Editorial

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Traditions in Mineral Resource based Industries

The theme of this Vidurava edition is on the mineral resources of Sri Lanka. It is indeed astonishing that a small island nation like Sri Lanka should be endowed with such a vast array of extractable basic mineral constituents and elements from naturally occurring composite deposits.

Although Sri Lanka may lack the financial strength and technological sophistication to transform some at least of the primary raw materials into secondary and tertiary high value elemental products, the country has not been spared of being in the limelight for millennia as a nation blessed with natural mineral resources. It is hoped that before long, with new tools such as nanotechnology at our disposal, Sri Lanka will be able to break into the competitive international markets with advanced and superior quality value added products from our mineral resources.

One of our contributing authors to this edition has declared that, 'nowhere in the world are so many gem varieties as occurring within such a small area of land'. This is no surprise, since no historical or philosophical rendering on Sri Lanka had ever missed a reference to this unique feature of our island nation since the dawn of the Christian era.

It is significant to note that Mohammedan pilgrims arriving from West Asian countries between the 4th and 12th Centuries AD had noticed the free and widespread surface occurrence of precious stones in the vicinity of the 'Mountain of Serendib' (Adam's Peak), which they faithfully believed to be the crystallized tears of their patriarch Adam, and of Eve, who had been conceived to have wept for centuries while taking the last lingering look at the abodes of paradise.

Let us now look back at a well known traditional mineral resource based industry that had its beginnings around the 4th Century BC, and which according to Dr. Ananda Coomaraswamy, ended unceremoniously in the first decade of the 20th Century. It is the iron smelting industry, where archaeological as well as scientific evidence had shown the existence of at least three ancient technological development phases, of which one located in the upper peneplains of Samanalawewa had demonstrated the feasibility of employing low cost energy from wind speeds, to generate the required smelting temperatures.

Currently there is no precise information of the existence of an industry extracting iron from crude iron ore. Apparently the high unit cost of energy is said to be the main reason for its absence. However, we must not forget that the ancient iron masters of Samanalawewa had perfected the art of low cost iron production with wind speeds, and had exported tons and tons of refined iron and high carbon steel ("Monsoon Steel") to West Asia from around 7th to 12th Century AD. These great iron technologists may have taken decades or even centuries to perfect an art that had been elusive and not found to be feasible elsewhere in the world.

The Gem Industry in Sri Lanka and its Environmental Impacts

Prof. M. Rupasinghe

Gems can be identified as a resource which occupies a foremost position among the natural resources found in Sri Lanka. By the term gem mining is meant the process of extracting this natural resource. It is considered that the gemming industry in Sri Lanka has a history of about 3000 years. However, this traditional industry may have a beginning running into a longer period.

When compared with other countries in the world engaged in the gemming industry, Sri Lanka appears to be a country employing dominantly the traditional mining technologies, though at present mechanical and semi-technological methods are used in addition to traditional technology for mining. These mining methods range from digging deep mines and adrift to shallow open mining and river bed mining.

In Sri Lanka traditional gem mining is mainly found in Balangoda, Ratnapura, Opanayake, Deniyaya, Rakwana, Elahera and Matale areas.

Although the mining industry is economically very profitable, it is associated with a considerable number of environmentally adverse effects. The environmental problems that arise can be briefly stated as follows:

- Damage to vegetational cover, plantations and paddy fields
- Damage to land and geomorphology
- Damage to man-made structures
- Impacts on human health
- Damage to streams and river banks
- Sedimentation and water pollution
- Damage to fauna

Damage to natural vegetation cover, plantations Paddy fields and soil erosion

The natural vegetation cover is directly affected due to complete uprooting of the vegetation associated with the mining operation in the gem gravel layer in areas anticipated to contain gems.

For the purpose of 'Construction' or reinforcement of the walls of mines in the inhabited areas, arecanut trees are used while during illicit gem

mining in the forested areas , various rare local trees are being utilized instead. Balangoda, Kalthota, Baduludena, the Sri Pada Forest Reserve and areas associated with the Sinharaja Man and the Biosphere reserve are some of the examples. For purposes of placing dredges between the horizontal and vertical squares (enclosures) in the mines in the inhabited areas a plant named Kekilla – *Gleichenia linearis* – which is an introduced species is used. However, in the forested areas valuable indigenous species are used as substitutes for this purpose. Both these practices have detrimental effects on biodiversity. Another adverse environmental effect of the mining industry is acute soil erosion during the rainy season resulting from the removal of the vegetational cover.

In forested areas illicit gemming is usually carried out in areas associated with the catchment areas of rivers. Therefore, such situations have adverse effects on the sustainability of water resources.

Gems are found as deposits chiefly in low lands. They are brought down to these areas from mountainous areas through the water that flows in streams. These gem deposits get separate as individual gems due to the disintegration of rocks. As a consequence paddy fields in the lowland areas in Ratnapura and the Southern Province have become gem bearing lands, and are subjected to mining. As a result of gem mining direct damage is caused to the paddy fields and other crops in those areas. Also the infertile soil thrown out of the mines mixes with the fertile top soil leading to changes in the soil characteristics, and the quality of the soil is diminished.

Damage to land and geomorphology

Large pits and many huge mountains of soil that have been dug out are a common sight in gem mining areas. Polwatte area in Matale can be shown as a very good example for this type of geomorphological damage.

The mountains of soil comprising infertile sub soil dug up during mining are physically unstable. They are subjected to erosion by rain water causing damage to the surrounding vegetation. The Raththota area in Matale is a good example for this type of situation. Mining and the heaps of soil dug out have completely changed the original geomorphology of the area.

Damage to man made structures

Digging of adits under roads, houses, irrigation channels, culverts etc. cause damage to this kind of constructions and buildings. A large number of examples for this kind of damage can be seen in a number of places including Ratnapura, Elahera, Matale and where other gem mining activities are carried out. Since the digging of adits can lead to sinking of the land surface, greater care must be taken when gem mining is carried out near such constructions.

Impacts on human health

Because rehabilitation (refilling of the pits) after the mining is not carried out in the proper manner, carriers of diseases such as mosquitoes increase in numbers. The spread of malaria due t o the increase in numbers of mosquitoes in the abandoned water filled mines is a major health problem associated with this industry. The water that gets collected in these pits is responsible for the foul smell in the environment.

The risk of mammals, reptiles and also human beings falling into these unfilled pits is another problem.

Damage to streams and river banks

The destruction of vegetation along the river banks, and the resultant collapse of river banks into the water, is caused by the digging of alluvial deposits for gems. An example of this type of dangerous destruction could be seen at Amban-Ganga and Elahera areas. Illicit gemming may have caused this situation in the Elahera area, where aggravation due to the use of 'Caterpillar' machines and dredges for digging the river bed can be seen.

Another adverse effect of mining in the river bed is the damage caused to the unique biodiversity of organisms living in the fresh water river bed systems. Their habitats may be subjected to unsuitable changes due to changes in the environment, and thereby threatening the existence of certain sensitive species.

Sedimentation and water pollution

Gem mining in rivers cause disturbances of silt and erosion of river banks, which in turn release suspended solids in large quantities into the water.

Increase in suspended solids lead to an increase in turbidity of the water and a decrease in light penetration. Both these adversely affect the biodiversity of plants and animals. The decrease in light penetration leads to a decrease in photosynthesis and thereby inactivates the food relationships in rivers and streams. Similarly since most of the species of fish found in streams and rivers of Sri Lanka are adapted to live in clear water, when the concentration of floating particles increases their spiracles get blocked threatening their existence. Increase in the addition of soil particles to water by various ways due to gem mining has aggravated the already existing problem of siltation caused by clearing of forests, cultivation activities etc. This has also acutely reduced the carrying capacity of waterways and dams. In addition to the above mentioned effects water pollution is also a major environmental effect associated with gem mining; when the amount of silt increases the amount of potable water decreases. In addition, the lack of adequate sanitary facilities for the temporarily resident labourers in gemming areas also leads to the pollution of water.

Damage to fauna

Large scale addition of very fine clay particles to water increases the turbidity of the water, and this leads to less light penetration causing an environmental imbalance in the rivers and steams. The effect of this was discussed under adverse effects of sedimentation and water pollution.

Damage to environment due to gem mining

The present situation in Sri Lanka regarding the gem mining industry and environmental effects

National Gem and Jewellery Act Number 50 of 1993 has also identified the necessity of minimizing the environmental effects associated with the gem mining industry. No person is permitted to carry out gem mining without a license from the National Gem and Jewellery Authority. In addition no machinery other then water pumps are permitted to be used in gemming carried out in rivers and paddy fields.

According to the gazette notification 722/22 of 24 June 1993 of the National Environmental Act, an Environmental Impact Assessment report is required for mining within a distance of 60 meters from the bank of a public water way which exceeds a width of 25 meters.

The National Environmental Action Plan of 1998-2001 has also identified gem mines and the mining of river beds for gems as problems associated with gem industry. In addition recommendations such as the re-examination of the regulatory framework of mining and mineral sectors, and making provisions for the rehabilitation of mining pits, were included in the above action plan.

Recommendations to minimize environmental damage

Gem mining is economically important for Sri Lanka because it is a major source of foreign exchange, and is also a source of employment for the rural population. At the same time it is essential to take steps to minimize environmental damage due to such mining activities. In addition to the steps presently implemented, the following recommendations are also proposed.

- Setting up of a section within the Central Environmental Authority to provide advice regarding the environmental problems arising from gem mining, and through this section the provision of knowledge to gem miners on the latest mining technology, and how they can be carried out.
- Prohibition in the use of heavy machinery for gemming on land
- Allowing the process known as Ganga Aderma (River Dredging) using mammoties only after very careful consideration of the adverse environmental effects that may be caused
- Looking into the refilling of adits at the end of the gem mining activity. (If extra payments are necessary for such investigations, the Advisor Authority must increase the license fee to cover the additional expenses).
- The Advisory Authority should take the necessary steps to completely prohibit illicit mining
- If a license has not been obtained from the licensing authority steps must be taken to prohibit the digging of horizontal adits from the gem mine and the mined areas. If permission has been granted earlier steps must be taken to fill up the adits at the end of the mining activity.
- The Advisory Authority must take the necessary steps to provide the latest instructions/advice to those who plan to start gem mining as well as to those who are already engaged in the industry.

