COPPER, LEAD & ZINC

Cu
Pb
Zn

The Chamber of Minerals & Energy Western Australia

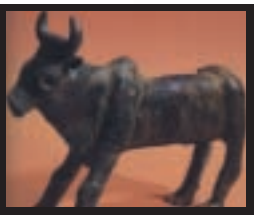
FORMATION and LOCATION

Lead ore

- The base metals - copper, lead and zinc - are often considered as a group because of their long history of use, and because two or more are commonly associated in sulphide orebodies. However, they have few common properties, and their market factors of price, supply and demand, are largely independent.
- Copper, lead and zinc are relatively abundant in the Earth's crust with average concentrations of about 55, 12 and 70 grams per tonne respectively (compared to gold at 0.001 g/t). To form a viable deposit, copper needs to be concentrated about 350 times, lead about 4,000 times and zinc 1,300 times.
- Copper is often found in alloy form with silver, lead, zinc and gold in sulphide, oxide and carbonate minerals. In Australia the main ore minerals of copper are chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4), covellite (CuS) and chalcocite (Cu_2S). Many orebodies contain some native copper, malachite ($CuCO_3.Cu(OH)_2$), azurite ($Cu_3(CO_3)_2.Cu(OH)_2$), cuprite (Cu_2O) and tenorite (CuO) in the near-surface weathered zone of an orebody.
- The main lead mineral is galena (PbS), which contains 86.6% lead. Cerussite ($PbCO_3$) and Anglesite ($PbSO_4$) commonly occur in the near-surface weathered or oxidised zone of the lead orebody. Native lead occurs in nature, but is rare.
- The most important mineral in an orebody containing zinc is sphalerite (Zn,FeS), that contains up to 67% zinc. Smithsonite ($ZnCO_3$, 52% zinc), willemite (Zn_2SiO_4, 59% zinc), franklinite ($(Zn,Mn)FeO(FeMn)_2O_4$, 17% zinc) and hemimorphite ($Zn_4Si_2O_7(OH)_2.H_2O$, 54% zinc) may occur in the near-surface weathered or oxidised zone of an orebody.
- Copper, lead and zinc deposits often form in a similar way. Hot (hydrothermal) fluids laden with dissolved metals move up through the crust along fractures and faults. Volcanic activity or hot granite bodies (batholiths) forcing their way to the surface often activate the fluid circulation. These fluids can be trapped below the surface in cracks where sphalerite, galena, copper sulphides, silver and trace amounts of gold may precipitate to make vein deposits. Where limestones occur, the fluids can fill cavities to form rich but patchy deposits known as 'Mississippi Valley Type' or MVT deposits. The Cadjebut mine in the Kimberley is an MVT deposit contained in Permian dolomites (altered limestone). Some fluids may reach the ocean floor in areas of underwater volcanic activity to form 'volcanogenic' deposits. The Scuddles deposit (225km east of Geraldton) is located within metamorphosed volcanics of an Archaean greenstone belt.
- The sulphides, which yield most of the copper, lead and zinc produced throughout the world, generally occupy the deeper parts of lodes that have not been exposed to weathering. Near the surface, they are altered by oxidation and other chemical actions to the carbonates, sulphates and oxides. These secondary minerals may form rich ore in the upper parts of many deposits. Owing to their characteristic green or blue colour, secondary copper minerals are easily seen where present. Some deposits are completely eroded away and may be recycled by natural processes into new deposits.
- Partially eroded deposits such as those at Broken Hill and Mt Isa were easily discovered due to the ore minerals recognised at the surface. Exposed deposits are becoming harder to find and exploration now investigates beneath the surface for future deposits. This is a more costly and difficult way to find orebodies but has been successful in locating the Scuddles mine, 140 metres below the surface.
- Western Australia's important base metal resources are the copper-zinc deposit at Scuddles (Golden Grove), the Nifty copper and Telfer gold-copper deposits in the Canning Basin and Cadjebut (Lennard Shelf) in the Kimberley.
- Western Australia's base metal deposits are contained within Proterozoic rocks (approximately 1,400 million years ago) at Nifty and Telfer, Archaean rocks (approximately 3,000 million years ago) at Scuddles and late Palarozoic rocks (approximately 350-400 million years ago) at Cadjebut.
- In deposits mined today, lead is extracted as a co-product of zinc and copper. More than half of the lead consumed today comes from recycling, rather than mining.

c 7000 BC

Discovery, mining and first use of copper for simple tools. First metal used by humans.

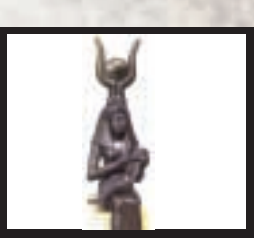


4000 - 3500 BC

First annealing and working of copper metallurgy begins. Copper first smelted at Timna in Israel.

