GEOLOGICAL AND ECONOMIC SIGNIFICANCE OF GEM GRAVEL DEPOSITS IN THE HAMBANTOTA DISTRICT

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ABBREVIATIONS

e.g.	=	*exempli gratia*
BS	=	British Standard
Ltd.	=	Limited
GND	=	Grama Niladhari Division
sq. km.	=	square kilometre
DS	=	Divisional Secretariat

CHAPTER ONE - INTRODUCTION

1.1 Gemstones and humankind

Gems or gemstones are unusually bright, colourful, or transparent materials that are relatively rare and are durable enough to be used in jewellery. Gems are mineral that have ornamental value. Most gemstones have three qualities that set them apart from common, run-of-the-mill minerals: beauty, durability, and some degree of rarity (Chesterman, 1979). For the most part, gems are minerals, with a characteristic crystal structure and chemical composition. Such materials as pearl, coral, amber, and jet, however, are also prized as gemstones even though they are the products of organic processes (Desautels, 1996). Gemstones have been artificially polished, faceted and shaped for decorative purposes. It is normally classified as precious (e.g. diamond, ruby and emerald) and semi-precious (e.g. garnet, zircon and topaz). Many gemstones are hard and free from natural imperfections (Allaby and Allaby, 1991).

Only about 100 minerals, out of an estimated 3,000 known minerals, are valued as gemstones. Of these, fewer than 20 are commercially important. They include diamonds, emeralds, and rubies of high quality and the size, the rarity of which makes them the most costly of all the gems; and such other precious and semiprecious gems as sapphires, amethysts, opals, garnets, carnelians, and jades.

Gemmologists classify each mineral as a separate species. Gemstones that are chemically and structurally identical but differ in colour are varieties of a single species. Thus, many stones that are usually considered as quite distinct by amateurs are seen by gemmologists as similar: rubies and sapphires are varieties of corundum - a mineral species; emeralds and aquamarines are varieties of the species beryl, which also produces a pink-to-red variety known as morganite.

In various cultures throughout history, certain preferences have developed for one kind of gemstone over another. These preferences, reflected in commercial price levels for gems, are based on several factors, viz. beauty, durability, rarity, and current fashion. Diamonds or the finest jade come as close as any gemstone to meeting all these requirements. Some gemstones meet only a minimum of these requirements, for example, turquoise is beautiful and fashionable but is neither particularly rare nor durable.

Gemstones are used as birthstones that are symbolically associated with the month of one's birth and are believed by some to bring the wearer good luck or good fortune.

Sri Lanka has been famous for more than 2500 years for its gemstones owing to the presence of many varieties of precious and semi-precious stones. However, until recently, exploration of gemstones was carried out using traditional methods only. Nearly one fifth of the whole island area consists of sedimentary deposits, metasedimentary and magmatic terrains that have gems and gemstones. This area is approximately bound from Alutgama, Nalanda, Polonnaruwa, Nilgala, Kataragama to Matara and includes southwestern lowlands. Traditional gem mining in these areas is concentrated mainly in the Ratnapura, Opanayake, Balangoda Deniyaya and Rakwana areas, and the methods of gems exploration are still based on information passed down by word of mouth (Dissanayake et. al, 1993).

An expression made by Chernush (1980) distinctly emphasises that “In Sri Lanka, anyone who wants to dig in his own backyard needs to have permission from the government. The temptation to dig is understandable: most of the country is potential gem-bearing land. With gemstones nearly everywhere, Sri Lankans sit on an immense treasure getting rich overnight".

1.2 Objectives and the significance of the study

Extensive gem bearing gravel are found in the coastal area, lower part of the Walawe basin, between Ranna and Pallemalala in the Hambantota district (Figure 1). They are of considerable geological significance in the study of palaeo-stratigraphy, geoarchaelogy and sea level changes. Minerals of the corundum family, mainly ruby, sapphire, cat's eye are found in these gem fields. They are associated with quartz and ironstone gravel that have been deposited as fluvial material under a dry climatic condition during the last glacial period. Accordingly, this study plans to identify the geological, archaeological and economic significance and focuses on the environmental degradation caused by gem mining in the Hambantota district.

In Sri Lanka, it is considered that most of the gem fields are situated in the southwest of the island. Within an area of about 2000 km^2 are to be found the delicate coloured varieties. New gem-bearing fields have been discovered at Elahera, Okkampitiya, Tissamaharama, Nuwara-Eliya, Horton Plains, Maskeliya and Kandy areas, and research has been undertaken to emphasise their stratigraphic, geologic and economic values. However, a study of the geological, archaeological and economic significance of gem gravel deposits at Sitralaka, Ussangoda, Karagan Lewaya and Maha Lewaya has not been undertaken in any previous study. Such a study would be of vital significance as it would facilitate:

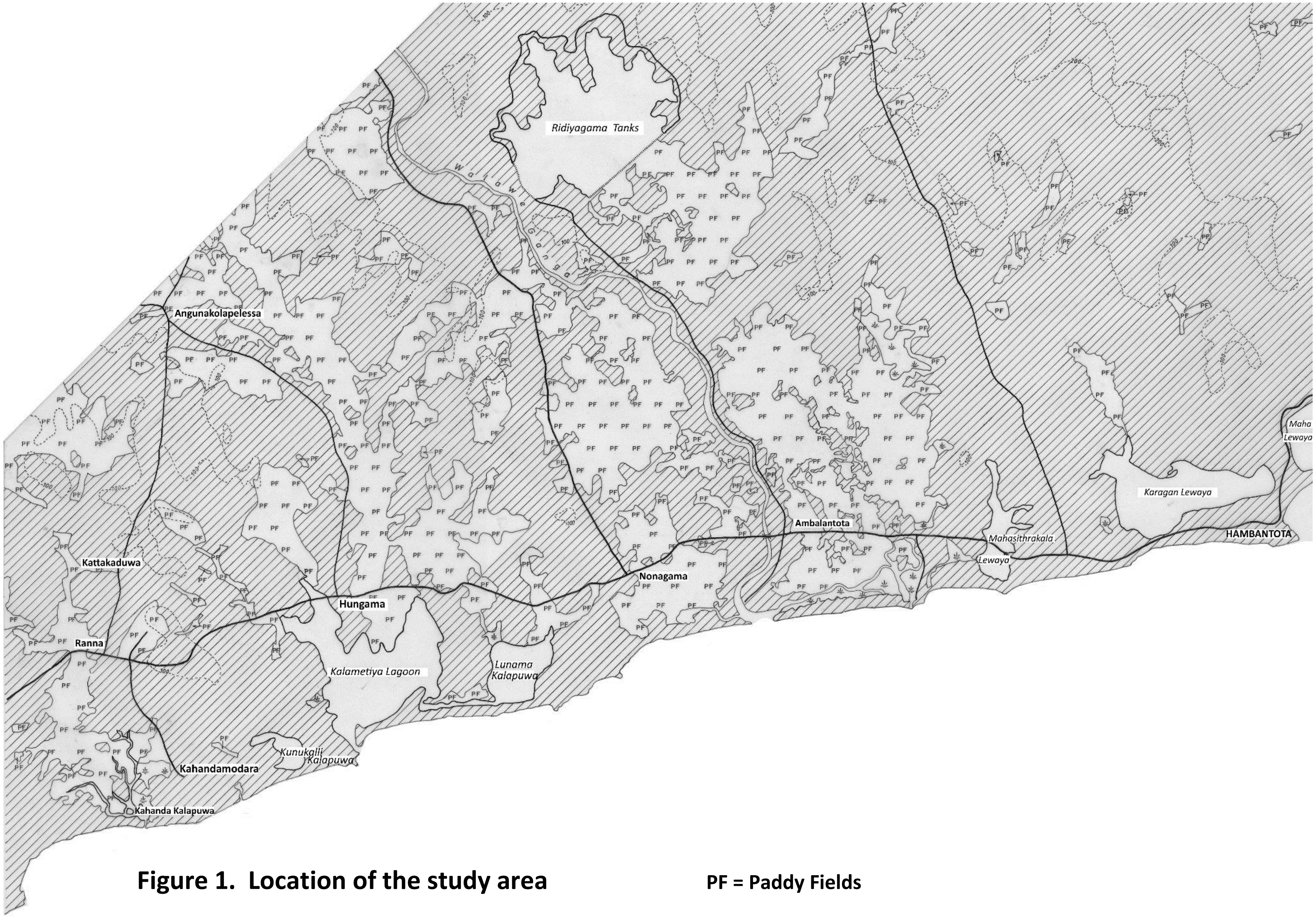

Figure 1. Location of the study area **PF = Paddy Fields**

(a) the examination of geologic sequence of gem deposits

(b) the collection of artifacts which would be highly valuable for palaeoenvironmental and archaeological research

(c) the promotion of the gemstone trade which presently is being operated illegally, and is ill-planned

(d) the control of environmental degradation of gem bearing gravel that is usually located in ancient stream beds in the present valleys

1.3 Methodology

The gem bearing gravel beds were mapped based on detailed field investigations. Field investigations were carried out between May 1995 and April 1996. For this study, gravel samples were collected from the cross-sections of road cuttings, dug-wells and gem pits at twenty locations for geologic analysis. The examined dug-wells and gem pits were less than 3m in depth.

First stage

More than 5 mm in size pebbles were removed manually after careful examination of the gravel sample. The rest of the samples were washed to remove clay-portions and organic matter. Separation of the grain sizes less than 250 µm mess sizes was undertaken using BS 410, Laboratory Test Sieve (Endecotts Ltd, London, England).

Second stage

The heavy minerals of the five samples were separated using the 1,1,2,2-Tetrabromoethane (CHBr2.CHBr2) to remove minerals with SG less than 2.9. Another five samples were treated with Cadmium Boro Tungstate to obtain minerals with SG higher than 3.3. Three more samples were treated in

CHBr2.CHBr2 and Cadmium Boro Tungstate to obtain minerals SG between 2.9 and 3.3.

Heavy fractions of three samples were separated using magnetic separation using Frantz Isodynamic Magnetic Separator. Before this separation all samples were sieved using mesh sizes 150 - 200 μm BS.

The mounted slides were observed under plane polarized light as well as crossed polars of petrologic microscope. All laboratory investigations were conducted at the Geological Survey and Mines Bureau in Sri Lanka.

1.4 Limitations

Extensive gem mining areas are concentrated on inland slopes, valleys and valley bottoms from ancient to recent times. Gem mining in the coastal areas has been neglected. This study, planing emphasis on the geologic and economic significance of coastal gem mining, is limited to the lowlands of the area around Ambalantota and Hambantota due to limited funds. The most expensive component of the study was travelling.

Owing to lack of maps and the lack of prominence of the gem mining areas in the Hambantota district, the researcher visited mining places using the 'hearsay' method consulting local people. Collection of samples for microscopic analysis to examine the availability of gem minerals were also rather difficult because road cuttings and dug-pits were scarce and scattered.

Also, limited laboratory facilities at the Department of Geography was a reason for seeking outside assistance to carry out detailed tests. Microscopic analysis had to be conducted on a limited number of samples which were collected from different locations in the study area. This was the main reason why more time was taken to submit the report within the stipulated time period.

1.5 Structure of the report

This comprehensive report consists of six chapters. Chapter One is an introduction to the study and provides an account of gemstones and their importance to humankind, the significance of the study, methodologies adopted and limitations. Chapter Two describes the general geological structure, geomorphology, climate, soil, vegetation and present landuse in the coastal gem mining area. Chapter Three focuses on the comprehensive description of gems and gemstones in Sri Lanka as well as in the area under study. Chapter Four discusses the main objectives of the study. The expected environmental degradation due to gem mining in the study area is revealed in Chapter Five. Chapter Six gives the conclusion of the study and makes recommendations for policy formulation.

CHAPTER TWO -PHYSICAL SETTING ANDLAND USE

Gem-bearing terrain in Sri Lanka is classified under three groups: highly probable, probable and moderate, amounting to a total of 22 percent of the land area (Dissanayake and Rupasinghe, 1993). Geologically these 22 percent of gem-bearing deposits are found in alluvial, elluvial and residual beds.

Extensive transported gem deposits of the flood plain around the lower Walawe Ganga basin is covered by buried rivers, streams and sediment filled lakes. The accidental finds of gemstones in these places led to the extensive mining of gems for nearly two decades especially in Mirijjavila (Hambantota West GND), Chitragala, Kapuwatta and Goyamkolamulla (Sisilasagama GND) areas. The study area, described here is situated in the southern part of Sri Lanka within longitude 80^0 48' - 81^0 16' and latitude 6^0 03' - 6^0 09'.

The study of physical features and their characteristics including the geological structure, landforms, climate, natural vegetation and soil, discussed here briefly is to highlight the geologic and economic significance of coastal gem deposits.

2.1 Geological structure

The main gem-bearing areas in Sri Lanka occupy the Highland Group (granulite facies metasediments), Vijayan Complex (Granitoids, migmatites and migmatitic gneisses) and the Southwestern Group (granulite facies metasediments). The high rate of weathering and denudation of the land for the past few million years had given rise to thick and extensive piles of alluvial sediments (Dissanayake and

Rupasinghe, 1993). Gem mining in these areas has continued without a break for more than a thousand years.

Geologically the southern region is underlained predominantly by the Vijayan Complex rocks (amphibolite facies) formed in the Precambrian era. The right bank of the Walawe Ganga lies on the Highland Complex rocks (predominantly granulite facies) whilst the left bank comprises biotite gneiss, hornblende-biotite gneiss, migmatitic and granitic in parts of the Vijayan Complex (Hapuarachchi, 1967 & 1968; Balendran, 1968; A Canada - Ceylon Colombo Plan Project, 1980; Geological Map of Sri Lanka, 1983; Cooray 1984). Their research indicates that the study site consist of two types of rocks:

(a) Hornblende and biotite gneisses with associated pegmatite and migmatite (Vijayan series).

(b) Quartz-feldspathic gneiss and granulite (Khondalite series).

The high rate of weathering and denudation of land involving these two types of rocks during the past few million years had given rise to thick and extensive piles of alluvial deposits. The alluvial deposits along the Walawe river and its environs indicate that the deposition pattern is related to the Pleistocene and Holocene epochs (Deraniyagala, 1987; Katupotha, 1989 & 1995). These deposits appear in a narrow zone due to the extension of low hills and ridges up to the sea. In some places many deposits are rich in gem-bearing gravel.

2.2 Geomorphology

Broadly, the southern coastal zone of Sri Lanka can be divided into three regions (Katupotha, 1992a), namely;

(a) Flat terrain - Lowland I (< 30 m)

(b) Flat to slightly undulating terrain - Lowland II (< 30 m)

(c) Undulating terrain - Lowland III (30-150 m).

