CHAPTER II

PREVIOUS WORK

Himalayas have attracted geologists since the middle of the 19th century, and the entire record of the geological studies in the Himalayas can be said to belong to three periods. The first period of sixty years, beginning with 1860, is noteworthy, for during this the foundations of Himalaya's stratigraphy were laid. The second period between 1920 and 1939 is the one during which the structural aspects of the Himalayas received greater emphasis. The impact of the development of concepts of large scale overthrusts in the Alps, is discernible in the structural studies of the

Himalayas during this period. During the third period from 1939-1965, particularly after the second world war, considerable knowledge of the local structures in the Himalayas has been added, both by Indian and foreign geologists. Recent work on various Himalayan regions, owe their origin to various agencies, viz. (1) studies carried out in connection with major engineering projects and prospecting for oil. (2) The mountaineering expeditions and traverses in isolated parts of the Himalayas, and (3) research work in various Universities.

The author has given in the following pages, a short account of the important investigations on Himalayas in the past. The job of summarising the Himalayan investigations was somewhat complicated and the author found it rather difficult to devise a satisfactory scheme to include all the previous literature. Keeping in view the requirements of the present thesis he has described the subject matter under the following three heads:-

1. Himalayas in general.
2. Previous work in Kumaon Himalayas.
3. Ranikhet and neighbouring areas.

To begin with an outline of the previous work on different areas, has been given in a chronological order. Obviously, this scheme has the slight drawback of lacking in a succinct account, but then it compensates by including the details of the works which appeared year after year - though quite often on widely scattered areas. The author, has therefore, in subsequent sections of this chapter, gradually enlarged upon the works on the Kumaon and Ranikhet regions in particular, to provide greater information to act as background for the present study.

1. HIMALAYAS IN GENERAL

Working on the Spiti area of Panjab Himalayas, Hay(1850) correlated the Indian formations with that of known European formations. Had Hay cared to bear in mind that the Himalayan formations homotaxially differ from the latter, his classification of Himalayan rocks would have been of great value for the future workers.

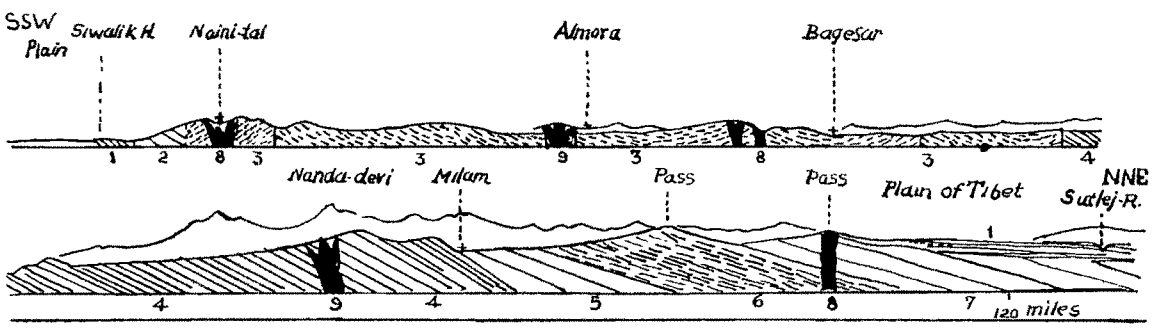
1850

The next publication is that on the Central Himalaya and the only one issued with a geological sketchmap, is that of Strachey(1851), who conducted a number of traverses in Central Himalaya. His sections, although not showing any thrusting, can still be considered

1851

Fig 7

The section across Central Himalaya by Captain Richard Strachey



1=Tertiary

2=Secondary & paleozoic ??

3=Metamorphic strata without fossils

4=Crystalline schists

5=Azoic slates

6=Palaeozoic

7=Secondary

8=Greenstone

9= Granite

a remarkable achievement of his times (Fig. 7). He has clearly distinguished the stratigraphical divisions of the high Himalayas from the "Azoic Slates".

Hooker(1854) came out with the first geological account of the Nepal region. He visited Nepal-Sikkim frontier and his account is confined mostly to a more detailed description of the signs of early glaciation with occasional mention of the rocks encountered.

1854

The most outstanding contribution to the geological studies of the Himalayas in the 19th century was that by Medlicott(1864). He gave the first connected account of the geology of the Lower Himalayas. He studied the geological structure and relation of the southern portion of the Himalayan range between the rivers Ganges and Ravee. His work not only laid the foundations on which our present knowledge of the Himalayan structure has been built and firmly established, but also his correlation and nomenclature of the rocks of Simla have undergone little alteration at the hands of the subsequent workers. He classified the Himalayan rocks of the area, into two series:-

1864

1. Sub-Himalayan series.

2. Himalayan series.

These two series, classified into various subdivisions, formed the following sequence:-

1. Sub-Himalayan series:-

Upper	Siwaliks	
Middle	Nahan	) Kasauli
Lower	Subathu	) Dagsai

2. Himalayan series:-

A. Unmetamorphosed:-

Krol	-	Limestone
Infra Krol	-	Carbonaceous Shale
Blaini	-	Conglomerate
Infra Blaini	-	Slates.

B. Metamorphics:-

Crystalline and sub-crystalline rocks.

Medlicott however did not give any definite opinion regarding the origin of Chor granite of Simla. He seems however to favour the intrusive nature of the granite.

Ball(1871) worked in the Nainital area and assigned glacial origin to the lakes of Nainital district. He reported

1871 the occurrence of green stone at Bhowali and Bhimtal in Kumaon.

Mallet's(1874) work was mainly restricted to Eastern Himalayas, and the present knowledge of Darjeeling gneiss

1874 is based mainly on the excellent work of Mallet. In conformity with the prevalent concepts of those times, he regarded the Darjeeling series as normal and autochthonous.

Middlemiss(1880) provides us with many structural interpretations and correlation. He assigned two ages to

1880 the Himalayan granitic rocks i.e., Pre-Triassic and Tertiary.

Oldham(1882) after traversing Almora to Mussoorie, published a paper wherein he described the rock types met

1882 with during his traverse.

Oldham(1884) wrote another paper on the Simla region of the Lower Himalayas, in which he reported the presence

1884 of mica schists and massive granitoid gneiss of the Simla area, and also attemped

to explain the evidenee of bedding schistosity.

McMahan(1886) working on the dolerites of the Chor published a paper in which he remarked that the mode of occurrence of the Chor dolerite shows that it is a late intrusive, and not a contemporaneous eruptive rock. In structure the rock is completely holocrystalline, more allied to gabbro than to lava.

