In this chapter, the author has attempted to reconstruct the regional structure of the Manali-Rohtang region. This is based on the detailed investigations carried out in the area under study and on the basis of observations made during the Manali-Leh expedition organized by the Centre of Advanced Study in Geology in 1969, of which the author happened to be a member. Part of the observations are also based on the work by the author during the course of the study of the geology of the Spiti Valley area under 'Terrain Evaluation', scheme of Ministry of Defence, Government of India.

The study of the rocks of the Manali area revealed that these have been repeatedly subjected to orogenic movements (See Chapter V on Structure) as the great Himalayan range and central crystalline axis emerge in each other at Rohtang Pass (Saxena, 1971, personal communication). At Rohtang, an overturned anticline trending NW-SE forms the youngest fold system, superimposed on the earlier folds trending almost N-S to E-W in the area (Chapter V). The rocks on the northern side of the study area show repetition of crystalline formations with steep dips in NE direction (Section Fig.5).

The rocks of Manali-Rohtang area show a general upward increase of metamorphism. This increase of metamorphic grade is not due to the inversion of metamorphic series, but is only apparent, and is due to the tectonic inversion such as a nappe
Scheme showing the possible relations between the development of metamorphism and Tectonics in the Manali region and the adjoining area.

Fig. 40

1. Caledonian and Palaeozoic

2. End of Mesozoic (Modified after Pande, 1967)

3.

4.

5.
structure (cf. Gansser, 1964; Wenk, 1968; Fuchs, 1968; Saxena, 1970) (Section Fig. 3.). This nappe extends southwards and is probably represented by a thrust (Jutogh) near Kulu which forms the Kulu nappe.

Ashigirei (1971, personal communication), who visited a part of this area along with the author, also agrees that the Manali-Rohtang region forms part of the root zone of a nappe extending towards south.

The central ridge, which is said to have come into existence during Devonian (Pande, 1967; Pande and Saxena, 1968) and in Proterozoic (cf. Khain and Milanovski, 1968; Saxena, 1970, personal communication) was separating the 'Himalayan basin' (Fuchs, 1968) or Miogeosyncline (Pande, 1967) from that of the 'Tethys basin' or Eugeosyncline (Pande, 1967) during the Mesozoic Era. The present author believes that the crystalline axis was possibly rejuvenated during the Himalayan orogeny. The spread of this rejuvenation is unknown. It is just possible that further north of Jaspa this crystalline zone may form the base of the Tibetan sediments. Similar relations of the rock units have also been found in the Simla Himalayas by Pande and Saxena (1968) and in the Nepal Himalayas by Frank and Fuchs (1970).

The highly crumpled and dragged nature of the lower grade units near Kulu below the Jutogh thrust show that this crystalline nappe was one of the most active tectonic elements of the Himalayan orogenesis.
The overturning of the root zone does not appear to be the cause of the crustal shortening but is due to the dragging upwards and outwards of the sediments near the root zone and their ultimate overturning and overthrusting towards the south. Because of the oblique transcurrent motion, the southern flank of the axis is thus more strongly folded than the northern one (Fig. 40). It is just possible that during the Himalayan orogeny the orogenic southern side was deformed in different times with the various phases of uplift.

The last uplift which had been a major and most prominent phase produced strong stretched recumbent folds which further deformed, the refolded ($F_1$ & $F_2$) structures in the area. The apparent tectonic transport direction appears to be from NE. These deformative processes resulted in the formation of the crystalline nappe (Kulu nappe) due to which high grade rocks (Manali formations) thrust over the medium to low-grade rocks (Chail Formation?) near Kulu. This conclusion is based on minor folds (especially the drag folds) and well developed lineations which trend NW-SE (See Chapter V , page 122 ). A strong NE mineral 'a' - lineation along the dislocation planes further supports this view.

During the overall rise of the mobile belt (cf. Ashgirei, 1968), additional stretching probably occurred and this might have caused movement along the normal faults below the nappe (Fig. 40 ) marked by the last episode of deformation.
West (1928) has regarded the Jutoghs as a large klippe composed of a flat recumbent fold whose roots have been identified north of the Sutlej valley and the thrust beneath it has been called as the Jutogh Thrust. Pascoe (1964) has said that "Nappe structures in the Himalaya is the rule rather than the exception........".

