GOVERNMENT OF KERALA

DISTRICT SURVEY REPORT OF MINOR MINERALS

(EXCEPT RIVER SAND)

ALAPPUZHA 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

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Thiruvananthapuram

Table of Contents

List of Figures

List of Tables

DISTRICT SURVEY REPORT OF MINOR MINERALS ALAPPUZHA 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

Alappuzha district situated in the southwestern part of the State, bounded by the Lakshadweep Sea in the west, Kottayam and Pathanamthitta districts in the east, Ernakulam district in the north and Kollam district in the south. The district lies between North latitudes 9^{o} 05' and 9^{o} 54' and East longitude 76^{o} 17' and 76^{o} 36'. Alappuzha is one of the well-developed coastal districts in southern part of Kerala State. Alappuzha district was formed on 17th August 1957.The district is unique for its wide and lengthy coastal plain. The total area of the district is 1,414 sq.km and is the smallest district accounting 3.64% of the area of the State, out of which more than 60% constitute the coastal low and backwater bodies. Coconut palm studded sandy flats garlanded with water bodies, extensive paddy fields, canals, lakes (kayals) all together make the district one of the most picturesque and beautiful parts of the State. As considerable part of the district is occupied by water bodies, navigation is one of the most important modes of transportation in the area. It is the only district in the State where there are no reserved forests. Kuttanad, also known as the "rice bowl of Kerala" has a predominant position in the production of rice. Alappuzha is well known for its coir industry with innumerable outlets for various finished coir products.

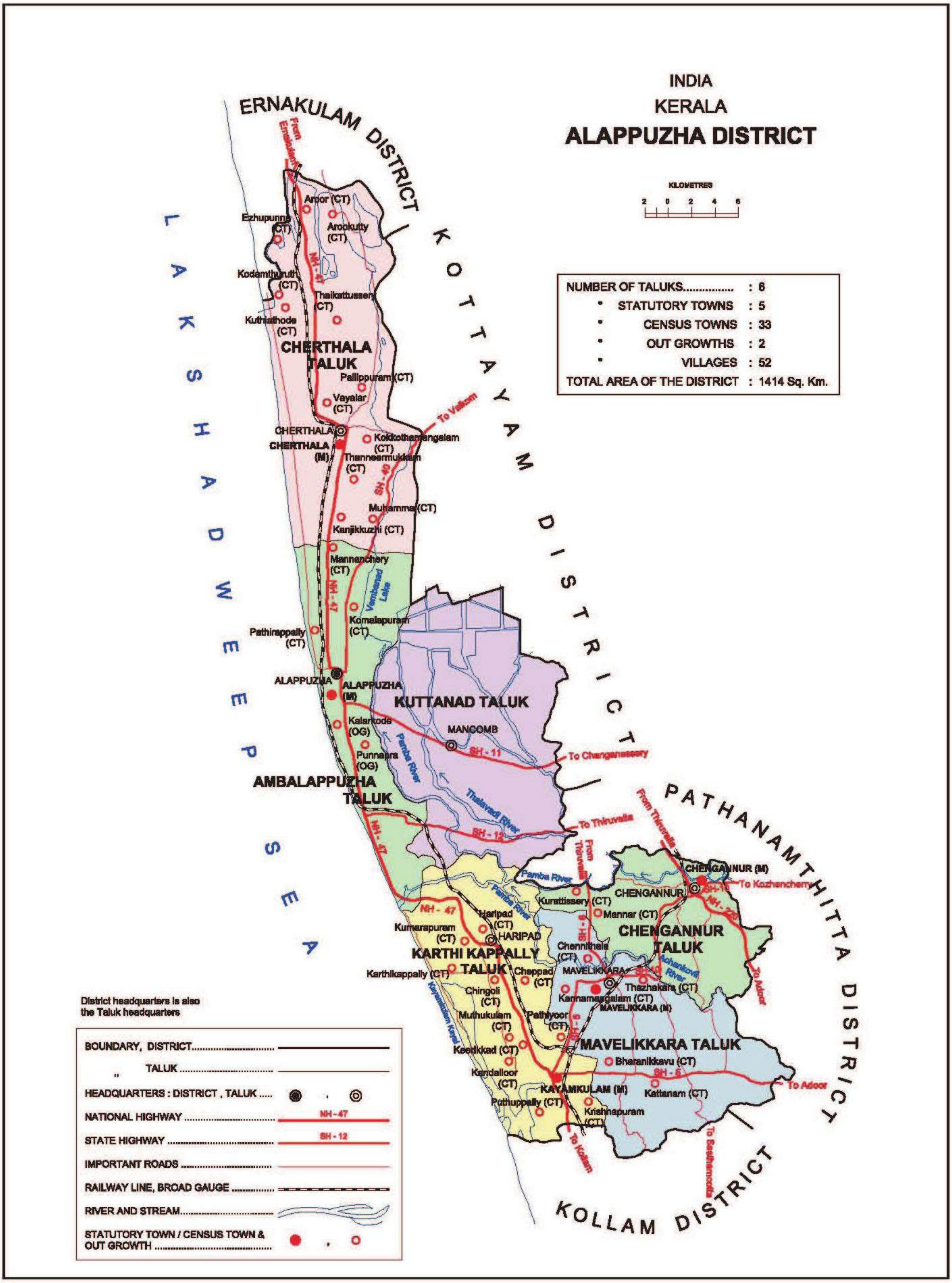
According to 2011 census, the district has a population of 2121943. Of the total population 1010252 are males and 1111691 are females. The population density is 1501 persons/sq.km, the highest among all the districts of the State.

Alappuzha is the Headquarters of the district. The district has 6 taluks viz. Sherthalai, Ambalappuzha, Kuttanad, Karthikapally, Chengannur and Mavelikara which have further been subdivided into 12 Community Development Blocks and 73 Grama Panchayats. There are five municipalities namely Chengannur, Alappuzha, Kayamkulam, Mavelikara and Cherthala.

The district is well connected by good roads and rail. The National Highway NH-47, the Main Central road (M.C road) and the Delhi - Mumbai - Trivandrum broad-gauge railway line are passing through this district. Alappuzha town is crisscrossed by navigable canals that are connected to Cochin in the north and other important towns in the east.

2 Drainage and Irrigation

Alappuzha district is drained mainly by *Pamba* River and its tributaries viz. *Achankovil* and *Manimala* Rivers. The *Pamba* River drains an area of 804 sq.km of the district and form a deltaic region skirting the south eastern, southern and south western fringes of *Vembanad* Lake. The *Manimala* River enters the Kuttanad area at Thondara and confluences with Pamba River at Neerettupuram. Achancovil Ar enters Kuttanad at Pandalam and joins Pamba River at Veeyapuram. Vembanad Lake, the largest back water in the State lies on the north eastern part of the district separating Alappuzha from Kottayam district.



INDIA
KERALA
ALAPPUZHA DISTRICT
KILOMETRES
NUMBER OF TALUKS................ : 6
" STATUTORY TOWNS : 5
" CENSUS TOWNS : 33
" OUT GROWTHS : 2
" VILLAGES : 52
TOTAL AREA OF THE DISTRICT : 1414 Sq. Km.
ERNAKULAM DISTRICT
KOTTAYAM DISTRICT
PATHANAMTHITTA DISTRICT
KOLLAM DISTRICT
LAKSHADWEEP SEA
CHERTHALA TALUK
KUTTANAD TALUK
AMBALAPPUZHA TALUK
KARTHI KAPPALLY TALUK
CHENGANNUR TALUK
MAVELIKKARA TALUK
Aroor (CT)
Arookutty (CT)
Ezhupunna (CT)
Kodamthuruth (CT)
Thaikattussery (CT)
Kuthiathode (CT)
Pallippuram (CT)
Vayalar (CT)
CHERTHALA
CHERTHALA (M)
Kokkothamangalam (CT)
Thanneermukkam (CT)
Muhamma (CT)
Kanjikkuzhi (CT)
Mannanchery (CT)
Komalapuram (CT)
Pathirappally (CT)
ALAPPUZHA
ALAPPUZHA (M)
Kalarkode (OG)
Punnapra (OG)
MANCOMB
Haripad (CT)
HARIPAD
Kumarapuram (CT)
Karthikappally (CT)
Cheppad (CT)
Chingoli (CT)
Muthukulam (CT)
Keerikkad (CT)
Kandalloor (CT)
Puthuppally (CT)
Pathiyoor (CT)
KAYAMKULAM (M)
Krishnapuram (CT)
Kattanam (CT)
Bharanikkavu (CT)
MAVELIKKARA
MAVELIKKARA (M)
Kannamangalam (CT)
Thazhakara (CT)
Chennithala (CT)
Kurattissery (CT)
Mannar (CT)
CHENGANNUR
CHENGANNUR (M)
From Ernakulam
To Vaikom
To Changanassery
To Thiruvalla
From Thiruvalla
To Kozhencherry
To Adoor
To Kollam
To Sasthamcotta
NH - 47
SH - 40
SH - 11
SH - 12
SH - 6
SH - 10
NH - 220
Vembanad Lake
Pamba River
Thakazhi River
Achankovil River
Kayamkulam Kayal
District headquarters is also the Taluk headquarters
BOUNDARY, DISTRICT
" TALUK
HEADQUARTERS : DISTRICT , TALUK
NATIONAL HIGHWAY
STATE HIGHWAY
IMPORTANT ROADS
RAILWAY LINE, BROAD GAUGE
RIVER AND STREAM
STATUTORY TOWN / CENSUS TOWN & OUT GROWTH

3 Rainfall and climate

The district has a tropical humid climate with an oppressive summers and plentiful seasonal rainfall. The period from March to the end of May is the hot season. This is followed by the southwest monsoon season, which continues till the end of September. During October and major part of November southwest monsoon retreats giving place to the northeast monsoon, and the rainfall up to December is associated with northeast monsoon season.

