GEOLOGY OF THE HIGHER CENTRAL HIMALAYA

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Preface

I was fascinated to study the mysteries of Himalayan mountains after my first visit to Shimla (formerly spelled 'Simla') as a student of geology. After my basic field training in the Caucasus Mountains, I was sent to Himalaya for further research work under the auspices of the Indo-Soviet scientific exchange programme between Friendship University, Moscow, and Panjab University, Chandigarh. This opportunity allowed me to work in the Shimla-Kulu area of Himachal Pradesh in the Lesser Himalayan zone. After joining the Wadia Institute of Himalayan Geology in 1973 I was entrusted with the task of exploring the unknown regions of the Higher Central Himalaya lying behind the lofty high peaks of Nandadevi (7820 m). These inaccessible terrains were used as routes for Indo-Tibetan tradesmen. Some scanty data were available due to the efforts of earlier stalwarts working at the end of the last century and to the traverses taken by late Professor Arnold Heim and Professor Augusto Gansser from Zürich University, Switzerland. The systematic geological surveying work was started in early seventies by the geologists of Wadia Institute, and I joined the expedition team in 1973. Every year from 1973 to 1981 the expeditions were organized and the task was taken up to cover the *terra incognita* in parts. The traverses were always through some passes of over 5000 to 6000 metres and they were not always negotiable, even in the summer time, due to inclemency of the severe weather conditions. A couple of times the expedition team has experienced narrow escapes in snow storm and blizzard.

This monograph is an outgrowth of my research in the Southern Lesser and inaccessible Higher Central Zone of the Himalayan mountain chain. The book comprises ten chapters and a bibliography. Keeping in my mind the expeditional work, some of the factual data, especially incorporating those long traverses and their systematic sketching in the field, I have also tried to give a first hand account dealing with not only the geology but also the other interesting episodes, viz. climatic hazards, negotiability of the terrain, ethnic groups living in this region and human logistic problems. There had occurred some incidents of landslides and heavy downpours when I walked throughout the night covering more than 60 km between Chamoli to Joshimath to deliver important messages for the expedition party. Chapter 3 includes fascinating discoveries made with the help of my colleagues. Coccolith, Dinoflagellates, Scoelecodont, Chitinozoan and other microorganisms changed the basic concept of geological columns from this classical area of Phanerozoic biostratigraphic research. This area was treated as paradise for study of classical stratigraphic sequence, and their correlation throughout the world; especially the 'Triassic of Himalaya' by Karl Diener has attracted attention all over the world for correlation. This chapter has also added to the new geological data available from Southern Lesser Himalaya. Chapter 4 is devoted to the tectonic framework of the Higher Zone, discussing the new concept of division of the Himalaya on the basis of Main Axial Zone and Root-Zone concepts. The long traverses across Higher rugged region and through gorges have been described in Chapter 5. I have tried to give a real and authentic picture of geology in the field. Problems related to structural zonation and synthesis of geological development have been highlighted in Chapter 6. In Chapter 7 the metamorphic and magmatic episodes have been synthesized with geochemical analyses and geochronological dating. Many friendly laboratories besides our own at WIHG extended support for doing geochemical analyses. I have tried to keep those analyses tagged up with geochronological dating and their outcrops of occurrence with the help of diagrams and profiles attached to the book. Sometimes the original field

Acknowledgements

The initiation of research work in Higher region of Central Himalaya came through the late Professor A. G. Jhingran after I joined the Wadia Institute in 1973. During the course of my expeditions I have received help in many ways from Professor K. S. Valdiya (Kumaun University, Nainital), Professor S. K. Shah (Jammu University, Jammu), Professor S. K. Tandon (Delhi University, Delhi), and Dr V. C. Thakur, Dr A. C. Nanda and the late Dr A. K. Khanna, as my former and present colleagues and members, in the Wadia Institute of Himalayan Geology. Besides them, Dr V. K. Gairola (B.H.U., Varanasi), Dr S. Kumar (Lucknow University, Lucknow) and Dr S. P. Jain (Panjab University, Chandigarh) took part in our other joint expeditions. The Ministry of Defence and the authorities deployed by the Government of India, in these regions, including the Indo-Tibetan Border Police, State Police Department of U.P. and the Civil Authority and other agencies have extended their help and logistic support; without their cooperation it would not have been possible to map and work in this *terra incognita*.

The Survey of India was very generous in providing the genuine help in map preparation and its clearance for the academic publication. For the geochemical analysis I am grateful to the Laboratories of Geological Institute, Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry; Academy of Sciences of USSR, Moscow, and the Geological Institute of the Armenian Academy of Sciences, Erevan. Professor G. D. Ashgirei, Head of the Department of Geology in Friendship University, Moscow, has been helpful to me as my guide and teacher throughout, for the researches in the Himalaya. Without his guidance and invitation for DSc thesis my researches would not have culminated in the present form. During my studies in the Department of Dynamic Geology in Moscow State University I had an opportunity to be in touch with the late Professor G. P. Gorshkov and Professor V. E Khain, corresponding member of the Academy of Sciences of USSR. Academician A. L. Yanshin, present Vice-President of the Academy of Sciences, USSR, inspired and helped in many ways to prepare this monograph. I am grateful to my Soviet colleagues especially to Professor Y. G. Safonov, Professor N. N. Trofimov, Professor G. P. Bagdasarian, Dr Y. Choporov, Dr (Mrs) O. B. Dmitrenko, Dr (Mrs) M. E. Raaben, Dr (Mme) Nina Umnova and many others who helped during the course of my preparation of this monograph by supporting laboratory data for palynological identification and doing photographic work. Dr Gerhard Fuchs (Austrian Geological Survey, Vienna) gave me consistent encouragement and helped in supplying geological analyses of barite specimens and has also kindly reviewed my book for the publisher, John Wiley & Sons, on their request. This is a very thoughtful gesture from his side. I express my thanks to Professor Augusto Gansser (Zürich, Switzerland), Professor Brian Windley, Dr Mike Searle (Leicester University, UK), Professor Peter Molnar (MIT, Cambridge, USA); Professor Mike Coward (Imperial College, London, UK); Professor Michel Colchen (Poitier University, France); Dr Patrick LeFort (CNRS, Nancy, France); Dr (Mme) Monique Fort (Paris University, France), and many other friends who helped me in this endeavour.