1886

McMahon's(1887) work was mainly on petrography and genesis of the gneissic granites of many area in Himalayas. Working on the Chor granite (1887) near Simla, he first regarded the granites as highly metamorphosed sediments but later on he revised his views and considered them to be of intrusive nature. In this latter work he has summarised his view on the origin of the Himalayan gneissose granite and contended that they were all identical and of Tertiary age and definitely of igneous origin.

1887

Middlemiss(1887), in his classical work established the following succession of the Garhwal rocks:-

	Sub-Himalaya (Siwaliks)
Outer formation	Nummulites
	Tal
	Massive limestone
	Purple slate
	Volcanic breccia
Inner formation	Schistose series with intrusive
	Gneissic granites

He invoked reverse faulting to explain the presence of schistose rocks over nummulites.

An year later, Middlemiss(1888) published his work on the crystalline and the metamorphic rocks of the Lower

1888 Himalayas, Garhwal and Kumaon.

In another paper Middlemiss(1890) described natural conditions governing mountain slopes of the Kumaon and

1890 Garhwal region and also discussed the geology of Nainital with special reference to the origin of Nainital lake.

Griesbach(1891) correlated the rocks of the "Inner formation" of Middlemiss with similar rocks of Spiti and called them Vaikrita System, consisting of mica schists, slates, and phyllites. He found this system to be overlain by Haimanta System in that region.

1891

Middlemiss(1894) published a very interesting stratigraphic account of the Siwalik formations. The Siwaliks were divided by him into three divisions - Lower, Middle and Upper - on the basis of lithological and physical characters of the rocks. He described the following sequence along the Ramganga valley in Garhwal:-

1894

Massive Limestone

-------- Fault ---------

Nahan - Lower Siwaliks

-------- Fault ---------

Middle Siwalik rocks

Nahan Lower Siwaliks

-------- Fault ---------

Upper Siwalik Boulder conglomerate

Middle Siwalik Sand rocks

Lower Siwaliks

In another paper, 'On the geology of Hazara', Middlemiss(1896) discussed the origin of the agglomerate series in Kashmir. According to him, either (1) it was the product of explosive volcanic action which preceded outpouring of the Panjal trap or (2) it was due to ice action. If the latter was true then the Panjal agglomerate series was homotaxial with the Talchir bed of Peninsular India. He was, however inclined to favour the former view.

1896

The work of Hayden(1904), on the geology of Spiti, is quite remarkable in which he has systematically classified the Palaeozoic formations.

1904

The first modern section of thrust folding over the entire width of Himalaya, although done in a schematic way, was presented by Loc'zy(1907), a Hungarian Professor, who after having rapidly traversed the Eastern Himalaya (1878) published his remarkable "Beobachtungen". His section of Kanchanjangha showing an enormous overfold with huge reversed series, thrust for 150-200 kms. towards the Indian plains, has been more correct at least in principle.

1907

Burrard(1912) in his paper on the origin of the Himalayas mentioned that geologists have found that the

1912

Himalayan folds are overthrust towards south; but the direction of the movement of the range can not be ascertained from such data. When folds are overturned towards south, they have the appearance of being pushed southward from the north, but another explanation that the sub-crust upon which the folds are standing erect is being moved northward and so folds overbalanced towards south.

In another paper Oldham(1912) tried to support his views on the structure of Himalayas by measuring the

1912

direction and intensity of the forces of gravity at different stations.

Working in Simla, Palmer(1920) sub-divided the rocks of the area into the following various groups:-

1920

Shali Limestone
Shali Quartzites
Madhan Slates
Subathu beds

and named them as Mule-Track series, (which later on was identified by Pilgrim and West (1928) as Chail series).

He discussed that the position of the Mule-Track series above less metamorphosed beds is due to thrusting.

Walker(1922) who worked in the Khasi and Garo hills of Assam Himalayas gave what may be called a true geological account of the area. For the first time, he outlined the geology of that region.

1922

Pilgrim and West(1926) gave an account of the granites of Chor mountain of Simla and considered them to be of intrusive origin.

1926

Wadia(1928) worked on the Agglomeratic slates of the Pir Panjal and obtained definite evidence regarding the true volcanic pyroclastic nature of this thick zone of slates. He considered these rocks as compact volcanic tuff, with a matrix which was largely devitrified, but leaving some unaltered original glass.

1928

Pilgrim and West(1928) mapped the Simla region, and their work is mainly based on field observations. They have suggested that the rocks of the Simla-Chakrata area lying to the north of Tertiary belt, are not in their normal position but they have undergone thrusting and inversion. Their work has led them to conclude

1928

that the metamorphic rocks which are really a part of the belt of rocks forming the Central axis of the Himalaya, have been forced southward for many miles along a nearly horizontal Jutogh Thrust plane, so as to lie now on the toe of unaltered rocks. These metamorphic rocks are named as Jutogh series on which the city of Simla is situated. They have postulated existence of other thrusts also below, the main Jutogh Thrust, of which the Chail Thrust is the most important. The sequence of events in Simla region as put forth by Pilgrim and West has been summarised as under:-

(a) Deposition of Jutogh Series.

(b) Basic igneous intrusion as sills and dykes.

(c) Recumbent folding and metamorphism.

(d) Intrusion of Chor granite at the close of folding and metamorphism.

They have given the following stratigraphical sequence of Simla Himalayas:-

Dagshai Series	Lower Miocene
----------Unconformity----------	
Uppermost Subathu beds	Upper Oligocene
----------Unconformity----------	

Subathu Series	Middle Eocene
----------Unconformity----------	
Krol Series	Lower Gondwana
Infra Krol beds	
Blaini beds	
----------Unconformity----------	
Shali limestone and slate	?
Simla Series (Infra Blaini)	
----------Unconformity----------	
Jaunsar Series	Purana
----------Unconformity----------	
Chail Series	Purana
Jutogh Series	Archaeans(?)