The district receives an average annual rainfall of 2965.4 mm. The southwest monsoon season from June to September contributes nearly 60.3% of the annual rainfall. This is followed by the northeast monsoon season from October to December, which contributes about 20.9% of the annual rainfall, and the balance 18.8% is received during the period from January to May months.

4 Meteorological Parameters

4.1 Temperature

Generally, March and April months are hottest and December and January months are coldest. At Alappuzha the maximum temperature ranges from 28.8 to 32.7ºC whereas the minimum temperature ranges from 22.6 to 25.5ºC. The average annual maximum temperature is 30.7ºC and the average annual minimum temperature is 23.9 ºC.

4.2 Wind

The wind is predominantly from east and northeast during morning hours and during the evening hours the predominant wind direction is from west and northwest. The wind speed is low in Kayamkulam. The wind speed is high during May (13.6 kmph) at Alappuzha.

4.3 Humidity

The humidity is higher during the monsoon period, June to September. It is around 87% at Alappuzha and 84% at Kayamkulam. All through the year, the humidity is high during the morning hours.

5 Geology

Khondalite is the oldest rock of the area and it includes quartzites which occur as lenticular bodies and garnet-biotite-sillimanite gneiss with or without graphite. The charnockite group of rocks including acid and intermediate varieties are found in the north eastern parts. Rocks of the migmatite group reperesented by biotite gneiss (quartzo-feldspathic gneiss) is noticed as small bodies in along the eastern margin of the district. Near Chengannur, a massive granite body representing the acid intrusive occurs. Hills in the southern and western parts are capped by Tertiary sedimentary rocks

(Warkalli Formations). Drilling by CGWB indicated that the Tertiary basin is deepest along the coastal plains of the district and is more than 600m deep south of Alappuzha town. The Kuttanad low land covering an area of approximately 100 sq. km. is reported to have plenty of semi-carbonised and partly decayed wood trunks, roots, branches, leaves etc. buried under a thin veneer of black carbonaceous clay. This region is locally known as Karipadams because of yielding of coal-like (carbonised wood) material from the paddy field. It is believed that this area is submerged forest of Quaternary period. The other Quaternary sediments include strand line/palaeo beach deposit (Guruvayoor Formation), fluvial deposits (Periyar Formation), tidal/mudflat deposit (Viyyam Formation) and beach deposit (Kadappuram Formation) *(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.

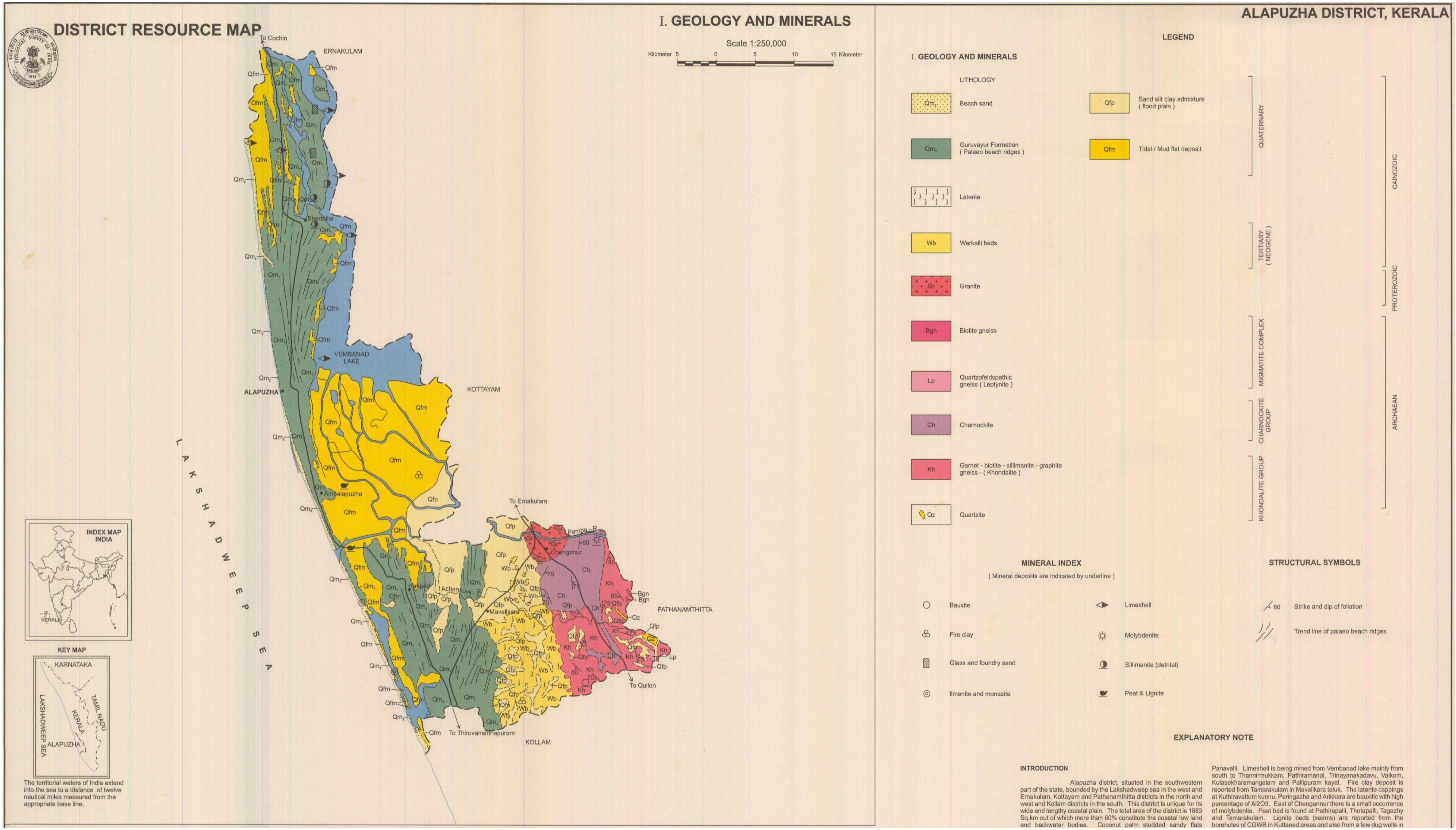


Figure 1: Geology and mineral resources of Alappuzha. *(Sourc: District Resource map, Alappuzha district, Geological Survey of India)*

6 Geomorphology

A major part of the district represents coastal plain characterised by landforms of marine, fluvial and fluvio-marine origin. The general elevation of the area is less than 6 m above mean sea level with some parts of the area below mean sea level in the range of 1-2 m. The widest part of the coastal plain of Kerala is seen in this district, in the stretch between Ambalappuzha-Thiruvalla. Haripad-Chengannur sections where its width is as much as 35km. The prominent landforms of this area are the coastal geomorphic features such as beaches, shore platforms, spit and bars, beach ridges. The beach ridges are suggestive of marine regression. Beach is very narrow and straight. The absence of extensive tidal plain and the intensive coastal erosion may be indicative of neo-tectonic activity. The beach between Purakkad and Trikkunnappuzha is undergoing active erosion. A small part of the district in the southeast forms part of mid land hard rocks.Backwaters in the form of lagoons (kayals), canals, and distributor systems of the rivers occupy a considerable part of the coastal plain. Vembanad kayal, Karthikapally kayal, Vayalar kayal and Vatta kayal are some of the prominent back water bodies. In addition to this, there is a conspicuous low lying area which is below the sea level (05 to 1m below msl) and is always under water logged condition. This is the Kuttanad area south of Vembanad lake i.e., the area east and southeast of Alappuzha town. It represents a low-lying deltaic region characterized by wetlands. All these water bodies are brackish during summer. The Thannermukkom barrage across Vembanad lake and the Thottappalli spillway help to a certain extent the incursion of sea water during the high tide. The low land region along the mouth of Pamba and Achenkovil rivers has helped to develop a well-marked distributor system and formation of delta. Kuttanad is also known as 'rice bowl of Kerala' as this region produces maximum paddy. Punnamada kayal, the venue of famous Nehru Trophy boat race, is also situated in Alappuzha district. Eastern part of the district is characterised by small laterite capped hillocks and narrow valleys representing the midland region *(Figure 2)*.

