SCIENCE EDUCATION SERIES

NO. 23

LIMESTONE RESOURCES OF SRI LANKA

by

P. B. ABEYSINGHE

NATURAL RESOURCES ENERGY & SCIENCE AUTHORITY
47/5 MAITLAND PLACE
COLOMBO 7

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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy & Science Authority. The Journal of the Natural Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which is of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy & Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy & Science Authority, and in particular Prof. V. Basnayake who is the Hony. Director of the Working Committee for the work they have done to make this project a success.

R. P. Jayewardene
Director-General

PREFACE

Limestone resources of Sri Lanka is a compilation of all the data available in the Geological Survey Department of Sri Lanka gathered during various stages of the last three decades. In recent years the general public has shown much interest in limestone resources as indicated by the numerous inquiries received by the Geological Survey Department. Therefore this book will serve as a useful source of reference to those interested in limestone as a mineral resource. However this compilation does not cover all the limestone resources available in the country as there are many localities where investigations have yet to be carried out.

I am extremely grateful to Mr. D. E. de S. Jayawardena, Director, Geological Survey Department for giving me permission to collect data from the unpublished reports of the Geological Survey Department and to Dr. M. M. J. W. Herath, former Director, Geological Survey Department, for his invaluable help and encouragement. I am thankful to Messrs M. P. K. de Silva and P. Nanayakkara for preparing all the illustrations. I am also indebted to the Natural Resources, Energy & Science Authority of Sri Lanka for the publication of this volume.

P. B. Abeysinghe

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Chapter 1

INTRODUCTION

1.1 Limestone

The term limestone is applied in a very broad sense to many forms of calcium carbonate, each with distinct physical properties and occurring in nature as a variety of rocks. Limestones vary greatly in both texture and composition. Some are hard, massive and break with a splintary or conchoidal fracture whereas the others are crystalline rocks composed of crystals of calcite having granular texture and white colour. There are still other varieties having dull chalk like appearance. All limestones contain small proportions of alumina, silica, magnesia and iron oxide with still smaller proportions of other oxides of sulphur, phosphorous etc. The pure varieties contain 99 percent calcium carbonate. In nature limestone can also occur with clay, sand, iron oxide, magnesia and bituminous matter and such mixtures are known as argillaceous, arenaceous, ferruginous, dolomitic and bituminous limestones respectively. Limestone occurs in many forms because of its ability to pass gradually from one form to another. These can be considered as limestones of secondary origin. Some of the more common secondary types associated with Sri Lankan limestones are marble, marl, dolomite, calc-spars, travertine, kankar and organic limestones.

Marbles are limestones which have acquired a granular or crystalline texture and are composed of minute calcite interspersed with coloured veins of other minerals with flakes of talc and mica. The term "marble" is also used, however, for various unaltered limestones which are capable of taking a high polish and of being used as decorative stones.

Marl is the term applied for friable earthy materials having a natural mixture of calcium carbonate and clay.

Dolomite consists of a double carbonate corresponding to $CaCO_3.MgCO_3$. Pure dolomite contains 54.3 per cent $CaCO_3$ and 45.7 per cent $MgCO_3$. However, in nature such ideal compositions are not generally available.

Calc-spar consists of calcite in crystals of considerable size and is an important source of such crystals. The principal varieties of calc-spar are: iceland-spar, slate-spar, satin-spar and dog tooth spar.

Travertine is limestone which has been deposited by springs, streams or percolating water containing carbon dioxide gas and calcium carbonate in solution. These are light coloured and are very often met with crystalline limestone bands.

Kankar is a nodular form of calcium carbonate generally in white or yellowish nodules.

Organic limestones are composed of the remains of living organisms and occur in thin layers and also masses of enormous thickness. They owe their origin to various shell covered creatures withdrawing calcium carbonate of which their shells are composed. Shell limestones consist chiefly of the fragmentary shells of marine creatures but some are of fresh water origin. Reef limestones are also of organic derivation.

1.2 Lime

If pure calcium carbonate is heated to a temperature of about $800^{o}C$ in a sufficiently large vessel the limstone will be decomposed into a white solid substance lime (or quick lime) and a colourless odourless gas, carbon dioxide. This decomposition can be written as :

$$CaCO_3 \rightarrow \underset{\text{(quick lime)}}{CaO} + CO_2$$

This means that 100 parts by weight of calcium carbonate when heated to $800^{o}C$ decompose to 56 parts by weight of CaO and 44 parts by weight of carbon dioxide. When water is added to quicklime, slaked lime is produced in the following manner :

$$CaO + H_2O \rightarrow \underset{\text{(slaked lime)}}{Ca(OH)_2} + \text{heat}$$

This means that 56 parts by weight of CaO with 18 parts by weight of water yield 74 parts by weight of slaked lime. Since this reaction is exorthermic a large proportion of water than stated is necessary: the surplus being driven off as steam leaving a dry powder as the final product. When slaked lime is used in motar it becomes hard and is reconverted to calcium carbonate by the action of atmospheric oxygen.

1.3 Uses of Limestone and its Derivatives

A large number of industries are based on limestone and its derivatives. Some of these are in:

a. Cement Industry
b. Agriculture
c. Metallurgical Processes
d. Lime wash, distemper and paints
e. Glass industry
f. Calcium carbide manufacture
g. Water and Sanitation
h. Paper Industry
i. Other

Cement Industry

Cement is strictly a synthetic, manufactured product, made by blending different natural and synthetic materials in order to achieve rather precise chemical proportions of lime, silica, alumina, iron and sulphate in the finished product. The most widely used cement is Portland cement and the other types used include masonary, patent mortars and motor mixes.

Portland Cement

Portland cement is manufactured by calcining a carefully proportioned mixture of limestone (75–77% $CaCO_3$) and clay (23–25%). The process of manufacture consists of the following steps:

1. grinding the raw materials to a fine homogeneous mixture
2. calcining or burning the mixture in a kiln to obtain clinker
3. grinding the clinker with the addition of gypsum to adjust the setting time.

Depending on whether the raw materials are ground and mixed in a wet or dry state the process of cement manufacture is wet or dry respectively. In Sri Lanka the cement plants in Kankesanturai and Puttalam employ dry process. In the wet process a large amount of fuel is required to drive off the moisture from the slurry.

Masonary Cement, Patent Motars, Motar Mixes

These are low quality cements manufactured by mixing various proportions of portland cement (50 to 60%) and pulverized limestone (40 to 50%). Certain organic chemical additives are also added to provide plasticity to the motar.

Agriculture

Limestone and lime are widely used to correct soil deficiencies such as:

a. to neutralize any acidity in the soil
b. to destroy objectionable bacteria in the soil
c. to increase the permeability of the soil
d. to accelerate the decomposition of most organic manures
e. to displace ammonia, potash and other substances from their insoluble compounds in the soil and make them available for the plant growth.

Metallurgical Processes

In the production of metals like iron, copper and lead from their ores, it is usually important to reduce both the metal and the other constituents of the ore to a molten state so that both may be drawn out of the furnace as fluids. Limestone is extensively used to combine with the silica and alumina present in such ores to form a readily fusible slag which can be drawn out of the furnace as required. Such use of limestone as a flux is quite common on account of their cheapness.

Lime Wash, Distemper and Paints

Lime wash is a simple mixture of slaked lime and water which is applied to walls. Lime wash is generally mixed with a binding agent such as common salt to produce a long lasting surface.

Distemper is the name given to lime which has been mixed with water and coloured by the addition of earthy pigments such as ochre, Indian-red or lamp black. Distempers are intermediate between white wash and paint.

Various forms of calcium carbonate are used in the paint and allied industries: a. as a pigment b. as a diluent c. as a primer d. in the production of putty. In each case the calcium carbonate should be perfectly white, of low density and fine. To satisfy these conditions precipitated calcium carbonate is usually employed in preference to limestone.

Glass Industry

The use of limestone or lime in the glass industry is

a. to render the glass more insoluble so that the glass can be unrestrictedly used in contact with water and chemical solution

b. to improve the mechanical properties of glass by making it less brittle and stronger

c. to improve the appearance of glass by providing more enduring lustre.

Limestone and lime are the lowest cost fluxing materials for glass. They flux the silica sand forming chemically fused calcium silicates.

Calcium Carbide Industry

Calcium carbide is manufactured by heating a mixture of quick lime and coke in an electric furnace to 2000°C. The following reaction occurs :

$$CaO + 3C \rightarrow \underset{\text{(Calcium carbide)}}{CaC_2} + CO$$

Calcium carbide is an important source of acetylene.

Water and Sanitation

Lime is used as a water treatment chemical to improve the quality of water for potable or industrial purposes. Lime is also employed as a coagulant in sewage plants. It coagulates the unsettleable solids that restrict removal by mechanical methods or by sedimentation.

Paper Industry

Lime is consumed in the paper industry by Sulphate Process pulp plants to causticize the "black liquor" (a waste sodium carbonate solution). Lime reacts with the sodium carbonate to regenerate sodium hydroxide (caustic soda) for reuse in the Sulphate Process in the following manner :

$$Na_2CO_3 + CaO + H_2O \rightarrow CaCO_3 + 2NaOH$$

Some paper mills use lime in the chemical coagulation or softening of their plant process water.

Building and Ornamental Stone

Limestone is used as a building material or a decorative stone. The plane limestone as well as carved limestone are used as decorative materials. The essential characteristic of a stone to be used for carving work is the uniformity in texture.

Other Uses

Other uses of limestone include the chemical process industries such as soda ash, bicarbonate of soda, caustic soda, insecticides, bleaching powder, inorganic salts and bases, magnesia products and organic chemicals.

Chapter 2

GENERAL GEOLOGY OF SRI LANKA

About four-fifths of Sri Lanka is covered with Precambrian metamorphic rocks (fig. 1) which on the basis of lithology, structure and age have been subdivided into the Highland Group, the Southwestern Group and the Vijayan Complex.

2.1 Highland Group

The Highland Group rocks are about 2 billion years old and consists of a varied assemblage of high grade metamorphic rocks which have formed under temperature and pressure ranges of around 700 to 800°C and 5 to 7kb respectively. These rocks comprise of granulites, schists, pelitic schists, gneisses, quartzites, marbles, charnockites, charnockitic gneisses and pyroclasites. These rocks occupy the entire central hill country of Sri Lanka including the Rakwana Hills on the south-west and the Knuckles massif on the north-east. The quartzites, marbles and schists are of sedimentary origin where as charnockites and pyroclasites are possibly of igneous origin. Charnockitic gneisses and the metasedimentary rocks such as quartzites, schists etc. are very intimately associated.

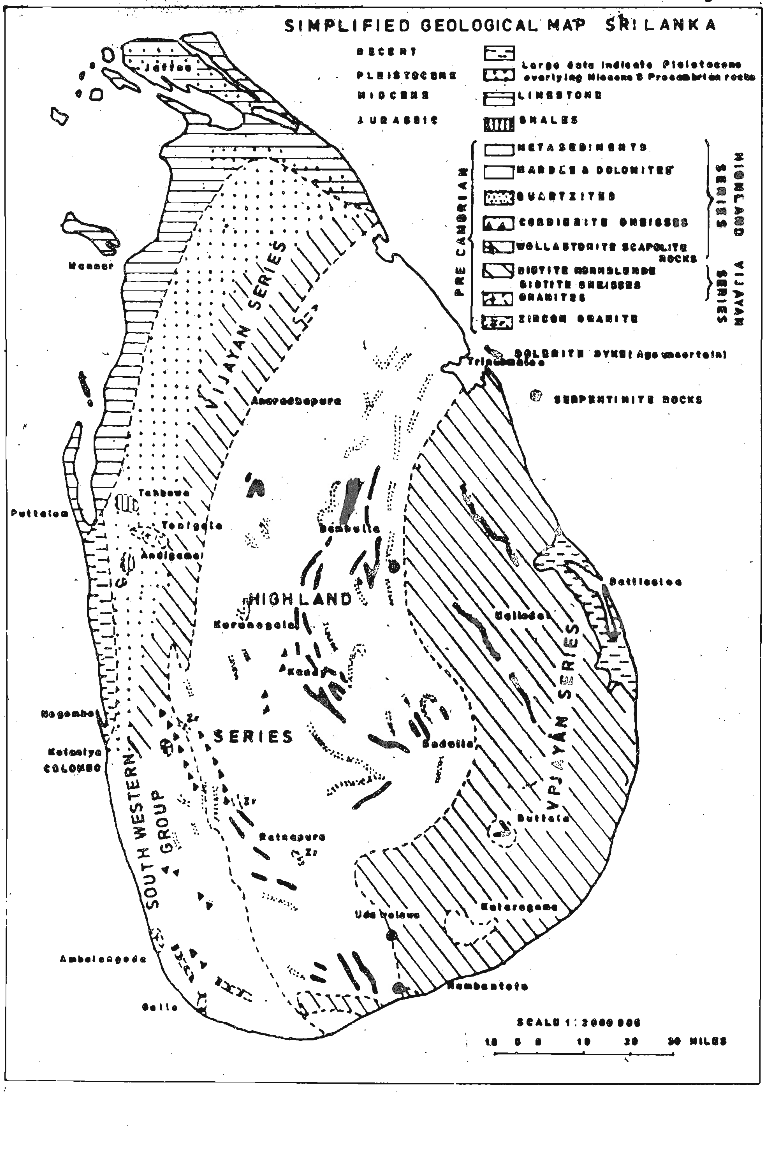
The marbles are widespread in the Highland Group and occur as persistent bands associated with quartzites and other metasedimentary rocks such as gneisses. However, marbles have a wide range of composition and are largely dolomitic (see Chapt. 4).

2.2 Southwestern Group

The Southwestern Group rocks, located in the southwestern part of Sri Lanka, are made up of schists, gneisses, granulites of metasedimentary origin and partly of other rock types of uncertain parentage. These show significant differences in lithology and metamorphic history when compared with the Highland Group rocks. Some of these differences are :

a. thin persistent quartzites and schists unlike the thick quartzites of the Highland Group

Fig. 1


SIMPLIFIED GEOLOGICAL MAP SRI LANKA
PRE CAMBRIAN
HIGHLAND SERIES
VIJAYAN SERIES
VIJAYAN SERIES
HIGHLAND
SERIES
SOUTH WESTERN GROUP
COLOMBO

b. narrow wollastonite bearing calciphyres unlike the thick marbles of the Highland Group
c. presence of cordierite bearing pelitic gneisses
d. presence of coarse grained intrusive charnockites
e. presence of abundant granitic gneisses.

