SCIENCE EDUCATION SERIES

No. 15

MINERAL BASED INDUSTRIES OF SRI LANKA

by

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NATURAL RESOURCES, ENERGY AND SCIENCE AUTHORITY
47/5 Maitland Place
Colombo 7
1986

MINERAL BASED INDUSTRIES OF SRI LANKA

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NARESA
1986

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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy and Science Authority. The Journal of the National 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 are 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 and Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy and 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

'The Mineral Based Industries of Sri Lanka' is one of a series of books which the Natural Resources, Energy and Science Authority issues from time to time. The primary aim of this volume is to provide the ordinary and advance level students with extra reading material of local interest, normally not covered by text books. It is therefore clear that others may also find this book of interest and use, if not in its entirety, at least in part. The present volume is not intended to be an exhaustive treatment of the subject; it, however, summarizes our knowledge of the major mineral based industries of the country.

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1986

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Chapter I

INTRODUCTION

The physical needs of man are met by the products of two basic sources - those of agriculture and those of mining. An adequate supply of minerals is therefore essential to the maintenance and improvement of his standard of living. Mineral resources are for all practical purposes considered non-renewable. As a generalisation it may be said that the richer mineral deposits of the world have been or are being exhausted and future needs for metals and minerals must be met from larger deposits of progressively lower grade.

Mineral deposits occur deep in the earth or at its surface in various forms and their importance to man, to economic and industrial development is only too well known. The evolution of the human race has been largely based on minerals and their development into various metals and other products. Minerals pervade our lives, our country's progress and its standing in the vital world of today. Everywhere we are reliant on minerals, for our travel, commerce and industry, and even for our pleasure and relaxation. The mineral resources of a nation critically influences its economic, political and social development; they provide bases for internal industrial growth, for national self-sufficiency and for external income from world trade.

Economic geology deals with mineral deposits - the mineral wealth in the very widest sense. The present alarming consumption of mineral resources and the exhaustion of the known mineral reserves means that new supplies must be discovered. This is where invaluable service can be rendered by geologists. The geologists' part in this is to discover and maintain supplies of mineral raw materials without which no country can be great or enjoy a high standard of living.

Geological Surveys are organisations of geologists and other technical specialists sponsored by National Governments. Their main purpose is to provide a basis of geological knowledge for industrial and regional development. They were among the first national scientific bodies to be organised in most countries. The Geological Survey of Sri Lanka has varied functions to perform when compared to other Geological Surveys of industrialised countries. In Sri Lanka there are no private prospecting organisations and this means that the State Geological Survey has not only to undertake the systematic study and recording of regional geological data and advice on all geological matters but has also to carry out mineral prospecting and exploration.

This book summerizes the major mineral based industries of Sri Lanka and an account is given of the State Manufacturing Corporations engaged in mineral activity. In order to appreciate the occurrence, distribution and development of the mineral raw materials, mention is made of some aspects of mineral prospecting and exploration and the main economic minerals are listed. The geology of the country is described and the future of the mineral industry is discussed.

Chapter 2

ECONOMIC MINERALS

The Earth describes many wonders of the world in which we live. We live on a planet whose continents and ocean basins are in a state of constant change. The Earth's history is divided into a number of eras. The oldest (AZOIC - without life) represents the unknown period during which the crust was formed. The crust consists of minerals and these occur as solid masses of rocks and they may be of igneous, sedimentary or metamorphic in origin. Economic mineral deposits are geological bodies which may be mined to recover one or more minerals or metals and the term "ore" is used for such a body of valuable minerals which can be extracted at a profit. Ores may yield a single metal or several metals.

Geological prospecting and exploration concerns itself with the problems of discovering economic mineral deposits. Prospecting covers the whole range of work directed to locating valuable mineral deposits. Once promising areas are recognised, prospecting is immediately followed by exploration. Exploration involves investigations for determining the industrial importance of a mineral deposit, for example, the quality and quantity of the mineral and the natural and economic conditions under which it occurs. The quantity of the mineral is measured by the volume it occupies. The aim of exploration therefore is to ascertain the shape and dimension of the deposit. Quality is determined by a study of the chemical and mineralogical composition and other technological properties and grades.

In the discoveries of many mineral deposits chance has played a significant role. Most mineral deposits have been located by the old time prospector who went in search of outcropping or detrital minerals. Their discoveries were due to keen observation and were mainly restricted to surface evidence. As the geological sciences advanced many new techniques have been perfected to locate surface and buried mineral deposits. Aerial photography and remotely sensed data (Landsat Imagery) are widely used in geological studies. Systematic geochemical prospecting is being applied throughout the world in mineral exploration and geophysical methods are now virtually standard techniques both in the search for oil and for metalliferous ore bodies.

The results of geological, geochemical and geophysical surveys when found promising must generally be augmented by a programme of drilling before oil and other mineral deposits can be worked. A diamond drilling programme is usually the final step in mineral appraisal prior to mining operations. Samples taken during drilling are subjected to a series of tests;

chemical, mineralogical and technological and the estimation of reserves which is the ultimate object; comprises the determination of quantty, quality and grade; distribution and checking the reliability of the estimated reserves and the economic importance.

The tonnage and grade of ore that may be expected from a mineral deposit need very careful estimation with a degree of confidence, as this is the basis for any mining venture. In the classification normally used to describe ore reserves (U.S.Bureau of Mines) terms such as measured, indicated and inferred are used. Measured ore is that which is actually known or proved as a result of detailed investigations including sampling and extensive drilling; indicated ore would mean ore for which tonnage and grade are computed partly from measurements and partly from geological evidence and inferred ore is ore for which estimates are based on geological knowledge and for which few or no measurements are available. Other factors which should be taken into account when assessing the economic value of a deposit include, accessibilty, 'transport facilities, hydrogeological conditions, availability of power, housing, medical facilities in the area under study and the distance to which the material is to be transported for treatment or use.

After a deposit has been located and the reserves are proved as economic, mining must be considered and this activity involves development work- work associated with getting the material out of the ground.

Mining methods may be suface or underground. Surface methods are much less costly than underground methods. Underground mining methods are generally much slower, hazards are greater and ventilation and ground water control are other factors to be taken into account. Once the material is mined it may have to be processed, low grade ore may have to be concentrated near the mine. This may involve simple processes such as hand picking to remove unwanted material, to complex milling and flotation processes. If further treatment is required, higher grade ore or concentrates are transported to favourable areas for smelting or other processes to extract the mineral.

Minerals are an exhaustible resource. Every mine is in time worked out or becomes too costly to operate. As a result there is continual search for new areas and development of new mines. Mineral deposits are fixed in location; they occupy very small areas and the limited distribution of a particular mineral may lead to monopolistic development in contrast to forest or agricultural activities. Mineral deposits are costly and there is usually a large factor of gamble in mineral search.

Even the deepest drill holes probe only a thin layer of the Earth's crust. In this slice which is accessible to us for study we find that it is composed of a variety of minerals and rocks. These mineral raw materials have undoubtedly played a major role in the development of many countries. Various systems of classification of minerals have been adopted.

For the purpose of this book, minerals are divided into four broadbased groups: energy group, ferrous and ferroalloy group, nonferrous group and nonmetallic group. In the simplest of many classifications, non-metallic minerals other than fuels have been further classified in to three groups according to their end usage; constructional minerals, process minerals and chemical minerals. In the first category occur the bulk aggregate construction minerals of low value (limestone, clays, gravel, sand, gypsum and asbestos). The process minerals include a variety of industrial minerals used in the abrasive, ceramics, glass and other industries. The last category comprises of the chemical and fertilizer minerals such as salt and phosphate. Table 1 gives a list of the minerals under the various groups.

TABLE I

CLASSIFICATION OF MINERALS

Energy Group	*Ferrous & Ferroalloy Group*	*Nonferrous Group*	*Nonmetallic Group*
Coal	Iron	Aluminium	Asbestos
Hydrogen	Chromium	Antimony	Calcium
Natural Gas	Cobalt	Arsenic	Clays
Peat	Manganese	Copper	Corundum
Petroleum	Molybdenum	Gold	Diamond
Thorium	Nickel	Lead	Feldspar
Uranium	Silicon	Magnesium	Garnet
	Tungsten	Mercury	Gems
	Vanadium	Platinum	Graphite
	Tantalum	Silver	Gypsum
		Tin	Mica
		Titanium	Phosphorus
		Zinc	Quartz
		Zirconium	Sand and Gravel
			Stone
		Rare-Earth	Sulphur
		Elements	Talc
			Salt
			Sillimanite

Chapter 3

GENERAL GEOGRAPHY AND GEOLOGY

Sri Lanka (Ceylon) is a tropical island and lies 32 km. to the east of the southernmost extremity of Peninsular India. It has an area of 65,600 square kilometres and is 432 km. long and 224 km. at its greatest width.

The Island may be divided into two main physiographic divisions:

1. The low lying coastal plain with little relief and traversed by rivers which have reached their base level of erosion.

2. The central highlands with immature drainage pattern and marked relief abounding in numerous strike ridges, hills and mountains.

The coastal plain is narrow in the western and southern parts of the Island. The general level varies from sea level to about 150 metres and some erosion renants may rise to 300 metres or more above sea level. The central highlands in certain parts rise steeply from the coastal plain - mainly in certain areas towards the south. The highest mountain (Pidurutalagala) attains an elevation of 2527 metres above sea level.

Sri Lanka lies in the monsoon region of south-east Asia and it has a humid tropical climate. The division into a Wet Zone and Dry Zone which merge in an Intermediate Zone is one of the most widely recognized geographical features of the Island. The average rainfall varies from below 1250 mm. in the north-west and south-east parts of the lowland zone to over 5000 mm. in the south-west slopes of the central hill country. The mean rainfall for the Island is 2000 mm. In the Wet Zone areas the average mean temperature varies between 70° and 85° F and in the Dry Zone it may be nearer 90°F. In the high-lands the mean temperature ranges between 58°F and 78°F according to elevation.

The rivers are for the most part radial. The upper reaches are mainly confined to the central hill country. The radial pattern is the dominant element in the drainage pattern of Sri Lanka. The greatest problem of Wet Zone hydrology is that of flood control. Inundation of low lying areas is almost inevitable and vast stretches of ground are subject to serious flooding during the wet seasons. This has resulted in the development of deep and extensive deposits of alluvial material along the lower reaches of the major river systems draining this region. In the Dry Zone it is a seasonal shortage of water which is a problem. Very few rivers rise in the Wet Zone and flow into the Dry Zone.

The main concentration of human settlement is in the Wet Zone in the whole of the western, south-western and central hills. In the Dry Zone areas, for example, in the north, north-central and east-central parts of the Island the concentration is light. The population of Sri Lanka in 1963 (Census of Ceylon 1963

Department of Census and Statistics) was approximately 11.5 million and in 1971 (Census of Ceylon 1971) the population was 12.7 million. In 1979 it was 14.5 million and at present the population is a little over 15 million growing at the rate of 1.7 per cent per annum. About 80 per cent of this population lives in the rural areas where agriculture is the main activity.

Over 90 per cent of the surface area of the Island is underlain by Precambrian rocks consisting of a complex series of high-grade metamorphic rocks, most of which have been derived from sediments and altered by one or more metamorphisms.

Associated with these metamorphic rocks are granites and granitoid rocks of igneous origin. Fig. I shows the outcrops of the main geological formations in the Island and Table II is presented to show the general succession of formations and the important mineral deposits in Sri Lanka.

Recent formations include a variety of unconsolidated materials, coastal sandstone, coral and shell formations. By far the most extensive deposits of recent origin are the alluvial deposits which are widespread along the lower reaches of major river systems of the Island. The Pleistocene deposits which are developed in the western and north-western parts of the Island are mainly gravels and red earths and laterites are well developed in the south-west sector of the Island and are clearly residual type deposits.

