



Industry Related Mineral Resources and the Value Addition Process

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A mineral resource can be defined as a natural resource obtained from the earth. So far about 4000 types of minerals have been discovered in the earth’s crust. These are composed mainly of the elements oxygen, silicon, aluminium, iron, sodium, calcium and magnesium. While about 97% of the volume of the earth’s crust is composed of these minerals the balance belongs to the group of native metal minerals (example gold, silver, platinum, chromium and copper).

If any mineral deposit can be mined to obtain a commercial profit then it is considered a mineral resource. If a mineral deposit discovered a few decades ago can be mined economically and profitably it is considered as a current mineral resource.

Mineral deposit

If a particular mineral is concentrated in a location of a higher concentration than that should be present in the earth’s crust then it is considered as a

Table 1: The concentration of metals in the earth’s crust and the concentration that should be present in a mineral deposit reference

Metal	Concentration in the earth’s crust %	Concentration multiple required	Value that should be present for mining
Al	8.6	4	32.8%
Fe	5.6	9	50.0%
Ti	0.86	50	-
Cr	0.0096	5000	-
Zn	0.007	700	5%
Cu	0.0055	180	1%
Ag	8 (ppb)	1000	-
Pt	5 (ppb)	1000	5(ppm)
Au	2 (ppb)	1250	5(ppm)
U	0.00016	1000	-
Ni	0.075	130	1%

mineral deposit. Table 1 gives the richness of metals in the earth’s crust and the minimum number of times at which the concentration of the metal should be present in the mineral deposit.

Value addition for minerals and its importance

The mineral obtained by mining is referred to as a raw material. The physical changes such as reducing the size, milling and concentrating brought about without altering the chemical

nature is referred to as upgrading the minerals finished products.

The price of the basic mineral could be increased by subjecting it to a value addition process. For example when quartz in the form of pieces is converted to quartz powder by milling its selling price increases by about three times.

Concentrating the mineral sand increases its purity and accordingly the price. The process used in this instance is

Industry Related Mineral Resources and the Value Addition Process

different to the value addition process employed for quartz.

It is possible to gain many advantages by value addition to minerals. Some of them are as follows:

It is possible to export the value added product at a higher price than the raw material; Development of technological knowledge in the country; ability to manufacture finished products using an extremely small quantity of raw material with modern technologies such as nano-technology; use of minerals without wastage and in an optimal manner; Creation of a competitive market and by increasing the demand for finished products; Creation of new industries thereby generating more employment avenues.

New industries related to mineral resource

The mineral resources in Sri Lanka may be categorised into the following groups.

Mineral sand

- i. Ilmenite sand
- ii. Rutile sand
- iii. Zircon sand
- iv. Monosite sand
- v. Garnet sand

Fertilizer material

- i. Phosphate
- ii. Dolomite

Raw materials for ceramic industry

- i. Quartz

- ii. Feldspar
- iii. Ball clay
- iv. Kaolin/China clay
- v. Calcite

Building material

- i. Rock aggregates
- ii. Limestone
- iii. Dimension stone (ornamental)
- iv. Corals and shells
- v. River sand

Export and other materials

- i. Graphite
- ii. Mica
- iii. Silica (Glass sand)
- iv. Salt
- v. Gems

Mineral related industries and minerals exports make a very large contribution to the Gross National Product of Sri Lanka. Gems, graphite, quartz, mica, phosphate, mineral sand, feldspar and clay are the main ones, most of which are exported as raw materials.

In Sri Lanka some of the mineral resources are used in local industries after mining, while other minerals are used in industries.

Quartz

- i. Vein quartz
- ii. Silica sand
- iii. Quartzite
- iv. Gem quality quartz

Vein quartz

This is formed by the solidification of the

hydrothermal liquid that comes up from within the earth. It is used for:

- i. Very pure, colourless quartz crustal optics
- ii. Circuits of all types of electronic equipment
- iii. Solar cells
- iv. High technology industries such as fiber optics

This is due to its resistance to chemical substances, hardness, low specific gravity and low magnetic and electrical properties.

