MINERAL SANDS

TiO_2

$FeTiO_2$

$ZrSiO_4$

The Chamber of Minerals & Energy
Western Australia

FORMATION a

Ilmenite rock sample

- The minerals in mineral sands originally occur in trace amounts (generally less than 0.1%) in igneous rocks such as granite, pegmatite and basalt. Highly metamorphosed rocks (rocks changed by pressure and time) provide the best source of mineral sands.
- Between 60 and 200 million years (Cenozoic - Mesozoic Eras) wind and water from ancient rivers and seas leached the minerals from the parent rock. As mineral sands are washed down to the sea they may accumulate as deposits in river channels or along coastal shorelines. This has occurred in Western Australia, east of the Darling Fault and within the Leeuwin-Naturaliste Complex where rocks have been weathered, liberating mineral sands - ilmenite, zircon, rutile, monazite, garnet and kyanite, plus light minerals (quartz and feldspar).
- As waves wash back on the beach, some of the lighter (less dense) sand is carried back into the sea, leaving the heavier (more dense) minerals behind. Since the Pleistocene Era, rises in sea level have allowed these sandy sediments to be reworked in a beach or shoreline environment. Heavy minerals have been concentrated into beach and dune deposits, with clays taken offshore and light minerals being removed along the beach.
- After formation, the sea level fell and the concentrations of mineral sands were protected from further erosion. The result is that, today, economic deposits occur at varying elevations up to 95 metres above the present sea level. Some deposits have been located up to 35km inland.

MINING

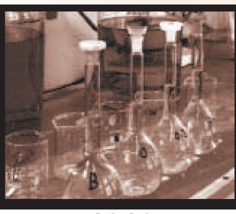
- During exploration, drilling on a grid pattern defines the presence or absence of a mineral deposit. If minerals are found to be present further drilling is then carried out to determine the extent of the deposit. Metallurgical test work is carried out on small amounts of ore to determine the most suitable type of equipment to separate the heavy minerals efficiently. Samples are assayed (tested) for moisture, clay, heavy minerals and sand content. As well, bulk samples are taken from unused drill samples and detailed mineralogical investigations are carried out.
- Before mining begins various detailed studies are undertaken. These include flora and fauna surveys, indigenous heritage surveys, hydrological studies and extensive community consultation. Environmental Management Plans are drawn up and once permission to mine has been granted by the government's mining and environment authorities, companies can begin work on establishing the mine.
- The first stage of the mining process is to remove the topsoil and stockpile it to rehabilitate the site after mining has been completed.
- There are three main mining methods;
  1. **Suction dredging** - A dredge lifts the ore from the bottom of an artificial pond, created over low grade deposits to allow rapid movement of large amounts of sand, through a large suction pipe which carries it to a separating plant. The dredge continues to slowly advance across the pond while the clean sand tailings are spread behind the pond where they will be revegetated at a later date.
  2. **Open cut mining** - Higher grade deposits containing moderately hard material or layers are mined using scrapers and bulldozers. The scrapers mine the ore from the top of the face to the bottom, as well as progressively mining across the whole face. This ensures that the ore being mined is a constant blend on a day to day basis. The scraper carries the ore to a screening plant where the ore is broken down into grains no larger than 2mm. The screened ore then proceeds through an intricate series of spirals to remove tailings and excess clay fines. The concentrate is stockpiled for separation and treatment.
  3. **Hydraulic mining** - With this technique the ore body is washed down using a water cannon. The ore is then pumped as a slurry to a wet concentrator which separates the valuable minerals from the waste material.

1791

William Gregor, a Cornish amateur chemist, examined sand from his local river and discovered the reactions which were to form the basis of the production of virtually all TiO_2 up to about 1960.

1795

The German chemist M.H. Klaproth independently discovered the same oxide in a sample of ore now known to be rutile, and named the element titanium after the Titans from Greek mythology.



1910

M.A. Hunter (USA) reduced $TiCl_4$ with sodium to obtain pure titanium. Subsequently the titanium dioxide process developed.

1934

Mineral sands were first mined in Australia at Byron Bay, New South Wales.

1949

Production in Cheynes Bay and economic deposit at Koombana Bay pegged. By the late1940s, mining had extended as rutile was being used in electrodes for radios in World War II.

1956

Production of mineral sands begins in Western Australia at Koombana Bay, followed by five other deposits in the Capel area over the next ten years.

nd LOCATION

- There are significant variations in the heavy mineral composition of an ore body. This occurs because weathering of the deposit by circulating ground waters concentrates some of the minerals at the surface and some at the base. Generally, the minerals in the top 3-5 metres have a high titanium dioxide (TiO_2) content, and a concentrate of zircon and monazite at the base of the deposit.
- The typical mineral composition is: ilmenite 80%, zircon 10%, leucoxene 5%, rutile 1%, monazite 0.5%, others 3.5%.
- Western Australia's major titanium mineral deposits are distributed between Geraldton, 260 km north of Perth, and the south coast, and are located at the present coastline or as relic deposits up to 35km inland.
- Mineral sands deposits occur along the coast of eastern Australia from central New South Wales to Cape York in Queensland. Large, ancient beach deposits are found as far inland as Horsham in Victoria and south-western NSW.

Major mineral sand mining and resource areas in WA.

