CHAPTER I
INTRODUCTION

1.1 General

Tectonic geomorphology is a relatively new, interdisciplinary field that encompasses structural geology, tectonics and surface processes. The most common goal of tectonic geomorphology research is to use Quaternary landforms and stratigraphy to infer the nature, patterns, rates, and history of near-surface processes. Tectonic geomorphology has proven to be a useful tool for identifying and quantifying active and geologically recent tectonic deformation (Pinter, 1996). Further, this subject provides a whole kit of tools for deciphering the most recent activity on structures (Pinter, 1996, Burbank and Anderson, 2001; Keller and Pinter, 2002). Tectonic geomorphology is a prime method to give insights on the recent, last phases of orogenic deformation, which is the result of the uninterrupted interaction between tectonic processes that tend to build up topography and counteracting surface processes. Ongoing tectonic deformation sustains these geomorphological features, whereas decreasing deformation or its cessation leads to their rapid deterioration by weathering and erosion.

In tectonically active mountain regions, the drainage network reflects the interaction between surface processes and the growth and propagation of the thrust faults and folds that have led to the formation of an orogen (Jackson and Leeder, 1994; Delcaillau et al., 1998; Alvarez, 1999; Burbank and Anderson, 2001; Schlunegger and Hinderer, 2001; van der Beek et al., 2002; Delcaillau et al., 2006; Ribolini and Spagnolo, 2008). The planar geometry of a present-day fluvial network sometimes leads to the identification of past drainage characteristics that can greatly improve the reconstruction of different deformative events that have determined the topographic growth of a mountain region (Harvey and Wells, 1987; Burbank et al., 1999; Friend et al., 1999; Mather, 2000; Jones, 2004).

Alluvial river systems respond primarily to changes in sediment and water supply, which are controlled by a number of key factors. Major extrinsic controls on river behaviour in a given geological setting are tectonics, land-use and climate change. In lowland settings, sea-level may also influence river behaviour. Additionally, river systems can respond dynamically to change within the system itself (intrinsic controls), for example base level changes brought about by river capture and lithologic variations (e.g. Mather et al., 2002; Stokes et al., 2002). A change in fluvial behaviour follows when the internal thresholds of the system are crossed (Schumm, 1979; 2000).

Stream geomorphology is intrinsically linked to tectonics. Rivers are sensitive to changes in tectonic deformation, adjusting over different periods of time depending on the physical properties of the host rocks, climatic effects and tectonic activity. Thus, the drainage system of a region records the tectonic deformation and stages of its evolution (Gloaguen, 2008).

River basins display organised relation between the constituent parameters of landforms and drainage. River morphology is the shape or form of the river along its length and across its width. Transporting materials are used in eroding the river bed (degradation) and thus shaping its morphology. Rivers have altered their channels through erosion and deposition through its geological history. Tectonic movement can change the base level of erosion, affect alluvial processes and evolution, and result in deformation of alluvial landforms. The study of landforms and deposits developed or modified by tectonic processes can provide relevant information about the activity of the related tectonic structures (Silva et al, 2003). Hence, selected aspects of river and stream morphometry can throw light on the evolution of escarpments (e.g. Kale, 2007) and neotectonic activity (eg. Chamyal et al., 2003; Luirei and Bhakuni, 2008; John and Rajendran, 2008; Mrinalini Devi, 2008).

West flowing rivers that originate from Western Ghats are fast flowing short rivers, and show various stages of gradation due to intense rainfall and high relief. These streams are characterized by rapids and waterfalls in the upper reaches, but gains maturity when they reach the plains. These rivers have steep gradients (~1/250) in the upper reaches suggesting youthful stages of development. Unlike other major rivers of India, these rivers do not develop deltas which may be due to the high energy shoreline (Soman, 2002). Most of these river courses are structurally controlled and coincides with prominent lineament directions. Chaliyar River flowing west is known for its placer gold deposit in Nilambur valley area. Occurrence of placer gold restricted only to Nilambur valley inspired to study the physiography of Chaliyar River drainage basin. The morphology of Chaliyar River drainage basin with oval shaped Nilambur valley in the centre where most of its tributaries flowing SE, S, SW, W and NE get merged and then flowing SW is typical for Chaliyar River.

1.2 International/National Status of Tectonic Geomorphology

Throughout the history of work on fluvial deposits, geologists and sedimentologists have tended to favour either climatic or tectonic controls of changes. Improvement in understanding the complex interactions of these controls increasingly shows that this is a gross over-simplification. New awareness of the numerous and complex feedbacks in the systems is making it imperative that the size of features and their time and spatial relationships are compared and determined.

The studies pertaining to the river basins began mostly in the early part of 19th century explaining the difference in their hydrological regimes. Studies by Horton (1932, 1945), Strahler (1952), Chorley (1957) and Schumm (1956) deal with the conceptual evolution of drainage basin, in terms of geomorphic approach. The studies on fluvial geomorphology and hydrology of large tropical rivers have been more focused during the last two decades (Kale et al., 1994; Sinha and Friend, 1994; Sinha and Jain, 1998; Kale, 1999, 2002; Dettinger and Diaz, 2000; Gupta, 2002; Thorne, 2002).

