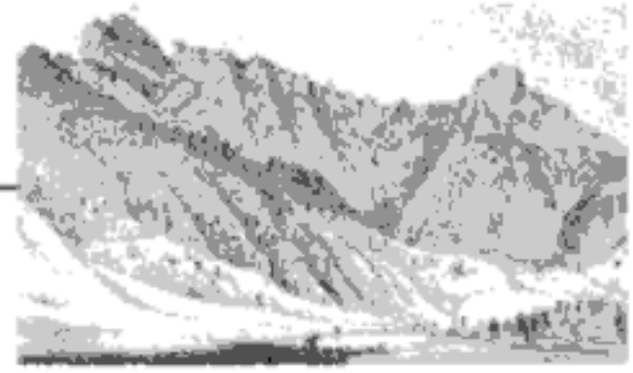
Chapter 2

PHYSIOGRAPHY



INTRODUCTION

Physiography deals with the study of the surface features and landforms of the Earth. On the basis of tectonic history, stratigraphy and physiography, India may be divided into the following four physiographic divisions (**Fig. 2.1**):

1. The elevated Peninsular region
2. The mighty Himalayas and their associated young folded mountains
3. The Indo-Gangetic-Brahmaputra Plains
4. The Coastal Plains and Islands.

ORIGIN AND PHYSIOGRAPHY OF THE PENINSULAR INDIA

The origin of rocks of Peninsular India is more than 3600 million years old. Before the Carboniferous period, it was a part of the Gondwanaland. In the opinion of geologists, during the Archaean Period, the India Peninsula never subsided under the sea permanently. It was more rigid, stable and had remained almost unaffected by the mountain building forces. However, it experienced block faulting and displacement during the subsequent periods as evidenced by the Dharwar and Gondwana formations and the fault valleys of the Narmada, Tapi and Son rivers.

It was during the Carboniferous Period that coal was formed in the Damodar, Son, Mahanadi and Godavari basins. During the Cretaceous Period, large scale vulcanicity produced the Deccan Trap (the Lava Plateau of India), comprising lava sheets of several thousand metres in depth. The Deccan Trap originated about 146 million years back when the magma flowed from the depth of about 40 km below the crust.

Major Geological Formations of the Peninsular India (about 3600 million years ago)

The plateau of Peninsular India exhibits a complex system of geological structures. It has some of the oldest rocks of the world from the Precambrian period (Archaean) and the youngest rocks of the Holocene epoch (Quaternary/Recent period). The major rock systems found in the Peninsular India have been described briefly in the following section:

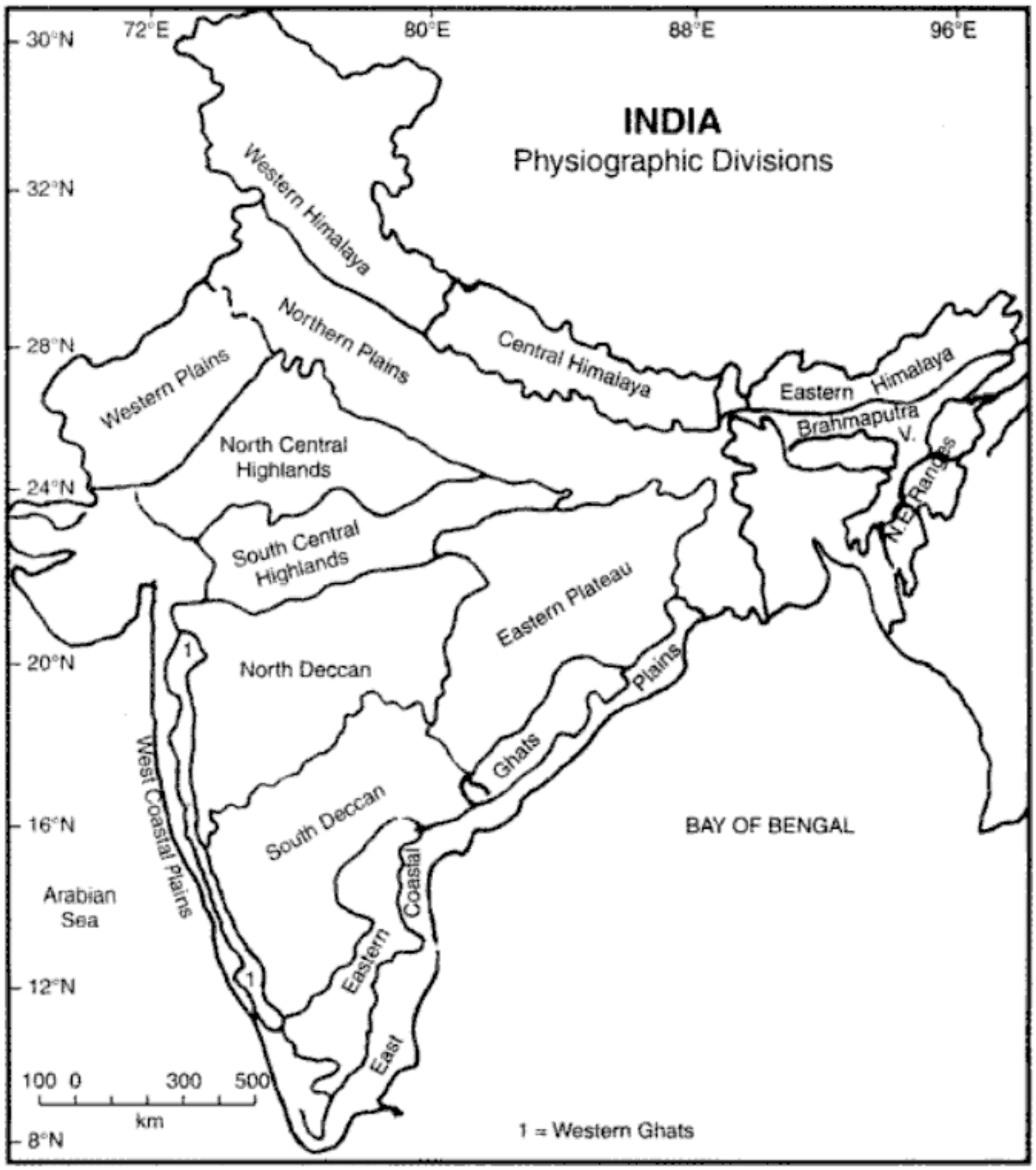


Fig. 2.1 *Physiographic Divisions*

1. The Archaean Group

Ancient crystalline and highly metamorphosed gneisses of the Archaean System are found in the plateaus of Tamil Nadu, Nilgiris, Karnataka, Andhra Pradesh, Maharashtra, Chhotanagpur, West Bengal, Orissa, Jharkhand, Chhattisgarh, Madhya Pradesh, Meghalaya, Mikir, Bundelkhand (U.P.) and the Aravallis (Rajasthan). The Bengal gneiss known as Khondolite is found in the Eastern Ghats. These rocks are rich in metallic and non-metallic minerals, precious stones and building materials.

2. The Dharwar System

These are the oldest metamorphosed-sedimentary rocks found in narrow geosynclines flanking the Archaean gneiss. They occur mainly in (i) Dharwar, Bellary and Hospet districts of Karnataka, (ii) the Chhotanagpur Plateau, (iii) the upper reaches of Godavari (Durg, Bastar, Dantewala, Chandrapur, etc.), and (iv) the Aravallis (Delhi, Rajasthan, and Gujarat).

It is presumed that the majority of the Dharwar rocks had escaped folding completely and had deposited into the hollows and the corrugations of landmasses or were only mildly folded. These rocks are rich in iron ore, manganese, mica, copper, zinc, lead, silver, gold, slate, asbestos, marble, and limestone.

3. The Cuddapah System

The Cuddapah formations (Andhra Pradesh) occupies the deep basins of: (i) the lower valleys of Penganga and Godavari, (ii) the Talcher Series between Mahanadi and Brahmani (Orissa), the upper courses of the Narmada and Son rivers, and (iii) west of Aravallis near Jodhpur. These rocks are rich in building material, shales, limestone, and sandstone. Some inferior quality of iron ore, manganese, copper, and asbestos are also found in these formations.

4. The Vindhyan System

The Central Indian Highlands known as the Vindhyan Mountains occupy a large basin extending from Chittorgarh (Rajasthan) in the west to Sasaram and Dehri-on-Son (Bihar) in the east. One branch of it extends from Sasaram to Hoshingabad (Madhya Pradesh). It occupies a large contiguous area stretching over one lakh sq km from the Chambal to Son rivers. Several isolated exposures of sedimentary rocks occur in the Bastar area of Chhattisgarh. In some of the exposures of the Vindhyan System are found the diamond bearing conglomerates. The Panna District of Madhya Pradesh and the Kurnool District of Andhra Pradesh are well known for diamond production. Elsewhere in the south, the upper Vindhyans are covered by the Deccan Traps. The Vindhyans are known for the good quality of building materials. They are rich in ornamental stones, precious stones, diamonds and materials used in ceremics. The historical monuments of the Medieval Period and majestic religious places like Stupa of Sanchi, Agra Fort, Fatehpur Sikri, Red Fort, Jama-Masjid, Birla Mandir, etc. have been constructed with the red-sandstones obtained from the Vindhyan Ranges.

5. Gondwana System

The coal belts of Peninsular India were developed during the Gondwana (Carboniferous) period. The Talcher Series, the Damuda Series and the Panchet Series are the products of this period. The rocks of the Upper Carboniferous Period, Permian, Triassic, Jurassic, Cretaceous, Tertiary, etc. are preserved in different parts of the Damodar, Mahanadi, Godavari and Krishna river basins.

6. The Deccan Trap

The Cretaceous system is a very widely distributed system in the country. The Gondwanaland developed fissures and its broken parts started drifting from each other. There was large scale upheaval of lava (basalt) from the interior of the Earth to form the Deccan Trap. The eruption of lava was of the Hawaiian or fissure type.This period is marked by the transgression of the sea (Narmada valley and Coromandal coast), and outpouring of huge quantity of basalt so as to form the Deccan Trap. There had been intrusions of the plutonic rocks such as gabbro and granite. The basalt of the Deccan Trap is used for the construction of roads and buildings. Moreover, there are quartzites, agates and carnelians in the lava formations of the Deccan Plateau.

7. The Tertiary System

The final fragmentation of the Gondwana took place during the Tertiary Period. There occurred faulting of the Peninsula alongwith the subsidence of the broken blocks beneath the Arabian Sea

and the Bay of Bengal. The Tertiary rocks are found in Kathiawar, Kachchh (Gujarat), Laki Series (Rajasthan), and along the Coromandal and Malabar coasts. In north-east, they are found in the Meghalaya Plateau; the Jaintia Series.

8. The Pleistocene Period

The Pleistocene deposits are found in the lower reaches and deltas of Mahanadi, Godavari, Krishna and Kaveri and the western coastal plains of Gujarat, Konkan and Malabar. These deposits are, however, more pronounced along the eastern coast of India.

Physiography and Relief Features of Peninsular India

Covering an area of about 16 lakh sq km, the peninsular upland forms the largest physiographic division of India. With a general elevation between 600–900 metres, the region constitutes an irregular triangle with its base lying between the Delhi Ridge and the Rajmahal Hills and the apex formed by Kanyakumari. It is bounded by the Aravallis in the north-west, Maikal Range in the north, Hazaribagh and Rajmahal Hills in the northeast, the Western Ghats (Sahayadri Mountains.) in the west and the Eastern Ghats in the east (**Fig. 2.1**). The highest peak of Peninsular India-Anai-Mudi (Nilgiris), is 2695 metres above sea level. According to Prof. S.P Chatterji (1964), the Peninsular Uplands can be divided into the following eight macro-physiographic units (**Table 2.1**).

Table 2.1 *The Physiographic Regions of Peninsular India*

Meso-Regions
1. The North Central Highlands
2. The South Central Highlands
3. The Eastern Plateau
4. The Meghalaya-Mikir Uplands
5. The North Deccan
6. The South Deccan
7. The Western Ghats or Sahayadri
8. The Eastern Ghats

Source: S.P. Chatterji, 1964, ***National Atlas Organisation***, Kolkata.

1. The North Central Highlands

The central highlands of peninsular India include the Aravallis, the Malwa Plateau, and the Vindhyan Range (**Fig. 2.2**).

(i) **The Aravallis**: It is a range that runs from north-east to south-west for about 800 km between Delhi to Palanpur (Gujarat). It is one of the oldest folded mountains of the world. Being highly denuded, its highest peak–Guru-Sikhar–is only 1722 metres in height. The Aravillis are mainly composed of quartzites, gneisses and schists of the Precambrian period. Northwest of Udaipur, the Aravallis are called Jarga Hills (1431 m). The Goranghat Pass separates Gurushikar from Mount Abu. The Great Boundary Fault (GBF) separates the Aravallis from the Vindhyan Mountains.

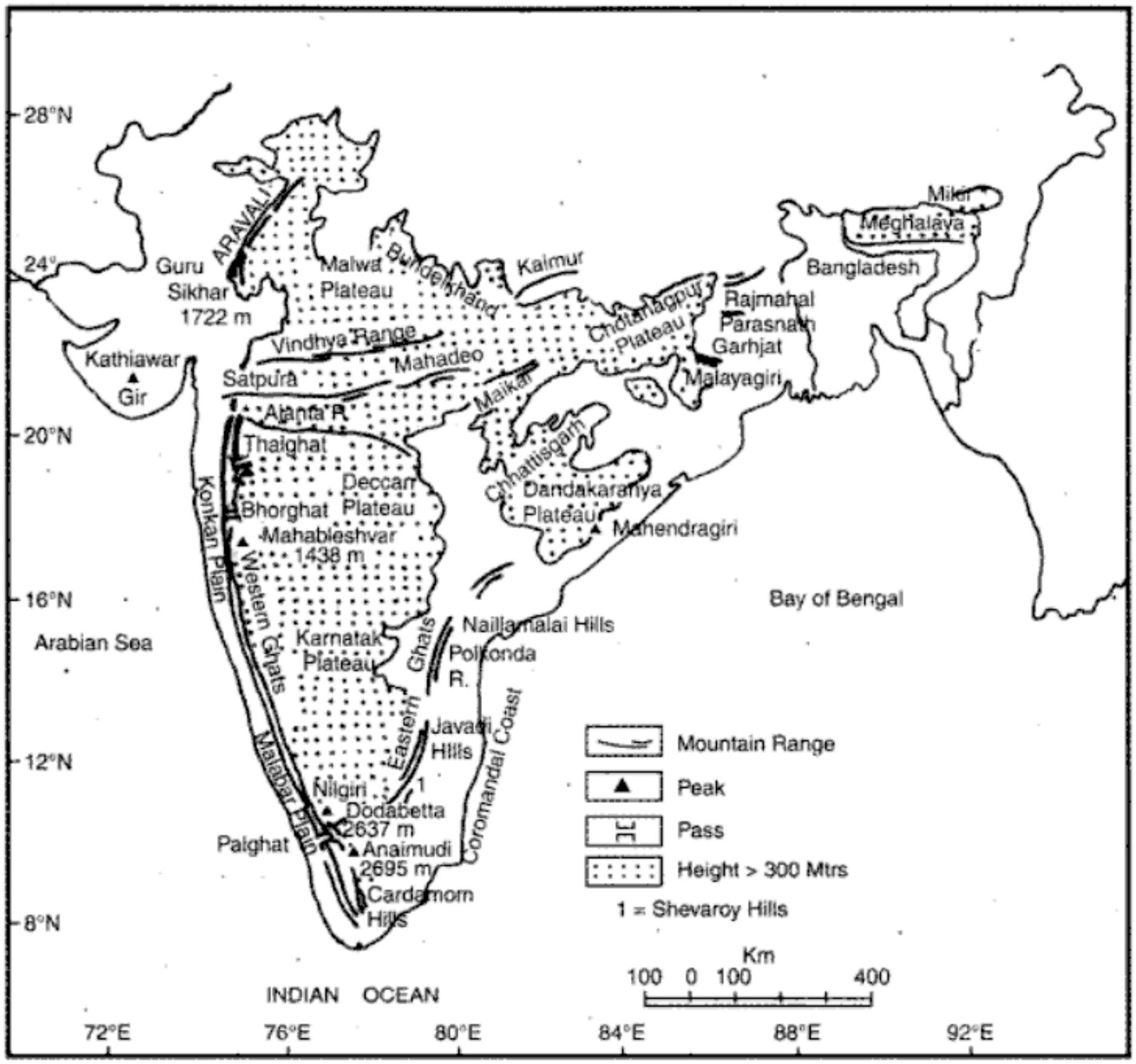


Fig. 2.2 Peninsular India: Relief

(ii) **The Malwa Plateau:** It is bordered by the Aravallis in the north, the Vindhyan Range in the south and the Bundelkhand Plateau in the east. The Malwa Plateau has two drainage systems, one towards the Arabian Sea (Narmada, and Mahi), and another towards the Bay of Bengal (Chambal, Sind, Betwa and Ken) joining the Yamuna river.

