MOUNTAINS AND RIVERS OF INDIA

21st International Geographical Congress
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THE HIMALAYA

Frontispiece]

[Courtesy : Dr. B. C. Law

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MOUNTAINS AND RIVERS OF INDIA

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FOREWORD

The first book that the Indian National Committee for Geography could think of in bringing out on the occasion of the 21st International Geographical Congress was Mountains and Rivers of India, and the choice of editing the book naturally fell on Dr. Bimala Churn Law, who had to his credit authorship of two publications of Calcutta Geographical Society (now Geographical Society of India), besides a large number of publications on a variety of subjects connected with Ancient Indian History, Archaeology etc. Dr. Law readily agreed to the proposal, despite his failing health, and made it possible for its publication without throwing any burden on the meagre financial resources of the National Committee for which he deserves sincere thanks.

A plan for the book was drawn up and number of persons, eminent in their respective fields, were requested to contribute papers so as to make this book as comprehensible as possible. A glance at the names of authors of various chapters as given in the contents of the book will convince one that every effort was made to get the right type of author for every chapter who could do justice to the topic he writes about. The National Committee for Geography expresses its thanks to all who had helped in bringing out this book, which throws considerable light on our mountains and rivers.

S. P. Chatterjee

CONTENTS

Page

PART ONE—MOUNTAINS OF INDIA

CHAPTER I

MOUNTAINS OF INDIA AS IN ANCIENT LITERATURE

India abounds in innumerable mountains and hills. An attempt has been made here to give a connected account of them from the ancient Indian and Greek sources as well as from the itineraries of the Chinese pilgrims. The *Tīrthayātrā Digvijaya* sections of the *Mahābhārata*, the *Jambukhaṇḍavinirmānaparva* of the same Epic, the *Kiṣkindhyākāṇḍa* of the *Rāmāyaṇa*, the *Kūrmavibhāga* section of the *Purāṇas*, the *Bhuvanakoṣa*, the *Jambudīpa-varṇanā*, the *Bṛhatsaṃhitā*, the *Parāsaratantra* and the *Atharvapariśiṣṭa* are greatly helpful in the study of the subject in question. Equally important from this point of view are the Buddhist *Nikāyas*, *Jātakas* and the *Jaina Agama* texts.

The two Jain works known as the *Jambudīvapaṇṇatti* and the *Vividhatīrthakalpa* are really very useful from geographical standpoint. The accounts of mountains given in the *Indika* of Megasthenes and in the writings of Arrian, Strabo, Diodorus, Plutarch and Pliny, as well as in the itineraries of Fa-Hien and Hiuen Tsang, are no doubt important. The District and Imperial Gazetteers are also an invaluable aid to the study of the subject. It must be admitted that the accounts which we get from these sources are substantially correct.

In Bhāratavarṣa, the ancient name of the Indian subcontinent, there were seven *Kulācalas* : (1) Mahendra, which is the mountain par excellence of the Kaliṅgas. The hermitage of Jāmadagnya existed on this mountain.[1] The *Bhāgavatapurāṇa* (X. 79) gives a very accurate description of the situation of the Mahendra range[2] (*Gayāṃ gatvā........ saptagodāvarīṃ veṇṇāṃ paṃpāṃ Bhīmarathiṃ tataḥ*). It appears from the Puranic description that the Mahendrādri was situated between the *Gangāsāgarasaṅgama* and *Saptagodāvarī* (*Bhāgavatap*. X. 79). Part of the Eastern Ghats near Ganjam is still called Mahendra Giri.[3] Pargiter thinks that the name should be limited to the hills between the Mahānadī, Godāvarī and Wain-Gaṅgā. The classical Sanskrit litera-

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1. *Bhāgavata*, X. 79.
2. Cf. *Raghuvaṃśa*, VI. 53-54.
3. Wilson, Visnupurana, II. 3. p. 127 n.

