MINERALS FOUND IN GEM BEARING GRAVEL IN THE RATNAPURA AND OKKAMPITIYA GEM FIELDS AND THEIR ECONOMIC USES

By

A.L.M.Gunasinghe

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Department of Natural Resources
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
Buttala 91100

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DECLARATION

The work described in this thesis was carried out by me at The Gem Institute, in Kandy. under the supervision of Mr. Senarath B.Basnayake and Prof. Mahinda Rupasinghe. A report on this has not been submitted to another university for another degree.

Certified by:-

External supervisor
Mr.Senarath B.Basnayake
Gemmologist
The Gem Institute
135/2/5 & 6,Kotugodella Vidiya
Kandy 20000
Tel: 081-2203994

Date: 05.09.2005
Signature

Internal supervisor
Prof. Mahinda Rupasinghe
Head of the Department
Department of Natural Resources
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
Buttala 91100
Tel: 055-2273988

Date: 31/8/2005
Signature

Research Student
Mr. A.L.M Gunasingehe
"Mihira"
Ayagama
Ratnapura 70000
Tel: 045-2250102

Date: 2005/08/31
Signature

Affectionately Dedicated

To

My Parents

And

Teachers

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ABSTRACT

The traditional gem minerals of Sri Lanka usually take only the high quality gems for selling and throw away the other remains. However, among these discarded stones, low quality corundum, spinel, zircon, tourmaline, garnet etc. are present. The aim of this research is to find out the areas which are abundant in such minerals, their weight percentages in the washed gem bearing gravel in Ratnapura and Okkampitiya gem fields and whether these minerals could be used for industrial and non-gem ornamental purposes.

Samples were taken from selected locations in Ratnapura and Okkampitiya gem fields. Minerals were identified by using there optical and physical properties, determined their weight percentages in the washed gem bearing gravel and found out economic uses of them.

The dispersion of the minerals in gem bearing gravel in Okkampitiya has a greater uniformity compared to minerals in the Ratnapura gem field. Radioactive minerals are abundant in residual and eluvial gem deposits compared to alluvial gem deposits. Garnet, zircon, spinel and tourmaline are the common gem minerals in the Ratnapura and Okkampitiya gem fields. Non gem quality minerals such as garnet, zircon, spinel and tourmaline are found to be rich in all samples. However, iron rich minerals such as magnetite, limonite, hematite etc. are found to be abundant in Rambuka, Kahawatta, Marapana, Pothupitiya and Kuruvita areas. Gem miners are unaware of uses for these minerals in industrial and non-gem ornamental purposes.

CONTENTS

LIST OF ABBREVIATIONS

HC	Highland Complex
VC	Vijayan Complex
WC	Wanni Complex
KC	Kadugannawa Complex
HSWC	Highland South Western Complex
BK	Buttala Klippe
SG	Specific Gravity
RI	Refractive Index
ct	Carat
wt	Weight
X	Unidentified mineral in the gem bearing gravel layer

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CHAPTER 01
INTRODUCTION

1.1 General Introduction

Gemstones are beautiful, glittering wonders of the mineral kingdom and are indeed rarities of nature. Sri Lanka's fame as one of the finest gem- bearing lands on earth is almost unparalleled. For thousands of year's valuable gem minerals such as sapphire, ruby, topaz, spinal, garnet have been recovered from sediments of rivers and streams draining the central highlands of Sri Lanka. According to Dissanayaka and Rupasinghe (1993), Sri Lanka may have the greatest proportion of land surface underlain by gem deposits, as well as the widest variety of gem minerals of any country in the world. Yet there has been little scientific study of the true gem potential of this island nation. Gem minerals are by far the most economically valuable mineral resource in Sri Lanka and it is imperative that the resource estimates be known and inventoried. The chance discovery of a gem by one miner will bring others into the region, and thus the haphazard exploration of the area continues. Modern scientific techniques have hardly been used for gem exploration in Sri Lanka and the apparent success of the local gem miners in unearthing valuable gemstones could perhaps be the reason for the lack of emphasis on the application of newer scientific techniques on gem exploration.

1.2 Previous studies

The first classic account on the valuable gemstones of Sri Lanka, notably corundum, ruby, beryl, chrysoberyl, and topaz was by Wadia and Fernando (1945). The nature of the gem minerals found in the alluvium of rivers was studied by these authors, with particular emphasis on their mechanisms of transport and deposition. Their study of the cross section of gem pits was one of the earliest scientific studies of its kind in Sri Lanka. Subsequent studies by others confirmed their findings.

Much of the studies that followed dealt only with mineralogy, provenance, origin and sedimentological characteristics (Wells, 1956; Cooray and Kumarapeli, 1960; Katz, 1972; Silva, 1976; Dahanayake et al., 1980; Munasinghe and Dissanayake, 1981 and Dissanayake and Nawaratne, 1981).

The study of the geochemistry of gem- bearing stream sediments using modern analytical facilities commenced in the early eighties, when several informative research papers were published (Dissanayake and Rupasinghe, 1992 and Dissanayake et al., 1994).

Among the notable contributions were those by Rupasinghe et al. (1984), Rupasinghe and Dissanayake (1984), Rupasinghe and Dissanayake (1985a) and Dissanayake and Rupasinghe (1992). These studies, for the first time, provided information on the trace elements of stream sediments, particularly the rare and rare earth elements.

1.3 Scope of the study

Though there have been several studies carried out for gems and there exploration only a few studies have focused in examining the gem bearing gravel layer (Dissanayaka and Nawaratne, 1981; Dahanayake and Ranasinghe, 1985; Dissanayake and Rupasinghe, 1995; Chandrajith et al., 1998). As noted in (Dissanayaka and Nawaratne, 1981; Dahanayake and Ranasinghe, 1985; Dissanayake and Rupasinghe, 1995; Chandrajith et al., 1998) gem bearing gravel layer is found to be different with respect to the area and also climate. Still no studies were done to identify the use of the minerals other than high quality gems in the gem bearing gravel.

Main Objectives:

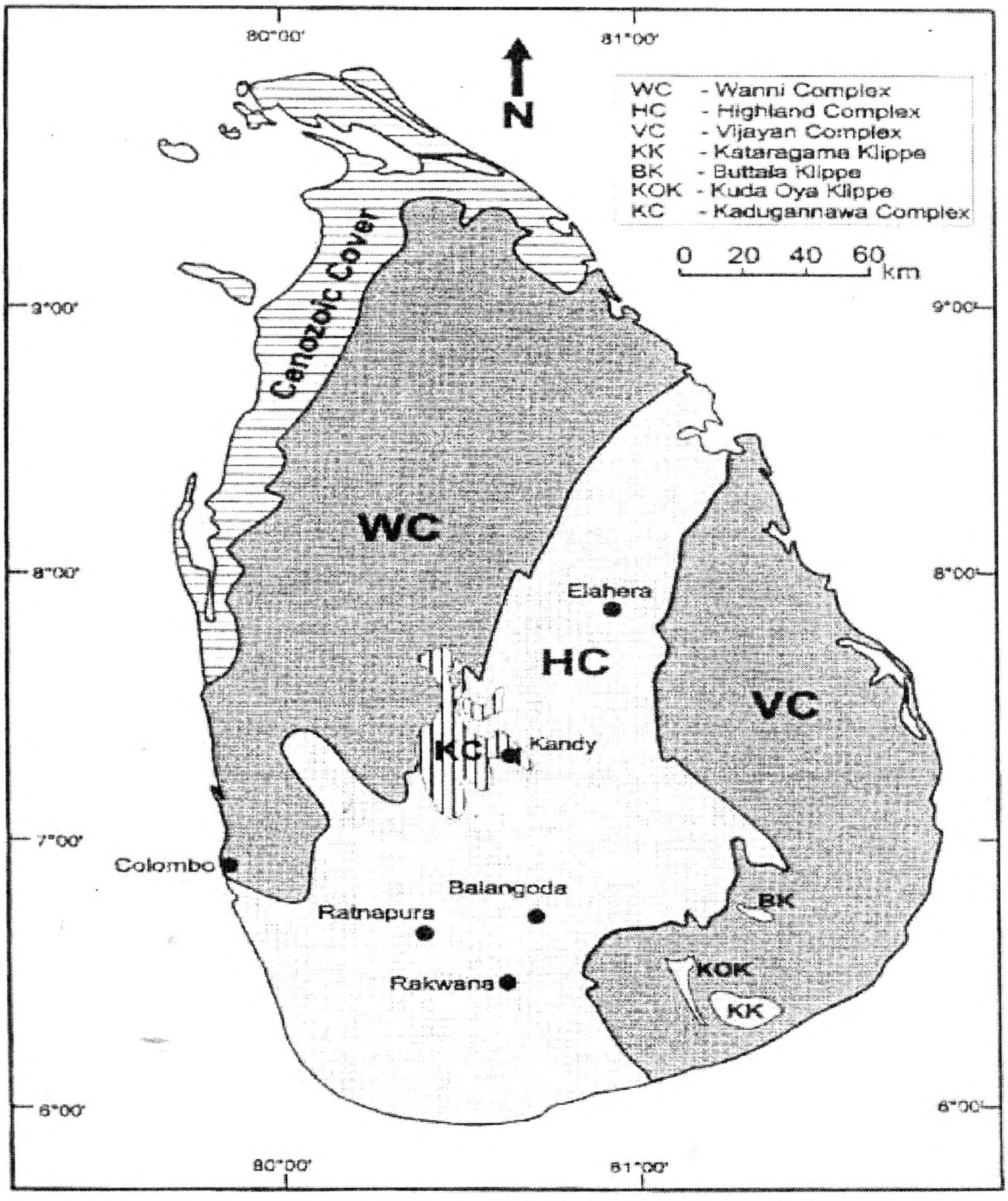
1. Identification of minerals in Ratnapura & Okkampitiya gem fields.
2. Determination of the weight percentage of minerals in the washed gem bearing gravel in Ratnapura and Okkampitiya gem fields.
3. To study the use of minerals present in the gem bearing gravel.

CHAPTER 02

GEOLOGY AND GEMS OF SRI LANKA

2.1 General geology

Figure 2.1 Simplified and generalized geological map of Sri Lanka Showing major lithotectonic units.



Source: Kroner et.al (1991) introduced this lithotectonic subdivisions.

Basement Complex of Sri Lanka into three main and one subordinate division and named as Highland Complex, Vijayan Complex, Wanni Complex and the Kadugannawa Complex.

2.1.1 Highland complex [HC]

The HC is characterized by felsic and mafic charnockite gneisses and other high grade gneisses of meta-sediments. The meta-sediments include quartzites, marbles khondalites, cordierites and wollastonite- bearing gneisses. The HC rock terrain lies in the central part of Sri Lanka extending NE-SW island. These rocks have been metamorphosed under granulite grade and subjected to several events of metamorphism and deformations causing many crystallization processes and interbanding of meta-sediments and interlayering with meta-igneous rocks (orthogeneisses). Previous studies show that the sedimentation age of these rocks is 2Ga (kroner et a1., 1991). The major rock types found in the area are charnockitic gneisses, Quartzites, Garnet-sillimanite gneisses (khondalites), marbles and other gneisses with garnet, biotite and cordierites.

2.1.2 Vijayan Complex [VC]

The vijayan complex is exposed in eastern and southern Sri Lanka. The depositional age of supracrustal rocks of Vijayan complex is around 1100Ma. It has been subjected to amphibolite grade metamorphism around 456-591Ma. The vijayan basement is composed mainly of granitoid gneisses (Tonalite to Leucogranite) and migmatites. Metasedimentary rocks are found in minor amounts as xenoliths. In contrast to Wanni complex horndblend bearing calc-alkaline plutonic rocks are common in this unit (Kroner et al., 1991).

2.1.3 Wanni Complex [WC]

The former West Vijayan Complex (Cooray, 1984) has been re named as the Wanni complex by Kroner et. al.. (1991). The Wanni complex also has been subjected to the same Granulite grade metamorphism of HSWC. However its supracrustal rock deposition was simultaneous to the Vijayan complex (1100 Ma). Paleo-metamorphic pressures of the Vijayan complex are lower than that of HSWC. Granitoid gneisses (migmatitic to charnokitic gneisses) and minor metasediments are the main rock types in the area (Kroner et. al., 1991). Comparison of modal ages, and paleo-pressure data suggests that this unit is considered as a separate metamorphic complex.

2.1.4 Kadugannawa Complex [KC]

The Kadugannawa Complex (KC) is situated within the HSWC, around Kandy and Peradeniya. This complex has zircon dates (660Ma-550Ma) and Nd model ages (1100ma) comparable to the Wanni complex (Kroner et. al., 1991). Parts of the Kadugannawa complex have experienced granulite grade metamorphism (Schenk et. al., 1991). Evidence for a retrogressive event has also been preserved at some locations. The KC is composed of hornblende - biotite and quartzo - feldspathic gneisses, minor amphibolites and anorthosite and supracrustal rocks.

There is no evidence to show that the KC is a nappe structure of the Wanni complex. Therefore it is recognized as a differentiated suite of calc-alkaline intrusive rocks intruded into rocks of the HSWC around 890-1000Ma ago. Most gem-bearing areas of Sri Lanka are underlain by the granulite grade metamorphosed Highland Complex. Some gem occurrences, such as in the Okkampitiya gem fields, are found outside the Highland Complex. However it is thought that the gems originated in the Highland Complex and were later transported by rivers and deposited in this area.

2.2 Geology of the study areas

2.2.1 Geology of the Ratnapura gem field

The Ratnapura gem field is by far the most important in Sri Lanka and is underlain by Precambrian metamorphic rocks of the charnockite-metasedimentary type. The main rock types found in this area are charnockites, garnet-sillimanite-granulites, amphibolite and perthite-bearing garnet-biotite granulitic gneisses. Of these, charnockites and politic garnet-sillimanite-granulites are found in greater abundance. Of particular significance is the occurrence of intrusive rocks of the zircon granite type, vein quartz and pegmatites (Rupasinghe and Dissanayake, 1985 a).

The Ratnapura gem field consists of Pleistocene or sub-recent alluvium with patches or streaks of gravel and heavy minerals laid down in the floodplains of streams, in channels of abandoned tributaries or in the talus fans at the foot of steep hillside slopes (Wadia and Fernando,1945). Heavy minerals including gems are deposited during periods of intense rainfall when they are mechanically removed from their source regions in the catchment areas.

2.2.2 Geology of the Okkampitiya gem field

Geological studies have shown that the combined HC-WC unit was over thrust on to the VC, and isolated remnants of HC rocks occur as "klippen" or "outliers" within the VC region. The Buttala klippe, which is found near the HC-VC boundary but in the area of VC, is one such occurrence (Kroner et al., 1991). Buttala klipen is surrounded by VC rocks and may be either large remnants of the HC that escaped deformation and restoration to form VC gneisses or thrust klippe (Corray, 1984). Although the critical contact between the Buttala klippe and the VC masked and obliterated by superficial deposits, recent mapping clearly show a zones of mylonite between the two complexes, Suggesting that the complexes have been juxtaposed by thrusting associated with deep seated tectonic collision (GSMB Moneragala-panama sheet 18, 2002). The study area is underline by marble, politic gneisses, quartzite, migmatite, basic granulite, miner pegmatites and calcsilicate rocks. Marble is the dominant lithology within the Okkampitiya region. Though marble is mainly composed with calcite and dolomite, other minerals such as diopside, phlogophite, spinel and forsterite are also present in minor amount. (Mathavan et al., 2000).

CHAPTER 03
GEMS OF SRI LANKA

3.1 Gemstones and their origin

Many diverse theories have been proposed for the origin of gemstones in Sri Lanka. The exact origin of Sri Lankan gemstones has been problematic (Dahanayake et al., 1980). However, the origin of aluminum-rich rocks within the former Highland basin has a significant bearing on the genesis of gemestones of Sri Lanka since it is the aluminous varieties of gem minerals that are most prevalent in the country (Gunaratne and Dissanayake, 1995). Gemstones are found to occur on hill tops and slopes as eluvial deposits and their source is underlying garnetiferous gneisses (Dahanayake et al., 1980).

In view of the fact that ninety percent of Sri Lanka's crystalline rocks are of the high-grade metamorphic type, it is reasonable to attribute a metamorphic parentage to many of Sri Lanka's gem deposits (Gunaratne and Dissanayake, 1995).

However, source rocks of some gemstones are of magmatic origin. According to Gunaratne and Dissanayake (1995), very high quality amethyst was found at Kekirawa. The region in the Matale-Rattota area has yielded considerable amounts of topaz off pegmatites. One of the best-known pegmatitic gem deposits in Sri Lanka is the moonstone deposit at Meetiyagoda.

3.2 Gem deposits of Sri Lanka

The following figure illustrates the scheme of classification of gem deposits of Sri Lanka proposed by Dissanayake and Rupasinghe (1995).

