GOVERNMENT OF KERALA

DISTRICT SURVEY REPORT OF MINOR MINERALS

(EXCEPT RIVER SAND)

KOTTAYAM DISTRICT

Prepared as per
Environment Impact Assessment (EIA) Notification, 2006 issued under Environment (Protection) Act 1986
by

DEPARTMENT OF MINING AND GEOLOGY
www.dmg.kerala.gov.in

November, 2016
Thiruvananthapuram

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DISTRICT SURVEY REPORT OF MINOR MINERALS KOTTAYAM DISTRICT

(This report is to be submitted along with application for Environmental Clearance (EC) for mining of all minor minerals except river sand)

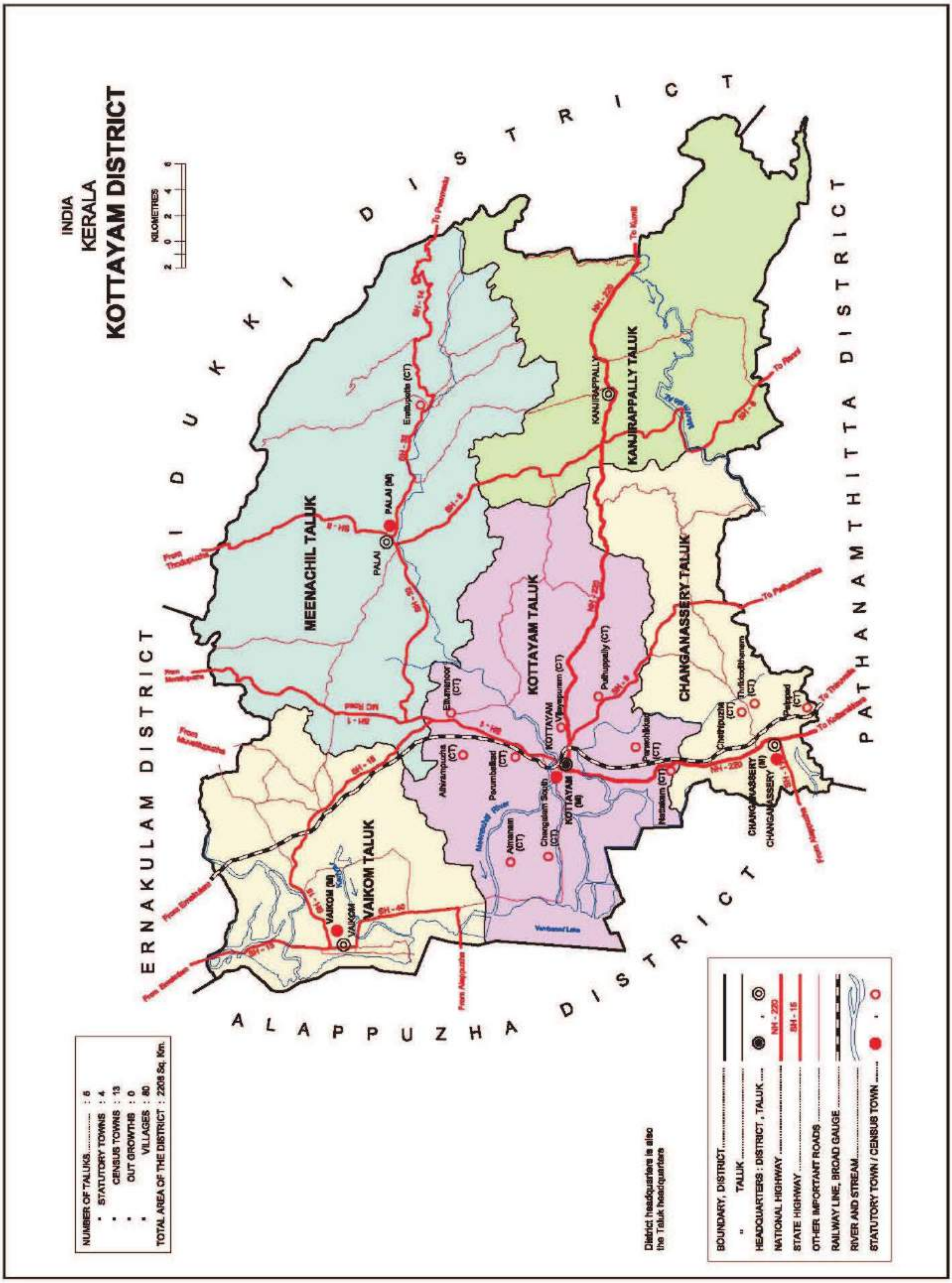
1 Introduction

The Kottayam district is popularly known as land of latex and letters. This is one of the leading places in the country for production of rubber and most of the Malayalam dailies and weekly magazines are published from here only. Kottayam is the first town to acquire cent percent literacy in the State and first English school in the State was started here. The district is famous for the largest inland water body in the State i.e., Vembanad lake. Panoramic backwater stretches, lush paddy fields, highlands, hills and hillocks, extensive rubber plantations, places associated with many legends and a totally literate people have given Kottayam District the enviable title: The land of letters, legends, latex and lakes. The city is an important trading center of spices and commercial crops, especially rubber. Kottayam is also called as "Akshara Nagari" which means the "city of letters" considering its contribution to print media and literature. Kottayam Town is the first town in India to have achieved 100% literacy (*a remarkable feat achieved as early as in 1989*).

Kottayam is situated between Western Ghats and the Vembanad lake and has an area of 2208 sq. km. Ernakulam, Idukki, Alappuzha and Pathanamthitta districts lie respectively to the north, east northeast, west, southwest and south of the district. Kottayam lies between latitudes 9° 15' and 10° 21' and longitude 76° 22' and 77° 25'. Kottayam is one of the districts in Kerala which has no sea coast.

The Kottayam district is divided into two revenue divisions viz. Kottayam and Pala. There are five taluks in the district viz Kottayam, Changanacherry, Vaikom, Meenachil and Kanjirapally. There are four municipalities Kottayam, Changanacherry, Pala and Vaikom and 11 blocks namely Madapally, Pallom, Ettumanoor, Kaduthuruthy, Vaikom, Uzhavoor, Lalam, Erattupetta, Kanjirapally, Vazhoor and Pampady. The total number of grama panchayats and revenue villages are 75 and 95 respectively.

In 2011, Kottayam had population of 1,979,384 of which male and female were 970,140 and 1,009,244 respectively. There was change of 1.32 percent in the population compared to population as per 2001. The total population living in rural area is 1,413,773 and urban area is 565,611 and indicates that the people living in rural population is 71.42 %. The density of the population is 896 per sq.km.


INDIA
KERALA
KOTTAYAM DISTRICT
KILOMETRES
MEENACHIL TALUK
KOTTAYAM TALUK
KANJIRAPPALLY TALUK
CHANGANASSERY TALUK
VAIKOM TALUK
ERNAKULAM DISTRICT
IDUKKI DISTRICT
PATHANAMTHITTA DISTRICT
ALAPPUZHA DISTRICT
NUMBER OF TALUKS : 5
STATUTORY TOWNS : 4
CENSUS TOWNS : 13
OUT GROWTHS : 0
VILLAGES : 80
TOTAL AREA OF THE DISTRICT : 2208 Sq. Km.
District headquarters is also the Taluk headquarters
BOUNDARY, DISTRICT
TALUK
HEADQUARTERS : DISTRICT, TALUK
NATIONAL HIGHWAY
STATE HIGHWAY
OTHER IMPORTANT ROADS
RAILWAY LINE, BROAD GAUGE
RIVER AND STREAM
STATUTORY TOWN / CENSUS TOWN

2 Drainage and Irrigation

The major rivers in the district are the Meenachil River, the Muvathupuzha River and the Manimala River. The Meenachil River flows through Meenachil, Vaikom and Kottayam taluks. The total catchment area of Meenachil River is 1272 sq km and is formed by several streams originating from the Western Ghats in Idukki district. The Poonjar river join at Erratupetta, the Chittar River join at Kondur and the Payapparathodu join at Lalam. Finally the river confluences with Vembanad Lake.

The Muvattupuzha River originates from Idukki district flowing mostly through vaikom taluk and joins with Vembanad Lake. The Manimala river flows through Kanjirapally and Chanaganacherry taluks. The Chittar joins it on its course further down the west as it flow towards Alappuzha district.

There is no major irrigation projects in this district, however, the Meenachil medium irrigation project is having a net ayacut of 9960 hectares and a catchment area of 155 sq. km. The minor irrigation is by tanks, dug wells and bore wells etc.

3 Rainfall and climate

The normal rainfall of the district is 2931 mm based on 1901-1999 data and the major contribution of rainfall is during South West monsoon followed by the North East monsoon. The analysis of rainfall data reveals that the distribution of rainfall increases from west to east. The highest rainfall recorded at Pala while the lowest recorded at Ettumanur. The annual rainfall ranges from 2435.9 to 3755.2 mm and the average annual rainfall of the district is 3169.28 mm.

In general the district has wet type of climate and four seasons are seen in this district. The hot summer season from March to May, the South West monsoon season from June to September, the North East monsoon season from October to December and cool climate prevails during January and February. The South West monsoon contributing nearly 59 % of the total rainfall and 21 % from North East monsoon.

4 Meteorological Parameters

4.1 Temperature

The temperature is more during the months of March to May and less during November, December and January. The maximum temperature ranges from 23.8 $^{\circ}$C to 26.0 $^{\circ}$C. The average annual maximum temperature is 29.8 $^{\circ}$C and the minimum temperature is 24.4 $^{\circ}$C. The average mean monthly maximum temperature ranges from 29.2 to 33.4 ^{0}C and minimum temperature ranges from 19.7 to 25 $^{\circ}$C.

4.2 Relative Humidity

The relative humidity is generally high, during the morning hours it goes up to 79 % and during evening hours it is around 76%.

4.3 Wind

The general direction of wind is from east to north east during morning hours and west to northwest direction during evening hours. The wind speed ranges from 6.7 to 10.9 km/h.

4.4 Potential Evapotranspiration (PET)

The annual Potential Evapotranspiration is 1424.1 mm based on Penman's method at Cochin meteorological station which is close to the district boundary. In general Potential Evapotranspiration is less during April to November while compared to the other months 3
and hence possibilities of recharge are more during these months. The monthly Potential Evapotranspiration ranges from 119.3 to 177.0 mm.

5 Geology

This area shows a very interesting correspondence between the major rock classes and their physiographic expression. The east comprises Precambrian metamorphic rocks and forms hilly ground. The central part is a low plateau, where Tertiary sediments containing lignite occur. These are followed by further west by a low plain, which is underlain by Quaternary Formations, fluvial or partly marine. The Charnockite Group dominates in areal distribution with charnockite, charnockite gneiss and diopside gneiss occupying the major part. Pyroxenen granulite (with hornblende granulite), magnetitie quartzite and cordierite gneiss occur as concordant bands within charnockite. The linear bands of quartzite (Khondalite Group) are the oldest rock of the area. Biotite geniss (composite gneiss) representing the Migmatite Complex has a limited areal extent, west of Ettumanur and along the eastern boundary. Three major granite bodies are emplaced in the district, two along the southwest and other in the east. Numerous dolerite and gabbro dykes trending NW-SE traverse the older basement rocks in the central and eastern parts. A prominent gabbro dyke extends from north to south with a NNW-SSE trend. Tertiary sediments comprising sandstone, clay with lignite intercalations are confined to the west and they occur as small patches, especially as capping on hillocks. Both the Archaean and Tertiary rocks are lateritised. Quaternary alluvial deposits occur to the west. They have been classified into various morphostratigraphic units, based on their environment of formation, as Guruvayur Formation (palaeo-marine), Periyar Formation (fluvial) and Viyyam Formation (fluvio-marine) *(Figure 1)*. The geology of the district given above may be read with the "Geology of Kerala" which is given as Annexure 1 for better understanding of geological succession and stratigraphic sequence.

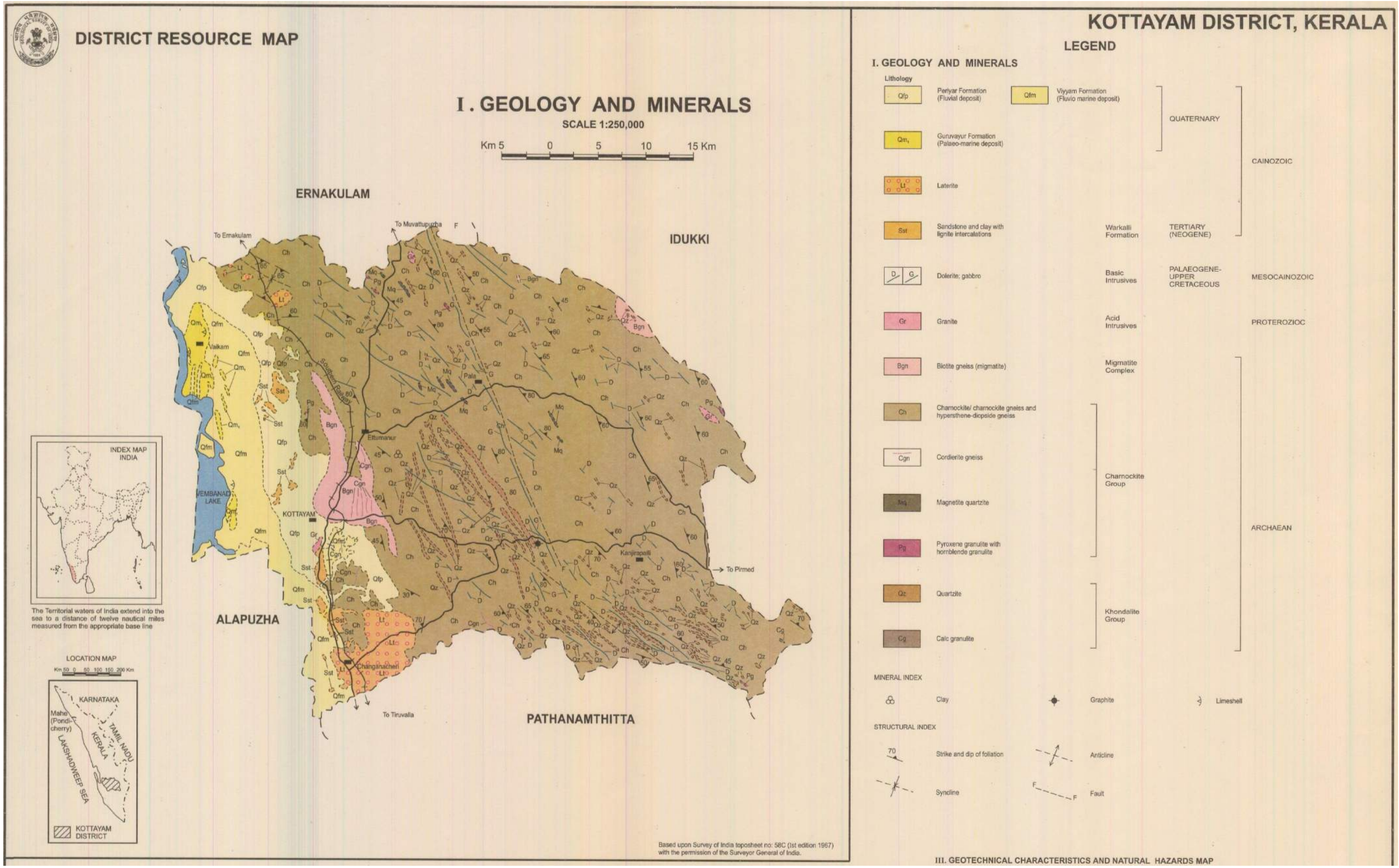


Figure 1: Geology and mineral resources of Kottayam. (*Source: District Resource map, Kasargod district, Geological Survey of India)*

6 Geomorphology

The district is divided into three well defined physiographical units from west to east viz. (i) western low lying fluvial landscape (coastal plain) followed by (ii) laterite capped midland region with moderate to gently sloping spurs towards east and (iii) the structurally controlled high hills and steep ridges in the east. A major part of the district is undulating peneplain. Because of a thick soil cover cash crops are widely cultivated. The low-lying fluvial landscape which is the flood plain of Muvattupuzha and Pamba rivers has thick fluvial sediments derived from the catchment area of these rivers. This fertile land is ideal for paddy cultivation. The high hills to the east have thin forest soil cover which supports luxuriant growth of plantation crops. The lowland is the area with an elevation of less than 7.5 m amsl which covers around 398.4 sq km and midland area having an elevation of 7.5 to 75 m amsl covers around 1287.75 sq km and the highland area with an elevation of more than 75 m amsl covers around 508.8 sq km and are mainly found in the eastern part of the district. The low lands are seen along the western portion of Vaikom, Changanassery and Kottayam taluks where as the Meenachil and Kanjirapally taluks fall in the highlands. Major part of Kottayam, Changanassery and Vaikom taluks fall in the midland region. Around upper Kuttanad (part of Changanassery taluk) particularly Pallom, Ettumanoor and Kaduthuruthy the ground elevation is generally 1 to 1.5 m below mean sea level. The maximum elevation is 1193 m amsl at Kursimudi *(Figure 2)*.