ture seems to agree with the description of the Bhāgavatapurāṇa and hence with the identification of Pargiter. The *Raghuvaṃśa* of *Kālidāsa* which refers to the hills more than once (IV, 39, 40, 43 ; VI, 54) seems to locate the range in the Kaliṅga country ; so also it seems to be the indication of *Uttara Naiṣadhacarita* (XII. 24) ; (2) Malaya of the Pāṇḍyas[1] ; (3) Sahya of the Aparāntas ;[2] (4) Śuktimat of the people of Bhallāṭa ;[3] (5) Ṛkṣa of the people of Māhiṣmatī ; [4] (6) Vindhya of the Āṭavyas and other forest-folks of Central India, and (7) Pāripātra or Pāriyātra of the Niṣādas.[5] Dhoyi says that Malaya is situated at a distance of 6 km from Śrīkhaṇḍādri. Kālidāsa mentions it in his *Raghuvaṃśa* (IV. 46). The Sahya may be identified with the northern portion of the Western Ghats.[6] Kālidāsa mentions it in his *Raghuvaṃśa* (IV. 52). A minor hill called the Trikūṭa is connected with the Sahya range.[7] The earliest mention of the *Pāripātra* (*Pārivāta*) is found in the (*Dharmasūtra* of Baudhāyana (1. 1. 25), who refers to it as the southern limit of Āryāvarta. It is known as Po-li-ye-ta-lo to the Chinese pilgrim, Hiuen Tsang, with a Vaiṣya king as its ruler. Some of the rivers had their sources in this mountain, namely, Vedasmriti, Vedavatī, Sindhu, Veṇvā, Sadānīrā, Mahī, Carmanvatī, Vetravatī, Vediśā, Siprā and Avarṇī.[8] The Pāriyātra is the western part of the Vindhya range extending from the sources of the Chambal to the Gulf of Cambay. It is that portion of the Vindhya range from which the rivers Chambal and Betwa take their rise.[9] The *Skandapurāṇa* refers to it as the farthest limit of *Kumārīkhaṇḍa*, the centre of Bhāratavarṣa. Pargiter identifies it with that portion of the modern Vindhya range which is situated west of Bhopal in central India together with the Aravalli mountains identified with the Apokopa by Ptolemy.[10] Rājaśekhara in his *Kāvyamīmāṃsā* places these seven *Kulaparvatas*[11] in the *Kumārīdvīpa* which refers to the Peninsular India with the Vindhya and the Pāripātra as its northern boundaries.

The Greek Geographer Ptolemy enumerates the following mountain ranges of India : the Apokopa, Sardonyx, Ouindion, Bettigo, Adeisathron, Ouxenton, Oroudian, Bepyrrhos, Maiandros, Damassa or

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1. *Raghuvaṃśa*, IV, 46.
2. *Ibid.*, IV. 52.
3. *Mbh.*, II, 30. 5 ff.
4. *Harivaṃśa*, 38. 19.
5. *Mbh.*, XII, 135, 3-5.
6. Pargiter, *Mārkaṇḍeyap.*, p. 285 note.
7. *Raghuvaṃśa*, IV, 59.
8. *Mārkaṇḍeyap.*, 59, 19-20.
9. Bhandarkar, *Hist. of the Dekkan*, Sec. 3.
10. McCrindle, *Ancient India as described by Ptolemy*, S. N. Majumdar's Ed. p. 355 ; *Mārkaṇḍeyapurāṇa Tr.* p. 286.
11. These are group mountains. Vide *Agnipurāṇa*, 108. 32.