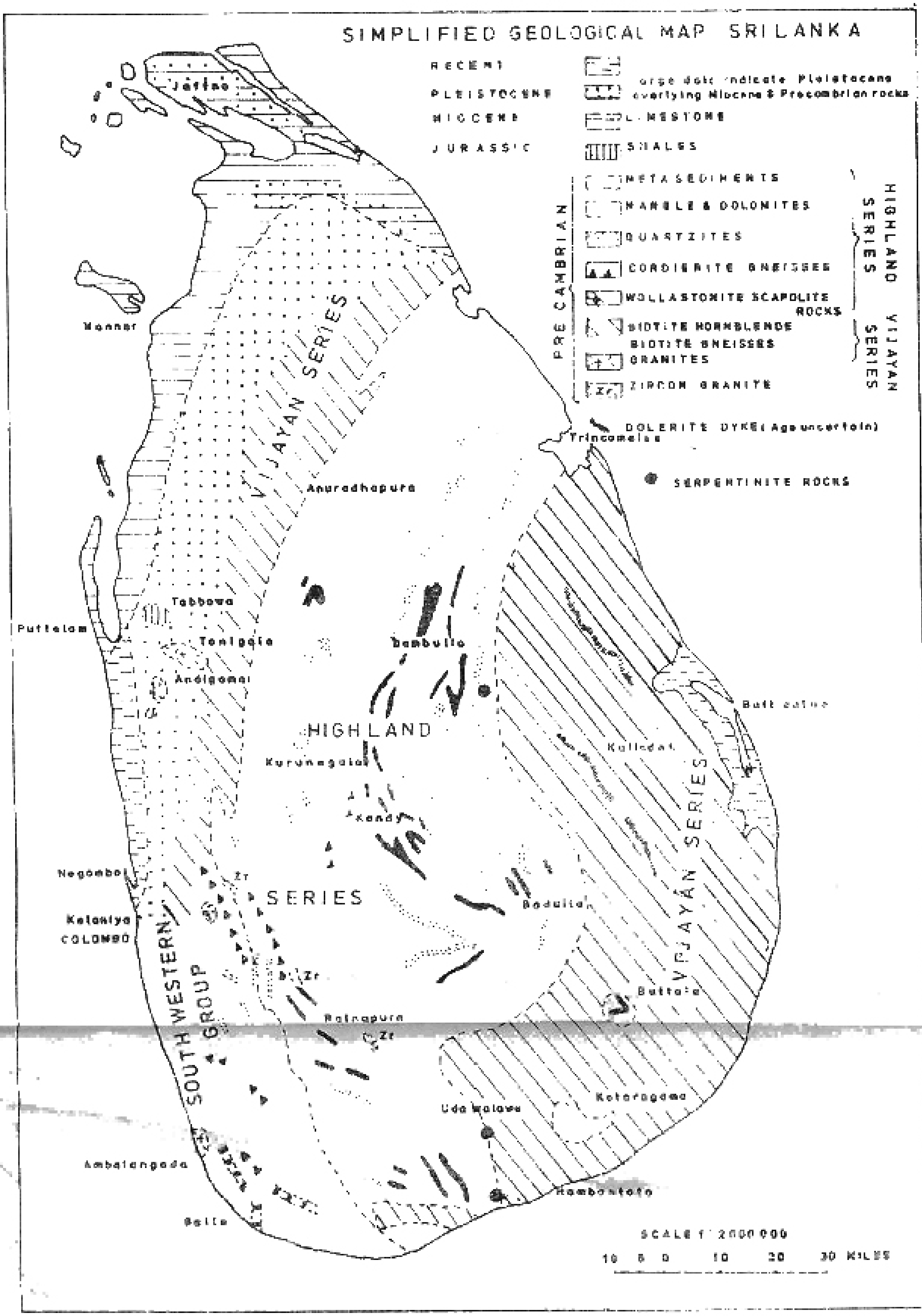

FIG 1: GEOLOGICAL MAP - SRI LANKA

TABLE II

GENERAL SUCCESSION OF GEOLOGICAL FORMATIONS AND PRINCIPAL MINERAL DEPOSITS IN SRI LANKA

Principal Geological Divisions		*Principal Formations*	*Important Mineral Deposits*	*Others*
Era	*Period*			
Anthropozoic	Holocene (Recent)	Recent residual and alluvial deposits, blown sand, coastal sandstone, coral and shell formations, beach mineral sands, gem gravels, peat, lagoonal and estuarine deposits	Kaolin, ball clay, refractory bond clay, residual and alluvial clay, silica sand, ilmenite, rutile, zircon, monazite, garnet, gem, coral, shell, sillimanite, clay, others.	Thorianite, thorite baddeleyite
Cenozoic	Quaternary (Pleistocene)	Laterites (may extend from Recent to Tertiary Perods), gravels, red earths.	Laterites, limonitic iron ore, red earths (sands), gem.	
	Tertiary (Miocene)	Limestone	Limestone	—
Mesozoic	Jurassic	Shales, carbonaceous shales and arkosic sandstone.	Shales	—
Palaeozoic	—	Absent	—	—
Archaeozoic	Precambrian	Highland Series (metasediments) Vijayan Series (gneissic complex) Southwestern Group (gneisses and metasediments) Intrusives (granites, dolorite dykes pegmatites)	Marble, quartz, felspar, graphite, mica, apatite, magnetite	Magnesite, allanite, cordierite, chert, wollastonite, sillimanite, copper, serpentinite.

(Modified after Herath 1980)

The largest development of sedimentary rocks occur in the north-western coastal belt extending from the Jaffna Peninsula in the north to the south of Puttalam on the west coast. This formation is of Miocene age and the rock type is a massive limestone of marine origin which is fossiliferous. Jurassic rocks are limited in extent and they are exposed in the Tabbowa, Andigama and Pallama areas north of Chilaw. These sedimentary rocks are composed of sandstone, grits, arkoses and shales. Similar Jurassic (Gondwana) rocks occur below the Miocene limestone of the Mannar area (Petroleum surveys-drill cores).

The Precambrian crystalline rocks which cover the major portion of the country consists essentially of a charnockite-metasedimentary series (Highland Series) and a complex of gneisses, granites and migmatites (Vijayan Series) and the south-western group of rocks. The Igneous rocks occcurring in Sri Lanka are mainly pegmatitic materials, zircon granites, some dolerite dykes and a few granites. Pegmatites of economic value are known in the Rattota, Talagoda and Alutepola areas. Numerous other pegmatites have been observed in other parts of the Island. Zircon granites outcrop in the Balangoda, Loluwa, and Parakaduwa areas. Dolorite dykes are confined to the Eastern Province (Maha Oya, Elahera, China Bay and Kantalai). Granites are developed in the Tonigala, Ambagaspitiya and Aluthgama areas.

Metamorphic rocks which cover the major portion of the Island are of Precambrian age and some rocks are over 2000 million years old. Three main groups are recognised:

(*a*) Highland Series - This Series is characterised by metamorphosed sediments and charnockitic rocks. The main rock types exposed are quartzites, marbles (mainly dolomites), garnet - sillimanitic - graphite schists, granulites and gneisses of various types including a variety of charnockitic rocks.

(*b*) Vijayan Series - This Series is mainly composed of granites, gneisses of various types and migmatites.

(*c*) South Western Group - This group is similar to the "Highland" Series. There are however differences between the two units in terms of both lithology and metamorphic history. Rock types in this group include thin quartzites, wollastonite bearing rocks, cordierite bearing gneisses, coarse charnockitic rocks and appreciable amounts of chert.

These rocks have been folded into a series of synforms and antiforms, generally trending in a north-west south-east direction. A good deal of controversy still remains about the sub-division of the Sri Lanka Precambrian. What can be generally agreed, however, is that the structures are everywhere complex. In recent years however the boundary between the Highland Series and Eastern Vijayan has been recognized as a mineralized zone. A number of Serpentinite rock outcrops have been located along this boundary and the Seruwila Copper magnetite deposit is also confined to this zone (Fig. 1).

Chapter 4

MINERAL BASED INDUSTRIES IN SRI LANKA

Even during ancient times minerals in Sri Lanka had their place in the life of the people. Hard rocks have been extensively used for building and other purposes. Pottery (earthenware), brick and tile were produced from plastic clays. Iron ores have been smelted on a cottage industry scale at several points. Lime has been produced and the Island has long been renowned for its gems.

In 1902 a State organization was set up to handle the mineral surveys of the Island. This institution then developed to what is known today as the Geological Survey Department of Sri Lanka. With the discovery over the years of a number of economic mineral deposits, by the Survey, the State soon realized the need to broaden the base of the economy by introducing manufacturing industries. Although the private sector is engaged in operating a variety of industrial units the major industrial concerns are operated by the State. In order to make maximum use of local mineral raw materials, mineral based industries have been established and these units are operated by State sponsored corporations. Except for the State Gem Corporation which functions under the Ministry of Finance and the Cement and Steel Corporations under the Ministry of Local Government Housing and Construction, all other corporations involved in mineral activity are administered by the Ministry of Industries and Scientific Affairs. The Ceylon Petroleum Corporation operates under the Ministry of Power and Energy.

In general the main objectives of Government Industrial policy has been and is, to make maximum use of indigenous raw materials and other natural resources. This would create and enable widespread employment opportunities by a choice of appropriate technology. The location of industries as much as possible in rural areas is also given consideration, taking into account the provision of infrastructure, raw material availability and markets for the finished goods.

Over the years most well established Corporations have expanded considerably. Some have participated in the establishment of limited liability companies with foreign collaboration for the manufacture of products primarily for overseas markets. For example, the Ceylon Ceramics Corporation in the mid seventies was responsible for the establishment of Lanka Porcelain Limited (Matale) and Lanka Wall Tiles Limited (Balangoda).

Foreign investment is welcomed by the State both in respect of the public and private sectors. Participation in equity (share) capital is permitted for capital investment. A Foreign Investment Advisory Committee

(FIAC) also functions under the Ministry of Finance. In order to assist the promotion of such new investment, foreign banks have been encouraged to establish branches in Sri Lanka and technical collaboration with foreign organizations too is encouraged and both the public and private sectors have already made use of this opportunity. Local Investment Advisory Committees also function under some Ministries.

The State has also established specific territorial areas to enable foreign and local investors to set up export oriented industries. The organization responsible for this is known as the Greater Colombo Economic Commission (GCEC). This body manages all the Investment Promotion Zones (IPZ) within the country. The IPZ provides the infrastructure, such as land, power, water, roadways and other facilities for setting up industry. The first IPZ has already been set up north of Colombo at Katunayake which is adjacent to the International Air Port. This Zone covers an area of around 400 acres (165 hectares).

The second IPZ is sited at Biyagama which is about 12 miles north-east of Colombo. This covers an area of about 200 acres. A few of the main features of this investment promotion package are as listed below.

1. Foreign investments are guaranteed by the Sri Lanka Government.

2. A tax holiday up to 10 years is available and further concessionary tax periods are negotiable.

3. Dividends of non-resident share holders are exempt from tax and remittances are exempt from exchange control.

4. There is also no import duty on machinery and equipment.

For purposes of this book only the major mineral based industries are discussed. Some industries established utilize entirely local raw materials, others use both local and imported materials, whilst still others like the Petroleum Corporation rely solely on imported materials. Table III is presented to show the production of mineral commodities in Sri Lanka for the year 1982. It is seen from this table that the value of mineral commodities produced in the country amounts to one billion rupees. Table IV lists the composition of the main minerals used in industry. These mineral raw materials are processed and exported or are used in local industries. The location of the various industrial units are shown in Fig. 2. All production and other figures quoted for State corporations have been rounded off and are for the year 1982 - 1983.