2. The South Central Highlands

The Vindhyan Range extends from Jobat (Gujarat) and Chittorgarh (Rajasthan) to Sasaram in Bihar. It extends for about 1050 km with general elevation between 450 to 600 metres. Apart from the Kaimur Hills in the east, the Maikal Range forms a connecting link between the Vindhyans and the Satpura mountains.

(i) **The Bundelkhand (Vindhyachal Plateau):** It is bounded by the Yamuna river in the north, the Vindhyans in the south, the Chambal in the north-west and Panna-Ajaigarh Range in the south-east. The Bundelkhand upland stretches over the districts of Banda, Hamirpur, Jalaun, Jhansi, and Lalitpur (U.P.), and Datia, Tikamgarh, Chhatarpur and Panna (M.P.).

The region is characterised by senile topography. The rivers like Betwa, Dhasan and Ken have carved out steep gorges, rapids, cataracts and waterfalls.

(ii) **The Vindhyachal-Baghelkhand or Vindhyachal Plateau**: It includes the plateaux of Satna, Rewa (M.P.) and Mirzapur (U.P.). Its elevation varies between 150 to 1200 metres with uneven relief. To the south of this lies the Narmada-Son trough (rift valley) characterised by the Archaeans and Bijwar series. South of this trough is the eastward extension of the Satpura which is an area of radial drainage. Among the basins, Singrauli and Dudhi (150-300 M) are Upper Gondwana basins, which are rich in coal deposits. Besides the Narmada and Son, this region is drained by the Karmanasa, Tons, Ken and Belandare rivers.

Parallel to the Vindhyas between the Narmada and the Tapi rivers is the Satpura Range. Satpura consists of Rajpipla Hills, Mahadev Hills and the Maikal Range. Dhupgarh (1350 m, near Pachmarhi) is the highest peak of Satpura. Amarkantak (1064 metres) is another important peak of the Satpura mountains.

3. The Chotanagpur Plateau

The Chotanagpur Plateau sprawls over parts of West Bengal, Jharkhand, Chhattisgarh, Orissa and northeastern part of Andhra Pradesh. This plateau has a series of the meso and micro plateaux (Ranchi, Hazaribagh, Singhbhum, Dhanbad, Palamu, Santhal-Parganas and Purulia districts of West Bengal). It is composed of Archaean granite and gneiss rocks with patches of Dharwar (mica-schists), the Damuda series of the Gondwana Period, and the lava flow of the Cretaceous Period.

Moreover, the Chhotanagpur Plateau consists of plateaux at different levels of elevation, the highest general elevation of about 1100 m in the mid-western part is known as ***pat*** lands. The rivers which drain the Chhotanagpur Plateau are Barakar, Damodar, Subarnarekha, and Koels. These rivers have carved out deep gorges, rapids, cataracts, and waterfalls in the plateau region.

4. The Meghalaya Plateau and Mikir Hills

Consisting of the Garo, Khasi, Jaintia hills and the outlying Mikir and Rengma hills, it is a plateau which has been detached from the Indian Peninsula by the Malda Gap. The Meghalaya Plateau has a chequered evolutionary history of emergence, submergence, planation surface with several phsases of erosion, sedimentation, diastrophism and intrusions. The Shillong Peak is the highest elevation (1823 m) in the Meghalaya Plateau, while Norkek (1515 m) is the highest peak of the Garo Hills. Mawsynram (25°15′N, 91°44′E) about 16 km west of Cherrapunji records the highest rainfall in the world.

The Mikir Hills are detached from the Meghalaya Plateau and are surrounded by plains from three sides. The southern range of the Mikir Hills is known as the Rengma Hills (900 m). The Mikir Hills are characterised by radial drainage with Dhansiri and Jamuna being the main rivers.

5. The North Deccan (Maharashtra Plateau)

The plateau of Maharashtra includes the entire state of Maharashtra, except the Konkan coast and the Sahyadris. It is mainly covered by the basalt of the Cretaceous Period. The basaltic sheet has a thickness of about 3 km in the western parts which diminishes towards the east and south-east. The most striking feature of the Maharashtra Plateau is the fault (1000 metres), giving rise to the present shoreline of the Arabian Sea.

Through the northern part of the Maharashtra Plateau flows the Tapi River from east to west. It has a gentle slope in the south and steep gradient in the north (towards the Satpura Hills).

(i) **The Mahanadi Basin**: Sprawling over the districts of Raipur, Bilaspur, Durg and Rajgarh, the Mahanadi basin is also known as the Chhattisgarh Plain. The region is largely dominated by the Archaean and Cuddapah formations. The Mahanadi river and its tributaries like Seonath, Hasdeo and Mana drain this plain.

(ii) **The Chhattisgarh Plain**: It is bordered by a series of hills and plateaux. The northern boundary is formed by the Lomari Plateau, Pendra Plateau, the Chhuri and the Raigarh Hills. The Korba coalfields of Chhattisgarh lie in this basin. The Gondwana formations are rich in bituminous coal which is supplied to the Bhilai Steel Plant. The western rimland includes the Maikal Range with crest line of 700–900 metres. The southern rimland includes the Dhalli-Rajhara Hills in southern Durg district and the Raipur uplands in the south-eastern Raipur district. The Rajhara Hill contains Dharwarian rocks in which iron ore of haematite type is found. The iron ore from the Dhalli–Rajahara mines is supplied to the Bhilai Steel Plant.

(iii) **Garhjat Hills:** The Garhjat Hills are also known as the Orissa Highlands. It is bordered by the Chotanagpur Plateau in the north, Mahanadi basin in the west, Eastern Ghats in the south and Utkal plains in the east. The region is mainly composed of Archaean rocks like granite, gneisses and magmatic rocks. The Gondwana, Talcher, Barakar and Kamathi series are also located in this region.

(iv) **Dandakaranya**: Sprawling over the Koraput and Kalahandi districts of Orissa, Bastar District of Chhattisgarh and East Godavari, Vishakhapatnam and Srikakulam districts of Andhra Pradesh, Dandakaranya is an undulating plateau. Its Abujhmar Hills provide one of the richest iron-ore deposits at Bailadila Range. It is drained by the Tel and Udanti; tributaries of Mahanadi, and the Sabari and Sileru; tributaries of Godavari rivers.

6. The South Deccan

The south Deccan consists of several plateaux:

(i) **Karnataka Plateau:** This plateau spans in the state of Karnataka and the Cannanore and Kozhikode districts of Kerala. It shows dominance of Archaean and Dharwar formations. This plateau has an average elevation of 600–900 metres. Mulangiri (1913 metres) is the highest peak in Baba-Budan Hills, followed by the Kudermukh (1892 metres) peak.

The northern upland of the Karnataka plateau is known as Malnad, while the southern part is called a Maidan. It is drained by the Kaveri and the Tungbhadra rivers. The Nandi valley is a summer resort in this region.

(ii) **The Telengana Plateau:** The plateau of Telengana consists of Dharwar and Cuddapah formations.

(iii) **The Tamil Nadu Uplands**: This upland lies between the South Sahyadri and Tamil Nadu coastal plains. It is largely covered by the Archaean rocks. The charnockites are found in Javadi and Shevaroy hills. Moreover, there are Cuddapah and alluvial formations. Between Coimbatore and Anaimalais, there is a broad gap, known as Palakkad Gap (Palghat), about 24 km wide, through which flows the Gayitri river from east to west joining Tamil Nadu with the coast of Kerala.

7. The Western Ghats

The Western Ghats or Sahyadris run parallel to the western coast for about 1600 km in the north south direction from the mouth of the Tapi river to Kanyakumari (Cape Camorin). The western

slope of Sahyadri is steep while the eastern slope is gentle. These are block mountains formed due to the downwarping of a part of land into the Arabian Sea. The Sahyadris form a watershed of the peninsula. All the important rivers of Peninsular India, like the Godavari, Krishna and Kaveri rise from the Western Ghats. The western rivers merging into the Arabian Sea are swift. The Gersoppa (Jog Falls) on Sharvati is the highest waterfall in India. The average elevation of the Western Ghats varies between 1000 to 1300 metres **(Fig. 2.3).**

The important peaks of the Western Ghats are Kudermukh (1892 m), Pushpagiri (1714 m), Kalsubai (1646 m) and Salher (1567 m), Mahabaleshwar (1438 m) and Harishchandra (1424 m). In the Nilgiris the Eastern Ghat joins the Western Ghat to form a mountain knot (Nilgiri) whose highest point is Anaimudi (2695 m). South of Nilgiri lies the Palghat (Palakkad Gap). The other important passes of the western Ghat are Thal Ghat and Bhor Ghat.

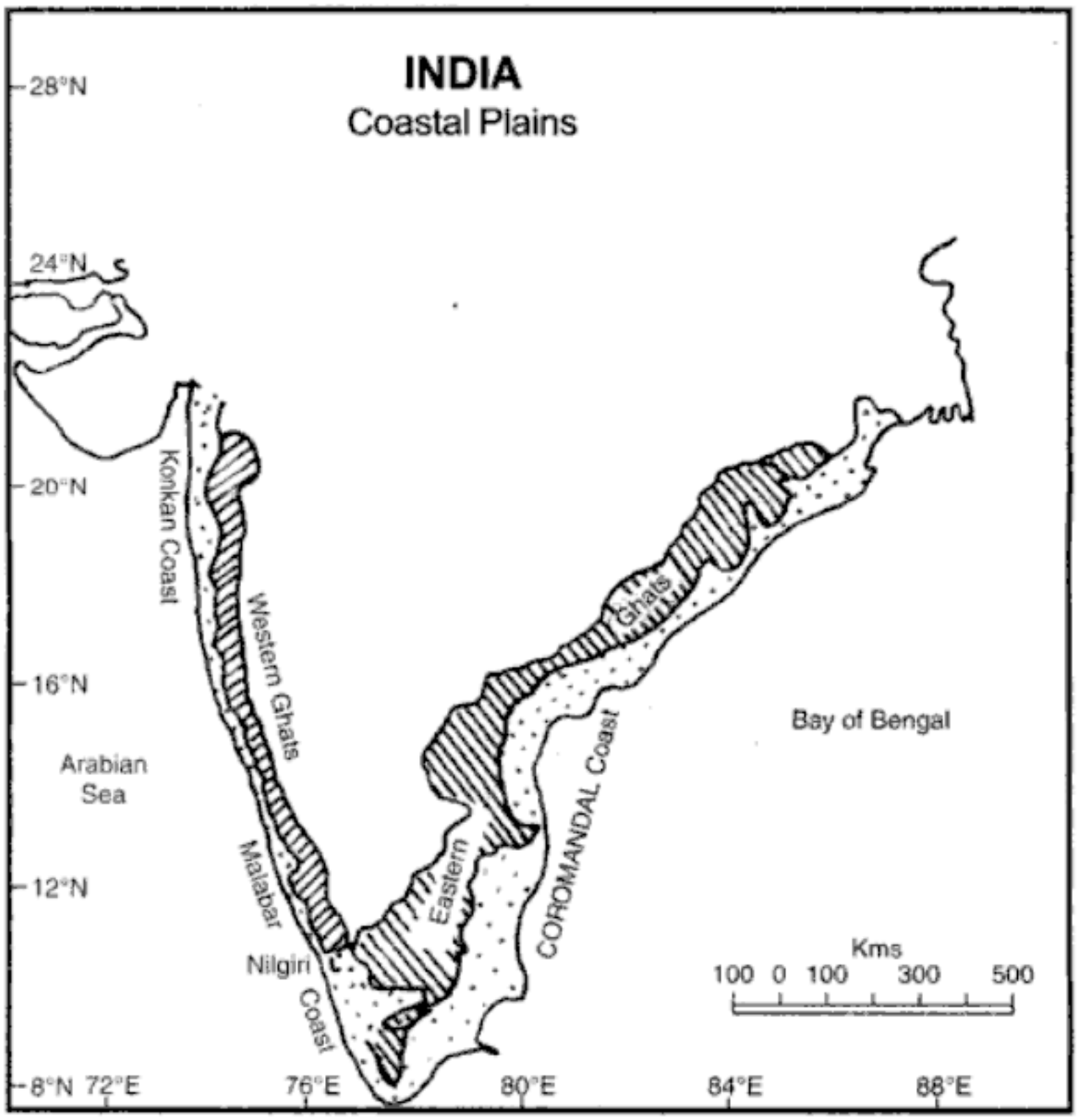


Fig. 2.3 The Eastern and Western Ghats and the Coastal Plains

Bhor Ghat: (Joins Mumbai with Pune): Having an elevation of about one thousand metres above sea level, the Bhorghat joins Mumbai with Pune. It is one of the most busy passes in the Western Ghats. The frequency of trains and commercial vehicles is enormous.

Goran Ghat: Lying to the south of Mount Abu, it connects the city of Udaipur with Sirohi and Jalore in Rajasthan. It is about 1200 metres above sea level. The surrounding rocks are desolate, characterised by thorny bushes and cacti.

Haldighat: It is a mountain pass in the Aravalli range of Rajasthan. Situated about 40 kilometres from Udaipur, it connects Rajsamand and Pali district. The name is believed to have come from the turmeric-coloured yellow soil. The mountain pass is historically important as the location of the historic battle of Haldighat which took place in 1576 between Rana Pratap Singh of Mewar and Raja Mansingh of Amber, General of the Mughal Emperor—Akbar the Great.

Harishchandra: The Harishchandra mountain ranges in the southern parts of Maharashtra from north-west to south-east. It stretches in the districts of Pune and Osmanabad. It is covered by degraded forests.

Jog Falls: The short westward flowing Sharavati river pours down the Western Ghats, forming one of the highest waterfalls in the world at 250 m.

Kalsubai: Situated in the state of Maharashtra, it is one of the highest peaks of Western Ghats. It is 1646 metres above sea level. Inhabited by tribal people, its forest wealth has diminished due to deforestation.

Kudarmukh: Situated in the state of Karnataka, the Kudarmukh range (1892 m) is rich in iron ore. The iron-ore is of haematite and magnetite type. Iron ore from here is exported to Iran through the port at Mangalore.

Mahabaleshwar: Having an elevation of 1438 metres, Mahabaleshwar is one of the important peaks of the Western Ghats. It is a religious and cultural tourist attraction for domestic and international tourists.

The Nilgiri Hills: The Nilgiri Hills in the Western Ghats cover an area of about 2500 sq km and rise over 2500 m. Udhagamandalam, one of southern India's most famous hill resorts, is located here.

Palghat (Western Ghats; joins Coimbatore with Kochi and Kozhikode): Also known as the Palakkad Gap, it lies to the south of Nilgiri Hills. It has an elevation ranging from 75 to 300 m above the sea level. The width of this gap is about 25 km. It joins the state of Tamil Nadu with the seaports of Kerala. The river Gayitri flows through it from east to west.

Pushpagiri: This is one of the highest peaks of the Western Ghats. Its elevation is 1714 metres above the sea level. It is the abode of Dravidian tribes. The forests are however, degraded and soil erosion is the main problem.

Salher: Having an elevation of 1567 metres above sea level, the Salher peak lies between Malegaon and Nashik. It is inhabited by tribal people. Heavy deforestation has reduced its aesthetic beauty and created numerous ecological problems.

Thal Ghat (Western Ghats; joins Nashik with Mumbai): Located in the Sahyadri Ranges, Thal Ghat is over one thousand metres above sea level. The National Highway No. 3 and the Bhopal-Indore Railway Line pass through the Thal Ghat.

8. The Eastern Ghats

The Eastetrn Ghats form the eastern boundary of the Deccan Plateau. It is a massive outlying block of hills. The average height of the Eastern Ghats is about 600 m. The Eastern Ghat is a series of the detached hills of heterogeneous composition which are called by various local names. Between Mahanadi and Godavari, the average elevation of the Eastern Ghats is about 1100 metres **(Fig. 2.3).** The peak of Singaraju (Orissa) with an elevation of 1516 metres is the highest peak of

the Eastern Ghats. Among other peaks Nimalgiri (1515 m) in the Koraput District and Mahendragiri (1501 m) in Ganjam District are the other important peaks. The predominant rocks of the Eastern Ghats are khondalites, metamorphosed-sedimentary, and charnokites (intrusive rocks being granite). Between the Krishna river and Chinnai are the Kondavidu, Nallamalai, Velikonds, Palkonda, and Erramala Ranges. Their continuation can be seen in the Seshachalam (Cuddapah and Anantapur districts), Javadi, Shevaroy, Panchaimalai, Sirumalai, and Varushnad Hills south west of Madurai (Tamil Nadu).

