Chapter 1
INTRODUCTION

1.1 Introduction

Rivers constitute the lifeline for any country and some of the world's great civilizations (e.g. Indus Valley, Mesopotamian, and Egyptian) have all prospered on banks of river systems. People of ancient India considered rivers as sacred and have personified them as deities and sung their praises in their religious literature. In the broader perspective of geological evolution, disappearance or disintegration of rivers, shifting of their courses, capture of one river by another and steady decline of discharge resulting in drying up of their beds, are all normal responses to several geological processes singly or jointly acting on the Earth's crust. These include tectonism, resulting from both orogenic and epeirogenic causes, sea level changes, and even climatic factors such as rainfall. Human interaction with river systems may also bring about several perceptible changes. A few of the south Indian rivers like the east-flowing Pennar, Palar and Cauvery draining into the Bay of Bengal and west-flowing Swarna, Netravathi and Gurupur draining into the Arabian Sea are known to have changed their morphology due to several of these causes.

Erosion processes and fluvial transport of materials have become a focus of revived attention more recently owing to their significance in land use and environmental aspects. Geological investigations of river basins and measurements of riverine transport of sediments and water can provide a reasonable estimate of several dynamic factors of a drainage basin. Most attempts to estimate denudation on a continental scale rely heavily on measurements of sediment yield from the rivers of the world. Considerable effort has been expended both to estimate sediment yield of the major rivers and to understand controls on sediment transfer within river systems. Studies on large rivers in transporting the denudation products of the continents to the sea have emphasized that topographical, lithological, and climatic factors play important roles in controlling the rate of weathering and continental denudation.
Assessing the impact of continental fluvial processes on the ocean require detailed studies of small and medium-size rivers in Asia. About 65% of fresh water and 80% of the sediment input to the oceans are from the tropics and a part of the subtropics (between 30°N and 30°S), where the major rivers are located (Eisma, 1988; Milliman, 1991). Rivers annually transport about $35 \times 10^3$ km$^3$ of fresh water (Milliman, 1991) and $4 \times 10^8$ tons of dissolved organic and inorganic matter (Emery and Milliman, 1978; Martin and Meybeck, 1979) to the world oceans. Small rivers (drainage basin <10,000 km$^2$) cover only 20% of the land area, but their large numbers result in their collectively contributing much more sediment than previously estimated. The estimates of contributions from small and large rivers to the total flux of particulate solids to the ocean has increased from ca. $16 \times 10^9$ ton/yr (large rivers alone) to ca. $20 \times 10^9$ ton/yr (Milliman and Syvitski, 1992). Of the total sediment yield to the world oceans, Indian sub-continent alone contributes about 35% (Milliman and Meade, 1983). Among the rivers of the Indian sub-continent, the sediment erosion is more significant than chemical erosion in the case of all the Himalayan rivers, whereas in the case of Peninsular rivers, chemical erosion is more significant. This is relatable to the active geodynamics of the Himalayas compared to the greater stability of the Peninsular shield, that make a marked difference to the eroding capacity of the rivers.

1.2 Sediment in stream channels

Alluvial stream channels are natural channels in which bed and bank materials have been deposited by the stream sufficiently recently and are still unconsolidated. These channels therefore are the product of processes produced by the interaction between flowing water and moving sediment. Furthermore, it is assumed that characteristic channel forms reflect the processes that produced them. Therefore, it is believed that an understanding of morphology, morphometry, and spatial relations of the characteristic forms in alluvial channels will facilitate deductions about the processes, which interact to produce the forms.

It is conceded that no two streams are exactly alike. The possible combinations and spatial arrangement of controlling variables such as climate, bed and bank material, and slope make each stream unique. Therefore, generalizations
concerning fluvial processes are nebulous and the more general the statement the more exceptions may be found. However, when a certain type or group of streams such as gravel-bed or alluvial streams are considered, the number of exceptions to generalized statements may decrease.

