Chapter IV

FIELD GEOLOGY AND GEOMORPHOLOGY

4.1 Introduction

Field observations of lithological and structural features are vital for the preparation of geological maps that show the areal distribution of geologic units and orientation of structural features like foliation, lineaments etc. Field studies play an important role in understanding the dynamics and evolutionary processes that carved the present day landscape and the complexities in the evolution of a drainage basin.

Extensive field work is carried at different locations in the study area. Each lithological, structural and morphological unit is inspected and recorded the details. The geomorphic expressions observed in the field are incorporated in the final geomorphologic map. The selected geomorphic features such as terraces, braids, strath terraces are mapped. In order to identify ideal stream profile sections, feasible transverse profiles along the Chaliyar River are mapped after taking consideration of the objective of the study.

4.2 Lithology

Chaliyar River drainage basin forms part of the Precambrian Peninsular Shield of India. The area is mainly represented by the Archaean high grade metamorphic rocks like charnockite and its gneissic form. Charnockite Group of rocks makes up the high hills and steep slopes flanking the undulating plains in the east and west. Enclaves of amphibolite, metapyroxenite, talc-tremolite-actinolite schist, metagabbro, banded magnetite quartzite, grunerite schist, quartz-sericite schist and fuchsite quartzite within the migmatite represent the vestiges of the Archaean Wayanad Supracrustals (Pillay and Koshy, 2002). These enclaves vary in size from very small bodies measuring a few centimeters to large bodies of several metres across. Dolerite is the younger basic intrusives and the younger acid intrusive is pegmatite and quartz veins. Innumerable quartz veins occur all over the area and they are the major source for the primary and placer gold. Towards the Nilambur valley, lithology changes to Archaean migmatites with hornblende-biotite gneiss constituting the major rock type. Local variations of hornblende - biotite gneiss to biotite gneiss and hornblende gneiss with or without garnet are also common. Two to three meter thick laterite capping is present over the
gneiss in the southern plain areas and thick soil cover encompasses most of the remaining area. Two generations of alluvium are observed, the older one occupying the higher levels of the flood plain, is indurate and partially lateritized, and the younger one is found in the present day river channels. The rugged terrains of the north, east, west and south of the study area are under thick forest cover. The midland of the drainage basin has been lateritized extensively resulting in the limitation of lithologic exposures to the river sections, road cuttings and well sections.

**Wayanad Supracrustals**

Wayanad Supracrustals are the oldest rock units, observed as enclaves within the Charnockite Group of rocks and migmatites. Wayanad Supracrustals comprise talc-tremolite-actinolite schist, amphibolite, magnetite quartzite, fuchsite quartzite and quartz-mica schist. Talc-tremolite-actinolite schist rock is well exposed on the right bank of Punnappuzha north of Konnamannu (Fig. 4.1a). Another band of talc-tremolite schist was observed at 2 km north of Vazhikadavu, extending in a NE-SW direction from Manalpadam along the northwestern side of Karakodupuzha. Magnetite quartzite veins are ubiquitous in the northern, southern and northeastern part of the Chaliyar River drainage basin. These impersistent bands vary in thickness from few metres to about 20 metres with strike length varying from few metres to about 3.5 km. The most prominent one is the Kurathimala ridge, 3 km north of Chungathara with NE-SW trend. This ridge contains several parallel bands of magnetite quartzite interspersed with quartz veins. Magnetite quartzite veins occur in association with talc-tremolite-actinolite schist at many places. At Tumbimala (Fig. 4.1b) and Aruvakkod areas, magnetite quartzite veins trend NW-SE. Width of these bands varies from a few metres to over 30 m and length a few tens of metres to hundreds of metres. Large bands of amphibolites are observed in the Maruda - Mannuchini, Kariam - Muriam and Munderi areas (Fig. 4.1c). Amphibolite exhibits various stages of migmatization - from amphibolite to migmatised amphibolite to hornblende gneiss. Amphibolite also occurs as enclaves within the migmatitic rocks (Fig. 4.1d).

**Charnockite Group**

Charnockite Group of rocks are the most wide spread rock units with charnockite, charnockite gneiss and pyroxene granulite members. The peaks, high hill ranges (Fig. 4.2a) gorges and valleys expose massive charnockite, which are presently
quarried out (Fig. 4.2b). Charnockite gneiss is restricted to the steep slopes of high hills (Fig. 4.2c). It is extensively migmatised to hornblende-biotite gneiss and biotite gneiss in the low-lying areas flanking these high hills. Exposures of these rocks are observed at Korampuzha and Ayirani areas. Pyroxene granulite occurs as enclaves, lenses and bands with the charnockite and charnockite gneiss (Fig. 4.2d).

Fig. 4.1 Wayanad Supracrustals of Chaliyar River drainage basin. (a) Talc-tremolite-actinolite schist (Location: north of Konnamannu); (b) highly fractured magnetite quartzite bands. Intense lateritization in the terrain has obliterated the physical characteristics of the rock (Location: Tumbimala); (c) amphibolite band in the hornblende-biotite gneiss (Location: Kariam - Muriam Reserve Forest); (d) enclaves of amphibolite in the hornblende - biotite gneiss (Location: Manali).
Migmatites

Migmatitic rocks occupy major part of the Nilambur valley comprising hornblende-biotite gneiss, biotite gneiss and hornblende gneiss. Hornblende-biotite gneiss and biotite gneiss (with or without garnet) are the dominant unit in the central and eastern part of the Nilambur valley (Fig. 4.3a,b). Biotite gneiss is also observed in the western part flanking the charnockite hills. Hornblende-biotite gneiss is observed in the northern part of the terrain and contains enclaves of amphibolite, magnetite quartzite, fuchsite quartzite and meta-ultramafics.
Fig. 4.3 Migmatitic rocks in Chaliyar River drainage basin. (a) Hornblende-biotite gneiss (Location: Kurumbalkotta), and (b) Garnet-biotite gneiss (Location: Kodinji).

