Geology and Mineral Resources of Sri Lanka

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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

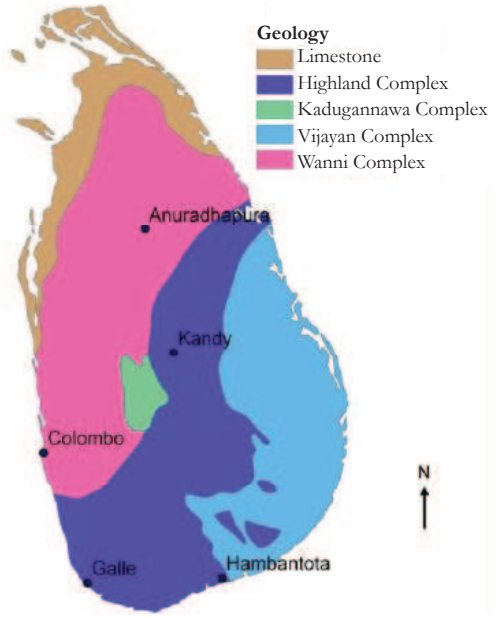


Figure 1 Geological formations of Sri Lanka

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.

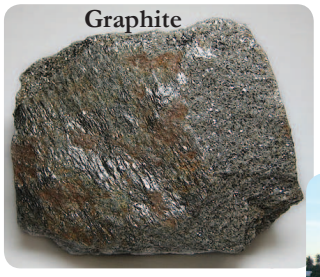
Gems are formed due to igneous activities as well as due to metamorphism. When the heavy minerals (Iron & Magnesium rich minerals are crystalized and separated, the remaining magma will become rich is volatile matter. When this volatile rich magma cool at a slow rate, gem varieties are formed (eg. in 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.

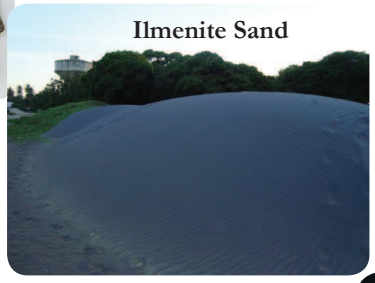
Graphite:

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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