In WIHG, analytical work was carried out by Drs B. R. Yadav, P. P. Khanna and M. S. Rathi. During the preparation of Mss I have had consistent support from Professor S. P. Nautiyal, Professor I. C. Pande, Shri S. N. Talukdar, Dr S. C. D. Sah (then Director of WIHG) and my colleagues in the Structure & Tectonics Groups of WIHG particularly to Drs K. S. Bist, and S. K. Paul. Thanks are due to Shri G. S. Khattri who

CHAPTER 1

Introduction

1.1 Cultural and Historical Background

He who regards,
with an eye that is equal
Friend and Comrade,
the Foe and the Kin man.
The Vice, the Wicked,
the Men who judge himself
and those who belong
to neither faction.
He is the greatest.
—*Bhagwad Gita*
(Ancient epic of India)

The mighty and magnificent Himalaya, by humbling those that come to them with their magnitude and power, gratifying them with their splendour and beauty, testing their manhood with glaciers and peaks, defying their spirit with their inviolate mysteries, enables man to acquire the qualities which only danger and nature in the raw can sharpen. The might of Himalaya has inspired and evoked the awe and wonder of the people of the Indian subcontinent from time immemorial. The central part of the Great Higher Himalaya, which forms the subject of the geological description in this monograph, comprises the northern region of Garhwal–Kumaun of the state of Uttar Pradesh in the Indian subcontinent (Figures 1, 2 and 3). The name of 'Kumaun' is derived from Kurmanchal (*Kurma* = Tortoise, *Anchal* = Mountain) as described in *Skanda Purana* (the Ancient epic of the Aryans). Lord *Vishnu* had assumed the incarnation of tortoise at Champawat in the Kali valley. It has been cited in the ancient literature that this region of Garhwal–Kumaun in the Central Himalaya bears the name of Uttarakhand (*Uttar* = North, *Khand* = regions). The Aryans had great reverence for this part of Himalaya and every river, glacier, and high mountain peak of this region was sanctified. The sacred shrines of Badrinath, Kedarnath, Gangotri, Yamunotri, Nanda Devi, and further north Kailash–Manasarovar are the most notable throne of Gods for Hindus. *Ved Vyas* attached so much importance to this region of Himalaya that he wrote *Up Purana* on this part of Himalaya. It has been described in *Puranas* that 'There is a region of *Swargya* (Heaven), the seats of the righteous where the wicked did not arrive even after a thousand births. There is not sorrow, nor weariness, nor anxiety, nor hunger, nor apprehension, the inhabitants are exempt from all infirmity and pain, and live in uninterrupted enjoyment. The goddess never sends rain upon them, yet the earth abounds with water. In this region there is no distinction or succession of ages, and time is no more'. The great poet *Kalidas* in his poem '*Purva Megha*' had been inspired by the natural romantic area of Himalaya and imagines that the clouds rest in Himalaya.

In ancient times the notable Himalayan kingdoms which flourished in this region were *Dwigarta*, *Trigarta*, and *Madra*. The kingdom of Brahmpura and Shrugna, in the southeast and northeast of Alaknanda, respectively, and kingdoms of *Badawra* and *Govisana* were confined in the south of Brahmapura in the terai region as described by Huen Tsang, a Chinese traveller (Cunningham, 1963). Although there is no archaeological finding to substantiate the extension of the Mauryan and Gupta empires to this

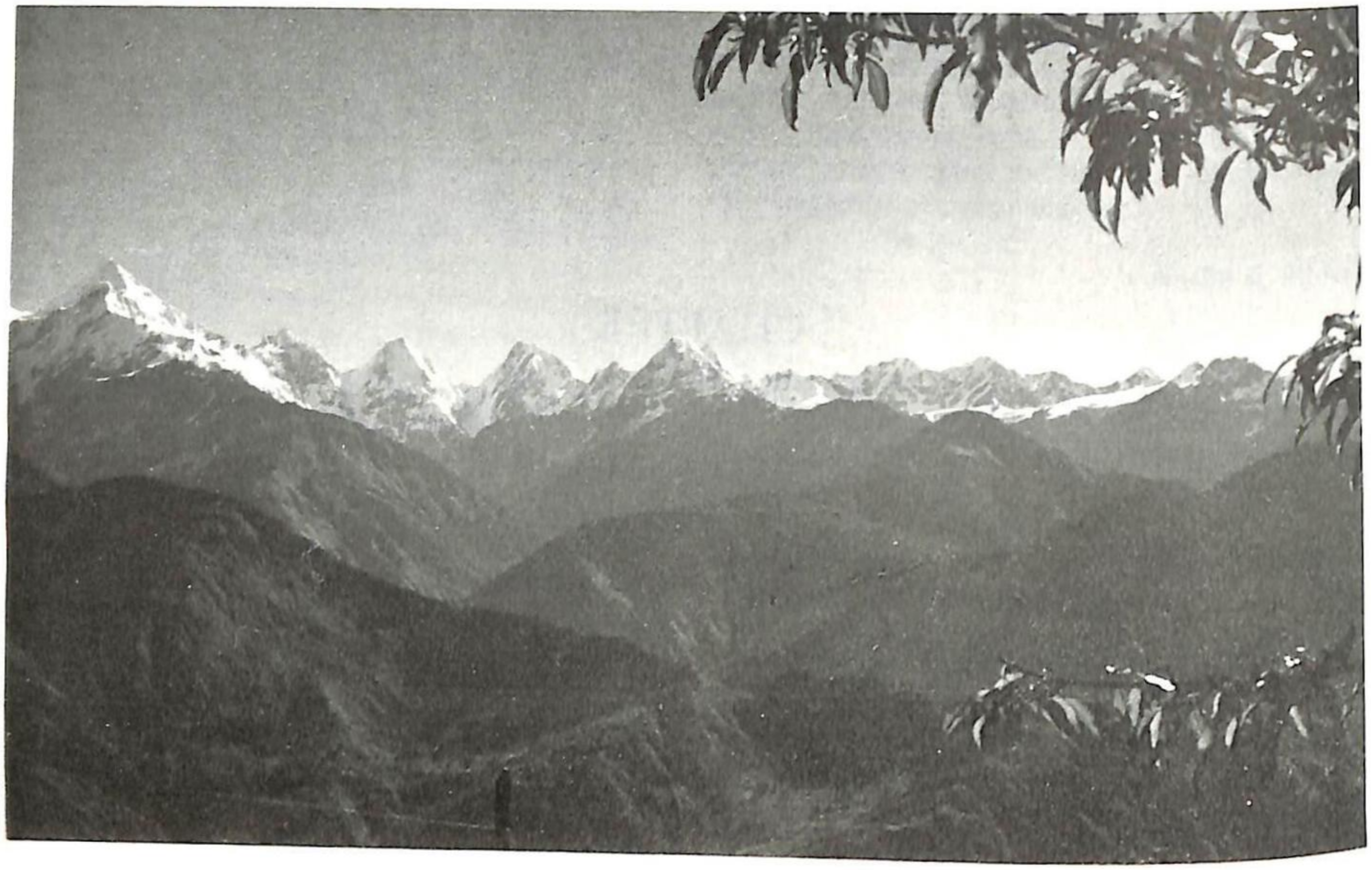


Figure 2. Panoramic view of Higher Central Himalayan Panchuli group of peaks (heights from left to right 6904 m, 6312 m, 6334 m, 6437 m and 6072 m).

