CHAPTER - II

GEOLOGICAL SETTING AND STRUCTURES
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This chapter aims at describing the various litho-units occurring in the area, their field setting and distribution together with the structures documented in them and their analyses.

LITHOCLASSIFICATION:

Lithostratigraphically the rocks of the area have been classified into two groups; Wangtu Gneissic Complex and Karcham Group. The former is characterised by medium to high grade biotite gneisses and schists, in which are emplaced lensoid bodies and small sheets of amphibolites, pegmatites and a few splilitic veins. This group covers more than 3/4th part of the area. The rest 1/4th of the area lies in the eastern part of the study area and exposes the rocks belonging to Karcham Group.

The Karcham Group in the area is represented by Rampur (Manikaran) Quartzite and Garnet-mica Schist Member. Based on the current bedding preserved in the psammite units, the sequence of Karcham Group is observed to be right-way-up. On
TABLE - 1

<table>
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<tr>
<th>Karcham Group</th>
<th>Psammitic gneiss</th>
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<tr>
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<td>Interbanded garnet-mica schist</td>
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<td>and psammitic gneiss</td>
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<td>Rampur Quartzite</td>
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<td>Wangtu Gneissic Complex</td>
<td>Interlayered augen gneiss and</td>
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<td>finely banded gneiss</td>
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the bases of grade of metamorphism and tectonic position (see Chapter-VI) Wangtu Gneissic Complex is considered older to Karcham Group. Table-1 thus also represents a broad sequence encountered.

This order of superposition also lends support from the relict current bedding structures in the psammitic gneiss (lying to the E of the area covered, map, Fig.5) and overlying the Garnet-mica Schist Member. The biotite gneisses of Wangtu Gneissic Complex structurally and texturally are of various types, viz., augen gneiss or porphyroblastic gneiss, banded gneiss and mylonite gneiss. The Garnet-mica Schist Member comprises grey garnet-mica schists interbanded finely with quartz schist and psammitic gneiss. It also contains bands of calc-gneiss.
There is a gross lithological change between the Wangtu gneisses and the overlying metasediments of Rampur Quartzite and Garnet-mica Schist Member. This marked lithological change has helped in classifying the gneisses into a separate group designated as Wangtu Gneissic Complex. This delineation is also evinced by the reported Rb-Sr ages which have returned whole-rock isochron age of 2030 ± 50 Ma for the Wangtu gneisses, the oldest age so far known for the Himalayan rocks of this region. The Rb-Sr age for psammitic gneisses overlying the Garnet-mica Schist Member is much younger (approx. 700 Ma, personal communication, Geochronology group, Department of Physics, Panjab University). Further the contact between the Wangtu gneisses and the Rampur Quartzite is observed to be a thrust, marked by about 1 m thick mylonite zone. The two groups are separated by Karcham Thrust (Table-1). Kakar (in press) has also included the Rampur Quartzite and Garnet-mica Schist Member in his Karcham Group.

It may be appropriate here to make a mention of Valdiya (1973, 1976, 1979), Sharma (1976, 1983) and Bhargava (1980, 1982) on their ideas about the classification of these rocks.

Valdiya (1973) recognised 'Vaikrita Thrust' to demarcate the base of high grade rocks of Joshimath Formation from the underlying low grade rocks of Munsiari Formation in the Kumaon Himalya. Later, in 1979, he extended his observations in the
Satluj valley and put a thrust about 3 km NE of Karcham and designated the rocks overlying the thrust as Vaikritas, on the basis of a break in metamorphism. Following Valdiya, Sharma (1976, 1963) designated the rocks underlying the 'Vaikrita Thrust' as Jutoghs and emphasised that the contact between these 'Jutoghs' and the overlying 'Vaikritas' marked a break in metamorphism between the two units. He stated that Wangtu gneisses and carbonaceous schists were of low grade and the overlying 'Vaikritas' being kyanite bearing were of high grade of metamorphism.