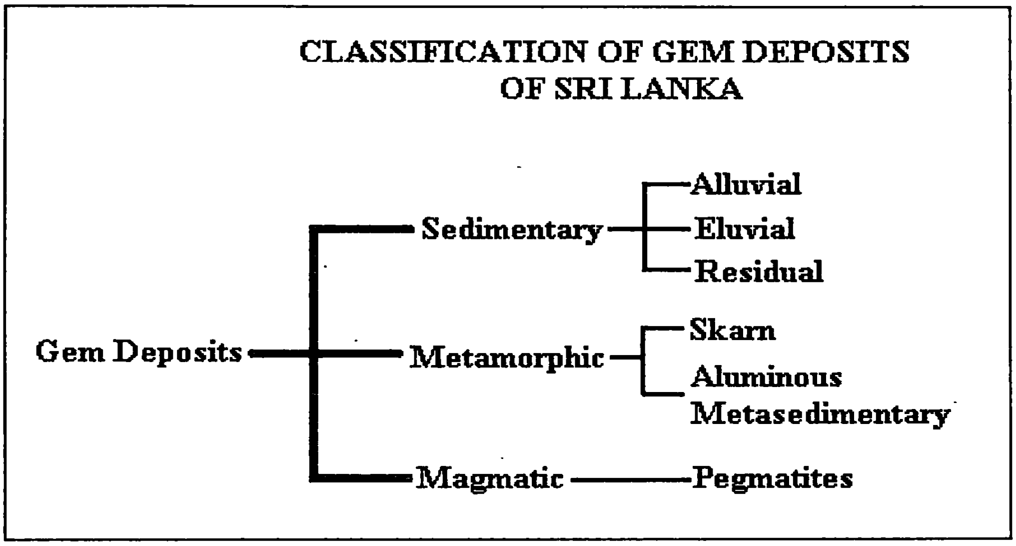


Figure 3.1 Classification of gem deposits of Sri Lanka (Modified after Dissanayake and Rupasinghe, 1995)

According to the above petrological classification there are three main gem deposits. They are the,

1. Sedimentary gem deposits
2. Metamorphic gem deposits
3. Gem deposits of magmatic origin

3.2.1 Sedimentary gem deposits

The sedimentary placer gem deposits occur in thin layer of gravel and sand termed *illam* (sinhala) in river beds and alluvial flood plains as well as in hill slopes and hillsides (Gunaratne and Dissanayaka, 1995). The Ratnapura gem field is mainly consisted of sedimentary gem deposits. Sedimentary gem deposits of Sri Lanka were classified by Dahanayake et al., (1980) into three types namely alluvial, eluvial, and residual gem deposits.

3.2.1.1 Alluvial gem deposits

Alluvial gem deposits are the most important source of gem minerals in Sri Lanka. Especially in Ratnapura gem field. Some of these deposits can reach depth of 40 meters and generally contain more than one gem bearing sedimentary layer (Locally called "*Illama*"). These deposits lie mostly in ald stream terraces and flood plains and are characterized by well rounded grains with several of varieties of gem stones (Dahanayake and Rupasinhe, 1995).

Alluvial type gem deposits cannot be seen in the Okkampitiya gem field. In the Ratnapura gem field Alluvial deposits are mainly found in Eheliyagoda, kuruwita, Ratnapura, Gileemale, Elapatha, Ayagama, Teppanawa, Kiriella, Kalawana, Uda Karwita, Delwala, Niriella, Nivithigala, Doloswala, Columbogama, Watapotha, Pathakada, Pelmadulla, balangoda, Rakwana, Rambuka, kahawatta, Pothpitiya, and Kolonna gem mining areas.

3.2.1.2 Eluvial gem deposits

Elluvial deposits are situated mostly on the hill slopes or on their slopes of 30 to 40 degrees and these deposits consist of mainly angular rock fragments, unsorted sand with gem minerals (Chandrajith et al., 1998).

This type of gem deposits can be seen in Pelmadulla and Ellawala near Eheliyagoda in the Ratnapura gem field. In the Okkampitiya gem field, this type of deposits can be seen occasionally.

3.2.1.3 Residual gem deposits

These deposits are characterized by beds containing gem minerals mostly deposited in-situ, and are found at depths ranging from a few centimeters to about ten meters below the surface. The deposits are generally found on flood-plains of rivers and streams and the source of the gem minerals is near by the residual gem deposits are characterized by layers of alternating sand, clays and laterites containing angular rock fragments. The study of the mineralogy indicates the nature of rock which lies in the vicinity, its depth depending on the intensity of weathering (Gunaratne and Dissanayaka, 1995).

Residual deposits can be seen in the Ratnapura and the Okkampitiya gem fields. In the Ratnapura gem field residual deposits can be seen at Endana in Nivitigala, at Bandarawattha in Ayagama, in Kahawatta and Ratganga.

According to field observations, most of the gem deposits in Okkampitiya area appear to be residual or in-situ type deposits (Chandragith et al., 1998).

In the Okkampitiya gem field residual type deposits can be seen in Kumbukkana, Eriyapola and Maligavila which are gem mining areas. In *A note on Buttala and Okkampitiya gem field in Sri Lanka* Chandrajith et al., mentioned that there is an unweathered hesonite deposit in the eastern border of the Okkampitiya gem field. In that paper they have also mentioned that there was a similar kind of deposits containing hessonite in the southern part of the Okkampitiya gem field, but it was not investigated by them.

3.2.2 Metamorphic gem deposits

3.2.2.1 Skarn and calcium-rich rock type

Skarn deposits are formed particularly where intrusion of pegmatitic fluids which melts into the carbonate rocks has occurred (Dissanayake & Rupasinghe, 1994). These gem phases are formed by reactions between the pegmatites and the calcareous rocks. In particular the following reactions take place during the intrusion of the fluids:

- *Fluid + marble Scapolite + Corundum +* $MgCO_3$+CO_2
- $MgCO_3$ *+ Corundum + Spinel +* CO_2

Ferroaxinite and garnet are also commonly associated with calcium rich skarn deposits.

3.2.2.2 Aluminous-metasedimentary type

High-grade metamorphosed meta-sedimentary rocks of Highland Complex are the major sources of gem minerals such as garnet, sillimanite and cordierite. In particular, many of the metamorphic rocks are enriched with alumina, with some highly aluminous compositions, called khondalites. The presence of aluminum in the meta-sedimentary rocks is extremely conductive to the origin of these minerals (Gunaratne and Dissanayake, 1995).

3.2.3 Gem deposits of magmatic origin

Pegmatites are coarse-grained, acid, granitic intrusions and several suites have been intruded into the metamorphic bedrock of Sri Lanka during several phases of activity throughout the geological evolution of the island. They have been reported as the source rock for gem deposits in several locations. Beryl and chrysoberyl containing pegmatites have been reported from Buttala area, some with exceptionally high quality blue-green aquamarines up to 800 carats in weight (Geological Survey Adm. Report 1968). Be-rich pegmatitic fluids are considered as the source of such gem bearing pegmatites (Rupasinghe et. al. 1984). Zircon bearing pegmatites have been recorded from several locations and one such large deposit is found in Balangoda area (Cooray 1984). Moonstone deposits have been reported from the areas around Balangoda and Kundasale and a new deposit of smoky moonstone was discovered at Imbulpe, east of Ratnapura (Harder, 1992).

3.3 Gem mining and extraction processes

The main types of gem mining are

1. Deep mining (pathal) and tunneling (dona)
2. River bed mining (ganga adeema)
3. Open pit shallow mining (pathas)

The recovery of gem deposits are also carried out by traditional methods which have been in practiced for generations, the method handed over from father to son. Surface deposits and deposits near the surface are recovered by cutting open pits. But the most common and traditional method is mining by shaft and tunnels.

The gem-pits are mined and constructed in a very simple manner that has not changed much since mining began in the island. Although the gravel-like material called *illam* containing the gem mineral can lie as deep as 40 meters, the economics of local mining dictate a maximum pit-depth of 15 meters. Excavation is carried out with basic implements, such as hoes and buckets. As the pit gets deeper, the walls are shored up by a framework of stout logs arranged in crisscross fashion. The only concession to modernity is a motorized pump that removes water from the pits.

When it is hauled to the surface, the *illam* is transported to a source of running water, where it is washed in convex, basket-like containers made of closely woven material. A reasonable quantity of the collected *illam* is taken into the basket and washed, by moving the baskets with a rhythmic rotation the mud is washed away, leaving coarse white quartz gravel. After washing, each basket is fitted atop the other until sufficient material has been accumulated for sorting.

The final stage of the mining process is the sorting (Figure 3.2), which is usually carried out by the mine owner or manager. The rough gem material is sorted by hand while holding the basket in the light of the sun so that any gem colour will glint and be revealed. Then it is inspected for colour and clarity by transmitted light. A unique feature of the island is that a variety of different gems may be found within the same pit.

Figure 3.2 Examining the "Nambuwa"

Chapter 04

Materials and Methods

Most information for this research project was gathered mainly from following sources.

1. Examination of over 40 "Nambus" from the Rathnapura gem field and the Okkampitiya gem field.
2. Visits by the author to gem mining areas mentioned in 3.1 below and to traditional gem fairs ("pola"s) in Monaragala and Ratnapura districts.
3. Personal communications with over 50 people from Sabaragamuwa and Uva provinces who were directly involved in the gem trade, mining, gem-testing, research and law enforcement.

4.1 Sample Collection

At first gem deposits in Ratnapura and Okkampitiya areas were identified. Special attention was given to Ratnapura gem field. Eheliyagoda, Kuruvita, Kiriella, Ayagama, Kalavana, Pothupitiya, Marapana, Pelmadulla, Kahawatta, Rakwana and Rambuka are the areas selected (Figure 4.1). Five sampling locations were selected (Figure 4.2) from Okkampitiya gem field. From each area in Ratnapura and Okkampitiya gem fields two "nambus" were collected. And the depth of the gem pits were measured up to *illam* layers with a meter tape.

Each "nambu" was taken by washing 50 Kgs of *illam*. The weight of the *illam* basket is determined by the weight of the minerals. It varies from 2.5 – 3 Kgs. Usually a quartz rich basket of *illam* is heavy about 2.5 Kgs while an iron rich basket of *illam* is heavy about 3 Kgs. Normally 20 baskets of *illam* apply for one "nambu". Therefore the amount of *illam* using per "nambu" for washing varies from 50 – 60 Kgs. Therefore all the data was calculated per 50 Kgs of *illam*. All the data mentioned in the table was taken by washing constant *illam* quantity.

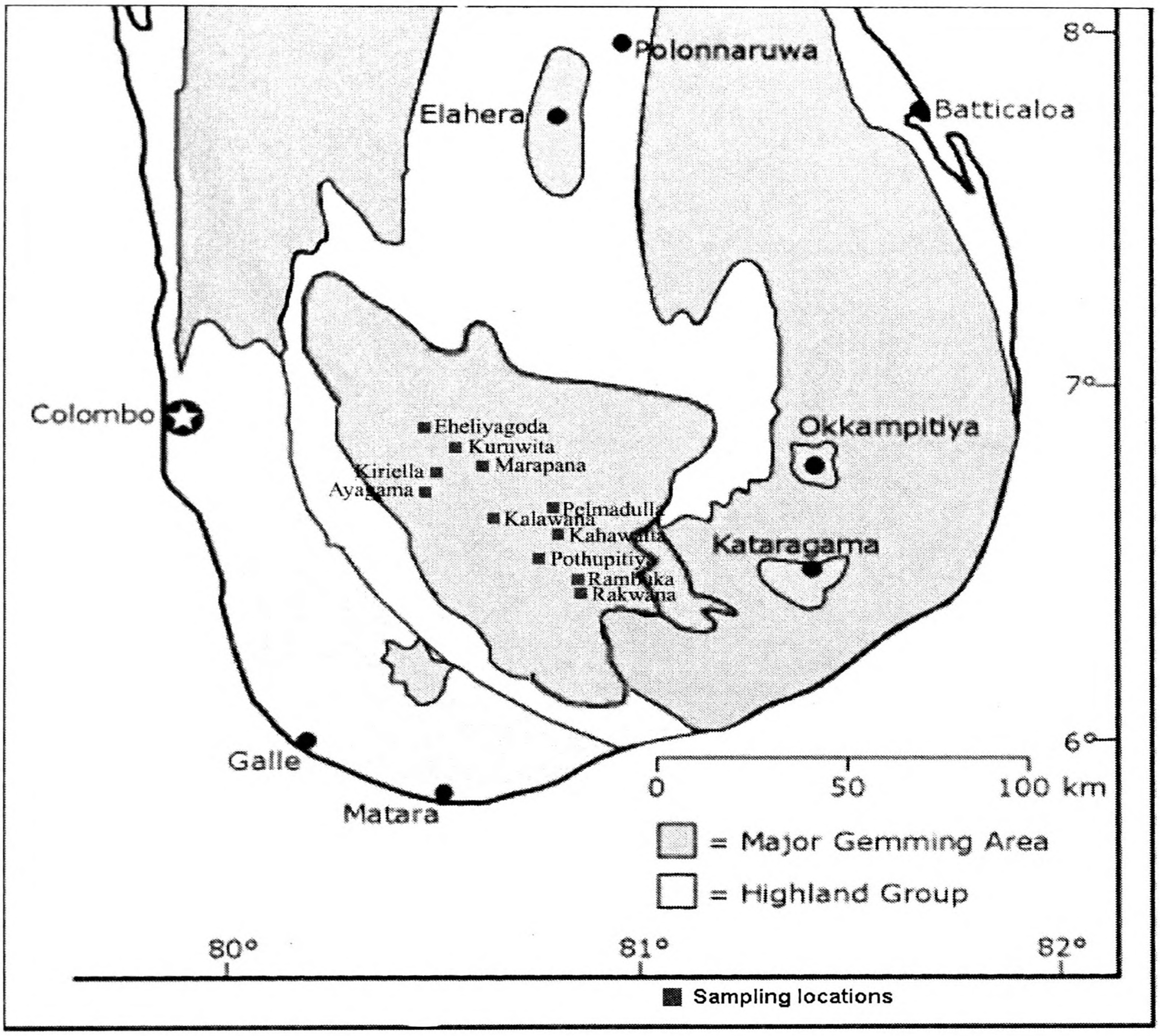


Figure 4.1 The sampling locations in the Ratnapura gem field.

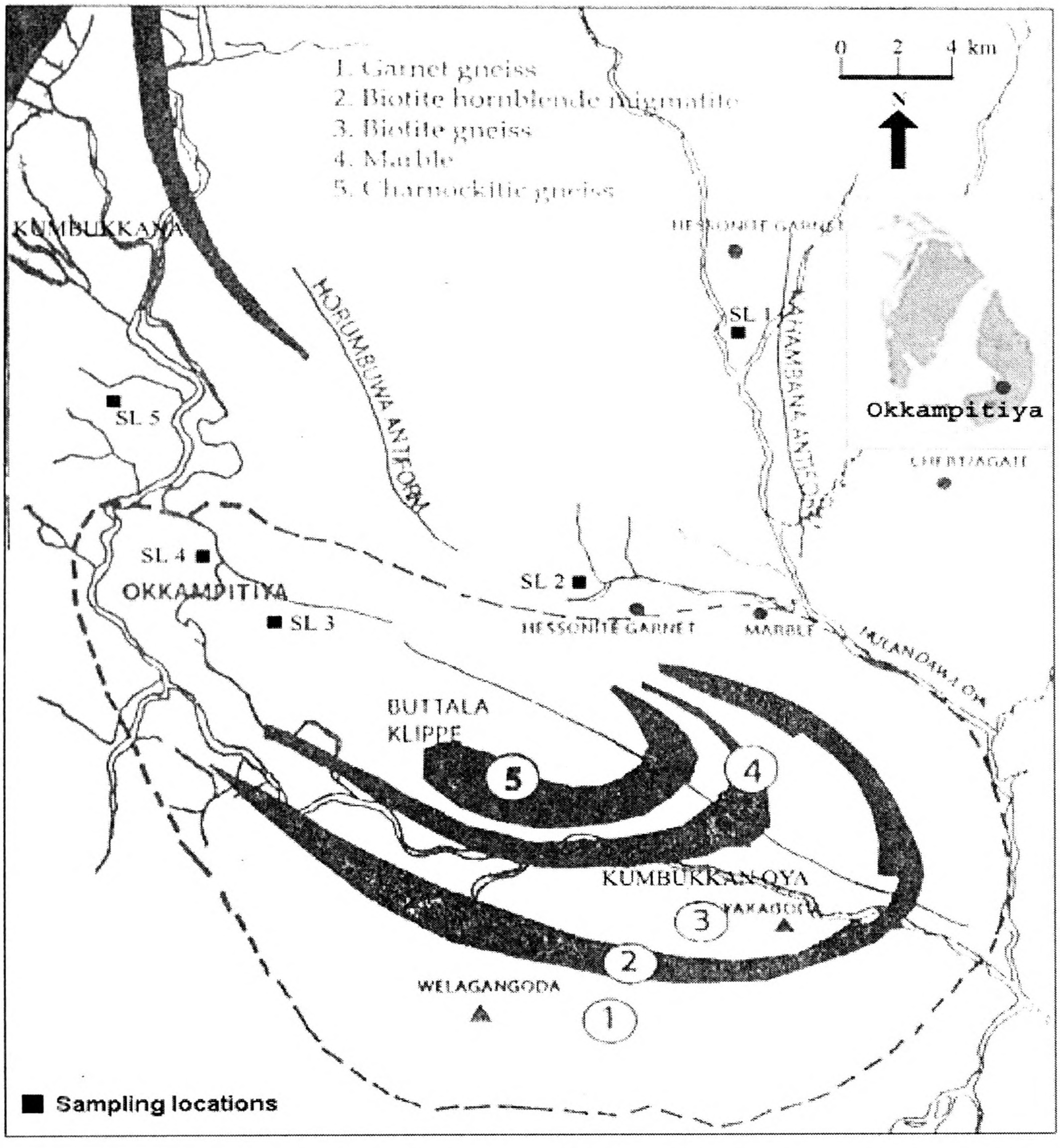


Figure 4.2 The sampling locations in the Okkampitiya gem field (modified from GSMB Monaragala-Panama sheet 18, 2002).

