CHAPTER II

PREVIOUS WORK

THE HIMALAYA

The Himalaya forming the largest mountain chain on the earth is housed with several highest mountain peaks. Flanked by the low-lying Indo-Gangetic plains in the south and the high Tibetan plateau in the north, it merges with the Pamirs in the east and with the Arakan Yoma Chain of Burma in the west, respectively.

Extending for about 2400 km, longitudinally from west to east, the Himalaya is divisible into five divisions namely Punjab, Kumaun, Nepal, Bhutan and Nefa Himalaya. Transversely it comprises Siwaliks, Lesser, Higher and Tethys Himalaya (Fig. II.1). Physiographically, in Kumaun the Himalaya forms a step like

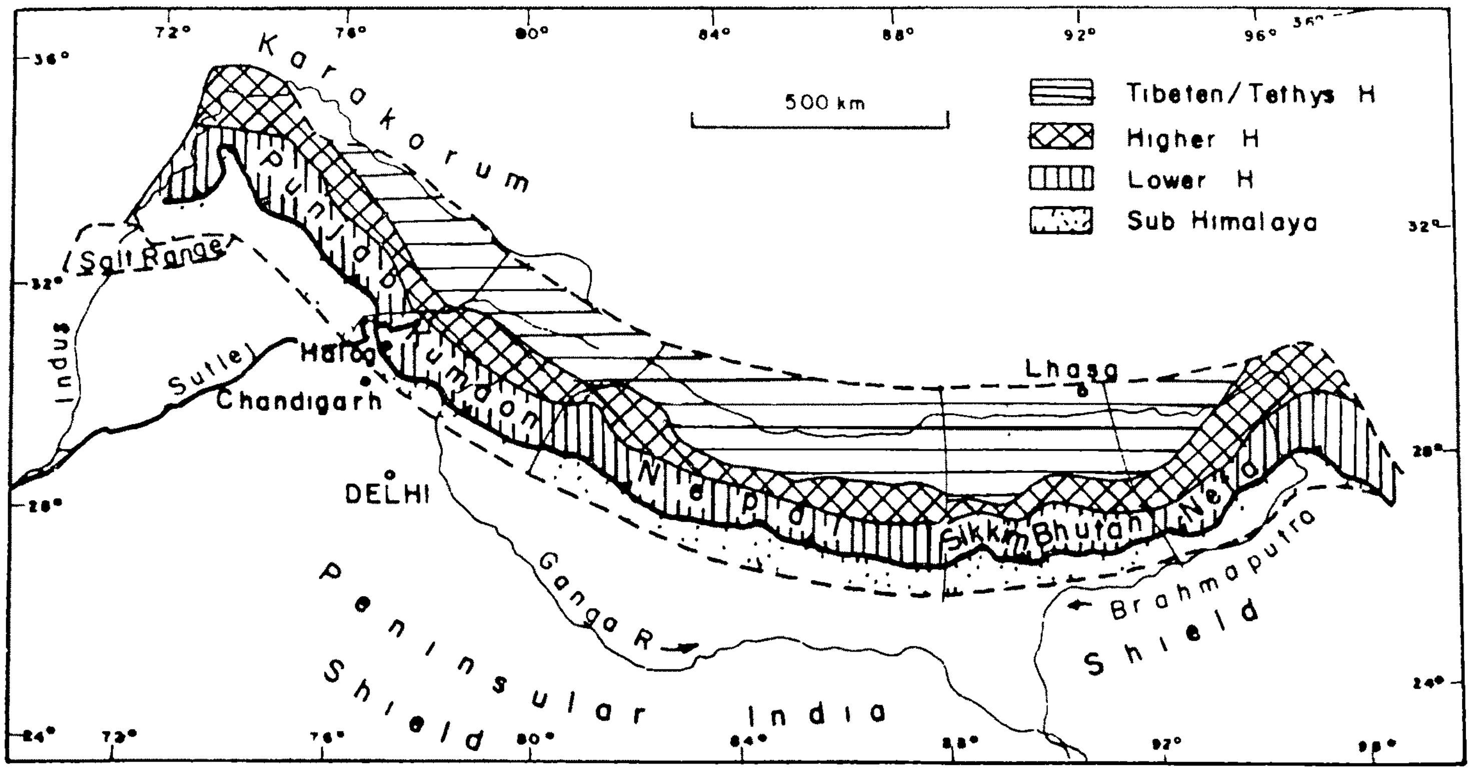


Fig II. 1 The Himalaya, its Geology & Geographical Divisions structure. Rising from the low lying Indo Gangetic plains in the form of Siwaliks it is separated by the Himalayan Frontal Fault from the plains of Uttar- Pradesh. The Siwaliks rise upto the elevation of 1000 m and merge into the Lower Himalaya further north (whose altitude is less than 3000 m) the Main Boundary Thrust separate the Lesser Himalaya from the Siwaliks.

The Higher (Great) Himalaya also known as the Central Crystallines are separated by the Main Central Thrust from the Lesser Himalaya and are characterised by some of the highest peaks of the world, rising generally upto the altitude from 3000 to 6000 m. A few rising even upto more than 8000 m. The Malari Thrust or the Trans Himadri Fault separates the Higher Himalaya from the Tethyan sediments. Beyond this further north the Tibetan Plateau forms an elevated platform with an average height of 3500 m and hence, it is also named as "the roof of the world".