PROCESSING

- The ore is put through a screening plant which breaks it down into individual grains. The heavy mineral grains are 0.05 to 0.3mm in size, material greater than 2mm is dumped back in the mining area.
- The heavy mineral concentrates are sent to a dry separation plant, and the individual minerals are separated using their different magnetic and electrical properties at various elevated temperatures. Separation equipment includes high tension rolls (electrical), high intensity magnets and electrostatic plate separators. Using electrostatic separation techniques the conductors (rutile and ilmenite) are separated from the non-conductors (zircon and monazite). Magnetic separation is used to separate the magnetic minerals (ilmenite and monazite) from the non-magnetic minerals (rutile and zircon).
- Ilmenite, the major mineral in Western Australian deposits, is increased in value by upgrading secondary ilmenite (58% TiO_2) to synthetic rutile (>90% TiO_2). This is done in plants at Capel, Geraldton and Muchea in WA using the two stage **Becher Process** which was developed by a joint industry and government initiative in Western Australia in the early 1960's.
- In the Becher Process secondary ilmenite, coal and sulphur are fed into a rotary kiln where the mixture is heated to a temperature in excess of 1 200˚C. This removes oxygen from the ore and produces metallic iron within the ilmenite. Ilmenite grains are converted to porous synthetic rutile grains with metallic iron and other impurity inclusions. Secondly, the iron is drawn out as hydrated iron oxide from the synthetic rutile grains and a mild acid treatment is used to dissolve the impurities and any residual iron. The synthetic rutile grains are washed, filtered, dried and transported to white-pigment manufacturing plants in Australia or exported for further processing.
- At Kwinana and Kemerton in WA, plants using the newer chlorination process produce white pigment by heating a mixture of synthetic rutile, coke and chlorine to form gaseous titanium tetrachloride ($TiCl_4$). The titanium tetrachloride is condensed to a liquid and most of the impurities separate as solids. It is then reheated to a gas and mixed with hot oxygen to form very fine crystalline rutile (raw white pigment). The displaced chlorine gas is recycled to the start of the process. The properties of the raw pigment produced from both pigment processes are enhanced for different uses by coating the crystals with white hydrous oxides of silica, alumina, titania or zirconia.

1963
A plant to produce titanium dioxide pigments from ilmenite by the sulphate process was established at Australind with Government assistance.

1968
The first plant began production of 'synthetic rutile' using the Becher process which was developed in Western Australia in 1963.

1970
Discovery of the major Eneabba deposit, followed by the Jurien deposit in 1971. Production from the Eneabba deposit commences in 1974.

1985
Jangardup deposit discovered in the south western corner of the State.

1989
Economic and environmental problems led to new investment in a replacement chloride process plant which began production at Kemerton.

2003
"Joshua Brook" housing estate was established on Iluka Resources' successfully rehabilitated mineral sands site, mined from 1986-1997. The first block of land sold in March 2003.

MINERAL SANDS STATISTICS

Value of Mineral Sands Mined in Western Australia

2003 – $753,765,923
2002 – $862,388,957

Royalty Receipts

2003 – $26,371,597
2002 – $25,665,693

Employment

In 2003 the heavy mineral sands industry directly employed 2,224 people.

Principal Mineral Sands Producers in Western Australia

CABLE SANDS (WA) PTY LTD
Jangardup, Sandalwood, Yarloop.

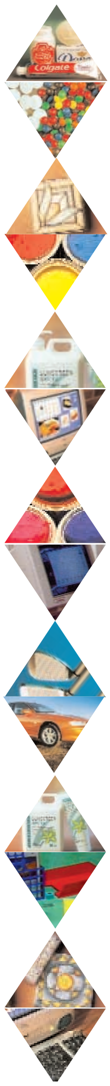
DORAL MINERAL SANDS
Dardanup.

ILUKA RESOURCES LTD
Capel, Eneabba.

TIWEST JOINT VENTURE
Cooljarloo.

GMA GARNET PTY LTD
Port Gregory (Garnet Sands).

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



MINERAL SANDS FACTS

One of the whitest substances on earth, titanium dioxide (TiO_2) gives colours a richness unmatched by any other pigment available today. Paint, paper and plastics all use TiO_2, so do sunscreens, cosmetics and food colouring. Rutile and ilmenite are the major raw materials for the world's paints and dyes.

The unique **opaque and reflective** properties of TiO_2 pigments have excellent brightness and high opacity for good hiding power (e.g. in paint for covering undercoats). Completely safe for human use, TiO_2 has replaced lead carbonate pigments in paints.

Titanium metal is used in high-technology aerospace design. Primarily used for airframe parts, space-craft and guided missile components, titanium is extremely useful due to its **strength-to-weight ratio**.

As a **non-reactive** metal, titanium is used extensively in making artificial joints and pacemakers in modern surgery, it won't corrode or react with other material. Zircon is the major source of zirconium, a **corrosion-resistant** metal that is used in nuclear reactors and chemical processing equipment.

Ilmenite and zircon are used in the steel industry for furnace linings and foundry moulds due to the mineral's ability to withstand **extreme temperatures**. Zircon has a melting point of over 2 500˚C. Zircon is used in its purest form to make nuclear fuel containers.

Research and development continues into the use of zirconium ceramics to improve diesel engines and in the metal extrusion industry where heat resistance and strength are required.

Ilmenite and zircon are used in the form of small beads as **abrasives**, such as sand-blasting abrasive.

Television colour and screen luminescence are dependent upon the production and separation of rare earth minerals from monazite. Rare earth elements are used in high-strength permanent magnets, catalysts, ceramics and colour television tubes.

Australia is the world's largest producer of **zircon** with WA accounting for 86% of national production.

MORE INFORMATION

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