1.3 Fluvial hydraulics

In many gravel-bed alluvial channels, pools, riffles and point bars appear to be produced at relatively high, channel-forming flows and are modified only at low flow. Under these conditions, conventional hydraulics apply at low flow, when the channel is essentially a rigid container for liquid phase. However, at high flow when appreciable sediment is being transported by the stream, the hydraulics becomes complex because many of the variables are not unique (cf. Maddock, 1969). Leliavsky (1966) distinguishes fluvial hydraulics from hydraulics in general as a necessity to understanding natural stream. Perhaps the most significant and early-recognised principle in fluvial hydraulics is de Leliavsky's (1894) convergence-divergence criterion: the processes by which bed forms like pools, riffles, and point bars are formed.

Excluding the fluid phase, the most obvious forms in an alluvial channel are bed forms. A bed form is any irregularity produced on the bed of an alluvial channel by the interaction between flowing water and moving sediment (Simons and Richardson, 1966). According to them there appears to be two main types of groups of bed forms: (a) pools, riffles, and point bars, which tend to give some gravel-bed channels their basic morphology; and (b) ripples, dunes, and antidunes, which are controlled by the fluid phase and are not generally a significant part of the basic channel morphology in gravel-bed channels. However, if sufficient sand is available, slowly migrating ripples and dunes at low flow may be superposed on and partly mask the more stable pools, riffles, and point bars.

Less than 5 percent of a stream's energy is available after overcoming friction. This is used for transporting sediment, which is carried in solution or suspension or dragged near the bed. The total amount of sediment transported is considered the load of the stream, differentiated according to the mode of transport. The total load of a stream therefore is the sum of dissolved load, suspended load, and bedload. Stallard, working in the basins of the Amazon and the Orinoco, has shown that in
the humid tropics where chemical alteration of the bedrock is advanced, the amount of dissolved load in streams could vary extremely, depending on neotectonics, relief, and rock types (Stallard, 1985). Suspended load and bedload imply a two-way operation. The sediment grains first have to be picked up from their position of rest on banks, bars, channel bed, etc. Second, they have to be kept moving. Sand grains are eroded first as they are only 0.06 to 2 mm in diameter and lack adhesion. Finer grains (silt and clay) are eroded at higher velocity than sand because of their property of adhering to each other. Clasts coarser than sand (pebbles, cobbles, and boulders) are eroded also at higher velocity because of their size. The coarser they are, the bigger is the velocity of entrainment. Such coarse material moves only at very high velocities, i.e., floods. As the velocity drops, sediment of a given size cannot be carried any longer and is therefore deposited, this time in a regular fashion from the coarsest to the finest. The velocity at which the grains begin to be deposited, indicating the end of transportation, is known as fall velocity. Clay and silt therefore, once entrained, can be carried for a long distance. Pebbles, cobbles, and boulders are only carried in floods and even then probably not too far. Sand is carried shorter distance than clay and silt, but is carried frequently.

Sediment deposited during falling stage of the hydrograph is stored in the channel awaiting transportation in the next high flow. Such sediment may be stored (a) on the bed in the middle of the channel as bed material (b) on the side and middle of the channel forming bars (c) on banks or (d) on flat areas next to the river. Floodplain material away from the bank may stay in storage for at least hundreds of years. Material forming bank, bar and bed may be eroded and transported much more frequently, but there is no evidence to support a continuous transfer of a sediment grain along the entire length of the channel. That happens only in rivers with a length limited to tens of km in extremely high-magnitude floods (such as following rainfall from a tropical cyclone) which may flush the channel free of sediment. In general, sediment on channel bed tends to decrease in size relatively rapidly in the first few km, and rather slowly thereafter. Bed material also gets moderately sorted within a short distance of transport. Beyond this distance, sorting improves at a slow rate.
The discharge and sediment load of Indian rivers are measured routinely at various discharge/gauge stations set up by the State and Central government agencies. Most measurements of the sediment discharge carried by stream omit bedload which is estimated to be 10% or less of the annual total load for many rivers. In some rivers, such as the Brahmaputra or the Zaire (Congo), bedload is high and one does not enjoy this short cut in sediment estimation (Meade, 1996). Sediment load is taken as a measure of physical weathering in the drainage basin. The relative fractionation of the total load into suspension (TSM-total suspended matter) and bed depends on hydraulic conditions. Primary silicates produce clay minerals and also yield coarser size population due to physical weathering. Both these components are transported by rivers and interaction (re-suspension, deposition etc.) will be regulated by hydraulic parameters such as velocity, bed gradient, channel shape, depth and other factors.