4.2 Sample Preparation

1. The amount of *illam* which is used for each "nambu" was weighed. (Kg)
2. If the number and quantity of minerals were large, they were taken for analyzing.
3. If the number and quantity of minerals were small, several "nambus" were mixed together and panning was done.
4. Lighter minerals were removed and heavier minerals were concentrated.
5. Concentrated minerals were air dried and weighed.
6. They were sieved and separated into two parts; one is greater than 4 mm and the other between 2 mm and 4mm.
7. The minerals between 2 mm and 4 mm were randomly selected for analysis using quarter and corner approach.
8. Other methods used for analysis minerals greater than 4 mm and 2 - 4 mm.

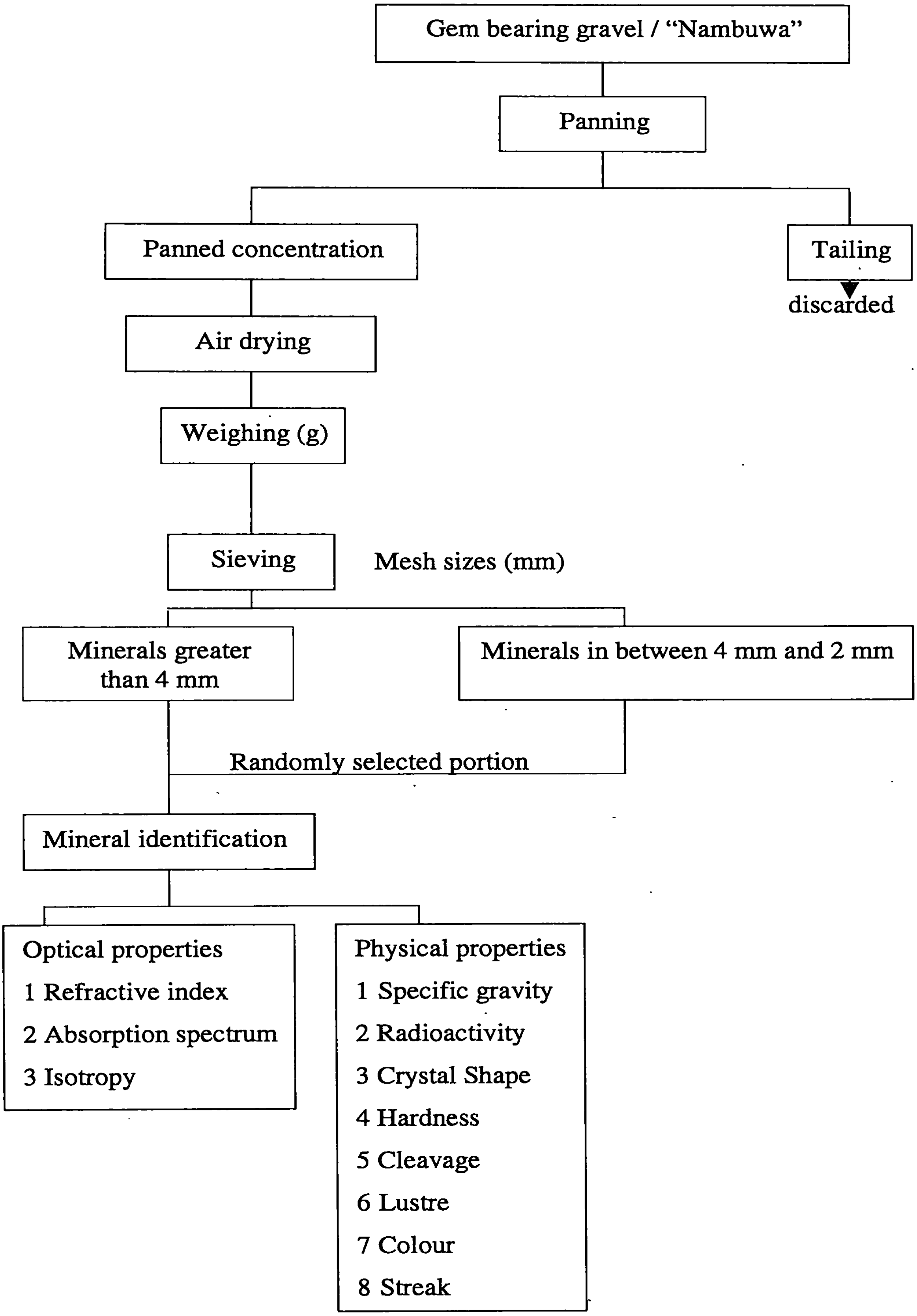

Gem bearing gravel / "Nambuwa"
Panning
Panned concentration
Tailing
discarded
Air drying
Weighing (g)
Sieving
Mesh sizes (mm)
Minerals greater than 4 mm
Minerals in between 4 mm and 2 mm
Randomly selected portion
Mineral identification
Optical properties
1 Refractive index
2 Absorption spectrum
3 Isotropy
Physical properties
1 Specific gravity
2 Radioactivity
3 Crystal Shape
4 Hardness
5 Cleavage
6 Lustre
7 Colour
8 Streak

Figure 4.3 Flow chart for sample preparation and mineral identification.

4.3 Mineral identification

Minerals were identified by using their optical and physical properties.

4.3.1 Optical properties

4.3.1.1 Refractometer

An instrument that measures the refractive index is a refractometer (figure 4.4). The refractive index is actually read off a numeric scale. The mechanism is based on the total internal refraction and the critical angle.

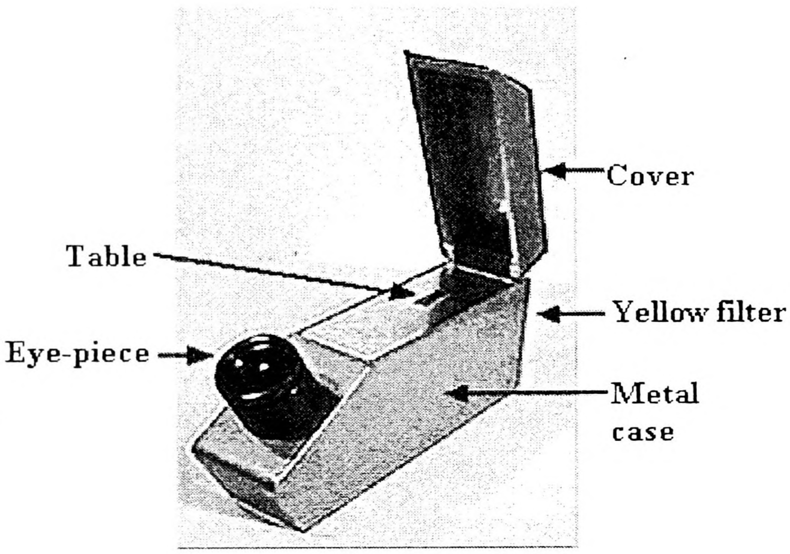


Figure 4.4 Parts of the refractometer

First, Stone to be tested is cleaned. Then set the sours of illumination. Small drop of contact fluid placed in the center of the refractometer prism and carefully place the stone (table facet down) over the fluid. The value on the scale is recorded and compared with the chart which is attached to the appendix.

4.3.1.2 Spectroscope

The spectroscope is useful in the identification of some gem varieties. This can be of use in the identification of some varieties which cannot be identified using the refractometer. Absorption of wavelengths within the visible range can be seen as a pattern of absorption lines and bands in the spectroscope.

- A gemstone is placed in front of a slit of the spectroscope, and light is directed into the stone (Figure 4.5).

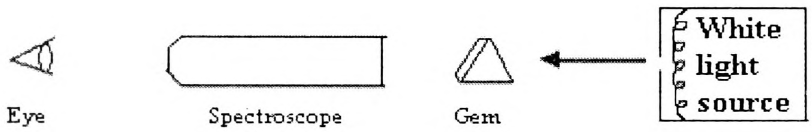


Figure 4.5 Checking spectra using the spectroscope

- Light transmitted through the gemstone shows an absorption spectrum. This was drown on paper.
- Wavelengths of light are also marked in ***nanometers*** as shown in following scale (Figure 4.6).

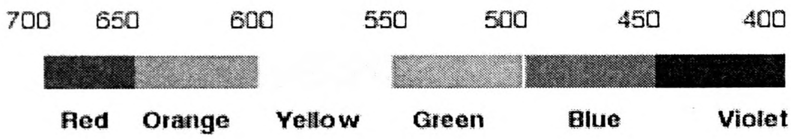


Figure 4.6 Spectroscope scale in nanometers

The spectra used to identify the minerals in samples are given in the appendix.

4.3.1.3 Polariscope

This instrument is used for examining gemstones between crossed polars. A gemstone is held between crossed polaroid plates, and the stone is rotated in a plane parallel to the polaroids. Only minerals with sufficient transparency can be examined with a polariscope. This is mainly used to check whether the stone is optically isotropic or anisotropic.

4.3.2 Physical properties

4.3.2.1 Specific gravity

The weight of the gem in air divided by the loss of weight in water gives the specific gravity of the stone or material.

The specific gravity of each mineral is the same within narrow limits (except in species like garnet and zircon where subgroups with definite specific gravities occur). If one can determine the specific gravity it may be useful in the identification.

Hydrostatic SG determinations by devising a way of weighing the stone in air and then in water. The conditions required are

1. A bridge is constructed for the left hand side of the balance. This sits above the pan without touching or otherwise interfering with the operation of the balance at any time in its use.
2. A beaker of water (distilled) is placed on the bridge.
3. An extremely thin lightweight copper spiral wire 'cage' (figure 4.7) is constructed which hangs from the left hand side of the balance arm. The spiral 'cage' is submerged in water.

Figure 4.7 Cage for holding minerals

4. A counterbalance wire is hung from the opposite side of the balance arm at the same position. This is cut so as to balance the 'cage' wire as completely as possible

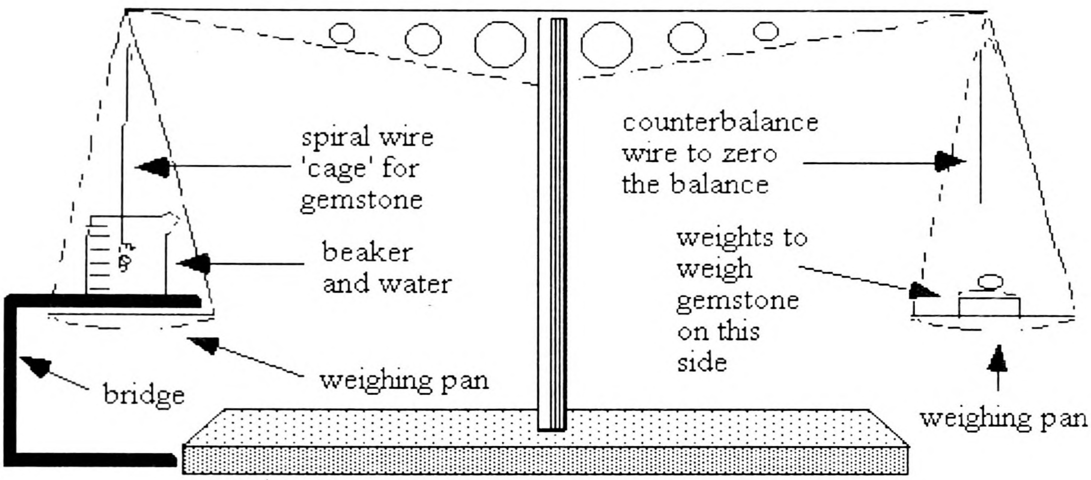


Figure 4.8 Chemical balance accurate to 3 decimal places (.001g)

Procedure to determine SG of a mineral over 3 ct

1. Clean the stone very carefully with a cloth. If it has wax or grease on it this must be removed. (Examine it for large flaws or inclusions which might affect the accuracy of the results.)

2. Place it on the left hand pan underneath the bridge and weight the stone. Record the result. Weighings are done to three decimal places.

3. Place the stone in the spiral cage and weigh it in water. Record the result. Brush off any bubbles on the stone or wire with a fine brush.

4. Subtract the second result from the first to find the difference. (The apparent loss of weight in water).

5. Calculate:

$$\frac{\text{Wt of stone in air}}{\text{Loss of wt in water}} = \text{S.G}$$

6. For more accurate results repeat the procedure at least three times and average the results. (The larger the object the more accurate the results.)

4.3.2.2 Radioactivity

The radioactivity of the samples verses weight was using the Geiger Mueller Counter. The unit taken is total count per minute. The sample was placed on the desk and the sensor of the instrument was placed about 1cm above the sample. Two measurements were taken, inside a room where other mineral samples are also stored and outside the room. The radioactivity was calculated for one gram of sample.

4.3.2.3 Crystal Shape

When minerals form in environments where they can grow without interference from neighboring grains, they commonly develop into regular geometric shapes, called crystals, bounded by smooth crystal faces. The crystal form for a given mineral is governed by the mineral's internal structure, and may be distinctive enough to help identify the mineral.

Examples,

Spinel - Frequently occurs in octahedral form

Zircon - Square or rectangular cross section; tetragonal prism form may be long or very short; together with the tetragonal bipyramid.

Tourmaline – The trigonal prism is often long and heavily striated vertically, with a rounded triangular cross-section.

Corundum – Trigonal prismatic or tabular six-sided crystals, often with flat basal terminations. Also occurs as six-sided bipyramids.

4.3.2.4 Hardness

The hardness of the mineral refers to its resistance to scratching. Hardness is measured on the Mohs Scale of Hardness.

Mohs scale

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

- Minerals in mohs scale can be used to make to a very small scratch on the mineral to be tested.
- Use a magnifying lens or microscope to see the result of the test.
- Hardness range of the tested mineral can be decided by this test. (Harder stones will scratch softer ones. Stones of the same hardness may scratch each other).

Hardness testing is acceptable for some rough material, but rarely done on fashioned gems, because, it is a destructive test, which may leave a groove on the specimen.

4.3.2.5 Cleavage

This is the tendency of a crystallized mineral to break in definite directions related to the crystal structure producing relatively smooth cleavage break surfaces.

Cleavage planes are always parallel to a particular cleavage face, i.e. cleavage plains in topaz are always parallel to the basal pinacoid.

Those with the least tendency to cleave include garnets, quartz, spinel (natural), beryl and zircon. Gemstones with a strong tendency to cleave include topaz, peridot, feldspars, synthetic spinel, and calcite.

4.3.2.6 Lustre

The lustre of a mineral depend on the extent to which its surface reflects light. Most terms used to describe lustre are self-explanatory: metallic, earthy, waxy, greasy, vitreous (glassy), sub-adamantine and adamantine.

Pyrite - Metallic lustre

Zircon – sub-adamantine lustre

Spinel – Vitreous lustre

4.3.2.7 Colour

Colour is the easiest physical property to determine. Colour results from a mineral's chemical composition, impurities that may be present, and flaws or damage in the internal structure.

However, colour alone cannot be used in the identification.

4.3.2.8 Streak

Streak is the true color of a mineral in the powdered form, obtained by rubbing the specimen across an unglazed porcelain streak plate. The streak and color of some minerals are the same. For others, the streak may be quite different (figure 4.9) from the color of the stone (table 4.1).

