NICKEL

Ni

The Chamber of Minerals & Energy Western Australia

FORMATION a

Nickel ore

- Nickel is one of the more common elements in the composition of the earth, but it is sparingly distributed in the earth's crust.
- Most of the world's known nickel resources occur in minerals such as garnierite ($(Ni,Mg)Si)_3.nH_2O$) and nickeliferous limonite (nickel mixed with hydrated iron oxide). These are secondary minerals contained in nickel-bearing laterite, highly leached soil that forms in regions of tropical climate such as in New Caledonia and Cuba. The tropical climate with high temperatures and abundant rainfall causes weathering of nickel-bearing mafic and ultramafic rocks (iron and magnesium rich) subsequently concentrating the mineral.
- The main nickel mineral in Australia is pentlandite $(Fe, Ni)_9S_8$ which occurs with pyrrhotite, pyrite and chalcopyrite in lodes, in mafic and ultramafic igneous rocks. In Australia, nickel-bearing ores and their host rocks mainly form parts of ancient volcanic lava flows.

MINING

- Nickel is mined by both open cut and underground methods. If an ore deposit is outcropping (partially visible above the ground) or occurs not far beneath the earth's surface it can be extracted using the open cut method of mining. Low operating costs allow low-grade deposits to be considered as economic ore bodies.
- In open cut mining the topsoil and overburden are first removed and stockpiled. Topsoil contains the organic component of the earth, and is stockpiled separately as it is essential for later rehabilitation of the mined area. As the mine increases in depth, the walls of the excavation are left at an angle to avoid collapse. Open cut mines use very large mobile machinery which enables high production rates. Large haul trucks carry the ore and waste to surface stockpiles.
- In shallow deposits the ore is often soft enough to be removed by excavators or back-hoes. With increasing depth, the rocks are harder and it becomes necessary to drill and blast before excavating. Nickel laterites are mined by surface operations up to 60 metres deep.
- Deeper sulphide deposits must be of higher grade to warrant the additional cost of underground mining. The most common methods of gaining access, and extracting ore from underground, is either by sinking a vertical shaft alongside the ore body, or by excavating an inclined roadway tunnel that descends to a point from which the ore can be extracted.
- Underground mining operations are more complex than open cuts with respect to access, ground support, ventilation, blasting and haulage. Access from the surface to underground orebodies is either by vertical or inclined shafts, horizontal tunnels (called drives) or downward sloping tunnels (called declines). In shafts, men and materials travel in 'cages' which are like elevators in a high-rise building, whereas in a decline all manner of vehicles drive up and down as required. Access to the ore body in both cases is by horizontal openings called 'levels' or 'adits'. Ventilation is achieved by having other shafts with fans at the surface to draw or blow fresh air through the mine. Equipment used underground is limited by the size of the shafts and tunnels.
- There are a variety of stoping (mining) methods depending on the nature and extent of the orebody. All methods involve drilling a pattern of holes into the rock, charging the holes with explosive, blasting the rock, bogging (digging) it out and carrying it to the surface.
- After mining, the ore is transported to a concentrator to upgrade the nickel content. The ore is fed through a series of crushers and grinding mills which break the rock down to about 0.1 mm in size, liberating the nickel minerals from the host rock.

WMC's Kalgoorli

The ancient Chinese used nickel in metal alloys.

1751

Nickel first isolated as a distinct element by the Swedish chemist Axel Cronstedt.

1823

Nickel alloys became popular in Europe for use in tableware.

1840's

Nickel mining begins in earnest, with deposits developed in France, Germany and Scandinavia.

1860

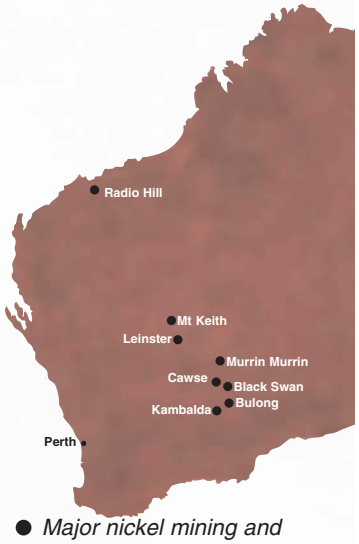
Nickel is used in coinage when Belgium started minting coins comprising 75% copper and 25% nickel.

