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GEOLOGY AND MINERAL RESOURCES OF THE STATES OF INDIA

PART IX – KERALA

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I INTRODUCTION

Kerala State, bounded by north latitudes 8º17'30" and 12º47'40" and east longitudes 74º51'57" and 77º24'47" covers an area of 38,864 sq km and is located in the southwestern part of the Indian Peninsular shield. This linear strip of land is bounded by the Western Ghats on the east and the Arabian sea on the west. The state is divisible into four broad physiographic units. They are: (i) the low-level coastal strip fringing the Lakshadweep sea, (ii) the landforms marked by laterite cappings between altitudes of 30m and 200 m, (iii) the foot hills of Western Ghats ranging in altitude from 200 to 600 m and (iv) the steeply rising Western Ghat hill ranges with altitudes reaching upto 2500 m. Of the total area, 35,955 sq km area is constituted by hard rock crystallines and the rest by soft sediments. The crystallines comprise charnockite, gneiss, granite, metasediments, gabbro and dolerite to mention the major ones. The sedimentaries occur mostly in the coastal areas. Mineral deposits of clay, bauxite, rare earth sands, glass sand, iron ore, limestone, gold, graphite, chrysoberyl etc. are known to occur in the state.

The geology of Kerala kindled the interest of even the earliest workers in the field. Buchanan in 1800 coined the term “laterite" after a study of the quarries near Angadipuram in the erstwhile Malabar. General Cullen (1840 – 60) discovered graphite occurrence in Travancore and was the earliest to study the sedimentary formations around Kollam. In the later part of the 19th Century, Bruce Foote, (1883) and William King,(1875,1878,1882) of the Geological Survey of India (GSI) took traverses across the State and recorded their findings on geology and mineral resources. In 1907, a Geology Department was formed in Travancore for systematic survey of minerals. Chacko (1922) and Masillamani (1914) made significant contributions to the geology of Kerala.

With the inception of Kerala Circle in 1962, GSI, in co-ordination with the State Department of Mining and Geology (DMG) and other Government agencies, took up the responsibility of systematic mapping and preliminary mineral surveys in the State. The systematic geological mapping of the State was completed in the year 1983. The officers of GSI involved in this achievement are Sarvashri T.M. Mahadevan, P.S. Rao, K.M. Sivadas, G. Mani, V.C. Jacob, J.N. Rao, D.V. Raju, A.R. Sawarkar, K.B. Nair, P.K. Thampi, U.S. Reddy, G.B. Nair, T.A. Selvan, S.R. Nair, K.V. Poulose, M.M. Nair, R. Srinivasan, Abdul Moghni, K.Bhaskaran Nair, S. Jayaram, L.S. Gopalakrishnan, A.K. Relan, S.T. Sambandam, S.D. Pawar, P.V. Sukumaran, K.T. Vidyadharan, M. Senthiappan, V. Rengamannar, C. Mallikarjuna, T.C. Lahiri, G.N. Varadan, S.G.Krishna, S.S.Raghavan, J.K.Attre, K.S.Adiga, P.Kapali, V.Padmanabhan, R.P.S.Chouhan, K.K.P.Singh, A.R.Nambiar, T.N. Rajan,

B. Venkataramana, Anil Kumar, J.S. David, Thomas Mathai and M.S. Raman. The geological and mineral map of Kerala (1995) on 1:500,000 scale is the culmination of this effort.

Mineral surveys in the state have brought out a number of occurrences of economic minerals, of which, some promising ones were taken up for preliminary exploration to assess their potential. As a result of this and by the efforts of the State DMG and the Kerala Mineral Exploration and Development Project(KMEDP), 15.73 million tonnes of bauxite(Rao and Varadan,1967; Rao and Srinivasan,1968, Sivadas and Nair, 1972); 370 million tonnes of clay (State DMG 1990; Poulose and Srinivasan,1967; Rajan, 2000); with an inferred potential of over 2000 million tonnes of clay in Kasaragod, Kollam and Thiruvananthapuram Districts (Mallikarjuna and Kapali 1980; Krishnan Nair and Koshy John, 1994 and 1995); 100 million tonnes of glass sands (State DMG 1984; Poulose and Nair, 1965); 9.57 million tonnes of graphite (Nair, 1967;Varadan and Krishna 1976; Muraleedharan, 1987; and State DMG and KMEDP, 1981); 100 million tonnes of iron ore(Rao and Reddy, 1972a,b &c; Mani,1965 and 1970;Mani and Rajagopalan Nair, 1967) and 12.09 million tonnes of limestone (Mani and Padmanabhan,1969; Rao *et al* .1974; Attre and Reddy, 1975) have been estimated. Gold deposits of Nilambur and Attapadi are being explored in detail by GSI. In addition, Kerala has rich deposits of beach sands containing ilmenite, monazite, zircon and sillimanite which are being explored by the Atomic Minerals Division.

In this volume, an attempt has been made to compile the available data on geology and mineral deposits occurrences of Kerala.

II 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).

III 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	Younger granites (550-390ma)	Alkali granites, granite, Granophyres and other acid intrusives
R		
O	Charnockites(younger) (550Ma)	Massive charnockite, incipient charnockite , Cordierite charnockite
T		
E	Ultrabasic/basics(Younger) (700-600Ma)	Perinthatta anorthosite, Kartikulam gabbro, Adakkathodu gabbro, Begur diorite
R		
O	Basic Intrusives (2100-1600Ma)	Agali- Anakkatti dykes
Z		
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
C		
A	Charnockite(older) (Ac) 2600Ma	Mafic granulite, pyroxene granulite, Banded magnetite quartzite and gneissic charnockite
R		
C	Khondalite Group (Ak)	Quartzite, mafic granulite, calc-granulite garnet-biotite-sillimanite-cordierite gneiss, garnet-biotite-gneiss, leptynite
H	Peninsular Gneissic Complex (PGC I) (Ap)	Foliated granite, hornblende gneiss, pink granite gneiss, biotite gneiss
A	(3000Ma)	
E	Layerd ultrabasic - basic Complex (3100- 3000Ma)	Peridotite, dunite, pyroxenite, anorthosite
A	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
N		

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. Charnockite has lesser predominance in Thiruvananthapuram and Kollam districts. In Attappady, the Bhavani Shear Zone is limited by the charnockite massif of the Nilgiri plateau on the north. Though the interrelationship of the Charnockite and the Khondalite is not clear, in many places there are intercalations rather than interlayering of one with the other. In Palakkad District, the Khondalite Group of rocks structurally overlie the charnockite. The occurrence of pyroxene granulite as fine and linear bodies within the charnockite of Tirur, suggests that charnockite is a product of migmatisation of pyroxene granulite(Vidyadharan and Sukumaran, 1978). Charnockite and charnockitic gneiss consist of quartz, feldspar and biotite. Garnet-bearing variants are also observed. The basic charnockite is more granulitic and contains clino- and ortho- pyroxenes, feldspar, biotite and garnet whereas the acid variety (alaskite/ enderbite) is greenish black, coarse-grained, massive to poorly foliated rock consisting of quartz, feldspar and pyroxenes. Basic charnockite has low- potash feldspar and more clinopyroxene. This is devoid of garnet and graphite, but shows a little amount of biotite(Chacko, 1922). Due to the polygenetic nature of the rock, geochemical and mineralogical variations do exist between charnockites reported from Kerala. In the Periyar valley region, in Idukki and Kottayam districts, pyroxenite and alaskite constitute the Charnockite Group (Nair, and Selvan, 1976).

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

Also charnockite has been subjected to retrogression and migmatisation.

ARCHAEAN TO PALEO 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^{o}10'00":75^{o}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 identified 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 polymetamorphic 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).

IV ECONOMIC MINERALS

The existing level of information on the mineral resources of the state indicate rich deposits of heavy mineral sands along the coast and rich clay deposits. Other significant occurrences include bauxite, iron ore, graphite, limestone and gold (Fig.I).

Geological Survey of India, State Directorate of Mining and Geology, Kerala Mineral Exploration and Development Project and a few other agencies are actively involved in the prospecting and exploration of minerals. A brief account of the mineral wealth of the state is given below, database being updated to 2000.

ALLANITE

Minor occurrences of Allanite are noticed at Puthiyamuthur (10°40'00":76°07'00"), Sholayar dam (10°17'00":76°45'00") and Ambalavayal in the state (see Appendix).

BAUXITE

In Kerala, bauxite is associated with laterite and occurs as cappings over the crystalline and Tertiary sedimentary rocks and form lateritic plateau rising from 50 to 150 m above the msl. The bauxitic clays are mainly restricted to south Kerala, ie., Thiruvananthapuram, Kollam and Alappuzha districts.The primary bauxite is massive in appearance, dull white, light pink to deep brown in colour and is found in north Kerala, viz., Kannur and Kasaragod districts.

The primary bauxites generally show high iron content with low silica whereas the bauxitic clays have moderate iron and high silica contents. Bulk of the primary bauxite is of low-grade with 40-45% alumina, whereas alumina content of the bauxitic clays usually ranges from 45 to 53% with high silica content (8% and above).

Some important deposits are located in Kannur, Kasaragod, Thiruvananthapuram and Kollam districts. On the basis of preliminary exploration,

GSI has estimated a total reserve of 15.73 million tonnes in Kannur, Kasaragod , Thiruvananthapuram and Kollam districts.

The bauxite in Kannur and Kasaragod districts are mostly high in iron (Fe_2O_3: 20-25%), moderate in alumina (Al_2O_3: 40-45%), and silica varying from 3 to 4%. The bauxite of Thiruvananthapuram and Kollam districts is high in silica (SiO_2 :8-12 %) and moderate in iron (Fe_2O_3 :11-15%).

Kannur District

Some promising bauxite deposits located in the district are Payyannur (12°06'20": 76°13'00") and Taliparamba (12°02'00": 75°21'00") areas where GSI has done preliminary exploration.

Bauxite occurs in Taliparamba, Pattuvam (12°02‘30": 75°21‘45") and Madayi (12°'15'00": 75°15'30"). A reserve of 1.5 million tonnes of bauxite of all grades with over 40% Al_2O_3 has been estimated.

Kasaragod District

Occurrences of bauxite are found in Kumbla Bela (12°34'00": 74°30'00"); Kumbla (12°35'00":74°57'00"), Yedanad (12°36'00":75°00'00"), Badiadka (12°27'44": 75°09'50"), Perla (12°38'30": 75°06'30"), Kanhangad (12°18'15":75°05 '15"), and Nileswaram (12°15'30": 75° 08'16").

Kumbla *:* Good quality bauxite was located in Kumbla area in Narayanamangalam, Ananthapur Gudda (12°34'40": 74°59 ‘50"), Pernegudda (12°34'40": 74°59'40"), Siddangoli and Patla ridge. Bauxite occurs over an area of 0.12 sq km in Ananthapur Gudda, over 0.23 sq km in Narayanamangalam and 0.04 sq km in Pernegudda hillock. The lateritised bauxite ore is generally confined to the top 3.5 metres. A total probable reserve of 1.83 million tonnes is estimated in these localities with 40% Al_2O_3 and less than 15% silica. Out of the 1.83 million tonnes, 0.3 million tonnes is commercial grade ($Al_2O_3 \leq 50\%$) (Rao and Srinivasan, 1968).

Nileswaram : In Nileswaram preliminary exploration has yielded a total of 8.1 million tonnes of bauxite in four blocks over an area of 1.0 sq km ranging in quality from 40 to 50% Al_2O_3 and around 8% silica. (Varadan *et al*, 1972).

Kanhangad : Preliminary exploration has indicated a probable reserve of 0.7 million tonnes of bauxite over an area of 0.12 sq km in Kanhangad Block- II situated about 12 km NNE of Kanhangad, near Periya. The Al_2O_3 content of the ore ranges from 40 to 54% (Varadan, 1974).

Kollam and Pathanamthitta districts

In Kollam District, the bauxite occurrences are at Churanad-Vadakkumuri (9°6'30": 76°39'00"), Adichanallur (8°53'00": 76°43'00") and Chittavattam (8°59'30":

76°42'00") area. At Churanad-Vadakkumuri, the bauxite horizon is 2 to 5.5 m thick upto a depth of 14.3 m over an area of 0.2 sq km. A probable reserve of 1.9 million tonnes. of ore with 48% to 50% Al_2O_3 has been estimated.

In Adichanallur, the average thickness of bauxite horizon is about 4.47m covering an area of about 0.02 sq km. A probable reserve of 0.26 million tonnes. with an average grade of 50% Al_2O_3 has been estimated. In Chittavattom area, bauxite horizon has an average thickness of 4.1 m over an area of 0.05 sq km. A probable reserve of 0.51 million tonnes of bauxite with an average grade of 48.4% Al_2O_3 and 8.87% SiO_2 may be available in this area (Sivadas and Nair, 1972).

Minor occurrences of bauxite are noticed in Pathanamthitta district (see Appendix).

Thiruvananthapuram District

Bauxite deposits are located at Mangalapuram (8°37': 76°49'), Sasthavattom (8°38'00": 76°49'00"), Ambalam (8°53'00":76°37'00"), Attippara(8°32'30": 76°53'30") and Mudapuram (8°37'00":76°49'00") area in Thiruvananthapuram district.

Mangalapuram-Chilampil: The average thickness of the bauxite horizon is 3 m within an area of 0.07 sq km indicating a probale reserve of 0.5 million tonnes of bauxite with an average grade of 40-50% Al_2O_3 (Sivadas and Nair, 1972).

Sasthavattam : The average thickness of the bauxite horizon is 2.57 m over an area of 0.06 sq.km. A probable reserve of 0.36 million tonnes. of bauxite with 50% Al_2O_3 has been estimated. Friable, dark grey bauxite occurs here as thin blankets. The friable, pisolitic bauxite is white to pink in colour.

Ambalam: The average thickness of the bauxite horizon is 1.5 to 2 m. the bauxite occurs as friable dark grey thin blankets. White and pink bauxite is pisolitic and analyses 40 to 50% Al_2O_3. A probable reserve of 0.01 million tonnes is estimated.

Attippara: The average thickness of the bauxite horizon is 2.2 m over an area of 0.012 sq km. A reserve of 0.06 million tonnes of bauxite with 40 to > 50% Al_2O_3 has been estimated in this area.

BUILDING MATERIALS

The crystalline rocks comprising charnockite, khondalite, leptynite and various gneisses are being actively quarried in the midland region for building stone and road metal purposes. The dyke rocks, mainly dolerite and gabbro are also useful as building material. The coastal and midland region has extensive laterite cover especially in Malappuram, Kannur, Thiruvananthapuram, Kollam and Kasaragod districts. In the coastal area the laterites are formed after the sedimentary rocks and in the midland and further east, the laterites are after the crystallines. The laterites are

extensively used as building blocks. A number of mechanised laterite quarries exist in, Malappuram, Kannur and Kasaragod districts.

CHRYSOBERYL

The occurrence of gem quality chrysoberyl (Beryllium aluminate) is known since long in Thiruvananthapuram and Kollam Districts. The distribution pattern of the gemstone workings indicate the prevalence of a more or less NW-SE trending 48 km long and 11 km wide chrysoberyl-bearing zone, extending from Attingal (8°42'00": 76°49'00"), in the north to Parassala (8°20'00": 77°09'00") in the south, in Thiruvanathapuram District. It occurs as an accessory mineral in (minor, impersistent and lenticular) swarms of pegmatite veins that traverse the Archaean gneisses of the area viz., garnet-sillimanite gneiss and associated garnetiferous and non-garnetiferous quartzo-feldspathic gneiss of the Khondalite and Charnockite groups. Chrysoberyl is won by two modes (i) from pegmatite (primary), and (ii) from gravels and old river beds (secondary).

Pegmatites occur in almost all types of rocks in the area but heavy mineral studies suggest that incidence of chrysoberyl is more and frequent in the provenance areas comprising khondalitic rocks than that of charnockites. Lateratized gravel beds representing palaeochannels proximal to the present day river course are supposed to be good prospect for chrysoberyl recovery, (Nair, 1989).

Thiruvananthapuram District

Chrysoberyl is found associated with pegmatites, concordant with gneissosity of the crystallines and containing minerals like muscovite and tourmaline in Thiruvananthapuram District,(Jacob,1965; Gopalakrishnan, 1971; Gopalakrishnan and Chauhan, 1974). The major occurrences are at Nemom (8°27'25:77°00'15") near Vellanad, Vengannur (8°25'30":77°02'30"), Chullimanur (8°38'00":77°01'00"), Uzhamalakkal (8°35'00":77°04'00"), Attingal (8°39'00":77°00'00"), Uriakod (8°33'00":77°05'00"), Konniyur (8°40'00":76°55'00"),Venjaramud (8°41'00": 76°55'00"), Pothencode (8°37'00"12": 76°54'05"), Ayittala, Koduvannur (8°44'00": 76°52'00"), Thottamala (8°44'00":76°53'00"), Parameswaran(08°41'35":76°55'40") and Chembur (8°41'00": 76°54'00"), Korani (8°40'00": 76°50'00"), Kolakkod (8°34'00": 77°03'00"), Nedumangad (8°36'00": 76°00'00"), Balaramapuram (8°25'29": 77°02'57"), Neyyattinkara (8°24'00": 77°00'50"), Parassala (8°20'00":77°09'00"), Cherukulathur (8°34'00":77°05'00"), Kiralikod (8°38'20":77°02'00"), Kokkottukonam (8°40'00": 76°55'00"), Ponnambi (8°40'00": 76°55'00"), Alandara (8°42'00": 76°53'00"),Venpakal (8°23'00": 77°04'00"), Kunnathukal (8°23'00":77°10'00"), Airayil Desam (8°20'00": 77°08'00"), Pottamavu (8°40'00":77°02'00"), Braimore (8°46'00": 77°06'00"), Mannikkal (8°39'00": 76°56'00") and Kallara (8°41'00": 76°54'00").

This precious stone is also recovered from river gravels (Jacob,1965; Gopalakrishnan and Chauhan, 1974) along the course of Karamana *Ar*, at Aruvikkara (8°34':77°01'), Killiar at Karakulam (8°34'00": 76°59'00"), Vamanapuram *Ar* at

Palode (8°43'00": 77°00'00") and Vamanapuram (8°43'00": 76°54'00"), Neyyar at Pongumud (8°28'00": 77°05'00") and Kulathupuzha *Ar* at Kulathupuzha (8°54'00": 77°03'00"). Chrysoberyl is also reported from the Tertiary gravels interbedded with clays and gritty, ferruginous sandstones at Pothencode (08°37'00": 76°48'56"), Andurkonam (8°36'00": 76°52'00") and Alumanur (8°39'00": 76°55'00").