Sri Lanka presently produces quartz of the size 0.1-10 mm (grit) and quartz powder of size less than 50 μ m. Quality control, concentrating silica in raw material, reduction of impurities to a minimum level, use of machinery for grinding and milling are employed for this value addition.

Use of vein quartz for very high tech industries

This does not take place in Sri Lanka, the primary reason being the very high unit cost of electricity and therefore presently not profitable. With



Industry Related Mineral Resources and the Value Addition Process

alternative energy sources, then it would be possible to manufacture products with High Technological value (Figure 1).

The fused quartz (shown in Figure 1) is the basic constituent in making products with high tech equipment.

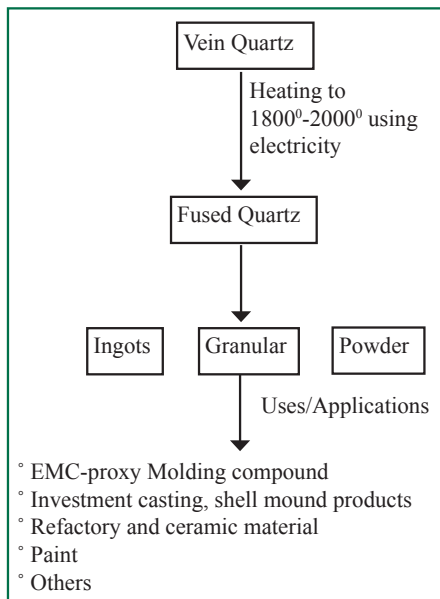


Figure 1 Value addition to vein quartz

Silica Sand

Used entirely for manufacturing products within Sri Lanka. Silica sand is used mainly in the manufacture of glass and glassware. The Si O₂ content in silica sand exceeds 98% while the remainder has fine grained heavy minerals such as ilmenite, and magnetite.

Quartzite

This is used in the manufacturing processes only within the country.

- i. Used after milling as an alternative medium for sand
- ii. Milled quartzite is mixed

with soil to reduce the alkalinity of soil

- iii. Large sized quartzite (lumps) are used in furnaces to retain the temperature

To obtain the material for (i) and (ii) mentioned above crushers can be used.

Gem quality quartz

Water clear fracture free gem quality quartz is used in the production of crest gems by cutting and polishing. Also (ii) amethyst, (iii) rose quartz, and (iv) yellow quartz – citrine, all of which can be used as gem minerals by cutting and polishing. In addition, (v) rose quartz is used in the manufacture of garden lamps and ornamental lamps in homes, (vi) candle holders and (vii) lucky charms (as spherical objects).

Mica

The Mica groups of minerals include 37 types of minerals. The common types among these are;

- i. Minscovite [KAl₂ (AlSi₃ O₁₀ (OH)₂] Aluminium mica
- ii. Phlogopite [KMg₃ (AlSi₃ O₁₀ (OH)₂] Magnesium mica
- iii. Biotite [K (Mg,Fe)₃ (AlSi₃ O₁₀ (OH)₂] Iron rich mica
- iv. Lepidolite [K (Li,Al)₂₋₃ (AlSi₃ O₁₀ (OH)₂] Lithium mica

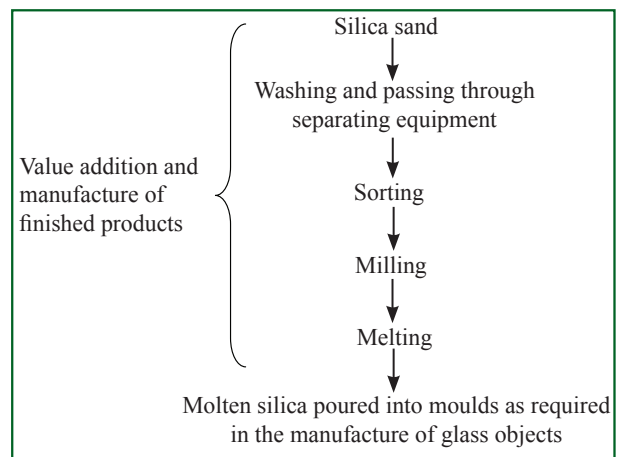


Figure 2 Value addition to Silica Sand

Presently Sri Lanka has not instituted the processes for making finished products using mica, which is now exported as scrap mica according to the buyers specifications.