(a) Flat terrain - Lowland I (< 30 m)

The coastal belt which has been altered by aeolian and marine influences between Tangalla and Bundala is formed of narrow and long beaches, beach ridges with medium and somewhat high dunes. In some places the dunes reach heights of 15 to 20m over bedrock. Salterns, salt marshes, mangrove swamps and mound topography (hummock relief) lie behind them. These features also reflect the configuration of the underlying bedrock surface. The bedrock outcrops which are too small and too low appear as erosional remnants. Sand spits are common features at the estuaries of the Walawe ganga and lagoons. Well-drained and imperfectly drained mixed aeolian, residual and alluvial soils occupy these areas. Lowland I is completely flat terrain and the slope is $1/2^{0}$ or 1^{0} (1:100 or 1:60 in gradient).

(b) Flat to slightly undulating terrain - Lowland II (< 30 m)

The natural levee deposits of the lower Walawe ganga basin comprise well-drained soils. The terrain (which can be called a flood plain) has slightly undulating topography which exhibits different landforms, e.g., channel scars, slip-off slopes, natural levees and slackwater areas, but rock-outcrops appear sometimes above 30m from the mean sea level on the low planation surfaces. Gravel surfaces in the area have well-drained to imperfectly drained soils. The drainage in the flood plain varies from imperfect to poor. The lower course of the Kachchigal Ara appears to consist largely of slackwater deposits with poorly drained soils. However, the clays of the old lagoon beds and just below the gravel beds are very plastic when wet. The gravels are known for their gem-bearing potential. This terrain slopes is 1^0 to 3^0 (1:60 or 1:20 in gradient).

(c) Undulating terrain - Lowland III (30-150 m)

Slightly undulating, undulating and rolling features appear particularly in the area between Udawalawe and Ridiyagama, and the area around Timbolketiya. Towards the east of Timbolketiya the relief forms are slightly undulating to moderately undulating terrain with well-drained soils. Dissected features and inselbugs in the areas around the Kiri Oya, Mau Ara, Guruwala Ara, Diyawini Oya and the Hambegamuwa Oya have been formed on intermediate planation surfaces. The gentle slopes or moderate slopes of undulating terrain vary between 3^0 and 6^0 (1:20 to 1:10 in gradient). The rocky knobs of the area rise from the surrounding plain, usually gently and sometimes abruptly, with steeper dome-like outcrops protruding 5 to 10m above the general surface.

The alluvial gem-bearing gravels are mainly concentrated in the flat terrain beyond the right and left banks of the Walawe ganga .

2.3 Climate

According to Köppen classification, the southern coastal zone, from Matara to Bundala coastal area is belong to Afw"i, Amw"i, Asi and Bsh climates (Thambyapillai, 1960).

A Rainy climate (Megathermal - high temperature and abundant moisture) - temperature of the coldest month over 18^0 C; no winters

B Dry climate (Terophytic - arid or semi-arid; the distribution of this climate is in terms of ‘precipitation effectiveness’ which is determined by the use of formulae

f Precipitation of the driest month is at least 6 cm

w" There are two distinct maxima of precipitation separated by two dry seasons

m short dry season exists but is compensated by heavy precipitation during the rest of the year

s Used when dry season comes during the high-sun period

i Range of mean annual temperature less that 5^0 C.

h not desert or steppe: mean annual temperature 18^0 C

The selected rainfall stations of the southern coastal zone show two maximum seasons (Fig. 2.1) during the inter-monsoon (April) and conventional- cyclic-depression and Northeast monsoon (October to November).

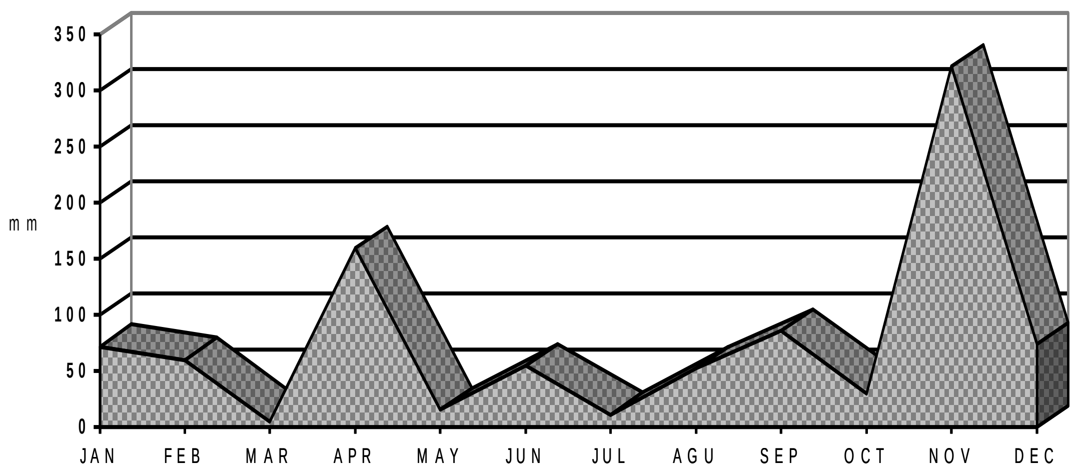

Figure 2.1 Monthly variations of rainfall recorded at the Hambantota Meteorological Centre - 1996

Mean annual temperature in the area is 27.5^0 C. The temperature figures for 1996 varies between 26.5^0 C (lowest in January) and 28.7^0 C (higest in May).

There is a close relationship between the mining and washing operation in the study area and distribution of rainfall and deficit of water.

2.4 Soils

Main soil types of the study area have a close relationship with geologic characteristics, micro-relief and climatic conditions.

Four main soil groups can be identified as follows (Soil Map of Sri Lanka);

(a) Reddish Brown Earth's with high amount of gravel in subsoil and Low Humid Glee Soils

(b) Reddish Brown Earth's & Solodized Solonetz (both (a) and (b) types lie on the undulating terrain)

(c) Alluvial Soils of variable drainage and texture (covers flat valley bottoms, water logged areas etc.)

(d) Regosols on recent beach and dune sand (forms barrier beaches, beach ridges, sand spits and dunes along the coast)

Rocknob plains and erosional remnants in the coastal plain are formed by granitic gneiss, quartzite, hornblende gneiss and hornblende - biotite gneissic rocks. The gravels in Reddish Brown Earth's, Alluvial Soils in flat valley bottoms and water logged areas and residual soils around rocknob plains and erosional remnants provide an indication of climatic changes during their formation and deposition.

Highly weathered crystals of various rock forming minerals and gemstones of these soils clearly show that they have devolved through the Quaternary period.

2.5 Vegetation & land use

According to Fernando (1968) and ‘A Canada - Ceylon Colombo Plan Project Report (Resources of the Walawe Ganga Basin 1980)’ the southern coastal lowlands are covered by riverine forest, swamp vegetation, mangrove and littoral vegetation. They are grown locally on the above mentioned Pleistocene and Holocene deposits. The distribution and extent of land use of the gem-bearing coastal zone have a close relationship to the geological structure, local relief, soil and drainage, and climate. It is distinctly different to that of the western and southwestern coasts specially due to climatic conditions and drainage patterns.

The coastal lowlands are covered by barren lands mainly of sand dunes. Medium sized dunes are 15 - 20m in height and they are active and migratory. Such areas were not studied in detail as they are not relevant to the study. Most of the dunes are covered by creeping vegetation as well as stunted trees such as *Spinifix littorerus* and *Ipomoea pescaprae* and scrublands (*Cassia auriculata* - Ranawara, *Feronia limonia* - Divul, *Dichrostachys cinerea* - Andara, *Carissa spinarum* - Karamba etc.). Among the trees scattered within the scrublands are *Manilkara hexandra* - Palu and *Nerium odorum* - Veera. The wet lands behind the sand dunes are occupied by mangroves along the estuary of the Walawe ganga and around lakes and lagoons.

Salt-pans, salt and brackish water lakes of the area are subjected to daily tidal flows. *Sonneratia alba* (Kirilla) is the dominant mangrove species of the area. Among other important mangroves are *Nypa fructicans* - Ginpol (which extend along the edges of lagoons and tidal creeks), and the *Rhizophora*, *Bruguira* and

Ceriops sp. Lowlands which are slightly above the mean high water spring level appear as freshwater marshes. Brackishwater and freshwater marshes are occupied mainly by *Typha angustifolia* (Hanmbupan) along the lower part of the Walawe basin (Katupotha 1992a).

The undulating and low ridge and valley topography (30 - 150m), behind the coastal lowlands are covered by sparsely used croplands, homesteads and chena cultivation as well as by dry zone thorny forests. The paddy lands have been concentrated in the fairly wide valley bottoms such as the area to the south of the Ridiyagama Tank and the area north of Angunakolapalessa.

Field investigations indicated that flat valley bottoms and water logged areas are barren lands with different types of vegetation, viz. scrublands, mangrove fringes, salt marshes (in salt-pans), brackishwater and freshwater marshes (in flat and flat to slightly undulating terrain). Croplands, homesteads, chenas in dry zone thorny forests and paddy lands are evident in wide valley bottoms. However, the concentration of gem-bearing gravels are mainly limited to scrublands, thorny forests and barren lands.

CHAPTER THREE - GEM AND GEMSTONE

3.1 Gems and gemstone

Gem is a mineral or organic substance that is cut and polished and used as an ornament. The qualities sought in gems are beauty, rarity, and durability. The unit of weight used for gems is the metric carat (200 mg). Gems are usually cut to bring out their color and brilliance and to remove flaws.

Gems can be grouped into several categories using different criteria:

(a) The precious stones are diamond, some forms of corundum (e.g., ruby and sapphire) and emerald

(b) The chief semiprecious stones include amethyst, aquamarine, garnet, jade, moonstone, opal, quartz, topaz, tourmaline, and turquoise

(c) The organic gems are amber, coral, pearl, and jet

(d) The synthetic gems produced by using the chemical elements of natural stones and includes diamonds, emeralds, rubies, and sapphires

3.1.1 Popular gems

The most popular and, therefore, the most important commercial gems include diamond, ruby, sapphire, emerald, and pearl. The ***Diamond*** (at 10 on Mohs' scale, the hardest of all known substances) is a mineral and one of two crystalline forms of the element carbon. It is the hardest substance known, and inferior stones are used as abrasives, in certain types of cutting tools, and as phonograph needles. Gem diamonds were first found in stream beds in India and in Borneo; many are now extracted from volcanic pipes in South Africa. Russia and Angola are also important producers. Famous diamonds include the Koh-i-noor, now among the English Crown jewels; the Cullinan, from which 105 stones were cut; and the Blue Hope diamond. Synthetic diamonds, produced since 1955, are now widely used industrially. Though most highly prized when colourless, diamonds can be yellow, blue, pink, or other colours.

Corundum is an aluminum oxide mineral (Al_2O_3) occurring in both gem and in common varieties. ***Ruby*** is coloured red by traces of chromium; the various colors of ***Sapphire***, however, are produced by traces of iron and titanium in the corundum. The ruby gem of the transparent red variety of corundum is found chiefly in Burma, Thailand, and Sri Lanka. Star rubies (showing an internal star when cut with a rounded top) are rare. Synthetic rubies are produced by fusing pure aluminum oxide. The sapphire gem is a transparent blue variety of corundum, found chiefly in Thailand, India, Sri Lanka, and Burma. Like rubies, some sapphires show an internal star when cut with a round top. Synthetic stones are made by fusing aluminum oxide, with titanium oxide added for color. The transparent gems, chief of which are ruby and sapphire, are colourless, pink, red, blue (oriental aquamarine), green (oriental emerald), yellow, and violet. Common varieties are used as abrasives (e.g., emery) and are blue-gray to brown in colour. Corundum is found in North Carolina, Georgia, Montana, Republic of South Africa, and Tanzania. The best gem corundum is found in Sri Lanka and elsewhere in Asia at places such as Mogok in Upper Burma, near Bangkok in Thailand, and Kashmir in India.

Beryl is an extremely hard beryllium and aluminum silicate mineral ($Be_3Al_2Si_6O_{18}$), occurring in crystals that may be of enormous size and are usually white, yellow, blue, green, or colourless. Beryl gets its colour from traces of chromium and a little iron. Beryl is the principal raw material for the element ***beryllium*** and its compounds. It is commonly used as a gem, the most valued variety being the greenish ***emerald***; the blue to bluish-green variety is ***aquamarine***. The best emeralds are from the Muzo and Chivor mines in Colombia. ***Aquamarine*** is a transparent blue to bluish-green variety of the mineral beryl and is used as a gem. Sources include Brazil, Madagascar, Russia, and parts of the U.S.A.

A typical jewellery store may carry several other kinds of gems: blue to bluish green aquamarine, pink to peach morganite, and other varieties (including those colored yellow green to green) of beryl; the complex borosilicate ***tourmaline***, which may be pink to red (rubellite), blue (indicolite), bright green, or several other colors. Tourmaline, complex aluminum and boron silicate mineral is also used as a gem. Colors are red, pink, blue, green, yellow, violet, and black; sometimes it is colorless. Two or more colors, arranged in zones or bands with sharp boundaries, may occur in the same stone. Tourmalines are found in pegmatite veins in granites, gneisses, schists, and crystalline limestone. Important sources include Elba, Brazil, Russia, Sri Lanka, and parts of the U.S.A.

The aluminosilicate ***topaz*** is straw- or golden-yellow, pink, green, blue, or brown in colour. Topaz is an aluminum silicate mineral [$Al_2SiO_4(F,OH)_2$], used as a gem. Commonly colourless or some shade of yellow, the stone is transparent with a vitreous luster. Topaz crystals occur in highly acidic igneous rocks and in metamorphic rocks. Important sources include Brazil, Siberia, Burma, and Sri Lanka.

Gem varieties quartz (silicon dioxide) include ***amethyst*** (purple), ***chrysoprase*** (green), ***citrine*** (yellow to brown), rock crystal (colorless), and rose quartz; and ***Opal*** is a stone often with brilliant color flashes that is usually dark and white (Australia) or transparent (anywhere from colorless to orange-to-red and found in Mexico). Opal, hydrous silica mineral ($SiO_2 \cdot nH_2O$) is formed at low temperatures from silica-bearing water, that can occur in cavities and fissures of any rock type. Gem opal has rich iridescence and a remarkable play of colors, usually in red, green, and blue. Most precious opals come from South Australia; other sources include Mexico (fire opal) and parts of the U.S.A as well as Sri Lanka.