Fig. 4.4 Younger intrusive rocks in Chaliyar River drainage basin. (a) Dolerite dyke cutting across the Chaliyar River course trending NE-SW; (b) Pegmatite vein in hornblende-biotite gneiss (Location: Kunnathupoyi); (c) sulphide rich quartz vein in the amphibolite country rock. This quartz vein form the of host rock for primary gold (Location: Devala); and (d) Quartz veins within the lateritized country rock. Fractures in the quartz vein are with limonitic stain (Location: Chungathara).
Younger intrusives

Basic intrusive in the Chaliyar basin is mainly dolerite (Pillay and Koshy, 2002). Boulders of dolerite are observed in the western part of the basin suggesting intense fracturing and weathering. Dolerite dykes are seen in the river course, cross cutting the Chaliyar River, west of Kunnathupoyi (Fig. 4.4a). These are exposed during the summer i.e., in the non-monsoon season when the river has meager flows. Acid intrusives in the basin are mainly pegmatite and quartz veins. Pegmatite veins cross-cut the migmatitic rocks along joint and fracture planes (Fig. 4.4b). Quartz veins are found abundantly in the migmatitic terrain and constitute the most important host rock for gold (Fig. 4.4c). Veins are emplaced along pre-existing fracture and joint planes without any preferred orientation. Quartz veins also exhibit fracturing (Fig. 4.4d).

Laterite

Intense lateritization has been observed in the midland and lowland zones of the drainage basin. Two to four meter thick laterite capping is present over the gneiss in the southern plain areas of the Chaliyar River drainage basin (Fig. 4.5). Intervening areas between stream courses in the lower plains are capped by laterite. At places it forms hard duricrust occurring on the top of flat-topped mounds.

4.3 Structure

The rocks of the area display three-phases of deformation. Evidences of the first phase of deformation (D_1) are seen as tightly appressed intrafolial isoclinal folds (F_1) as observed in hornblende-biotite gneiss at Vazhikadavu (Fig. 4.6a). At the left bank of Chaliyar River at Canoli, F_1 folds are well exposed in the hornblende-biotite gneiss (Fig. 4.6b). The second phase of deformation (D_2) also is represented by moderately tight to open folds (F_2) with its axial trace in a NE - SW direction. Axial planes of F_1 and F_2 folds are co-parallel and a number of antiformal and synformal folds have been found in the NE parts Nilambur valley, after F_2 folding. Fig. 4.6c shows tight- to open-fold (F_2) in hornblende-biotite gneiss at Nilambur. Tight- to open-folds observed in hornblende gneiss represent the second phase deformation (Fig. 4.6d). The third phase of deformation (D_3) had given rise to broad open warps with axial trace trending NW-SE to N-S. The dominant foliation trend is NE-SW, parallel to the axial trace of F_1/F_2 folds. The dip of foliation is nearly vertical or steep, towards NW or SE.
Fig. 4.5 Laterite profile of about 4 m thick. The top portion has a thin layer of regolith (~3 cm) and is underlain by the charnockitic bedrock (Location: West of Edakkara).

Fig. 4.6 Foldings in the migmatitic rocks in Chaliyar River drainage basin. (a) Tight appressed intrafolial fold (F₁) in hornblende-biotite gneiss; (b) Tight to open folds (F₂) in hornblende-biotite gneiss (Location: left bank of Chaliyar River at Canoli); (c) F₂ fold in the hornblende- biotite gneiss at Nilambur; (d) folding in the sheared hornblende gneiss at Edavanna. Brocken lines show the folded bands.
Faults, fractures and brittle shearing are ubiquitous in the drainage basin. Faults of mega-scale, meso-scale and micro-scale are omnipresent in the rocks exposed in Chaliyar River drainage basin (Fig. 4.7). Fractures and joints are very commonly observed in the area. These fracture planes and joint planes trigger slumping and landslides, probably due to tropical humid climate and intense monsoonal rainfall.

Brittle shearing trending N-S is traced at Adyanpara falls (Fig. 4.8a) and that of ductile shearing represented by mylonites at Arimbrakattumala (Fig. 4.8b).

Fig. 4.7 Faults observed in Chaliyar River drainage basin. (a) Mega-scale faults at Adyanapara falls. E - W trending younger fault (F₁) cut across the N - S trending F₂ fault; (b) Meso-scale fault in the charnockite gneiss at the left bank of Karimpuzha (Location: Nedungayam); (c) Meso-scale fault in the biotite gneiss (Location: Chattallur); (d) Micro-scale fault in the hornblende-biotite gneiss. Location: Manali
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Fig. 4.8 Shearing observed in the rocks of Chaliyar River drainage basin. (a) Brittle shearing with N-S trend in charnockite (Location: Adyanpara waterfalls); (b) Mylonite developed in a ductile shear zone (Location: Arimbrakuttumala).

Fig. 4.9 Different erosional landforms in the study area. (a) Residual hill (Location: Kurathimala); (b) structural hill (Location: Polakkod); (c) denudational hills seen in the upper reaches of Punnapuzha River; (d) vertical cliffs where the Precambrian rocks are well exposed (Location: Adyanpara).
4.4 Landforms

Fluvial geomorphology in each drainage system reflects a unique adjustment of the river to physical, climatic, tectonic and anthropogenic processes. Fluvial landforms in the study area can be broadly classified into erosional and depositional landforms. Erosional landforms are characterized by landforms like strath terrace, pediment, valleys and interfluves, hills and mountain ridges and depositional landforms like bars, depositional terraces, braids, valley fills/channel fills are observed.

