		1 000
Lithium*			
Manganese	10 000 000		100 000
Molybdenum	200 000		5 000
Palladium*			
Platinum*			
Silver	10 000		500
Tantalum	100 000		1 000
Tungsten	10 000		500
Vanadium	10 000		500
Fuels			
	tonnes		
Black coal	1 000 000 000		100 000 000
Brown coal	10 000 000 000		1 000 000 000
Uranium	40 000		10 000
	cubic metres		
Crude oil	30 000 000		3 000 000
Natural gas	30 000 000 000		3 000 000 000
Oil shale§	100 000 000		10 000 000
Gemstones			
Diamonds*			
Opals*			
Sapphires*			
Other gemstones*			

Mineral	Deposit size: Large more than	Medium < >	Small less than
Used mainly for **Building and construction**			
	tonnes		
Asbestos	10 000 000		100 000
Gypsum	100 000 000		5 000 000
Limestone	10 000 000		2 000 000
Used mainly for **Chemicals and fertilisers**			
	tonnes		
Phosphate rock	200 000 000		200 000
Salt‖			
Sulphur¶			
Other minerals			
	tonnes		
Barite	5 000 000		50 000
Clays:			
Bentonite†			
Fireclay†			
Fullers earth†			
Kaolin†			
Stoneware, tile and pipe clay†			
Diatomite*			
Dolomite	10 000 000		2 000 000
Felspar*			
Garnet*			
Magnesite	10 000 000		100 000
Mica*			
Mineral sands:			
Ilmenite	10 000 000		5 000 000
Monazite	50 000		20 000
Rutile	500 000		200 000
Zircon	1 000 000		500 000
Peat*			
Silica	2 500 000		1 000 000
Sillimanite*			
Talc	10 000 000		1 000 000
Vermiculite*			

* Individual deposits classed by BMR
† Individual deposits classed by state departments of mines
‡ Class limits refer to tonnes of bauxite
‖ Based on production capacity of individual treatment centres
¶ Based on size of sulphide source
§ Oil content

The various patterns of mineralisation that have occurred over geological time are used in the following text as the basis for describing Australia's mineral resources.

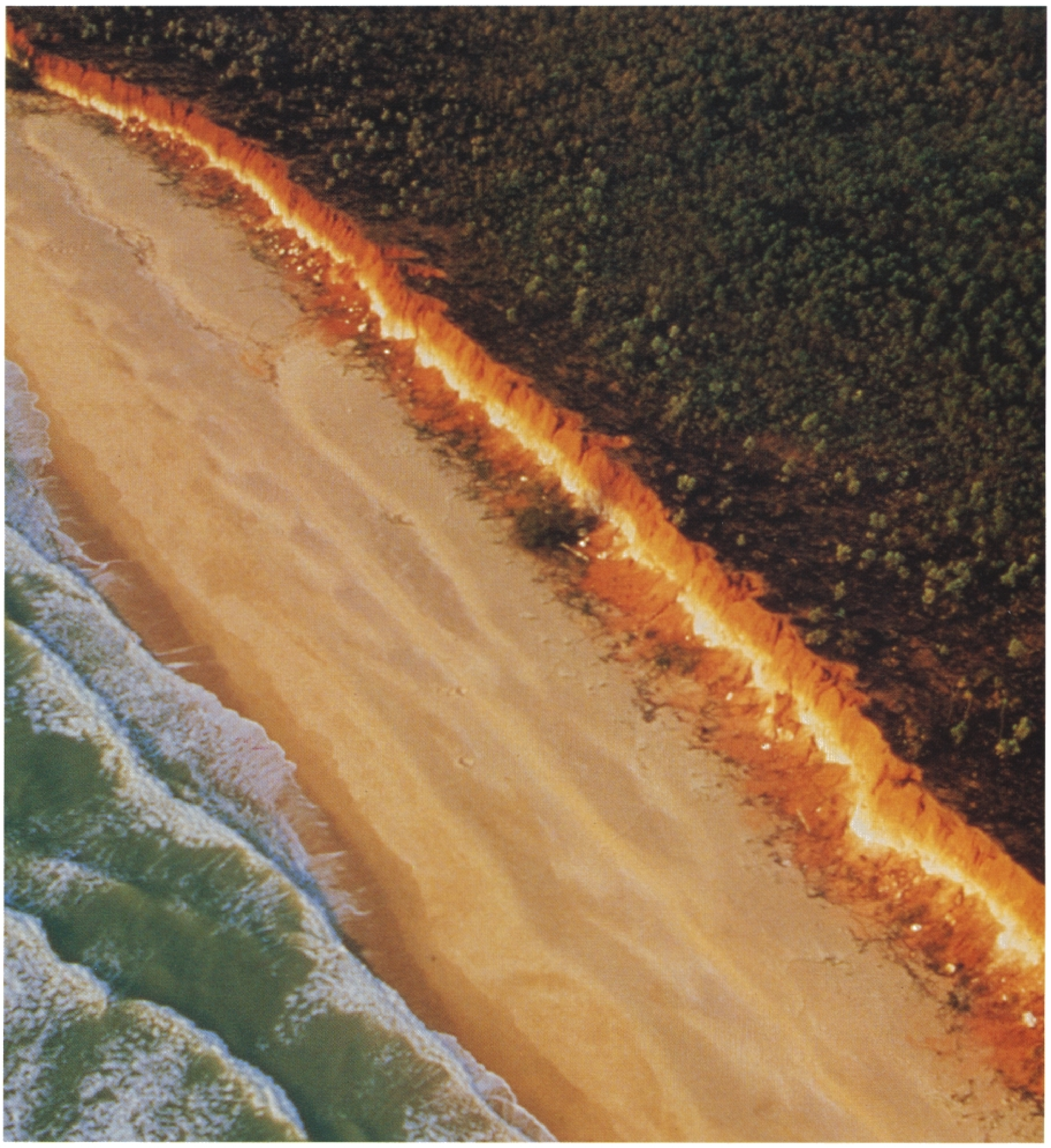
In general, mineralisation within major metalliferous structures, as shown on the 1:5 million scale map 'Minerals other than Fuels', is summarised according to mineral 'provinces'. Each province denotes a geographic grouping of a particular type of mineralisation (characterised by one or a combination of metals) in an exposed craton or area of cratonic cover. Examples from the Archaean and the Proterozoic include the 'gold province' within the *YILGARN BLOCK*, the 'Broken Hill province' in the *WILLYAMA BLOCK* and the 'Hamersley iron province' in the *HAMERSLEY BASIN*. Mineral provinces in the Palaeozoic tend to coincide with parts or all of particular fold belts; hence Palaeozoic mineralisation is described in terms of these fold belts. A 'field' is part of a mineral province.