The step like feature is due to the thrusting of enormous landmasses one over the other. The origin and evolution of this gigantic mountain chain have been a matter of considerable debate. Earlier workers (Middlemiss, 1880; Auden, 1934 and 1937; Heim and Gansser, 1939; Gansser, 1964; Nautiyal, 1955; Pande, 1950) were greatly influenced by Alpine orogenic model. Later workers invoked various concepts to explain the Himalayan orogeny. A brief account of the existing concepts is as follows.

Geosynclinal concept

This model envisages evolution of Himalayan mountain chain from two parallel geosynclines which were separated by the present crystalline axis. Biogenetic conditions prevailed in the northern geosyncline (precursor Tethys Himalaya/Tibetan Himalaya) preserving a fully developed fossiliferous succession right from the Lower Palaeozoic to early Tertiary. Although, the southern (precursor of the Lesser Himalaya) geosyncline was believed to have environmental conditions similar to those of its northern counterpart, but the lack of fossil record was attributed to poor preservation. Wadia (1957) designated the barrier (the crystalline axis) separating the two major geosynclines as the 'Central Himalayan Geanticline'. Pande and Saxena (1968) contended that the crystalline barrier came into existence towards the south of the geosyncline which gave rise to the Tibetan Himalaya and was uplifted for the first time during the Ordovician. As a consequence of the rise of this Central Barrier, another geosyncline was formed towards the south of the axis at the close of the Palaeozoic. Singh (1979) proposed that the Lesser and Central Himalaya constituted an integral part of the Peninsular shield and hence extended the northern limit of the Indian Plate further north of even Central Crystallines. Valdiya (1984) also used the concept of miogeosyncline and eugeosyncline.

Continental drift theory

Wadia (1931) suggested a compressive force acting from north, due to which the Himalayan sediments were folded and thrusted, and gave rise to the present Himalayan mountain chain. Holmes (1944) suggested the Tibetan Plateau as the median mass forming a part of the geosynclinal block but later on he (1965) visualised the underthrusting of Indian mass beneath the Tibetan plateau. Hess (1955) considered the Indus Suture Line as the relic of a closed ocean, which lay between India and Asia. Whereas Gansser (1964) described the Indus Suture Line as a sudden root like down buckling. He envisaged this tectonic feature to be the boundary between the Indian Peninsular block and the Eurasian block.

Block uplifting concept

The supporters of the Belussov's (1962) concept of vertical uplift, attributed the evolution of the Himalaya to the uplift of crustal blocks along deep fractures and faults (Hagen, 1959; Pande, 1967; Eremenko and Datta, 1968; Ashgirei, 1975). Mehdi et al. (1972) suggested the hypothesis of successive generation of grabens and horsts in Kumaun Himalaya. Raiverman (1992) suggested that the disposition of pre-collision lineaments occurring over the Indian Shield bear relationship to those occurring on the Eurasian plate across the orogenic chain. Also the available fossil evidence does not support separation of the Indian plate from that of Asia in the past and according to him an orogenic model based on the upward movement of a sub-crustal magmatic and basification front rising from the mantle facilitated by deep fracture zones is more viable.

Plate tectonic concept

Most of the recent workers however use the plate tectonic model to explain evolution of Himalaya (Fuchs and Frank, 1970; Le Forte, 1975; Molnar and Tapponnier, 1975 and Valdiya, 1980). Fuchs (1970) suggested convergence of the Indian and Eurasian plates at shallow depths along the Himalayan Mountain Front. Dewey and Bird (1970), Molnar and Tapponnier (1975 and 1977) and Le Forte (1975) conceived the origin of the Himalaya as a result of collision of the two plates - the Indian Peninsula and the Asian continent. Sinha - Roy (1976) proposed that the Himalaya might represent reconstituted and 'digested' upthrust microcontinental blocks which tectonically rest over the deformed cover rocks, deposited in the Himalayan basin. Singh (1979) on the basis of sedimentological studies and unfossiliferous nature of the Lesser Himalayan sediments demanded the northern limit of the Indian Plate to be extended further north of Himalaya. Sychanthavong and Merh (1978) extending their proto-plate tectonic theory postulated that all the Precambrian rocks of Himalaya belong to the Aravalli protocontinental shield. Merh et al. (1986) based on their studies on the amphibolites of Kumaun Himalaya, unequivocally stated that the geological setting of the two provinces is quite comparable.

Chamyal and Vashi (1989) and Chamyal and Manudip (1994) on the basis of the structural studies also considered the crystalline rocks of Kumaun to be equivalent to the rocks of Ajabgarh Series of the Delhi Group.