The name ***garnet*** [Fe,Mg,Ca,Mn)3(Al,Fe,Cr)2(SiO4)3], is applied to a group of silicate minerals. It is used chiefly as gems and abrasives. The most common gem varieties are red, but garnets are also yellow, brown, and green. They are found in many types of rock throughout the world.

Less common gems include the beryllium aluminate ***chrysoberyl***, especially its cat's-eye variety and the fascinating alexandrite variety, which appears green in daylight but appears red in artificial incandescent light; ***garnet***, such as the red Bohemian pyropes and Indian almandines; ***peridot***, a yellow green variety of the mineral species olivine, a magnesium-iron silicate; the magnesium-aluminate ***spinal,*** in its red and mauve varieties; ***tanzanite,*** a sapphire blue variety of the mineral species zoisite, a calcium-aluminum hydroxy silicate; and ***spodumene,*** in its green to yellow green varieties or the beautiful lavender lilac kunzite variety.

Turquoise in a hydrous aluminum and copper phosphate mineral Al2(OH)3PO4.H2O+Cu. This usually found in microscopic crystals, it is opaque with a waxy luster, varying in color from greenish gray to (GEM-quality) sky blue. Because of their porosity, the gem varieties absorb dirt and grease, changing the color to an unattractive green; exposure to heat or sunlight can also harm the color. The finest specimens are from Iran; other sources are the Sinai peninsula and the SW U.S.A.

Serpentine, widely distributed hydrous magnesium silicate mineral ($3MgO \cdot 2SiO_2 \cdot 2H_2O$), formed by the alteration of other minerals or rocks containing magnesium. Usually green, it may also be reddish, yellowish, black, or nearly white. It is sometimes used as a gem; massive varieties are used like marble for decoration, although they are too easily damaged by exposure to be used for exteriors. Fibrous serpentine (chrysotile) is a commercial asbestos.

Numerous other good gem species are sometimes available for collectors, including ***cordierite, sphene***, and ***alusite, benitoite,*** and ***euclase***. Ornamental gemstones, beautiful but not suited for fashioning into transparent cut gems, include ***coral***, ***nephrite*** and ***jadeitejade, jet, lapis lazuli, malachite, rhodonite,*** and various varieties of quartz including ***agate, jasper***, and ***carnelian***.

Feldspar is a group of potassium-sodium-and calcium-aluminum silicate minerals ($KAlSi_3O_8$, $NaAlSi_3O_8$, and $CaAl_2Si_2O_8$) and their isomorphic mixtures. The three pure members are called orthoclase, albite, and anorthite. As constituents of crystalline rocks, the feldspars form much of the earth's crust. Pure feldspar is colourless and transparent, but impurities commonly make it opaque and colourful. Potassium feldspars are used in making porcelain and is a source of aluminum in making glass. The plagioclase feldspars (those ranging in composition from albite to anorthite) are commonly gray and occasionally red. ***Moonstone*** is a gem variety. Moonstone found in Sri Lanka, Burma, and Madagascar and is used as a gem. The refraction of light by its thin, paired internal layers causes its milky, bluish sheen.

Jasper, opaque, impure ***chalcedony***, usually red but also yellow, green, and grayish blue is also used as a gem. Ribbon jasper has colours in stripes. Bloodstone or heliotrope, green ***chalcedony*** spotted with red is used as a gem. It is found in India, the U.S.A., Brazil, and Australia. Lapis lazuli is a gem composed of lazurite and other minerals in shades of blue, and usually flecked with ***pyrite***.

Most often it is found in massive form in metamorphosed limestone and it has been used since ancient times for beads and small ornaments. Lapis lazuli was the original pigment for ultramarine and was the “sapphire” of the ancients.

Malachite in a green copper carbonate mineral Cu2CO3(OH)2, found in crystal and, more commonly in massive form. It is used as a gem, a copper source, and, when ground as a pigment. It occurs associated with other copper ores in the U.S.A, Chile, Russia, Zimbabwe, Zaire, and Australia.

Fine ***pearls*** are the products of only a certain genus of oysters, Pinctada, which deposit layers of pearl over irritants that have got inside their shells. It is a hard, rounded gem formed by certain bivalve mollusks, particularly the pearl oyster and the freshwater pearl mussel. In response to an irritation caused by a foreign object such as a parasite or a grain of sand within the shell, the mantle (specialized layer of tissue between the shell and body mass) secretes layers of calcium carbonate, identical in composition to mother-of-pearl, around the object. In several years, a pearl is formed. Pearls vary in shape (from round to irregular) and colour (white to black). Cultured pearls, mainly from Japan, are produced by placing a small bead in the mantle of an oyster.

3.2 Gem deposits of Sri Lanka

Sri Lanka is well known for a variety of gems and gemstones. Geological investigations pertaining to the major gem-bearing areas of Sri Lanka have shown that the gem deposits are controlled by the geological structure (Mendis *et al*., 1993). Ninety percent of Sri Lanka is underlain by Precambrian metamorphic rocks and divided into three major divisions namely the western Vijayan

Complex (Wanni), Highland/southwestern Complex and eastern Vijayan Complex (Cooray, 1984; Herath, 1984; Kroner *et al.* 1991). The rocks of those complexes are closely associated with one another in an inter-bedded relationship. The charnockites are the prominent group of rocks in the Highland Complex and most of the gem-bearing deposits in Sri Lanka are confined to the Highland Complex, particularly Southwestern Complex. The largest gem deposits in the country are located in this complex especially in the areas of Awissawella, Balangoda, Kahawatta, Rakwana and Ratnapura. Out of the Southwestern Complex, Elahera, Okkampitiya and Hasalaka are the other high potential gem fields in Sri Lanka (Mendis *et al*., 1993).

The sedimentary gem-bearing deposits in Sri Lanka are classified into three types: residual, eluvial and alluvial (Dahanayake *et al.* 1980). The residual beds related to gem-bearing deposits are mostly concentrated *in situ* whereas eluvial beds have gem minerals transported along slopes of ridges deposited away from the parent rocks. Depending on location with respect to the micro-relief of the hill slopes and the flat areas cut into by valleys, the eluvial deposits often pass imperceptibly into the alluvial deposits. Most of the alluvial gem minerals transported along streams are deposited at a greater distance from the parent rock. Dissanayake and Rupasinghe (1995a) classified the regional-wise gem deposits in Sri Lanka from a petrological and structural point of view (Table 3.1). This table indicates that the economically valuable gemstones of the corundum group are distributed in sedimentary, metamorphic and magnetic deposits.

Dissanayake and Rupasinghe (1993a & 1993b) classified gem-bearing areas as highly probable, probable and moderate areas, based on topographic sheets (1:63,360). The authors mention 5.5 percent as highly probable, 4.7 percent probable and 11.9 as percent moderate gem-bearing areas.

The highly probable areas include present, newly discovered and rediscovered gem fields of Elahera, Hasalaka, Bibile, Passara, Moneragala, Buttala, Okkampitiya, Kataragama, Ratnapura, Rakwana, Deniyaya and Morawaka. Current gem-mining activity is centred in the Elahera region which extends from the southern part of the Attanakadawala in Polonnaruwa area to southwest and southwards into Kurunegala, Matale and Rangala areas. The Elahera area has a much larger gem potential than is known at present along the tributaries of the Mahaweli river. Bibile, Passara, Moneragala, Buttala, Okkampitiya and Kataragama areas form a north-south trending major gem field and contain gem-bearing sediments brought in by streams draining the eastern Vijayan Complex boundary. Ratnapura, Rakwana, Deniyaya and Morawaka gem fields constitute the largest and the best known alluvial gem mining areas in the country.

The mining of gem pits in these areas sometimes extend more than 25 m in depth. The other highly probable areas identified are Embilipitiya in the Uda Walawe region, Ruwanwella in Awissawella area, areas Imaduwa and Matara.

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TABLE 3.1. CLASSIFICATION AND DISTRIBUTION OF GEMS AND GEMSTONES OF SRI LANKA

PETROLOGY	DEPOSIT	AREA	GEMSTONE
	Alluvial	Ratnapura, Rakwana, Balangoda, Opanayaka, Hasalaka, Bibile, Passara, Okkampitiya, Deniyaya	Corundum, zircon, spinal, chrysoberyl, garnet, beryl, tourmaline, topaz, silli-manite and cordierite
SEDIMENTARY	Eluvial	Pelmadulla	
	Residual	Elahera	
	Skarn	Bakamuna	Corundum and spinal
METAMORPHIC	Aluminous Sedimentary	Elahera	Corundum and spinal
	Marble and Syenite	Ohiya	Corundum and spinal
	Biotite-sillimanite	Polgahawela	Corundum
		Meetiyagoda	Moonstone
		Awissawella and Getahetta	Corundum - Pockets and semi-precious stones
MAGMATIC	Pegmatite	Buttala	Beryl & Chrysoberyl, ekanite, garnet, spinal and tourmaline
		Kolonna	Different kinds of Corundum crystals
		Elahera	Chrysoberyl, corundum, garnet, iolite, kornerupine, sinhalite, sphene, spinal, zircon, Topaz, fluorite and tourmaline

Source: Dissanayake and Rupasinghe (1993a & 1993b)

Dissanayake and Rupasinghe (1993a) describe the probable areas as those areas in the vicinity of Elahera around the Attanakadawala and Pallegama and Rakwana-Ratnapura gem fields. The southeasterly trending of Kuda Oya and Kirindi Oya basins contain gem sediments stretching from Wellawaya across to

Tissamaharama. Other such probable areas are the hills and valleys around Maskeliya, Hatton, Welimada, Boralanda and Bandarawela. The upper catchment areas of the Walawe Ganga particularly Godakawla and Uda Walawe are the other potential regions of valuable gem-bearing deposits.

The moderate areas consist of regions that border the more probable ones and where the geomorphic conditions are suitable for the accumulation of gemstones. Accordingly Dissanayake and Rupasinghe (1993b) state that the stretch from Ruwanwella to Hambantota across Matara, the southwest part of Sri Lanka is best classified as “moderate”. Agalawatta, Hiniduma and Udagama areas comprise such tracts of land. The southern areas at Okkampitiya and Buttala, tributaries of Menik Ganga, tributaries of Mahawela Ganga at Hanguranketa, Minipe, Mahiyangana and Hasalaka regions have useful gem-bearing formations.

The occurrence of the gem minerals in the study area of the coastal zone of Hambantota district is a moderate probability. The land surface of the highly probable, probable and moderate is 1.4, 10 and 170 sq km respectively in the Ambalantota topographic sheet. The field survey emphasises that they are concentrated in lagoon beds, stream channels and crests of the undulating surface as sedimentary deposits (Figure 2.1).

3.3 Gem minerals and gemstones of Sri Lanka

Sri Lanka has a variety of gems such as sapphires, rubies, spinals, garnets, tourmalines and other valuable gemstone have been recovered from stream valley sediments for centuries. The discovery of gem deposits in Sri Lanka is still based on the *hearsay* method of gem miners. However, Rupasinghe *et al.* (1994) has summarised source of the applications of scientific techniques used in gem exploration in Sri Lanka. Further, the authors have discussed electron microprobe analysis of 201 rock samples yielding 435 determinations from gem bearing granulite terrain of Sri Lanka as a potentially useful method of gem exploration.

Rupasinghe *et al.* (1994) states that in view of the indication that Ca-rich rocks could also be a probable rock source of gem minerals in Sri Lanka, special attention should paid to the Ca- and Mg-rich minerals of the rock types. Among the other probable sources are pegmatite and Al-rich high-grade metamorphic rocks. Mg-rich ilmenite, geikielite, Mg-rich spinal, Ca-rich scapolite, Ca-Mg. pyroxcene (salite), Ca-rich garnet (grossularite) and mineral containing REEs such as spene, davidite and monazite show as good indicator minerals of gems. Furthermore, the authors emphasised that even low-quality corundum and spinals could be considered as indicators through these means.

Some important gemstones in Sri Lanka have been described by Rupasinghe (1995). Based on the hearsay method and scientific methods a wide range of gemstones have been found in the country. Coomaraswamy (1903), Wadia and Fernando (1944), Wells (1956), Cooray and Kumarapeli (1960), Hapuarachchi (1989) and many researchers have described the occurrence, distribution, petrogenic significance, geophysical and geochemical properties pertaining to the gem family, corundum. *Ruby*, *sapphire* and *geuda* are the main gem varieties of the mineral corundum. Colour quality is very important to rubies and sapphires. A wide range of red to pink and red to reddish violet rubies are found in Sri Lanka. The “hotpink” quality pink sapphire in the ruby group is also found in Sri Lanka.

Sri Lanka produces very fine blue to blue star sapphires. The best quality is very similar to the famous Kashmir blues. The lighter blue sapphires in Sri Lanka have a high brilliancy. The asteriated stones are usually grayish blue displaying unusual “double stars” (two stars in one stone). It is very rare, but has been reported in Sri Lanka.

Besides rubies and blue sapphires, Sri Lanka produces fine yellow, golden yellow, violet sapphires. Some light pink rubies irradiated to produce a pinkish orange *padmaraja* colour have been reported. Geuda is a low gem-quality corundum. It can be changed to a blue or yellow sapphire by heat treatment. Historical documents and folk-tales indicate that huge corundum stones (weight in carat - 563 or more carat) have been reported in Sri Lanka, but some of them are in foreign museums.

Alexandrite and *chrysoberyl* cat's eye belong to the mineral chrysoberyl. Brownish, yellow and green cat's eye are the most common in Sri Lanka, while alexandrite cat's eyes are the most rare and expensive gemstones. Rakwana and Morawaka areas are famous for the chrysoberyl. Topaz is generally colourless. Topaz mineralisation is due to a high concentration of fluorine. The topaz enhancement is a combined treatment process that develops a bright blue colour. Topaz is irradiated first in a nuclear reactor, and then heat-treated. Matale is the most famous area for topaz mining.

Moonstone is the most valuable among the feldspar gems. A famous moonstone deposit is located in Meetiyagoda, Galle district. Moonstones are mined from kaolinised feldspar-rich pegmatite. Smoky moonstones with attractive blue shiller, has recently been found in Imbulpe in the Ratnapura district. Moonstones with a very white shine were found near Embilipitiya.

Two types of *beryl(aquamarine and emerald)* are found in Sri Lanka. The aquamarine gem deposits are from Kegalle and they are also present in the Horana, Rakwana, Morawaka and Matara areas. Although emeralds were not reported in Sri Lanka, recently emeralds were discovered in the Hambantota area. Emerald gem pits in this area are not very deep - about 70 cm below the surface, and is situated not far from the sea.