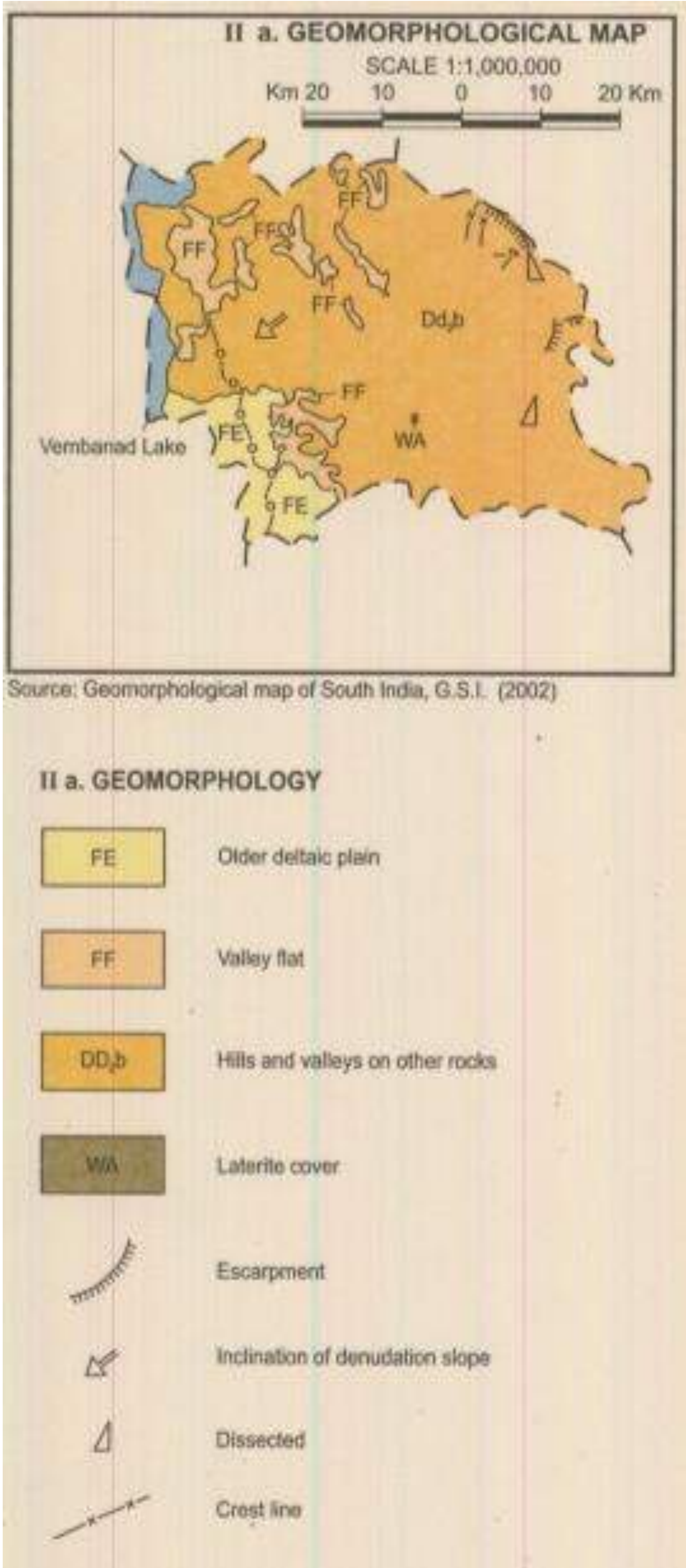
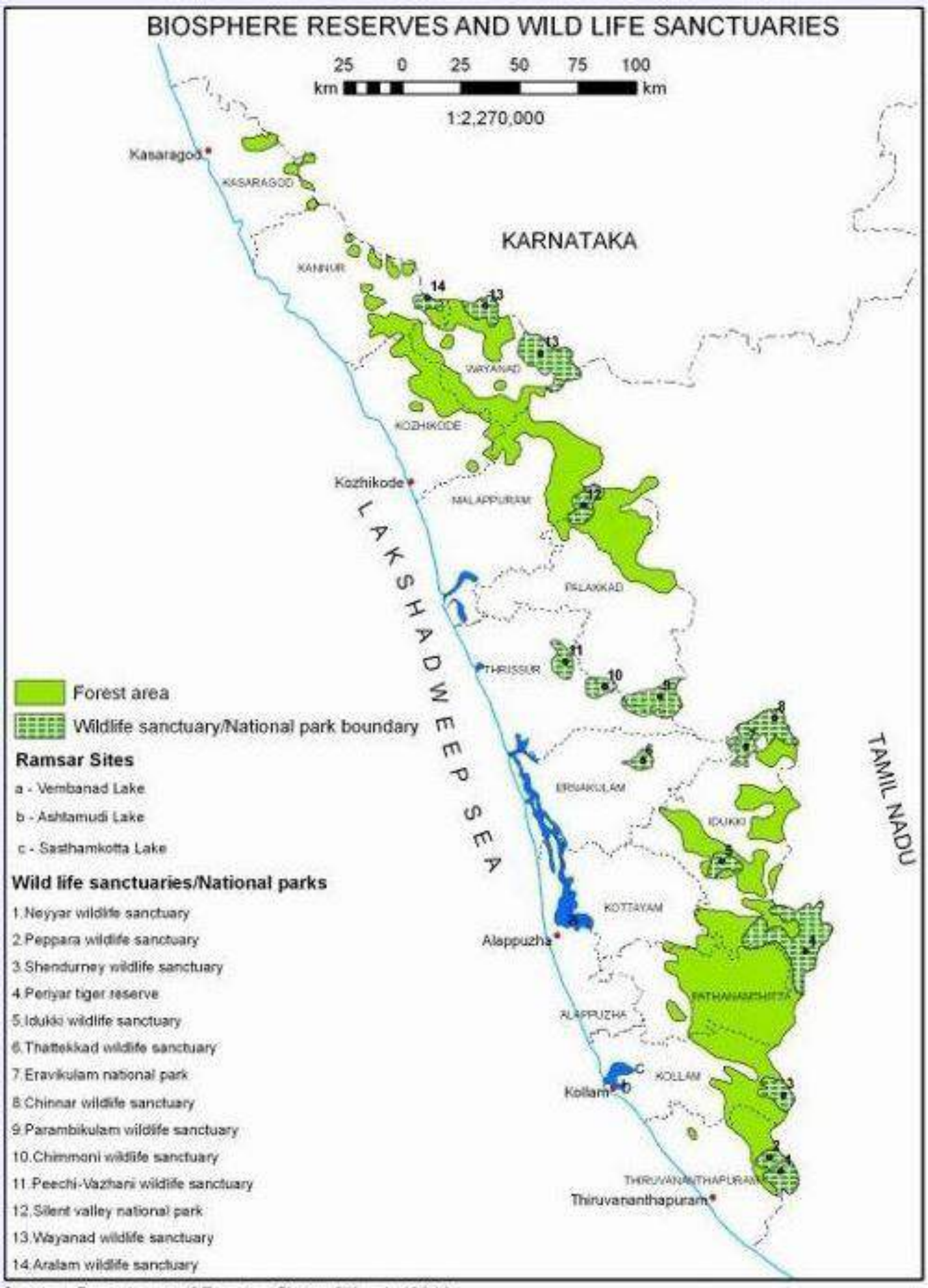


Figure 2: Geomorphology of Kottayam. (*Source: District Resource map, Kottayam district, Geological Survey of India)*



Source : Department of Forests, Govt. of Kerala, 2010

7 Soil types

The soil types occurring in Kottayam district can be broadly grouped into four types on the basis of their physico-chemical properties and morphological features. They are (a) Lateritic soil. (b) Riverine alluvium, (c) Brown hydromorphic, and (d) Forest loams.

lateritic soil

The lateritic soil is the pre-dominant soil type, which covers almost the entire midland areas of the Katya district. The surface soil is mostly reddish brown to yellowish red in colour and the texture ranges from gravelly loam to gravelly clay loam. Heavy rainfall and high temperature prevalent in the area are conducive to the process of formation of this soil type. It is well drained and the presence of organic content is low. This soil is poor in nitrogen, phosphorous and potassium. It is acidic in nature with a pH value ranging from 5.0 to 6.2.

Riverine alluvium

The occurrence of these soils is restricted along the river courses and their tributaries. They show wide variation in their physico-chemical properties depending on the nature of the alluvium that is deposited and the characteristics of the catchments area drained by the river. They are very deep soils with surface textures ranging from sandy loam to clay loam. These

soils are characterised by moderate amount of organic matter, nitrogen and potassium. Presence of mica flakes has been observed in the alluvial soils.

Brown hydromorphic soil

These soils are mostly confined to valley bottoms between undulating topography in the midland and in low-lying areas. They have been formed as a result of transportation and sedimentation of material from adjoining hill slopes and also through deposition by local streams. These soils are very deep and brownish in colour and exhibiting wide variation in physico-chemical properties and morphological features. The surface soil texture varies from sandy loam to clay. Their pH value ranges between 5.2 and 6.4 and are acidic in nature.

Forest loam

These soils are the products of weathering of crystalline rocks under forest cover. They are occurring in the eastern hilly areas. These are dark reddish brown to black in colour. The surface texture varies from loam to silt loam. They are characterised by a surface layer very rich in organic matter. Generally they are acidic, rich in nitrogen and their pH ranging from 5.5 to 6.3.

8 Groundwater scenario

Geohydrologically the area is divisible into six zones based on groundwater potential. Groundwater occurs under water table conditions in alluvium, laterites and weathered mantle of the crystalline rocks whereas in the deep fractured crystalline rocks the groundwater occurs under semi confined to confined conditions.

There are four types of hydrogeological units encountered in the district viz., Crystallines (shallow & deeper), Tertiary sediments, Laterites and Alluvium *(Figure 3)*.

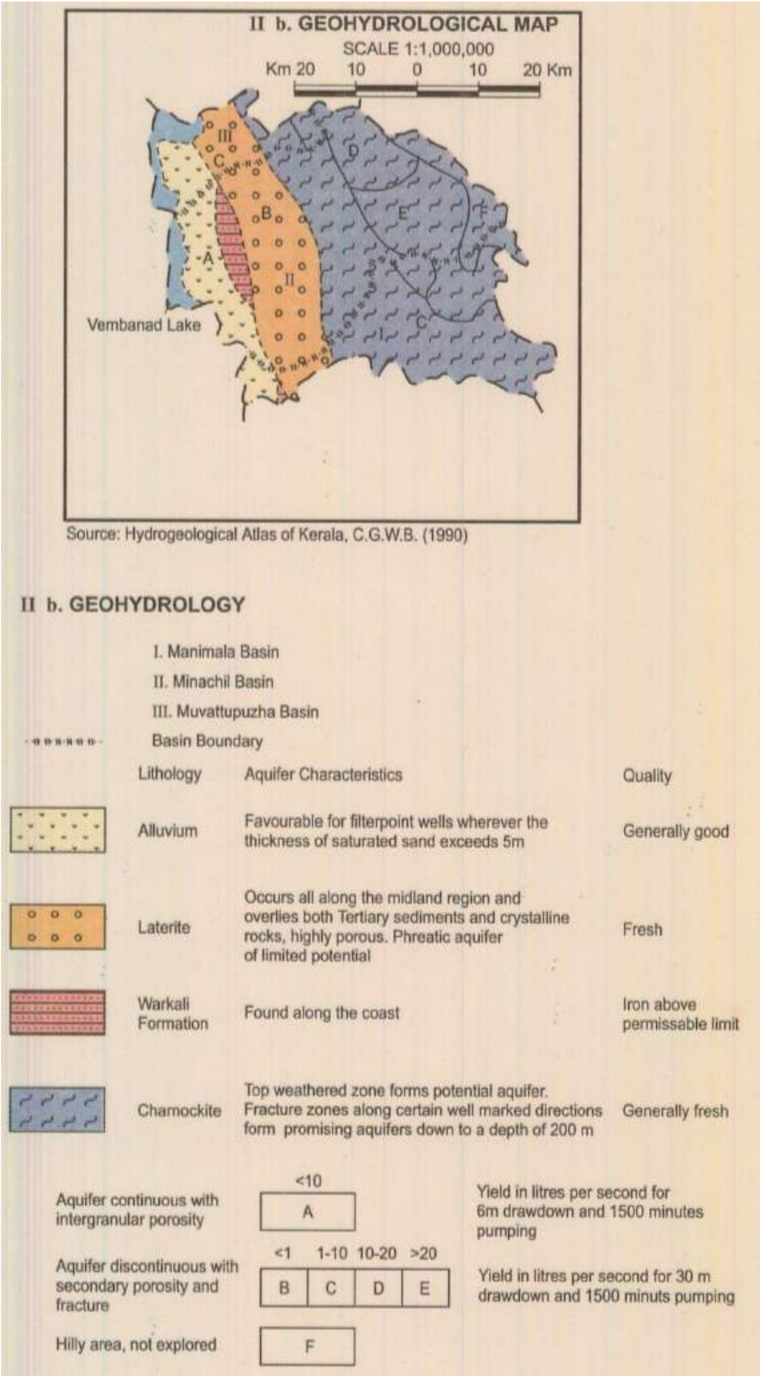


Figure 3: Geohydrology of Kottayam. (*Source: District Resource map, Kottayam district, Geological Survey of India)*

Natural hazards

The area comes under zone III and indicates moderate seismicity *(Figure 4)*.

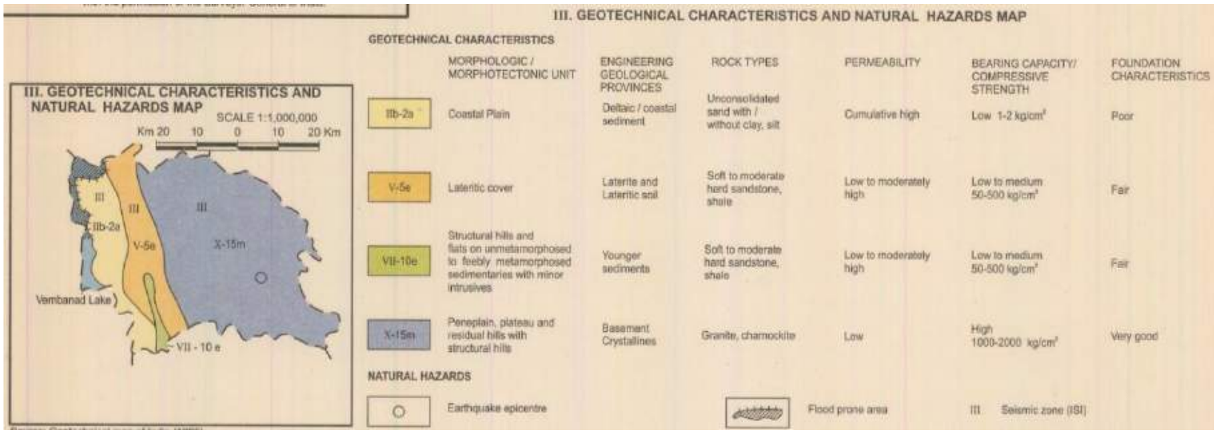


Figure 4: Geotechnical characteristics and natural hazards map of Kottayam. (*Source: District Resource map, Kottayam district, Geological Survey of India)*

9 Mineral Resources

9.1 Major minerals

The district has fairly good deposits of graphite, associated with the Khondalite Group. Main occurrences are around Aranikunnu, Paika and Chirakadavu. Minor, irregular, lenticular bands of magnetite quartzite are noticed in the vicinity of Aranikunnu and Kunnathumalai. The Vembanad Lake situated along the western margin of the district is known for good deposits of limeshell. Areas north of Thanneermukkom to Vaikom, Kulashekharamangalam, pathiramanal and Kumaragom are promising. Mining leases have been issued to co-operative societies for manually mining the lime shells.

9.2 Minor Minerals

9.2.1 Ordinary Earth

Ordinary earth is the common name used for the soils. Soil is made up of three main components – minerals that come from rocks below or nearby, organic matter which is the remains of plants and animals that use the soil, and the living organisms that reside in the soil. The proportion of each of these is important in determining the type of soil that is present. But other factors such as climate, vegetation, time, the surrounding terrain, and even human activities (eg. farming, grazing, gardening, landscaping, etc.), are also important in influencing how soil is formed and the types of soil that occur in a particular landscape. The formation of soils can be seen as a combination of the products of weathering, structural development of the soil, differentiation of that structure into horizons or layers, and lastly, of its movement or translocation. In fact, there are many ways in which soil may be transported away from the location where it was first formed. Soils represent one of the most complex and dynamic natural systems and are one of the three major natural resources, other than air and water. Knowledge of their chemical, physical and biological properties is a prerequisite both for sustaining the productivity of the land, e.g. agriculture, and for conservation purposes. Soil is an integral part of a terrestrial ecosystem and fulfills numerous functions including the capacity to generate biomass and the filtering or buffering activities between the atmosphere and the groundwater in the biosphere. Soils have many important functions. Perhaps the best appreciated is the function to support the growth of agricultural and horticultural crops. Soil is the mainstay of agriculture and horticulture, forming as it does the medium in which growth and ultimately the yield of food producing crops occurs. Farmers and gardeners have worked with their soils over many centuries to produce increasing amounts of food to keep pace with the needs of a burgeoning world population. The soil's natural cycles go a long way in ensuring that the soil can provide an adequate physical, chemical and biological medium for crop growth. As well as being essential to agriculture, horticulture, forestry and natural and semi-natural systems, soil also plays an important role for our fauna. The soil itself contains millions of organisms, the exact nature and role of which we are still trying to determine. Undoubtedly, the soil flora and fauna play a vital role in cycles which are fundamental to the ability of the soil to support natural and semi-natural vegetation without additions of fertilizer and other support mechanisms. They breakdown plant debris, take in components from the atmosphere, aerate the soil together with many other functions that make the soil such an important medium.