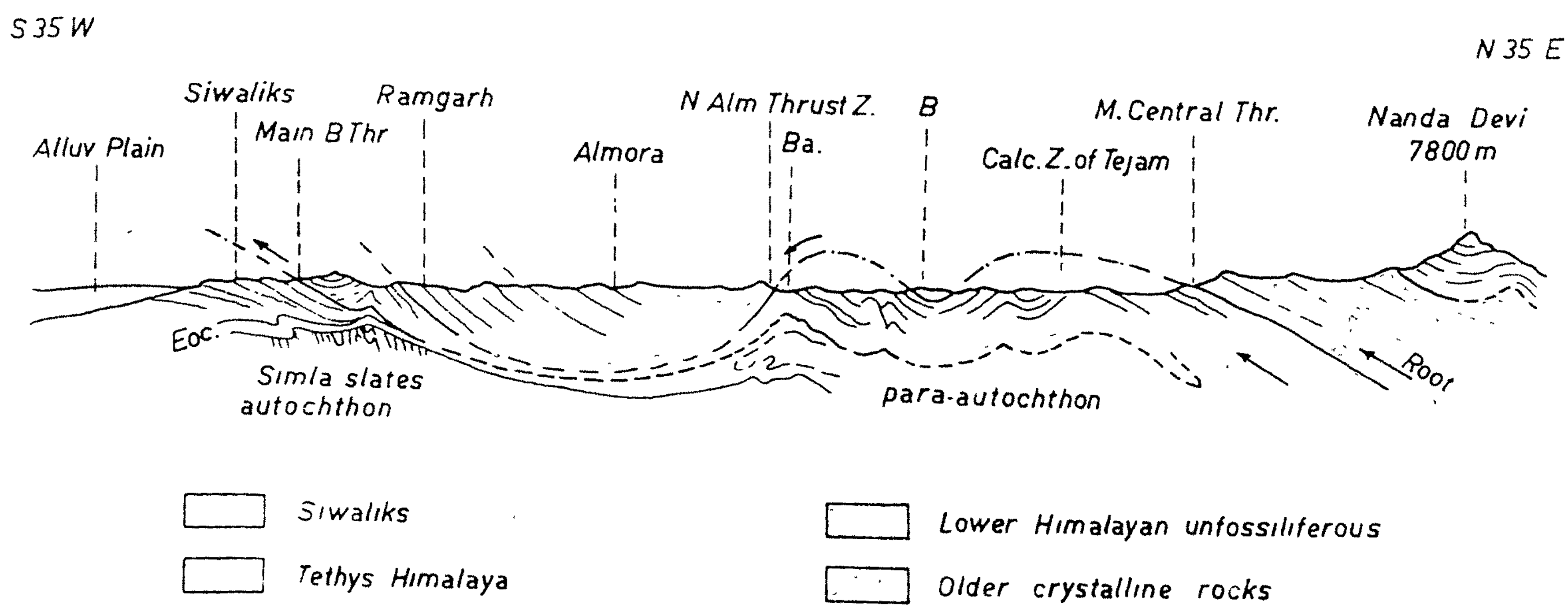
THE KUMAUN HIMALAYA

In Kumaun the Great Himalaya forming the backbone/central ridge of the great mountain arc is geodynamically a crucial region. The Central Crystallines as they are generally referred, comprise schists, gneisses, granites, quartzites and amphibolites and are thrusted over the younger metasedimentaries of Lesser Himalaya. Himalaya, from the distant past has received much attention of geologists from all the parts of the world, and a synthesis of their work provides a rather coherent picture of the Himalayan geology and throws light on the stratigraphy and structure of this lofty mountain chain. The Kumaun Himalaya, an important sector of the Himalayas has received maximum attention and in the following lines the author has endeavoured to give a cogent picture of the work done by the various previous workers.

The earliest geological work on Kumaun Himalaya was published way back by Strachey (1851), who took a few traverses in Central Kumaun Himalaya and his cross-section through plains to the High Himalayas comprise an excellent achievement of his time. Stolizcka (1865) designated the Central zone of Himalaya as the 'Central

Gneiss'. During the last century most valuable contributions to the geological studies of the Kumaun Himalaya came from Meddlicott (1864), Malet (1874), Middlemiss (1880, 1888 and 1890) and Greisbach (1891). Their contributions laid the foundation for subsequent studies on Himalayan structure and stratigraphy. Middlemiss (1890) visualised large scale steep reverse faulting to explain the presence of metamorphic series over unmetamorphosed nummulites.

The beginning of the 20th century received equal attention during which the structural aspects of the Himalayas received greater attention. Prof. Loczy (1907) gave the concept of the thrust folding over the entire width of Himalaya. Pilgrim and West (1928) who investigated the Simla region were first to apply the principle of low-angle thrusting. Auden (1934, 1937) worked out the structure and stratigraphy of Simla, Garhwal and Kumaun region. The work of Heim and Gansser (1939) forms another landmark towards the understanding of the Himalayan geology. They undertook varied traverses right from the Gangetic plains upto the Mount Kailash. They extended Auden's concept in Garhwal eastward into Kumaun and named the crystalline thrust unit corresponding to the Garhwal Nappe as 'Almora Nappe'. Delineating the North Almora Thrust and South Almora Thrust (bounding the Almora Nappe), they considered the thrust separating the crystallines from the underlying metasedimentary group as the Main Central Thrust (Fig. II.2). They also studied the Central Crystallines in fair detail in the Sarju-