The Kerala Mineral Exploration and Development Project(KMEDP) studied the occurrences of Thiruvananthapuram and Kollam districts between 1978-1980. The project has ascertained the occurrence of chrysoberyl, cat's eye, alexandrite, ruby, sapphire, beryl, acquamarine, topaz, zircon, sphene and spinel. The occurrences are confined to (1) pegmatites traversing the crysatlline rocks, (2) gravels in river channels and (3) older gravels often consolidated and lateritised. The quality of the gemstones is assessed to be fair to good (Garson, 1979a).

Kollam District

Minor occurrences of chrysoberyl are noticed in Kollam District (see Appendix).

CLAY

In Kerala, residual and sedimentary clays are found. The former is a weathering product of the feldspars in the gneisses and granites. Sedimentary clay is found in association with the Tertiary sedimentaries along the coastal belt of Kerala.

Kerala is an important producer of kaolinitic clay, ball clay and china clay. Mining of clay is confined to Thiruvananthapuram, Kollam, Ernakulam, Kannur and Kasaragod districts. The state produces annually an average of 1.08 lakh tonnes of processed china clay forming 9.08% of the country's annual production. The production of crude and processed china clay in the districts of Thiruvananthapuram, Kollam and Kannur are as follows:

District	Crude	Processed
Kannur	31.4%	24.4%
Kollam	36.0%	43.5%
Thiruvananthapuram	29.4%	31.8%

Fire clay and ball clay are also mined in the state

Alappuzha district

Fire clay: The State Department of Mining and Geology has estimated a reserve of 1 million tonnes of fire clay from Thamarakulam (9°28'00": 76°37'00"), in Mavelikkara taluk.

Brick clay**:** Sandy silt deposited in the Vembanad lake and alluvium of the Achankovil *Ar* flood plains around Kulanada (9°14'30': 76°40'45"), Ullanur (9°14'45": 76°42'00") and Tumbamon (9°13'15": 76°43'00") are locally utilised for the manufacture of country bricks. The alluvium, rich in sand fraction is found to be suitable for moulding into bricks. The thickness of brick clay deposits at Munro Island (9°31'25": 76°21'25") is of the order of 0.5 to 1 m from the surface, while at places around Pandalam it goes up to 2.3m and occasionally even up to 7m.

Ernakulam District

China Clay**:** One metre thick china clay occurs at Trikkakara (10°02'00": 76°20'00") about a metre below the ground surface.

The State Department of Mining and Geology(DMG) has located clay deposits at Mulanthurthy (9°54'00":76°24'00"), Amballoor (9°52'30":76°23'30"), Kanjiramattom (9°49'00":77°32'00"), Thekkumbhagam (8°57'00":76°34'00"), Manjummal (10°05'00": 76°18'00") and Manjali (10°09'00": 76°16'00"). A reserve of 4.70 million tonnes of china clay is estimated.

The Tertiary sedimentary rocks are generally underlain by china clay. A promising occurrence is reported around Kanthachapel at Tiruvankulam (9°56'30"; 76°22'30").The clay occurs over an area of 100m x 50m; its thickness being 7 to10 m.

At Vettukkunnu near Kandanedu (9°54'50": 76°22'46") china clay is being mined. The clay is white with shades of red and contain some grit.

Fire clay**:** Occurrence of fire clay has been located at Amballoor (9°52'30": 76°23'30"), Kanjiramittam (9°54'00": 76°28'00"), and Kozhimedu areas and a total reserve of 0.70 million tonnes has been estimated by the State Department of Mining and Geology. At Puthenchira (10°15'00":76°4'30"), Kodungallor (10°13'30": 76°12'00") and Poonamangalam (10°18'25":76°12'00"), a reserve of 2.3 million tonnes of fire clay has been estimated.

Tile clay and Brick clay**:** Investigations by the State DMG have revealed a total reserve of 12.9 million tonnes of tile clay and 8.35 million tonnes of brick clay in Kaladi (10°09'57":76°26'20"),Chengal(10°09'22":76°25'43"),Mattoor (10°09'22": 76°25'23"), Vengur (11°40'00":76°10'30"), Parur (9°51'40":76°22'45"), Naithode (10°10'23":76°24'00"), Sreemoolanagaram (10°08'12":76°27'40") and Manjapra (10°12'58":76°27'40") in Aluva taluk. The thickness of the deposit is found to be 1.7 m to 2.5 m.

Kannur District

Clay of both sedimentary and residual origin are known to occur in Kannur district. An inferred reserve of 10 million tonnes is estimated.

China clay**:** China clay occurs at the base of the Tertiary sedimentary rocks. The Payyangadi (12°01':75°15'00") china clay deposit, 1.5 km NW of Payangadi Railway

Station is over 10m thick and is overlain by 30m pile of Tertiary clay, lignite and laterite. China clay is also seen near Chovva (11°52'00":75°22'00"). The State DMG has estimated a total reserve of 14.85 million tonnes of china clay at Timri (12°14'00":75°14'00"),Kooval(11°46'50":75°54'45"),Payangadi 12°05'00":75°15'00"), Erinapuram (12°02'45":75°15'30"),Ramapuram (12°10'25":75°17'15"), Cheruthazham (12°02'00":75°14'00"), Panayathanaparamba, Vattali (11°48'30":75°52'30"), Putturam, Attachirakkal, Achakunnu and Kariyaman. DMG and KMEDP, based on detailed exploration in Cheruthazham area estimated a reserve of 2.30 million tonnes (DMG, 1990). They have demarcated an area of 0.6 sq.km in Payangadi area (Madai village) as being mineable reserves of china clay. The reserve of china clay estimated in the area is 17 million tonnes (KMEDP, 1995). The character of the clay confirms its utility in ceramic industries.

Ball clay : It occurs at Puttuvam (12°02'30": 75°21'45"), Erinapuram and Payangadi (12°01'30":75°15'30") areas. The State DMG has estimated a reserve of 0.4 million tonnes in Kannur district.

Fire clay : The DMG has estimated a reserve of 0.15 million tonnes at Pattuvam.

Tile clay : The Quaternary clay used for the manufacture of roof tiles and bricks contain fine sand, silt and clay. The clay is highly plastic and ferruginous. About 20 million tonnes of tile clay is calculated. The dominant blocks are situated at Pattuvam (12^{o}01'30":75^{o}18'30"-3.2 million tonnes) and Kattayil- Kaithapram area (12^{o}6'30":75^{o} 15'20"; 12^{o} 07'10":75^{o}17'40": Nair, 2000 and 2001).

Kasaragod District

China clay **:** A total resource of 385 million tonnes of china clay is estimated for the district spread over 23 blocks. China clay is being mined in the district at a number of places. A china clay quarry owned by Hindustan Clay Ltd., is situated at about 2.5 km northwest of Nileswaram (12°15':75°07'00). Here, the clay horizon is 10 m thick and is overlain by 10-12 m of Tertiary sedimentary rocks. The clay content is 40%. In Pudukkai area a 10 m thick clay horizon is reported. A total reserve of 1.0 lakh tonnes of clay was indicated in the leasehold area of the company and 2.4 lakh tonnes as inferred reserves. Exploratory drilling by DMG at Kodankote mala (12°12'25" 75°08'15") reveals that 0.12 sq km area comprises kaolinite clay-bearing with an average thickness of 11m and the tentative reserve of 2.5 million tonnes.

At Periya (11°50':75°51'30"),10 km northeast of Kanhangad (12°18'15": 75° 05'15"), the thickness of the clay varies from 7.5m to 15m, beneath an overburden of hard ferruginous laterite. Here, the overburden to clay ratio is nearly 1:1. At Kalanad (12°27'00":75°01'00") the residual clay is over 7 m thick. The overburden constitutes 25 m thick Tertiary sediments. Investigation for kaolinitic and refractory clays in Jerrugatta (12°44'30":74°55') and Vorkady (12°44'55":74°56'35") near Manjeshwar established a 2 to 4.5 m thick clay horizon over an area of 4.5 hectares.

The investigation to estimate the reserves of clay in the leasehold of M/s. Super Clays and Mineral Mines Company was undertaken by the State DMG. The

average thickness of sedimentary clay is 3.4 m and the residual clay iss 9.9 m. A reserve of 1.0 lakh tonnes has been estimated in the area and 2.6 lakh tonnes as inferred reserves.

Exploration for, both sedimentary and residual clay was taken up by GSI during 1994-96 in Palai (12°15'40":75°09'40") block, east of Nileswaram. The total resource potential of clay estimated in 20 boreholes in an area of 1.565 sq km is 44 million tonnes, which include 25 million tonnes of residual clay and 19 million tonnes of sedimentary clay. The clay is kaolinite type and characterisation studies indicate its suitability for textile, rubber, paper, insecticides and ceramic industries (Rajan, 2000).

In an area of 310 sq km in the district, 23 primary clay bearing blocks were delineated in an area of 46 sq km by large-scale mapping on 1:25,000 scale along with logging of wells, road / rail cuttings and mine sections. The thickness of the clay zone varies from 0.5 m to 8.5 m and that of the overburden from 4.5 to 20 m. The clay is generally grayish white, cream, creamy white or off-white in colour and slakes easily. A resource potential of 385 million tonnes of clay is estimated from these blocks. The flood plains of rivers and streams have fairly thick layers of tile clay. Sixteen such blocks were delineated, of which Pulluru (12°21'20":75°05'40"), Mannatta (12° 21'00": 75°06'40"), Kizhakkumkara (12°19'40": 75°05'40"), Arangadi (12°25'40":75°10'00") and Kakkut (12°16'00": 75°10'30") are the promising areas. A resource potential of 6.9 million tonnes of tile clay is estimated (Krishnan Nair, 1998 and 1999).

Tile clay**:** The area is rich in tile clay and brick clay deposits. 16 nos. of good tile clay prospects having a reserve of about 7 million tonnes. were delineated .

Kollam District

*China clay***:** Kollam District has by far the largest potential of china clay in the state. The best known occurrence is at Kundara (8°57':76°41').In an area of 200 sq km from Paripalli (8°48'30":75°45'36") to Kundara (9°57'20":76°40'30"), along the eastern margin of the Tertiary sedimentary basin, 14 blocks covering an area of 40 sq km were delineated as sedimentary clay-bearing. The thickness of the sedimentary clay varies from 1m to 14m with an overburden thickness of 1m to 10m. The recoverability of clay varies from 40 to 98%. The resource potential of sedimentary clay in these blocks is estimated as 470 million tonnes.

In the same area, 12 blocks covering an area of 12 sq. km is found as residual clay-bearing. The thickness of overburden in these blocks ranges from 6m to 20m and that of the clay horizon from 1 to 10m. The average recoverability of clay is about 50%. The total resource potential in these blocks amounts to 72 million tonnes (Koshy John, 1997 and1999).

Kundara: Investigations were carried out for proving the China clay reserve over an area of 0.0515 sq.km. The chemical analysis of washed clay samples has indicated that the Al_2O_3 content varies from 31.07 to 39.96%, Fe_2O_3 content from 0.20% to 2.28%, CaO content from 0.24% to 1.16%, TiO_2 < 1.1% and SiO_2 content varies from 43.24% to 52.59% MgO upto 0.42% and LOI from 8.97% to 15.47%. A total reserve of 0.8 million tonnes has been estimated in the area**.** China clay is used for paper coating, textile, medicine, detergents, oil refinery, ceramics, paint, plastic, rubber, insecticides.

A tentative reserve of 320 million tonnes of China clay has been reported in 13 blocks in Kollam district. This estimation is mostly based on the well sections. The important blocks are:

1. Anchalummood- Kuripuzha area – 60 million tonnes. (8 ^{o} 55'50":76 ^{o} 36'10")
2. Valliman area (8 ^{o} 58'30":76o38'20") - 15 million tonnes.
3. Kanjirakotusseri – Kumbalam area (8^{o}58'20":76^{o}40'20"); (8^{o}59'20": 76^{o} 39' 30") – 160 million tonnes.
4. Bharanikavu-Chakkuvalli area (9^{o}3'30":76^{o}38'20"; 9^{o}5'10":76^{o}38'20") - 15 million tonnes
5. Mulavana area (8^{o}59'30":76^{o}40'40") - 25 million tonnes.

These reserves were calculated by considering the small areas.

Mulavana (8°59'00":76°41'00"): The State DMG has identified 0.16 sq.km area as clay bearing. Further detailed work has indicated that an area of 0.065 sq.km contains a total clay reserve of 1.56 million tonnes. The average thickness of sedimentary clays and kaolinitic residual clay were found to be 4.4 m and 6.9 m, respectively. The washed clays on analysis gave an average 48.61% SiO_2, 38.79% Al_2O_3, 1.37% Fe_2O_3, and 0.24% TiO_2. The thickness of overburden varies from 1.0m to 11m. A total reserve of 1.56 million tonnes of clay was estimated in six blocks with a probable reserve of 0.026 million tonne of sedimentary clay in one block and a possible reserve of 0.11 million tonnes of sedimentary clay and 0.077million tonnes. of residual clay in another block.

Vellichikala (8°53'30":76°43'13"): The detailed investigation in Vellichikala over an area of 0.26 sq.km has indicated 16.25 hectares to be clay bearing. The average overburden thickness is 12.5m. Total reserve of clay, both sedimentary and residual, is 7.4 million tonnes. Investigation by the GSI (1980) indicated 6.5 million tonnes of clay at Muttanam (8°49'45":76°46'15"), Kummallur (8°51'30":76°44'30"), Kaithakuzhi (8°52'45":76°44'00"), Kudiyichirakonam (8°54'00":76°42'00"), Nallila (8°55'30":76°42'30") and Kumbalam (8°59'30":76°39'45"). In Pallimon village the State DMG drilled 20 boreholes and estimated a reserve of 2.5 million tonnes of clay in 13 hectares.

Perumpuzha (08°56'53":76°41'22"): Drilling indicated nearly 10 hectares as clay-bearing. a tentative estimate indicates 4.3 million tonnes of clay which include 1.3 million tonnes of sedimentary clay and 3 million tonnes of residual clay.

Kalluvathukkal: (08°50'30":76°46'30"): Pale white to white sedimentary clay and kaolinitic residual clay together constitute 15m thick clay horizon over an area of 0.07 sq km.

Chattanur: (8°51'28":76°42'52"): An estimated reserves of .08 million tonnes of clay is being worked by the Vaveleru clay mines (Paulose and Srinivasan, 1967)

Perayam: The State DMG has located deposits of china clay at Chirakara (8°44'30":76°43'30"),Kaithacode(8°57'00":74°44'00"),Pallimon 08°53'40":76°43'06'), Vellichikala (8°53'30":76°43'13"), Kunnathoor (09°03'40":76°40'32"), Vadakumthala and Muthupilakad (09°02'40":76°39'50") and estimated a total reserve of 29.70 million tonnes. The thickness of clay ranges from 12 to 20m.

Ball Clay**:** Deposits of fairly plastic, grey ball clay occur within the Tertiary sandstone at Kumbalam (08°59'28":76°39'50"), Kanjirottusseri (8°58':76°38') and Mulavana (8°59'00":76°41'00"). The clay is rather impure due to high content of marcasite. A reserve of 1.3 million tonnes has been estimated by DMG from the occurrences near Polachira (8°50'30":76°42'30") and Padappakkara (8°59'00":76°39'00").

Fire clay**:** Small deposits of earthy, plastic, detrital clays occur at Kundumon (8°56':76°37'),Vellichikala(8°53'30":76°43'13"),Pallimon,Pavumba9°06'20":76°35'33 Ambalathumbhagam (09°04'32":76°39'40") and Vadakkumthala. A reserve of 8.10 million tonnes is estimated from these areas by the State DMG.

Kottayam District

Minor occurrences of clay deposits are recorded in a number of places in the district (see Appendix).

Kozhikode District

Residual clay**:** Residual clay is found near Kottuli (11°16'00":75°47'30"), near Mavur (11°15'45": 75°57'15"), Nallur (11°10'00":75°50'45"), Iringavur (11°55'30":75°57'30"), Talukottur (10°58':75°55'), south of Kottasseris (10°43'30".76°07'30") and Chelambra (11°09'00":75°52'00"). The occurrence around Nallur appears significant. The average thickness of clay is 2-3m. The total reserve in Nallur area would be of the order of 7.1 million tonnes (Pawar and Chauhan, 1980).

Based on the study of hill cut and well sections the following areas are demarcated as residual clay-bearing (1) Kodiyeri, (2) Adiyur, (3) Mandarathur, (4) Payyoli,(5) Naderi, (6) Muzhikkamit, (7) Karavannur and (8) Kuruvangad

Kodiyeri (11°44'30":75°31'15") is situated 3 km east of Tellicherry town. The clay, generally is rich in micaceous minerals and non-plastic. Clay potential is 3 million tonnes.

Adiyur (11°40':75°35'30") is 6 km south of Mahe (11°42'30":75°32'00"). The clay potential is 1.35 million tonnes.

Mandarattur (11°36'30":75°40'30") lies 11 km east of Badagara (11°35'45":75°35'). The clay, in general is non-plastic and grit content varies from 10 to 30%.

Payyoli (11°31'30":75°39'00"): The deposits around Payyoli township near the backwaters of Agalappuzha and Murat River is of semi-plastic variety.

Naderi (11°27'45":75°43'00"): Clay is reported on a hill slope east of Mattambi Kadavu Bridge. The clay is non-plastic and coloured in various shades of red. Clay potential is of the order of 2.4 million tonnes.

Tile clay**:** Tile clay deposits occur in most of the river banks as flood plain deposits or as lake deposits. These are greenish white, deep brown to purple, highly plastic and rich in fine humus. The important localities are Purameri (11°40'45": 75°37'45"), Irigannur (11°42'00":75°36'15"), Orkkatteri (11°39':75°:35'45"), Chorod (11°36'30" : 75°35'30"), Muttungal (11°36'45":75°35'00"), Chemmarattur (11°36'44": 75°38'30"), east of Payyoli (11°31'30":75°39'00") and Vokali (11°29'30":75°44'00").

Malappuram District

Sedimentary Clay**:** Sedimentary clay occurs around Farokh (11°11'00":75°50'00") in 3 blocks. In each block 2 to 3 lenses of clay are seen and the aggregate thickness in different block is 4 to 5 m. The clay is semi-plastic, white to pinkish white in colour with a grit content of 5 to 10%. The inferred reserve is 0.97 million tonnes (Pawar and Chauhan, 1980).

The sedimentary clay exposed in Ponnani (11°46'30":75°55'00"); Chammannur (10°40'30":76°11'00") areas shows pinching and swelling. The clay is white with light pink shades, plastic and contains 10 to 20% grit. The average thickness of clay beds vary from 0.5 to 3m. The thickness of overburden is 6 to 8m and the inferred reserve is around 60 million tonnes (Pawar and Chauhan, 1980).