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Geology and Mineral Resources of Sri Lanka

Sarath Jayatileke

Earth crust consist of three types of rocks.

i. Igneous rocks
ii. Metamorphic rocks
iii. Sedimentary rocks

What is a rock:

Rock is a solid mass consisting of one or more minerals.

What is a mineral:

Mineral is a solid substance of natural, inorganic material with a defined crystal structure and chemical composition.

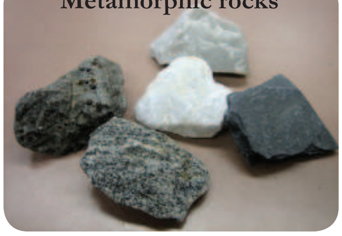
Igneous rocks:


Igneous rocks

These are formed by solidification of magma (lava) generated through volcanic activities. When lava solidification takes place on the surface, these rocks are called extrusive rocks. If lava solidified inside the earth's crust, then it is called intrusive rock.

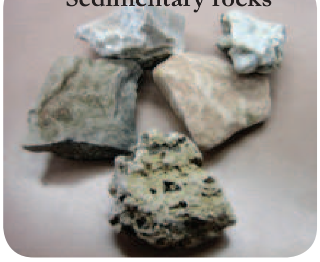
Metamorphic rocks:

When igneous rocks and sedimentary rocks are subjected to metamorphism, that is subjected to very high pressure and / or high temperature, the minerals present in these rocks are recrystalized or reacted in solid or semi solid state to form new minerals and forms of new type of rock. This newly formed rock is known as metamorphic rock.


Metamorphic rocks

Sedimentary rocks:

When igneous and metamorphic rocks exposed to various different weather conditions and other erosion activities (living organisms etc.,) , they break in to parts. These broken pieces will be transport by gravity, water, wind, glacial etc., and deposited and later covered with other materials like clay and other debris. These material will be compacted and cemented to form a hard solid mass called sedimentary rock.


Sedimentary rocks

In Sri Lanka 90% of the area is covered by Precambrian (over 600 million year old) metamorphic rocks. The other 10% which is in the Northern part of Sri Lanka consists of Miocene age (0–25 million years) lime stone. Few Jurassic age out crops are also available in this area. Most of these rocks are covered by recently formed clay laterite, red earth and soil deposits. The Precambrian metamorphic rocks are further classified into few more groups as given below in Figure 1,considering their age of formation, mineral combination, metarmorphosed conditions etc.

i. Highland / South Western complex :
This group of rocks consists of gneisses, schists, charnockite etc., which are

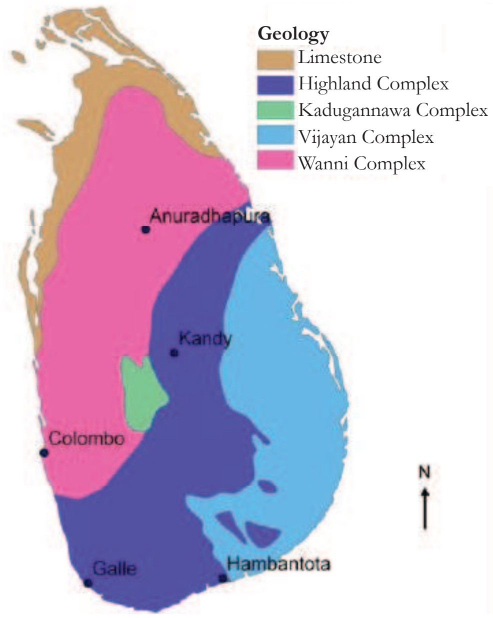


Figure 1 Geological formations of Sri Lanka

characterized by presence of garnet – sillimanite – quartz – feldspar – graphite etc., and crystalline limestone.

ii. Vijayan complex : This group of rocks are dominated by lower grade metamorphic gneisses of hornblende and biotite.

iii. Wanni complex : In this group of rocks the most common rock types are gneisses of hornblende and biotite, migmatitic and charnockite etc.

Mineral Resources of Sri Lanka

Figure 2 (back cover) shows the locations of mineral deposits of Sri Lanka. The minerals presently being exploited are briefly described below.

Gemstones:

Sri Lanka is famous for high quality blue sapphires and star sapphires. Various varieties of gemstones such as corundum (blue sapphire, ruby, yellow sapphire, pink sapphire, white sapphire, star sapphire, etc.,) spinel, garnet, Almandine , Grossular, Tourmaline (complex boro – silicate), Zircon, chrysoberyl (cat's eye), Beryl (Aquamarien) and quartz are available in Sri Lankan gem beds. Other than the above mentioned gem varieties, rare gem varieties like cordierite, andalusite, apatite, Kornerupine, Sinhalite, taaffeite and Ekanite are also occasionally found in Sri Lankan gem beds.

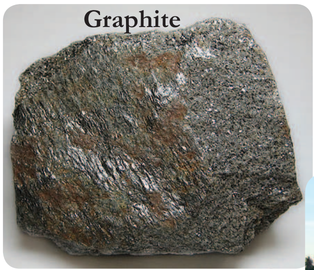
Gems are valuable because of scarcity (rare), high hardness, chemical resistance and its beauty. If the minerals of gem varieties do not exhibit luster, clarity etc., that is, if it is not beautiful they are not considered as gems. For example there are corundums without any luster and totally opaque, which are not considered as a gems. There are corundums showing milky colour and translucent or semi transparent material known as geuda. These geudas could be transformed to gem variety/ blue sapphire through a heat treatment processes. These heat treatment processes were initially developed by Thailand gem traders and now it is being practiced in Sri Lanka.

Gems are formed due to igneous activities as well as due to metamorphism. When the heavy minerals (Iron & Magnesium rich minerals are crystalized and separated, the remaining magma will become rich is volatile matter. When this volatile rich magma cool at a slow rate, gem varieties are formed (eg. in pegmatities). Gems are also formed during metamorphism, specially in contact metamorphism. Gems found in Sri Lankan gem beds are of secondary origin. That means, gems formed in igneous and metamorphic rocks get separated due to weathering of those rocks and transported by running water and deposited in low lying areas. In Sri Lanka, in addition to these sedimentary gem beds, gems are also found as in-situ deposits. That is gems are found in the weathered rock/soil. These are characterized by the original crystal shape, whereas the secondary deposits are rounded in shape due to wear and tear during transportation. Example for an in-situ deposit is the gem deposit recently found in Kataragama.

Other than the heat treatment for corundum, some other techniques are also used to enhance the colour of some other varieties of gems. One of them is X - ray/gamma treatment for Topaz to change/ enhance colour.

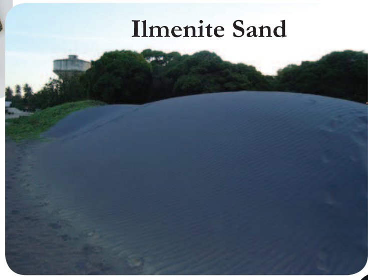
Graphite:

Sri Lankan graphite is very famous in the world for its purity (97 – 99 %) and high crystalinity. Chemically graphite is Carbon (C), and it is in a layer form, hence it is very soft. Because of its softness and layered structure it slips very easily. Because of this slippery nature it is used in making pencils and as a lubricating material. Graphite is a good electricity conducting material, and is used in electrical industry as carbon brushes in motors, electrodes, high temperature electrical elements under reduction condition, etc. It should be noted that the hardest material in the world is diamond and its chemical composition is also Carbon (C), but its crystal structure is cubic system. Diamond has not been reported from Sri Lankan soil/rocks.



Graphite

Graphite is commercially mined at Bogala , Rangala (both in Kegalle District) and Kahatagaha (Dodangaslanda in Kurunegala District). Bogala mine is over 400 meters deep and Kahatagaha mine is about 650 meters deep. The total production from these mines are exported without any value addition (raw graphite) other than grading (matching the C percent and particle size). Other than these three localities graphite is also available in the southwestern region of Sri Lanka, but currently there are no mining operations in this area. The processed graphite products including graphite nano particles and nano tubes, are very expensive. The latest product developed using graphite is graphene, which has a wide application in electronic industry. Presently raw graphite is exported at around US $ 1 per kg where as the price of graphene is over US $ 6,000 per kg.



Ilmenite Sand

Mineral Sand:

A well known mineral sand deposit in Sri Lanka is at Pulmoddai, north of Trincomalee. The major minerals in this deposit are ilmenite and rutile. Other associated minerals are zircon, monazite, garnet, sillimanite and few other heavy minerals. This is the only commercially exploited mineral sands deposit in Sri Lanka, although several other mineral sand deposits are available as beach mineral sand deposits. Some of them are along the beach north of Trincomalee (Nayaru & Nilaveli), Induruwa (Galle district) and along the Mannar beach (Kudremalai). Ilmanite is black in colour and raw rutile is of a dark honey colour. Therefore, all these ilmenite rich beach mineral sand deposits can be easily identified due to their unique black colour. The ilmanite content of the Pulmuddai deposit is around 70%, while Zircon is about 9% and rutile is 8%. These minerals are separated by physical separating techniques using spiral classifiers, magnetic separators, high voltage separators etc..

The important chemical element in ilmenite and rutile is Titanium. Titanium minerals are used to extract the Titanium metal and also to produce the titanium pigment. Titanium metal is strong, light weight, and can stand high temperatures. Therefore, it is used in the air craft industry and also in space travel. Titanium pigment, rutile, is extensively used in the paint industry to impart whiteness, opacity and brightness. It is also used in paper , rubber, plastic and other industries.

Mineral Sand

In addition to the above mentioned ilmanite rich beach mineral sand, garnet sand rich beach mineral sand deposits are available in the Southern coastal area (Dondara and Hambantota). These deposits are not

commercially extracted.
All these beach mineral sand deposits are formed by the depositing of heavy minerals brought to the beach by sea currents and waves. The lighter material, silica sand is washed back leaving the heavy mineral on the beach. All the heavy and light minerals are components of the inland's rocks. When the rocks are weathered, these minerals are separated, and the separated particles are washed away by running water through rivers and finally carried to the ocean, and then they are brought back to the beach by sea currents.