Classification of soils (ordinary earth) commonly found in the district

The topo-lithosequence along with variation in rainfall, temperature and alternate wet and dry conditions particularly from the western coast to high ranges in the east and swift flowing rivers lead to the development of different types of natural vegetation and soil. The soils can be broadly grouped into coastal alluvium, mixed alluvium, acid saline, kari, laterite, red, hill, black cotton and forest soils. Soil map given below may be referred to find out its occurrences.

Mixed Alluvium

These soils are developed from fluvial sediments of marine, lacustrine and riverine sediments or its combinations. They occur below 20m MSL in the lowland plains, basins, valleys and along the banks of major rivers. The mixed alluvium is mainly noticed close to coastal alluvium, Kuttanad and adjacent area and kole lands of Thrissur district. The soils are frequently flooded and submerged. The soils of depressions and broad valleys are subject to occasional flooding and stagnation. The ground water table of these soils is generally high and it reaches above the surface during rainy season. A wide variation in texture is noticed in these soils. Sandy clay loam to clay is the predominant texture. Sandy loam soils are also met with. Light grey to very dark brown is the common colour of the soil. Paddy, other annuals and seasonal crops like banana, tapioca and vegetables are grown here.

Laterite soil

Laterite and laterite soil are the weathering products of rock in which several course of weathering and mineral transformations take place. This involves removal of bases and substantial loss of combined silica of primary minerals. In laterite and laterite soils, over acidic rocks, induration and zonation are more pronounced. This induration is greater if the iron content is higher. These soils mainly occur in the midlands and part of lowlands at an elevation of 10 to 100m above MSL as a strip between the coastal belt and hilly mid-upland. The area comprises of mounds and low hills with gentle to steep slopes. Laterite soils are generally suitable for most of the dry land crops. It is mainly cultivated with coconut, arecanut, banana, tapioca, vegetables, yams, pepper, pineapple, fruit trees etc. The percentage of gravel content in the soil and reduced soil depth limits the choice of crops. In laterite outcropped area with shallow soils, only cashew can be grown with vegetables.

Hill Soil

The hill soils mostly occur above an elevation of 80m MSL. The area is hilly and has highly dissected denudational hills, elongated ridges, rocky cliffs and narrow valleys. The general slope range is above 10%. The texture of these soils generally ranges from loam to clay loam with average gravel content of 10 to 50%. In addition, stones and boulders are noticed in the subsoil. These soils have reddish brown to yellowish red/strong brown colour. Generally, increase in clay content is noticed down the profile. The depth of the soil varies considerably from 60 to 200 cm depending on erodability of soil and past erosion. These soils are mostly friable and subject to heavy soil erosion. The area is suitable for all dry land crops like rubber, coconut, arecanut and fruit trees based on the topography. Crops such as banana, pepper, pineapple, vegetables can be grown in foot slopes.

Forest Soil

These soils are developed from crystalline rocks of Archaean age under forest cover. They occur along the eastern part of the State, generally above an elevation of 300m above MSL. The area is hilly and mountainous with steep slopes, escarpments, elongated rocky summits and narrow 'V' shaped valleys. The depth of the soil varies considerably depending on erosion and vegetative cover. The soils are generally immature due to slow weathering process. Rocky outcrops and stones are noticed on the surface. Gneissic boulders under different stages of weathering are noticed in the subsoil. The texture of the soil ranges from sandy clay loam to clay with reddish brown to very dark brown colour. Forest trees, shrubs and grasses are grown here.

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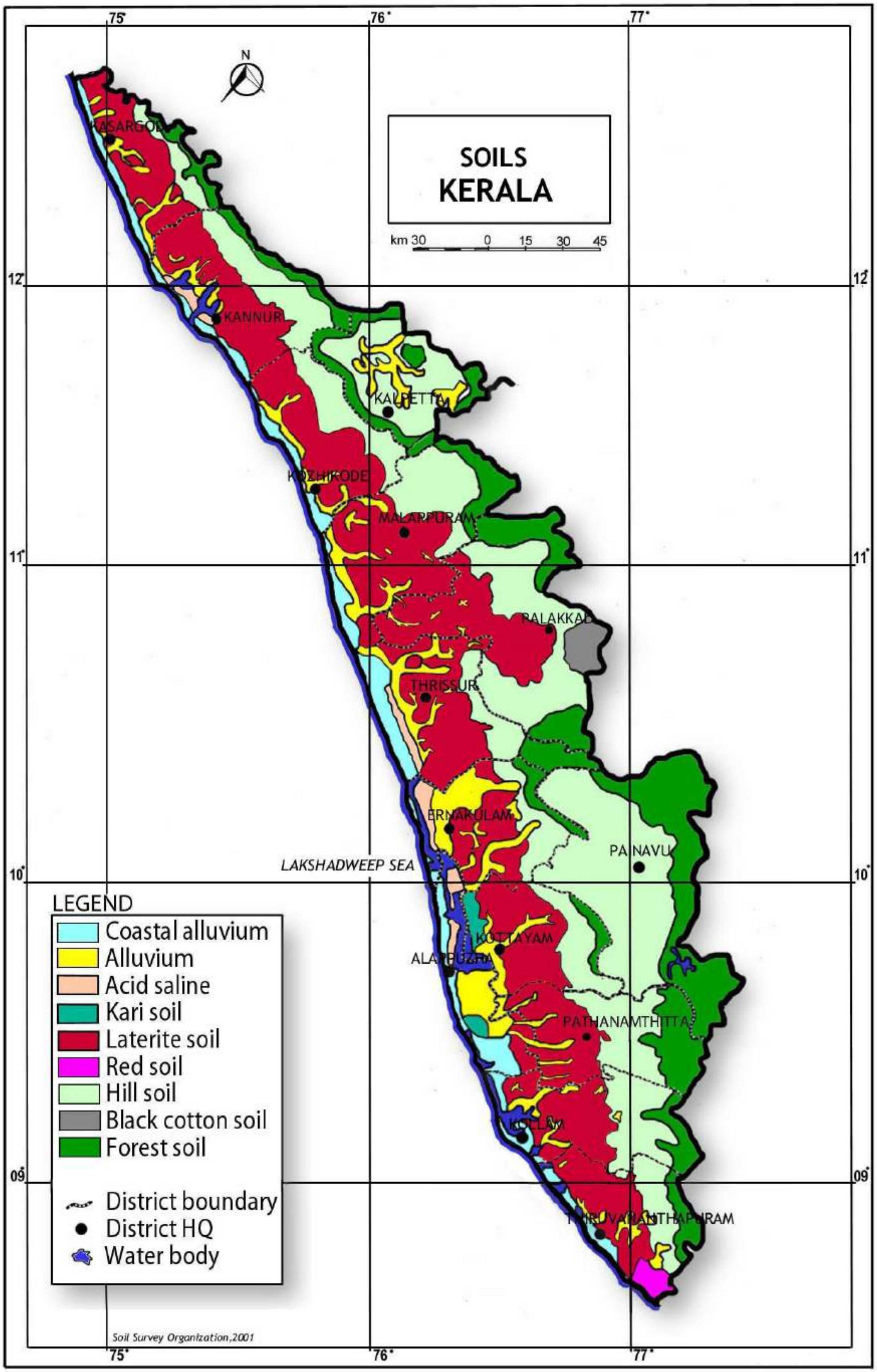
SOILS
KERALA
km 30 0 15 30 45
N
75°
76°
77°
12°
11°
10°
09°
KASARGOD
KANNUR
KALPETTA
KOZHIKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
PAINAVU
LAKSHADWEEP SEA
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
LEGEND
Coastal alluvium
Alluvium
Acid saline
Kari soil
Laterite soil
Red soil
Hill soil
Black cotton soil
Forest soil
District boundary
District HQ
Water body
Soil Survey Organization,2001

Mining of ordinary earth

Usually ordinary earth is mined for levelling of ground for construction of buildings. Since ordinary earth is very important to mankind, it is not wise to mine ordinary earth for filling purposes alone. However, for the construction of roads and other infrastructure, ordinary earth as mined after obtaining quarrying permit from the Department of Mining and Geology. Mining and transporting ordinary earth/soil without the permission of Department of Mining and Geology is an offence. Department issues pass for transport of ordinary earth. Dealer's license is not issued for ordinary earth as it is not considered as a mineral mined for commercial purposes.

9.2.2 Ordinary Clay (tile/brick clay)

Clays and clay minerals occur under a fairly limited range of geological conditions and are produced by weathering of silicate minerals containing calcium, magnesium, sodium, or potassium reacting with carbonic acid, carbonates, and bicarbonates. These soluble products are removed by ground water, while the remaining elements, aluminium, silicon, and oxygen combine with water to produce stable clay minerals. The environment of formation include soil horizons, continental and marine sediments, geothermal fields, volcanic deposits, and weathering rock formations. Extensive alteration of rocks to clay minerals can produce relatively pure clay deposits that are of economic interest. Clay formed at the site of the parent rock is known as primary or residual clay; the one carried away or transported and deposited elsewhere is known as secondary clay. For obvious reasons, the former is purer with less impurity (5%–15%), while the latter may contain mica, quartz, and iron oxide as impurities. Geological factors such as conditions at the time of deposition and post-depositional changes have an important influence on the properties of sediment.

Buildings and utensils made of clay date back to the earliest periods of man's civilized development, and the use of clay is intimately associated with his history. Tile and brick kilns are closely associated with Kerala's culture and traditional architecture, which is continued in modern buildings as well.

In Kerala, tile/brick clay occurs in the wetlands/paddy fields in the lowlands and midlands. The clay extracted is used for a variety of purposes such as manufacture of roofing, flooring, and decorative tiles, wire cut (mechanically made) and ordinary bricks (manually made), and pottery wares. Studies carried out in clay mining areas of Kerala have proved that unprecedented increase in the development needs of the state and the subsequent increase in the resource extraction scenarios, especially that of clay mining, have led to rapid degradation of the wetlands (paddy fields), which is significantly reflected in the declining agricultural productivity of the state. Mining of clays several meters below the prescribed levels, water draining from the unaffected paddy lands into the adjacent mine pits, and subsequent pumping of water for further mining impose severe problems on the hydrological regime, lowering the water table and creating severe water shortage problems in the mining areas. The additional expenditure incurred to meet the freshwater requirements of the people living in areas adjacent to mining sites is increasing year after year, which undermines the short-term economic benefits of resource extraction.

Tile and brick clay mining and its processing provide employment opportunities to a considerable section of the people in the midland and lowland areas of Kerala. Adding to this, thousands of labourers in the construction industry also indirectly depend on the products manufactured from these clays. Under these circumstances and also with respect to the demand incurred, complete restriction of extraction activities does not prove to be viable.

In the study report published by National Center for Earth Science Studies on the impact of clay mining, following recommendations were given with respect to tile/brick clay mining: "It is of imminent importance to regulate random mining from the paddy fields/wetlands of Kerala by allowing only location-specific resource extraction under well-conceived guidelines. It is also crucial to limit the extraction of tile and brick clays to meet indigenous and local demand only. This is to save the prime agricultural land and also to increase the rice production in the area. The depth of mining should be demarcated so as to regulate mining with respect to the water table condition in the summer season. Also, adequate measures are to be taken to regenerate the natural ground water table using the stored water in the clay mine pits for irrigating the agricultural crops of the hinterland areas. This will enhance the net agricultural productivity of the area in addition to saturating the aquifer systems in the hinterlands. Awareness creation among the public about the adversities of clay mining and as well as the economic benefits of using clay bricks for construction purposes will serve in the protection of our wetlands/paddy fields. Recycling of building materials should also be considered in order to reduce mining of tile and brick clays. The abandoned clay mine areas left behind as fallow lands or water logged areas can be used for productive purposes such as fish farm ponds or irrigation ponds that promise some utility to the society. Also, suitable guidelines should be framed to streamline the tile and brick clay mining activities of the state on an eco-friendly basis."

The Kerala Conservation of Paddy Land and Wetland Act, 2008 and Rules made thereunder which was enacted for conservation of paddy land and wetlands of Kerala imposes restrictions in mining of tile/brick clays in such areas. The said Act and Rules are implemented by Revenue Department. In addition, Government have setup District Expert Committee to monitor and control the mining activities of ordinary clay. In Kerala Minor Mineral Concession Rules 2015, it is mandated that No Objection Certificate from the District Collector concerned, based on the recommendation of the District Expert Committee constituted by the Government in this regard, is to be produced by the applicant in the case of application for extraction of ordinary clay. In addition, Bank guarantee from any Nationalized or Scheduled Bank at the rate of Rs. 300/- (Rupees three hundred only) per cubic metre for the purpose of reclamation of pits that will be formed after quarrying in the area permitted, in respect of application for extraction of ordinary clay. Based on the request of the entrepreneurs working in tile/brick clay based industry, Government have instructed the Department of Mining and Geology to carry out survey to identify the mineable tile/brick clay deposits of Kerala and the work in this respect is progressing.

The Quaternary alluvium in places like Kidangur, Karinthura and Arumanur has good quality tile and brick clay deposits.

9.2.3 Ordinary Sand

In Kerala Minor Mineral Concession Rules, 2015, the ordinary sand is defined as sand used for non-industrial purpose. This includes both river sand and sand excavated from inland areas like palaeo-channels. Since a separate Act has been enacted by Government of Kerala namely, The Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001 (hereafter referred to as Sand Act, 2001) and since the mining of river sand is controlled by Revenue Department by virtue of the powers conferred by the said Act and the Rules made thereunder, the Department of Mining and Geology now regulates the mining of sand which do not comes under the purview of Sand Act, 2001.

The ordinary sand (other than river sand) occurs in the palaeo-channels. The word palaeo-channel is formed from the words “palaeo” or “old,” and channel; i.e., a palaeo-channel is an old channel. Palaeo-channels are deposits of unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive river and stream channel systems. These are typical riverine geomorphic features in a location representing drainage streams, rivers, rivulets which were flowing either ephemeral or perennial during the past time and now stands either buried or lost or shifted due to tectonic, geomorphologic, anthropogenic process/activities, as well as climatic changes. When a channel ceases to be part of an active river system, it becomes a palaeo-channel. In order to tap the ordinary sand occurring in palaeo-channels, the Department entrusted the study of identification of palaeo-channels in major river basins of Kerala to Geological Survey of India (GSI). GSI resorted to remote sensing studies using satellite imageries and delineated some of the palaeo-channels. However, since such deposits falls in paddy land/wetlands of Kerala, it is difficult to extract such sand on account of restrictions imposed by various Acts and Rules.

The Kerala Conservation of Paddy Land and Wetland Act, 2008 and Rules made thereunder which was enacted for conservation of paddy land and wetlands of Kerala imposes restrictions in mining of ordinary sands occurring in wetlands and paddy fields. The said Act and Rules are implemented by Revenue Department. In addition, Government have setup District Expert Committee to monitor and control the mining activities of ordinary sand. In Kerala Minor Mineral Concession Rules 2015, it is mandated that No Objection Certificate from the District Collector concerned, based on the recommendation of the District Expert Committee constituted by the Government in this regard, is to be produced by the applicant in the case of application for extraction of ordinary sand. In addition, Bank guarantee from any Nationalized or Scheduled Bank at the rate of Rs. 300 (Rupees three hundred only) per cubic metre for the purpose of reclamation of pits that will be formed after quarrying in the area permitted, in respect of application for extraction of ordinary sand.

The mining of ordinary sand from palaeo-channels also case some environmental concerns. Since sand is a good aquifer, the mining of aquifer system poses threat to ground water availability in surrounding areas. However in certain cases, the mining of such sand from paddy lands increase the productivity of paddy as excess sand in the paddy lands are not good for paddy.

In Kerala, due to shortage of river sand and ordinary sand occurring in palaeo-channels, the construction industry now uses manufactured sand obtained by crushing of crystalline rocks. A number of palaeo-channels are present in Kottayam district where mining of ordinary sand is carried out especially in Vaikom Taluk

It may be noted that since the Revenue Department is taking care of all types of mining activities related to river sand and since sand auditing and other studies are carried out under the aegis of the Revenue Department, this report shall not be used for the purpose of obtaining prior environmental clearance for mining of river sand.

9.2.4 Laterite

Laterite is a soil and rock type rich in iron and aluminium, and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They develop by intensive and long-lasting weathering of the underlying parent rock. Tropical weathering is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land area containing laterites is between the tropics of Cancer and Capricorn.

Angadipuram Laterite is a National Geological Monument identified in Angadipuram town in Malappuram district. The special significance of Angadipuram to laterites is that it was here that Dr. Francis Buchanan-Hamilton, a professional surgeon, gave the first account of this rock type, in his report of 1807, as "indurated clay", ideally suited for building construction. This formation falls outside the general classification of rocks namely, the igneous, metamorphic, or sedimentary rocks but is an exclusively "sedimentary residual product". It has a generally pitted and porous appearance. The name laterite was first coined in India, by Buchanan and its etymology is traced to the Latin word "letritis" that means bricks. This exceptional formation is found above parent rock types of various composition namely, charnockite, leptynite, anorthosite and gabbro in Kerala. The laterite profiles in different types of rocks vary depending on the composition of parent rock. For example in Charnockites, the thickness of the profile ranges from 2 m to 10 m with humus zone on the top with thin pebbly zone (with ferruginous pellets in clayey matrix), underlain by vermicular laterite with tubular cavities of various shapes and size filled with kaolinitic clay. This is followed by thin layer of lithomarge. Further below completely weathered, partly weathered or fresh parent rock occur. In some places one can see hard duricrust at the top.