4.4.1 Erosional landforms in the upper reaches of the Chaliyar River drainage basin

Erosional landforms in the Chaliyar drainage basin are mainly observed in the upper reaches as structural hills and valleys, denudational and residual hills, and valleys and interfluves.

Structural hills and valleys

A number of hills and valleys of the area owe their configuration to structural deformation. Linear sharp crested folded hills and hogbacks are observed in the study area especially in the upper reaches i.e., in the Western Ghats and Wayanad Plateau. West of Palakkod (Fig. 4.9b), hogback crested hills are found folded. Sudden change in the valley trend from NE to SW direction indicates the drastic change in the direction of valley development suggesting the strong tectonic domain which contributed to the development of Nilambur valley.

Denudational hills

Denudation hills can be structural in origin but may not preserve the structural identity due to the strong erosional activity. These are areas of medium to high relief with altitude ranging from 100 to 600 m above MSL (Fig. 4.9c).

Residual hills

These are low relief mounts with an elevation ranging from 40 m to 100 m above MSL. These are remnant of structural hills, terraces or pediments. In most of the area it occurs as isolated hills in plain. The well developed residual hill is observed at Kurathi Mala (Fig. 4.9a).

Valleys and interfluves

Incised valleys bordered locally by cliffs and separated by interfluves that are too elevated for inundation by the present day stream. In the upper reaches, valleys are
bordered by 10 to 20 m cliff where the Precambrian rocks are well exposed (Fig. 4.9d). The intervening area, between two stream channel courses in the upper Western Ghats region, the lower lateritic plains and planar floodplain surfaces with thin soil cover are considered as interfluves. Here the interfluves are just a few feet higher than the valley floor.

4.4.2 Fluvial landforms

Fluvial landforms identified during field studies are terraces - strath terraces, fill terraces of different levels, and terraces developed within the alluvial fan deposit, palaeochannels, palaeo-alluvial fans, pebble beds, present day stream bed, sand-, braided- and point bars, channel fills, and alluvial river and active flood plain.

Terraces

In the Chaliyar river basin, three terraces have been demarcated from the aerial photographs and satellite imagery and were subsequently verified during field checks. Chaliyarpuza, Punnappuzha and Karimpuzha have very remarkable fluvial terraces mainly aligned along the meandering courses. Most of these terraces are unpaired suggesting that rejuvenation took place continuously (Fig. 4.10a,b). There is no evidence of still - stands of the stream during deepening of the valley. The staggered elevation of the terraces below the original stream valley floor suggest that lateral abrasion was accompanied by down cutting as the stream wandered from one valley side to the other. Such continuous incision or rejuvenation commonly results from localized tectonic uplift, gradual tilting, climatic change or change in load volume relation of the streams. Based on the relative height and age of formation, these terraces are classified into $T_1$, $T_2$ and $T_3$. These terraces can be classified as erosional, cut and fill unpaired terraces, and are commonly the products of tectonism or sudden change in the climatic regime.

In the upstream direction of the Chaliyar River and its tributaries erosional activity prevails over accumulation and strath terraces predominate; whereas when the stream reaches Nilambur valley area, the fill terraces preponderate. Strath terraces are also observed in the downstream part of the tributary streams of Chaliyar River predominantly along the left bank of the streams (Fig. 4.10).

In the Nilambur valley area, the fill terraces are again incised exposing the pebble beds of the older terrace, along the present day river course as observed in
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Ambalappoyi area (Fig. 4.11a). Chaliyar River has incised through the bedrock along a fault plane trending NE-SW adjacent to the Manavedan School at Nilambur (Fig. 4.11b). Here the upthrown part of the bedrock forms the $T_1$ terrace and lateritized sandy horizon further east forms the $T_2$ terrace. Interestingly, $T_1$ terrace is unpaired whereas $T_2$ terrace is paired. River incision along the fault plane is also observed at Nedungayam in Karimpuzha River (Fig. 4.11c). Here the bedrock is exposed along the river bed. The left bank of this stream forms strath terrace ($T_2$) which is about 12 m thick, while the right bank of the river is only half a meter above the present stream bed. This clearly indicates normal faulting with E – W trend, where the southern block has been upthrown and northern block has been down thrown. The present day Karimpuzha is flowing along the E – W fault plane of this normal fault. At Canoli Teak Garden, $T_2$ terrace is about 10 m thick on the right bank of Chaliyar River (Fig. 4.11d). Absence of $T_1$ terrace and scouring away of the $T_2$ terrace in the right bank of Chaliyar River indicates the river incision through well developed $T_2$ terrace. Terrace seen on the left bank in this area is strath terrace mantled by thin layer of clayey sand and quartz pebbles. At Tana, along the left bank $T_1$ terrace is being developed by migrating of the stream towards the right bank by scouring away the $T_2$ terrace (Fig. 4.11e, f).

**Younger terrace ($T_1$)**

The $T_1$ terraces are recent low-level terraces of low relief and are particularly concentrated along the meandering courses and sharp bends of the streams. They lie at a much lower physiographic levels i.e., between 10 - 20 m above MSL and are composed mostly of unconsolidated to slightly consolidated river sand, silt and clay intercalation with a thickness varying from 1 to 4 m. Well developed $T_1$ terraces are observed at Edavanna, Panankayam, and Nilambur areas (Fig. 4.12).

$T_1$ terraces of Chaliyar River and its tributaries are well developed and stabilized by thick vegetation (Fig. 4.12 a, b). At places these terraces are paired while becomes unpaired at some other locations. It can be inferred that localized tectonic activity has influenced in the development of unpaired $T_1$ terraces at places.