Significance of the Peninsular Plateau

Richly endowed with natural resources, Peninsular India has an important role in the economic development of the country. The importance of Peninsular India is mainly because of the following benefits from its location and rock formations:

(i) The Peninsular region of India is rich in both the metallic and non-metallic minerals. Mineral ores like iron, manganese, copper, bauxite, chromium, mica, gold, silver, zinc, lead, mercury, coal, diamond, precious stones, marble, building materials and decorative stones are found in abundance in this physiographic region. About 98 per cent of the Gondwana coal deposits of India are also found in the Peninsular region.

(ii) A substantial part of the Peninsular India is covered by black earth (Regur soil). The regur soil is conducive for the successful cultivation of cotton, millets, maize, pulses, oranges and citrus fruits. Some areas of south Peninsular India are suitable for the cultivation of tea, coffee, rubber, cashew, spices, tobacco, groundnut and oilseeds.

(iii) On the southern and eastern parts of Peninsular India are large stretches of Archaean, Dharwar, Cuddapah and Vindhyan formations in which red, brown and laterite soils have developed over time. These soils are the bases of rural economy.

(iv) The Western Ghats, Nilgiris and the Eastern Ghats are covered by thick tropical moist deciduous and semi-evergreen forests. These forests provide teak, sal, sandalwood, ebony, mahogany, bamboo, cane, rosewood, iron-wood, and logwood as well as a large variety of forest products.

(v) The rivers flowing eastward into the Bay of Bengal make several gorges, waterfalls, rapids and cataracts, which have been harnessed for the generation of hydro-electricity. The rivers originating from the Western Ghats offer great opportunity for the generation of hydel power and irrigation of agricultural crops and orchards.

(vi) There are numerous hill stations and hill resorts, of which Ooty, Udhagamandalam, Kodaikonal, Mahabaleshwar, Khandala, Metheron, Pachmarhi, and Mount Abu are the most important.

(vii) Apart from teak and fuelwood, the forests of Western and Eastern Ghats are rich in medicinal plants.

(viii) The hilly and mountainous areas of the Peninsula are the abodes of many scheduled tribes. South of the Vindhyans is a predominance of Dravidian culture.

THE HIMALAYAS

The Himalayas consist of four lithotectonic mountain ranges, namely (i) the Trans-Himalaya or the Tethys Himalaya, (ii) the Greater Himalaya, (iii) the Lesser Himalaya, and (iv) the Shiwalik or

the Outer Himalaya. The Indian Himalayas extend from the eastern boundary of Pakistan to the border of Myanmar for about 2500 km with a varying width of about 500 km in the west and about 320 km in the east. They lie to the north of the Ganga–Brahmaputra Plains and are separated from the plains by the Himalayan Front Fault (HFF). They include parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Nepal, Sikkim, Bhutan and Arunachal Pradesh. Their offshoots run in a north–south direction along the India–Myanmar boundary through Nagaland, Manipur, and Mizoram.

Origin of the Himalayas

The origin of the Himalayas has been a point of contention among the geologists and geomorphologists. It is a complex mountain system having rocks from the Pre-Cambrian and Eocene periods. Mostly formed of sedimentary and metamorphic rocks, it has been subjected to intense folding and faulting. The main theories about the origin of the Himalays are as under:

(i) The Geosynclinal Origin

The main supporters of the geosynclinal origin of the Himalayas are Argand, Kober and Suess. According to these geologists, the disintegration of Pangaea, about 200 million years back, led to the formation of a long Tethys Sea between the Lauratian Shield (Angaraland) of the north and the Gondwanaland of the south. This sea was occupying the region of Himalayas during the Mesozoic Era (180 m years ago). At the end of the Palaeozoic and beginning of the Mesozoic Eras, the Tethys almost girdled the whole Earth running from Europe in the west to China in the east. Eroded material from the two land masses (Eurasian Shield - Angaraland and Gondwanaland) was deposited in the Tethys Sea and assumed considerable thickness due to the sinking nature of the sea bed (**Fig. 2.4 and Fig. 2.5**). During the Cretaceous Period, the bed of the sea started rising which led to the folding of three successive ranges of the Himalayas. The first upheaval led to the formation of the Greater Himalayas during the Eocene Period (about 65 m years back). Similarly,

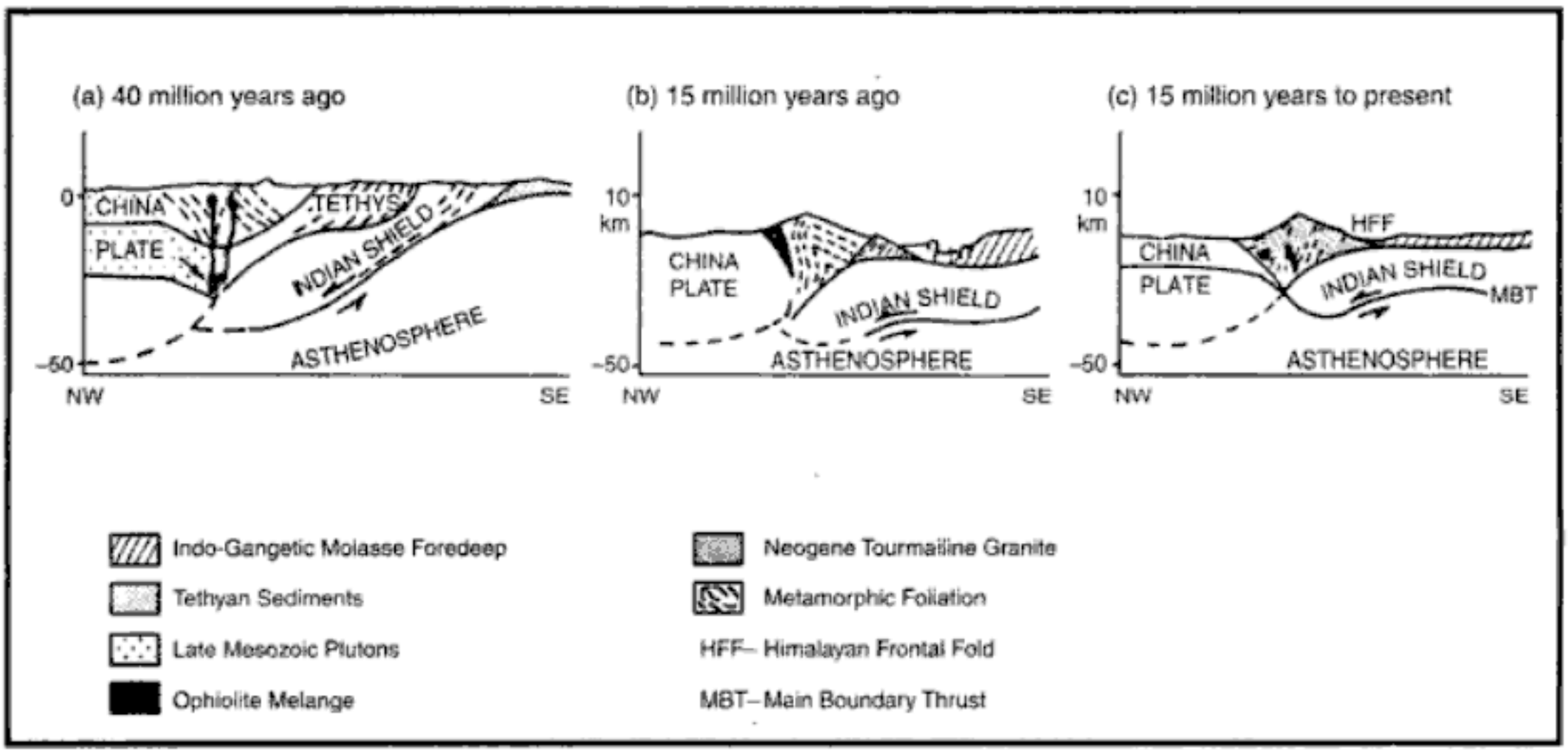
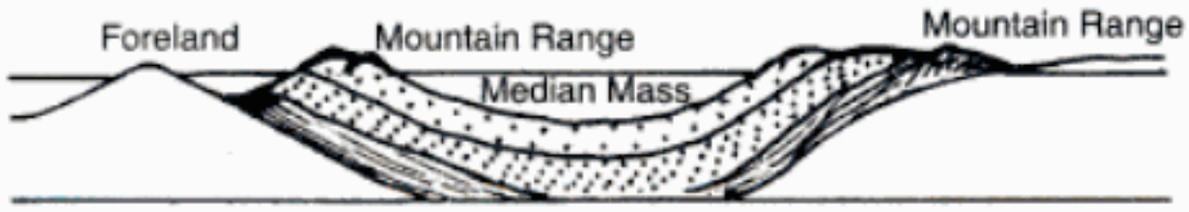


Fig. 2.4 Origin of the Himalayas



After L.Kober, "Der Bau der Erde" 2nd Ed., 1928.

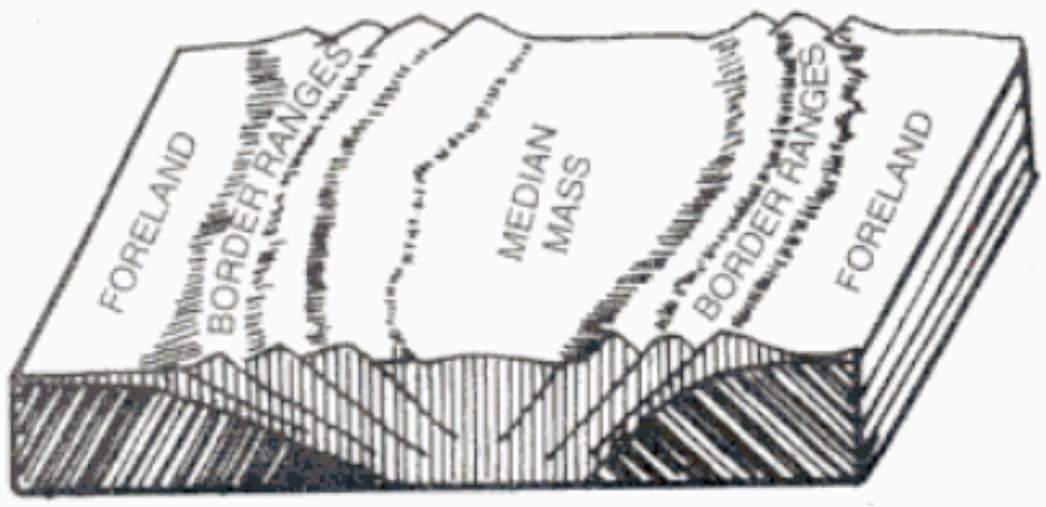


Fig. 2.5 Formation of the Himalayas

the second upheaval took place during the Miocene Period (about 45 million years back) resulting in the formation of the Lesser Himalayas, and the third upheaval started in the Pliocene period (about 1.4 million years back) resulting in the formation of the Shiwaliks or the Outer Himalayas.

(ii) The Plate Tectonic Origin of the Himalayas

The theory of Plate Tectonics was put forward by W.J. Morgan of Princeton University in 1967. This theory is based on the concept of 'Sea-Floor Spreading' advocated by H.H. Hess. According to this theory, about 70 or 65 million years ago there was an extensive geosyncline, called the Tethys, in place of the Himalayas. About 60–30 million years ago the Indian plate came very close to the Asian plate and started subducting under the Asian plate (**Fig. 2.6**). This caused lateral compression due to which the sediments of the Tethys were squeezed and folded into three parallel ranges of the Himalayas. It has been estimated that this convergence has caused a crustal shortening of about 500 km in the Himalayan region and is compensated by sea floor spreading along the oceanic ridge in the Indian ocean region. Since the northward movement of the Indian plate is still continuing, the height of the Himalayan peaks is increasing. The Indian Plate is moving northward and the center of rotation is constantly changing. The northward drift of the Indian Plate and the subcontinent of India have been shown in **Fig. 2.7 and Fig. 2.8.**

The continent-to-continent collision between the Indian and the Asiatic plates started around 65 million years ago and caused the Himalayas to rise from the Tethys geosyncline. Thus, the first major phase of uplift in the Himalayas occurred around 65 million years ago. This orogenic movement elevated the central axis of ancient crystalline and meta-sedimentary rocks which have been intruded by large masses of granite. It is believed that the first major phase of uplift initially produced the Ladakh and Zaskar ranges of the Trans-Himalayas before the formation of the Great Himalayas. Hence, it is to be realized that except the Kashmir part of the Himalayas, the Himalayan ranges have not developed from a geosyncline and are made up of elements formerly connected to the marginal parts of the Indian shield. During the main Himalayan orogeny, this continuous geosynclinal sedimentation led to the underthrusting of the Indian shield against the Tibetan Massif which buckled down the geosynclinal deposits, resulting in the outflow of a large amount of ultrabasic rocks known as ophiolites. These ophiolites are seen as exotic blocks on the

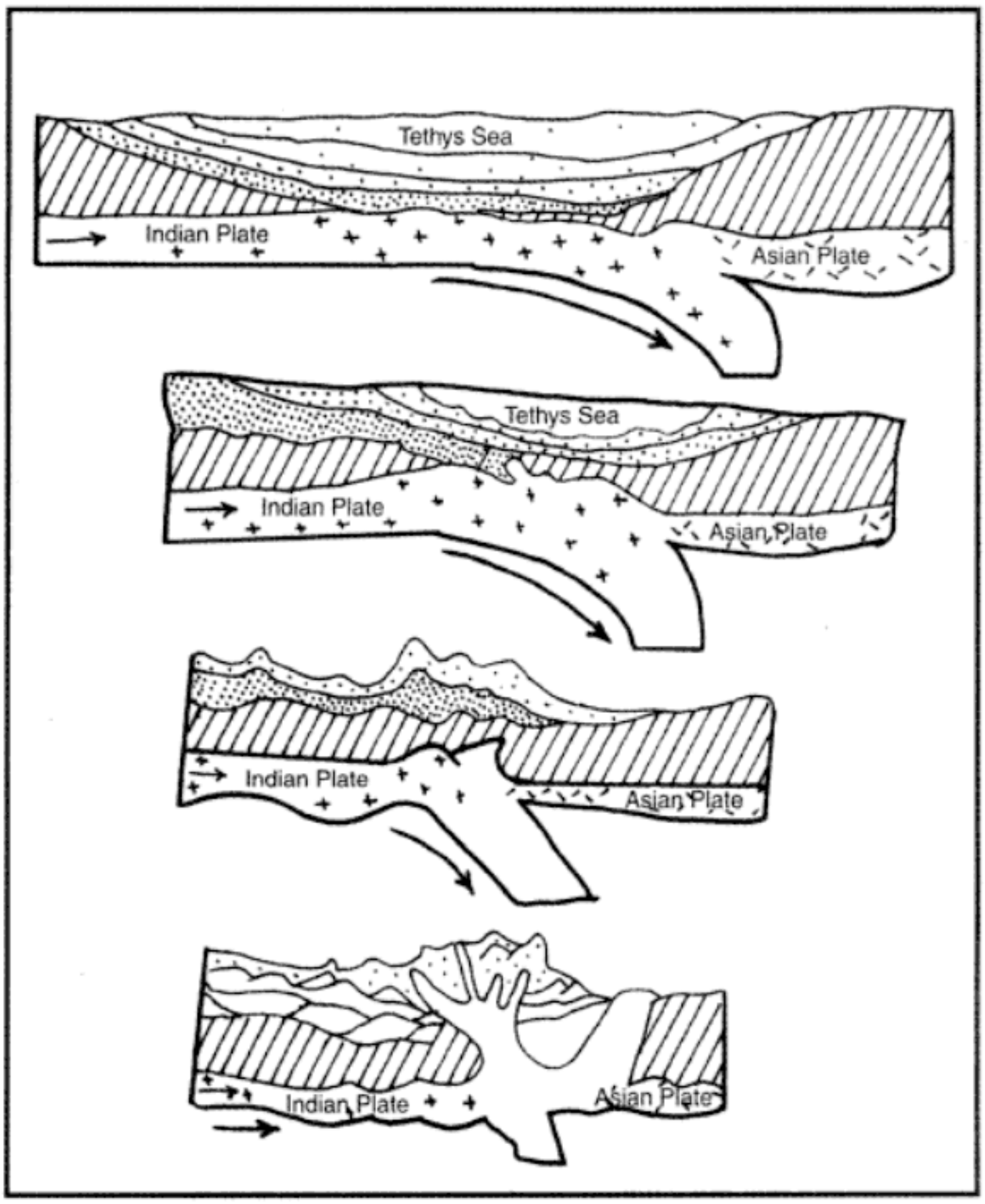


Fig. 2.6 Plate Tectonics and Origin of the Himalayas

Ladakh and Zaskar Ranges of the Trans-Himalayas. The end effect of the buckling of the geosyncline was not only the crustaline thrust effect on Ladakh and Zaskar leading to their rise as ranges, but also the creation of the sharp tectonic line of the Indus suture along which large geosynclinal areas disappeared.