The mineralogical study of laterites reveals that all the silicate minerals have been transformed to a mixture of goethite, hematite and kaolinite in laterite samples developed over charnockite. Further studies revealed that pyroxenes have been altered to goethite while feldspars gave rise to kaolinite. Quartz is cracked, eroded and disintegrated. Monazite and Zircons are found as accessory minerals.

Laterite and bauxite show a tendency to occur together. Aluminous laterites and ferruginous bauxites are quite common. The most common impurity in both is silica. Laterite gradually passes into bauxite with decrease in iron oxide and increase in aluminium oxide. The laterite deposits may be described on the basis of the dominant extractable minerals in it: (i) aluminous laterite (bauxite), (ii) ferruginous laterite (iron ore), (iii) manganiferous laterite (manganese ore), (iv) nickeliferous laterite (nickel ore) and (v) chromiferous laterite (chrome ore). Laterite with Fe_2O_3:Al_2O_3ratio more than one, and SiO_2:Fe_2O_3 ratio less than 1.33 is termed as ferruginous laterite, while that having Fe_2O_3:Al_2O_3 ratio less than one and SiO_2:Al_2O_3 ratio less than 1.33 is termed as aluminous laterite. Laterite can be considered as poly-metallic ore as it is not only the essential repository for aluminium, but also a source of iron, manganese, nickel and chromium. Furthermore, it is the home for several trace elements like gallium and vanadium which can be extracted as by-products. In Kerala laterites are extracted as building stones which are used for construction of building. Laterite as a building stone possesses one advantage that it is soft when quarried and can be easily cut and dressed into blocks and bricks which on exposure to air become hard. In addition, laterite (aluminous laterite) is extracted for industrial purposes (for eg. Cement industry). In addition to aluminous laterite, bauxites are also mined in Kerala. Hence, while granting mineral concession for laterite it is necessary to carry out the chemical analysis to establish whether the mineral is bauxite or aluminous laterite.

9.2.5 Granite Dimension Stone and Granite (building stone)

For administrative purpose the hard crystalline rocks which do not have any economic minerals are classified as granite dimension stones and granite (building stones). The definition given in the Kerala Minor Mineral Concession Rules 2015 is as follows:-

'Granite dimension stones include all types of granites, dolerite,charnockite, leptynite and other crystalline rocks of Acid, Intermediate, basic and ultra basic groups of igneous and metamorphic origin which are suitable for cutting to pre-determined sizes, polishing, carving and amenable for making value-added products in decorative monumental and ornamental fields of industry as a high-value item. Granite (building stone) include all those group of rocks specified above which are not suitable for using as dimension stones as specified therein, but can be used as ordinary building stones, road metal, rubble and ballasts after breaking into irregular pieces by blasting or otherwise as low value item. The Rules insists that the rocks having the quality of granite dimension stone shall not be quarried for granite building stone as these two types of rocks have different values/royalties'.

The granite dimension stone of Kottayam belongs to the following geologic setting:-

- Charnockite-Khondalite belt (colour ranges from pale green with mottled red, bluish green with cordierite, deep dark green, greyish white)
- Dolerite-Gabbro dykes, Proterozoic intrusive hypabasal dyke swarms (colour: dark greenish blue, black and dark gray with black spots).

All Archean and Proterozoic rocks of Kerala (refer section on Geology of Kerala) which are not listed above as granite dimension stone falls under the category of granite (building stone) and are found below ordinary earth/laterites/and other sedimentary rocks. In some cases such rocks are exposed as hillocks without any overburden.

9.2.6 Lime shell

In Kerala, the lime shell occurs in the backwaters/estuaries, river mouths and lagoons along the coastal tract. By far the largest reserves of lime shell are known to occur in Vembanad lake and adjoining portions comprising parts of Alappuzha, Ernakulam and Kottayam Districts. Lime shell is being mined in Kottayam district.

10 Details of minor mineral concessions

Permission for mining will be granted on case to case basis on ascertaining the availability at the site and only if conditions stipulated in the KMMC Rules 2015 are satisfied (The reader may refer the KMMC Rules 2015 available in the website www.dmg.kerala.gov.in for more details in this regard). The concession will be granted only if other statutory licenses like Environmental Clearance, Explosive Licence, consent to operate issued by State Pollution Control Board, NOC issued by Revenue Department (as the case may be), Dangerous and Offensive Trade Licence issued by Local Self Government Institutions, NOC related to Coastal Regulation Zone (as the case may be), NOC issued by Forest (as the case may be) etc. The mineral concession will not be granted in the ecologically sensitive areas, ecological fragile zones etc. The details of valid minor mineral concessions issued by the Department are given in the tables below:-

Table 1: Details of revenue collection for the period 2014-'15, 2015-'16 and 2016-'17

2014-'15						
	Granite Building Stone	**Laterite**	**Ordinary Sand**	**Brick Clay**	**Ordinary Earth**	**Total**
April	289160		50000		348240	**687400**
May	705000	30000	77550		98280	**910830**
June	280000	10000	55830			**345830**
July	15000		40000		20000	**75000**
august	238445		58735		465738	**762918**
Sep	275000		62500		1405766	**1743266**
Octo	440000		150000		950925	**1540925**
Nov	220000		40000		2001164	2261164
Dece	100000		15000		3384002	**3499002**
January ----15					3378711	**3378711**
February					2530625	**2530625**
March	10545063				3467331	**14012394**
Total	**13107668**	**40000**	**549615**		**18050782**	**31,748,065**
2015-'16						
April	685300		66920		3285651	**4,037,871**
May	742039				3627321	**4,369,360**
June	2869623				950182	**3,819,805**
July	2730293				298900	**3,029,193**
august	1157507				232760	**1,390,267**

Sep	4139379				533144	**4,672,523**
Octo	3971985	75000			644040	**4,691,025**
Nov	1540438			70410	650020	2260868
Dece	2324690				1070098	**3,394,788**
January ----16	972560	108610			1731880	**2813050**
February	153800			480012	2191690	**2825502**
March	7334017	75000		860,000	2349190	**10,618,207**
Total	**28621631**	**258610**	**66920**	**1,410,422**	**17564876**	**47,922,459**
2016-'17						
April	4414300		288000	240000	2691620	**7,633,920**
May	1645061	75000		80000	1989080	**3,789,141**
June	974730				385400	**1,360,130**
July	2442320				938740	**3,381,060**
august	558556	48000			1514820	**2,121,376**
Sep	6664000	41000			2441600	**9146600**
Octo	1710688	5760		6368	2352080	**4,074,896**
Total	**18409655**	**169760**	**288000**	**326,368**	**12313340**	**31,507,123**

Table 2b: List of Quarrying Permit granted under CRPS for Granite Building Stone during 2016-'17

Sl. No	Name and address of CRPS Holders	Taluk	Village	Sy.No	Area (in Ares)	Validity
1	P.S. Sebastian, Pamplaniyil, Teekoy.P.O.,	Meenachil	Teekoy	175/2	17.37	12.01.2017
2	A.C. Baby, Cheruvankalayil, Memuri.P.O.,	Meenachil	Kuravilangadu	02-02-01	03 Ares	12.01.2017
3	K.V. Paul, Kandamkettiyil, Kalathoor.P.O.,	Meenachil	Kuravilangadu	248/2	4 Ares	14.01.2017
4	V.T.Umman, Vadakkanmannoor.P.O., Areeparambu.P.O.,	Kottayam	Pampady	115/10, 122/1-10	5.15	17.01.2017
5	A.V. Joseph, Ambazhathunkal, Poonjar South.P.O., Kottayam	Meenachil	Erattupetta	23/2	9	17.01.20117
6	Joseph Ulahanna, Tharamangalathu, Ettumanoor.P.O., Kottayam	Meenachil	Kanakkary	81/4	8.92	19.01.2017
7	P.P. Sebastian, Parayidathil, Koruthodu.P.O., Mundakkayam	Kanjirappally	Koruthodu	275/5-1	3.74	19.01.2017
8	K.N. Balakrishnan, Kunnel, Velloor.P.O.,	Kanjirappally	Erumely	45/2, 46	9.8	31.03.2016
9	Sneha Jose, Poovathinal, Amparanirappel.P.O., Kottayam	Meenachil	Kondoor	136/2	19.8	02.03.2017
10	Dominic Joseph, Valumannel, Anakkallu.P.O., Kanjirappally.	Kanjirappally	Kanjirappally	119/1	9.79	31.03.2016
11	C.J. Sunny, Cheramperil, Edakadathy.P.O.,	Kanjirappally	Erumely South	120/1-8	9	03.03.2017
12	P.T. Georgekutty, Kavitha Industries, Kangazha.P.O.,	Changanacherry	Kangazha	70/3	4.28	08.03.2017
13	Josekutty Philip, Veluthedathukattil, Ambaranirappel.P.O.,	Meenachil	Kondoor	133/3-1-1	4.05	08.03.2017
14	Jacob George, Mecattukummannuparambil, Teekoy.P.O.,	Meenachil	Thalanadu	96/1-1	15	15.03.2017
15	Jose Avirachan, Mattathil, Njeezhoor.P.O.,	Meenachil	Kadanadu	445/3-4	4 Ares	
16	Shri. P.C. Jomon, Parayil, Uzhavoor East.P.O.,	Meenachil	Vellilapally	202/1	19.95	05.04.17
17	Shri. Augustin George, Nellamthadom, Kanajirappally.P.O., Kottayam.	Kanjirappally	Kanjirappally	264/3-1	3.96 Ares	05.04.2017

18	P.M. Cherian, Palakunnel, Amanakara.P.O., Ramapuram	Meenachil	Vellilappally	Sy7. No. 8/1	13.93	10.04.2017
19	Jose Joseph, M/s. Silver Rubbles & Quarry Unit, Vellimoozhiyil, Payappar.P.O.,	Meenachil	Lalam	410/1-1, 5,6	49.77 Ares	10.04.2017
20	Joice Sebastian, Kochumuriyil, Manimala.P.O.,	Changanacherry	Vellavoor	233/5-1, 233/5	18.7	19.04.2017
21	Sinu Varghese, Manyathu, Kangazha.P.O.,	Changanacherry	Kangazha	70/6,	9.25	20.04.2017
22	Jerry Jacob, Paripeettathottu, Nariyanani.P.O.,	Kanjirappally	Edakunnam	176/7, 8,9,10	12.6	20.04.2017
23	Biju Varghese, Punnathanathu, Ramapuram.P.O.,	Meenachil	Ramapuram	51/2-1	9.8	26.04.2017
24	K.J. Thomas, New Mary Matha Metal Crusher Unit, Poulickal Kavala.P.O.,	Kottayam	Kooroppada	224/2, 2-3	8.09	27.02.2017
25	Alex Augustin, Chokkattu, Kadanadu.P.o.,	Meenachil	Vellilapally	41/1-2	19	03.05.2017
26	Joice Greorge, Valiyaprambil Bharangnaganam.P.O.,	Meenachil	Bharananaganam	287/4	9.09	12.05.2017
27	George Joseph, Kozhuppamkutty, Marangoly.P.O.,	Vaikom	Njeezhoor	132/6	29.79	12.05.2017
28	Chacko Thommy, Cheruvankalayil, Memuri.P.O.,	Meenachil	Kuravilangadu	1/1A, 2/2	8.5	17.05.2017
29	Rajesh Mathew, Puthenpurackal, Pattithanam.P.O.,	Meenachil	Kanakkary	201/2, 201/4	9	19.05.2017
30	Rejimon, Arackal, Irumpayam.P.o., Vaikom	Vaikom	Vadayar	467/5	9.81	23.05.2017
31	George Joseph, Thenganakunnel, Moonnilavu.P.O.,	Meenachil	Moonnilavu	149/1	9.61	23.05.2017
32	Thressiamma Thomas, GramaSree Rural Project Centre, Erathuvadakara.P.O., Changanacherry	Changanacherry	Vellavoor	122/5	4.05	23.05.2017
33	M.P. Thomas, Puthiyaparambil Enterprises, Nedumkunnam.P.O.,	Changanacherry	Nedumkunnam	33/2-1, 27/6, 24/2/14	39.8	26.05.2017
34	Justin Joseph, Vallikkattil, Ettumanoor.P.O.,	Kottayam	Ettumanoor	268/6	11.2	02.06.2017
35	Reji Abraham, Puttananickal House, Veliyannoor.P.O.,	Meenachil	Veliyannoor	299/14	4.56	08.06.2017

36	Salu.V. Jose, Vadakkemangalathu, Marangattupilly.P.O.,	Meenachil	Vallichaira	243/1	19.1	21.06.2017
37	P.M. Joseph, Thekkanattu, Ettumanoor.P.o.,	Kottayam	Ettumanoor	424/9, 424/10	18.9	26.06.2017
38	P.C. Vasudevan Nair, pulimoottil, Mattakkara.P.O., Kottayam	Kottayam	Akalakunnam	207/5-1, 207/5-25	8	03.07.2017
39	Shaji Thomas, Melethiruvizha, Manalikkara.P.O., Kanyakumari.	Changanacherry	Nedumkunnam	24/2-8	30	03.07.2017
40	P.T. Georgekutty, Kavitha Industries, Kangazha.P.O., Changanacherry	Changanacherry	Kangazha	72/11	9.1	07.07.2017
41	Augustin George, Nellamthadom, Kanjirappally.P.O.,	Kanjirappally	Koovappally	103	9	10.07.20178
42	K.J. Thomas kutty, Kannathanathu, (Rejency Granaites)Vadasserykkara.P.o., Pathanamthitta.	Changanacherry	Vellavoor	232/5-1, 232/5-2	18.22	10.07.2017
43	K.J. Thomas, New Mary Matha Metal Crusher Unit, Poulickal Kavala.P.O.,	Kottayam	Kooroppada	228/5	8.55	10.07.2017
44	Suraj Thomas, Vettikkattuparayil House, Neendoor.P.O.,	Meenachil	Kanakkary	79/9, 79/6, 79/6-1	10	21.07.2017
45	Juby Stiji, Ponnammakkal House, Kanakkary.P.O.,	Meenachil	Kanakkary	91/1, 91/10, 91/13	18	21.07.2017
46	K.M. George, Kizhavallyvadakkethil, Manjoor.P.O., Kottayam	Meenachil	Kanakkary	77/4	8	28.07.2017
47	Sijo Kurian, Nelluvelil, Thalanadu.P.O.,	Meenachil	Thalanadu	90/2, 90/4	5	28.09.2017
48	T.S. Shylesan, Thavalappara, Kanam.P.O.,	Kanjirappally	Erumely North	48/2	19.53	04.10.2016
49	M.C. Joseph, Madickankal, Thalunkal.P.O.,	Kanjirappally	Mundakkkayam	68/1-2	4.05	06.10.2017
50	Martin Joseph, Karingada, Nedumkunnam.P.O.,	Changanacherry	Nedumkunnam	24/2-3	43.6	16.10.2017
51	Suraj Thomas, Mg. Partner, Seven Star Granites, Manimala.P.o.,	Kanjirappally	Manimala	219/2	9	16.10.2017
52	M.V. Roy, Muttathupara, Kalathoorprayar.P.O.,	Changanacherry	Vellavoor	180/2-1	6	17.10.2017

53	M/s. A.J. Granites, Poochakkeril Buildings, Kuzhimattom.P.O.,	Changanacherry	Nedumkunnam	24/2-10	38.27	18.10.2017
54	James Sebastian, Anakkanattu, Marangattupally.P.O.,	Meenachil	Kurichithanam	374/1A,1	4.2	21.10.2017
55	C.N. Gopalan Nair, Myladivadakkethil, Velloor.P.o.,	Kottayam	Pampady	122/3-1	9	30.10.2017
56	Shibu Koshy, Variamparambil, Velloor.P.O.,	Kottayam	Pampady	105/2(part)	7.5	30.10.2017
57	Rajesh Roy, Mg. Partner, Universal Granaites, Poovathunkal, Alanadu.P.O.,	Meenachil	Kondoor	121/1	29.4	01.11.2017
58	A.S. Sudharsanan, Iranikkattu House, Kunnappally, Peruva.P.O.,	Vaikom	Mundakkkayam	199/1A5	3	08.11.2017
59	Biju.K. Joseph, Kurichathu (Karimundackal), Palai.P.O.,	Meenachil	Kurichithanam	381/13, 381/15	19.6	15.11.2017
60	A.B. Prasad, Edattu House, Thampalakkad.P.O.,	Kanjirappally	Kanjirappally	197/5-4	9.6	17.11.2017
61	V.M. Mathai, Vettukallel, Uzhavoor.P.O.,	Meenachil	Uzhavoor	156/1	17.76	17.11.2016
62	P.S. Sebastian, Pamplaniyil, Teekoy.P.O.,	Meenachil	Teekoy	175/1, 175/2	36	17.11.2017
63	P.S. Sebastian, Pamplaniyil, Teekoy.P.O.,	Meenachil	Teekoy	170/1, 170/4, 175/1	36	17.11.2017
64	K.V. Joseph, Kulathunkal, Poonjar.P.O.,	Meenachil	Kondoor	364/2	9.85	28.11.2017
65	P.S. Rajeev, Planthottathil, Palampra.P.O.,	Kanjirappally	Koovappally	102	4.8	29.11.2017
66	C.J. Sebastian, Chelattu, Karinilam.P.O., Mundakkayam	Kanjirappally	Mundakkkayam	321/3	9.6	01.12.2017
67	M.N. Raju, Sree Narayana Metal Cusher Unit, Mavalathukuzhiyil, Peruva.P.O.,	Vaikom	Mulakkulam	223/2	9.69	06.12.2017
68	M.S. Sreedharan, Maruvathanakal, Thidanadu.P.O.,	Meenachil	Kondoor	116/1-2	8.5	06.12.2016
69	Rajesh Roy, Mg. Partner, Universal Granites, Poovathinkal, Alanadu.P.O.,	Meenachil	Bharananganam	270	16.16	06.12.2017
70	Jossy Joseph, Thekkekara, Poovatholy.P.O.,	Kanjirappally	Manimala	222/5-3, 222/6, 221/6-1, 221/6	49.1	06.12.2017