3000 - 2500 BC

Copper first alloyed with other metals, starting the Bronze Age in southern Europe. Zinc ores were used for making brass (zinc-copper alloy) in Mesopotamia, centuries before zinc was recognised as a distinct element.



1000 BC

Use of bronze diminished with the onset of the Iron Age, though copper continued to be used for its other properties.

100 BC

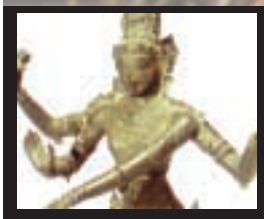
Brass (25% Zn, 75% Cu) was used extensively in Ancient Rome and China.

500 - 900 AD

Brass-making technology in Europe all but lost during the Dark Ages.

MINING

- Ancient copper and lead mines were of small scale and used shallow pits and shafts dug by hand to extract the oxide and carbonate ores for crushing and smelting. Base metal mining in Western Australia is on a much larger scale, highly mechanised and uses open cut, underground shaft and decline methods.
- Open cut projects are best suited to weathered and near-surface primary deposits. Low grade deposits of 0.5-1.5% metal content can be mined effectively this way. The soft weathered rock is broken up using explosives and front-end-loaders. The ore is then loaded onto dump trucks and delivered to the mill for crushing and processing.
- Underground mining uses open stope methods to clear large blocks of ore up to 45 metres high. A stope is a tunnel coming off the major shaft or decline that is part of the orebody. After each section is drilled and blasted, specially designed front-end loaders haul the ore to primary underground crushers. The coarsely crushed ore is then transported to the surface by skips using a shaft or by dump trucks using a decline and delivered to the mill for further processing.
- When mining in a stope is finished, waste rock and tailings produced by processing are then mixed with cement and pumped back in, filling the cavity and providing structural support for further stoping nearby.
- At the completion of mining, all remaining stopes are filled, the shaft is sealed, the open cut pit is filled in or converted to an artificial lake and surrounding waste dumps are covered with topsoil and rehabilitated with local native plants.



1200 AD

Metallic zinc was processed in India by reducing calamine (smithsonite, $ZnCO_3$) and organic substances with wood. Around 1500 AD, large-scale zinc production undertaken in India and China.

1746

Zinc was rediscovered in Europe by Marggraf who showed it could be obtained by reducing calamine with charcoal.

1850's

Copper first discovered and mined in Western Australia along with lead at Northampton and Nabawa until late 1880's.

1883

Charles Rasp discovered the rich, large Broken Hill lead-zinc-silver deposit in New South Wales, which is still being mined today.

1900 - 1920

Copper was produced from oxide ores in the Ravensthorpe, Whim Creek and Leonora areas. At Broken Hill in 1912, the first worldwide commercially viable method of extraction of zinc minerals from the ore was perfected.

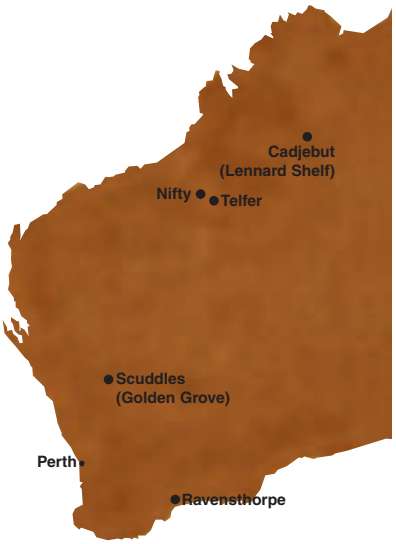
1923

The rich lodes at Mt Isa were discovered in Queensland and developed despite the remote location and harsh environment.

PROCESSING

ZINC & LEAD

- At the surface, the ore is subjected to additional crushing and fine grinding in large rotating tumblers containing various sized steel balls called a 'ball mill'. The finely ground ore is then concentrated through flotation processes and gravity methods. At the Cadjebut mine, a flotation cell called a 'flash cell' has been included between the coarse and fine grinding ball mills that removes up to 78% of the free lead from the pulp.
- Ground ore, water and special chemicals are mixed and constantly agitated in banks of flotation cells. Air is blown through the mixture in each cell and the fine lead and zinc sulphide particles stick to the bubbles which rise to form a froth on the surface of the flotation cell. The tailings sink to the bottom of the cell and are removed. The froth is skimmed off and the resulting zinc sulphide concentrate is dried. This process upgrades the ore, which may contain only 3% lead and 8% zinc, to concentrates of more than 76% lead and 60% zinc. More than 95% of the zinc in the ore can be recovered using flotation methods.
- Lead and zinc concentrates are then transported to the nearest port facility and shipped to a refinery or smelter within Australia or overseas for further processing. Over three quarters of Australia's lead concentrates and less than half the zinc concentrates are processed domestically.