part of the interior Himalaya, scripture has been found on a quartzite boulder of the Jaunsar formation at Kalsi on the left bank of the Yamuna (50 km northwest of Dehra Dun). It is clear that the emperor Ashoka in the third century BC extended his empire up to this region. During the medieval period of the Muslim invasions, a large number of Rajput princes and Brahmin priests had fled to the valleys of Himalaya. In the middle of the 16th century, Rana Balakalyan Chand of the Chand dynasty established his empire in Almora. In the same century, Raja Ajaipal took the incentive to integrate the scattered fifty-two fortresses (*Garh*) and their territories into Garhwal (fort/integrated territory). The races contributing to the culture were notably Kiratash, Khas, Scythian, and Mongoloid.

Further north, the regions known as Bhot Mahals, Painkhanda, and Johar were mostly inhabited by the Bhotiya tribe (Figure 4). This region with Tibet formed one of the ancient culture groups known as *Shaukas*, who were perhaps the descendants of the *Sakas* inhabiting Central Asia (Pande, 1962). The Bhotiyas today usually write their name with their race and the village to which they belong *viz*., Rana, Singh, etc., recalling their belonging to the Rajput clan of Rajasthan. The Bhotiyas are found in every part of the country along Indo-Tibetan border that is sacred to the Hindus. The notable centres of Bhot culture are situated in Mana in the Krishanganga valley, Niti in the Dhauliganga valley, Johar in the Goriganga valley, Darma in the Dharmaganga valley, and Byans in the Kali river valley. From the Tibetan side there had been influx of Lamas and Huniyas known as the Khampas settling in the higher valley (Pant, 1935). The trade route of the Bhotiyas from the Indian side and the Khampas from the Tibetan side were through the passes of Mana (5611 m), Niti (5068 m), Shalshal (4496 m), Kungribingri (5578 m), Lamphya Dhura (5532 m), and Lipulekh (5453 m) (Figure 4).

In 1906, C. A. Sherring, then Deputy Commissioner of Almora, gave a vivid account of the Bhotiyas in his book *Western Tibet and British Borderland*. The passages described in the *Kumaun Himalayas* by M. S. Randhawa (1970, p. 123–125) reads, with modification: '*Bhot*, or more correctly *Bod*, is really the same word as

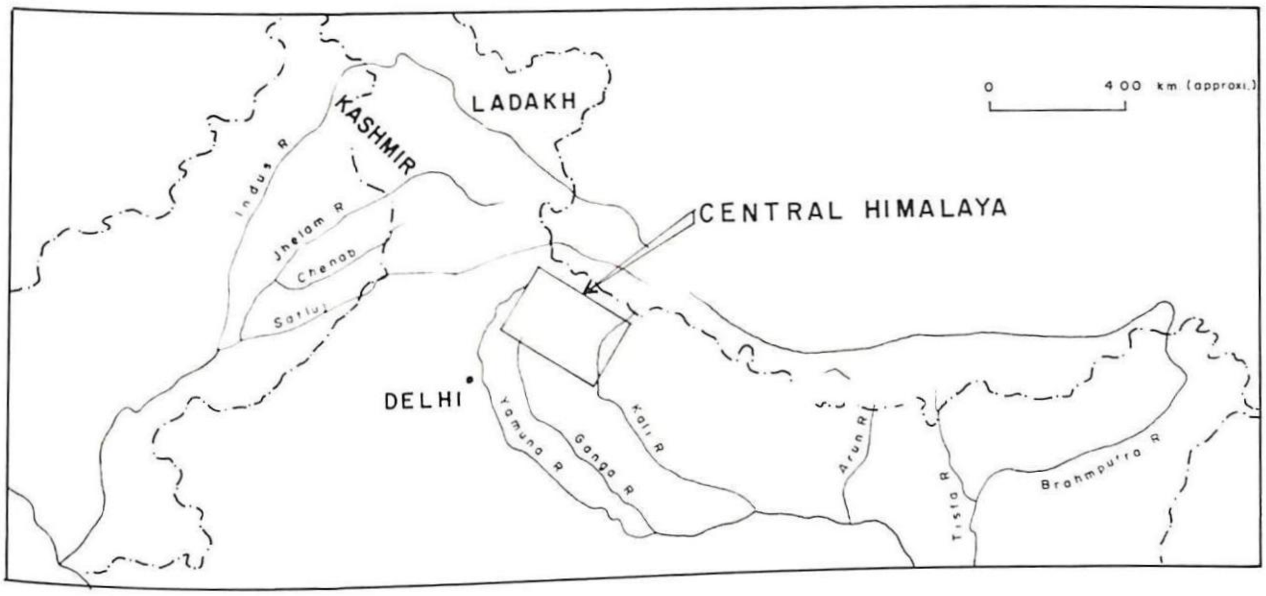


Figure 3. Location map of Central Himalaya.