The author, however, observed that the Wangtu gneisses and garnet-mica schists are also high grade rocks on the basis of sillimanite and staurolite found by him in these rocks. Thus the induction of 'Vaikrita Thrust' on the basis of presumed metamorphic break becomes untenable. Even, Valdiya (1979, p. 149) himself observed that, "there is no structural discordance indicating the existence of a thrust plane, nor are there geomorphic expressions of the weak-zone. Rather, there seems to be an unbroken succession of rocks. However, there is an abrupt change in the grade of metamorphism and composition of lithology."

Bhargava (1980) believes a thrust between the top of Rampur Quartzite and the Garnet-mica Schist Member. The existence of this thrust is not that crucial as the nature of
the contact between the Wangtu gneisses and the Rampur Quartzite. For the normal contact between the Rampur Quartzite and Wangtu gneisses would mean that their contact is either a normal stratigraphic contact or an unconformity between the two. The author observed the existence of 1 m thick mylonitized-zone between the base of Rampur Quartzite and top of Wangtu gneiss. This tectonic contact has been designated as Karcham Thrust.

The regional picture of the Wangtu gneisses is that of a dome as envisaged by Berthelsen (1953). This interpretation is apparent from the regional map compiled by Bhargava (1982), reproduced here in Fig. 6.

Shreedhar et al. (1986) and Kakar (in press) agree with Tewari et al. (1978) who believe the existence of a thrust at the base of Rampur Quartzite as stated earlier, the former designated it as Karcham Thrust.

Wangtu Gneissic Complex:

A major part of the area is covered by the Wangtu Gneissic Complex which shows thick mappable bands of two types of gneisses: augen gneiss and finely banded gneiss. The deepest lithological unit is augen gneiss which is then repeated twice again being separated by two layers of finely banded gneiss.
The complex is overlain successively by Rampur Quartzite and the Garnet-mica Schist Member of Karcham Group. The Rampur Quartzite pinches out to the NW of Karcham where Garnet-mica Schist Member comes directly in contact with the Wangtu gneiss. The contact between the two groups is marked by a 1 m thick mylonitic zone (Karcham Thrust). The whole-rock Rb-Sr isochron age for Wangtu Gneissic Complex has been reported to be of the order of 2030 ± 50 Ma, with initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio at 0.710 (Sharma, 1976; Pandey, 1981).

The Wangtu Gneissic Complex has been mapped on a 1:25,000 scale and two lithological units, augen gneiss and banded gneiss, have been delineated. These bands have stratigraphic repetition and are also repeated due to major folding (see map, Fig.5). The contact between these two lithological units is not always sharp. The augen gneiss shows variation in the size of augen and contains locally finely banded gneisses, in bands measuring about 1 m. The existence of a major fold resulting in the repetition of the lithounits is seen by a change in attitude of gneisses from N-S trend with dip varying 40°-50°, E, near Karcham, to ENE-WSW, dipping 50°-55° NNW, near Wangtu. Local variation in the amount of dip is due to mesoscopic warping and folding. Regionally a persistent attitude is dominant and is well observed along a road section between Tapri and Runang and other sections (map, Fig.5).
Pegmatite and aplite veins occur in the gneisses, both along and across the foliation. Metabasic rocks, now amphibolites, predate the pegmatite-aplite acid phase and the metamorphism of gneisses. The aplites generally occur sub-parallel to the foliation of the gneisses. Small bands of psammitic gneiss are seen interbanded with the Wangtu gneisses. Encrustation of sulphur on the rock surface is a common feature especially near Tapri and Karcham. Sharma (1976) reports the existence of a radioactive mineral autunite, in the gneisses.

Augen gneiss: It is the most well represented rock unit and is seen widely distributed in the area. Three bands of augen gneiss were encountered while working on a section along Satluj river. These bands were also observed in the other sections of the area. Good exposures of augen gneiss are met with near Kaksthal and Tapri, around Ramni and between Kilba and Baltarang Mill. The exact variation in total thickness of augen gneiss bands cannot be deciphered since the lower most band of this gneiss which forms the core of the major antiformal fold is not fully exposed. The measurable total thickness as measured in sections varies between 900 to 1100 m. The outcrop of augen gneiss takes a turn to the north of Satluj near Tapri where the fold closure is seen.