Apatite deposit:

Chemical composition of apatite is Calcium Phosphate with Florine, Chlorine, and hydroxide. Apatite is also called as rock phosphate. Rock phosphate is commercially used as a fertilizer to provide Phosphorous (P) to plants and P is needed for the physiological processes of plants. The rock phosphate deposit in Sri Lanka is at Eppawala in the Anuradhapura District. This deposit covers on area over 7.5 km2 and the estimated quantity is over 50 million tons. The P_2O_5 content of this apatite is around 35%, but its solubility is low to use as a phosphate supplement for short term crops like paddy. Powdered rock phosphate is used as a fertilizer for long term crops like Tea, Coconut, and Rubber etc. The solubility could be improved by mixing with sulphuric acid to convert phosphate in to supper phosphate. This reaction improves the solubility by about 20%. The solubility could be further improved by the action of phosphoric acid, and converting it to triple supper phosphate. The treatment of rock phosphate with these acids is not an environmental friendly process.

Apatite deposit

The Eppawala apatite deposit is presently being mined and ground to powders by Government owned Lanka Phosphate Ltd.

Dolomite, Calcite and Magnesite deposits:

These are known as crystalline lime stone and also as marble. Dolomite is a combination of Calcium Carbonate and magnesium carbonate and its magnesium content may go up to 22 percent. Calcite and magnesite are nearly pure calcium carbonate and magnesium carbonate respectively. The term dolomitic limestone is also used when MgO content is 10 to 18 percent. Generally crystalline limestone is white in colour, but other colours like ash, green, yellow etc., are also found as small pockets. Crystalline lime stone deposits are scattered throughout the Highland – South Western, Vijayan and Wanni complexes. Some of the well known localities for limestone deposits are Anuradhapura, Habarana, Matale, Kandy, Ratnapura, Balangoda, Badulla, Bibile, Welimada, Ambilipitiya, Hambantota, Kataragama, etc.

The dolomitic limestone is the most abundant type of material, while calcite is occasionally found as pockets within dolomite and dolomitic limestone. Well known occurrence of calcite deposits are in Balangoda and these are mined for calcite. Other calcite pockets found in other areas are too small. The only Magnesite deposit so far identified is in Randeniya (Wellawaya) which is also surrounded with dolomite. The quantity is estimated to be about 4,000 tons.

Dolomite is presently being mined and powdered for use as a ferlizer to provide Magnesium for plants. For this purpose MgO content should be higher than 18%. This powdered material is also used to stabilize the soil and to adjust the pH value of soil. Dolomatic limestone is mined to produce quick lime and slaked lime for the building industry. For this purpose dolomitic limestone with low MgO content is preferred. Pieces of Dolomitic limestone (4 – 7 mm size) are heated (burned) at around 900 – 950°C in a vertical kiln to produced quick lime. This burning process is a continuous process loading from the top as alternate layers (about half a meter thick) of limestone and undried logs. Product is unloaded from the bottom. This burnt lime is marketed as quick lime or as hydrated lime powder after adding water or as slaked lime, as a paste. This dolomite lime became important as a substitute for coral lime, since coral mining has been banned to protect coastal erosion.

Other than the above mentioned major uses, dolomitic limestone is also used as a minor raw material in ceramic and glass industry. Powders are also used in the rubber and paint industries as a filler material, and also to produce wall finishing materials. Sri Lankan crystalline lime stone cannot be cut into marble slabs due to its coarse crystalinity nature.

Calcite is softer than the other two varieties (calcite is 3 and other two are around 4 in the Moh's scale), and hence it could be ground easily. Therefore calcite powder is used as a filler in industries. Calcite is also used in other industries as a minor raw material, filler, soft abrasive materials, etc.

Limestone Deposits:

There are four main groups of limestone deposits available in Sri Lanka.

1. Crystalline limestone (Marble – Dolomite, Calcite etc.), which has been described above.
2. Sedimentary limestone deposits
3. Coral limestone deposits (inland and shallow sea waters)
4. Shell deposits

The entire Jaffna peninsula and northern coastal area from Puttalam (several kilometers into the country) is covered with Miocene age hard compacted sedimentary limestone. Calcium carbonate content varies widely from low values to over 95 percent. Sand is present as large particles of impurities. Most of the area of the deposit is covered with a thick over burden. The only limestone quarry in operation is at Aruwakkali about 20 km away from Puttalam. It is an open cast mine for the cement factory at Puttalam. The C_aCO_3 content of the limestone should be more than 75% for use in cement manufacturing (unless it is blended and matched). Presence of silica and clay is not a problem because limestone is mixed with clay (Alumino silicate) before fed into the rotary kiln to produce clinker. (Clinker is the output of kiln, which is ground and mixed with small amount (less than 5%) of gypsum to produce cement.

Coral limestone is found in many parts of the coastal line around the country. Well known coral beds are found along the southern coast, specially in Ambalangoda and Hikkaduwa. Inland coral deposits are also found in the southern area , which are covered by sand, silt and mud. Extraction of coral from the sea was banned to protect erosion, but there are no restrictions to mine inland coral, provided no environment damage is caused. Inland coral is used to produced MgO-free quick lime and hydrated lime.

A huge collection of sea shells is found in Hungama covering an area of about 3 km x 3 km to a depth of about 3 m from the surface. A lime processing plant was in operation under the Ceylon Ceramic Corporation during the 1970s and the 1980s in Hungama. These inland sea shells were also used to produce precipitated Calcium Carbonate, which was used as a raw material for tooth paste.

Vein Quartz Deposits:

Chemical composition of quartz is SiO2 and the name vein quartz is used for the quartz deposits in the form of a vein, which had originated due to igneous activities. Vein quartz deposits of high purity (over 98 percent Silica) are found in many parts of the country. Some of them are in Galaha (Kandy), Rattota, Balangoda, Pelmadulla, Embilipitiya, Ratnapura, etc. High purity quartz are important to produce fused quartz and Silicon, which are used in computer chips and other electronic devices. Other than that there is a demand for high purity silica powders of submicron size in various industries. Grinding of quartz is comparatively difficult because of high hardness (Moh's scale hardness is 7). In Sri Lanka vein quartz is mainly used in the ceramic industry as a major raw material.

Feldspar Deposits:


Feldspar

Feldspar is an alumino silicate of potassium, sodium and calcium, and occurs due to igneous activities as veins or dykes (as pegmatites). Feldspar deposits are found in many parts of Sri Lanka. Some of them are in Rattota, Namaloya, Koslanda, Balangoda etc. In Owella (Rattota) deposit feldspar occurs with other pegmatite minerals such as quartz, biotite (mica) and fluorite (calcium floride), as thick bands with clear boundaries. This deposit occurs up to more than 600 meters below the surface. Feldspar is one of the major raw material in ceramic and glass industries.

Mica:


Mica

Mica is a group of minerals of the hydrated alumino silicate of iron (Fe), magnesium (Mg), potassium (K), sodium (Na) etc. Mica could be easily identified by its unique flaky structure. The most common types of mica in Sri Lanka are phlogopite (Mg rich mica) and biotite (Fe rich mica). Muscovite (K rich mica) also occur in certain areas (Kabitigollawa). Some of the mica deposits are found in Matale, Talatu Oya, Badulla, Maskeliya, Haldumulla, Kabitigollawa, Balangoda etc. One of the underground mines is at Wariyapola, Matale for Phlogopite and muscovite was mined in Kabitigollawa.

Mica mining in Sri Lanka has been reported even prior to 1900. During the Second World War period the demand for mica increased. Presently the important commercial variety is muscovite, which is white or colourless. Phlogopite is also in demand if it is in large sheets. Mica is graded into sheets, scrap, flake and powders. Mixing and processing of mica has to be done with extra care, to avoid contact with eyes and also in inhaling. The flakiness nature of mica tends to adhere to eyes, lungs, etc, and is also difficult to remove.

Mica can withstand high temperatures, high di–electric strength, and is an electrical insulator. Because of these properties sheet mica is used in electrical and electronic industries. Mica powder is used as a filler in plastics, paints, some printing inks and papers. Ground mica is also used as a lubricant for special purposes, and also for heat and electrical insulating purposes.

Silica Sand:

Silica sand can be grouped in to three types, river sand, sea sand and industrial sand. River sand is a material derived from weathered rock and transported by running water. River sand, if not excavated, will be carried to sea and accumulated in shallow sea and beach. River sand is mainly used in building construction, specially for concrete, since it does not contain chloride and sulphate, which adversely affect (corrosion) reinforced steel in concrete. Due to the rapid growth of the construction industry, river sand was extracted extensively creating a shortage of river sand. Because of this reason it has become a necessity to use sea sand for construction. Now sea sand is pumped to form domes and allowed to wash away chloride and sulphate by rain water, till sand become good enough to use in building construction. Washed sea sand is characterized by the presence of high shell content.

White colour high purity (over 98 % SiO_2) Silica sand deposits are found in Marawila, Nattandiya and Madampe (in Chilaw District) and also in Ampara and Jaffna peninsula. Silica sand is extracted from Nattandiya and Madampe areas for use as a major raw material in glass and ceramic industries.

Iron ore:

There are few iron ore deposits discovered in Sri Lanka, but they are small deposits compared to the known world iron ore deposits. The Sri Lankan identified deposits are in two forms, that is hydrated iron oxide (limonite and gothite), which occur near the surface and oxide form (Magnetite).

The hydrated type of small iron ore deposits are scattered in Sabaragamuwa Province (Ratnapura, Rakwana, Balangoda, Kalawana etc.) and in the Southern Province (Ambalangoda, Akuressa, Deniyaya etc.). These deposits are in the form of small hillocks and as scattered boulders of about 2 – 4 meter width, but not extended in depth. The most important of these deposits are located at Dela, Naragolla, Opatha and Poranuwa in Ratnapura District and Wilpita in Galle District.