Mica that is very much weathered can be used in the manufacture of K-containing fertilizer. Such research has been carried out in Sri Lanka.

The following are being manufactured using mica in countries with advanced technologies.

- i. Mica gasket
- ii. High temperature mica sheet
- iii. Mica heater
- iv. Mica tape
- v. Mica capacitors
- vi. Mica powder

Graphite

The main factor for producing value added products from mica is the availability of technologically competent and well trained personnel.

Industry Related Mineral Resources and the Value Addition Process

Graphite is used in industries associated with the use of high tech equipment, because of its non resistance to high temperature, chemical stability, lubricant property, and high electrical and heat conductivity.

Mica of a range of sizes from mica lumps to micrometer sized powder, and containing varying percentages of carbon, is presently being exported from Sri Lanka after upgrading their quality. During this upgrading process the graphite in middling graphite (low grade unprocessed graphite) and the very small quantities of graphite in rocks is extracted by grinding. Floating is used to extract the fine powder.

Sri Lanka also manufactures articles such as batteries, pencils and crucibles which do not require high percentage of carbon.

Phosphate

Out of the industries in Sri Lanka, fertilizer manufacture can be considered as the main one. Because the P in the phosphate deposit has a low solubility it has been used for the long term crops with good results. Also it is possible to get good results for short term crops grown in acidic soils. This is because the solubility of this phosphate is somewhat high in an acidic medium.

Eppawala Rock Phosphate Fertilizer (ERP)

Fertilizer with about 28% P_2O_5

is manufactured by grinding the phosphate rock - that is the mineral Apatite and its matrix. It is not possible to obtain this percentage by grinding the phosphate only. The required level can be obtained by mixing in the Apatite mineral after grinding.

High grade Eppawala Rock Phosphate (HERP)

This fertilizer is manufactured by grinding the Apatite mineral only. Here the P_2O_5 content in 40%.

In technologically developed countries the following fertilizer types are also manufactured.

- i. Super phosphate
- ii. Nitro phosphate
- iii. Ammonia phosphate
- iv. Calcium magnesium phosphate
- v. Phosphate tock powder
- vi. Rhenaniya phosphate

Sri Lanka has not manufactured these fertilizer types due to the high cost of production.

In addition Apatite can be used in the manufacture of medicinal substances, animal foods, ceramic industry, artificial bones, detergents, paints and rubber industry.

Feldspar

In Sri Lanka at present feldspar

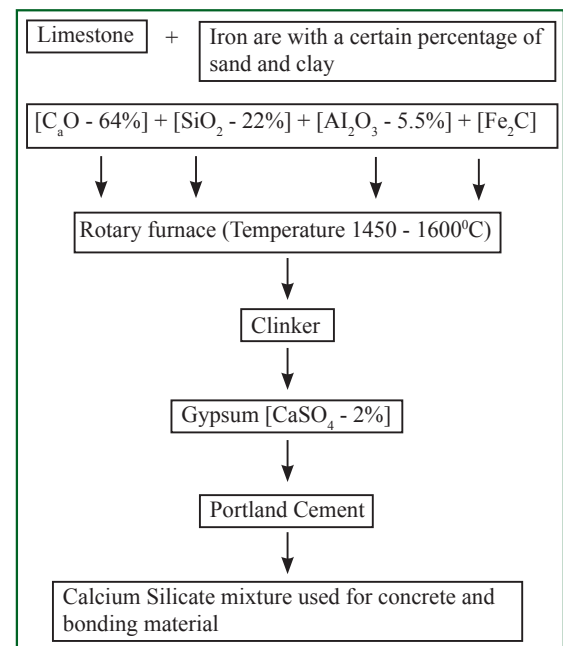


Figure 3 Process of cement manufacture

is used in glass, ceramic, paint, plastic, rubber, welding, electrode and tile industries. Feldspar is used in varied industries due to its properties.

