Heavy Minerals

Mineral sands contain suites of minerals with high specific gravity known as ‘heavy minerals’. They include economically important minerals rich in titanium, zirconium and rare earths.

Formation and Location

Mineral sand deposits are formed from the erosion and weathering of pre-existing igneous rocks such as granite, pegmatite and basalt. Over 60 to 200 million years the combinations of wind and water from ancient rivers and seas have leached the minerals from their past rocks and concentrated them into beach and dune deposits. The result is that, today, mineral sand deposits can occur at varying levels above the present sea level. Some deposits have been located far inland from the present coastline such as Horsham in Victoria. Generally, the minerals in the top 3-5 metres have a high titanium dioxide (TiO\textsubscript{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%.

- Rutile (TiO\textsubscript{2}) is a red to black, naturally occurring titanium dioxide with a theoretical TiO\textsubscript{2} content of 100%, but impurities such as Fe\textsubscript{2}O\textsubscript{3} and Cr\textsubscript{2}O\textsubscript{3} reduce this to 93–95%.
- Ilmenite (FeTiO\textsubscript{3}) is black and opaque when fresh, but has typically undergone some weathering and iron removal, so TiO\textsubscript{2} contents are between 45 and 65%.
- Leucoxene is the name given to highly altered ilmenite. Grains are brown or grey with a waxy lustre and TiO\textsubscript{2} content of 68%.
- Zircon (ZrSiO\textsubscript{4}), a colourless to off-white mineral, is the world’s major source of zirconium products.

Mineral Sands Exploration & Techniques

Geologists select areas for exploration by researching an area’s geology, topography, soil types and geological history. Areas are drilled with a widely spaced grid to identify any occurrence and concentration of minerals. If the results are promising, samples are taken from a more closely spaced grid.

When a favourable deposit has been identified, the main exploration method is drilling. Usually small, four wheel drive mounted reverse circulation (RC) drilling rigs are used. The RC drilling method – where air or water is forced down an annular tube and cuttings are returned up the central tube – produces a clean uncontaminated sample at the surface. These are bagged at 1 or 1.5 metre intervals and, if heavy mineral is present, sent to a laboratory for analysis. Samples are wet sieved and the amount of heavy minerals, clay and sand determined.

During drilling, attention is paid to recording the presence of ground water and rock as these can substantially reduce the profitability of a potentially economic deposit. After each hole is drilled it is filled in or plugged using cuttings to prevent injury to livestock or native animals. If drill samples contain significant heavy minerals, further analysis determines the proportions of valuable minerals and their suitability for commercial use.

# Once a Mining Work Authorisation has been obtained, mining can begin

Mineral Sands Mining

Mineral sands are mined by surface mining methods including open cut mining, suction dredging and hydraulic mining.

The first stage of the mining process is to remove all timber and topsoil from the mine site. The topsoil is stockpiled for later rehabilitation of 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.

**Processing**

Various methods which include magnetic, gravity and electrostatic separation as well as chemical processes, are then used to separate the sands into individual mineral species.

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).

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. Plants using the newer chlorination process produce white pigment by heating a mixture of synthetic rutile, coke and chlorine to form gaseous titanium tetrachloride (TiCl4). 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.

**Uses**

The minerals extracted from mineral sands are used in a diverse range of products from toothpaste, confectionery, TV screens, aircraft parts, ceramics, paint pigments, catalysts and abrasives to nuclear fuel containers, guided missile components and high strength magnets.

**References:**

- The Chamber of Minerals Energy Western Australia
- SA Department for Manufacturing, Innovation, Trade, Resources and Energy
- Iluka Resources