2.3 Vijayan Complex

The group of rocks on both sides of the Highland Group constitutes the Vijayan Complex. These rocks extend from the central foot hills to the coast and consist of predominantly gneisses, migmatites and granitic rocks. These rocks are about 1.8 billion years old. The granitic rocks vary from granitic to granodioritic.

2.4 Intrusives

Intruding the metamorphic rocks of Sri Lanka are some granites, dolerites, pegmatites and a carbonatite.

Granites

Tonigala Granite, which occurs as two sheet like bodies each about 1.5 km wide running for 15 to 20 km in an ESE-WSW direction in the area between Puttalam and Galgamuwa in northwestern Sri Lanka, intrude the western Vijayan Complex. The Tonigala Granite is pinkish, medium grained and composed of quartz, microcline, microperthite and biotite with subordinate oligoclase with clear albitic rims (Cooray, 1978). The age of the Granite is about 985 million years.

Several small occurrences of hornblende granite occur within a radius of 8 km of Arangala in the Alutgama area. Two varieties of granite are present, namely, a coarse grained porphrytic variety with a flow structure, and a grey medium grained variety which occurs as patches and xenoliths in the former (Cooray, 1965). These granites consist of quartz, orthoclase, oligoclase-andesine, hornblende and biotite with accessory zircon, apatite, magnetite and monazite.

Zircon granites containing metamict zircons are known from a few places. These are exposed at Balangoda, Beruwala and Loluwa.

Pegmatites

Pegmatites, which are important sources for mica, feldspar, radioactive minerals and gems, are common and mainly intrude the Highland Group rocks of the island. Some of the radioactive and rare earth minerals known in the Sri Lankan pegmatites are thorianite, thorite, monazite, zircon and allanite.

Carbonatite

An apatite body intruding the granite gneisses at Eppawela is classed as an apatite-magnetite carbonatite. (Jayawardena, 1976). Over 25 million tons of ore have been proved in this deposit.

Dolerites

Numerous dolerite dykes are present in the eastern part of the country. The largest of these, the Kallodai Dyke, is more than 100 km long and trends in a NW-SE direction. More dolerite dykes are located in Vakaneri, Trincomalee, Kantalai, Kalkudah and Buttala. All these are classed as quartz dolerites. There are some narrow olivine dolerites in the Alutgama area.

2.5 Sedimentary Rocks

The sedimentary rocks covering about one-fifths of the country can be grouped as follows :

Recent	– Coral reefs, alluvium, lagoonal and estuarine clays, beach and dune sands, beach rock.
Pleistocene	– Red earth, terrace gravel, ferruginous gravel, Ratnapura beds.
Miocene	– Jaffna limestone, Minihagalkande beds.
Jurassic	– Tabbowa beds, Andigama–Pallama beds.

Jurassic Beds

Jurassic beds in Tabbowa basin consist of arkose, feldspathic sandstone, siltstone and mudstone. Fossil plant impressions in the siltstones and the mudstones establish the stratigraphic position of the Tabbowa beds as Upper Gondwana (Upper Jurassic) (Sitholey, 1944). Some fossil plants present are Cladophebis Zeylanica, C. reversa, Sphenopteris Wadiai, Taeniopteris Spatulata, Nilssonia fissa and Ptilophyllum. Some of these are identical with those found in the Upper Gondwana deposits of Rajmahal in Damodar Valley of India and in east coast patches near Madras. The thickness of the Tabbowa beds would be at least 500m as suggested by the isostatic anomaly map (Hatherton et al., 1975). At Andigama, 30 km south of Tabbowa, a sequence of alternating brown and black carbonaceous shales covering an area of over 30 sq. km. as revealed by four drill holes is present. The core from one of the holes had thin coal seams. Selected core samples of carbonaceous shale yielded 15 genera of pteridophytic and other trilete spores along with gymnospermous forms (Cooray, 1978). The microflora assemblage as a whole indicates an age ranging from middle to upper Jurassic (upper Godwana). Gravity data suggests the presence of 900 m to 1200 m of sediments within the Andigama basin.

Miocene Beds

Miocene Beds in Sri Lanka consist of almost wholly Jaffna limestone and are confined to the northwestern corner of Sri Lanka, the Jaffna peninsula and the surrounding islands. Its total extent is about 2100 sq. km. The Jaffna limestone is hard, partly crystalline, compact, indistinctly bedded and creamy coloured. It is massive in parts and at times contains richly fossiliferous layers which weather into a honey combed mass (see Chapter 4). Other sedimentary formations of possibly Miocene age occur at Minihagalkande in the southwestern corner of the island.

Post-Miocene

A discontinuous layer of ferruginous gravel layer with variable thickness up to 6m. thick in places lies unconformably on either Miocene limestone (north of Puttalam) or Precambrian (Battulu Oya and Chilaw). Overlying the ferruginous gravel layer is a Red Earth formation which is an unstratified, uniform, soft loamy deposit, consisting chiefly of sand and silt with an admixture of highly oxidized clay. It forms prominent ridges and elongated plateaus which are parallel to the present coast line. The quartz grains are well rounded, frosted and pitted and somewhat similar to those of dune sands.

Other Post-Miocene beds in Sri Lanka include a) lagoonal and lacustrine deposits deposited mainly between the present shore line and the Red Earth formation, b) estuarine deposits in Beira Lake, Colombo, c) beach and dune sands, d) beach rock (composed of quartz and shell fragments cemented with calcium carbonate) at several places on the west from Karaitivu to Matara, e) coral reefs distributed along the coastal stretches of the island (see Chapter 4).

Chapter 3

RESERVES AND RESOURCES

The words reserves and resources are commonly used when ore deposits are described.

3.1 Reserves

Reserves refer to known ore bodies that may be worked at some future time. Measured reserves are those actually known or proved as a result of detailed investigations including sampling and extensive drilling; indicated reserves would mean ores for which tonnage and grade are computed partly from measurements of geological evidence and inferred reserves are those for which estimates are based on geological knowledge and for which few or no measurements are available.

3.2 Resources

Resources can be classified into two types namely reasonably assured resources and estimated additional resources. Reasonably assured resources refer to ore deposits of such grade, quantity and configuration that it could be recovered within the given production range with currently proven mining and processing technology. Estimated additional resources refer to unexplored extension of known deposits which are expected to be discoverable in the given cost range.

3.3 Prospecting for Limestones

The information on chief localities of limestones are generally available in the Geological Survey Department of any country. Knowing the chief localities of limestones it is not difficult to trace out the boundaries of the limestone bands. Once the boundary of a limestone band is established it is necessary to ascertain the grade and the tonnage of the limestone available prior to any mining venture. In estimating the tonnage, the thickness of the limestone band must be known. In an unworked area this is by no means easy and requires considerable skill and experience. Very often it is necessary to carry out a well planned drilling programme. During the drilling programme it is possible to collect samples at various depths for chemical analyses and also to obtain information on the cavernous nature of the rock and the presence or absence of deleterious material. Drilling is a very costly task and therefore it is of utmost importance that maximum information be obtained during the drilling operations. There are different methods of drilling and the method employed depends on the information one needs to gather. In the Sri Lankan limestone terrains it is found through experience that only diamond drilling yields all the information necessary to calculate the tonnage of a limestone deposit with a reasonable degree of confidence. Knowing the thickness of the limestone band the volume of the deposit can be estimated by ascertaining the surface area. The tonnage of the deposit can then be calculated knowing the density of the limestone. In the calculations ample allowance must be made for caverns, intercalated beds and other material.

3.4 Limestone Quarrying

The term quarrying is applied to all methods used for obtaining a mineral deposit from open excavations or quarries. The term mining is generally used when the stone is removed through a sloping adit or by means of a vertical shaft. By far the largest proportion of limestone and other forms of calcium carbonate are obtained by simple methods of quarrying. Very often limestone bands are covered with unwanted superficial material such as clay, gravel, sand, grass and soil. This overburden can be of variable thickness and its removal involves problems in quarrying which are almost as great as those in connection with the removal of limestone itself. It is important to decide which portion of the deposit should be worked because some portions are of higher quality than others. The greatest uniformity in the quality of the material is usually obtained by working selected portions separately in benches. In some cases uniformity of the product is best obtained by mixing material from several portions in prearranged proportions.

Chapter 4

LIMESTONE RESOURCES OF SRI LANKA

4.1. Recent Limestones

4.1.1 Shell Beds

Shell beds are known in a number of localities along the coastal stretches of Sri Lanka. The largest of them, extending from Hungama to Bundala has been investigated by the Geological Survey Department (Pethiyagoda, 1978).

Hungama — Bundala Shell Bed

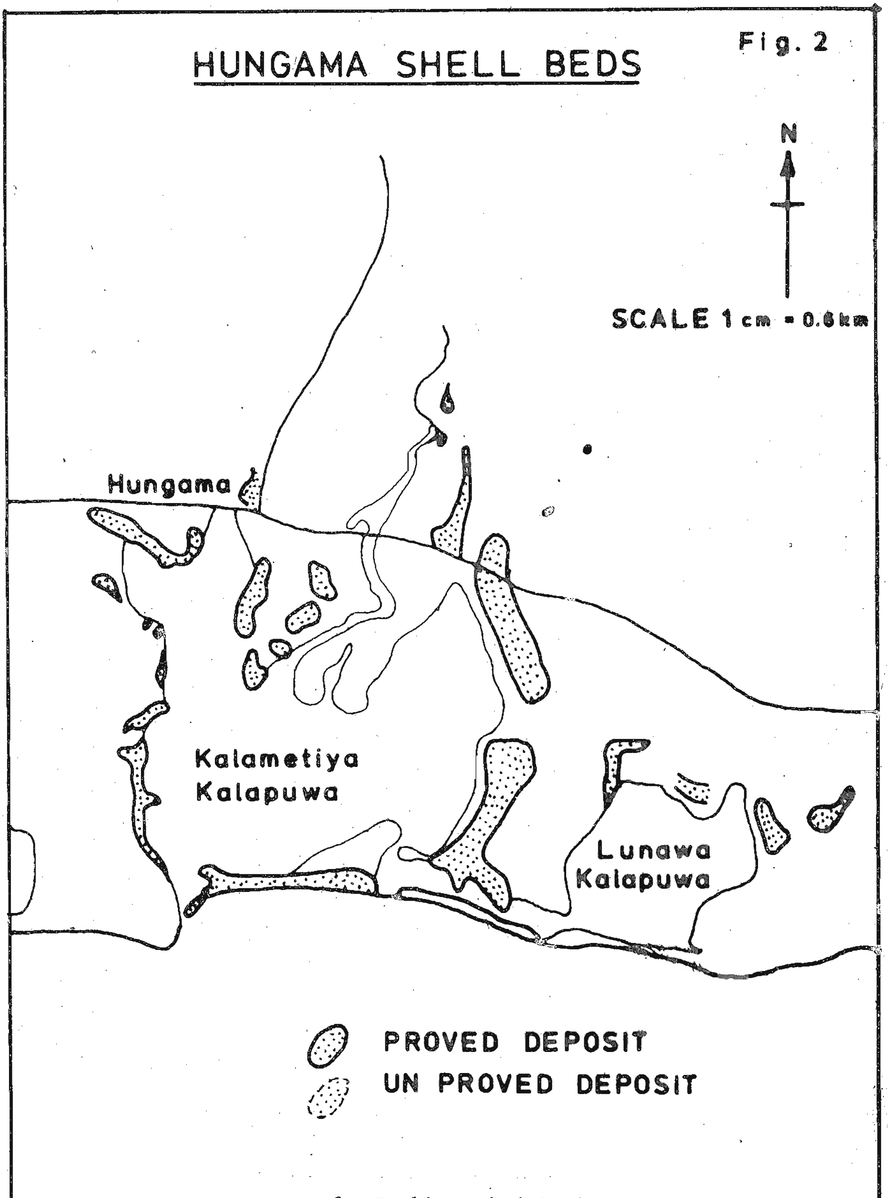
The shell bed from Hungama to Bundala, extends a distance of about 40 km. Hungama is located in the southern coastal area of Sri Lanka and is about 50 km. from Matara along the Kataragama road.

Geology

Shell beds occur mostly close to the existing lakes and lagoons (fig. 2). The thickness of the beds generally decrease away from the lakes and lagoons. In most areas the shell beds are not exposed much above the flood plain except in isolated cases such as the shell beds near the Fisheries Department circuit bungalow in Karametiya, where they have reached the levels of about 7m above the flood plain. In cross-section the occurrence of shell beds with respect to the bed rock and the overburden can be diagrammatically shown as in fig. 3. The overburden consists of brown/grey clayey soil except in the sand dune areas near Ussangoda. Due to the thickness and the compactness of the overburden scattered shells are rare on the surface even in the presence of thick layers underneath. Exposed pebbly layers of bed rock is a definite indication of the absence of shell material in the area.

The thickness and the lateral extent of the shell beds are highly variable from place to place. Thicknesses ranging from a few cm to 3m have been observed although they seldom exceed 1m. The underlying strata controls the thickness and the lateral variations.