The intermontane basins in the Indus suture zone of Ladakh continued to receive molasses sedimentation in this period. The second major uplift which took place around 45 million years ago, caused the rapid uplift of the southern mountain front of the Lesser Himalayas, giving rise to the extremely rugged and youthful Pir-Panjal, Dhauladhar, Karol, and Mahabharat Ranges abruptly and steeply. The Greater Himalayas and the Lesser Himalayas are separated by the Main Central Thrust (MCT). These spurs of the Lesser Himalayas again formed, in their turn, the intermontane basins of Kashmir, the Karol-basin, Dun Valley (Uttrakhand) and the Kathmandu Valley of Nepal. The foredeep which was formed further away received the thick sequence of terrestrial sediments called Shiwaliks from the middle-Miocene to the middle-Pleistocene periods, covering a span of

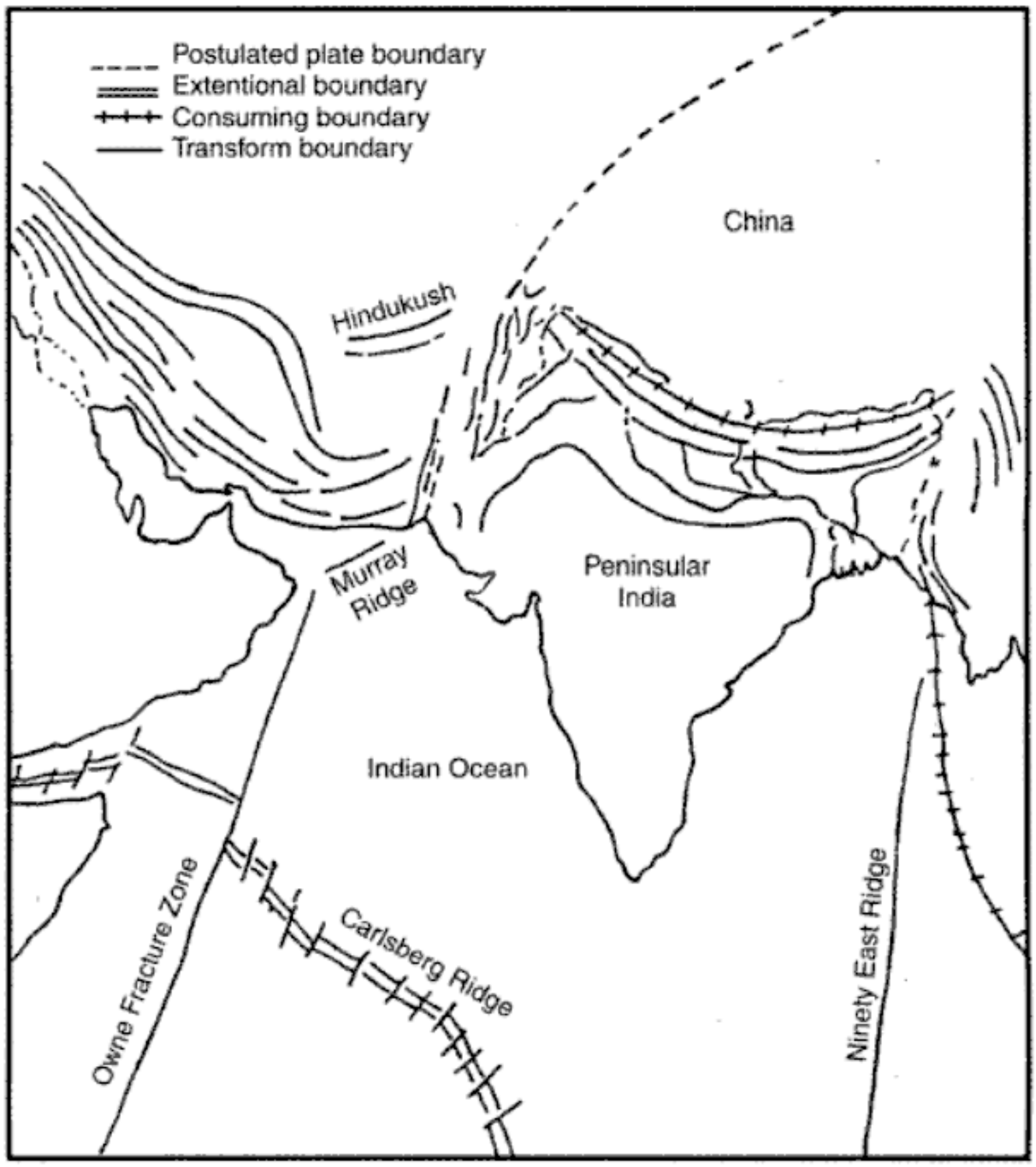


Fig. 2.7 Northward Drift of the Indian Plate

about 1.4 million years. The Lesser Himalayas and the Shiwaliks are separated from each other by the Main Boundary Thrust (MBT). The 5000 metres thick Shiwaliks dominated by boulder and conglomerate, reflect the progressive uplift of the Himalayas from which they have been derived as a result of the third major phase of uplift. The Shiwaliks are separated from the Northern Plains of India by the Himalayan Front Fault or HFF (**Fig. 2.9 and Fig. 2.10**).

The Shiwaliks form the normal Jura type of structures with wider basin-like synclines alternating with steep, often faulted, asymmetric anticlines. At present, the Himalayan Front Fault (HFF) is quite active recording frequent tremors and earthquakes .

Physiographic Divisions of the Himalayas

For a systematic study of the physiography and relief, the Himalayas may be divided into the following four divisions from north to south:

1. The Trans-Himalayas
2. The Greater Himalayas

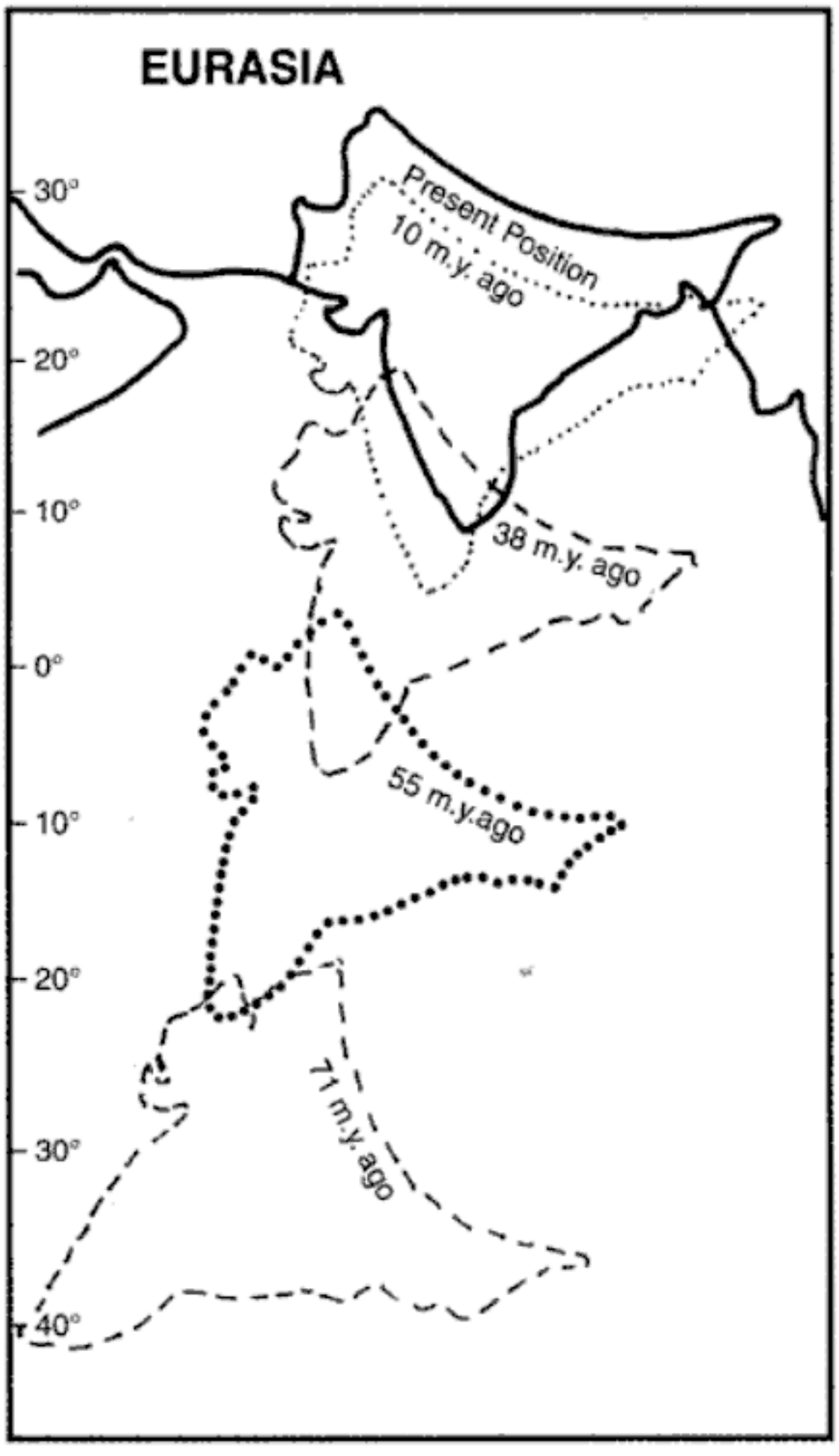


Fig. 2.8 Northward Drift of the Indian Subcontinent

3. The Lesser Himalayas
4. The Shiwaliks or the Outer Himalayas.

1. The Trans-Himalayas

The Trans-Himalayas are about 40 km wide. They contain the Tethys sediments. The rocks of this region contain fossils bearing marine sediments which are underlain by 'Tertiary granite'. It has partly metamorphosed sediments and constitutes the core of the Himalayan axis. It has a great accumulation of debris in the valleys of defeated streams which could not maintain their southerly course across the rising barrier of the Himalayas (**Fig. 2.10**).

2. The Greater Himalayas

The Greater Himalayas rise abruptly like a wall north of the Lesser Himalayas. The Main Central Thrust separates the Greater Himalayas from the Lesser Himalayas. The Greater Himalayas are

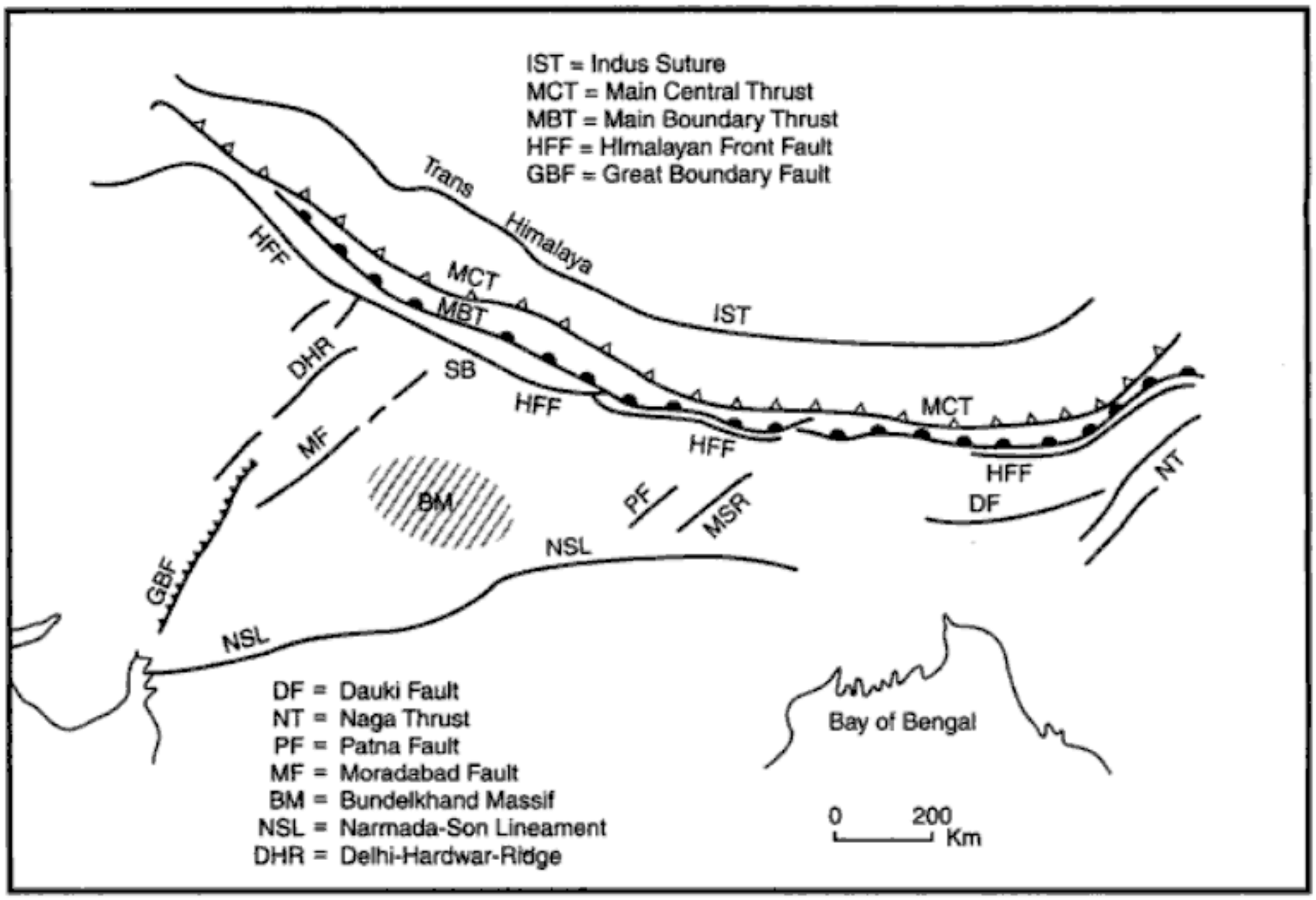


Fig. 2.9 Major Faults of the Himalayas

about 25 km wide with an average height above 5000 metres. Almost all the lofty peaks of the Himalayas lie in this zone. The Greater Himalayas are composed of crystalline, igneous or metamorphic rocks (granite, schists, and geneiss). The basal complex of the Himalayas is Archaean. At places, due to heavy thrust, older rocks are found overlying the newer rocks. The Greater Himalayas are almost a contiguous range. The range has very few gaps mainly provided by the antecedent rivers. The Greater Himalayas receive less rainfall as compared to the Lesser Himalayas and the Shiwaliks. Physical weathering is pronounced. Erosion is, however, less effective over the Greater Himalayas as compared to the Lesser Himalayas. Being lofty, they have very little forest area.

3. The Lesser Himalayas

The width of the Lesser Himalayas is about 80 km with an average height of 1300–5000 m. It consists, generally, of unfossiliferous sediments or metamorphosed crystalline. The main rocks are slate, limestone and quartzites. Along the southern margin of the Lesser Himalayas lies the autochthonous belt of highly compressed Upper Palaeozoic to Eocene rocks, often containing volcanic material. Examples of autochthonous belts are found between Murree and Panjal thrust in Kashmir, Giri thrusts in the Shimla region and Karol and Main Boundary Thrust (MBT) in Garhwal region. This region is subjected to extensive erosion due to heavy rainfall, deforestation and urbanisation.