1.4 Geochemical relationships between rocks and sediments

The chemical composition of stream sediments are better understood in comparison with the chemical composition of their probable source rocks. It is one of the important considerations in stream sediment geochemical studies (e.g. Cullers et al., 1988; Cullers, 1994) since stream sediments represent the rock materials derived from within a drainage basin. It is therefore necessary to study the behavior of these geochemical indicators in modern sediments with good provenance control (e.g. Cullers et al., 1988). Chemical weathering of rocks is involved in the consumption of atmospheric CO₂. Compared to carbonate weathering, the flux of atmospheric CO₂ consumed during the silicate weathering is high (Broecker and Peng, 1994; Macfarlane et al., 1994). The elemental composition of rock forming minerals and minerals formed during weathering make up a greater proportion of the elemental composition in stream sediments (Stendal and Theobald, 1994). In this respect, materials from present-day river systems are useful, because they integrate some of the lithological and chemical diversity of the local upper continental crust (Dupre et al., 1996)

Similarly, in order to understand the geochemical budget of individual elements, the chemical composition of river-borne sediments needs to be known. Several attempts have been made to estimate the average composition of modern
river sediments, but the present understanding of sediment chemistry is limited to information available on the large sediment-carrying rivers of the world. On the other hand, our present knowledge of chemical composition of bedload sediments of small rivers is limited and scarce. In this background, the present work have studied various aspects of the chemical composition of a small river system on the basis of reconnaissance-scale sampling of bed sediments. An attempt is made in this study to understand some aspects of erosion, sediment transport mechanism, source area weathering conditions and provenance characteristics of the Chaliyar River Basin, which is one of the important and most intensively utilised basins in Kerala based on mineralogical and geochemical studies carried out on bedload sediments of the river system during the period 1996-99. The present doctoral work also incorporates a detailed study of bulk geochemistry in conjunction with the texture and mineralogy of bedload sediments in the Chaliyar main channel and its major headwater tributaries, and thereby to infer the provenance characteristics and the factors involved in the evolution of sediments as well as their changes in composition and petrography with degree of transport. In addition to this, an attempt is made to understand the distribution of gold in sediments, the variation in gold particle shape, chemistry and grain morphology in this dynamic fluvial system. The emphasis on gold arises from the fact that the source areas of Chaliyar are known for gold mineralization and extensive old workings.

1.5 Study area

The Chaliyar basin lies between Lat. (N) 11° 08’ & 11° 38’ and Long. (E) 75° 45’ & 76° 35’ and spreads over parts of Malapuram, Kozhikode and Wynad districts of Kerala and Niligiri district of Tamil Nadu. Chaliyar is the third largest river in Kerala with a catchment area of around 2900 km² and originates from the Niligiri hills at an elevation of 2100 m. The Chaliyar river joins the Arabian sea south of Calicut after flowing for a distance of ~140 km. The drainage area is dominated by rain forests of medium to high productivity and is submitted to a humid tropical climate. The major tributaries in the head water regions are Chali puzha, Punna puzha and Karim puzha. The name Punna puzha/Ponnu puzha (golden stream) points out that the river is known for its concentration of alluvial gold. During its course the river cuts through a number of lithologies like gneisses, charnockite, metapelites, schists and
quartz reefs of Precambrian age. Laterites, older and younger gravels, sediments along river terraces, alluvium and soil represent Sub-Recent to Recent deposits seen in the basin. The Chaliyar is the major river which drains the Wynad Gold Fields (WGF). It is worth noting that the headwater tributaries flow exclusively above laterites developed over gneissic country rocks. However, the downstream tributaries that joins lower reaches of Chaliyar main stem is underlain essentially by charnockite. The present study essentially pertains to the main stem of the river which is around 80 km in length.