The augen gneiss contains well-developed augen generally of K-feldspar and also of feldspar and quartz. The latter have been designated as pseudo-augen (Mehnert, 1971).
the composition of augen are discussed in petrography (Chapter-III). The size of the augen attained is up to 10 cm in length and exceptionally it exceeds 15 cm as seen near Chagaon village. The augen have sharp boundaries with the matrix and are mostly aligned parallel to the foliation surfaces (Fig. 7a). Quartz veins of thickness up to 20 cm criss-cross at places and sometimes exhibit ptygmatic folding. Amphibolite bodies are common. The original bedding in the augen gneiss is almost lost. At places transposed bedding (Fig. 8d) may be noticed at distinct lithological contacts.

Banded gneiss: It is a well-developed unit in the area, exposed around Wangtu, old Tapri and Thokru villages and measures between 300 to 3250 m in thickness. This unit occurs in two horizons separated by augen gneiss. The whole sequence is also repeated due to folding. This gneiss is characterised by stromatic structure or banding which is remarkably persistent and measures from 6 to 15 cm thick bands formed of alternate leucocratic and melanocratic layers. Schist bands are occasionally seen interbanded with the banded gneiss. Amphibolite sheets and lensoid bodies run mostly parallel to the foliation and a few cut across it. Pegmatite and aplite veins and sheets are disposed both along and across the foliation and are sometimes tourmaline bearing. The rocks exposed around old Tapri follow the trend of underlying augen gneiss and the outcrop takes a turn towards north of Satluj, which is suggestive of existence of a major fold.
Mylonite gneiss: A thin zone of about 1 m thick mylonitized gneiss occurs between the uppermost augen gneiss band of Wangtu Gneissic Complex exposed in the area and the Rampur Quartzite evincing a thrust contact between the two lithounits near Karcham. This thrust contact has been designated as Karcham Thrust. The augen have been drawn in the plane of foliation. The dip of the shear zone is parallel with the general trend of the foliation and layering of the quartzite which is NW-SE, dipping 50° to NE. In the present classification Rampur Quartzite has been included in Karcham Group.

Karcham Group:

Only a small portion of the Karcham Group is exposed in the eastern part of the investigated area, where it is represented by Rampur (or Manikaran) Quartzite followed by Garnet- mica Schist Member which in turn is followed by psammitic gneiss lithounit. Karcham Group is thus characterised by a different suite of metasediments compared with the underlying Wangtu Gneissic Complex.

Rampur Quartzite: Based on the work of Tewari et al. (1978) and Bhargava (1982) who have shown the continuation of Rampur Quartzite in the Karcham area, its designation as Rampur Quartzite has been accepted. Sharma (1976) and Bhargava (1980), however, designated it as Manikaran Quartzite.
Rampur Quartzite forms a band of about 50 m thick, of white to brownish-white, vitreous and foliated quartzite composed almost entirely of fused and flattened quartz grains. Presence of tiny flakes of mica are discernible at places which pronounce its foliation. The current bedding preserved in the quartzite reveals its right-way-up disposition and hence for the overlying sequence which follows it without any break. The quartzite maintains a fairly persistent attitude in the area with some variation in strike from N-S to NNW-SSE and dip 50°, E to ENE. It, however, appears at Karcham and continues further NW and then is not seen in the map area again. Regionally, it appears again and limits the boundary of the Wangtu Gneissic Complex (Fig. 6) as shown by Bhargava (1982).