TABLE III

SRI LANKA — PRODUCTION OF MINERAL COMMODITIES — 1982

Commodity	*Quantity (Long tons)*	*Value (S.L. Rupees)*	*Producer*
Ilmenite	68,282	27,224,000	Mineral Sands Corporation
Rutile	7,212	41,610,000	Mineral Sands Corporation
Zircon	5,789	11,578,000	Mineral Sands Corporation
Monazite	304	409,000	Mineral Sands Corporation.
*Garnet	2	4,000	Gelogical Survey Department.
*Silica Sand	500	125,000	Private - Public Sector
*Quartz	2,000	500,000	Ceramics, LWL, LPL Private.
Apatite	13,993	10,627,972	SMMDC
Limestone	1,615,907	59,580,514	Cement Corp.
*Dolomite	9,000	2,250,000	Private - Public
Salt (common)	176,437	74,103,540	Salt Corp.
Mica	291	1,435,524	SMMDC
Graphite	8,803	61,843,998	SMMDC
Felspar	2,923	906,000	Ceramics Corp.
Clay (cement)	62,591	1,741,202	Cement Corp.
Kaolin	8,206	13,000,000	Ceramics Corp.
Ball Clay (raw)	8,554	1,539,000	Ceramics Corp.
Ball Clay (refined)	737	734,000	Ceramics Corp.
*Brick-Tile Clay	1,820,000	54,600,000	Cottage Industry
*Brick - Tile Clay	378,000	12,040,000	Public - Private
Gems		400,000,000	State Gem Corp.
*Stone	2,000,000	200,000,000	Private-Public
Sand (river)	3,000,000	120,000,000	Private-Public

*Accurate figures not available (estimated)
Except for gems-value of production shown.
Gems - value of export
Coral, shell and gravel and others not included.
Geological Survey Department
Compiled by - Herath 1984 - NARA

Total value of mineral commodity
Rs. 1,102, 577, 750
Rs: 1,103 million - 1982
Rs: 700 million - 1978
Rs: 250 million - 1973

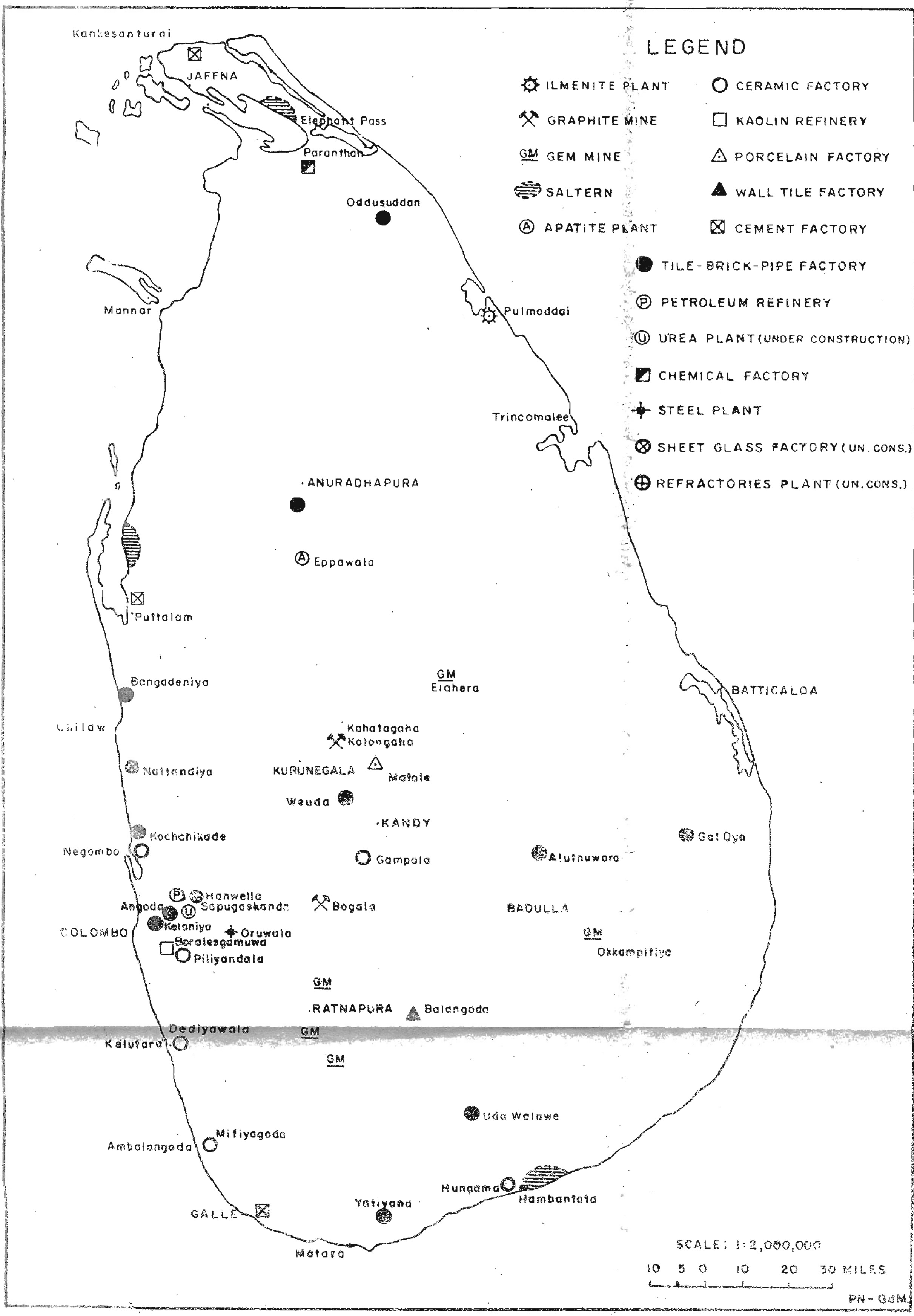

FIG. 2. LOCATION OF INDUSTRIAL UNITS AND MINES

TABLE IV

THEORETICAL COMPOSITION OF THE ECONOMIC MINERALS USED IN INDUSTRY

Mineral	*Formula*	*Theoretical Composition*
Kaolinite	$Al_2O_3 . 2SiO_2 . 2H_2O$	Al_2O_3 -39.50, SiO_2 - 46.54 H_2O-13.06
Phlogopite	$K_2O. 6MgO. Al_2O_3. 6SiO_2. 2H_2O$	Variable
Biotite	$K_2O.6(Mg.Fe)O.Al_2O_3 6SiO_2$ $2H_2O$	Variable
Muscovite	$K_2O. 3Al_2O_3. 6SiO_2 . 2H_2O$	K_2O-11.8, Al_2O_3-38.5, SiO_2 45.20 H_2O - 4.50
Goethite	$Fe_2O_3.H_2O$	Fe_2O_3- 85.50, H_2O - 14.50
Limonite	$2Fe_2O_3. 3H_2O$	Variable (water)
Magnetite	Fe_3O_4	FeO - 31, Fe_2O_3 - 69
Limestone	$CaCO_3$	CaO - 56.1, CO_2 - 43.9
Dolomite	$CaCO_3$ - $MgCO_3$	CaO-30.4, MgO-21. 79, CO_2 -47.90
Apatite	$Ca_3(PO_4)_2$	—
Fluorapatite	$Ca_5(PO_4)_3F$	CaO-55.5, P_2O_5-42.30, F-3.80
Chlorapatite	$Ca_5(PO_4)_3 Cl$	CaO-53.80,P_2O_5-41.00; Cl-6.80
Quartz	SiO_2	SiO - 100
Felspar (Microcline)	$K_2O.Al_2O_3.6SiO_2$	K_2O-.16.90, Al_2O_3 - 18.40, SIO_2 - 64.70
Ilmenite	FeO. TIO_2	TIO_2- variable (53% Sri Lanka)
Rutile	TiO_2	TiO_2 - 100
Zircon	$ZrO_2. SiO_2$	ZrO_2-67.20, SiO_2-32.80
Monazite	(LaCe) PO_4	Thoria content variable (9-10% Sri Lanka)
Garnet (Almandine)	$Fe_3Al_2(SiO_4)_3$	FeO-43.30, Al_2O_3- -20.50, SiO_2- 36.20
Graphite	C	Variable carbon content (over 90% common)
Halite	NaCl	Na-39.40, Cl-60.60

Chapter 5

ENERGY RESOURCES AND INDUSTRIES

Although Sri Lanka is devoid of minerals in the energy group it would be useful to have a knowledge of the energy resources development potential within the country. In the absence of coal, petroleum and natural gas, the country has to depend on the imports of all fuel materials. The water power potential however, has enabled the development of hydro-power. With the accelerated Mahaweli development programme a series of new hydropower stations have been established. In Sri Lanka the total approximate energy consumption pattern is as follows:

Firewood	—	60 percent
Petroleum products	—	27 percent
Hydro Electricity	—	13 percent

Petroleum is no recent discovery. In the eighteenth century when the history of American petroleum began the 'Black Oil' was collected from the surface of marshes and sold in bottles. In 1840 a chemist from Yale University distilled the contents of a bottle of the 'Black Oil' and the extract he obtained was light and inflammable. Whale oil which had previously been used for lighting was becoming scarce and petroleum oil lamps were developed. It was Edwin Drake who sank the first bore hole in search of petroleum in June, 1859. By the greatest of chances he happened to pierce the ground at the correct place, and on the 27th August, 1859 oil began to flow.

The origin of petroleum is connected with enormous quantities of minute marine life burried in shallow ocean bottoms. Slow decomposition of this material is believed to result in the formation of tiny droplets of oil. Increasing compaction of sediments forces the droplets out into porous earth strata like sandstone, which is a good reservoir for accumulation of oil. Useful quantities are formed when a trap structure exists for holding the migrating oil within the reservoir. The crude oil emerges from petroleum wells as a thick viscous, and sometimes evil-smelling brown or dark green liquid. The crude oil so obtained has to be refined to produce fuel and a variety of other petroleum products. Chemically, petroleum is a mixture of compounds of carbon and hydrogen. World crude oil production is around 50 million barrels a day (1 barrel = 42 US gallons). Saudi Arabia is a very large producer of crude oil (10 million b/d). Natural gas occurs in association with petroleum as also in gas fields and a commercial natural gas field is rich in methane the most stable of the petroleum hydrocarbons.

Sri Lanka is devoid of petroleum. The Ceylon Petroleum Corporation was established in 1961. It commenced operation in 1962 as an importer and supplier of refined petroleum products. In 1969 the oil refinery was established with imported crude oil and the Corporation started manufacturing several types of blended products and by-products (Table V). This refinery has an annual capacity to process around 2.3 million tons of crude oil.

The Corporation has also implemented an offshore oil exploration programme within Sri Lanka's territorial waters. In this regard several blocks have been farmed out for offshore oil exploration. The Corporation sank their first bore hole in search for oil in February, 1974. Exploration concession contracts have now been signed with various foreign prospecting companies on a production sharing basis. No cost is incurred by the Corporation.

The first hydropower station to be constructed in Sri Lanka was the Laxapana Power Station with an installed capacity of 25 MW and was declared open in 1950. In the Mahaweli Ganga Development Scheme, the master plan envisages the construction of 15 reservoirs on the Mahaweli Ganga, its tributories and the Maduru Oya. The total capacity of the main stations are assessed at around 500 MW in the Master Plan. The installed capacities and the expected annual energy outputs of the generating stations as at 1983 and power stations under construction and those

TABLE V

CEYLON PETROLEUM CORPORATION

Established	June 1961
Main Activities	Import, storage and distribution of petroleum products. Refining of imported crude oil in petroleum refinery. Operation of a lubricating oil blending plant at Kolonnawa. Marine bunkering trade and sole bunkering authority at all ports of call. Sole authority for aviation refuelling. Manufacture of agrochemicals, candles, liquid petroleum and naptha. Handles charter arrangements for import of Petroleum products. Operates Nylon 6 plant. Programme concerned with exploration for oil.
Manufacture	Petroleum and other products from crude oil. Refinery capacity to process 2.35 million tons of crude oil per annum
Location	Sapugaskanda - Colombo District
Production and Value	Petroleum products — 1.80 million tons Lubricating oil — 13 million litres Candles — 30,000 cases Value — Rupees 9 billion
Uses	Domestic and export
Exports	Bunkering, Aviation and Direct exports Value Rupees 3 billion
Raw Materials	100 per cent imported
Employment	Persons - 5200
Capital Employed	Rupees - 300 million
Development	Installation of a single point buoy mooring (SPBM) facility at Colombo port to improve crude oil discharge facilities. Airport development project to handle efficient fuel supplies. Tank Farm development project - Trincomalee. Handles programmes connected with oil exploration

TABLE VI

SRI LANKA POWER STATIONS

(Existing — Under construction — those planned)

Existing Hydro	*Power (MW)*	*Annual Energy Capability (Gwh)*
Kotmale	134	—
Victoria	210	—
Old Laxapana	50	325
Inginiyagala	10	60
Uda Walawe	6	22
Wimalasurendra	50	105
Polpitiya	75	355
New Laxapana	100	410
Ukuwela	40	220
Bowatanna	04	135
Canyon	30	144
Existing Thermal	**Power (MW)**	**Annual Energy (Gwh)**
Sapugaskanda	80	—
Kelanitissa	170	—
Chunnakam	12	30
Pettah	03	02
Under Construction or Planned for development	**Power (MW)**	**Annual Energy (Gwh)**
Randenigala	122	—
Moragahakanda	40	—
Maduruoya	8	—
Rantambe	46	—
Samanalawewa (Walawe ganga)	120	—

Ceylon Electricity Board

planned for development under the accelerated programme of Mahaweli development and the Walawe ganga project are presented in Table VI. Sri Lanka's electrical energy, however, will be met mostly by her hydropower resources till about the year 1990. From there onward the development in this source of energy is expected to be slow and other forms of energy may have to be considered to supply the energy needs of the country. Other available forms of energy resources in the country which are not of immediate economic value include the occurrence of low grade peat, uranium mineralization in certain parts of Sri Lanka showing low values and the occurrence of a series of thermal springs.

Peat is used as a fuel in many countries. In Sri Lanka the largest known deposit of peat is in the Muturajawela swamp, situated on the west coast about 15 km. north of Colombo. The deposit covers an area of 34 sq. km. with an average thickness of 4 metres of peat. Investigations by the Geological Survey Department have proved 50 million tons (wet basis) of peat in the area. Actual reserves are much larger. Drying is one of the great problems of peat workings. The peat contains 80 - 90 percent water. This could be reduced to 10 - 15 percent by slow drying over a period of 10 - 12 days. Table VII shows the results obtained for type samples of peat. The material is of a low grade and the formations are not of a uniform character. The deposits cannot be considered of value until further investigations.