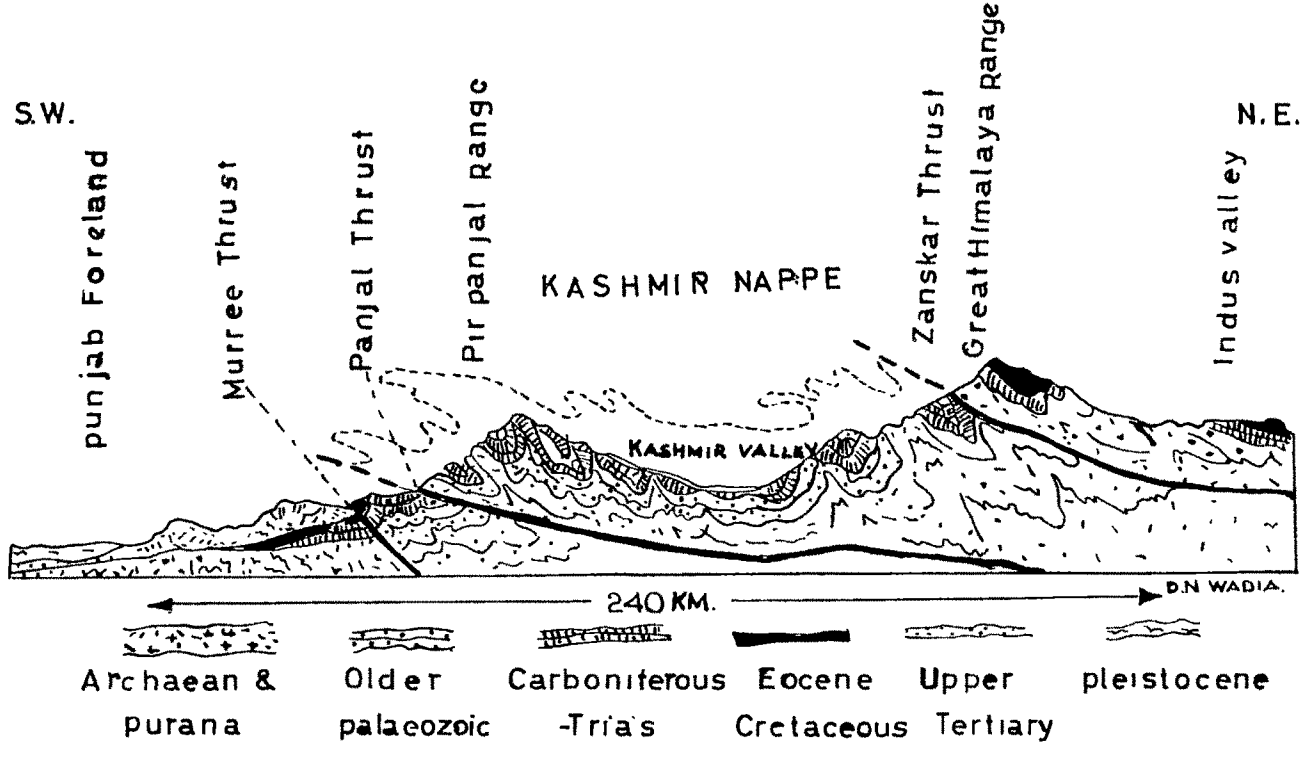
The most outstanding contribution to the Himalayan studies, came from Wadia(1931). His classical work which dealt with the rocks tectonics and orogeny of the N.W. Himalayas, constitutes an important milestone in the progress of the Himalaya's geological studies. He pointed out the most striking feature of the N.W. Himalaya - the way in which the strike of the mountains, after following an arcuate SE-NW direction from

1931

Assam to Kashmir, makes a great bend in Hazara, rapidly curving round through an E-W. to N-S direction, and producing thereby a great re-entrant angle in the alignment of the mountains between Abbottabad on the S.W. and Kashmir valley on the N.E. Wadia's(1931) work in the south of this syntaxial area has shown that both from structural as well as from stratigraphical point of view, there is a complete geological continuity around this re-entrant. The structure and stratigraphy on the Hazara side of the syntaxis is the mirror image of the structure and stratigraphy on the Kashmir side. Wadia has concluded that there has been a single Himalayan movement from the North which has come up against some underground obstacle around which it has been forced to diverge. He suggested that a tongue of the ancient and stable Peninsular rocks extends upto the N.W. beneath a covering of Cenozoic rocks, and that this formed the obstacle to the folding movement coming from the north, so that original north and south direction of movement has been resolved into a NE-SW direction in Kashmir and a NW-SE in Hazara. In that part of Kashmir area investigated by him, three structural elements are defined.

Fig 8

DIAGRAMMATIC SECTION ACROSS THE KASHMIR HIMALAYA, SHOWING THE BROAD TECTONIC FEATURES



(1) The tongue of the Foreland, its peneplaned surface being buried under a thick cover of Murree sediments.

(2) The belt of autochthonous, mainly recumbent, folds consisting of rocks ranging in age from Carboniferous to Eocene, thrust against and over the foreland covered under the Murree series - the Murree thrust. Southward overfolding and thrusting with a dominant north-east dip is the prevalent structural tendency of this region.

(3) The Nappe zone of inner Himalayan rocks which has travelled far along an almost horizontal thrust (the Panjal thrust) so as to lie fitfully sometimes against a wide belt of the autochthon, at other times almost against the foreland. The Kashmir nappe is composed mostly of pre-Cambrian sediments (Sulkhala series), with a superjacent series (Dogra slates), forming the floor of the Himalayan geosyncline that has been ridged up and thrust forward in a nearly horizontal sheet-fold. On this ancient basement lie synclinal basins containing a more or less full sequence of Palaeozoic and Triassic marine deposits in various parts of Kashmir (Fig. 8).

The most important feature of this region described by Wadia is the occurrence of two great thrusts delimiting the autochthonous belt. These thrusts have been traced round the syntaxial bend from Hazara to Dalhousie. Of these two thrusts, the inner (Panjal thrust) is the more significant, involving large horizontal displacements. The outer, the Murree thrust, shows greater vertical displacement and is steeper in inclination.

Hayden and Burrard (1932) published a book on the geography and geology of the Himalayan mountains and Tibet,

1932

where they divided the Himalayan rocks into two groups - (i) Metamorphics composed of granite gneiss and crystalline schists and (ii) a series of fragmental rocks of undoubtedly sedimentary origin such as slates, quartzites, conglomerate and limestone. In their opinion "the gneiss is perhaps intrusive in the metamorphics, but whether it is wholly an igneous rock or is a composite gneiss formed by injection and rolling out of granite veins along the foliation of mica schists is yet unknown".

Wadia (1932) in his note on the geology of Nanga Parbat (mts. Diamir) and adjoining part of Gilgit dist.,

1932 Kashmir described that the gneisses and orthogneisses intrusive in metamorphics, along their periphery are more of the nature of injection or permeation gneisses.

Auden's (1933) work summarises his findings on the problem of the age of certain Himalayan granites. On the

1933 basis of the presence of small pebbles of granite in volcanic breccia (pre-upper Carboniferous age), he has inferred that some of the granites are pre-Trias in age and supported the view of Middlemiss (1880).