Three magnetite deposits have been identified in Sri Lanka. They are at Wilagedara, Panirendawa and Seruwila. The Wilagedara deposit is too small to be mined. The deposit at Panirendawa has been estimated to contain around 5.6 million tons of magnetite, but they are four separate blocks, and these occur underground about 25 – 170 meters below the surface. Therefore, excavation of this deposit is costly and not economical. The Seruwila deposit extends below to about 70 meters from the surface. The iron content is high, but considerable amount of copper (in the form of Chalcopyrite) is also associated in this magnetite ore. Therefore, the direct smelling process cannot be used to extract iron from this ore. In Sri Lanka there are no iron extraction industries from iron ore. There are few companies producing iron and steel from scrap iron. Iron smelling process consumes very high energy.

Clay:

Clay is not a primary mineral and it is a product of weathering of primary minerals. Chemically it is hydrated alumino silicate. Clays, characterized by fine grain become plastic when mixed with water. Clay deposits are basically grouped into two types.

i. Primary or residual or in–situ clay deposits : This type of deposits are formed due to weathering of primary rock minerals or due to action of hydrothermal solution on primary minerals mainly feldspar and mica. These deposits are characterized by large grain (particle) size compared to secondary clay deposits and also by the presence of other mineral particles like quartz, feldspar, mica, ilmanite etc.

ii. Secondary or sedimentary clay deposits : When rocks are weathered some of the rock forming minerals (eg. Feldspar, mica) gets converted to clays. These clays are carried away by air, water and glaciers (mass of ice) and get deposited in river banks, river mouths (delta) lakes, sea etc. to form sedimentary clay deposits, and these processes of transportation and sedimentation continue for a very long period. Clay of this type is characterized by fine grain (particle) size and contaminated with organic matter.

The main clay minerals present in clays are Kaolinite, Montmorillonite and micaceous clay minerals. Properties of these clay minerals differ from each other, hence characteristics of clay are governed by the percentage of these clay minerals in the deposit. Kaolinite is comparatively less plastic and of high refractoriness (stand for high temperatures of about 1600 oC). Montmorillonite is highly plastic and of less refractoriness. Hydrous mica clays give intermediate plasticity and refractoriness.

Clay is the main raw material in the ceramic industry. Two varieties of clays, that is Kaolin and Ball clay, are mixed to obtain the required properties.

Kaolin (also known as China clay) consist of mainly Kaolinite and deposits are formed by weathering of feldspar. This kind of raw clay has to be refined to remove other associated mineral particles (Silica, Ilmenite, etc.) before it is used in the ceramic industry. Well known Kaolin deposits in Sri Lanka are located at Boralasgamuwa and Metiyagoda. Boralasgamuwa deposit has already been extracted and exhausted, but there are few more deposits nearby but cannot be mined because the area is urbanized. Kaolin deposits are also available under the Nugegoda town, but they cannot be mined. A new Kaoline deposit has been found in Millaniya (Bandaragama) and extraction has already started. Kaoline is mainly used in the ceramic industry and also used in paint, rubber, paper and some other industries.

Ball clay deposits are a kind of sedimentary clay deposit characterized by very fine particles, high plasticity and is usually gray in colour but turns to white or cream colour on firing. Ball clay is added to the ceramic body mixture to improve the plasticity. There are ball clay deposits in flood plains of rivers in Kalutara area. A well know ball clay mine is at Dediyawala (Kalutara) which has been mining for the last forty years.

Alluvial clay deposits are formed by sedimentation of clays in river banks and lakes. These are characterized by the presence of high organic matter and impurities. Some of the alluvial deposits in the dry zone of Sri Lanka are characterized by comparatively higher amounts of montmorillonite. Alluvial clay deposits are wide spread in the country and are being mined in a small scale for brick, tile and pottery industries.

Rock (stone) deposits:

Rocks (stones) cut to slabs or into different shapes and sizes (dimension stone) are used in building industry with or without polishing. The commercial name for this is granite, and it is used as a floor tile or wall tile. Rocks are also used to produce monuments and also as paving blocks. Other than the above mentioned purposes, rocks are crushed in to pieces to be used as coarse aggregate for concrete and road construction. These types of quarries are wide spread through out the country.

Other than the above mentioned mineral deposits, there are few minerals deposits in small quantities, which are not sufficient to excavate economically. They are:

Wollastonite:

This is in fibrous form in veins of 2 to 7 centimeter width, in the calc gneisses in Ambalangoda and Galle areas. Wallastonite could be used as a fluxing material in the ceramic industry, and as a filler material in paint, rubber and paper industries.

Serpentine deposits:

Two serpentine deposits occur at Udawalawe and Rupha (Walapane). The Udawalawe deposit is dark green in colour and occur at several meters below ground. Rupha deposit is associated with marble, and is also called green marble, and is exposed to the surface.

Peat:

Peat is available in Muturajawela swamp, but cannot be used as a fuel due to high moisture content.

Rare Earth Elements (REE):

Rare earth elements are the elements from atomic numbers 57 to 71. In Sri Lanka some of these have been found in small quantities, but recently there is an interest to carry out a survey for these minerals by several foreign parties.

Monozite is one of the mineral resources that contain REE and it is found in mineral sand deposits (about 0.3 percent) in Sri Lanka. Monozite is also found in many places in Matara, Nuwaraeliya, Teldeniya, Balangoda, etc.

Thorianite and thorite have been reported from Bambarabotuwa (in Sabaragamuwa), in Galle District and in Balangoda.

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Industry Related Mineral Resources and the Value Addition Process

Deepani Weerakoon

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 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.

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%
Fc	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%

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 in 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 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 50µm. 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


Quartz

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.

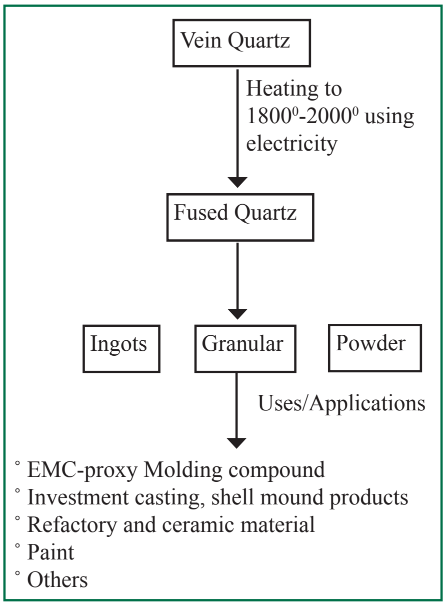


Figure 1 Value addition to vein quartz

Silica Sand

Used entirely for manufacturing products within Sri Lanka. Silica sand is used mainly in the manufacture of glass and glassware. The $Si\ O_2$ content in silica sand exceeds 98% while the remainder has fine grained heavy minerals such as ilminite, 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 [KAI_2 ($AISi_3$ O_{10} $(OH)_2$] Aluminium mica
ii. Phlogopite [KMg_3 ($AISi_3$ O_{10} $(OH)_2$] Magnesium mica
iii. Biotite [K $(Mg,Fe)_3$ ($AISi_3$ O_{10} $(OH)_2$] Iron rich mica
iv. Lepidolite [K $(Li.AI)_{2-3}$ ($AISi_3$ O_{10} $(OH)_2$] Lithium mica

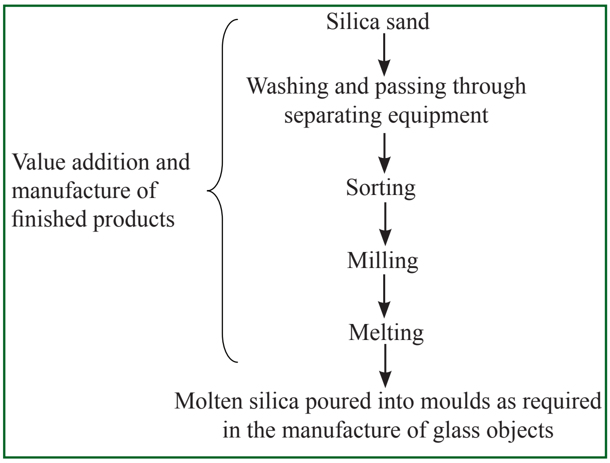


Figure 2 Value additon to Silica Sand

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.

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

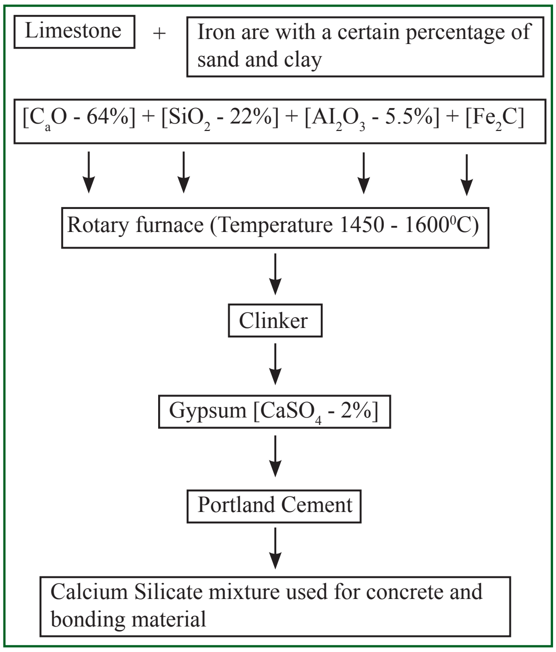


Figure 3 Process of cement manufacture

- In the glass industry it is important to reduce the high melting points of other substances (the melting point of quartz is 1600^{0}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