The main variations are observed in the matrix of the shell beds. They are grey-brown clayey matrix and the light coloured sandy matrix. The former is found



After Pethiyagoda (1978)

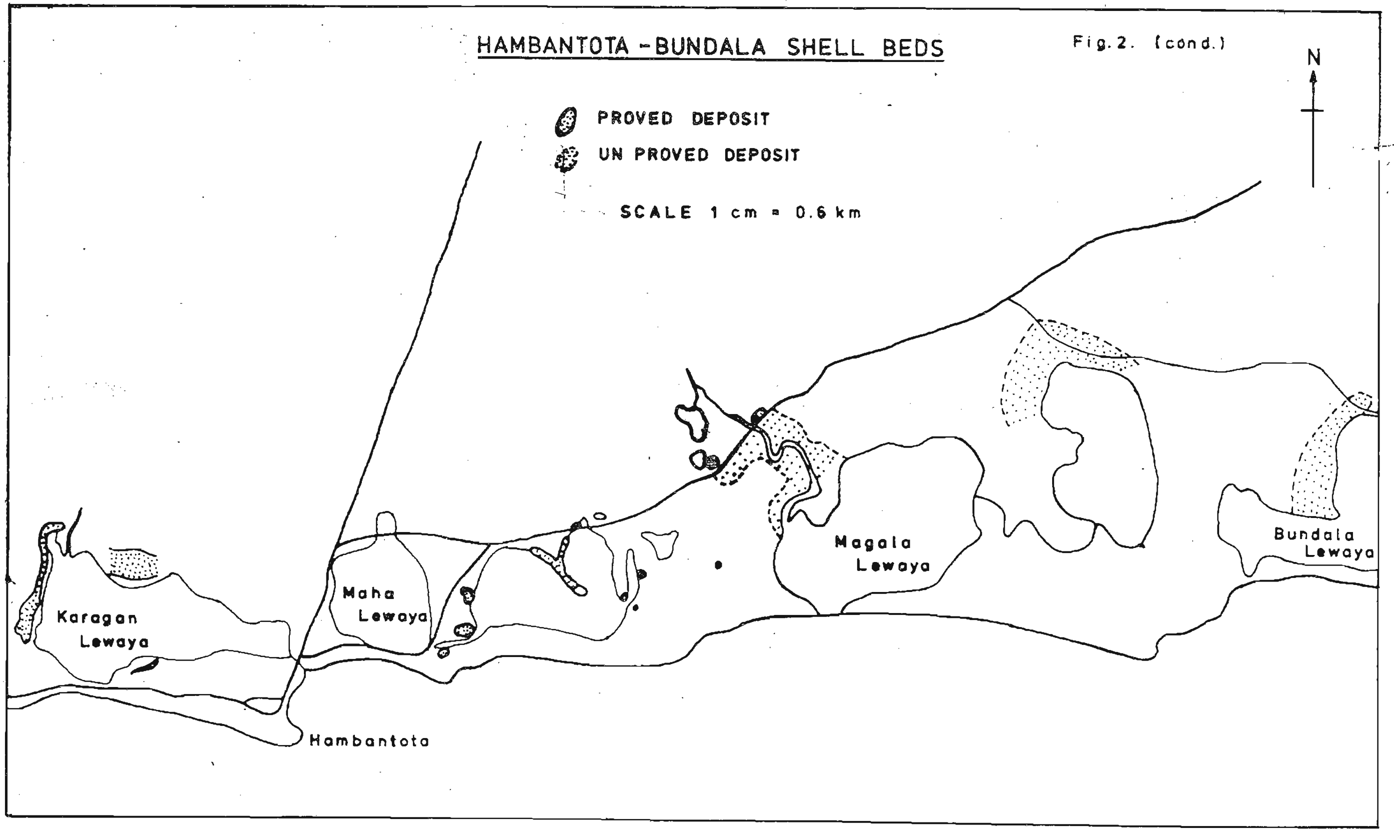
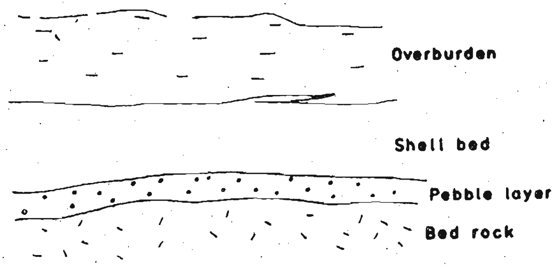
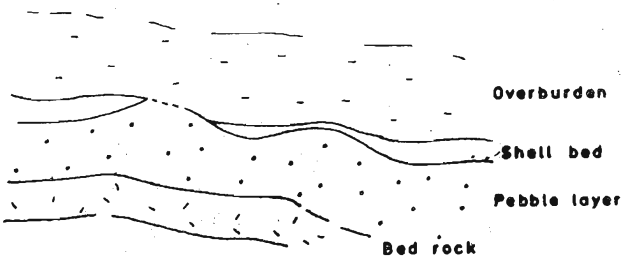

HAMBANTOTA - BUNDALA SHELL BEDS
Fig. 2. (cond.)
N
PROVED DEPOSIT
UN PROVED DEPOSIT
SCALE 1 cm = 0.6 km
Karagan Lewaya
Maha Lewaya
Magala Lewaya
Bundala Lewaya
Hambantota

Fig. 3



- Uniform shell bed in cross section
(NOT TO SCALE)



Discontinuos shell beds

nearer the lagoon whereas the latter is nearer the beach. The shells are almost always in framework structure with interstitial matrix. Pelecypods are the main variety of shells with a few gastropods occurring in isolated localities. The presence of Cardium Cerythiums, Plamorbis and Cypreol in the Hataragala area has been reported. Two major varieties of shells appear to dominate the area. They are smooth biconvex shells measuring 1–3 cm wide and strongly plicate shells measuring 2–5 cm. The deposit comprises around 95 per cent of the former and around 4 per cent of the latter. The distribution of the latter type is not uniform over the area, being more concentrated in the area that shows a clayey matrix. Chemical analysis of a sample obtained from Hatagala area shows: SiO_2–1.15%, Al_2O_3–0.41%, Fe_2O_3–0.33%, CaO–54.89%, MgO–0.20% and loss in ignition–43.10%. Mining of shells in this area has been going on for over 20 years, especially in the Hungama and Thenne areas. Where the overburden is thin, the shell bed is recovered by quarrying after scraping off the overburden. When the overburden is thick, pits are put down to the layer of shells from where tunneling along the bed is carried out. The thin beds are not exploited at present. In the sieving of shells for marketing a fair proportion of the small size shells and shell fragments are discarded.

As no bore hole investigations have been carried out only a lower limit for the reserves are given. Assuming an average bed thickness of 0.6m for the Hungama area, it is estimated that the deposit contains about one million tons of shell material. Further work including auger boring should be carried out in the areas where the deposit is not yet proved, especially around the lakes and lagoons. As the shell bed extends over a considerable area, a large number of small workings seem to be the most economical way of exploiting the deposit. Mining must be more systematic if full use is to be made. The common practice of not mining the thin shell beds should be reduced to a minimum.

4.1.2 Coral Limestones

Coral limestones are quite common in many coastal stretches of Sri Lanka. There are extensive coral developments on the southwestern coastal belt of the island. Some specific localities are Colombo, Mt. Lavinia, Hikkaduwa, western coast of Kalpitiya Peninsula, between Puttalam and Mannar, north coast of Jaffna Peninsula and on the coast between Vakaneri and Kalkudah. The most extensive occurrences are at the coastal area extending from Ambalangoda to Matara. These occurrences have been investigated in 1979 by the Geological Survey Department (Gurusinghe, 1979).

Ambalangoda to Matara

A stretch of 90 km. along the coast from Ambalangoda to Matara has been investigated. The investigation was mainly confined to a study of the existing pits, quarries and wells including geological mapping. The main objective of the survey was to locate reserve areas, mainly inland, for the widespread lime burning industry of the area.

Deposits of coral occur inland along the coastal plain as patches and lenses. They are best developed in the Akurala–Hikkaduwa area where they extend to depths of far below an overburden of 1 to 2m. Coral reef complexes form gigantic natural breakwaters off the coast at various localities such as Akurala, Hikkaduwa and Polhena. In general the overburden of coral deposits consists of 0.5 to 1.5m black sandy soil followed by 0.3 to 1.8m thick bed of a fossiliferoous sandstone. Underlying the coral deposits, a pebbly layer of weathered basement rocks is observed in some localities. The deposits consist of loosely packed finger coral associated with heavy blocks of massive corals usually mixed with pelecypods and gastropods. The corals are best preserved in their position of growth in the sediments. As the thickness of the lateral extent of the deposits are highly variable from place to place, no spatially consistent structural parameter may be measured. Thus a systematic picture according to the thickness is not practical although it is evident that the deposits closest to the sea are the thickest. Chemical analysis of a coral sample from Ambalangoda area shows: $Ca0$–51.5%, $Mg0$–0.5%, Fe_20_3–0.5%, $A1_20_3$–3.4%, $Si0_2$–2.0% and loss on ignition–42.7%.

The coral deposits are of many different kinds. The dominant coral type is Acropora which makes up about 75 per cent. Other coral types such as Trachpyllia, Galexea, Tubipora, Pocillepora, Fonia, Fungia, Danae etc. are also present in minor amounts. Pelecypods are mainly Cardiums, Cerythiums, Ostrreas etc. The largest clan observed in the field is Tridacna. It is a coarsely corrugated shell as much as 45cm in length and weighing about 3 kg.

For a realistic estimate of the reserves it is essential to carry out a more detailed field programme involving drilling. It is evident that the deposits closest to the sea are the thickest and these are almost entirely exhausted. More investigations have to be conducted inland to look for more reserves of limestone. Measures should be taken to prevent mining operations at the coastal tretches as this will have adverse effects on erosion of the land.

4.2 MIOCENE LIMESTONE

Along the northwestern coastal strip of Sri Lanka is a prominent band of Miocene limestone. At Kankesanturai and Jaffna Peninsula the limestone band is quite extensively exposed and at localities such as Aruakalu, Parappukadanthan, Mulankavil and Kondachchi it is fairly well exposed.

The typical Miocene limestone is massive in parts but some layers are richly fossiliferous and weather into a honeycombe mass. Sandy beds containing grains of magnetite, garnet, zircon, monazite and mica are also present which are probably derived from the Precambrian Series of rocks to the east. The band is generally overlain by a characteristic red earth formation, the presence of which is useful in locating the buried limestone. The overburden depth along the belt varies from zero to around 60m.

The limestone at Kankesanturai and Aruakalu are being used for manufacture of cement by the Ceylon Cement Corporation. Detailed investigations have been conducted at Aruakalu and semi detailed investigations were conducted at Kankesanturai and Parappukadanthan by the Geological Survey Department.

At Minihagalkande there are minor occurrences of nodular limestone with fossil sponges and echinoids.

4.2.1. Aruakalu

Aruakalu is situated about 30 km. north of Puttalam along the coast. The area can be approached by a motorable road leading to Eluwankulam from Puttalam. From Eluwankulam to Aruakalu there is a haul road constructed by the Ceylon Cement Corporation. Detailed investigations at Aruakalu commenced initially in 1958 (Fernando et al., 1958) and later more drilling was done in 1969. In 1978 a drilling programme was carried out in the Dutch Bay (south of Aruakalu) along a thin coastal strip. In 1980 to 1981 more investigations were carried out in the area southeast of Aruakalu Hill.

The main objective of the detailed survey conducted during the period 1958 to 1960 was to assess the quality and quantity of limestone available for a proposed cement industry. 54 drill holes were put down in the area which was then covered with a thick forest. Field investigations revealed that the limestone at north Aruakalu is hard and grade in composition from calcareous sandstones through siliceous limestone to pure limestones. In the north east sector (fig. 4) of Aruakalu Hill rounded knobs of high grade limestone with thin siliceous beds were exposed (now mined) on a ledge trending in a more or less north-south direction. Coral limestone is exposed at a few locations on this ledge and the associated limestone are generally sandy with small rounded pebbles up to about 5 cm. in diameter. Similar high grade limestones are also exposed in the south west sector of Aruakalu Hill near Irikalanchena at lagoon level. The limestone band is covered with an overburden composed of brick red loams, the depth of which varies from less than a meter to more than 40 meters.

Limestone samples obtained from cores were of high quality and had calcium carbonate percentages of over 90 per cent (table I). However, the limestone obtained after quarrying had values in the region of 80 to 85 per cent, due to contamination with red earth material overlying the limestone bed. However, limestone obtained from this area can still be used in the cement industry. At times certain localized patches of limestone are more siliceous than the rest, and in such cases the low grade limestone has to be blended with high quality limestone. Generally it is found that the limestone obtained from the southwestern quarry is of higher quality than those of the northeastern quarry.

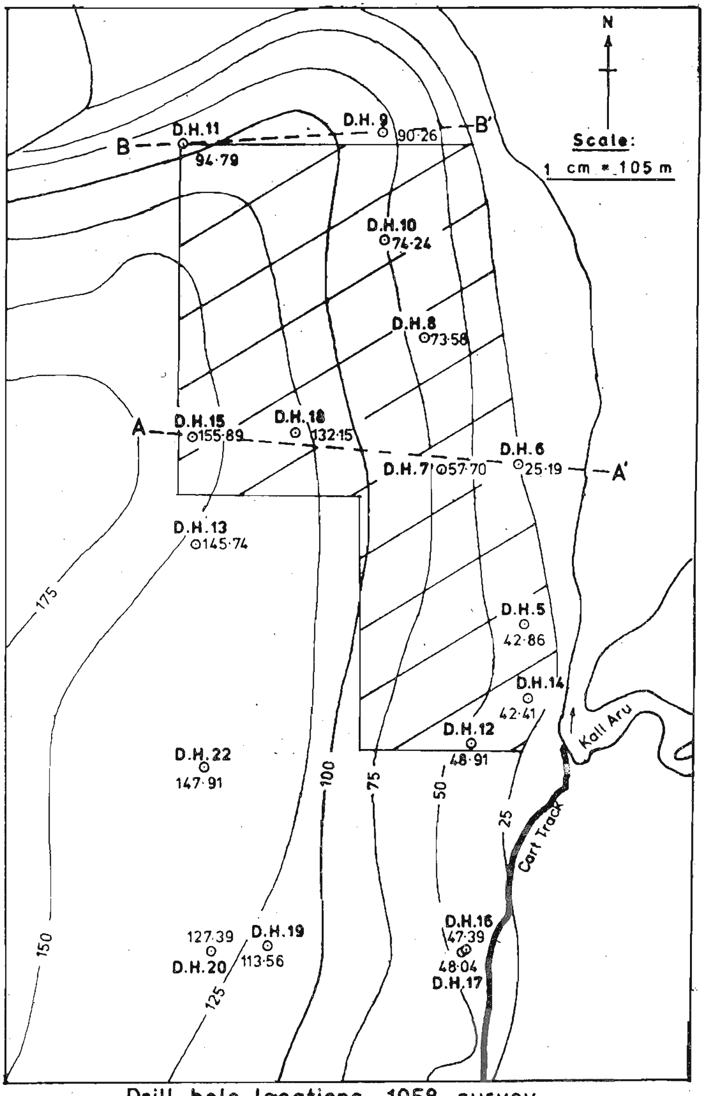
Another important feature in the limestone quarry is the non-uniformity of the overburden depths. Within Aruakalu Hill the overburden depths vary from zero to about 40 meters. The thin strip along the coast at the western border of Aruakalu Hill show overburden depths of less than 12 meters. But beyond 150 meters from the coast towards the hill there is rapid increase in overburden depths. The highest overburden depths are at the Aruakalu Hill and the area east of it.