Deposits of Uranium have so far not been identified in Sri Lanka. In 1979 an Islandwide stream sediment survey was undertaken by the Geological Survey Department with assistance from the International Atomic

TABLE VII

CHEMICAL ANALYSES OF MUTHURAJAWELA PEAT

Sample No.	1-1*A*	3 - *A*	8 - *C*	10 - *C*	13 - *A*
Moisture %	78.34	82.22	83.52	79.39	70.69
Ash %	16.95	24.92	11.24	30.46	27.65
Volatile Matter %	56.07	44.01	51.22	42.69	46.25
Nitrogen %	0.855	0.430	0.918	0.701	0.726
Total Sulphur %	4.15	5.08	5.14	4.78	3.56
Fixed Carbon %	26.98	31.07	37.54	26.75	26.00

Ash Content — range 10 to 30 percent (Average 20)
Sulphur Content — range 1 to 8 percent (Average 5)
Moisture — range 80 to 90 percent
Nitrogen Content — less than 1 percent

Geological Survey Department,
Colombo 2.

Energy Agency (IAEA) to identify Uranium mineralization. The survey which was continued in 1983 was a reconnaissance type geochemical exploration programme which helped to demarcate areas for future more detailed surveys. The promising areas include the Kalaoya, Galgamuwa, Polonnaruwa, Rukam-Mahaoya, Kalmunai, Hanguranketa, Passara and Rakwana areas, (Personal communication - Jayawardene 1984).

These areas are mainly composed of highly metamorphic rocks. Rocks of Jurassic age (shales, sandstone and arkose) are confined to the Kalaoya area. The averge Uranium values obtained for the stream sediments are in the region of 30 ppm. U_3O_8. Although anomalous areas have been demarcated, detailed surveys to identify source rocks, followed by a programme of drilling and sample testing have to be undertaken to detect the presence of Uranium ores that are commonly regarded as ore grades. Uranium in hard rock formations should show high values for economic exploitation. In soft rock formations low grade ores could be exploited economically (30 - 500 ppm.). The Geological Survey has plans to carry out follow up work on systematic lines in the field of Uranium exploration.

It is believed that thorium utilizing nuclear reactors appears a possibility in the future. This would create a substantial market for thorium when successful thorium thermal and breeder reactors are developed. Thorium is also used in the manufacture of gas mantles, aircraft alloys, refractories and catalysts. In Sri Lanka thorianite and thorite have been found to occur in moderate amounts in the Bambarabotuwa, Maddegama, Niriella, Malwela, Balangoda, Ratnapura and Pelmadulla areas. The best known monazite deposit is located in Kaikawala and Polkotuwa in the beach sands near Induruwa. Monazite also occurs at other points and in the beach mineral sands which are processed at Pulmoddai. Over 250 tons of Monazite could be produced per annum in the country. Table VIII is presented to show typical analyses of monazite, thorianite and thorite from Sri Lanka.

TABLE VIII

CHEMICAL ANALYSES OF MONAZITE, THORIANITE AND THORITE SRI LANKA

MONAZITE

Constituents	*Dondra*	*Ratnapura*	*Beruwela*
Thoria ThO_2	9.51	10.29	8.65
Ceria C_2O_3	28.70	27.37	27.35
Lanthanum La_2O_3	28.56	30.13	31.08
Yttrium Y_2O_3	1.05	2.14	0.95
Ferric Oxide Fe_2O_3	0.10	0.81	0.15
Alumina Al_2O_3	1.31	0.17	9.78
Lime CaO	0.89	0.41	0.20
Silica SiO_2	—	1.03	1.60
Phosphorous pentoxide P_2O_5	28.91	27.67	27.50
Titania TiO_2	0.05	—	0.15
Total	99.08	100.02	98.41

Geological Survey Department
Colombo 2

THORIANITE AND THORITE

Constituents	*Thorianite (Kondurugala)*	*Thorite (Kondurugala)*
ThO_2	76.22	66.26
C_2O_3	8.04	7.18
La_2O_3	—	—
ZrO	traces	2.23
UO_3	12.33	0.46
Fe_2O_3	0.35	1.71
PbO	2.87	—
SiO_2	0.12	14.70
CaO	—	0.35
P_2O_5	—	1.20
H_2O	—	6.40
Total	99.93	99.89

(Imperial Institute)
London.

Dondra and Beruwela - Beach sand deposits
Ratnapura - Gravel deposits

A survey of hot springs in Sri Lanka has been undertaken by the Geological Survey Department. At present they cannot be considered as a geothermal resource for power generation. They do not appear to have any direct connection with volcanic activity as in some other parts of the world. For instance Japan has very rich potential reserves of geothermal energy with about 65 active volcanoes. At present Japan's geothermal power generation output amounts to about 250 MW. In Sri Lanka Hot Springs are located in the Eastern parts of the country where dolerite dykes are well exposed. Nine springs have been identified and the waters from these springs record a temperature (Table IX) in the range 34°C to 55°C which is considered fairly low. These hot springs are of no economic value at the moment.

Sri Lanka is poor in energy mineral resources The country is devoid of petroleum, coal and natural. gas. Crude oil is imported and refined and exploration for oil is in progress. The monazite occurrences (beach mineral sands) are the only deposits which may be of some value as an energy source in the distant future. The prospects for locating economic deposits of uranium are poor. The peat deposits are of no economic value. A number of hot springs have been located and these do not show any promise as a geothermal energy resource. The only present day worthwhile resource as far as energy is concerned is the water power potential of the Island.

TABLE IX

LIST OF THERMAL SPRINGS IN SRI LANKA

Location Number	Name	Discharge Litres/hr	Temperature °C	Total, Mineralisation grams/litre
1	Rankihiriya	1200	—	—
2	Kanniyai	Approximate	42	0.222
3	Galwewa	minimum	—	—
4	Kapurella		55	0.870
5	Maha Oya		54	0.990
6	Marangalla		47	--
7	Wahawa		—	—
8	Kivulagama		34	0.550
9	Mahapelessa		44	6.490

After Fonseka et al (10)

Chapter 6

FERROUS AND FERROALLOY GROUP AND INDUSTRIES

Except for some minor occurrences of a few of the minerals listed in this group, which are only of academic interest, economic deposits are not known to occur in the Island and only iron ore occurs as deposits of any commercial value. The use of silicon (silica) in alloy form (ferro-silicon) is firmly established in the iron and steel industry. Sri Lanka has extensive deposits of high grade silica used in the ceramics and allied industries; silicon alloy and silicon metal is not produced in the country and this material (silica) is described under the non-metallic group of minerals and industries.

Steel is the most useful metal known to man. It is strong and durable. The term steel is really a generic one, representing hundreds of products of differing characteristics. Steel is a combination of iron and carbon (carbon-usually less than one per-cent) with other elements added. The making of steel is a long chain of events. The steel industry is really a group of allied industries. Mining and quarrying, transportation on a vast scale, iron smelting, steel refining, shaping and forming are all included. Each process involves enormous capital expenditure.

The basic raw materials of large scale steel making are iron ore, coal which is converted to coke and limestone. The chief iron minerals are haematite (Fe_2O_3) - 70 percent iron, magnetite (Fe_3O_4) - 72.4 percent iron, limonite (Fe_2O_3 H_2O) - 59 percent iron and siderite ($FeCO_3$) - 48 percent iron. Mixed ores vary from 25 to 69 percent iron. Coke which is specially made for smelting iron ore is prepared in a closed vessel in the absence of air (reducing atmosphere) thus preserving the full calorific value of the product. The coal when molten is made to solidify into hard material of fixed carbon. In round figures one ton of coal yields 860 kg. of coke. Limestone is used as a flux in both iron-making and steel making It combines with the impurities to form a slag that floats to the surface of the molten mass. The slag is discarded. Steels are usually described as carbon steel or alloy steels. Both contain carbon. Carbon steel is the general purpose steel and accounts for nearly 90 percent of all steel produced. Alloy steels are made to meet special requirements. For example chromium increases hardenability and tensile strength and improves corrosion and abrasion resistance. It is usually associated with nickel additives to form the well known nickel-chrome stainless steels in extensive use throughout the world.

The steel making operations fall into three main phases:

(*i*) The making of iron:

The first metallurgical step is to reduce the iron ore to metallic iron. This process is carried out commonly in what is termed a blast furnace. The metallic iron provided by such a furnace contains a relatively high proportion of carbon (about 4 percent). There are also special steel plants using electric arc furnaces in which scrap metal is remelted for further use.

(*ii*) The making of steel:

The carbon content of the metallic iron is then lowered usually to less than one percent by an oxidation process in another type of furnace so refining the metal into steel. The Bessemer process, open hearth process and the recently developed basic oxygen steel making process are some processes employed for the making of steel. At this point the metal is also given whatever special properties may be required by the addition of alloying materials (manganese, chromium, nickel, etc.). Molten steel is tapped from the furnace into ladles of up to 375 ton capacity. The ladle is positioned above a row of upright ingot moulds standing on rail cars. The molten steel is then poured through a nozzle into each mould and allowed to solidify into ingots.

(*iii*) The shaping of steel:

Steel has a temperature range at which it is remarkably plastic (800°C - 1200°C). It can be cast while liquid and then forged or rolled in successive steps to produce any one of the many required shapes. Rolling is by far the most common method of shaping. The term integrated steelworks implies that all three of the major phases of production are undertaken on the one site. Many plants in the industry are not integrated. Some rolling mills buy in cold steel in billet, bloom or slab form (terms used when ingots are reduced to smaller sizes). This applies to the Sri Lanka Steel Corporation where the products are manufactured from imported steel billets and wire rods. These have to be re-heated throughout to the correct rolling temperature for the manufacture of various products.

The Sri Lanka deposits of iron ore are negligible in relation to the world's large deposits. The total iron ore reserves are in the region of 10 million tons. However, the importance of the iron ore lies mainly in the fact that they can, given other favourable conditions, support a small scale iron and steel industry. Two types of deposits are present in the Island—hydrated iron oxides (limonite) and magnetite. The first type is confined to the south west sector of the Island. The deposits are small, scattered and mainly on the surface. Reserves are in the region of 2 million tons and the largest deposits occur in the Ratnapura area (Dela and Noragolla). The average iron content is 53 percent.

In the second category three magnetite deposits have been located at Wilagedara (1959), Panirendawa (1962) and Seruwila (1971). The first is too small to be of any economic value. The second has a proved reserve of 6 million tons and gives a plus 65 per cent iron concentrate after beneficiation. The deposit is, however, broken up and cannot be mined as a single unit. One block containing 3 million tons of magnetite is the only ore which could be considered for mining. As the iron ore occurs at depths ranging from 80 to as much as 300 feet below the surface mining costs will also be very high and it may not be economical to mine this deposit. The third deposit is at Seruwila in the Trincomalee area. This deposit extends to depths of 200 feet from the surface at some points. The magnetite is associated with copper minerals, pyrite and apatite. This deposit is one of the most promising deposits of iron ore in Sri Lanka which could eventually support the steel industry. However, no feasibility studies have been undertaken so far to assess the suitability of Sri Lanka iron ore for the manufacture of steel.

The Steel Corporation was established in 1961 (see Table X). Its initial purpose was to manufacture rolled steel rounds and drawn wire from imported billets and wire rods. A rolling mill and wire mill went into production as the first stage. The rolling mill has a capacity to produce 72,000 tons of rolled products per annum and the wire mill could produce 12,000 tons of wire rods per annum. At

TABLE X

CEYLON STEEL CORPORATION

Established	September 1961
Main Activities	Manufacture and sale of steel and related products
Manufacture	Manufacture of products from imported steel billets (imports to be terminated) Rolling mill capacity - to produce 72000 tons of rolled products Wire mill capacity - to produce 12000 tons of wire products Steel foundry, grinding media, pig iron, alloy steel and stainless steel. Manufacture of local steel billets to replace imported material - plant in production stage
Location	Oruwela - Colombo District
Production and Value	Rolling mill - rounds, ribbed bars, angles, flats hoops, others - 25000 tons Wire mill - drawn wire, galvanized wire, barbed wire, mesh and others - 2700 tons Welding electrodes - 27000 kgs. Steel foundry - 425 tons Fabricated steel - 236 tons Soldering lead - 7 tons Billets (local) - 10000 tons Value - Rupees 350 million.
Uses	Domestic
Raw materials	Scrap steel is being used to produce local billets
Employment	1500 persons
Capital Employed	Rupees - 270 million
Development	Studies on local iron for third stage steel project

present the steel project depends partly on imported raw materials. The Stage II project envisages the collection, processing and smelting scrap in an electric arc furnace and producing billets by a continuous casting process. These billets were to substitute their importation and provide the entire requirements of the rolling mill. The second stage project has now been completed. Stage III of the Steel project consists of iron making to feed the Stage II process of steel making. This will concentrate on utilizing the the local deposits of iron ore. Studies have yet to be undertaken on the technological process of conversion of local ore which will be economical for continuous use in the electric arc furnaces.