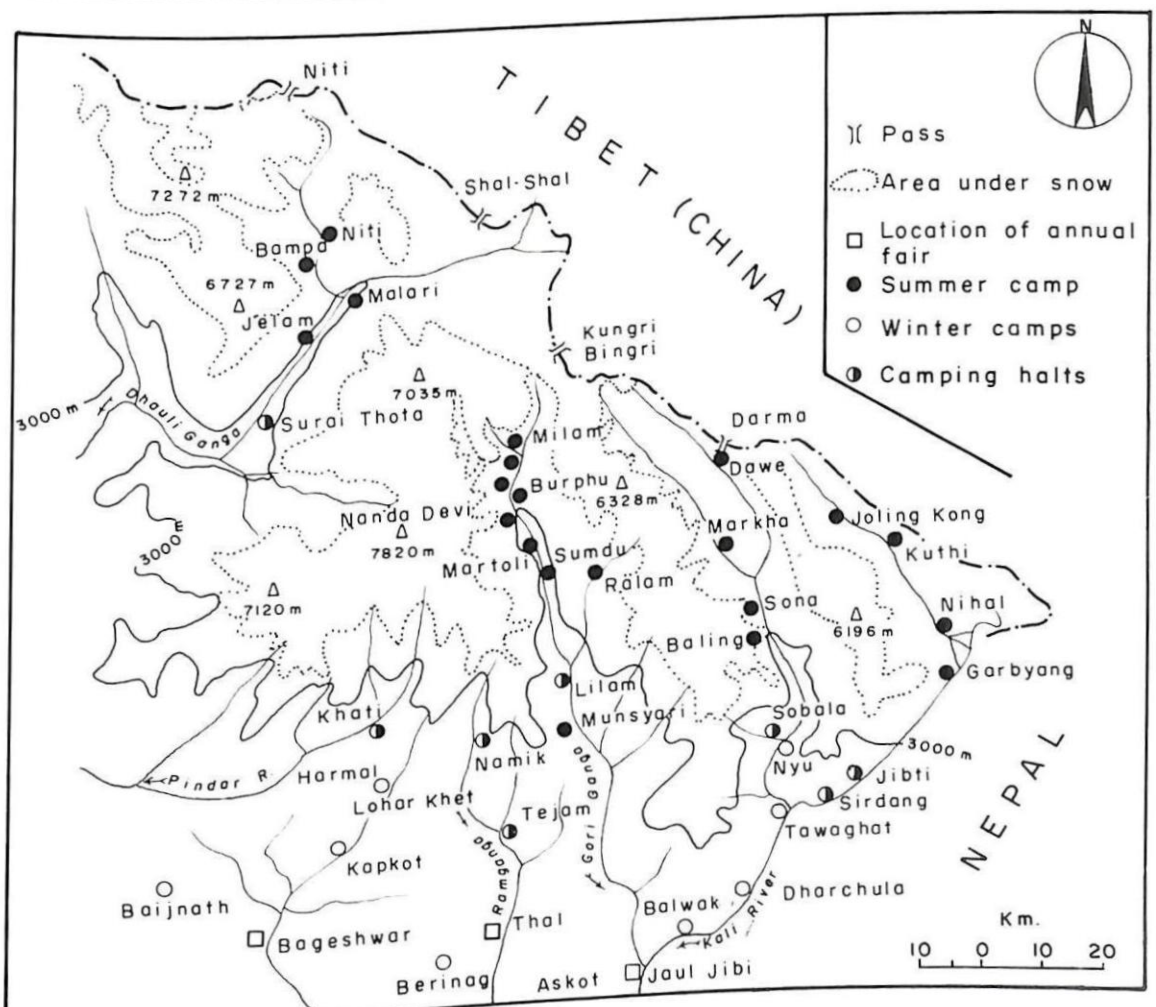


Figure 4. Map showing the inhabitant nature of local population and their seasonal migration (modified after Singh, 1971)

Tibet. The Bhotiyas of our hills are found in that very tract of the country which has been described as being so very sacred to the Hindus. They are to be found at the mouths of all the passes into Tibet. Those by the Mana Pass, near the holy temple of Badrinath, and those by the Niti Pass are known as *Tolchas* and *Marchas*, whereas those by the Unta Dhura Pass (5450 m) in Johar are *Shokas* (otherwise called *Rawats*). Amongst them there are also some Tolchas and Marchas. All these comprise the western division of Bhotiyas, who are in their own estimation superior to all other Bhotiyas, with whom they will not eat or marry, and whose ordinary language they cannot talk, as they have forgotten it. South of the Johar, Bhotiyas are the Jethora Bhotiyas, who do not trade but are cultivators. These have a Tibeto-Burmese dialect of their own (called Rankas or Shokiya and Khun) and consider themselves the first settlers (*Jeth* means elder brother). Lastly there are the eastern Bhotiyas living in the valley of the Darma Ganga, which is subdivided into three patties or subdivisions, *viz.* the Darma, Chandas, and Byans patties. These are much more backward than the others, and their customs are therefore all the more interesting. They are looked down upon by the other Bhotiyas because of their primitive ways, and although all Bhotiyas called themselves Hindus, the acknowledgement of the eastern Bhotiyas Hinduism extends to little more than the name, whereas the eastern Bhotiyas or Jethora, have made some progress in Brahmancial rites and customs. All Bhotiyas everywhere are divided into two castes, *viz.* Rajputs or upper class or Dumras, or low caste'.

During our expedition it was observed that the Bhotiyas in the Darma and Byans valleys are a more romantic people. The Bhotiyas are only Kumaunies who drink alcoholic liquor, brewing it from barley in their homes. 'Rambang' are social gatherings, particularly for all young people to contract marriages. The men and women enjoyed drinking, dancing, and singing at the *Rambang* festival, practising free love and giving an opportunity to the women to select their life-companion. The Bhotiyas are a quite hard-working people but are more superstitious.

Since independence, these tribes have been given more facilities and they have been classified under the schedule tribes categories with the result there has been much improvement in living standards, education, and agricultural facilities, and there is a modern postal system, even in the interior part of the region. As a personal experience, everywhere I found them most sincere and hard working even in the inaccessible and dangerous locations of the expedition.

J. H. Batten, of the British Civil Service (BCS) who retired as Commissioner of Kumaun in 1877 records: 'Kumaun was conquered by the British from the Gurkhas in 1815 and the Honourable Edward Gardner was subsequently promoted to the Residency of Nepal was the first British ruler of Kumaun. Mr. G. W. Traill (after whom the Traill Pass of the Pindari glacier is named) who was then an Assistant under the Resident of Delhi, was first offered the appointment of Commissioner of Kumaun'. Since then the political control and administrative reforms of Kumaun and Garhwal were subject to the British rule until independence. Uttarakhand together with the twin Garhwal and Kumauni cultures are at present represented by eight hill districts, *viz.* Chamoli, Uttarkashi, Pithoragarh, Naini Tal, Almora, Pauri, Tehri and Dehra Dun. The area of this monograph falls in the northern part of the first three districts adjoining the Tibetan border in the north and eastern border with Nepal across Kali River (Figure 4).