4. The Shiwaliks or Outer Himalayas/Sub-Himalayas

The Shiwaliks extend from Jammu Division of Jammu and Kashmir State to Assam. In width, Shiwaliks vary from 8 km in the east to 45 km in the west with an average elevation of about

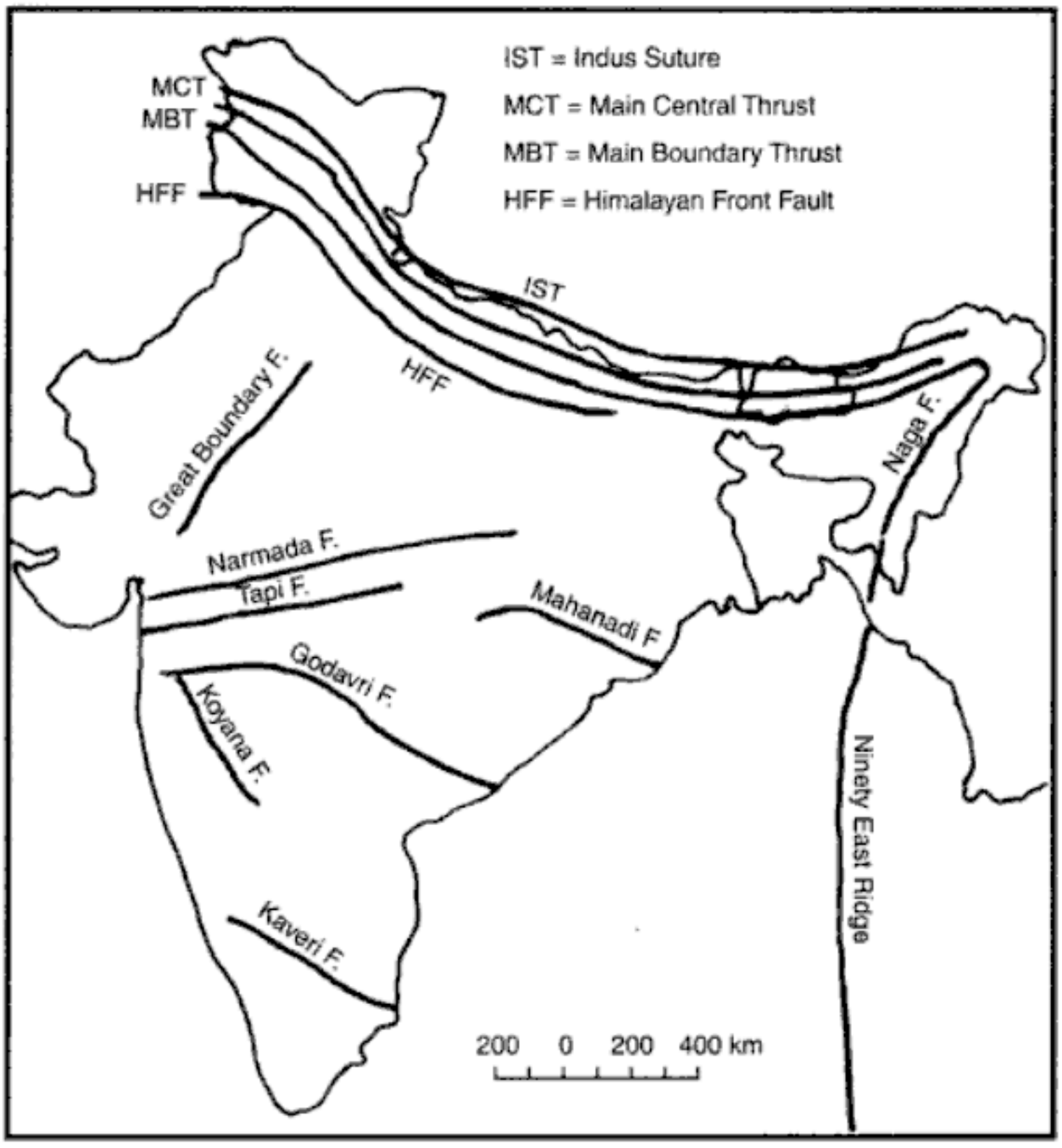


Fig. 2.10 Major Faults of India

1300 m above sea level. It is not a continuous range. It is broader in the west and narrows down in the east. Between the Shiwaliks and the Lesser Himalayas are longitudinal valleys called Doons/ Duns. Some of the important Duns are Dehra Dun, Potli, Kothri, Kathmandu, Chumbi and Kyarda. The Shiwaliks are mainly composed of sandstones, sand-rocks, clay, conglomerates and limestones, mostly belonging to the Upper Tertiary Period.

Longitudinal Divisions of the Himalayas

The Himalayas have also been divided by Sir S. Burrard into four divisions, namely (i) The Western Himalayas, (ii) The Kumaun Himalayas, (iii) The Nepal Himalayas, and (iv) The Assam Himalayas. Prof. S.P. Chatterjee (1973), divided the Himalayas into the following six transverse divisions (**Fig. 2.11, Fig. 2.12(a)** and **Fig. 2.12(b)**):

1. The Kashmir Himalayas
2. The Himachal Himalayas
3. The Kumaun Himalayas
4. The Sikkim Himalayas
5. The Arunachal Himalayas
6. Purvachal Himalayas

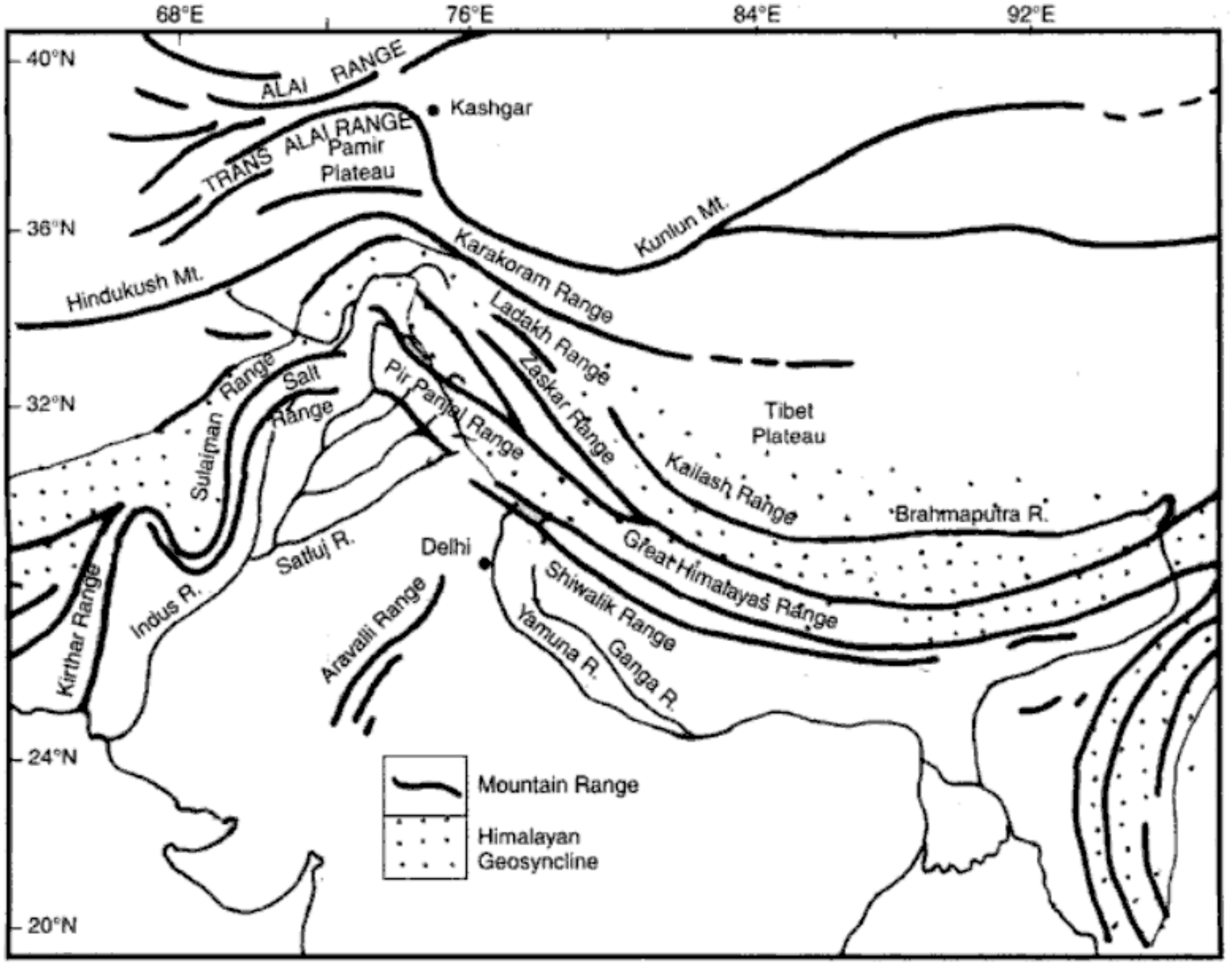


Fig. 2.11 Physiographic Divisions of the Himalayas

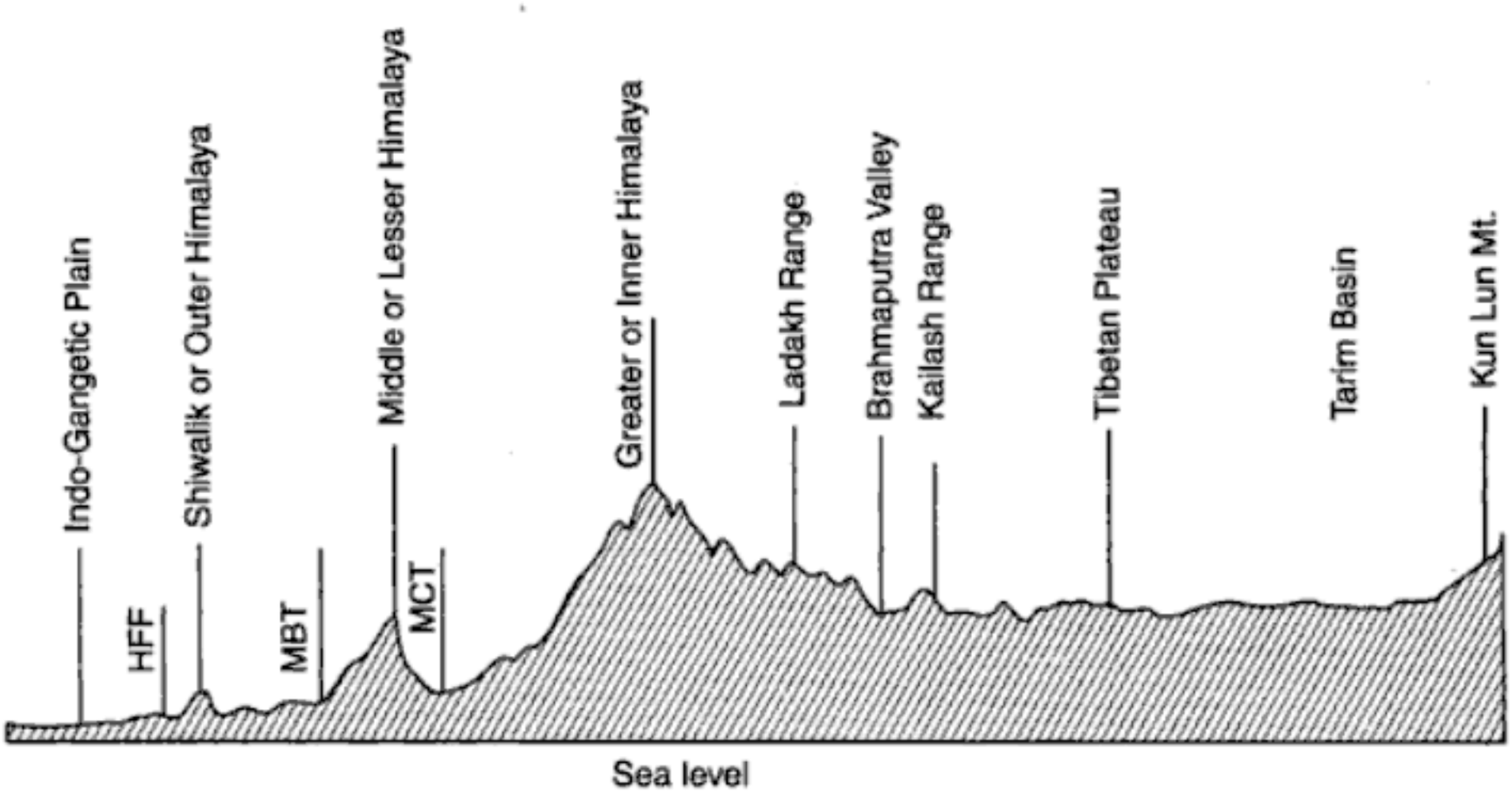


Fig. 2.12(a) Himalayan Complex

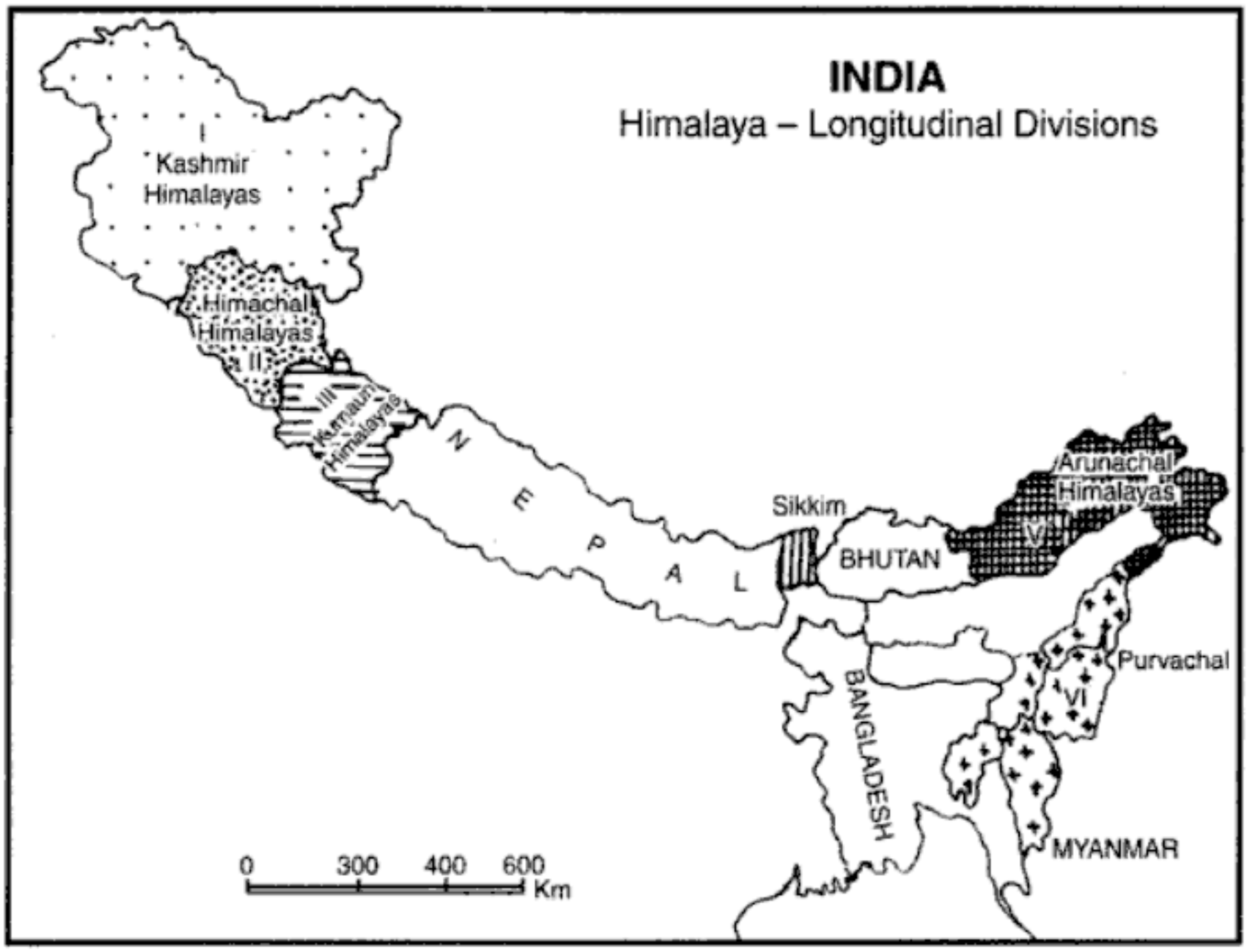


Fig. 2.12(b) Himalayan—Longitudinal Divisions

1. The Kashmir Himalayas

Sprawling over an area of about 350,000 sq km in the state of Jammu and Kashmir, the range stretches about 700 km in length and 500 km in width. With an average height of 3000 m, it has the largest number of glaciers in India. The Ladakh region of the Kashmir Himalayas is characterised by cold desert conditions. Surrounded by the Greater Himalayas and the Lesser Himalayas is the Kashmir Valley. It is a structural longitudinal 'Doon' (D.N. Wadia). A special feature of the the Vale of Kashmir is the *Karewa* (lacustrine) deposits consisting of silt, sand and clay. These karewas are mainly devoted to the cultivation of saffron and have orchards of apple, peach, almond, walnut and apricot. Kashmir Himalayas are characterised by high snow covered peaks, deep valleys, interlocked spurs and high mountain passes. Pir-Panjal, Banihal (Jawahar Tunnel), Zoji-La, Pensi-La, Saser-La, Lanak-La, Jara-La, Taska-La, Chang-La, Umasi-La, and Qara-Tagh-La (Karakoram) are the important passes of the Kashmir Himalayas (**Fig. 2.13**).