Table 4.1 Streak colour for a few common minerals

Material	Colour of mineral	Steak colour
Pryite	Metallic gold	Black
Quartz	Pink, brown	White
Magnetite	Black	Black
Limonite	Oily brown	Yellowish brown
Hematite	Black	Red to redish brown

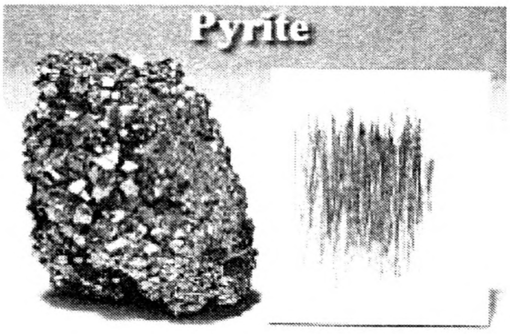


Figure 4.9 Streak of pyrite on a porcelain plate

The combination of luster, color, and streak may be very useful in the identification of the mineral.

4.4 Exploration of traditional knowledge

Discussions were held with the gem miners to gather information on the high and low quality gems found in the *illama* and to find out the use of "nambuwa". A questionnaire prepared to get information from gem miners and buyers is attached to the appendix.

CHAPTER 05
RESULTS AND DISSCUSION

5.1 Data and charts

The Pelmadulla sample (figure 5.1) consisted of 35% of iron rich minerals, 27% of Quartz and 8% of "X" mineral while the percentage of the "X" mineral was comparatively high in this sample compared to other areas, Ratnapura and Okkampitiya. It is called "Wedibeheth Nambuwa" by gem miners. In this sample, gem minerals consisted nearly 25%. These gem minerals are mainly spinel, tourmaline, zircon and garnet. The weight percentages of them are 13%, 2%, 8% and 2% respectively. This sample also consisted of 2% pyrite and 2% radioactive minerals. Most of the radioactive minerals found in alluvial gem deposits were observed in the Pelmadulla sample.

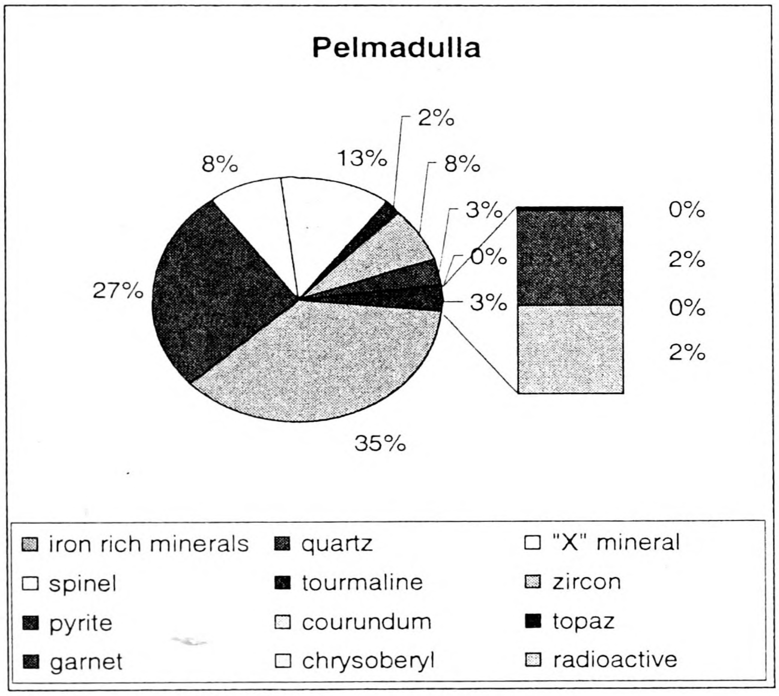


Figure 5.1 Percentage weight of minerals in the Pelmadulla sample.

"X" mineral: unidentified mineral in the gem bearing gravel layer.

Iron rich minerals: mainly consisted of hematite, limonite and magnetite.

Presence of quartz in the Eheliyagoda sample (figure 5.2) was 77%, while iron rich minerals and "X" mineral were 13% and 2% respectively. It also consisted of 1% pyrite. In this sample nearly 7% were gem minerals such as spinel, tourmaline, zircon and garnet. The weight percentages of them are 3%, 2%, 1% and 1% respectively. Compared to the Kuruvita and Pelmadulla samples this can be introduced as quartz-rich gem gravel.

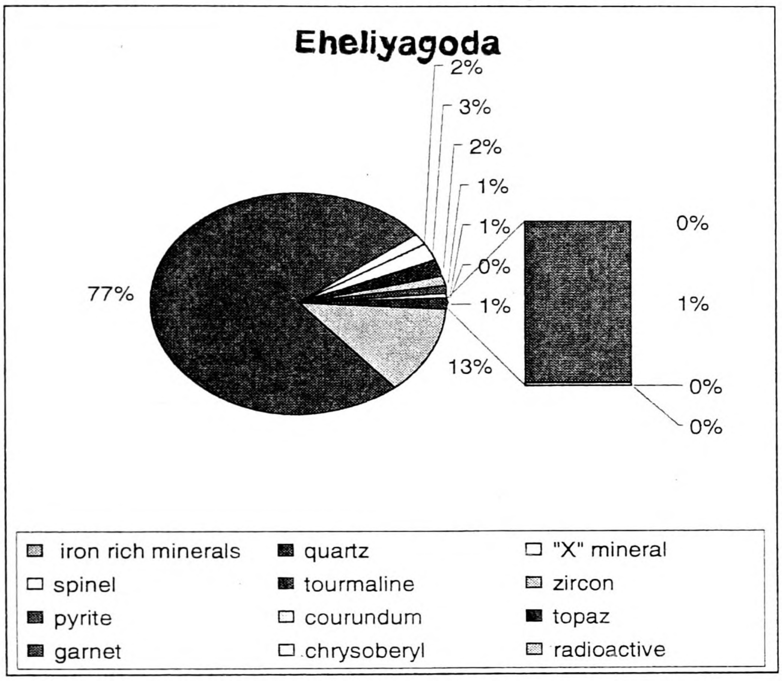


Figure 5.2 Percentage weight of minerals in the Eheliyagoda sample.

The percentage of the iron rich minerals in the Kuruvita (figure 5.3) area was 72% while those of quartz and "X" mineral were nearly 13% and 4% respectively. It also consisted of 1% pyrite. This sample consisted of 9% gem minerals. They were spinel (5%), tourmaline (1%), zircon (2%) and garnet (1%). A sample was also obtained from alluvial gem deposit. It consisted of 1% radioactive minerals. This sample had a high percentage of iron-rich minerals compared with that of Okkampitiya.

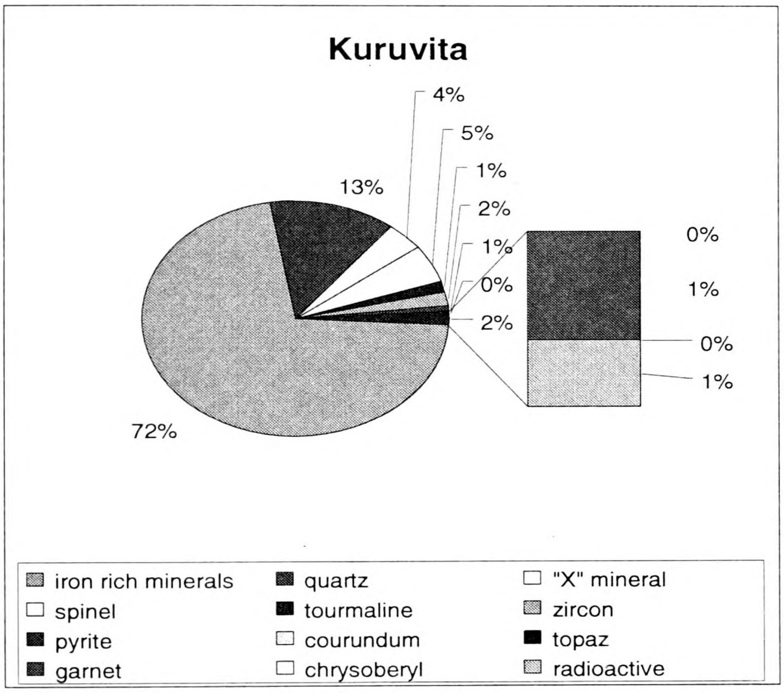


Figure 5.3 Percentage weight of minerals in the Kuruvita sample.

Weight percentage of quartz in the sample taken from Kiriella (figure 5.4) was 76%. It also consisted of iron rich minerals (12%), "X" mineral (3%) and pyrite (2%). In this sample the weight percentage of the gem minerals was 7%. [spinel (2%), tourmaline (2%), zircon (1%) and garnet (2%)].

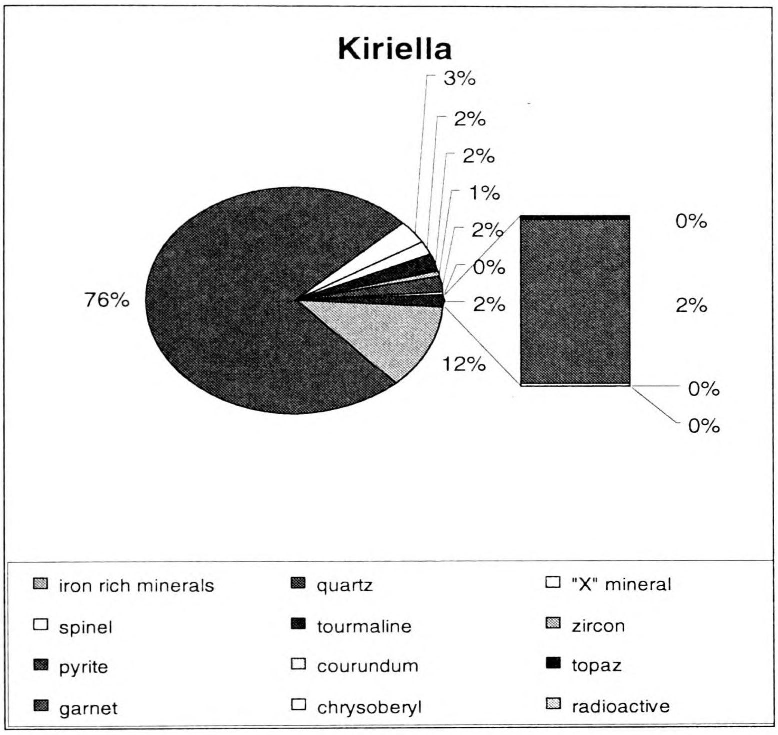


Figure 5.4 Percentage weight of minerals in the Kiriella sample.

The weight percentage of quartz in the sample which was taken from Ayagama (figure 5.5) was 87%. It also consisted of iron rich minerals (1%), "X" mineral (2%) and pyrite (2%). The weight percentage of the gem minerals in this sample was 7%. [spinel (1%), tourmaline (3%), zircon (1%) and garnet (2%)].

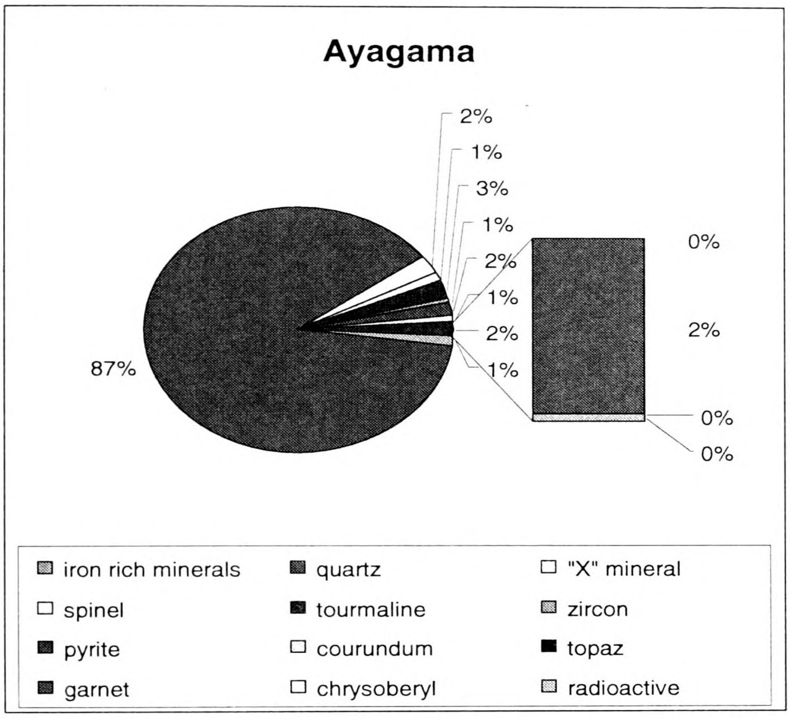


Figure 5.5 Percentage weight of minerals in the Ayagama sample.

The weight percentage of the quartz in the sample which was taken from Kalawana (figure 5.6) was 77%. There was also iron rich minerals (8%), "X" mineral (4%) and pyrite (3%). In this sample the weight percentage of the gem minerals was 8%. [spinel (2%), tourmaline (3%), zircon (1%) and garnet (2%)].

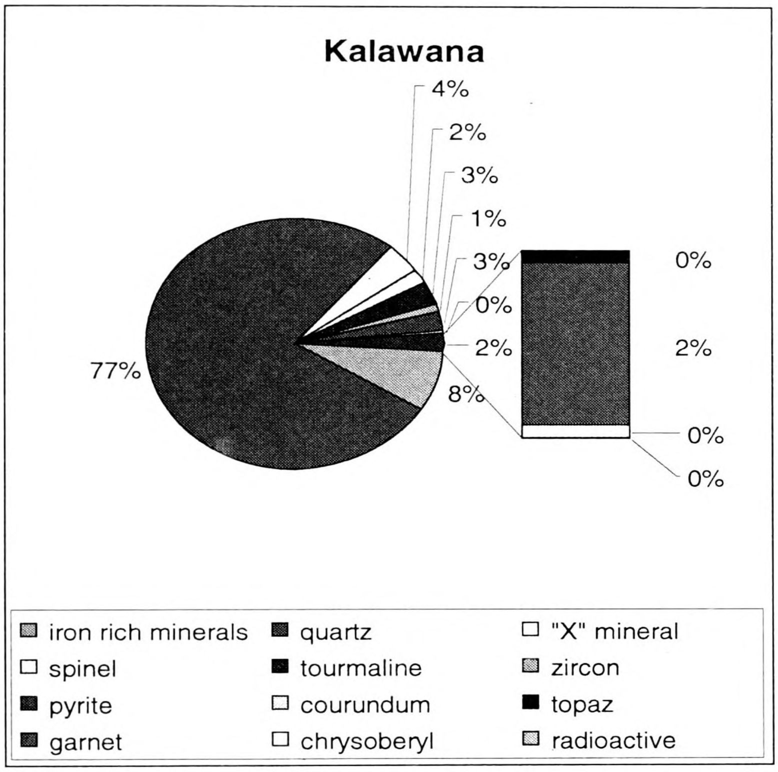


Figure 5.6 Percentage weight of minerals in the Kalawana sample.

The sample taken from Pothupitiya (figure 5.7) consisted of 75% iron rich minerals, 14% quartz and 1% pyrite. No "X" mineral was found in this sample. In this sample the weight percentage of the gem minerals was 10%. [spinel (5%), zircon (3%) and garnet (2%)].

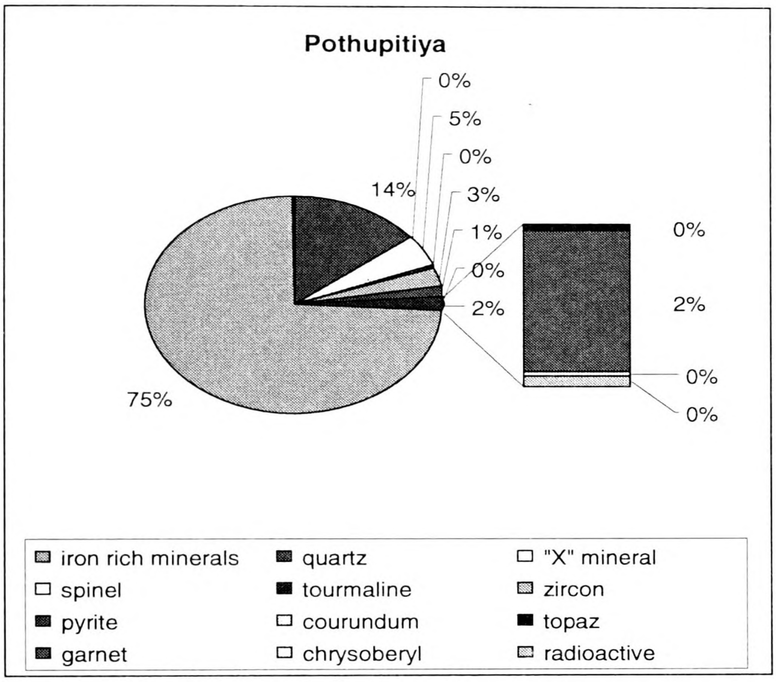


Figure 5.7 Percentage weight of minerals in the Pothupitiya sample.