Dobassa and Semanthinos. Of these Apokopa (the punishment of the gods) has been identified with the Aravalli mountains.[1]. Ouindion has been identified with the Vindhya, Bettigo with Podigai, the Tamil name of Malaya, Ouxenton with the Ṛkṣavant, Adeisathron with the Sahyādri and the Oroudian with the Vaidūrya mountain.[2] Megasthenes says that India possessed many large and small navigable rivers having their origin in mountains. The geographer Ptolemy like Megasthenes and Epic and Pauranic writers groups the Indian rivers according to the mountains and hill ranges out of which they have emanated. The position of mountain as given by him is hopelessly incorrect but some clue to their identification can be gathered in his description of rivers issuing from each mountain. He seems to have some old traditional list of Indian rivers which he utilised in his geography, Ptolemy describes the Ṛkṣavant as the source of the Toundis, the Dosaran and the Adamas and the Ouindion as that of the Namadas and the Nanagouna. The Dosaran has been identified with the Daśārṇa of the Purāṇas and the Namadas and the Nanagouna with the Narmadā and Tāptī respectively. Ptolemy says that the Dosaran is said to have issued from the Ṛkṣa which is so called because it existed in the locality containing bears[3]. By the Ṛkṣavant he meant the central region of the modern Vindhya range, north of the Narmada, while the Ouindion stands for only that portion of the Vindhya wherefrom the Narmadā and the Tāptī rise.[4] The Vindhyapādaparvata[5] is the mountain Sardonyx of Ptolemy. It may be identified with the Satpura range which is the source of the Tāptī. Kālidāsa places the Mandāra in the Himalaya in the vicinity of the Kailāsa and the Gandhamādana.[6]

Ptolemy seems to have come into the possession of some old traditional lists of Indian mountains which he made use of in his geography and which was utilized later by Epic and Pauranic writers.

Northern India

The *Himavanta* (snowy), mentioned as the *parvatarāja* in an early Buddhist work,[7] is the only *varṣaparvata* which is placed within the geogra-

1. Ptolemy, *Ancient India*, 1927 Ed., p. 355.

2. *Ibid.*, p. 356 ; pp. 76 ff ; vide *Mbh.*, Vanaparva, lxxxviii, 8343 ; lxxxix, 8354-61 ; *JRAS.*, April, 1894, p. 245.

3. *Mbh.*, XII, 49. 76.

4. Law, *Geographical Essays*, p. 109.

5. Kālidāsa mentions it in his *Meghadūta* (Pūrvamegha, 19). The *Mahābhārata* calls it the Vindhya parvata (Ch. 104, 1-15).

6. *Kumārasaṃbhava*, VIII. 23, 24, 29 and 59.

7. *Aṅguttara Nikāya*, I, 152 *Himavant* occurs in the *Atharvaveda* xii, 1. 11 ; vi, 95. 3 ; iv, 9. 9 ; v, 4. 2. 8 ; 25. 7 ; vi, 24. 1 ; *Ṛgveda*, x, 121. 4 ; *Taittirīyasaṃhitā*, v. 5. 11. 1 ; *Vājasaneyīsaṃhitā*, xxiv, 30 ; xxv, 12 ; *Aitareya Brāhmaṇa*, viii, 14. 3.

phical limits of *Bhāratavarṣa*. According to ancient geographers, the name Himavanta was applied to the entire mountain range that stretches from the Sulaiman along the west of the Punjab and the whole of the northern boundary of India to the Assam and Arakan hill ranges in the east. According to the *Mahābhārata* and the *Mārkaṇḍeya Purāṇa*, the Himalayan range is said to have stretched from sea to sea like the string of a bow. The Śākyas and the Koliyas were transported by the Buddha to the Himalaya and the Buddha pointed out to them the various mountains in the Himalayan region, e.g., Golden mountain, Jewel mountain, Vermilion mountain, Collyrium mountain, Crystal mountain etc. The Kailāsa range formed a part of the Himalayan mountain but the *Mārkaṇḍeya Purāṇa* takes it to be a separate mountain. According to Alberuni, Meru and Niṣadha, described as *Varṣaparvatas* in the Purāṇas, were connected with the Himalayan chain. The Himalayan mountain is the source from which the ten rivers have their rise.[1] The *Apadāna* mentions a few other mountains in the neighbourhood of the Himavanta *Kadamba*, *Kukkura* (better *Kukkuṭa*), *Kosika*, *Gotama*, *Paduma*, *Bharika*, *Bhūtagaṇa*, *Lambaka*, *Vasabha* (Vṛṣabha), *Vikaṭa*, *Samaṅga* and *Sobhita*. The Maināka is the name of a mountain of the Himalayan range mentioned in the *Taittirīya Āraṇyaka* (1.31.2).[2] The Hemagiri and Indraparvata are associated with the Himalaya.[3]