Extensive studies have been carried out from different parts of the globe to establish the control of the endogenic tectonic processes on the surface geomorphic features (Scheidegger and Ai, 1986). Drainage pattern of an area acts as a sensitive tool in discovering the tectonic processes that express themselves as the structural design of the bed rock. Relationship between the drainage patterns to the fractures in the bedrock is a well documented concept (Vaidhyanadhan, 1971; Bannister and Arbor, 1980; Pohn, 1983; Deffontaines and Chorowicz, 1991; Polishook and Flexor, 1983; Radakrishna, 1992; Sinha Roy, 2001; Burbank and Anderson, 2001; Delcaillau et al., 2006). Streams respond to vertical displacement along faults by aggradation or degradation has been well documented by Holbrooke and Schumm (1999); Marple and Talwani (1993); Personious (1995).

Howard (1967) discussed in detail about the utility of drainage analysis for geological interpretation especially in low lying flat terrain. In regions of active plate motions, the drainage analysis forms a major tool in identifying the neotectonic movements and also in quantifying the displacements along the faults and fractures. (Ouchi, 1985; Schumm, 1986; Dumont et al., 1991; Deffontaines et al., 1994; Jackson et al., 1996; Audin et al., 2003; Pellegrini et al., 2003).

Morphometric analysis to draw conclusions on neotectonic activity in South Central Indiana by Miller (1998); in NE Lithuania by Cesnulevicius (2003); in Hungary by Petrovszki (2009); in Southern Western Ghats by Thomas et al. (2010) are some of the pioneer works that establish the relationship of morphometry and tectonism. Avena et al. (1967) introduced few parameters of the hierarchy of the drainage network like hierarchical anomaly number and hierarchical anomaly index. Ribolini and Spagnolo (2008) studied drainage network geometry versus tectonics in French-Italian Alps.

Fluvial responses to active tectonics was affirmed by various researchers like Burnett and Schumm (1983); Gregory and Schumm (1987); Marple and Talwani (2000); Valdiya and Rajagopalan (2000); Sinha and Roy, (2001). Tectonism constructs landscapes through uplift and subsidence; climate affects the degradation of the landscapes by chemical and physical erosion. These aspects were extensively studied by Ouchi (1985); Keller (1986); Keller and Pinter (2002); Holbrook and Schumm (1999) and Schumm et al. (2002) and provided detailed reviews of response of alluvial rivers to active tectonics and suggested that rivers respond differently during longitudinal and lateral tilting. The concept of landscape evolution space (LES) is introduced as a tool for assessing landscapes and geomorphic systems, intended to be a systematic means for assessing the various factors that contribute to the potential for change in geomorphic systems (Phillips, 2000). Tucker (2004), studied the drainage basin sensitivity to tectonics and climatic forcing, while Burningham (2008) and Catuneanu et al. (2001) studied the contrasting geomorphic response to structural control. Tectonics and landscape evolution with response to non-cyclic unique events on the time scale of global tectonics were studied by Benvenuti et al. (2008), Gelabert et al. (2005), Guarnieri et al. (2008), Giambni et al. (2005), Coltorti et al. (2000), Ollier (1995) and others. Field-based investigations, laboratory experiments and numerical models have shown that variation in the style of bedrock deformation, due to rock uplift, causes perturbations in the fluvial network (Ouchi, 1985; Burbank, 1992; Gupta1997; Mueller and Talling, 1997; Jackson et al., 1998; Hasbargen and Paola 2000; Hallet and Molnar, 2001; Vetel et al., 2004; Ghassemi, 2005).

Geomorphic evolution of longitudinal profiles have been studied by many researchers like Siedl et al. (1994), Radoane et al. (2002), vander Beek et al. (2003), Duvall et al. (2004), Anderson et al. (2005), Bishop et al (2007), Harma et al (2007), Phillips et al. (2008) and Singh et al. (2010). The shapes of longitudinal profiles reflect the stage of watershed evolution, channel sediment and bedrock types, tectonics, climate and sea-level change were explained by various researchers (Yatsu, 1955; Seidl and Dietrich, 1992; Sambrook Smith and Ferguson, 1995; Snyder et al., 2003; Goldrick and Bishop, 2007). Importance of bedrock river incision in landscape evolution has spurred research on the morphology and distribution of bedrock channels (Miller, 1991; Wohl, 1992b, 1998, 1999; Tucker and Slingerland, 1994; Montgomery et al., 1996; Montgomery and Buffington, 1997; Tinkler and Wohl, 1998; Whipple and Tucker, 1999; Massong and Montgomery, 2000; Snyder et al., 2000; Whipple et al., 2000; Montgomery and Gran, 2001). The study of the longitudinal profiles of the streams could be a useful way of assessing the Late Cenozoic tectonism on the development of the drainage network (Mackin, 1948; Rhea, 1993; Giamboni, 2005; Howard et al., 1994; Radoane et al., 2003; Gelabert et al., 2005). River longitudinal profiles can have knick points or knickzones which indicate either a stream in disequilibrium where the upstream retreat communicate changes in the base level to the upstream valley (Bishop et al., 2005) or dynamic equilibrium between fluvial processes and tectonic movements (Snow and Slingerland, 1990; Weissel and Seidl, 1998; Whipple, 2001; Bishop et al., 2005; Babault et al., 2006; Larue, 2008).