In his paper on the geology of Krol belt (Simla), Auden (1934) has mainly dealt with the description of the

1934 rock types. In this paper he has correlated the rocks of British Garhwal with that of Simla Chakrata area and Hazara Kashmir region. He has also discussed the position and age of the granites of the area. He has written, "It is singular feature that Dudatoli and Landsdowne granites occur synclinally at the top of synclinal succession of slates and schists". He mentioned that the general similarity and

characters of the Hazara, Chor, Landsdowne and Dudetoli granites suggest that their correlation is permissible. According to him, they were intruded during the Palaeozoic Era.

West(1934) in a later work, compared the structure of Simla and Kashmir Himalayas. He found that (1) the sedimentary rocks of the Krol belt correspond to Wadia's autochthonous zone in Kashmir, while Jutogh and Chail series and gneissose granite correspond to Wadia's nappe zone. (2) Auden's Krol thrust (Simla) corresponds to Wadia's Murree thrust in Kashmir and (3) Pilgrim and West's Jutogh thrust (or possibly their Chail thrust) to Wadia's Panjal thrust.

1934

According to West, the chief difference between the Kashmir and Simla Himalayas is that, in Kashmir several basins of fossiliferous sedimentary rocks are found resting in syncline on the top of Kashmir nappe while in Simla hills nothing of this sort is seen until one reaches Spiti - on the northern side of the Central axis.

Auden's (1935) paper incorporates the details of a number of traverses in Garhwal, Nepal and Sikkim Himalayas

1935 has reported the schistose and gneissose rocks equivalent to Dudatoli schistose series described by Middlemiss. This paper mainly deals with the lithological units and metamorphic aspects of the rocks.

Auden's most outstanding and classical work (1936) is that on the structure of the Himalaya in Garhwal(Fig.9).

1937 In this paper, he has given the following sequence of rocks in Garhwal.

Formation	Thickness	Probable age
Siwalik	16,000'	Upper Miocene to Pleistocene
Nummulitic	-	Eocene
Tal	6,500'	Upper Cretaceous
Krol	4,000'	Permian to Triassic
Blaini	2,000'	Talchir (Uralian)
Nagthat	3,000'	Devonian
Chandpur	4,000'	Lower Palaeozoic or pre-Cambrian

According to Auden, the above mentioned rocks are tectonically arranged to show the following structural succession:-

Garhwal nappe	Chandpur (metamorphosed)	
	------ Thrust ------	
	Nagthat	Little metamorphosed
	Chandpur	
	Boulder beds, slates and limestones of uncertain stratigraphical horizon occur in one outlier below metamorphosed Chandpurs	
----------	Garhwal Thrust ----------	
Krol nappe	Nummulitic	
	Tal	
	Krol	
	Blaini	
	Nagthat	metamorphosed and unmetamorphosed
	Chandpur	
----------	Krol Thrust ----------	

	Dagshai nummulitic	
Autochthonous		Siwalik
	Simla slates	

Fig 10

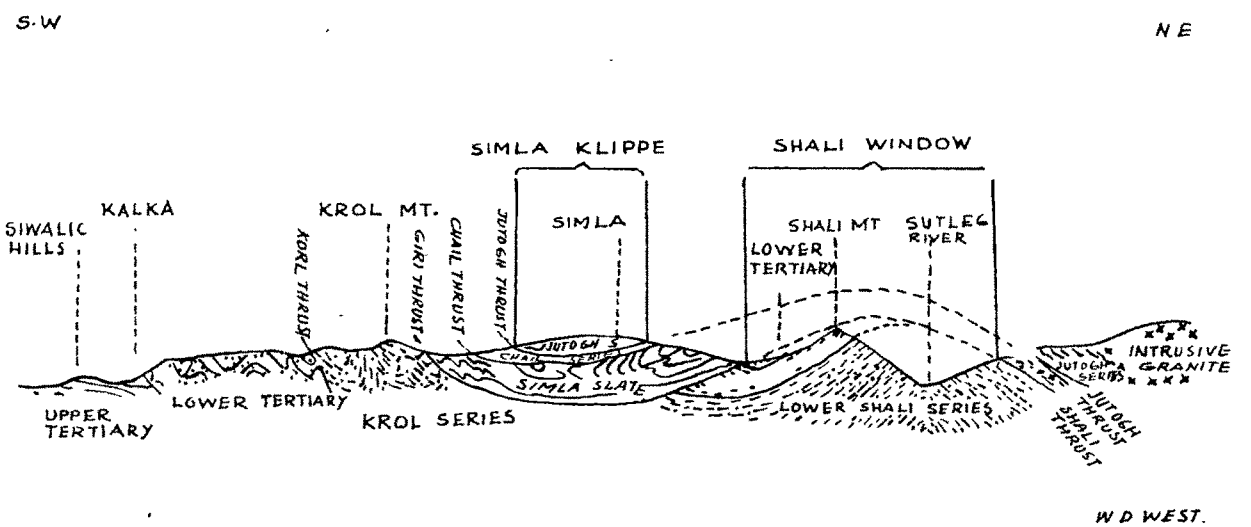
SECTION THROUGH THE SIMLA HIMALAYAS

0 8 16 KM.

Horizontal Scale

0 3030 6060 METRES

Vertical Scale



He made a comparison of the structure of Garhwal with that of eastern Himalayas. According to him, in the eastern Himalayas, there are two main thrusts:-

(1) The thrust causing the Gondwana rocks to lie upon Siwaliks.

(2) The thrust separating the Daling series from underlying Gondwana.

These two thrusts are respectively analogous to Krol and Garhwal thrusts of the Garhwal Himalaya. In both the areas schistose rocks are thrusted upon Gondwanas or their equivalents.

Evans, Wadia, and Auden (1938) gave an account of the significance of Boundary faults in the Sub-Himalayas.

West(1939) published his famous paper on the Shali window near Simla in which after dealing briefly with the stratigraphy of that area, he has discussed the structure at length (Fig. 10). He has postulated an immense thrust (Shali) which has brought a sheet of older rocks to rest more or less horizontally upon younger rocks, the whole having been subsequently gently

1939

warped and partly denuded thus forming a Klippe of older rocks near Simla, resting upon younger and a window of younger rocks appearing from beneath older ones at Shali.

1939

The work of Heim and Gansser (1939) forms another landmark. Their geological observations on the central Himalayas formed a part of the Swiss expedition to Himalayas. They have dealt with various geological aspects such as petrology, stratigraphy and tectonics of Kumaon, N.W. part of Nepal and Tibet Himalayas. They traversed in Siwalik border region of Kumaon, the great thrust fold region of Darjeeling, the central high range of Nandadevi and Badrinath, the northern range of Tethyan Himalaya and the Tibet Himalaya. Their identification of rocks, regional correlation and tectonic interpretation are so perfect that their work will remain unique for many years to come.