Hemavata (*Himavā*, *Himācala*,[4] *Himavantapadesa*, *Himādri*, *Haimavata*)—This mountain (known to the Greeks as Imaos) which is called *nagādhirāja* by Kālidāsa is mentioned in the *Atharvaveda* (xii, 1, 11) as well as in the *Ṛgveda* (x, 121.4). The *Taittirīya Saṃhitā* (v. 5. 11. 1), *Vājasaneyī Saṃhitā* (xxiv, 30 ; xxv, 12), *Aitareya Brāhmaṇa* (viii, 14.3) and *Bhāgavatapurāṇa* (I, 13. 29 ; I, 13. 50) also refers to it. According to the Great Epic,[6] the Haimavata region was situated just to the west in Nepal (*Nepālviṣaya*) and according to the same Epic it mainly comprised the *Kulindaviṣaya* (Ptolemy's *Kunindrae*), representing the region of high mountains in which the sources of the Ganga, Yamuna and Sutlej lay. It may thus be taken to include the *Himācalapradeśa* and some parts of Dehra Dun. The Himalaya is described in the *Kunāla Jātaka*[7] as a vast region, 500 leagues in height and 3,000 leagues in breadth. The *Kūrmapurāṇa* (30. 45-48) refers to it. The *Yoginītantra* mentions this moun-

1. *Milinda*, p. 114.
2. Cf. Weber, *Indische studien*, 1. 78.
3. Pargiter, *Mārkaṇḍeyapurāṇa*, 369 n. ; *Mbh.*, ii, 30. 15.
4. *Padmapurāṇa*, Uttarakhaṇḍa, vs. 35-38 ; Vide also Pāṇini's *Aṣṭadhyāyī*, IV, 4. 112.
5. *Kumārasambhava*, I......*Himālayo nāma nagādhirājaḥ*......Cf. *Kālikāpurāṇa*, Ch. 14. 51.
6. *Mahābhārata*, Vanaparva, Ch. 253.
7. *Jātaka*, No. 536.

tain (1/16). The *Kālikāpurāṇa* (Ch. 14.1) also mentions it. In the Epic and Purāṇas the Himavanta is classed both as a *Varṣaparvata* and a *Maryādāparvata* (boundary mountains).[1] The author of the *Mārkaṇḍeyapurāṇa* knew the Himavat to have stretched from the eastern to the western sea like the string of a bow[2]. The statement of the *Mārkaṇḍeyapurāṇa* is supported by the *Mahābhārata* (VI. 6. 3) and *Kumārasaṃbhava* (1.1). The eastern Himalayan region extending up to Assam and Manipur roughly constituted the Haimavata division of the Jambudvīpa in respect of which Aśoka introduced the Nābhakas and Nābhapaṃtis in his Rock Edict XIII.[3] According to Bāṇa's *Harṣacarita* (Ch. VII) Arjuna subdued the mount Hemakūṭa[4] to complete the Rājasūya sacrifice. Bāṇa's *Kādambarī*, (śl. 16) points out that the Himalaya mountain was white with crystals or made up of crystal rocks. This Himalayan region (*Himavantapadesa* in Pali) of the Jambudvīpa extended northward, according to the Pali accounts, as far as the south side of the Mount Sumeru (Pali Sineru). The southern boundary of the Haimavata division of India is indicated by the Kalsi set of Rock Edicts, the Asokan monoliths at Niglīva, Lumbinī, and those in the district of Champaran.[5] The *Haimavatapadesa* has been identified by some with Tibet, by Fergusson with Nepal, and by Rhys Davids with the Central Himalaya. According to ancient geographers the name Himavanta was applied to the entire mountain range stretching from Sulaiman along the west of the Punjab and the whole of the northern boundary of India upto the Assam and Arakan hill ranges in the east. Aśvaghoṣa refers to this great mountain and places the central province between this mountain and the Pāripātra.[6] The Himalaya mountain occurs in Luders' List No. 834. The Monghyr grant of Devapāla refers to Kedāra which is situated in the Himalaya. The *Kālikāpuraṇa* (Ch. 14.31) says that Śiva and Pārvatī went to the fall of the Mahākauśikī river in the Himalayan mountain. The beauty of the Himalayan mountain which is a mine of various kinds of gems is not marred by the glacier.[7] It contains various kinds of minerals on its summit.[8] The sages take shelter on its sunny summit, the caves of which are covered by clouds.[9] The Kirātas,[10]