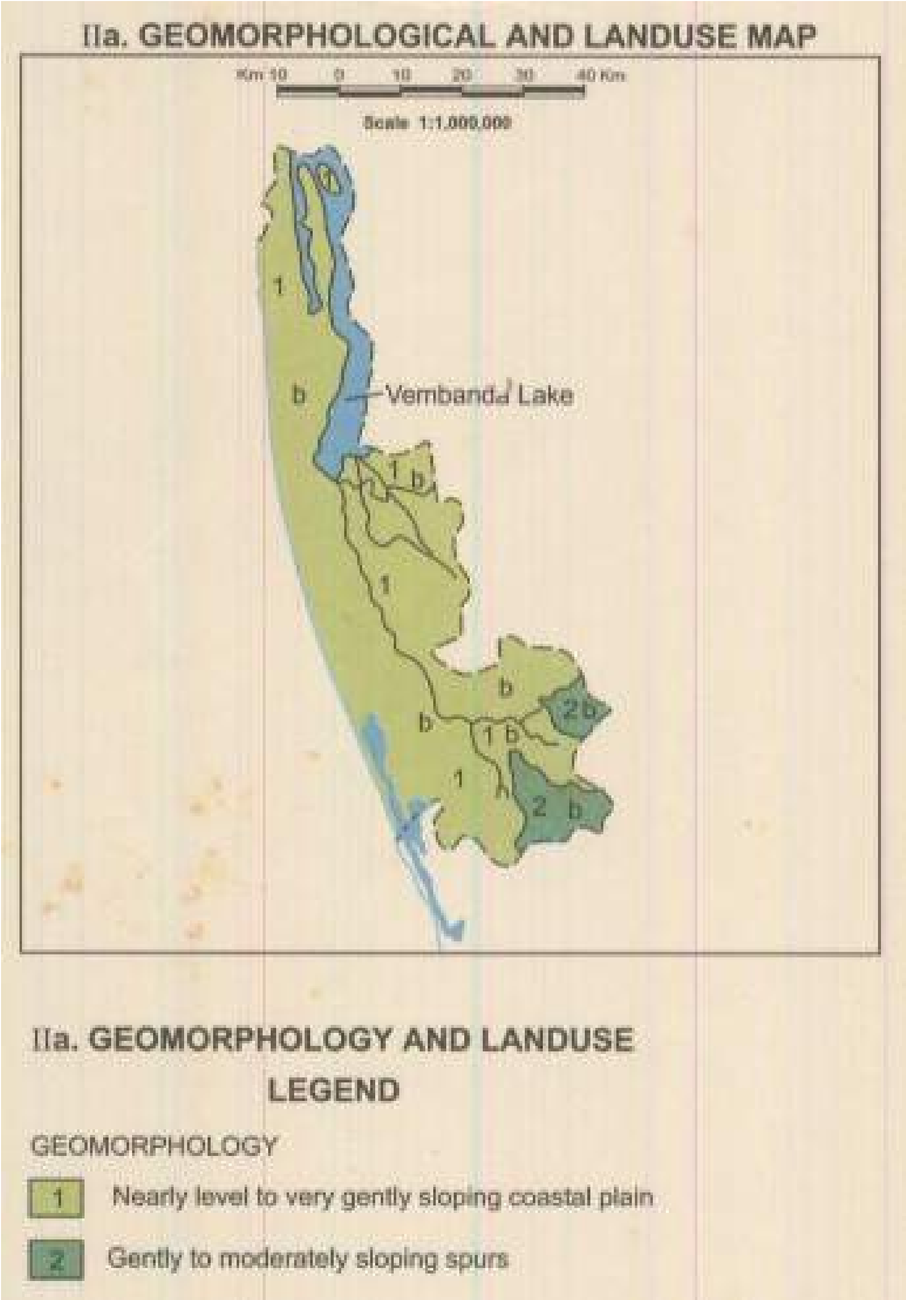


Figure 2: Geomorphology and landuse of Alappuzha. *(Source: District Resource map, Alappuzha district, Geological Survey of India)*

7 Soil types

On the basis of morphological and physico-chemical properties, the Soil Survey Division of Department of Agriculture, Govt. of Kerala has classified the soils of the district into four types viz. (1) Coastal alluvium (Entisols), (2) Riverine Alluvium (Inceptisols) (3) Brown hypidimorphic soil (Alfisols) and (4) Lateritic soil (Oxisols).

Coastal Alluvium (Entisols)

These soils are seen along the western parts of the district all along the coast and have been developed from recent marine and estuarine deposits. The texture is dominated by sand fraction and is extensively drained with very high permeability. These soils have low content of organic matter and of low fertility level.

Riverine alluvium (Inceptisols)

These soils occur mostly in the central pediplains and eastern parts of the area along the banks of Pamba River and its tributaries and show wide variation in their physico-chemical properties depending on the nature of alluvium that is deposited and characteristics of the catchment area through which the river flows. They are very deep soils with surface textures ranging from sandy loam to clayey loam and moderately supplied with organic matter like nitrogen and potassium.

Brown hydromorphic soil (Alfisols)

These are mostly confined in the western low-lying areas of the district along the coast. These soils have been formed as a result of transportation and sedimentation of material from the adjoining hill slopes and also through deposition by rivers and exhibit wide variation in their physical and chemical properties. They are moderately supplied with organic matter like nitrogen, potassium and deficient in lime and phosphate.

Lateritic soil (Oxisols)

The lateritic soil is the result of weathering process of Tertiary and Crystalline rocks under tropical humid conditions and is seen in the south-eastern part of the district. Heavy rainfall and temperature prevalent in the area are conducive to the process of formation of this soil type and have been formed by leaching of base and silica from the original parent rock with accumulation of oxides of iron and aluminum. They are poor in nitrogen, phosphorous, potassium and low in bases. The organic content is also low and is generally acidic with pH ranging from 5.0 to 6.0.

8 Land use

The Kerala State Land Use Board has computed the area under various uses. The following table represents the land under various categories.

Sl. No	Category	Area in hectares	% of total area
1	Geographical area	141400	100
2	Built up land	1894	1.34
3	Agriculture land	121762	86.04
5	Water bodies	17550	12.4
6	Waste land	297	0.21
7	Others	26	0.02

9 Groundwater scenario

Alappuzha district consists of Coastal alluvium comprising sand and clay along the coastal region and flood plain deposits in Kuttanad region. Residual laterite formations are encountered in the south-eastern parts of the district and granites are encountered in and around Chengannur area. Charnockite, Khondalite and Granites form the basement. Charnockites and Khondalites are encountered at depth. They are overlain by Tertiary sedimentary formations. The laterite/alluvial sediments overlay the Tertiaries. Domestic water requirements of the district are met from groundwater source on a large scale. The area consists of two hydrological zones – (i) moderate to low permeability zone and (ii) fairly good ground water potentiality zone. The Pamba river flows in the area forms a part of the deltaic region. As most of the area is underlain by Tertiary sediments, the ground water potential is fair to good. The entire area is an arable land, except the coastal tract where coconut plantation is predominant *(Figure 3)*.

