DIMENSIONS OF HIMALAYAN GEOLOGY

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Preface

End of writing is time of satisfaction and contemplation for an author. Satisfaction because he has no more work to do, despite full awareness of the reality that justification to available knowledge is beyond his capacity. Particularly when such summaries are attempted. Contemplation arises from the anxiety of acceptability of the work by fellow colleagues and readers, yet attempts continue.

Irresistible divine fascination of Himalaya is not without a challenge so is the case with scanning of available geological literature of Himalayan dimensions. My 'generalist' approach in the research field has helped me in this work. Turmoil of many tens of millions of years in Himalayan terrain is fully reflected in contrasting geological interpretations of Himalaya by different investigators that too spread in very diverse type of sources (books, journals, reports etc.) that made extremely difficult situation for me to accommodate each and every viewpoint. The written text is just selection of few types of rubbles from highly specialized myriad aspects from the mammoth mountain of knowledge and is aimed at to apprise the post-graduate students of the earth sciences about the current developments in Himalayan Geology. Framing of chapters is slightly unusual, contents of some chapters like paleontology, petrology and geochronology could have been easily incorporated in other chapters. This would result into diffusion of focus or thrust. For the sake of smoothness in presentation and also dealing with large number of interrelated topics repetitions of basic facts at some places have occurred. Many important references have been omitted because of their non-availability and because of this the text suffers to that extent. A locality is described by different spellings, in those cases popular spelling was adopted. My own ideas such as social geology, safety maps and remobilized cratonic nature of the Higher Himalaya are also included in the text at relevant places. Several new references have been added in the text during proof reading stage.

Idea to publish a note on Himalayan Geology for students in the Quarterly Journal of the Geological Association & Research Centre was proposed to editor Dr. S Saxena. He accepted this but suggested instead note I should write a book. His advice ultimately culminated in the form of this book. Beneficial discussions on Himalayan geology with Dr K.P. Juyal, Dr A.K. Dubey and Dr. A.C. Nanda and Dr. V.C. Thakur, senior scientists, of Wadia Institute of Himalayan Geology (WIHG), Dehradun is gratefully acknowledged. I am thankful to my colleagues Dr. M.N. Joshi, Dr. B. K. Pandey, Dr M. S. Anantharaman, Dr. P.C. Bahukhandi and Prof. J. D. Badhe for over the years of discussions on Himalayan Geology. Dr. R. K. Pande, principal, deserves special mention for promoting academic excellence in the campus. I am grateful to directors of WIHG for allowing me to avail facilities of their institute. Appetite for knowledge is satisfied in the library of WIHG, I am thankful to librarian Mr. Saeed Ahmad and to Mr. S. S. Bhandari for sustained cooperation.

Creativity and enthusiasm of post-graduate students are reflected in compilation of Geological Map of Himalaya (one cm to twelve km scale, perhaps largest one), Tectonic Zonation Map of Himalaya (one cm to forty km scale) and Geological Map of Uttaranchal (one cm to five km scale). These maps involved labor of 4000 man-hours, yet need some improvement. Namita Jindal, Sharat Dutta, Neetu Chauhan, Jagwant Kaur, Rashmi Pradhan, Arpita Sinha, Preetika Bahuguna, Ruchika Sharma and Kuldeep Singh of 2005 batch have compiled these maps in Department of Geology. I acknowledge their meticulous efforts gratefully. Love to own creation tempted me to incorporate miniature versions of these maps in the text. I am thankful to Ms. Namita Jindal, Ms. Divya Dudeja and Mr. Suraj Prasad Bhatta for their support during writing of this book. I am thankful to Mr. Hemant Jain of Satish Serial Publishing House for prompt publication of this book.