- In the glass industry it is important to reduce the high melting points of other substances (the melting point of quartz is 1600°C. By using feldspar it is possible to lower this temperature.
- Because it does not have a definite melting point, it turns into a liquid at a wide range of temperatures. It provides a medium to mix the clay and the quartz well in the ceramic industry. It also softens the raw material and acts as a bonding agent.
- It is used in the rubber and paint industries because it does not react with chemicals and does not undergo changes under acidic or alkaline conditions.
- It is used in the production

Industry Related Mineral Resources and the Value Addition Process

of enamel because it has a composition similar to that of enamel cement. Thus the articles produced acquire a good finish.

In addition it is used in the manufacture of artificial teeth, toothpaste and welding equipment. Sri Lana has most of the industries mentioned here.

Limestone

- i. Miocene lime stone
- ii. Dolomitic lime stone/calcite
- iii. Corals and shells

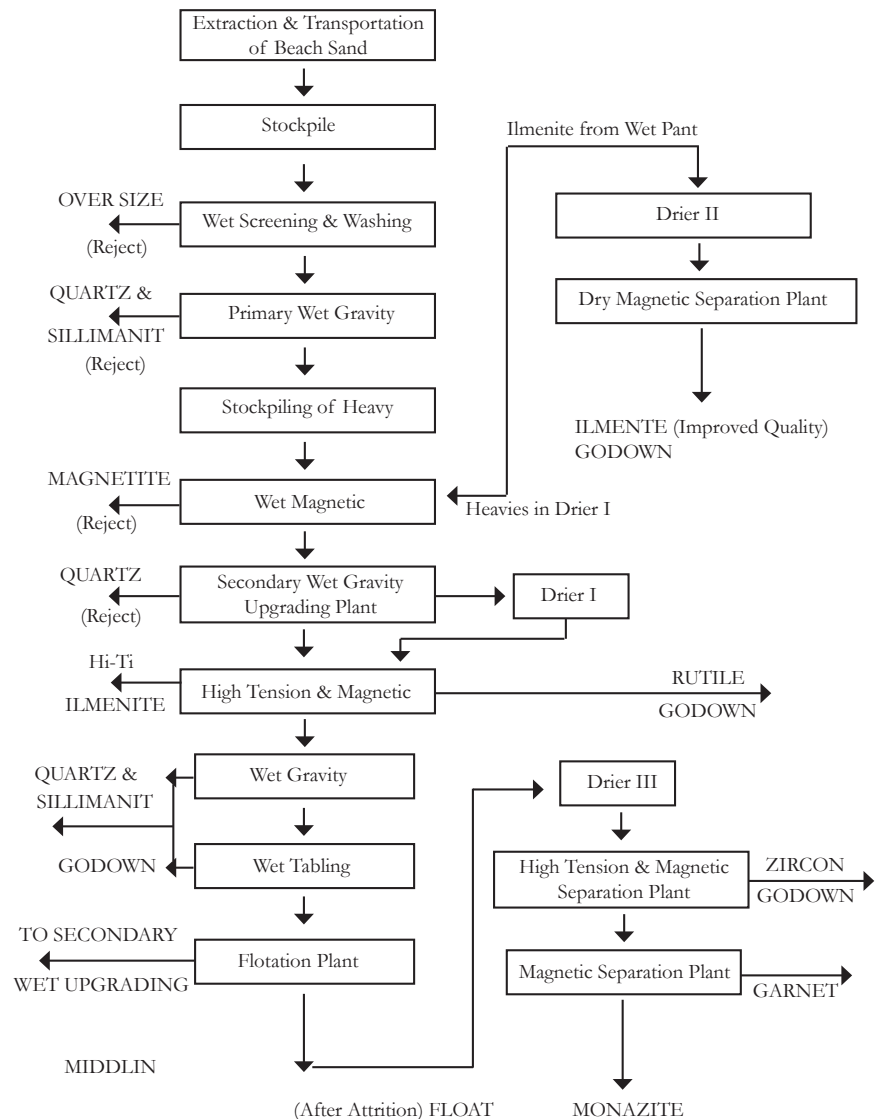
Miocene limestone is used as the main raw material in the cement industry. It is also used in iron extraction, ceramic industry, textile, glass, paper and rubber industries. Limestone in which the Magnesium content is 19% or more is Dolomite. This is used mainly for (i) the manufacture of fertilizer (ii) poultry feed (iii) for iron and steel industries (as a refractory agent) and (iv) for sculpturing of statues.