The Himadri: Called the abode of gods, this section of the Himalayas has many snow capped peaks, such as Nanda Devi, Kamet and Trishul.

2. The Himachal Himalayas

Stretching over Himachal Pradesh, it occupies an area of about 45,000 sq km. All the three ranges (the Greater, the Lesser and the Outer Himalayas) are well represented in this region. The northern slopes of the Himachal Himalayas are bare and show plains and lakes, while the southern slopes are rugged and forest clad. Rohtang, Bara-Lacha, Imis-La, and Shipki-La are the important passes which join Himachal Pradesh with Tibet (China). The beautiful and highly productive

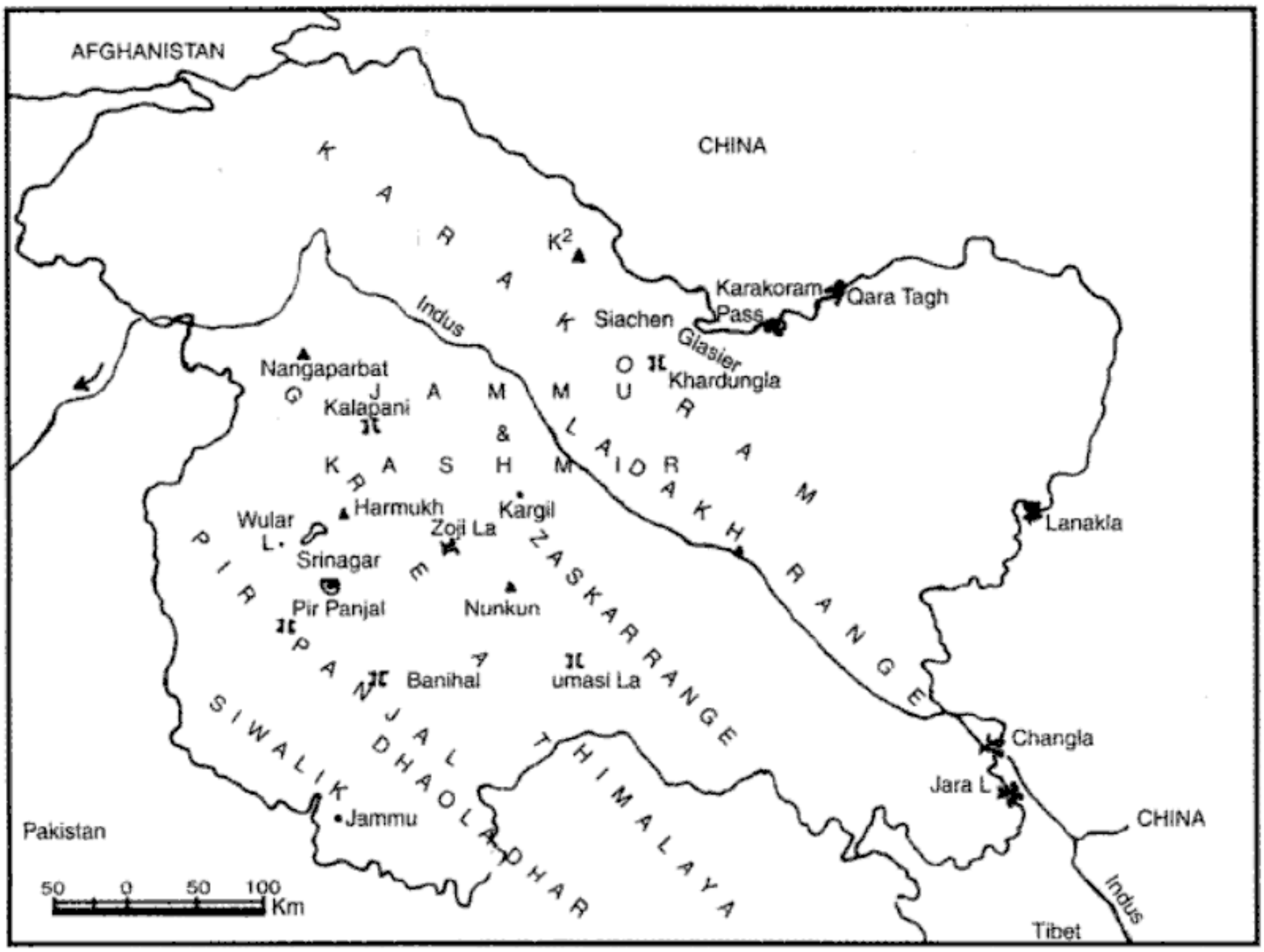


Fig. 2.13 Passes of the Kashmir Himalayas

valleys of Kangra, Kullu, Manali, Lahul, and Spiti lie in Himachal Pradesh. These valleys are well known for orchards and scenic beauty. Shimla, Dalhousie, Chamba, Kullu-Manali are the important hill stations of this region.

3. The Kumaun Himalayas

The Kumaun Himalayas lie between the Satluj and the Kali rivers, stretching to a length of 320 km and occupying an area of about 38,000 sq km. Its highest peak is Nanda Devi (7817 m). Among the other peaks Kamet (7756 m), Trisul (7140 m), Badrinath (7138), Kedarnath (6940 m), Dunagiri (7066 m), Jaonli or Shivling (6638 m), Gangotri (6615 m), and Bandarpunch (6320 m) are important. Gangotri, Milam, and Pindar are the main glaciers of Uttarakhand. The important hill stations include Mussorrie, Nainital, Ranikhet, Almora, and Bageshwar. The Kumaun Himalayas are connected to Tibet by a number of passes namely, Muling-La (5669 m), Mana Pass, Niti Pass, (5068 m), Tun-Jun-La, Shalsal Pass, Balcha Dhura, Kungrinbingri Pass, Lampiya Dhura, Mangsha Dhura , Marhi-La (4993 m), and Lipu Lekh.

4. The Central Himalayas

This range stretches from river Kali to river Tista for about 800 km occupying an area of about 116,800 sq km. A major part of it lies in Nepal except the extreme eastern part called Sikkim Himalayas and in the Darjeeling District of West Bengal. All the three ranges of the Himalayas are

represented here. The highest peaks of the world like Mt. Everest (8850 m), Kanchenjunga (8598 m), Makalu (8481 m), Dhaulagiri (8168 m), Annapurna (8075 m), and Gosainath (8014 m) are situated in this part of the Himalayas. It has very few passes. The passes of Nathu-La and Jelep-La (4538 m in Sikkim) connect Gangtok (Sikkim) with Lhasa (Tibet, China).

Kanchenjunga: Situated on the border of Sikkim and Tibet, it is the third highest mountain peak in the world. It is 8,598 metres above sea level and remains snow covered throughout the year. Some of the important rivers of India like Kosi and Tista have their origin in this mountain.

5. The Eastern Himalayas

These lie between the Tista and the Brahmaputra rivers, covering a distance of about 720 km with an area of 67,500 sq km. The Eastern Himalayas occupy the state of Arunachal Pradesh (India) and Bhutan. In this part, the Himalayas rise very rapidly from the plains of Assam, and the foothills of Shiwaliks are very narrow. The Eastern Himalayaa include the Aka Hills, the Daphla Hills, Miri Hills, Abor Hills, Mishmi Hills, and Namcha Barwa. It has a number of mountain passes among which Bomdi-La, Tse-La, Dihang, Debang (Arunachal Pradesh) are the most important. In the Eastern Himalayas, due to heavy rainfall, fluvial erosion is quite pronounced.

On the southern border of Arunachal Pradesh, the Himalayas take a southerly turn and the ranges are arranged in a north-south direction. Passing through the states of Arunachal Pradesh (Tirap Division) Nagaland, Manipur, Tripura, and Mizoram, the Himalayas are locally known as Purvanchal. The main hills of the Eastern Himalayas are Patkai-Bum (Arunachal Pradesh), Naga-Hills (Nagaland), Manipur Hills, Blue Mountains (Mizoram), Tripura Range, and Brail range. On the border of Nagaland and Myanmar lies the Arakanyoma. These hills are heavily forested. Northern Myanmar is connected through Diphu, Hpungan, Chaukan, Pangsau, and Likhapani (Arunachal Pradesh). Southwards, a pass joins Imphal (Manipur) with Mandalay (Myanmar). The Purvanchal is joined by the Meghalaya Plateau in the west. The extension of the Myanmar mountain chain continues southward up to Andaman and Nicobar Islands and even up to the Archipelago of Indonesia.

The Syntaxial Bends of the Himalayas

The general east-west trend of the Himalayas terminates suddenly at its western and eastern extremities and the ranges are sharply bent southward in deep knee-bend flextures which are called syntaxial bends. The western syntaxial bend is near Nanga Prabat where the Indus has cut a deep gorge. The geological formations here take sharp hairpin bends as if they were bent round pivotal points obstructing them. There is a similar hair- pin bend in Arunachal Pradesh where the mountains take a sharp bend from the eastern to southern direction after crossing the Brahmaputra river. The tectonic strike also undergoes a deep knee-bend from an easterly to southerly trend **(Fig. 2.14).**

Main Passes of Himalayas

Aghil Pass (Karakoram-Ladakh): Situated to the north of K^2 in the Karakoram at an elevation of about 5000 m above the sea level, it joins Ladakh with the Xinjiang (Sinkiang) Province of China. It remains closed during the winter season from November to the first week of May (**Fig. 2.15**).

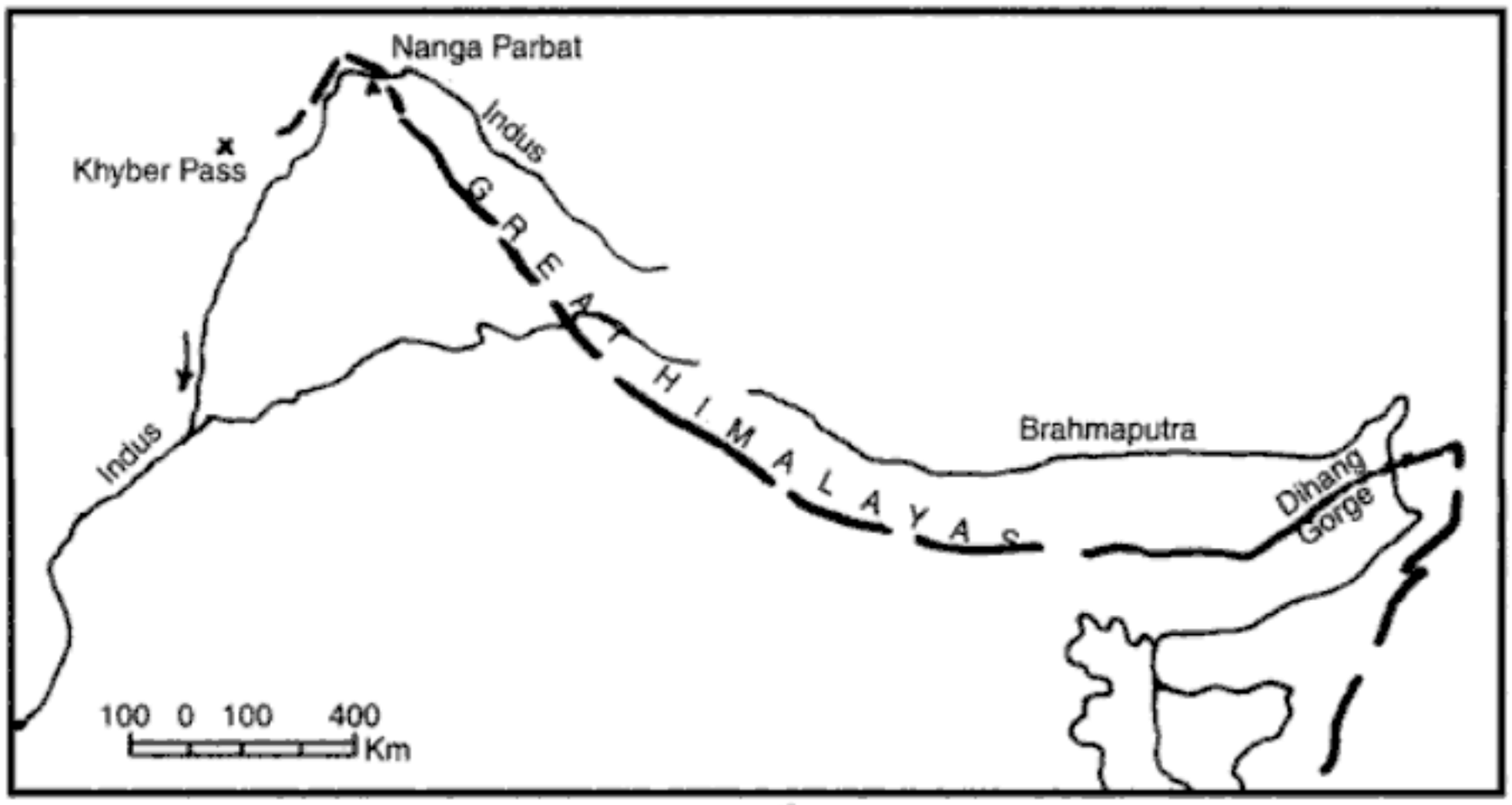


Fig. 2.14 The Syntaxial Bends of Himalayas

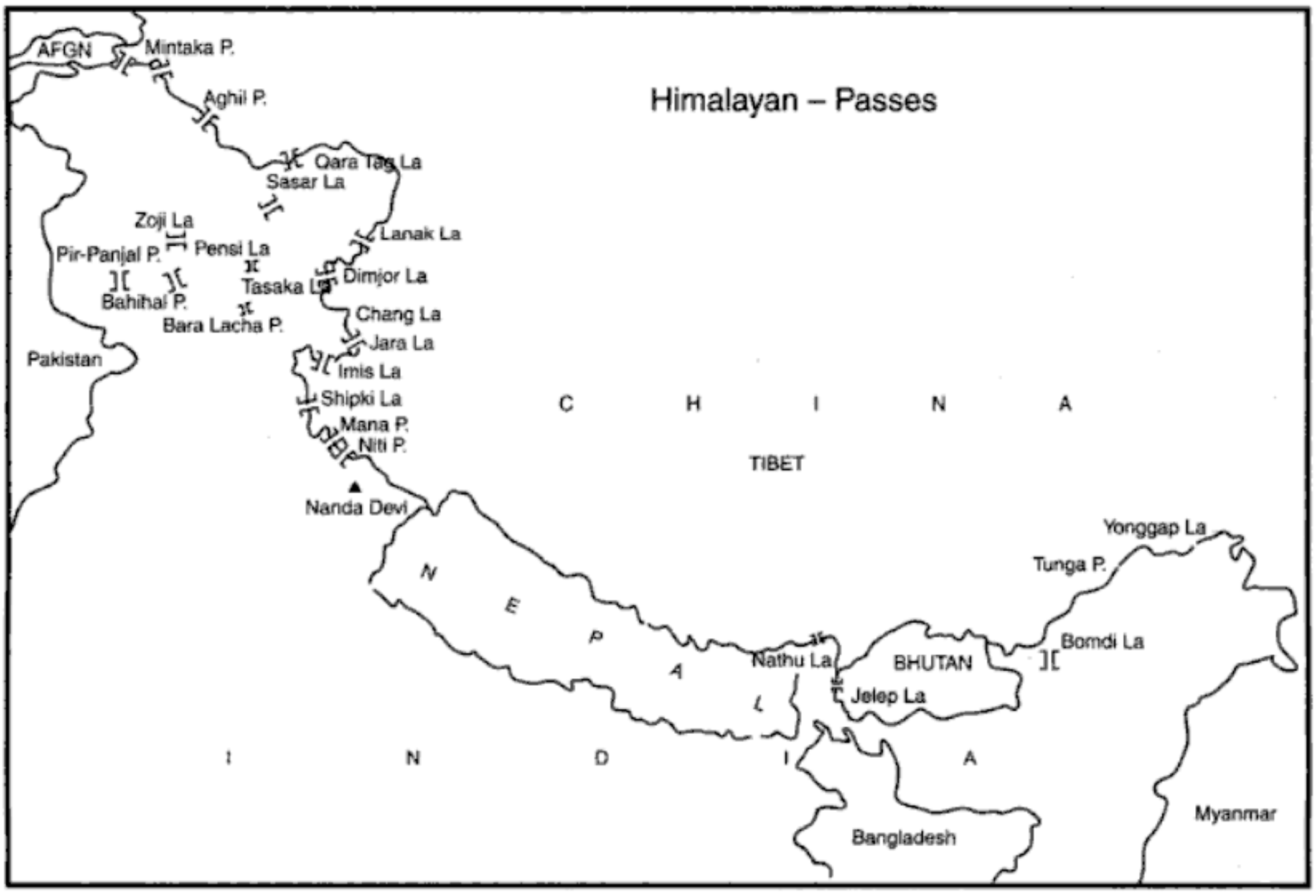


Fig. 2.15 Main Passes of the Himalayas

Banihal Pass (Jawahar Tunnel): Situated at an elevation of 2832 m in the Pir-Panjal Range, it joins Jammu with Srinagar. The pass remains snow covered during the winter season. The Jawahar Tunnel (named after Pandit Jawaharlal Nehru), inaugurated in December 1956, was constructed for round-the-year surface transport.