December 22, 2005

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Satish Serial Publishing House, New Delhi
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Mayadhyaksena prakrtih suyate sacharacharam (Geeta, 9.10)
I preside over all the animate and inanimate physical actions of the nature

CHAPTER - I

INTRODUCTION

The majestic mountain Himalaya (Sanskrit: Himalaya i.e. house of snow) is a glorious creation of nature. The Himalaya mountain commands unique reverence by the Indians due to its religious significance particularly its snow clad peaks houses the large number of Hindu deities and innumerable number of mythological lores are written in its backdrops. Holy river Ganga famed for imperishable water originates from its lap and above all the mountain has inspired and continuously inspiring many writers and poets by its serene charm. Besides its cultural, religious and literary significance, the mountain provides effective guard against invasions by man and chilly Siberian wind. Curiosity and courage of Man forced him to explore the giant, relentlessly from time immemorial to unearth haloes of mysteries woven around it. No doubt many of them have sacrificed themselves in the pursuit of their tasks. Same sprit also guided the geologists, geographers and nature explorers to write its story on the scientific pedestals. Despite being one of the extensively and thoroughly probed regions, yet new modifications of the existing thoughts are the order of the days. However, incessative activities of wide ranging investigations provided a fairly precise geological account of this supreme Mountain Range.

1.1 Wider Geographical Frame of the Himalaya

The Himalaya is a part of the Alpine- Himalayan mountain chain. The Alpine-Himalayan mountain range is nearly 10000 km long and encompasses nearly 3.0 M sq km area. This curvilinear range is known by several regional names between its western end in Spain in Europe to eastern end in Indonesia in Asia; it is called Baltic's in Spain, Alps in Switzerland, Dinarides and Carpathians in Poland, Atlas in Greece, Antolides- Zagros in Iran, Sulaiman in Afghanistan and Pakistan, Himalaya in Pakistan, India, Nepal, Bhutan, Arakan in eastern India and Myanmar, Andaman-Nicobar in India and Indonesian islands.

The Alpine-Himalayan Range has a very long, of the order of nearly 200 Million annum (Ma), and complex tectonic and evolutionary history. Its different segments evolved in different periods of time and are intimately linked with right from the time of break up of Pangaea to present. The geological history is much older for example in case of Himalaya this dates back to Archaean-Proterozoic boundary or even to Late Archaean. Some parts of this chain have been assembled and fragmented several times in the past.

1.2 Geographical Frame of the Himalaya

The classical geographical and geological texts divide Indian sub-continent into three parts the southern part is called peninsular India, middle flat part is called Indo-Gangetic Plain and the northern one is called extra-peninsular India or Himalaya (Fig. 1.1). These three divisions show marked contrast in their geological (stratigraphical, structural, petrological, geochronological and tectonic characters) and geographical (geomorphic and topographic) settings (Krishnan, 1982). The major part of the peninsular India is comprised of the polyphase deformed and metamorphosed rocks of the Archaean and early Proterozoic age and younger sedimentary rocks mainly of Cuddapah, Vindhyan and Gondwana supergroups and smaller groups/ formations and vast Deccan Volcanic Province- the largest volcanic province in the world. The equally vast, largest molassic sedimentary province of the world and relatively flat surface Indo – Gangetic Plain is of Quaternary origin and to the north of this stands out latest orogenic product the Himalaya.