71	Ebin Jose, Nanjilathu, Arumanoor.P.O.,	Meenachil	Meenachil	460/5, 461/5, 461/5-1	12.99	31.01.2018

Table 2c: List of Quarrying Permit granted for Granite Building Stone

Sl. No	Name and address of QP holders	Taluk	Village	Sy.Nos	Area	Validity
1	Joshy Josua,Mg. Partner P.V Granites Moonilvu P.O	Meenachil	Moonilavu	24,24/1,2,3	54.55Ares	31.03.2017
2	M.A. Nalinakshan Nair, Mg. Partner, Mankombu Granites, Moonnilavu.P.O.,	Meenachil	Moonilavu	46/1, 46/1-1, 46/1-2, 46/1-3	48	26.07.2017
3	Sinil.V. Mathew, Varakukalaparambil, Aruvithura.P.O.,	Kanjirappally	Edakkunnam	12/1, 12/2, 11/1-1	90	16.08.2017
4	Ebin Jose,Nanjilathu House, Arumanoor P.O	Meenachil	Meenachil	459/1,2,461/4-1	0.9840 Ha	06.03.2017
5	Jose Joseph,Vellimoozhiyil Payappar P.O Pala	Meenachil	Lalam	410/1-1,5,6	92.51 Ares	31.03.2016

Table 2d: List of Quarrying Permit granted under CRPS for Laterite Building Stone during 2016-‘17

Sl. No	Name and address of CRPS Holders	Taluk	Village	Sy. No	Area	Validity	Cont. No.
1	K.Y. George, Kochuplamveettil, Maravanthuruthu.P.O., Vaikom.	Vaikom	Chempu	171/2-1	8.09	26.01.2017	9447139042
2	Rejimon, Arackal, Irumbayam.	Vaikom	Vadayar	467/5	9.81	23.05.2017	9947865893
3	Selinamma, Kalappuramyalil, Mannar.P.O.,	Vaikom	Vadayar	404/1	8.09	26.05.2017	9995136077
4	Ulahannan Chacko, Mulayamkottu puthenkulangara, Karikodu.P.o., Vaikom	Vaikom	Mulakkulam	189/4A	5.35	20.10.2017	447569074
5	Shajimon.A.V., Arackal, Erumbayam.P.O.,	Vaikom	Mulakkulam	251/1A11	9.76	01.11.2017	9447414223

Table 2e: List of Quarrying Permit granted under CRPS for Ordinary earth during 2016-‘17

Sl. No	Name and address of CRPS Holders	Taluk	Village	Sy. No	Area	Validity
1	P.M. Chandran, Secretary, S.N.S.E. Trust, Madhumoola.P.O., Changanacherry.	Changnacherry	Nedumkunnam	256/2, 256/4	26.33	23.01.2017
2	M/s. Palathra Constructions (P) Ltd., Chengalam East.P.O., Kottayam	Kottayam	Chengalam East	402/1	18.6	31.03.2017
3	Baby Nicolas, Kalloor, Thekkethukavala.P.O.,	Kanjirappally	Chirakkadavu	39/3, 39/4	21	15.02.2017
4	Sobhanakumary, Karikombil House, Kadayanikkad.P.O.,	Changnacherry	Vellavoor	192/3	4.38	25.01.2017
5	Trusty, St. Antony's Church, Mundathanam.P.O.,	Changnacherry	Kangazha	364/3	8.1	28.02.2017
6	Ahalya Ammal, Valliyil Madathil, Velloor.P.o., Kottayam.	Vaikom	Velloor	557/1B	9	04.02.2017
7	James Jacob, Karottumundackal, Perumbaickadu.P.O.,	Kottayam	Perumbaickad	297/5/5-2, 298/4	15.2	08.03.2017

Table 2f: List of Quarrying Permit granted for Granite Building Stone aggregates during 2016-'17

Sl. No.	Name and address of CRPS Holders	Taluk	Village	Sy. No	Area	Validity
1	T.T. Thomas, Thottupuram, Manalunkal.P.O.,	Kottayam	Akalakunnam	140/2-1	4.08	03.05.2017

Table 2g: List of Quarrying Permit granted for Brick clay during 2016-'17

Sl. No.	Name and adress of CRPS Holders	Taluk	Village	Sy.No	Area (in Ares)	Validity
1	Indira Dileepkumar, Thekkumcheril, Kidangoor(S).P.O.,	Meenachil	Puliyannoor	426/3, 426/3A	6	01.07.2016
2	Sony George, Vaithundathil, Punnathura West.P.O., Kottayam	Kottayam	Ayarkunnam	126/1	20.25	20.07.2016
3	P.B. Siby, Padickaveettil, Cherpunkal.P.O.,Kottayam	Meenachil	Puliyannoor	424/6-2A	5	27.07.2016
4	Thomas Mathew, Maraangattil House, Kongandoor.P.O.,	Kottayam	Ayarkunnam	66/11, 66/12	16	13.08.2016
5	T.K. Binoy, Thottathil, Mevelloor.P.O.,	Vaikom	Mulakkulam	416/1B3, 416/1A7, 1A, 1B4	20	11.06.2016

Table 2h: List of special mineral concession granted for ordinary earth during the period from 02.12.2016 to 13.3.2017

Sl. No.	Name & Address of the Permit Holder	Issuing date	Taluk	Village	Sy. No.	Validity
1	Joseph Varghese, Valiyaplackal Vimalalayam, Kollad.P.O., Kottayam	02.12.2017	Kottayam	Panachikkad	362/12, 362/12-19	31.12.2016
2	Rajappan, Ikkarakunnel, Vadakara.P.O., Vaikom	13.12.2017	Vaikom	Velloor	760/2A	28.12.2016
3	Devasia Joseph, Mappilaparambil, Kuravilangadu.P.O.,	16.12.2016	Meenachil	Kuravilangadu	268/2-1	16.02.2017
4	C.M. Rajan, Chelacknirappel, Kurianadu.P.O., Monippally.	22.12.2016	Meenachil	Monippally	329/19, 18-1	27.01.2017
5	George John Anickal, Kuravilangadu.P.o.,	31.12.2016	Meenachil	Kuravilangadu	607/3	30.03.2017
6	Saji Thomas, Uthimattathil, Kalathoor.P.O.,	31.12.2016	Meenachil	Kuravilangadu	107/6-1	15.02.2017
7	N.K. Sasidharan Nair, Kochukalambukattu, Manganam.P.o.,	06.01.2017	Kottayam	Athirampuzha	303/8, 285/74	25.03.2017
8	Dileep Wisvanathakaimal, Sudharama House, Pathamuttam.P.o.,	06.01.2017	Kottayam	Panachikkad	315/5-3	15.02.2017
9	Chacko, Kondakasseril, Kuzhimattom.P.o.,	06.01.2017	Kottayam	Panachikkad	328/2	15.02.2017
10	Mariamma Thomas, Perumbayil ninnum, Thekkumthadathil, Paraprarn.P.O.,	06.01.2017	Kottayam	Muttuchira	820/5	28.02.2017
11	Paily Varghese, valiyakalathil, Kuravialangadu.	06.01.2017	Meenachil	Kuravilangadu	82/2	06.01.2017
12	Joji Jacob, Ottakandathil, Elakkad.P.o.,	06.01.2017	Meenachil	Kuravilangadu	499/1-4	06.01.2017
13	Thressiamma George, thekkemailadiyil, Karimbani.P.o.,	07.01.2017	Kottayam	Akalakunnam	28/3-2, 3-3	10.01.2017
14	P.D. Antony, Pathiyamattathil, Kuravilangadu.P.O.,	07.01.2017	Meenachil	Kuravilangadu	23/8	28.02.2017
15	Rugmini Madhavan, Kottnthalavalliyil, Nasrathuhil.P.O.,	07.01.2017	Meenachil	Kuravilangadu	4/3 (12), 4/3-1	22.01.2017

16	Nevin Joseph, Naduvilekurichiyil, Thalayolapparambu.P.O.,	07.01.2017	Vaikom	Vadayar	393/4B1	07.03.2017
17	Ajithkumar, Varikkad, Chambakkara.P.o.,	10.01.2017	Changanacherry	Karukachal	61/4-2	30.01.2017
18	Raju,.V. Jose, Vadakkel, Manalunkal.	10.01.2017	Kottayam	Akalakunnam	344/5	28.02.2017
19	C.P. Molly, Puthoornedumattathil, Peruva.P.o.,	10.01.2017	Vaikom	Mulakkulam	213/7A2	28.02.2017
20	Thressiamma George, thekkemailadiyil, Karimbani.P.o.,	10.01.2017	Kottayam	Akalakunnam	28/3-2, 28/3-3	28.02.2017
21	Siby Joseph, Mattathil, Mamood.P.O.,	10.01.2017	Changanacherry	Madappally	262/5-3	10.02.2017
22	Appachan Mathew, Kavarikkalayamattathottathil, Kaduthuruthy.	12.01.2017	Vaikom	Kaduthuruthy	787/1A, 787/1B	27.02.2017
23	Radhakrishnan, Samoohamadom, Kottamuri.P.O.,	12.01.2017	Changanacherry	Thrikkodithanam	416/4-4	**28.02.2017**
24	Chinnamma Pqaily, Kalariyil, Mulakkulam South.P.o.,	12.01.2017	Vaikom	Mulakkulam	443/8B, 445/1A	28.02.2017
25	Midhunkumar.K.S. Kavilkunnel, thuruthy.P.o.,	19.01.2017	Changanacherry	Vazhappally	1234/11-2, 134/9, 10	25.02.2017
26	V.J. Kurian, Veliyathu, Kuravilangadu	19.01.2017	Meenachil	Kuravilangadu	251/2-2	30.04.2017
27	Johnspon.P. Vellaiparambil, Pattupara, Kuravilangadu	19.01.2017	Meenachil	Kuravilangadu	239/2-7	28.02.2017
28	Assistant Exe. Engineer, Soluthern Rail Way, Construction Section, Kalayamkulam.	01.02.2017	Kottayam	Athirampuzha	567, 576	31.03.2017
29	Medical Officer, VHCL, ayarkunnam.P.O., Kottayam	02.02.2017	Kottayam	Ayarkunnam	37/7, 38/2,	31.03.2017
30	Siby Jose, Assariparambil, Kuravilangadu.P.o.,	02.02.2017	Meenachil	Kuravilangadu	453/6	03.03.2017
31	Devasia Thomas, Kalluvelil, Kuravilangadu.P.o.,	02.02.2017	Meenachil	Kuravilangadu	82/3	31.03.2017
32	Ajithkumar, Muttuchirayil, Poothakkuzhy.P.o.,	08.02.2017	Kottayam	Pampady	206/7-4	07.03.2017

30	E.C. Mathew, Chirakkarottu, Amayannoor.P.O.,	14.02.2017	Kottayam	Perumbaikkad	446/6	28.02.2017
31	M.K. Varghese, Moodankallunkal, Poothakkuzhy.P.o,	20.02.2017	Kottayam	Pampady	378/1-2	31.03.2017
32	Bindhumol, Kunnathu, Vazhoor.P.o.,	20.02.2017	Kottayam	Anikkad	341/7-15	05.03.2017
33	Sunil, Korandithanathu, Vazhappally.P.O.,	20.02.2017	Changanacherry	Madappally	393/7-2	10.03.2017
34	Thiru Hrudaya Madam, Kurissumoold.P.O.,	20.02.2017	Changanacherry	Madappally	13	10.03.2017
35	Saramma Chacko, Kizhakkemailakkttu, Vakathanm.P.o.,	20.02.2017	Changanacherry	Thottackadu	54/5, 54/17	15.03.2017
36	Deputy Exise Commissioner, Kottayam	22.02.2017	Kottayam	Kottayam	5	12.03.2017
36	Mijo Joseph, Chittakkattu, Kurianadu.P.O.,	22.02.2017	Meenachil	Monippally	95/6-1	15.03.2017
37	Biju Nair, Sanker Nivas, Thrukkothamangalam	22.02.2017	Changanacherry	Vakathanam	22/14	13.03.2017
38	Mathew.K. Thanavelil, Puthuppally.P.o.,	22.02.2017	Kottayam	Puthuppally	188/6, 188/1-9	20.03.2017
39	Joji.C. Abaraham, Chakkukulathu, Kuravilangadu	23.02.2017	Meenachil	Monippally	37/4-2, 37/4-4	31.03.2017
40	Narayanan, Mukalelkunnel, ayarkunnam.	23.02.2017	Kottayam	Ayarkunnam	432/5	31.03.2017
41	Thomas Abraham, Maruthumkuzhy, Amayannoor.	23.02.2017	Kottayam	Ayarkunnam	153/10, 153/11, 153/15	31.03.2017
42	Gopinathan Nair, Manackaparambil Puthenveettil, Pakalomattom	28.02.2017	Meenachil	Kuravilangadu	542/7-11	31.03.2017
43	Sreedharan, Marangattuparambil, Thrukkothamangalam	01.03.2017	Changanacherry	Vakathanam	112/14	16.03.2017
44	M.M. Mathew, Madathinal, Koothrapally.P.o.,	02.03.2017	Changanacherry	Karukachal	262/15	02.04.2017
45	Philip Jacob, Airumala Thekkparambil, Pangada.P.O., Kooroppada	02.03.2017	Kottayam	Pampady	446/7-4, 446/7	15.03.2017
46	Mathai.T.V. thiduthiduppel, Poothakkuzhy.	02.03.2017	Kottayam	Pampady	218/16,15	02.04.2017
47	P.S. Philip, Paluvannathadathil, Kurianadu.P.o.,	02.03.2017	Meenachil	Monippally	80/6-1	02.04.2017
48	Mathew Punnoose, Panthappallil, S.H. Mount.P.O.,	02.03.2017	Kottayam	Kooroppada	49/1-3	15.04.2017

49	Bibin Zacharia Power of Attorny, Sakker Hussin, Panackal, Vazhoor.P.o.,08.03.217	08.03.2017	Kanjirappally	Chirakkadavu	288/6	08.05.2017
50	Joy Thomas, Muthukulathu, Monippaly.P.O.,	09.03.2017	Meenachil	Monippally	205/16	30.04.2017
51	K.S. Sebastian, Namboosseril, Kuravilangadu	09.03.2017	Meenachil	Kuravilangadu	4/2A, 4	31.05.2017
52	Phiph Thomas, Parackalaya Nirappel, Njeezhoor.P.o.,	09.03.2017	Vaikom	Njeezhoor	185/2	20.04.2017
53	Babukutty Eapen, Mamoottil, Kuzhimattom.P.o.,	09.03.2017	Kottayam	Panachikkad	647/5	08.04.2017
54	Russyraj Abdul Khadar, Kuttickal, Velloor.P.O.,	09.03.2017	Kottayam	Kottayam	4	15.04.2017
55	Iytty Iype, Thannickal, Kottayam	09.03.2017	Kottayam	Muttambalam	28	15.03.2017
56	Sheela Kucheria, Karikkattuparambil, Mannarakkayam.P.o.,	13.02.2017	Kanjirappally	Chirakkadavu	282/2-3	30.04.2017
57	Thomas, Vathappallil, Ayarkunnam.P.O.,	13.02.2017	Kottayam	Ayarkunnam	262/12-1	13.04.2017
58	Parukutty Amma, Sreekumara Sadanam, Mammood.P.O.,	13.03.2017	Changanacherry	Madappally	123/6	13.04.2017
59	V.P. Prasad, Mukkattu, Thottackadu.P.O.,	13.03.2017	Changanacherry	Thottackadu	450/13-1	13.04.2017
60	Ancy Antoney, Karikottu, Eravuchira.P.O.,	13.03.2017	Changanacherry	Thottackadu	286/18-2	30.03.2017

Table 2i: List of dealer's licenses granted for Granite (building stone) *(valid as on November 2016)*

Sl. No.	Concession no.	Date of grant	Name & address of DL holder	Sy. Nos.	Village	Taluk	Area (hectares)	Panchayat	Tenure of land (private/government)	Quantity (tonnes)	DL Appli. Fee (Rs.)	DL Fee (Rs.)	Valid up to
1	86/2016-17/GBS/DL/2733 / DOY/ML/2016	02.11.2016	S.Unnikrishnan, Proprietor, Aravinda Crusher Industries, Vallichira.P.O.,	453/8	Vallichira	Meenachil	34.80 Ares	Karoor	Private	5000	10000	40000	01.11.2017
2	87/2016-17/GBS/DL/2731 / DOY/ML/2016	02.11.2016	Biju Tom, Moothasseril House, Payappar.P.O.,	369/2	Lalam	Meenachil	36.35 Ares	Karoor	Private	5000	10000	40000	01.11.2017
3	88/2016-17/GBS/DL/2868 / DOY/ML/2016	03.11.2016	C.D. Soman Pillai, Chennamkulam , Vazhoor.P.O.,	21/8	Vazhoor	Changanacherry	10.14Ares	Vazhoor	Private	5000	1000	4000	02.11.2017

11 References

1. District Resource Map, Kottayam district, Kerala. Published by Geological Survey of India.
2. Detailed Information on Bauxite in India Geological Survey of India. 1994. http://www.portal.gsi.gov.in/gsiDoc/pub/DID_Bauxite_WM.pdf
3. Rajan, T. N. and Anil Kumar, P. S. 2005. Geology and Mineral Resources of the States of India Part IX – Kerala. Geological Survey of India Miscellaneous Publication No. 30.
4. Sreehari S. 2013. Ground Water Information Booklet of Kottayam district, Kerala. Technical Reports: Series 'D'. Central Ground Water Board.
5. www.kerenvis.nic.in
6. www.keralasoils.gov.in
7. www.dmg.kerala.gov.in

Geology of Kerala

Physiography

Physiographically the state can be divided into four domains from east to west, viz., the Western Ghats, the foothills, the midland and the coastal low- land.