Calcite is present in crystalline limestone. It is used in (i) paper and (ii) ceramic industries. CaO is formed when water is added to limestone that is heated to a high temperature.

Shells and corals are also constituents used for producing lime. 100% CaO can be obtained from these after mining and burning in kilns.

Mineral sand

- i. Ilmenite sand
- ii. Rutile sand



Schematic flow chart proposed for the IRZ Plant - Pulmoddai

Figure 4 Mineral Sand Separation - Pulmoddai

- iii. Zircon sand
- iv. Monacite sand
- v. Garnet sand (Rababa)

Value addition process in Sri Lanka

Presently 'Lanka Mineral Sands – Pulmudai' which is a Sri Lankan company dealing with mineral sands carries out the separation of these sands based on their density and using processing equipment (the table for separation of mineral sands is

attached). Very small quantities of ilmenite, rutile and zircon are concentrated from monicite sand and exported.

Besides this, private companies also further improve the quality of the failings (discarded fraction) from the Pulmudai deposit using technologically advanced processing and separation equipment, and export the products.

Industry Related Mineral Resources and the Value Addition Process

Accordingly high foreign exchange is earned by exporting ilmenite, rutile and zircon sand after increasing the concentration and also after grinding to smaller sized particles.

In technologically developed countries the metal Titanium (Ti) is extracted from the minerals ilmenite and rutile. Due to its high strength, lightness, ability to withstand high temperatures and resistance to acids, it is used in the metal parts of airplanes and jets, war tanks, bone parts and propeller parts in ships. Further more Titanium is used in pigment, paint, varnish, plastic and paper industries. The concentrating process and the products manufactured in the technologically developed countries is given in diagram 6.

The production of rutile can be given as a value addition method for ilmenite. This is carried out in many countries. There are two ways of doing it.

- i. By using hydrochloric acid
- ii. By using sulphuric acid

According to the hydrochloric acid method about 55-65% ilmenite can be improved to artificial rutile of 56% TiO_2 .

Here the smaller sized iron oxide is completely separated from the larger sized artificial rutile.

Stages of the process

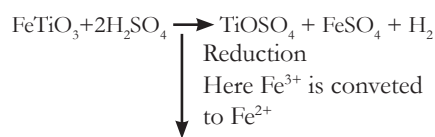
- i. Oxidation - Burning with air in a rotary furnace
- $$4 FeTiO_{3(s)} + O_{2(g)} \rightarrow 2Fe_2O_{3(s)} + 2TiO_{2(s)}$$

- ii. Reduction - Heating at a temperature of more than $1200^{\circ}C$ with Brookite, Coal and Sulphur in a rotary furnace.

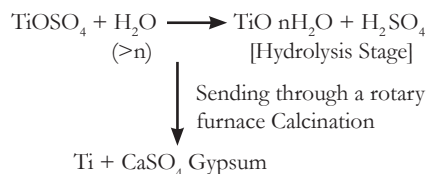


- iii. Exposure to air - Mix with ammonium chloride and air
- $$4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_{(s)} + 2Fe_2O_3$$

- iv. Reduction of acidity - It is possible to completely remove the remaining iron oxide by the addition of 0.5M hydrochloric acid.
- v. Sulphuric acid method - Dissolve the ilmenite sand well in concentrated sulphuric acid. Then the Titanium is converted to Titanyl sulphate and iron sulphate.