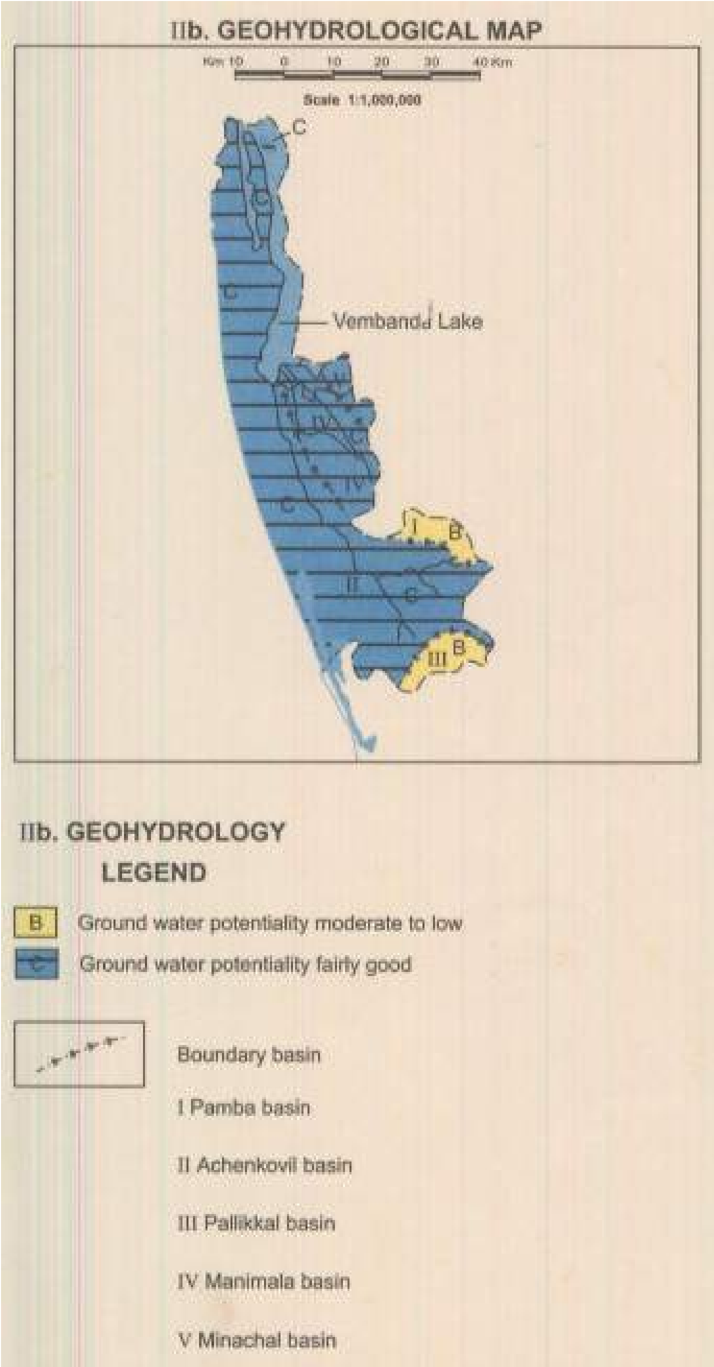


Figure 3: Geohydrology of Alappuzha. (*Source: District Resource map, Alappuzha district, Geological Survey of India)*

10 Natural hazards

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

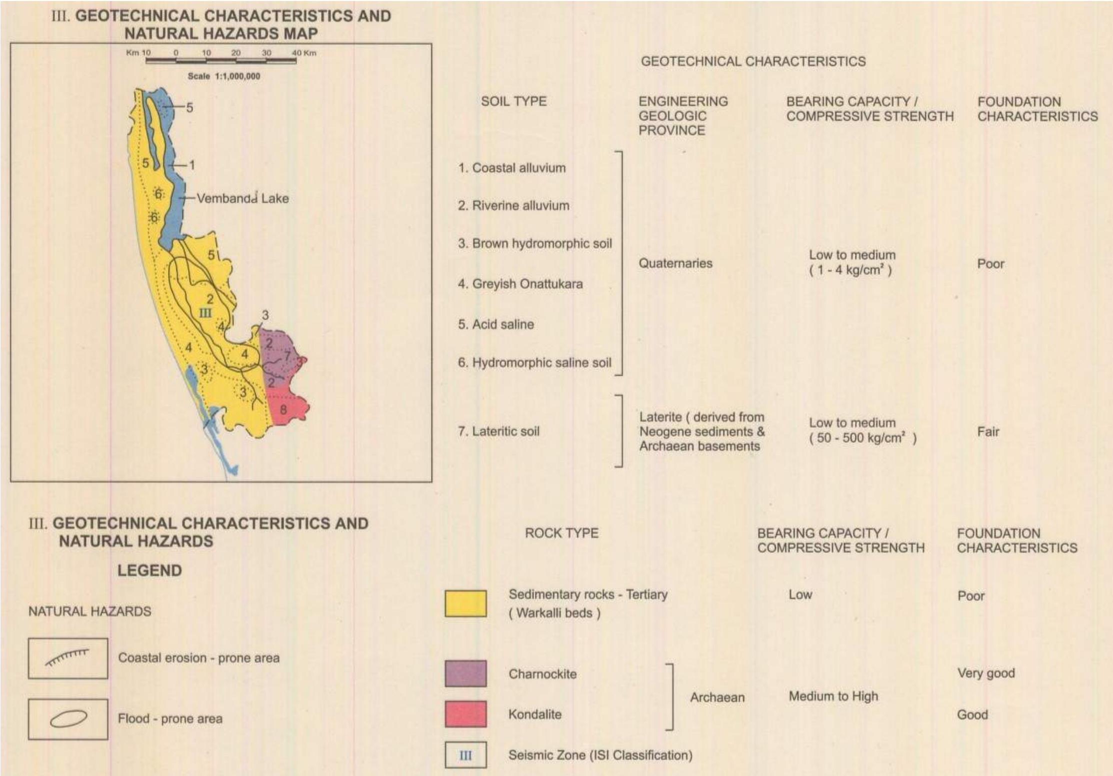


Figure 4: Geotechnical characteristics and natural hazards map of Alappuzha. (*Source: District Resource map, Alappuzha district, Geological Survey of India)*

11 Mineral Resources

11.1 Major minerals

The main economic minerals that are being mined are silica sands and limeshell. The beach sand is reported to have high concentration of ilmenite and monazite. The sand deposits north of Cherthala contain sillimanite also. Occurrence of bauxite, molybdenite, peat and lignite has been reported from various parts of the district.

White silica sands, with more than 95% SiO_2 occur between Alappuzha and Cherthala with extension upto Panavalli. Limeshell is being mined from Vembanad lake mainly from south to Thanneermukkom, Pathiramanal, Thrinayanakadavu, Vaikom, Kulasekharamangalam and Pallippuram Kayal. The laterite capping at Kuthiravattom kunnu, and Peringazha are bauxitic with high percentage of Al_2O_3. East of Chengannur there is a small occurrence of molybdenite. Peat bed is found at Pathirapalli, Thottapalli, Thakazhi and Thamarakulam.

A number of silica sand mines work in Alapuzha district especially in Cherthala Taluk. A number of value addition units work in Alapuzha district for value addition of silica sand.

11.2 Minor Minerals

11.2.1 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.

Coastal Alluvium

These soils of marine origin are identified along the coastal plains and basin lands as a narrow strip. The elevation of the coastal area is generally below 5m MSL. The area has high water table and in some areas it reaches above the surface during rainy season. The soils of the coastal plains are very deep with sandy texture. The texture generally ranges from sand to loamy sand with greyish brown to reddish brown and yellowish red colour. Sand content ranges from 80% and clay up to 15%. Even though these soils have high water table, the water holding capacity is poor due to the predominance of sand. Coconut is the major crop in the area. Cashew and other fruit trees are also grown.

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.