1946

In a later paper Wadia (1946) discussed the significance of thrust structure in the Salt Range. He pointed out that the role of thrusts in disturbing stratigraphic position in Salt Range is not sufficiently recognised, and even when recognised, its significance is not fully credited because

of an apparent lack of discordance in the bedding planes. According to him, the thrust structure of the Salt Range is an established fact and is sometimes confused with the nappe hypothesis postulated by Cotter (1933) and Gee (1934) which have suggested bodily shift of the entire mountain mass of the Salt Range from the north. This view, according to Wadia may be correct or not; but the mechanism which brought the Khewra-Warcha salt gypsum beds under the purple sandstone, can be better explained by the dislocation and relatively small overthrust of the lower limb of an inverted anticline or monocline formed during the block upheaval of the Potwar plateau at a period so late as the Pliocene (post - middle Siwalik).

Auden (1948) in his inspection note on the Ramganga Dam site, Garhwal dist. (U.P.) explained the tectonics and structure of that area. His findings are summarised below:-

1948

(a) Outerzone of Siwalik rocks of late Tertiary age, with some major thrust faults of the third rank. The sequence of formation is as follows:-

Recent	Recent gravels	large boulder gravels, cobble gravels, sand and silts.
Plio-Pleistocene	Upper Siwalik	Cobble conglomerates, clays.
Pliocene	Middle Siwalik	Sandrock with horizons of calcareous nodules, pebblebed, clays.
	Lower Siwalik	Sandstone, clay and shale.

(b) Inner zone of pre-Tertiary and Eocene rocks, with major overthrust faults of the first and second rank. The tectonic sequence is as follows:-

Landsdowne thrust unit

---------- Thrust plane (1st rank) ---------

Bijni thrust unit

---------- Thrust plane (2nd rank) ---------

Krol thrust unit

Nummulitic

Tal

Krol

Blaini

---------- Thrust plane (2nd rank) ---------

Lower Siwalik of the zone (a)

Auden found that the faults and thrust planes in the outer Siwalik zone involve formations as young as the Pleistocene and could therefore be as late as of Recent age.

West(1949) while summarising the work of Auden in Tehri and British Garhwal, mentions that the Barahat series, occurs as a tectonic window called by Auden as "The Chamoli window". He further comments that the structure of the Garhwal Himalaya is essentially the same as that of Kumaon Himalaya, independently determined by Heim and Gansser(1939), and the two areas could be compared as below:-

1949

Garhwal Himalaya (Auden, 1939)	Kumaon Himalaya (Heim and Gansser, 1939)
Thrust at the foot of main Himalayan range forming the N.E. boundary of the "Chamoli window".	Central thrust
Garhwal series in "Chamoli window".	Tejam calc-zone, occuring in anticlines below crystallines.
Overthrust sheet of Dudatoli - Ranikhet - Almora.	Crystalline Almora thrust zone.

Petermicsh's (1949) views on the granitisation of batholithic dimensions in the Nanga Parbat region (Kashmir) are noteworthy. Discussing the gneissic rocks of Nanga Parbat, he writes (1949,p.207), "These rocks have undergone regional metamorphism during early Tertiary orogeny. Regional metamorphism of argillites progresses from slate and phyllites, though mica schists, biotite para-gneiss, kyanite schist to sillimanite para-gneiss are due to lit-par-lit replacement as against mechanical injection along active foliation planes makes banded gneiss. The metamorphic isograde is seen to be independent of depth and a function of differential introduction of heat from below. The degree of metamorphism and granitisation are systematically linked and connection of heat by the granitisation solution is held responsible for high grade regional metamorphism in the upper part of the crust".

1949

In his two papers, Pande(1949,1950), has elaborated some aspects of the geology of the Ramgarh area (Nainital). Pande(1950) discussed the rock types and igneous activity in that area. He correlated

1949,1950

the rocks of the area with the 'Inner schistose series' of Middlemiss.

Lately Auden (1951) has suggested an upper Miocene to Pleistocene age for the Krol and Garhwal nappes.

Boileau(1954) has brought in an entirely a new concept in the study of Himalayan geology. He has reverted back to an old concept that the Krol series is equivalent to Vindhyan system of Peninsular India. He strongly advocates that Blaini boulder beds are equivalent to Kaimurs, which according to workers like Pilgrim and West (1928), Wadia (1933) and Auden (1937) represent the boulder beds equivalent to Talchirs of Permo-Carboniferous period. The view put forwarded by Boileau requires further testing in the field.

1954

Ghosh (1956) in his presidential address to Indian Science Congress summarised the recent advances in the study of the geology and structures of the eastern Himalayas. Considering the Darjeeling area, he suggested that the inverted zone of progressive metamorphism on regional scale and the development of metamorphic

1956

minerals are probably due to rise of the isotherms in the subsiding Daling geosynclines. This was accompanied by injection of granitising material in the deeper zone. The inversion was related to N-S orogenic movement as a result of which metamorphic rocks were overfolded on a gigantic scale in a recumbent fashion with nearly E-W axis causing the high grade metamorphic rocks of the lower part to rest on less metamorphosed Dalings.

Pande (1956), continuing his work on Ramgarh area, has considered the green "porphyries" to be in fact

1956 migmatites.

Subramaniam (1960) has explained that Dolomite of Almora is clastic and at places bands show curved round

1960 rings with a correct top of the bed.

Valdiya (1961) records the occurrence of stromatolitic structures in the dolomitic limestone of Pithoragarh, U.P.,

1961 which he ascribed to the Algal, genus Collenia and suggested that the magnesite deposits there are the result of primary precipitation of magnesium carbonate aided by the activity of Algae.

Ganju and Srivastava (1961) in their paper on the petrology of the Dagshai sandstones (Simla) proved that

1961

they are lithic arenites and postulated two source areas - one sedimentary and the other low-grade metamorphic. According to them the mixed detritus was probably sorted under current action in a shallow sea.

In their (1962) another paper on a study of the agglomeratic slates near Bren, Kashmir, they proved that

1962

large parts of this formation were of pyroclastic origin, and suggested that the rocks were originally rhyolitic crystal - vitric welded tuffs which have been subsequently metamorphosed, devitrified and altered to a felspathic quartz-sericite slate.

Saxena and Kanwar (1962), in their paper on the garnet porphyroblasts in the mica schists of Jutogh series near the

1962

granites of the Chor area, have explained that the garnets have developed by metamorphic differentiation. According to them, the various stages of the development of garnets, as observed under microscope, very clearly show the phenomenon.

In an interesting paper, Valdiya (1962) has given an outline of the stratigraphy and structure of the southern part of Pithoragarh of eastern Kumaon.