Western Ghats

The hill ranges of the Western Ghats rise to an altitude of over 2500m above the MSL and the crest of the ranges marks the inter-state boundary in most of the places. A breach in the continuity of the ranges marks the Palghat Gap with a sinistral shift of 50 km between the shifted crests. The Wynad plateau and the Munnar (10°57'00": 77°31'00") upland fall within this zone.

Foothills

The foothills of the Western Ghats comprise the rocky area from 200 to 600m.above MSL. It is a transitional zone between the high -ranges and midland.

Midland region

This forms an area of gently undulating topography with hillocks and mounds. Laterite capping is commonly noticeable on the top of these hillocks. The low, flat-topped hillocks forming the laterite plateau range in altitude from 30-200m and are observed between coastal low-land and the foothills.

Coastal low- land

Coastal low-land is identified with alluvial plains, sandy stretches, abraded platforms, beach ridges, raised beaches, lagoons and estuaries. The low- land and the plains are generally less than 10m above MSL.

Rivers

Kerala is drained by 44 rivers, many of which orginate from the Western Ghats. Except Kabini, Bhavani and Pambar which are east - flowing, the rest of rivers are west- flowing and join the Arabian Sea. A few of them drain into the backwaters. Most important rivers (with their length in km in paranthesis) of the state, are Chandragiri(105), Valapatnam (110), Achankovil (120) Kallada (121), Muvattupuzha (121), Chalakudy (130), Kadalundi(130), Chaliyar (169), Pampa (176),Bharathapuzha (209) and Periyar (244).

Geology

Geologically, Kerala is occupied by Precambrian crystallines, acid to ultra basic intrusives of Archaean to Proterozoic age, Tertiary (Mio-Pliocene) sedimentary rocks and Quaternary sediments of fluvial and marine origin (Fig.I). Both the crystallines and the Tertiary sediments have been extensively lateritised.

Based on the detailed studies by GSI during the last three decades, the following stratigraphic sequence has been suggested.

	Quaternary (Q)	Pebble bed Kadappuram Formation(marine) Periyar Formation(fluvial) Viyyam Formation(fluvio-marine) GuruvayurFormation(Palaeo-marine
	Mio-Pliocene(N_{12}) (TertiaryTt)	Laterite Warkalli Formation (Sandstone and clay with ligniteintercalations) Quilon Formation (Fossiliferous limestone and calcareous marl).
	Mesozoic (61-144Ma.)	Gabbro / Dolerite dykes
P R O T E R O Z O I	Younger granites (550-390ma)	Alkali granites, granite, Granophyres and other acid intrusives
	Charnockites(younger) (550Ma)	Massive charnockite, incipient charnockite , Cordierite charnockite
	Ultrabasic/basics(Younger) (700-600Ma)	Perinthatta anorthosite, Kartikulam gabbro, Adakkathodu gabbro, Begur diorite
	Basic Intrusives (2100-1600Ma)	Agali- Anakkatti dykes
	Migmatite/gneiss/older granitoid(PGC II) (Ptm)(2500-2200Ma	Garnet- biotite - gneiss with associated migmatites, quartzo-felspathic gneiss, hornblende gneiss, hornblende- biotite gneiss, quartz- mica gneiss
	Vengad (APtv) Group	Quartz-mica schist and quartzite, conglomerate
A R C H A E A N	Charnockite(older) (Ac) 2600Ma	Mafic granulite, pyroxene granulite, Banded magnetite quartzite and gneissic charnockite
	Khondalite Group (Ak)	Quartzite, mafic granulite, calc-granulite garnet-biotite-sillimanite-cordierite gneiss, garnet-biotite-gneiss, leptynite
	Peninsular Gneissic Complex (PGC I) (Ap) (3000Ma)	Foliated granite, hornblende gneiss, pink granite gneiss, biotite gneiss
	Layerd ultrabasic - basic Complex (3100- 3000Ma)	Peridotite, dunite, pyroxenite, anorthosite
	Wynad Schist Complex (Aw) (3200Ma)	Talc-tremolite schist , fuchsite quartzite, amphibolite, calc granulite, quartz sericite schist, kyanite quartzite, garnet - sillimanite gneiss/ schist, magnetite quartzite, kyanite mica schist

Base not recognised

The Archaeans

Rocks of Archaean Era encompass a wide spectrum of litho-assemblages ranging from khondalite, charnockite, gneiss and meta-sedimentary rocks occupying the Western Ghats including the foothill region. The Khondalite and Charnockite Group are correlated with the Eastern Ghat Supergroup based on the overall similarity in lithology and geochronology.

Wynad Supracrustals

The meta-sedimentary, and ultramafic rocks occurring in the Wynad District generated keen interest among the GSI geologists in 1970s. The high-grade Wynad supracrustal rocks are correlated with the Sargur Schist Complex of the Karnataka (Nair, *et al*, 1975; Adiga, 1980). The schistose rocks are characterised by intense deformation, medium to high-grade metamorphism, migmatisation and lack of sedimentary structures. The schist complex consists of meta-ultramafites, schist, meta-pelites, meta-pyroxenite, serpentinite, talc-tremolite rock and amphibolite.

The meta-sedimentaries occur as thin linear bodies within the migmatites. These consist of pelites, psammopelites and quartzites. The predominant rock types are corundum- mica schist, kyanite schist, quartz- mica schist and iron stone.(Anil Kumar *et al*,1993).

These rocks occur as narrow arcuate belts, lenses, and other forms of enclaves within Peninsular gneisses and charnockite. The group can be divided into medium-to low- grade metasedimentary rocks and meta-mafic and meta-ultramafic rocks. The lithology of the high-grade schists consist of quartz-mica schist with kyanite, quartz-sericite schists,quartzites,magnetite quartzite, fuchsite quartzite and meta-ultramafites. Their contact with the surrounding gneisses are concordant due to later co-folding. Several linear belts of such high-grade schists and ultramafite enclaves occur as isolated bands within the granulite and gneissic terrain of Kasaragod and Kannur districts.

Layered ultrabasic- basic complex

Remnants of layered basic- ultabasic complex are reported from Attappadi area(Nambiar 1982).The ultramafics are represented by meta-pyroxenite, meta-dolerite, peridotite with chromite and meta-gabbro (Lahiri *et al*, 1975). The anorthosite of Attappadi is only a few metre thick. Occurrences are around Narsimukku, Pudur and Melmulli areas. An east-west trending narrow lenticular body of serpentinised dunite is reported from Punalur mica mine belt.

A minor body (200 m long and 10-15m wide) of anorthosite was reported within pyroxene-granulite-charnockite terrain from Katanjari *parambu* of Kasargod district (Adiga, 1979). Another dismembered layered igneous complex consisting of alternate layers of peridotite and pyroxenite within charnockite was traced around Panathadi area of Kannur District (Adiga, 1980).

Peninsular Gneissic Complex- I (PGC-I)

The rocks of Peninsular Gneissic Complex(PGC) are exposed in the northern parts of Kerala adjoining Karnataka . This consists of a heterogeneous mixture of granitoid materials. The equivalent rocks of PGC in Kerala include hornblende-biotite gneiss (sheared), biotite-hornblende gneiss, foliated granite and pink granite gneiss. Granite gneiss is exposed along the intra-State boundary of Palakkad District as well as in Idukki District. Pink granite gneiss, though widespread, is best developed in Devikolam (10°04'00": 77°06'30"), and Udumbanchola (10°00'00":77°15'00") areas of Idukki District.

This consists of gneisses showing preponderance of either hornblende or biotite. The percentage of hornblende and biotite varies from place to place. This can be traced from Manantoddy to further northwest upto the west coast. West of Manantoddy, the rock is hornblende gneiss. It shows coarse granulitic to gneissic texture and is composed of hornblende, feldspar, quartz, pyroxene, biotite and garnet. Alkali feldspar shows alteration to clay and sericite. Biotite is mainly secondary after hornblende.

Around Mahe and Thalasseri, the biotite gneiss(Nair *et al.*, 1974) is medium-grained and gneissose rock consisting of alternate layers of mafics and felsics.

Khondalite Group

The Khondalite Group of rocks include calc-granulites, quartzite and para-gneisses of pelitic parentage. Para-gneisses are ubiquitous and are well-developed in the southern part of the state, particularly, in Thiruvananthapuram and Kollam districts. Calc-granulite and quartzite occur as bands within the para-gneisses and amidst the Charnockite Group and migmatitic gneisses.

Calc-granulite

Calc-granulite occurs as linear bands mainly in the eastern part of Kollam and Thiruvananthapuram District, northeast and east of Munnar in Idukki district and in parts of Palakkad District. The rock is generally medium to coarse-grained, inequigranular and granoblastic in texture. It consists of diopside and plagioclase. Minerals like wollastonite, scapolite, calcite, garnet, spinel, sphene, quartz and apatite are also present in different proportions.

Quartzite

Quartzite occurs as linear bands amidst the khondalitic gneiss, charnockite and migmatitic gneisses. These bands are exposed between Pathanamthitta (9°15'45": 76°47'00"), and Muvattupuzha (9°59'00": 76°35'00") in Ernakulam District. The rock is coarse-grained and generally white in color with a brownish coating on the weathered surface. It consists of granular quartz with subordinate feldspar, garnet and iron oxide.

Garnetiferous biotite-sillimanite gneiss

Garnetiferous biotite- sillimanite gneiss is well-developed in the southern part of the state. It occurs in close association with the migmatitic gneisses, charnockite and charnockite gneisses, mostly as weathered outcrops. Sillimanite- rich bands occur alternating with garnet - rich portions or with quartzo-feldspathic layers. Rutile and iron oxides are the common accessory minerals.

Charnockite Group

Charnockite Group shows great diversity in lithology comprising pyroxene granulite, hornblende pyroxenite, magnetite quartzite, charnockite and hypersthene-diopside gneisses and cordierite gneiss. Charnockite and charnockitic gneiss have preponderance over all other crystalline rocks covering 40 -50% of the total area of the State. The charnockites are well-exposed in the central and northern parts of Kerala including the high–hills of the Western Ghats. Char nockite has lesser predominance in Thiruvananthapuram and Kollam districts. In Attappady, the Bhavani Shear Zone is limited by the charnockite massif of the Nilgiri plateau on the north. Though the interrelationship of the Charnockite and the Khondalite is not clear, in many places there are intercalations rather than interlayering of one with the other. In Palakkad District, the Khondalite Group of rocks structurally overlie the charnockite. The occurrence of pyroxene granulite as fine and linear bodies within the charnockite of Tirur, suggests that charnockite is a product of migmatisation of pyroxene granulite(Vidyadharan and Sukumaran, 1978). Charnockite and charnockitic gneiss consist of quartz, feldspar and biotite. Garnet-bearing variants are also observed. The basic charnockite is more granulitic and contains clino- and ortho- pyroxenes, feldspar, biotite and garnet whereas the acid variety (alaskite/ enderbite) is greenish black, coarse-grained, massive to poorly foliated rock consisting of quartz, feldspar and pyroxenes. Basic charnockite has low- potash feldspar and more clinopyroxene. This is devoid of garnet and graphite, but shows a little amount of biotite(Chacko, 1922). Due to the polygenetic nature of the rock, geochemical and mineralogical variations do exist between charnockites reported from Kerala. In the Periyar valley region, in Idukki and Kottayam districts, pyroxenite and alaskite constitute the Charnockite Group (Nair, and Selvan, 1976).

The available age data indicate that the massive charnockites are older and their ages range between 2155 and 2930 $\pm$ 50 Ma (Soman ,1997).

Also charnockite has been subjected to retrogression and migmatisation.

Archaean to Palaeo-Proterozoic

Vengad Group

A succession of schistose rocks in parts of Tellicherry taluk in Kannur district is described as Vengad Group of rocks (Nair, 1976). The Vengad Group comprises of basal conglomerate, quartzite and quartz-mica schist. The contacts are highly gradational. The conglomerate shows graded bedding and quartzite shows current-bedding.

An angular unconformity marked by conglomerate horizon extending from Kuthuparamba (11°49‘30": 75 °34'00") to Vengad (11°53‘30":75 °32'00") in Kannur district, separates the younger quartz-mica schist and quartzite from the older schistose and gneissic rocks. The lithology consists of basal oligomictic conglomerate, quartzite, quartz-biotite-muscovite schist and biotite quartzite. The schists are exposed over an area of 300 sq km having a lensoidal shape with its longer axis trending in NW-SE direction. The basement rock is gneissic or migmatitic with relicts of high-grade schists, ultramafites and quartzites of the Wynad Schist Complex. Four major occurrences of conglomerate are noticed in a NW-SE direction over a length of 10 km.

Lack of migmatisation, presence of primary structures and low-grade metamorphic minerals characterize these rocks.

Migmatite\ Gneiss\ Granitoid (PGC-II)

Quartzo-feldspathic gneiss

Migmatite includes variety of gneissic rocks which are next in importance to charnockite as a dominant litho-assemblage. Quartzo-feldspathic gneiss occurring along the contact zone between garnet-biotite gneiss and garnet-sillimanite gneiss of Thiruvananthapuram area represents an original intrusive phase. It is a feebly foliated, fine-grained, leucocratic granulitic rock occurring in close association with garnet-sillimanite gneiss and garnet-biotite gneiss with gradational contact relationship in the southern parts of Kerala. The origin of this rock is attributed to stress-induced injection of acid materials into the host rocks(Nageswara Rao and Raju,1970).

Garnet- biotite gneiss

Garnet-biotite gneiss is well-developed in the northeastern parts of Kollam and Thiruvananthapuram districts. This carries inclusions of pyroxene granulite and disseminations of graphite at many places (Jacob, 1965). It consists of quartz, microperthite, biotite, plagioclase and graphite. This rock also occurs in the northern parts of Palakkad District in close association with khondalite, charnockite and hornblende gneiss. These rocks are subsequently formed by retrogression and migmatisation of the Khondalite Group.

East of Kottayam and Idukki districts, light grey, pink garnet-bearing biotite gneiss is widely seen. It is a gneissic granulite. The presence of biotite and concentration of garnet in layers give the rock a banded appearance.(GSI, 1995).

Hornblende gneiss, hornblende-biotite gneiss, quartz- mica gneiss

These rock types occur within the migmatites and associated retrograded charnockite. The naming is purely based on the preponderance of the minerals and these rocks occur in the Periyar valley area east of Thodupuzha.(Nair and Selvan,1976). These medium-grained , foliated, banded rocks consist of alternate layers rich in hornblende or biotite. Bands of coarse to medium- grained light grey to pink granite traverse these rocks. Hornblende- biotite gneiss showing lit par lit relationship with the granite gneisses is the dominant rock type in the Periyar valley. This is admixed with contorted bands and enclaves of pyroxene granulite, calc-granulite and hornblende- biotite granulite. These are highly deformed.

In the Palakkad gap area, these gneisses occur over a large area, showing migmatitic structures such as agmatites, nebulites, schlierens, ptygmatic folds, quartzo-feldspathic neosomes and ferromagnesian palaeosomes.(Muraleedharan and Raman, 1989).

Proterozoic

Basic intrusives

Basic dyke emplacements within the Archaean crystalline rocks of Kerala are spread throughout the entire length and breadth of the state. Of these, dolerite dyke occurring north of the Palakkad gap had given Proterozoic age whereas in the south this dyke is of Phanerozoic age. The older basic dykes are metamorphosed along with the country rocks and are now recognised as epidiorite and amphibolite. Another set of dykes, apparently post-dating the regional metamorphic event are subjected to thermal metamorphism. Clouding and sericitisation of feldspars and uralitisation of pyroxenes are common in such dykes. In the absence of chronological data such dykes are considered to be of Proterozoic age. Most of the dykes are vertical in disposition and are traced as linear features. *En-echelon* pattern of some dyke swarms suggests that magmatic intrusion was controlled by shearing of the host rock., Mineralogically, the dykes are made up mostly of plagioclase feldspar and pyroxene(augite and aegirine-augite) with magnetite, apatite and olivine as accessories. The ENE-WSW dolerite dyke swarm of Agali- Anakkati area in Palakkad District within the Bhavani Shear zone showed in isotopic age from 1900 to 2000 Ma (Radhakrishna and Mathew Joseph, 1993). The rock is highly jointed and altered (Jacob, 1965). Similar basic intrusive bodies are traced in the Achankovil shear zone in Vazhamuttam (9°14'00":76°46'40"), Kulasekhara pettah (9°16'00":76°47'45") (Thomas Mathai *et al*, 1984). Sheet-like bodies of fine to medium-grained, dark coloured meta-gabbro occurs in Periyamuli (11°13'00"; 76°43'00") for about 20 km in ENE-WSW direction, Karuvarai (11°04'00"; 76°32'30") and few gabbro bodies south of Thuvapattu (11°06'30"; 76°44'45") in Attapady valley, Palakkad district. Meta-gabbro forms small hillocks east of Payyanam (10°31'00"; 76°21'00"), southwest of Kainur (10°36'00"; 76°09'00") and Chemmannur (10°41'00"; 76°01'00"), Vaga (10°35'00"; 76°06'00") and Arthat (10°37'00"; 76°03'00") in Trichur District (Mahadevan, 1962).