Morphometric parameters were used to explain the geomorphic evolution by various workers (Bagchi, 1960; Niyogi, 1968; Basu and Kar, 1968; Singh and Kumar, 1969). Sen (1971) studied the relationship between longitudinal profiles and bed rock over which they flow. Agarwal (1972); Pal (1973); Subrahmanyan (1974); Padmaja (1975); Sen (1977); Bedi (1978); Reddy and Reddy (1983); Rawat et al. (1983;) Singh et al. (1985) gave an account on the quantitative geomorphic parameters and made an attempt to draw a conclusion on the geomorphic evolution of different drainage basins. Vaidyanathan and Nageshwara Rao (1978) treated some aspects of the geomorphic evolution of Krishna delta. Malik and Mohanty (2007) suggested the tectonically active nature of the major and secondary hinterland faults and its influence on the evolution of drainage and landscape along northwestern Himalaya.

Radhakrishna (1993) explained the Neogene uplift and geomorphic rejuvenation of Indian Peninsula. Structure and tectonics of the south west continental margin of India was highlighted by Subrahmanyan et al. (1995). Neotectonically controlled catchment capture of Banas and Chambal basins were discussed by Kale (1999). Kale (2002) gave an overview on the fluvial geomorphology of Indian rivers. Jain and Sinha (2004) explain the fluvial dynamics of anabranching river system with reference to Bhagmati River in Himalayan foreland basin. Factors influencing the sinuosity of Pannagon stream, a tributary of Muvattupuzha River in Central Kerala was discussed in depth by Aswathy et al. (2008). Rao et al. (1996) gave evidences of late Quaternary neotectonic activity and sea level changes along the western continental margins of India. Gunnel and Fleiout (1998) described the shoulder uplift of the western Ghat passive margin. Prasad et al. (1998) studied the geomorphology, tectonism and sedimentation in Nal Region, Western India and conclude that tectonics play a vital role in the evolution of this region. Geomorphic signatures of active tectonics in Bist Doab interfluvial tract of Punjab were studied by Bhatt et al. (2009). Chamyal et al. (2003) explain the Late Quaternary geomorphic evolution of the Lower Narmada Valley, Western India and its implications for neotectonic activity along the Narmada–Son Fault. Maurya et al. (1997) explained the Holocene valley fill terrace on the lower Mahi valley, Gujarat. Valdiya (2001) suggests that Late Quaternary horizontal strike-slip and oblique-slip displacements are responsible for temporary blockages of river flow in Kerala and in western Karnataka region. The modifications of Holocene landforms, including formation of deep incisions across ridges in the undulating terrains, the descent of old winding rivers has cascades and water falls through gorges across fault-delimited ridges, the occurrence of planar scarps and triangular facets devoid of gullies are with but a few straight furrows, the repeated blockages of streams as they cross or follow the NNW-SSE trending faults, and the higher than normal seismicity in some areas of faulted Dharwar terrain, indicating geologically recent and continuing tectonic movement (Valdiya, 2001).

River Response to neotectonics in central and southern Kerala was studied by Valdiya and Narayana (2007). Their investigations are directed to find out whether the anomalous behavior of rivers and their tributaries and the landform peculiarities in central Kerala represents a terrain that responds to neo-tectonic activity. They suggest that activities along the lineament manifest in swerving of rivers and change of the originally meandering system to a one characterized by loops of a variety of shapes – U-shaped, box like, distorted triangular and rectangular. Valdiya and Narayana (2007) further conclude that ongoing vertical and horizontal movements on the faults have altered the gradient of rivers creating impediments or barriers and the resulting blockage. They suggest that present day ponding of the rivers suggest ongoing/neo-tectonic movements.

In Precambrian terrain with structures resulting from multiple facies of metamorphism and ductile deformation and superimposition of brittle joints and faults, the relationship between drainage and structure is poorly understand. Further, there is a general observation that the terrains are also quite inactive and drainage pattern would generally be dendritic due to the prolonged exposure to weathering and denudation. To unravel the role of active tectonism in the drainage basin evolution in such Precambrian terrane, the present study was taken up and is unique due to its multidisciplinary approach. An integrated approach, combining morphometric, morphostructural, longitudinal profile analysis and qualitative and quantitative geomorphologic and field evidences has been employed to bring a comprehensive picture of the tectonic history of Chaliyar River drainage basin.

1.3 Objectives of the Present work

The present study envisages the following objectives.

- To understand the drainage system of Chaliyar River drainage basin.
- To delineate/infer lithological and structural controls on the evolution of Chaliyar River drainage system.
- To understand the role of tectonics in the evolution of Chaliyar River drainage basin and to assess the degree of tectonic activity.

- To decipher various geomorphic features and landforms, their characteristics and evolution.
- To propose a morphotectonic model for the evolution of Chaliyar River drainage system and Nilambur valley.

1.4 Study Area

Chaliyar River drainage basin is cored by Precambrian Peninsular Shield covering an area of 2923 km^2 and lies between Murat and Kabini basins in the north and Kadalundi basin in the south. It is bound by latitudes 11°06’07”N and 11°33’35”N and longitudes 75°48’45”E and 76°33’00”E falling in Survey of India (SOI) degree sheets 58A and 49M (Fig. 1.1). The basin comprises parts of four districts viz. Kozhikode district cover an area of 626 km^2 in the northwest, Wayanad district over an area of 112 km^2 in the north, Malappuram district spreads over an area of 1784 km^2 in the east and south and Nilgiri district of Tamil Nadu over an area of 378 km^2 in the northeast.