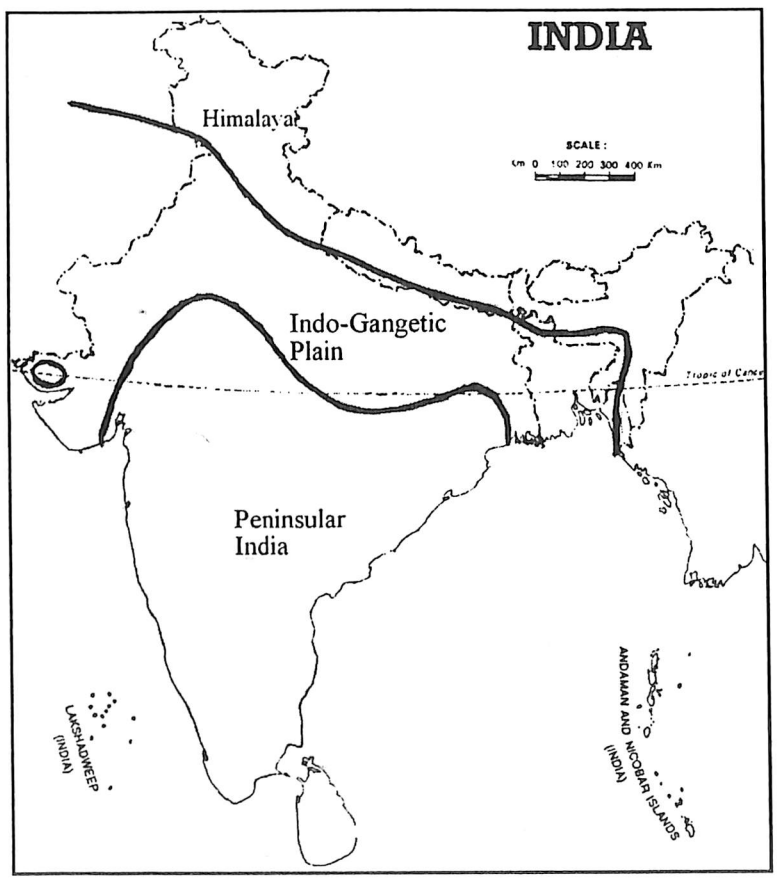

Figure 1.1: Tripartite divisions of Indian subcontinent

Geographically, the mountain divides the largest continent Asia into two unequal parts called North Asia and South Asia. The term Himalaya is geologically restricted to mountainous terrain situated between the river Brahmaputra in the east and river Indus or Sindhu in the west. Its southern and northern frontiers are also geomorphologically driven i.e. plain of Indo-Gangetic Alluvium and Tibetan Plateau respectively. The NW-SE trending Himalayan

terrain is nearly 2500 km long (96°E to 70°E longitude) 240-320 km wide (29°55' to 33°20' in E to 33°-30° in W latitude). Himalaya is a tectonic mountain and to draw its boundary on the geomorphological basis is not worthwhile as tectonic elements associated with Himalayan orogeny also present across the above mentioned geomorphic realms. The mountain range occupies nearly 0.7 million (M) square kilometer or 7.0 lakh (one lakh equals to one tenth of a million) land area. The *sensu stricto* mountain range runs through countries like India, Bhutan, Nepal, Pakistan and Tibet (China).

1.3 Divisions of the Himalaya

The vast Himalayan territory for the sake of simplification is classified into divisions and sub-divisions. This exercise is attempted through geographical or latitudinal and geological or longitudinal basis.

1.3.1 Latitudinal Divisions

Burrard and Hayden (1907) divided the Himalaya latitudinally into following four divisions:

1. Assam Himalaya

The term Assam Himalaya defines a 720 km long region confined between the river Brahmaputra in the east and river Tista in the west. The name is adopted from the erstwhile eastern state of Assam of India. However, the present day boundaries of the Assam state slightly touches the Himalaya because large number of smaller states have been carved out from this once sprawling state after independence. Tsangpo River of Tibet flowing in west to east direction takes a sharp swing around the mountain Namcha Barwa in Tibet and flows in the southwest direction in Indian Territory; the river on entering into India is rechristined as the river Brahmaputra. The Assam Himalaya includes Arunachal Pradesh Himalaya, Sikkim Himalaya Darjeeling Himalaya of West Bengal state and Bhutan Himalaya. Several smaller regions on the basis of sharp geographical identity like Afa Hills, Daphla Hills, Miri Hills, and Abor Hills etc. have been recognized within the Assam Himalaya.

2. Nepal Himalaya

This 800 km long region situated between the river Tista in the east and the river Kali (Mahakali) in the west, covering the entire geographical area of the Nepal. Following the administrative set up of Nepal, the Himalaya in Nepal is divided into Eastern Nepal Himalaya, Central-, Western-, Midwestern- and Farwestern Nepal Himalayas.