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

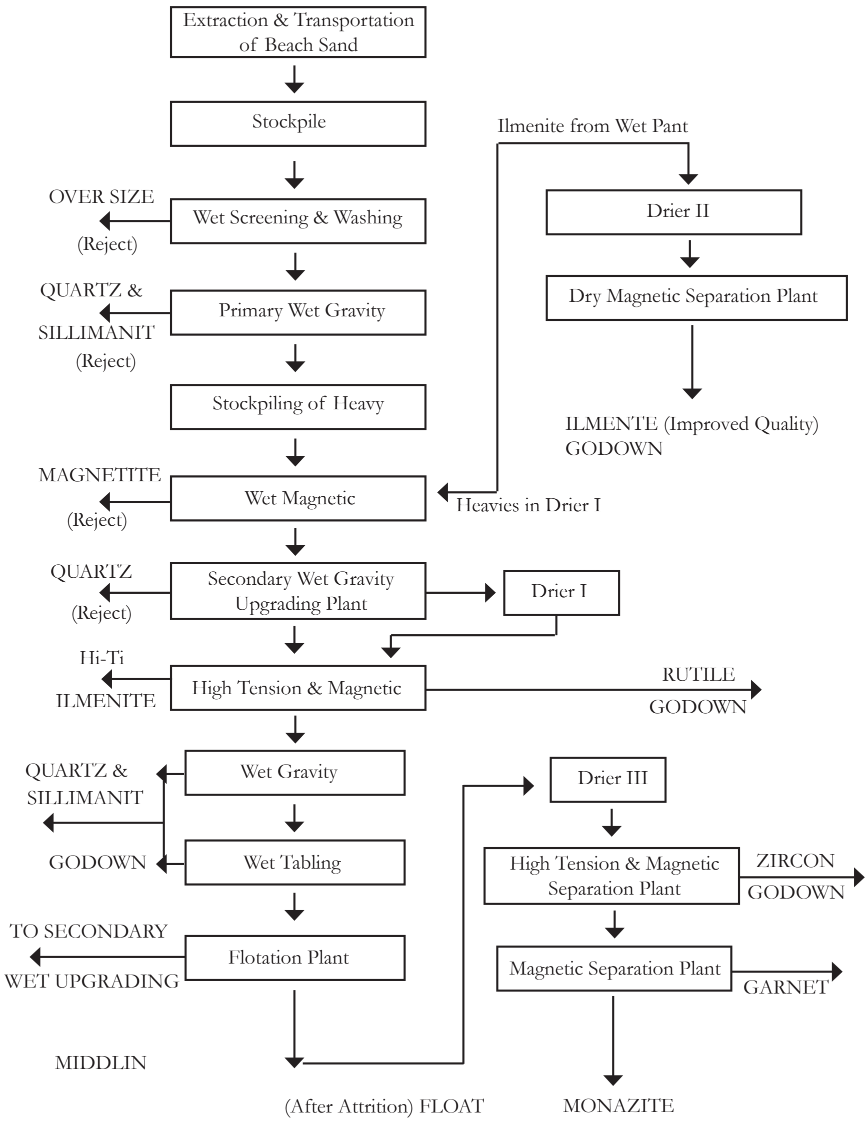
Miocene limestone is used as the main raw material in the cement industry. It is also used in iron extraction, ceramic industry, textile, glass, paper and rubber industries. Limestone in which the Magnesium content is 19% or more is Dolomite. This is used mainly for (i) the manufacture of fertilizer (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.

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

$4 FeTiO_{3(s)} + O_{2(g)} \longrightarrow 2Fe_2O_{30} TiO_{2(s)} + 2TiO_{2(s)}$

ii. Reduction - Heating at a temperature of more than 1200^0C with Brookite, Coal and Sulphur in a rotary furnace.

$Fe_2O_3.TiO_2 + 3CO_{(g)} \longrightarrow 2 Fe_{(s)} + 2TiO_{2(s)} + 3CO_{2(g)}$

iii. Exposure to air - Mix with ammonium chloride and air

$4 Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_{(s)} + 2Fe_2 O_3$

iv. Reduction of acidity - It is possible to completely remove the remaining iron oxide by the addition of O.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.

$FeTiO_3 + 2H_2SO_4 \longrightarrow TiOSO_4 + FeSO_4 + H_2$

↓ Reduction
Here Fe^{3+} is conveted to Fe^{2+}

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

$TiOSO_4 + H_2O \longrightarrow TiO\, nH_2O + H_2SO_4$
(>n) [Hydrolysis Stage]

↓ Sending through a rotary furnace Calcination

$Ti + CaSO_4$ Gypsum

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.

Raw garnet rich sand
↓ Jaw Breaking
↓ Double Rolling
↓ Wheel milling
↓ Water scrubbing
↓ Drying
↓ Winnowing
↓ Classifying - sieving
↓ Table concentration to separate by density and size
↓ De-watering
↓ Drying
↓ Classifying
↓ Classified products according to intended use

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

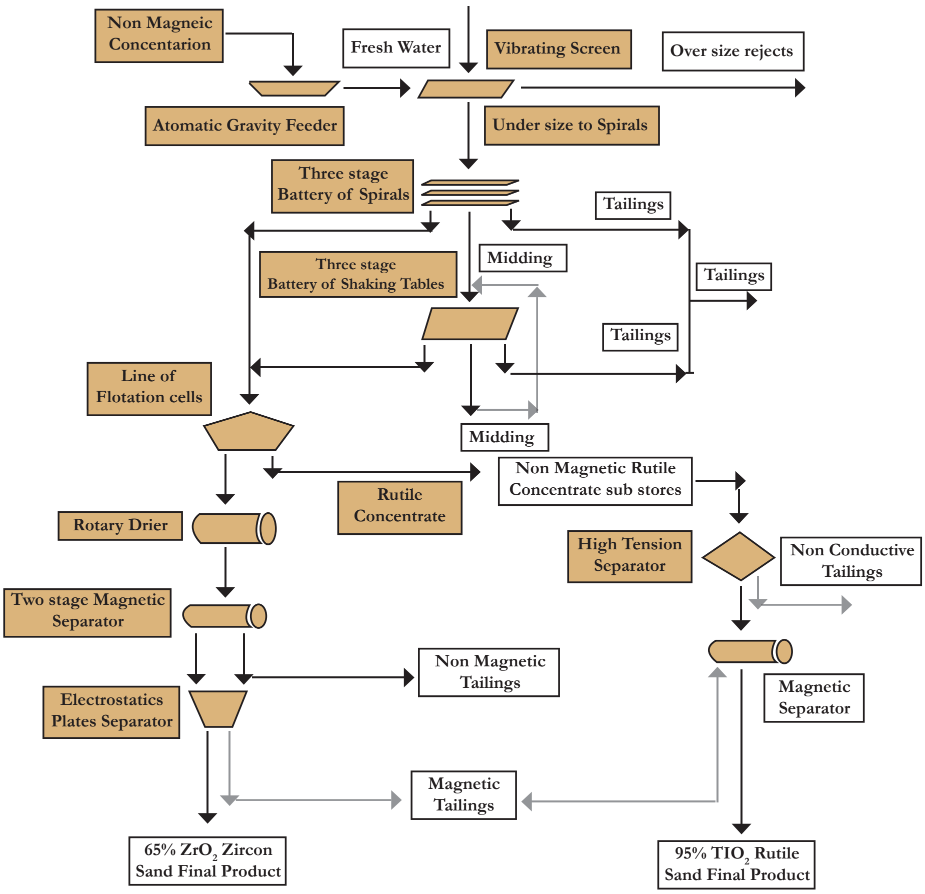


Figure 5 Schematic Flow Sheet Existing in Processing Plant of a Private Company

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 Dediyawala 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:

$$Fe_2O_3 + 3CO = 2\,Fe + 3CO_2$$

$$Fe_2O_4 + 4CO = 4\,Fe + 4CO_2$$

$$CO_2 + C = 2\,CO$$

$$C_s = \underline{C}$$

$$Fe_{(s)} = Fe_{(l)}$$

S = Soild 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 ¼" 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.

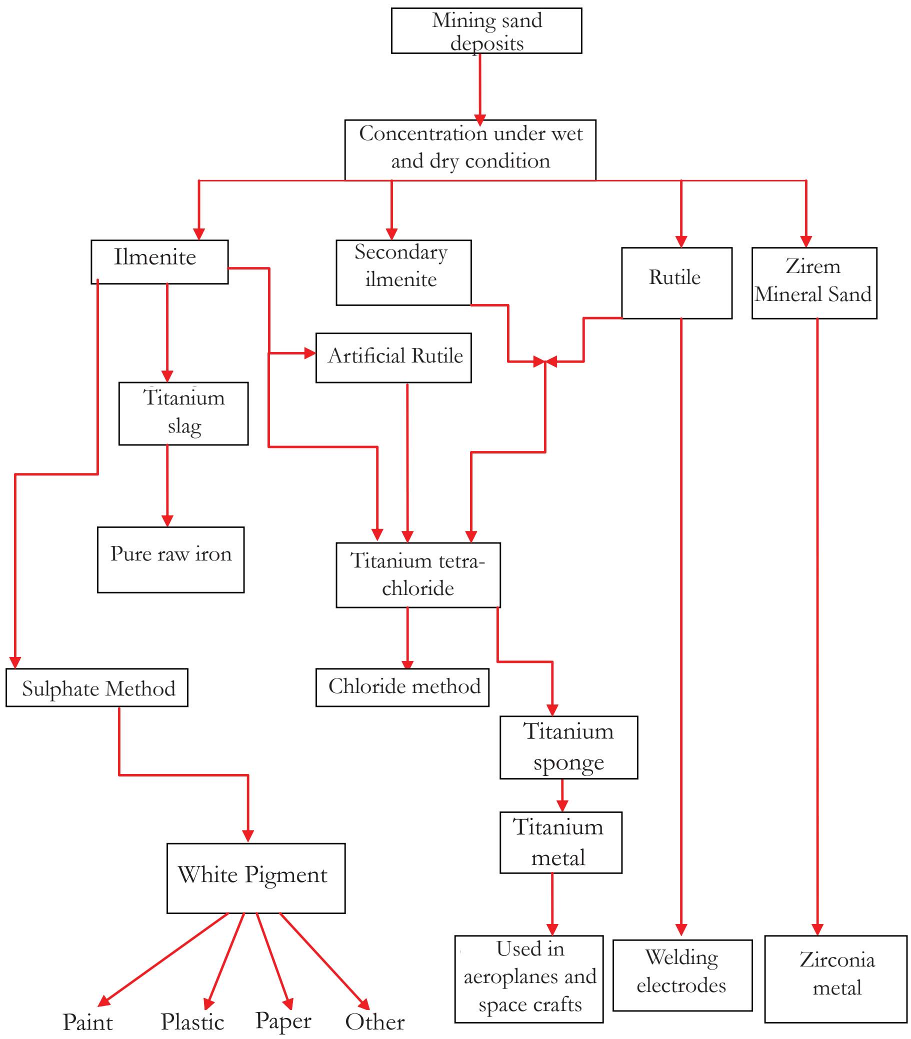


Figure 6 Value addition process of mineral sand

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 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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Nanomaterials for Economic Development