Dykes in north Kerala show , NW-SE, NE-SW and NNW-SSE trends. Host rocks are charnockite, gneisses and supracrustals(Radhakrishna *et al* 1991). Dykes are mainly dolerite but occasional meta-gabbro or meta-norite are also traced. In Agali- Anaikatti area of the Attapadi- Bhavani shear zone, dykes are confined within a 20-25km wide zone and extend from west of Agali to eastward for about 100km following a ENE-WSW direction.(Radhakrishna, *et al*, 1999).

The rock consists of 95% calcic plagioclase, 5% clinopyroxenes and subordinate amounts of magnetite. There are a number of concordant and discordant basic intrusive of dolerite and gabbro,meta-gabbro, meta-norite, meta-pyroxenite and anorthositic gabbro. These are not mappable and are seen in Pappinpra (11°06'20", 76°05'56") Velli(11°04'00":76°07'45"), Kalpetta (11°04'12":76°05'32). An extensive basic diorite has been mapped over an area of 25 sq km at Panavalli (11°53'30",76 ° 2'30"; Nair, *et al* 1976).

The rock is composed predominantly of calcic plagioclase (95%) rest clinopyroxene with subordinate amount of magnetite. Another relatively small body of anorthosite is around Kalivalli (11°51'30"; 76°12'30") in south Wynad taluk, Wynad District.

Ultrabasic/ basic intrusive (younger)

Perinthatta Anorthosite

A major elliptical body of anorthosite spread over an area of more than 50 sq.km is reported from Perinthatta (12°10'00":75°17'30";Vidyadharan *et al*, 1977). The anorthosite is with a very irregular border and a tongue-like projection into the country rock of charnockite and pyroxene granulite of Kannur District.The anorthosite is coarse to very coarse-grained, and shows variations from pure anorthosite to gabbroic anorthosite and gabbro from the centre to the periphery suggestive of zoning. The modal composition corresponds to nearly 95% plagioclase (An_{58-72}) and <10% clinopyroxene, apatite, calcite and magnetite. The gabbroic variants have more of mafics.

The structural configuration suggests that the anorthosite was emplaced in synformal structure as a phacolith. The flow-banding in anorthosite indicates its syntectonic emplacement. The Perinthatta anorthosite is assigned a Proterozoic age.

Ezhimala gabbro-granophyre complex

The major high-relief feature proximal to the Perinthatta anorthosite is constituted by the gabbro-granophyre Complex (Nair and Vidyadharan, 1982). The granophyre massif is fringed by the gabbro to the east and south. The Bavali fault running north of the complex is presumed to have dismembered the body from the Perinthatta anorthosite. Locally, the gabbro has anorthositic differentiates within it. Veins of granophyre traverse the gabbro at places give rise to breccia-like structures. The granophyre shows a sharp contact with the gabbro into which it intrudes. Rapakivi structure is observed within the granophyre. According to Nair and Vidyadharan (1982) rocks of Ezhimala complex display bimodal character with conspicuous basic and silicic components.

Kartikulam and Karraug Gabbro

Two gabbro bodies namely Kartikulam gabbro and Karraug gabbro are located northeast of Manantoddy bordering the Karnataka (Nair *et al*, 1975).The gabbro body at Kartikulam occupies an area of about 45 sq.km. with an elliptical shape within the gneissic terrain. The actual contact with the gneiss is concealed but it is believed to be sharp. At many places, the gabbro is agmatised by coarse quartzo-feldspathic material.

The gabbro is coarse-grained and of uneven texture consisting essentially of plagioclase and pyroxene. Variation to anorthositic composition is noticed. The plagioclase is of labrodorite composition and shows alteration to sericite at places (Rema Warrier and Venkataraman, 1986). The pyroxenes are uralitised to varying degrees.

The Karraug gabbro body is located east of it and south of the Kabini River. It shows similar features as that of the Kartikulam gabbro. The rock shows phenocrysts of feldspar set in a fine matrix of flaky minerals.

Adakkathodu gabbro

At Adakkathodu(12°31'35"; 75°10'25"), northwest of Manantoddy, a 8 km long meta-gabbro, is intrusive into the basement gneisses on three sides and the Wynad schists in the east. It occurs proximal to the Bavali fault/lineament. It encloses, patches of quartz-sericite schists and biotite gneiss. (Nair *et al*, 1975). The rock is mesocratic to melanocratic, medium to coarse grained consisting mainly of pyroxene and plagioclase. The rock shows sub-ophitic texture and consists of enstatite and intermediate plagioclase of andesine-labrodorite composition (Nair *et al*, 1976). While the gabbro bodies of Kartikulam and Karraug to the east are olivine-bearing, the Adakkathodu gabbro is enstatite- bearing. Olivine, augite and zoned feldspars are recorded from the eastern body while the western body is enstatite- bearing, without the zoning in feldspar.

Begur diorite

An extensive basic diorite body (25 sq.km.) has been traced north of Manantoddy in the Begur Reserve Forest (Nair, *et al*, 1976). It extends from Thirunelli to the Karnataka State border. The southern contact is with augen gneisses indicating emplacement along shear zones while the northern one with sillimanite gneisses. Aplite and dolerite veins are seen traversing the rock mostly parallel to the regional foliation. The rock is mesocratic to melanocratic, coarse-grained and consists of pink to grey feldspar, hornblende and biotite.

The rock is feebly gneissic and at places porphyritic (Rema Warrier and Venkataramana, 1986). The phenocrysts are mostly plagioclase. Mafics at times swerve round the phenocrysts giving rise to augen structure. Hornblende is altered to biotite and chlorite. Accessories include epidote, apatite, zoisite and opaques.

The diorite shows tholeiitic charcteristics.The diorite is considered as a transitional rock from the gabbro with which it is spatially associated in the nearby area with the plagioclase become more sodic.

Charnockites [younger]

The area south of Palakkad exposes charnockite over large areas.The charnockites are represented by acid microperthitic charnockite and intermediate gneissic charnockite occurring in association with garnetiferous biotite gneiss and khondalite (Narayanaswamy and Purna Lakshmi, 1967). Massive charnockites are developed on a regional scale and occur as mappable litho-units (Raju and Gopalakrishnan, 1972), around Nedumangad. The massive charnockites in majority of the cases are acid and intermediate in composition. The rock is medium to coarse-grained and shows xenoblastic texture. It is composed of quartz, feldspar, pyroxenes, garnet and graphite with accessories like biotite, zircon, apatite and monazite.

Small patches, lenses or veins of charnockite occur in the gneisses of amphibolite facies in the Thiruvananthapuram area (Nageswara Rao and Raju, 1970). Here, the incipient charnockites are thought to have formed by transformation of paragneisses. (Hansen *et al*, 1987; Santosh *et al*, 1990). A few dominant varieties of incipient charnockites have been categorized by Ravindra Kumar and Chacko (1986) on the basis of their mode of occurrence, association and chemical processes involved in their development. At Kottavattom, north of Thiruvananthapuram, the charnockite consisting of quartz, K-feldspar, plagioclase, biotite, garnet and orthopyroxene as essential minerals and graphite, zircon, ilmenite, monazite, apatite, rutile and magnetite as accessory minerals are products of transformation of gneisses into coarse-grained charnockites along a system of conjugate fractures and foliation planes. (Saritha and Santosh, 1996).

Cordierite or Charnockite Gneiss

Cordierite bearing large linear zones of charnockites were reported around Pathanamthitta (Nageswara Rao and Jacob, 1967) area. Cordierite charnockites or orthopyroxene-garnet-cordierite bearing gneisses (Sinha Roy *et al*, 1984; Santosh, 1987) occur as discontinuous bodies in the northern parts of Thiruvananthapuram and in selected stretches further south around Koliakode. The rock is composed of cordierite, orthopyroxene, plagioclase, K-feldspar, spinel and quartz and a little garnet and biotite.

The growth of cordierite and orthopyroxene took place concomitantly during the conversion of gneisses to charnockites. At Nellikala in Pathanamthitta, the cordierite occurs as anhedral grains of variable sizes in the charnockites (Nandakumar, 1996).

Younger granites

The granites and its variants occur around Chengannur in Alappuzha and Pathanamthitta districts, Munnar in Idukki District, Peralimala in Kannur district and Kalpetta and Ambalavayal in Wynad District. Many of these granites occur as later emplacements along crustal fractures and faults. The Achenkovil – Tamraparni tectonic zone, the Attapadi shear zone, Bavali shear zone and the Moyar shear zone are all marked by granitic emplacements

Ambalavayal granite

The Ambalavayal (11°37‘15"; 76 °03‘30") granite having an oval shape covers an area of 50 sq.km. The granite is light pink in color and is composed of quartz, pink feldspar, hornblende and biotite. The pegmatites traversing the granite show occasional flakes of molybdenite. The Amabalavayal granite occurring in the proximity of the Bavali lineament is thought to be emplaced during its reactivation. The granite is intrusive into the hornblende-biotite gneiss (migmatite) and the Wynad Supracrustals (Anilkumar *et al*, 1993). Four types of granites are recorded, viz.,foliated granite, pink granite, grey granite and aplitic granite.

The foliated granite consists of quartz, microcline, orthoclase, plagioclase, biotite, hornblende, chlorite, calcite and zircon .The pink granite is a medium-grained consisting of quartz, microcline, plagioclase, sericite, chlorite, apatite, rutile, zircon and biotite. The grey granite is a medium-to fine-grained rock consisting of quartz, microcline, sericite, biotite, chlorite and calcite. The aplitic granite is a very fine-grained massive rock consisting of quartz, microcline, orthoclase, plagioclase, sericite, biotite, calcite, chlorite, apatite and opaques.

K-Ar age of Ambalavayal granite (560± 30 Ma, Nair, *et al*,1985) is lower than Rb-Sr age (595 ± 20 m.a Santhosh *et al*, 1986), but is higher than that of U-Pb-age(505±20ma, Odom,1982). The reason for this variation in the date may be attributed to the different techniques adopted and also to the presence of biotite of multiple generation.

Munnar granite

The Munnar (10°05'00";77°05'00") granite with an areal extent of 50 sq km is an E-W trending irregular body emplaced within the migmatite and apophyses extend into the surrounding gneisses. The granite dated to be 740 ± 30 m.y (Odom, 1982) is traversed by pegmatite, aplite and quartz veins. Three types of granite are recorded. Foliated granite, Coarse pink granite and medium grey granite.The foliated granite consists of stringers and streaks of mafics consisting of biotite, hornblende, chlorite and magnetite alternating with felsics consisting of quartz and potash feldspar. Potash feldspar is predominantly orthoclase. The closely spaced foliations are persistent but discontinuous.This granite forms a domal structure south of Munnar. It has a sharp contact with the migmatite. Coarse pink granite consists of pink feldspar, quartz and a little amount of mafics. Mafics are biotite, sphene and hornblende. Medium grained grey granite, consists of quartz, feldspar, biotite, chlorite, zircon, sphene, epidote, calcite and sericite.

Major element data of Munnar granites do not show any significant variation amongst the three granites. Content of iron is more in medium grey granite and foliated granite. Different variation diagrams reveal a slight tendency towards alkali granite. The foliated granite shows more percentage of orthoclase than the other two granites. (Nair and Anil Kumar, 1990)

Ezhimala granophyre – granite complex

A prominent granophyre body forms the hill known as Ezhimala, covering an area of 20 sq km in Kannur District. The granophyre is associated with gabbro and granite and is traversed by dolerite dykes. Two types of granophyres have been deciphered;coarse- grained leucocratic one and medium - grained one with more mafics. Drusy type, confined to higher elevation contain numerous vug lines with secondary minerals like quartz and calcite. Rocks of Ezhimala Complex display bimodal character with conspicuous basic and silicic components and total lack of rocks of intermediate composition typical of anorogenic suites (Nair and Vidyadharan, 1982). The granophyre is pink to ash grey coloured, massive, fine to coarse- grained, holocrystalline with equigranular texture. The granites are of two types. The major light pink granite with less of mafics show gradational relationships with the more greyish porphyritic variant (Varadan and Venkataraman, 1976).

Granophyre shows a typical granophyric intergrowth of quartz and feldspar forming the ground mass with phenocrysts of potash feldspar and some zoned plagioclase. The groundmass is totally of orthoclase. Augite is the chief ferro-magnesium mineral. Accessories include apatite, sphene, epidote, calcite and magnetite. Texturally the rock shows variation from coarse-grained leucocratic types with less mafics in the southern portion of the hill and medium to coarse grained type towards northern parts.

Minor outcrops of rapakivi granites are recorded within the granophyres of Ezhimala Complex. Anorthosites of Perinthatta and Kadannappally and granite, granophyre of Ezhimala together form the Ezhimala Complex. The light pink granite with less mafics is the major variety showing a gradational relationship with the more greyish porphyritic variety. The porphyritic variety, at places, shows rapakivi structure. The porphyritic granite shows mantled feldspar megacrysts. This variety grades into porphyritic granites without mantled feldspar and at higher levels grades into granophyre.The granite contains 60% of orthoclase feldspar, 5-10% of plagioclase, 20-25% of quartz with 4% of biotite, epidote, magnetite and fluorite. The low initial Sr $_{87}$/ Sr $_{86}$ ratio indicate that the rocks have a relatively minor amount of older sialic material . The Rb-Sr age of the granophyre is estimated to be 678 m.y (Nair and Vidyadharan, 1982). The Ezhimala Complex lies in close proximity to the Bavali lineament suggesting reactivation along the lineament and intrusion of the body.

Kalpatta granite

The Kalpatta ((11°36'15";76°05'15") granite is an oval- shaped intrusive into the Wynad schist and covers an area of 44 sq km (Rao and Varadan, 1967). The rock is grey coloured, medium-grained, homogenous biotite granite and has sharp contact with the country rock. A feeble foliation is imparted to the granite at places by biotite flakes. Xenoliths of amphibolite / hornblende gneiss are visible near the periphery. Irregular veins of pegmatite / aplite traverse the granite and also the enclaves. The K-Ar age of the biotite from the Kalpatta granite is dated as 512 ± 30 m.a (Nair *et al*, 1985) and 527 m.a (GSI). Presence of enclaves and absence of significant replacement textures along with the geochemical characteristics assign a magmatic parentage for the granite. The proximity of the pluton to the Bavali lineament probably suggests intrusion along this fracture.

Three types of granites such as coarse grained biotite-granite, fine grained biotite granite, and porphyritic granite are mapped on the basis of texture, colour and mode of occurrence. Coarse-grained granite is a massive bluish grey rock with large xenoblasts of quartz and feldspars. The accessories include biotite, zircon, apatite and sphene. Blastesis of feldspar and sphene are common. Microcline, orthoclase, and plagioclase are seen as the major feldspar. Plagioclase composition varies from albite to oligoclase. This rock is exposed in Trikkaippetta

($11^0$35'04":$76^0$08"41":), Manikkunnu ($11^0$35"41":76^0 07'09"), Kuttamangalam ($11^0$30'08":$76^0$07'11":) (Anilkumar *et al*, 1993).

Fine biotite-granite is a fine grained massive rock exposed around Muttilmala ($76^0$06'38":$11^0$37'06"). It consists of orthoclase, quartz, microcline, biotite, sericite, zircon, sphene, apatite and opaques. Myrmekitic quartz is recorded. Pophyritic granite consists of myrmekitic quartz, microcline, sericite and biotite. Very coarse grained biotite with included crystals of orthoclase, microcline and albite are common. Except for the texture, all the three granites show similar characters. (Anilkumar, *et al* 1993). Based on Rb-Sr dating , Kalpatta granite is dated 765 Ma. (Odom 1982).

Chengannur granite

The Chengannur (9°18'45"; 76°31'00") granite in Pathanamthitta District is an oval shaped body with the long axis trending in east-west direction covering an area of 15 sq.km in and around Chengannur. The granite is intrusive into the charnockite gneisses. The body is emplaced close to the Achankovil shear zone. K-Ar date of the hornblende indicates an age of 550 m.a (Soman *et al*, 1983). The Chengannur granite is inferred to be a post kinematic granite of magmatic parentage.

Two types of granites are recorded. One is medium-grained pink granite and the other is coarse-grained grey granite. The former consists of quartz, perthitic feldspar, plagioclase, biotite, hornblende, apatite and zircon. The composition of plagioclase varies from albite to oligoclase. Microcline perthite is also seen. The coarse grained grey granite consists of perthite, plagioclase, hornblende, biotite, quartz with occasional occurrence of hypersthene,apatite and zircon. Hornblende and biotite are less common by occurred minerals than hypersthene. Relicts of hypersthene are also seen. This granite may be a product of granitisation of charnockite. K_2O content always exceeds that of Na_2O . The high SiO_2,high alkali, high Fe/Mg ratio, high values of Gallium indicate that the granite belongs to alkali type. It might have an origin from recycled and rehydrated continental crust. (Nair and Anil Kumar,1990).