1962

He has found that the lower Himalayas of the eastern Kumaon are made up of two thrust sheets or nappes. The lower thrust sheet corresponds to Krol nappe and the upper sheet corresponds to the Garhwal nappe.

In another paper, Valdiya (1962) reported the discovery of stromatolitic structures from the lower Shali limestone of Tatapani (Simla) and correlated that with Naldera limestone of the basal Simla series (Algonkian) and with Deoban limestone.

1962

Valdiya (1962) also gave an account of the Champawat granodiorites and associated metamorphics of the Lohaghat sub-division of Almora (U.P.). He concluded that the Champawat granodiorites constitute a composite body of batholithic dimension connected with the Himalayan geosyncline.

1962

An year later Valdiya (1963) describes the structure and stratigraphy of the Lohaghat sub-division (U.P.) in great detail.

1963

The origin and nature of the gneissic rocks of Kumaon was discussed by Pande and others (1963) who concluded

1963

that these gneissic rocks are of migmatitic origin and of Tertiary age.

In a recent report, Wadia and West (1964) have briefly and lucidly discussed the structure of the Himalayas. They

1964

wrote that in Simla-Garhwal area the geological evidence suggests more than one period of orogeny. The earliest is pre-Eocene, as Subathu sediments are found resting unconformably on the strata of Palaeozoic and Mesozoic ages. A large scale post-Subathu movement resulted into translation of sheets of rocks southward along low angle thrusts in a series of 'nappes', possibly with granite intrusion in root zone. This movement is likely to have taken place at the beginning of lower Siwaliks (Mid-Miocene) times, giving rise to a change in the deposition from arkoses to conglomerates containing Krol belt pebbles in the foot hills, though the latter was affected by the final orogenic activity at the end of Siwalik (lower Pleistocene) times. The 'nappes' belt also moved further southwards at this time, coming to rest directly against Siwalik sediments in places.

Valdiya (1964) in a note on the tectonic history and evolution of the Himalayas explained the main orogenic events in the history of geosynclinal evolution and the final emergence of the Himalayas, and compared in a general way with those of Alps. In his another publication (1964) on the tectonic design of the Himalayas, he has described the various structural units of the Himalayas into five zones:-

1964

(1) The autochthonous Siwalik zone, comprising Jura-type simple open folds affected by steep reverse faulting which resembles with the molasse zone of the Alpine border.

(2) The parautochthonous lesser Himalayan zone of early Tertiary formations beneath the overthrust Krol nappe.

(3) The Krol nappe system - mostly unfossiliferous sediments comparable to the Helvetic nappes of the Alps.

(4) The Kashmir nappe system, which embraces the Kashmir-, Jutogh-, Garhwal- and Kathmandu- nappes are built of pre-Cambrian crystallines and are characterised by huge recumbent folds and may be compared with Pennine nappes.

(5) The Tethys Himalaya, consisting of Cambrian to Eocene fossiliferous sediments is comparable with the East-Alpine nappes.

In still another paper (1964), on the unfossiliferous formations of the lesser Himalayas and their correlation, Valdiya has discussed that the unfossiliferous sedimentary formations of the lesser Himalayas are divisible into two main lithological units, the argillo-calcareous and the arenaceous groups. The first group includes the Simla slates, the Deoban limestone and the Shali series of the Panjab Himalaya; the calc-zones of Pithoragarh and Tejam and the Baxa series of the eastern Himalayas. The arenaceous group includes the Jaunsar-Nagthat series and the Khaira quartzites of the Panjab Himalaya; the Chamoli-Berinag quartzites of Kumaon and possibly the Miri quartzites of the N.E.F.A. This group is characterised by abundant metamorphosed basic volcanics, representing probably penecontemporaneous lava flows. These lesser Himalayan groups may be compared with the Purana groups of Rajasthan and M.P.

1964

Nautiyal and others (1964) gave a connected preliminary account of the geology of Bhutan Himalaya which lies in the Himalayan orogenic belt. They have mentioned that the foothill zone comprises the autochthonous Siwalik system and the highly folded narrow wedges of the coal-bearing Gondwanas, Permo-Triassic which are underlain by metasediments, comprised by schists, phyllites, quartzites, marbles, etc. (Chekha series).

1964

Raina (1964) has attempted to correlate all the detached outcrops of limestones, from Nepal border to Jammu and suggests that they occur as 'Klippen' and either the remnants of an earlier extensive 'Shali nappe' or detached glided masses from the 'Krol and Shali nappes'.

1964

Valdiya (1965) in a note, has given an account of the petrographic study of the sedimentary, low-grade metamorphic and basic volcanic rocks of the southern part of the Pithoragarh dist., U.P.

1965

Sarkar (1965) has published a paper where he has discussed the tectonic pattern of the part of Almora nappe zone around Almora. His findings may throw new light on the tectonic pattern and structural evolution of the area.

1965

Pande and Das (1965) have undertaken a statistical study of the optic axes of quartz grains in the younger quartzites of Chaukhatia area near Almora (U.P.). According to them the study of the structural features and the fabric of the quartzites has a close relationship between them.

1965

An interesting and informative paper by Krishnaswamy and Swaminath (1965) gives a general appraisal of the geology of Himalayas and Alps. The authors have indicated similarities between the two regions in the development of the Molasse basins, the overthrust sheets and the emplacement of granites. They have also discussed the dissimilarities in the nature of the facies belts and the tectonic patterns.

1965

They have attempted a probable correlation of the various parts of the Himalayan chain, which has been reproduced here; for it gives a bird-eye view of the Himalayan stratigraphy and tectonics.