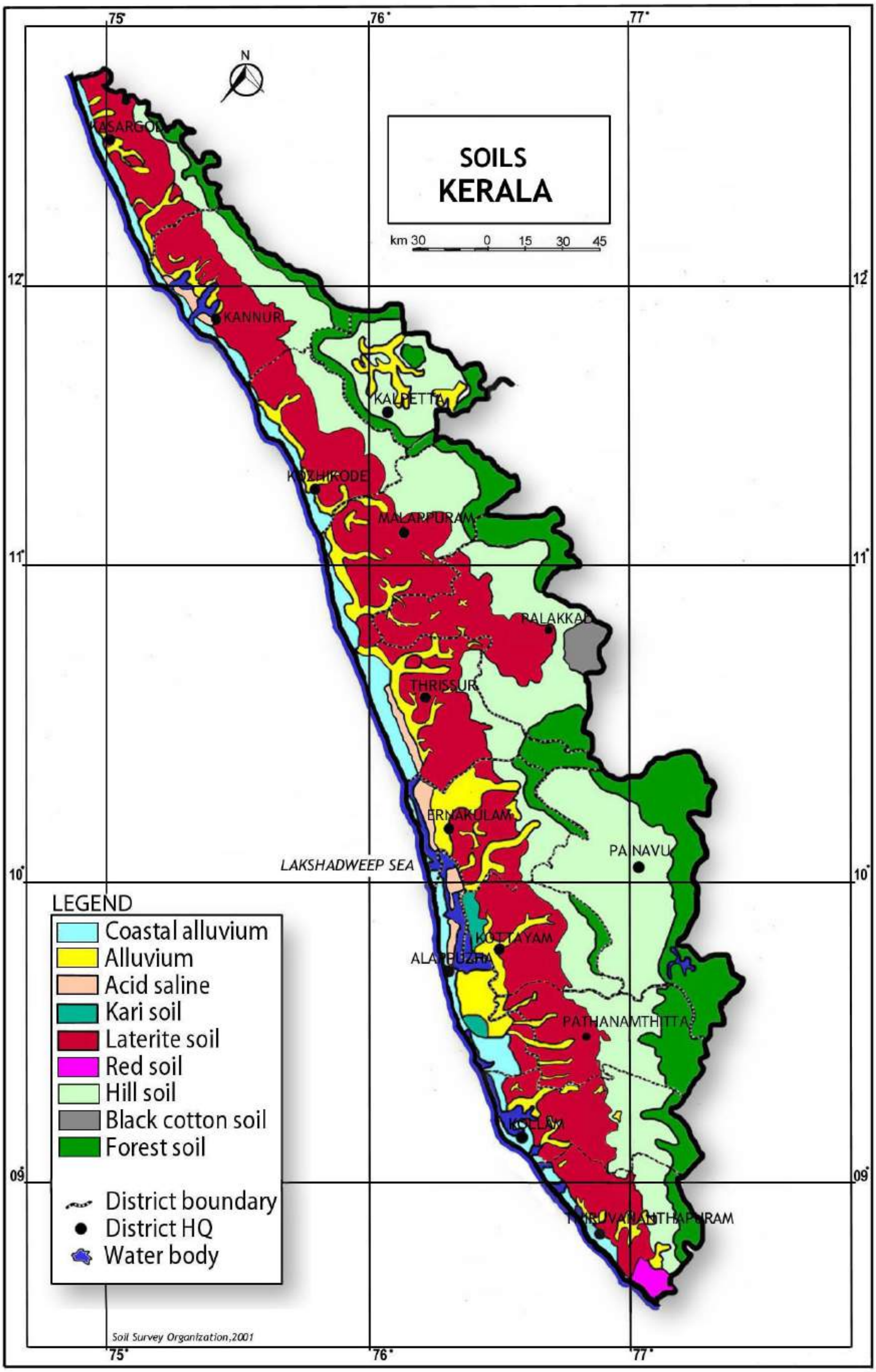


Figure 5: Soils of Kerala

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.

11.2.2 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. Fire clay deposit is reported from Thamarakulam in Mavelikkara taluk.

11.2.3 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.

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.

11.2.4 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.

11.2.5 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 (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'. All Archaean and Proterozoic rocks of Kerala (refer section on Geology of Kerala) 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. In Alapuzha district due to thick sedimentary cover, crystalline rocks are not exposed and hence there are no granite building stone quarries in Alapuzha district. Due to this there a number of minor mineral depot working in Alapuzha district for the sale of granite building stone aggregates like metal and manufactured sand;

11.2.6 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/collected by co-operative society from Vembanad Lake. However, the collection of limestone is restricted to manual methods.

12 Details of minor mineral concessions and revenue collection

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.

In Alappuzha district there are few minor mineral quarries that too for laterite. It may be noted that since granite building stone quarries are not available, a number of dealers licnces have been issued for the sale of granite aggregates in the disrrict.The details of valid minor mineral concessions including dealer's licences issued by the Department are given in the table below:-

Table1: Details of revenue collection for the period 2013-'14, 2014-'15 and 2015-'16

(Amount in Rs.)

Minerals	2013-14	2014-15	2015-16
Major			
Lime Shell	1286405	2184520	2219600
Silica Sand	10329601	14389368	15106958
Total (Major)	***11616006***	***16573888***	***17326558***
Minor Mineral			
Granite (building stone)	791760	607238	2019344
Lime Shell	83995	6000	51076
Laterite	391082	103877	1558134
Ordinary clay	287105	138609	236500
Ordinary Earth	1595545	3153022	8354665
Ordinary Sand	948662	366563	560940
Total(Minor)	***4098149***	***4375309***	***12780659***
Grand Total (Major & Minor)	**15714155**	**20949197**	**30107217**

Table 2a: List of Quarrying Permit granted under CRPS for Laterite Building Stone

Sl. No	Concession holders name & address	Concession No.	Mineral	Sy.No. Village Taluk	Area	Validity From - to
1.	Madhu.G Thadathivila thekkethil,Chooraloor P.O, Mavelikkara	No.27/15-16/MM/ LBS/ DOA/2922/15 Dt.4.1.16	LBS	309/6 Thekkekkara Mavelikkara	4.40 Ares	4.1.16 to 3.1.17
2.	Vinod Kumar Sreevilasom Chunakkara Mavelikkara	No.28/15-16/MM/ LBS/ DOA/1638/15 Dt.6.1.16	LBS	62/11 Chunakkara Mavelikkara	18.00 Ares	6.1.16 to 5.1.17
3.	Muraleedharan Pillai Krishnamruthum Vettiyar, Mavelikkara	No.29/15-16/MM/ LBS/ DOA/99/16 Dt.11.1.16	LBS	108/14-5 Chunakkara Mavelikkara	9.61 Ares	11.1.16 to 10.1.17
4.	Suresh Kumar Ratnalayam Puthenchantha P.O Vallikunnam Mavelikkara	No.9/16-17/MM/ LBS/ DOA/1830/16 Dt.23.11.16	LBS	556/11 Thamarakkulam Mavelikkara	9.44 ares	23.11.16 to 22.11.17

List of dealer's licenses 2016-2017

Sl. No.	Mineral	License no.	Date of grant	Name & address of concession holder	Sy.No.	Village	Taluk	Area (ares)	Panchayat	DL fee (Rs.)	Quantity in (Metric ton)	Valid up to
1.	GBS	1-GBS/16-17/MM/DOA/666/16	6.4.16	C.D. Ajith, Krishna Crusher Metals, Chathiyara, Thamarakulam	506/1-3, 506/1, 502/13-1, 506/1-5	Thamarakulam	Mavelikkara	126.68	Thamarakulam	40000	10000	5.4.17
2.	GBS	2-GBS/16-17/MM/DOA/558/16	29.2.16	Jaya Kumar.T, Puthukadavil, Muttom P.O, Harippad	274/36, 37-1	Cheppad	Karthikappally	23.74	Cheppad	8000	2000	5.4.17
3.	GBS	3-GBS/16-17/MM/DOA/681/16	6.4.16	Jithin Jacob, Kuttithekkethil, Nangiyarkulangara P.O, Harippad	596/6-4	Pallippad	Karthikappally	32.48	Pallippad	4000	1000	31.3.17
4.	GBS	4-GBS/16-17/MM/DOA/696/16	6.4.16	Sunil Kumar, Suresh Bhavanam, Erumakkuzhy, Nooranadu	45/8	Palamel	Mavelikkara	18.55	Palamel	4000	1000	5.4.17
5.	GBS	5-GBS/16-17/MM/DOA/617/16	6.4.16	P.K. Satheesh, Sajibhavan, Kallimel P.O, Mavelikkara	52/1, 52/16, 17-2, 17-3, 17	Chennithala	Mavelikkara	16.81	Chennithala - Thripperunthura	4000	1000	31.3.17

6.	GBS	6-GBS/16-17/MM/DOA/618/16	6.4.16	P.K. Satheesh, Sajibhavan, Kallimel P.O, Mavelikkara	21/9	Vettiyar	Mavelikkara	8.70	Thazhakkara	2000	500	31.5.16
7.	GBS	7-GBS/16-17/MM/DOA/619/16	6.4.16	P.K. Satheesh, Sajibhavan, Kallimel P.O, Mavelikkara	249/32	Chengannur	Chengannur	16.00	Chengannur	4000	1000	31.3.17
8.	GBS	8-GBS/16-17/MM/DOA/693/16	18.4.16	Ratheesh. M.R, Rajeshbhavanam, Karimulakkal, Komaloor P.O	433/14	Thamarakulam	Mavelikkara	10.50	Thamarakulam	8000	2000	17.4.17
9.	GBS	9-GBS/16-17/MM/DOA/557/16	18.4.16	Sibi Thomas, Conso Rocks, Eara P.O, Neelamperoor	186/1, 189/1	Neelamperoor	Kuttanad	80.00	Neelamperoor	72000	18000	17.4.17
10.	GBS	10-GBS/16-17/MM/DOA/559/16	18.4.16	Dileep, Manesseril, Cheravally, Kayamkulam	184/79	Kayamkulam	Karthikappally	15.42	Kayamkulam	8000	2000	17.4.17
11.	GBS	11-GBS/16-17/MM/DOA/688/16	18.4.16	Thomas Raju, Neduvoppil (H), Neelamperoor P.O, Kurichi	84/4	Neelamperoor	Kuttanadu	23.17	Neelamperoor	48000	12000	17.4.17
12.	GBS	12-GBS/16-17/MM/DOA/642/16	18.4.16	C. Beenakumari, Vanitha Metals, Noorandu Sanitorium P.O, Nooranad, Alappuzha	698/1-11, 2-12	Nooranadu	Mavelikkara	93.20	Nooranadu	20000	5000	18.4.16