Tile Clay**:** Tile clay occurs in the river terraces and stream banks. The river banks of Chaliyarpuzha, Kadalundi and Ponnai rivers are significant. Farokh (11°11'00":75°50'00"), Alinilam (11°45'00":75°51'45"), Velipram (11°11'30":75°51'15") and Valakkad (11°14'35":75°57'28") are the important tile clay occurrences along the banks of Chaliyar puzha. Here the thickness of tile clay ranges from 4-10m. Tirurangadi(11°02'25":76°55'15") on the bank of Kadalundi River and Tirunavaya(10°52'30":75°59'00") on the Ponnani River bank are important occurrences of tile clay. Tile clay also occurs around Challisseri (10°44'00":76°05'00").

Palakkad District

China clay occurrences in Mookuthala, Kaithaparambu and Makkolil together constitute an estimated reserve of 0.4 million tonne.

Thrissur District

Thick deposits of brick, tile and pottery clay occur around Chalakudy (10°01'00":76°22'00"), Pudukkad (10°24'00":76°15'00") and Pannukulam (10°33'00":76°12'00"). The clay extends to a depth of more than 10m. The State DMG estimated a reserve of 1.6 million tonnes of fire clay in Poomangalam.

Thiruvananthapuram District

The kaolinised gneisses at the base of the Tertiaries have given rise to good quality china clay at several places in the district. The State DMG based on reconnaissance surveys estimated a reserve of 38 million tonnes in Melthonnackal (8°38"05":76°51'22"), Azhoor (8°38'31":76°49'29"), Pallippuram (8°35'30": 76° 51' 30"), Chilampil (8°37'00":76°50'00") and Sasthavattam (8°38'45":76°49'30"). The DMG has also identified nine potential clay-bearing blocks with an areal extent of 500 hectares.

Melthonnakal Block – IV: Situated adjacent to the existing mine of Ms/English Indian Clays Ltd., the block measures about 9.50 hectares. Based on 10 boreholes a total reserve of 2.10 million tonnes is estimated with an average thickness of 13 m (DMG & KMEDP, 1990). Physical test of the clay indicated its suitability for paper coating/filler purposes.

Melthonnakal Block V (a): The 60 hectares prospect of clay is located SE of the mine of M/s English India Clays Ltd and on the northern side of Pothencode-Mangalapuram road. 21 boreholes drilled in the block indicate the average thickness of china clay as 6.37 m in 43 hectares (DMG and KMEDP, 1991). In this block 4 million tonnes of china clay exists in the free hold area.

Melthonnakal and Pallipuram Block V (b):It is located south of Mangalapuram-Pothencode road in Melthonnakal and Pallipuram (9°44'00":76°21'40")villages. The total reserve estimated is 6.35 million tonnes of china clay which is suitable for paper coating, ceramic and filler applications.

Veiloor Block III(a): A total reserve of 7.56 million tonnes (possible) china clay is estimated in the block located west of NH-47, 1 km northwest Mangalapuram. Out of the 13 boreholes 88 have intercepted white clay with an average thickness of 12m.

Veiloor Block III(b): Situated west of NH-47 the block falls east of the clay mines of M/s Kerala Industrial Polymeres, M/s Bharathi Clays and M/s Standard Clays. Eight boreholes have been drilled and an area of 19 hectares is identified as clay-bearing with an average thickness of 15m. The total reserve estimated is 6.7 million tones.

Veiloor Block IV (a): Eight boreholes were sunk in the block covering an area of 10 hectares located west of the clay mines of M/s KIP, M/s Bharathi Clays and M/s Standard Clays. A probable reserve of 1.5 to 2 million tonnes of china clay is estimated tentatively.

Veiloor (Bishopthopu area) Block IV(b): The cumulative thickness of white clay beds ranges from 12 m to 30 m as evidenced in six boreholes. A reserve of 6.8 million tonnes is estimated tentatively.

Akkulam (8°31'25":76°54'30") deposit is an important china clay occurrence extending over an area of 0.32 sq km with a thickness of 8 to 10m. The total reserve of clay may be large but the grit content appears to be very high limiting the amount of utilizable clay. Paniyamunnu (8°34':76°34') is the other deposit worth mentioning. Detailed exploration for sedimentary clay by drilling has been carried out by GSI around Pallipuram, Mangalapuram and Chilambil and 9 million.tonnes reserve has been estimated.

Occurrences of residual clay are reported from north of Kottukal (8°23'20": 77°02'30"), around Kalliyur temple (8°25'30":77°00'30"), north of Kulangaradesam (8°25'30":77°00'30")), and Akkulam (8°31'25":76°54'30"). In these areas, thickness of white residual clay ranges form 2 m to 4 m with a grit content of 40% to 50% and the overburden thickness varies from 2 m to 8m. A reserve of 3.2 million.tonnes has been estimated (Mallikarjuna and Kapali, 1980).

In an area of 250 sq km, from Kazhakkuttam (8°34'00":76°52'30") and Paripalli (8°48'30":76°45'36"), in the northern part of the district, 26 blocks covering an area of 47 sq km have been delineated as sedimentary clay-bearing through logging of open wells, rail and road cuttings and mine sections along with detailed mapping on 1:25,000 scale. The average thickness of the sedimentary clay is of the order of 10.5m with an overburden of 8 to 10m. The SiO_2 content of the clay ranges from 43 to 63%, Al_2O_3 from 20 to 43%, Fe_2O_3 from 0.13 to 3.4% and TiO_2 <1%. The total inferred resource potential of sedimentary clay is 1780 million tonnes (Koshy John, 1996,1997,1999 and 2000).

Sedimentary clay : Good quality sedimentary clay is reported from the following localities.

(1) Puvar (8°24':77°04') to Venganoor (8°25'40":77°02'00"), (2) North of Venganoor to Tiruvallam (8°27'30":76°58'), (3) Kariavattom (8°33'30":76°53'30") to NE of Kazhakuttam (8°34':76°52'30"), (4) Pallipuram (9°44'00":76°21'40") to Tonnakkal (8°37'30":76°51') to Chilampil (8°37':76°50') to 1 km south of Chirayinkil (8°39'30":76°47'25") and (5) around Varkala (8°44":76°43'00").

Detailed investigation in Pallipuram has established a resource position of 4.9 million tonnes of sedimentary clay. The AI_2O_3 content of the clay varies from 37 to 53%, Fe_2O_3 content from 0.41 to 0.76% and TiO_2 from 0.56 to 1.19%. At Chilampil, in an area of 150 m x 60 m a probable reserve of 0.16 million tonne clay with

comparable attributes of Pallipuram deposit is estimated (Poulose and Sreenivasan, 1967).

From Puvar to Venganoor the total area of the sedimentary belt is approximately 30 sq km and the area of promise is 2 sq km. The approximate reserve is 25 million tonnes. The sedimentary patch north of Venganoor to Tiruvallam is about 18 sq km. The area of promise is 0.45 sq km around Punkulam (8°25'08":76°58'51"). The approximate reserves is 4.5 million tonnes.

Deposit of good quality sedimentary clay is observed north and northeast of Kazhakuttam over an area of 0.25 sq km. The average thickness of clay horizon is about 4 m with an overburden of 6-8 m. The grit content in the clay is less than 5%. The approximate reserve is 2.5 million tonnes.

Around Varkala, an area of 2.5 sq km is found to be clay bearing. The average thickness of the clay horizon is 2 m and the thickness of overburden ranges from 15 to 18 m. The approximate reserve is 12.5 million tonnes. The clay is ball clay variety.

Over an area of 4.73 sq km covering Kunnuvila , Muttappalam (8°42':76°40'), Vettukada(08°29'50":76°54'),Vennikadu(08°42'27":76°44'55")Muthanam,(08°49'45": 76°46'15"), Kovur (11°16'00":75°50'00"), and Kazhakuttam (8°34'00":76°52'30") resources of 23.06 million tonnes of clay is inferred (Mallikarjuna and Kapali, 1980).

Tile and brick clay**:** The State DMG on detailed investigation by auger drilling in Amaravila-Maruthur-Kadamkuzhy area of Neyyattinkara taluk estimated 2.48 million tonnes of clay suitable for tile and brick industry in area of 0.60 sq km .

CORUNDUM

A well dump about a kilometer ESE of Perla (12°38'30":75°06'30") in Kannur district showed pegmatite vein within charnockite containing translucent, purple to pinkish semi-precious corrundum.

Corundum is observed at the contact of meta-ultramafite and quartz-feldspar-biotite gneiss, at Maddaru (11°41'30":76°12'00") 10 kilometres NW of Sultan Bathery (11°39'30":76°15'30"), along the Sultan Bathery-Naduvayal (11°44'30":76°06'30") road in Wynad District. Excavational pits in the contact zone revealed the occurrence of steatite with barrel and spindle- shaped corundum bodies. The width of the veins occurring within the meta-ultramafites varies from 1 to 2 cm and length from 5 to 10 cm. Corundum occurring at the core is fresh and grey coloured. Corundophyllite, the alteration rim, is light pink to rose-red in colour. The width of the alteration rims varies from <0.5 cm to as much as 1 cm. The size of the corrundum crystals vary from 1 cm x 2 cm to 2 cm x 8 cm. The mineral is grey to blue, occasionally translucent. Another occurrence of corundum is reported from Manatana (11°54"40':75°46') in Kannur District. Slightly pinkish, translucent stout crystals of

about 6cm x 3cm size occur in mica schist, 1.5 km southeast of Manatana. Majority of the crystals are translucent to opaque in nature. Semiprecious varieties are also available.

The State DMG investigated the lateritised gravel occurring at shallow depth at Channappara near Peravoor (11°54'30":75°46'00") and identified the occurrence of corundum. The corundum varies in colour from pale brown, reddish brown to purple and exhibit, hexagonal prismatic habit. The lateritised older gravel bed covers an area of about 1 sq km.

DIMENSION STONES

The dimension stone industry is its infant stage. From the resource surveys carried out in the state so far, it has become conclusively evident that although good quality dimension stones are available in Kerala, the determination of their resource position and retrievability is rather difficult when compared to the other southern states because of the deep weathering profile, high population density and related socio-economic factors. The studies so far carried out have revealed that the areas are amenable only for small-scale. Selective quarrying and the identified deposits would yield a few flawless stones. The existing dimension stone quarries are located in the Khondalite-charnockite belt of southern Kerala (Muraleedharan et al. 2003). A variety of crystalline rocks occurring all over Kerala qualify to be considered as commercial grade granites. The following rock types evince characteristics worthy of categorizing as commercial grade granites: (1) granitoid including pink and grey granites, granophyre, porphyritic granite, syenite and anorthosite; (2) gneiss including leptynite and khondalite and (3) basic intrusives such as dolerite and gabbro. Recent investigations in Pathanamthitta District delineated three potential types: Tropical Green, Paradiso and Pink, with type areas as Narikuzhy (9°19'39":76°49'15"), Mylapra (9°17':76°47'52") and Omallur (9°14':76°46') (Muraleedharan *et al*, 1998).

In Kannur, Malappuram, Wynad and Palakkad Districts, charnockite gneiss and granite gneiss are found to be suitable as dimension stones. These two types are Tropical Green and Banded Grey respectively. A broad estimation of the reserve position of the prominent types of the dimension stones in these districts indicated a probable reserve of 2.76 milliom cu.m. of multicoloured granite occurring upto 10 m below the surface (Durairaj et al. 2003). As the present studies are of a most preliminary nature further assessments of the individual prospects will have to be carried out before commercial exploitation is undertaken.

The KMEDP have estimated a reserve of 1 lakh cubic metres of black granite from three prominent dykes located in Dhanyam-Kalpatti in Palghat District, of which about 30% is recovered.

GLASS SAND

White glass sands occur between Alappuzha (9°28'20":76°20') and Cherthala (9°41':76°20') with extension to Panavalli (9°48':76°21') in Alappuzha district. The area forms a linear stretch 35 km in length along the western side of the Vembanad lake. The glass sand deposits are mainly in (1) Cherthala-Alappuzha; (2) Kokothamangalam (9°41'30":76°21'30") and (3) Pallipuram (9°44'00": 76°21'40") – Panavalli areas (Poulse and Nair, 1965). The estimated reserves based on detailed investigation and auger drilling are given in the Table 1:

Table 1 -Reserves of Glass sands

Area	Workable areas of white sand (sq km)	Average thickness (m)	Total reserves (million tonnes)
Kokothamangalam	1.0	1.9	2.9
Pallipuram-Panavalli	2.9	2.1	8.7
Cherthala-Alappuzha	14.0	1.5	30.0
Total			**41.6**

Palaeo-beach ridges extending from Nirkunnam (9°23'45": 76°21'15"), in the south up to Alappuzha in the north, contain high concentration (up to 90%) of white sand. These sand deposits covering length of 8-9 km and width of 1-2 km, form the southern continuity of the Cherthala glass sand deposit.

An area of 2.6 sq km in Pallipuram-Cherthala taluk, Alappuzha District contains 3 million tonnes white silica sand. The reserve of the grey and brown silica sands available in the area is estimated to be about 7.5 million tonnes.

The DMG had inferred a total reserve of 70 million tonnes of glass sand in Pallipuram, Panavalli, Varanad, Maruthurvattom, Cheramangalam and Kanjikuzhy, bounded by latitudes 7°44'45" - 7°46'35" and longitudes 76°20'45" - 76°20'00" in Alappuzha District. Detailed investigations in Pallipuram area established a reserve of 6.8 million tonnes of white sand and 7.65 million tonnes of brown sand (Iyer, 1984).

The DMG analysed a sample of sand from Varanad in 1979 at National Metallurgical Laboratory, Madras to determine the suitability of the sand for foundry purposes and glass manufacturing. The tests indicate its suitability for foundry purpose, sheet rolled and polished glass manufacturing. According to NML the sand

has high sintering range, high silica content of 4 sieve distribution and good physical properties on blending with bentonite and yellow destrin.

Preliminary estimates by KMEDP (1993) in Pallipuram, Thycattusseri and Panavalli indicate a resource position of 28.54 million tonnes of glass sand. Tests on the Pallipuram sand by the Regional Research Laboratory (CSIR), Thiruvananthapuram indicate the superior quality of the sand for silica refractories and glass manufacture. Tests conducted on the brown sands occurring below the white sands in Varanad and Cherthala areas show that the brown sands are superior in quality as compared to the white sands, for glass manufacturing.

Kannur District

The coastal sands extend up to 8 km (maximum) inland in Payyanur-Velur area and taper down towards north and south.

GOLD

Malappuram District

KMEDP in Maruda (11° 23' 30"; 76° 18' 00") estimated a reserve of 0.55 million tonnes of primary gold of average grade of 4g/t over a strike length of 350 m upto a depth of 100m. Later, Mineral Exploration Corporation Limited validated the reserves through detailed exploration including pilot scale exploratory mining.

Alluvial gold: The placer gold in soils, gravels and river sands of Nilambur valley, known since long, was worked for a brief period. Investigations by GSI has delineated broadly two zones of gravel- bearing placer gold.

Zone – I : Pandi *puzha* – Chaliyar *puzha* zone

Zone – II : Punna *puzha* – Karakkodu *puzha* – Maradi *puzha* zone.

The total possible reserve of gravels in these zones is of the order of 8.5 million cu.m, roughly estimated to contain 1972.5 kg of gold (Sawarkar, 1965).

The KMEDP has estimated a possible reserve of two and a half million Cum of auriferous gravel in a stretch of 18 km in Punna puzha and Chaliyar puzha beds, of an average grade of 0.1 g/cu.m. with an indicated reserve of 30 million Cum. The volume of gravel estimated at Karadokundu area in Nilambur valley by KMEDP is 102507 cu.m. with an average grade of 0.08 g/cu.m. The volume of gravel estimated in the Thottapala in Kunnapuzha River is 70834 cu m with an average grade of 0.39 gm/cu m (Cvetkovic and Krishnakumar, 1981).

With the assistance of BRGM, France the data was reviewed and confirmed the incidence of gold on the present day channel with an average grade of less than 0.05 g/t (0.1 g/cu.m.). To further augment the reserves extended geochemical surveys

were done in 570 sq km to locate the course of alluvial gold and identified a number of anomalies.

Primary gold: GSI took up investigation in Kappil (11°14'30": 76°14'30"), Mankada (11° 01' 21" : 76°10'39"), Kadannamanna (11° 01'44": 76° 10'00") and Valambur (11°'30'00": 76°12'28") areas for primary native gold.

Preliminary exploration (GSI) by test drilling has indicated six parallel lensoid zones in *en echelon* pattern in Kappil (11°14"30":76°14'30") prospect and two lensoid lode zones in Mankada (11°01"30":76°10'45") prospect. The rocks exposed in the area are Archaean crystallines represented by auriferous quartz veins, biotite-hornblende gneiss, quartz-magnetite granulite (QMG), charnockite and amphibolite. Gold mineralisation is restricted to the highly sheared and fractured quartz vein/QMG within biotite-hornblende gneiss and amphibolite. The average grade of the lode zones in Kappil prospect ranges from 4.58 ppm to 1.248 ppm gold. The second level drilling in Kappil prospect has confirmed the depth persistence of lensoid lode zones which were identified in the first level drilling**.** Preliminary estimate indicates 0.06133 million tonnes of 4.152 g/t gold at 3g/t cut-off grade and 0.0737 million tonnes of 1.248 g/t of gold at 1 g/t cut-off grade in Kappil. (Nair *et al*, 2001). The lode zones delineated in the first and second level borehole are lensoid, parallel and discontinuous in nature and are confined to the axial trace of first generation fold.

In the Mankada prospect, two mineralized zones have been identified. The first zone is highly sheared quartz and garnet rich QMG and basic charnockite carrying disseminations of pyrrhotite. The second zone is made up of QMG with rich pyrrhotite.(Nair and Varma, 1999). The average grade of gold in these zones ranges from 0.28 to 1.42g/t.

Other prospects for gold are Kadannamanna (11^o2'00":76^o10'00")and Valambur(11^o 00'30":76^o 12'20"). The rocks exposed are charnockite and its variants, pyroxene granulites, pyroxenite, amphibolite and QMG. Both these prospects do not show any potential zone of gold mineralization (<0.19 ppm) (Muraleedharan and Nair, 1996).

Palakkad District

Gold mineralisation has been reported by GSI in epigenetic quartz veins emplaced within amphibolite/granite gneiss/quartz biotite gneiss in Puttumala (11°03'15":76°38'30") in Attapadi valley. A structurally-controlled mineralized zone with an average width of 1.75 m has been traced with a value of 7.3 g/t gold (Nair *et al*, 1994). Gold in Puttumala is associated with pyrite, galena, chalcopyrite in the quartz veins. Gold occurs as small blebs occluded within or as thin films in pyrite.

The gold bearing lodes of Attapadi belong to amphibolite, quartz-biotite gneiss and pink granite gneiss. In the Puttumala block gold mineralisation is confined to the epigenetic quartz veins intruding subparallel to the antiformal fold axis.

Stratigraphic, lithological and structural controls have played an important role in the localization of the gold mineralization. A mineralized zone with an average grade of 10 g/t has been established in Puttumala East block (Nair *et al,* 1995).