1.6 Geographic setting of Chaliyar basin

The basin includes parts of highly rugged Niligiri hills, the Nilambur valley with moderate relief and the more or less plain land between Nilambur and river valley. The basin covers parts of Mallapuram, Kozhikode and Wynad districts of Kerala. Nilambur valley is located in Malappuram district of Kerala bordering the Niligiri district of Tamil Nadu. Nilambur town lies about 40-60 m above sea level with some low hills rising to 180 m. The area is drained by Chaliyar river and its tributaries, where the main river is flowing from north to south. Punna puzha forms a major tributary in NE-SW direction. The lower reaches of the Chaliyar River is blessed with fertile alluvial soil and is densely populated and cultivated by the farming community. A good motorable road from Kozhikode to Mysore intersects the area. Nilambur lies 100 km to the north-east of Kozhikode.

1.7 Hydrological and sediment load characteristics of Chaliyar river basin

The chemical and sediment load carried by river depends on discharge and hence monthly variations in material transport is commonly observed for a number of rivers (Gibbs, 1967; Grove, 1972). Hydrological and sediment gauge data are available for the year 1993-94 from a single station of the Southern Water Resources Division (SWRD), Central Water Commission (CWC) at Kuniyil across the Chaliyar river. The total annual discharge from Chaliyar basin is around 45613 Cumec days, over 60% of it is in the monsoon months (July and August). The run off (in 1000 MC ft.) for Chaliyar river (Beypore) is 185. It is observed that the Chaliyar river is a truly monsoonal river, sediment discharge approaching to zero during non-monsoon months.
The dynamics of sediment transport complicates attempts to quantify both the influence of transport mode and intensity on channel form and the total denudational yield of sediments from the catchment. Suspended sediment and bedload transport are successively more discontinuous, responding variously to changes of stream discharge and sediment supply. It is well established that only bed material load has a definite relationship with water discharge whereas the wash load (the fine fraction of suspended material as defined by the Subcommittee on Sediment Terminology of the American Geophysical Union) carried by a river may not be related to discharge. While the amount of wash load is dependent upon the availability of material in watershed and the processes of bank/sheet erosion, the transport of bed material load depends upon the hydraulic conditions and characteristics of bed material. As expected the maximum sediment load transport in the Chaliyar river (in Metric Tonnes) takes place between July and October (data source: Water Year Book 1993-94). However, the maximum sediment load transport takes place in the monsoon months (July and August) which also corresponds to the maximum water discharge. The sediment yield rate of catchment area during monsoon period is 0.1216 mm while during non-monsoon period is 0.0030 mm (data source: Water, Year Book 1993-94).

1.8 Geomorphic and Geologic setting

1.8.1 Geomorphology of Chaliyar basin and drainage pattern

Geomorphologically the Chaliyar drainage basin includes parts of distinct provinces like the Wynad plateau and the Nilgiri hills at higher altitudes, the Nilambur valley forming the slopes of the foot hills and low lands adjoining the main trunk of the Chaliyar river. Nilambur valley region has the characteristics of the gently undulating peneplain of semicircular shape, the area represents a low level tract bounded on the east and north by lofty hills of the Wynad and Nilgiris. The general elevation of the Nilambur valley is between 40-60 m above the sea level. Numerous mounds and ridges are enclosed in small flat land patches in between (mostly paddy fields). Susceptibility to weathering and denudational processes control the topography to a great extent. The low lying strips in the area is composed of schist and gneises, which are more susceptible to weathering; whereas banded magnetite
quartzite, basic intrusives being less susceptible to weathering stand out as mounds and prominent hills. The flanks of these mounds and hills are highly lateritised.

The northern and eastern parts of the area are occupied by high hills of the Western Ghats, forming the southern slopes of the Wynad plateau and western flanks of Niligiri hills. The average elevation of the plateau is 966 m above M.S.L., the highest hill of the plateau falling in the area is the Elambaleri rising to a height of 2260 m. Deep gorges and mountain stream are characteristic of these ranges. The eastern and southern parts of the area falls in the Muriam and Nilambur Reserve Forests respectively and are infested with wild animals of varied types. Incidentally the Nilambur valley forms the western part of the area enclosed within two major shear zones viz., the Moyar shear trending E-W in the north and the Bhavani shear trending ENE-WSW in the south.