1.2 Orography

The Great Himalayan range, forming an enormous curvilinear arch over a length of 2500 km between the eastern and western extremities of Burma and Pakistan (Figure 3), is highly rugged with horned peaks, serrated crests of ridges, cirques, and hanging glacial valleys, and cascades of gushing icy water through deep canyons or dammed as lakes.

The area with which this monograph deals is within the Higher and Tibetan Zone of Central Himalaya, constituting northern Uttarakhand of Garhwal and Kumaun. It falls within the longitudes 79°5′ to 81°0′ and latitudes 30°0′ to 31°1′, excluding the territories across the Tibetan and Nepalese borders, and encompassing an area of approximately 20,000 km^2 (Figure 3). Geologically this is the area lying north of the Main Central Thrust (MCT), which pass through Helang–Loharkhet–Dharchula, limited in the north by the Tibetan watershed and in the east by the Kali river boundary with Nepal. According to Griesbach (1891), the Central Himalayan region consists of (a) The Southern range (line of great peaks); and (b) The Northern range (line of the watershed) which is rimmed by the Tibetan plateau in the north and the lower Himalaya in the south. Burrard and Hayden (1934) subdivided the Himalaya into three geological zones: (1) *Outer sub-Himalayan zone* composed of sediments for the most part of Tertiary age; (2) *Central* or *Himalayan zone* comprising the ranges known as the lesser Himalaya, a line of high peaks; and (3) *Northern* or *Tibetan zone* lying behind the axis of Great Himalayan range and composed of strata from the Cambrian to the Tertiary. Later, in their classic monograph on Central Himalaya, the late Arnold Heim and Professor Augusto Gansser (1938) called the studied region of the Central Himalayan zone the *High Himalaya* dividing it into (1) The Central High Range (Nampa–Nanda Devi–Badrinath: 15–30 km; and (2) The Northern Ranges or Tethys–Himalaya (20–35 km). Thus, in the present context we shall be dealing with the Central Himalaya in general.

The magnificent group of peaks confined in the central high ranges are the highest peaks of India: Nanda Devi (7820 m), Nanda Devi East (7439 m), Kamet (7758 m), Mana (7274 m), Chaukhambha (7140 m), Trisul (7122 m), Dunagiri (7068 m), Deoban (6979 m), Kalanka (6933 m), Panch Chuli (6905 m) (Figure 2), Changbang (6866 m), Nanda Kot (6863 m), Mrigathuni (6857 m), Devisthan (6680 m), Nanda Khat (6674 m), Penwali Dhar (6665 m), Nilkanth (6597 m), Nanda Ghunti (6314 m), and others (Figures 2 and 4).

1.2.1 Drainage

The above mentioned peaks are separated by the main river valleys of the Alaknanda, Dhauli Ganga, Girthi Ganga, Pindari, Gori Ganga, Darma Ganga, and Kali. The profiles of these valleys are convex with steep valley walls and terraces at different levels indicating the uplifting phases of Himalaya (Figure 1).

Parallel to the southern snowy ranges with the peaks mentioned earlier for the High Central Himalayan ranges, run the northern ranges, sometimes connected by ridges forming the watershed or by broad valleys of great height, over three to four thousand metres. These form a water 'divide' between the drainage systems of the Ganges and the Indus or Sutlej. They are mostly snow free except in the upper reaches of Lissar and Byans and all the passes leading to Tibet are situated on this high land ridge. In the Indian part of this region we have only the drainage pattern of Ganga. The Ganga headwaters rise in the Nanda Devi, Kamet, Badrinath, and Kedarnath group and consisting of two great branches: Alaknanda and Bhagirathi (west of the described area). The Alaknanda is formed by the headwaters of the Dhauli and the Vishnu which are separated by the Kamet peaks. Amongst the prominent streams that join the right bank of the Kali on its Indian side are: Kuti Yangti, Darma (+ Lissar) Ganga and Gori Ganga (+ Gonkha Gad from the Unta Dhura Pass, and the Bamlas and Safed Glaciers). These rivers come down the steep gradient with great volume and strong current. Recently, in 1977, torrential rain caused devastating floods and landslide, which created havoc and led to the death of a complete unit of border guards along with their supply dump and animals at the confluence of Darma and Kali Rivers near the hamlet Tawaghat.

1.2.2 Glaciers

The central higher zone of Garhwal and Kumaun is occupied by a vast area of glaciers and glacial topography (Figure 4). The whole glaciated area could be divided into five groups: (1) Badrinath–Satopath group; (2) Kamet East and North group; (3) Dhauli Ganga Group; (4) Nanda Devi–Pindari–Milam Group; (5) Kala Baland Panch Chulhi–Nama Group. From the earlier works on the Central Himalayan glaciers, reports worth referring to for the details are Strachey (1857), Grinlinton (1912, 1914), and Raina (1963). The Himalayan glaciers provide many features of mountain glaciation which are different to the sheet glaciation features of Greenland and Antarctica. The entire water supply for irrigation and hydroelectric projects related to the northern Indian rivers originating in the Himalaya is dependent not only on the rainfall but on the snowfall and glacial thaw. The data from the Himalayan glaciers for the last seventy years indicates a continuing recession of glacier termini which is a pointer of the negative glacier balances. The Milam glacier between 1849–1957 (108 yr) retreated for 1350 m, whereas the Pindari glacier between 1847–1966 has shown a recession of 2840 m in 121 years. The southern slopes of the Great Himalayan Range and the Nanda Devi–Badrinath group have a snow line of approximately 1200 m lower than the near zone of the inner Great Range and the Kamet group of peaks. U-shaped valleys, truncated spurs with sawn-off faces, aretes, horns, pyramidal and conical peaks, serrated crests of ridges, cirques, glacial troughs, cols, knife-edged precipices, smooth rock walls, steep head-walls, glacial lakes, etc., are the prominent erosional features. The depositional features are represented by talus cones, snow-avalanches, snow-bridges, dead ice, debris deposited by terminal, lateral, medial, group- and surface cover-moraines. The Himalayan glaciers occupy both antecedent and consequent troughs. Alaknanda, Dhauli, Gori and Darma for example are antecedent glacial drainage surviving mountain uplift. During the Pleistocene, these glaciers extended down the valleys, whereas in recent times they have retreated due to ablation. The glacial lakes are formed by the damming of valleys by moraines, which are the remnants of ancient large glaciers, *viz.* Satopath Tal below Chaukhambha, Hemkund in the Bhyundhar valley, Rupkund on the outer slopes of Nanda Ghunti, Pari Tal below the Unta Dhura Pass near the snout of Saphed Glacier, and the Joling Kong lake between Bedang and Kuti village on the watershed between Darma and Kuthi Yangti.