The sample taken from Marapana (figure 5.8) consisted of iron rich minerals 76%, quartz 13% and "X" mineral 1%. Pyrite cannot be seen in this sample. The weight percentage of the gem minerals in this sample was 10%. [spinel (4%), tourmaline (2%), zircon (2%) and garnet (2%)].

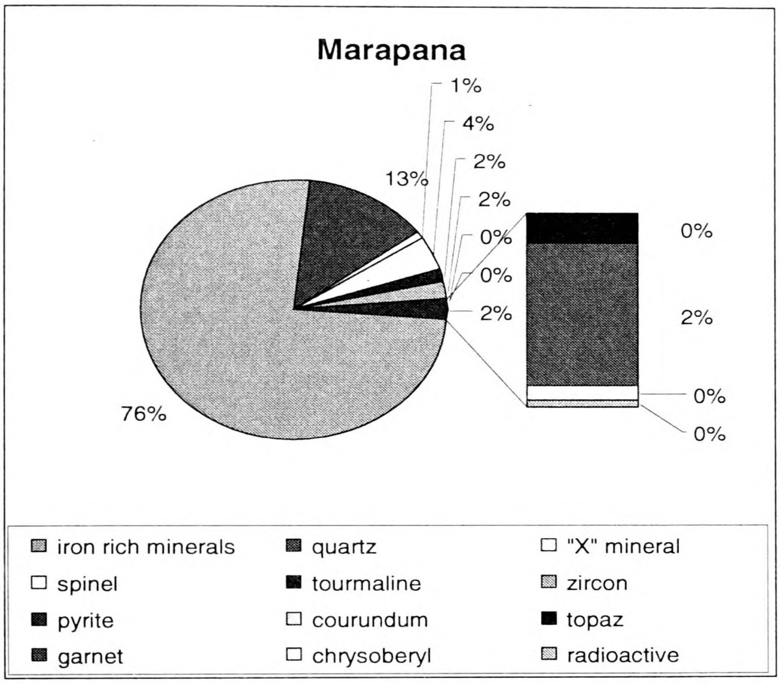


Figure 5.8 Percentage weight of minerals in the Marapana sample.

The percentages of the weight of the sample taken from Kahawatta (figure 5.9) were consist of 70% iron rich minerals, 15% quartz, 2% "X" mineral and 1% pyrite. In this sample nearly 12% were gem minerals. [spinel (4%), tourmaline (2%), zircon (2%) and garnet (4%)].

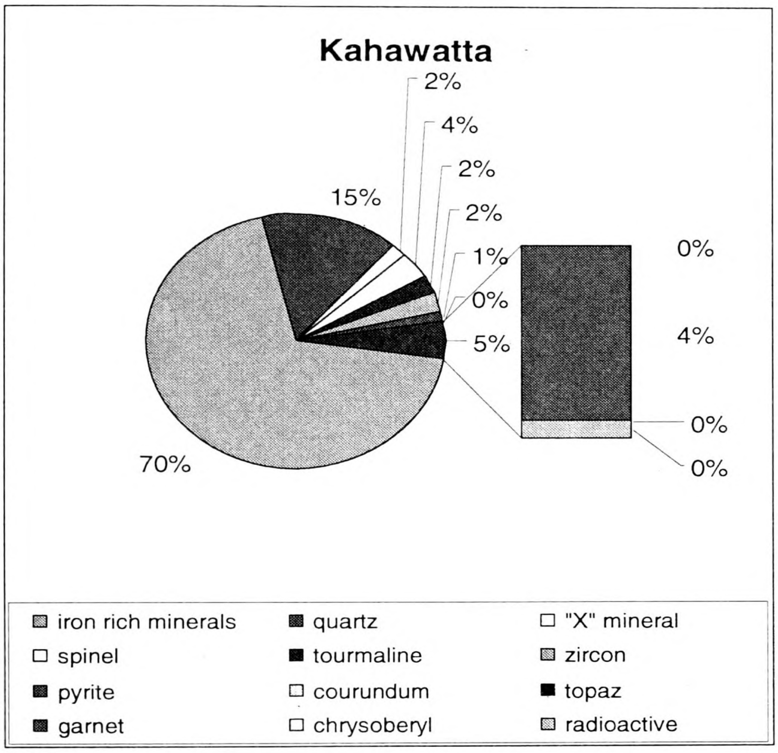


Figure 5.9 Percentage weight of minerals in the Kahawatta sample.

The weight percentages of the sample taken from Rakwana (figure 5.10) were 72% iron rich minerals and 18% quartz. "X" mineral and pyrite were not found. In this sample nearly 10% were gem minerals. [spinel (4%), tourmaline (1%), zircon (3%) and garnet (2%)].

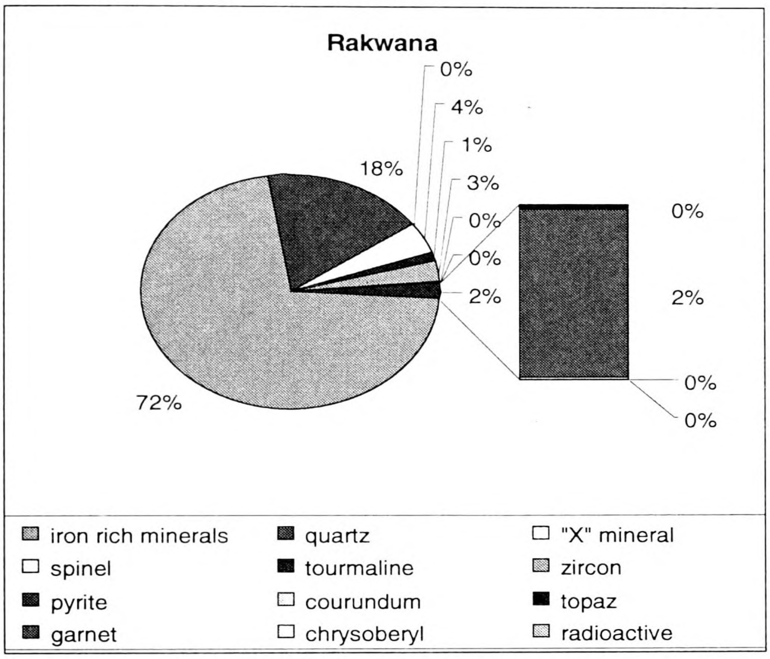


Figure 5.10 Percentage weight of minerals in the Rakwana sample.

The weight percentages of the sample taken from Rambuka (figure 5.11) were 77% iron rich minerals, 14% quartz and 1% pyrites. "X" mineral was not found. In this sample nearly 8% were gem minerals such as spinel (3%), tourmaline (1%), zircon (2%) and garnet (2%). This gem gravel sample consisted as rich in iron bearing minerals.

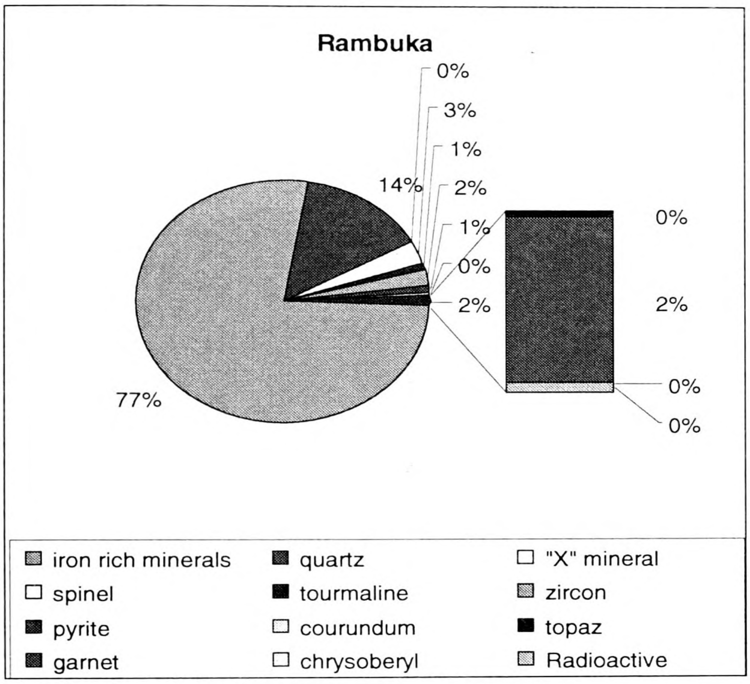


Figure 5.11 Percentage weight of minerals in the Rambuka sample.

The weight percentages of the sample SL 1 taken from Okkampitiya (figure 5.12) were 53% iron rich minerals, 32% quartz and 2% "X" mineral. The percentage of pyrite was low (~9 g). However, it was consisted of 1% radioactive minerals. In this sample nearly 12% were gem minerals. [(4%), tourmaline (1%), zircon (6%) and garnet (1%)].

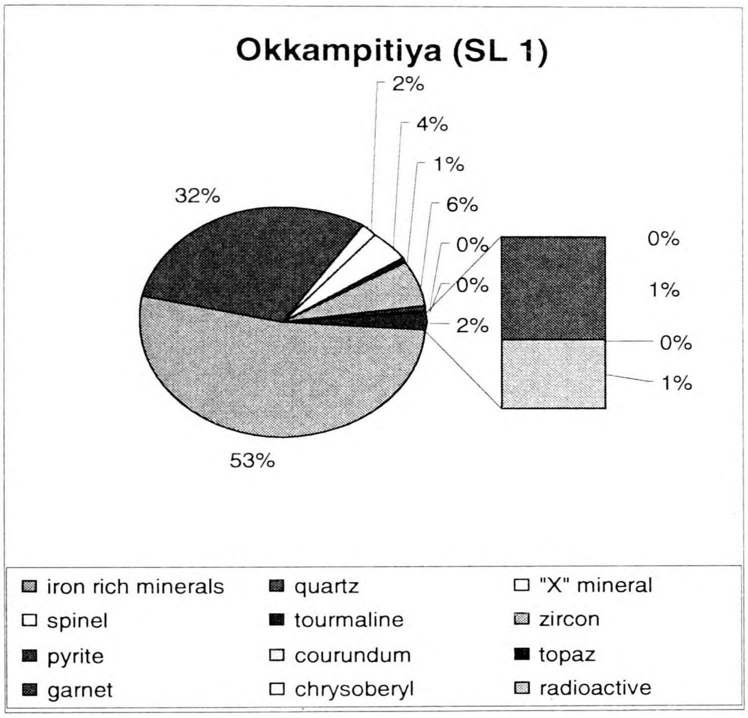


Figure 5.12 Percentage weight of minerals in the Okkampitiya (SL 1) sample.

The weight percentages of the sample SL 2 obtained from Okkampitiya (figure 5.13) were consisted of 56% iron rich minerals, 26% quartz, 2% "X" mineral and 1% pyrite. It was also consisted of 1% radioactive minerals. In this sample nearly 13% were gem minerals. [spinel (5%), tourmaline (1%), zircon (6%) and garnet (1%)].

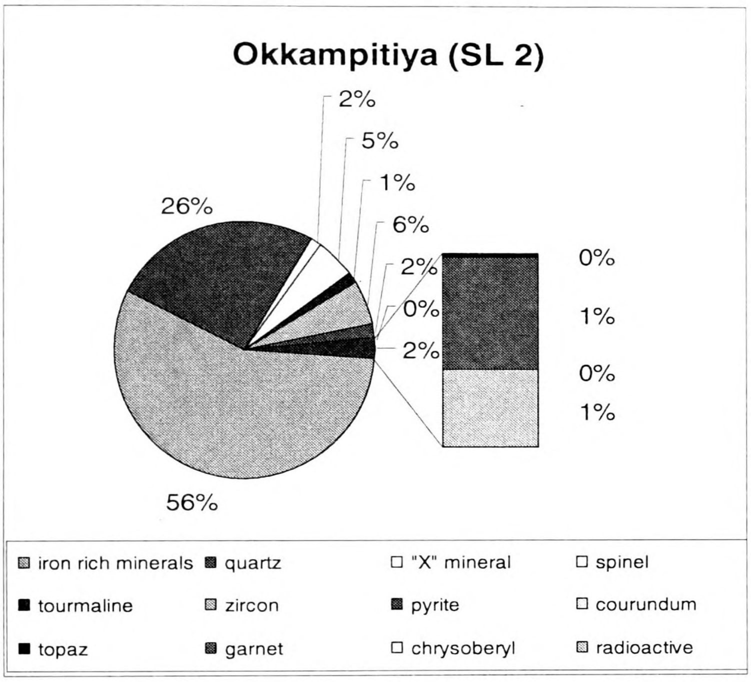


Figure 5.13 Percentage weights of minerals in the Okkampitiya (SL 2) sample.

The weight percentages of the sample SL 3 taken from Okkampitiya (figure 5.14) were consisted of 52% iron rich minerals, 25% quartz, 4% "X" mineral and 1% pyrite. It was also consisted of 1% radioactive minerals. In this sample nearly 17% were gem minerals. [spinel (3%), tourmaline (2%), zircon (10%) and garnet (2%)].

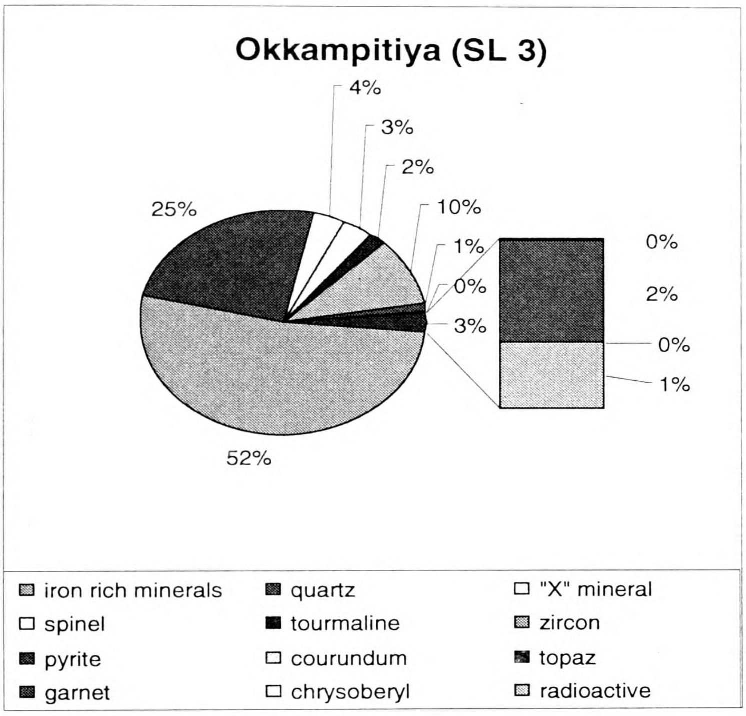


Figure 5.14 Percentage weight of minerals in the Okkampitiya (SL 3) sample.

The weight percentages of the sample SL 4 taken from Okkampitiya (figure 5.15) were consisted of 54% iron rich minerals, 25% quartz, 3% "X" mineral and 2% pyrite. It was also consisted of 1% radioactive minerals. In the sample SL 4 nearly 14% were gem minerals. [spinel (4%), tourmaline (2%), zircon (5%) and garnet (3%)].

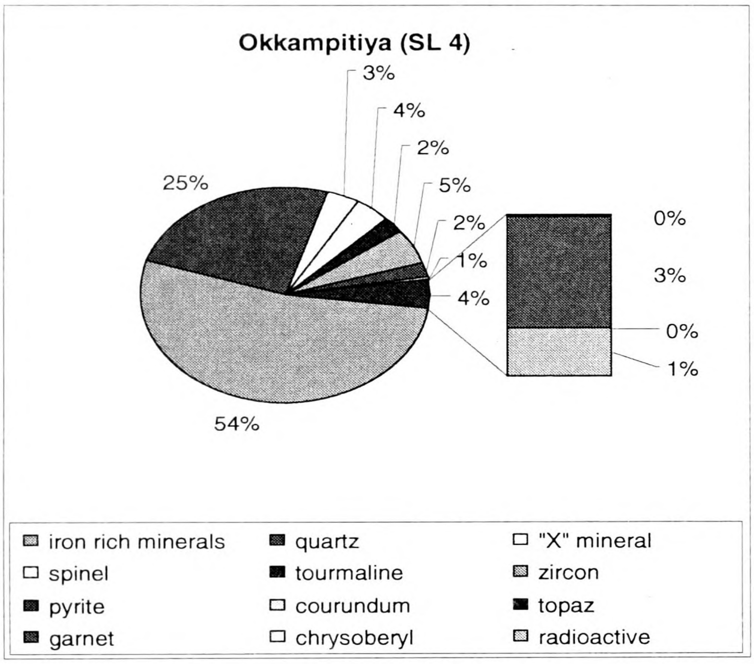


Figure 5.15 Percentage weight of minerals in the Okkampitiya (SL 4) sample.