The relatively low relief of the Wynad plateau facilitated thick accumulation of residual soil concealing the bed rock. However, along the southern slopes of the plateau deforestation resulted in the exposure of the top soil to running water directly causing the removal of soil very rapidly.

Nilambur region is drained by Chaliyar river towards south. Punna puzha, Chali puzha and Karim puzha are the major tributaries draining the region. The perennial tributaries originates from Wynad plateau and hills surrounding the valley.

The lower reaches of the Chaliyar main channel shows a sudden change in the geomorphology beyond ~110 km from the source in the downstream direction. The channel takes a sharp bent at ~110 km and beyond this the river shows meanders at consistent intervals. Two major tributaries joins the right bank of the main stem beyond 110 km. The above change in the geomorphology and may be in the relief of the channel is reflected in the bi-modality of several parameters like texture, mineralogy and geochemistry of bedload sediments, undertaken in the present study which is discussed in the subsequent chapters.

The drainage network analysis by Cvetkovic (1980) of Nilambur region shows it to be dendritic combined with rectangular drainage (Fig. 1.1). The later is more characteristic for the area close to the confluence of Punna puzha with Chaliyar river. Dendritic pattern is typically developed on rocks with uniform resistance. The over print of rectangular drainage pattern over the dendritic pattern as seen to the north of
Nilambur, is due to the presence of right angle fault system. The drainage density of whole Nilambur valley is of medium texture (Cvetkovic, 1980).

The geomorphological studies of laterites by Sambandam and Krishnan Nair (1982) in parts of Nilambur valley has led to the identification of five sets of landforms formed during polycycles of erosion. The landforms consist of remnants of two older planation surfaces without laterite cover, two surfaces with laterite cover and the plains of contemporary cycle laterite. The vestiges of first two surfaces have been identified around 550 m and 350-400 m above sea level based on accordant summits, flat crests and smooth profile of ridge crests. The remnants of next two older surfaces occur around 150-230 m and 45-130 m above sea level forming summits of ridges, mesas and hillslope benches. The plains (planation surface-V) of contemporary cycle consist of pediments (1-1.5 km wide) and coastal plain (3-5 km wide) formed by the dissection of the above surfaces. All the five surfaces had been carved out in the charnockitic and migmatitic rocks and the last three surfaces are covered by primary laterite (5-8 m thick) derived from above rocks. The internal topography of the remnants of surfaces III and IV are subdued with central part of the summits subrounded. They collectively show regional basinward as well as seaward slope of about 1° and individual remnants show local slopes of about 1° - 2° towards the tributary valleys. The coastal plain and central parts of the pediments slope less than one degree while the slope of peripheral part of the pediment varies from 1° - 7°.

The operation of geomorphic processes on landscapes during periods of tectonic stability leads to the formation of planation surfaces having subdued topography. The geochemical weathering of the rocks on such plains leads to the formation of laterites. The polycyclic nature of the landforms of the region and the distribution of laterites at different level on the planation surfaces are due to repetitive regional uplifts (epeirogenic) with intermittent periods of quiescence or tectonic stability. During the periods of quiescence, the planation surfaces were carved out and laterites were formed over them pari passu with planation.
1.8.2 Regional Geology

The area forms part of the Southern Indian Granulite terrain and is underlain by Precambrian metamorphic rocks (Fig. 1.2).

The geologic framework of southern India is broadly defined by granite-greenstone terrane in the north and a granulite facies terrane in the south. Gold deposits of economic significance occur in both terranes (cf. Ziauddin and Narayanaswami, 1974; Radhakrishna and Curtis, 1991 and 1999); the Kolar Gold Field is located in the Archean low-grade terrane, and the Wynad Gold Field in the Proterozoic high-grade terrane. The Wynad-Nilambur Gold Field consists of lowlands bounded on the east and north by the high hills of Wynad and Nilgiris. The major rock types in this area comprise hornblende gneiss, granitic gneiss, pyroxene granulites inter-banded with magnetite quartzites, charnockites and granulite-grade metapelites.

In several places, at the margin of the quartz lodes with the host rocks, veins, and aggregates of carbonate minerals (principally calcite) have developed. Thin calcite veins, stringers, and pods also fill fractures within the quartz lodes and some times cut across and extend into the country rock. From the field relations, Santosh et al. (1995) inferred that the timing of carbonate precipitation was during the late, or post-emplacement stage of the quartz reefs.