As mentioned earlier, Bhargava (1982) has marked the thrust at the top of this quartzite band thus including it in his Jeori-Wangtu-Gneissic Complex. The writer has observed that a thrust exists between the Wangtu Gneissic Complex and the base of the Rampur Quartzite. The existence of a thrust at the top of quartzite is not as crucial and important as at the lower contact of quartzite because of the following observations: firstly, the contact between Rampur Quartzite and the overlying Garnet-mica Schist Member is a normal one and without any break; secondly, the contact between Rampur Quartzite and the Wangtu gneiss is more crucial than between top of quartzite and the Garnet-mica Schist Member. The latter point has already been elaborated in the preceding discussion on regional geology.
Garnet-mica Schist Member: With no apparent break, the Rampur Quartzite is overlain by Garnet-mica Schist Member. It is composed of a few bands of banded psammitic gneiss and calc-gneiss followed by thinly interbanded garnet-mica schist and quartz rich layers. The latter forms a major portion of the unit. The psammitic gneiss occurs in 10-20 cm thick bands with a few mm to 2 cm thick quartzite layers of various shades of light grey colour. Thin layers of marble are also encountered with psammitic gneiss. The garnet-mica schists conspicuously show the development of isoclinal folds in which transposed bedding is a notable feature (Fig. 8d). It also shows the development of almandine garnet upto 5 mm across and also staurolite (see Petrography, Chapter-III and also Chapter-IV for XRD analysis) which establishes its medium grade of metamorphism. The presence of diopside in calc-rich bands also lends support to it. The central part of the litho-unit is more schistose in which profuse development of garnet metacrysts is noticeable. Tight and isoclinal mesoscopic folds are frequent which maintain their limbs almost parallel to the general foliation trend (NE-SW) and plunge upto 15° in either direction. Later crenulations are also prominent (see under structures). Intersection lineation is also noticed and maintains its trend parallel to the axes of isoclinal or reclined folds.

Psammitic gneiss: It is a massive indurated gneiss, showing thin psammitic bands in various shades of grey varying
in thickness from a few mm to a few cm. The major portion of the Karcham Group is represented by this member but the study area covers only a part of this unit. The banding in psammitic gneiss is a relict original structure, which at places excellently exhibits the relict current bedding and penecontemporaneous deformational structures. The psammitic gneiss contains a few bands of about 5 cm thickness of quartz-garnet rock which occur parallel to the layering of the gneiss.

Amphibolites:

Amphibolites occur as irregular lenticular bodies, generally concordant but also as dykes, having a maximum thickness of 4 m. Most of the amphibolite bodies exhibit a subparallel alignment along the foliation except at a few places where they are disposed at high angle to the foliation. The foliation in the amphibolites is strong and is produced by the preferred orientation of hornblende prisms and mica flakes. The parallelism of foliation in the amphibolites and the gneisses indicates that the emplacement of the former occurred before or synchronously with the metamorphism of host country rocks. Depending upon the mineral constituents the amphibolites show greyish-green to dark-green colour. They are boudinaged at times but their impersistent occurrence in the field is not due to stretching alone.
The amphibolites of the area belong to ortho-
parentage (see Chapter-V on Geochemistry, also Shreedhar,
et al., 1986). Field relations like sharp contact with the
country rocks, their massive character and association with
calcium deficient rocks, also suggest their igneous origin.
Quartzo-feldspathic veins are sometimes noticed cutting the
amphibolite bodies.

**Pegmatites:**

Pegmatite veins and sheets are widely spread in the
study area, running usually across the foliation (Fig.9) with
contacts dipping 60° or more and striking NW-SE to N-S. These
vary in thickness from a few cm to 5 m and exceptionally upto
10 m. such as near Tapri.

Mineralogically, the pegmatites are uniform in
composition. The principal mineral constituents are feldspars,
quartz and muscovite with biotite and tourmaline as mafic
constituents, and occasionally beryl. K-feldspars and
plagioclases are perthitic and antiperthitic in nature; beryl
crystals are of light-green colour measuring 2-4 cm across and
rarely upto 10 cm across (cf. Sharma, 1976), and are of
prismatic habit. Near the margin of pegmatite body a crude
foliation sub-parallel to that of the country rocks, is formed
by micaceous minerals. Pinch and Swell structure in pegmatites
is a common feature forming boudin (Pl. IID and IIIE) or lensoid
bodies measuring up to 50 cm in length and up to 20 cm in width.