5.2 Dispersion of Minerals in Ratnapura and Okkampitiya areas

The weight percentage of iron rich minerals of the samples taken from Ratnapura gem field vary from 1% to 77%. However, in Okkampitiya gem field the content of iron rich minerals vary in between 40% - 56%. Iron rich minerals are abundant in gem gravel in Rambuka, Kahawatta, Marapana, Pothupitiya and Kuruvita areas.

The weight percentage of quartz in the samples from the Ratnapura gem field, varies from 13% to 87%. But that of Okkampitiya gem field varies from 25% - 47% . In the samples obtained from Kalawana, Ayagama, Kiriella and Eheliyagoda were rich in quartz while the content of quartz in Kuruvita, Marapana, Pothupitiya, Kahawatta, Rambuka and Rakwana was low.

The weight percentage of "X" mineral of the samples taken from Ratnapura gem field ranged from 0 to 8 % while that of Okkampitiya gem field it varied from 2% to 4%. Kalawana, Pelmadulla and kuruvita areas are rich in "X" minerals.

In the samples taken from Ratnapura gem field, the weight percentage of spinel vary from 1% to 13%, but that of Okkampitiya samples, it was from 3% to 5%. The highest weight percentage of spinel (13%) was found from Pelmadulla area. The amount of spinel found in Kuruvita, Pothupitiya and Okkampitiya SL 2 samples was also high.

The weight percentage of tourmaline in the samples of Ratnapura gem field varies from 0.3% to 3% while that of Okkampitiya gem field it varies from 1% to 2%. The most amount of tourmaline was found in the Ayagama and Kalawana samples.

The weight percentage of zircon in the samples of Ratnapura gem field varies from 1% to 8%, But in the Okkampitiya samples it is between 3% and 10%. The highest percentage of zircon (10%) was recorded from Okkampitiya SL3 sample. In the Pelmadulla sample the percentage of Zircon was 8%.

5.3 Type of "nambu" according to the major mineral type

Once the gems are recovered after washing the gravels are discarded. This discarded material is termed "Nambuwa" by the gem miners. According to gem miners mainly two kinds of "Nambus" are found in the Ratnapura and Okkampitiya gem fields. They are the "Tel-borella nambuwa" (Figure 5.19a) and "Tiriwana nambuwa"(Figure 5.17).

"Tiriwana nambuwa" is white in colour because it mainly consists of quartz. In the Ratnapura gem field the "Nambus" found in Eheliyagoda, Ayagama, Kiriella, and Kalawana are "Tiriwana nambus" while "Eriyapola" gem mining area in the Okkampitiya is fairly rich in quartz. "Tiriwana nambuwa" consists of high amount of tourmaline while the amount of pyrite is also somewhat high. In addition, the amount of radioactive minerals in "Tiriwana nambuwa" is less.

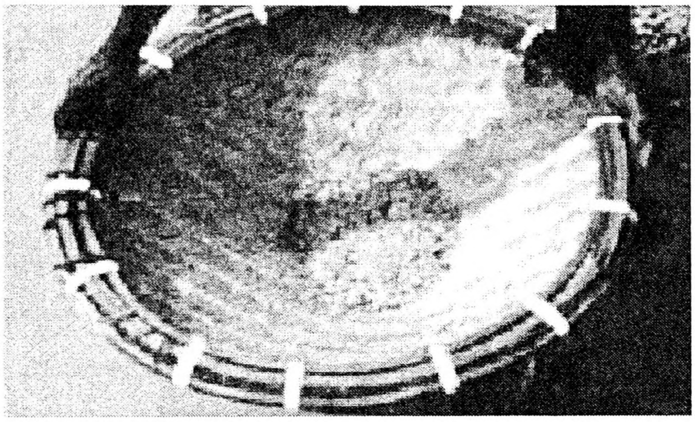


Figure 5.17 "Tiriwana nambuwa" taken from Ayagama.

Sometimes the bottom of "Tiriwana nambuwa" is bluish-graey in colour and gives out a light. It is because of the concentration of "X" minerals (Figure: 5.18b) in the bottom of the washing basket. Because of the bluish-gray colour and the high metallic luster the mineral "X" takes the color of gun powder, and its smell is also like that of gun powder. Therefore the gem miners called it the "Wedibeheth Nambuwa" (Figure: 5.18a). The cause for the concentration of "X" minerals in the bottom of the washing basket is the specific gravity of this mineral (4.9) which is somewhat higher than that of other heavy minerals. Gem miners say, that the areas which consists of this "wedibeheth nambuwa" are rich in yellow sapphires and white sapphires.

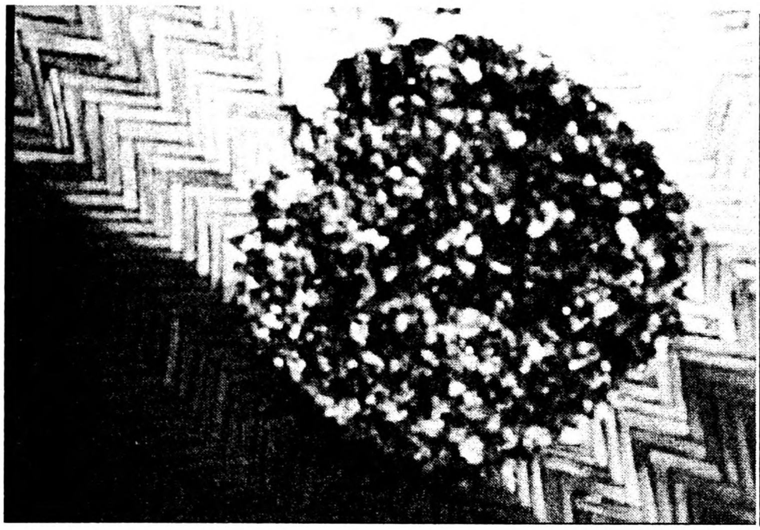


Figure 5.18a "Wedibeheth nambuwa" taken from Pelmadulla.

Figure 5.18b "X" mineral taken from "wedibeheth nambuwa".

The "Tel-borella nambuwa" mainly consists of iron rich-minerals (Figure 5.19b). Iron rich minerals are brown in colour with dull lustre. Therefore the "Tel-borella nambuwa" takes the colour brown. "Tel-borella nambus" are mostly found in the Ratnapura gem field. Especially in Kuruvita, Pothupitiya, Marapana, Kahawaththa, Rakwana and Rambuka areas. Most of the "nambus" found in the Okkampitiya area are also likely to be "Tel-borella nambus", but they are not as dark as the nambus found in the Ratnapura gem field. The reason for this is that the **Iron-rich minerals : Quartz** ratio, in the Okkampitiya gem field is less than that is the Ratnapura gem field. Usually "X" minerals can also be seen everywhere in the Okkampitiya gem field.

According to the gem miners, the most valuable gems found in Galukagama, Edandawala, Teppanawa, Karapincha, Kosgala, Urupelauva and Paradise which are near Kuruvita and Elapatha near Ratnapura were in "Tel-borella nambus".

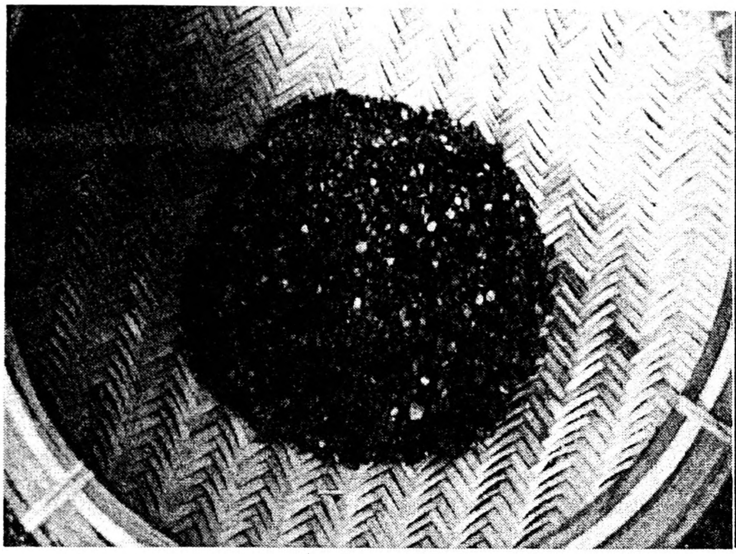


Figure 5.19a "Tel-borella nambuwa" taken from Kuruvita.

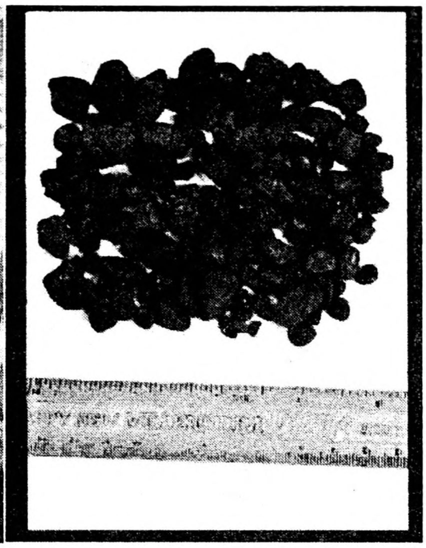


Figure 5.19b Iron rich minerals taken from "Tel-borella nambuwa".

5.4 Information taken from gem miners and buyers

Yellow sapphire and "geuda" are the main precious gems found in the Okkampitiya gem field. Zircon and spinel are also found there in abundance. Garnets are also abundant and hessonite is predominant. Rambuka and Rakwana are famous for best quality blue sapphires. Ruby and "Nil ottu" are mostly found in Niwithigala and Kuruwita areas. Rubies are mostly found in Balangoda Aluthnuwara area also. Ayagama, Galathura and Idangoda areas are famous for yellow sapphires. When these yellow sapphires are heat treated their colours will be enhanced well. Delgamuwa which is close to Kuruvita and Aluthnuwara close to Balangoda are also famous for yellow sapphires. Zircon and alexandrite are mostly found in Kukulu ganga. Most of the Zircons found there are colourless. Alexandrites are found in abundance Niriella, Nivithigala, Karavita, Pothupitiya and Kalawana Thennahena. Gileemale, Kuruvita, Karapincha, Halpe and Hapurugala close to Ratnapura are famous for star sapphires and star rubies. Diyahinna which is close to Embilipitiya is well known for rose garnets. Garnet, hessonite, zircon, "geuda" and yellow sapphires are found in Embilipitiya area.

"Ottus" are found in the Eheliyagoda area. Aquamarines are found in Karapincha which is close to Ratnapura. Garnets and "Poonakkan" (moonstone) are found in abundance in the Balangoda area. The most valuable gems were found in Galukagama, Edandawala, Teppanawa, Karapincha, Kosgala, Urupelauva and Paradise near Kuruvita and Elapatha and Pelmadulla. Most expensive gem a blue sapphire was found in Pelmadulla recently. White sapphires and cat's eyes are mostly found in pelmadulla area. Peridots are very rare in Sri Lanka. But occasionally they are found in Eheliyagoda and Okkampitiya areas.

Illama is generally a 0.5-1.5m thick horizon of gem-bearing gravel capped above and below by blue-green coloured clay. However, both from reports and personal observations and intervies showed that there is considerable variation in the thickness, extent and composition of the *illam*, the later of which has appears to have some correlation with the gem content of the gravels. According to gem miners, some areas the *illam* is shallow (<3m below the surface), thin (10-20 cm), generally characterised by quartzose gravels and blue grey clay and is laterally impersistant, presumably occupying depressions in the underlying bedrock surface. At other sites it is several tens of meters (20-30m) below the surface, 0.5-1.5 m thick and laterally extensive (several 100 m^2) and is occasionally repeated, with several *illam* horizons encountered as the shaft or pit is dug. This type of occurrence may represent a buried river valley or flood plain. Generally there is no way to predict multiple bands unless there has been earlier mining in the same area. Gem miners report however that there is no direct correlation between thickness of the *illam* and gem content and that the thinnest *illam* can yield significant gems whilst the thickest can be barren. In terms of bulk mineralogical composition of the *illam* there is a broad range from clay dominated to those containing fine-grained sand. The former are generally bluegreen- grey in colour and have high clay content whilst the sandier *illams* are dark greens, brown and black. Both are often associated with high contents of organic material which releases a pungent odour when the *illam* is excavated and in fact presents some difficulties when extracting the *illam* from deeper, poorly ventilated shafts and pits.

5.4.1 Prices of high quality gems among gem buyers in Ratnapura

The prices of high quality gems were considered in the interviews and listed in table 5.1 per carat. Table 5.2 described the price of high quality gems with weight above one carat.

Table 5.1 Price per carat of high quality gems of weight 1ct.

Gem variety	Weight (1ct = 0.2 gram)	Prices of rough stones	Prices of cut and polish stones
Alexandrite	1ct	Rs: 8000	Rs: 10,000 – 15,000
Ruby	1ct	Rs: 6500 – 7000	Rs: 10,000 – 12,000
Blue sapphire	1ct	Rs: 6000	Rs: 8000 – 10,000
Star ruby	1ct	Rs: 3000 – 4000	Rs: 6000 – 10,000
Star sapphire	1ct	Rs: 3000 – 4000	Rs: 6000 – 9000
Cat's eye	1ct	Rs: 3000	Rs: 6000 – 8000
Alexandrite cat's eye	1ct	Rs: 3000	Rs: 6000 – 8000
Pink sapphire	1ct	Rs: 3000 – 5000	Rs: 6000 – 7000
Orange sapphire	1ct	Rs: 2500	Rs: 5000 – 7000
Colour change spinel	1ct	Rs: 500 – 750	Rs: 5000 – 7000
Yellow sapphire	1ct	Rs: 1500	Rs: 3000 – 5000
Colour change garnet	1ct	Rs: 1000 – 2000	Rs: 3000 – 5000
White sapphire	1ct	Rs: 1500	Rs: 2000 – 2500
Spinel (red / blue)	1ct	Rs: 500 – 750	Rs: 1000 – 1500
Hessonite	1ct	Rs: 300 – 350	Rs: 750 – 1000
Rose garnet	1ct	Rs: 300 – 350	Rs: 750 – 1000
Blue topaz	1ct		Rs: 750 – 1000
Aquamarine	1ct	Rs: 200 – 300	Rs: 500 – 750
Chrysoberyl	1ct	Rs: 200 – 250	Rs: 500 – 600
Zircon (green)	1ct	Rs: 200 – 250	Rs: 500 – 600
White topaz	1ct		Rs: 300 – 500
Zircon (yellow)	1ct	Rs: 100 – 150	Rs: 300 – 350
Tourmaline (green / yellow)	1ct	Rs: 100 – 150	Rs: 300 – 350

- The colour change effect of spinel is identified after cutting and polishing. Therefore the price change becomes significant after cutting and polishing of spinel.

Table 5.2 Average prices per carat of high quality gems of weight 5 to 20 ct.

Gem variety	Weight (1ct = 0.2 gram)	Prices of rough stones (per carat)
Alexandrite	10 ct	Rs: 700,000
Ruby	10 ct	Rs: 300,000
Star ruby	20 ct	Rs: 300,000
Star sapphire	20 ct	Rs: 250,000
Pink sapphire	25 ct	Rs: 150,000
Blue sapphire	10 ct 20 ct	Rs: 45,000 – 50,000 Rs: 500,000
Orange sapphire	10 ct	Rs: 30,000 – 40,000
Yellow sapphire	10 ct	Rs: 25,000
"Kowangu pushparaga"	10 ct	Rs: 20,000
White sapphire	5 ct	Rs: 10,000
Rose garnet	10 ct	Rs: 5000 - 7000
Zircon (green)	10 ct	Rs: 3500 – 5000
Zircon (yellow)	10 ct	Rs: 2000 - 3000

5.5 Uses of minerals in gem bearing gravel

5.5.1Creative works of art using low-quality gemstones

Pictures are created by using gemstones by skilled craftsmen. They use high and low quality gemstones polished or unpolished according to the portrait they make. Generally they use ruby, blue, sapphire, zircon, garnet, spinel, tourmaline, peridots, aquamarine, amethyst, citrine, smoky quartz, milky quartz and moonstone. Sometimes chert also been used. Following gems (Table 5.3) are used for getting different kinds of colours.