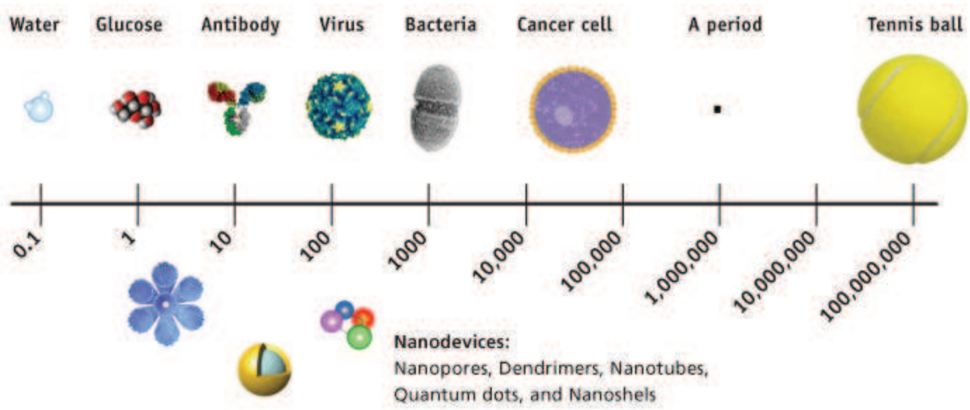
Muditha Senarath Yapa and Veranja Karunaratne

Sri Lanka, though a small island, is geographically rich in mineral resources. Typical nature of mineral resources is that the ores eventually will exhaust specially in the case of over-mining. Currently, most of our mineral resources are mined and consumed internally or externally without addition of much value to the raw form. Nanotechnology developments have presented an ideal space to add value to mineral resources in a sustainable manner. In the value chain of nanomaterials, nano-intermediates and nano-enabled products, it has to be noted that though nano-materials present the lowest value addition to raw materials, yet they are the building block of the nano-intermediates and nano-enabled products.

Nanogold

Nanomaterials are defined through their characteristics, usually in the size range between 1 and 100 nm at least in one of the dimensions. Chemical and physical characteristics of the materials take drastic changes due to surface to volume ratio increase and the quantum confinement effects when the 100 nm size is reached. Some of the properties such as optical, electrical, and magnetic aspect ratio effects can be exploited to create useful nano-intermediate and nano-enabled products. Most importantly, some of these useful changes in properties could be achieved by adding nanomaterials up to around 5% by weight of the bulk materials. Some such enabled products are already available in the market.

The web site http://www.nanotechproject.org/inventories/consumer/ lists 1317 nano-enabled consumer products registered with them from 30 countries around the world (visited 23rd November, 2012). Among these the incorporation of the antibacterial properties of Silver nanoparticles into fabrics, the use of non-scattering (thus transparent) UV blocking sun screen in lotions, and making tennis rackets which are lighter like a feather but stronger than steel with carbon



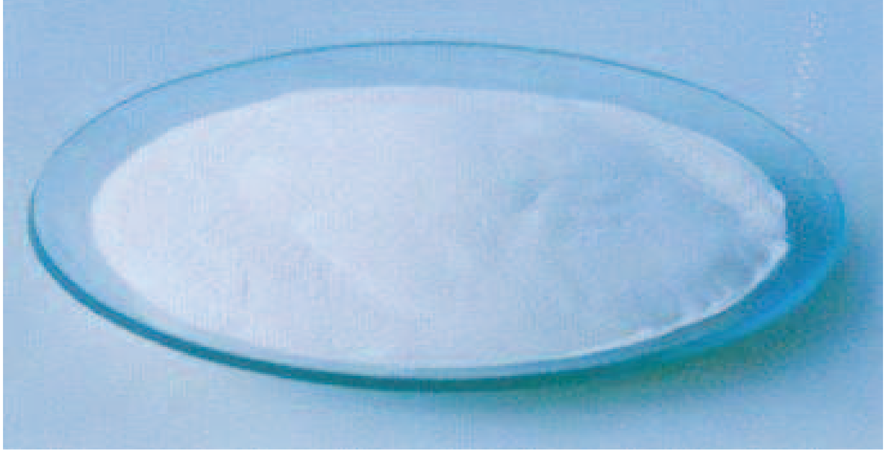
nanotube composites, are some examples of such products with enhancements via novel properties of nanomaterials. According to Lux Research Inc., nanotechnology will account for $2.4 trillion of revenue by the year 2015. Out of that, Nanomaterials will account for $3 billion and nano-intermediates will account for nearly $500 billion. This provides a fabulous opportunity for a country like Sri Lanka where non-renewable mineral resources are abundant in a smaller land mass. Let's look at some of the sustainable utilization possibilities for Sri Lanka's main minerals with the new technology developments.

Beach sands

North-eastern beaches in Pulmoddai are covered with black sands where 70 – 80% of it is in the form of Ilmenite. Ilmenite is the main source of Titanium products (mainly titanium dioxide and the metallic Titanium). In the past half a century, Sri Lanka has surface mined the beach sand and exported Ilmenite and Rutile after a minimal separation. Sri Lankan Ilmenite has over 55% of titanium dioxide content. The ore is estimated to be around 4 million metric tons, which gets replenished during the monsoon season. It is estimated to last 25 years at the mining rate of 150,000 MT annually (http://sundaytimes.lk/051002/ft/4.html). In 2012, the average price of Ilmenite was around $200 per MT whereas titanium dioxide at around $4200 per MT, metallic Titanium at $13,000 pet MT and nano-titanium dioxide was around $10,000 per MT. Nano-titanium dioxide has good transparency because the particle size is less than the wavelength of visible light but has excellent UV-A and UV-B absorbance. In usual formulations these properties

Montmorillonite clay

Nano-titanium dioxide



could be achieved between 0.5 – 8% doping of nano-titanium dioxide depending on the application. At the Sri Lanka Institute of Nanotechnology (SLINTEC), the technology to extract pigment titanium dioxide and nano-titanium dioxide from Ilmenite is currently undergoing scale up, while the technology to extract metallic titanium is being investigated. SLINTEC is seeking investors to take all these technologies to commercial production.

Clay minerals

Not all clays fall within the nomenclature of "nano-clays". Montmorillonite (Bentonite) is a clay mineral with nanoscale gallery spaces. In north western Murunkan area, the clay deposit contains about 40% of Montmorillonite (MMT). Due to the nano size gallery spaces they could be used in many composite applications. Market prices of MMT clays vary depending on composition as well as the purity and percent composition. Two major types of nano-clays based on composition would be Sodium-MMT and Calcium-MMT.

Organoclays are produced using Sodium-MMT as the base. Organics are reacted with high exchange capacity Sodium-MMT where organics are exchanged with Sodium. They are used in oil based paints, high temperature grease, in oil based drilling mud and several other niche markets. Prices vary from $1500 - $4000 per MT. Calcium-MMT is acid activated to produce bleaching clays which are used to clarify edible oils and beverages. Total volume of the bleaching clay market is estimated to be 850,000 tons priced at $250 - $600 per ton.

Estimated market size by 2009

Technology/application	Estimated market size*(by 2009)
Polymer/clay nanocomposites	Over 1 billion pounds
Packaging	367 million pounds
Automotive	345 million pounds
Building and construction	151 million pounds
Coatings	63 million pounds
Industrial	48 million pounds
Others	67 million pounds

Currently there is no industry for producing nano-clays and nano-clay composites in Sri Lanka. SLINTEC has developed extraction and purification methods for MMT from Murunkan clays. Currently the technology is being developed for organic clays.

Graphite

Graphite based nano-structures are the most talked about nanomaterials in the world. Since graphene won the Nobel Prize for Physics in 2010, electronics industry has invested considerable amounts of money and time in graphite based nanomaterials (nanocarbons). Nanocarbon products include single-walled carbon nanotubes (SWNT) and multi-walled carbon nanotubes (MWNT), fullerenes, graphene, carbon nanofiber and nanodiamonds.

Production capacity for all products increased from 996 metric tons in 2008 to more than 2190 tons in 2009, and to 4065 tons in 2010, and is expected to exceed 12,300 tons in 2015, a compound annual growth rate of 24.8% a year. Total production value is expected to reach about $435 million in 2010 and reach a value of $1.3 billion in 2015 (http://www.innoresearch.net). Sri Lanka has been a graphite producer since the year 1675.

Most of Sri Lankan graphite is mined underground as vein graphite. Sri Lanka is the only country where vein graphite is mined and it is the purest form (reaching 99.5%) available in nature (Simon Moores, Industrial Minerals, 2012). Currently Sri Lanka is a graphite-exporter in the raw form without value addition. Though Sri Lankan miners may be making a profit, the opportunity provided by new markets for nano-graphite is not going to last for a long time. SLINTEC is waiting for graphite producers of Sri Lank to join hands to explore these new opportunities.

There are other minerals such as apatite, quartz, magnetite, silica sand, feldspar, monazite, serpentinite, mica and gem minerals where nanotechnology could provide sustainable ways to develop mineral resources of Sri Lanka. SLINTEC has provided an opportunity for Sri Lankan industrialists to take a leap of faith into the world of nanotechnology.

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Minerals, Rocks and their Economic Significance

Prof. M. Rupasinghe

Earth' Crust

The Earth's crust is its uppermost thin layer of rocks. Like the skin of an apple in relative terms, it is extremely thin in comparison to the radius of the earth (~ 6371km). The crust is on average 5-8 km thick under the oceans and about 35 km thick in continental areas. Crust is mainly made of rocks and minerals. In most areas the top layer is covered with a thin film of soil or sediments which have been formed by weathering and degradation of rocks and minerals.

What is a Mineral?

A mineral is defined as a naturally occurring inorganic solid, that possesses an orderly internal atomic arrangement (structure) with a specified chemical composition or compositional range.
"Naturally occurring" means that it has to be formed by natural geological processes and is not man made as in the case of steel or synthetic gemstones.