Chaliyar River forms the third largest river in Kerala rising in the Elambaleri hills in the Wayanad plateau. Six major streams Chaliyarpuzha, Punnapuzha, Kanjirapuzha, Karimpuzha, Iruvahnipuzha and Cherupuzha constitute the Chaliyar River drainage system. Other important tributaries are Kurumanpuzha, Pandipuzha, Maradipuzha, Kuthirapuzha and Karakkodupuzha. Most of these rivers have their origin in the Nilgiri hills in the east and Wayanad hills in the north, where they form a number of rapids and waterfalls. The river joins the Lakshadweep Sea south of Kozhikode near Beypore after flowing over a distance of about 169 kms in the name ‘Beypore’ River.

1.5 Previous work in the Study area

The area forms part of the Western Ghat and extensive study of southern part of the Western Ghat was carried by Radhakrishana (1967); Gunnel and Fleitout (2000); Ollier(1985); Subramanya (1987); Widdowson (1997); Gilchrist and Summerfield (1994); Chand and Subrahmanyam (2003).

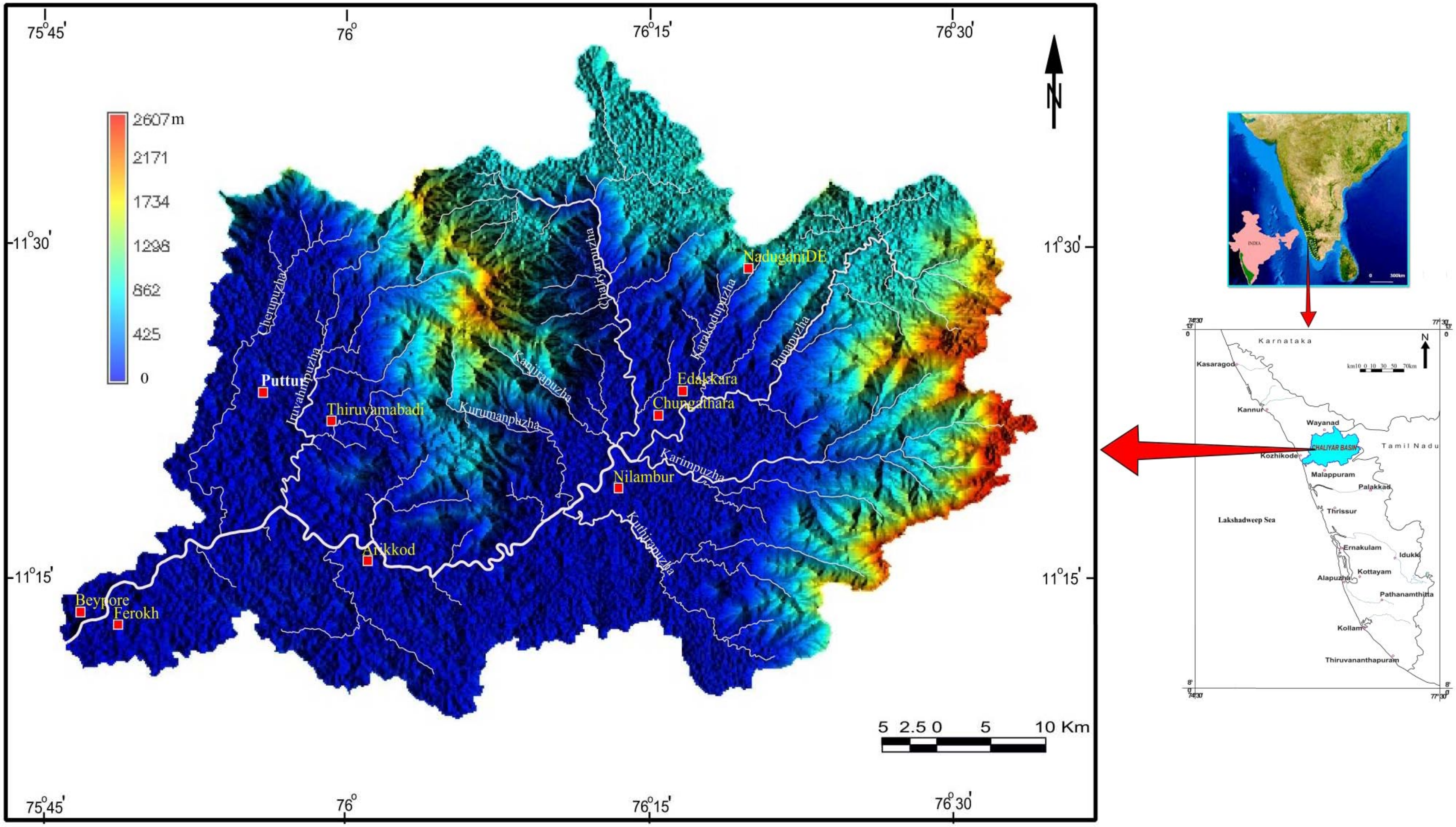

Fig. 1.1 Digital Elevation Model (DEM) aspect map (source: SRTM) of Chaliyar River drainage basin with its main tributaries and important locations. The terrain map of Peninsular India (source: Google Erath) is shown on the right side top; whereas the bottom right shows the map of Kerala (the shaded area is Chaliyar River drainage basin).