Preliminary exploration for gold in Kallekara block, Attapady valley has brought out a gold quartz lode varying in thickness from 1-5 m and extending discontinuously for a strike length of 300 m. Hornblende gneiss, migmatite amphibolite and quartz biotite gneiss/schist are the main rock types exposed in this block,(Nair and Pillay, 1999).

One major sulphide- bearing quartz vein (8 m width and 260 m length) with visible specks of gold within the migmatitic amphibolite was delineated in the Mundayur block. Geophysical studies indicate a pinch and swell nature of the quartz vein. Both structural as well as lithologic controls are involved in this mineralization. In this block, gold is occurring as gold-silver alloy (Au 95.15% & Ag 4.21%).
(Nair and Maji, 1999).

Preliminary investigation for gold mineralization carried out in Kanhirapuza-Muthikulam-Srikrishnapuram sector in Mannarkkad taluk has resulted in the delineation of 25nos of widely separated old workings. The old workings were confined to the sheared and silicified portions of the banded Iron formation. The gold content varies from 0.04 to 0.2ppm. A sporadic value of 0.49ppm was obtained from the remobilised quartz veinlets showing smoky colour. Gold values are obtained from Karimala ($10^0$56'55":$76^0$34'30"), Chulliamkulam ($10^0$55'25":$76^0$34'15"), Anamooli ($11^0$1'3"6:$76^0$31'13") ,Ponnamkod ($10^0$56'48":$76^0$31'12")and Poonchola($10^0$59'30": $76^0$35'00") areas(Mathew Joseph *et al* 2002).

Wynad District

Primary gold : Primary lodes of gold are known in Meppadi (11°33':76°08'), Chundale (11°34'00":76°03'00"), Vayittiri (11°33'00":76°02'00"), Tariode (11°39'00":75°58'00"), Vattam (11°38':76°50'), Kuthimada, Karumsanthod, Thavingal (11°50'00":75°58'00"); Venmani (9°15'30":76°37'00"), Kakkarikunnu and Mananthoddy (11°03':76º 00'00") areas of Wynad district. The tenor of gold bearing reefs in Wynad Gold Fields is generally 2 to 3 g/t.

GRAPHITE

Graphite is found in association with the Khondalite Group in Alappuzha, Ernakulam, Idukki, Kollam, Kottayam, Thrissur and Thiruvananthapuram districts. In the Thodupuzha (9°53'45":76°43'00")- Muvattupuzha belt, graphite is litho-bound, while the Thiruvananthapuram-Kollam, occurrences though essentially litho-bound are structurally readjusted. Field analysis and beneficiation test (IBM, AP Govt. Crucible Factory and NHL) on samples from different occurrences in the state have established their easy amenability for concentration by floatation process.Over 100 million tonnes of reserve is calculated.

Alappuzha District

Graphite in the form of minute flakes in garnet-sillimanite gneiss is reported from 2 km SE of Kudaishanad (9°11'30":76°40'00"). Here, a graphite-rich band of 0.5 to 1 m width trending NW-SE has been recorded within the weathered zone. Graphite constitutes 20-30% of the rock.

Ernakulam and Idukki Districts

Flaky graphite occurs as streaks and disseminations in Khondalite rocks. The most important deposits of graphite occur at Vadakod (9°56'00":76°40'00"), Nagapuzha (9°57'00":76°41'30"), Nirampuzha (9°57'45":76°39'45"), Manakkad (9°54'00":76°42'00"), Piralimattam (9°55'00":76°38'00") and Peringazha (9°57'15":76°36'15"). In Vadakod, the graphite horizon has strike persistence of 2200 m and depth persistence upto 100m. The width of the graphite horizon varies from 30 to 130m. A total of 5 million tonnes of graphite with 3% FC has been estimated. This includes 3.8 million tonnes of ore with >5% FC (average 6.90%) and 1.2 million tonnes of ore with >3% FC (average 3.74%) (Krishna et al, 1982). The graphite content in the host rock varies widely, both strike-wise and dip-wise. The graphite is flaky, the flakes ranging in size from few mm to nearly 15 mm. Graphite occurs (1) as an essential constituent of the graphite-biotite gneiss, (2) acicular and radiating needles and disseminations in calc- granulite, (3) minor disseminations in the garnetiferous-biotite gneiss and (4) occasional flakes in quartz veins.

In Nagapuzha (9°57'00":76°41'30") area, occurrence of graphite is traced over a strike length of 1562 m and the graphite horizon has a width of 10 to 35m. A total reserve of 1.06 million tonnes ore with 5% of graphite content has been estimated upto a depth of 70 m below ground level. Additional reserves of 0.54million tonnes with 5-10% of graphite and 0.53million tonnes with >10% graphite have been arrived at beyond 70m depth (Varadan and Krishna, 1976). The DMG has estimated a reserve of 150,000 tonnes of ore with 40% graphite content at Nagapuzha and adjoining areas in Thodupuzha taluk, Idukki District.

The graphite-bearing biotite gneiss occurring in Nirampuzha is associated with quartzite and pyroxene granulite. Based on drilling data a total reserve of 519161 tonnes of graphite with an average FC percent of 5.35 is computed. The reserves with more than 5% FC amounts to 197491 tonnes with 8.8% average FC and that with <5% FC amounts to 321670 tonnes with 3.23% FC (Muraleedharan, 1987).

In Manakkad (9°54'00":76°42'00") east block, a graphite reserve of 37,000 tonnes and in Manakkad west block 3,20,000 tonnes have been estimated upto a depth of 100mts. The content of the graphite horizon ranges from 7 to 23.5%. The graphitic zone extends for 140m strike length with a thickness ranging from 1.2 m to 7.2 m. In Piralimattam, about 35,600 tonnes of graphite ore is estimated in seven horizons with an average grade of 5 to 21.25%. In Peringazha, about 36,400 tonnes of ore with graphite ranging from 9.1 to 30.8% has been estimated.

The KMEDP has estimated 598000 tonnes of ore with 5% FC in Vadakkod and 748000 tonnes of ore with 7.3% FC in Nagapuzha in Ernakulam District (Zharov and Nair, 1981), the details of which are given in Table-2.

Table-2 Reserve, grade and recovery percentage of graphite

Location	Ore reserve (tonnes)	Grade F.C %	Recoverable graphite (tonnes)	Concentrate (%)	Recovery (%)
Nagapuzha	748000	7.3	43000	89	79
Vadakkode	598000	5.0	24000	91	80

Kottayam District

In Aranikunnu (9°33'00":76°37'00"), old workings for graphite are present. In proximity of these old workings are more ore less in the same strike extension, graphite-bearing gneisses of over 2 m in thickness are seen in a road cutting.

The KMEDP proved 3,48,000 tonnes of graphite ore with 2% FC content in Paika area (Zharov et al, 1981). In Chirakadavu (9°09'45":76°31'00") area, 7,00,000 tonnes of ore containing just over 3% FC was estimated. The recoverable graphite in Chirrakadavu is estimated as 16,800 tonnes with a concentrate percentage of 88 and recovery percentage of 80 (Garson, 1979b).

Kollam and Pathanamthitta districts

Graphite occurrences have been identified at Karupanthod (9°04'00":76°57'00"), Perumtholil (9°03'45":76°57'05") and Changapara (9°03'00":76°58'00") in the Punalur mica mine area. The graphite occurs as disseminations and coarse flakes in granet-sillimanite gneiss in the Perumtholil area. The graphite occurs as bands or lenses of garnet-graphite schist in the garnet sillimanite gneiss over a length of 50m with an average thickness of 70cm and a down dip extension of about 50m in Karuppanthodu and Changapara areas. The average graphite content is 15%. The recoverable graphite estimated in Karippanthodu occurrence is 500 tonnes (Jacob, 1968). Ore dressing at IBM indicated that the beneficiated product is suitable for lubricant, paints and dry cells (Agarwal and Pradhan, 1968).

Thiruvananthapuram district

The notable graphite deposits in Thiruvananthapuram District are at Changa (8°35'00":77°04'00"), Vellanad (8°34'00":"77°03'00"), Kuttichal (8°34'00":77°06'00"), Vengannur (8°25'00":77°02'00") and Chengallur (8°27'00":77°05'00"). In Changa area, the graphite lode is noticed for a strike length of 50 m with an average thickness of 30cm and upto a depth of 100m. A probable reserve of 3,000 tonnes with average graphite content of 75% was estimated (Jacob, 1967).

ILMENITE AND MONAZITE BEACH SANDS

Alappuzha District

The sandy beach over a length of 17 km from west of Nirkunnam (9°23'45":76°21'15") to south of Trikkunnapuzha (9°16'00":76°24'00") is rich in ilmenite sand. Ilmenite content ranges from 10 to 40% with pockets up to 90% of the ore. The concentration in this part of the coast is the northern continuation of the famous Chavara (9°57'53":76°32'35") heavy mineral deposit.

Kannur and Kasaragod districts

Concentration of heavy minerals such as garnet, ilmenite and monazite occurs along the coast between Kumbla and Mangalore. Concentration of ilmenite sands is found south of Valapattanam River and 1.6 km WSW of Azhikkod.

Kollam District

The occurrence of large quantity of ilmenite and monazite in the coastal sands of Varkala (8°44'00":76°43'00"), and Chavara (09°57'53":76°32'35") are well known. The main deposits are between Neendakara, Chavara and Kozhithottam. These deposits are being worked by the Kerala Minerals and Metals Ltd. and Indian Rare Earths Ltd.

Malappuram District

A 15 km stretch of the coastal tract between south of Ponnani to Balangod is endowed with concentration of heavy mineral sands.

A deposit of ilmenite occurs over a total length of 15 km from 3 km south of Balangod (10^o47'00":75^o56'00") to Ponnani (10^o47':75^o56'). It is a 15-40 metre wide deposit with thickness varying from 2 cm to 14 cms. The heavy minerals contain about 49% of ilmenite, 15% garnet, 10% magnetite and 5% zircon. Atomic Mineral Divn. has estimated a reserve of 9,15,000 tonnes of ilmenite, 1,80,000 tonnes of magnetite, 2,30,000 tonnes of garnet and 4000 tonnes of zircon.

Thiruvananthapuram District

Concentration of heavy minerals like ilmenite and monazite in beach sands are found in Vizhinjam, Kovalam and near Veli and Varkala. The AMD has estimated a reserve of 3.33 million tonnes of heavies from these areas out of which ilmenite constitutes a reserve of 2 million tonnes .

Offshore resources

Investigations in the inner shelf areas of Kerala by the Marine Wing, GSI(1984-90) have delineated 130 sq km area, in the offshore of heavy mineral bearing Kollam-Varkala sector. The heavy mineral content in the sandy sediments off Varkala varies from 1 to 12% and <1 to 20% in the Chavara offshore.

The probable resources upto a depth of 4 m from the seabed in the Chavara sector within 4 to 12 m isobath zone are (1) Ilmenite-0.9 million tonnes, (2) Rutile- .07 million tonnes, (3) Zircon-0.06 million tonne and (4) Sillimanite-0.3 million tonnes (Senthiappan *et al*, 1992).

IRON ORE

Numerous bands of iron ore (magnetite) varying in strike length from a few metres to a few km have been reported from charnockite and gneissic rocks by several workers. The important bands are those around Kozhikode town and Nilambur (11°16'00":76°13'20") – Manjeri (11°07'30":76°07'30") area in Malappuram District. A reserve of 100million tonnes is estimated.

Kozhikode District

The important occurrences found in the district are:

Cheruppa (11°15'00":75°55'00"): Iron-ore occurs in magnetite-quartz-diopside-hypersthene gneiss along the crest of a ENE trending Δ158 m hillock over a strike length of 800 m with a thickness varying from 44 m to 56m. The total reserve of the ore is of the order of 10.7 million tonnes of 31.7 to 35.5% of total Fe (Mani, 1970).

Eleyettimala (11°23'00":75°46'00"): Iron-ore occurs interbedded with biotite, biotite-diopside and biotite-hornblende gneisses and granulites. The iron ore formation is exposed as a southwest plunging overturned antiform, cross folded at its eastern end into a southwest plunging synform. The ore body has a thickness of 14 to 50m. The zone of intense oxidation extends to an average depth of 40m from the surface. A combined probable and possible reserve of 19.2 million tonnes, with 31.5 to 39.4% of the total Fe is estimated (Rao and Reddy, 1972 a).

Nanminda (11°24'00":75°46'00") : Iron-ore occurs interbedded with country rocks confined to doubly plunging synforms over a total area of 0.2 sq km. The thickness varies from 2 m at the margins to 16m in the central portions of synformal strips. A reserve of 4.3 million tonnes of ore with an average total Fe content of 41.2% has been estimated (Rao and Reddy, 1972 b).

Naduvallur (11°23'00":75°49'00"): Iron-ore formation (magnetite-quartz-grunerite-diopside rock) occurs interbanded with country rocks viz., biotite, biotite-hornblende and biotite-diopside gneisses and granulites. The total exposed area of the formation is about 0.17 sq km. The vertical thickness varies from just 1m near the margins to 40 to 50 m in the troughs of the synform and in areas of local recumbent fold. The formation is oxidised in the exposed area. A probable reserve (Rao and Reddy, 1972 c) of 3.73 million tonnes of unoxidised ore is estimated within mineable depth in this block. The average iron content of the ore is 33.70%. A probable and possible reserve of 5.84 million tonnes of oxidised in situ ore and 0.22 million tonnes of oxidised slumped ore are estimated in this block. Average Fe content of oxidised in situ ore is 38.99% (Rao & Reddy, 1972 c).

East and West Hill Band : The band of magnetite quartzite skirting the West and East hills in the northern part of Kozhikode town occupies an area of 0.1 sq km. The band here is about 40 m in width and extends for a length of about 1700 m. It occurs in the form of a 'S'-shaped body with the strike direction varying from E-W to ENE-WSW, NNE-SSW and finally E-W at the eastern extremity. The dip of 60 to 70° is mostly to the south while in the nose and at the eastern end the dip is to the east. The band, on West and East hill, actually forms the southern and eastern part of a tight antiform eastward plunging isoclinal trough, the northern limb of which is disconnected and detached and found as an outcrop on the Tourist Bungalow Hill. Unlike the other major deposits, the West and East Hill makes up a low ridge (hardly 10 m above the surrounding plains) in the heart of Kozhikode town. A reserve of 0.7 million tonne of unoxidised magnetite quartizite ore(Fe: 41.5%) is estimated from this area unto depth of 10m.

Alampara (11°35':75°52'): This deposit is located along the crest of a 2km long NNW-SSE trending hill range in the foot hills of the Western Ghats. Here the iron ore formation (magnetite-quartzite-grunerite-gneiss) is associated with grunerite gneiss and granulite and also as interbanded with biotite-hornblende-gneiss. It is folded along a NNW-SSE trending axis into an isoclinal syncline with a reversed eastern and normal western limb. The plunge of the axis is at about 50^0 towards SE and axial plane dips at 70^0 towards ENE. It is exposed as bands and lenses over a strike length of 2.6km with an outcrop width varying from 20 to 40 m.

A shear zone of about 300 m width trends sub-parallel to the axis of the major fold. Iron ore formation is exposed over a strike length of over 1000 m on the eastern limb and about 1560 m on the western limb. True thickness of the iron ore formation on the limbs varies from 25-60 m. and increases gradually towards the trough where it is having a vertical thickness of 145 m. The depth of oxidation is found to extend upto 40 m.

Drilling has indicated that the iron-ore body varies in thickness from 20 m to 60 m on the limbs and attains the greatest thickness of 145 m on the trough of the fold. The zone of intense oxidation extends to a depth varying from 30 to 40 m from the surface. The total reserve of iron-ore estimated upto 44 m above MSL is 35.2 million tonnes comprising of 9 million tonnes of oxidised ore with an average grade of 35.5% total Fe and 26.2 million tonnes of unoxidised ore with Fe content of 35.2%. In addition, a possible reserve of 16.6 million tonnes of unoxidised ore is estimated upto 100 m below the drainage level (Reddy, 1975).

Idukki District:

Minor iron ore occurrences are recorded in the district from many places such as Kaliyar estate (9 °58'00":76°46'00") in Kotapara (9°53'00":76°55'00"), northwest of Idukki (9°50'00":76°58'00"), Kalliparamudi (9°55':76°58') area south of Panamkutty (9°57'00":76° 50'00") and in Nulliamina (10°01'00":76°45'00") and area near Neriyamangalam (10°03'00":76°47'00"). These bands are inpersistent and the content of magnetite is low.

Malappuram District

Korattimala area (11°22'00": 76°16'00"): The iron ore formation occurs in the form of a thin, linear band of magnetite-grunerite quartzite within the gneissic rocks consisting of hornblende gneiss and hornblende-biotite gneiss together with grunerite schist. The main occurrence extends as a narrow band from south to north for over a strike length of 1.92 km. The ore body is a coarse-grained rock grading towards west into grunerite schist. Dip is steeply towards W,WNW and NW at 70-85^{o}.

In the south it has a strike length of 1.18 km with an average thickness of 20 m, whereas in the north it has an average thickness of 8 m.

The estimated oxidised ore is 1.89 million tonnes. of ore upto a depth of 30 m from the surface and 2.52 million tonnes of unoxidised ore between 30 m depth and 80 m RL. The oxidized ore contains 37.8% of total Fe and the unoxidised ore contains about 33.6% of Fe which can yield nearly 43% of magnetite concentrate containing 63% Fe (Lahiri, 1975).

Palakkad District

Numerous thin bands of magnetite quartzite were located in Palakkad district (see Appendix).

KANKAR

Occurrences of *kankar* worth mentioning are reported in the victinity of Nettuvangai (10°51'00": 76°43'00"). *Kankar* occurs at several places in Chittur taluk of Palakkad District. Detailed prospecting revealed a reserve of 3.5 million tonnes of *kankar* in Chittur (9°54'30: 76°40'42') and Kozhinjampara (10°43'30':76°50'30') areas in Palakkad District.

KYANITE

Minor occurrences of kyanite are reported from Kollam and Kannur districts (see Appendix - I).

LIMESHELL

Alappuzha and Ernakulam districts

Limeshell is being collected from the Vembanad lake since long time. In Vembanad lake and ajoining areas limeshell occurs in an area of 25 sq km and the total probable resource estimate is 2.5 million tonnes (Poulose and Nair, 1965). South of Thannirmukkam (9° 40'00":76°24'00"), the limeshell horizon is persistent almost throughout the lake of which about 15 sq. km area northeast and south of Pathiramanal (9°32'00":76°23'00"), is the most promising. North of Thannirmukkam there is a narrow strip of shell deposit from 0.8 km north of Trinayanakadavu (9°42'00":76°23'00") to Vaikom (9°45'00":76°24'00"). At Kulasekharamangalam

(09°05'05":76°29'40") and Pallipuram *kayal*, two minor occurrneces are found. The shell horizon in the Pathiramanal-Kumarakom (9°56'00:76°26'30') area is the most promising and extends for an area of 15 sq km. The thickness of this horizon is 5 to 6 m where the water depth is 2 m.