A mineral should be in a "solid" state within the normal temperature ranges of the earth's surface. According to this strict definition, water and liquid/gas hydrocarbons are not minerals. "Inorganic" means that the substance is not derived from organic material or by an organism. For example, coal and peat which are derived from plants or pearls formed by organisms are not minerals by this definition. However, in general use ground water and petroleum are considered under mineral resources.

"Specified chemical composition" means that all occurrences of that mineral have a chemical composition that is fixed or varied within a specific limited range. For example: the mineral halite (known as "rock salt" when it is mined) has a chemical composition of NaCl. It is made up of an equal number of atoms of sodium and chlorine.

"Ordered internal structure" means that the atoms in a mineral are arranged in a systematic and repeating pattern. The atomic structure of any part of a mineral is the same irrespective of location within the mineral mass or location.

Classification of Minerals

While most minerals are compounds of two or more elements, some minerals are made up of a single element. Gold, silver and copper are called native elements and occur in nature in relatively pure form. The vast majority of minerals are compounds or combinations of elements. For a given mineral these combinations are consistent. For halite, the chemical formula is NaCl or sodium chloride. Each sodium atom is combined with one chlorine atom. The formula for Quartz is SiO_2, silicon oxide. For every atom of silicone, there are two atoms of oxygen.

There are over 4000 known minerals on earth. Each one is a unique substance with its own chemical formula. Most of these are very rare. Earth crust is mainly made of about 20 common rock forming minerals. Oxygen (O) silicon (Si), and Aluminium (Al) are commonest chemical elements in the earth crust. Quartz (SiO_2) is the most abundant mineral in the crust. There are several mineral families called "Rock Forming Mineral Families". Within each family, again there are several minerals with chemical variation of mainly Fe, Mg, Ca, K and Na. These families are:

(1) Feldspar
(2) Pyroxene

(3) Amphibole
(4) Mica

Mineral Classification

Minerals can be classified based on a number of criteria such as compositional characteristics, structural and crystallographic characteristics, practical use and their geological affinity. Two such common classifications are given below:

Chemical Classification of Minerals:

- Native elements
- Sulphides
- Oxides
- Nitrates
- Phosphates
- Sulphates
- Halides
- Silicates

A Classification Based on Applications:

Energy Minerals	Metallic Ore		Industrial Minerals
Coal	Ferrous & Ferroalloy Minerals	Non-Ferrous Minerals	Non Metallic
Peat	Iron	Bauxite (Aluminium)	Asbestos
Uranium ore	Chromium	Copper Ore	Clays
Thorium ore	Cobalt	Gold	Gemstones
Thorium minerals	Manganese	Lead	Graphite
Petroleum	Nickel	Zinc	Phosphates
Petroleum	Molybdenum		Feldspar
			Quartz
			Mineral sand

Rocks

Rocks exist all over the earth crust, beneath the soil or sediment cover. In fact, rocks are composed of various combinations of minerals. In the simplest terms, rocks can be considered as aggregates of minerals. Depending on the physical conditions of formation (Temperature and Pressure) appearance and physical characters of the rocks can be very different. There are three major categories of rocks namely, igneous rocks, metamorphic rocks and sedimentary rocks. Igneous rocks are formed at high temperatures (900-1500oC) by volcanic processes at or near the earth surface or at depths by intrusion. Sedimentary rocks are formed at or near the surface under relatively low temperature/pressure conditions by surface processes. When an igneous rock or metamorphic rock is subject to additional pressure and temperature through burial and heating by igneous processes this third category of rocks named metamorphic rocks are formed. The process is called metamorphism.

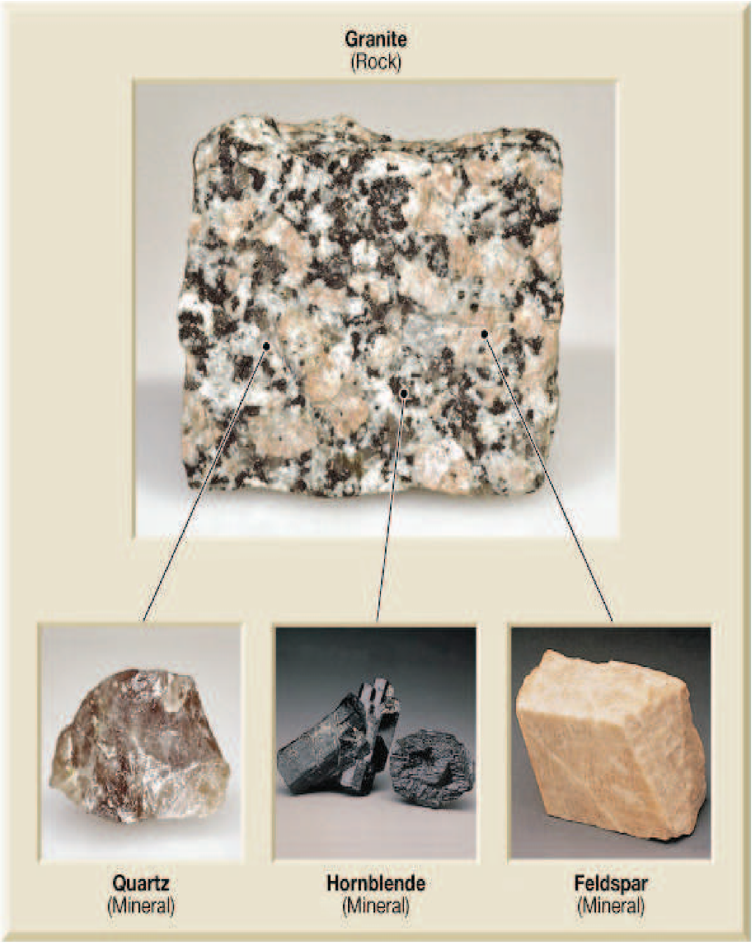
Economic Minerals and Mineral Based Industries in Sri Lanka

Sri Lanka is reasonably endowed with non-metallic minerals but not with metallic and energy minerals. The economic minerals of Sri Lanka include industrial minerals such as clays, mineral sand (ilmenite, rutile, zircon, garnet & monazite), silica (quartz), limestone, dolomite, apatite (phosphate rock), graphite, feldspar, mica and gemstones (see Figure, 2 Mineral Resources Map of Sri Lanka). No energy minerals are extracted yet on land or within the Exclusive Economic Zone of Sri Lanka offshore. However, the presence of hydrocarbons within western offshore area has been reported recently. Detailed exploration by CAIRN, India is in progress.

All mineral deposits in Sri Lanka except for graphite and gemstones are mined in quarries or surficial pits by open-cast method. The only underground working mines are for graphite which are located at Kahatagaha and Bogala. The Graphite mine at Ragedara has also been re-opened recently.

Except for a few involvements by the government owned companies such as Lanka

Phosphate Ltd. on Eppawala apatite deposit, Lanka Mineral Sands Ltd. for Pulmoddai mineral sand deposits, and Kahatagaha Graphite Ltd., the mineral industry of the country is now in the hands of the private sector.



Clay Deposits and Related Industries

Clay is the main ingredient in the body mixture of ceramic ware, wall tiles, bricks and tiles. Clay deposits of Sri Lanka include kaolin (kaolinite/ china clay), ball clay (a mixture of kaolinite, gibbsite, vermiculite and boehmite), and brick and tile clay (a mixture of kaolinite, gibbsite, goethite and vermiculite deposits). Kaolin (china clay) deposits mainly occur in the southwestern sector of the country. Well known kaolin deposits are in Meetiyagoda and Borellasgamuwa areas. Much of the deposit at Meetiyagoda has been exploited and the mining activities in Borellasgamuwa area are hindered by rapid urbanization. Ball clays are mainly found in flood plains of the southwestern sector. Main ball clay deposits are at Dediyawala in Kaluthara District. Surveys to find out new deposits are being currently conducted in the southwestern part of the country. One of the well established mineral industries in Sri Lanka is the ceramic industry. There are a number of local companies which produce high quality ceramic ware for export and local use.

Feldspar

Microcline (K-feldspar) deposits occur mainly in Rattota, Thalagoda, Kaikawala in the Matale district and Koslanda area. Among these, the largest deposit is in Owella estate, Kaikawala. Feldspar is mainly used in the manufacture of glass, pottery, vitrified enamels and special porcelain. As important raw materials of the local ceramic industry, export of both clays and feldspar are not allowed.

Silica Quartz

Vein quartz deposits of high purity (SiO_2%>99.65) occur in many parts of the country. Significant deposits are found in Galahad, Opanayake, Rattota, Balangoda, Mahagama, Randeniya and Meegahakiwula areas. It is estimated that over 1,000,000 MT of vein quarts occur in these deposits. Currently, export of vein quartz is allowed subject to prescribed degree of value addition such as in the powder form or as crushed quartz. A minor percentage (~4%) is utilized locally in ceramic and allied industries.

Silica Sand

Deposits of inland silica sand are common and well known deposits occur in the Marawila, Nattandiya and Madampe areas. A very large deposit of silica sand occurs in the form of sand dunes in Ampan-Vallipuram areas. Major use of inland high purity silica sand is in the glass industry. In addition, vast amounts of silica sand are excavated from flood plains and river beds to be used as fine aggregates. Use of dredged sea sand for construction purposes has been encouraged but still sea sand is mainly used as filling material.

Mineral Sand

Mineral sand is a mixture of refractory heavy minerals such as ilmenite, rutile, garnet, zircon, monazite together with some silica sand. Usually, the deposits appear as stretches of black sand along the beach or occur as raised beaches. In Sri Lanka, well known beach sand deposits are encountered at several points of northeastern and northwestern coastal stretches. Although the mixtures of these minerals are not uncommon, it is only at certain points they are sufficiently concentrated for economic exploitation. Well known deposits are at Pulmoddai, Nayaru, Koduwakattumalai and Tavikkalu. At Pulmoddai deposit 70-75% of the black sand is ilmenite, 8-10% is zircon, 6-8% is rutile and about 0.5% is monazite. Garnet concentrated sands are reported from Dondra Head and Hambanthota.