Drilling investigations carried out to 1980 to 1981, by the Geological Survey Department indicate that the overburden depths at south-east of the southern sector of Aruakalu region (fig. 5) are less than 14 meters. During this investigation 40 bore holes with a meterage of 1619 were drilled in the grid shown in fig. 5.

The non-uniform depths commonly seen in Aruakalu limestone are characteristic of terrains where the surface of the bed has been subjected to erosion prior to deposition of the material on it. Two diagrammatic cross-sections are given in figs. 6 & 7.

The drilling programme carried out in 1958 to 1959 has proved limestone reserves of 10.7 million tons in the northeastern sector of Aruakalu and 8.8 million

Fig. 4



Drill hole locations 1958 survey,
Aruakalu North - Eastern Sector.

Table I

Average carbonate percentages of high grade limestone – Northeastern sector of Aruakalu, 1958 survey. Drill hole locations are given in Fig. 4.

Drill Hole No.	Average Carbonate Percentage
5	94.6
6	92.8
7	94.6
8	89.3
9	94.6
10	91.0
11	96.4
12	92.8
14	96.4
15	96.4

tons in the southwestern sector. These are reserves available above the water table having an average overburden depth of about 12 meters. About 5 million tons of limestone have already been used for the cement industry.

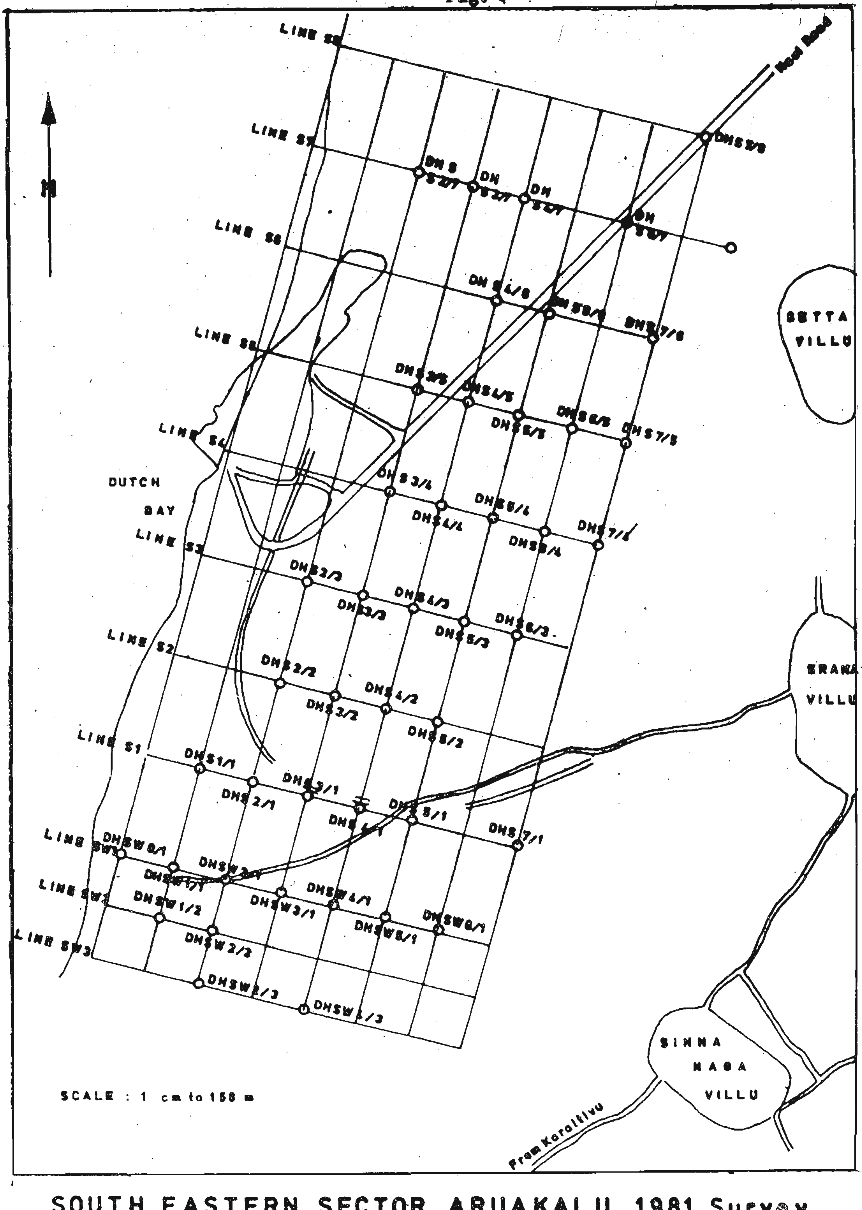
The investigations in 1980 to 1981 indicated additional reserves of over 8.6 million tons of high quality limestone above the water table.

The present method of obtaining limestone at Aruakalu is by quarrying and is definitely the most economical method for the terrain. However, the quarrying operations have been carried out in an unscientific manner. The lack of adequate planning prior to quarrying has led to waste of material and also the future quarrying operations complicated.

4.2.2. Dutch Bay

A drilling programme was conducted in 1978–1979 (Abeysinghe and Ranasinghe, 1979) in a small area of the Dutch Bay (fig. 8) to assess the the quality of limestone available. 38 drill holes were done during this programme. An area of approximately 333m. 3333m. was investigated. 333m being the distance from

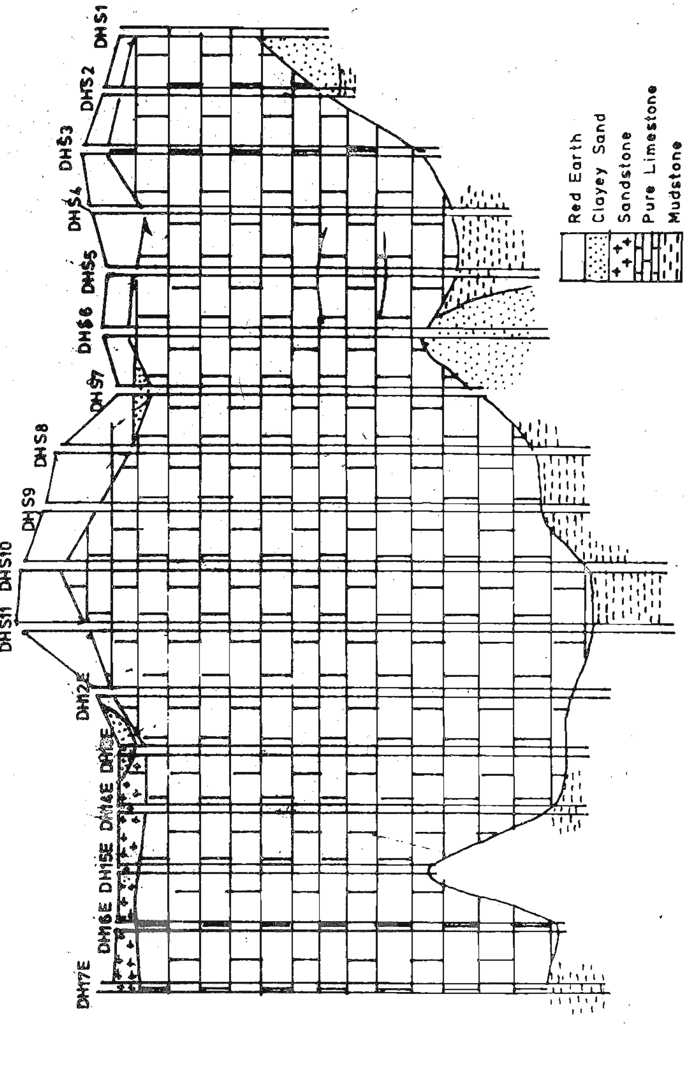
Fig. 5

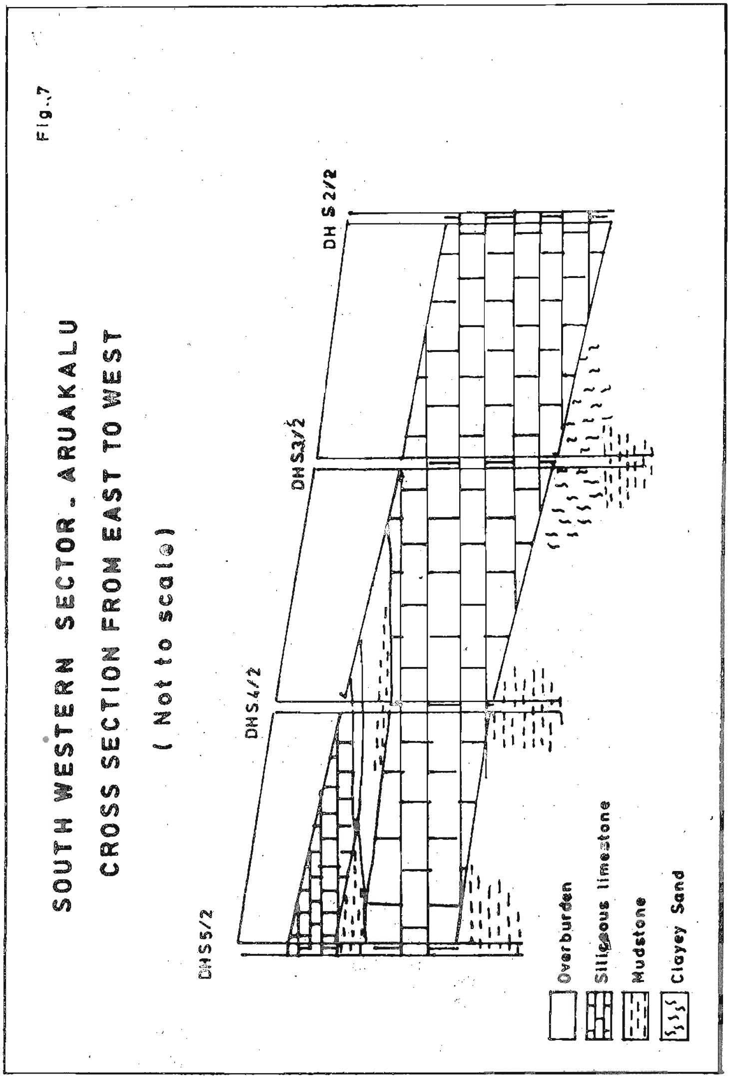


SOUTH EASTERN SECTOR ARUAKALU 1981 Survey
DRILL HOLE LOCATIONS

FIG. 8

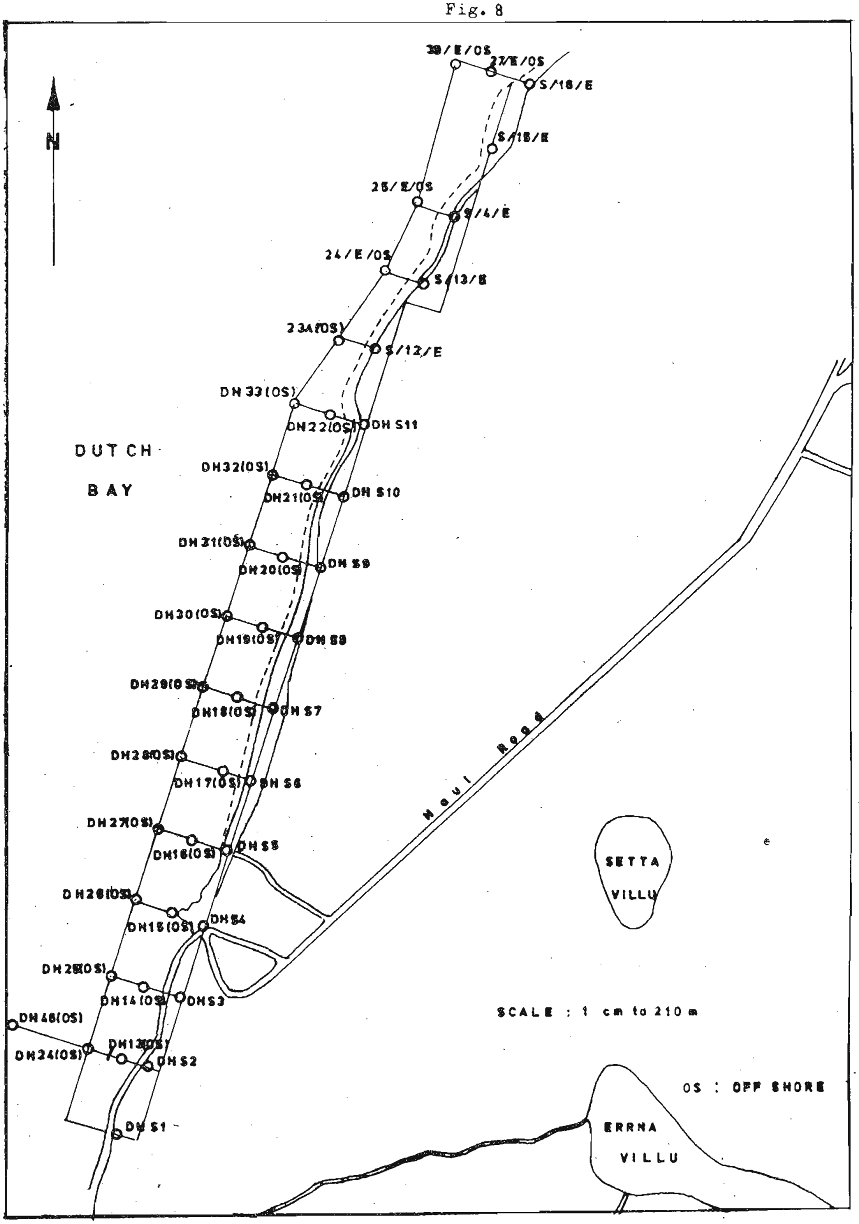
CROSS SECTION FROM NORTH TO SOUTH - ARUAKALU
(Not to scale)





SOUTH WESTERN SECTOR - ARUAKALU
CROSS SECTION FROM EAST TO WEST
(Not to scale)

Fig. 8



DUTCH BAY - ARUAKALU DRILL HOLE LOCATIONS
1979 Survey

the coast towards the Bay and 3333m being the length along the coast. There is a maximum water depth of around 3m in this area which drops to about 1.5m during low tide. There is a thin layer of sediment (15 to 25cm) on the limestone bed.