1.2.3 Climate

The southern part of the area of the Main Central Thrust, consisting of crystalline metamorphic rocks and some granite and basic magmatic rocks, experiences heavy rain (37–50 cm) during the monsoon season commencing by the end of June and continuing until the middle of September (Figure 5). The pioneer explorers of the nineteenth century, Hughes and Waagen (1878), record that they took traverses early in August 1873 along the track from Almora to Milam and came back via the Niti Pass. They wrote: 'We were in almost constant rain during our first ten marches, and, however enthusiastic our aspirations in the cause of geology at the outset of each day's journey were, they could not withstand the depressing effect of recurring downpour of water and we hurried to shelter as the most prudent course to pursue. It was not until we reached the Bhotia village of Rilkot, that we passed out of the regime of rain'. And this Rilkot is situated just in the shadow zone. The high rampart of Nanda Devi and its adjoining extension towards the east and west functions as a blocking wall for the profuse and copious clouds of the southwest monsoon, causing a 'shadow zone' behind it (rainfall approximately 15 cm). Thus in the Tethyan zone of Central Himalaya there is no heavy downpour, causing Tibet to be a high altitude desert. The snowfall is unpredictable in the 'shadow zone'. During our 1978 expedition in the Unta Dhura Pass area, the party was stranded for four days between 17 to 21 August at Dung due to continuous heavy snowfall. The area in the 'shadow zone' is usually open from the end of May until the middle of September. Passes like Unta Dhura have perpetual snow specially on the northern slopes. However, the fresh wet snowfalls with gusting stormy winds are more dangerous for the explorers in this area. Usually after 10 am the high passes experience speeding wind from the Tibetan side making it impossible even to stand still without any support. Another hazard is the ultraviolet radiation causing severe sunburn. Worst comes to face the explorer when there is unprecedented snowfall washing away the foot-trail made on the extremely steep slopes of hard rocks and debris of rock fall. In such conditions communication is completely cut off and there exist no supply lines. The ponies carrying the supplies start biting each other's backs and tails in the absence of green grazing pastures. In searching for a trail path, trekking parties have been washed away by the sudden gushing of glaciers, avalanche, and sludge into deep gorge of rivers. Our experience during August 1978 between Unta Dhura-Dung and Milam in the Gonkha Gad-Gori valley is to be taken as lesson for future work in this part of Himalaya.

1.3 Flora and Fauna

1.3.1 Flora

Natural vegetation in Himalaya is divided into four broad groups according to altitude: (1) Subtropical zone (below 1200 m); (2) Temperate zone (1200–1800 m); (3) Subalpine zone (1800–3000 m); and (4) Alpine zone (3000–4500 m). In the central high Himalayan zone, the last three zones are encountered. The temperate forests are generally dominated by Chir pine (*Pinus longifolia*) and Banj oak (*Quercus incana*) and bamboo shrubs. On the way to the Pindar glacier, the beautiful sparaeas of white and crimson colours with wild rose bloom everywhere between the Dhakuri and Khati camping sites.

In the southern fringe of the area crystalline rocks over the Main Central Thrust grows the

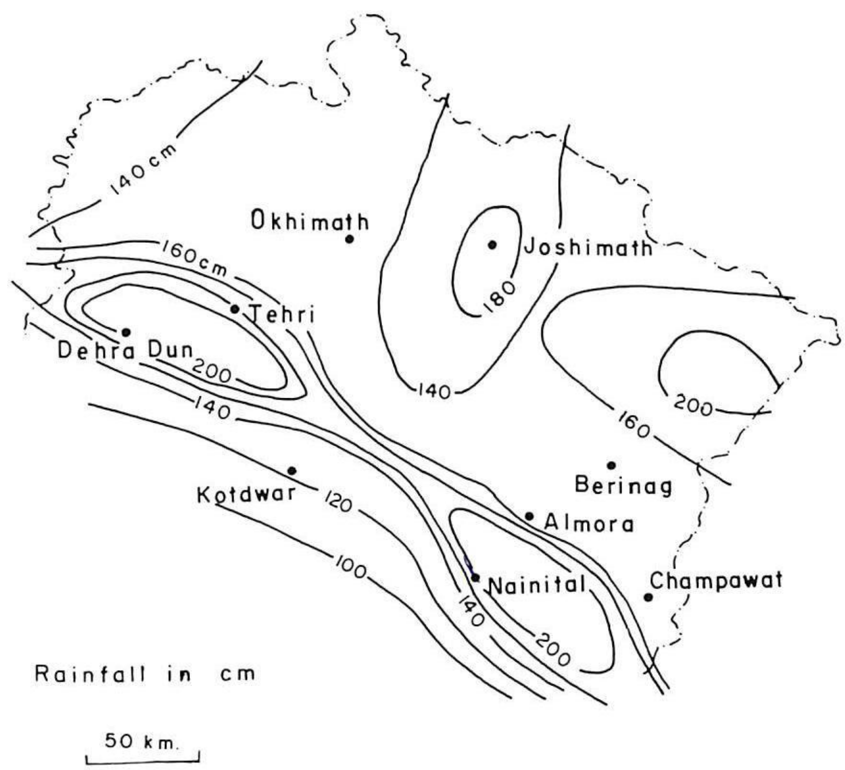
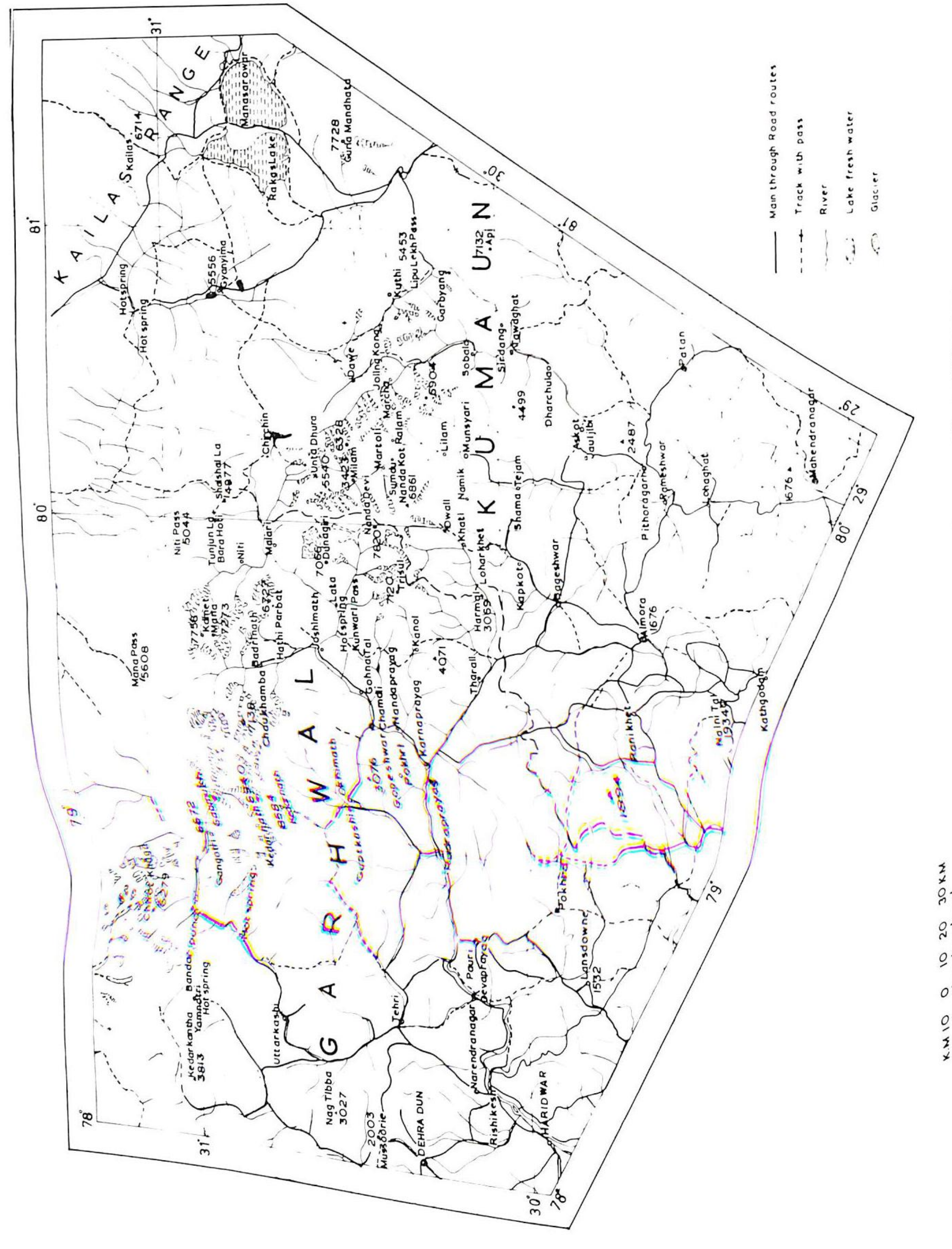