By further addition of water these can be removed as hydrates.



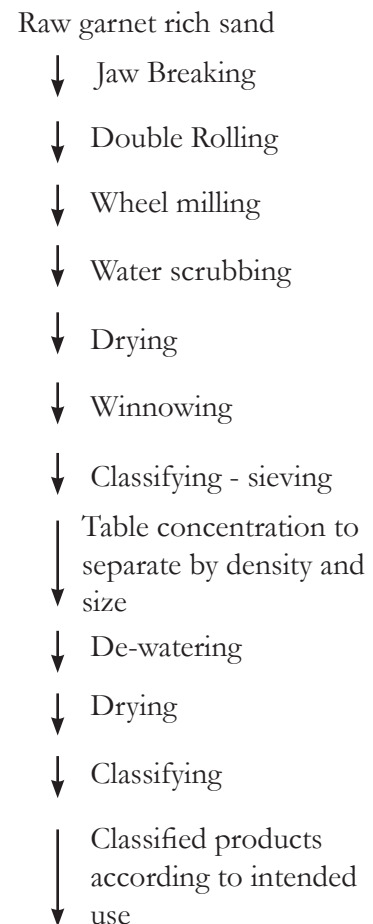
Because the value addition to the minerals ilmenite and rutile by heating, concentration and filtration involves very complex technology and initial high expenditure Sri Lanka does not have any value addition industries with mineral sands.

Garnet sand

The considerably large mineral garnet is used in making

jewellery associated with the gem industry. Also the fine garnet sand is used in many industries such as an abrasive agent for engraving work in the glass industry and for cutting iron.

Garnet sand is processed as shown below.



Industrial clay

There are different types of clay used in industry.

- i. Kaolin/China clay
- ii. Ball clay
- iii. Brick tile clay

Kaolin clay

This is used mostly in the manufacture of white coloured crockery items, sanitary items