The investigations revealed that about 32 million tons of limestone are available in this area having carbonate values of more than 90 per cent (table II). However as expected there are significant quantities of chloride and alkali (table III). The limestone could still be used in the manufacture of cement with slight modifications of the plant.

The above investigation will definitely be of use for future purposes. However, there is no need to use this material at present or in the near future as there are sufficient reserves on land above the water table for another at least 15 years at the present rate of consumption. Furthermore, there would be much more material below the water table in land, the mining of which would be easier and cheaper than those of the Bay. The chloride and alkali contents in the material are less in comparison to those of the Bay material.

4.2.3 Parappukadanthan

The Miocene limestone is well exposed at Parappukadanthan, located about 7 km north of Murunkan. The area can be approached from Mannar along the road leading to Madu Camp through Tirukeswaram and Adampan. The distance from Mannar to Parappukadanthan is about 17 km. Limestone is also exposed at Sinnapikarachchan located about 7 km northeast of Parappukadanthan.

A survey for limestone in parappukadanthan area (Abeysinghe, 1979) commenced in January 1978 by the Ceylon Cement corporation with the assistance of the Geological Survey Department. The objective of the survey was to estimate the amount of limestone available above the water table in the two areas namely Parappukadanthan and Sinnapikarachchan. However, it was possible to complete drilling only in an area of about 4 sq. km (fig. 9) at Parappukadanthan as the programme had to be terminated due to other priorities.

The limestone exposed at Parappukadanthan is massive, hard and is of high quality. It is cavernous in places. The quality seems to be superior to those of Aruakalu. However, there are red earth pockets within the limestone, similar to those at Aruakalu though not as extensive.

Table II

Summary of drill hole data – Dutch Bay investigation, 1979. Drill hole locations are given in Fig. 8.

Drill Hole	Water Depth ft. & in.	Thickness of Limestone	Average Carbonate %	Core Recovery	Remarks
S 13	3' 4"	48' 6"	94.1	52.1	Bottomed at limestone
S 14	3' 6"	62. 6"	94.6	54.8	"
S 15	3' 6"	64' 6"	95.6	45.6	"
S 16	5' 0"	51' 0"	96.4	36.5	"
S 17	4' 5"	73' 0"	95.2	31.9	penetrated the limestone bed
S 18	5' 0"	75' 4"	–	25.9	"
S 19	5' 9"	95' 0"	–	30.7	"
S 22	5' 0"	54' 3"	90.2	18.3	"
S 23E	–	–	94.7	–	"
Average	4' 6"	65' 7"	94.4	36.9	

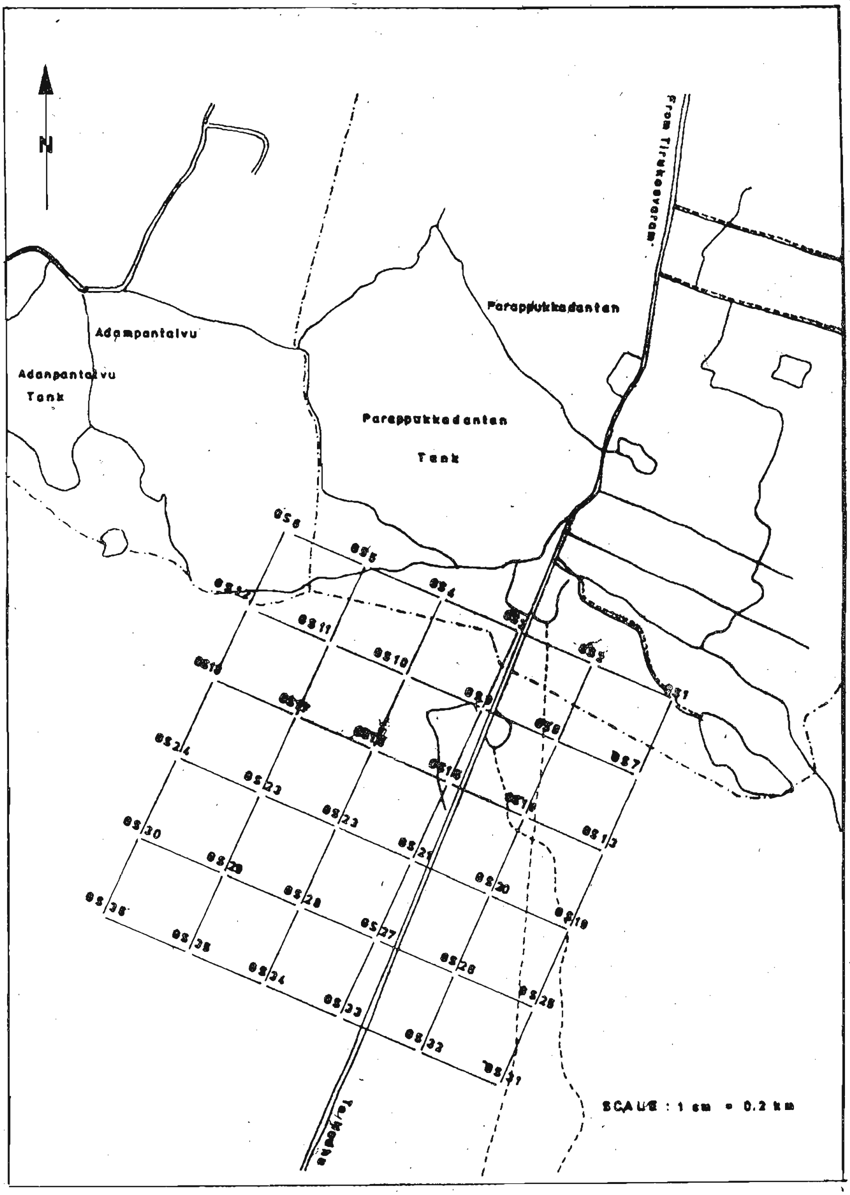
Table III

Chloride, Sulphate and Alkali percentages – Dutch Bay investigation, 1979. Drill hole locations are given in Fig. 8.

Drill Hole	Average Cl%	Average SO_4^{--} %	Average Na % as Na_2O	Average K% as K_2O
S 1	0.113	n.d.	0.083	0.009
S 2	0.096	n.d.	0.011	n.d.
S 3	0.006	n.d.	0.001	n.d.
S 4	0.013	n.d.	0.004	n.d.
S 5	0.072	n.d.	0.006	n.d.
S 6	0.126	n.d.	0.102	0.019
S 7	0.104	n.d.	0.082	0.018
S 8	0.079	n.d.	0.063	0.007
S 9	0.159	n.d.	0.095	0.023
S10	0.159	n.d.	0.131	0.033

n.d. = not detected

DRILL HOLE LOCATIONS - PARAPPUKKADANTAN
1978 Survey Fig. 9



Thirty drill holes covering a meterage of 371 were completed in the area. A summary of the bore hole data is given in table IV. All the holes were terminated at a level just below the water table. The water table is at a depth of 9 to 10 meters. Investigations revealed that the upper surface of the limestone bed is highly eroded and uneven. The average overburden depth is about 7 meters whereas that of the area recommended for exploitation is 4 meters. The overburden is entirely made up of red earth except for a thin gravelly ferruginous layer between the limestone and the red earth. The average carbonate percentage is around 90 (table IV).

The tonnage available above the water table in the area indicated in fig.9 is around 11 million tons. There are other promising areas in the vicinity where detail investigations have not been carried out. Therefore the total tonnage available in the Parappukadanthan area would be much more than 11 million tons. The availability of clay at the Murunkan clay field, south of Parappukadanthan, make the area a suitable location for a cement plant.

At present limestone at Parappukadanthan is being extensively used as a road metal and a building stone. This has led to a waste of a valuable raw material. The Precambrian rocks around Madu Road could be used as building stones and road metals instead of the limestone.

4.2.4. Kankesanturai

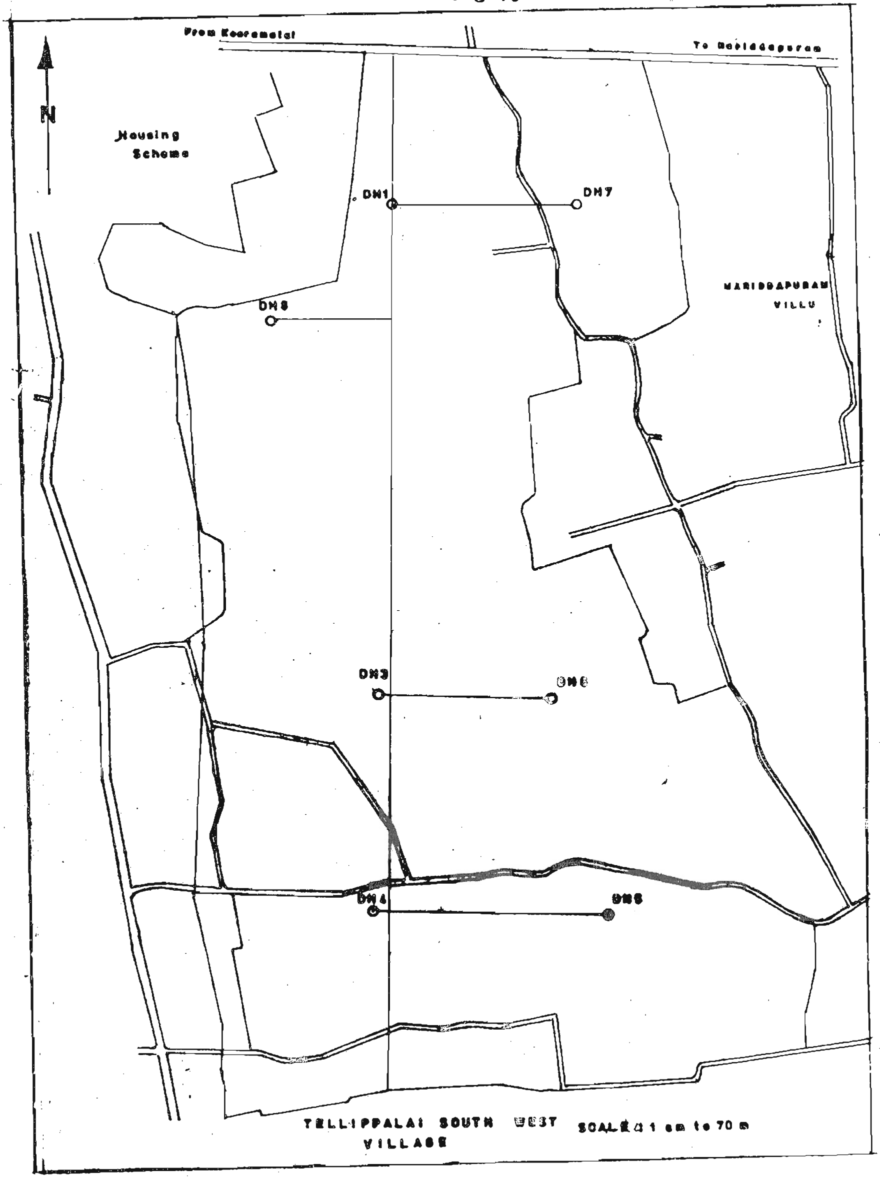
Kankesanturai is situated at the northern border of the Jaffna Peninsula. The entire Jaffna Peninsula is covered with Miocene limestone and is exposed at many localities. The rock is massive, hard, fossiliferous and is of very high quality. The presence of large quantities of limestone at Kankesanturai has led to the opening up of a cement factory in early 1950's. In 1980 the Ceylon Cement Corporation embarked on a programme to install an additional facility by the year 1982 and therefore made a request to the Department of Geological Survey to carry out a limestone survey within the Corporation land in order to assess the limestone reserves available above the water table (Abeysinghe, 1980). During this investigation eight drill holes were completed in an area where the Corporation has earmarked for acquisition. The area under investigation was south-west of Keeramalai road and is about 0.8 sq. km. in extent. The locations of the drill holes are given in fig. 10. The total meterage drilled during this programme was 230. A summary of the drill hole data are given in Table V. The average overburden depth is about 1.5 meters. A cross-section along the drill holes 1 to 4 is given in fig. 11. The average thickness of the limestone above the water table during the dry

Table IV

Summary of drill hole data – Parappukadanthan. Drill hole locations are given in Fig. 9

Drill Hole	Overburden	Thickness of limestone	Average CO_3^{--}%	Core recovery %	Remarks
1	10' 10"	21'	88.4	89.6	–
2	10' 00"	–	–	–	Up to 32' 8" the rock is highly siliceous limestone and sandy clay
3	12' 06"	–	–	–	Up to 26' 11" impure limestone and below that is a sandy layer up to 31' 11"
4	10' 00"	18'	88.6	43.6	–
7	15' 00"	–	–	–	Impure limes= tone up to 33' 08"
8	11' 00"	–	–	–	Up to 24' impure limestone and below that is a sandy layer of 33'
9	4' 00"	12'	92.5	92.0	Below 17' impure limestone
10	10' 00"	16'	87.2	64.0	–
11	13' 00"	13'	95.6	10.5	–
12	11' 00"	20'	95.3	27.5	–
13	15' 00"	–	–	–	Up to 37' impure limestone
14	3' 00"	12'	87.5	90.7	Below 15' impure limestone upto 32'
15	6' 9"	20'	94.7	89.0	Below 27' impure limestone upto 37'
16	2' 6"	27'	92.6	82.5	–
17	22' 00"	8'	93.2	47.9	–
18	13' 00"	15'	93.8	53.5	–

Fig. 10



LIMESTONE INVESTIGATION - KANKESANTURAI

DRILL HOLE LOCATIONS - 1980 Survey

Table V

Sumary of drill hole data – Kankesanturai. Drill hole locations are given in fig. 10

Drill Hole	Overburden	Thickness of limestone	Water Table	Average CO_3^{--}
D.H. 1	2' 7"	187' 5"	27' 00"	91.8
D.H. 2	3' 0"	69' 0"	14' 09"	86.6
D.H. 3	3' 10"	69' 2"	17' 06"	89.4
D.H. 4	4' 00"	66' 0"	19' 04"	88.1
D.H. 5	4' 03"	65' 09"	24' 09"	95.1
D.H. 6	3' 06"	69' 6"	22' 09"	95.9
D.H. 7	3' 10"	67' 2"	24' 00"	89.5
D.H. 8	15' 00"	55' 0"	25' 03"	88.1

season is about 8 meters. The carbonate percentages of the limestones are around 90. The red earth and the clayey pockets within the limestone are much less than at Aruakalu and therefore negligible contamination of the quarried material. In 1983 a second factory at Kankesanturai commenced its production under Lanka Cement Limited.