Chapter 7

NON-FERROUS MINERAL GROUP AND INDUSTRIES

The base metals lead and zinc have so far not been found in Sri Lanka. A copper deposit has however been discovered at Seruwila in the Trincomalee area. The copper minerals are associated with magnetite. About 4 million tons of copper-magnetite ore has been proved. Of this reserve 40 per cent is iron (Fe) and 1.50 to 2.00 per cent is the average overall copper content of the deposit. Until further reserves are proved this deposit cannot be considered an economic deposit. The precious metals gold, silver and platinum are absent. Of the light metals, magnesium (mainly dolomite deposits) and titanium (ilmenite and rutile) occur as exploitable deposits. High alumina clays occur in the Island and no bauxite deposits have been located. Monazite is the principal source of rare-earth elements and the mineral occurs in the beach mineral sands. Allanite, another source of rare-earth elements occur in moderate amounts in the Matale area. Zirconium is also recovered as the mineral zircon from the beach sands of the Island. The only industry which has been established on the above raw materials is the refining of beach sands to recover ilmenite, rutile and zircon, all of which are exported.

Ilmenite and rutile are the mineral source of all world titanium requirements. Titanium minerals are mainly used in the manufacture of titanium dioxide pigment used in surface coatings where it imparts whiteness, opacity and brightness to paints. It is also used in varnishes and lacquers, in paper coatings and fillers, in the plastic industry, in rubber tyres, in floor coverings, ink, porcelain, enamels and in many other products.

In Sri Lanka although the minerals ilmenite, rutile, zircon and monazite occur widespread in the beach sands of the Island, the largest deposit which is exploited is located at Pulmoddai in the north east coast, north of Trincomalee. The deposit is estimated to contain over 4 million tons of raw beach mineral sands.

In certain places these sands have a composition - ilmenite 70 to 72 per cent, zircon 8 to 10 percent, rutile 8 per cent, monazite 0.3 per cent and sillimanite 1 per cent. The Ceylon Mineral Sands Corporation was established for the purpose of exploiting this deposit (see Table XI). The Corporation has now established an integrated mineral sands complex with an intake capacity of 200,000 tons of raw mineral sands for processing per annum. No titanium based industries have so far been established. The entire output of ilmenite, rutile and zircon is exported.

Although there are no other mineral based industries utilizing raw materials from this mineral group it would be useful to note the occurrences of large reserves of dolomite in the country. A number of

TABLE XI

CEYLON MINERAL SANDS CORPORATION

Established	December 1956		
Main Activities	Processing of beach mineral sands for the recovery of ilmenite, rutile, zircon, monazite and others		
Manufacture	Only processing undertaken Wet gravity upgrading plant - upgrades the heavy mineral content to 95 per cent Wet magnetic separation plant - separates the ilmenite and the non magnetic tailings The non magnetic tailings is the feed stock for the Rutile - Zircon plant which produces rutile, zircon and monazite. Plant capacity - 150,000 tons ilmenite, 14,000 tons rutile and 10,000 tons of zircon.		
Location	Pulmoddai (north east coast)		
Production and Value	Ilmenite	—	80,000 tons
	Rutile	—	8,000 tons
	Zircon	—	5,800 tons
	Value	—	74 million rupees (1983)
Uses	Mainly export		
Exports and Value	Ilmenite	—	30,600 tons
	Rutile	—	12,200 tons
	Zircon	—	16,500 tons
	Value	—	85 million rupees (1983)
Raw Materials	Local beach sands		
Employment	Persons - 600		
Capital employed	Rupees - 225 million		
Development	Studies undertaken to establish local industry based on recovered minerals. Proposal to set up synthetic rutile project		

minerals are used as raw materials for magnesium compounds production. Dolomite $CaMg(CO_3)_2$ contains up to 22 per cent magnesia (MgO), Magnesite $MgCO_3$ has a theoretical magnesia content of 47.6 per cent and brucite $Mg(OH)_2$ contains up to 69 per cent magnesia. These are the main magnesium minerals. Sea water magnesite is produced in many countries where resources of magnesite are not available. Sri Lanka is also devoid of economic deposits of magnesite. Sea water magnesite can be produced by a simple chemical reaction. Sea water contains sulphates and chlorides of sodium, potassium, calcium and magnesium. If calcium hydroxide is added to sea water, the magnesium sulphate and chloride react to form insoluble magnesium hydroxide which is precipitated. The calcium hydroxide required for the process is obtained by calcining dolomite or limestone and slaking the later with water to form the hydroxides:

$$CaMg(CO_3)_2 \rightarrow (CaO+MgO) + H_2O \rightarrow Ca(OH)_2 + Mg(OH)_2$$

Dolomite heated + water ⟶ slaked dolomite. The slaked dolomite is allowed to react with sea water in reaction tanks which are agitated. The precipitated magnesium hydroxide is then concentrated by settling, dried and calcined. The reaction may be represented by the equation:

$Mg(OH)_2$	$MgCl_2$		$CaCl_2$
+	⟶	2 $Mg(OH)_2$ +	
$Ca(OH)_2$	$MgSO_4$	magnesium hydroxide	$CaSO_4$
Slaked dolomite	sea water	(precipitated)	by-products

The calcined (heated) $Mg(OH)_2$ contains approximately 97 per cent MgO. The possibilities of producing magnesia from sea water in Sri Lanka are promising as large quantities of dolomite are available in the Island. Magnesite and dolomite are only valuable for their magnesia (MgO) content. Magnesia has a high melting point, is chemically inert and is suitable for many refractory purposes (withstands very high temperatures). Magnesia is also used as a fertilizer to treat magnesium deficient soils.

Chapter 8

NON-METALLIC **MINERAL GROUP** AND **INDUSTRIES**

Sri Lanka is fairly rich in the non-metallic group of minerals. They rank from bulk commodities such as sand, gravel and stone down to gemstones which are measured in carats. There is, however, a deficiency of local reserves of commercially acceptable grades of certain minerals and these have to be imported. The main non-metallic minerals that occur in the Island include graphite, mica, gemstone, industrial clays, quartz, feldspar, limestone, apatite, garnet, cordierite sillimanite, wollastonite, serpentinite, sand, gravel and stone. Salt is produced by evaporating sea brines.

From this group of minerals, graphite, small quantities of mica, and gemstone are exported. The industrial clays, quartz and feldspar are used in the ceramics industry. Limestone is used in the cement industry and silica is used in the glass industry. Apatite is crushed for direct application to certain crops. Salt is produced from sea water and this material is used for the manufacture of caustic soda. Garnet is processed in small quantities and is used as an abrasive (sand gaper manufacture). The sand, gravel and stone industry although scattered and is not confined to a single unit, is one of the largest mineral based industries of the Island. The entire building activity in the country and all development projects have to depend on this industry for the supply of sand, gravel, stone and concrete aggregate. This industry has, however, not been given the recognition that it deserves. All other minerals listed are of no commercial value.

Graphite is one of the naturally occurring crystalline forms of carbon. Its chief characteristics are its black colour, metallic lustre, extreme softness, high conductivity for heat and electricity, high refractoriness and chemical inertness. Graphite mining and exports have continued since 1821. The highest recorded exports have been during the war years, for example, 34,411 tons in 1916 and 27,734 tons in 1942. At present graphite exports are in the region of 5,000 tons per annum.

Graphite occurs in veins, pegmatites and disseminated flakes in the country rock. The vein type deposits are exploited. The reserves of graphite are large and graphite is mainly concentrated in anticlinal structures generally trending in a north-south direction. The best known deposits of graphite are at Meegahatenne and Pelawatte in the Western Province, Arukgammana (Bogala) and Siyambalawela (Sabaragamuwa Province) and Ragedara and Maduragoda (Kahatagaha -Kolongaha) - (North Western Province). The two operating mines are the Bogala and Kahatagaha-Kolongaha mines. The graphite industry was nationalized in 1971 and it is now operated by the State Graphite Corporation which was established in the same year and renamed the State Mining and Mineral Development Corporation (SMMDC) in 1979 - (see Table XII).

TABLE XII

STATE MINING AND MINERAL DEVELOPMENT CORPORATION

Established	July 1971
Main Activities	Mining, separation, refining and preparation of graphite and the minerals - mica, apatite and quartz. Sale and export of these minerals Providing assistance and technical know-how to those interested in the mining industry Establishment of local industries based on minerals mined.
Manufacture	Apatite crushing and grinding Refining and up - grading graphite Curing of mica
Location	Mining complex — Kahatagaha-Kolongaha mines — Bogala mines Apatite plant — Eppawela Mica curing — Colombo and Kandy Area
Production and Value	Graphite — 5530 tons Mica — 170 tons Apatite — 15000 tons Value — 95 million rupees
Uses	Mainly export — Graphite and Mica Domestic - Apatite
Exports and Value	Graphite — various grades - 4600 tons Value — 70 million rupees
Raw Materials	Local - only mining undertaken
Employment	Persons — 2300
Capital Employed	Rupees '90 million
Development	Establishment of new mines after exploratory work. Prospecting for mica and development of mines Development of the apatite mine - Eppawela Proposal to establish mineral based industries.

Graphite mined in the Island is very high in the content of carbon and grades over 90 per cent carbon are common. Graphite is classified into a number of grades for export purposes depending on particle size, carbon content and structure. Although the Island has' some of the world's best graphite with high carbon contents, graphite based industries have so far not been established. Negligible quantities of graphite are, however, used in the pencil industry and in the cottage graphite crucible industry. There is, therefore, plenty of opportunities for the further development of graphite mines in Sri Lanka and for the establishment of industries based on graphite.

Higher grades of graphite are used for the manufacture of crucibles and lubricants and dust grades for foundry facings and polishes. Graphite is also used in dry cells, as a refractory material and in the Steel industry to increase the carbon content of steel.

Another mineral which is mined in small quantities for export only is mica. The important commercial types of mica are muscovite (potash mica), phlogopite (magnesium mica) and less frequently biotite (ferro-magnesium mica). Commercial mica is broadly classified as sheet mica, scrap and flake mica. Sheet mica because of its ability to withstand high temperatures, high di-electric strength and electrical insulation capability, has found wide use in the electrical and electronic apparatus industries. Most scrap and flake mica are processed into ground mica which is used in a variety of industries and as a filler for various types of plastics, floor coverings and paints.

The main types of mica found in the Island are phlogopite, muscovite and biotite. Vermiculite also occurs at some places. Vermiculite is the name applied commercially to hydrated mica. When heated vermiculite expands into cellular granules occupying 16 times the original volume. This expanded material is suitable for use as an insulating medium. Mica is mainly confined to the central parts of the Island and to the Kebitigollawa area north of Anuradhapura. The mica industry in Sri Lanka dates back as far as 1896 when mining was carried on in the Badulla and Haputale districts. During the second world war, mica mining was encouraged by the State and although the prices were favourable, very little mica was offered for sale. Mica mining in Sri Lanka is mainly confined to shallow depths and only weathered material is obtained which is usually passed as scrap mica. With deeper mining good grades of sheet mica could be obtained. Exports of mica from the Island are largely scrap grades. The quantities exported are also small. The average annual production of mica is around 100 tons.

In recent years the systematic development of the mica industry has been considered. Promising deposits have been studied and a few deposits selected for detailed investigations with a view to commercial exploitation. The development of the mica industry is at present a function of the State Mining and Mineral Development Corporation. No mica based industries have been established in the Island.

Sri Lanka has long been renowned for its gems. The 'Mahawansa' the great historical record of the Island, refers to the singular reputation of the Island for its gems. It is also believed that Sinbad's Valley of Gems in the Arabian Nights is probably the Ratnapura gem fields. Sri Lanka has therefore been famous for its gems since early historical times.

The main gem bearing area of Sri Lanka which has been known for centuries comprises a series of parallel hill ranges separated by longitudinal valleys and situated in the Sabaragamuwa Province. The neighbourhood of Avissawella, Ratnapura, Rakwana and Balangoda' has undoubtedly supported the most actively worked gem pits in the Island, for a number of decades. Outside this area, Okkampitiya and Elahara areas are noteworthy. The precious stones of Sri Lanka with the exception of moonstone (at Meetiyagoda), corundum and some tourmalines and a few garnets which have been found in situ are all obtained from old alluvial deposits.