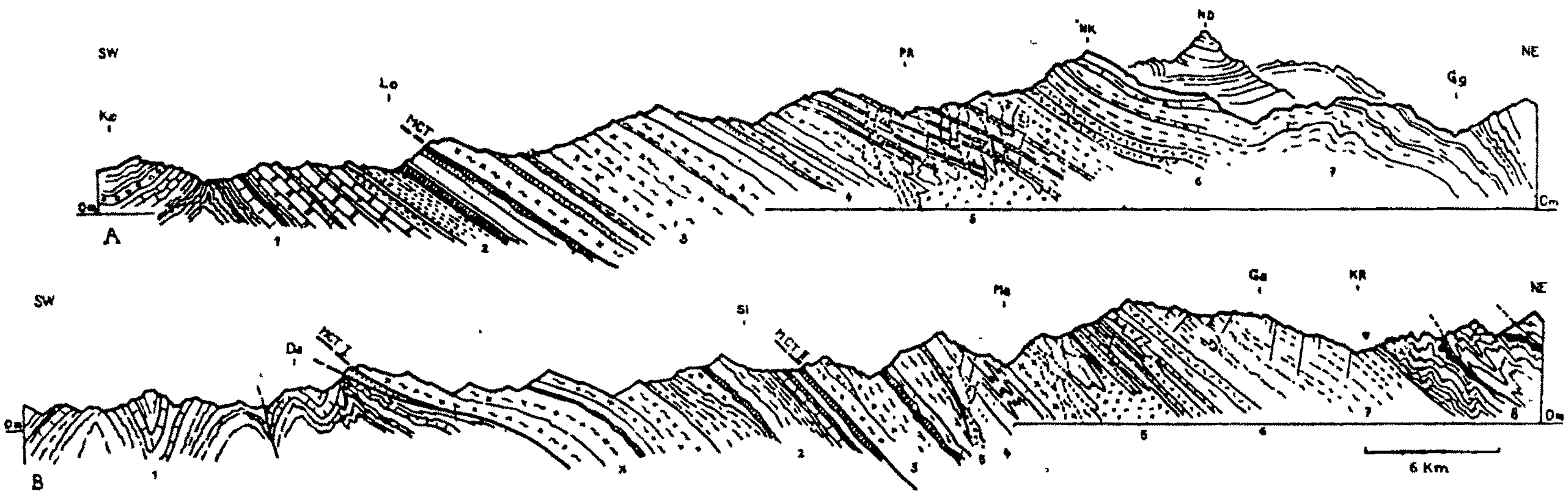
GENERALISED SECTION ACROSS KUMAON HIMALAYA (HEIM AND GANSSER , 1939)
FIG II. 2

Pindar, Goriganga and Kali valleys.

Gansser (1964) in his monograph on the geology of Himalaya, slightly modified his former ideas (Heim and Gansser, 1939) and concluded that (op. cit. p. 90) "in the Himalaya we deal with proper bedding thrusts not with recumbent nappes". The geological section across the Main Central Thrust and the crystalline core of the Kumaun Himalaya through the Nanda Devi and along Kali river as given by Gansser (1964) are reproduced (Fig. II.3 A,B). West (1949), mentioned that the structure of the Garhwal Himalaya, is essentially the same as that of Kumaun Himalaya and the two areas are comparable.

Among the recent workers, the contribution by Pande (1949, 1950 and 1963) are noteworthy. Pande et al. (1963), summarising the results of their investigations established four general metamorphic episodes in Kumaun, viz. load metamorphism, progressive regional metamorphism and granitisation in that order. Pande (1963) for the first time unequivocally suggested a migmatitic origin of gneissic rocks of Kumaun.

Misra and Valdiya (1961) and Valdiya (1962 , a, b, c) found stromatolitic structures with convex side downwards in the Pithoragarh section and the presence of cross-bedding and ripple marks in quartzites of the Pithoragarh zone indicating an inverted section. This led them to conclude that the whole section of inner



Geological sections through the MCT and the Crystalline Core of the Kumaon Himalayas (Central Himalayas). (Redrawn from GANSSER 1964). Section A through Nanda Devi. Section B along Kali River (W border of Nepal), to Garbyang. 1. Precambrian sediments of Lesser Himalayas. Metamorphism increasing towards MCT. 2. Precambrian metasediments of Lesser Himalayas with schists, quartzites and amphibolites just below thrust, repeated in Sirdang area below MCT II. 3. Gneisses, partly migmatitic of lower part of crystalline core. 4. Metaquartzites and high grade schists in middle section of crystalline. 5. Leucogranites with dykes intruding zone of marbles, lime-silicates and psammite-gneisses. The relation of leucogranites with the upper high grade carbonate zone of the main crystalline is widespread. A certain three-fold division of the main crystalline core is also evident in Nepal and the eastern Himalayas. 6. Typical biotite porphyroblast-schists, ending the main metamorphism of the crystalline core (Budhi schists). 7 Late Precambrian to Cambrian argillaceous Tethys-Himalayan sediments. 8. Folded and imbricated sediments from Ordovicium to Permian of the Tethys Himalayas. Da – Darchula, Ga – Garbyang, Gg – Gonganga (Valley), Ka – Kapkot, KR – Kuti River, Lo – Loharkhet, Ma – Malpa, ND – Nanda Devi (7,820 m), NK – Nanda Kot, PR – Pindari River, Si – Sirdang.

FIG II. 3

zone in the Lower Kumaun Himalaya was inverted. Subsequently Valdiya (1970, 1980, 1981, 1988) has now recently given a broad lithotectonic succession of Kumaun Himalaya (Table II.1).

According to Valdiya (1988) the Tejam Group of rocks are over thrust by a huge succession of the Berinag Formation, comprising sericite rich coarse grained to granular quartz arenite interbedded with amygdaloidal vesicular basalts and chloritic tuffs. The Berinag Formation covers a very vast tract of the Inner Lesser Himalayan belt. The imbricating Almora Nappe overlies the Ramgarh Nappe. The Almora Nappe covers a vast area in central Kumaun. The nappe and its many klippen in the inner sedimentary belt are made up of the three formations.