Bara Lacha (Himachal Pradesh with Leh-Ladakh): Situated in the state of Jammu and Kashmir at an altitude of 5045 m. It is on the National Highway connecting Manali and Leh. Being a high mountain pass, it remains snow covered from November to mid-May.

Bomdi La (4331 m, Arunachal Pradesh): Situated to the east of Bhutan in the Greater Himalayas in Arunachal Pradesh at an altitude of about 2600 m above sea level, it connects Arunachal Pradesh with Lhasa, the capital of Tibet. It remains closed in the winter season owing to snowfall and adverse weather.

Burzail Pass (Srinagar with Kishan-Ganga Valley): Situated at an altitude of more than five thousand feet above sea level, this pass connects Ladakh with China. Being snow covered during the winter season it remains closed for trade and transsport.

Chang-La (Ladakh with Tibet): Situated at an elevation of over 5270 m, it is a high mountain pass in the Greater Himalayas. The road after Chang-la is extremely steep, leading to the small town of tangtse. The pass has a temple dedicated to Chang-la Baba after whom the pass has been named. Being snow-covered, it remains closed during the winter season.

Debsa Pass: Situated at an elevation of 5270 m above sea level, it is a high mountain pass in Greater Himalayas between the Kullu and Spiti districts of Himachal Pradesh. This pass provides an easier and shorter alternative to the traditional Pin-Parbati Pass route between Kullu and Spiti.

Dihang Pass: Situated in the state of Arunachal Pradesh at an elevation of about 4000 feet this pass connects Arunachal Pradesh with Mandalay (Myanmar).

Diphu Pass (Arunachal Pradesh with Mandalay in Myanmar): Situated in the eastern part of Arunachal Pradesh, Diphu Pass provides an easy and shortest access to Mandalaya (Myanmar). It is a traditional pass between India and Myanmar which remains open throughout the year for transportation and trade.

Imis La: Situated at an elevation of over 4500 m, this pass provides an easy access between Ladakh and Tibet (China). It has a difficult terrain, steep slopes, and remains closed during the winter season.

Khardung La: Situated at an elevation of more than six thousand m above sea level, it is the highest motorable pass in the country. The road, however, remains closed during the winter season.

Khunjerab Pass (Karakoram): Situated at an altitude of more than five thousand feet in the Karakoram Mountains, it is a traditional pass between Ladakh and the Sinkiang Province of China. It remains snow covered during the winter season from November to mid-May.

Jelep La (4538 m): Situated at an elevation of 4538 m above sea level, this pass connects Sikkim with Lhasa. It passes through the Chumbi Valley.

Lanak La: Situated at an altitude of about five thousand metres in the Aksai-Chin (Ladakh), it connects Ladakh with Lhasa. The Chinese have constructed a road to connect the Xinjiang (Sinkiang) Province of China with Tibet.

Likhapani (Arunachal Pradesh): Situated at an altitude of more than four thousand metres above sea level, the Likhapani Pass joins Arunachal Pradesh with Myanmar. For trade and transport, it remains open throughout the year.

Lipu Lakh (Uttarakhand): Situated in the Pithoragarh District, it connects Uttarakhand with Tibet. The pilgrims for Mansarovar Lake travel through this pass. Landslides in the rainy season and avalanches in winter create great problems for movement and transportation.

Mana Pass: Situated at an elevation of 5611 m above sea level in the Greater Himalayas, it connects Uttarakhand with Tibet. It remains snow covered for about six months during the winter season.

Mangsha Dhura Pass: Situated at an elevation of more than five thousand metres in the district of Pithoragarh, the Mangsha Dhura Pass connects Uttarakhand with Tibet. The pilgrims for Mansarovar cross this pass. Landslides create great problems for tourists and pilgrims.

Muling La (Uttarakhand): Situated north of Gangotri, this seasonal pass joins Uttarakhand with Tibet. It remains snow covered during the winter season.

Nathu La (Sikkim): Nathu La is located on the Indo-China border. The pass, at 4310 m above sea level, forms part of an offshoot of the ancient Silk Road. Nathu-La is one of the three trading border posts between India and China. After the 1962 war it was reopened in 2006.

Niti Pass: Situated at an altitude of 5068 m above sea level, the Niti Pass joins Uttarakhand with Tibet. It remains snow covered during the winter season between November and mid-May.

Pangsan Pass (Arunachal Pardesh): Situated at an elevation of more than four thousand metres above sea level, this pass connects Arunachal Pradesh with Mandalaya (Myanmar).

Pensi La: Situated in the Greater Himalayas at an elevation of more than five thousand metres above sea level to the east of Zoji La, this pass connects the Valley of Kashmir with Kargil (Ladakh). It remains snow covered from November to mid-May.

Pir-Panjal Pass: The traditional pass from Jammu to Srinagar, this pass lies on the Mughal Road. After partition of the Subcontinent, the pass was closed down. It provides the shortest and easiest metalled road access from Jammu to the Valley of Kashmir.

Qara Tagh Pass: Located in the Karakoram Mountains at an elevation of more than six thousand feet above sea level, this pass was an offshoot of the Great Silk Road. It remains snow covered during the winter season.

Rohtang Pass: Located at an elevation of 3979 m above sea level, this pass connects the Kullu, the Lahul and Spiti valleys of Himachal Pradesh. It has excellent road access, constructed by the Border Road Organisation (BRO). Traffic jams are common occurrences caused by the heavy movement of military vehicles, buses, taxis, trucks and goods carriers.

Shipki La : Located at an altitude of more than 6000 m above sea level through the Satluj Gorge, the Shipki-La joins Himachal Pradesh with Tibet. It remains snow covered during the winter season.

Thang La (Ladakh): Located at an elevation of 5359 m above sea level, it is a mountain pass in Ladakh (J & K). It is the second highest motorable mountain pass in India after Khardung La.

Traill's Pass: Located at an elevation of 5212 m above sea level in the Pithoragarh and Bageshwar districts of Uttarakhand, it is situated at the end of the Pindari Glacier and links Pindari Valley to Milam Valley. Being steep and rugged, this pass is very difficult to cross.

Zoji La: Located at an altitude of 3850 m above sea level, it joins Srinagar with Kargil and Leh. Because of heavy snowfall, it remains closed from December to mid-May. The Border Road Organisation (BRO) has been trying to keep the road open for most part of the year. Beacon Force of Border Road Organisation (BRO) is responsible for clearing and maintenance of the road during the winter season. Recently, the Srinagar–Zoji-La Road has been declared a National Highway (NH-1D) by the centre.

Glaciers and Snowline

The lower limit of perpetual snow is known as 'snowline'. The snowline in the Himalayas has different heights in different parts, depending on latitude, altitude, amount of precipitation, moisture, slope and local topography.There are about 15,000 glaciers in the Himalayas lying between the two syntaxial bends in the east and the west. In the Assam Himalaya, the snowline is about 4400 metres, whereas in the Kashmir Himalayas it varies between 5100 to 5800 metres. In the Kumaun Himalaya the snowline is about 5200 metres and about 5500 metres in the Karakoram. On the Tibetan side, the altitude of the snowline is about 900 metres higher owing to great desiccation of the region and scarcity of moisture. Thus, there is a direct relationship between the presence of moisture and the altitude of the snowline. In general, more the moisture in the atmosphere, lower the altitude of the snowline and vice versa.

Table 2.2 *Altitude of Snowline in the Himalayas*

Himalayan Region	*Altitude of Snowline*
1. North Eastern Himalayas (Arunachal Pradesh)	4400 m.
2. Kashmir Himalayas	5100 m to 5800 m
3. Kumaun Himalayas	5200 m to 5500 m
4. Karakoram	5500 m and above

The main glaciers in the northern mountains are found in the Greater Himalayas and the Trans-Himalayan mountains (Karakoram, Ladakh and Zaskar). The Lesser Himalayas have small glaciers, though traces of large glaciers are found in the Pir-Panjal and Dhauladhar ranges. Some of the important glaciers of the Karakoram and the Himalayas are given in **Fig. 2.16 (Table 2.3).**

Table 2.3 *Main Glaciers of India*

Name of the glacier	*Location*	*Length in km*
1. Siachin	Karakoram	75
2. Sasaini	Karakoram	68
3. Hispara	Karakoram	61
4. Biafo	Karakoram	60
5. Baltora	Karakoram	58
6. Chogo Lungma	Karakoram	50
7. Khordopin	Karakoram	41
8. Rimo	Kashmir	40

(Contd.)

Fig. 2.16 North-West Himalayas—Major Glaciers

(*Contd.*)

9. Punmah	Kashmir	27
10. Gangotri	Uttarakhand	26
11. Zemu	Sikkim/Nepal	25
12. Rupal	Kashmir	16
13. Diamir	Kashmir	11

Most of the glaciers of the Lesser Himalayas are smaller in size, ranging from 3 to 5 km in length. There are, however, some larger-sized glaciers also in Karakoram and the Greater Himalayas. Some of the important glaciers are Siachen (75 km), Sasaini (68 km), Hispara (61 km), Biafo (60 km), Baltora (58 km) (Karakoram mountains).The Chogo Lungma Glacier (50 km) terminates at an altitude of 2070 m, the lowest recorded in the Himalayas **(Fig. 2.16).** In Uttrakhand, Gangotri, Milam and Pindari are the main glaciers. The glaciers of Karakoram are the remnants of the Pleistocene Age. The diurnal rate of movement of these glaciers is between 8 to 15 cm at the side and 20 to 30 cm in the middle. The glaciers of the Pir-Panjal are less numerous and smaller in size as compared to those of the Karakoram and the Greater Himalayan ranges. The longest glacier of the Pir-Panjal is Sonapani glacier in the Chandra Valley of Lahul and Spiti region. Its length is about 15 km at an altitude of about 4000 m near the Rohtang Pass.The largest glacier in the Nun-Kun peak is the Gangri Glacier which is about 13 km in length. The glaciers of the Nanga Parbat Massif are small in size and are moving fast due to a steep slope. The Chungphar, Rakhiot, Buzhi and Tashan are the other important glaciers of the Pir-Panjal Range. The glaciers are not only the source of Himalayan rivers, but also maintain a regular supply of water in these rivers during off-monsoon period. The Himalayan glaciers are, however, receding.

Ice Ages in India

The subcontinent of India recorded several ice ages. A brief description of the Indian Ice Ages has been given in the following section:

1. The Dharwar Ice Age

The moraine deposits and other glaciated topographical features observed in the Dharwar District of Karnataka indicate an ice age during the Dharwadian Period, i.e. about 700 million years ago.

2. The Gondwana Ice Age

The Telcher Series (Orissa) of the Gondwana System provides a good proof of the glaciation during the Gondwana Period.

3. The Pleistocene Ice Age

During the Pleistocene Period the effect of ice age was noticed in the Himalayas, especially in the Karakoram and the Greater Himalayan ranges. The erratic rocks, boulders, cirques, eskers, rock polishing, buff-coloured sands, and luminated clays inter-stratified among the *karewas* deposits of Kashmir, Bhadarwa (Doda), and Ladakh give enough proof of the Pleistocene glaciation. The Pleistocene glaciation also led to the formation of a number of high altitude glacial lakes of the Himalayas. The Kailash-Kund, the Sanasar Lake near Batote, the Gulmarg-basin, the Sheshnag, and the Gangabal Lake are some of the examples of this type of lakes. The Peninsular part of India has no evidence of Pleistocene glaciation.

The Significance of the Himalayas

The mighty Himalayas are the most pronounced and dominating physiographic feature of the subcontinent of India. It has often been said that the Himalayas are the body and soul of India. The significance of the Himalayas has been given briefly in the following lines:

1. Climatic Influence

The impact of the Himalayas on the climate, especially on the distribution of precipitation and temperature, is quite significant. The altitude of the Himalayas, their sprawl and extension intercept the summer monsoon coming from the Bay of Bengal and the Arabian Sea. They also prevent the cold Siberian air masses from entering into India. Had there been no Himalayas, the whole of northern India would have been a desert. According to the latest meteorological studies, the Himalayas are responsible for the splitting of the jet streams into two branches, and these in turn, play an important role in the arrival, success and failure of the monsoons in India.

2. Defence

Throughout history, the foreign invaders never entered India from the northern side. Despite modern technology of warfare, the Himalayas have great defence value. At present, a network of highways has been developed up to China, Tibet, Nepal, and Bhutan borders.

3. Source of Perennial Rivers

Most of the perennial rivers of northern India have their origin in the glaciers, lakes, and springs of the Himalayas. These rivers sustain the teeming millions of the India population.

4. Source of Fertile Soils

The perennial rivers and their tributaries carry enormous quantities of alluvial soils. In fact, the Great Plains of India are covered by the fertile alluvial soils deposited by the rivers coming down from the Himalayas.

5. Generation of Hydroelectricity

The Himalayan Mountains offer numerous sites suitable for the generation of hydel power. The Bhakra-Nangal Dam, Silal, Dulhasti Projects, Tehri Dam, etc., are some of the important hydel-power generating multi-purpose projects located in the Himalayas.

6. Forest Wealth

The Himalayan ranges are very rich in forest resources. There is horizontal zonation of vegetation in the Himalayas. The natural vegetation in the Himalayas varies from the humid tropical to the conifers and alpine pastures. These forests provide fuelwood, timber, gum, resins, lac, medicinal herbs, and a variety of materials for the industries. At the higher altitudes are the alpine pastures (mergs) used by the tribals for grazing cattle during the summer season.

7. Orchards

The Himalayas are known for the apple, peach, cherry, pear, mulberry, walnut, almond, and apricot orchards.

8. Minerals

The Himalayas are rich in many metallic and non-metallic minerals. Coal is found in Jammu Division of Jammu and Kashmir. Copper, lead, zinc, nickel, cobalt, gold, silver, antimony, tungsten, magnesite, limestone, semi-precious, and precious stones are found in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. The poor accessibility is however, a barrier in the exploitation of the mineral wealth of the Himalayas.

9. Tourism

The Himalayas are known for their scenic and aesthetic beauty all over the world. The Himalayas offer cool, invigorating climate when the neighbouring plains are in the grip of scorching heat of the summer season. Millions of national and international tourists visit the hill stations in the Himalayas. The famous tourist centres in the Himalayas are Srinagar, Pahalgam, Gulmarg, Sonmarg, Yushmarg, Wular-round, Chamba, Dalhousie, Dharamshala, Shimla, Solan, Kangra, Kullu, Manali, Mussoorie, Nainital, Ranikhet, Almora, and Darjeeling.

10. Pilgrimage

Apart from places of tourist interest, the Himalayas have numerous shrines and pilgrimage centres. Some of the important shrines in the Himalayas are the Amarnath, Hazratbal (Srinagar), Kailash, Vaishno Devi, Kedarnath, Badrinath, Gangotri, Yamunotri, Jwalaji, etc.