EAST

Sub-zone Nos.	Kashmir (Wadia)	Punjab (West & Auden)	Garhwal (Auden)	Kumaon (Heim & Gansser)	Nepal (Auden, Hagen and Dardet)	Darjeeling-Sikkim (Ghosh)	Assam Himalaya (Ghosh)
14.				Trans-Himalaya			
13.				Counter thrust of Darohan zone			
12.				Thrust of Exotic Blocks			
11.	Tethyan Facies with Ultrabasics	Tethyan Facies with Ultra-basics	Tethyan Facies	Tethyan facies with thrusts in the zone	Tibetan & Tethyan facies.	Tethyan facies.	
10.	Crystal-lines.	Crystallines with Rampur and Mashnu windows (Bertheless)	Crystalli-nes with Shuttu Window (Tewari)	Crystalline Central zone	Crystallines.	Crystallines.	
9.	Main Himalayan Thrust.	Main Hima-layan Thrust.	Main Hima-layan Thrust.	Main Central Thrust	-	-	
8.	-	Shali window of Permotrias with frinage of Early Tertiary	Deoban-Chamoli Windows of Permo-Trias	Windows of Permo-Trias Calc-zone of Tejam	-	-	

Sub-zone Nos.	Kashmir (Wadia)	Punjab (West & Auden)	Garhwal (Auden)	Kumaon (Heim & Gansser)	Nepal (Auden, Hagen and Dardet)	Darjeeling-Sikkim (Ghosh)	Assam Himalaya (Ghosh)
6.	Pir Panjal Thrust.	Chail/Jutogh Thrust	Garhwal Thrust	South Almora Thrust	Thrust	-	Thrust(?)
5.	-	Krol Nappe	Krol Nappe with Windows of Early Tertiary & Pre-Cambrian(?)	Krol nappe-Syncline of Nainital.	Nawakot Nappe with autochthonous or par-autochthonous Pekhara zone in a Window.	-	Permo-carboniferous sediments-Krol(?)
4.	Murree Thrust	Krol Thrust	Krol Thrust				
3.	Para-autochthonous zone of post Nummulitics and pre-Siwaliks (Murrees) and inlier of Mesozoic.	Para-autochthonous zone of post-Nummulitics and pre-Siwaliks (Dagshai-Kasaulis-Dharmasala).	Para-autochthonous zone of Nummulitics and Pre-Siwalik rocks (Dagshais)				

2. PREVIOUS WORK IN KUMAON HIMALAYA

From the preceding account it will be seen that the Kumaon Himalaya has been investigated in the past by a number of workers viz., Middlemiss, Oldham, Auden, Heim and Gansser, Pande and Valdia.

Oldham

Oldham (1883), after taking a traverse between Almora and Mussoorie, published a paper in which he gave the distribution of various rock types met with during his traverse. He noticed the presence of schists and gneissose granite from Almora to Mussoorie. He also mentioned the occurrence of slates along the road between Dwarhat and Ganai and limestone on the eastern side of the valley near the peak of Dunagiri.

Middlemiss

Middlemiss (1887) spent several years in the foothill region of Kumaon, mapping the area between Ganges and hills around Nainital. About Nainital area he remarked, "The geology of Nainital, in its purer scientific aspects is neither very attractive nor very instructive, as larger part is filled up with large blocks of mountain slides". He established that, "At Nainital,

the Krol belt is encountered as a continuation of that in the border region of Simla. The thrusted syncline of Nainital recalls the border of the syncline of Mussoorie". According to him the north Almora thrust, which borders Almora crystalline zone, was a straight fault well defined at Dwarahat and Diwalikhal.

Auden (1936) in his paper on the structure of Himalayas in Garhwal, has stated that the Krol nappe and Garhwal nappe are superimposing one on the other. He considers that the gneissic granite of Ranikhet, Dwarhat is intruded into phyllites of the same type. He further suggested that the Dudatoli-Dwarhat-Ranikhet-Almora region represents a syncline or a group of synclines which may be outliers of Garhwal nappe.

Auden

Heim and Gansser (1939) took a number of traverses in Kumaon Himalaya and their contribution is very valuable. On Nainital area, their views are not clear. They found the region to the SE of Nainital extremely complicated by crushing, crumpling and numerous local faults of different directions.

Heim & Gansser

According to them, the variegated clay shales with quartzite along the road to Ranikhet partly corresponded to the Nagthat series of Tehri-Garhwal. Upto Bhowali, the dips are due WSW. But from Bhowali to Almora via Ramgarh, the dips were recorded with more or less regularity towards NE. The rock series from Bhowali to Almora, about 15 kilometers in thickness, seems to be reversed in its north-eastern part. "Indeed, from the Nathua Khan pass to the Kali Rau gorge, the metamorphism gradually increases upward and this not only apart from the granite intrusion."

" On the other hand, the sedimentary series of the Ram Gad valley with its regular stratification shows all the aspects of a normal series. Possibly the tectonical position of Nathua Khan is that of a recumbent syncline. The series is intensely stretched. Beautiful slickensides in the direction of the north-eastern dip were encountered on the surface of a quartzite layer SW of Nathua Khan. However, no signs of a major thrust-fault were found" (Heim & Gansser, 1939, p.28).

It is not possible to describe the work of Heim & Gansser in full here, and adequate purpose will be served by looking at the given section, prepared by them (Fig.11).

Pande has been working in the Kumaon Himalaya for the last 20 years. In an early paper Pande (1950) gave an account of the lithology, stratigraphy and structure of the rocks of Ramgarh area. In his (1956) another paper on "Migmatites of Ramgarh, dist. Nainital", he classified migmatites into four groups:-

(i) Massive migmatites
(ii) Augen migmatites
(iii) Foliated migmatites
(iv) Mylonised migmatites.

Pande

According to him, the migmatites have formed due to lit-par-lit injection along the privilaged paths by fluids coming from depth. He considers the Tertiary age of this migmatite. Pande and others (1963) have published a paper on, "The migmatites of Kumaon hills (U.P.)", in which they have given a generalised geological map of Kumaon Himalaya and gave the origin of migmatites. According to them the gneissic rocks of Kumaon are of metasomatic origin.

Working in the eastern part of Kumaon Himalaya Valdiya jointly with Mishra (1961) published a paper on "The calc-zone of Pithoragarh with special reference to the occurrence of stromatolites". The paper records the occurrence of stromatolitic structures in the dolomitic limestone of Pithoragarh (U.P.). They ascribed this structure to algal genus Collenia. It is suggested by them that the magnesite deposit overlying this limestone is the result of primary precipitation of magnesium carbonate, aided by the activity of the algae. This zone was described as 'Calc-zone of Pithoragarh', which they correlated with the Deoban limestone of Chakrata area.

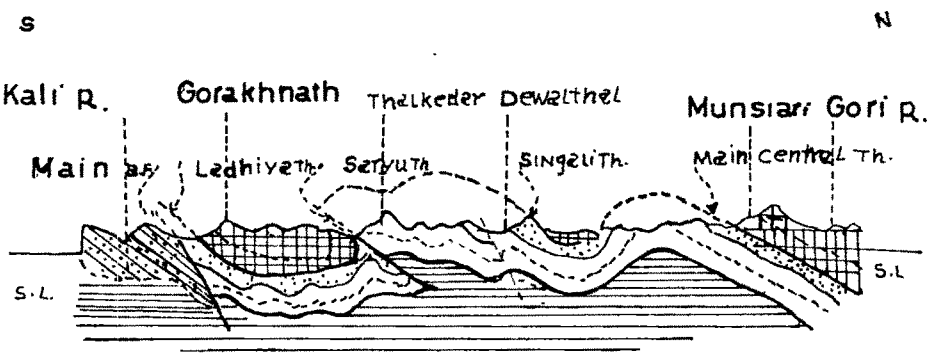
Valdiya & Mishra

Valdiya (1962) in his next paper on the Champawat granodiorites and associated metamorphics of the Lohaghat sub-division (Almora), writes that like most of the great batholithic bodies of the geosynclinal fold mountains, the Champawat granodiorite belongs to two different pulse of eruption. The great central mass is predominantly granodiorite while the younger group of rocks occuring chiefly as sheet, dykes and veins, is more leucocratic and poorer in biotite.