Nilambur forms the eastern extension of Wynad gold belt. Gold is hosted by metamorphic rocks which consist mainly of biotite-hornblende gneiss, amphibolite, charnockite, pyroxene granulites and actinolite schist. Pegmatites, quartz veins, metagabbro, dolerites, norites represent the later intrusives. Laterite, older and younger gravels, recent river terraces, alluvium and soil represent the Sub-recent to recent deposits.

Banded-magnetite-quartzite (BMQ) forms elongated lenses and bands within the biotite-hornblende gneisses and stands out as hills and mounds due to its resistance to weathering. The strike of the BMQ varies from NW to EW in the southern parts to NS in the northern sector of the region. The general structure of the rocks in the southern sector of Nilambur conforms to the Dharwarian trend (Davay, 1975).
A few outcrops of pyroxene granulite are exposed west of Chaliyar puzha and along Karim puzha. Charnockite is observed south of Porur. Tremolite-actinolite-chlorite schists and talcose-carbonate rocks are exposed as lenticular bodies/isolated outcrops in Manali west of Edakkara. The rock types of Nilambur have resemblances to the occurrences in Wynad Gold Field and are presumed to be equivalents to those at Dharwars (Mahadevan, 1965). Dykes of norite, meta-dolerite and metagabroo are restricted to the southern part of the area.

The area is traversed by numerous quartz veins and quartz stringers. These quartz veins traverse almost all the rock types and are of two varieties viz (i) milky white and massive type and (ii) small veins with ferruginous material and cavities typical of sulphides leaching. All the rock units of the area mentioned above are lateritised. Extensive laterite cover is seen as mounds, on the high grounds and on the flanks of the hills. Ferruginous and gravelly-pebbly laterites of secondary origin and insitu laterites have developed over the Pre-cambrian rocks. Soil forms a thin veneer over the laterite. Alluvium occupies the river valleys and depressions between mounds and ridges.

As described in the previous sections lateritization is wide spread in the region. Laterite profiles in the Nilambur valley generally consist of humus zone at the top followed by a pebbly layer. Further below is vermicular laterite. In some of the profiles, pallid zone consisting of kaolinitic clay is developed over granitic gneiss. This is followed by completely and partly weathered zones which merge with fresh parent rock below. Contacts between the various zones are gradational. All the weathering units are not exposed/present in a single profile. Maximum thickness of the weathering profile is 32 m over biotite-hornblende gneiss seen in the quarry cutting near Nilambur whereas bore holes in Maruda indicate a maximum thickness of 22 m (Narayanaswamy and Krishna Kumar, 1996). The laterites are compact and have brick red to purplish colour with cavities filled with kaolinitic clay. Laterites are also classified into two groups in terms of their genetic relation - (i) primary, the term used for insitu weathering product, (ii) secondary, for that formed by partial or complete consolidation of transported lateritic material.
1.8.3 Structure

The rocks of the Wynad - Nilambur Gold Field have been multiply deformed. The region falls within the Moyar-Bhavani lineament, a transcrustal shear system extending NW-SE from the western part of the craton and swinging to NE-SW in the east, dissecting major crustal blocks in southern India (Drury et al., 1984). Recent Nd-isotope data (Harris et al., 1994) indicate that this shear zone is of late Proterozoic age and is a major crustal divide between the Archean block in the north and the Proterozoic granulite blocks in the south.

Several mesoscopic shears and faults have developed within the major zone of shear, which are now occupied by quartz veins carrying gold and sulphide mineralization (Santosh et al., 1995). The veins comprise milky translucent quartz, fresh and unsheared. They occur as a series of sub-parallel, moderate to steeply dipping reefs, trending NNE-SSW to NE-SW, with widths varying from a few tens of centimeters up to few meters. Some veins extend in strike length up to 1600 m, as in the Richmond mine, and to an exposed depth of over 70 m as in the Solomon mine (cf. Ziauddin and Narayanaswami, 1974). All the reefs are emplaced within zones of faults/shears that cut across the regional metamorphic fabric of the country rocks. The quartz veins do not display any preference to particular lithology, but show a strong structural control.