Cvetkovic (1980) carried out drainage network analysis and concluded that the major patterns observed in the basin are dendritic and rectangular with medium texture. 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. PIXE analysis of trace pollutants in Chaliyar river water were carried out by Kennedy et al. (1998). Geochemistry and Mineralogy of Chaliyar River Sediments with Special Reference to the Occurrence of Placer Gold were studied by Hariharan (2001). Xavier et al. (2005) gave a detail study on the fluxes of nitrogen in Chaliyar River.

Geological mapping on different scales was carried out in this area by Geological Survey of India officers Sawarkar (1965), Nambiar and Rao (1980), Rengamannar, et al. (1984), Anil Kumar (1985) and Anil Kumar (1995). Exploration of primary and placer gold was taken up different organizations like KMEDP, Geological survey of India and Directorate of Mining and Geology, Kerala State. Some of the important investigations and exploration works carried out are: Young (1829); Lake (1890); Crookshank (1940); Thiagarajan (1958); Narayanaswami (1958), Rao (1965); Mahadevan (1965); Cvetkovic, 1980; Cvetovic and Krishnakumar, (1981.); Pillay and John (2002). Nilambur valley is known for gold panning along Chaliyar River and its tributaries like Punnapuzha, Karimpuzha, Kanjirapuzha and Chaliyarpuzha 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 Wayanad - Nilambur belt and auriferous gravel of Nilambur valley were from Geological Survey of India (eg., Crookshank, 1940; Narayanaswami, 1963; Mahadevan, 1965; Sawarkar, 1980) and the exploration for primary/lateritic/placer gold was carried out by KMED project (eg., Cvetkovic, 1980; Anthrapar et al., 1985), CESS (Narayanaswamy, 1994; Narayanaswamy and Krishna Kumar, 1996) and Geological Survey of India (eg., Nair and Suresh Chandran, 1996).

1.6 Physiography

The Chaliyar river basin can be physiographically divided into four well-defined units viz., highland, midland, low land and coastal plains. Based on the relief pattern and topographic alignment, the basin can be divided into five physiographic sub-units.

(i) High ranges with an elevation ranging from 600m to 2600m. This form part of the Wayanad plateau and the high hill ranges with steep slopes of the Western Ghats, (ii) Foot hills of Western Ghat with elevation ranging from 300 to 600 m above MSL comprise rocky mounds and slope areas of the high hills, (iii) Upland regions consisting of the ridges and valleys, isolated hills with altitudes ranging from 100-300 m. At places these units are lateritic, (iv) Mid-land zone with elevation ranging from 10 to 100 m characterized by rolling topography with lateritic ridges, isolated hills and alluvial valleys, and (v) Low-land characterized by coastal stretches and alluvial plains with an elevation of < 10 m.

Highlands are depicted by the hill ranges of Nilgiri and Wayanad plateau of the Western Ghats with elevations > 600 m above MSL and forms an important physiographic province. The average elevation of the Wayanad plateau is 966 m above MSL and the highest peak is the Elambaleri hills rising to a height of 2260 m from where the Chaliyar River originates. The basin has its highest elevation of about 2554 m at Makurti peak in the east. The topography is very rugged and the crest of the mounds and hills are generally very sharp and narrow with very steep slopes. Deep gorges and mountain-fed streams are characteristics of the hill ranges.

The undulating western fringe of the highlands and the lateritized spurs forms the midland region. Midland region of the Chaliyar River drainage basin with elevation ranging from 300-600 m occupy a very narrow strip of elongated spurs separated by ravines merge with relatively gentler slopes of the lowlands.

Lowlands consists of dissected peneplain with an altitudinal range of 10-300m includes the Nilambur valley, which runs in NE-SW direction and is broadest in the central part with an elevation ranging between 10 to 40 m above MSL. The plains have a rolling topography with isolated mounds with a maximum elevation of 212 m. Floodplains, river terraces, channel and valley fills, colluviums and isolated mounds and hills are parts of the lowlands. The coastal plain in the west where the river debouches into the sea has an elevation reaching a maximum of 10 m above MSL. Coastal alluvial plains, floodplains, marshes, river terraces and palaeo-beach ridges constitute the coastal plain.

1.7 Regional geology

The high grade metamorphic terrane occurring in the southern tip of India known by the name Southern Granulite Terrane (SGT) consists of major units of the Archaean continental crust, such as granulites, gneisses, greenstones and a variety of younger intrusions. The SGT is considered as an ensemble of fragmented and imbricated crustal blocks separated by east-west trending crustal-scale shear systems, which include Cauvery shear zone (CSZ) and Achenkovil shear zone (ASZ) (Chetty, 2006). South of Achenkovil shear zone (ASZ), exposes an assemblage of migmatised meta-sedimentary and met-igneous rocks. From north of Achenkovil shear zone to the southern flank of Palghat Gap, the rocks are mainly charnockite (massive charnockite and charnockite gneiss) and migmatites. Northern flank of the Palghat gap is consists of metasedimentary sequence of khondalite and cal-granulite with crystalline limestone bands. Northern part of Kerala comprises granulites, schists and gneisses intruded by younger acid and alkaline plutons (Soman, 2002).