Valdiya

Fig 12

Tectonic section from Munsiari to Kali Valley near Tanakpur after K.S. Valdiya



Lower Siwaliks of Tanakpur Area

Unknown Autochthonous

Calc zone of pithoragarh
Quartzite zone
] Krol Nappe

Crystalline zone of
Askot & Lohaghat
] Garhwal Nappe

0 5 10 MILES

In his another paper on the stratigraphy and structure of the southern part of Pithoragarh (U.P.) Valdiya (1963) has recognised three stratigraphical formations in the area:-

(i) The above discussed calc-zone.

(ii) The quartzite zone constituting quartzite and phyllites equivalent to Nagthat (Jaunsar) series.

(iii) The crystalline zone of Askot consisting of schists and gneisses which is correlated with the Chandpur (Daling or Darjeeling) series.

The sedimentary zone occupying a vast tectonic window between the crystalline zone corresponds to the Krol nappe, the whole sedimentary pile represents the lower limb of a mighty recumbent anticlinal fold, thrust from north to south. The thrust beyond crystalline zone of Askot and Lohaghat represents two detached outliers of a single thrust sheet corresponding to Garhwal nappe (Fig. 12).

Sarkar and others (1965) have done systematic analysis of structural features of a part of Almora nappe

Sarkar & others around Almora and have attempted to suggest the possible tectonic pattern. According to them the country rocks which mainly include garnetiferous mica schists, quartzites, graphite schists, granite gneisses and granites, are characterised by three S-planes and four types of linear structures. S_2 (axial plane cleavage) transects S_1 (bedding) near fold hinges, but subparallel to S_1 in the limbs. S_3 is later strain-slip cleavage on puckered S_2. Linear structures include L_1-axes of recumbent and isoclinal folds of first generation; L_2-intersection of S_1 and S_2; L_3-slickenside, groove and mineral lineation on S_1 and S_2; and L_4-minor puckers on S_2. They have suggested that the recumbent folds of the first generation are developed by translatory movement varying in direction between due north and west. Sarkar (1964) has explained the age of regional metamorphism in this part of Himalaya as Lower Oligocene and also concluded that the age of granitisation appears to be of the same age.

3. PREVIOUS WORK IN RANIKHET AND NEIGHBOURING AREA

Not much work has been done in the past in the Ranikhet and its neighbourhood. The area practically

remained unworked except for some observations made by Fox (1920), Auden (1935) and Heim and Gansser (1939). Srinivasan (1961), Sharma (1962), Pande (1963) and Das (1965) have also made some casual references to this area.

Fox (1920) took traverse from Ranikhet to Karnaprayag and upto Hardwar, in connection with Hardwar-Karnaprayag railway survey, and recorded briefly the rock types encountered.

Fox

During his traverses in Himalayas, Auden (1935) followed the route from Ranikhet to Dwarhat, Diwalikhal, Karnaprayag and upto Badrinath. About the present area, he writes (p.133), "from Ranikhet to Dwarhat occurs a complete association of phyllites, garnet mica schists, graphite schists and quartzites intruded by granite, which in some cases is porphyritic. The same series is again found west of Lobah. He observed that structurally Ranikhet-Almora region is a syncline or a group of synclines."

Auden

About the present area, Heim and Gansser (1939) mentioned, "In the west of Chaubatia there is a large wall

Heim & Gansser

of gneiss partly broken down in the shape of mountain slides. It is a real orthogneiss with augen upto 2 cms., and is about 50 metres thick. This gneiss supports nearly horizontally another series of mica schists extending to Ranikhet. According to them the gneiss of Ranikhet corresponds tectonically to the granite of Almora which is more massive, partly on account of its much greater thickness. At Ramikhet, as well as SW of Almora, the upward progressive metamorphism is considered as reversed stratigraphical series.

While describing their traverse from Ranikhet northward to Karnaprayag they have observed (p. 47) that descending northward to Gagas river, a series of mica schists, quartzites and gneiss is traversed. The dip increases upto 40° due NE. The dip remains unchanged as far as the crest of Chaura, where the garnetiferous mica schists form a symmetrical syncline of WNW strike.

Srinivasan (1960-61), in a note on the geology of Chilianaula area, west of Ranikhet has given a lithological

Srinivasan account of the rock types. He has suggested four metamorphic episodes undergone by the rocks of the area.

First episode is related with the folding. First schistosity appeared during this and the sediments are metamorphosed upto garnet grade.

The first episode was followed by retrogressive metamorphism evidenced by the degeneration of garnet in the schists.

The third episode is related to granitisation. It was of progressive nature.

Finally the last episode of the metamorphic history is retrogression. This episode seems to coincide with one of the Himalayan orogenic movements.

Sharma (1962) has published a paper on the occurrence of basic intrusion at Ranikhet. The paper records the discovery of an olivine dolerite found as laccolith, ~~is~~ intruded in the gneisses near Moonground of Ranikhet. He has assigned a Tertiary age to this intrusion.

Sharma

Pande (1963), in his paper on migmatites of Kumaon hills, has recognised the following episodes in the metamorphic history of the Kumaon Himalaya:-

Pande

Episode I :- Load metamorphism resulting in the formation of first cleavage.

Episode II :- Progressive regional metamorphism during which the rocks were folded, related with the development of main schistosity at an angle to first one.

Episode III :- Widespread dislocation movement, degeneration of garnet and biotite, and formation of ferrimuscovite and chlorite.

Episode IV :- Permeation of fluids from depth along the privilaged paths like foliation and cleavage, resulting in the formation of porphyroblastic gneiss parallel to biotite foliation and development of garnet in garnet.

The author, in collaboration with Merh (1965), has published in brief the structural and metamorphic characters

of the Ranikhet area. He has

Vashi & Merh

found that the regional metamorphism and migmatisation as shown by the rocks of the Ranikhet area clearly show that the above phenomena are intimately related with the orogenic movements which deformed the geosynclinal sediments. The details of his findings are now included in the present work.