The area is characterised by shear induced tension gashes and retrograded metamorphism as evident from the general observation of the contact zones between greenstone belt and granulite mobile belt. The regional trend of foliation is NNW-SSW with steep dips to SE. The foliation swerves to EW and NW-SE directions towards the foot of Wynad hills.

1.9 Economic geology

The geologic importance of the Wynad plateau and the Nilambur valley lies in their gold resources. The auriferous nature of some of the quartz veins of these areas has been established beyond doubt by earlier workers. Mineralization is confined to zones of intense shearing and dislocation which have acted as loci for emplacement of auriferous veins. The vein gold system of the Wynad - Nilambur Gold Field is associated with the Proterozoic granulite facies terrane of southern India. In the quartz veins, native gold occurs along fracture planes in quartz and as
fine disseminations within sulphide minerals. Gold also occurs as subsequent grains, thin flakes, veins and as inclusions within pyrite, the principal sulphide mineral. Chalcopyrite, pyrrhotite and arsenopyrite are also identified as subordinate gangue minerals. The abundance of pyrite and gold are directly correlated, in that lodes rich in pyrite are usually found to contain more gold. Since the gold-bearing quartz veins are localized within this shear zone, it is inferred that the gold metallogeny in Wynad is post-Archean and most probably of late Proterozoic age, correlatable with late Proterozoic incipient charnockite formation and carbonate metasomatism found farther east and south of the terrain (cf. Farquhar and Chacko, 1991; Wickham et al., 1994). Stable isotopic evidences (Santosh et al., 1995) suggest a model involving derivation of CO₂ by degassing of underplated mantle-derived magmas and transfer of juvenile CO₂ to higher crustal levels through felsic magmatic conduits. They also envisage a common link between Proterozoic CO₂ influx and incipient charnockite formation, carbonate alteration, and gold mineralization in this terrain.

There are many abandoned gold workings in laterites near Nilambur town. Illegal mining activities are still prevalent in these areas. The main old workings are confined to the regions south of Nilambur town. A few occurrences are located to the north. Gold dust, grains and even nuggets are known to be present in the lateritic cover resting on the auriferous rocks of the Wynad belt in the Nilambur valley. Intensive panning is still going on even during the summer months in the Nilambur valley.

One of the principal modes of occurrence of gold in the area is as placers along the first order streams in the region. Nilambur is known for gold washing along the streams draining the area since previous century (Ainslie, 1826; Nicolson 1874; Smyth 1880). Gold occurrences have been reported in older gravels forming terraces and recent placers found in present day river channels draining the area (Sawarkar, 1965, 1980; Nair et al., 1987). First report on the primary gold mineralization from Wynad - Nilambur belt and auriferous gravel of Nilambur valley were from Geological Survey of India (Crookshank, 1940; Narayanaswami, 1963; Mahadevan, 1965; Sawarkar, 1980) and the exploration programme for primary/lateritic/placer gold recently carried out by KMED project (Cvetkovic, 1980; Anthrapar et al., 1985), CESS (Narayanaswamy, 1994; Narayanaswamy and Krishna Kumar, 1996) and GSI
(Nair and Suresh Chandran, 1996) have given a surge to the exploration activities in Wynad-Nilambur area. A number of quartz veins, most of them trending NE or NW were traced around Maruda (Vidyadharan and Sukumaran, 1978). They established the auriferous nature of some of these quartz veins by panning the soil nearby. Therefore the contention of earlier workers that the primary source for the alluvial gold in Nilambur valley lies only in the well known auriferous tract of Pandalur - Devala of Tamil Nadu is not valid. Certainly the Maruda source must be contributing a substantial amount to the alluvial gold in the Nilambur valley - Chaliyar river. From the sediments of Chaliyar river and Punna puzha and their tributaries gold is even now being won by local panners (paniyars) using wooden pans (maravi).

Vidyadharan and Sukumaran (1978) reported an old working for gold right in the quartz vein south east of Maruda for a strike length of approximately one kilometer in a NE-SW direction. It is also reported to have produced lot of gold. It is gathered that panning the minewaste and the adjoining soil indicated specks of gold and during monsoon hundreds of people get engaged in panning here.