3. Kumaun Himalaya

Area confined between the rivers Kali and Satluj is designated after Kumaun division of Uttaranchal state of India as Kumaun Himalaya. Three major regions namely the Kumaun and Garhwal of Uttaranchal and northern fringes of Uttar Pradesh and a part of the state of Himachal Pradesh fall in this division. This division is 320 km long and is geologically best-explored one and the longitudinal divisions show their optimal development in this sector.

4. Punjab Himalaya

It is 560 km long region bounded by the rivers Satluj and the Indus, in the west. Though Himalayan rocks and structure continues beyond the Indus also. Therefore, small territory situated across the Indus River, in west, is also included. The name was adopted from the Punjab state of before independence of India in 1947. However, the present day Punjab province of India and Pakistan have small Himalayan fringe in their political boundaries. The smaller regions in this sector known as Himachal Himalaya, Jammu Himalaya, Kashmir Himalaya, Ladakh Himalaya, Karakoram Himalaya, Pakistan Himalaya, Salt Range, Potwar Plateau etc.

Himalaya takes sharp turns on its eastern and western extremities toward south and south-southwest respectively. These sharp bends are called Eastern and Western syntaxes or bends.

Using the nearly central position of Nepal, Himalaya is also divided into three major regions namely the Western Himalaya i.e. Kumaun and Punjab Himalaya, Central Himalaya i.e. Nepal Himalaya and the Eastern Himalaya.

Himalaya has developed across several countries and in each country Himalaya passes through several large states which are further divided into number of regional units for examples in Pakistan Himalaya is present in Azad Kashmir or Pakistan Occupied Kashmir, Kohistan, Potwar Plateau; Kashmir, Jammu, Ladakh and Karakoram in Jammu and Kashmir; Garhwal and Kumaun in Uttaranchal, in Farwestern, Midwestern, Western, Central and Eastern Himalaya in Nepal; Darjeeling Himalaya in West Bengal.

1.3.2 Geological / Tectonic or Longitudinal Classification

This classification is widely followed as it is based on several distinctive geological characters such as structure, tectonics, stratigraphy, petrology, geomorphology and evolutionary history of the Himalaya. The general strike direction of the Himalaya is northwest-southeast in the west and east northeast-west southwest. Several linear belts of contrasting geological characters are developed roughly parallel to the general strike direction. These divisions or belts (Plate 1.1) frequently pinches and swells but in over all setup they show rough parallelism with respect to each other and are separated through major tectonic dislocations or faults. Different workers have identified three to eight divisions in the Himalaya. The commonly accepted classification is as follows:

Trans Himalaya

——————Main Mantle Thrust or Karakoram Thrust——————

Indus- Tsangpo and Shyok Suture Zones

—————— Indus Tsangpo Thrust ——————

Tethyan Himalaya

—————— Tethyan Thrust/Unconformity/Gradational Contact ——————

Higher Himalaya

—————— Main Central Thrust ——————

Lesser Himalaya
——— Main Boundary Thrust ———
Outer Himalaya
——— Main Frontal Thrust ———
Indo- Gangetic Plain