Figure 5. Annual rainfall map of Central Himalaya

Rudraksh tree (*Elaeocarpus ganitrus*). *Rudraksh* (literally meaning 'red-eyed' in *Sanskrit*) is the brick-red coloured dried berry. When the *rudraksha* are dried, the fissures on its hard surface vary from one to fourteen in number, and are known as 'faces' (*Mukha*). An *ek-mukhi* or single-faced is difficult to obtain while the most commonly available ones are the five-faced (*panch-mukhi*). From time immemorial the *rudraksha* have not only been venerated by the Hindus, with the berries being used for rosaries to aid both prayer and meditation, but have been valued for therapeutic effects, and as a gauge to differentiate between hygienic and unhygienic food. Nowadays it is being argued whether the beneficial effects of *rudraksha* in the cases of hypertension, high blood pressure, mental disorders, and coronary malfunctioning could be accepted. Occasionally some species of deciduous forests are observed. Moist conifer forest with deciduous trees are the dominant vegetation of the lower subalpine zone. Amongst the oaks are: *Banj* oak (*Quercus incana*, *Quercus himalayansis*), *Maru* oak (*Quercus dilatata*), and *Kharsu* oak (*Quercus semicaprifolia*). The other most common associations are the *Rhododendron arboreum* and *Abies webbiana* forests. The high alpine forests are mainly composed of silver fir (*Abies pindrow*), blue pine (*Pinus excelsa*), spruce (*Picea morinda*), Cypress (*Cupressus torulosa*), deodar (*Cedras deodar*), birch (*Betula utilis*), *Rhododendron campanulatum*, *Rhododendron lepidotum*, *Salix elegans* and dwarf bamboo (*Arundinaria falcate*). The high level birch forests are usually found in the slopes north of main great Himalayan lands, i.e. Tethyan sedimentary zones, usually between 3000–4000 m. The silver–grey stems and branches of birch are very attractive from a distance. The birch forests are sustained by snow in winter and by rainfall in summer emerging with profuse flowers in early June. The bark of birch, the '*Bhojpatra*', is like paper and was used for writing in the ancient India. In the pastures the shepherds were found to use it as packing paper. The whitish, violetish and light-coloured rhododendrons (*R. anthopogon*, *R. campanulatum* and *Salix elegans*) are found in the Pindar valley. Further up there is a gradual transition to Alpine pastures.

The meadows on the northern slopes of the Martoli and Malari area on the left bank of the Girthi Ganga and in the valley of flowers remain



ure 6. Drainage and communication map of Central Himalaya

covered with snow till the first week of May. With the advent of the melting of the snow, a colourful carpet of purple primulas, blue Corydalis, and yellow Gangea bloom and cover the meadows. In July–August appears the famous blue poppy (*Mecanopsis aculeata*), the queen of Himalayan Alpine meadow.

The valley of flowers situated near Badrinath was brought to the lime light in the world of botanical sciences by Frank Smythe in 1931. He camped in the valley for a month and collected material for the Botanical Gardens in Edinburgh, Scotland. John and Margaret Legge visited the valley in 1939 and, while camping, Margaret unfortunately slipped from a rock slope while picking flowers. The epitaph on her tombstone reads: 'I shall lift my eyes up to the Himalayas, from whence cometh my help'.

Some of the flowers in this eye-feasting valley are: creamy anemones, large purple asters, the rare white androsace, the blue borage, the rosy-petalled cypripedium, blue forgetmenots, green and chequered fritillaries, pink geraniums, purple and dwarf irises, dwarf larkspurs, the indigo-coloured nomocharis, blue and yellow pansies, mauve polemoniums, the blue poppy, white and red potentillas, dwarf rhododendrons, primulas in pink, blue, and deep purple, ranunculus and the *Brahma kamal*, etc.