Table 5.3 Gems and their colours used in creative works of art.

Gems	Colour
Blue sapphire and "geuda"	Dark blue to light blue
Ruby	Deep red
Zircon	Dark green, deep orange, pale yellow
Peridot	Light green, brownish green, pale green, olive green
Tourmaline	Black, brown, yellowish brown
Aquamarine	Bluish green, pale blue, yellowish blue
Spinel	Blue, pink, reddish purple, greenish blue
Garnet (spessartite)	Brownish red, reddish orange
Hessonite	Pale yellow, brownish yellow, honey yellow
Citrine	Pale yellow, deep yellow, brownish yellow

Milky quartz	Milky white
Rose quartz	Rose pink
Moonstone	Grayish white, yellowish orange with blue sheen
Smoky quartz	Light brown to dark brown

Some of those gems are burnt for three purposes.

01) To get an even colour distribution within the stone (eg. "dot ottu", "iri ottu").

02) To get a better transparency within the stone (eg. Zircon).

03) To enhance the colour (eg. Zircon, aquamarine, amethyst, Smoky quartz).

When "dot ottu" and "iri ottu" are heat treated the uneven colour distribution becomes even. When "diesel geuda", "milky geuda", "silky geuda" and "dun geuda" are heat treated, a blue colour develops. This is an economical way of making blue sapphires.

Because of the sub-adamantine lustre of zircons they are heat treated to lighten the colour to look like diamond. Pale yellow zircons are obtained from brownish yellow and dark red varieties, which are abundance in Sri Lanka. while colourless or yellow colour zircons are obtained from reddish brown zircons.

Bluish green aquamarine is heat treated to obtain blue colour. Brown tourmaline which is abundant in Sri Lanka is heat treated to obtain yellow brown tourmaline.

Smoky quartz is heat treated to lighten the darker shades or to make it colourless or yellow (citrine).

Heat treatment of amethyst produces citrine.

Natural citrine is scarce in Sri Lanka. Therefore citrine is obtained by heat-treating amethyst or smoky quartz.

Heat treatment helps to reduce dark colours of gems and to change colours. These gems are heat treated in a traditional way by using coconut husk and coconut shells as fuel and they are burnt in a home made furnace made of bricks and clay. While heat treating these gems may be broken into small pieces due to inclusions, cracks, fractures and flaws. However, even broken pieces can be used for certain purposes.

In making portraits heat treated and natural gems are broken in to small pieces from 2mm to 8mm by machines. Then they are sieved in to different size of fractions. Next they are carefully fixed by using special solvent cement formula selecting glass, metallic surface or paper board.. Artificial paints are not used for making portraits.

Following creations are made of using 'precious' and 'semi-precious' gemstones. Natural colours of gems impart beauty to the artifacts.

This picture (Figure 5.20a) was made of ruby, hessonite, citrine, black tourmaline, milky quartz and amethyst.

Figure 4.20a Gem-studded picture.

This creation (Figure 5.20b) was made of blue sapphires, green zircon, black tourmaline, amethyst, milky quartz and peridot.

Figure 4.20b Gem-studded picture.

This picture (Figure 5.20c) was made of ruby blue sapphires, hessonite, citrine, garnet, peridots, amethyst milky quartz and black tourmaline.

Figure 5.20c Gem-studded picture.

This gem-studded picture (Figure 5.20d) was made of chert, green zircon, peridot, citrine, milky quartz and black tourmaline.

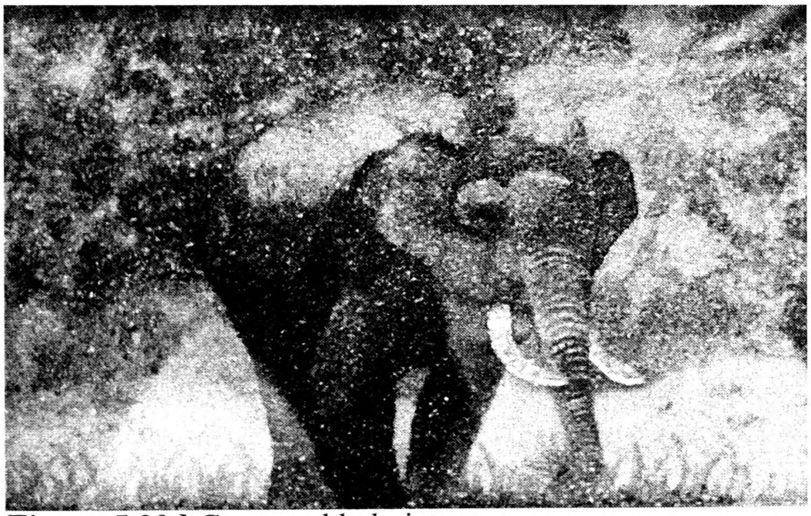


Figure 5.20d Gem-studded picture.

5.5.2 Rare occurrences within gem bearing gravel

In some gem bearing gravels rare occurrences (Figure 5.21 to 5.31) are found. Some times they may be very precious. But gem miners are unaware of the value of those minerals. Because, they are associated with their source rock or with other minerals. Some time they try to break the rock pieces and take only the valuable minerals. That is very destructive, because those rare occurrences have educational and historical value. On the other hand they are gift of nature. Following are such rare occurrences found in the Ratnapura and Okkampitiya gem fields.

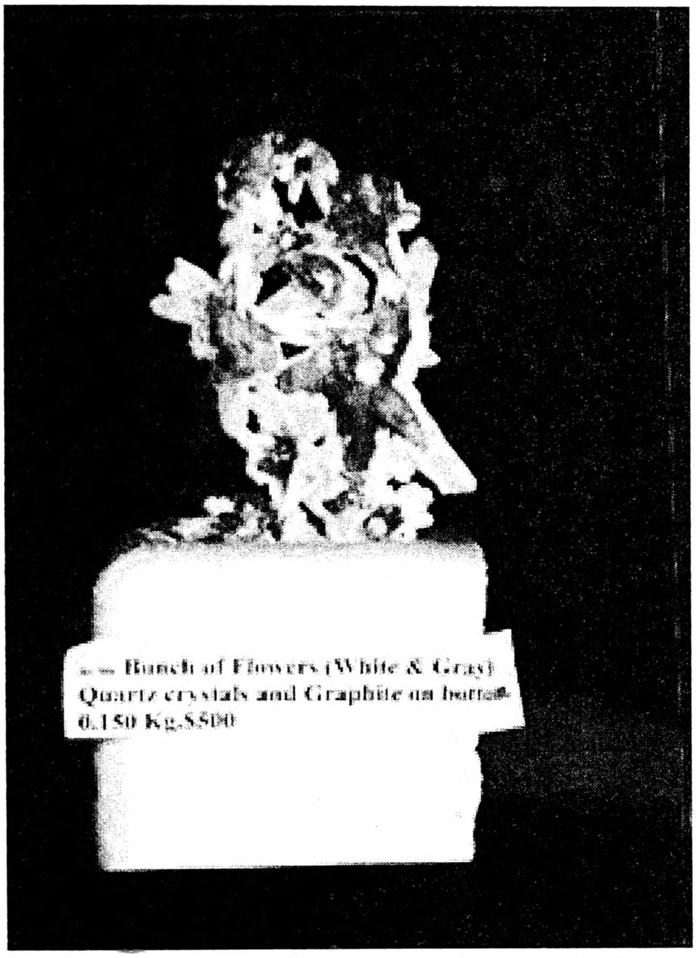


Figure 5.21 Quartz crystals associated with graphite.

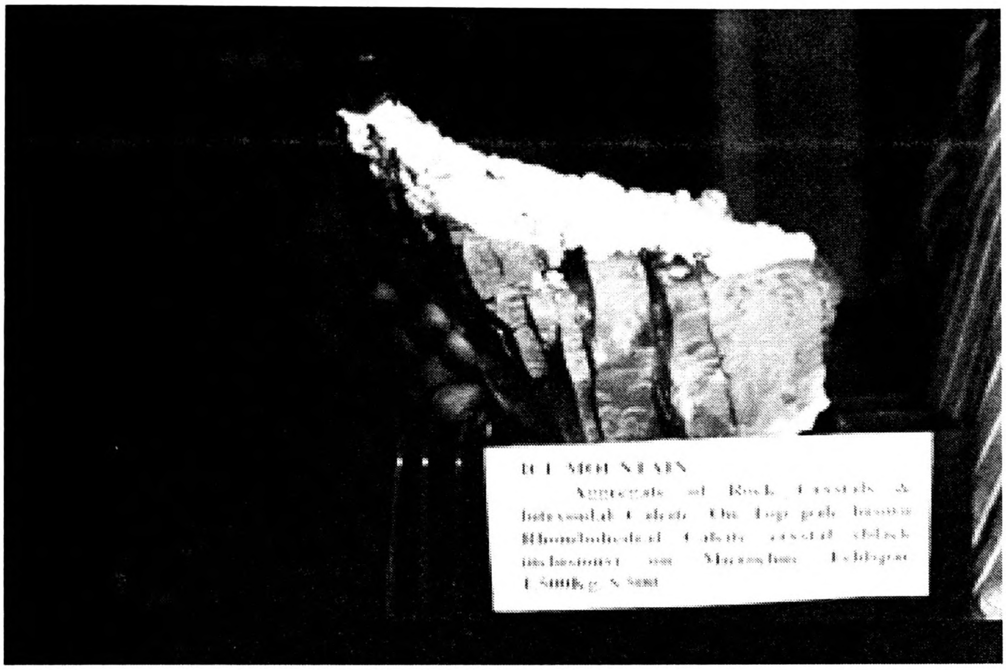


Figure 5.22 Rhombohedral calcite crystal attached to the aggregate of rock crystal with Feldspar layer.

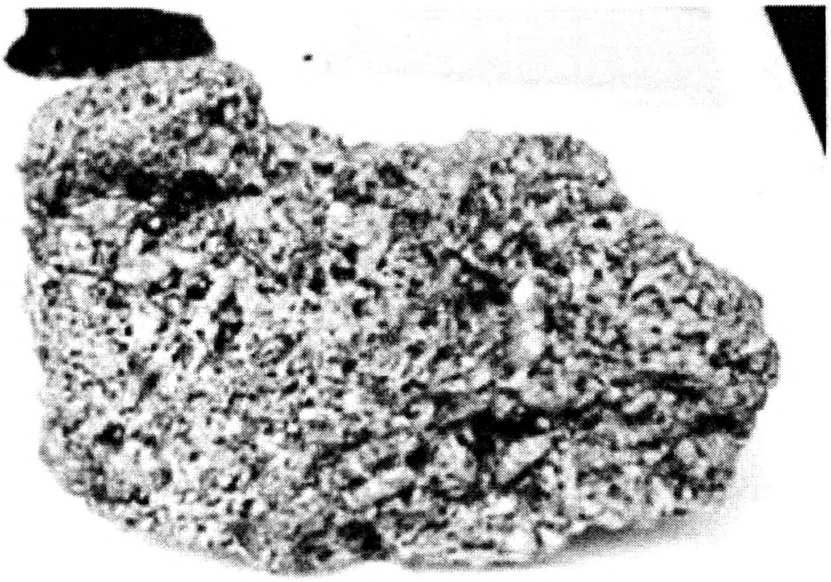


Figure 5.23 Corundum crystals are embedded in feldspar found in the Okkampitiya gem field.

Figure 5.24 Hornblende crystal (Katukumbura, Kolonna).

Figure 5.25 Amethyst crystals and calcite crystals in feldspar matrix.

Figure 5.26 Tourmaline crystals embedded in quartz.

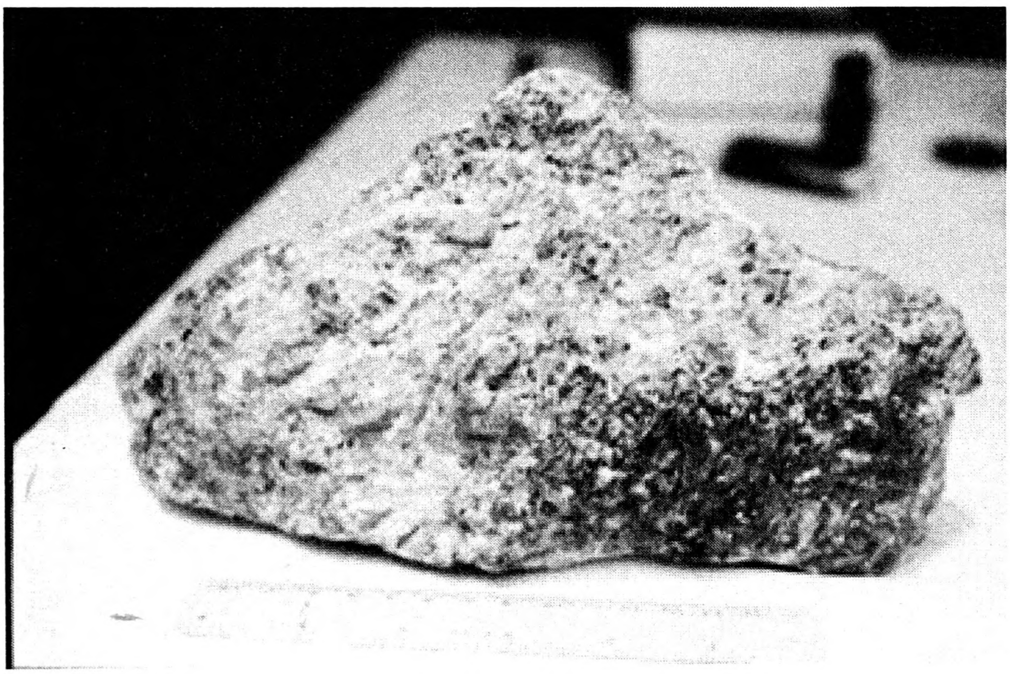


Figure 5.27 Corundum crystal embedded in granite rock.

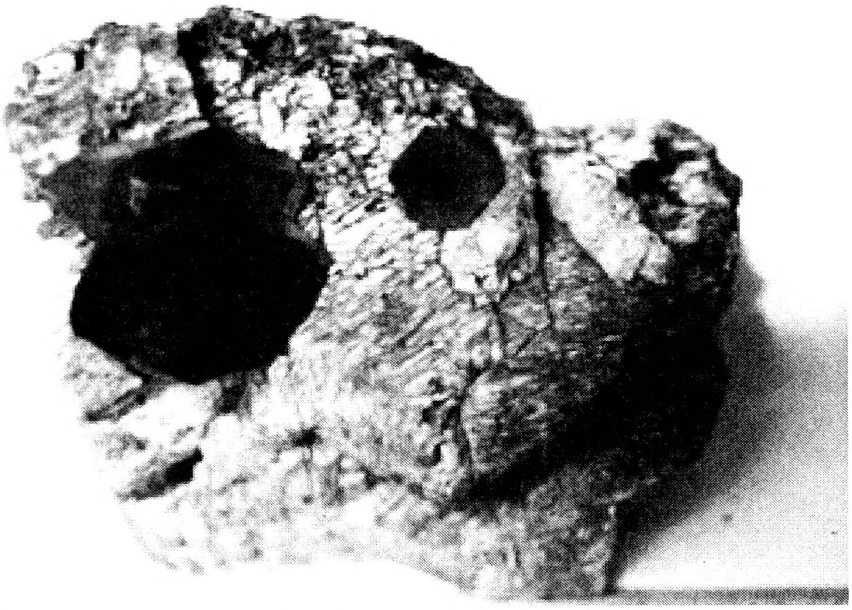


Figure 5.28 Smoky quartz crystals on microcline feldspar.

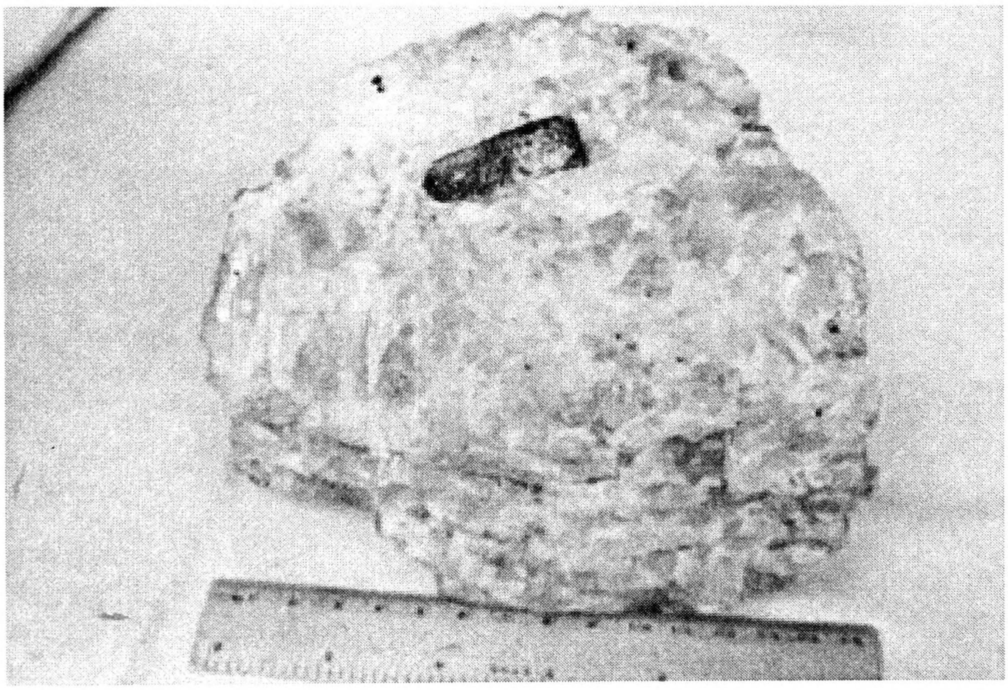


Figure 5.29 Blue apatite crystal embedded in calcite.