The succession of formations in a typical gem pit may be classified into **3** categories:

1. Superficial layers of various soil types from a metre to 12 meters thick usually represents the overburden.

2. A layer or layers of pay-gravel which is the gem bearing gravel. The miner refers to it as the 'illam'. The 'illam' layer may be even a metre in thickness and is encountered at shallow depths ($<$ **3** metres) or at depths up to about 12 metres.

3. The next formation is the decomposed rock which is termed the 'Malawa.' All gem pits should theoretically end work on striking the 'Malawa' layer or decomposed rock.

Once the gems are recovered after washing, the gravels are discarded. This discarded gravel is termed 'Nambuwa'. Up to recent times large light coloured corundum (semi transparent) has been discarded. This light coloured corrundum, termed 'Geuda', is now heat treated to enhance its blue colour. The most abundant constituent of gem gravel is quartz in well rounded pebbles. The gem miner has come to regard these pebbles as an infallible companion of gemstones in the field and is guided in his search for pay-gravel by this criterion. In regard to gems in the pay-gravel there is a notorious uncertainty and variation in the content of gems. Some ,pay-gravel may draw blanks while pits dug a few metres **away** may yield very high priced gems.

Most of the gem varieties in the Ratnapura and Elahara areas are found associated with garnetiferous gneisses and skarn - type marble deposits. Deraniyagala (1958) studied a number of fossils embedded in the gem gravels of the Ratnapura area and his work indicates a Pleistocene age for the majority of the Ratnapura gem gravels. Wadia and Fernando (1945), however, mentions that the gem gravels do not all belong to any one particular age as erosion of the particular rocks of the surrounding area proceeded continuously through each succeeding geological age.

There are only a few instances known of gemstones occurring in rocks. The weathering process in previous geological ages have been responsible in exposing pegmatite veins and rocks containing a number of minerals of gem **quality.** These outcrops of rock and pegmatite material have been subjected to a renewed process sf weathering through countless ages of time. The gradual sorting action of the water has therefore resulted in the deposition in favourable sites of gem gravel and sands which have subsequently been sealed by a covering of alluvial deposits as in the Ratnapura valleys.

The mining methods employed although primitive, using only manual labour, are time honoured methods of ancient Sinhalese tradition. They involve little capital outlay and are quick and efficient. When the pay-gravel is near the surface open cast mining is used to recover the gem gravel ((placer mining) . When the overburden is of considerable depth the most common method is to sink pits, (gemming by pits). Gemming in beds of rivers is less conimon (dredging). In recent years some modernization has been introduced into the gem mining industry.

The gemming season normally extends from December to May, the drier part of the year in the South West parts of the Island. Under the existing law a licence to mine must be obtained from the State. The actual work of mining in a property is carried out on a remarkable system of co-operative sharing sf labour, expenses and profits. This system of sharing is unique in a highly uncertain business. Table XIII is presented to show the main gem varieties of Sri Lanka.

TABLE XIII

SRI LANKA GEM VARIETIES

Mineral	Gem Varieties
Corundum	Star Sapphire, Ruby and Star Ruby, Yellow, Blue, Green. Orange, Pink and White Sapphire.
Chrysoberyl	Alexandrite and Cat's Eye.
Beryl	Aquamarine - Colourless, Pink, Yellow
Topaz	White and Yellow topaz. Blue, green, violet and red topaz (pale tints).
Tourmaline	Black, pink, rose-rd, blue, brown, green varieties.
Garnet Pyrope Almandine Grossularite	Pyrope -deep red to black. Almandine - deep crimson, red to violet. Grossularite - honey yellow to brownish yellow, also known as Hessonite or cinnamon stone
Spinel	Spinel - deep red, green,-violet.
Zircon	Brown. Green. Blue, Red, Orang: and Yellow varieties
Quartz	Rock crystal, amethyst, rose quartz, smoky quartz Citrine (yellow) cat's eye quartz and star quartz.
Feldspar	Moonstone and amazon stone

(After Herath, 1980)

Gem cutting in Sri Lanka is by machines of primitive construction operated by hand. During the past decade however, modern and up-to-date machinery has been introduced to the industry.

With a view to develop the gem industry of Sri Lanka the State Gem Corporation (see Table XIV) was established in 1971. The Corporation now handles issue of permits for gemming, buys cut and uncut gems, and all exports of gems from the Island have to be

TABLE XIV

STATE GEM CORPORATION

Established	November 1971
Main Activities	Issue of gemming licences Auctions of gem bearing land Issue of trade and lapidary licences Purchase of gems - cutting and polishing Operation of a modem gem testing laboratory Retail trade of gems and jewellery Sole authority for export of gems Provides training facilities
Manufacture	Cutting - polishing - jewellery
Location	Main office and laboratory - Colombo Private sector gem mining scattered but concentrated in the Ratnapura area.
Production and Value	Accurate figures for production not known Value of gems channelled through the Corporation - 600 million rupees
Uses	M inly for export Manufacture of jewellery - export and local sales
Raw Materials	100 per cent local
Employment	Estimated to be very large in the private sector mining industry and jewellery trade
Capital	Not available
Development	The Corporation has made a significant contribution towards establishing a round gem industry in Sri Lanka. Establishment of a modem laaidary unit Programme for training lapidarists Establishment of a jewellery unit Situate sales exhibition centres overseas Gem exports — 1971 - 2 million rupees — 1975 - 182 million rupees — 1982 - 500 million rupees

channelled through the Corporation. A modern gem testing laboratory with training facilities has been established. In 1971 exports of gems from the Island were valued at Rs. 3,446,293 and in 1977 the export figures were in the region of 500 million rupees and in 1982 exports were around 600 million rupees. These figures indicate the increasing confidence owners of gems are beginning to have in the Corporation.

With the possible exception of Brazil, no other country in the world produce such an abundance and variety of precious and semi-precious stones as Sri Lanka. The possibility of expanding the jewellery industry has great promise, specially in the rural areas of Sri Lanka.

The Industrial Clays (kaolin, ball clay and brick and tile clays), quartz (silica) and feldspar are mainly used in the ceramics industry. Silica sands in Sri Lanka are also used in the glass industry (mainly the manufacture of bottles), china clays occur at Boralesgamuwa and Meetiyagoda and the reserves are estimated to be over a million tons of raw clay. When refined 40 percent china clay could be obtained. China clay refineries have been established at Boralesgamuwa and Meetiyagoda. Ball clay deposits are extensive and the largest deposit stretches for a distance of 8 miles in the Dediyawala area (Kalutara). A small area at Dediyawala has been investigated and nearly 500,000 tons of ball clay have been proved for the purpose of establishing a ball clay plant which went into production in 1976. Alluvial clay deposits for the brick, tile and pipe industry are concentrated in the lower reaches of the major river systems of the Island including other low lying areas. Some residual clays are also been used in the brick industry.

Feldspar is the principal rock forming mineral. Microcline feldspar (also called potash feldspar) occurs in various pares of Sri Lanka. In Sri Lanka feldspar is used mainly in the glass industry and ceramics industry and mining of feldspar is carried out in the Matale area. The largest deposit of feldspar is in the Owella Estate (Kaikawela), Matale District.

Silica is the most abundant oxide in the earth's crust and occurs as free silica and combined with other elements and compounds. In Sri Lanka silica occurs as vein quartz, silica sand and quartzite. The best known deposits of vein quartz occur in the Ratnapura and Matale districts. These deposits are mined for use in industry. Deposits of silica sand arc widespread in the Marawila — Nattandiya and Madampe areas. A large deposit also occurs in the Jaffna Peninsula at Ampan-Vallipuram. Quartzites occur in the central highlands. The pure varieties could be used in industry.

The term 'ceramics' covers nearly one-third of the field of industrial activity in the world. All ceramic products require high temperature treatment in their manufacture. Since the dawn of civilization man has recognized that clay could be made plastic with water, moulded and then transformed into durable shapes by the action of heat. On these facts has been based the science of technology of the industry of ceramics.

Although clay forms the main raw-material for the manufacture of ceramic products, other non-clay materials are also used for example, quartz, feldspar, dolomite and other materials.

Kaolin is the term applied to white firing clays. It is also called china clay. Kaolinite is the typical clay mineral of kaolin or china clay and most other clay materials used in industry. Kaolinite has the composition :

$$Al_2O_3.\ 2\ SiO_2.\ 2\ H_2O.$$

It is a hydrous aluminium silicate. Most hydrated minerals lose water when they are heated and this briefly is what happens when kaolinite is heated above about 450" C. When the water is driven off the residue still retains some of the crystalline features of the original kaolin mineral and is therefore called meta-kaolin. When meta-kaolin is further heated over about 1,000" **C** the products are mullite and silica. Mullite has the composition $Al_2O_3.\ 2\ SiO_2$. Mullite is formed when any clay which can withstand high temperature (refractory clay) is fired. At high temperatures liquid is formed and on cooling, the material solidifies to a glass and is hard and durable.

The Ceylon Ceramics Corporation (See Table XV) is the largest user of ceramic raw materials. The cottage brick and tile industry is mainly concentrated, in the flood plains of the Kelani river, Kalu Ganga and Maha Oya and the modern tile industry (private sector) is confined to the Maha Oya-Kochchikade area. The State also operates about 10 tile factories. These are scattered all bver the Island. The public and.

TABLE XV

CEYLON CERAMICS CORPORATION

Established	August 1959
Manufacture	Ceramic products and processing ceramic raw materials. Crockery, sanitary ware, mosaics and floor tile, electrical insulators, brick, tile and pipe, pottery and ornamental and fancy ware. Processes kaolin and ball clay and manufacture hydrated lime.
Location	Ceramic complex (Piliyandala and Negombo), Brick - pipe and tile complex (10 scattered units), Kaolin refineries (Boralasgamuwa and Meetiyagoda), Ball clay plant (Kalutara), Lime plant (Hungama). Refractories plant (Hanwella). Fancyware (Gampola) Limited Liability Companies - Lanka Porcelain Ltd. (Matale), Lanka Wall Tiles Ltd. (Balangoda) Tableware Plant (Dankotuwa). Floor Tile Plant Homagama
Production and Value	Crockery - 3800 tons Kaolin -8000 tons Sanitary ware - 1125 tons Ball clay (raw and refined) - 9000 tons Insulators - 290 tons Hydrated lime - 1530 tons - Mosaic tiles - 280 tons Brick and tile -22 million units Pottery -31 tons Limited Liability Companies not included Value of production - 230 million rupees.
Uses	Domestic and Export
Raw Materials	Percentage of local to total used - 60 per cent.
Employment	Persons - 6003
Capital Employed	Rupees 522 million (1983)
Development	Research arid Development laboratories have been modernized and up to date equipment installed. Further expansion of the ceramic industry considered.

private sector including the cottage industry consumes per annum nearly 1,500 acre feet of clay (depth into area - say 10 feet of clay over 150 acres = 1,500 acre feet of clay). Together they produce nearly 500 million bricks and over 80 million roofing tiles and other clay products (earthenware pipes, floor tiles and fancyware) per annum. The State operates the major ceramic units. They include a nnmber of pottery centres, a ball clay plant, two kaolin refineries producing over 6,000 tons of refined kaolin per annum and two ceramic factories (Negombo and Piliyandala) producing over 7,000 tons of ceramicware per annum and the products include domestic crockery, sanitaryware, wall tiles, mosaic tile, electro-ceramics and miscellaneous ornamental and fancyware.

Other factories operated by the Ceylon Ceramics Corporation include a lime plant at Hungama and a refractory products plant at Hanwella. The Ceylon Ceramics Corporation has also established a number of limited liability companies and thesemanufacture wall tiles (Lanka Wall Tiles Ltd.), floor tiles (Lanka Tiles Ltd.) Porcelain (Lanka porcelain Ltd.) and a second porcelain factory at Dankotuwa has also been established. All these products are for export. The Corporation has also re-structured its research and development facilities and has now established a modern research centre to cater to the entire ceramic industry.

Although Sri Lanka has extensive deposits of silica sand of very high purity and vein quartz showing values of over 99 per cent SiO_2 the glass industry in the Island has not shown any signs of development. Only glass bottles are made at present. Sheet glass is not produced. The great bulk of the glass produced today is of the soda (sodium carbonate) – lime (limestone) - silica (silica sand or quartz) type with a small addition of alumina (felspar). Pyrex type glass is a very high silica glass (80 percent silica), with low alkali content and the use of boric oxide (B_2O_3).

The Cement Industry of the Island is based on the Miocene limestone occurrences in the north and north west of Sri Lanka. Natural sources of calcium include limestone (CaCO,), Dolomite (CaCO,. $MgCO_3$) marl, chalk, shell, coral and other minerals, The largest consumer of limestone is the cement industry.