1.3.2 Fauna

In general there has been adopted three faunal zones in the Himalaya. The wild animals in the Middle and Inner Himalayan zones found over 2000 m to 5500 m are to be referred here only. Notable amongst them are musk deer (*Moschus moschiferus*), barking deer (*Cervulus muntajae*), Himalayan black bear (*Ursus torquatus*), and the goat families, *viz. thar* (*Hemitragus jemlaicus*), *goral* (*Nemorhoedus goral*); and the sheep *bharal* (*Ovis nahura*). In the desert part of Tibetan zone the wild horse Kyang (*Equus hemionus Pallas*) are commonly met with watching the travellers. These pony-like horses are not suitable for load carriage because of their weak backbones. Yak (locally called *Jhaboo*) is the most common animal used for transportation. But their numbers are much less in the Indian part. Most commonly the local breed of ponies are used for transportation. Ponies used on the plains in the military farms have been found to be unsuitable for the rarified air at an altitude over 4500 m, and most of them succumb due to heart failure and shock. The goat and sheep families in the inner zone are nowadays found grazing on the high escarpment grounds, and they were profuse even at the trekking level, but due to indiscriminate poaching they are vanishing fast.

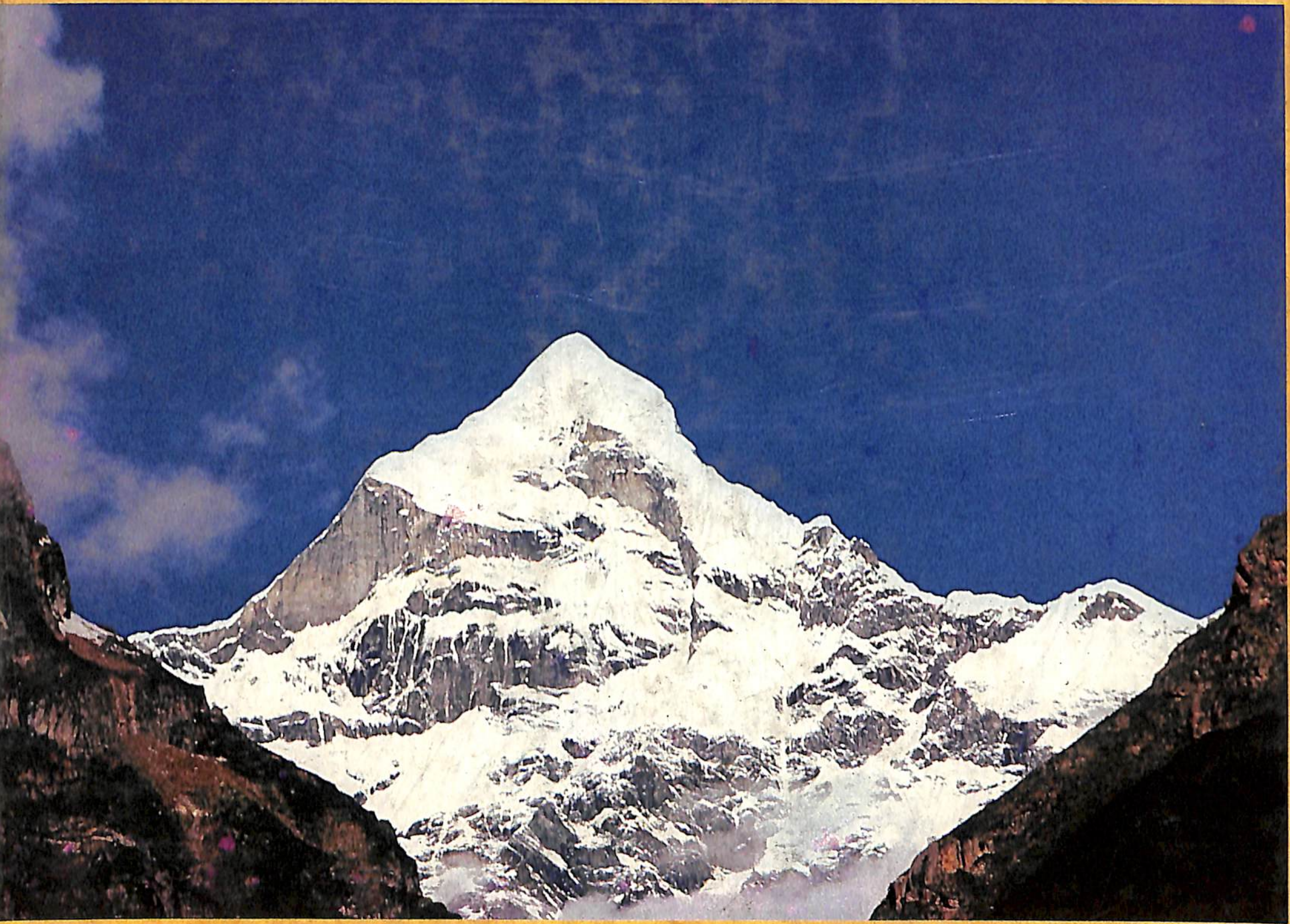
GEOLOGY OF THE HIGHER CENTRAL HIMALAYA

Anshu K. Sinha, *Wadia Institute of Himalayan Geology, Dehra Dun, India*

This book provides geological information from an area of Higher Himalaya which is not normally accessible to geologists. The author has obtained special permission from the Indian Government to visit this area which covers 20,000 km^2 and which has an average height ranging from 3000 to 8000 m above sea-level. The result of a decade of research in this region, the book includes the first geological map of the area. Stratigraphic columns have been revised and updated to include newly found microfauna. New findings have also been interpreted to develop the tectonic framework. The geological features are analysed using geochronological dating and geochemistry to provide a comprehensive view of the area. Potential economic deposits of barite and associated polymetallic mineralization are identified for the first time.

The book opens new frontiers of knowledge for geologists interested in plate tectonics and mountain building.

Anshu K. Sinha is head of the tectonics group at the Wadia Institute of Himalayan Geology. He obtained his PhD from Friendship University, Moscow and was awarded his DSc by Moscow State University in 1982, based upon his work in the Higher Central Himalaya. Professor Sinha represents the Indian subcontinent on the UNESCO IUGS Scientific Committee of the International Geological Correlation Programme. He is the Indian national correspondent on the International Lithosphere project, covering Himalaya and neighbouring regions, and works on the Indo – Soviet Coordinating Programmes in Earth Sciences. He travels widely in the course of his work and has visited a number of academic institutes in USSR, Europe and Asia.



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