Ancient Supracrustals are represented by ultramafite and metasedimentary schistose rocks found to occur as en-echelon linear bands and enclaves within the charnockite and gneisses. The high-grade Wayanad Supracrustals rocks are correlated with the Sargur Schist Complex of the Karnataka (Nair, et al., 1975; Adiga, 1980). The schistose rocks are characterized by intense deformation, medium-to high-grade metamorphism, migmatization and lack of sedimentary structures. The schist complex consists of metaultramafite, schist, metapelite, metapyroxenite, serpentinite, talc-tremolite rock and amphibolite. The metasedimentaries of Wayanad Supracrustals occur as thin linear bodies within the migmatites. These consist of pelite, psammopelite and quartzite. The predominant rock types are corundum- mica schist, kyanite schist, quartz-mica schist and iron stone (Anil Kumar et al., 1993).

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 sheared hornblende-biotite gneiss, biotite-hornblende gneiss, foliated granite and pink granite gneiss.

The Khondalite Group of rocks includes calc-granulites, quartzite and garnetiferous-sillimanite gneiss and paragneisses of pelitic parentage 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 paragneisses and amidst the Charnockite Group or rocks and migmatitic gneisses.

Charnockite Group of rocks shows great diversity in lithology comprising pyroxene granulite, hornblende pyroxenite, magnetite quartzite, charnockite, hypersthene-diopside gneisses and cordierite gneiss. Charnockite and charnockite gneiss have preponderance over all other crystalline rocks covering 40-50% of the total area of the State. The charnockite are well-exposed in the central and northern parts of Kerala including the high–hills of the Western Ghats. The oldest rock, so far dated in Kerala is the massive charnockite, which yielded U-Pb zircon age of 2930±50 Ma (Soman, 2002).

Migmatite includes variety of gneissic rocks which are next in importance to charnockite as a dominant litho-assemblage (Rajan and Anilkumar, 2005). Quartzo-feldspathic gneiss, garnet-biotite gneiss, hornblende gneiss, hornblende-biotite gneiss, quartz-mica gneiss are the major rock units and show migmatitic structures such as agmatites, nebulites, schlierens, ptygmatic folds, quartzo-felspathic neosomes and ferromagnesian paleosomes (Muraleedharan and Raman, 1989).

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 recognized as epidiorite and amphibolite. Another set of dykes, apparently post-dating the regional metamorphic event are subjected to thermal metamorphism (Rajan and Anilkumar, 2005). 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 metagabbro or metanorite are also traced. Younger basic intrusive 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 (Rajan and Anilkumar, 2005).

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. Some of them are located at Amblavayal, Kalpatta, Pariyaram, Munnar, Chengannur and Angadimogar. Pegmatite veins occur throughout the terrain and are mineralogically classified as simple and complex based on mineralization (Soman, 2002).

The Tertiary sedimentary formations lie unconformably over the Precambrian 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 Quilon Formation which is more compact marly sand with shell fragments and thin horizons of limestone (King, 1882).

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 bauxite patches also occur within the laterites.

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. 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 in the entire stretch of Kerala coast. 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 (Nair, 2007).

1.8 Geology of the study area

The area forms part of the Precambrian metamorphic shield with rocks of Wayanad Group, Peninsular Gneissic Complex, Charnockite Group and Migmatite Complex, which are traversed by younger basic and acid intrusive (Fig. 1.2). Small isolated capping of Tertiary deposit (Warkali Formation) is seen to the west. The Quaternary sediments unconformably overlie the basements rocks of the coastal tracts and valleys.

Wayanad Group

The oldest rock type exposed in the area belongs to the Wayanad Group. They include small linear bands and enclaves of talc-tremolite-actinolite schist, irregular and linear bands of amphibolite/metagabbro, carbonate rock, fuchsite quartzite, thin impersistant bands of hornblende granulite and banded iron formation. The supracrustals of Wayanad Group occur as small patches, lenses, bands and enclaves within the rocks of the Charnockite Group and Migmatite Complex.

Peninsular Gneissic Complex (PGC-I)

Peninsular Gneissic Complex consists of heterogeneous mixture of granitoid materials. Sheared hornblende-biotite gneiss of Peninsular Gneissic Complex is restricted to the northern part and is mainly composed of biotite, hornblende, quartz and feldspar and is well-foliated and at places shows augen and agmatitic structures. The percentage of hornblende and biotite varies from place to place.

Charnockite Group

Charnockite/charnockite gneiss is the most widespread rock type in the study area and has preponderance over all the crystalline rocks covering about 50% of the total area in the basin. Charnockite Group of rocks makes up the high hills and steep slopes flanking the undulating terrain in the eastern and western part of the basin.