**Older terrace ($T_2$)**

The middle level terraces ($T_2$) are about 1 to 7 m thick and are seen along the edges and lower levels of the mount flanking the alluvial valleys as well as in the valley flats proximal to the present day river system. In Punnapuzha River, $T_2$ terrace is found...
perched at a height of 6 m from the channel near Nallathanni, which has been recently artificially terraced for construction purpose (Fig. 4.12d). In the Chaliyar River, east of Bhudan Colony and in Ambalappoyi area, T2 terrace is found developed to a height of 5 m from the present day river level on the right bank (Fig. 4.12e). T2 terrace is also well developed along the left bank of Chaliyar River ranging in thickness from 3 to 10 m (Fig. 4.11d). Near Mannathi temple, the surface expression exhibits scattered pebble of quartz over the ferruginous matrix (Fig. 4.12f).

T2 terraces of Chaliyar River and its tributaries are well developed and stabilized with a thick canopy of vegetation, particularly teak forest (Fig. 4.13a), coconut and arecanut cultivation. They are composed of semi-consolidated fine- to coarse-grained sand (Fig. 4.13b) and ferruginous at places (Fig. 4.14a). Alternate bands of ferruginous sandy layer in these terraces indicate a series of deposition of sediment and subsequent exposure of the sediment to then existing atmospheric condition. In one of the vertical sections of T2 at Tana, graded bedding and cross-bedding could be observed (Fig. 4.14b).

**Oldest terrace (T3)**

In the Nilambur valley, along and between the Chaliyar River and Punnapuzha River, the oldest terraces (T3) have been observed. These terraces occur as small hillocks and mounts and consist of lateritized and matured oligomictic gravel bed. In many places these are overlain by soil cover and secondary laterite of 0.5 to 1 m thickness. These terraces can be classified as the depositional terraces of Chaliyar and Punnapuzha. They are not preserved well due to intense anthropogenic activity and erosion, but are clearly seen when pits are taken for agricultural purposes (Fig. 4.15a) and also in some well sections (Fig. 4.15b). On the left bank of Chaliyar, west of Chungathara, T3 terrace is exposed and extends to a few hundreds of metres in N-S direction and is about 80 m wide. The gravel bed with thickness ranging from 0.5 to 8 m, is composed mainly of quartz cobbles of about 50 cm diameter and smaller amount of quartz pebbles. The gravels are sub-rounded to rounded and elongated (Fig. 4.15c). The gravels are cemented in lateritized ferrugeneous matrix showing no preferred orientation or imbrications and are ill-sorted (Fig. 4.15d,e,f). The gravel bed is composed mainly of quartz cobbles with subordinate amount of quartz pebbles.
Fig. 4.10 Types of terraces in Chaliyar River drainage basin. (a) Unpaired terrace of Chaliyar River at Mambad. The left bank terrace (T<sub>1</sub>) is 1 m thick and is rock cut, while the right bank terrace (T<sub>2</sub>) is almost at the level of present day stream bed. T<sub>2</sub> terrace is about 5 m thick and covered by thick vegetation; (b) unpaired terrace of Chaliyar River at Arikkod. T<sub>1</sub> terrace on the right bank is depositional while the left bank is erosional terrace (T<sub>2</sub>). Variation in the elevation of terraces is clearly observed; (c) Strath terrace observed along the left bank of Chaliyar River at Edavanna; (d) Strath terrace observed along the left bank Kuthirapuzha at Vadapuram; (e) Strath terrace observed along the right bank Chaliyar River at Mambad, and (f) paired terrace (T<sub>1</sub>) of Iruvahnipuzha at Mukkam.
Fig. 4.11 River incision in Chaliyar River drainage basin. (a) Filled terrace ($T_1$) which have been re-incised as seen on the left bank of Chaliyarpuzha at Ambalappoyi area. Pebble bed at the bottom is overlain by a layer of silty sand and clay; (b) Chaliyar River getting incised along a fault plane in the bedrock. Lateritized older terrace ($T_2$) can be seen on the right (eastern) side of the photograph (Location: near Manavedan School, Nilambur); (c) bed rock incision along the fault plane at Nedungayam in Karimpuzha River. Here strath terrace has a thickness of 12 m from the water surface at the time of photo capturing (15/05/2007); (d) Well developed $T_2$ terrace of about 10 m thickness on the right bank of Chaliyar River at Canoli Teak Garden. The thickness of $T_2$ and absence of $T_1$ terrace signifies the incision of the river through $T_2$ terrace; (e) $T_2$ terrace on the right bank being incised by the Chaliyar River at Tana; (f) Erosion of $T_2$ terrace on the right bank and development of $T_1$ terrace on the left bank of Chaliyar river at Tana.
Fig. 4.12 Depositional terraces of Chaliyar River and its tributaries. (a) Thickly vegetated well-developed T₁ terrace along Chaliyar River at Edavanna; (b) T₁ terrace developed on the left bank of Chaliyar River at Panankayam; (c) T₁ terrace on the left bank of Chaliyar River near Nilambur; (d) stabilized T₂ terrace of Punnapuzha River near Nallathanni; (e) slumped T₂ terrace of Chaliyar River near Bhudan Colony. Here the thickness of terrace is about 6 m and is mainly composed of semi-consolidated fine grained sand; (f) loosely scattered quartz pebbles of T₂ terrace over the laterite near to the temple at Mannathi. This pebble bed extends over an area of about 2 km² from the present day Chaliyar River to the west.
Fig. 4.13 (a) Canopy of teak plantation over the T<sub>2</sub> terrace at Canoli Forest area. (b) Upper part of the vertical profile (top 1m) of the T<sub>2</sub> terrace shows thick column of fine sand stabilized but not oxidized.