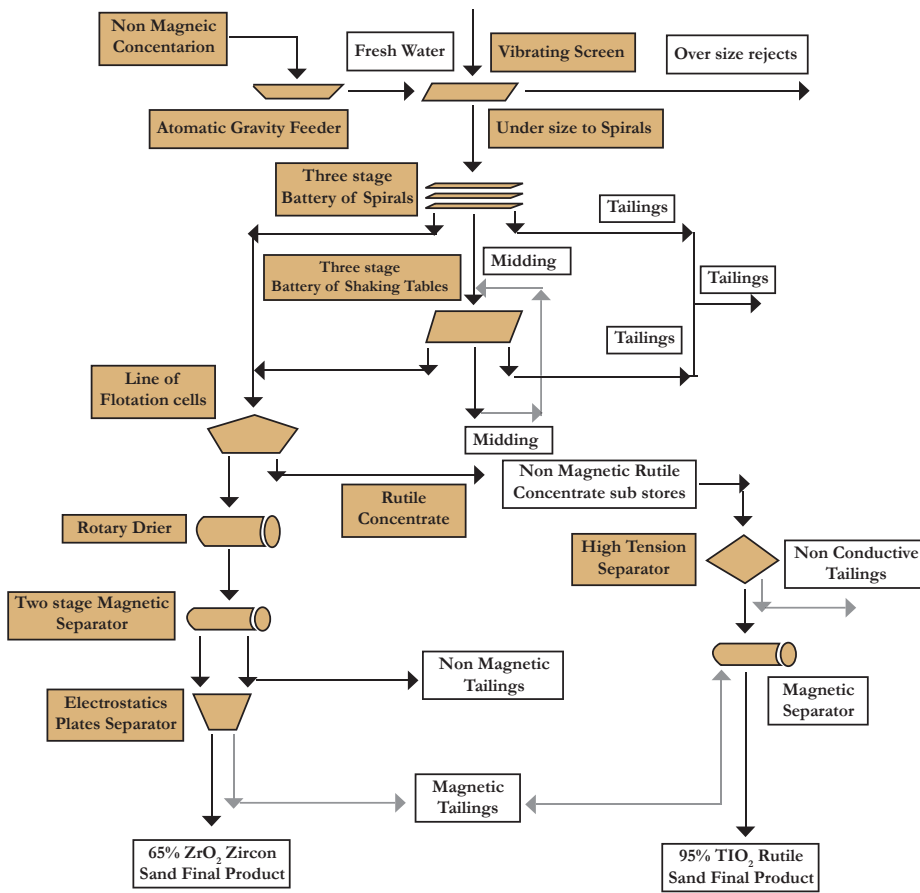


Figure 5 Schematic Flow Sheet Existing in Processing Plant of a Private Company

and ornamental items. Kaolin clay deposits are found in Mitiyagoda, Boralesgamuwa and Piliyandala areas. Smaller sized deposits are reported from Kalutara, Aluthgama and Benthota areas. This raw material is mainly used within the country for making finished products, and a situation has arisen where it is not possible to supply the demand. There is a clay purification plant at Mitiyagoda to improve the quality of mined clay.

- Super-grade clay should be of over 88% whiteness and is used in the porcelain industry.
- H-grade clay should be of

about 88-86% whiteness and is mostly used in the tile industry.

Ball clay

This is grey coloured clay. Large deposits are found in Dediawala in Kalutara area, while in areas such as Malabe, Aluthgama and Benthota smaller deposits are found. It is mainly used in the tile industry and is also used in the rubber, paint and paper industries.

When ball clay has about 2% content of quartz pieces, it is considered to be of very good quality. However, even if the content is 3-4% it is accepted as suitable for industry.

Roof-tile – Brick clay

Reddish-brown coloured clay mixed with sand and found associated with main rivers is called roof-tile- brick clay. Clay with a composition of about 25-30% sand is suitable for the brick making industry. Clay mixed with the required amount of water to obtain the correct consistency is cut in to shape using a mould and then dried. Subsequently, they are ‘burnt’ in a furnace to obtain stronger tiles and bricks.

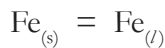
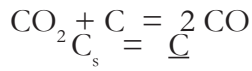
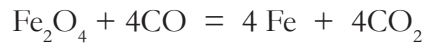
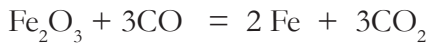
Iron/Iron ore deposits

Iron-ore deposits in Sri Lanka differ from one another based on how they were formed, percentage of iron present and the impurities in them. Steel products are made by value addition to the iron extracted from iron ore.

After mining, the iron ore is subjected to grinding, milling and selected quantitatively based on the percentage of iron present. Subsequently it is made into pigiron using various methods. For this the most commonly used method is to place it in a Blast Furnace, and pigiron with a concentration of 92-94% iron is separated out by a direct oxidation process. To manufacture steel, pigiron is mixed with metals such as Mn and Ni and then further oxidized using coal.

The reactions taking place during this process are as follows:

Industry Related Mineral Resources and the Value Addition Process



S = Solid stage

l = liquid stage

Rock and Dimension stone

About 9/10th of the rocks in Sri Lanka are igneous and sedimentary rocks which have been subjected to metamorphism. These are of a very high grade with respect to strength and quality.

Value added products in Sri Lanka

Rocks are used in the construction of buildings, highways and roadways. Rocks of sizes ranging from 6"x9" to 1/4" are produced and classified according to their use in the industry. Also the aggregate waste remaining during the grinding of the rock is mixed with cement and water to make cement bricks.