1897

Nickel-bearing minerals noted in the gold-rich veins in the Eastern Goldfields of Western Australia.

nd LOCATION

- The West Australian deposits were formed 2,700 million years ago in the Archaean time period as a result of volcanic activity where ultramafic rocks extruded onto the surface of the earth through vents or cracks in the earth's crust. The lava flows carried droplets of nickel sulphides which eventually settled to the bottom of the flows as they cooled and slowed. The sulphides collected within the depressions at the base of the flows, forming long, ribbon-like ore bodies. The ores are located in Archaean blocks of WA.
- The nickel grade of sulphide ore typically ranges from 1-4%, and that of lateritic ore from 1-2%. Economic demonstrated resources (i.e. those sufficiently tested by drilling and able to be economically extracted at current prices with existing technology), total almost nine million tonnes.
- All of Australia's nickel production is from Western Australia and Queensland. Nickel sulphide deposits are mined in Western Australia at Kambalda, Leinster and Mount Keith by underground and open cut methods. Nickel laterite deposits are mined at Murrin Murrin, Cawse and Bulong.

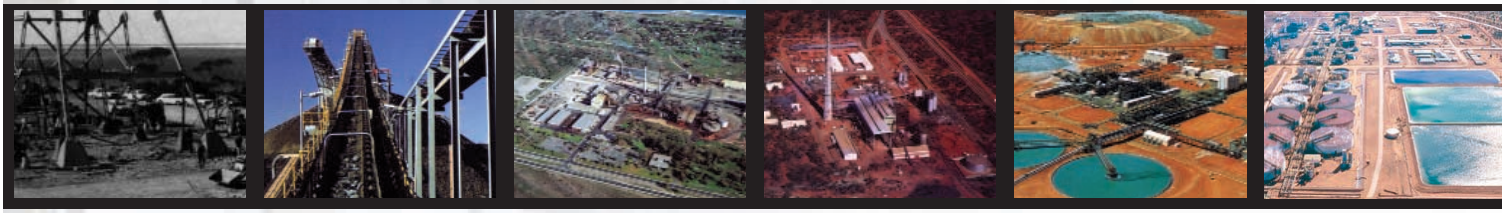


Major nickel mining and resource areas in WA

PROCESSING

- **Concentration** - While still at the mine site, the sulphide ore is crushed to a fine powder and mixed with water. The slurry is fed into a rotating mill, where heavy steel balls grind the rock to a fine pulp. The pulp from the mills is fed into flotation cells, the mixture is agitated with compressed air and a propeller. The agitation, together with the compressed air, causes bubbles to form. The chemical reaction causes the nickel sulphide particles to stick to the bubbles and float to the surface, producing a concentrated nickel froth. The froth is collected from the surface of the cell and re-treated in the same way a number of times, increasing the grade of concentrate each time. Over 90% of the nickel in the initial ore is recovered into a concentrate that contains around 10% to 12% nickel, which is then filtered and dried prior to dispatch to a smelter as a fine powder.
- **Smelting** - Flash smelting utilises the heat energy from the reaction (ie exothermic) which occurs when the iron and sulphur are burnt in an oxidising atmosphere. The nickel 'matte' sinks to the bottom of the furnace and the remaining material called 'slag' floats to the top. The heavier nickel matte is separated from the 'slag' which is returned to the flash furnace to be re-concentrated. The high grade matte is collected, dried and packaged for export, or further refining.
- **Refining** - In the refining process, the slurry is first treated to remove metals and sulphur. Then it is treated to remove copper. The copper free solution is finally purified in a nickel reduction process which causes the nickel to form as a 99.8% pure metal.
- Unlike nickel sulphides, nickel laterites are mineralogically and chemically complex which makes processing more complicated. High-pressure acid leaching (HPAL) is becoming an economic way of processing nickel laterites.
- In high-pressure acid leaching (HPAL), slurry from the ore preparation plant is contacted with sulphuric acid at temperatures of 250° - 280° C and under high pressure for 60 minutes, leaching nickel and cobalt into solution. This process generally proves successful in extracting high levels of nickel and cobalt whilst minimising the extraction of iron and aluminium. The nickel cobalt liquor is recovered and processed by solvent extraction to produce separate nickel and cobalt products.
- Environmental restrictions and the cost of treating low grade ore are driving the need for clean and environmentally safe hydrometallurgical processes and research into bacterial mineral processing (bioleaching) is well established. This process has been operated at Radio Hill nickel mine.

lie nickel smelter



1966
Western Mining Corporation Ltd (now WMC Resources Ltd.) discovered the first known important economic concentration of nickel in Australia at Kambalda, 50 km south of Kalgoorlie.