It is estimated that over 12,000,000 MT of mineral sand occur along the beaches and in raised beaches of the island. Currently, Lanka Mineral Sands Ltd. (former Ceylon Mineral Sand Corporation) has been extracting ilmenite and rutile using magnetic and gravity separation techniques. Minerals thus separated are exported without much value addition.

Limestone

Sedimentary limestone belonging to Miocene age extends from Puttalam to Jaffna Peninsula along the northwestern coastal belt of Sri Lanka. Limestone is well exposed at several places including Aruwakkalu, Mannar, Pooneryn and Kankasanthurai. Material exposed at these localities is mainly $Ca CO_3$ and is suitable for the cement industry. Currently limestone excavated at Aruwakkalu fulfills the $Ca CO_3$ requirement of the local cement industry. Export of limestone is not allowed.

Crystalline Limestone (Marble)

Chemically crystalline limestone (marble) is $CaMg(CO_3)$ with a variable CaO/MgO ratio. Magnesium rich varieties (dolomitic marble) are used as a fertilizer for long term crops, and for scrubbing powder, while calcium rich varieties are burnt to produce lime in place of coral based lime products. Thick bands of marble occur in the Highland Complex of Sri Lanka especially in Digana (Kandy), Mathale, Dambulla, Naula, Bakamoona areas and in the central highlands. Export of limestone is not allowed.

Apatite (Rock Phosphate)

A deposit of rock phosphate with proven reserves of 24,000,000 MT and another 15,000,000 MT of inferred reserves are located at Eppawala near Anuradhapura. Currently, this deposit is mined by a government owned company (Lanka Phosphate Ltd.), and crushed phosphate is produced for local phosphate fertilizer requirements of long term crops. The optimum utilization of this deposit could be possible only if the phosphate rock could be converted to soluble phosphate fertilizer such as Single Super Phosphate (SSP), Triple Super Phosphate (TSP) Di-Ammonium Phosphate (DAP) or Mono-Ammonium Phosphate (MAP). If this valuable phosphate deposit could be developed, large sums of money drained to overseas countries on fertilizer, could be saved.

Graphite

Graphite mining in Sri Lanka dates back to the time of the 1st World War. There was a great demand for Sri Lankan graphite both during the periods of 1st and 2nd World Wars mainly because of its high purity. A large number of shallow pits and few major mines were in operation during these periods. Of these, only Kahatagaha and Bogala Mines are in operation at present. There is a potential for the establishment of graphite based industries such as crucibles, carbon brushes, refractory bricks, electrodes, paints and lubricants. Unfortunately, bulk of the graphite mined in Sri Lanka is exported in raw form.

Iron Ore

There are three (03) known metamorphic iron ores and few scattered supergene deposits in Sri Lanka. Metamorphic deposits are at Panirendawa near Chilaw, Seruwila and Buttala. These deposits are very small in size in comparison with iron ores in other parts of the world. However, in view of increasing demand for iron there is revived interest in these occurrences.

Gemstones

Sri Lanka has long been renowned for its gemstones. Perhaps nowhere in the world are so many gem varieties as occurring within such a small area of land. A variety of gem minerals from corundum, chrysoberyl, beryl, topaz, tourmaline, garnet, spine and quartz families are found in alluvial or colluvial deposits or in-situ. Rare stones such as Sinhalite, Ekanite and Taaffeite are perhaps unique to Sri Lanka. Traditional gem mining area was Sabaragamuwa (Rathnapura) but Okkampitiya, Elahera, Horton Plains and many other areas within the Highland Complex of the country are also now known for occurrence of precious and semi-precious stones.

Mica

The main types of mica found in the country are phlogophite, biotite and muscovite. Important commercial types are phlogopite and muscovite. Phlogopite mica is found in the areas of Thalagoda, Madumana, Talathu-Oya, Badulla, Maskeliya, Madugoda, Udumulla, Naula, Haldummaulla and Kebithigollawa. Sheet mica is mainly used in electrical appliances and in the electronic industry. Scrap mica is usually ground and then used as a filler in plastics and paint industry.

Hard Rocks Suitable for Dimension Stones and Construction Material

Recent rapid infrastructure development in the country has created a great demand for road metals, rock boulders and rock aggregates. Since most parts of the island are underlain by high-grade metamorphic rocks there are numerous hard rock exposures that could be harvested for dimension stones or quarry material such as road metals or rock boulders. Since haphazard quarrying could lead to many environmental and social issues, such activities have to be monitored and regulated. However, this industry has managed to supply sufficient quantities of construction material required for the development efforts and earn valuable foreign exchange by export of value added products.

Mineral Production and National Economic Development

Many of the world's richest countries have benefited greatly from minerals extraction. Australia, Canada, Finland, Sweden, and the United States, for example, have all had extensive mineral industries and used them as a platform for broad-based industrial development. In more recent years, a number of developing countries also have achieved minerals-led development. For example, Chile, whose copper production accounts for 35% of world output, is now among the group of 'high human development' countries (ranked 39th by UNDP). Here, too many of the rewards have been reaped locally: the mining capital of Antofagasta is relatively prosperous and in recent years unemployment has been falling despite the arrival of immigrants from other regions. Africa can also provide positive examples. One of the most successful mining countries has been Botswana, a major producer of gem diamonds that has also had one of the world's highest economic growth rates. But some other countries with mineral development seem to have been considerably less successful.

There are a number of ways of deciding which countries qualify as "mineral economies":

Minerals output can be set against gross domestic product (GDP), or the dependence of foreign-exchange earnings on mineral exports can be considered. In 34 nations, mainly developing and transitional economies, mineral exports of metals, ores, and fuels (including oil) represented 25% or more of total merchandise exports in 1999. Another indication of minerals dependency is the proportion of government revenue that comes from mining. However, any country that wishes to translate mineral wealth in the ground into human development for its people faces stiff challenges. These include:

- Creating and sustaining mineral wealth while protecting environmental quality and other social and cultural values;
- Sharing the surpluses or economic rents from mineral production equitably among different levels of government, local communities, and mining companies;
- Converting non-renewable resources (mineral wealth) into renewable ones by investing in physical and human capital, and doing so in a way that also helps protect the interests of future generations;
- Maintaining a stable economic environment while coping with the exchange-rate impact of mineral exports, fluctuating international commodity prices, and the demands for structural adjustment; and
- Dealing with the impact of the mining sector on crucial issues of governance, in particular corruption, regional tensions over how revenue is shared, and human rights.

Capturing Mineral Wealth

The existence of mineral deposits is no guarantee of economic development. Whether deposits turn out to be a blessing or a curse will largely depend on governments, on the quality of their institutions, on their capacity to manage these resources. Some governments have tried to maximize their incomes through higher taxes and royalties and by limiting the repatriation of profits. They also imposed various controls on what the corporations could import or export, and required that companies employ a certain proportion of national staff. When this did not yield the desired results, there were mandatory joint ventures with national companies, caps on the percentage of foreign ownership. However, it was clear that some of these measures were not bringing the desired results. Some state mining companies, rather than contributing to the national budget, became a drain, as subsidies were required to keep them afloat. Many governments acknowledged that state ownership and public-sector management were failing to deliver anticipated social and economic benefits, and that over-regulation was discouraging investment. Last three decades saw much economic liberalization and a greater belief that the best option was to allow the private sector to take the lead in spearheading development.

Post Mining Responsibilities

In the longer term, many mineral-intensive economies must also plan for the time when minerals run out. Prudent governments will consider the best ways to use their earnings for productive investment. Broadly there are two options. The first is to make investments that will produce a measurable financial return. These could include real estate or financial assets such as stocks and bonds. The second option is to invest in assets that produce less measurable return. This could involve physical infrastructure, for example, as well as human development in the form of skills development and health and education services.

Most poor or developing countries are likely to choose this approach. In any case it is extremely important to recognize early in project planning that there will be terminal costs, what these will be, and how they will affect a government's obligations.

Terminal costs are numerous, diverse, and sometimes very large. Examples might include:

- Sudden increase in unemployment and other social costs as a region is faced with relatively high unemployment
- Need to pay to maintain roads, telecommunications, electrical supply, or other infrastructure which were previously done by mining companies
- Need to look after rehabilitation and post rehabilitation maintenance work

There needs to be some clear agreement on the role of national government.

Table 1: Production and Export Data for Sri Lanka Minerals (2011)

Mineral Commodity	Total Production (tonnes)	Export (tonnes)	Local Use	Foreign Exchange Earned (Rs. Value in millions)
Mineral Sand (ilmenite, rutile & zircon)	65566	80750	Negligible	1992
Graphite	3357	3324	Negligible	450
Mica	2927	2927		131
Vein Quartz	34903	33354	1500	1114
Gemstones	9154 (thousand carats)	9154 (thousand carats)		10027
Dimension Stones	6247	6247	---	180
Sea Sand	86200	14250	Bulk locally used	21
Feldspar	53337	0	Used in local industry	Save valuable foreign exchange for raw material export
Kaolin & Ball Clay	63000	0	Used in local industry	
Silica Sand	58355	0	Used in local industry	
Calcite	14674	0	Used in local industry	
Limestone	1231209	0	Used in local industry	
River Sand	7046431 (m3)	0	Used in local industry	
Dolomite	195000	0	Used in local industry	
Apatite	58254		Locally used	
Salt	87256	0	Locally used	

Export and Import of Minerals and Mineral Based Products – Sri Lanka

Major mineral exports of Sri Lanka are mineral sand, quartz, graphite and mica. Export income from these minerals for the year 2011 is given in the Table 1. Major mineral based products that earn foreign exchange are ceramic tableware, porcelain tableware, wall tiles, floor tiles and ornamental stones. The earnings through export of these items in 2011 exceeded rupees 4/5 billions. Although Sri Lanka has a well-established cement industry, country still has to import nearly 50% of its requirement. The total cement consumption during the year 2011 was about 5,000,000 tonnes. Despite the fact that there is a large rock phosphate deposit at Eppawala, country still spends billions of rupees on fertilizer imports.

In consideration of spending on other imports on mineral raw material and mineral based products it can be concluded that there is a large deficit in mineral export trade. In order to improve this situation, export of value added products in place of raw materials and development of existing mineral deposits should be encouraged.

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