A reserve of 0.79 million tonnes of limeshell has been estimated by the DMG in certain parts of Vembanad lake and in adjoining areas (Table-3).

Table 3- Reserves of lime shell

Locality	Coordinates	Reserves (million tonnes)
Kulasekharamangalam	09°05'05":76°29'40"	0.18
Pallipuram	09°44'00":76°21'40"	0.10
Vechoorpadam	-----	0.26
Thannirmukkam	09°40'20":76°23'35"	0.25

Kannur and Kasaragod districts

In Payyannur (12°7'00":75°14'00") and adjoining areas, detailed investigation by the DMG for limeshell indicated a total reserve of about 0.75 million tonnes as given in Table 4.

Table-4. Reserves of limeshell

Kandankali	12°45':75°12'30"	0.31
Udumpanthala	12°06':75°10'50"	0.07
Kunnariyam	12°03':75°13'00"	0.04
Kunhimangalam	12°05':75°14'00"	0.008
Kari-Moicha	12°13'30":75°8'30"	0.10
Keloth-Tayinori	11°53':75°49'00"	0.14
Payyanki	12°11': 75° 00'50"	0.05
Nileswaram	12°15':75°07'00"	0.04

The shells occur in clay beds and are overlain by yellow sands and sandy clays which vary in thickness from 0.30 m to 7.50 m. The thickness of the limeshell bed varies from 5 cm to 40 cm in Payyanur and Nileswaram. In the Kandankali, Keloth -

Tayanori and Kari-Moicha areas, the thickness of the shell bed varies from 0.05 m to 1 m.

Malappuram District

The DMG has established a reserve of 0.14 million tonnes of limeshell in Kanjiramuttu, Iswaramangalam and Edappad areas.

Thrissur District

DMG investigated the limeshell occurrences at Naduvilakkara, Vadanapally, Chettuva and Kappad and estimated 0.33 million tonnes.

LIMESTONE

Kollam District

Shell limestone belonging to the Quilon Formation of Tertiary age is exposed near Padappakkara (8°58'30":76°38'00") and Kondalaseri with 1-1.5 m thickness over a strike length of 30m. Quilon beds (limestone) also occur at the following places i.e: Nedumangalam (8°50'00" : 76°41'00"), Niravilasseri (8°55'00" : 76°36'00"), Kannanallur (8°50'00": 76°39'00") and Edavai (8°01'00": 76°41'00"). The DMG has prospected and estimated a reserve of about 2.2 million tonnes of shell limestone in Karunagapalli (9°05'00": 76°32'00") and Pozhikkara (08°48'45":76°44'28") areas.

Palakkad District

Crystalline limestone in association with calc-granulites is found at Pandarettu (10°52'00":76°47'00") (Mani, 1962) in Palakkad taluk and Vannamadai (10°42'00": 76°51'00") in Chittur taluk.

The limestone deposits of Pandarettu is confined to the isoclinal antiform with steep dip towards south and plunge 51° towards N75°-80°E, within the garnet-biotite gneiss and khondalite. It is, however, exposed in the field as detached outcrops. Exploratory drilling indicated that the southern and northern limbs of the antiform are likely to be over 90 m in true thickness over a length of about 100m and 150m respectively. The limestone analyses over 50% CaO, <0.8% MgO, <2%R_2O_3, <5% SiO_2, <0.1% P_2O_5 and <0.2% S. A total reserve of 2.2 million tonnes of limestone above 390 m RL and another 9.8 million tonnes of possible reserve up to 300 m RL are estimated (Rao *et al*, 1974).

Vannamadai block: The deposit in Vannamadai (10°42'00":76°51'00") block comprising of over 60 bands and lenses of crystalline limestone in association with calc-granulites extends for a strike length of 3kms in WNW-ESE direction.The individual outcrop varies in size from 0.5 x 0.5 m to 110 x 23 m. The bands dip 60-70^o towards south. The limestone is medium- to coarse-grained with crystals of calcite measuring upto 2 cm across. In the middle and eastern part of the area it becomes coarse-grained. Mostly it is light pink in colour, but other shades of gray and yellow

are common. It is essentially made up of calcite and with a little of diopside, biotite and garnet. The cumulative length of these bands is about 1100 m and spreads over 9,000 sq m area (Reddy , 1975).

The probable reserve of limestone from this area is about 59,000 tonnes (Mani, 1965). Narasimhan (1967) estimated reserves of limestone at 92,910 tonnes in Karumanda-Kavandanur (10°42'45":76°52'15"), Palakkad District. Janardhana Iyer (1970) has estimated a probable reserve of 2,96,000 tonnes of crystalline limestone in Ambattapathy and near Thavalam in Chittur Taluk, Palakkad District. DMG (Janardhana Iyer, 1970; Gopinathan Achari, 1971) has prospected for crystalline limestone in Gopalapuram($10^0$42'00":76^0 53'00"), Ambattapatty and Kumarannur area in Chittur taluk, and estimated a reserve of 14,63,500 tonnes of limestone.

Gopalapuram block: This deposit is of dimension 10 x 400m and is highly heterogeneous in nature because of admixing with a variety of calc-silicates. The probable reserves of limestone from Gopalapuram band is estimated to be of the order of 82,000 tonnes (Mani ,1965).

Kollam District

Fossiliferous limestone of Tertiary age belonging to the Quilon beds are exposed near Padappakara and Kondalasheri with 1 to 1.5 m thickness over a strike length of 30 m. Other occurrences are Nedumangalam (8^o50'00": 76^o41'00"), Niravilasseri (8^o55'00":76^o 36'00")Kannanallur (Palaeo-beachridges extending from Nirkunnam (9°23'45" : 76° 21' 15"), in the south up to Alappuzha in the north, contain high concentration (upto 90%) of white sand. These sand deposits covering length of 8-9 km and width of 1-2 km form the southern continuity of the Cherthala glass sand deposit.

An area of 2.6 sq km in Pallipuram-Cherthala taluk, Alappuzha District contains white silica sand of 3 million tonnes. The reserve of the grey and brown silica Kottiyam (8^o52':76^o46'), Mayyanad (8^o 50':76 ^{o} 39') and Edavai (8^o 01':76^o41'). The DMG has estimated a reserve of about 2.2 million tonnes of fossiliferous limestone.

MAGNESITE

Investigations by the DMG and GSI have brought out a number of occurrences of magnesite in the form of veins and veinlets within altered peridotite rocks in Attapady valley, Palakkad District. The deposits in Kalkandi (11°09'15":76°38'45") and Mulli (11°13'00":76°43'15") are significant. In Kalkandi and Mulli the magnesite-bearing perioditite is about 25 m wide and extends for a strike length of 300 m in ENE-WSW. Magnesite veins vary in thickness from a few mm to as much as 30 cm. Though the thick veins follow the strike of the host rock, veinlets criss-cross the peridotite body. In the magnesite occurrence at Narasimukku (11°07'30":76°38'30"), the magnesite-bearing horizon is about 100 m long and 20 m wide. The maximum thickness of the magnesite vein in the Narasimukku occurrence is 15 cm. The average chemical composition of the magnesite is 43.6% MgO, 4.2%

SiO_2, 0.7% Fe_2O_3 and 0.7% Al_2O_3, 1.9% CaO and 48.7% LOI. Compositionally, the Attapady magnesite is comparable to that of the Chettipatti deposit of Salem District in Tamil Nadu (Nambiar, 1982).

Through drilling and pitting the DMG has estimated at Mulli a reserve of 15,000 tonnes (43.20-47.79% MgO and 7.09% SiO_2). Out of the 15,000 tonnes 10,000 tonnes is assessed as refractory grade (Nair and Krishna Kumar, 1978). A reserve of 22,500 tonnes of magnesite is estimated in Salayur area (11°12'45"; 76°43'42") (43.05% to 46.73% MgO and 1.52% to 6.59% SiO_2). Occurrence of lenticular bodies of magnesite of 3 to 4 m width and 40 to 55m length is reported at two places near Narasimukku (11°7'45"; 76°58'40") (Sundaram, 1982).

MERCURY

Mercury is reported to occur in the native state as minute globules in the laterite capping over hornblende-biotite gneisses in Murat (11°34': 75°37'), Kozhikode District.

GSI took up investigation for Mercury in Badagara area (11°35'30" : 75°35'30"), Kozhikode District under Project ARBAKI and drilled 19 boreholes. One borehole located 4 metres away from the reported mercury occurrence yielded high values ranging from 286 to 5527 ppb Hg up to a depth of 17 m from the surface. Hg values in all the other boreholes range from 20 to 100 ppb. The pit in which mercury was originally reported shows values ranging from 1390 to 2350 ppb Hg (Rao and Reddy, 1974).

MICA

Phlogopite and muscovite mica occur in pegmatite veins traversing charnockite and leptynite rocks. Occasional mica schist bands are also reported from these rocks.

Ernakulam District

Large books (30cm x 10cm x 2.3cm) of muscovite mica occur in a pegmatite vein striking N60°W at a depth of 2.5 m from the surface at Cheradi (9°54'00": 76°47'00"). Muscovite mica is also reported at Edamaruku (9°54'00": 76°47'00").

Kollam District

Good quality phlogopite mica of medium-size was extracted from mica mine situated about 2km east of Karavur (9°04':76°56'00") 12 km NE of Punalur (9°1:76°55'00") town. The mica occurs at the contact of pegmatites in calc-gneisses and dunite. Phlogopite mica is observed mainly at three places viz. (i) within the Punalur(9^0 1'00": 76^0 55'00") mine, (ii) associated with pegmatite 450 m west of the mine in a paddy field and (iii) within a similar pegmatite body south of Manjakkalu about 1.4 km west of the mine.

The deposit in the Punalur mica mine seems to be the largest. The phlogopite mica was exploited intermittently from 1910 till 1960. It seems that the mining

operations were suspended due to slump in mica market and increased cost of dewatering. The mica sheets still persist in depth with the same abundance. The phlogopite mica deposit appears to be of contact metamorphic type, developed along the contract of dunite and pegmatite with the garnetiferous gneiss partly in association with calc-silicate rock.

Palakkad District

Occurrence of thin books of muscovite are distributed in the pegmatites veins traversing between Agali and Kulukkur.

Thiruvanathapuram District

Occurrence of Phlogopite mica is seen at Vattiyoorkavu near Thiruvanathapuram in association with a norite dyke (Chacko, 1922).

MOLYBDENITE

Kollam, Pathanamthitta and Idukki districts

Minor occurrences of molybdenum are reported from these districts (see Appendix).

Wynad District

Molybdenite is reported from pegmatites traversing the granites of Ambalavayal (11°37'15":76°3'00") and Kalpatta (11°37'30":76°05'15"). Here, blueto lead grey flakes of molybdenite of 0.5 cm to 4 cm size occur within pink feldspar and amphiboles. The granite body, in general has a relative abundance of molybdenum (11 ppm) as compared to the normal value of 2 ppm Mo in granite.

Molybdenite occurrence in Chingeri (11^{o}37'16":76^{o}12'11") Ambalavayal area is associated with the pink foliated granite. It occurs as fine disseminations or as fracture fillings. Even though the host rock is ideal for porphyry type of molybdenite deposit, the low value of Mo (<10 to 18 ppm) is not encouraging. Compared to the average crustal abundance of molybdenum in granite (1.1 ppm) the Chingeri occurrence is encouraging but it does not constitute a viable deposit due to impersistent nature of the mineralization.(Anil Kumar and Suresh Chandran, 1994).

Molybdenite mineralization is confined to the low-dipping fractures. Detailed pedogeochemical and lithogeochemical sampling yielded more than 10 ppm of Mo with occasional high spot values of Mo'at Chingeri and Thovarimala (75^{o} 5'25"E: 11^{o} 36'38", Muraleedharan , 1995).

PEAT AND LIGNITE

Alappuzha District

The peat bed at Pathirapalli is about 1.0 to 1.50 m thick. The areal extent of the exposure is 1000 m x 50 m along a canal section. It is extracted by local people for household fuel.

Recent investigations for lignite by the GSI in the area extending from Sasthamcotta (9° 02'30" : 76°37'45") to Mavelikkara (8°15' : 76°32') in parts of Kollam and Alappuzha districts have brought out encouraging results.

Lignite associated with carbonaceous clay occurs within the Warkalli Formation. Lignite is intimately associated with carbonaceous clay and their ratio varies from 1:25 to 1:10. The proximate analysis show that in lignite, the Fixed Carbon (FC) ranges from 4.43 to 40.93%, ash content from 42.38 to 71.28%, volatile matter from 16.69 to 64.26% and moisture from 4.46 to 22.86%. Compared with Neyveli lignite (Tamil Nadu) the lignite of Kerala has very high ash content and lower calorific value. However, it could be suitably used for blending with superior grades in boilers and furnaces.

Six prospects covering an area of 8 sq.km have been identified for detailed exploration. The thickness of lignite and carbonaceous clay varies from 3.5 to 7.4m. The total reserve of carbonaceous clay and lignite is over 36.5 million tonnes (Krishnan Nair and Koshy John, 1994).

Semi-carbonized wood is often found in the marshy black clay areas between Thottapally (9°19'00":76 ° 24'00") and Tkazhy (9 ° 23'00":7°24'00") and around Tamarakulam (9 ° 08'00": 76 ° 37'00").

Occurrence of lignified wood in various stages of decomposition have also been noted in the Kuttanad area.

Ernakulam District

A peat bed of 30 cm thick covered by 30 cm of silty clay is reported from the Quaternary sediments northeast of Trippunithura (9°57'00" : 76°21'00"). The areal extent of the occurrence is about 40,000 sq.m.

Kannur District

Thin lignite seams and black clays at the base of the sea cliff at Kannur were examined in 1943. Two seams of lignite (1) 50 to 75 cm and (2) > 30 cm in thickness were reported.

Another two seams of lignite (the top seam about 4.75 m and the bottom seam about 1.50 m thick) from a dug well section within the Military Hospital compound (Kannur) were examined during 1963-64. Chemical analysis of lignite indicated

moisutre content of 28.2%, volatile matter 45.6%, (FC) 13.4% and ash content 12.8%. The lignite is admixed with carbonaceous clay and is highly lenticular. Overburden is 8m from the ground level.

The DMG based on detailed exploration estimated 5.40 million tonnes of lignite in an area of 1.19 sq km in Media. Lignite in Media occurs in multiple seams with an average cumulative thickness of 4.65 m and the calorific value ranges from 1583 to 4556 K Cal/kg, the average being 2830 K Cal/kg. Pilot scale studies by (KMEDP 1995) indicate greater than 96% combustion efficiency

Kasaragod District

Dug well inventories by GSI revealed that, in an area of about 4 sq. km, around Ankakalari (12°16'30" : 75°08'40") and Palai (12°15'40":75°09'40") areas, about 4 km east of Nileswaram (12°15'00":76°07'00"), , lignite and carbonaceous clay occur at depths varying from 5 to 14.5 m from the ground level. The lignite and carbonaceous clay horizon has a thickness of 1 to 1.5 m. The overburden comprises clay, sandy clay and friable sandstone of Warkalli Formation capped by laterite. The carbonaceous clay and lignite horizon is underlain by good quality primary clay of about 5 m thickness. A few dug wells near Kanhangad (12°27'00":75°01'00"), south of Kasaragod (12°30'00" : 74°59'00"), also indicate the occurrence of carbonaceous clay and lignite of 0.5 to 1m thickness at a depth of 12 to 15m below the surface.

Detailed exploration by KMEDP and DMG (1990) in Nileswaram-Ankakalari-Palai-Chathamath areas has delineated lignite seams at a depth of 18m from ground level with an average cumulative thickness of 4m and average calorific value of 2250 K Cal/Kg. The tentative reserve estimate in these areas is 2 million tonnes.

Exploratory drilling in Kadankote mala (12°12'25" : 78°08'15") near Cheruvathur indicated lignite seams with a cumulative thickness of 2.75 m at a depth range of 16.70 to 33.40m. A tentative reserve of 1 million tonnes of lignite is estimated.

Kollam and Thiruvananthapuram districts

Cement-grey or black clays, often peaty, stiff and impervious, with lignified stumps and twigs of wood (about 4m in length) occur at Varkala (8°44'00":76°43'00"). An investigation by GSI has revealed that lignite is found only in the form of stray carbonised stumps of wood occurring in the black clay beds of Warkalli sediments and does not form a regular bed or seam. Carbonaceous zones containing lignite are also known at Arikara (9°16':76°38'), north of Nadayara Kayal, Cherumthusseri (south of Kanjirakottu kayal), Tamarakulam (9° 8'00":76°37'00") and Puliyoor (9°18'00": 76°35'00").

West of Pozhikkara-Paravur (8°48':76°40'), a 3m thick lignite bed occurs above 1m thick fossiliferous limestone and below 9m thick sandstone of Warkalli Formation.

QUARTZ

Deposits of quartz, a source of silicon used for manufacture of silicon carbide, abrasive silica gel, ferrosilicon and silica bricks, occurs in Sultan Battery taluk of Wynad district at Puthode, and Nenmeni and at Edavaka, Thrillisseri, Thavanjal and Prey in Mananthavady taluk.

SCHEELITE

Occurrence of scheelite in the Attapady valley (Palakkad district) was reported by GSI. Samples of heavies collected from the Siruvani river and its tributaries were found to contain grains of scheelite. The primary tungsten mineralisation in the form of scheelite is stratabound and confined to the hornblende gneiss and talcose rock. The tungsten values range from 30 ppm to 2500 ppm.

The KMEDP explored the area between 1977 and 1987. Scheelite mineralisation is found in the form of (a) thin films along the foliation and joint planes in biotite gneiss, (b) as tiny crystals in biotite-hornblende gneiss and biotite gneiss, (c) as disseminations in amphibolite and (d) as discrete grains or clusters of grains in veinlets of quartz criss-crossing the amphibolites.

The most extensive and consistent area (about 28 sq. km) of high scheelite counts is on the banks of the Siruvani river, around Kadirampadi-Chittor (11°03'45" : 76°39'15"), Thundur, Solayur (10°40'00":76°07'00"), Kadampara (11°05'08":76°41'55"), Ramanathapuram (11°09'05":76°39'10") and Kanjirapuzha (10°59'55":76°32'40") in Palakkad district.

Most of the scheelite occurrences are confined to the hornblende gneiss band of Utukuzhy (11^{o}4'44":76^{o}41'42"). It occurs as disseminations or concentrations parallel to the banding of the host rock. It also occurs as coating on the joints along with quartz veinlets.