Based on literature and hearsay evidence, the significant gem minerals discovered in Sri Lanka are summarised in Table 3.2. The mineral *serendibite* is rare and can be mistaken for sapphire. The *sinhalite* occurs with serendibite in the layers in the contact zone between crystalline limestone and intrusive granite. The colour varies from pale brown, greenish brown to dark brown. The gemstone *ceylonite* is a type of spinal black in colour. It was identified for first time in 1952. The gem mineral taafeite is occasionally found in alluvial deposits in the Eheliyagoda and Ratnapura areas. The red variety is rare and has a high value.

The *ekanite* is a green translucent water-worn stone. This radio-active mineral was first discovered and identified in 1961 by F.L.D. Ekanayake. *Matara diamond* is common zircon gemstone of Sri Lanka. The colours range from colourless to pale-yellow or green. *Uvite* is a kind of tourmaline of dark colour and is commonly found in the Uva province. Brown, green, black and bicoloured tourmalines are also found in Sri Lanka.

TABLE 3.2. SIGNIFICANT HEREDITARY GEM MINERALS OF SRI LANKA

MINERAL	CHEMICAL COMPOSITION	LOCALITY	PARENT ROCK
Serendibite	Ca2(Mg,Al)6(Si,Al,B)6O20	Gangapitiya	Crystalline limestone
Sinhalite	MgAlBO4	Elahera and Awissa- sawella and Rathna-pura (occasionally)	
Ceylonite	MgAl2O4	Elahera	Sedimentary deposits
Taprobanite	Mg3Al8BeO16	Eheliyagoda and Rath-napura	Alluvial deposits
Ekanite	ThCA2Si8O20	Ratnapura, Rakwana and Passara	
Matara diamond	ZrSiO4	Common	
Uvite	WX3Y6(BO3)3Si6O18	Uva Province	Sedimentary deposits

Source: Rupasinghe, M.S. 1995

CHAPTER FOUR - GEOLOGIC AND ECONOMIC SIGNIFICANCE

4.1 Gems and gemstones in the study area

The field survey was conducted in several locations to examine the geological and economic significance of gems and gemstones in the study area. Three approaches that were used to identify gemstones and gem minerals are as follows:

(a) visits to current operating sites

(b) collection of samples from profiles of road-cuts, dug pits and sub-surface gravel deposits of gullies

(c) collection of samples from road-cuts, dug pits and mining areas for microscopic analysis

Visits to current operating sites

The economically valuable and common hereditary gemstones in current mining sites and their common features are given in Table 4.1 and 4.2.

Six places, namely Chitragala-Tankiwala, Goyamkolamulla, Kapuwatta, Mirijjavila, Telijjawila and the cemetery (Sisilasagama) are the main current gem operating sites. All these places are state lands. The lands at Goyamkolamulla has been auctioned by the Government in 1995 for gem mining, but in other places illegal mining is in progress. Gem mining at Mirijjavila and Rotalawewa is also conducted on state land and is illegal. All these places are located in former lagoon edges (beach) and lagoon beds.

TABLE 4.1 SIGNIFICANT HEREDITARY GEMSTONES OF THE CURRENT GEM MINING PLACES

GD DIVISION	LOCALITY	GEMSTONE
Sisilasagana	Chitragala -Tankiwala	Cat's eye, chrysoberyl, blue sapphire, ruby, garnet, zircon, tourmaline
Sisilasagama	Kapuwatta	Chrysoberyl, geuda, cat's eye, blue sapphire and other stones
Sisilasagama	Goyamkolamulla	Cat's eye, blue sapphire, ruby, chrysoberyl
Sisilasagama	Cemetery	Cat's eye, blue sapphire, ruby, chrysoberyl
Mirijjavila	Lagoon reservation	Cat's eye, ottu, geuda, blue sapphire and dalan
Telijjavila	Crown lands	Cat's eye, ottu, garnet, blue sapphire

Source: Field investigations

TABLE 4.2 COMMON FEATURES IN EACH MINING PLACE

LOCALITY	NATURE OF THE LAND	DEPTH (in metres)	EXTENT (in hectares)
Chitragala -Tankiwala	Crown lands	5	6 - 7
Kapuwatta	Crown lands	3	1 - 2
Goyamkolamulla	Auction lands	2 - 3	25
Cemetery (Sisislasagama.)	Crown lands	1 - 2	3
Mirijjavila	Crown lands	2 - 3	3
Telijjavila	Crown lands	5 - 6	6 - 7

Source: Field investigations

Collected samples from profiles of road-cuts, dug pits and sub-surface gravel deposits of gullies

Collection of samples from profiles of road-cuts, dug pits and sub-surface gravel deposits of gullies was undertaken at the following locations: at Udamamala, Ridiyagama Farm (left side on the way to the Walawe Dam), on the way, in front of the Farm and Mahalewaya. Most of the areas are undulating crests. They are covered by dark-reddish and dark-brown soil, ironstone gravel and quartz pebbles.

Collected samples from road-cuts, dug pits and mining areas for microscopic analysis

Microscopic analysis was carried out on several samples collected from road-cuts, dug pits and mining areas. Samples were collected from undulating crests as well as from lagoon beds at Godawaya, Gapothumulla, Kattakaduwa, Mahajjawa, Mirijjavila and Siribopura and the details of the sites are mentioned in Table 4.1.

Macro level and microscopic analyses of the samples indicate that precious (cat's eye, chrysoberyl, blue sapphire, ruby, ottu, geuda) and semiprecious gemstones mainly consist of green & honey tourmaline, spinal, topaz and garnet (for further details see 4.2).

4.2 Geologic significance

In the identification of gems and gemstones at macro level and gem minerals at micro level, geophysical and geochemical analyses as well as past experience are very significant. Dissanayake *et al.,* (1993) described that when identifying an area with high gem potential five methods are important:

(a) Traditional method

(b) Interpretation of topographic and aerial photographs

(c) Field observations on bedrock

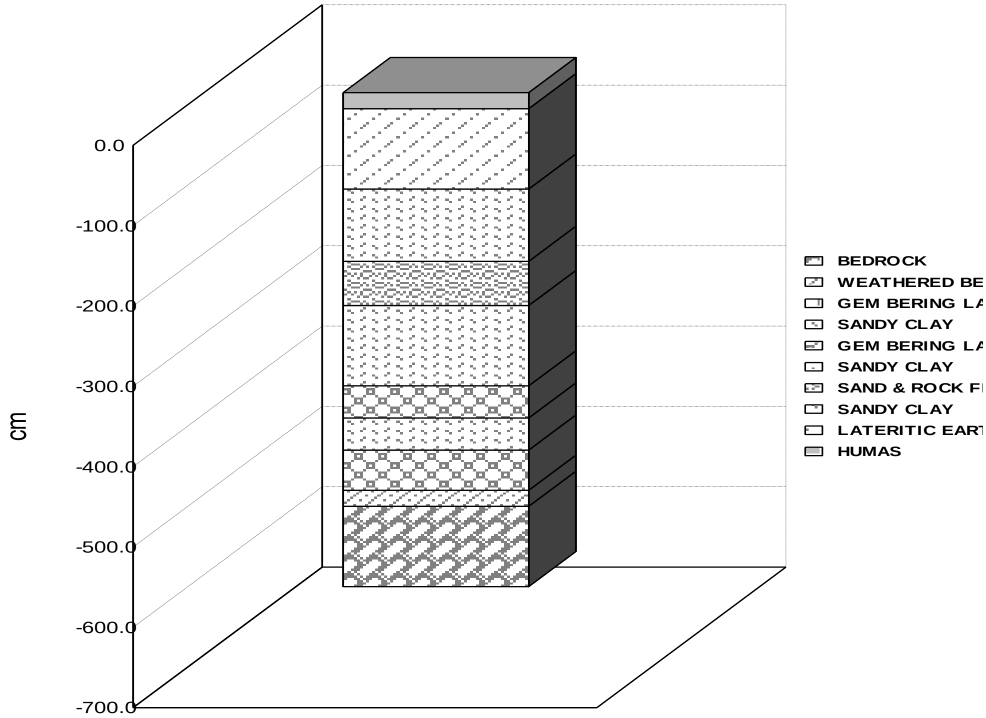
(d) Observation of heavy minerals in stream sediments

(e) Interpretation of geochemical data

The traditional gem miners have learned to locate gem deposits by direct participation in mining. Written literature is not available pertaining to this method, but it is done in a systematic way by considering the geologic characteristics of the gem-bearing zones. Geologic characteristics include distance to earlier mining sites, topography, surface structure, sequence of the gem-bearing beds *(illama)* and the underlying decomposed rock layer *(malawa).*

Geologically, the decomposed layer is very significant in the traditional method. It is in the underlying, the lowest gem-gravel beds where there is more than one gem-bearing layer. The dip of the surface in particular helps to locate the thickness and the abundance of gem-bearing layers (Dissanayake *et al.,* 1993). Geologic sequence of the typical gem pits have been described by Wadia and Fernando (1944), Deraniyagala (1958), Cooray (1972) and others. Sketch sections of selected areas are illustrated in Figure 4.1.

Dissanayake *et. al.,* (1993a & 1993b) further describes that it is possible to locate the presence of an abundance a heavy minerals by using contour lines as an indicator. Regions of high concentration of heavy minerals are obvious targets for the exploration for gems, but delineating the target areas and narrowing them down further needs additional ground surveys. *In-situ* and alluvial gem deposits of folds and valleys, folds and within the faults zones and tectonically highly disturbed areas can be located by using structural maps. *In-situ* and residual gem deposits in the working areas normally occur in association with the axial planes of synclinora/antilicnora structures, fault zones and lineament zones (Dissanayake *et al.,* 1993; Mendis et. al., 1993).



Source: Dissanayake *et. al.*, (1993)

Figure 4.1 Geologic sequence of an alluvial gem deposit in the Ratnapura area

Geochemical drainage surveys have been developed from this practice to tracing heavy minerals in stream gravels. Geochemical analysis of the heavy mineral fraction often emphasises the anomalous concentration of geochemically immobile elements such as Au, Sn, W, Hg, Ta and Nb (Gold, Tin, Wolfram, Mercury, Tantalum and Niobium).

Anomalous concentration of rare earths and rare elements, fluorine-bearing minerals, Rb/Sr ratios of stream sediments have been used in geochemical analysis to explore gem deposits of Sri Lanka (Gamage *et. al.*, 1992). Accordingly, physical characteristics of the minerals, geologic structures that favour accumulation of alluvial gem deposits, structural features that are conductive to *in-situ* gem formations and geophysical surveys and geochemical analysis can be used separately or together in the exploration of gems and gemstones.

Gem mining of coastal deposits in selected areas is undertaken mainly in alluvial areas. Therefore, samples from current gem-pits, road-cuts and dug pitsfor macro-level examination and microscopic analysis were collected from the lower flood plain of the Walawe basin and other streams. As mentioned in Chapter 2, morphologically these areas are located in flat terrain, flat to slightly undulating and undulating terrains. Soils of these areas are covered with Reddish Brown Earths with a high amount of gravel in subsoil and Alluvial Soils of variable drainage and texture.

4.2.1. Geological significance of gem-bearing deposits in the study area

To discuss the geologic significance of gem-bearing deposits in the study area, attention was focused on current operating sites and on other gem-bearing gravel deposits of undulating crests.

A typical gem pit at Sithrakala Lewaya between Ambalangoda and Hambantota is shown in Plate 4.2.1. This pit was about 2.5m in depth. The top layer was about 40 cm in thick and contained brownish clay and sand. The second layer showed that it was light brown and grayish in colour (1.10m in thick). Fine to coarse quartz sand and clay are contained in the soil. Brown fine to coarse quartz sand gravels with clay are appeared in the third layer (about 50 cm in thickness). This layer was somewhat compact. All these layers have been formed by flowing of terrestrial and tidal waters. The fourth layer was bluish in colour. Fine to medium quartz sand as and clay are contained in the soil. This should be a lagoon deposit in origin. The alluvial gem gravels *(illama)* are found underneath of this layer. When we visited to the site, the miners had not broken the *illama*.

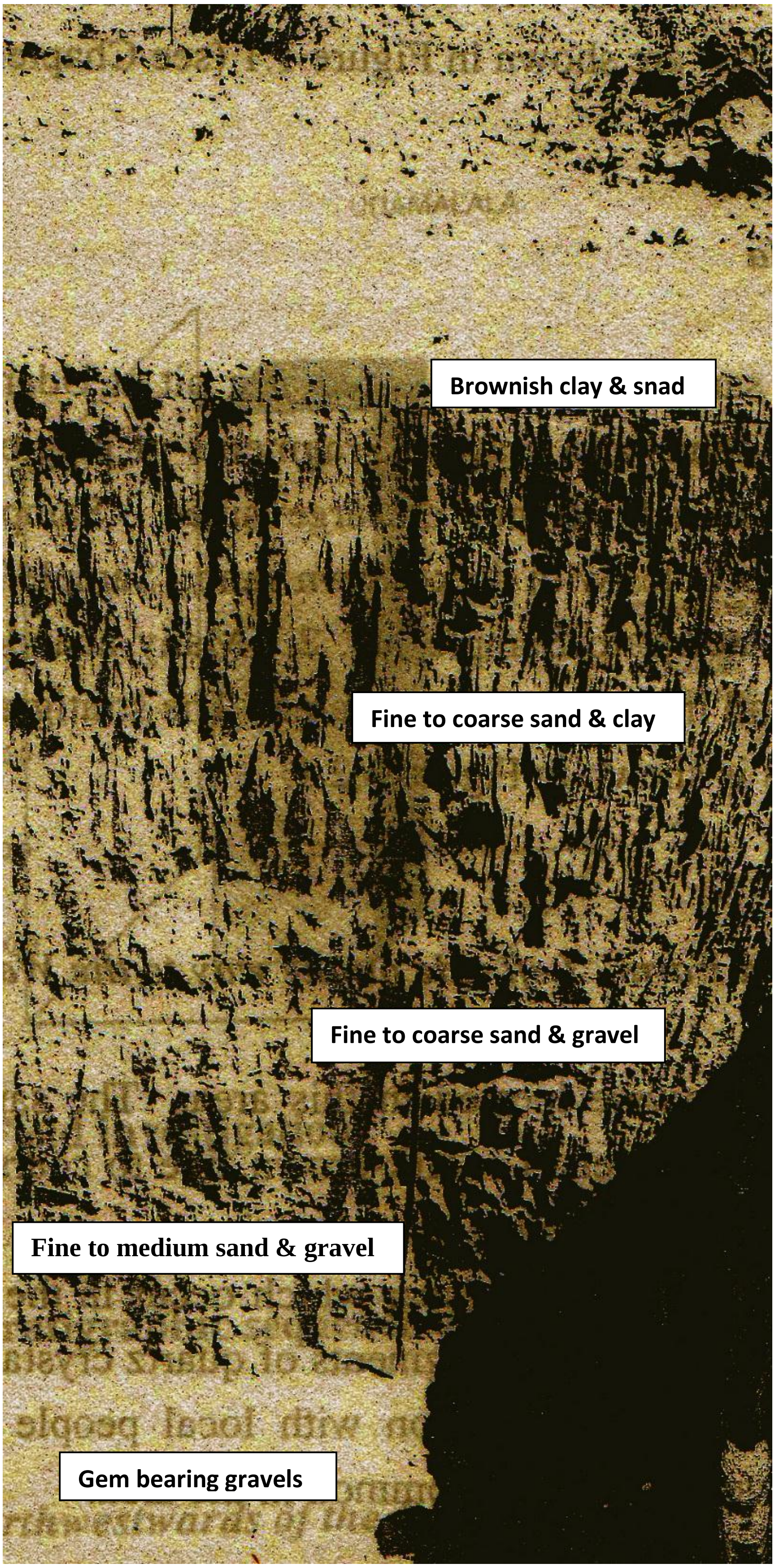


Plate 4.2.1 A typical gem pit at Sithralaka Lewaya between Ambalangoda and Hambantota.