The tonnage available above the water table in the area earmarked for acquisition is in the region of 12.5 million tons. The possible reserves below and above the water table are over 35 million tons. The reserves above the water table in the surrounding area is around 37 million tons and above and below the water table is around 104 million tons. The values given above have to be confirmed by a more detailed drilling programme. In Kankesanturai area the limestone available for exploitation is rather limited due to the thick population. Therefore steps should be taken to acquire the available land (about 2.5 sq. km.) in the vicinity of the cement factory in order to run the cement plants without shortages of raw materials.

4.2.5. Mulankavil

The Miocene limestone is exposed at Mulankavil which is located about 55 km. from Mannar along Pooneryn road. The rock is massive and seems to be of high quality. No detailed investigations have been conducted to assess the amount of limestone available.

CROSS SECTION ALONG
D.H.1 to D.H.4

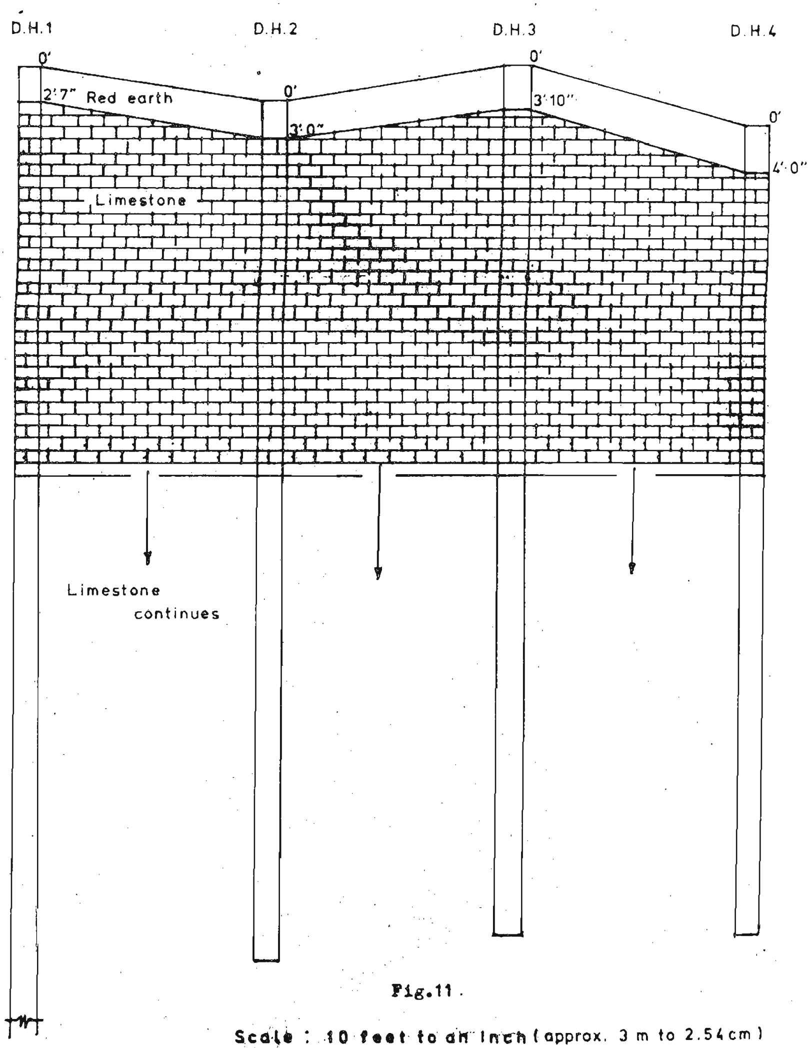


Fig.11.

Scale : 10 feet to an Inch (approx. 3 m to 2.54 cm)

4.2.6 Kondachchi

At Kal Aru bordering the Cadju Plantation at Kondachchi are a few exposures of Miocene limestone. Drilling investigations carried out in the adjoining plantations by the Irrigation Department has revealed that the limestone is at very deep levels having overburden depths of around 58 meters, and is comparatively more siliceous than in the other regions. However more investigations are necessary to confirm the above observations.

4.3 PRECAMBRIAN MARBLES

The most common variety of limestone in Sri Lanka is the Precambrian marble. Thin prominent discontinuous bands running in a north-south direction are quite common in the central highland of Sri Lanka. Some of the localities having extensive marble exposures are Matale, Kandy and Habarana regions. These occur in association with the metasedimentary rocks.

The colour of marble is generally white or greyish white when relatively pure and greenish or dark greenish when impure. The texture generally varies from fine grained to coarse grained and chemically they vary from calcitic or dolomitic varieties to impure varieties. The relative proportions of calcite and dolomite vary from band to band even within a few meters and is generally impossible to distinguish between calcite and dolomitic varieties in the field. The commonest accessory minerals are forsterite, phlogopite, diopside, apatite, spinel, graphite and pyrite.

A detailed study of the Sri Lankan marbles has first been attempted by Goomaraswamy in 1902. Since then investigations have been carried out at Polonnaruwa region (Vitanage, 1949), Rangala region (Cooray, 1961), Ratnapura, Godakawela region (Hapuarachchi, 1961), Kandy area (Jayawardena, 1971) and two locations in Badulla and Hakgala (Karunaratne, 1980).

4.3.1. Marbles around Polonnaruwa

The distribution of marbles in Minneriya area is shown in fig. 12. Among the large number of marble bands the thickest one is that exposed east of Habarana (Vitanage, 1959) at the road cutting (between 2 km and 5 km posts on Habarana-Polonnaruwa road) for a width of nearly 1½ km. Here several cherty layers which

DISTRIBUTION OF PRECAMBRIAN MARBLE IN MINNERIYA

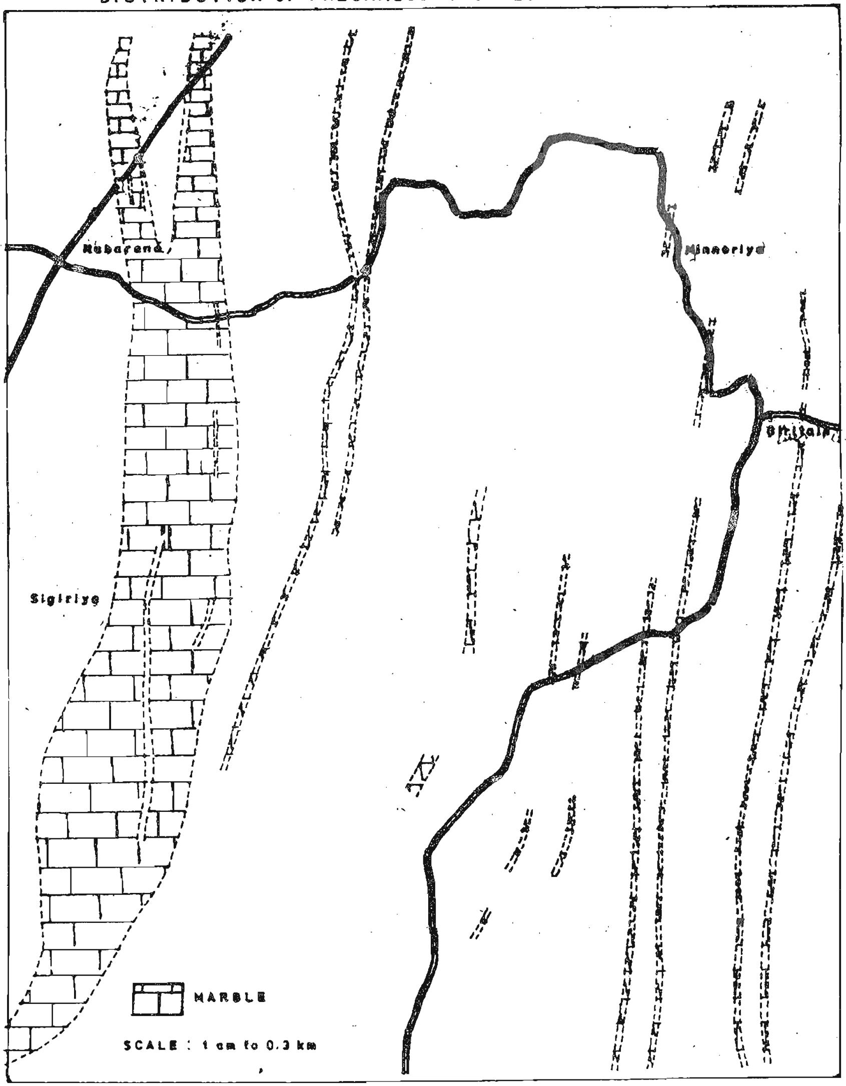


Fig. 12

form minor low ridges and a series of narrow outcrops of garnet-sillimanite graphite schists have been interbedded with the marble band. The marble occupies the crest of a local anticlinal fold. It can be traced to a distance of over 33 km from Habarana southwards through Polattawa east of Sigiriya, Nikawatuana and Ereula. The several exposures of similar marble in the south-south-west near Lenodara and Nalanda indicate that the Habarana marble may be the northerly continuation of Matale-Nalanda marble bands (Coates, 1935). East of this major marble band, a series of marble bands ranging in thickness from 10m to 66m are exposed regularly. Some of the marble outcrops such as the one at Katukeliyawa consist of thin zones of marble alternating with beds of quartzite and charnockite. Two sets of parallel marble bands on either side of Sudukande quartzite ridge seem to be quite persistent and continue southwards for nearly 80 km.

The marble contains olivine, brown phlogopite, apatite, graphite and spinel as accessory minerals. Partial chemical analyses of some samples (table VI) show calcium oxide values ranging from 30.20 to 44.48 per cent and the magnesium oxide values ranging from 2.96 to 20.80 per cent. The easterly bands are dolomitic.

4.3.2. Marbles around Rangala

There are no large conspicuous bands of marble in the Rangala one inch topographical sheet unlike in the Habarana and Matale areas to the north and north-west (Cooray, 1961). The marbles are best developed in the south central portion of the sheet in the area around Pallewatta. One of the best known bands though least accessible is that in which a Nitre Cave has been formed; another cave occurs on the Patanegedara band in the north west. In the south west portion of the Rangala one inch sheet narrow bands of marble are seen at Narampanawa, Diganegamedda, Arattana, Poddalgoda and Bambarella (Knucles Group).

The chemical analyses of some samples collected in the above region (table VII) show calcium oxide values ranging from 24.8 to 50.90 and mgO values ranging from 1.03 to 20.87 per cent.

4.3.3. Marbles around Kandy

A brief survey for marbles and dolomite in the Kandy area was conducted by the Geological Survey department (Jayawardena, 1971). There is extensive development of marble and dolomite at Ampitiya, Talatu Oya, Gangapitiya and Digana areas. Seven locations (fig.13) have been investigated and 28 samples were analysed.

Table VI

Partial chemical analyses of Marble — Habarana area

Sample No.	CaO%	MgO%	Acid Insolubles
K 1174	31.36	19.64	3.42
K 1211	44.48	17.81	5.59
K 1233	33.21	18.88	4.42
K 1280	41.47	10.48	3.74
K 1241	43.80	2.96	8.92
K 1246	32.70	18.80	0.73
K 1189	24.87	13.77	1.97
K 1280D	33.05	18.52	2.70
K 1019	30.20	20.80	1.92
K 1280B	31.01	18.80	3.14

K 1280 — Habarana Limestone band
K 1280D — Habarana Limestone band

K 1280 — Composite of 5 samples collected at ¼ mile intervals across the outcrop

K 1241 Narrow bands — Habarana area
K 1211 Narrow bands — Habarana area

for other sample locations see Vitanage (1959)

Table VII

Chemical analyses of Marble — Rangala area

Sample No.	1	2	3	4
SiO_2	0.51	2.45	11.18	5.19
TiO_2	0.02	n.d.	0.02	0.06
Al_2O_3	0.31	3.6	1.13	0.81
Fe_2O_3	0.03	0.80	0.01	0.54
FeO	0.17	n.d.	0.71	
MnO	0.02	n.d.	0.10	0.05
MgO	21.03	12.15	18.27	7.90
CaO	31.37	33.10	35.18	42.61
Na_2O	Tr.	n.d.	0.31	0.05
K_2O	Tr.	n.d.	n.d.	0.33
H_2O^+	n.d.	n.d.	n.d.	0.56
H_2O^-				0.21
CO_2	46.04	48.10	32.50	41.58
P_2O_5	Tr.	n.d.	0.20	0.04
Total	99.51	100.20	99.61	99.93

1. from Naranpanawa
2. Upakariya – Gurulupotha foot path
3. 41 m.p. – Kandy – Weragantota Rd.
4. Composite analysis of 345 sedimentary limestone

Partial analyses of Marble

	1	2	3	4	5	6	7
Acid Insolubles	6.69	4.93	4.80	10.71	11.54	15.40	36.90
Total Oxides	1.02	1.02	1.43	4.53	1.96	4.25	2.50
CaO	50.90	30.68	30.58	29.62	28.93	28.58	24.00
Loss on ignition	40.50	43.10	43.36	39.99	38.74	30.37	23.80
Total	100.14	99.93	100.12	100.64	99.73	99.47	100.02