The area covered by the author is situated near the point where the two major ranges coalesce. The ranges are Dhauladhar and Pir Panjal. Zanskar range also joins the Pir Panjal range in the nearby vicinity. In this zone traverses have revealed that:

1. the Rohtang Pass range is an overturned anticline trending NW - SE;

2. within this overturned anticline plunging both ways, are present folds trending NNE - SSW and N - S. The folds are overprinted by the regional overturned;

3. on the north-western, northern, and northeastern flanks of the Rohtang Pass overturned anticline in the Lahaul valley and to the northeast in the Spiti valley, the metamorphites, migmatites, gneisses etc. are overlain by sedimentary cover of the Tethyan basin which shows a complete succession of rocks ranging in age from Cambrian unto the uppermost Cretaceous;

4. these rocks show a well developed fossil fauna which has helped in fixing up the stratigraphy of the sediments in no uncertain terms;
since these crystallines form the basement for the fossiliferous type sedimentaries it has been concluded (Saxena, 1970, personal communication) that the crystallines in general form the floor of the Tethyan type basin to the north of the central crystalline axis and are Pre-Cambrian in age;

within the crystallines are present granites and pegmatites exhibiting cross-cutting relationships with the metamorphite, migmatites, etc, and therefore, these are definitely of younger age. One such example was observed by the author near J-spa while taking a traverse from Manali to Leh (about 500 km.);

the radiometric dating carried out on the micaceous minerals of some of the granitic and migmatitic rocks by Saxena and Miller (personal communication) indicate that the radiogenic ages older than Tertiary in the case of mica have been lost on account of the fact that the orogeny within part of the mobile belt was sufficiently severe to obliterate most of the radiogenic dates older than Tertiary;

geological evidence also collaborate the view;

the area forms a part of the root zone from where the thrust and nappes have originated which have travelled far to the south of the central crystalline axis, over-riding the
unmetamorphosed of the lesser and outer
Himalayas. The crystalline rocks occurring
near Kothi, Rehla and Mari have been identi-
fied with the Jutogh of the type area and
the Chor area (Saxena and Pande, 1969);

11. this phenomenon has led to the widely seen
phenomenon of the inverted sequence of meta-
morphism to which reference observations have
been made by workers like Medlicott, 1864;
Oldham, 1893; Pilgrim and West, 1928; Wenk,
1968; Saxena and Pande, 1968, 1969; Fuchs,
1963, 1968; Saxena, 1970;

12. this phenomenon of nappes and thrust sheets
is also responsible for a number of window
structures all over the lesser Himalayan zone
of the Himalayas;

13. the structural pattern ensuing, therefrom,
is rather complicated and in sharp contrast
to the simple folded structures seen to the
north of the central crystalline zone;

14. metamorphism is confined only to the previously
metamorphosed groups of the rocks;

15. no metamorphism or very little metamorphism
leading to the development of the slate and
occasionally phyllites is seen in the paleozoic,
mesozoic and tertiarys of the lesser Himalayan
zone of the Kumaon Himalayas thereby indicating
that orogeny though involved a large scale
deformation on regional magnitude was not
coupled with regional metamorphism (by metamorph-
ism the author here means the extensive develop-
ment of new mineralogical assemblages). Saxena
and Pande (1969) have arrived at similar
conclusion. This also indicates that probably the geotherms were concentrated only in the root zones and the central crystalline zones and therefore did not influence the sedimentary rocks of lesser and outer Himalayan belt;

16. as reported by Billing (1960) that "Whenever we see kyanite in the field at least ten miles of rock has been eroded away". Carey (1962) too observed that "Metamorphosed cores commonly reach the kyanite zone which requires burial to some 18 to 20 km. for its gneisses." It appears that this part of the area where the kyanite schist is one of the principal type must have been at Kata-zone depths;

17. since the rocks appear to be kata-zonal and also form the basement of the Cambrian sediments, it follows that they belong to the basement crystalline zone which was eventually uplifted during the Tertiary orogeny and later on was involved in thrusting etc.

The probable mechanism for such translation during the Tertiary orogeny from the basement horizons to the present high level in the Himalayan have been discussed by Pande and Saxena (1968).