13.	GBS	13-GBS/16-17/MM/DOA/754/16	18.4.16	Reji Vargheese, Chalevadakkethil, Muttom P.O, Harippad	694/11, 690/3	Karthikappally	Karthikappally	6.85	Karthikappally	4000	1000	17.4.17
14.	GBS	14-GBS/16-17/MM/DOA/753/16	18.4.16	V.S. Unnipillai, Valiyaparambil Veedu, Kallimel P.O, Mavelikkara	41/3-1	Kannamangalam	Mavelikkara	04.41	Mavelikkara	8000	2000	17.4.17
15.	GBS	15-GBS/16-17/MM/DOA/667/16	25.4.16	Chandrasenan,Kakkanattusserril, Prayar North, Prayar	656/11	Puthuppally	Karthikappally	02.64	Devikulangara	4000	1000	31.3.17
16.	GBS	16-GBS/16-17/MM/DOA/2882/15	25.4.16	Divakaran. K,Suresh Bhavanam, Pallippad, Karippuzha	162/6/2	Kannamangalam	Mavelikkara	05.70	Chettikulangara	4000	1000	24.4.17
17.	GBS	17-GBS/16-17/MM/DOA/595/16	25.4.16	K. Jayakumar, K.B. Crushers, Govindamuttom, Puthuppally, Kayamkulam	61/10-13-2, 61/10-13	Puthuppally	Karthikappally	36.8	Devikulangara	40000	10000	24.4.17
18.	GBS	18-GBS/16-17/MM/DOA/698/16	25.4.16	Saju, Puthezhathu House, Varappuzha P.O, Ernakulam	11/12-7, 12-10	Aroor	Cherthala	16.14	Aroor	4000	1000	27.3.17
19.	GBS	19-GBS/16-17/MM/DOA/708/16	25.4.16	Jaleel P.M, Parayampurakkal, Uliyanoor P.O, Aluva	417/7A	Aroor	”	04.05	Aroor	4000	1000	25.3.17

20	GBS	20-GBS/16-17/MM/DOA/721/16	2.5.16	Shankaranarayanan, Kuttiyil, Kallimel P.O, Mavelikkara	146/8,5-2	Nooranadu	Mavelikkara	6.90	Nooranadu	4000	1000	1.5.17
21	”	21-GBS/16-17/MM/DOA/720/16	2.5.16	Preeja Prasad, Kuttiyil, Kallimel P.O, Mavelikkara	2/12-2	Vettiyar	”	12.14	Thazhakkara	4000	1000	1.5.17
22.	GBS	22-GBS/16-17/MM/DOA/762/16	2.5.16	P.N. Sarasamma, Raj Cavity Blocks, Indistrial Area, Kallimel P.O, Mavelikkara	483/4	”	”	14.17	”	24000	6000	1.5.17
23	”	23-GBS/16-17/MM/DOA/766/16	4.5.16	Anwar Hussain Rawther, Thyvilayil Industries, Vettiyar, Mavelikkara	172/1, 172/19	Vettiyar	Mavelikkara	18.60	**Thazhakkara**	8000	2000	3.5.17
24	”	24-GBS/16-17/MM/DOA/756/16	4.5.16	Jacob. K.J, Kochukattil, Nangiyarkulangara, Harippad	185/2	Chingoli	Karthikappally	10.55	Chingoli	8000	2000	3.5.17

25	”	25-GBS/16-17/MM/DOA/755/16	6.5.16	Saifudeen, Manglavil, Kumarapuram P.O, Harippad	349/3	Kumarapuram	Karthikappally	07.25	Kumarapuram	4000	1000	5.5.17
26	”	26-GBS/16-17/MM/DOA/801/16	6.5.16	Subash Kumar, Vilavolil Vadakkethil, Muttom P.O, Harippad	236/1	Cheppad	Karthikappally	6.8	Cheppad	4000	1000	5.5.17
27	’	27-GBS/16-17/MM/DOA/767/16	13.5.16	Vinod, Alamballil, Pilappuzha, Harippad	170/1-2, 6-3, 6-2	Chingoli	Karthikappally	15.57	Chingoli	8000	2000	12.5.17
28	”	28-GBS/16-17/MM/DOA/894/16	13.5.16	Abdul Shukoor, Kattayyathu Puthanpurayil, Kattil Kadavu, Karunagappally	203/29-2, 203/29-2-C	Krishnapuram	Karthikappally	4.05	Kayamkulam Municipality	12000	3000	12.5.17
29.	”	29-GBS/16-17/MM/DOA/800/16	18.5.16	Saju.B, Dwaraka, Mahadevikad P.O, Karthikappally	26/9-2	Karthikappally	Karthikappally	3.24	Karthikappally	4000	1000	16.5.17
30.	”	30-GBS/16-17/MM/DOA/68/16	18.5.16	Renjith Vijayan, Renjith Bhavanam, Manappally	440/18	Vallikunnam	Mavelikkara	9.91	Vallikunnam	4000	1000	17.5.17

31	”	31-GBS/16-17/MM/DOA/888/16		Biju Varghese, Puthenparambil, Anamparambal North P.O, Thalavady	505/4	Thalavady	Kuttanad	14.50 ares	Thalavady	4000	1000	17.5.17
32.	”	32-GBS/16-17/MM/DOA/760/16	23.5.16	Raveendran.S, S.V. Nivas, Kizhakkekkara North P.O, Alappuzha	18/8	Purakkad	Ambalappuzha	20.00 ares	Purakkad	8000	2000	22.5.17
33.	”	33-GBS/16-17/MM/DOA/689/16	27.5.16	Vargheese John, Mullathanathu House, Nangiyarkulangara, Harippad	27/1-2	Cheppad	Karthikappally	4.72 ares	Cheppad	4000	1000	26.5.17
34	”	34-GBS/16-17/MM/DOA/779/16	30.5.16	Komalan, Sruthinilayam, Arunoottimangalam, Mavelikkara	74/18,19, 20	Thekkekara	Mavelikkara	4.8 ares	Thekkekkara	4000	1000	30.5.16
35	”	35-GBS/16-17/MM/DOA/778/16	30.5.16	Chandradas, Nadayil Padeettathil, Arunoottimangala	126/18	Thekkekara	Mavelikkara	6.10	Thekkekara	8000	2000	29.5.17

				m P.O, Mavelikkara								
36.	”	36-GBS/16-17/MM/DOA/1009/16	30.5.16	Martin Vargheese, Kattarakalathil, Pandy P.O, Karuvatta	128/5	Harippad	Karthikappally	12.88 ares	Harippad	4000	1000	29.5.17
37	GBS	37-GBS/16-17/MM/DOA/961/16	2.6.16	K.N. Rajan, Kuttiyil Veedu, Kuttomperoor P.O, Mannar	291/4	Mannar	Chengannur	5.56 ares	Mannar	4000	1000	1.6.17
38	”	38-GBS/16-17/MM/DOA/901/16	2.6.16	P.K. Satheesh, Saji Bhavan, Kallimel P.O, Mavelikkara	21/6	Vettiyar	Mavelikkara	20.7 ares	Thazhakkara	4000	1000	2.6.16
39	”	39-GBS/16-17/MM/DOA/989/16	2.6.16	Radhakrishnan, Pokkattu House, Kallimel P.O, Mavelikkara	39/25-2, 25-80, 25	Thazhakkara	Mavelikkara	09.15	”	4000	1000	1.6.17
40	”	40-GBS/16-17/MM/DOA/663/16	3.6.16	Anil Kumar.P.K, Devi vilasom, Arunoottimangalam P.O, Mavelikkara	84/9-2-1	Kattanam	Mavelikkara	6.07 ares	Bharanikkavu	8000	2000	2.6.17

41	”	41-GBS/16-17/MM/DOA/664/16	3.6.16	. P. Kuttappan, Panachivilayil, Arunoottimangalam P.O, Mavelikkara	752/9	Vettiyar	Mavelikkara	17.60 ares	Thazhakkara	8000	2000	2.6.17
42	”	42-GBS/16-17/MM/DOA/1017/16	6.6.16	Sulfi.K, Panachoor tharayil, Cheppad P.O, Muthukulam	598/11-3, 19	Chingoli	Karthikappally	07.05 ares	Chingoli	4000	1000	31.12.16
43	”	43-GBS/16-17/MM/DOA/768/16	8.6.16	Suresh.T, Souparnika, Arunoottimangalam P.O, Mavelikkara	131/3	Thekkekkara	Mavelikkara	10.60 ares	Thekkekkara	4000	1000	7.6.17
44	”	44-GBS/16-17/MM/DOA/1079/16	10.6.16	Sabu Kuriyakose, Managing Director, Kavunkal Granite P.Ltd. Vadasherikkara, Pathanamthitta	144/108E, 144/108F& 144/108G	Kayamkulam	Karthikappally	23.67 ares	Kayamkulam Municipality	20000	5000	9.6.17