(i) Saryu Formation; comprises chlorite-sericite schist (phyllonite), biotite-sericite-garnet schist, garnetiferous micaceous quartzite and associated (1900 ± 100 m.y.) augen gneiss (Trivedi et al., 1984).

(ii) The syntectonic batholithic body of Champawat granodiorite embraces quartz biotite rich tonalite, granodiorite and granite of trondhjemitic suite, dated 560 ± 20 m.y. (Trivedi et al., 1984).

(iii) And at the top, forming the core of the Almora Syncline is the Gumalikhet Formation constituted of carbonaceous phyllite

Table II.1 : Lithotectonic succession of Kumaun Himalaya (Valdiya, 1988).

Jungbwa Ultrabasics

---------------------Jungbwa Thrust---------------------

Kiogarh Ophiolitic Melange

---------------------Kiogarh Thrust---------------------

Tethyan succession

(late Precambrian to late Cretaceous)

--------------Trans Himadri (Malari) Fault---------------

Vaikrita Group

(Precambrian)

--------------Main Central (Vaikrita) Thrust--------------

Munsiari Formation

(early Precambrian)

---------------------Munsiari Thrust---------------------

(Schuppen zone)

-----------------------------Thrust-----------------------------

Berinag Formation

(Precambrian)

---------------------Berinag Thrust---------------------

Damtha Tejam Group

(Precambrian)

(Base not exposed)

Almora Group

(With 550 ± 50 m.y. granite)

---------------------Almora Thrust---------------------

Ramgarh Group

(With 1900 ± 100 m.y. porphyroids)

---------------------Ramgarh Thrust---------------------

Krol Succession

(late Precambrian-lower Cambrian)

--------------Krol or Main Boundary Thrust--------------

Siwalik Group

(Late Tertiary)

-------------------Himalayan Frontal Fault-------------------

Ganga Plain with Bhabar Fan

(Quaternary-Recent)

and graphitic schist interbedded with black meta-graywacke.

The Munsiari Formation immediately below the Main Central (Vaikrita) Thrust is a severely deformed and tectonically condensed package forming an imbricate zone. It has been described as the roots of the Ramgarh and Almora Nappes (Heim and Gansser, 1939; Gansser, 1964; Valdiya, 1962, 1980 b, 1981). The Baijnath Dharamgarh-Askot Klippen are made up of the basal augen gneisses (1810 $\pm$ 20 m.y. old with S_r isotope ratio of 0.7092 $\pm$ 0.0015) as is the root Munsiari Formation constituted dominantly of augen gneisses dated 1830 $\pm$ 200 m.y. and (S_r isotope ratio 0.725) 1890 $\pm$ 200 m.y. (Bhanot et al., 1977).

The Vaikrita Group is divisible into four formations (Valdiya, 1973; Valdiya and Goel, 1983). It is demarcated by Main Central (Vaikrita) Thrust (Valdiya 1979) in the south and is at an higher stratigraphic level (Fig. II.4) than the Munsiari Thrust regarded as the Main Central Thrust by other workers. The steep Malari Thrust regionally described as the Trans Himadri Fault (Valdiya, 1987, 1988 b) bounds the Vaikritas in the north. The Vaikrita is extensively intruded by mid Tertiary (28-20 m.y.) batholiths of granites and dykes and veins of tourmaline rich adamellite and pegmatite. The invasion of granite has caused widespread migmatisation brought about by pervasive and permissive penetration of magma along foliation planes and joints (Powar, 1972).