Geology of the samples collected for macro level investigation

Ten samples from six locations were collected for macro analysis. All the locations mentioned below are shown in Figure 1.1 (see Chapter 1).

Location 1 - Udamalala

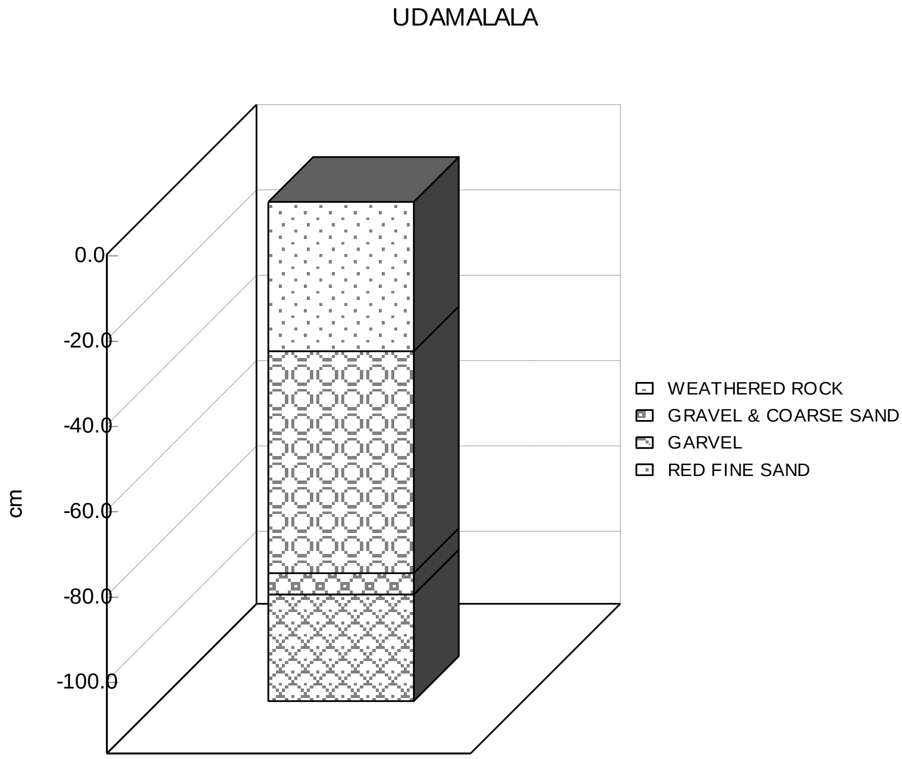
Three dark-brown soil samples were collected at a pit at Udamalala. Sample No. 1 contained quartz sands and gravel. Fragments of plagioclase feldspar, 2-3 mm in size were found but not of large sizes. Sample No. 2 was composed of ironstone pebbles with dark-brown sand. Sample No. 3 was also composed of similar material to Sample No. 2. Many abandoned gem pits were found in the site and in the neighboring area. The stratigraphic sequence of the collected samples is shown in Figure 4.2.1.

Location 2 - Ridiyagama Farm, Left side on the way to the Walawe dam

Many abandoned gem pits were located in this area. The sample sites are shown in Figure 1.1 (see Chapter 1). Dark-brown fine to coarse quartz sand gravels and of small size (ironstone) are contained in the soil. It also continued fragments of plagioclase feldspar which occur in the area and was uncommon in the observed samples. Fragments of quartz crystals and garnets (dead-stones) were also found. Discussion with local people revealed that chrysoberyl, ruby and blue sapphire are common in the area.

Location 3 - Ridiyagama Farm (left bank of the Walawe dam)

Coarse quartz sands, ironstone pebbles with plagioclase feldspar fragments were commonly found in dark-brown soil. Parts of quartz crystals were also found and local people stated that crysoberyl, ruby and blue sapphire are also present in the area.



Source: Field investigations

Figure 4.2.1 Stratigraphic sequence of a soil pit at Udamalala

Location 4 - Northwestwards of the Ridiyagama tank

The undulating crests of the area are covered with gravel deposits. Gullies have developed on these crests due to the heavy seasonal rainfall. In many places, sandy and gravel horizons can be differentiated clearly. Parts of quartz crystals and fragments of plagioclase feldspar of 3 - 5 mm in size were mixed with angular quartz gravel and coarse sands. Abandoned old gem pits in the area revealed that mining activities have taken place on a large scale at one time.

Location 5 - Mahalewaya, Sample No. 1

The soil in the area is brownish-black in colour and contains coarse sand and ironstone gravel. Fragments of clear quartz and smoky quartz in the area are also common. In this area, many abandoned mined gem pits indicate that gemstones were present

Location 6 - Mahalewaya, Sample No. 2

The soil in this location is dark-brown in colour. Angular quartz gravel, 3 mm or more in size were found. The availability of clear quartz fragments and parts of crystals indicate that the area is rich in semi-precious gemstones.

Field evidence makes it clear that the abandoned mining pits, piles of gravel thrown from pits (quartz pebbles and ironstone gravel), unwashed gravel piles (illam) at the above mentioned sites are rich in different kinds of gemstones.

Geology of the samples collected for microscopic analysis

Microscopic analysis was conducted on several samples collected from road-cuts, dug pits and mining areas. The microscopic analysis shows that semiprecious gemstones mainly consist of green & honey tourmaline, spinel, topaz and garnet. Minerals of corundum family are rare, locally concentrated gold dust was also noticed. The results of the microscophic analysis are shown in Table 4.2.2.

Sample No. 1. Godawaya

The sample collected at Godawaya is located very close to the sea (about 50m from the present coast line). The coastline is fully occupied by *in-situ* rocks and high boulders. Between these rocks and lowlands undulating crests are covered by superficial deposits. The bedrock at Godawaya is overlained by reddish-brown gravels, rock debris and aeolian sands. Presently a large metal quarry is operating in this place. The bedrock at Ussangoda is overlained by dark-red gravels. Highly weathered garnet crystals are found in bedrock at Ussangoda coast.

Gravels in both places contained weathered gemstones (katta). Microscopic analysis indicates that gem and other heavy minerals such as zircon, rutile, sillimanite, quartz, garnet, monazite, spinal, tourmaline and ilmenite can be found at Godawaya.

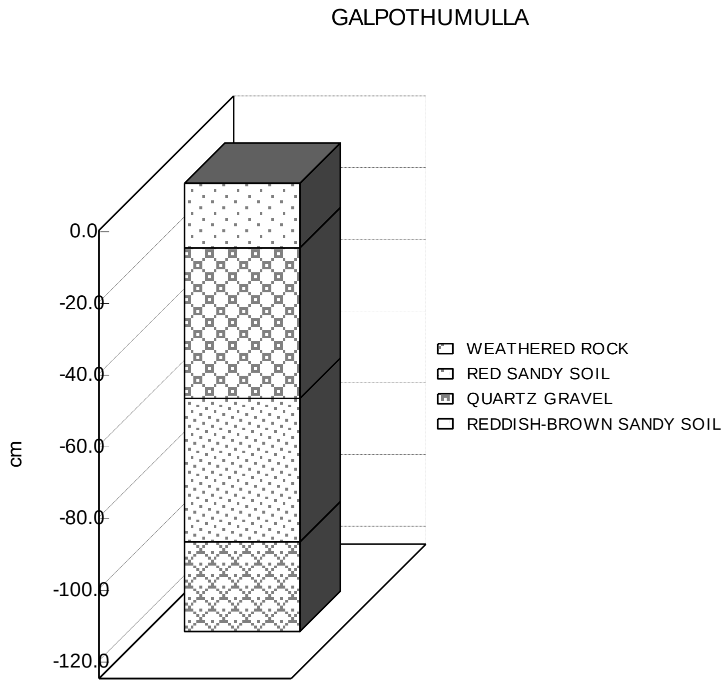
TABLE 4.2.2 HEAVY MINERAL CONTENT OF SOME SELECTED LOCALITIES (MICROSCOPIC ANALYSIS)

Sample No.	Locality	Specific gravity	Types of minerals
1	Godawaya	> 2.9	
	1.2A/5^0 slope/n. mag		zircon, rutile, sillimanate, quartz
	1.2A/5^0 slope/n. mag		zircon, garnet, rutile, sillimanate, quartz
	1.2A/20^0 slope/n. mag		garnet, rutile, monazite, spinal, tourmaline
	0.8A/20^0 slope/n. mag		garnet, ilmenite, rutile
2	Galpothumulla	2.5 medium	zircon, sillimanate, ilmenite, magnetite, spinal, rutile, tourmaline
3	Kattakaduwa		zircon, sillimanate, garnet, magnetite, rutile, tourmaline
4	Mahajjawa		zircon, garnet, ilmenite, magnetite, rutile, spinal (?), corundum (?), hypersthene
5	Mirjjavila		rutile, quartz, zircon, ilmenite, magnetite, tourmaline, feldspar
6	Siribopura		Hypersthene, Zircon, Rutile, Garnet

Source: Field Investigations

Sample No 2. Galpothumulla

Three soil strata can be found at the sample location at Galpothumulla. The top layer consists of reddish-brown soil and is 18 cm thick. The second layer composes of gravel (of thickness between 18 cm and 60 cm). The gravels are below 5 mm in size. Crystal shaped gravel and red soil in the third layer is 40 cm in thickness. Gravels at Galpothumulla, Godawaya and Ussangosa and other areas contained weatherd gemstone graves, and these layers lie on the weathered bed rock. Macroscopic analysis of the sample at Galpothumulla is rich in gems and other heavy minerals like zircon, sillimanate, ilmenite, magnetite, spinal, rutile and tourmaline.



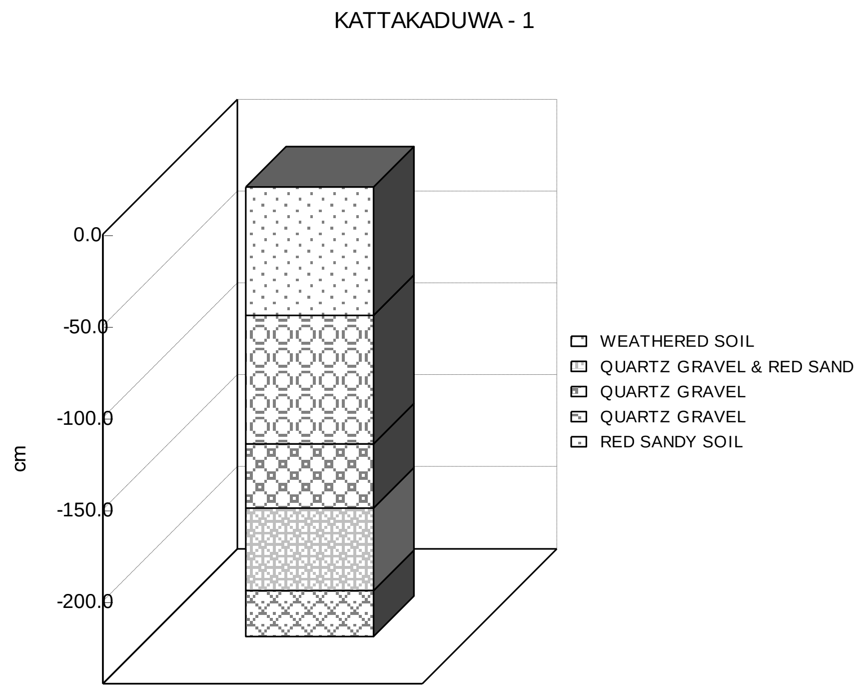
Source: Field investigations

Figure 4.2.2 Stratigraphic sequence of a soil pit at Galpothumulla

Likewise, Quaternary gravel deposits at Ussangoda are underlained on the highly weathered bedrock. The deposit contained gemstone crystals and clear quartz fragments. These deposits are mainly fluvial in origin. As well, highly weathered garnet crystals are found (circled patches) in bedrock at Ussangoda coast.