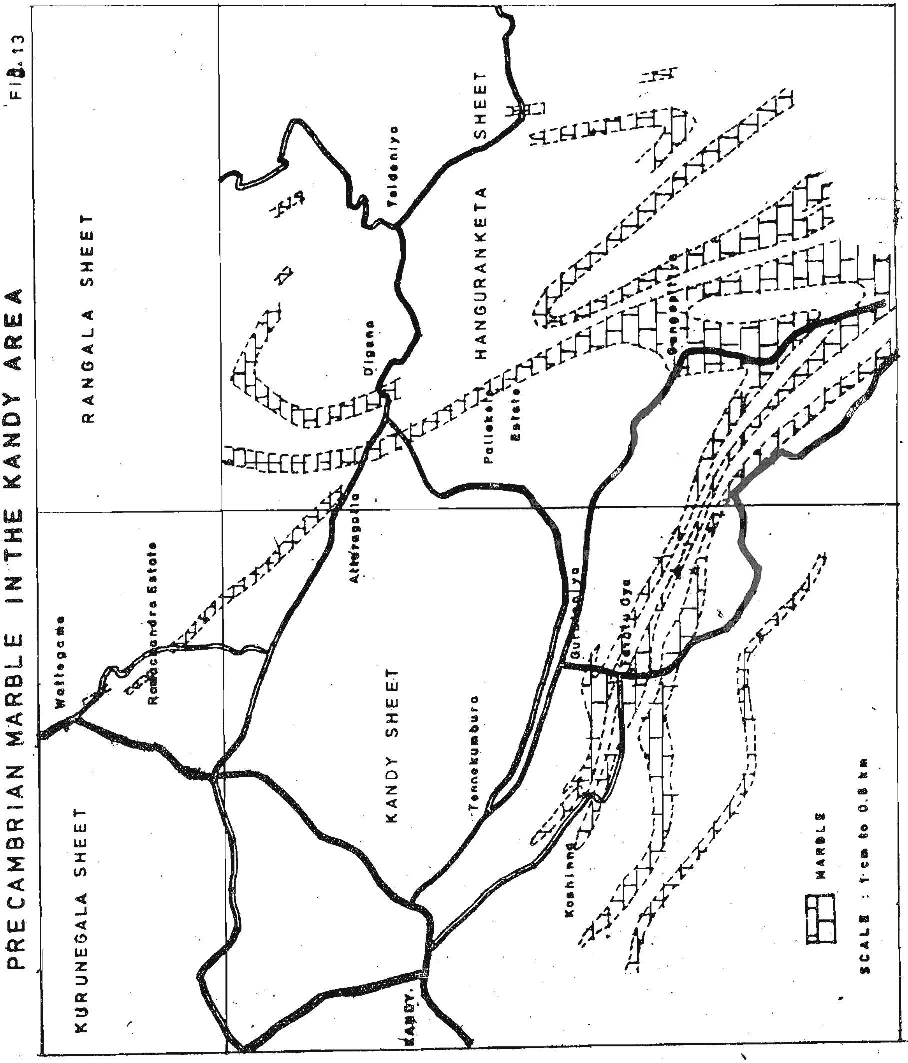
1. Bambarella Estate
2. Between culvert 40/8 and 39¼ on Kandy-Weragantota Road
3. Culvert 38/8 Kandy-Weragantota Road
4. Between culvert 38/12 and 38/13 on Kandy-Weragantota Road
5. Foot path ½ km. south of Leloya
6. Gomagoda Road
7. Stream near south end of Welakumbura village

Digana

The marble at Digana is about 2 km. in length and about 170 meters wide. It rises to about 10 meters from the ground level. The accessory minerals identified are diopside, apatite and graphite. Chemicals analyses of some samples from this locality has shown that the marble is dolomitic (table VIII). It is well exposed over an area of about 0.1 sq. km. and the quantity of dolomitic marble available is in the region of 500,000 tons. At this location marble is obtained by quarrying and involves drilling and blasting. The quarrying is relatively easy as the marble band runs at a higher contour level. The east west joints in the marble facilitate quarrying as it breaks into blocks of about 0.7 meters in length.

Pallekelle Estate

The dolomitic marble at Pallekelle (table IX) Estate forms a prominent band at least 25 meters wide which runs in a NW–SE direction from east of Digana to Gangapitiya. The marble is coarse grained and the accessory minerals are diopside, phlogopite and apatite. The quantity available is around 500,000 tons.



After Jayawardena (1971)

Table VIII

Partial chemical analyses of Marble – Digana

Sample No.	Acid Insolubles	CaO%	MgO%
GM 1	4.22	30.10	19.65
GM 2	3.12	29.50	20.59
GM 3	2.11	29.64	22.31
GM 4	2.79	28.93	20.67
GM 5	2.17	29.39	22.05
GM 7	2.95	28.99	22.51
GM 8	2.60	28.87	21.80

samples were collected at random mostly along the length of the outcrop

Table IX

Partial chemical analyses of Marble – Pallekelle Estate

Sample No.	Acid Insolubles	CaO%	MgO%
G 1	16.73	20.95	15.73
G 2	0.49	30.80	20.33
G 3	1.80	29.43	21.30
G 4	24.55	27.53	12.40
G 5	1.50	29.46	18.96
G 6	0.91	29.72	21.67
G 7	5.00	30.50	20.45

samples were collected at random mostly along the length of the outcrop

Attaragalle and Karagastenne

These two deposits are in the vicinity of Digana and the marbles are dolomitic in character (table X). The accessory minerals present are diopside, graphite, phlogopite and apatite. The tonnage available has not been estimated.

Table X

Partial chemical analyses of Marble – Karagastenne and Attaragalle

Sample No.	Acid Insolubles	CaO%	MgO%
A 1	2.59	30.20	20.88
A 2	2.12	30.28	21.28
A 3	3.47	29.83	21.51
A 4	1.80	29.28	20.82
A 5 (Impure)	83.68	8.13	0.93
K 1	1.67	30.19	21.56
K 2	2.37	29.57	21.95
K 3	1.01	29.98	21.69
K 4	3.16	28.65	22.58

Ampitiya

A prominent dolomitic marble band, at least 165 meters wide crosses the Kandy Talatu Oya road close to 5 km. post. The dolomitic marble is massive with prominent bedding planes. This band extends south eastwards from Ampitiya through Koshinna to Talatu Oya and continues towards Hanguranketa. At the Ampitiya quarry dolomitic marble is exposed over an area of about three acres. It contains accessory minerals such as diopside and graphite. The tonnage available at this site is around 10,000 tons. One sample from the quarry shows CaO percentage of 29.33 and MgO percentage of 22.33.

Koshinna

The quarries are located on the Talatu Oya Gurudeniya road and the dolomitic marble trends in a WNW–ESE direction. this band is at least 35 meters wide. It contains minor amounts of graphite and diopside. One set of vertical joints was observed at 320 degrees. The joint planes facilitate the blasting operations as the blocks break into convenient sizes. The tonnage available is around 20,000. One analysis shows CaO percentage of 31.90 and MgO percentage of 29.95.

Wattegama

The quarry is located in an estate called Ramachandra near Wattegama. The dolomite marble is about 13 meters wide. The general trend of the band is NW–SE with a steep dip to the east. At present marble is used for the manufacture of slaked lime. The tonnage available in this area is around 40,000. The analyses show that CaO content varies from 29.55 to 34.02 per cent and MgO content from 20.15 to 23.65 per cent.

4.3.4. Marbles around Badulla

Redeepana

A band of marble exposed at Redeepana, 2 km. along Mahiyangana road has been investigated by the Geological Survey Department (Karunaratne, 1981). It occurs in association with a garnetiferous granulite rock having north south strike and westerly dip and covers an area of about 0.25 sq. km. The average thickness of the marble band is about 400 meters. The accessory minerals present are phlogopite, spinel and apatite. A few partial analyses show that the marble is dolomitic and the CaO varies from 25.51 to 30.50 and the MgO varies from 12.76 to 22.47 per cent. The tonnage estimated is around 25 million tons.

Hakgala

A dolomitic marble exposed at Hakgala, located along Nuwaraeliya-Welimada road, has been investigated by the Geological Survey Department. A few analyses show that CaO values range from 27.51 to 30.19 per cent and MgO varies from 17.29 to 21.01 per cent.

4.3.5. Marbles around Ratnapura

The marbles in this region occur as discontinuous bands interbedded with metasedimentary rocks. They are impure due to the presence of various accessory minerals. The proportions of these impurities are extremely variable and even within a small outcrop the marble changes from almost snow white and pure marble to dark and impure types. Following are some localities where marbles are exposed in the Ratnapura region. The available chemical analyses are listed in table XI.

Weragama

Weragama is situated about 10 km. from Ratnapura. The marble outcrops in paddy fields and forms low ridges. It is generally coarse and some of the calcite crystals are about 3 cm. across. Blue apatite is a common accessory mineral.

Wadumulla

Wadumulla is situated about 4 km. from Ratnapura in the Ratnapura Palawela road. The marble has been used earlier for making lime. It is medium grained rather impure and contains spinel, flakes of graphite and phlogopite, pyrite and apatite.

Gillimale

Gillimale is situated about 11 km. from Ratnapura. The marbles are exposed in a tributary flowing into the Kaluganga. It is a coarse grained marble with a few impurities. Accessory minerals present are forsterite, phlogopite, apatite and spinel.

Table XI

Partial analyses of Marble from Ratnapura and Godakawela areas

Sample No.	E 31	E 32	E 33	E 34	E 35
SiO_2	10.89	8.02	5.61	2.66	3.66
Al_2O_3	1.69	0.58	1.81	2.07	2.20
Fe_2O_3	0.86	0.93	0.87	0.93	1.10
CaO	34.58	28.27	32.29	32.67	41.94
MgO	18.98	21.98	20.25	21.12	12.30
Loss on Ignition	34.75	40.32	40.45	40.95	39.15

E 31 – Paraketiya, E 32 – Wadumulla, E 33 – Weragama,
E 34 – Gillimale, E 35 – Palugampola.

XI (Contd.)

Sample No.	Acid Insolubles.	CaO%	MgO%
106 A	3.07	42.30	12.32
106 B	20.83	43.11	0.95
89	0.48	38.52	18.85
90	13.84	31.47	15.31
64	5.63	31.68	20.63
L 15	13.93	29.87	17.66
L 16	5.89	29.62	18.75
L 17	15.59	28.02	16.82
L 18	18.37	27.51	16.91
L 19	11.50	30.56	18.06
L 20	15.88	28.17	16.08
80	18.16	29.86	22.13
81	19.28	31.59	1.06
L 1	2.41	30.62	21.69
L 2	0.06	30.44	21.30
L 3	11.81	30.33	17.14
L 4	13.21	30.71	16.05
L 5	11.52	28.74	18.35
L 6	3.86	29.97	21.10
L 7	1.22	30.61	21.62
L 8	3.78	30.71	20.01
L 9	7.04	27.88	22.36
L 10	8.55	31.12	18.73
L 11	7.03	32.12	19.03
L 12	10.68	31.33	19.03
L 13	2.73	29.20	21.74
L 14	6.49	32.64	17.23
78	4.98	30.92	20.20
79	2.53	30.56	20.96
L 21	16.24	42.10	0.58
L 22	9.41	46.29	0.69
L 23	5.38	48.61	1.13
L 24	12.86	45.11	0.34
L 25	25.46	35.77	3.13

106 A tos106 B – Hunuwalakande
64 to L 15 to L 20 – Uduwela
78 to 79, L 10 to L 14 – Maratenne deposit 2
89.90 – Paletalawa
80 to 81, L 1 to L 9 – Maratenne deposit 1
L 20 to L 25 – Godakawela

Palugampola

Palugampola is situated about 2 km. from the Ratnapura-Balangoda road. The marble is exposed in a stream and its purity is extremely variable. It is medium grained and contains diopside, phlogopite, feldspar and flakes of graphite.

Uda Niriella

The Niriella dolomitic marble is located south west of Ratnapura about 12 km. along the Karavita road. The marble occurrences in the area are confined to the four bands running more or less parallel to one another and striking about $N50^{o}E$. Their grain size varies from medium to coarse. The accessory minerals are forsterite, diopside, phlogopite, apatite, spinel and minute flakes of graphite.

Thirteen drill holes were done in this area covering a total meterage of 390. The chemical analyses show that the rock is dolomitic having CaO within the range 20.50 to 33.33 per cent and MgO within 17.60 to 27.11 per cent.

Guruluwana

Guruluwana is situated about 17 km. north east of Ratnapura. The marble is coarse and impure.

Paraketiya

Paraketiya is situated about 10 km. east of Ratnapura. The marble is exposed in a small stream and is rather impure with accessory minerals such as forsterite, pyroxene, spinel, apatite and phlogopite.

Hunuwalakande

Hunuwalakande is situated north of Opanaike. A large outcrop of impure marble occurs in this locality.

Uduwela

Uduwela is situated 12 km. from Balangoda and east of Morahela. Marble outcrops at the edge of a paddy field for a distance of over 330 meters. Pure and impure bands occur in the area. The marble is coarse, crystalline and accessory minerals present are forsterite, diopside, phlogopite and spinel.

Paletalawa

Paletalawa is situated 20 km. from Balangoda along Pinnawela road. A large outcrop of impure marble containing accessory forsterite, diopside, phlogopite, apatite and spinel occurs in the area.

Maratenne

A number of deposits of marble occur in Maratenne located in the upper Balangoda area. There are three well defined bands trending in a N60°W direction. These bands are over 330 meters in length and outcrops rise to about 7 meters from the ground level in places.

Panane

Panane is situated south of Balangoda and forms part of the south east sector of Ratnapura one inch topographical sheet. Marble in this area is medium to coarse grained rather impure and consists of forsterite, phlogopite, diopside, apatite, spinel and flakes of graphite.

Godakawela

Marble outcrops from Godakawela to Pallewela a distance of about 8 km. and from Pallewela to Ranwela a distance of 8 km. This area is in the north east sector of the Rakwana one inch sheet. Majority of the exposures are fairly impure and coarsely crystalline. The MgO content is low and the acid insolubles are very high.