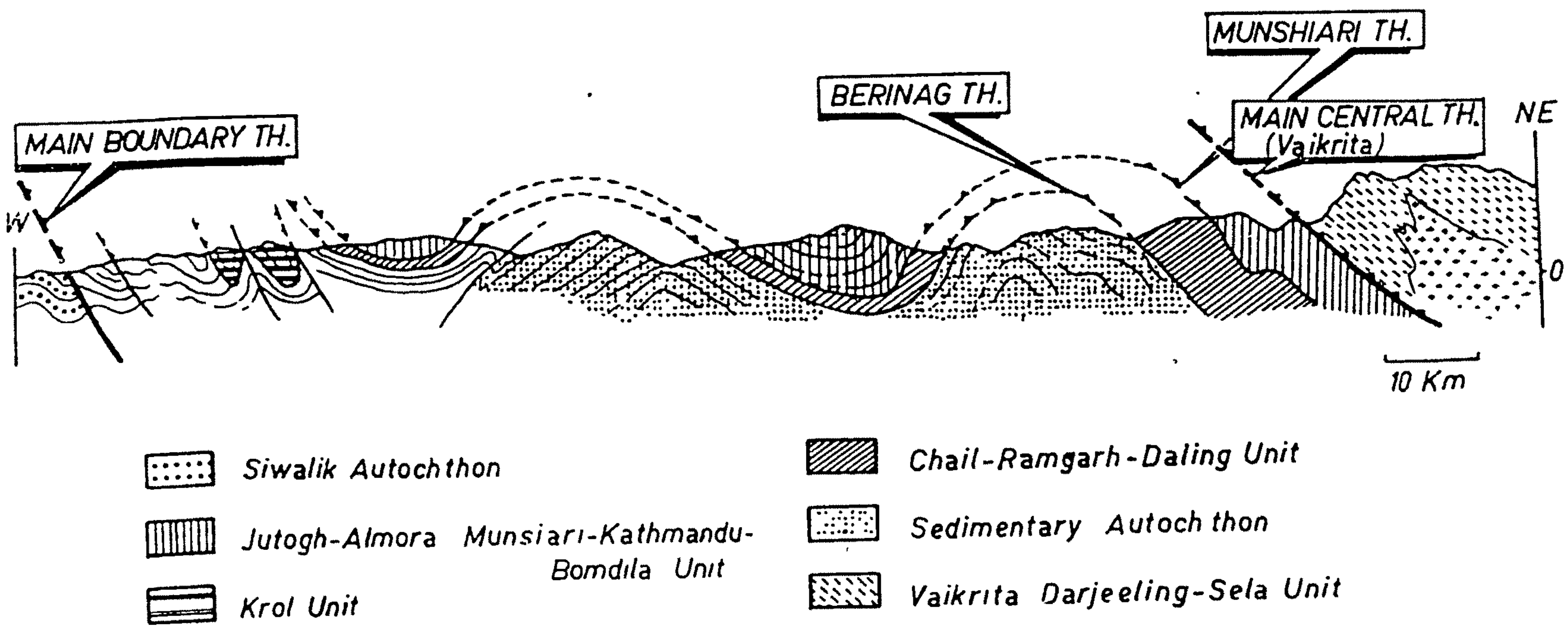


FIG II.4 STRUCTURAL FRAMEWORK ENVISAGED BY VALDIYA (1980)

The contributions to the geology of Kumaun by Merh and his associates (Merh and Vashi, 1965; 1966; 1976; Merh, 1977; Vashi and Laghate, 1972) threw new light on the structure and stratigraphy of the southern part of Kumaun Lesser Himalaya. These workers studied almost all the aspects of Kumaun rocks in great detail. They have worked out a complete sequence of structural events on the basis of minor structures and also have correlated them with the metamorphic history. Merh (1968) in his short note on the structural and metamorphic aspects of the Central Kumaun gave some broad ideas about the geological evolution of the Kumaun region.

Mehdi et al. (1972), Agrawal and Kumar (1973), Kumar et al. (1974) and Kumar and Agrawal (1975), putforth an altogether new tectonic framework for the evolution of Kumaun Himalaya. They invoked the concept of vertical uplift and subsidence along deep seated faults. They opined that the various thrusts like, South Almora Thrust, North Almora Thrust and Main Central Thrust, are independent faults having developed at different stages of Himalayan uplift. Powar (1980) divided the Nainital-Almora area of Kumaun Himalaya into four lithotectonic units, the first three falling in the Outer Lesser Himalayan belt and the last within the Inner Lesser Himalayan belt. Ahmad et al. (1980) did not agree with Valdiya's (1979) attempt of suggesting two almost subparallel thrust in Kumaun.

Recently, Chamyal (1991) revising the concepts of previous workers has reinterpreted the geology of Kumaun Lesser Himalaya. He has ruled out the thrust at the base of the arenaceous horizon (Loharkhet quartzites) and has instead invoked an unconformity. Chamyal (1991) gave an integrated picture of the regional stratigraphic framework for the metasediments lying between the Main Central Thrust and the Main Boundary Thrust. He has revised the stratigraphy on the basis of the occurrences of chloritic horizons of spilitic origin and also the existence of an unconformity at the base of Loharkhet/Bageshwar Formation.

In a recent publication Chamyal and Manudip (1994), have provided the structural set of the Higher Kumaun Himalaya. According to them the rocks of Higher Himalaya have atleast undergone effects of deformation and metamorphism of two generations - Precambrian and Tertiary. Invoking four fold episodes in the Central Crystallines they believed that the Crystalline mass comprised an integral part of peninsular India, having been affected by pre-Himalayan orogenies the frontal portion of the Indian shield was shattered and MCT geofracture was developed, which was reactivated during the Himalayan orogeny. They further opined that the Crystalline block (upthrusted block) might have undergone drastic deformation and transformation at depth during Himalayan orogeny.

THE GRANITOIDS

About 143 years back Strachey (1851) for the first time reported granitic rocks in Kumaun. He considered them to be intrusive bodies rising and cutting right from below. Stoliczka (1865) designated the gneissose rocks of the Himalaya as 'Central Gneiss'. Whereas Middlemiss (1880) assigned two different ages to the granitic rocks of the Himalaya : pre-Triassic and Tertiary. Oldham (1883) regarded the Almora granite to be intrusive. McMohan (1887) worked mainly on the petrography and the genesis of gneissic granites of Himalaya and considered the Chor granites to be intrusive in nature. Auden (1933) who worked extensively in Kumaun thought that the non foliated granites of Almora were igneous in origin which had intruded into the crystalline Chandpurs in Pre-Triassic time.

In their book on the Geography and Geology of the Himalayan mountains and Tibet, Burrard and Hayden (1934) were not able to ascertain whether the gneisses were wholly igneous or composite gneisses had formed due to injection and rolling out of granite veins along the foliation of mica schists.