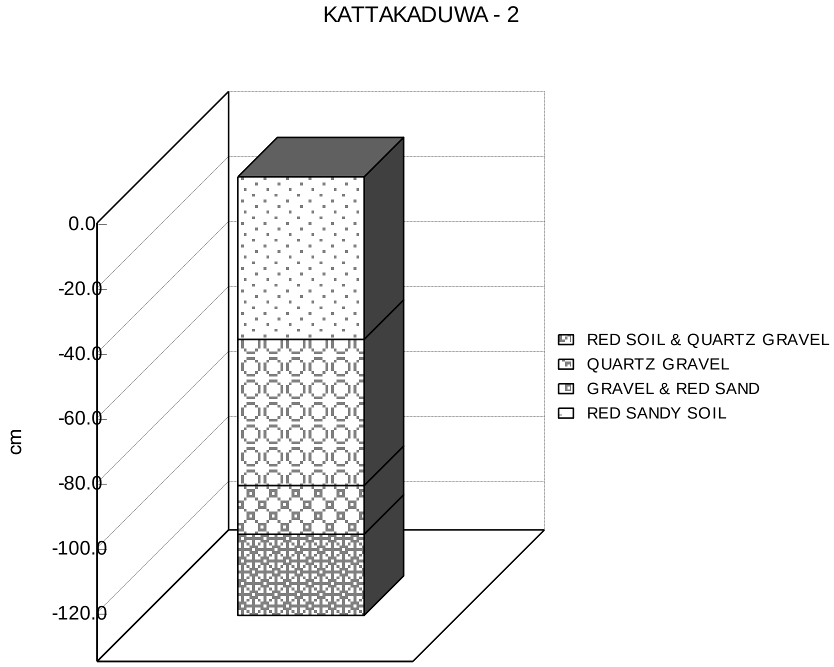
Sample No 3. Kattakaduwa

The area is located on an undulating crest between Hungama and Angunukolapelessa. Samples were collected from two locations for microscopic analysis. The soil profile at location - 1, contains five soil profiles. Reddish-brown top sandy-soil layer is 70 cm thick. The second layer is composed of ironstone gravel. The quartz gravel, between 2 cm and 5 cm in size mixed in red soil. All these layers are underlain on weathered rock. LocationNo. 2 at Kattakaduwa, the top sandy soil layer is 50 cm in thick. The second layer extends up to 95 cm from the end of first layer and contains ironstone pebbles (below 10 mm in size). In this layer, the distribution of quartz pebbles are scattered. Between 95 and 110 cm from the surface, the third layer constitutes quartz pebbles. These pebbles are below 10 mm in size. The exposed lowest layer at the site contains red soil and it is mixed with rough quartz pebbles. The microscopic analysis of the samples at Kattakaduwa shows that zircon, sillimanate, garnet, magnetite, rutile and tourmaline minerals are rich in the area.



Source: Field investigations

Figure 4.2.3 Stratigraphic sequence of a soil profile at Kattakaduwa -1



Source: Field Investigations

Figure 4.2.4 Stratigraphic sequence of a soil profile at Kattakaduwa -2

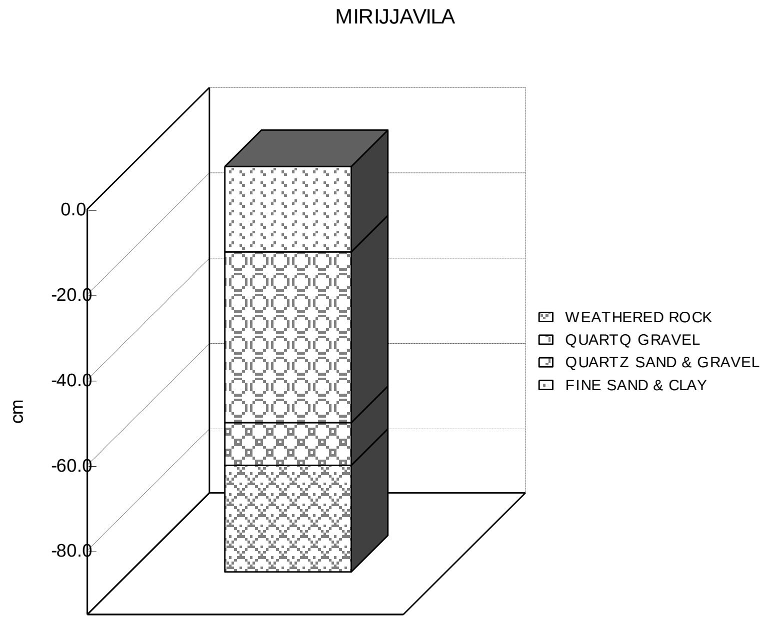
Sample No 4. Mahajjawa

Mahajjawa is located about 4 km to the north from the present coastline (from Wewakanda to Embilipitiya road). Undulating crest of the area is covered by gravel deposits. Due to the seasonal erosion gullies have been developed. Microscophic analysis of the samples collected from these gullies indicates that these deposits are rich in zircon, garnet, ilmenite, magnetite, rutile, spinal (?), corundum (?), hypersthene minerals.

Serial No 5. Mirjjavila

Mirijjavila takes place as a current gem mining site. Many pits are located in at the western and northern edges of the Mirjjavila lagoon. The top layer consists of fine sand with clay. It has 20 cm in thickness. The second layer is constitute from reddish-brown soil with ironstone pebbles. The pebbles are 10 mm in size and the thickness of the layer is 40 cm. The third layer extends from 60 cm to

70 cm and contains quartz and feldspar pebbles (Figure 4.2.2). All these layers are placed on decomposed, weathered bedrock. Cat's eye, ottu, geuda, blue sapphire and other varieties of precious and semi-precious stones can be found at macro level (Plates 4.2.2 and 4.2.3). Microscopic analysis indicates that rutile, zircon, ilmenite, magnetite, tourmaline and feldspar are rich in the area.



Source: Field investigations

Figure 4.2.5 Stratigraphic sequence of a soil pit at Mirijjavila

Sample No 6. Siribopura

Hypersthene, Zircon, Rutile, Garnet are the heavy minerals that was found from a gravel pit on the both sides of Hambantota - Monaragala road.

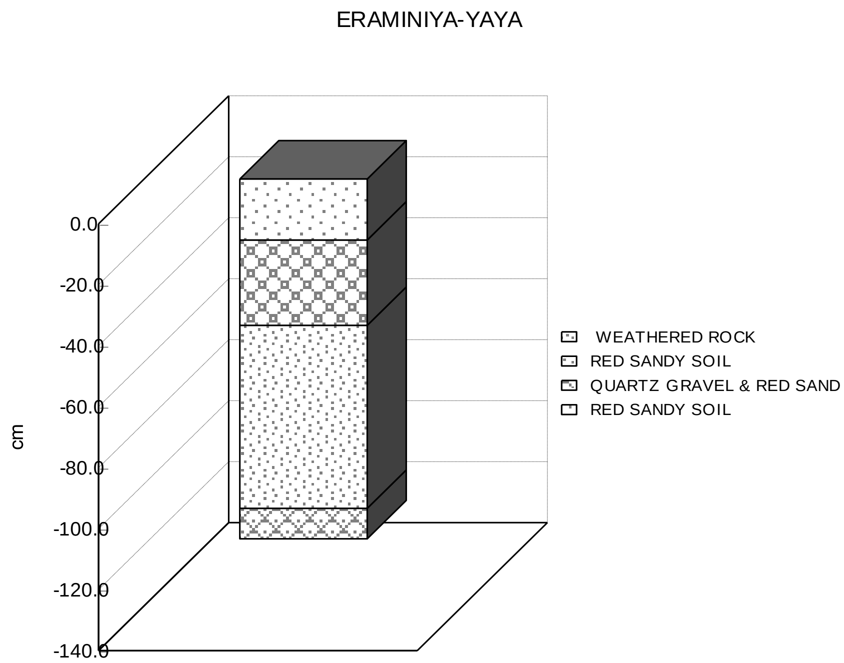
It is very difficult to identify the crystal shape of the fragments due to the roundness in most of the above samples Nos. 1 - 6 even by the microscope. It is possible to infer that these gem minerals have rolled several miles from the Central Highland towards the coastal plain with running water.

Sample No 7. Eraminiya-yaya

The sample area is located on an undulating crest. The quartz gravel mixed with red soil in the Eaminiya-yaya area contains quartz crystals (Figure 4.2.6).The surrounding area (where the sample is collected) has vein quartz on the surface. If these vein quartz are searched carefully, it will be possible to pick some quartz crystals from this place.

Plate 4.2.2. Washing operations and washed gem gravels from Mirijjavila pits. It is necessary to remove the top gravel to find the gemstones

Plate 4.2.3. Washed gemstone pebbles from Mirijjavila pits. Cat's Eye, yellow sapphire, ottu, geuda, spinel and garnet have among these pebbles



Source: Field investigations

Figure 4.2.6 Stratigraphic sequence of a soil pit at Eraminiya-yaya

Based on field investigations, the following observations were made pertaining to the investigated sites:

(a) Although the deposits are not so deep (less than 3 m), they are overlaid by fluvial and wind-blown deposits.

(b) the stone artifacts, clear quartz and chert fragments of the overlying deposits indicate a distinct separate human culture that existed during the period of deposition.

Associated quartz and ironstone gravel of the gem-bearing layers has been deposited as fluvial material under a dry climatic condition during the early and late Pleistocene epochs. Formal and informal discussions held with the inhabitants of the area revealed that:

(a) Open mining pits with stagnant and polluted muddy water provide breeding grounds for malarial and other types of mosquitoes

(b) The muddy water pools act as fatal spots for wild-animals, and sometimes even for people.

The presence of different varieties of gem minerals and gold dust in the slides leads to the conclusion that mining has economic value in spot-localities. The traditional manual mining methods are suitable to obtain gems due to the deposition sequence and concentration of gems. A public awareness programme is needed for sustainable use of the gem-bearing gravel deposits in private and government lands to avoid desultory usage and improper management.

4.3 Economic significance

Out of about 100 gem minerals, only about 20 gemstones are commercially important They include diamonds, emeralds, rubies and sapphires of high quality and size, whose rarity makes them the most costly of all the gems (precious gems); and such other semiprecious gems as, amethysts, opals, garnets, carnelians, and jades.

Throughout history, certain preferences have developed for the choice of one gemstone or another. This choice, reflected in cultural values and commercial price levels for gems, are based on beauty, durability, rarity, and current fashion. The use and value of gems and gemstones is different from person to person and civilisation to civilisation. Accordingly, gemstones are used to ward off evil influences of the planets, are used as birth stones, as jewels and personal ornaments.

Gemstones are used as birthstones and are symbolically associated with the month of one's birth. Many people believe it will bring the wearer good luck or good fortune.

In the Old Testament in the description of the garments to be made for Aaron, the High Priest (Exod. 28:17-21), the breastplate is to carry four rows of three gemstones each; each stone representing one of the twelve tribes of Israel. Various translations of the Bible offer different lists of these stones, and, in any case, what the ancient Jews meant by sardius (in the King James version) was a red stone that might have been ruby, garnet, or carnelian. Topaz could refer equally to topaz quartz or to citrine. Other stones, as well, were identified only by colour, so that sapphire and lapis lazuli were often confused, as were emerald with other green stones and diamond with white sapphire or white topaz.

The New Testament names the foundation stones of the New Jerusalem (Rev. 21:19-21), and although the order of the names is not the same as that in the Old Testament, and the list does not include all of the same names, the New Testament list is believed to be derived from the description of the stones in Aaron's breastplate.

The gems that have traditionally been used as birthstones are listed below. It may be noted that this list and the New Testament list of foundation stones in parallel to one another, if the cycle of months is begun with March. The American National Association of Jewellers adopted their own list in 1912, and today many synthetic stones are also used as birthstones.

The stones have long been associated with particular kinds of luck or talent. The wearer of the blood-red garnet, for example, may be sure of fidelity in love. The purple amethyst is Saint Valentine's stone and in addition protects its owner from drunkenness. The aquamarine imparts courage; the diamond, happiness; and the emerald, Venus's stone, love; the pearl, wealth or health; and the ruby, freedom from care (Grolier multimedia Encyclopedia, 1996).

Gem cutting

Gem cutting is the art of cutting and polishing rough gems in order to transform them into rounded or faceted gems suitable for jewellery. The expert cutting of a gem greatly enhances its value by giving it harmonious proportions and by bringing out to the fullest its luster, brilliancy, colour, and fire. A craftsman who cuts gems is called a lapidarist.

The two major gem cuts are the cabochon cut and the facet cut. The cabochon cut is usually reserved for gems that are opaque (like turquoise), translucent, chatoyant (having a changing colour, like opal), or asterismal (reflecting a star-shaped light, like the star sapphire). A cabochon-cut gem has smooth, curved surfaces. Most gems that can produce a high degree of brilliancy, color, or fire, for example, diamonds, aquamarines, and sapphires receive a facet cut. Facet cutting uses smooth, flat faces, which are cut into the gem at precise angles so that the greatest amount of light is refracted. Some facet-cut gems may have more than 100 facets. The two main facet cuts are the brilliant cut and the step (or trap) cut. The brilliant cut, with its kite-shaped facets, is often used on gems that are round in form, and is almost always used on diamonds. The step cut, which has trapezoidal facets, is reserved for gems that are square in form, such as emeralds and rubies.

A lapidary cuts a gem by shaping it against a grinding wheel, or lap, that is sprinkled with an abrasive powder. Especially hard gems are cut and polished on metal laps that use diamond powder as the abrasive. Diamond faceting was probably developed during the 15th century in the Low Countries; the full brilliant cut was perfected in Venice in the 17th century. Antwerp and Amsterdam have been leading diamond-cutting centres for over three centuries. Since World War II, Tel Aviv and New York City have also become important centers.

4.4 Social and economic background in gem mining area

Detail studies were carried out in the areas of Chitragala pits (Sisilasagama GND), Goyamkolamulla and Kapuwatta pits (Sisilasagama GND), lagoon reservation (Mirijjavila GND) and Rotalawewa (Telijjavila GND). The following table shows that the locational details of the current mining sites (Table 4.3.1).

TABLE 4.3. 1DETAILS OF THE CURRENT GEM MINING SITES

GND DIVISION	LOCALITY	EXTEND (in hect.)	DISTANCE FROM SEA	AVERAGE DEPTH	REMARKS
Sisilasagana	Chitragala (Tankiwala)	6.0	200 - 300m	25 cm - 7m	Illegal mining
Sisilasagama	Kapuwatta	2.0	1.5 km	3m	Illegal mining
Sisilasagama	Akkarapanaha & Goyamkolamulla	more than 25.0	1.6 - 2.0 km	2 - 3m	Auction lands
Sisilasagama	Cemetery	2.0 - 3.0	200m	50 cm - 1m	Illegal mining
Mirijjavila	Lagoon reservation	3 - 4	300 - 400m	2 - 2.5m	
Telijjavila	Crown Lands (Rotalawewa)	3.0	1.5 km	4 5m	Illegal mining

Source: Field investigations

The illegal mining in this area is conducted in state Lands. Selected lands are rarely auctioned and following fees are involved:

(1) auction fee for the land vary between Rs. 3000/= and 7000/=

(2) permit fee Rs. 500/=

(3) deposit fee Rs. 3000/= (filling up of gem pits and mine shafts at the end of the operations

The miners in the area said that they are unable to pay this money as an initial expenditure due to their poverty. However, it is easy to obtain license for private land, if anyone has Jaya Bhumi permit (LL permit). For state lands, the mining license must be obtained from the State Gem and Jewellery Corporation through the DS.