The limestone deposits of the Island fall into four main groups:

1. Sedimentary limestone deposits of Miocene age (over 95 per cent CaCO,).

2. Crystalline limestone (marble) deposits of Precambrian age (CaCO, variable).

3. Coral limestone deposits along coastal. areas (over 95 per cent $CaCO_3$).

4. Shell deposits along coastal areas (over 95 percent CaCO,).

Sedimentary limestone deposits of Miocene age are best developed in the Jaffna Peninsula where they occur as a hard compact limestone with a calcium carbonate content of well over 95 per cent. These deposits which extend to great depths are also developed as far as Puttalam in the north west coastal belt of the Island. The over-burden (red-earths) at some points (Aruwakalu Hill area - Puttalam) may be over 30 m. thick. The chief impurities in the limestone are varying amounts of clay and silica and traces of magnesia.

Portland cement is one of the hydraulic cements that sets in the presence of water. The composition for Portland cement can be obtained by combining clays and limestone in the correct proportion. The burning is carried out in large rotary kilns with inside diameters up to 10 feet and lengths up to 250 feet. As the raw material moves down the revolving kiln it encounters hot gases moving in the opposite direction and so is heated up to around 1,600°C when it reaches the hot end. It is then discharged in the form of clinker nodules. The clinker is cooled in a rotary cooler, ground in ball mills and bagged. As Portland cement would ordinarily set too rapidly, a retarder of 3 percent gypsum is added. The Ceylon Cement Corporation (see Table XVI) operates 2 cement factories in the limestone area, one at Kankesanturai and the other at Puttalam. A clinker grinding plant is aiso located at Galle. The Corporation was established in 1959 to take over the KKS plant set up in 1950. The two cement factories produce approximately 650,000 tons of cement per annum, and the two plants have an installed capacity of 950,000 tons per annum.

TABLE XVI

CEYLON CEMENT CORPORATION

Establishment	January 1959
Main Activities	Manufacture of cement - mining limestone and clay
Manufacture	Two cement plants - Kankesanturai and Puttalam-Clinker grinding plant - Galle
Production and Value	Total production - 503,000 tons Value - 760 million rupees
Uses	Domestic
Exports	Considered if excess cement is available
Raw Materials	Percentage of local to total used - 45 per cent
Employment	Persons - 4500
Capital Employed	Rupees - 530 million
Development	Development of limestone and clay mines Proposal to manufacture high value cement products.

Except for the cement industry no other large scale industry using limestone has been established. Quick lime (CaO) is produced by the cottage industry using coral and shell as raw material. These operations are confined to the coastal areas. A modern lime plant has also been established by the State at Hungama. This plant uses the shell deposits at Hungama. Limestone ($CaCO_3$) when calcined (burned becomes quick lime (CaO). When the oxide is slaked with water hydrated lime is produced ($Ca(OH)_2$). The lime hydrate is extensively used in the building industry. Dolomite is also crushed and prepared in the Island for the treatment of magnesium deficient soils.

Phosphate rock is a commercial term for a rock containing one or more phosphate minerals, usually calcium phosphate. The majority of known deposits are found in igneous rocks (Carbonaiites) and in sedimentary rocks (phospherites). The major phosphorus minerals of most phosphate rock are in the apatite group, fluorapatite and chlorapatite. Phosphorus is one of the three major plant food elements, and its principal use is in the production of fertilizer. Chemical analysis is usually reported as per cent phosphorus pentoxide (P_2O_5) or as tricalcium phosphate $Ca_3(P_4O_2)$ also known as bone phosphate of lime (BPL). Sedimentary phosphate provides the bulk of the world's production of phosphate rock. Tunisia and Florida are important producers of phosphate rock.

In Sri Lanka phosphate rock (apatite) was discovered by the Geological Survey Department in April, 1971 at Eppawala. The phosphate rock of the carbonatite type is well exposed in some areas such as in the Kiriwelhena Hill. Drilling investigations carried out by the Geological Survey Department have revealed that the deposit extends to a depth of 125 m. or more from the surface. The apatite is classed as a chlorine rich fluorapatite. The average P_2O_5 content of rocks is 35 per cent or more. Samples containing 40 per cent P_2O_5 content are not uncommon. Proved reserves in the area are about 25 million tons and the inferred ore reserve is in the region of 60 million tons
3 of apatite ore.

The Eppawala apatite when finely ground has a limited use as a fertilizer because of its relatively slow availability of P_2O_5 The rock consists essentially of tricalcium phosphate which is insoluable and therefore cannot be used by plants. By acidulation a large proportion of the material is converted to monocalcium phosphate (super phosphate), a soluble form which is readily available to plant life. Superphosphate is produced by mixing sulphuric acid with finely ground phosphate rock, and has about 16 to 20 per cent available P_2O_5. Triple phosphate is a much more concentrated fertilizer with 45 to 50 per cent available O The largest consumer of sulphuric acid is the phosphate industry.

Studies undertaken on the Eppawala apatite have revealed that although the apatite is a high grade ore (35 per cent P_2O_5) it is however not suitable for conventional processes for the manufacture of phosphate fertilizer. Recent studies by a foreign firm have been successful in identifying a commercial acceptable method for the manufacture of phosphate fertilizers with the Eppawela appatite as raw material. In connection with the overall development of the phosphate rock deposit the State has plans to identify a collaborator for the manufacture of fertilizer for local use and for purposes of export. Till such times a final decision is taken for foreign collaboration the apatite is ground and used as a direct applicant for perennial crops (tea and rubber). Approximately 20,000 tons per annum of the material is ground and supplied to the Fertilizer Mixing Industry. The Sri Eanka apatite however is considered suitable for the manufacture of fused magnesium phosphate fertilizer. A deposit of serpentinite rock (hydrated magnesium silicate) has already been located for this purpose at Uda Walawe. Serpentinite is a raw material necessary for the production of fused magnesium phosphate fertilizer.

The State Fertilizer Manufacturing Corporation was established in May, 1966 with the main objectives being the manufacture, processing and marketing of fertilizer and industrial chemicals (see Table XVII). The Corporation operates a Urea plant at Sapugaskanda and this establishment consists of an Ammonia Unit (Capacity 540 tons a day) and a Urea Unit (Capacity 940 tons a day). Naphtha which is required for the manufacture of urea is obtained from the Ceylon Petroleum corporation. It is estimated that the local annual demand for Urea is at present around 150,000 million tons. (The SFMC is to be closed down).

Sodium Chloride (NaCl) commonly called kitchen salt is the commonest salt in sea water. This mineral salt called halite, is characterised by its easy solubility in water, its distinctive taste, cubic cleavage and its crystal form. In Sri Lanka salt is extracted from sea water by solar evaporation. The salt producing pans or salterns are located is **3** main regions and the State owned salterns are as follows:

Northern region	—	Elephant Pass, Kallundai, Irupalai, Kurunchativu.
Western region	—	Palavi, Mannar, Puttalam.
Southern region	—	Hambantota, Maha Lewaya, Palatupana.

TABLE XVII

STATE FERTILIZER MANUFACTURING CORPORATION

Established	May 1966
Main Activity	Operation of a nitrogem-as fertilizer manufacturing plant
Manufacture	Urea the nitrogenous fertilizer is manufactured from naphtha (main raw material) which is obtained from the Ceylon Petroleum Corporation refinery
Location	Urea plant - Sapugaskanda
Production and Value	Urea - 130,000 tons Value - 750 million rupees
Uses	Domestic - some exported Local demand - around 150.000 tons.
Raw materials	Local and imported
Employment	Persons - 900
Capital	Not available
Development	To increase production to 280,000 tons of urea per annum Development of the Eppawela apatite deposit for the manufacture of phosphate fertilizer

The National Salt Corporation (Table XVIII) operates the State owned salterns. The local demand for salt is in the region of 120,000 tons per annum and around 130,000 tons of salt are manufactured at present, The Corporation also exports small quantities of salt to Africa arid the Maldives. About 6,000 tons of gypsum are also produced which is supplied to the Ceylon Cement Corporation. An Epsom salt plant has been established at Hambantota with a capacity of 1000 tons per annum. This product (Magnesium sulphate)

TABLE XVIII

NATIONAL SALT CORPORATION

Established	December 1957
Main Activities	Control of salterns Production and distribution of salt Services to private sector to ensure quality products. Operation of an Epsom salt plant
Manufacture	Salt is manufactured by solar evaporation of sea or lagoon brine.
Location	Jaffna (north), Puttalam (west) and Hambantota {south). Number of salterns - 14 Total acreage of salterns - 5000
Production and Value	Total yield per annum 150,000 tons Value - 62 million rupees
Uses	Domestic - small quantities exported Country's annual demand - 120,000 tons
Raw Material	Local
Employment	Persons - 700
Capital Employed	Rupees - 60 million
Development	Establishment of a caustic soda - chlorine project at Embilipitiya Development of Bundala saltern Establishment of a refined salt unit Establishment of a new factory to refine Plaster of Paris Proposal to manufacture Potassium sulphate

would be sold to the State Fertilizer Manufacturing Corporation for use as a fertilizer. Small quantities of refined salt are also produced by the Corporation. The Corporation has commenced production of Iodised Salt to cater to the requirements of local hospitals. The manufacture of P. V. C., Soda Ash, Plaster of

Paris and Chalk are other proposed projects of the Corporation. The Corporation also supplies raw material (salt) to the Paranthan Chemicals Corporation for the manufacture of Caustic Soda and Chlorine.

Caustic soda arid chlorine are manufactured by the Paranthan Chemicals Corporation from salt obtained from the Salt Corporation. The factory is situated at Paranthan.

The Paranthan Chemicals Corporation was established in 1956 (see Table XIX) to operate the Government Chemicals Factory at Paranthan.

The main activities of the Corporation are:

1. Manufacture of Caustic Soda and Chlorine.

2. Development, manufacture and sale of by-products - Hydrochloric acid, Zinc Chloride, Ferric Chloride and Table salt.

3. Import and sale of caustic soda.

The Corporation manufactures around 2000 tons of caustic soda per annum and imports nearly 5000 tons of caustic soda per annum. The country's requirements are in the region of nearly 10,000 tons per annum. In order to meet this demand the Corporation proposes to establish a second caustic soda-, chlorine factory with a capacity of 10 tons per day of caustic soda.

TABLE XIX

PARANTHAN CHEMICAL CORPORATION

Established	April 1956
Main Activities	Manufacture of caustic soda and chlorine Imports of caustic soda
Manufacture	Caustic soda and chlorine produced by electrolysis of brine - main raw material is common salt Hydrochloric acid produced from wet sniff chlorine produced by the caustic soda - chlorine plant By - products - table salt, ferric chloride and zinc chloride
Location	Paranthan
Production and Value	Caustic soda - 1425 tons Liquid chlorine - 900 tons Hydrochloric acid - 370 tons Table salt - 520 tons Ferric chloride - 53 tons Zinc chloride - 7 tons Value - 30 million rupees
Uses	Domestic
Raw Material	Percentage of local to total used - 100 per cent
Employment	Persons - 540
Capital Employed	Rupees 22 million
Development	Proposal to establish a second Caustic soda plant at Embilipitiya

Chapter 9

MINERAL POLICY

The mineral system can be defined as a series of activities that begin with the location of resources in the ground and ends with final consumption. Activities include exploration for and the discovery of minerals including their processing and sales. The mineral system has a positive impact on the economy. It generates income and employment directly and indirectly. Even in a country like Sri Lanka, the mineral system gives impetus to the development of the country.

Mineral policy is the sum of government decisions and actions that influence the mineral system, and the ways in which the system itself affects the economy and society in general. Mineral policy contains more than laws and regulations that directly influence mineral exploration, extraction and processing. Other policy elements include export-import permits, regional development funds, pollution control laws, taxation and social development programmes.

Sri Lanka is not a major world mineral producer. Mineral related activities, however, have profound effects on the lives of many Sri Lankans. The value of production of mineral commodities in Sri Lanka in the year 1982 was in the region of one billion rupees. The mining industry including the mineral based industrial units (private - public sector industries) together with the cottage mineral industries (brick and tile, lime and others) employ around 80,000 persons. Sri Lanka will continue to depend on other nations for crude oil supplies and for supplies of coal for energy purposes, these being two important mineral raw materials which have to be imported. In the future, international factors will also have an impact on Sri Lanka's ability to increase benefits from minerals such as graphite and ilmenite and even gems, the bulk of which are exported. Such factors include the emergence of large trading blocs, resource-procuring strategies of other nations, international corporations and increased competition from other producing nations.