Fig. 4.14 (a) T<sub>2</sub> terrace of Chaliyar River along the right bank consisting coarse- to fine-grained sand. At places the sand horizons are oxidized; (b) vertical section of T<sub>2</sub> terrace on the right bank of Chaliyar River. Below a thin layer of soil coarse-grained to fine grained sand is seen which shows graded bedding. Below the graded bedded sandy horizon, cross-bedding is seen which is further followed by graded bedded sandy horizon (Location: Tana).
Fig. 4.15 Oldest terraces of Chaliyar River. (a) T₃ terrace of Chaliyar River well exposed when excavated for agricultural activity (Location: Kaippini); (b) T₃ terrace exposed in a well section. The 7 m thick pebble bed is very compact and lateritized; (c) Quartz pebble in the lateritized T₃ terrace exposed at Patiripadam; (d) Lateritized quartz pebble bed well - exposed in a well-section at Patiripadam; (e) sub-rounded to rounded pebbles seen in the T₃ terrace exposed along a road cutting at Nilani; (f) Gravel bed exposed in a well section at Nilani. Gravels vary in size from few cm to 45 cm.
**Terraces within the alluvial fan**

These terraces are cut in the alluvial fan material and are erosional terraces. Four such terraces are identified at Vellimattam where the alluvial fan is cut by Ezhuvithodu stream (Fig. 4.16a). This type of terraces is characterized by polymictic pebble beds with hornblende–biotite gneiss, biotite gneiss, amphibolite and quartz as pebbles overlain by a thin sandy horizon (Fig. 4.16b).

Fig. 4.16 Erosional terraces in Chaliyar River drainage basin. (a) Erosional terrace developed along Ezhuvathodu stream which flows through alluvial fan deposit; (b) polymictic pebble beds in the terrace within the alluvial fan (Location: Vellimattom).

**Palaeochannels**

Karimpuzha tributary has three palaeo-courses trending in the NE-SW direction for a stretch extending from Nedungayam to Chekuthankundu (Fig. 4.17a). Kallanthodu tributary with SW flow direction is supposed to be the palaeochannel of Karimpuzha (Fig. 4.17b). This stream is presently active only in the rainy season. Palaeochannels along Punnapuzha River are observed near Edakkara, Valluvasseri (Fig. 4.17c), Chungathara (Fig. 4.17d) and Manali. Karakkodupuzha River flows through a very wide alluvial valley with thick sequence of gravel bed, sand and silt layer appears as a miss-fit river for such a broad alluvial valley. So this SW flowing stream is considered as the earlier main course of Punnapuzha. The palaeochannels of Chaliyar River are seen at several places (Fig. 4.17e, f).

The sediment in the palaeochannels varies in size from cobbles to pebbles and from fine sand to silt (Fig. 4.18a). Cobbles and pebbles are mainly of quartz. At places it is highly oxidized resulting in the formation of limonitic oozes (Fig. 4.18b). This thick sedimentary layer is mined out for the manufacture of bricks.
Fig. 4.17 Palaeochannels at different locations in Chaliyar River drainage basin. (a) Palaeochannel of Karimpuzha stream at Karappuram and (b) at Kallanthodu, palaeochannel of Karimpuzha flowing southwest is active only during rainy season; (c) palaeochannel of Punnapuzha at Valluvasseri Reserve Forest; (d) palaeochannel of Punnapuzha at Chungathara. Presently silty clay is mined for tile and brick manufacturing; (e) palaeochannel of Chaliyar River at Kurathipadam; f) palaeochannel of Chaliyar River at Ichambatur - Ramachampadam area.
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Fig. 4.18 Vertical cross-sections showing sediment deposit in a palaeochannel. (a) Sediment is made up of assorted pebbles, gravel, sand and silt; (b) sediment composed of quartz pebbles, sand and silt. Oxidized sand/silt and limonitic oozes are prominent in this vertical profile (Location: Valluvasseri Reserve Forest). Graded bedding is observed with sediment grading from pebbles to fine sand.

Fig. 4.19 Sediment deposits of alluvial fans. (a) Vegetation seen over the palaeo-alluvial fan at Nedungayam; (b) sub-rounded to rounded pebbles and boulders exposed in a trench at Nedungayam; (c) rounded to sub-rounded boulders and pebbles that have been excavated from the pit. Size of the boulders varies from few cm to 1 m (Location: Nedungayam); (d) rounded to sub-rounded pebbles exposed in pits dug for rubber plantation at Kaippini.
Palaeo-alluvial fans

Alluvial fans are aggrading deposits of alluvium deposited by a stream debouching from a canyon onto a surface or valley floor. Once in the valley, the stream is unconfined and can migrate back and forth, depositing alluvial sediments across a broad area. An individual deposit looks like an open fan with the apex being at the valley mouth, when viewed from above. The development of pediments and alluvial fans is progressive with the uplift of mountains and subsidence of adjacent basins (http://pubs.usgs.gov.,2004). In the present study, alluvial fans are observed in Karakkodu, Nedungayam, Vellimattam, Pattakarimaba and Kolikkadavu areas.

The Nedungayam alluvial fan developed by the Karimpuzha River covers an area of about 40 km$^2$. These alluvial fans comprise materials ranging in size from boulders to pebbles, sand and silt. They have a gentle slope and elevation ranges between 20 and 60 m. A number of alluvial fans are identified at Nedungayam, Pattakarimba, Karakkodu, Vellimattam and Kolikkadavu. All these fans located at the foothills at the break of slope with an elevation ranging from 10 to 60 m. They assume very gentle slope with traces of channel ways and hold luxuriant vegetation as observed at Chekuthankundu (Fig. 4.19a).

The surface of the fan deposit is sandy followed by ill-sorted and unconsolidated sediment comprising pebbles, cobbles and boulders. The alluvial fan is characterised by sub-rounded to rounded clasts varying in size from pebbles to boulders (Fig. 4.19b,c,d). These boulders and pebbles are mainly hornblende-biotite gneiss, charnockite gneiss, amphibolite, biotite gneiss and quartz veins. The rounding is due to the elongated catchment area upstream of the fan apex, as clasts are rounded during prolonged bed load transport and are temporarily arrested upstream of the fan apex as channel bars. The fan material comprises unsorted debris flow deposit and sandy layer. These clasts are remobilized and entrained in debris-flows on the fan during events of anomalous discharge (storm events). The clasts are mainly gneissic and show a progressive fall in maximum clast size from 60 cm to 10 cm away from the fan apex.

Pebble beds

Older lateritised gravel beds on the Chaliyar River course are well exposed in NW of Mannathi and south of Kaippini (Fig. 4.20a), SW of Pookkottumannu, Pongallur
and near the confluence of Karimpuzha and Chaliyar Rivers. These gravel beds are also observed at Pattiripadam and east and north of Yutirkulam in Pandipuzha stream (Fig. 4.20b). Lateritized gravel beds occur as flat topped mounds consisting of pebbles, cobbles and boulders of vein quartz (80%), amphibolites, gneisses, magnetite quartzite etc. embedded in laterite matrix. These pebbles are rounded to well-rounded and spheroidal to discoidal in shape. The sphericity, roundness and sorting of the pebbles increases downstream but size decreases.

Lateritized older gravel beds are well exposed on the western side of Punnapuzha River. It occurs as detached gravel bed extending from east of Sankarankulam to the point where Punnapuzha joins Chaliyar River. At Palunda and Perunkulam also detached outcrops of lateritised gravel beds are observed. North of Maruda, gravels bed with huge boulders of quartz and magnetite quartzite is well exposed. The gravel bed at Nilani - Kaippini area abruptly ends on the edge of a paddy field (younger alluvium) and again exposed in some of the wells further south at a distance of about 150 m as explained by Cvetkovik, 1980. In Manali area, this lateritized gravel bed consists of cobbles of smaller sizes (< 15cm) and the matrix content is of equal volume to that of its gravel content. Around Kuttimunda, gravel beds are exposed on the lower slope of a mound but have only small areal extent.

Younger pebble beds are part of the younger terraces or palaeochannels and are not lateritized (Fig. 4.20c). Minor oxidation at places is observed as seen in Valluvasseri Reserve Forest (Fig. 4.20d).

**Streambed**

Chaliyar River has a streambed of non-uniform width and the tributaries show braiding and meandering even in the upper reaches. In the upper reaches stream bed is very active with waterfalls and rapids (Fig. 4.21a,b). Stream bed consists of sediments of varying size ranging from boulders to clay. Lower order streams (1st, 2nd and 3rd) flow through a bed with angular to sub-rounded boulder beds (Fig. 4.21b). When the stream reaches 4th to 6th order, the stream bed is mainly composed of pebbles (Fig. 4.21c) and at its highest order (7th order), the bed is mainly composed of sand (Fig. 4.21d).
Fig. 4.20 a) Pebble beds beneath the thick vegetation exposed along a road cutting (Location: South of Kaippini); b) older pebble bed seen east of Yutirkulam. Quartz pebbles are embedded in compact and highly ferruginous matrix; (c) Younger pebble bed in a palaeochannel of Karimpuzha near Nedungayam; (d) Slightly oxidized pebble beds in a vertical section palaeochannel at Valluvasseri Reserve Forest.

**Sand bars, braided bars and point bars**

Sand bars are common along the stream and are sparsely to moderately vegetated. Materials in the bars vary from fine sand to pebbles to cobbles. Sand bars of Chaliyarpuzha and Punnapuzha tributaries at places are moderately vegetated as observed in Ambalppoyi and Nellukuthu Reserve Forest (Fig. 4.22a,b).

At the break of hill slope, almost all the tributaries of Chaliyar River get braided, and are stabilized with thick vegetation cover. The Karimpuzha tributary shows strong braiding in its course from Chekuthankundu to Cherupuzha (Fig. 4.23a). In these areas, the stream loses its energy and sheds all the sediment it carried during its course and
causes to develop braided channels. At Karulayi, the braided bars are partially stabilized with moderate vegetation (Fig. 4.23b). Similarly, braided bars of Punnappuzha tributary are prominent and stabilized as in Karandakundu area and at Palakkalpara, near Edakkara (Fig. 4.23c,d).

Point bars, formed due to channel lag deposits are observed in the Chaliyar River at many places Kizhuparambu, Chikkod, Puttalam, Vadasseri and Edavanna and are made up of sand, silt and gravel bed (Fig. 4.24a,b).

**Channel fills**

Channel fill is one of the most widely spread geomorphological feature in the study area (Fig. 4.25a,b). Occurrence of large channel fills adjacent to overbank strata and absence of laterally adjacent channel fills in the drainage basin indicates mainly a single channel river. This can also be called as filled-up valley flats where small streams flow through broad valley flats and comprise colluvial materials on the top and sand-silt intercalation below.

**Alluvial river and active floodplain**

Alluvial rivers flow between banks and on a bed of sediment that is transported by the river (Schumm, 1986). These rivers are sensitive to changes of sediment load, water discharge and variations of valley floor slope and therefore deformation of the valley floor by active tectonics can cause pattern change, aggradation and degradation (Schumm, 1986). Higher order (7th order) stream of Chaliyar River can be considered as alluvial river and flows through thick bed of sediment towards downstream (Fig. 4.26a). Active flood plain occurs adjacent to the present day active channel and defines the geomorphic unit that is continuously modified by the overbank flow (Fig. 4.26b).

**4.5 Field evidences of active tectonism**

Tectonic deformation modifies the relief of a terrain, whereas topography gives the first and indispensable indication of the distribution and arrangement of morphological structures. Several present-day tectonic landforms have been used to indicate the activeness of crustal structures (Keller and Pinter, 1996). Globally significant interactions between surface processes, tectonics and climate have been proposed to explain structure of mountain areas (Bishop et al., 2003).
Fig 4.21 Stream bed characteristics from the upstream to downstream portion of rivers in the Chaliyar River drainage basin. (a) Rapids in a sub-tributary of Chaliyar River (Location: Thusharagiri); (b) waterfall in one of the tributaries of Chaliyar River (Location: Adyanpara); (c) boulder stream bed of Karimpuzha (Location: Chekuthankundu; (d) sub-angular to sub-rounded pebble bed in the upper reaches of Chaliyarpuzha (Location: Nilambur Kovilakam Forest); (e) sub-angular to sub-rounded gravel beds of Chaliyar River; (f) Sandy stream bed of Punnapuzha stream in its lower reach (Location: Edakkara).
Fig. 4.22 Sand bars with moderate vegetation cover (a) in Chaliyarpuzha stream at Ambalappoyi area; (b) in Punnapuzha stream in Nellukuthu Reserve Forest. Vegetation type and density indicates the stability of the bars.

Fig. 4.23 Braiding observed in the river channel at different places in the Chaliyar River drainage basin. (a) Karimpuzha stream west of Chekuthankudu (stabilized braided deposit by thick vegetation); (b) at Karulayi (partially stabilized braided deposit; (c) & (d) Punnapuzha River observed at Karandakundu (stabilized) and near Edakkara respectively. Both braided deposits are stabilized.
Fig. 4.24 Meandering and point bar deposit in Chaliyar River at a) Arikkod and (b) Edavanna. These point bar deposits are composed of medium- to coarse-grained sand. At places alternate bands of sand and silt are also observed.

Fig. 4.25 Channel fills observed in the Chaliyar River sub-basin at (a) Enanti and at (b) Muthedam. Channel fills consist of medium to coarse-grained and silty clay admixture. Most these channel fills in the study area are used for paddy cultivation.

Fig. 4.26 a) Chaliyar River close to its mouth. The river banks comprise thick layer of sediments (sand, silt, clay intercalation). A number of tile factories are located along the river banks; b) Chaliyar River mouth with broad flood plain at Beypore.
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Streams play an important role in the evolution of a landscape and can give us valuable information with respect to erosion rates and tectonic movements. Since rivers respond rapidly to tectonic changes they are a prospective instrument to modern geomorphology (Gloaguen, 2008). Influence of active tectonism on the development of landforms expressed in the form of various tectono-geomorphic features like change in drainage patterns, discontinuities in stream courses, deformation in river terraces, morphology of active mountain fronts, landslides within the drainage basins (Ouchi, 1985; Keller and Pinter, 1996; Schumm et al, 2000; Burbank and Anderson, 2001). More details are discussed in the next chapter (Chapter V).

The presence of some landforms gives evidences for the control exerted by structures on the fluvial geomorphology of Chaliyar River drainage basin. Some of the landforms identified in the basin are unpaired terraces, offset streams and shutter ridges, alluvial fans, deflected streams, landslide, fluvial capture due to headwall erosion and anabranching streams. Field relations of some of these landforms are discussed in the foregoing sections.

4.5.1 Unpaired terraces

Unpaired strath terraces are very common in the middle reaches of all the tributaries as observed in Edakkara, Edavanna, Arikkod etc. (Fig. 4.27) and are formed in response to coeval continuous vertical incision and lateral erosion of the river, controlled by episodic tectonic uplifts. Differential deposition is evident from the unequal height of the terraces. Unpaired strath terrace reflects river incision along fault planes, where the strath terrace forms the upthrown part of the normal fault.

4.5.2 Deflected stream

Channel deflection along fault axis is a very common phenomenon in the Chaliyar River drainage basin. Strath terraces with slicken slide faces and sudden deflection of streams are observed in Chaliyar river near Kurathi Mala and in Punnnapuzha at Chungathara (Fig. 4.28a,b).

4.5.3 Palaeo-alluvial fans

Reactivation or movements along normal faults during Quaternary Period in the Western Ghat can be determined from the alluvial fan deposits (Fig. 4.19b,c,d). Assorted loose sediments varying in size from boulders to fine sand could be identified
in the fan deposit. Alluvial fan deposits are seen in Karakkodu, Nedungayam, Vellimattam, Pattakarimaba and Kolikkadavau. In most places these alluvial fan deposits are incised by streamlets which later join downstream. This appears like a braided stream or can be called as anabranching stream.

4.5.4 Landslides

Evidences of palaeo-landslide are well preserved in the study area. In SOI toposheets of 1971 edition the landslide prone areas are documented. From the inventory of records of Geological Survey of India, it is understood that recurring of landslide in the same area is a common phenomenon.

Remnants of Palaeo-landslides could be traced at Anappara near Sankara Mala and Mamankara near Karuppumpatti. In Anappara area, angular rock fragments within sticky yellowish lateritic soil overlain by sandy layer was observed in an abandoned well-section (Fig. 4.29a). Along a road cutting at Mankara below thickly vegetated area angular and assorted rock fragments embedded in a matrix of lateritic material (muddy and black in colour at the bottom part) was observed (Fig. 4.29b). Further down slope, large boulders of massive charnockite embedded in fine and medium grained sandy horizon also could be traced (Fig. 4.30). All the formations/deposits suggest that landslides are taking place in the study area for a long time. Slumping/land sliding on a small scale is continuously taking place in this area. Scars of recent landslide also could be traced all along the upper reaches of the Chaliyar River drainage basin (Fig. 4.31).

4.5.5 Faults

Evidences of faults in the field include faulted scarp, presence of slicken slides on rock faces, vertical cliffs, pseudotachylyte veins etc. Such evidences are recorded in the Chaliyar River drainage basin (Fig. 4.32). Formation of pseudotachylyte is associated with seismic activity and are observes as veins cutting through the fault planes as observed in Adyanpara (Fig. 4.33).
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Fig. 4.27 Unpaired terrace of Chaliyar River at Edavanna.