45	”	45-GBS/16-17/MM/DOA/806/16	15.6.16	Sabu, Sabu Bhavanam, Mankamkuzhy, Mavelikkara	85/26	Vettiyar	Mavelikkara	04.00 ares	Thazhakkara	4000	1000	14.6.17
46.	”	46-GBS/16-17/MM/DOA/899/16	15.6.16	Usman Kunju, Sudheer Bhavanam, Cheppad P.O, Muthukulam	315/7-2	Muthukulam	Karthikappally	3.24 ares	Muthukulam	4000	1000	31.3.17
47.	”	47-GBS/16-17/MM/DOA/1049/16	23.6.16	Rajeev.R, Ponnuveedu, Peringala P.O, Kayamkulam	215/52	Kayamkulam	Karthikappally	09.65 ares	Kayamkulam Municipality	8000	2000	22.6.17
48.	”	48-GBS/16-17/MM/DOA/1093/16	29.6.16	K.M. Punnose, Union Block Industries, Kallisserry P.O, Chengannur	446/12	Thiruvanvandoor	Chengannur	13.96 ares	Thiruvanvandoor	12000	3000	28.6.17
49	”	49-GBS/16-17/MM/DOA/1133/16	29.6.16	Sinil. V. Mathew, Excel Granite, Parathodu P.O, Kanjirappally	46/44-5, 46/38	Pathiyoor	Karthikappally	13.18 ares	Pathiyoor	8000	2000	28.6.17

50.	SS	1-SS/16-17/MM/DOA/1106/16	13.6.16	G. Raju, Managing Partner, M/s New R.V. Enterprises, K.R. Puram, Cherthala	130/9-4-2, 130/7B2, 130/3-2, 130/7A1, 128/3B, 130/7A7, 130/3-6, 130/7B, 130/6, 130/8-4, 130/7A3, 130/3, 130/6-2	Pallippuram	Cherthala	96.87 ares	Pallippuram	40000	10000	12.6.17
54	GBS	50-GBS/16-17/MM/DOA/1117/16	1.7.16	Sahadevan.K, K.S. Bhavanam, Pullikkanakku P.O, Kayamkulam	398/1	Bharanikkavu	Mavelikkara	10.80 ares	Bharanikkavu	4000	1000	30.6.17
52	”	51-GBS/16-17/MM/DOA/1116/16	4.7.16	Basheer.A, Vettathethu, Vallikunnam, Mavelikkara	215/12	Vallikunnam	Mavelikkara	10.25	Vallikunnam	4000	1000	3.7.17
53.	”	52-GBS/16-17/MM/DOA/1115/16	8.7.16	Devadasan, Karukayil Devadithya,	622/11-4, 11-3	Kattanam	Mavelikkara	4.86	Bharanikavu	4000	1000	7.7.17

				Arunoottimangalam, Mavelikkara								
54.	”	53-GBS/16-17/MM/DOA/1103/16	8.7.16	Harikumar.P, Pulloor veedu, Pullikanakku, Kayamkulam	182/68	Kayamkulam	Karthikappally	3.65	Kayamkulam Municipality	8000	2000	7.7.17
55	GBS	54-GBS/16-17/MM/DOA/1095/16	13.7.16	Thomas John, Kulangara House, Chingavanam, Kottayam	61/1	Champakkulam	Kuttanad	8.00	Nedumudy	16000	4000	12.7.17
56	”	55-GBS/16-17/MM/DOA/1221/16	18.7.16	Devasya.D, Kunnakkattu House, Anchal P.O, Palamukku, Kollam	247/5	Palamel	Mavelikkara	2.30	Palamel	4000	1000	17.7.17
57	”	56-GBS/16-17/MM/DOA/1247/16	18.7.16	AnilKumar.K, Kattirethu veettil, Kayamkulam P.O, Alappuzha	145/97	Kayamkulam	Karthikappally	4.5	Kayamkulam Municipality	4000	1000	17.7.17
58	L.S	1-LS/16-17/MM/DOA/1148/16	1.7.16	V.K. Vijayappan, Vattathara, Muhamma P.O, Alappuzha	161/7	Thanneermukkom South	Cherthala	12.15	Muhamma	8000	2000	30.6.17

59	GBS	57-GBS/16-17/MM/DOA/1304/16	1.8.16	Sarath, Sarath Villa, Karuvatta North P.O, Alappuzha	429/18	Karuvatta	Karthikappally	6.15 ares	Karuvatta	8000	2000	30.7.17
60	GBS	58-GBS/16-17/MM/DOA/1306/16	1.8.16	Abdul Sathar, Plamoottil thekkethil, Pullikkanakku P.O, Kayamkulam	84/19-2	Krishnapuram	”	03.94 ares	Krishnapuram	8000	2000	30.7.17
61	GBS	59-GBS/16-17/MM/DOA/1307/16	1.8.16	Ayoob.S, Kollakkuttiyil, Krishnapuram P.O, Kayamkulam	30/13-1	Vallikunnam	Mavelikkara	04.45ares	Vallikunnam	8000	2000	30.7.17
62	GBS	60-GBS/16-17/MM/DOA/1071/16	1.8.16	Sarasamma, Raj Cavity Blocks, Industrial Estate, Kallimel P.O	493/18,9, 500/22	Thazhakkara	Mavelillara	20.16 ares	Thazhakkara	16000	4000	30.7.17
63	GBS	61-GBS/16-17/MM/DOA/1230/16	8.8.16	C.N. Murali, Chuttimalayil House, Pennukkara P.O, Chengannur	608/13, 608/20	Ala	Chengannur	4.62	Ala	8000	2000	28.6.17
64	GBS	62-GBS/16-17/MM/DOA/1305/16	8.8.16	K.M. Jose, Kuttikkattil, Kallissery P.O, Chengannur	435/14, 435/30, 435/15,435/15-3	Thiruvanvandoor	”	7.22	Thiruvanvandoor	16000	4000	7.8.17

65	GBS	63-GBS/16-17/MM/DOA/1424/16	10.8.16	C.M. Anas, Cheruvallikkudy, Edavoor P.O, Ernakulam	68/9, 68/10, 68/11	Vallikunnam	Mavelikkara	42.8	Vallikunnam	20000	5000	9.8.17
66	GBS	64-GBS/16-17/MM/DOA/1421/16	10.8.16	T.V. Vijayakumar, Muthirakkalathundil, Venmony P.O, Chengannur	176/6, 173/21, 175/1-2, 175/ 2-2, 175/16, 175/17, 173/23, 173/5, 173/4-2, 173/ 3-2, 173/20, 173/22	Venmoney	Chengannur	86.33	Venmony	40000	10000	9.8.17
67	GBS	65-GBS/16-17/MM/DOA/1287/16	12.8.16	Radhakrishnan, Pokkattu, Kallimel P.O, Mavelikkara	113/20, 5,16	Kattanam	Mavelikkara	9.07	Bharanikav	4000	1000	11.8.17
68.	GBS	66-GBS/16-17/MM/DOA/1389/16	19.8.16	Gopalakrishnan Unnithan, Palanilkkunnathil, Nooranad P.O, Mavelikkara	347/18	Palamel	"	4.80	Palamel	4000	1000	18.8.17
69	GBS	67-GBS/16-17/MM/DOA/1423/16	19.8.16	Muhammad Basheer, Vaniyan parambu,	370/5-2	Punnapra	Ambalappuzha	21.49	Punnapra South	8000	2000	18.8.17

				Vandanam P.O, Alappuzha								
70.	GBS	68-GBS/16-17/MM/DOA/1388/16	22.8.16	Sunny Ouseph, Thekkethottiyil, Muthalakkedom. P.O, Thodupuzha	611/12-3	Pazhaveedu	"	3.64	Alappuzha Municipality	8000	2000	21.8.17
71.	GBS	69-GBS/16-17/MM/DOA/1422/16	22.8.16	Sethunadhan, Sethupuram, Karuvatta P.O, Alappuzha	458/5-B, 458/5-C	Kumarapuram	Karthikappally	2.33	Karuvatta	4000	1000	21.7.17
72	GBS	70-GBS/16-17/MM/DOA/1408/16	22.8.16	G. Sreekumar, Sreebhavanam, Akamkudy P.O, Nangiyarkulangara, Harippad	22/4	Cheppad	"	5.00	Karthikappally	4000	1000	31.7.17
73	GBS	71-GBS/16-17/MM/DOA/1445/16	25.8.16	SureshKumar.M.S, Mangalabhavan, Puliyoor P.O, Chengannur	205/3-1	Puliyoor	Chengannur	6.32	Puliyoor	4000	1000	24.8.17