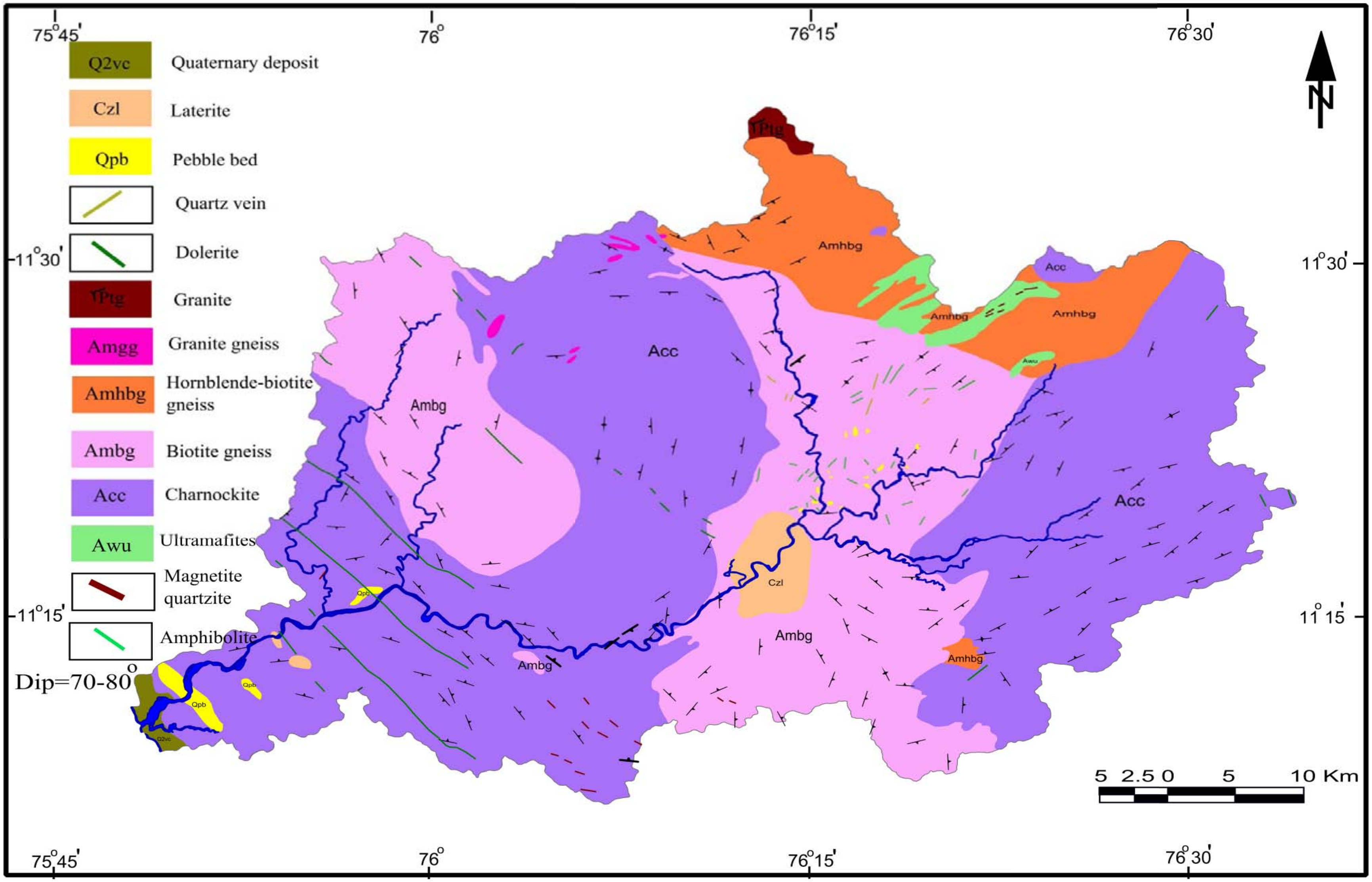

Fig. 1.2 Geological map of Chaliyar River drainage basin (after GSI, 1995).General trend of foliation is NE-SW, NW-SE, NNE-SSW and ENE-WSW dipping steeply (70-80º).

Table 1.1 General geology of Chaliyar River drainage basin (GSI, 1995)

Era	**Period**	**Group**	**Lithology**
Quaternary	Holocene	Marine	Sand
		Fluvio-marine	Clay and silt
		Fluvial	Sand, silt, clay
	Pleistocene	Palaeo-marine	Sand
			Pebble bed
Tertiary	Mio-Pliocene		Laterite
	Mesozoic	Acid Intrusive	Quartz vein
	(61-144 Ma)	Basic intrusive	Pegmatite
			Dolerite
PRECAMBRIAN	Proterozoic	Migmatite Complex	Hornblende gneiss
			Hornblende-biotite gneiss
			Granite gneiss
		Charnockite Group	Charnockite/charnockite gneiss
			Pyroxene granulite
	Archaean	Peninsular Gneissic Complex	Hornblende-biotite gneiss
		Wayanad Group	Magnetite quartzite
			Quartz-mica schist
			Fuchsite quartzite
			Amphibolite
			Metapyroxenite
			Talc-tremolite-actinolite schist
Base not recognized			

Charnockite is mainly intermediate type consisting essentially of hypersthene, diopside, secondary hornblende, biotite, sodic plagioclase and waxy quartz. In some areas it occurs as thin bands and well-foliated and is often veined by pegmatite along the foliation planes. Pyroxene granulite of Charnockite Group occurs as small lenses and enclaves within the gneisses and charnockite. It is a melanocratic, fine-grained rock with granulitic texture.

Migmatite Complex

Migmatite Complex comprises hornblende gneiss, hornblende-biotite gneiss and granite gneiss. These are medium grained, coarse-grained, mesocratic showing gneissic to granular texture and composed of hornblende, biotite, plagioclase, quartz and garnet as major minerals. Hornblende-biotite gneiss is seen as linear bodies trending NW-SE and show lit par lit relation with the granite gneiss. Granite gneiss occurs as oval shaped body and is feebly foliated, pink and equigranular. The origin of granite gneiss is attributed to stress-induced injection of acid materials into the host rock (Rajan and Anil Kumar, 2005). The rocks of Migmatite Complex show migmatitic structures such as agmatite, nebulites, schlierens, ptygmatic folds, quatrzo-feldspathic neosomes and ferromagnesian palaeosomes.