Anomalous values for tungsten (3.13 ppm) are mostly confined to the residual soil derived from hornblende-gneiss, (Nair and Gopala Rao, 1992).

SILLIMANITE

Sillimanite is an integral part of the placer sands found along the west coast of Kerala. *In situ* occurrences of the mineral are reported from the Khondalite Group.

Alappuzha District

Placer sillimanite is reported from silica sands at Kokkothamangalam (9°41':76°21'), Pallipuram (9°44'00":76°21'40") and Panvalli (9°48'00":76°21'00"), beteen Alappuzha and Shertala where a reserve of 41.6 million tonnes of sand have been estimated. Sillimanite is present to the extent of 9.5% in ten finer fractions (100 mesh and below) of the raw sand.

Sillimanite is reported from Ullanur (9°43'45":76°42'00") and Maveripara (9°12'30": 76°41'30"). It consistutes 25 to 30% of the rock where the rock is extensively rich in sillimanite. It also occurs as monomineralic bands within garnet-sillimanite gneiss. Bands over 21.15 cms in width, are measured at a quarry in Maveripara.

Malappuram and Palakkad districts

The hills ∆ 3428 (11 ^{0} 43' 15" : 76^0 13' 30") south of Muthikulam Forest Rest House, such as Periyakunjara Malai, Elival Malai (10°53'00":76°39'00") and Paliyanikonam Malai are composed of garnet-sillimanite gneiss containing large segregations of sillimanite occurring as parallel bands. Garnet-sillimanite gneiss with segregations of sillimanite is reported from Chittur, Palakkad and Perinthalmanna taluks.

TALC-STEATITE

Steatite bands of Wynad Schist Complex occur in association with talc-tremolite, chlorite-actinolite rock. Impure steatite has been reported from Sultan's Bathery (11°39'30":76°15'30") area (Rao and Varadan, 1967). Tremolite-actionolite-talc schist occurs near Muralamutu (11°20'00":76°19'00") and Arnapalam (11°23'00":76°17'00") in Kannur District. Bands of talc and steatite occur in Pazhassi (11°54'00":76°35'00"), Iritty (11°59'00":75°41'00") and Edamala (11°52'00":75°39'00") areas in Kannur District (Krishna and Nair, 1973). The talcose rocks in these areas occur as detached outcrops in a linear fashion. The length of the talcose bands varies from 2 to 3 km and width from 30 to 40m.

Steatite bands ranging in width from 90 to 180m. are reported from Kallur (11°42'00":76°12'30") in Wynad District. The steatite body trending in NW-SE for about 300m contains massive and silvery grey to light green talc derived from the alteration of peridotite (Vidyadharan, 1981). In South Wynad, steatite bodies occur as concordant bands within the pyroxene granulite, chranockite and migmatites. Width of the individual bands vary from 50 to 60 m with a strike length of 500-2000 m. The steatite body consists mainly of talc-tremolite-chlorite. Massive and foliated types are identified. In some occurrences lateritisation of the steatite is observed upto a depth of 0.4 m. The steatite blocks, tested show a loss of weight upto 0.50 to 1.50% at 700^{0}C and 4.6 to 5.8% at 1100^{0}C. This deposit is after tremolite as is evident from the presence of pseudomorphs of tremolite which in turn is indicative of its origin from the pyroxenite.

The probable reserve estimated in Chedleth (11°44'30":76°14'00"), south of Chingati (11°44':76°08"), Gudalur (11°43'00" : 76°13'30"), Kakkadam (11°41'15":76°13'), Kallur (11°42'15":76°12'30"), Munnanakuzhi (11°42'00":76°11'15), Ottakutti (11° 42' 30":76°12'30"), Paplasseri (11°42'30":76°11'30"), Pazhuppathur (11°40'30":76°14'), Puthuvitu(11°41'45":76° 17'),Punchavayal(11°38'30":76°16'45"), Tattur (11° 44' 15" : 76°15'30"), Tanivayal (11°39'00":76°12'30"), Vakeri(11°41'15":76°12'30") Vengur (11°40':76°10'30"), Yerrulathur (11 ^{0} 44'45": 76^0 00'00") , east of ∆3428 is

approximately 12.05 million tonnes (Vidyadharan, 1981; Vidyadharan and David, 1984).

Nalluru (11°56'30':75°42'00") : The talcose rocks found in the Nalluru deposit in Thalasseri Taluk, Kannur district trend N80°W-S80°E with sub-vertical dips to south (Krishna and Nair, 1973; Vidyadharan and Nair, 1974). Talc-chlorite, besides talc-tremolite rock and boulders of quartz vein, magnetite quartzite, weathered granite and quartzo-feldspathic rocks are also observed. The talc body occurs as linear detached outcrops with an average width of 60m. Lateritisation is noticed upto a depth of 4m. The quality of talc improves below 5-6m depth. The specific gravity of talc varies from 2.6-2.8 after heating up to a temperature of 1200°C. They also show a loss of weight of 4 to 8%, linear shrinkage of 1 to 2% and volume shrinkage of 4 to 8%. The MgO content varies laterally and depthwise (7.2% to 22.8%), SiO_2 is 27.2 to 51% and often Ni is 800 ppm and Co 120 ppm. Agricultural experiments on the use of talc (magnesium silicate as a micro-nutrient) by applying 2000 kg of talc / hectare shows an increase of 1.5 to 2 quintal / hectare of grain production.

The talcose body of Nalluru can be used in insecticides or as filler in rubber industry and as a lubricant in greases. It is not suitable for textile and paint industries and other cosmetic industries due to high content of Fe and Al and low content of Mgo. Since, talc can resist temperature upto 1200^{o} C without shrinkage and cracks it can be used for spark plug industry.

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APPENDIX-I

Minor occurrences of minerals

Mineral	Locality	Host rock
Allanite	**(Wynad District)**	
	Puthiyamuthur (10°40'00":76°07'00")	Charnockite
	Sholayar dam (10°17'00":76°4500")	
	Ambalavayal (11°37'15":76°00'03")	Granite
Bauxite	**(Pathanamthitta District)**	
	Kuthiravattom kunnu (9°16'00":76°37'00")	
	Pumangala (9°17'00":76°33'00")	
	Arikkara (9°16'00":76°38'00")	
	Adikattukulangara (9°10'00":76°40'00")	
	(Thiruvananthapuram District)	
	Kolamuttam (8°42'30":76°46'00")	
	Andurkonam (8°30'15":76°53'00")	
	Kiluvalam (8°40'00":76°49'30")	
	Kavalur (8°42'45":76°47'15")	
	Manjamalai (8°37'00":76°52'10")	
	Muttapalam (8°38'40":76°48'50")	
	Korani (8°39'15":76°50'00")	
Chrysoberyl	**(Thiruvananthapuram District)**	
	Kurumbal (8°32'30":76°58'30")	In Tertiary gravels
	Venpakal (8°23'00":77°03'30")	
	Cheruvathurkonam (8°25'00":77°02'00")	
	(Kollam District)	
	Talachira (8°58'00":76°51'00")	In quartz pebble beds and pegmatites
	Ilampazhannur (8°52'00":76°55'00")	
Clays i)Tile and Brick clay	**(Ernakulam District)**	
	Aluva (10°06'00":76°21'00")	
	Perur (9°51'00":76°22'00")	
	Angamali (10°11'00":76°23'00")	

	(Kollam District) Karintura (9°02'00":76°40'00") Pathur (9°03'00":76°42'00")	
	(Kottayam District) Punathera (9°40'00"76°36'00") Ammanur (9°38'00":76°35'00") Kidangoor (9°41'00":76°37'00")	
	(Thiruvananthapuram District) Arumanoor (8°20'30":77°04') Karamana (8°29'00":76°58'30") Kazhakuttam (8°34'00":76°52'30")	
ii)China clay	**(Kannur District)** Erinapuram (12°02'00":75°14'00") Kannapuram (11°48'00":75°19'00") Ramapuram (12°02'45":75°15'30") Cheruthazham (12°02'00":75°14'00")	
	(Kasaragod District) Chimeni (12°14'00":75°14'00") Chandragiri (12°25'00":75°15'00") Karivallur (12°10'00":75°11'00")	
	(Kollam District) Nooranad (9°10'30":76°30'00") Chunakara Vadakku (9°12'30":76°37'30") Nadurilemuri (9°11'30":76°37'10") Panayil (9°09'45":76°38'45")	
	(Thiruvananthapuram District) Nadayara (8°45'00":76°43'00") Ilakamon (8°47'00":76°44'00") Mangalapuram (8°37'00":76°54'00") Tonnakkal (8°37'00":76°51'00") Chilampil (8°37'00":76°50'00")	
iii) Koalinite/ Montmorillonite	**(Thiruvananthapuram District)**	Suitable for paper industry
	Chilampil (8°37'00":76°50'00")	
	Mangalapuram (8°37'00":76°54'00")	
	Kottukal (8°23'00":77°02'30")	Grit bearing clay
	Kalliyur (8°25'30":77°00'30")	High grit clay
	Kulangaradesam (8°25'30":77°00'30")	
iv)Ball clay	**(Thiruvananthapuram District)** Nadayara (8°45'00":76°43'00")	

v)Bauxitic clay	**(Thiruvananthapuram District)** Arumannor (8°20'30":77°04'00") Chovara (Karichal) cliff (8°21'30":77°01'00") Truppapur (8°32'30":76°53'00") Manvila (8°32'30":76°53'30") Murukkumpuzha (8°36'30":76°50') Sasthavattam (8°38'45":76°49'30")	
vi)Fire clay	**(Wynad District)** Vythiri (11°43'00":76°02'15") Chundele (11°34'00":76°02'00")	
Corundum (Translucent semiprecious variety)	**(Kasaragod District)** Perla (12°38'30":75°06'30")	Pegmative veins within charnockite
Glass sand (Impure)	**(Ernakulam District)** Nettur (9°22'00":76°44'00")	
Coastal sands	**(Kannur District)** Cheruthazam (12°04'30":75°15'30") Kunhimangalam (12°05'00":75°14'00")	
Coastal sands	**(Kasaragod District)** Cheruvathur (12°13'00":75°09'50")	
Gold	**(Malappuram District)** Kadannamanna (11°01'44":76°10'00")	Quartz-magnetite granulite
Graphite (Streaks and disseminations of graphite)	**(Ernakulam District)**	
	Avoli (9°57'30":76°37'30") Peringazha (9°57'15":76°36'15") Pottamala kunnu(9°59'00":76°32'00") Memadangu (9°55'00":76°38'00") Karimukal (9°59'00":76°24'00")	Khondalite
	(Kottayam District) Vallavur (9°47'00":76°30'00") Indanad (9°44'00":76°39'00") Kallambakka (9°47'00":76°32'00")	Garnet- biotite gneiss/ biotite gneiss

	Vazhur (9°33'00":76°43'00")	Garnet- biotite gneiss/ biotite gneiss
	Puvarani (9°39'00":76°43'00")	
	Idamala (9°38'00":76°40'00")	Garnet- biotite gneiss/ biotite gneiss
	Aranikunnu (9°33'00":76°37'00")	
	(Pathanamthitta District)	
	Kikkolur (9°21'15":76°46'20")	Garnet-sillimanite gneiss/charnockite gneiss
	Ranni (9°22'00":76°48'00")	
	(Thiruvananthapuram District)	
	Karuppur (8°36'00":77°01'00")	Garnet-sillimanite-biotite gneiss
	Changa (8°34'00":77°04'00")	
	Vellanad (8°34'00":77°03'00")	
	Kuttichal (8°34'00":77°06'00")	
	Vengannur (8°25'00":77°02'00")	
	Chengallur (8°27'00":77°05'00")	
	Puliarakonam (8°29'00":77°08'00")	
	Attipara (8°30'00":76°54'00")	
	Kilattingal (8°41'00":76°48'00")	
	Amaravila (8°23':76°06'00")	
	Koranamkod (8°25'00":77°08'00")	
Ilmenite-garnet monazite sands	**(Kozhikode District)** Coastal tract between Beypore (11°10'00":75°48'15") and Kallayi river	
Iron-ore	**(Idukki District)**	
	Kaliyar Estate (9°58'00":76°46'00")	Biotite gneiss
	Kotapara (9°53'00":76°55'00")	
	Idukki (9°50'00":76°58'00")	
	Kalliparamudi (9°55'00":76°58'00")	
	Panamkutty (9°57'00":76°50'00")	
	Neriyamangalam (10°03'00":76°47'00")	
	(Malappuram District)	
	Nilambur (11°16'00":76°13'20")	Magnetite-quartzite/ Grunerite gneiss/ hornblende gneiss
	Kalikkavu (11°10'00":76°20'00")	
	Chambrasseri (11°08'00":76°16'00")	
	Manjeri (11°07'30":76°07'30")	
	(Palakkad District)	
	Anakatti Checkpost (11°11'00":76°45'00")	

	Siruvani Estate (10°57'00":76°41'00")	
	Mannarghat (10°55'00":76°28'00")	Garnetiferous biotite gneiss/ charnockite gneiss
	Singaparai (10°58'00":76°36'00")	Magnetite quartzite
	Kilur (10°51'00":76°22'00")	
	Mannampatta (10°54'00":76°27'00")	
	Karivallur (10°53'00":76°22'00")	
	Valur (10°52'00":76°23'00")	
	Nadupati (10°36'00":76°44'00")	
	Elival (10°53'00":76°39'00")	
	Narasimukke (11°09'00":76°38'00")	
	Galachimala(11°10'15":76°33'40")	
	Malleswaram (11°05'54":76°33'22")	
	(Kollam District)	
Lateritic iron ore (25-35% Fe)	Mulavana (8°59'00":76°41'00")	
	Tonipara (8°47'00":76°41'00")	
	(Thrissur District)	
	Hillock 251 (10°33'00":76°45'00")	Surface enriched ironstones within laterite
	(north of Adatt and in Velangans area (10°33'00":76°10'00")	
	(Wynad District)	
	Pathiri forest (11°47'00":76°05'00")	
Kyanite	**(Kollam District)**	
	Vadaman (8°57'00":76°55'00")	Weathered pegmatite in contact with garnet biotite gneiss
	(Kannur District)	
	Iritty (11°59'00":75°41'00")	In metasedimentary rocks
Limeshell	**(Kannur District)**	
	Tellicherry (11°44'30":75°27'30")	
	Dharmadam (11°46'30":75°28'00")	
	Poothal (11°49'00":75°29'00")	
	Melur (11°48'30":75°28')	
	Mandalur (11°49'30":75°28')	
	Azhikkod (11°57'00":75°18'00")	

	(Kasaragod districts) Kasaragod (12°30'00":74°59'00")	
	(Kozhikode District) Puduppanam (11°34'45":75°36'15") Thiruvangur (11°22'30":75°44'30") Kadalundi (11°08'15":75°50'12") Korapuzha Murat river Ayalapuzha	
	(Union Territory) Mahe (11°42"30":75°32')	
	(Kollam District) Ashtamudi kayal	
	(Malappuram District) Edappal (10°47':76°)	
	(Thrissur District) Chettuva (10°32'00":76°03'00")	
Limestone	**(Idukki District)** Yellapalli estate east of Munnar: (10°57'00":77°31'00")	Crystalline limestone, high in silica
	(Pathanamthitta District)	
Muscovite (mica)	Othara (9°21'00":76°57'00") Kikolur (9°21'15":76°46'20") Uzhavpara (9°22'15":76°48'45") Ranni (9°22'35":76°46'45") Vechurchira (9°25'00":76°51'00")	Pegmatites
	(Palakkad District)	
	Agali (11°07'30":76°38'30") Kurukkur (11°07'00":76°44'30") Vettattur (11°01'00":76°19'00")	Pegmatite in biotite gneiss
	(Thiruvananthapuram District)	
	Vattiyoorkavu (8°28'00":76°55'00") Vellanad (8°33'00":77°04'00")	Calc gneisses/ Garnet biotite sillimanite gneiss
	(Wynad District)	
	Meppadi (11°33'00":76°08'00")	Sheared garnet biotite

		gneiss
Molybdenum	**(Pathanamthitta District)** Kunnathukara (9°19'30":76°42'00") Ondekadu (9°19'00":76°42'30")	Granite
	(Kollam District)	
	Kottavasal (9°04'00":77°07'30")	Pegmatite vein within Kalpetta granite
	(Wynad District) Muttil (11°36'30":76°06'45")	
Lignite	**(Alappuzha District)** Tottapally (9°19'00":76°24'00") Tagazhy (9°23'00":76°24'00") Puliyoor (9°18'00":76°35'00")	Warkalli formation
	(Kottayam District) Vaikom (9°44'45":76°24'45") Kumaragom (9°56'00":76°26'30")	Warkalli formation
	(Kannur District) Ochathidle (12°14'00":75°11'00")	Warkalli formation
	Kasaragod district) **(**Kadankote mala (12°12'25":75°08'15")	Warkalli formation
	(Kollam District) Tamarakulam (9°08'00":76°37'00")	Warkalli formation
	(Kozhikode District) Beypore (11°10'00":75°48'15") (on the banks of the Beypore river)	Warkalli formation
	(Wynad District)	
Steatite	Vengur (11°40':76°10'30") Maddaru (11°41'30":76°12'00") Paplasseri (11°42'30":76°11'30") Kakkadam (11°41'15":76°13'00")	Pyroxene granulite, charnockite and migmatite
	(Kannur District) Ellerenni (12°02'30":75°32'00")	

Taliparamba (12°02'30":75°21'30") Kurumathur (12°02'30":75°25'30")	Talc tremolite rock

APPENDIX-II

Locality Index

Sl.No.	Locality	Latitude	Longitude	Toposheet No.
1.	.3428	11º 43' 15"	76º 13' 30"	58A/2
2.	Adakkathodu	11°55'35"	75°50'25"	49 M/13
3.	Adichannalur	08°53'00"	76º 43' 00"	58 D/9
4.	Adikattukulangara	09º 10' 00"	76º 40' 00"	58C/12
5.	Adiyur	11º 40'00"	75º 35' 30"	49 M/10
6.	Agali	11º 07' 30"	76º 38' 30"	58A/12
7.	Airayil Desam	08°20'00"	77°08'00"	58 H/3
8.	Akkulam	08º 31' 25"	76º 54' 30"	58 D/14
9.	Alampara	11º 35' 00"	75º 52'00"	49 M/14
10.	Alandara	08°42'00"	76°53'00"	58 D/14
11.	Alapuzha	09º 28'20"	76º 20'00"	58 C/7
12.	Alinilam	11º 45'00"	75º 51' 45"	49 M/13
13.	Alumanur	08°39'00"	76°55'00"	58 D/14
14.	Aluva	10º 06' 00"	76º 21' 00"	58 B/8
15.	Amapalam	11º 23'00"	76º 17'00"	58A/7
16.	Amaravila	08º 23'00"	77º 06'00"	58H/3
17.	Ambalam	08°53'00"	76°37'00"	58 D/9
18.	Ambalathumbhagam	09°04'32"	76°39'40"	58 C/12
19.	Ambalavayal	11º 37' 15"	76º 03'00"	58 A/2
20.	Amballoor	09°52'30"	76°23'30"	58 C/1+5
21.	Ammanur	09º 38'00"	76º 35'00"	58 C/10
22.	Anakatti checkpost	11º 11'00"	76º 45'00"	58A/12
23.	Anamooli	11º 01' 36"	76º 31' 13"	58 A/12
24.	Anchalummood-Kuripuzha	08°55'50"	76°36'10"	58 D/9
25.	Andoorkonam	08°36'00"	76o52'30"	58 D/14
26.	Andurkonam	08º 30' 15"	76º 53'00"	58 D/14
27.	Angamali	10º 11'00"	76º 23'00"	58 B/8
28.	Ankakalari	12º 16' 30"	75º 08' 40"	48P/3
29.	Arangadi	12°25'40"	75°10'00"	48 P/3
30.	Aranikunnu	09º 33'00"	76º 37'00"	58 C/10
31.	Arathiparamba	12°06'00"	75°15'30"	48 P/8
32.	Arikara	09º 16'00"	76º 18'00"	58 C/7