Thus, gold in the Chaliyar basin occurs in three geological setups viz. (a) primary gold occurring in the quartz veins; (b) alluvial gold seen in the older gravels forming high and middle level terraces, which are invariably lateritised and (c) detrital gold seen in the present day river gravels/in the bed of the river channels. Recent offshore exploratory survey by the Geological Survey of India has also revealed interesting concentrations of gold in the marine sediments from the area adjacent to the place where Chaliyar meets the Arabian sea. More detailed discussions on different types and the occurrences of gold in the region is given in chapter 7.

A number of pegmatites are seen in the Wynad region. Although many of them are mica-bearing they may not be of economic significance owing to their small extent.

Some of the quartz veins in the Nilambur valley may be of optical quality. Magnetite quartzite bands are also numerous in the area, but are of small dimensions.

Laterites as well as the crystalline rocks of the area are extensively used as building materials. Sand for construction purposes is mined from river channels and adjacent areas.
1.10 Environmental geology

In the plateau area of Wynad, deforestation and plantation of tea, coffee and spices like cardamom have resulted in environmental degradation and signifies increased human activity in the region. The uncontrolled use of pesticides, insecticides and herbicides in tea, coffee and cardamom estates may be polluting the surface and subsurface waters.

Coming down to the foot hills of Wynad to the Nilambur valley the problem is of a different type. Here, the illicit panning for gold by local people add lot of mercury to the river water. The panners use mercury for amalgamating the gold fines occurring associated with other heavies. For the past one decade or so the Chaliyar has become notorious for being a polluted river by industries like Mavoor Gwalior Rayons.

The strongly contrasting physiography of the hilly terrain and uncontrolled deforestation of the steep slopes by local settlers poses still another problem. This causes tremendous erosion of the top soil and frequent landslips during monsoons. Landslips, locally called "Urulpottal", resulting in loss of life and property are frequently reported at some parts in the Nilambur valley. Another side effect of deforestation is the heavy loss of water by evaporation from the streams so that many minor streams, which otherwise would be perennial go dry during summer.

Sand mining from the river channels too have attracted the concerns of environmentalists.

1.11 Accessibility

The area is easily accessible by road and rail. There are good net work of roads, Nilambur lies right on the Calicut - Ooty road is connected to Shornur. The railway broad gauge track which ends at Nilambur Road is connected to Shornur Junction of the Southern Railway.

1.12 Climate

The Chaliyar basin enjoys a humid tropical climate with alternative dry and wet season. The annual temperature ranges between 22° to 33°C. The area receives 300-400 cm/yr of rainfall, of which 75 per cent is received during southwest monsoon (June to August) and the rest during northeast monsoon (September to November).
Rainfall increases towards the hilly terrain. The dry weather is prevalent during January to May.

1.13 Objectives of the present work

The present research work is carried out with the following objectives:

1) to understand the elemental concentration and its distribution in the Chaliyar basin sediments in relation to mineralogy, texture and the degree of transport they have undergone;

2) to infer the provenance and weathering/transportation conditions utilizing major, trace and rare earth element analysis, by studying the bulk geochemistry of bedload sediments of Chaliyar river;

3) to estimate the concentration of gold in the Chaliyar river sediments and to establish geochemical affinity and differential migration of selected trace elements like Cu, Zn, Ni, Cr, Co and V in relation to gold in fluvial system;

4) to understand the various physical features like outline, shape, roundness, flatness index and rim characteristics of gold particles from different locations of Chaliyar river and their relationship with distance of transport from lode/lateritic source;

5) to study the chemical variation in gold grains and identify the factors causing it; and

6) to understand the mode of occurrence, genesis of gold associated with the Chaliyar river sediments and to have a preliminary estimate of placer gold in the main channel.
Fig. 1.1: Drainage pattern of Chaliyar basin. The inset is the key showing the map area in Kerala.
Fig. 1.2 Map showing the Chaliyar river, simplified lithology of the basin. The inset is the key showing the map area in Kerala. (Modified after GSI, 1995).