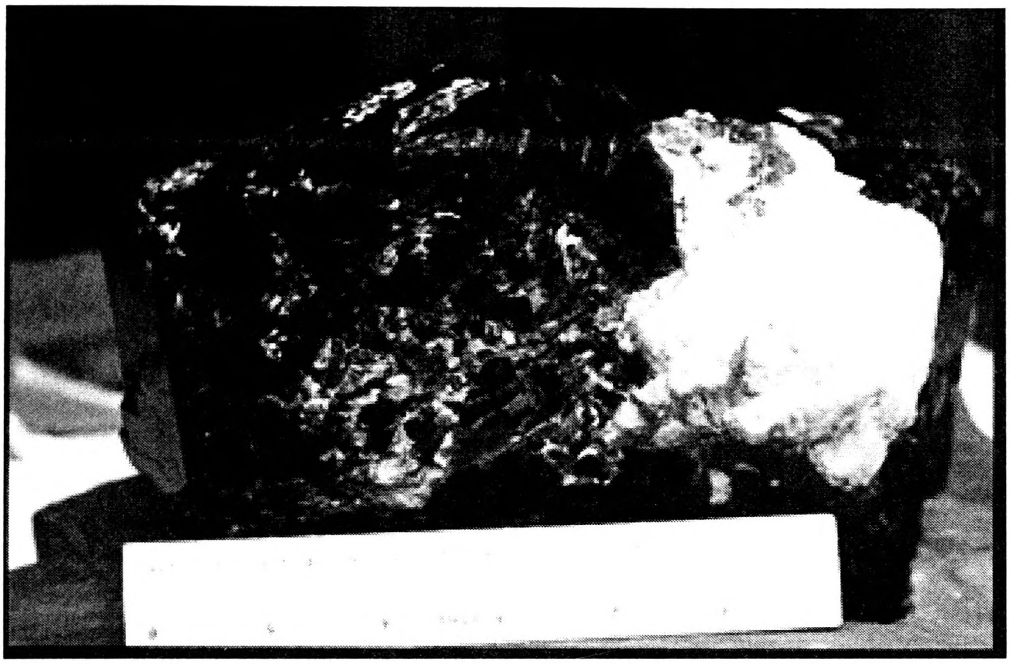


Figure 5.30 Aggregation of gem quality olivine crystals, feldspar, quartz and apatite on a feroedinite hornblende crystal.

Figure 5.31 Metamict allanite (Highly radioactive).

5.5.3 Other industrial uses of minerals

5.5.3.1 Uses of garnet

1. WaterJet Cutting

   In high-pressure water jet cutting of marble, granite, artificial stones, concrete, aluminum, titanium, high strength steel and steel bridge decking, automotive glass, textiles, corrugated boxboard, plastics laminates, aerospace composites, etc.

2. Sand Blasting (For blast cleaning for preparation before painting)

   In high-quality coated and bonded abrasives such as abrasive papers, clothes, wheels, etc.

3. Water Filtration

   As bedding in water filtration and water softening as garnet adsorbs heavy metal.

4. Other Applications

   a. Micronised form of garnet is used for polishing of glass faceplates of televisions, computer monitors and optical glasses.
   b. Polishing & precision finishing of high pressure valves.
   c. In anti-skid paints and surfaces, as garnet lasts longer and provides excellent bonding.
   d. For stone washing of denim fabrics, providing only fading of dye but not damaging the cloth or stitching.
   e. Used in industrial flooring as garnet withstands more wear & tear and provides better grip.

5.5.3.2 Uses of zircon

1. Zircon's hardness makes it useful as an abrasive. The melting point of zircon is over 2500° C, so it is used in the steel industry to line blast furnaces. Because zircon products are resistant to corrosion and heat, they are used in engines, used in electronic, spacecraft and the ceramics industries.
2. Zircon products are also used in computer disc drives, for lightweight warmth and protection in clothing, and in many domestic products such as ballpoint pens and wear-resistant knives.

3. Zircon contains the metal zirconium, which is extremely hard and resistant to corrosion. Zirconium is used in nuclear reactors and chemical processing plants.

5.5.3.3 Uses of pyrite

Pyrite is used in the manufacture of sulfur, sulfuric acid and sulfur dioxide. Pellets of pressed pyrite dust are used in the recovery process of iron, gold, copper, cobalt and nickel. It is also used to make inexpensive jewelry.

5.5.3.4 Uses of tourmaline

1. Tourmalines are cut as precious gems, carved into figurines, cut as cabochons, sliced into cross-sections and natural specimens are enthusiastically added to many a rock hound's collection.
2. There are many unique properties of tourmalines. First, they are piezoelectric which means that when a crystal is heated or compressed (or vibrated) a different electrical charge will form at opposite ends of the crystal (an electrical potential). Conversely if an electrical potential is applied to the crystal, it will vibrate. These properties may be useful in the future to make electronic equipment (Ex. Thermometers, wrist watches and dust cleaning equipments.).

CHAPTER 06
CONCLUSION

The dispersion of the minerals in the gem bearing gravel in Okkampitiya has a greater uniformity compared to Ratnapura gem field. Radioactive minerals are abundant in residual and elluvial gem deposits compared to alluvial gem deposits. 1% of radioactive mineral were recorded in samples from Okkampitiya gem field. Radioactive minerals are abundant in iron-rich gem bearing gravel, compared to quartz-rich gem bearing gravel. Tourmaline and pyrites are mostly found in quartz-rich gem bearing gravel than iron-rich gem bearing gravel. Garnet, zircon, spinel and tourmaline are the common gem minerals in the Ratnapura and Okkampitiya gem fields. Gem miners are not engaged in using these gem minerals for industrial and non-gem ornamental purposes. Non-gem quality minerals can be used in many profitable ways.

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APPENDIX I

A questionnaire prepared to get information from gem miners and buyers.

1. What are the areas famous for gems in the Ratnapura and Okkampitiya gem fields?
2. What are the best locations in each area for collecting the most representative samples?
3. How deep are the gem pits?
4. How thick are the *illam* layers?
5. What kind of "Nambus" are found there? (Tel-borella, Wedibeheth, Tirivana etc.)
6. What are the varities of gems found there?
7. What are the qualities of gems found there? (High quality or low quality)
8. How much do they cost? (High quality)
9. What do you do with the low quality gems? (If they sell them, their prices)

APPENDIX II

Refractive indices

Mineral Name **RI**

```
Calcite................1.486-1.658
Chalcedony.............1.53-1.539
Cordierite.............1.54....  .01
Quartz.................1.55....  .009
Citrine................1.55....  .009
Amethyst...............1.544-1.553
Agate..................1.544-1.553
Beryl..................1.577-1.60
Aquamarine.............1.577-1.583
Ekanite................1.60....none
Topaz (white)..........1.63....  .008
Apatite................1.63-1.640
Tourmaline.............1.616-1.652
Enstatite..............1.663-1.673
Peridot................1.65-1.69
Kornerupine............1.665-1.682
Peridot................1.654-1.69
Olivine................1.67....  .02
Sinhalite..............1.699-1.707
Diopside...............1.68-1.71
Taaffeite..............1.72
Spinel.................1.712-1.736
Hessonite..garnet......1.745
Chrysoberyl............1.745....  .005
Alexandrite............1.745-1.759
Pyrope.................1.74....  .015
Corundum...............1.766-1.774
Ruby...................1.76-1.77
Sapphire...............1.76-1.77
Almandite..garnet......1.79
Zircon..low............1.80....  .01
Spessartite..garnet....1.81
Zircon...high..........1.96-2.01
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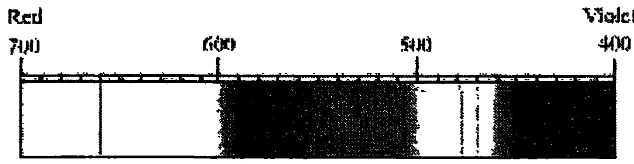
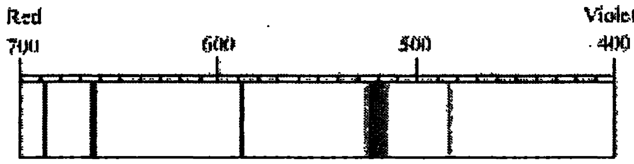
APPENDIX III

Absorption Spectra

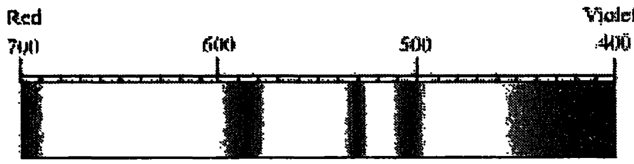
Ruby



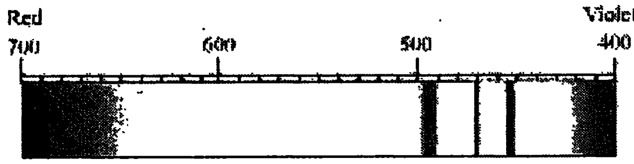
Zircon



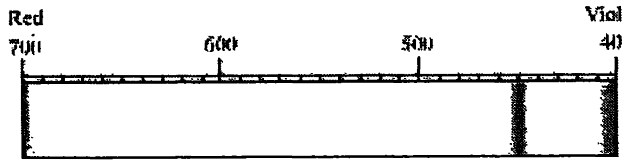
Almandine garnet



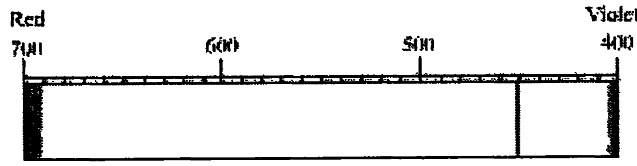
Peridot



Yellow Chrysoberyl



Sapphire (blue)



APPENDIX IV

Minerals between 2 mm - 4 mm

	Depth (m)	iron rich minerals (g)	quartz (g)	"X" mineral (g)	spinel (g)	tourmaline (g)	zircon (g)	pyrite (g)	courundum (g)	topaz (g)	garnet (g)	chrysoberyl (g)	radio active (g)
Pelmadulla	20 to 35	782	540	126	273	34	124	65	4	1	34	*	10
Eheliyagoda	18 to 20	273	1248	24	59	45	15	18	3	*	28	1	*
Kuruvita	5 to 35	1249	264	58	127	18	32	8	*	*	21	*	8
Kiriella	10 to 15	126	1243	49	34	41	12	37	3	*	43	*	*
Ayagama	10 to12	10	859	34	12	36	4	18	3	*	26	*	*
Kalavana	12 to 15	115	674	48	28	38	19	31	3	4	38	2	*
Pothupitiya	15 to 18	850	218	*	84	9	48	16	1	2	34	1	4
Marapana	20 to 25	678	126	6	58	29	26	*	4	5	27	3	2
Kahawatta	25 to 35	759	215	12	48	24	34	12	2	*	68	*	6
Rakwana	20 to 25	1168	315	*	79	21	52	*	5	*	47	*	*
Rambuka	20 to 25	986	129	*	52	24	37	15	4	2	32	*	1
Okkampitiya (SL 1`)	2 to 2.5	345	214	24	46	12	73	9	3	*	16	*	3
Okkampitiya (SL 2`)	3 to 3.5	512	142	18	60	18	86	21	*	*	22	*	2
Okkampitiya (SL 3`)	2 to 2.5	421	116	31	34	20	115	11	2	1	27	*	4
Okkampitiya (SL 4`)	3.5 to 4	354	218	27	48	21	59	17	4	*	34	*	9
Okkampitiya (SL 5`)	3 to 4	297	368	28	36	17	38	19	1	3	41	*	3

Minerals greater than 4 mm

	Depth (m)	Iron rich minerals (g)	quartz (g)	"X" mineral (g)	spinel (g)	tourmaline (g)	zircon (g)	pyrite (g)	courundum (g)	topaz (g)	garnet (g)	chrysoberyl (g)	radio active (g)
Pelmadulla	20 to 35	450	376	145	152	24	137	47	3	2	22	*	43
Eheliyagoda	18 to 20	132	1167	28	24	31	24	24	9	*	18	*	*
Kuruvita	5 to 35	986	152	65	37	28	29	12	1	*	12	*	12
Kiriella	10 to 15	253	1056	57	26	34	16	29	4	2	15	1	*
Ayagama	10 to12	23	1350	27	16	27	12	24	12	*	17	*	2
Kalavana	12 to 15	98	1463	57	20	45	14	38	5	*	14	2	*
Pothupitiya	15 to 18	1268	194	*	52	*	37	22	2	1	18	1	*
Marapana	20 to 25	1342	231	18	49	18	31	*	3	4	14	1	*
Kahawatta	25 to 35	849	134	24	38	27	24	12	1	*	29	*	4
Rakwana	20 to 25	1134	264	*	64	13	39	*	2	2	21	1	*
Rambuka	20 to 25	1450	321	*	38	10	29	13	1	*	18	*	2
Okkampitiya (SL 1`)	2 to 2.5	684	397	18	38	9	52	*	2	*	11	*	15
Okkampitiya (SL 2`)	3 to 3.5	714	427	15	48	12	34	17	1	1	9	*	19
Okkampitiya (SL 3`)	2 to 2.5	543	348	38	31	17	68	5	3	*	7	*	18
Okkampitiya (SL 4`)	3.5 to 4	615	238	32	31	24	38	21	8	1	14	*	12
Okkampitiya (SL 5`)	3 to 4	687	786	31	27	20	26	16	7	*	17	*	11

Total mineral quantities in samples

	Depth (m)	iron rich minerals (g)	quartz (g)	"X" mineral (g)	spinel (g)	tourmaline (g)	zircon (g)	pyrite (g)	courundum (g)	topaz (g)	garnet (g)	chrysoberyl (g)	radio active (g)	Total (g)
Pelmadulla	20 to 35	1232	916	271	425	58	261	112	7	3	56	*	53	3394
Eheliyagoda	18 to 20	405	2415	52	83	76	39	42	12	*	46	1	*	3171
Kuruvita	5 to 35	2235	416	123	164	46	61	20	1	*	33	*	20	3119
Kiriella	10 to 15	379	2299	106	60	75	28	66	7	2	58	1	*	3081
Ayagama	10 to12	33	2209	61	28	63	16	42	15	*	43	*	2	2512
Kalavana	12 to 15	213	2137	105	48	83	33	69	8	4	52	4	*	2756
Pothupitiya	15 to 18	2118	412	*	136	9	85	38	3	3	52	2	4	2862
Marapana	20 to 25	2020	357	24	107	47	57	*	7	9	41	4	2	2675
Kahawatta	25 to 35	1608	349	36	86	51	58	24	3	*	97	*	10	2322
Rakwana	20 to 25	2302	579	*	143	34	91	*	7	2	68	1	*	3227
Rambuka	20 to 25	2436	450	*	90	34	66	28	5	2	50	*	3	3164
Okkampitiya (SL 1)	2 to 2.5	1029	611	42	84	21	125	9	5	*	27	*	18	1971
Okkampitiya (SL 2)	3 to 3.5	1226	569	33	108	30	120	38	1	1	31	*	21	2178
Okkampitiya (SL 3)	2 to 2.5	964	464	69	65	37	183	16	5	1	34	*	22	1860
Okkampitiya (SL 4)	3.5 to 4	969	456	59	79	45	97	38	12	1	48	*	21	1825
Okkampitiya (SL 5)	3 to 4	984	1154	59	63	37	64	35	8	3	58	*	14	2479

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Mrs.T.N.NEIGHSOOREI
(MSSc.PGD.ASLA,BA)
Librarian
Sabaragamuwa University of Sri Lanka
P.O.Box 02 Belihuloya,Sri Lanka
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