33.	Arthat	10°37'00"	76°03'00"	58 B/2
34.	Arumanoor	08º 20' 30"	77º 04' 00"	58H/3
35.	Aruvikkara	08°34'00"	77°01'25"	58 H/2
36.	Attipra	08º 30'00"	76º 54'00"	58D/14
37.	Avoli	09º 57' 30"	76º 37' 30"	58C/9
38.	Azhikkod	11º 57' 00"	75º 18'00"	49M/5
39.	Azhoor	08º 38' 31"	76º 49' 29"	58 D/14
40.	Badagara	11º 35' 30"	75º 35' 30"	49M/10
41.	Badiadka	12°27'44"	75°09'50"	48 P/3
42.	Balangod	10º 47'00"	75º 56'00"	49 N/13
43.	Balaramapuram	08°25'29"	77°02'57"	58 H/3
44.	Beypore-Kallayi river	11º 10' 00"	75º 48' 15"	49M/16
45.	Bharanikavu	09°03'30"	76°38'20"	58 C/12
46.	Braimore	08°46'00"	77°06'00"	58 H/1
47.	Chakkuvalli	09°05'10"	76°38'20"	58 C/12
48.	Chalakudy	10º 01'00"	76º 22'00"	58B/8
49.	Challisseri	11º 44' 00"	76º 05'00"	58A/2
50.	Chamrasseri	11º 08'00"	76º 16' 00"	58A/8
51.	Chandragiri	12º 25'00"	75º 15' 00"	48P/7
52.	Changa	08º 35' 00"	77º 04' 00"	58H/2
53.	Changapara	09º 03'00"	76º 58'00"	58C/16
54.	Chathamath	12º 16' 00"	75º 10'00"	48P/3
55.	Chattanur	08°51'28"	76°42'52"	58 D/9
56.	Chavara	09º 57' 53"	76º 32' 35"	58D/9
57.	Chedleth	11º 44' 30"	76º 14'00"	58A/2
58.	Chelambra	11º 09'00"	75º 52'00"	49M/16
59.	Chellepparambu	11°14'30"	75°59'00"	48 M/16
60.	Chembur	08°41'00"	76°54'00"	58 D/14
61.	Chemmannur	10º 40' 30"	76º 11' 01"	58B/2
62.	Chemmarattur	11º 36' 44"	75º 38' 30"	49M/10
63.	Chengal	10°09'22"	76°25'43"	58 B/8
64.	Chengallur	08º 27'00"	77º 05'00"	58H/3
65.	Chengannur	09°18'45"	76°31'00"	58 C/11
66.	Cheradi	09º 54'00"	76º 47'00"	58C/13
67.	Cheramangalam	10º 10' 20"	76º 13' 45"	58B/4

68.	Cherthala	09°41'00"	76°20'00"	58 C/6
69.	Cherukulathur	08°34'42"	77°04'35"	58 H/2
70.	Cheruppa	11º 15'00"	75º 55' 00"	49M/15
71.	Cheruthazham	12°05'00"	75°14'00"	48 P/4
72.	Cheruvannur	11°12'08"	75°49'35"	49 M/15
73.	Cheruvathurkonam	08º 25'00"	77º 02' 00"	58H/3
74.	Chettuva	10º 32'00"	76º 03'00"	58B/2
75.	Chilampil	08º 37'00"	76º 50' 00"	58D/14
76.	Chimeni	12º 14'00"	75º 14'00"	48P/4
77.	Chingati	11º 44'00"	76º 08'00"	58A/2
78.	Chingeri	11º 37' 16"	76º 12' 11"	58A/2
79.	Chirakadavu	09º 09' 45"	76º 31'00"	58C/12
80.	Chirakara	08º 44' 30"	76º 43' 30"	58 D/10
81.	Chirayinkil	08º 39' 30"	76º 47' 25"	58 D/14
82.	Chittavattom	08°59'30"	76°42'00"	58 D/9
83.	Chittur	09º 54' 30"	76º 40' 42"	58 C/9
84.	Chorod	11º 36' 30"	75º 35' 30"	49 M/10
85.	Chovva	11°52'00"	75°22'00"	49 M/5
86.	Chovvara	08°21'00"	77°01'30"	58 H/3
87.	Chruvathur	12º 13' 00"	75º 09' 50"	48P/4
88.	Chulliamkulam	10º 55' 25"	76º 34' 15"	58 B/9
89.	Chullimanur	08°38'27"	77°01'30"	58 H/2
90.	Chundale	11º 34'00"	76º 02'00"	58 A/2
91.	Chunkara Vadakku	09º 12' 30"	76º 37' 30"	58C/12
92.	Devikulam	10°04'00"	77°06'30"	58 F/4
93.	Dharmadam	11º 46' 30"	75º 28' 00"	49M/5
94.	Edamala	11º 52' 39"	76º 39'00"	49M/9
95.	Edamaruku	09º 54'00"	76º 47' 00"	58 C/13
96.	Edappad	11°05'05"	76º 16' 40"	58 A/8
97.	Edavai	08º 45'80	76º 42'00"	58 D/9
98.	Eleyettimala	11º 23' 00"	75º 46'00"	49 M/15
99.	Elival	10º 53'00"	76º 39'00"	58 B/9
100.	Elival malai	10º 53'00"	76º 39' 00"	58 B/9
101.	Ellerenni	12º 02' 30"	75º 32' 00"	48P/12
102.	Erinapuram	12º 02' 45"	75º15'30"	48 P/8

103.	Farokh	11º 11'00"	75º 50'00"	49 M/16
104.	Galachimala	11°10'15"	76°33'40"	58 A/12
105.	Gopalapuram	10º 42'00"	76º 53' 00"	58 B/14
106.	Guddalur	11º 43'00"	76º 13' 30"	58 A/12
107.	Hillock 251	10º 33' 00"	76º 45' 00"	58B/14
108.	Idaikode	08°40'11"	76°50'49"	58 D/14
109.	Idamala	09º 38'00"	76º 30'00"	58C/10
110.	Idukki	09º 50'00"	76º 58'00"	58 C/13
111.	Ilakamon	08º 47'00"	76º 44'00"	58D/9
112.	Ilampazhannur	08º 52'00"	76º 55'00"	58 D/13
113.	Indanad	09º 44'00"	76º 39'00"	58C/10
114.	Iringavur	11º 55' 30"	75º 57' 30"	49 M/13
115.	Iritty	11º 59' 00"	75º 41' 00"	49 M/9
116.	Jerrugatta	12º 44' 30"	74º 55'00"	48 L/14
117.	Jrigannur	11º 42' 00"	75º 36' 15"	49 M/10
118.	Kadalundi	11°08'15"	75°50'12"	49 N/13
119.	Kadampara	11°05'08"	76°41'55"	58 A/12
120.	Kadankote Mala	12°12'25"	75°08'15"	48 P/4
121.	Kadankotemala/Kelankotemala	12º 04'00"	75º 35' 45"	48P/12
122.	Kadannamanna	11º 01' 44"	76º 10'00"	58A/4
123.	Kadirampadi-Chittoor	11º 03' 45"	76º 30' 15"	58A/12
124.	Kainur	10°36'00"	76°09'00"	58 B/2
125.	Kaithacode	08º 57' 00"	76º 14' 44"	58D/9
126.	Kaithakuzhi	08°52'45"	76°44'00"	58 D/9
127.	Kaithapram	12°07'10"	75°17'40"	48 P/8
128.	Kakkadam	11º 41' 15"	76º 13'00"	58A/2
129.	Kakkut	12°16'00"	75°10'30"	48 P/3
130.	Kaladi	10°09'57"	76°26'20"	58 B/8
131.	Kalanad	12°27'00"	75°01'00"	48 P/3
132.	Kalikkavu	11º 10' 00"	76º 20'00"	58A/8
133.	Kalivalli	11°51'30"	76°12'30"	58 A/1
134.	Kaliyar estate	09º 58'00"	76º 46'00"	58C/13
135.	Kalkandi	11º 09' 15"	76º 38' 15"	58A/12
136.	Kallakere	11º 07' 17"	76º 40' 00"	58A/12
137.	Kallambakka	09º 47' 00"	76º 32'00"	58C/9

138.	Kallara	08°41'00"	76°54'00"	58 D/14
139.	Kalliparamudi	09º 55'00"	76º 58'00"	58C/13
140.	Kalliyur temple	08º 25' 30"	77º 00' 30"	58H/3
141.	Kallur	11º 42' 15"	76º 12' 30"	58A/2
142.	Kalluvathukkal	08°50'30"	76°46'30"	58 D/13
143.	Kalmukkur	11º 07'00"	76º 44' 30"	58A/12
144.	Kalpatta	11º 37' 30"	76º 05' 15"	58A/2
145.	Kambilmaloth	11°58'00"	75º 24'00"	49 M/5
146.	Kandanedu	09°54'50"	76°22'46"	58 C/1+5
147.	Kandankali	12º 45'00"	75º 12' 30"	48P/1
148.	Kanhangad	12°18'15"	75°05'15"	48 P/4
149.	Kanjikuzhy	09º 44' 45"- 09º 46' 35"	76º 20' 45"- 76º 20'00"	58C/6
150.	Kanjirakotusseri	08°58'20"	76°40'20"	58 D9
151.	Kanjiramattam	09°49'00"	77°32'00"	58 C/9
152.	Kanjirapuzha	10º 59' 55"	76º 32' 40"	58B/9
153.	Kanjirattusseri	08º 58' 00"	76º 38' 00"	58D/9
154.	Kannanallur	08º 50'00"	76º 39'00"	58D/9
155.	Kannapuram	11º 48'00"	75º 19'00"	49M/5
156.	Kannur	11º 53'00"	75º 21' 35"	49M/5
157.	Kappad	11º 52' 45"	75º 25' 10"	49M/5
158.	Kappil	11º 14' 30"	76º 14' 30"	58A/4
159.	Karakulam	08°34'00"	76°59'00"	58 D/14
160.	Karamana	08º 29'00"	76º 58' 30"	58D/15
161.	Karavur	09º 04' 00"	76º 56'00"	58C/16
162.	Karhangad	12º 27' 30"	75º 01'00"	48P/3
163.	Kariavattom	08º 33' 30"	76º 53' 30"	58D/14
164.	Karimala	10º 56' 55"	76º 34' 30"	58B/9
165.	Kari-Moicha	12º 13' 30"	75º 08' 30"	48P/4
166.	Karimukal	09º 59'00"	76º 24'00"	58C/5
167.	Karintura	09º 02' 00"	76º 40'00"	58C/12
168.	Karivallur	12º 10'00"	75º 11' 00"	48P/4
169.	Karumanda-Kavandanur	10º 42' 45"	76º 52' 15"	58B/14
170.	Karunagapalli	09º 05' 00"	76º 32'00"	48C/12
171.	Karupanthod	09º 04'00"	76º 57' 00"	48C/16

172.	Karuppur	08º 36'00"	77º 01'00"	58H/2
173.	Karuvarai	11°04'00"	76°32'30"	58 A/12
174.	Kasaragod	12º 30' 30"	74º 59'00"	48L/14
175.	Kattayil	12°06'30"	75°15'20"	48 P/8
176.	Kavallur	08º 42' 45"	76º 47' 15"	58D/14
177.	Kazhakkuttam	08º 34'00"	76º 52' 30"	58D/14
178.	Keloth-Tayimori	11º 53'00"	75º 49'00"	49M/13
179.	Kidangoor	09º 41' 00"	76º 37'00"	58C/10
180.	Kikkolur	09º 21' 15"	76º 46' 20"	58C/15
181.	Kilattingal	08º 41'00"	76º 48'00"	58D/14
182.	Kilur	10º 51'00"	76º 22'	58B/5
183.	Kiluvalam	08º 40'00"	76º 49' 30"	58D/14
184.	Kiralikod	08°38'20"	77°02'00"	58 H/2
185.	Kizhakkumkara	12°19'40"	75°05'40"	48 P/3
186.	Kodiyeri	11º 44' 30"	75º 31' 15"	49M/10
187.	Kodungallor	10°13'30"	76°12'00"	58 B/4
188.	Koduvannur	08°44'00"	76°52'00"	58 D/14
189.	Kokkottukonam	08°40'00"	76°55'00"	58 D/14
190.	Kokothamangalam	09º 41' 30"	76º 21' 30"	58C/6
191.	Kolakkod	08°34'00"	77°03'00"	58 H/2
192.	Kolamuttam	09º 16'00"	76º 37'00"	58C/11
193.	Kondaleasseri/Kundarasseri	08º 57' 55"	76º 41' 25"	58C/7
194.	Konniyur	08°40'00"	76°55'00"	58 D/14
195.	Kooval/Kuvel	11°46'50"	75°54'45"	49 M/13
196.	Koranamkod	08º 25'00"	77º 08'00"	58H/2
197.	Korani	08º 39' 15"	76º 50'00"	58D/14
198.	Korattimala	11º 22' 00"	76º 16' 00"	58A/7
199.	Kotapara	09º 53'00"	76º 55'00"	58C/13
200.	Kottasseri	10º 43' 30"	76º 07' 30"	58B/2
201.	Kottavasal	09º 04'00"	77º 07' 30"	58G/2
202.	Kottayam	09°35'00"	76°31'00"	58 C/10
203.	Kottiyam	08º 52'00"	76º 36'00"	58D/9
204.	Kottukal	08º 23' 20"	77º 02' 30"	58H/3
205.	Kottuli	11º 16'00"	75º 47' 30"	49M/15
206.	Kovalam	08º 23' 44"	77º 58' 47"	58D/15

207.	Kovur	11º 16'00"	75º 50'00"	49H/15
208.	Kozhinjampara	10º 43' 30"	76º 50' 30"	58B/14
209.	Kozhithottam	8º 41' 30"	76º 44' 50"	58D/10
210.	Kudaishanad	09º 11' 30"	76º 40' 00"	58C/12
211.	Kudiyichirakonam	08°54'00"	76°42'00"	58 D/9
212.	Kulanada	09°14'30"	76°40'45"	58 C/12
213.	Kulangaradesam	08º 25' 30"	77º 00' 30"	58H/2
214.	Kulasekharamangalam	09º 08'00"	76º 23'00"	58C/8
215.	Kulasekharapettah	09°16'00"	76°47'45"	58 C/15
216.	Kulathupuzha	08°54'00"	77°03'00"	58 H/1
217.	Kumarakom	09º 56'00"	76º 26' 30"	58C/5
218.	Kumbalam	08°58'20"	76°40'20"	58 D/9
219.	Kumbla	12°35'45"	74°56'57"	48 L/14
220.	Kumbla Bela	12°34'00"	75°30'00"	48P/6
221.	Kummallur	08°51'30"	76°44'30"	58 D/9
222.	Kundara	08°57'00"	76°40'30"	58 D/9
223.	Kundumon	08º 56'00"	76º 37'00"	58D/9
224.	Kunhimangalam	12º 05'00"	75º 14'00"	48P/4
225.	Kunnariyam	12º 03' 00"	75º 13'00"	48P/4
226.	Kunnathoor	09º 03' 40"	76º 40' 32"	58D/9
227.	Kunnathukal	08°23'00"	77°10'00"	58 H/3
228.	Kunnathukara	09º 19' 30"	76º 42' 00"	58C/11
229.	Kurukkur	11º 07'00"	76º 44' 30"	58A/12
230.	Kurumathur	12º 02' 30"	75º 25' 30"	48P/8
231.	Kurumbal	08º 32' 30"	76º 58' 30"	58D/14
232.	Kuthiravattomkunnu	09º 16' 00"	76º 37' 00"	58C/11
233.	Kuthuparamba	11°49'30"	75°34'00"	49 M/9
234.	Kuttamangalam	11°30'08"	76°07'11"	58 A/2
235.	Kuttanad	09°27'00"	76°26'30"	58 C/7
236.	Kuttichal	08º 34'00"	77º 06'00"	58H/2
237.	Kuttiyadikal Mala	11°01'52"	76°42'00"	58 A/12
238.	Madayi	12°15'00"	75°15'30"	48 P/8
239.	Maddaru	11º 41' 30"	76º 12'00"	58A/2
240.	Mahe	11º 42' 30"	75º 32'00"	49M/10
241.	Malleswaram	11°05'54"	6°33'22"	58 A/12

242.	Manakkad	09º 54'00"	76º 42'00"	58C/9
243.	Mananthody	11º 03'00"	76º 00'00"	58A/4
244.	Manathana	11º 54' 40"	75º 46' 00"	49M/13
245.	Mandarathur	11º 36' 30"	75º 40' 30"	49M/10
246.	Mangalapuram	8º 37' 20"	70º 50' 55"	58D/14
247.	Manikunnu	11°35'41"	76°07'09"	58 A/2
248.	Manjakkala	09º 03' 30"	76º 50' 45"	58C/16
249.	Manjali	10°09'00"	76°16'00"	58 B/8
250.	Manjamalai	08º 37'00"	76º 52' 10"	58D/14
251.	Manjapra/Manhapra	10°08'12"	76°24'30"	58 B/8
252.	Manjeri	11º 07' 30"	76º 07' 30"	58A/4
253.	Manjeshwar	12°42'20"	74°53'32"	48 L/14
254.	Mankada	11º 01' 21"	76º 10' 39"	58A/4
255.	Mannampatta	10º 54'00"	76º 27'00"	58B/5
256.	Manjapra	10º30'00"	76°32'00"	58 B/11
257.	Mannarkkad	10º59'30"	76°28'00"	58 B/5
258.	Mannatta	12°21'00"	75°06'40"	48 P/3
259.	Mannikkal	08°39'00"	76°56'00"	58 D/14
260.	Manvila	08º 32' 30"	76º 53' 30"	58D/14
261.	Maruda	11º 23' 30"	76º 18'	58A/7
262.	Mattoor	10°09'22"	76°25'23"	58 B/8
263.	Mavelikkara	08º 15'00"	76º 32'00"	58C/12
264.	Maveripara	09º 12' 30"	76º 41' 30"	58C/12
265.	Mavur	11°15'40"	75°57'30"	49 M/15
266.	Mayyanad	08º 50' 00"	76º 39'00"	58D/9
267.	Mellthonnackal	08º 38' 05"	76º 51' 22"	58D/14
268.	Melur	11º 48' 30"	75º 28' 00"	49M/5
269.	Memadangu	09º 55'00"	76º 38'00"	58C/9
270.	Meppadi	11º 33'00"	76º 08'00"	58A/2
271.	Manjumala	10°05'00"	76°18'00"	58 B/8
272.	Mookuthala	08º 54'00"	76º 39' 57"	58D/9
273.	Moraza	11°58'30"	75°20'30"	49 M/5
274.	Mudappuram	08°38'00"	76°49'00"	58 D/14
275.	Mulanturthy	09°54'00"	76°24'00"	58 C/1
276.	Mulavana	08°59'30"	76°40'40"	58 D/9