A discussion has held with mining people in all localities. Persons at Chitragala said that a villager from the Embilipitiya area found gem mineral in the soils of from a small pit dug using a memmoty. But those outside Hambantota district believed that it is impossible to locate gems in the Hambantota area and they believed that to make it possible to find gemstones, the gems should be cracked by saltwater. However, a pit of 2 to 3m depth may dug with people from the Kahawatta area and quality gemstones obtained. After that the outsiders started mining operations on large scale within a short period. Persons (women who entered scrublands to collect fire-wood and hunters) sometimes picked up lustred stones from washed out gravel in stream beds. Many of these stones were identified as gems. At the beginning, the earths washed using wicker trays or milk-strainers.

The miners stated that there are no basic facilities for cutting and polishing of gemstones in the area. Only sometimes it will be possible to sell cut and polished gemstones according to their remarkable weight This reason is responsible for sale gems in raw form. Gemstones in the area can easily be sold a credit but the miners said that such money is very difficult to obtain. This reason is the cause for low price of gemstones in the area. If a valuable gemstone is found in a pit, the cunning buyers try to get it at low prices. Such buyers deceive the people stating that the stones are cracked or dead (katta) ones. Therefore, miners try to sell gems outside the area secretly. Sometimes they bring such stones to Guruge Gems or Lakmini Gems for sale. No foreigners visit these areas to buy gems except rarely and purchase small stones.

At the beginning of the mining operation in the area miners lacked experience. The experienced miners and washing operators were from Ratnapura, Balangoda, Pallebedda, Embilipitiya and Kahawatta areas. They tried to get lands at low prices from the local people. After be friending local people, some buyers offer Rs. 10,000/= to 15,000/= and become miners. Many villagers worked as labourers for digging pits. However, during the past twenty years many local miners gained good experience pertaining to mining operations, breaking of gem gravels (illama) and identification of gemstones, but they have no knowledge of cutting and polishing. Except for a few persons (mudalalies) from Chitragala and Mirijjavila there were who became rich from gem-business in the area.

Currently the member of people engaged directly and indirectly in gem mining in the Hambantota district as about 250, but in 10 to 15 years there were 1250 to 1500. Many families in the area have 4 to 6 dependents and, therefore, family labour, including women and children are used for different activities.

If the mining group consists of five persons the shares would be as follows:

(a) For illegal mining in sate lands it is not necessary to pay the license fee land-rent is divided equally. If anyone has a mining permit, for freehold ownership or for state land, he can obtain one-fifth from the total income. For e.g. people of Goyamkolamulla provided their lands expecting one-fifth as land-rent.

(b) If one person spends for the whole operation for e.g. food, water-pump charges etc. he is entitled to receive half.

(c) If any person provides a water-pump including supply of fuel he is entitled to receive one-sixth of a income. Therefore, some miners have keeping own water-pump.

The people said that if Police or Officers of Gems and Jewelry Corporation took into custody the water-pumps, instruments using for washing operations and a tractor (transportation means) in illegal mining, it cause payment of a high penalty plus double transportation fee for owner of the tractor. Because of this reason, miners stated that holding a mining permit is more useful and helpful than illegal mining.

Due to the seasonal dryness in the Hambantota area for nearly 8 to 9 months the water deficit is very high. This reason is responsible for failure of agriculture and drying up of lagoon beds. The closing up of lagoon mouths, especially the Karagan Lewaya, by sand bars act as a barrier against the tide water moving into the lagoons and inland lakes. Consequently the lagoon beds and surrounding undulating crests become highly dry lands (Nelumpatwila and Karagangoda area) and people are unable to continue gem mining operations. This water deficit is adversely attack for washing operations. Likewise, during the rainy season tidal water moves into lagoons and lakes and the lowlands are covered by water thus closing the gem pits and stopping mining activities. Owing to such natural obstructions the miners have a limited period for their activities. Further, people said that due to the low practice of agricultural activities in the area, gem mining provides an alternative source of income to them. If they are unable to get valuable stones, people continue mining as livelihood because they have no other source of income for their family.

They state that the environmental impact through gem mining is very low. However, the field investigation revealed that the threat from mosquitoes is very high during the mining period, but with sea-water entering lagoons and lakes the larvae cannot live and moreover they are swallowed by lagoon fish and water-frogs. Gem gravels brought to that lagoons and lakes to wash cause sedimentation at the bottoms. Furthermore, gravel heaps can be seen in many locations causing infertility of the soil (Plate 4.4.1).

Plate 4.4.1. Infertile soil and gravel heaps are found due to gemminingin the Sithralakala lagoon coast.

4.5 Significance of paleao-climatic changes

Late Pleistocene and Holocene epochs and their events in Sri Lanka

The age of man or the Great Ice Age is designated as "Quaternary". It began ca. 2 million years ago and continue up to the present (Fairbridge, 1968). It comprises two epochs namely; "Pleistocene - Glacial Epoch" and "Holocene - Recent or Post Glacial Epoch. Subdivisions of the Pleistocene and Holocene epochs and its correlation to worldwide glacial and interglacial stages and climatic changes have been identified from pelagic foraminifera of the Atlantic, Caribbean and Pacific deep-sea cores as well as inland deposits by many scientists. Katupotha (1995) summarised these events to correlate with Late Pleistocene and Holocene events and associated deposits in Sri Lanka.

Deraniyagala (1958) regards the heavy tectonic actions such as faulting, tilting, dislocation and block hosting which occurred during the Pleistocene period as having caused the mixing of fossils of different ages to occur in gem bearing deposits of Ratnapura. The eustatic and the climatic sequences of the Pleistocene period are also identified on the basis of faunal elements from middle Pleistocene to Holocene. Accordingly 'Ratnapura Stages I and II appeared in the middle Pleistocene and 'Ratnapura lll' and 'Bellanbendi Stage' appeared in the Late Pleistocene (Katupotha, 1994). Further, 'Balangoda Stage' has been correlated with the Late Würm, and 'Colombo Stage' with the present climate.

Deraniyagala (1986) proved that Late Pleistocene alti-thermal episodes have occurred in Sri Lanka. Aragonite of land snails of coastal dunes at Bundala was dated at 21,000±400 and 25,450±750 yr B.P. (two more dates at the same area were dated at 22,800 and 28,400 yr B.P. by thermo-lumnescence) and the Pathirajawela deposits are dated at 28,440 and 64,380 - 74,200 yr B.P. The basal gravel at Pathirajawela overlained by wind blown sand at 64,300 - 74,200 yr B.P. and may tentatively be correlated with early Würm. This could be another episode of low strand of sea-level in the Early Würm. Further, Deraniyagala explains that the data on the rate of tectonic uplift for the southern Indian and Sri Lankan region can be used to speculate as the highest coastal gravel of the southwestern part of Sri Lanka at about 80 - 60 m msl and could in fact be correlated with a ca. 30 m high sea-level with the middle Pleistocene (Hosteinian interglacial) at about 300,000 - 265,000 yr B.P., on the same basis, the 25 m gravel found in theBundala - Levengoda area can be correlated with the 'Eem interglacial' at ca. 125,000 - 75,000 yr B.P.

In the submerged peneplain which is bounded externally by the 100 fathom (ca. 180 m) in the continental shelf of Sri Lanka, remains of channels of some larger rivers andsunken forests can be identified (Deraniyagala, 1958). Wickramaratne et al. (1988) reported that the western continental shelf consists predominately of sand sized particles, 2 mm to 0.067 mm in diameter, composed of lithogenic quartz and biogenic carbonates. Most shelf sediments had been deposited in shallow water during the last low stand of sea-level and recent sediments are found accumulated only in nearshore areas and on the continental slope. During the above mentioned period, the outer shelf area was starved of sediments due to their removal through submarine valleys and canyons. This has resulted in the absence of calcareous skeletal material in the outer shelf area.

The sea-level was about 120 m below from the present level during the Last-Glacial Maximum. The Post-Glacial transgression (PGT) appears to have started around 18,000 - 17,000 yr B.P. and lasted from about 10,800 to about 10,300 yr B.P. At many locations of the tropical and subtropical coasts the sea-level remained within 3 - 5 m from the present level during the mid- Holocene (Fairbridge, 1961; Walcott, 1972; Pirazzoli, 1987). The colour and constituents of the sand and height of the beach ridges as well as weathering conditions have been used as indicators for the study of the evolution of coastal lowlands of Sri Lanka especially in the Late Pleistocene period (Katupotha 1988a, 1988b, 1988c, 1988 d and 1991).

Thermo-lumnescence and C-14 dates of geologic samples in southwestern and southern coastal zones clearly emphasise that there was a relationship between climatic changes and the Late Pleistocene-Holocene events (Deraniyagala, 1986; Katupotha, 1995 a & 1995b). Most of those dates further indicate that the Late Pleistocene and Holocene events in Sri Lanka can correlate with other tropical areas particularly Africa, Madagascar, Brazil, India and Malaysia.

The periods mentioned above indicates that the deposition of many gravel beds and overlained deposits have been followed by palaeo-tropical dry and wet climatic changes. It is possible to infer that the gem minerals have rolled several miles from the Central Highlands towards the coastal plain by running water. Based on field investigations, the following observations have been made:

(a) although the deposits are not so deep (less than 3 m), they are overlaid by fluvial and wind-blown deposits

(c) associated quartz and ironstone gravel of the gem-bearing layers deposited as fluvial material under a dry climatic condition during the early and late Pleistocene epochs

(b) the stone artifacts and pottery fragments of the overlying deposits indicate distinct separate human cultures that existed during the period of deposition (mainly in early and late Pleistocene and Holocene epochs).

4.6 Archaeological significance

The gravel deposits, Red Beds and stone tools in Quaternary deposits in Sri Lanka were already described emphasising different aspects by Wayland (1919), Wadia (1941), Deraniyagala (1958), Cooray (1967 and 1984), Cooray and Katupotha (1992) and Deraniyagala (1986). Based on these discussions it is possible to correlate with long fluvial phases in Sri Lanka which was followed by worldwide interglacial 'stages 2nd and 4th' (between middle Pleistocene-Eemian and Late Pleistocene-middle Würm). Accordingly associated quartz and ironstone gravel of the gem-bearing layers were deposited during these fluvial material phases.

Earlier research on Quaternary deposits along the southern coastal zone of Sri Lanka revealed that animal bones, human bones and different kinds of artifacts are rich in shell beds (Katupotha, 1995). The shell beds at Hungama - Ovitigodayaya (paddy field) and Hungama - Pallegama (Ihalagama Yaya) were composed of highly weathered pieces of elk bones and pottery fragments. Well polished oval-shaped stone artifacts, stone balls, human bones, a skull of a serpent and other animal bones as well as pottery fragments were mixed with those shell beds at Hungama Pansalwatta. Two morphologically distinctive beds had been deposited at Bataata (Gurupokuna) and Kalametiya areas. The beds at Gurupokuna appeared as about 3 m thick deposits on mounds and on a former lagoonal beach while Kalametiya - Henagahapugala - beds were deposited on a rocky headland (with a thin soil cover) which is about 14 m high from the above msl. Many pieces of pottery were mixed with the shell bed in this area. Many shell patches between Maha Lewaya and the Pallemalala area, on the eastern bank of the Malala Oya are also composed of stone artifacts and quartzite pebbles. Based on the colour of the quartzite pebbles, it is possible to infer that these may have been fired.

The gem deposits in the study are located at some point very close to the above mentioned shell beds as well as their environs. Sometimes the shell beds overlay the gem gravel deposits. The informal discussions with gem miners and residents who settled in the surroundings stated that it is possible to find stone artifacts, animal bones, highly weathered wood samples etc. but no pottery fragments. This position clearly emphasises that the gem gravel deposit has been formed before the Holocene epoch. However, it was not possible to collect a considerable amount of such material to examine palaeo and archaeological significance. Accordingly, this research opens out other research disciplines to scientists who are keenly interested in such areas.

CHAPTER FIVE - ENVIRONMENTAL POLLUTION

5.1 Environmental pollution due to gem mining in the study area

The term “environment” broadly indicates the surroundings of an individual organism or a community of organisms, ranging up to the entire biosphere, the zone of Earth that is able to sustain life (Cadle, Richard, D. 1996).

Environmental pollution is any discharge of material or energy into water, land, or air that causes or may cause acute (short-term) or chronic (long-term) detriment to the Earth's ecological balance or that lowers the quality of life. Pollutants may cause primary damage, with direct identifiable impact on the environment, or secondary damage in the form of minor perturbations in the delicate balance of the biological food web that are detectable only over long time periods.

Land pollution is one of the components of environmental pollution, and it is the degradation of the Earth's land surface through misuse of the soil by poor agricultural practices, mineral exploitation, industrial waste dumping, and indiscriminate disposal of urban wastes.

Due to gem exploration and mining activities on a large or small scale, the land degradation and other environmental components are polluted by distinct means. Rupasinghe and Cooray (1993), explain the effects and the impact of gem mining on the environment. The gem mining methods vary from deep mining and tunnel mining to shallow, open pit mining and river-bed mining resulting in environmental damage. Dissanayake and Rupasinghe (1995) discuss the environmental impact of mining, erosion and sedimentation in Sri Lanka. The authors emphasis that particularly gem mining has been responsible for serious problem of soil erosion and river siltation. A large number of illegal mines leave spoils resulting in damage to nearby paddy fields, crops, rivers and streams. These aspects are very significant to both legal and illegal mining areas in Sri Lanka.

The environmental damage resulting from common gem mining methods has been discussed by Rupasinghe and Cooray (1993). These methods are:

- morphological damage to land areas
- damage to vegetation cover
- damage to forests
- damage to fauna
- damage to stream and river banks
- sedimentation
- water pollution

In Sri Lanka, the types of gem mining vary due to local relief, geological structure and stratigraphic sequence. These types include deep mining, tunnel mining, river bed mining, shallow open pit mining and mechanised mining. In the study area, shallow open pit mining is practised owing to surface morphology, local geological structure and stratigraphic sequence of the superficial deposits.

Morphological damage to land areas

In all gem mining areas large open craters and soil heaps can obviously be seen. The Sisilasagama and Chitragala mining sites are well known for this damage.

Large craters, 4m x 5m or more in size, are full of fresh water or brackish water during the rainy seasons and high tide flow. These pits become muddy craters in dry periods and together with soil heaps create manmade undulating terrain. Obviously they become breeding grounds for mosquitoes and also lead to wild elephants as well as other wild animals getting drowned in them (Plate 5.1).

Plate 5.1 Polluted stagnant water pools at Mirijjavila. These pits endanger wildlife too.

Soil heaps thrown up during excavation are unstable and infertile. They are dispersed by rain water causing damage to lagoon beds, other water pools, micro fauna and flora.