Heim and Gansser (1939) envisaged two types of granitic rocks in Almora- the orthogneisses and the true granites. The true granites are also interbedded concordantly with the schists and do not show any contact metamorphism. Yet, they regarded them to be ortho-rocks as the contact margins as well as the primary unconformities were obliterated by repeated tectonic influences. Dividing the acid igneous rocks of Kumaun into older and younger ages, they envisaged that the orthogneisses were older whereas the white tourmaline granites and aplites being younger. The Kailash granites on the basis of the presence of hornblende were assigned pre-Tertiary age because they differed from the younger Himalayan tourmaline granites mineralogically. In general they considered the various occurrences of these rocks all over Kumaun to be concordant sheets of igneous origin intruded into the metasedimentaries.

Nautiyal (1941) too, regarded the granites of Almora to be of igneous origin, intrusive into the metasediments. Peter Misch (1949) while describing the gneissic rocks of Nanga Parbat visualised granitisation of batholithic dimensions. He observed that the gneissic rocks had undergone regional metamorphism of argillites which showed progression from slates and phyllites, through mica-schists, biotite para-gneiss, kyanite schist to sillimanite para- gneiss were due to lit-par-lit replacement against mechanical injection along active foliation planes. The metamorphic isograde was seen to be independent of depth and was a function of differential introduction of heat from below. Kharkwal (1951) regarded the rocks of Lohaghat-Champawat area to be of intrusive nature. Pande (1956) suggested that the rocks of Ramgarh area were formed as a result of metasomatic granitisation. Pande et al. (1963) for the first time unequivocally suggested a migmatitic origin of gneissic rocks of Kumaun.

Valdiya (1962 a) who studied the granodiorites of Champawat opined that like most of the great batholithic bodies of the geosynclinal fold mountains, the Champawat granodiorite was a composite body. The central mass emplaced synkinematically was predominantly granodiorite with local transition into quartz diorite and trondhjemite on one hand and into quartz monzonite on the other. The younger group of rocks occurring chiefly as sheets, dykes and veins were strikingly leucocratic almost devoid of any ferromagnesian minerals and were emplaced post-kinematically i.e. after the main orogenic activity. Considering the granodiorite body to be intrusive he suggested that the augen gneisses which formed the southern marginal facies of the main body were the products of granitization.

Gansser (1964) revising his earlier views opined that the Almora granite instead of being intrusive does not cut through its surrounding gneisses and schists. It seemed to correspond to a syngenetic granitization without discordant offshoots. This massive body also included xenoliths of psammitic biotite rocks frequently. Considering the Askot and Baijnath as thrusted masses he did not comment much about the nature of rocks and assigned intrusive nature to the tourmaline granites belonging to the youngest and post-orogenic rock types of Himalaya. Sarkar et al.

(1965) mentioned that there was a gradational variation from schists through granite gneiss ultimately to the granites and these varieties from Almora were hence a product of granitisation. They assigned a Lower Oligocene age based on the Ar^{40}/K^{40} dating of mica-schists to the regional metamorphism which accompanied granitisation.

The later workers who worked on the granitic rocks of the Almora Nappe (Merh and Vashi, 1965, 1966; Das, 1969; and Desai, 1968) supported the metasomatic origin of these rocks. Misra and Banerjee (1968) on the basis of their studies in the Sarju-Pungar valley referred to the Askot and Baijnath Crystallines as both para as well as ortho-gneisses. However, they could not discern any boundary between the crystallines and the adjacent metasedimentaries.

According to Pande and Powar (1969) in Almora and Lal (1969) in Masi Bazar area the granitic rocks have been formed by the introduction of anatectic melt into the metasediments. Sharma (1970), concluded that the oligoclase bearing granites in Kumaun are anatectic and the albite bearing ones are metasomatic in origin. Das (1971) also believed in the anatectic origin of the granitic rocks of Chaubatia - Ranikhet area. Shah (1972) also indicated metasomatic origin of these rocks around Almora.

Powar (1972) who studied the granitic rocks of the Central Crystalline zone in north-eastern Kumaun, on the basis of field and mineralogical studies suggested that these rocks are the result of permissive emplacement of granitic melt along the foliation planes of metasedimentary rocks. Agrawal et al. (1972) concluded that these rocks were formed as a result of the introduction of granitic melt into the metasediments along 'priviledged paths' constituted by foliation. Kashyap (1972) on the basis of geochemical studies coupled with petrographical and field evidence revealed that metasomatic transformation of the phyllites was effected by introduction of sodic and subsequently by potassic solutions. Ahmad (1975) who described the geology of Loharkhet-Dhakuri area in fair detail could not comment on the exact origin of these rocks.

Misra et al. (1973) who studied the petrochemistry of Almora Crystallines opined that the entire metamorphic evolution was a result of isochemical changes superimposed by anatexis. Misra and Bhattacharya (1976) called the migmatic granites of the Central Crystalline zone around Dhakuri as syntectonic which probably owed their origin to crustal anatexis during continent-continent collision. Karanth (1977) classified the Almora granitoids into two main categories:

(i) Veins of intrusive granitic material,

(ii) bands of granitised pelitic rocks with or without a median portion of intrusive granitic rock.

Powar and Bhale (1978) suggested that the granitic rocks of Masi area of Kumaun have resulted from the permissive emplacement during regional metamorphism of anatectic magma into metasediments. Divakara Rao et al. (1978) based on the petrochemical studies on the gneissic granites of Central Crystallines suggested metamorphism and migmatisation of Precambrian metasediments followed by granitic intrusions around 500 M.Y. to support their origin.