Sri Eanka has established a number of mineral based industries operated by the Public Sector. Majority of these industries use local mineral raw materials, mainly the non-metallic minerals and special mention may be made of the Ceramic industry of Sri Lanka which has established itself utilizing every possible ceramic raw material of the Island and its products are of very high international standards. No industry based on local raw materials can, however, prosper unless the reserves and potentialities of the raw materials used are known and fully understood and the problems associated with their behaviour and use are solved. If the industries, established or proposed to be established, are to progress, research and development facilities should be available. Industrial research and industrial development are not independent but interdependent. Efficient and continuous research along with quality control in the various stages of production are vital factors in achieving the goal of increased production and higher quality.

Mineral policy should first seek, whenever possible, to increase diversification and growth of national economies based on minerals. This would include not only increased mineral processing but also more mineral-based manufacturing prior to export, and strengthened ties with other sectors of the economy.

Under certain circumstances, it may be desirable to modify the rate at which economic diversification or increased financial returns are sought from minerals. For example, mineral policy should seek conservation for future use or stretched-out-development where there is a possibility of depletion. Whatever direction mineral policy may take in the future, the first consideration must be to assure an adequate supply of minerals, whether from domestic or foreign sources to meet the country's needs. The overall balance and emphasis of policy will change over time. Mineral policy must therefore maintain its general goal of obtaining for the Island, the best benefits from minerals.

Up to very recent years there have been no private prospecting companies in Sri Lanka and the Geological Survey Department has been responsible for all activities connected with mineral exploration in the Island.

With the coming into operation of the new Mines and Minerals Law of 1973 (although not fully implemented), the absolute ownership of all minerals is vested in the Republic of Sri Lanka and granting of prospecting and mining licences is the responsibility of the Director, Geological Survey. With the operation of this act there has been a rationalization of mining and also increased mineral production, with more revenue to the State from mining rents and royalties. The implementation of this Law would also aid the conservation of the Island's mineral wealth and also initiate mining activities for thebenefit of thenation as a whole.

Modern mining and processing methods have become so capital intensive that countries like Sri Lanka cannot expect to bring a sizeable project into operation on their own. Sri Lanka has therefore to decide whether it is able and willing to attract private capital (foreign or domestic) and the mining laws and the fiscal policies should be such as to encourage investment in mining and mineral exploration. Mineral legislation should provide the administrative framework for this purpose. In addition to the normal mining code, legislation should include a special taxation regime compatible with existing investment codes and social legislation. The taxation regime is perhaps the most important element of any national mining policy for it constitutes an important means for achieving many policy objectives.

It has been stated as a matter of policy that it is Government's intention to create and maintain a favourable investment climate in order to encourage the private sector - both local and overseas based companies - to accelerate in partnership with the Government, the development and exploration of Sri Lanka's mineral resources. Finally, it may be stated that the terms which any Government can offer or negotiate with concession holders depends primarily on how much competition for- prospecting rights actually exists in the country. This will depend on the geological environment and the mineral potential of each country.

Chapter 10

SUMMARY AND CONCLUSIONS

Sri Lanka is fairly rich in the non-metallic group of minerals and a series of industries have been established based on mineral raw materials. These are mainly in the public sector. It is expected that the mineral policy in future will be re-shaped, to place greater emphasis on increased economic diversification and better financial returns from mineral development. To ensure mineral supply for national needs is important specially when taking into consideration crude oil and coal supplies for the energy sector as Sri Lanka is devoid of both these materials. Research and development by the State industrial research organizations, private and public sector industry and universities should play a key role in mineral industry development in the country. The State should also frame the necessary laws to obtain the maximum benefits from available mineral raw materials. The mining laws and fiscal policies should be such as to encourage investment in mining and mineral exploration by attracting private capital (foreign and local) where possible.

The present industrial policy is to expand the scope of activities of all sectors (public and private). Its main aim is to create an efficient public sector especially affecting public extraction of mineral resources and areas considered to be of strategic importance. The other sectors are given the opportunity to compete on equal and non discriminatory terms in areas not reserved exclusively for the public sector.

Immediate response to this new outlook on industry has resulted in increased industrial activity and also enhanced results. However, with the new economic policies (open economy) of the State, inflow of sub-standard goods into the country continues, and this area needs careful monitoring. It has also been observed in certain areas of industrial activity that the older industries are unable to compete with newly established concerns which enjoy various tax and other concessions. This discrepancy also needs re-examination.

As far 'as mineral based industries are concerned, serious consideration should be given to the establishment of local industries based on minerals such as ilmenite and rutile, graphite, silica sands and vein quartz and the Epawela phosphate rock (apatite) including the garnet sands of Hambantota. These minerals occur in economic quantities.

Substantial benefits can accrue to Sri Lanka from a properly structured and administered mineral industry. While providing foreign exchange earnings, mining also produces revenue through taxes and royalties, stimulates development of depressed regions, improves the professional and technical skills of nationals and for some countries provides a nucleus for economic development.

The results of mineral surveys carried out by the Geological Survey of Sri Lanka has enabled the establishment of a series of mineral based industries. The State should therefore recognise the achievements of the Survey by re-structuring of the Department to provide better working conditions together with properly equipped laboratories.

The value of mineral commodities produced in the country amounts to one billion rupees. The State can collect a substantial revenue from taxes and royalties. This, however, cannot be achieved without the implementation of the mines and minerals law of 1973 (with amendments if any) which up to now (1986) has not been implemented.

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GLOSSARY

Abrasive	—	Substance capable of rubbing or grinding down (quartz or silica in sand paper).
Aerial Photography	—	Photographs taken from the air. Widely used by scientists. Three dimension effects could be obtained when pairs of photos are viewed with a stereoscope.
Allanite	—	Mineral source of the rare - earth elements cerium, lanthanium and yttrium oxides.
Alloy	—	Mixture composed of metals.
Anticline	—	An arch - fold in stratified rocks.
Antiform	—	Arch - shaped arrangement of strata. Similar to an anticline.
Apatite	—	A phosphate mineral. Used to manufacture phosphate fertilizer.
Arkose	—	A coarse - grained sandstone.
Asbestos	—	A fine fibrous variety of serpentine.
Ball Clay	—	A sedimentary kaolinitic clay of very high plasticity and white burning.
Ball Mill	—	A fine grinding rotating unit used in pottery.
Bauxite	—	Hydrated aluminium oxide. The chief ores of the metal aluminium. The common ore mineral is gibbsite - Al_2O_3 $3H_2O$

Calcine	—	burn or **beat treat.**
Carat	—	Measure of weight for precious stones (1 carat - 200 mg.)
Carbon	—	**A** non-metallic chemical element. Also occurs as the minerals graphite and diamond. Diamond is **the hardest** known mineral. Graphite is very soft.
Caustic Soda	—	Sodium Hydroxide
Chalk	—	**A** soft rock consisting of fine grained calcium carbonate.
Charnockite	—	**A** rock characterized by the presence of the mineral hypersthene. The rock is greenish in colour.
Chert	—	A general term for **a** cryptocrystalline (showing crystalline structure only when magnified) siliceous rock.
Clinker	—	Unground cement as it issues from the rotary kiln.
Cordierite	—	A magnesium aluminium silicate mineral - purple in colour.
Dolomite	—	**A** double carbonate of calcium **and** magnesium ($CaCO_3 . MgCO_3$)
Dolerite	—	A basic igneous rock.
Dyke	—	**A** igneous rock or igneous intrusion sometimes intruded in a vertical position.
Equity	—	Value of shares issued by a company.
Era	—	**A** prime division of geological time.
Epsom salt	—	Magnesium sulphate.

Ferrous	—	Containing iron.
Flotation	—	Separation of compounds of crushed ore by their different capacities to float.
Fossil	—	The remains - impression or trace of rocks of an animal or plant.
Foundry	—	A place where metal is melted and moulded.
Garnet	—	A family of minerals (pyrope, almandite, grossularite and others). Also occurs as a gem.
Geochemistry	—	Chemistry of the earth.
Geology	—	The science of the earth.
Geophysics	—	The study of the physical state of the earth.
Gneiss	—	A banded high grade metamorphic rock.
Granite	—	Igneous rock, essentially composed of quartz, felspar and a dark mineral (hornblende or biotite).
Granitoid	—	Granitic rocks.
Granulite	—	Texture in a metamorphic rock, when minerals form a equigranular mosaic.
Grit	—	A vague term for any sedimentary rock that looks gritty (containing small particles.)
Graphite	—	Black, Soft mineral consisting essentially of carbon. Graphite is used in the pencil industry.
Gypsum	—	Hydrated calcium sulphate ($CaSO_4.2H_2O$) from which Plaster of Paris is made.

Hydrogeology	—	Geological activities concerned with the study of water.
Igneous rock	—	Rocks formedfrom magma - molted rock material.
Ilmenite	—	Ferrous titanate - $FeO.TiO_2$.
Jurassic	—	It is the central member of the 3Mesozoic systems in the Geological time scale (135 - 180 million years old).
Kaolin	—	A white firing clay. Predominently composed of the mineral kaolinite. Widely used in the ceramic industries.
Laterite	—	A weathering product developed in the tropics. Locally known as cabook.
Lead	—	a non-ferrous metal. Galena is the chief lead ore.
Limestone	—	A rock consisting chiefly of carbonate of lime - $CaCO_3$
Limonite	—	Hydrated iron oxide. Goethite is also a hydrated iron oxide.
Lithology	—	The general chsracter of a rock.
Marble	—	A limestone that has become recrystallized to a hard mosaic of calcite crystals.
Marl	—	An impure calcareous clay.
Magnesite	—	Magnesium carbonate - $MgCO_3$
Magnetite	—	Magnetic iron oxide - Fe_3O_4
Metamorphic rock	—	A term used for altered rocks
Metasedimentary	—	Metamorphosed sedimentary rock.
Metal	—	Any of a class of substances such as gold,

silver, copper, lead, tin and others.

Mica — Group name for a series of silicates, the most important of which is muscovite.

Migmatite — *An* incompletely granitized rock with a **mixed** appearance.

Milling — Grinding.

Mineral — An inorganic substance with a definite chemical composition (sometimes may vary very slightly) and occurring in the earth's crust. Rocks are composed of various minerals.

Miocene — *A* division of the Tertiary Period in the Geological time scale. Duration 15 million years.

Monazite — Important thorium bearing mineral

Naphtha — Inflammable oil got by dry distillation of petroleum.

Peat — *A* superficial accumulation of vegetable matter decomposed to a limited extent.

Pegmatite — *A* coarse grained rock of igneous origin mainly composed of quartz **and** felspar.

Placer — Deposit of sand or gravel containing valuable minerals in particles. The deposit may be in a stream bed, beach
3 or in other similar occurrences.

Pleistocene The latest period of geological time extending back perhaps a million years or so.

Porcelain	—	*A type* of vitreous ceramic whiteware.
Precambrian	—	Oldest in the geological time scale. Extends from 600 to 4500 million years ago.
P. V. C.	—	Polyvinyl chloride.
Quartz	—	A fairly hard mineral - the common crystalline silica - SiO_2
Quartzite	—	*A* rock .almost completely siliceous.
Remotely sensed data	—	Also referred to as landsat imagery or satellite imagery - photographs taken from space.
Rutile	—	Titanium oxide occurring in beach sands - black in colour.
Refractory		Ability to withstand very high temperatures over 1600°C.
Smelting	—	Extract metal from ore by melting.
Sillimanite	—	*A* refractory mineral with the composition Al_2SiO_5.
Sedimentary rock	—	A rock formed from the consolidation of sediments.
Sandstone	—	*A* sedimentary rock - a consolidated sand.
Shale	—	*A* laminated clayey material - sedimentary origin.
Schist	—	*A* metamorphic rock with foliated structure and which splits up in thin irregular plates.
Synform	—	A trough - fold in rocks - the opposite of an anticline.

Single Point Buoy Mooring System	—	The **SPBM** facility provides crude oil from tankers to be pumped directly to on - shore storage tanks.
Skarn	—	Skarn type rocks are those which **have** replaced limestone or dolomite by contact metamorphism.
Serpentinite	—	*A* greenish mineral - hydrous magnesium silicate.
Soda ash	—	Anhydrous (without water) sodium carbonate Na_2CO_3.
Uranium	—	Radioactive metallic element. The important oxides are U_3O_8, UO, and UO_2. Used as a source of nuclear energy.
Urea	—	Nitrogenous fertilizer -
Vermiculite	—	Group name for certain altered biotite micas. When rapidly heated to 900°C vermiculite exfoliates (comes **off** in layers) **and** the volume increase is about 20 per cent.
Wollastonite	—	*A* calcium metasiiicate ($CaSiO_3$) mineral - used in the ceramics industry