4.3.6 Marbles around Mihintale

Field investigations around Mihintale have shown two significant occurrences. The first locality is between Ukalankulama and Pahalagama, about 2 km. east of 142 km. post on the Mihintale-Medawachchiya road. The marble near Ukulankulama is medium to coarse grained. The overburden is about 1.5 to 3m. The band can be traced 2 km. south near Pahalagama where the marble outcrop is about 13 to 16 meters wide. The second locality is about a kilometer south of the main Kandarawa marble quarry. The overburden is about 1.5 to 3 meters. This is the southerly continuation of a fairly large band of marble at Kandarawa.. Marble can be obtained from the southern part of the main Kandarawa marble band. The general strike of the band is N30°E with westerly dip of 70°

The marble band is about 13 meters wide and is characterized by a wide zone of massive calcite crystals. The calcite crystals range from 10 to 20 cm. in length. The zone is about 5 meters wide in parts. On the eastern part of the quarry it is interbedded with granitic rocks and medium grained limestone. The whole marble band pinches out on the northern part of the quarry near the bed of Kandarawa Oya.

4.3.7. Marbles around Matale

Marbles occur extensively in the area around Matale (fig. 14). No detail surveys were undertaken in this area to assess the quality and quantity of the availability of marbles. However, lime making is a well established cottage industry in the area.

4.3.8. Petrographical studies of Marbles

Petrographic studies of samples from the Rangala area (Cooray, 1961) have shown that the marbles are made up of a mosaic of calcite and dolomite in which the silicate minerals occur either as scattered individual crystals or in clusters. The carbonate minerals are intimately intergrown, the dolomite appearing to penetrate the calcite. Forsterite is colourless in thin section and occurs in large rounded to subidiomorphic grains with recognisable prismatic faces. Phlogopite is found as pale brown bladed cystals which show the characteristic faint pleochroism. Phlogopite crystals may be completely enclosed in calcite or small portion of calcite crystals may be found in them. Diopside occurs as pale green or more commonly colourless rounded to prismatic crystals and easily distinguishable from forsterite by its well developed prismatic cleavage. Apatite in thin section appears as colourless, clear, euhedral crystals. Spinel is colourless or pale green in thin section. Generally marbles in other areas show similar characteristics.

DISTRIBUTION OF PRECAMBRIAN MARBLE AROUND MATALE

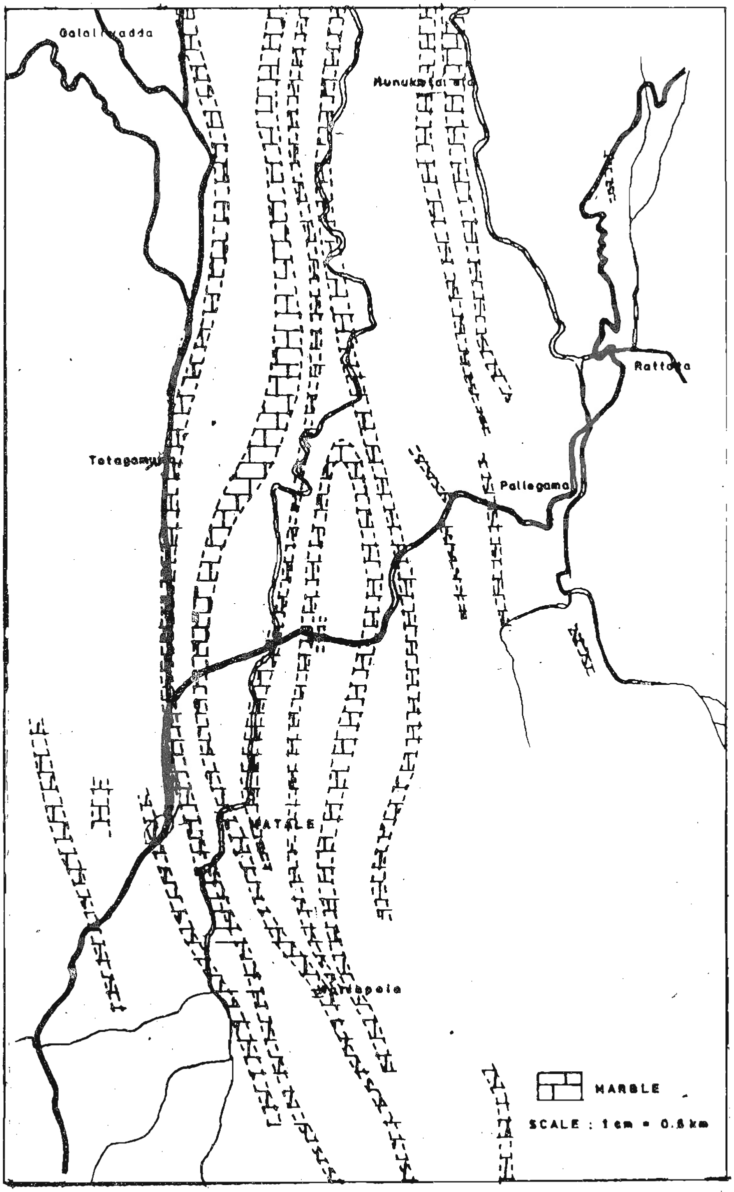


Fig. 14

Chapter 5

ENVIRONMENT OF DEPOSITION

Presence of fossil assemblages in a rock formation enables to add constraints on their environments of deposition. For instance the rocks which have formed under deep seated conditions carry different fossils to those which have formed under shallow water conditions. Likewise the rocks which have formed under marine conditions carry different fossils to those that have formed under fresh water conditions. Therefore detailed studies of fossils in a rock formation will enable to identify their depositional environment in great detail, namely, whether lagoonal, brackish, marine, shallow or other environments.

5.1 Recent Limestones

Shell Beds

The shell beds in Hungama consist of mainly Pelecypods with minor gastropods, Cardium Cerythiums, Pamerbis and Cyreol. These fossils are typical of lagoonal environments. Presence of such fossil assemblages in the Hungama area therefore suggests that the lagoonal environments prevailed during geologically recent times.

Coral Limestones

The occurrence of both pelecypod valves together with coral colonies in the sub-surface of the coastal plain from Ambalangoda to Matara suggest that the area had been subject to periods of regressions.

5.2 Miocene Limestone

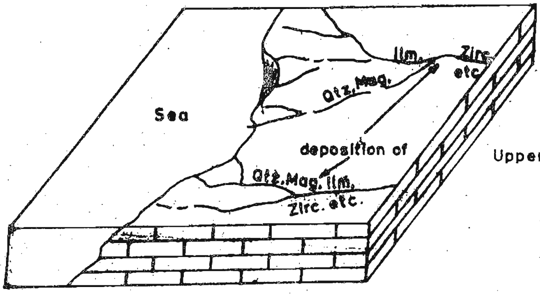
A varied assemblage of fossils is found in the Miocene Limestone and it includes foraminifera, lamellibranch, gastropods, echinoids, corals, calacareous algae, bryozoa and arthozoa. The characteristic foraminifer in the Jaffna Limestone is Taberina Malabarica which together with the association of other forms dates the Jaffna limestone as belonging to the upper part of Lower Miocene (Cooray, 1967). Such a varied assemblage of marine forms is characteristic of modern coral reefs. It is thus probable that the marine creatures whose fossilized remains are found in the Jaffna Limestone lived in and around coral reefs of the Miocene sea in which the limestone beds were laid down (Cooray, 1967). Occasional storms would have led to the destruction of the reefs from time to time and to the bringing in of coarse material containing quartz, magnetite, zircon and other minerals by the flood water of rivers. Subsequent regression of the Miocene sea or upliftment of the land has exposed the limestone bed for erosion as revealed by the fluted weathered uneven surface. The presence of prominent (a few cm. to about 1m. thick) well rounded pebbles, mainly of quartz and feldspar on the limestone bed suggests that a number of water ways from inland have been discharged to the sea through the limestone formations. These events were then followed by the formation of sand dunes (fig. 15) which are now seen as red earth. The red colour is due to the leaching of iron minerals such as ilmenite, magnetite etc. trapped within and on the limestone bed underneath, and redeposition in the form of ferric compounds caused by the oxidizing conditions which prevailed at the surface. Such leaching can be facilitated by carbonic acid which is common in circulating water in limestone terrains.

5.3. Precambrian Marble

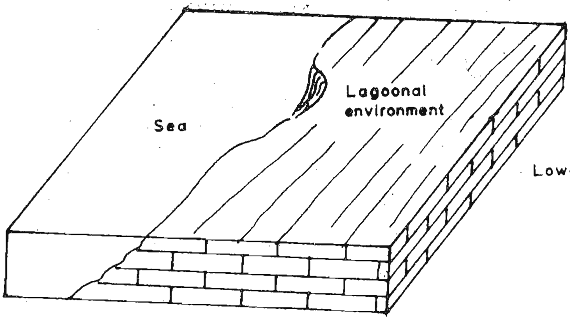
Coomaraswamy (1902) suggested that the marbles of Sri Lanka are of intrusive origin. Adams (1929) drew the attention to the striking resemblance of the Marbles of Sri Lanka to those of Grenville Series of Canada which are sedimentary in origin. Vitanage (1959) suggested that the common assemblage of quartzite and marbles in the area around Polonnaruwa is of a marine sedimentary sequence commonly formed in fairly stable shelf environments"foreland facies" (Pettijohn, 1956). Also he pointed out that most of these lithologic units approach the requirements of the blanket type sedimentary unit characteristic of sedimentary sequences "generally related to the quiescence stage of diastropism". Cooray (1961) stated that the marbles of the Rangala area have resulted from the regional metomorphism of a dominantly calcareous group of sediments containing varying amounts of clayey and ferruginous matter.

The close association of the marbles, quartzites and other pelitic rocks having clear cut boundaries extending long distances strongly endorses the view that the limestone has formed in a fairly stable shelf environement. The limestone thus formed would have been subjected to intense metamorphism in late Precambrian times resulting in marble with complicated fold patterns observed in the Kandy, Hunguranketa and Matale regions.

Fig.15



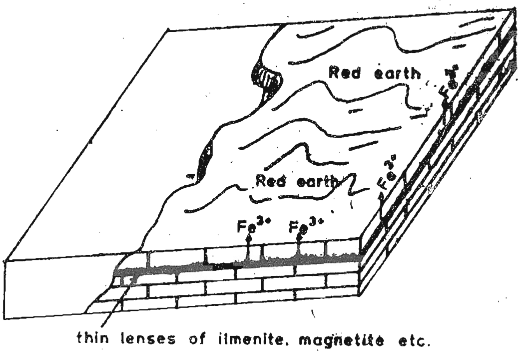
Regression of sea or upliftment of land, rivers discharging to the sea depositing minerals such as quartz magnetite ilmenite zircon etc.



Development of limestone in a lagoonal environment.

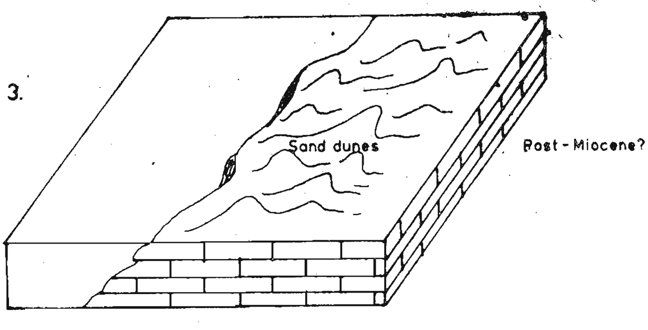
Diagrammatic sketch of the evolutionary history of Miocene and red earth belt of northwestern Sri Lanka.

Fig. 15. (continued)



Development of Red earth due to leaching of iron from minerals such as ilmenite, magnetite etc. present on the limestone bed. Acidic solution containing HCO_3^- promotes such leaching.

3.



Development of Sand dunes on limestone and river beds.

Chapter 6

SUMMARY AND CONCLUSIONS

The limestones in Sri Lanka can be grouped into the following categories :

1. Recent Limestones:– Shell Beds, Coral Limestone
2. Miocene Limestone
3. Precambrian Limestone:– Marble, (some approaching dolomite in composition)

Shell beds are widespread in the southern coast of Sri Lanka extending from Hungama to Bundala. Coral limestone occurs in many coastal stretches of Sri Lanka; more extensive developments being at the south western coastal stretch. Miocene limestone occurs in the north western coastal belt extending from Puttalam to Jaffna Peninsula. Miocene limestone at Aruakalu and Kankesanturai are being used in the cement industry. Precambrian marble is the most widespread variety of limestone in Sri Lanka. These occur in association with metasedimentary rocks distributed in many parts of the island. The marbles in most of these localities are generally dolomitic (MgO – 18 to 25%). The purer marbles are used in the lime industry (e.g. Matale area) and the dolomitic varieties (e.g. Ampitiya area) are used as a fertilizer to correct magnesium deficiencies and also in the ceramics industry.

The use of limestones in various industries has enabled the country to save an enormous amount of foreign exchange. However, limestone being an exhaustible resource it is important that maximum use of this valuable raw material is made. Inefficient management of raw materials will invariably lead to disastrous results. Some of the most important factors in the proper management of the raw materials are :

a. correct assessment of the quality and quantity of the raw material available
b. use of the raw material in the most profitable industry
c. feasibility studies on the correct location of the plant etc. taking into consideration the availability of raw materials and other infra structure facilities
d. correct mining methods by making use of the expert knowledge of mining engineers etc.
e. adequate precautionary measures for preservation of the environment.

For the better management of the limestone resources of the island the following remedial measures need to be taken into consideration :

1. systematic mining operations should be carried out in the Aruakalu deposit.
2. quarrying of limestone in Parappukadanthan and other areas for use as a road metal should be avoided.
3. unsystematic exploitation of shell beds in Hungama area and inland coral deposits in Hikkaduwa area should be given serious consideration. There are a number of large disused pits in these areas which are water logged. These pits could be used for inland fisheries development.
4. coral mining in the sea bed should be avoided as this leads to considerable coastal erosion as happened in recent years in the south western coastal belt of the island.

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