THE GREAT PLAINS OF INDIA

The Great Plains of India lie to the south of the Shiwalik separated by the Himalayan Front Fault (HFF). It is a transitional zone between the Himalayas of the north and Peninsular India of the south. It is an aggradational plain formed by the alluvial deposits of the Indus, Ganga, Brahmaputra and their tributaries. The plain stretches for about 2400 km from west to east. It has varying width; 90-100 km in Assam, 160 km near Rajmahal (Jharkhand), 200 km in Bihar, 280 km near Allahabad and 500 km in Punjab. In general, the width of the plain increases from east to west **(Fig. 2.17).**

The Great Plains of India consist largely of alluvial deposits brought down by the rivers originating in the Himalayan and the Peninsular region. The exact depth of alluvium has not yet been fully determined. According to recent estimates the average depth of alluvium in the southern side of the plain (north of Bundelkhand) varies between 1300 to 1400 metres, while towards the Shiwaliks, the depth of alluvium increases. The maximum depth of over 8000 metres has been reached near Ambala, Yamunanagar and Jagadhri (Haryana).

The Great plains are remarkably homogeneous with little variation in relief features for hundreds of kilometers. The monotony of the physical landscape is broken at micro-level by the river bluffs, *Bhurs,* levees, dead-arms of river channels, the ravines and ***khols***. Changing river courses in the areas of frequent floods is a unique geomorphic process in the plains. The frequent floods, although a cause of immense damage to life and property, lay down fresh layer of silts in the flood-plains every year, providing rich fertile soils.

Origin of the Great Plains of India

There is no unanimity amongst the geologists about the origin of the Great Plains of India. The puzzling questions are related to the enormous thickness of the alluvium, nature of the depression, mode of its formation, subterranean rock-beds and the underlying geological structure. Some of the important views about the origin of the Northern Plains of India have been presented briefly in the following section:

1. Alluviation of the Foredeep

According to Edward Suess, an eminent Austrian geologist, a 'foredeep' was formed in front of the high crust-waves of the Himalayas as they were checked in their southward advance by the more

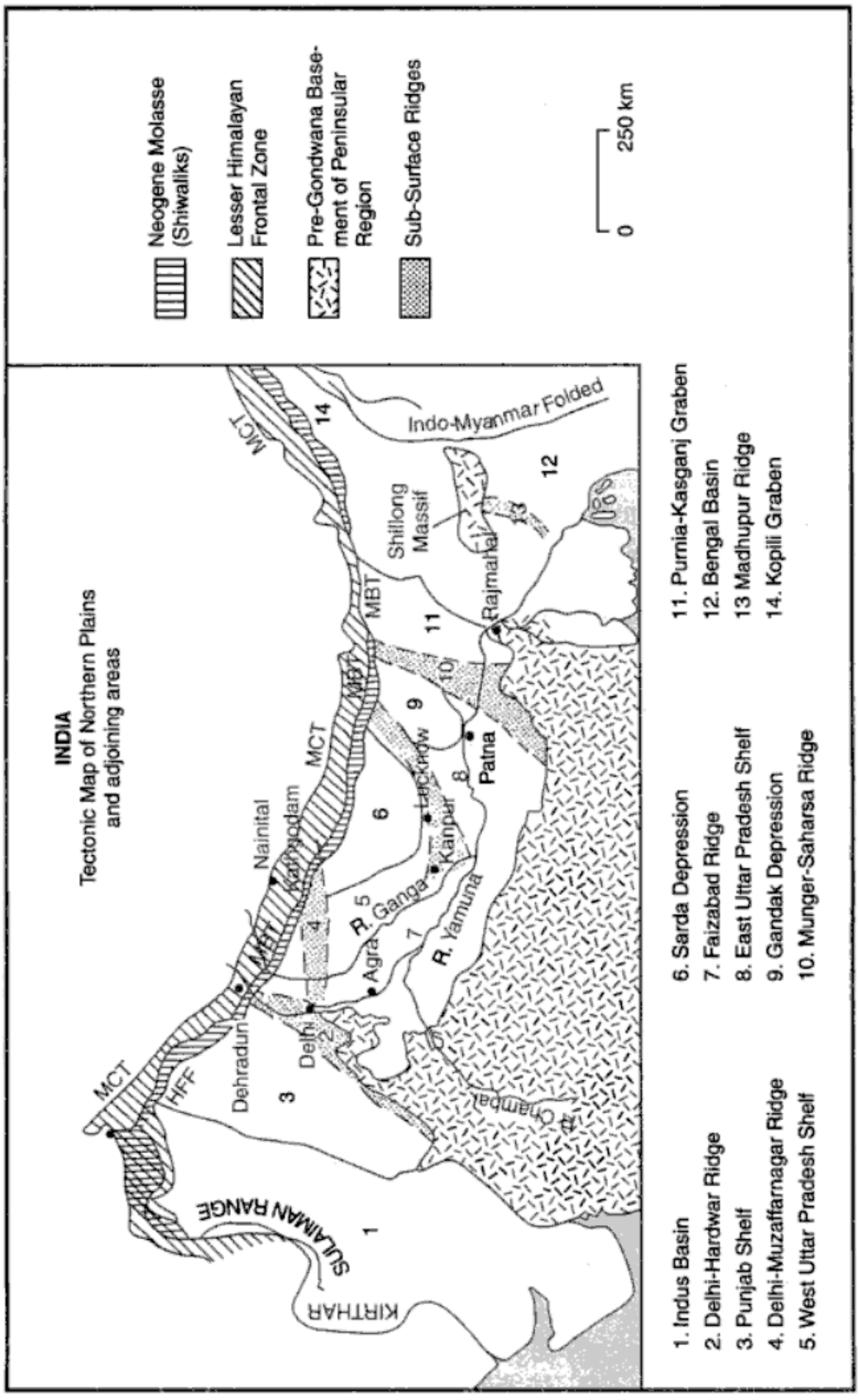


Fig. 2.17 The Great Plains of India and adjoining areas

3. Recession of the Sea

In the opinion of Blandford, during the Eocene Period, Peninsular India was joined together with Africa. During that period, there was one sea extending from Assam Valley to the Irrawaddy river (Myanmar) in the east and another from Iran and Baluchistan to Ladakh (Indus Valley) in the west. During the last part of the Eocene Period, arms of the Western Sea extended up to Punjab. Due to the rise of the Himalayas during the Miocene Period, these seas started receding by gradual deposits of sediments from the Himalayan rivers. After a prolonged period of sedimentation and subsidence, these gulfs (Gulf of Sind in the west and the Eastern Gulf up to the Shillong Plateau) were filled up, resulting in the formation of the Northern Plains of India.

The evidences cited in favour of the recession of the sea include: (i) the occurrence of limestone rocks in Kumaun-Garhwal region of Uttarakhand, (ii) the presence of saline water lakes in Rajasthan, (iii) the joining of the islands of the Gulf of Kachchh with the mainland, (iv) the seaward extension of the Sundarban Delta, (v) the emergence of new islands near Bangladesh coast, and (vi) the presence of marine fossils in the sediments of the Northern Plains of India. The theory, however, fails to give convincing arguments so far as the region of the central portion of the plain is concerned.

4. Remnant of the Tethys

Some of the geologists and geomorphologists opine that the Great Plains of India are a remnant of the Tethys Sea. According to them, after the upheaval of the Shiwaliks, the remaining part of the Tethys was left as a large trough which was joined to the Bay of Bengal in the east and the Arabian Sea in the west. Rivers from the Himalayas deposited their load in the trough. Because the Himalayas were rising during that period, rivers experienced rejuvenation and greater quantity of eroded material which increased the thickness of the alluviums. Due to infilling of the central part of the trough the seas located in the east and the west started receding, and the Great Plains of India came into existence.

5. Recent Views

According to the recent views, the Northern Plains of India represent a sag in the crust formed between the northward drifting of the Indian Subcontinent and the comparatively soft sediments accumulated in the Tethyan basin when the latter were crumpled and lifted up into a mountain system. Subsequently, it was filled up by the river deposits.

Physiographic Divisions of the Great Plains of India

The Great Plains of India are a remarkably homogeneous surface with an imperceptible slope. In fact, they are a featureless alluvial fertile plains formed mostly by the depositional process of the Himalayan and Vindhyan rivers. These rivers deposit enormous quantity of sediments along the foothills. Beyond the foothills, the rivers deposit the alluvium in their flood plains. The Northern Plains of India may be divided into the following sub-regions:

1. The Bhabar Plain

It lies to the south of the Shiwalik from west to east (Jammu Division to Assam). Its width is however, more in the western plains than in the eastern plains of Assam. In width, the Bhabar tract is generally 8 to 15 km, consisting of gravel and unassorted sediments deposited by the rivers

Sundarbans: The largest mangrove swamp in the world, the Sundarbans, or the beautiful forest, gets its name from the Sundari tree which grows well in marshland. It is home to the Royal Tiger and crocodiles.

4. The Brahmaputra Plain

Stretching over an area of about 56,275 sq km, it is the eastern part of the Great Plains of India. It is about 720 km long and about 80 km wide. The region is surrounded by high mountains on all sides, except on the west. It is a depositional plain. The general altitude of the Brahmaputra Plain varies between 130 m in the east to only 30 m in the west (**Fig. 2.21**). The Assam Valley is characterised by a steep slope along its northern margin but the southern side has a gradual fall from the Meghalaya Plateau. The whole length of the plain is traversed by the Brahmaputra. Due to the low gradient, the Brahmaputra is a highly braided river having numerous islands. Majuli

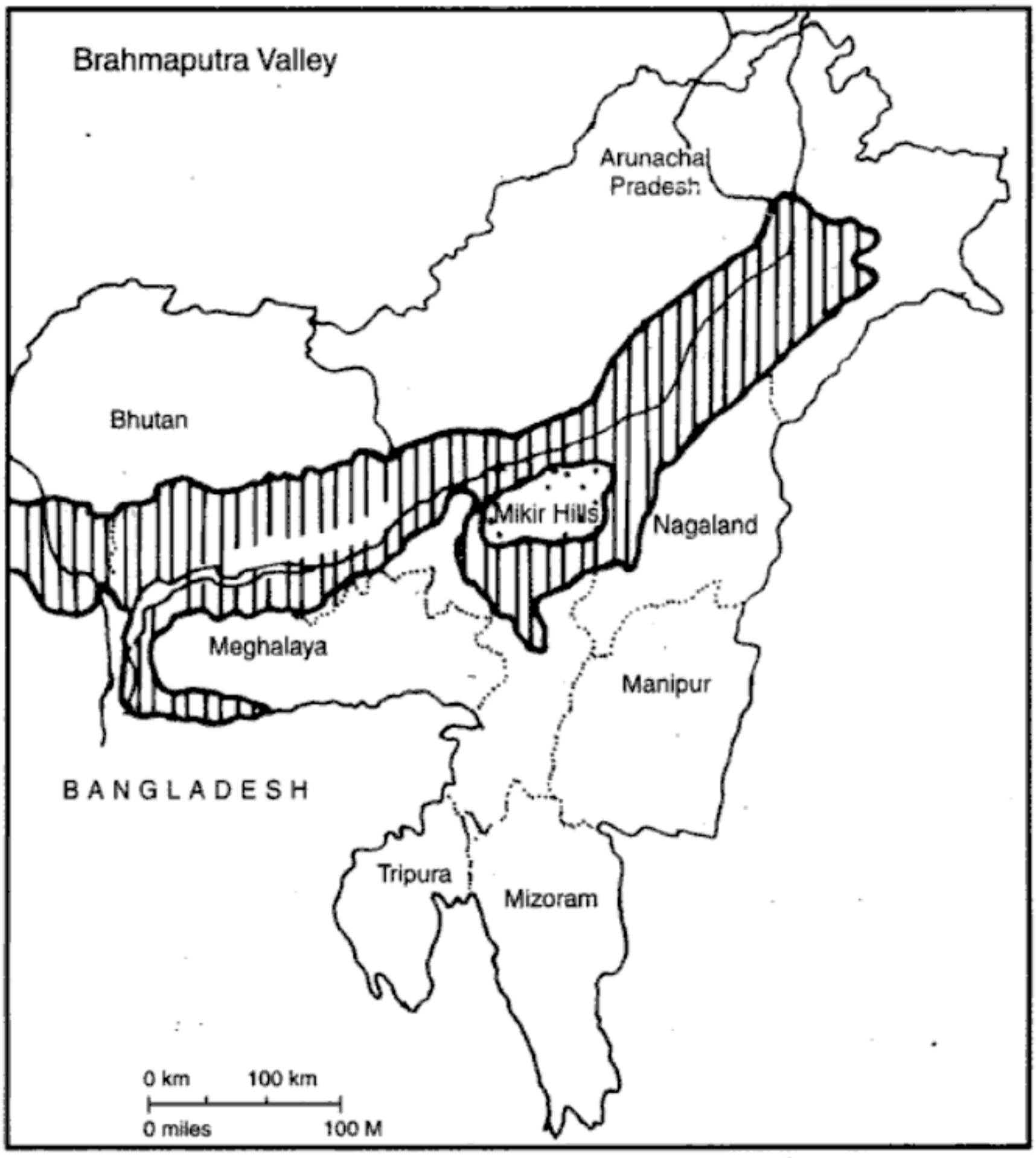


Fig. 2.21 Brahmaputra Valley

The Andaman Islands are thickly forested and have a rich marine life among the reefs. The islands are a birdwatcher's paradise with 242 species recorded. The entire region falls in a major earthquake zone. The Barren Island in the Andamans has an active volcano.

In the Bay of Bengal, there are two volcanic islands (Barren and Narcondam) situated within 80 km east of the Andaman Islands. The Andaman Islands have been formed by the extension of the Tertiary mountain chain of Arakanyoma. The main rocks of these islands are sandstone, limestone and shale. The Nicobar group of islands comprise 18 islands of which only 11 are inhabited. The physiography of the Nicobar islands is mainly of coral origin.

Rice is the main crop in Andaman and Nicobar Islands. Coconut and arecanut are the main cash crops of Nicobar. Tropical fruits like pineapple, a variety of bananas, sweet papaya and mango grow on a smaller scale in the Andaman group of islands.

The Tribal population in the Andaman Islands is fast dwindling. Most of its present inhabitants are migrants from Bangladesh, Myanmar, and India and Tamils from Sri Lanka. Some of the well known surviving tribes of the Andamans and Nicobar are the Onges, Jarawas and Sentinelese.

One of the largest and also the rarest crabs in the world, the *Giant Robber Crab*, can be found in the Wandoor Marine Biosphere Resrve in south Andaman and Great Nicobar Islands. Its powerful claws help it to climb the coconut tree and break the hard shell of its fruit.

The Arabian Sea Islands

There are 43 islands in the Arabian Sea, out of which only 10 are inhabited. The shortest distance from the mainland (Calicut) is about 109 km. Kavaratti, located on the island of this name is the capital of Lakshadweep. Lakshadweep islands are separated from the Maldive Islands by the Eight Degree Channel. Hills and streams are absent on these islands. The Minicoy is the largest (4.5 sq km) and has a light house and a weather observatory. Fishing is the main occupation of the people of Lakshadweep. In Lakshadweep coconut is the only major crop, although pulses and vegetables are also grown. The sea around the island is rich in marine life **(Fig. 2.23).**

Offshore Islands

There are numerous islands in the delta region of Ganga and in the Gulf of Mannar. Among the Western coast islands Piram, Bhaisala (Kathiawar), Diu, Vaida, Nora, Pirtan, Karunbhar (Kachchh coast), Khadiabet, Aliabet (Narmada-Tapi mouths), Butchers, Elephanta, Karanja, Cross (near Mumbai), Bhatkal, Pegioncock, St. Mary (Mangalore coast), Anjidiv (Goa coast), Vypin near Kochi, Pamban, Crocodile, Adunda (Gulf of Mannar), Sri Harikota (mouth of Pulicat Lake, Pairkud (mouth of Chilka Lake), Short, Wheeler (Mahanadi-Brahmani mouth), and New Moore, and Ganga-Sagar and Sagar (Ganga Delta). Many of these islands are uninhabited and administered by the adjacent states.

EARTHQUAKES IN INDIA

Earthquakes are vibrations of the Earth caused by ruptures and sudden movements of rocks that have been strained beyond their elastic limits. In other words, earthquakes are movements within the earth caused by natural or man-made stresses. Earthquakes are casued by (i) volcanic eruptions, (ii) ruptures and sudden movements of rocks (folding and faulting), (iii) movement of plates (plate tectonics), and (iv) anthropogenic factors.