1967-71
Nickel Boom! A major world nickel province discovered between Norseman and Wiluna.
The nickel sulphide deposit was found on Leinster Downs Station by Selcast Exploration.

1970
WMC's Kwinana nickel refinery commenced nickel production

1973
WMC opened the nickel smelter at Kalgoorlie.

1995
WMC Resources opened its nickel mine at Mt Keith

1999
Anaconda's Murrin Murrin mine produced its first nickel output in May 1999 and cobalt in July 1999 from laterite deposits.

NICKEL STATISTICS

Total Quantity of Nickel Mined in Western Australia

In 2003 Western Australia accounted for all of Australia's nickel production and 18% of world nickel production.

The value in 2003 of Western Australia's total nickel industry was A$2.76 billion. The price in 2003 averaged A$14,663/t.

In 2003, WA accounted for 18% of world and 100% of Australia's nickel production.

Employment

In 2003, 5,714 people were employed by the nickel mining and processing industry in WA.

Primary Nickel Producers in WA

MINARA RESOURCES LIMITED
Murrin Murrin.

MPI MINES LTD
Black Swan.

OM GROUP INC
Cawse.

PRESTON RESOURSES LTD
Bulong.

WMC LTD
Kambalda, Leinster, Mt Keith.

Current statistics are available from the Statistics Digest on the Department of Industry and Resources website at www.doir.wa.gov.au

NICKEL PROPERTIES

Its name is derived from the term 'Kupfer-nickel' or Devil's copper, so called by the Saxon miners who discovered the copper red/brown mineral in the middle ages, and found to their disgust, that they were unable to extract the metal from the ore.

The chemical symbol for Nickel is Ni and its atomic number is 28. It has a specific gravity of 8.9 and a relatively high melting point at 1,453˚C. Nickel is a hard, **silvery-white metal** with a similar hardness and strength to iron, but more **ductile** and easier to work and machine.

It has the ability to impart its special features and physical properties to other metals. When alloyed with other elements nickel imparts **toughness, strength, resistance to corrosion**, and various other **electrical, magnetic, and heat resistant properties**. At least 3 000 nickel alloys have been identified - more than 80% of the world's nickel production is used in alloys.

About 60% of world nickel output is used in the manufacture of **stainless steels** (a group of iron-based alloys that contain chromium, carbon, and other elements). When nickel is added to stainless steels their **corrosion resistance and strength** is considerably increased. Alloy steels containing nickel are therefore widely used in the chemical industry, pipelines to carry seawater and in the highly stressed components for motor cars such as crank-shafts and axles. Nickel is also widely used in the manufacture of coins.

Monel Metal, which contains more than 67% nickel, is a highly corrosion-resistant alloy used in shipbuilding, food processing equipment, hospitals and laundries. **Kovar**, an alloy of nickel, iron and cobalt, has a similar **coefficient of thermal expansion** to glass and provides gas tight glass-metal seals for electrical equipment.

Nickel alloys are able to withstand temperature extremes and are resistant to fracturing under stress. Nickel is used in the storage and transportation of corrosive chemicals and liquefied gases, which require especially low temperature conditions. Many alloys, usually containing more than 50% nickel, have been developed for high temperature strength in aircraft gas turbines and jet engines.

Nickel also rates as a **strategic metal**, and is important in steels used for armour plating, gun forgings, shells and bullets.

Nickel is also used for catalysing the addition of hydrogen to natural oils ie converting the oils into solids which can be used in soap and margarine.

MORE INFORMATION

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The Chamber of Minerals and Energy of Western Australia

7th floor, 12 St Georges Terrace, Perth WA 6000 Telephone: (08) 9325 2955 Facsimile: (08) 9221 3701

Internet: http://www.cmewa.com Email: info@cmewa.com

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