The major sedimentary-associated mineralisation which began in the Palaeozoic and may still be continuing today is described under each individual mineral. This was the age of fossil fuel formation. The most recent mineralisation, associated with the largely unconsolidated surface cover, is also described in terms of each mineral.

Bold type is used from hereon in the text to distinguish the names of individual mines/deposits and treatment plants which appear on the maps 'Fuels' and 'Minerals other than Fuels', for example **Broken Hill, Blair Athol** and **Risdon.**

The distribution of mineral deposits through space and time displays patterns that parallel tectonic evolution and the growth of continents. These patterns resulted from the complex interplay of a variety of geological factors, including the degree of evolution of the crust, global patterns of cratons and orogenic zones, the chemical composition of magmas emplaced at a particular place and time, whether the magmas were derived from the earth's mantle or by remelting of crustal material (and the nature of that crustal material), the distribution of sedimentary basins and the tectonic events which have affected the region over geological time.

In Australia the most important metalliferous ore-forming periods were a few comparatively short intervals in the Archaean, the Early and Middle Proterozoic, the Middle and Late Palaeozoic and the Tertiary–Quaternary. The most productive environments have been mafic–ultramafic volcanic rocks with minor sediments (gold and nickel in the *YILGARN BLOCK*); closed basin sedimentation (lead–zinc at **Mount Isa** and **Broken Hill**); secondary concentration (iron ore in the *HAMERSLEY BASIN*, lateritic bauxite); and felsic volcanic environments (gold, copper, lead and zinc in the Tasman Fold Belt).



Bauxite cliffs near Weipa, Gulf of Carpentaria (Qld)
The red bauxite and underlying bleached clay visible in these cliffs developed during the Tertiary, evidently over several lateritic weathering cycles.

How mineral deposits are formed

Mineral deposits are the products of normal igneous, sedimentary and metamorphic rock-forming processes. In special circumstances these processes have concentrated particular minerals in amounts substantially above their average crustal abundance.

Formation of most mineral deposits requires a coincidence of factors: a mineral source, transport and concentrating mechanisms and a favourable depositional site. Depending on the geological processes responsible, deposits are classed as igneous-associated or sedimentary-associated. However, many deposits show the effects of more than one process and may be partly igneous and partly sedimentary in origin.

In addition igneous and sedimentary mineralisation may be modified and further concentrated during metamorphism; for example by remobilisation and redeposition of metals in structurally deformed zones such as faults or folds, or by recrystallisation into a coarser grained form. The complex Broken Hill silver–lead–zinc orebodies display features indicative of such a multi-stage history.

Finally, weathering, in particular groundwater movement, affects near-surface zones of all deposits and has been a significant factor in the formation of some orebodies or in increasing the grade of parts of them. The vast lateritic bauxite deposits of northern and western Australia are good examples of the role of weathering in ore formation.

Igneous-associated deposits

Igneous activity gives rise to a broad spectrum of deposit types. Variations among them reflect differences in host magma composition, depth of magma emplacement and the chemistry of the elements concerned.

The fundamental mechanism for the concentration of igneous ores is 'magmatic differentiation', a physico-chemical phenomenon whereby magmas do not crystallise homogeneously; rather, different minerals crystallise in a sequence depending on (among other things) their melting-points. This process tends to concentrate certain elements, particularly those forming minerals which crystallise early or late in the sequence. For example, early crystallising nickel sulphides may settle to the bottom of the magma in sufficient quantity to form ore deposits. At the other extreme, elements such as gold, tin and tungsten accumulate in the last remaining fluids of the magma and therefore tend to occur in the upper part of the igneous rock mass or in the rocks surrounding the upper part of the mass.

Sedimentary-associated deposits

The mechanical processes of sedimentation and chemical processes of precipitation tend to concentrate minerals in larger, more continuous deposits than those formed by igneous processes. These sedimentary-associated deposits are classified according to the ore-forming processes instrumental in their formation.

The broad classes of deposits are:

- *chemical and biochemical*—including limestone, evaporites and some base metal and iron deposits;
- *organic*—particularly coal, oil shale and petroleum;
- *detrital*—where the valuable minerals are concentrated at the surface by the sorting action of water or wind; and
- *secondary*—formed through the concentration of valuable elements just beneath the surface by weathering.