277.	Mulli	11º 13'00"	76º 43' 15"	58A/12
278.	Mundalur	11º 49' 30"	75º 28'00"	49M/5
279.	Mundayur	11º 38' 00"	76º 38' 00"	58A/12
280.	Munnankuzhi	11º 42'00"	76º 11' 15"	58A/2
281.	Munnar	10°05'15"	77°03°45"	58 F/4
282.	Munro Island	09°31'25"	76°21'25"	58 C/6
283.	Muralamuttu	11º 20'00"	76º 19'00"	58A/7
284.	Murat	11º 34' 00"	75º 37' 00"	49M/10
285.	Murukkumpuzha	08º 36' 30"	76º 50'00"	58D/14
286.	Muttanam	08°49'45"	76°46'15"	58 D/13
287.	Muttapalam	08º 42' 00"	76º 40'00"	58D/10
288.	Muttil	11º 36' 30"	76º 06' 45"	58A/2
289.	Muttilmala	11°37'06"	76°06'38"	58 A/2
290.	Muttungal	11º 36' 35"	75º 35'00"	49M/10
291.	Muvattupuzha	09º 59' 00"	76º 35'00"	58C/9
292.	Mylapra	09º 17'00"	76º 47' 52"	58C/15
293.	Nadayara	08º 45'00"	76º 43' 00"	58D/9
294.	Naderi	11º 27' 45"	75º 43'00"	49M/11
295.	Nadupati	10º 36' 00"	76º 44' 00"	58B/10
296.	Nadurilemuri	09º 11' 30"	76º 37' 10"	58C/12
297.	Naduvallur	11º 23' 00"	75º 49'00"	49M/15
298.	Naduvayal	11º 44' 30"	76º 06' 30"	58A/2
299.	Naduvilakkara	09º 01' 15"	76º 37' 45"	58C/12
300.	Nagapuzha	09º 57'00"	76º 41' 30"	58C/9
301.	Naithode/Nayalam	10°10'23"	76°24'00"	58 B/8
302.	Nallila	08°55'30"	76°42'30"	58 D/9
303.	Nallur	11º 10'00"	75º 50' 45"	49M/16
304.	Nanminda	11º 24' 00"	75º 46'00"	49M/15
305.	Narasimukku	11º 07' 30"	76º 38' 30"	58A/12
306.	Narikuzhy	09º 19' 39"	76º 49' 15"	58C/15
307.	Nedumangad	08°36'12"	77°00'20"	58 H/2
308.	Nedumangalam	08º 50'00"	76º 41'00"	58D/9
309.	Neendakara	08º 56' 25"	76º 32' 45"	58D/9
310.	Nemom	08°27'25"	77°00'15"	58 H/3
311.	Nenmeni	10º 35' 55"	76º 42' 45"	58B/10

312.	Neriyamangalam	10º 03' 00"	76º 47'00"	58B/16
313.	Nettur	09º 22'00"	76º 44'00"	58C/11
314.	Nettuvangai	10º 51'00"	76º 43'00"	58B/9
315.	Neyyattinkara	08°24'00"	77°00'50"	58 H/3
316.	Nilambur	11º 16'00"	76º 13' 20"	58A/3
317.	Nileswaram	12º 15' 30"	76º 08' 16"	48P/3
318.	Nirakunnam	09º 23' 45"	76º 21' 15"	58C/7
319.	Nirampuzha	09º 57' 45"	76º 39' 45"	58C/9
320.	Niravilasseri	08º 55' 00"	76º 36'00"	58D/9
321.	Nirkunnam	09º 23' 45"	76º 21' 15"	58C/7
322.	Nooranad	09º 10' 30"	76º 30' 00"	58C/8
323.	Nulliamina	10º 01' 00"	76º 45'00"	58B/16
324.	Ochathidle	12º 14'00"	75º 11'00"	48P/4
325.	Omallur	09º 14' 00"	76º 47'00"	58C/16
326.	Ondekadu	09º 19' 00"	76º 42' 30"	58C/11
327.	Orkkatteri	11º 39' 00"	75º 35' 45"	49M/10
328.	Othara	09º 21' 00"	76º 57'00"	58C/15
329.	Ottakutti	11º 42' 30"	76º 12' 30"	58A/2
330.	Padappakkara	08°58'30"	76°38'00"	58 D/9
331.	Palai	12º 15' 40"	75º 09' 40"	48P/3
332.	Pallimon	08º 53' 40"	76º 43' 06"	58D/9
333.	Pallippuram	08º 35' 30"	76º 51' 30"	58D/14
334.	Pallipuram	09º 44'00"	76º 21' 40"	58C/6
335.	Palode	08°43'00"	77°00'00"	58 D/14
336.	Pamapuram	12°02'45"	5°15'30"	48 P/8
337.	Panamkutty	09º 57'00"	76º 50'00"	58C/14
338.	Panavalli	09º 48'00"	76º 21'00"	58C/5
339.	Panayil	09º 09' 45"	76º 38' 45"	58C/12
340.	Pandarettu	10º 52'00"	76º 47'00"	58B/13
341.	Paniyamunnau	08º 34'00"	76º 34'00"	58D/10
342.	Pannukulam	10º 33'00"	76º 12'00"	58B/2
343.	Paplasseri	11º 42' 30"	76º 11' 30"	58A/2
344.	Parameswaram	08°41'35"	76°55'40"	58 D/14
345.	Parassala	08°20'00"	77°0900"'	58 H/3
346.	Paravur	08°48'00"	76°40'00"	58 D/9

347.	Paripalli	08º 48' 30"	76º 45' 36"	58D/13
348.	Parur	09°51'40"	76°22'45"	58 C/1+5
349.	Pathanamthitta	09°15'45"	76°45'30"	58 C/15
350.	Pathiramanal	09º 32'00"	76º 23' 00"	58C/6
351.	Pathiri Forest	11º 47'00"	76º 05'00"	58A/1
352.	Pathur	09º 03' 00"	76º 42'00"	58C/12
353.	Pattuvam	12°02'30"	76°21'45"	48 P/8
354.	Pavumba	09°0620"	76°35'33"	58 C/12
355.	Payangadi	12°01'30"	75°15'30"	48 P/8
356.	Payyanam	10°31'00"	76°21'00"	58 B/713
357.	Payyanki	12º 11'00"	75º 50'00"	48P/16
358.	Payyannur	12°06'20"	75°13'00"	48 P/8
359.	Payyoli	11º 31' 30"	75º 39' 00"	49M/10
360.	Pazhassi #	11º 54'00"	75º 35'00"	49M/9
361.	Pazhuppathur	11º 40' 30"	76º 14'00"	58A/2
362.	Peppinpra	11°06'20"	76°05'56"	58 A/4
363.	Peralimala	11°54'12"	75°38'46"	49 M/
364.	Peravoor	11º 54' 30"	75º 46'00"	49M/13
365.	Peringazha	09º 57' 15"	76º 36' 15"	58C/9
366.	Perintalmanna	10º 58' 30"	76º 13' 30"	58B/1
367.	Perinthatta	12°10'00"	75°17'20"	48 P/8
368.	Periya	11°50'00"	75°51'30"	49 /49
369.	Periyamuli	11°13'00"	76°43'00"	58 A/12
370.	Perla	12º 38' 30"	75º 06' 30"	48P/2
371.	Perumpura/Perumpunna	11°55'28"	75°44'00"	49 M/9
372.	Perumpuzha	08°56'53"	76°41'22"	58 D/9
373.	Perumtholil	09º 03' 45"	76º 57' 05"	58C/16
374.	Perur	09º 51'00"	76º 22'00"	58C/5
375.	Piralimattam	09º 55' 00"	76º 38'00"	58C/9
376.	Polachira	08º 50' 30"	76º 42' 30"	58D/9
377.	Ponmudi	08°28'00"	77°05'00"	58 H/3
378.	Ponnambi	08°40'00"	76°55'00"	58 D/14
379.	Ponnamkod	10º 56' 48"	76º 31' 12"	58B/9
380.	Ponnani	11º 46' 30"	75º 55'00"	49M/13
381.	Pooncholа	10º 59' 30"	76º 35'00"	58B/9

382.	Poothal	11º 49'00"	75º 29' 00"	49M/5
383.	Pothencode	08°37'00"	76°48'56"	58 D/14
384.	Pottamala kunnu	09º 59'00"	76º 32'00"	58C/9
385.	Pottamavu	08°40'00"	77°02'00"	58 H/1
386.	Pozhikara-Paravur	08º 48' 00"	76º 40'00"	58D/9
387.	Pozhikkara	08º 48' 45"	76º 44' 28"	58D/10
388.	Prey/Periya	11º 50' 40"	75º 49'00"	49M/13
389.	Pudukkad	11º 24'00"	76º 15' 00"	58A/3
390.	Puduppanam	11º 34' 45"	75º 36' 15"	49M/10
391.	Puliarakonam	08º 29'00"	77º 08' 00"	58H/3
392.	Puliyoor	09º 18'00"	76º 35'00"	58C/11
393.	Pullur	12°21'20"	75°05'40"	48 P/3
394.	Pumangala	09º 17'00"	76º 33' 00"	58C/11
395.	Poomangalam	10°18'25"	76°12'00"	58 B/3
396.	Punalur	09º 01' 00"	76º 55' 00"	58C/16
397.	Punathera	09º 40'00"	76º 36' 00"	58C/10
398.	Punchavayal	11º 38' 30"	76º 16' 45"	58A/6
399.	Purameni	11º 40' 45"	75º 37' 45"	49M/10
400.	Putenchira	10°04'30"	76°12'00"	58 B/4
401.	Puthiyamuthur	10º 40'00"	76º 07'00"	58B/2
402.	Puthuvitu	11º 41' 45"	76º 17'00"	58A/6
403.	Puttumala	11º 03' 15"	76º 38' 30"	58A/12
404.	Puttuvam	12°02'30"	75°21'45"	48 P/8
405.	Puvar	08º 24'00"	77º 04' 00"	58H/3
406.	Puvarani	09º 39' 00"	76º 43'00"	58C/10
407.	Ramapuram	12º 02' 45"	75º 15' 30"	48P/8
408.	Ranganathapuram	11º 09' 05"	76º 39' 10"	58A/12
409.	Ranni	09º 22' 00"	76º 48'00"	58C/15
410.	Salayur	11º 12' 45"	76º 43' 42"	58A/12
411.	Sasthamcotta	09º 02' 30"	76º 37' 45"	58C/12
412.	Sasthavattam	08º 38' 45"	76º 49' 30"	58D/14
413.	Sherthalai	09º 41'00"	76º 20' 00"	58C/6
414.	Sholayar dam	10°17'00"	76°4500"	58B/11
415.	Sholayur	11°04'15"	76°42'00"	58 A/12
416.	Singaparai	10º 58'00"	76º 36'00"	58B/9

417.	Siruvani Estate	10º 57' 00"	76º 41' 00"	58B/9
418.	Solayur	10º 40'00"	76º 07' 00"	58B/2
419.	Sreemolanagaram	10°08'12"	76°24'30"	58 B/8
420.	Sultan Bathery	11º 39' 30"	76º 15' 30"	58A/6
421.	Talachira	08º 58'00"	76º 51'00"	58D/13
422.	Taliparamba	12º 02' 30"	75º 21' 30"	48P/8
423.	Talukottur	10º 58'00"	75º 55'00"	49N/13
424.	Tamarakulam	09º 08'00"	76º 37'00"	58C/12
425.	Tanivayal	11º 39'00"	76º 12' 30"	58A/2
426.	Tariode	11º 39'00"	75º 58'00"	49M/14
427.	Tattur	11º 44' 15"	76º 15' 30"	58A/6
428.	Thakazhy	09º 23'00"	76º 24'00"	58C/7
429.	Thamarakulam	09°28'00"	76°37'00"	58 C11
430.	Thannirmukkam	09°40'20"	76°23'35"	58 C/6
431.	Thavinjal	11º 50'00"	75º 58' 00"	49M/13
432.	Thekkumbhagam	08°57'00"	76°34'00"	58 D/9
433.	Thiruvallam	08º 27' 30"	76º 58' 00"	58D/15
434.	Thiruvananthapuram/Trivandrum	08°28'30"	76°5'20"	58 D/15
435.	Thiruvangur	11º 22' 30"	75º 44' 30"	49M/11
436.	Thodupuzha	09º 53' 45"	76º 43'00"	58C/9
437.	Thonnakkal	08º 37' 30"	76º 51'00"	58D/14
438.	Thottapalli	09º 19'00"	76º 24'00"	58C/7
439.	Thovarimala	11º 36' 38"	75º 05' 25"	58A/2
440.	Thuvapattu	11°06'30"	76°44'45"	58 A/12
441.	Timri	12°14'00"	75°14'00"	48P/4
442.	Tirurangadi	11º 02' 25"	76º 55' 15"	58M/16
443.	Tiruvanvaya	11º 52' 30"	75º 59'00"	49M/13
444.	Tonipara	08º 47'00"	76º 41' 00"	58D/9
445.	Toruvankulam	09°56'30"	76°22'30"	58 C/1+5
446.	Tottamala	08°44'00"	76°52'00"	58 D/14
447.	Trikkaipetta	11°35'04"	76°08'41"	58 A/2
448.	Trikkakara	10°02'00"	76°20'00"	58 C/1+5
449.	Trikkunnapuzha	09º 16'00"	76º 24'00"	58C/7
450.	Trinayanakadavu	09º 42'00"	76º 23'00"	58C/6
451.	Trippunithura	09º 57'00"	76º 21'00"	58C/5+1

452.	Truppapur	08º 32' 30"	76º 53' 00"	58D/14
453.	Tumamon	09°13'15"	76°43'00"	58 C/12
454.	Udumbanchola	10°00'00"	77°15'00"	58 F/4
455.	Udumpanthala	12º 06' 00"	75º 10' 50"	48P/4
456.	Ullanur	09º 43' 45"	76º 42'00"	58C/10
457.	Ullanur	09°14'45"	76°42'00"	58 C/12
458.	Uriakod	08°02'45"	77°04'15"	58 H/2
459.	Utukuzhy	11º 04' 44"	76º 41' 42"	58A/12
460.	Uzhamalakkal	08°35'00"	77°04'00"	58 H/2
461.	Uzhavapara	09º 22' 15"	76º 48' 45"	58C/15
462.	Vachchaapathi	11°04'51"	76°44'00"	58 A/12
463.	Vadakod	09º 56'00"	76º 40' 00"	58C/9
464.	Vadaman	08º 57' 00"	76º 55'00"	58D/13
465.	Vaga	10°35'00"	76°06'00"	58 B/2
466.	Vaikom	09º 45'00"	76º 24' 00"	58C/5+1
467.	Vakeri	11º 41' 15"	76º 12' 30"	58A/2
468.	Valakkad	11°14'35"	75°57'28"	58 M/16
469.	Valambur	11º 30'00"	76º 12' 28"	58A/2
470.	Valapattanam	11°55'30"	75°21'30"	49 M/5
471.	Valliman	08°58'30"	76°38'20"	58 D/9
472.	Valur	10º 52'00"	76º 23'00"	58B/5
473.	Vamanapuram	08°43'00"	76°54'00"	58 D/14
474.	Vannamadai	10º 42'00"	76º 51'00"	58B/14
475.	Varkala	08°44'00"	76°43'00"	58 D/10
476.	Vattali	11°48'30"	75°52'30"	49 M/13
477.	Vattam	11º 38'00"	75º 50' 00"	49M/14
478.	Vattiyoorkavu	08º 28'00"	76º 55'00"	58D/15
479.	Vayittiri	11º 33'00"	76º 02' 15"	58A/2
480.	Vazhamuttam	09°14'00"	76°46'40"	58 C/16
481.	Vazhur	09º 33' 00"	76º 43'00"	58C/10
482.	Vechurchira	09º 25' 00"	76º 51'00"	58C/15
483.	Velangans	10º 33' 00"	76º 10' 00"	58B/2
484.	Veli	08º 30' 25"	76º 53' 35"	58D/14
485.	Velipram	11º 11' 30"	75º 51' 15"	49M/16
486.	Vellanad	08º 34'00"	77º 03'00"	58H/2

487.	Vellavur	09º 47' 00"	76º 30' 00"	58C/5
488.	Velli	11°04'00"	76°07'45"	58 A/4
489.	Vellichikala	08º 53' 30"	76º 43' 13"	58D/9
490.	Velur	11°23'50	75°45'30"	49 M/15
491.	Vengad	11°53'30"	75°32'00"	49 M/9
492.	Venganur	08º 25' 40"	77º 02' 00"	58H/3
493.	Vengur	11º 40' 00"	76º 10' 30"	58A/2
494.	Venjaramud	08°41'00"	76°55'00"	58 D/14
495.	Venkadu/Vengad	11º 52' 57"	75º 32' 00"	49M/9
496.	Venmani	11º 49'00"	75º 55' 50"	49M/13
497.	Vennikadu	08°42'27"	76°44'55"	58 D/10
498.	Venpakal	08º 23' 00"	77º 03' 30"	58H/3
499.	Vettattur	11º 01'00"	76º 19'00"	58A/8
500.	Vettukad	08°29'50"	76°54'00"	58 D/15
501.	Vizhinjam	08º 22' 35"	77º 59' 30"	58D/15
502.	Vokoli	11º 29' 30"	75º 44' 00"	49M/11
503.	Vorkady	12°44'55"	74°56'35"	48 L/14
504.	Yedanad	12°36'00"	75°00'00"	48 L/14
505.	Yellapalli Estate (Munnar)	10º 57' 00"	77º 31'00"	58B/9
506.	Yerrulathur	11º 44' 45"	76º 00'00"	58A/2