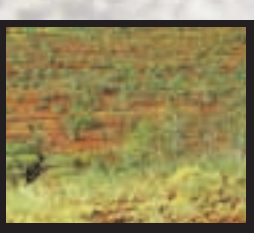
- *Major copper, lead & zinc deposits in W.A.*

COPPER

- Most copper ore is processed to produce a concentrate at or near the mine. This is either transported to a refinery or processed further on site.
- Copper-bearing minerals are concentrated by the flotation process, which separates the grains of ore mineral from the waste material, or gangue. Depending on the type of copper-bearing minerals in the ore and the treatment processes used, the concentrate can contain between 25% and 57% Cu. The concentrate is then processed in a smelter.
- Alternatively, high quality copper is produced from mined ore by a three-stage method. The crushed ore is subjected to heap leaching, solvent extraction and electrowinning processes.
- Processing copper sulphide ores begins with successive stages of crushing in ball mills to a particle size less than 0.3mm. The crushed ore is then mixed with an acrylamide polymer and water to form pellets. These pellets are stacked into the 'leach pads'.
- Leach pads are large lined ponds with outlet pipes at the base. The ore is irrigated, using sprinklers and drippers, with a solution of sulphuric acid. The acid seeps through the crushed ore and leaches the copper from its mineral host. The copper bearing solution known as 'pregnant liquor' is drained and pumped to the solvent extraction plant where the copper is extracted and the acid recycled to the leaching process.
- At the solvent extraction plant copper is removed from the solvent, cleaned in a flotation cell and a series of filters, and pumped as a near-pure solution to a tank for 'electrowinning'. The copper solution acts as an electrolyte within cells containing stainless steel cathodes and lead-alloy anodes. When current is added, copper metal is deposited on the cathodes whilst oxygen and acid is produced at the anodes.
- After about seven days, the copper plates (now cathodes) are stripped from the steel cathodes and collected in three tonne bundles. These are shipped from the nearest port largely to Australian manufacturers for domestic use. The copper cathodes produced by electrowinning contain 99.99% copper that is suitable for electrical uses.
- Various methods of smelting can be used to convert the concentrates to copper metal. One method is to melt them with fluxes in a smelter furnace to produce copper matte, which is a mixture mainly of iron and copper sulphides usually containing 50% to 70% Cu. The molten matte is poured into a converter, which contains more fluxes, and converted into blister copper, which is about 99% pure. The blister copper is further refined in an anode furnace and finally electrolytically refined to pure cathode copper.

1975
The copper-uranium-gold deposit was discovered at Olympic Dam in South Australia.

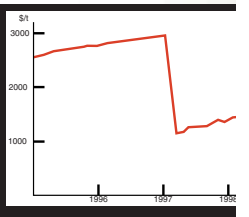
1979
Scuddles (Golden Grove) copper-lead-zinc deposit was discovered.



1983
The Nifty copper deposit was discovered.

1990
The largest base metal operation developed in Western Australia, the Scuddles copper/zinc project, began production.

1993
Production of copper from the Nifty deposit near Telfer began.



1996
Sumitomo's manipulation of copper prices reaches record high of A$4,380/t before collapsing to A$2,730/t in a week, causing disruption of the copper industry worldwide.

COPPER FACTS

The chemical symbol **Cu** and name **copper** is from the Latin cuprum, a corruption of 'aes Cypruim', meaning 'metal from Cyprus', one of the earliest and most important sources of copper in the Mediterranean.

Its beauty makes it highly desirable for making ornaments and jewellery due to copper's **red colour** and **bright metallic lustre**.

Copper is an excellent **conductor of electricity**. Half of the world's copper production goes into electrical applications.

Copper is very **ductile** and can be drawn into thin wires – ideal for electrical cables.

Copper is very **malleable** and can be beaten into thin sheets without fracturing.

A good **heat conductor**, copper is used for thin-walled copper tubing in air conditioning and refrigeration units, motor vehicle radiators and home heating systems.

Copper's **corrosion resistance** and ease with which it can be joined make it suitable for plumbing fittings and water reticulation systems, automotive fuel lines, hydraulic systems and equipment used in and near the sea.

Copper **alloys** are very important, as many are harder, stronger, and tougher than their individual components. Alloys with tin (bronze) and zinc (brass) are still in common use today. Copper is also used in coins in most countries.