Peralimala granite

The Peralimala (11°09'19":75°38'46") alkali granite is a linear intrusive body emplaced along the axial trace of a mega fold in EW direction. Peralimala intrusive body occurs as a diatreme of alkali composition with a maximum linear extension of 15 km and a width of 3 km. Based on colour, texture, composition and mode of occurrence four types of granites are identified.

These are pink gneissic granite, porphyritic granite, grey granite and pink granite. Pink alkali granite is a coarse-grained rock consisting of microcline, orthoclase, plagioclase, quartz, hornblende, epidote, aegirine, sphene, calcite, perthite and apatite. Quartz is present in only subordinate amounts. Feldspar content is very high. The preferred orientation of feldspar gives a crude alignment. At Perumpunna, (75°44'00":11°55'28") pink gneissic granite shows preferred orientation of biotite and pyroxene. The porphyritic granite occurs as a lensoidal body containing quartz, feldspar, pyroxene and hornblende. Feldspar forms the phenocrysts in a matrix of quartz-feldspar and mafics. Grey granite is a coarse- to medium- grained rock with microcline, quartz, orthoclase, perthite, hornblende and zoisite. Light grey granite is a medium-grained rock consisting of microcline, orthoclase, plagioclase (albite to oligoclase), epidote, aegirine, hornblende and rutile. The major element chemistry of the granite do not show much variation. The pink granite shows high content of potash. A negative correlation for K_2O content with respect to SiO_2 is very pronounced for pink granite owing to its alkaline nature. Barium and strontium show very high values for Peralimala granite. (Anilkumar *et al*,1993).

Sholayur granite

The Sholayur (11°04'15";76°42'00") granite, is exposed around Kuttiyadikal Mala ($11^0$01'52":$76^0$42'00") and Vachchapathi ($11^0$04'15":$76^0$44'00"). It is a homophanous medium-grained, pink coloured granite, consisting of quartz, orthoclase, microcline, oligoclase, perthite, aegirine augite, biotite, hornblende and sphene. In some places, calcite, apatite, sericite are also observed. The schlierens mark the contact zone of the granites with the host rock. This granite is emplaced within the Wynad supracrustals. SiO_2 varies from 58.76 to 73%, Al_2O_3 14% to 17%, Na_2O 1.8% to 2.4% and K_2O 0.8 to 1.5%. The distribution of SiO_2 is highly non-uniform within the same type of granite. The pink granite is becoming alkali granite at places.(Anil Kumar and Nair,1992).

Intermediate intrusives

The syenite body at Mannapra (10°30'00";76°32'00") is exposed as an elongated NW-SE trending body covering an area of 8 sq km in Thrissur District. The syenite intrusive, makes sharp contact with the charnockite near the charnockite-migmatite contact. The rock is medium to coarse- grained at its peripheries and tends to be coarse-grained towards the centre. Mineralogically, the rock is composed of alkali feldspar, orthopyroxene, clinopyroxene and amphibole with minor amounts of plagioclase, biotite and opaques. A small syenite (Angadimugar syenite) body is located in Kumbala village (12°35'15"; 76°07'00") and about

20 km east of Kumbla in Kasaragod District. The intrusive body has an elliptical outline and covers an area of 5 sq km. The body is intrusive into the Khondalite Group and encloses enclaves of amphibolite in the peripheral parts. The rock is medium to coarse grained, light grey and massive.

Mesozoic intrusives

Basic intrusives

Basic intrusives in Kerala, mainly represented by dyke swarms in NNW-SSE to NW-SE trend, cut across all the metamorphic rocks and the earlier structural trends. Their unmetamorphosed nature and stratigraphic relation with the country rocks prompted their correlation to the Deccan Trap volcanism.

The basic dykes have been emplaced into the migmatites and charnockite in NNW-SSE to NW-SE and ENE-WSW directions along distensional and shear fractures respectively. Dolerite dykes of Kerala are mostly quartz tholeiites rarely clinotholeiite. The basic dykes of Pathanamthitta ($9^0$15'45":$76^0$45'30") are genetically unrelated types. These dykes have not undergone any internal differentiation during intrusion.

The variation in the chemistry of individual dykes may be due to the cogenetic differential sequence. Dolerite dykes intrude the country rocks at an angle greater than 80^0. The dolerite dykes of Kuttuparamba ($11^0$49'30":$75^0$34'00") in Kannur District shows cross cutting relationship with all the formations. The basic dykes of Vamanapuram ($8^0$43'00":$76^0$54'00") are either gabbroic or doleritic intruding the gneissic rocks. These are trending NNE to SSW and NNW to SSE directions and are unmetamorphosed. Mineralogically all these dykes show more or less same composition except the meta-dolerites. Variation in the trace elements like Ti, Zr can be attributed to the differential degree of partial melting of the mantle material. (Nair and Gopala Rao, 1989).

The unmetamorphosed Idamalayar gabbroic dyke with a NNW-SSE trend is traced for over 80 km in the central part of Kerala. The rock is mesocratic, medium-grained, porphyritic and is composed of plagioclase (andesine to labradorite), hornblende and opaques. The reported age of 75 m.y for the Idamalayar dyke (Subramaniam, 1976) links it in time-relationship with Deccan Trap volcanism.

The NNW-SSE trending leucogabbro dykes in central Kerala dated by whole rock K-Ar method gave an age of 81 ± 2 m.y and the NW-SE trending dolerite dyke 69 ± 1 m.y. The dolerite dykes are thought to have represented the feeder system for Deccan Trap volcanic sequences (Radhakrishna *et al*, 1994).

Basic dykes of Pathanamthitta area yielded ages of 99 Ma to 117 Ma and there are dykes which have yielded ages 104 ± 5 Ma, 127 ± Ma and 476 ± Ma. These wide variations may be due to a protracted history of emplacement and the effect of Eocambrian to palaeozoic tectonothermal events affecting this region (Sinha Roy and Ramakrishnan, 1983.)

In Thiruvananthapuram District, Anakudi and Nedumannur dolerite dykes are dated by K-Ar method and the whole rock ages are 104 ± 5 Ma and 127 ± 2 Ma respectively (Sinha Roy and Ramakrishnan,1983).

Tertiary Sedimentary rocks

Mio-Pliocene sedimentary rocks are fairly widespread in the southern coastal belt, their remnants being noticeable in the central and northern coastal areas. These sedimentary rocks consist of a series of variegated clay and sandstones with lenticular seams of lignite, known as Warkalli Formation, underlain by more compact marly sands with shell fragments and thin horizons of limestone (Quilon Formation).

The Tertiary sediments have a gentle dip towards west. The Warkalli Formation extends in a narrow belt from Thiruvananthapuram (8°28'30": 76°57'20") to Kasaragod (12°30'00": 74°59'00") between coastal and midland regions with intervening promontories of the crystalline rocks. The Quilon Formation is mainly seen at Paravur (08°48'00": 76°40'00") Padappakkara (08°58'30": 76°38'00") and some other places around Kollam and Alappuzha districts.

Quilon Formation

The Quilon Formation consisting of fossiliferous shell limestone alternating with thick beds of sandy clays and calcareous clays have been reported from Padappakkara (type locality),Nedumgolam, Edavai (8°45'20";76°42'00") and Varkala (8°44'00": 76°43'00") and Cherthala (9°41'00":76°20'00") along the west coast of Kerala. The Quilon limestone contains numerous fossils of foraminifera, corals, echinoids and molluscs. The Lower Miocene age for lower stratigraphic horizons and the Upper Miocene age for the topmost beds of the Quilon Formation indicate the lower and upper age limits of these marine sediments. The predominance of black clays, sandstone, bluish grey brackish water shell limestone and nodular limestone clearly indicate deposition in a lagoonal condition .

Warkalli Formation

The Warkalli Formation of Mio-Pliocene age extends all along the Kerala coast.The type section of the Warkalli Formation described by King (1882) is from the sea cliff at Varkala. The exposed section at Varkala cliff is 28-30 m thick consisting of unconsolidated sands of variegated clays, white plastic clays, and carbonaceous sandy clays enclosing impersistent seams and lenses of lignite. The carbonaceous clays and lignite are often impregnated with nodules of marcasite.

Fairly thick beds of carbonaceous clays with lignite seams occur around Nadayara kayal, Tamarakulam (9°08': 76°37'), Puliyur (9°18'00": 76°35'00"), Payangadi (12°00'20": 75°15'40"), Nileswaram (12°15'00": 75°07'00"), Kanhangad (12°17'40': 75°05'00") and in the cliff sections near Cheruvathur (12°13'00": 75°09'50").The most characteristic feature of the Warkalli Formation is the impersistent nature of the constituent beds, suggestive of shallow basin margin deposits.

Laterite

Kerala is the home of the laterite as it was first named by the Dutch traveller, Buchanan 1807. Laterite is widespread in its distribution in the midland region of Malappuram, Kannur and Kasaragod districts where it forms well-defined mesas. The Archaean crystalline rocks and the Tertiary sedimentary rocks are extensively lateritised. The laterite has wide areal distribution in the State and occurs at all levels upto 2000 m, height though mostly restricted to an altitude of 50-150 m above MSL. in the coastal and midland region. A few bauxitic patches also occur within the laterites. The thickness of laterite cappings varies from a few metres to 50 metre at places. At Chovvara (8°21'30"; 77°01'30") in Thiruvananthapuram District and Chattannur (8°50'30"; 76°46'30") and Kundara (8°57'00": 76°40'30") in Kollam District, a zone of about 2 m thick bauxite is recognised at the contact between the crystallines and the overlying sedimentary rocks. The overlying sedimentary column is also blanketed by laterite of varying thickness. The bauxite at the base of the sedimentaries indicates an earlier pre-Warkalli spell of lateratisation. Further, the erosional features on the top part of the bauxite horizon corroborates the antiquity of the earlier spell of lateritisation (Mallikarjuna and Kapali, 1980).

Generally, the laterite after the crystalline rocks is compact and the top crust moderately indurated. The dark brown crust passes downward to pink and buff coloured soft laterite. Quartz veins, joints and fractures can be traced from the top to the bottom of the laterite profile. The laterite profile over pyroxene granulites, meta-ultramafites and gneisses are characterised by relict foliation that conforms to those of the subjacent rocks which indicate the *insitu* nature of the laterite. Porous and spongy texture is discernible in laterites, after meta-ultramafites. Laterite after the Tertiary sedimentaries is well indurated at the top for about 2 to 5 m. Downwards, the profile grades into soft laterite with remnants of gritstone and culminates into a zone of variegated clay.

Quaternary sediments

Recent to sub-Recent sediments of coastal sands, sticky black clay with carbonized wood, silty alluvium and lagoonal deposits are observed mostly in the low-lying areas from Kollam (11°27'00": 75°40'30") to Ponnani and between Kannur (11°51'30":75°21'45") and Nileswaram (12°15'30":75°08'16"). Alluvium is observed along the major river valleys. At places, along coastal tracts, there are raised sandy beaches composed of fine grained reddish sandy loam known as “terri" sands. Palaeo-beach ridges alternate with marshy lagoonal clay in the coastal area.

The sandy stretches are widest between Alappuzha (9°30': 76°20') and Kottayam (9°35': 76°31'), upto 25 km inland from the shoreline. The Quaternaries of the coastal plain have been classified into (i) the Guruvayur Formation representing the earlier strandline deposits with an elevation of 5-10 m; (ii)the Viyyam Formation of tidal plain deposits; (iii) Periyar Formation being mainly of fluvial deposits and (iv) the Kadappuram Formation representing the beach deposits (Krishnan Nair, 1989).

A pebble bed is traced in Valapattanam and Taliparamba river banks in Kannur district. It is exposed south of Valapattanam (11°55‘30": 75 °21‘30"), Kambil maloth (11°58‘:75 °24‘), Morazha (11 °58'30": 75°20'30") and Arathiparamba (12°06'00": 75°15‘30"). The size of the pebbles ranges in dimension from 4.5 cm x 3 cm to 7 cm x 3 cm with occasional cobbles of size 13 cm x 12 cm. The base of the pebble bed is generally 20 to 40 m above MSL and at places, the pebble bed directly rests over the basement rocks. The pebbles are mostly of quartz and rarely of granite and pyroxene granulite. The distribution of the pebble bed along the major river banks demonstrate it to be flood plain deposits, probably of early Quaternary period (Nair *et al*, 1976). In Malappuram and Kozhikode districts, the pebble bed is traced in the riverine terraces at Mavur (11°17'45":75°59'00"), Cheruvannur (11°12'8": 75°49'35") and Chellepparambu (11°14'30":75°59'00"). In Thiruvananthapuram District, the Quaternary pebble bed occurs at an elevation of 45 to 50 m above MSL at Pothenkode (8°37'00":

76°48'56"), Idaikode (8°40'11":76°50'49"), Attingal (8°41'49": 76°48'56") and Andoorkonam (8°36'00": 76°52'30").

Submerged upright tree trunks have been reported from a number of places in the coastal area of Kottayam and Alappuzha districts, indicating neotectonic reactivation in the area. Carbon dating of a sample from the submerged forest at Iravimangalam indicate an age of 7050 ± 130 B.P (Pawar *et al*, 1983).

Structure

The structural grain of the southern Peninsula is controlled mainly by the NNW-SSE trending near longitudinal Dharwarian trend which had folded all earlier structures. Since Kerala State falls in the western limb of the mega-structure almost all the rock distribution is aligned in NW-SE direction. However, detailed structural studies carried out in selected parts of the Kerala (Nair and Nair, 2001) had shown that (a) the earliest folds (F_1) which are represented both on mesoscopic and megascopic scale are tight appressed folds of asymmetrical nature which had given rise to axial plane foliations with characteristic platy mineral alignments (b) the F_2 folds on these foliations (post-folial) are open symmetrical and have developed mainly on megascopic scale and control the disposition of the major lithologies. (c) Subsequent folds (F_3) which deform F_1 and F_2 axial plane traces are broad folds on mega-scale identified with the longitudinal Dharwarian trends and (d) a broad swerve on these Dharwarian trends in ENE-WSW is also decipherable (Fig.2).

Detailed analysis of the remote sensing data had revealed the presence of a number of significant lineament patterns in WNW-ESE, NW-SE, NNW-SSE, NNE-SSW and ENE-WSW directions (Nair, 1990). Mega and intermediate lineaments in WNW-ESE were originally crustal fractures and shears which got sealed or obliterated by a number of igneous emplacements of alkali granite, syenite, gabbro, anorthosite, granophyre etc. The emplacements along the Bavali lineament and those along the Achenkovil lineament both of which trending in this direction had given ages ranging from 500 – 678 Ma. Hence they are iden tified to be the oldest lineament. The Bavali lineament forms the western termination of the Moyar shear. The NW-SE trending lineaments constitute mega lineaments and coincide with the basic dykes occurring throughout the length and breadth of the state. These dykes have given ages ranging from 61 to 144 Ma. The NNW-SSE trending lineaments are generally intermediate lineaments and are attributed to fractures, faults and major joint patterns in the area. It is recognized that the NNW-SSE trending lineaments define a weak zone along which the west coast evolved by faulting. The eastern limit of the Tertiary basin is found restricted along this lineament direction. These lineaments occurring along the west coast are be active as suggested by the progradation of the coast west of these lineaments (Nair, 1987). The lineaments in NNE-SSW are prominent and are identified with major fractures and this together with those in NNW-SSE are taken to constitute a conjugate system of faults in a N-S compressive regime due to the collision of the Indian plate. The ENE-WSW trending lineaments are intermediate lineaments and are well- developed in the northern parts of the Kerala . Since these lineaments truncate other lineaments as evidenced especially in the coastal stretches it is considered the youngest. Many a recent tremors reported are aligned in this direction and hence considered neotectonically active.

Metamorphism

The Precambrian crystalline rocks of Kerala are chiefly metapelites, charnockites with associated gneisses and granulites, schistose rocks with distinct metapelitic and metamafic / ultramafic affinity and granitic derivatives which include the Peninsular gneisses and migmatites. Except the Wynad schists and the Vengad group, the bulk of the crystalline rocks show granulite to upper amphibolite facies of metamorphism. Wynad schist displays a prograde amphibolite facies metamorphism and the retrogression of these rocks leads to lower amphibolite facies metamorphism. The vast charnockite belt occurring on either side of the Wynad schist belt, in north Kerala, shows petrographic evidences of prograde and retrograde reactions (Nambiar, 1996). The rocks of the Vengad Group show greenschist to lower amphibolite facies of prograde metamorphism. The older intrusive bodies show effects of incipient metamorphism, marked by clouding of feldspar and bending of twin lamellae.

Recent investigations on the pressure – temperature range for the formation of characteristic mineral suits within the metamorphic rocks provide a fair idea on the poly-metamorphic history of the rock suits. Rocks of the Khondalite belt of south Kerala indicate a temperature range of 650 to 850°C and pressures 5 to 6 kb (Srikantappa *et al*, 1985). In the Thiruvanathapuram area, the temperature at the peak of metamorphism indicated by the mineral assemblages of the calc-silicate rocks is about 830ºC at 5 K bar considering the vapour absent garnet forming equilibria (Satish Kumar and Santosh, 1996). The scapolite equilibria indicates a peak metamorphic temperature of above 800ºC. Stable isotopes in the marble bands suggest that there was no pervasive infiltration of external fluids. Local infiltration of external carbonic fluid took place during decomposition. Synthesis of such data from different lineament/shear bound segments in Kerala indicate varying metamorphic conditions and uplift history. It is also summerised that there is a progressive decline in the uplift of different segments from north to south (Soman, 1997).


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS