Based on geophysical evidences, Molnar and Tapponier (1987) have suggested that the crust south of Indo Suture Zone is a part of the Indian craton but Naqvi and Rodger (1989), on the other hand, stated that Precambrian of Himalaya is not simply correlatable with the Precambrian of Aravali craton #. However, there is a general consensus and probably agreement that the Great Himalayan Orogeny might have erased all the Himalayan structural evidences and associated metamorphism irrespective of Indian and/or Tibetan plates. Hodges (2000) has suggested that the entire metamorphism of Himalayan Orogen can be partitioned into Protohimalayan, Eohimalayan and Neohimalayan corresponding to Cretaceous - Early Eocene period, middle Eocene to late Oligocene and early Miocene to recent respectively. Since Himalaya is a thrust bound orogenic belt and a resultant of continent-continent collision tectonism it is apparent that the normal stratigraphic sequences are obliterated or disordered. Therefore, tectonostratigraphy plays a vital role in the Himalayan belt.

Tectonostratigraphy deals with distinguishing megasequences and their interpretations in terms of tectonic settings at the time of their accumulation (Watkinson et. al. 1977). It is closely related to sequence stratigraphy and regional tectonics. In other way, tectonostratigraphy refers either to rock sequence in which large scale layering is caused by the stacking of thrust or nappes in areas of thrust tectonics or the effects of tectonics on lithostratigraphy.
In a collisional zone like Arunachal Himalaya, it is difficult to establish a normal stratigraphic sequence due to very large scale thrusting or nappes. In this zone to define the geology in terms of tectonic units is well explained. Therefore, tectonostratigraphy is the only tool to handle the complicated history of Arunachal Himalayan evolution.

Indian plate rocks in the central Himalaya have traditionally been divided into orogen parallel fault bound tectonostratigraphic zones (Jopesh, 2004). But such traditional treatment is not applicable in case of Mishmi block of Arunachal Himalaya.

Tectonically Arunachal Himalaya has been divided into three major domains comprising the

1) Western Arunachal Himalayan Block (WAHB)

2) Eastern Arunachal Himalayan Block (EAHB)

3) Indo-Mayanmar Mobile Belt (IIMB). EAHB is also termed as Mishmi Block (D.R. Nandy, 2001)

The WAHB bears a true Himalayan signature, which is a lateral extension from Western Himalaya through Nepal Himalaya, Sikkim Himalaya and Bhutan Himalaya up to Barne fault (probably inclusive of Siang Domal structure). All the lithopackages of Sub- Himalaya, Lesser Himalaya, Higher Himalaya and Trans Himalaya are present here. Whereas EAHB or Mishmi Block is a separate thrusted geo-unit transported from Mogok Belt of Burma (Nandy, 2001), juxtaposed like
tectonic roof or umbrella over the two pillars like WAHB and Indo Myanmar Mobile Belt (IMMB) (Sarma et al., 2009).

The Trans-Himalayan Belt comprises of the Lohit Granitoid Complex with gabbro, diorite, granodiorite and tonalite. The Eastern Tertiary Belt comprises of Tertiary and Quaternary sediments of Naga-Patkoi Belt is the extreme end of the orographic curvature of Arunachal Himalaya.

The present research has permitted the determination of the tectonostratigraphy of one section i.e. along Dibang valley of the Arunachal Himalaya. Accordingly, traditional Sub Himalaya, Lesser Himalaya, Higher Himalaya, Tethyan zone and Trans Himalayan concepts are reviewed and a more realistic tectonostratigraphic thrust bound tectonic package will be presented here. A short account of the lithostratigraphic approach is given here. While discussing lithostratigraphy of Dibang Valley, references of the Lohit Valley (adjacent geotransect) is also dealt with so that a comprehensive account of the Mishmi block may be presented for easy access.

5.1 Litho-Stratigraphy of Dibang Valley

Lithostratigraphic framework of the NW-SE trending Mishmi Block is worked out from two different traverses along Roing-Mayudia-Hunli-Anini geotransects of Upper Dibang and Lower Dibang districts and Tezu- Hayuliang- Walong geotransect in Lohit and Anjaw districts of Lohit valley respectively. The sequence is presented in Table 5.1, which includes Roing/Tezu Gneiss (Mesoproterozoic), metavolcanosedimentaries of Dibang Group (probably Cretaceous), Mayudia mafic-
ultramafic layered complex, Lohit granitoids (probably Tertiary) and Pleistocene river terrace.

5.1.1 Pleistocene River Terrace (PRT)

In this geotransect Pleistocene river terraces are exposed at the lowest altitude at 1 km north of Roing along Deopani river and marks the southern limit of Pliestocene lithounit. It extends about 8 km along Roing-Anini road almost across the lithostrike and they are thrusted over by Proterozoic gneiss in Dibang valley. This tectonic contact is marked by Mishmi thrust (27°52'11" N: 96°21'1”E). In Lohit valley Pliestocene starts at Kamlang (27°45'23" N: 96°21'14’’E) and is overlain by Proterozoic gneiss at 39 km post (27°52’11” N: 96°21’1”E) from Dirak or 1 km before Parasukund. Siwalik and Gondwana sequence of Western Arunachal Himalaya are characteristically missing in the Mishmi Block (Table- 5.1) or acts as blind sequence (Sarma et.al, 2009a). Conventional MBT of Western Arunachal Himalaya is not traceable rather Mishmi Thrust marks as MBT in Dibang sector at 8 Km from Roing town along the Roing-Anini geotransect.

5.1.2 Proterozoic Roing Gneiss (PRG)

Biotite gneiss, augen gneiss, thinly bedded amphibolite and quartzites are the main components of the Roing gneiss in Dibang valley and Tezu gneiss in Lohit valley. They are the strike continuity and form a linear belt in NW-SE direction. The Proterozoic gneissses from Dibang and Lohit valley is correlatable with the highly mylonitised Bomdila gneiss of Tawang Sector of western part of Arunachal Himalaya.
They are highly deformed showing evidences of ductile shearing and characterized by well-developed schistosity and gneissosity. Alternate bands of felsic (quartz and feldspar) and mafic (micas) are seen. The feldspar augens are rotated both clockwise and counterclockwise and make 10° to 30° with respect to the direction of tectonic flow (schistosity), and the schistosity is deflected round the rigid augens. Amphibolites associated to augen gneiss are thinly bedded, medium grained and schistose. The thickness of the gneissic belt is more in the Lohit valley than the Dibang valley. Parasukund or Brahmakund of Lohit Valley is essentially confined in the augen gneissic terrain (Sarma et al., 2006). The presence of augen gneiss along NW-SE trending Ithun river valley is purely structure controlled and represents the core part of the major Ithun anticline (Burhauddin and Nandy, 2004; Sarma et al., 2007). In Dibang valley Proterozoic Roing Gneiss at lower structural level acts as foreland and hinterland is the mafic – ultramafic units of Mayudia Hill Complex and probably this is the reason why a new term Mayudia Thrust may be suggested.

5.1.3 Dibang Group (DG)

Metasedimentary and metavolcanic rock associations unconformably overlying the gneissic basement is designated as Dibang Group and exposes in both the geotrancsects. The thickness of Dibang Group in Dibang valley is almost double the Lohit Valley. They are divisible into two distinct stratigraphic units-

1) metavolcanic Ithun Formation followed by

2) metasedimentary Hunli Formations (Burhauddin and Nandy, 2004).
The Ithun Formation is well exposed along the Ithun river valley up to its confluence zone with the Dibang River and further southwest towards Rayalli village. Metabasites (amphibolite, hornblende schist and actinolite-chlorite schist) are intercalated with laterally persistent but discontinued quartzite bands of varied thickness. The quartzite is hard, massive, hardly micaceous and medium grained. Thickening and thinning are due to layer parallel extension. The Hunli Formation comprises of alternating layers of metapelitic rocks, quartz-chlorite + actinolite schist, carbonaceous phyllite, garnetiferous phyllite and intercalation of limestone. Hunli Formation conformably overlies the Ithun formation and is widely exposed in Dibang Valley. This Formation seems to be lateral equivalent of Tidding and Yang Sang Chu Formations (Singh, 2004). The contact between Ithun and Hunli formation is well exposed along the road section near Ithun River Bridge towards Hunli and in between Rayalli and Arzu, while the similar contact is insignificant in the Lohit Valley although it can be marked at Tidding river bridge (27°58'7.3"N: 96°23'8.6"E). The grey coloured, hard and compact limestone bands are traced at many places (SW of Hunli, Arzu, Endolin and near Rayalli in Dibang valley and at Tidding bridge in Lohit valley). The crystalline variety of limestone displays significant fold structures of three generations. GSI has mapped this limestone belt and suggested as cement grade but the Government of Arunachal Pradesh uses such a resource for construction of roads only. Nandy (2001) has reported kyanite staurolite minerals from metapelites near Etalin of Dibang valley. Similarly Thakur and Jain (1975) also have reported the presence of chlorite to kyanite/staurolite zones from Lohit valley metapelites. Presence of kyanite from metapelites of Lalpani area of Lohit valley is also reported by
Dutta Gupta and Dutta (1993-94) have suggested that the Roing, Mayudia and Hunli areas of Dibang valley can be designated as Mayudia Group. They claim that gneisses, schistose amphibolites, garnetiferous mica schists with carbonate bands, feldspathic quartzite, crystalline carbonate bands and biotite gneiss/schists form Ithun Formation unconformably overlain by Hunli Formation comprising carbon phyllite, crystalline limestone, phyllite, chlorite schist and green quartzite. Both these two Formations are effected by intrusive of basic dykes and sills, granite and ultramafics. On the other hand some people argue that Mayudia Group or Dibang Group represent the conventional Lesser Himalayan Sequences (LHS).

**5.1.4 Mayudia Mafic- Ultramafic Complex (MMUC)**

The Mayudia mafic-ultramafic complex represents a sequence of layered ultramafics (peridotite / serpentinite), coarse-grained pyroxenite, hornblendite, dunite and basic schist. They are intercalated with chert, mafic dykes/sills, carbonate rocks and leucogranitic veins. The mafic and ultramafic bodies occupy the core of the Mayudia synformal structure over a width of more than 10 km in the Mayudia hill ranges in Dibang valley geotransects. The rocks are found to be hard, compact, dense, greyish to greenish black in colour and show bouldery appearance. They are sheared and both dextral and sinistral shear senses are common. Serpentine bears the evidence of stretching lineation, striation, more shinning and polished showing network fabrics. Anastomosing foliation, delta type of rotation marked by megacryst of olivine,
pyroxene rough and pitted structures and lenses in the form of discontinuous blocks or sheets are very common features. The ultramafic rock shows beautiful radiating fabrics (probably spinifex texture) and a pillow structure near the Mayudia Pass and Ardzo. Isolated bodies of ultramafics near GB Garh, north of Ardzo, Tidding, and near Ryalli are comparatively more serpentinised than the Mayudia outcrop. The schistose basic assemblages are represented by basic volcanics/ tuff with thin intercalations of chert, mafic and felsic dykes/sills. Ultramafics are found as small lenses, enclaves within augen gneiss in Lohit valley. Thickness of this mafic-ultramafic lithounits of Dibang valley gradually decreases towards Lohit valley. On the other hand, whether MMUC is continuing further south east along Tezu-Hayuliang-Walong geotransect is doubted. Can Tidding metavolcanics be a counterpart of Ithun formation or there are two phases of mafic ultramafics expulsion, one being the tectonically dismembered namely non-schistose and schistose? It needs thorough investigation along strike extension, which is virtually impracticable due to inaccessibility, thick forestation and snow covering. Nandy (2001) has shown a stratigraphic sequence of the two valleys as:

Lohit Granitoid Complex

---------Lohit thrust---------

Tidding Group

--------- Tectonic contact -------

Lohit Group
------- Mishmi Thrust -------

Siwaliks?, Pleistocene, Recent alluvials

However, the ultramafic parts of Mayudia of Dibang and Tidding of Lohit are considered as a part of Ophiolitic Suite representing a suture zone correlatable with ITSZ (Indus Tsangpo Suture Zone) of Tibet. Intercontinental basin concepts with oceanic floor upliftment model as against intracontinental evolution of basin followed by under thrusting of the Indian slab are the two possible models, which needs rethinking.

5.1.5 Lohit Granitoid Complex (LGC)

According to some workers of GSI (with reference to some unpublished reports) the metasedimentary to volcanic lithopackages are separated from Northern Crystalline Mass (i.e Lohit Granitoid Complex, LGC) by a major thrust named as Lohit Thrust (Nandy and Banerjee, 1968; Nair and Shankar, 1981), whereas some others are in favour of an intrusive relations (Chattopadhyay and Chakraborty, 1980; Boral and Saha, 1981; Nandy, 2004)

Huge occurrences of intrusive masses of diorite – granodiorite- tonalite and granite masses associated with high-grade gneissose / schistose assemblages are designated as Lohit granitoid complex (LGC) by earlier workers (Nandy, 2001 and a few references therein). This NW-SE trending monotonous body is also named as Mishmi massif, thrusting over the metavolcanics and metasedimentary components of the Dibang Group. This thrust is conventionally named as Lohit thrust by early
workers (Nandy op.cit). The granite is leucocratic comprising of quartz, feldspar, hornblende and biotite as dominant mineral phases. The tongues and apophyses are clearly seen. The rock is schistose, pulverized, mylonitised and is supposed to be thrust over the metasedimentaries of DG as Lohit Thrust (Nandy et al., 1975). The so-called Lohit thrust is believed to be the eastern continuation of Main Central Thrust (MCT) of Western Himalaya. But the present study signatures a few evidences about the Lohit thrust. They are

i) In the Lohit section a huge litho section of gneisses are seen and they mark a contact zone with the Tidding metavolcanosedimentary units around Tidding.

ii) Around Wallong interface between gneiss and granitoids is well marked.

iii) In Dibang valley also highly folded faulted gneiss are seen after metasedimentovolcanic sequence.

They are associated further north by Lohit granitoid. Tuting metavolcanics are seen which probably marks the interface between Lohit granitoids and gneisses. Similar observations are seen in the southeastern strike continuity around Desali (Rajesham and Dutta, 1983) and between Tidding and Mitiliang in Lohit Valley (Chattopadhyay and Chakraborty, 1975). The thickness of the LGC is more in Lohit valley as compared to Dibang valley. In reality, the southern boundary of the granitoid is closely associated with banded gneisses of acidic and basic composition in both geotransects. It is probable that the asssociated gneisses belong to Proterozoic and are
intruded by Lohit granitoid. Detailed field based observations and geochronology may throw some insight into the problem, whether Lohit Thrust is located between gneisses and metavolcanosedimentary units or between LGC and DB.

As regards tectonostratigraphic succession of the Dibang valley and Lohit valley, a few authors’ tabulated successions are given below for references and correlation. Gururajan and Chowdhury (2003) have advocated lithostaratigraphic succession of the lohit valley as follows:

<table>
<thead>
<tr>
<th>Eastern Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lohit Plutonic Complex-------------------Walong Thrust--------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Western Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>Lohit Thrust---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tidding Suture zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidding Thrust-------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upper units-metapelites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mishmi Crystalline ------</td>
</tr>
<tr>
<td>Thrust--------------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Units --Bomdila Gneiss</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCT--------------------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lesser Himalayan rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mishmi Thrust----------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alluvium</th>
</tr>
</thead>
</table>

Further Gururajan and Chowdhury (2007) claims that lower parts of Mishmi Crystalline is equivalent to Bomdila Group of WAH and MCT is placed at the base of this unit. They have dated LPC as 64±10 Ma. Chaudhury et al (2009) have further...
elaborated lithostratigraphic sub divisions of the Lohit, Dibang and Siang valley where they have shown Siwalik Group followed by Gondwana Group below Lesser Himalayan Sequences (only available in Siang valley). And the other two valleys Lesser Himalayan rocks (from south to north) are separated from Lesser Himalayan Crystalline by Bomdila thrust and HHC are tectonically thrust over LHC along MCT. HHC is overlain by Tidding Suture zone along Tidding thrust and lastly Lohit thrust tectonically brought the multiple crystalline sequences of LPC. Walong thrust is place between Eastern units and Western units of the LPC. Mishra also suggested tectonostratigraphic succession of the Mishmi block as follows (from south to north):

LGC (Lohit Granitoid Complex)

-------------Lohit Thrust-------------

Tidding Formation

-------------Tidding Thrust-------------

Mayudia group

-------------MCT-------------

Lalpani Group

-------------Lalpani Thrust-------------

Sewak Group

-------------Mishmi thrust-------------

Brahmaputra alluvium

With respect to the above stratigraphic successions, an attempt has been made to revise the tectonostratigraphic succession as follows (Table.5.1):
**Table 5.1** Modified tectonostratigraphic succession of the Dibang valley of Eastern Arunachal Himalaya (modified after Burhauddin and Nandy, 2004)

<table>
<thead>
<tr>
<th><strong>Lohit Granitoid Complex</strong></th>
<th>Diorite, granodiorite, tonalite, gabbro, granite, Leucogranite, mafic dykes and sills</th>
<th>Tertiary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Italin Formation</strong></td>
<td>Garnet-staurolite-kyanite schist, garnetiferous amphibolites, quartzite</td>
<td></td>
</tr>
<tr>
<td><strong>--------------------------</strong> Intrusive /DSZ/Lohit Thrust <strong>--------------------------</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tuting Metavolcanics</strong></td>
<td>Amygdular sheared Basalt, ultramafics, serpentinite, crystalline limestone, metavolcanics</td>
<td>Cretaceous</td>
</tr>
<tr>
<td><strong>Tidning Metavolcanics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mayudia Mafic-Ultramafic complex</strong></td>
<td>Ultramafics (peridotite/serpentinite/pyroxenite); dunite, amphibolites with interlayering of cherty quartzite, leucogranite veins, garnetiferous graphite schist, Hornblendite dykes/sills.</td>
<td></td>
</tr>
<tr>
<td><strong>--------------------------</strong> Mayudia Thrust <strong>--------------------------</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GROUP</td>
<td>Formation</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DIBANG</td>
<td>Hunli Formation</td>
<td>Quartz-chlorite ± actinolite schist with thick carb. Phyllite, phyllite and thin intercalations of limestone, carbonate rock.</td>
</tr>
<tr>
<td></td>
<td>Ithun Formation</td>
<td>Amphibolite intercalations of quartzite</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>------DSZ------------------------</strong></td>
</tr>
<tr>
<td></td>
<td>Roing Gneiss</td>
<td>Augen gneiss in association with amphibolites and quartzite, hornblende schist. Actinolite schist.</td>
</tr>
<tr>
<td></td>
<td>Bomdila Gneiss</td>
<td>Meso-proterozoic</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>------Mishmi Thrust------</strong></td>
</tr>
<tr>
<td></td>
<td>Pleistocene River terrace/ Quaternary sediments</td>
<td></td>
</tr>
</tbody>
</table>

**Mishmi Thrust**
5.2 Metamorphism

The area under study witnessed a series of rocks belonging to Proterozoic to Cenozoic period and registered characteristic imprints of metamorphism. From the lower structural level to higher structural level, the Himalayan metamorphic belt of Arunachal Himalaya display a series of sequence of quaternary sediments/Pleistocene river terrace at the southern end of the Indian Territory, Siwalik, Gondwana, LHS (LHC+LHSS) and HHS. The Tethyan sequence and Tibetan plateau are located in the north and geographically belong to Tibetan Territory. The above sequences are differentiated by a number of significant Thrust system namely MFT, MBT, MCT, ITDS etc. The western, central and Siang sectors portray significant inverted metamorphism but there are some exceptions in the Dibang and Lohit valley sectors of the Eastern Arunachal Himalaya (Mishmi massif). References of tectonic framework and inverted metamorphism of rest parts of the Central and Western Great Himalaya may be quoted here and it is apparent that the entire belt from West to East displays a significant southward convexity and classic inverted metamorphism. Sharma (2005) has categorically mentioned that such types of inverted metamorphic signatures are nowhere observed in plate tectonic related orogenic belts of the world. He has further suggested that the basement-cover relationship of Himalayan orogenic belt is very much complicated and hence deformational cum metamorphic history needs rethinking why most of the precollisional signatures either disappear or readjusted during syn Himalayan orogeny.
Based on mineral assemblages and their textural relationships Jain et al. (2002) have advocated that Himalayan metamorphic belt displays three notable episodes of metamorphism namely

1. Pre Himalayan metamorphism
2. Syn Himalayan or main Himalayan metamorphism and
3. Post Himalayan metamorphism

They have further classified Himalayan metamorphism into \( M_1 \) (Premetamorphism), \( M_2 \) (Synmetamorphism) and \( M_3 \) (Postmetamorphism) corresponding to \( D_1, D_2 \) and \( D_3 \) phases.

In the study area, the effects of metamorphism and the gradual changes during prograde metamorphism as well as retrograde phases are registered in the different lithounits specifically metasedimentary and metavolcanics, mylonitic augen gneiss and hardly mafic and ultramafics with increasing grade of metamorphism. Increase of metamorphic grade with increasing structural high as evidenced in rest parts of the mountain belt is not significantly noted in the Dibang valley although the same inverted metamorphism is observed in the adjacent Lohit valley. As the two valleys (Dibang and Lohit) are significantly strike extension of one another, therefore it would be probably wise to accept the concept of metamorphic inversion in the Dibang valley too. Sharma et al. (2009) have noted basic differences between WAH (Western Arunachal Himlaya), IMMB (Indo Myanmar Mobile Belt), Siang sector and Mishmi Block (both Dibang and Lohit valley) of Eastern Arunachal Himalaya in terms of strike extension, lithology, lithosequences, structure, metamorphism as well as absence or presence of Tethyan
sequences and claimed that Mishmi block maintains a separate entity in the geological history and not a continuation either of IMMB or Western Arunachal Himalaya.

An attempt has been made in this chapter to trace the metamorphic history on the basis of mineral assemblages of the rocks of the different stratigraphic units, formation of different index minerals like biotite, garnet, kyanite and staurolite in the metapelites associated with other mineral components of the metabasic, metavolcanic, gneisses and other schistose rocks of the area. Based on the presence of such mineral assemblages, concepts of zones, facies, facies series and grades are made use of.

However, metapelites are undoubtedly the most diagnostic indicators of the gradual transformation that took place with increasing grade and consequently, it is on the basis of these rocks that Barrrovian zones could be recognized.

Metapelites are fine to medium grained strongly anisotropic, foliated and crenulated rocks having biotite, muscovite, garnet, staurolite, kyanite and quartz as the dominant mineral phases. Pretectonic to most pervasive phase during D$_2$ is marked as garnet$_1$ showing intrafracture oblique to CS$_2$ foliation (Figs. 5.1, 5.7, 5.8, 5.12) and syntectonic growth of garnet (garnet$_2$) porphyroblasts during D$_2$ deformation are very significant in the metapelites at a lower structural level between Mayudia and Hunli (Figs. 5.2, 5.10, 5.11), where as staurolite and kyanite both are characteristically developed in metapelites near Italin (Figs. 4.34 & 4.35). Syntectonic garnet (garnet$_2$) displays overgrowth of post tectonic rim (Figs. 5.2, 5.3, 5.9, 5.14). Post tectonic (garnet$_3$) to D$_2$ deformation is seen to occupy S$_i$ fabric equals to S$_e$ (Fig.4.39). Garnet$_2$ porphyroblast is zoned and occasionally alters to chlorite and / or biotite and such
alteration along grain boundary or fracture zone is a sign of retrogression phase (Fig. 5.13). Garnet$_2$ sometimes found in skeletal form and syntectonically developed with S$_1$ fabric named by micas, quartz and magnetite (Figs. 4.2, 4.78) in augen gneiss and Lohit granitoid. Some garnet porphyroblast had overgrown the CS$_2$ foliation during Himalayan orogeny without flattening and deformation suggesting post tectonic to major recrystallisation stage during D$_2$ Himalayan episode and they are referred to as garnet$_3$ (Figs. 5.4--5.6). There is a change in the grain size of the metapelites from fine grained phyllitic rocks of the garnet zone to the medium to coarse grained schistose rocks. The two index minerals (kyanite and staurolite) occur together in a matrix mainly consisting of quartz, biotite, muscovite, plagioclase, magnetite, zircon and apatite. Muscovites are highly crenulated and S$_3$ crenulated cleavage is formed (Fig. 5.15). Staurolite developed during D$_2$ phase (staurolite$_1$) and D$_3$ phase (staurolite$_2$) showing evidences of sygmoidal rotation with lots of S$_1$ fabric (Figs. 4.36 & 4.37). It is interesting to note that some garnet incorporate highly crenulated CS$_2$ fabric. Such crenulations are formed during F$_3$ folding and as crenulations are incorporated by garnet, therefore, growth of garnet may be referred to as garnet$_4$ and might have grown either during D$_3$ or last part of D$_3$ itself (Figs. 5.5, 5.6, 5.8). Everywhere CS$_2$ foliation is parallel to the thrust planes or tectonic contact zones. kyanite blades in metapelites are oriented parallel to the regional pervasive foliation (CS$_2$). In LGC syntectonic garnet (garnet$_2$) are showing rotational fabric (Figs. 4.77 & 4.78). Biotite and muscovite along with elongate quartz define regional foliation during Himalayan orogeny and such shear foliation is designated as CS$_2$ and they wrap around k-feldspar porphyroblast and sometimes big flakes of mica showing evidences of grain granulation. The latter one is
designated as mica fish and belongs to syn Himalayan orogeny. In spite of repeated check, no sillimanite is found neither in the form of prismatic/rhombic nor in fibrolitic form from low to higher structural level. Some authors have reported sillimanite in the form of fibrolite at some higher structural level around Italin. If it is so, such fibrolite is present it may be related to hydrogen metasomatic origin (Vernon, 1979) and/or deformation induced fibrolitisation along small scale shear zones (Wintsch and Andrews, 1988), the second possibility is apparently more realistic in the present area. Therefore, it is apparent that metapelitic rock bears the evidences of upper part of greenschist to middle part of amphibolite facies metamorphism. This observation is in conformity with the observation made by Nandy et al., 2005 and Sarma et al., 2009.

Metavolcanics contain actinolite, epidote, quartz, plagioclase and occasionally tremolite along with opaque minerals and they set the fine to medium grained foliated matrix. They are partly mylonitised and CS foliation and is characteristically wrapped around actinolite porphyroblast. Syntectonic cpx porphyroblast are seen to have developed during Himalayan orogeny in ultramafics (Figs.4.61 & 4.62). Quartz forms the ground mass as elongate inequant grains and sometimes occurs as S1 fabric into actinolite grains. Zoned post D2 olivin in ultramafics is observed and sets in a granoblastic matrix (Fig.4.63). In metabasics and sheared amphibolites, brown coloured asymmetric hornblende porphyroblasts are found and they are rotated both dextrally and sinistrally (Fig. 4.23). Garnet and hornblende porphyroblasts both occur together and the former is partly altered to mica (Fig.5.13). The CS2 fabric is deflected around such porphyroblasts suggesting growth during Himalayan deformation. Post tectonic hornblende (post D2) porphyroblast are also observed and truncation of CS2 is
more prominent at the boundary of such porphyroblasts (Fig...). Due to shearing, both actinolitic hornblende and hornblende porphyroblasts are marginally crushed and grain granulation is seen resulting development of epidote at the contact zone. Similar characters are seen in augen gneiss composed of k feldspar - plagioclase - quartz - biotite - muscovite - apatite - tourmaline - zircon and occasionally garnet. Garnets are sometimes found as skeletal form and take part in the formation of $CS_2$. Feldspar and quartz grains are marginally crushed and feldspar are rotated both along dextral and sinistral motion. In mafic and ultramafic rocks pyroxene and sometimes olivine porphyroblasts show rotational habit and $CS_2$ foliation wraps them. Such porphyroblasts are developed during Himalayan orogeny.

Presence of garnet, staurolite and kyanite as index minerals in metapelites and hornblende, actinolitic hornblende, clinopyroxene in metabasites indicates that the rocks have undergone metamorphism under garnet to staurolite kyanite zones belonging to greenschist and middle part of amphibolite facies (Winkler, 1965; Turner, 1968) which corresponds to epidote – amphibolite facies of Thomson and Norton (1968) and greenschist – amphibolite transitional facies of metamorphism (Turner, 1978). The overall grade concept as proposed by Winkler (1976), if applied, it can be can also be equated with medium grade metamorphism.
Fig. 5.1 Pretectonic garnet (Garnet₁) to Main Himalayan Orogeny (D₂); CS₂ foliation wrap around garnet porphyroblast resulting shadow zone occupied by felsic matrix, garnet shows intra fractures oblique to CS₂ in metapelite.

Fig. 5.2 Syntectonic garnet (Garnet₂) developed during Main Himalayan Orogeny (D₂); Overgrown of M₃ garnet as rim (inclusion free zone); CS₂ foliation wrap around garnet porphyroblast in metapelite.

Fig. 5.3 Post tectonic garnet (Garnet₃) to Main Himalayan Orogeny (D₂); CS₂ foliation penetrates into garnet porphyroblast as Sᵢ fabric; neck zone of the two garnets is occupied by micaceous matrix in metapelite.
Fig. 5.4 Syntectonic garnet - extreme right-(Garnet$_2$) to Main Himalayan Orogeny (D$_2$) is overgrown by inclusion free outer rim -(Garnet$_3$); CS$_2$ foliation truncate garnet porphyroblast ; CS$_2$ is crenulated by F$_3$ folding showing development of S3 cleavage in metapelite.

Fig. 5.5 Syntectonic to D$_3$ garnet - extreme right-(Garnet$_3$) or post tectonic to Main Himalayan Orogeny (D$_2$) bears crenulated F$_3$ as S fabric; inclusion free outer rim is interpretated as Garnet$_4$;

Fig. 5.6 Same as Fig. 5.5
Fig. 5.7 Pretectonic garnet (Garnet₁) to Main Himalayan Orogeny (D₂); CS₂ foliation wrap around garnet porphyroblast; garnet shows straight S; fabric marked by tiny particles discordant to CS₂ in metapelite.

Fig. 5.8 Pretectonic garnet (Garnet₂) to Main Himalayan Orogeny (D₂); CS₂ foliation is passing through garnet porphyroblast; garnet shows slight curve S; fabric with inclusion free post tectonic rim in metapelite.

Fig. 5.9 Post tectonic garnet (Garnet₃) to Main Himalayan Orogeny (D₂); CS₂ foliation truncate around garnet porphyroblast; garnet shows Sₘ fabric equivalent to Sₑ fabric in metabasite.
Fig. 5.10  Syntectonic garnet (Garnet2) to Main Himalayan Orogeny (D2); S fabric marked by small elongate, almost equant quartz minerals showing curved, 'Z' pattern trails of inclusions and CS2 is deflected round the porphyroblast in metapelite.

Fig. 5.11  Syntectonic garnet (Garnet2) to Main Himalayan Orogeny (D2); S fabric marked by small elongate, almost equant quartz minerals showing curved, 'S' pattern trails of inclusions and CS2 is deflected round the porphyroblast in metapelite.

Fig. 5.12  Pretectonic garnet (Garnet1) to Main Himalayan Orogeny (D2); CS2 foliation wrap around garnet porphyroblast; garnet shows straight S fabric marked by tiny particles of quartz and micas in garnetiferous phyllite.
Fig. 5.13  Post tectonic garnet (Garnet$_3$) in amphibolites showing alteration to micas at the centre. Hornblende plates are partially sheared along grain boundary and epidote is developed.

Fig. 5.14  Post tectonic garnet (Garnet$_3$) incorporating $S_h$ fabric amphibolites showing alteration to micas at the centre. Hornblende plates are partially sheared along grain boundary and epidote is developed.

Fig. 5.15  Highly crenulated mica schist forming $F_3$ folding with formation of $S_3$ along strain zone; partial discreet zonal planar fabric is seen in metapelite.