Younger Intrusive

Basic and acid intrusives of Mesozoic Period are very common in this terrain. NNW-SSE to NW-SE trending basic dykes occur in the study area at places. They cut across all the older metamorphic rocks and structural trends. Their unmetamorphosed nature and stratigraphic relation with the country rocks prompted their correlation to the Deccan Trap volcanism (Rajan and Anil Kumar, 2005). The gabbro dykes are sheared. Quartz veins and pegmatite veins criss-cross almost all the rock types in the area. Most of these quartz veins are major source for primary gold.

Laterite

Lateritization is very prominent in the midlands within the charnockite and migmatites. Laterite in this area is about 2 to 8 m thick and is very hard, cavernous and ferruginous. Laterite is restricted to the mid-land regions and restricted to an altitude of 100-200m above MSL. Laterite after the crystalline rocks is compact and the top crust is moderately indurated (Rajan and Anil Kumar, 2005). Quartz veins, joints and fractures can be traced in a laterite profile.

Quaternary sediments

Quaternary sediments are confined to the coastal tracts and valleys and along the river stretch. Based on the environment of deposition, these deposits are further subdivided into different morphostratigraphic units-marine, palaeomarine, fluvial and fluviomarine. The oldest unit is the palaeo-beach deposit of marine origin consisting of medium- to coarse-grained sand, composed mainly of quartz. The tidal and mud-flat deposits of fluvio-marine origin comprising mainly silt and black clay, beach and barrier beach deposits of marine origin consisting of medium- to fine-grained quartz sand with minor amount of heavy minerals and the point bar, channel bars and flood plain deposits of fluvial origin which is an admixture of sand, silt and clay are grouped into the recent deposits. Pebble beds are observed on either side of the Chaliyar River mouth at Beypore. These pebble beds are predominantly composed of quartz but occasionally charnockite gneiss pebbles are also observed. They are well-rounded to spherical in shape with clayey matrix. The thickness of the pebble bed is about 1 to 6 m and is seen at 20 m above MSL.

Structure

The trend of foliation of the rocks is generally NW-SE with steep dips to either side. The foliation trend swings to ENW-WSW in Nilambur valley. Tight appressed folds of asymmetrical nature, which have given rise to axial plane foliation with characteristic platy mineral alignment is the earliest formed folds (F_1). F_2 folds (post-folial) are open symmetrical folds and control the disposition of major lithologies. F_3 folds are open warps which deform the F_1 and F_2 folds and have a broad swerve in ENE-WSW direction is also decipherable in the study area.

1.9 Climate

The basin enjoys a tropical humid climate with sweltering summer and high monsoon rainfall. Generally March and April are the hottest and December and January are the coolest. The maximum temperature ranges from 22ºC to 32.9ºC and the minimum temperature ranges from 22ºC to 25.8ºC. The average annual maximum temperature is 30.9ºC and minimum is 23.7ºC. The temperature starts rising from January reaching the peak in April. It decreases during the monsoon months. On an average about 3000 mm of rainfall occurs annually in the basin.

The principal rainy seasons are the southwest (June-September) and northeast (October-November) monsoons in India. The pre-monsoon months (March-May) are characterized by major thunderstorm activity and the winter months (December-February) by minimal cloudiness and rainfall (Ananthakrishnan et al. 1979). *Sahyadri* (Western Ghats) has a significant influence on the intensity and distribution of rainfall over Peninsular India. As a mountain barrier, the *Sahyadri* polarizes precipitation along its crest. As moist airflow during the southwest monsoon ascends, the windward slope receives copious rainfall (Anu and Mohankumar, 2004). Thus, the *Sahyadri* forms the watershed for a large number of rivers. These rivers have high run-off and sediment load during the monsoon months.

Southwestern India experiences a tropical climate with seasonally reversing wind patterns and large variations in precipitation. Along the west coast of India, the southwest (SW) monsoonal winds of oceanic origin are established by mid-May. During the SW monsoon, winds blow from southwest during May-September, but change to a northeasterly direction during the northeast (NE) monsoon. These winds continue to grow strong until June, when there is a sudden 'burst' or strengthening of the southwest winds. The winds are the strongest during July and August, but become weak in September, ahead of the NE monsoon, which lasts through October and November. The wind speed is generally 15-20 km/hr during the SW monsoon, but lower (10-12 km/hr) during the NE monsoon. Summer (southwest) monsoon (June-September) accounts for a major part of the average annual rainfall (> 300 cm), whereas the winter monsoon (October-January) accounts for about 50-60 cm rainfall. Temperature in the region ranges between 23° and 37°C (Narayana, 2006).

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Rivers in mountainous terrains commonly carry higher sediment loads and yields than do upland rivers, whose loads and yields in turn, are higher than those of lowland rivers. A better relationship was documented between the annual variability of rainfall and sediment transport. The positive relationship among rainfall, run-off and sediment discharge suggests that precipitation and run-off exert a first order control on the sediment discharge of Kerala Rivers (Narayana, 2007). Tectonic uplift/subsidence alters the fluvial regime with resultant changes in rates of sediment erosion and deposition.