74.	GBS	72-GBS/16-17/MM/DOA/1046/16	31.8.16	Thaha Kunju, Kulathinte padeettathil, Kannampalli bhagam, Kayamkulam	Block 24, 73/3-2, 60/2-2, 73/2-2, 73/3, 60/2, 73/2	Keerikkad	Karthikappally	8.90	Kayamkulam Municipality	8000	1000	30.8.17
75.	GBS	73-GBS/16-17/MM/DOA/1509/16	31.8.16	Thomas John, Kulangara Veedu, Chingavanam P.O, Kottayam	478/6	Thiruvanvandoor	Chengannur	4.2325	Thiruvanvandoor	20000	5000	18.8.17
76	GBS	74-GBS/16-17/MM/DOA/1517/16	5.9.16	Lukose Mathew, Kakkamparambil, Vakathanam P.O, Kottayam	455/8,9 10-1, 10-2	Thiruvanvandoor	Chengannur	22.83 ares	Thiruvanvandoor	8000	2000	23.5.17
77	L.S	DL.No. 2-LS/16-17/MM/DOA/1569/16	26.9.16	Hamsa, Choolachirayil, Perumbalam P.O, Cherthala	285/3	Perumbalam	Cherthala	1.61 ares	Perumbalam	4000	1000	25.9.11
78	GBS	75-GBS/16-17/MM/DOA/1547/16	26.10.16	Nissar.K, Panachortharayil, Cheppad P.O, Muthukulam	535/14	Muthukulam	Karthikappally	5.00 ares	Muthukulam	4000	1000	25.10.17

79	GBS	76-GBS/16-17/MM/DOA/1594/16	26.10.16	Soumya. M.V, Mannil Veedu, Naranganam(W) P.O, Kozhancherry	5/16-1, 5/16-2	Thycattusserry	Cherthala	2.60 ares	Thycattuserry	4000	1000	25.10.17
80.	GBS	77-GBS/16-17/MM/DOA/1734/16	26.10.16	Roopesh Kumar, Kaitha tharayil, Eramathoor P.O, Mannar, Mavelikkara	282/8-2, 282/ 8-7, 282/8-4, 282/ 8-3, 282/8-5	Mannar	Chengannur	9.1 ares	Mannar	4000	1000	25.10.17
81	GBS	78-GBS/16-17/MM/DOA/1566/16	26.10.16	Nazar Ashraf, Thammanathuparambil, Thammanam, Ernakulam	11/13-2	Aroor	Cherthala	16.19ares	Aroor	4000	1000	25.10.17
82	GBS	79-GBS/16-17/MM/DOA/1154/16	31.10.16	Raju.C, Kottuvallykizhakkethil, Cheravally, Kayamkulam	148/1-E	Kayamkulam	Karthikappally	2.81ares	Kayamkulam	4000	1000	30.10.17
83	GBS	80-GBS/16-17/MM/DOA/1635/16	31.10.16	Saritha.G, Madathinkal, S.L. Puram. P.O, Cherthala	328/4-2	Kanjikuzhy	Cherthala	22.60	Kanjikuzhy	4000	1000	30.10.17
84	GBS	81-GBS/16-17/MM/DOA/1550/16	2.11.16	Reji Joseph, Narikkatt, Vazhoor, Chamampathal P.O, Kottayam	525/7-2, 525/7	Muthukulam	Karthikappally	7.65 ares	Muthukulam	8000	1000	1.11.17

85	GBS	82-GBS/16-17/MM/DOA/1508/16	4.11.16	Ranjesh.M.R, Mundakathil, Thalavady P.O, Alappuzha	85/11-4, 85/11-2	Ramankary	Kuttanadu	11.12	Ramankary	4000	1000	3.11.17
86	GBS	83-GBS/16-17/MM/DOA/1549/16	16.11.16	Baiju.G, Padannayil, Muthukulam, Alappuzha	423/11-4	Arattupuzha	Karthikappally	4.05	Arattupuzha	4000	1000	19.10.17
87	GBS	84-GBS/16-17/MM/DOA/1756/16	16.11.16	Shaji.P, Kochutharyil, Puthiyavila P.O, Kandaloor	254/2-2	Kandaloor	Karthikappally	4.05 ares	Kandaloor	4000	1000	15.11.17
88	GBS	85-GBS/16-17/MM/DOA/1672/16	18.11.16	Razeena, Muttanisseril, Eruva(E) P.O, Kareelakulangara, Kayamkulam	46/2, 46/3	Pathiyoor	Karthikappally	12.00 ares	Pathiyoor	4000	1000	17.11.17
89	GBS	86-GBS/16-17/MM/DOA/1848/16	21.11.16	Sunny Thomas, Keekattil (H), Kallisserry P.O, Chengannur	631/18-1, 631/19	Chengannur	Chengannur	3.67	Chenganoor Municipality	4000	1000	20.11.17

90	GBS	87-GBS/16-17/MM/DOA/1616/16	21.11.16	Manoharan.R, Mahesh Bhavanam, Muthukulam, Kayamkulam	167/8, 167/9	Keerikkad	Karthikappally	3.45 ares	Keerikkad	4000	1000	20.11.17
91	GBS	88-GBS/16-17/MM/DOA/1674/16	23.11.16	Sudin. P. Sukumar, Pampala (H), Kuttemperoor P.O, Mannar	635/7-1, 635/25, 635/5	Kurattisserry	Chengannur	10.55 ares	Kurattisserry	4000	1000	22.11.17
92	GBS	89-GBS/16-17/MM/DOA/1595/16	23.11.16	Radhakrishnan, Krishnavilasom, Cherukunnam, Thekkekkara, Mavelikkara	68/14	Thekkekkara	Mavelikkara	8.00 ares	Thekkekkara	4000	1000	22.11.17
93.	GBS	90-GBS/16-17/MM/DOA/1931/16	30.11.16	Binu Idiculla, Parankammoottil, Muttom P.O, Harippad	471/9	Cheppad	Karthikappally	5.80 ares	Cheppad	4000	1000	24.11.17
94.	GBS	91-GBS/16-17/MM/DOA/1939/16	30.11.16	Sajeev. S, Manu Bhavanam,	270/6B, 7/C	Cheppad	Karthikappally		Cheppad	4000	1000	29.11.17

				Evoor P.O, Cheppad				2.84 ares				
95.	GBS	92-GBS/16-17/MM/DOA/1938/16	30.11.16	Saji.D, Thundil(H), Kayamkulam P.O, Alappuzha	167/74-2	Kayamkulam	Karthikapally	5.26 ares	Kayamkulam	4000	1000	29.11.17
96	GBS	93-GBS/16-17/MM/DOA/1940/16	30.11.16	Gopalakrishnan.K, Puthenveettil(H), Kandaloor P.O, Kayamkulam	618/11-2, 618/12-2	Kandaloor	Karthikapally	10.11 ares	Kandaloor	4000	1000	29.11.17

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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	Younger granites (550-390ma)	Alkali granites, granite, Granophyres and other acid intrusives
O T	Charnockites(younger) (550Ma)	Massive charnockite, incipient charnockite , Cordierite charnockite
E R	Ultrabasic/basics(Younger) (700-600Ma)	Perinthatta anorthosite, Kartikulam gabbro, Adakkathodu gabbro, Begur diorite
O Z	Basic Intrusives (2100-1600Ma)	Agali- Anakkatti dykes
O	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
I	Vengad (APtv) Group	Quartz-mica schist and quartzite, conglomerate
A R	Charnockite(older) (Ac) 2600Ma	Mafic granulite, pyroxene granulite, Banded magnetite quartzite and gneissic charnockite
C	Khondalite Group (Ak)	Quartzite, mafic granulite, calc-granulite garnet-biotite-sillimanite-cordierite gneiss, garnet-biotite-gneiss, leptynite
H A	Peninsular Gneissic Complex (PGC I) (Ap) (3000Ma)	Foliated granite, hornblende gneiss, pink granite gneiss, biotite gneiss
E	Layerd ultrabasic - basic Complex (3100- 3000Ma)	Peridotite, dunite, pyroxenite, anorthosite
A N	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 ± 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^{o}06'20", 76^{o}05'56") Velli(11^{o}04'00":76^{o}07'45"), Kalpetta (11^{o}04'12":76^{o}05'32). An extensive basic diorite has been mapped over an area of 25 sq km at Panavalli (11^{o}53'30",76 ^{o} 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$\pm$ 30 Ma, Nair, *et al*,1985) is lower than Rb-Sr age (595 $\pm$ 20 m.a Santhosh *et al*, 1986), but is higher than that of U-Pb-age(505$\pm$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