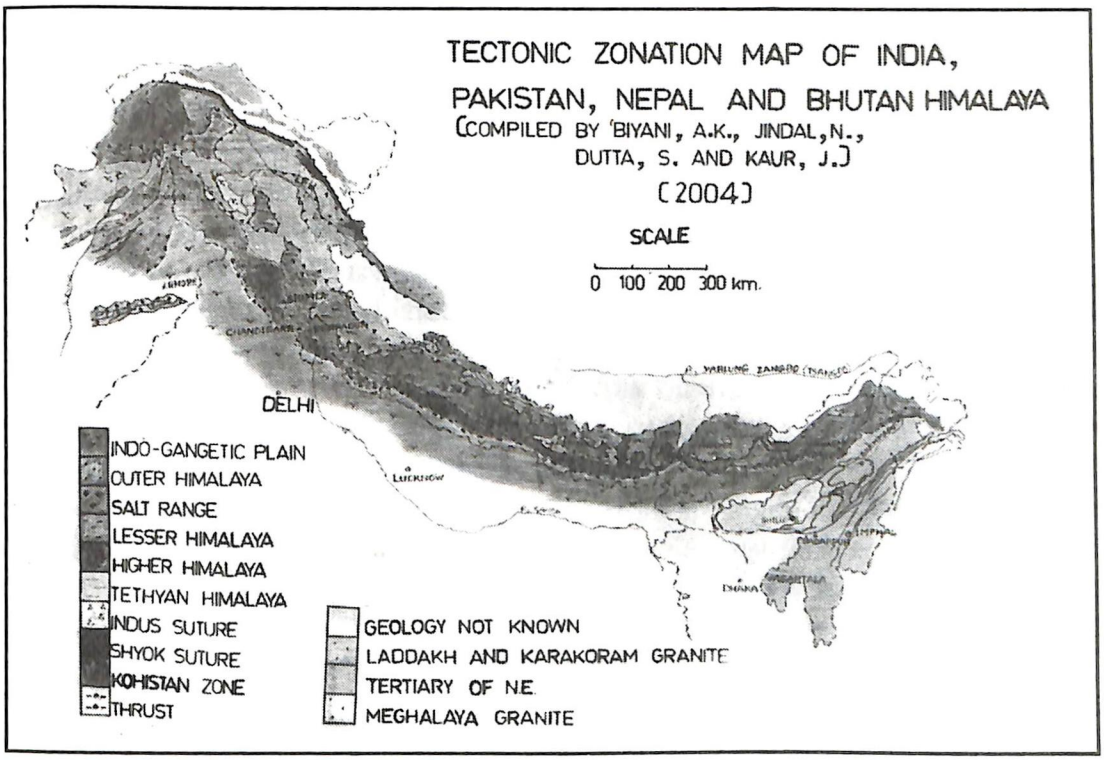

Plate 1.1. Tectonic zones or belts of Himalaya

Relatively small region of northern Pakistan and Ladakh of India across the river Indus in the west that belongs to southern part of the Eurasian plate exhibits Himalayan characters and is designated as Trans Himalaya and remaining all divisions are the part of Indian plate.

These longitudinal divisions of Himalaya are well developed in the east of Kashmir but in Kashmir and also in Pakistan some divisions disappear, or thinly developed and even in the western Kashmir alluvium of Indo-Gangetic Plain has come in contact with Tethyan Himalayan sequence.

In practice, geological workers for clear identity of a region combine together the longitudinal and latitudinal divisions. For examples, Outer Arunachal Himalaya, or Higher Kumaun Himalaya or Himachal Tethys Himalaya. Some terms also used to describe location with specific and non-specific sense e.g. Garhwal Himalaya covers entire Garhwal Division of Uttaranchal and Shimla Himalaya means region around the Shimla in Himachal Pradesh.

The Himalaya can be best described on the longitudinal basis as good geological similarity exist between one end to other end of a division and is adopted for subsequent structural, tectonic and stratigraphical descriptions of the Himalaya.

A brief account of important geological characters of these divisions is as follows:

1. Indo-Gangetic Plain

It is nearly 2700 km long and approximately 200 km wide in the east but gradually widens to 450 km in the west and covers nears of 8.0 lakh sq km area in Bangladesh, India, Nepal and Pakistan. It is a vast, featureless, highly fertile plain formed by deposition of Quaternary alluvium or molassic sediments brought mainly by the Himalayan Rivers from the north.

2. Outer Himalaya

This 10-50 km wide division is also known as Sub- or Siwalik Himalaya. It is formed due to upliftment of a part of foreland basin filled up with Neogene Quaternary molassic sediments brought by the Himalayan Rivers. The Himalayan Frontal Thrust and the Main Boundary Thrust delineate the southern boundary of Outer Himalaya with the Indo-Gangetic Plain and northern boundary with the Lesser Himalaya respectively.