There are very large rocky ridges in Sri Lanka of varying colours and strength. Even though the investment required for the dimension stone industry is very high, the technological process is not very complex as for other minerals. In the dimension stone industry Sri Lanka manufactures for export blocks of size 6'x8'x12', mineral slabs cut to the sizes of 6"x8", and thickness about 1.5 cm with area of 2.1 square feet. It

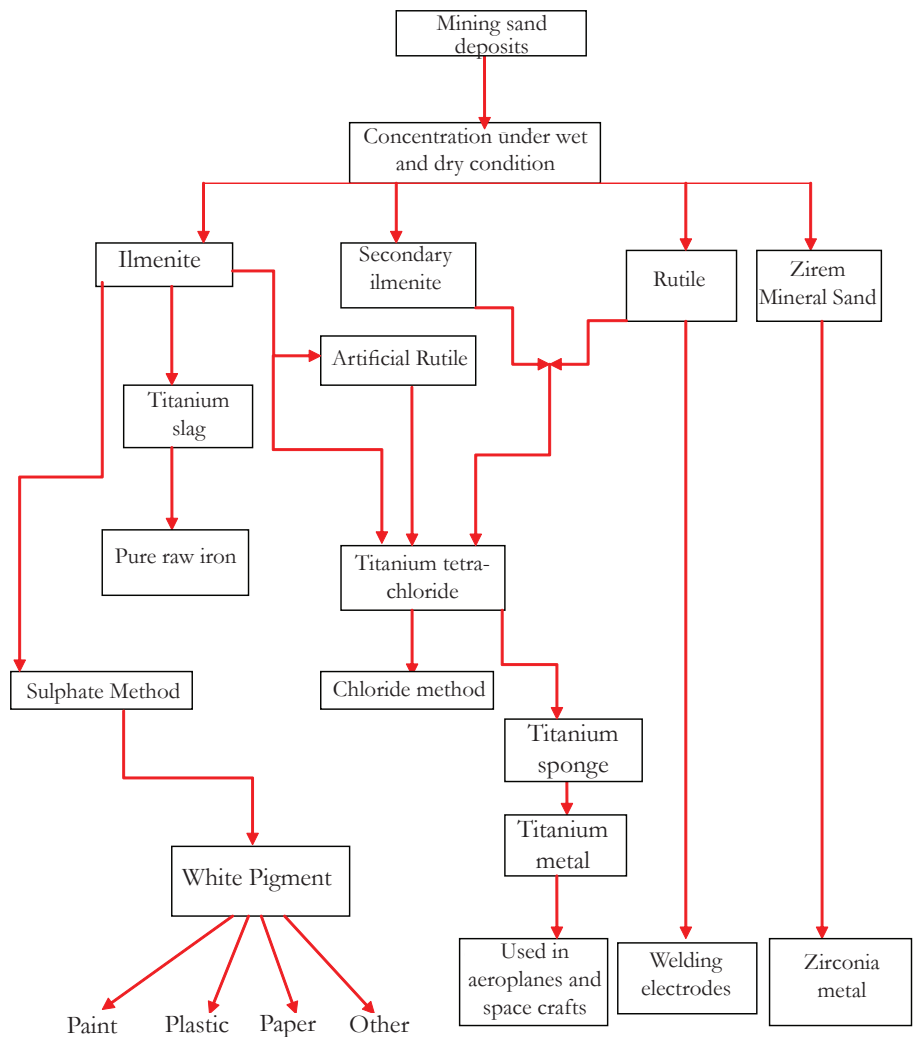


Figure 6 Value addition process of mineral sand

is possible to earn very high foreign exchange by exporting these and this is 10 to 20 times more than the earnings when these are sold within the country. A specialized technology and equipment is necessary for this. For this industry the colour of the rocks, strength, absence of fractures and weak zones, unweathered (fresh) rocks and a very low level of radioactive elements are the properties that should characterize the rocks for this industry.

In addition ornamental carvings and sculpturing of statues is carried out using these rocks.

The production of paving stone slabs is a new industry. Even if the rock is weathered for a certain extent it can be used for this industry. There is a demand for this in the export market.

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