STRUCTURES IN THE AREA:

The regional disposition of the rocks of the study area has already been presented under regional geology. In brief, it may be stated here, that the area forms the eastern part of the Wangtu Gneissic Complex which makes its appearance due to its domal structure (cf. Berthelsen, 1953). The rocks of this complex belong to deeper crustal level and represents the oldest crustal part exposed in this part of the Himalaya. This is corroborated by Rb-Sr radiometric age of 2030 ± 50 Ma and also the initial value of \( ^{87}\text{Sr}/^{86}\text{Sr} \); which is 0.710 (cf. Sharma, 1976; Pandey, 1981). The western part of this domal structure is exposed in the study area where it exhibits an antiformal structure. This is revealed by detailed mapping of the litho-units of the area, variation in attitudes and repetition of litho-units. The general trend varies from E-W in the Wangtu area to N-S in the Karcham region. This fact is also brought out by the outcrop patterns of the gneisses. This antiform thus forms a major structure in the area. The other major structure is the Karcham Thrust, which has already been described at some length in the previous pages. The structures of the area may be classified as follows:
1. Relict sedimentary structures
2. Folds
3. Planar structures
4. Linear structures and
5. Joints.

Relict sedimentary structures:

There are a few sedimentary structures preserved in the area of which relict lamination and current bedding need special mention.

The term lamination has been used here as defined by Pyane (1942) and Mckee and Weir (1953) for a rock unit less than 1 cm in thickness and is defined by colour and/or lithology variation ($P_l$, $M_c$).

Relict current bedding: It is present in both the litho-units of Karcham Group i.e. Rampur Quartzite and Psammitic Gneiss ($P_l$, $M_{III C}$). It shows a right-way-up disposition for both these units and thus forms a basis for establishing the stratigraphy in the area, at least in the rocks of Karcham Group. The psammitic gneiss also shows relict penecontemporaneously deformed (fold) structures.

Folds:

Three generations of folds have been recognised in
the rocks of the study area which show variation in style and attitude of the axial surfaces.

First phase folds ($F_1$): These are reclined, isoclinel and recumbent type of folds (Fig. 8c) and are developed on mesoscopic scale as they have been observed on the outcrop level only. On large scale these folds have not been observed nor their presence is reflected by the outcrop pattern or the geometry of the fold structures.

The $F_1$ folds are associated with a strong axial planar foliation indicating that the rocks, underwent a strong phase of regional metamorphism and synchronous deformation during the $F_1$-phase.

Transposed bedding (Fig. 8d) in the garnet-mica schist is developed due to extreme flattening and thinning of the limbs of $F_1$ folds. The plot of $F_1$ fold shows a variation in attitude and plunge due to later folding. The notable trends are: plunge $10^\circ$ due N $30^\circ$ W; axial plane NE with $10^\circ-15^\circ$.

Second phase folds ($F_2$): They are developed both on macroscopic and mesoscopic dimensions. The domal structure of Wangtu Gneissic Complex belongs to this episode also. On mesoscopic scale these are symmetrical to asymmetrical, open
to tight folds plunging 30° towards north and north-east direction. A few mesoscopic folds, however, plunge in opposite direction especially those observed in the smallest part of the area south of Karcham.

Third phase folds ($F_3$): These structures were produced when the rocks were in brittle state and include crenulation folds belonging to the last phase of deformational history of the area. They are well-developed/are superimposed over $F_1$ or $F_2$ folds and plunge in the NE direction. Local faults and shears are seen parallel to fracture cleavage and crenulation cleavage.

Planar structures:

The relict primary planar structures comprise bedding planes which are defined by colour and lithological variations are designated as $S_0$. It is recognisable only at lithological contacts and in psammitic gneisses. The secondary foliations recognised in the rock units are $S_1$, $S_2$, $S_3$ and $S_4$.

$S_1$ is the most prominent foliation in the rocks of the area forming the axial surface of $F_1$ folds. Where $F_1$ folds are not apparent this foliation is strongly exhibited by gneissosity and schistosity as is evidenced by parallelism
between the axial planar fabric and the foliations. In gneisses it is obviously represented by gneissosity. The schist bands in the gneisses have schistosity parallel to the gneissosity. In Garnet-mica Schist Member, it is prominent and has the strike trend of \( S_1 \) surfaces varying from N-S to NE-SW with dips varying from 25° to 40°. Both the types of \( S_1 \) surfaces i.e. gneissosity and schistosity is almost parallel to the original \( S_0 \), which, however, is obliterated. The conclusion is based on the observations where lithological contacts between gneisses and schists and psammitic bands are discernible. Further, the contact between the Rampur quartzite and Wangtu gneisses shows a parallel orientation with \( S_1 \) surfaces.