3. Lesser Himalaya

It is also known as Lower Himalaya and is 50-80 km wide. It is mainly made up of poorly fossiliferous, thoroughly deformed rocks of Middle Proterozoic to Cambrian age. These sedimentary and low-grade metamorphic rocks with fair presence of intrusive and extrusive igneous rocks are of autochthonous, para-autochthonous and of allochthonous nature. The Lesser Himalaya also has localized presence of Paleozoic (Permian) and Palaeogene rocks. The Main Boundary Fault in the south and Main Central Thrust (MCT) in the north limit this division.

4. Higher Himalaya

It is also known as Central (Greisbach, 1891), Great or Inner Himalaya. This remobilized cratonic mass is of more than 20 km in thickness and its maximum width in Western Himalaya is 52 km. It is mainly made up of low to medium grade metamorphosed, green schist to upper amphibolite facies, sedimentary and igneous rocks of Proterozoic age. Higher Himalayan domain is confined between MCT in south and the Tethyan Thrust in the north. Three metamorphosed thrusts sheets namely the Chail (low grade), Jutogh (medium grade) and Vaikrita (high grade) are identified in it. These rocks show inverted disposition of metamorphic isograds and giving distinction to the Higher Himalaya of world's largest terrain of inverted nature.

5. Tethyan Himalaya

This segment is also referred as Tibetan Himalaya and is named after once existing, now disappeared, intercontinental Tethyan Sea. It is mainly made of nearly 10-12 km thick fossiliferous sedimentary rocks of Late Proterozoic to Late Mesozoic/ Eocene age. Due to tectonic overhauling, this supposed to be continuous belt is dismembered into separate blocks i.e. of Kashmir, Lahaul-Spiti in Himachal Pradesh, Kumaun, Nepal, Bhutan and Sikkim and is also present in Tibet.

6. Indus Tsangpo Suture Zone

This division joins the Indian and Eurasian Plates. Indus-Tsangpo Thrust marks its contact with the Tethyan Himalaya. Ophiolites, high-pressure metamorphic rocks, molassic sediments and intrusive and extrusive igneous rocks constitute the suture zone. It is mainly developed in Tibet, however, in India and Pakistan it is present in the Ladakh and Karakoram regions where it is branches out into two sutures zones namely the southern Indus Suture and the northern Shyok Suture.

7. Trans Himalaya

This zone is a part of southern Eurasian Plate and in India and Pakistan it is mainly developed in northern Ladakh (an administrative division of state of Jammu &Kashmir) and northern most Pakistan. It comprises of Kohistan area, Shyok Suture of Ladakh and Karakoram Zones of Western Himalaya; workers like Thakur (1992) included the suture zones in the Trans Himalaya. This zone also continues in the Tibet where ophiolites, flysch and molasse are grouped into Kailash Range, Yarlung-Tsangpo Belt, further in the east it is represented by Lhasa Block. The Indus and Shyok Sutures run parallel to each other in northern Kashmir, pointing to complex evolutionary processes operated in the western Himalaya. Ophiolites in the suture zones represent oceanic floor of Mesozoic age. Karakoram Zone is situated in further north of Shyok Suture. The contact between Karakoram Zone and Shyok Suture is designated as Main Karakoram Thrust (MKT). The Karakoram Zone has basement of metamorphic rocks over which 5 km thick sedimentary rocks of Paleozoic and Mesozoic occur with granitic intrusives.

Pamir Knot

Another interesting feature with Himalaya is that it is among one of the several mountains chain radiating out from the Pamir Knot, located little south of the center of Asia. The Himalaya is situated to the east of the Pamir Knot, and to the north of the Himalaya, Karakoram Range occurs. In the further north, the Kunlun mountain range in China making border of Tibetan Plateau originates from the Pamir Knot. The Altyn Mountains extend northeastwards from the Kunlun; the Tien Shan is the northern most branches of the Pamir Knot and the Altai Mountains of the further north. To the west of the Pamir Knot the Sulaiman range occurs in the south-west direction which continues further west as the Zagros Mountains along the coast of Iran and the Hindukush runs in the westward direction, the Hindukush is called Elburz Mountains in the further west along the border of the Caspian Sea.