Damage to vegetation cover

Gem mining in the study sites have led to the depletion or total destruction of vegetation cover. To create large craters as a gem pit mangrove species at lagoon edges and thorny scrubs cresting undulating areas are cut down. Eventually the miners destroy the salt marshes of the lagoons. These vegetation types and associated habitat prevent soil erosion and provide food for quadrupeds, mammals, reptiles as well as for birds.

Damage to forests

In scrublands *Cassia auriculata* (Ranawara), *Feronia limonia (*Divul) and *Dichrostachys cinerea* (Andara) and economically valuable trees such as *Manilkara hexandra* (Palu) and *Nerium odorum* (Veera) are destroyed by miners at the start of excavation. Besides this the non-fertile layers thrown up from gem pits can get mixed with fertile soil. It probably causes to damage to seasonal crops in the area.

Damage to fauna

Lagoons and nearby undulating crests are habitats for fish, birds, quadrupeds, reptiles etc. These habitats are breeding grounds for fauna. Due to the pits and heaps morphology as well as mixture of non-fertile soil with top soil and the water damage natural habitats. It depletes the fish and other water borne animals, reptiles and mammals as well as endemic birds (fishing owl, kingfisher, sea-gull etc.).

Plate 5.2. Due to the pits and heaps morphology as well as mixture of non-fertile soil with top soil and the water damage natural habitats.

Damage to lagoon beds

Digging of large scale pits, e.g. Mirijjavila Lewaya and Sithrakala lagoon have obviously caused damage the lagoon beds (see Plates 4.2.2, 4.4.1, 5.1 and 5.2). This is aggravated by illegal gemming.

Sedimentation

Transportation and suspension of soils by rain water as well as by spring tide cause sedimentation of lagoons and other water ways. Sometimes siltation and filling of lagoon mouths floods the land during the rainy season. Gemming, therefor, creates problems involving the with whole lagoon and other wetland systems.

Water pollution

Water is an essential commodity frequently used in the process of gem mining, but during the mining process and washing operations water gets polluted (Plate 5.2). The addition of tiny and microscopic particles to water ways can further polluted surface water. Moreover temporary human habitations in mining areas do not provide any toilets and sanitary facilities. This adds to human waste to the waterways and the groundwater supplies creating health problems to the nearby inhabitants.

All these environmental damages and impacts from gemming are interrelated. Most of this damage to the environment is caused by illegal gem mining. Illegal gem mining is significant due to the lack of land auction by the State Gem Corporation. Environmental impact is felt on lagoon beds, lagoon embayments, undulating crests and also streams.

CHAPTER SIX - SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This chapter summarises the results obtained from this research and makes conclusions and recommendations. Chapter 1 relates to the introduction to gemstones and humankind, the significance of the study, methodology, limitations and structure of the report.

The second chapter is a comprehensive account of the physical characteristics and the landuse in gem mining areas along the coast. Geological structure, geomorphology, climate, soil, vegetation and land use in the area have been discussed briefly. These physical factors and landuse patterns have a close relationship in the distribution of gem gravel deposits and its usage.

Chapter three highlights the different variety of gems and gemstones. This chapter further discusses the gem deposits, gem minerals and gemstones of Sri Lanka in detail. The study of geological and economic significance are mentioned in Chapter four. This chapter is the core area of the study.

Chapter five reveals the possible human impact on gem mining. The miners damage private and government lands due to desultory usage and improper management. Chapter six provides the summary of the research and finally contains the conclusions and recommendations.

6.2 Conclusions and recommendations

Sri Lanka is well known for its vast gem potential and it is economically important as a foreign exchange earner. Gem mining and industry in Sri Lanka has been famous for more than 2500 years and it is closely tied up with culture in many ways. Gem industry is a source of employment in different ways directly and indirectly for rural as well as for urban people. However, until recently, exploration of gemstones was carried out using traditional methods only in inland areas.

Coastal gem mining is a neglected field to compared to inland mining continuing illegally yet. This industry is undertaken by local organised small groups, but they did not become rich. However, two or three persons became somewhat rich, though not as rich as the businessmen from the Ratnapura, Balangoda or Kahawatta areas. There are no gem cutting and polishing centres and sales centres are located in the area. The lack of experience and knowledge has been responsible for this situation. The gemstones in the area are sold as raw stones to outsiders.

Coastal gem mining is highly unsystematic and wasteful. The environmental damage resulting from common gem mining methods in the coastal belt has caused morphological damage to land areas, vegetation cover, forests, fauna and to stream banks. This has led to sedimentation and water pollution.

Stagnant and polluted muddy water pools caused by mining for gemstones provide breeding grounds for malarial and other types of mosquitoes during the rainy season. The muddy water pools act as fatal spots for wild-animals, and sometimes even for people. Some pits endanger wild-elephants too. The scrubs, stunted trees and wetlands of the area provide suitable breeding grounds for different kinds of birds (peacock etc.) and many wild animals (deer, elk, elephants etc.). But damage to those habitats contribute to the depletion of such animals. Mining pits and infertile soil and piles of pebbles are a hindrance and discourage the prevalence of wild-life.

Public awareness is needed for proper use of gem gravel deposits and for the protection of the environment and health of the people in the area. Such an awareness programme can be undertaken by rural level societies, youth clubs and with the help of secondary school level students at Divisional Secretariat level. Towards this purpose a close relationship among the State Gems and Jewellery Corporation, CCD, Department of Wildlife, Forest Conservation Department and Divisional Secretariats is needed.

Therefore, it is very important that the following to steps are taken to minimise damage to the environment as a result of such mining activities:

(1) At present there is no licensing system covering coastal gem mining. In 1995 some lands were auctioned by the State Gem Corporation for gem mining at Goyamkolabokka. But many local miners were not eager to buy due to the uncertainty of gemstones being available and lack of money for the license fee and the deposit. However, to minimise and conserve the environment licensing is necessary and an awareness and service programme could be made a part of the responsibility of the licensing authority.

(2) Present manual mining methods are suitable for the area. The availability of open lands in the area is not conducive to placing of heavy machinery such as bulldozers as areas can be encroached upon. Prohibition of such practices are highly recommended.

(3) There is no monitoring authority for a supervisory role. The monitoring authority should be established to supervise the filling up of gem pits

and mine shafts at the end of operations, raising licensing fees and deposits if necessary and to pay for the exercise of a supervisory role. When as an individual person is unable to get a license, small groups can be organised for this purpose.

(4) The illegal mining in the area is highly damages the lagoon beds as well as the coastal wetland ecosystem. Therefore, illegal mining should be checked and licensing should be compulsory. The monitoring authority should take action to enforce a complete ban of illegal gem mining.

REFERENCES

A CANADA-CEYLON COLOMBO PLAN PROJECT. Resources of the Walawe Ganga Basin. The Government Press, Ceylon, 1960.

ALLABY, A. & ALLABY, M., 1991. The Concise Oxford Dictionary of Eart Sciences. Oxford Univeristy Press.

BALENDRAN, V.S. 1968. Unpublished Geological Map of the Hambantota sheet (1:63,360), Geological Survey Department, Colombo 2.

CHERNUSH, AKOSH., 1980. Dazzling jewels from the muddy pits enrich Sri Lanka. Smithsonia magazine, 69-74.

CHESTERMAN, W. CHARLES., 1979. The Audubon Society Field Guide to North American Rocks and Minerals. Alfred A. Knopf, New York, pp 13-48.

COORAY P.G. 1967. An Introduction to the Geology of Sri Lanka. Ceylon National Museum Publication, Colombo, pp 184-176.

COORAY, P.G. 1968. A note in the occurrence of beachrock along the west coast of Ceylon. Journal of Sedimentary Petrology, 38, 650- 654.

COORAY P.G. 1984. An Introduction to the Geology of Sri Lanka. 2nd Revised Edition, Ceylon National Museum Publication, Colombo, pp 140- 142.

COORAY, P.G. & KATUPOTHA, J. 1992. Geological evolution of the coastal zone of Sri Lanka. Proc., Symposium on "Causes of Coastal Erosion in Sri Lanka". CCD/GTZ, Colombo, Sri Lanka, 9-11, Feb. 1991, 5-26.

COORAY, P.G., & KUMARAPELI, P.S., 1960. Corundum in biotite-sillimanite gneiss from near Pogahawela, Ceylon. Geological Magazine, xcvii (6), 480-487.

DERANIYAGALA, P.E.P., 1958. The Pleistocene of Ceylon. Ceylon National Museum Publication, Colombo.

DERANIYAGALA, S.U., 1986. Pleistocene coastal sediments in the Dry Zone of Sri Lanka: chronology, palaeo-environment and technology. Ancient Ceylon, 6, 50-62.

DESAUTELS, PAUL E., 1996. Gems. Grolier multimedia Encyclopedia. Grolier Electronic Publishing Inc.

DISSANAYEKE, C.B. & RUPASINGHE, M.S., 1993a. A prospecotrs' guide map to the gem deposits of Sri Lanka. Gems & Gemology, 173-181.

DISSANAYEKE, C.B. & RUPASINGHE, M.S., 1993b. New gem localities in Sri Lanka. Resource Goelogy (special isse), 16, 271-275.

DISSANAYEKE, C.B. & RUPASINGHE, M.S., 1995a. Classification of fem deposits of Sri Lanka. Geologie en Miginbouw, 14, 79-88.

DISSANAYEKE, C.B. & RUPASINGHE, M.S., 1995b. Environmental impact of mining, erosion and sedimentation in Sri Lanka. Intern. Journal of Environmental Studies, 8, 1-15.

DISSANAYEKE, C.B., RUPASINGHE, M.S. & NAWARATNA, S.W., 1993. Gem expolrations: traditional and new methods. Sri Lanka Geuda, 15-25.

FAIRBRIDGE, R.W. 1961. Eustatic changes in sea level. Physics and Chemistry of the earth, 4, 99-185.

FAIRBRIDGE, R.W., 1968: Quaternary Period. In: R.W. Fairbridge, (Ed) Encyclopedia of Geomorphology. Rein Hold Books Cor., New York, pp 912-931.

FERNANDO, S.N.U., 1968. The Natural Vegetation of Ceylon. Lake House, Colombo, Sri Lanka.

GAMAGE, S.J.K., RUPASINGHE, M.S. & DISSANAYAKE, C.B., 1992. Application of Rb-Sr ratios to gem exploration in the granulite belt of Sri Lanka. Journal of Geochemical Exploration, 43, 281-292.

GROLIER MULTIMEDIA ENCYCLOPEDIA., 1996. Grolier Electronic Publishing Inc.

HAPUARACHCHI, D.J.A.C., 1989 Journal of the Geological Society of Sri Lanka, 2, 5-9.

HERATH, J.W., 1984. Geology and occurrence of gems in Sri Lanka. Journal of National Science Council of Sri Lanka, 12 (2), 257-271.

GEOLOGICAL MAP OF SRI LANKA. Compiled by the Geological Survey Department, Colombo, 1982.

KATUPOTHA, J., 1988a. A Comparative Study on Coastal Landforms in the Western Part of Sri Lanka. Geogr. Sci. (Hiroshima University), 43 (1), 18-37.

KATUPOTHA, J., 1988b. Hiroshima University radiocarbon dates 1, west and south coasts of Sri Lanka. Radiocarbon, 30 (1), 125-128.

KATUPOTHA, J., 1988c. Hiroshima University radiocarbon dates 2, west and south coasts of Sri Lanka. Radiocarbon, 30 (3), 341-346.

KATUPOTHA, J., 1988d. Evidence of high sea level during the mid-Holocene on the southwest coast of Sri Lanka. Boreas 17, 209-213.

KATUPOTHA, J. 1992a. Geomorphic Surfaces of the River Basins along the Western and Southern Parts of Sri Lanka. NARESA, 1992 Unpublished Report).

KATUPOTHA, J. 1992b. New evidence of Holocene sea-level changes of Sri Lanka. Journal of the Geological Society of Sri Lanka, 4, 39-44.

KATUPOTHA, J. 1994. Quaternary research in Sri Lanka. Journal of the Geological Society of Sri Lanka,

KATUPOTHA, J, 1995. Evolution and the geological significance of Late Pleistocenefossil shell beds on the southern coastal zone of Sri Lanka, published by NARESA, Sri Lanka, Final report (64 pages).

MENDIS, D.P.J., RUPASINGHE, M.S. & DISSANAYAKE, C.B., 1993. Application of srtuctural geology in the exploration for residual gem deposits of Sri Lanka. Bulletin of the Geological Society of Finland, 65, Part 1,31-40.

PIRAZZOLI, P.A., 1987. Sea-level changes in the Mediterranean. In: Michael J. Tooley and Ian Shennan (Ed.), Sea-Level Changes, Basil Blackwell Ltd, Oxford, 152-181.

RUPASINGHE, M.S., 1995. Some important gemstones of Sri Lanka.. Handbook on Geology and Mineral Resources of Sri Lanka. K Dahanayake (ed.). GEOSAS-ll, Colombo Sri Lanka, 19-24.

RUPASINGHE, M.S., & COORAY, P.G. 1993. The effects of gem mining on the environment. The Sri Lankan Geuda, 43-56.

RUPASINGHE, M.S., DISSANAYAKE, C.B. & MENDIS, D.P.J., 1994. Use of indicator minerals in gem explorations: study of a granulitic terrain in Sri Lanka. Journal of Southeast Asian Earth Science, 9 (3) 249-254.

SURVEY DEPARTMENT OF SRI LANKA, 1977. Soil Map of Sri Lanka, Printed by Survey Department of Sri Lanka, 1977.

SWAN, B. (1982). The Coastal Geomorphology of Sri Lanka: An Introductory Survey. Armidale, N.S.W., pp 84-89.

THAMBYAPILLAI, G., 1960. Climatic regions of Ceylon-1: according to the Köppen classification. Tropical Agriculturist, v CXVI, 147-177.

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WADIA, D. N. 1941. The geology of Colombo and its environs. Spol. Zeyl., 23, 10-18.

WADIA, D.N. & FERNANDO, L.D.J, 1944. Gems and semi-precious stones of Ceylon. Records of the Ceylon Department of Mineralogy, Professional paper 2, 13-44.

WALCOTT, R.I., 1972. Past sea levels, eustacy and deformation of the earth. Quaternary Research, 2, 114.

WAYLAND, E.J., 1919. Outline of the stone age of Ceylon. Spol. Zeyl., 11, 85-125.

WELLS, A.J., 1956. Corundum from Ceylon. Geological Magazine. xcii, 25-31.

WICKREMARATNE, W.S, RANATUNGA, N.G. and WIJAYANANDA, N.P., 1988. Continental shelf sediments of western Sri Lanka. Proceedings, 44th Annual Ses., 1988, Part l, SLASS, Colombo, P 135.