Valdiya (1980) who wrote a monograph on the geology of Kumaun Lesser Himalaya, referred to the granitic rocks of the three lithotectonic settings : in the autochthonous sedimentary zones as very discordant minor intrusives, in the Ramgarh Nappe and its equivalents as cataclastically deformed and retrograded porphyritic granite and in the Almora Nappe, its Klippen and root as concordant elongate lenses of granodiorite-granite complex grading marginally into augen gneisses.

Valdiya (1983) distinguished four tectonically distinct and lithostratigraphically diverse settings. The porphyritic granites of Lower Himalaya of Precambrian age (~ 1900 M.Y.) which are uprooted and perhaps represent granitic basement. Compositionally different and younger in age (~ 600 M.Y.) the tonalitic-granodioritic bodies, possibly bearing testimony to the occurrence of Precambrian (2000±100 M.Y.) orogeny. Both the above suites have been intruded concordantly by strikingly leucocratic adamellites.

The Kata-metamorphic assemblages of the Higher Himalaya which represent the uplifted and thrust up early Precambrian basement rocks, characterised by batholiths, stocks, dykes and veins of granites and aplites of Middle Tertiary age. The fourth types are the granites of Indus-Tsangpo-suture zone giving 60-70 M.Y. age.

Thakur (1983) based on their tectonic setting and radiometric ages, has been able to categorize the granites into Pre-Himalayan and Himalayan or Late Himalayan granites. Granites of the first category are i) 1800-2000 M.Y., ii) 1200-1400 M.Y. and iii) 500 M.Y. granites. The Himalayan granites are Tertiary 4-18 M.Y. (Badrinath granite) and cross-cut the Pre-Himalayan granites.

Powar (1983) studied the granitic rocks of Eastern sector of Kumaun. He opined that the field relations viewed in conjunction with petrographical and chemical data suggested that the granitoids are of S-type and have resulted from permissive emplacement of anatectic melt into the mesograde sediments. Divakar Rao (1983) who made a study of granites and gneisses of Himalayas came to the conclusions that the Almora granite, Champawat granite and granodiorite were intrusive in nature whereas the Kali gneisses were products of granitisation. Sharma (1983) studied the granitoid belts of Himalaya in fair detail. For the granitoids of Higher Himalaya like most workers he agrees that they were formed from anatectic melts generated during Himalayan orogeny.

Trivedi et al. (1984) gave two whole rock Rb-Sr isochron ages for the granites of Lesser Kumaun Himalaya. The older around 1800 M.Y. corresponded to the granites and gneisses of Ramgarh Nappe, the basal portions of the synformal Almora Nappe and the Askot-Dharamgarh Klippen in the Inner Lesser Himalaya. While, the comparatively younger age 550 M.Y. was found restricted to the massive Champawat granodiorite - Almora granite Nappe. Merh (1984) observed that in Kumaun Himalaya, the transformation of schists into gneissic granites appeared to have been brought about by a process of slow permeation and progressively increased metasomatic action of emanations from depth.

Chamyal (1987) who studied the crystalline rocks of Dhakuri area in Kumaun in detail proposed that the granitisation in the area took place during the first deformational episode along with formation of almandine garnet and staurolite. Saxena and Divakar Rao (1988) while studying the U, Th distribution in granitoids from Joshimath - Badrinath area suggested the leucogranites to be of anatectic origin which showed increase in U enrichment.

Valdiya (1988) proposed that the granitoid rocks underwent upper amphibolite to lower granulite facies metamorphism at 600 - 650^{0}C and more than 5 K bar and migmatisation associated with 28-20 M.Y. old S-type granites which formed during the culmination of metamorphism and thrust deformation.

Roy and Valdiya (1988) on the basis of tectonometamorphic evolutionary study of the 'Central Crystallines' divided them into two major tectonic units. They observed that the upper unit was constituted of high grade psammitic metamorphics associated with anatectic granites of the Vaikrita Group. Chamyal and Vashi (1989) stated that the older crystallines which occupy the cores of synformally folded Main Central Thrust and occur as inliers of Baijnath and Askot beyond the M.C.T. contain granitoids which are of both intrusive as well as granitised varieties.

Sinha (1992) in his book on the 'Geology of the Higher Central Himalaya' has studied these granitoids in fair detail and has called them as para-gneisses and gneisses and schists of psammitic type. Singh et al. (1993) proposed A-type (anorogenic) affinities of the Champawat intrusives. According to them the biotite rich enclaves within the granitoids of Dhunaghat area could represent restites which were later modified by metasomatism. They suggested that the chemical data pointed to some degree of fractional crystallisation for Champawat granitoids.

Agarwal (1994) on the basis of the presence of mylonite zones bordering as well as occurring within the Almora crystalline zone, suggest the possibility of branched-up small duplexes from a common 'sole thrust'. Doubting the synformal nature of the Almora Nappe, a model has been proposed wherein the Almora Crystalline zone represents only a small portion of a large thrust sheet which covered the whole of the Lesser Himalaya once. The synformal nature according to him was probably due to back-thrusting in the later phases of its tectonic development. Hussain et al. (1994) who studied the petrochemistry and tectonic setting of the Champawat Granite Suite of Lesser Himalaya, proposed that this concordantly emplaced polyphase granite suite is a well differentiated, polyphase, calc-alkaline, peraluminous S-type granitoid batholith. They have interpreted it to be the product of anatexis of supracrustals at middle to lower crustal levels and that it shows characters of continental collision environment.