Copper **compounds** have a variety of important uses. Copper oxide (CuO) is used as a fungicide and dye pigment. Copper sulphate ($CuSO_4$) is used to kill harmful algae for water purification and as a trace element in fertilisers. The blue-green colour of treated timber is the result of copper naphthanate and copper-chrome-arsenate which have been introduced under pressure to help protect the wood from termites.

Copper is an essential element in the growth and survival of most animals and plants.

LEAD FACTS

The chemical symbol for lead is **Pb** from the Latin name 'plumbum', denoting water conductors or spouts, hence the origin of 'plumber'. However, the name **lead** we use today is of Anglo-Saxon origin.

Lead, like zinc, is a **bluish-white** metal of **bright lustre**.

It is very **resistant to corrosion**. Lead pipes bearing the insignia of Roman emperors, used as drains from baths, are still in service. Red lead (Pb_3O_4) is used as an anticorrosion paint on steel.

The metal is **very dense** at 11.34 g/cm^3. Lead is effective as a sound and vibration absorber and is used as a radiation shield around X-ray equipment and nuclear reactors.

Care must be taken when handling lead as it is a **cumulative poison**. Environmental concern with lead poisoning has resulted in a national program to eliminate the lead tetraethylene in petrol.

Lead exists in **two oxidation states** +2 and +4 in the solid state, however, only the +2 form is soluble.

It's abundance, price and electrical conductivity (though average) make lead ideal as a **method of power storage** in the form of lead-acid batteries. Today, most lead is used in batteries for motor vehicles and communications.

Lead's softness, **malleability** and **ease of smelting** accounted for its early use in pipes and lead sheeting for construction purposes, and current use for electrical cable sheathing.

Lead **alloys** include solder, ammunition and various anti-friction metals.

Lead **compounds** such as lead oxide PbO are used in producing high quality crystal, achromatic lenses (grey or single colour lenses), TV and computer screens and pottery glazes.

Lead is the ultimate **product of atomic decay** of the heavier elements such as uranium and thorium, and mainly exists in four main isotopes; Pb^{208}, Pb^{207}, Pb^{206} and Pb^{204}.

Lead is **easy to recycle** and about a third of worldwide lead production is recovered from scrap.

ZINC FACTS

Zinc comes from the German word 'Zink' which is a corruption of the Greek word 'Zinn' or 'Tin' with which zinc was long confused.

Zinc is a **bluish-white**, **lustrous** metal that has never been found naturally in its pure form.

The pure metal is **brittle** at ordinary temperatures, but becomes **malleable** by heating to 100-150°C.

A **fair electrical conductor** in its pure form, zinc can be alloyed to improve its electrical properties. Zinc-bromide and nickel-zinc power cells are amongst the new generation of batteries.

The metal can form numerous **alloys** with other metals. Brass, nickel silver, commercial bronze, spring brass, soft solder and aluminium solder are some of the more important alloys.

Zinc is **resistant to corrosion** under normal weather conditions and is ideal as a protective coating (galvanising) on steel beams, sheet steel and vehicle panels in the automotive industry. Worldwide, 50% of zinc produced is used for galvanising.

Zinc **compounds** are vital to modern civilisation. Zinc Oxide (ZnO) is a unique and very useful material, and is widely used in the manufacture of paints, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, textiles and electrical equipment.

It has **unusual thermal and optical properties**. Zinc sulphide (ZnS) is used in making luminous dials, X-ray and TV screens and fluorescent lights.

Zinc is an **essential element** in the growth of humans, animals and plants.

COPPER, LEAD & ZINC STATISTICS

Quantity and Value of Copper produced in Western Australia
2003 - 59,098 tonnes valued at $140,285,105
2002 - 66,761 tonnes valued at $148,593,748

Royalty Receipts - Copper
2003 - $4,804,046
2002 - $4,994,097

Principal Copper Producers in Western Australia
NEWMONT AUSTRALIA Golden Grove.
ADITYA BIRLA GROUP Nifty.

Quantity and Value of Lead produced in Western Australia
2003 - 56,491 tonnes valued at $24,621,925
2002 - 70,397 tonnes valued at $44,902,919

Royalty Receipts - Lead
2003 - $1,618,765
2002 - $1,699,051

Quantity and Value of Zinc produced in Western Australia
2003 - 175,125 tonnes valued at $137,237,186
2002 - 218,803 tonnes valued at $173,064,117

Royalty Receipts - Zinc
2003 - $8,036,022
2002 - $8,710,570

Principal Lead - Zinc Producers in Western Australia
NEWMONT AUSTRALIA Golden Grove.
WESTERN METALS LTD Lennard Shelf.

Employment
In 2003 the base metals industry directly employed 1,100 people.

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

MORE INFORMATION

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