Another knot also exists to northwest of the Pamir Knot. It is known as Armenian Knot and is located near the Black Sea. Elburz and Zagros Mountains are part of this knot.

1.4 Himalayan Putras

Himalayas has fascinated the men since time immemorial and has been mentioned in the oldest Hindu scriptures like Vedas, Smritis', Upanishads, Ramayana, Mahabharat and literary work of ancient writers like Kalidas and other s. Incidentally, the Mahabharat provides the first classification of Himalaya into the Outer Lesser, Higher and Trans Himalaya perfectly corresponding with the geographical/ geological classifications.

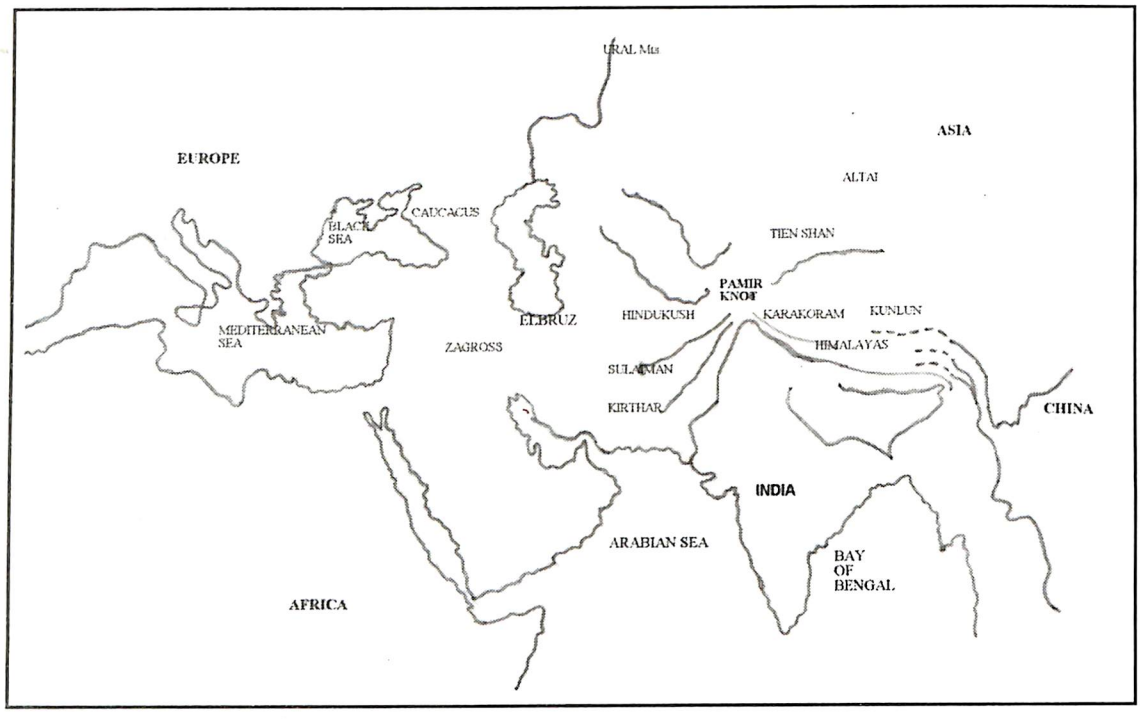

Figure 1.2. Pamir Knot

The scientific investigation of the Himalaya started comparatively late. The initial scientific investigations of the 17th and 18th century had limited objectives i.e. to acquire topographical and geographical details for trade purpose of the East India Company. Sorkhabi (2005) has ably summarized the history of geological and geographical investigations in the Himalaya. This chronological account of geographical and geological survey in Himalaya is mainly compiled from Sorkhabi's article.

Earliest geographical information of various regions of the Himalaya are provided by Keay (1781), Goft (1819, 1825), George Trebeck (1819-1825), Henry Starchy (1846) and Robert Starchy (1848), Thomas Thompson (1847-48), Andrew Fleming (1848-52), Colebrook (1867), B. Hodgson (1849), Leadflow (1817-21), G. Everest (1848-50), Voysey (1818-23) and Dangerfield (1820-23). Many among these workers were associated with the Survey of India.