Fig. 4.28 a) Chaliyar River showing deflection in the river profile north of Kurathimala. The stream takes right angle bend at the junction of the two normal fault axes. Left bank is the upthrown part of the faults. Fault $F_1$ is older to $F_2$ fault; b) highly fractured rock along the fault plane along Punnapuzha. Deviation in the channel course along the fault zone and ponding are clearly seen.
Fig. 4.29 (a) Angular rock fragments (quartz, charnockite and hornblende gneiss) seen in an abandoned well-section at Anappara; (b) angular assorted rock fragments of quartz, charnockite and hornblende gneiss seen along a road cutting at Mamankara. Inset figure shows the close shot of the angular fragments.

Fig. 4.30 Large boulders of charnockite embedded in the fine to medium grained sand horizon. These boulders are rootless and are distributed in the downstream part of Karakkodupuzha suggesting a rolled down-mass during landslides.
Fig. 4.31 Features of landslides observed in Chaliyar River drainage basin (a) Scar of the landslide seen on the ridge, west of Nadugani; (b) close-up view of the landslide scar of Fig. 4.31a; (c) scars of the landslide seen on a ridge northwest of Nadugani. Broken line indicates the lineament trends and the circle portion shows two adjacent scars of landslides that took place at two different period; (d) Close up view of the scars of two landslides shown in Fig. 4.31c; (e) Scar of an palaeo-landslide observed on a ridge, NW of Nadugani. Broken lines indicate the trend of lineaments; (f) scar of palaeo-landslide, north of Nadugani.
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Fig. 4.32 Evidences of faulting in Nilambur valley. (a) Vertical fault scarp face on the western side of Adyanpara waterfalls. The fault zone has N-S general trend; (b) fault zone appears to be a horst and graben (microtopography) type multiple faults; (c) & (d) slicken slide faces along a fault zone in charnockite gneiss at Vellimattam and Nedungayam respectively. Arrow indicates the direction of movement.

Fig. 4.33 (a) Pseudotachylite vein within the brittle shear zone at Adyanpara waterfalls. Pseudotachylite otherwise known as fault rock is an evidence of frictional melting of the wall rocks during rapid fault movement associated with a seismic event; (b) pseudotachylite where parallel fractures/joints are observed. Broken line indicates the contact zone of the pseudotachylite with country rock.
4.6. Summary

Chaliyar River drainage basin forms part of the Southern Granulite Terrane with within the Charnockite and Migmatitic Group of rocks. Charnockite is the most extensive rock type followed by the migmatitic rocks. Younger acid and basic intrusive cut across the older rocks but are highly fractured. Quartz veins in this area are the primary source of gold. The geological milieu of Chaliyar River drainage basin is comparable with any other part of the SGT. Extensive lateritization in the mid-land part of the study area has obliterated the general characteristics of the rock types.

Field relationship of structural aspects of the Chaliyar River drainage basin represents three phases of deformation. The first deformation ($D_1$) synchronous with ultrahigh temperature metamorphism resulted in the gneissic layering in NNW-SSE direction. The secondary compositional banding of the gneisses and the migmatites is a transposition structure and are represented by tightly appressed rootless isoclinals folds ($F_1$). Second stage of deformation ($D_2$) includes small-scale appressed near isoclinal folds with thickened hinges, defined by the NNW-SSE planar fabrics. Planar surfaces of the first two deformation structures are further folded during the stage of deformation ($D_3$) represented by open folds. These three stages of deformation has been well studied in other parts of Kerala by Narayanaswamy (1976); Sinha-Roy (1980); Nair and Nair (1980); Nambiar (1982); Soman et al., (1990). In Precambrian granulite terrain, field identification of shear zones is difficult as the high grade metamorphism causing the brittle nature of the rocks tend to underplay the evidences of block movements, brecciation etc. (Soman, 2002). However field evidences that support shearing and faulting such as slicken-slides, mylonitization, lineation, scarp lines, pseudotachylite veins etc. could be traced out during the field studies.

Landforms viz., in the Chaliyar River drainage basin were closely studied during the field work. Gradational variation in the grain size of sediments could be identified from the dead to the river mouth. Chaliyar River attains its 7th order at a distance of 45 km from the source where as the total length of the stream is 169 km.

Field evidences like strath terraces, unpaired terraces, palaeochannels, palaeo-alluvial fans, landslides and fault scarps very well support the influence of active tectonism in the development and carving of present day Chaliyar River drainage basin. Development of strath terraces all along the left bank of the Chaliyar River course
indicate that the river is flowing through fault plane with upthrown block forming the left bank and the downthrown part forming the right bank. Strath terraces and exposure of T₂ terraces on the left bank of Chaliyar River affirms river incision along fault/fracture planes. Well developed T₁ terrace on the right bank and scouring of T₂ terrace in the right bank reflects the channel migration towards the left bank. Palaeochannels of Karimpuzha, Punnapuzha and Chaliyarpuzha also support the channel migration towards the left banks. Lateral migration of SW flowing Kallanthodu resulted in the present day west flowing Karimpuzha leaving behind a thick pebble bed. Karakodupuzha is a misfit stream flowing through a wide alluvial plane and is considered as the palaeochannel of Punnapuzha.

Palaeo-alluvial fan deposit with a thick boulder bed overlain by sandy horizon now under a thick canopy of teak plantation can be explained by the reactivation of faults along the Western Ghat scarp. The streams were then over-loaded with sediments and resulted in the development of anabranches and braids in the upper reaches. Evidences of palaeo-landslides and scars of recent landslides indicate tectonically active nature of the basin. Pseudotachylite veins observed in one of the fault zone indicates a seismic activity resulted in landslides. Pseudotachylite is observed at the base of some large landslides in the study area, which suggests the movement of large coherent blocks as observed in the Arequipa volcanic landslide, Peru by Legros et al. (2000).