\( S_2 \) surfaces are the foliations in the Wangtu gneiss corresponding to the axial-surfaces of \( F_2 \) folds which have a low angle plunge in ENE, NE and NNE directions. Plots of axes of these folds (Fig. 10) suggests their genetic relation with major \( F_2 \) antiform.

\( S_3 \) is a crenulation cleavage in the schists {\textsuperscript{dipping} 30° due NE-SW. \( S'_3 \) is the close spaced jointing which has been observed in the more massive rock units of the study area, trending 73° due SW.
Linear structures:

The term 'linear structure' has been used here as defined by Cloos (1946) as, "any kind of linear structure within or on a rock". Only a few linear structures have been encountered in the area and are described below:

Intersection lineation: The lines of intersection of the S-surfaces produce intersection lineation and is displayed as trace of one surface over the other. In the study area, this type of lineation is represented as intersection lineation of $S_0$ and $S_1$ surfaces in the schistose and gneissic rocks and also as rodding in the more psammitic units. It is not a very common feature in the area. This type of lineation shows a plunge $N30^\circ W$ amounting to about $15^\circ$. This type of lineation is also exhibited by intersections of $S_1/S_2$ and $S_2/S_3$. The former is more common and has plunge towards north and north-east direction.

Mineral lineation: The development of mineral lineation in the study area is very restricted. It is seen only in amphibolites where prismatic hornblende needles have aligned themselves in a preferred orientation in the foliation plane. This lineation has a plunge of $20^\circ$ in direction $S70^\circ E$. 
Boudin: Boudin or boudinaged structure is caused in the more competent layers when they are subjected to tensile stresses. This structure is present in the more psammitic bands (Fig. 8b) which are separated by rather thick incompetent layers. Apart from some psammitic bands the structure is more common in the amphibolites and pegmatites which are sub-parallel to the foliation of the country rocks.

Joints:

These are divisional planes or surfaces that divide the rock and along which there has not been visible movement parallel to the plane (Billings, 1960). Statistically two sets of joints have been recognised and the mean trend noticed is NW with dip amount 62°-73° and NE with dip amount 74°-78° (Fig. 11). The most prominent large scale joints are master joints which form dip slopes and their intersection form depressions and at high altitudes they form sites for the accumulation of ice.

Shears (minor faults):

Shears are noticed at many places in the area. Some of the shear zones show movement upto 1-2 m. Along some of
Fig. 4 Plots to the poles of $S_1$-surfaces
GEOLOGICAL MAP OF THE WANGTU-KARCHAM AREA DISTT. KINNAUR H.P. INDIA

GEOLOGICAL SECTION ALONG A-B

LEGEND
- PSAMMITIC GNEISS
- HANDED GNEISS
- GNEISSIC SCHIST
- SCHIST
- LIMESTONE
- MARBLE
- MARLY MARBLE
- AQUIFER
- EASTERLY JOINT
- WESTERLY JOINT
- STUPEFY
- TERMINATION
- TWINNING
- CRYSTAL

Fig. 5
Fig. 6 Regional geological map of the area between Rampur and Karcham. Area investigated is indicated.
a Light grey coloured augen gneiss with porphyroblats of feldspar near 6 Km stone on Tapri-Wangtu section. Foliation mainly marked by biotite.

b Lense of quartz and feldspar in gneiss near 2 Km stone on Tapri-Wangtu section.

Fig. 7
Fig. 8  (a) Deformation of primary structures in psammitic gneiss.
(b) Folded boudinage of quartzo-feldspathic layer in augen gneiss.
(c) Reclined fold in quartzo-feldspathic layer in augen gneiss.
(d) Tight isoclinal F₁ fold in banded staurolite-garnet schist in which thin layers exhibit transposed bedding (inset).
Fig. 9 Pegmatite vein in augen gneiss near 7 Km stone exposed on the Tapri–Wangtu road section.
Fig. 10 Plot of F-rich fold-axes (Lower hemisphere)
Fig. 11 Plot of Joint Planes