P. Cautley (1830s) and H. Falconer initiated geological survey in Himalaya. They described fossils of Siwalik range. J.D. Hebberg (1842) provided on account of area between Kali and Satluj rivers and divided the rocks into primary and secondary formations. This was followed by Golden Age (1850-1890) of the Himalayan Geology, notable contributions in this period is made by Stuffwood, Delabeche, D. H. William, J. McClelland, R.D. Oldham, John, G., Henry, B., W. T. Medlicott, H.B. Medlicott, W. T. Blanford, O. Feistmental and R. Lydikker. Work of these pioneers is followed in detailed area specific investigations. C. L. Greisbach (1891) described the Central Himalaya, Middlemiss (1910) carried out detailed survey of Kangra earthquake. R.D. Oldham (1899) first time observed P and S waves, S. G. Burrard and H. H. Hayden (1907) described Himalayan physiography, G. E. Pilgrim and W.

D. West (1928) described geology of the Shimla area, Wadia (1931) provided an account of Kashmir Himalaya, J. B. Auden (1934-37) carried out investigations in Garhwal Kumaun region, A Heim and A. Gansser (1939) wrote a classical book on Central Himalaya, G. Dainelli (1922, 59), A. Desio (1930-60), P. Bordet (1960), D. Krummenacher (1956), A. Lombard, P. Misch, H.J. Schneider (1956) H. H. Hayden and T. Hagen described the geology of Nepal. Contributions of J. Coggin Brown, C. Diner, E.R. Gee, W. D. Gill, N.E. Odell and H. DeTerra are also highly praised worthy.

In the post - 1960 period boost to geological investigation in Himalaya is given by the Geological Survey of India, exploration activities of Oil and Natural Gas Corporation Ltd., Wadia Institute of Himalayan Geology and by the various academic and research institutions of India and abroad. Combined efforts of these organizations yielded enormous volume of data and better appreciation of geology. Several books, monographs, memoirs and records have been written in this period and several national and international journals have brought out specially focused issues on Himalaya and many issues of journals are exclusively devoted to Himalayan geology and few journals exclusively deal with the Himalayan Geology.

Among important books written on Himalaya geology are: Central Himalaya by A. Heim and A. Gansser (1939), Geology of Himalayas by A. Gansser (1964), Geology of Kumaun Lesser Himalaya by K. S. Valdiya (1980), Geology of Bhutan Himalaya by A. Gansser (1983), Geology of Higher Central Himalaya by A. K. Sinha (1989), Geology of Western Himalaya by V. C. Thakur (1992), Geology of Lower (Garhwal) Himalaya by P.S. Saklani (1993). Geology of Nepal Himalaya and Adjacent Countries by C. K. Sharma (1990) Tectonic and Metamorphic Investigations of Kumaun-Garhwal-Himachal Lesser Himalaya by I. C. Pande (1991), Geology of Arunachal Pradesh by G. Kumar (1997), Dynamic Himalaya by K. S. Valdiya (1998), Geology of Himachal Pradesh by S. V. Srikantia and O.N. Bhargava, Foreland sedimentation in Himalayan tectonic regime: a relook at orogenic process by V. Raiverman (2002), Geology of Uttar Pradesh and Uttaranchal by G. Kumar (2005) and research contributions in many volumes are edited by P.S. Saklani since 1978 and also by other workers engaged in Himalaya. The Geological Society of India has started a textbook program on geology of Indian states and in this series three textbooks pertain to geology of Uttar Pradesh and Uttaranchal, Arunachal Pradesh and Himachal Pradesh states have been published so far.

The Government of India duly recognizes dedication of many of these workers by conferring various honors on them. The Royal Society of England conferred honor of fellowship to Prof. D. N. Wadia for his outstanding geological investigations in Himalaya. However, positive contributions of thousands of workers have also witnessed questionable research by a few, for example, fossils reporting by V. J. Gupta.