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1. *Agnipurāṇa*, 108. 22-23.
2. *Kārmukasya Yathāguṇaḥ*, 54. 24 ; 57. 59.
3. Barua, *Asoka and His Inscriptions*, Pt. I, p. 101.
4. Pargiter says that the Hemakūṭa was a mountain or group of mountains in the Himalaya in west Nepal (Mārkaṇḍeyap., p. 360).
5. *Ibid.*, pp. 81-82.
6. *Saundaranandakāvya*, II, v. 62.
7. *Kumārasaṃbhava*, 1. 3.
8. *Ibid.*, 1. 4.
9. *Ibid.*, 1. 14.
10. They lived in the eastern valley of the Brahmaputra. Ptolemy says that they

the wild tribe of hunters, can trace the course of the lions on this mountain; when the elephants are killed here, the mark of blood is washed away by the waters from the ice.[1] The self luminous roots and herbs give light to the Kirātas at night, living with their wives in the dark caves of the Himalaya.[2] The Himalayan tract which is thickly covered with snow is troublesome to those who walk on it.

The Mainākagiri, identified with Siwalik range of outer Himalaya, is mentioned in the Yoginītantra (2. 4. pp. 128-29) and in Bāṇa's Kādambarī (p. 86). In the Himalayan region there was a mountain called the Daddara.[3] A mountain named Caṇḍagiri stood by the side of the Himalaya and close by there was a forest.[4] Another mountain named Dhammaka existed near the Himalaya where the first Buddha Dīpaṅkara lived in a hermitage built for him.[5] Aśoka,[6] Gotama[7] and Kadamba[8] existed not far from the Himalaya. Cāvala[9] has been described to be not far off from the Himalaya.

A valuable study has been made of the Himalayan plants and animals in the past, and there is reference to these in ancient Indian literature. The Himalayan forests are said to have abounded in elephants living in herds or as rogues distinguished as *Vāmanika* (dwarfish), *uccākaḷārika* (high class elephants), *uccākaṇeruka* (a tall female elephant), and *chaddanta* (six tusked). The Chaddanta elephants are associated with the Chaddanta lake and noted for the high quality of ivory. The Himalayan region contained horses of diverse breeds, *sindhu* and *valāha*. It is noted for the yak having white fur (*Kumārsaṃbhava*, 1. 13). There were four species of lions: (1) those looking like cows, pigeon-coloured and eating grass, (2) black lions, (3) light yellow lions, and (4) those possessing big manes. There were ordinary tigers, panthers, hyenas, bears, cats, dogs, rhinoceros (*khagga* or *palāsada*), gayals, bulls, buffaloes, and diverse species of deer (*mṛga*), goats and rams.

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had their settlement in Uttarāpatha. (McCrindle, *Ancient India*, p. 277). They also lived in eastern India. According to Ptolemy Kirrhadia was the land of the Kirātas. They are mentioned in the *Mahābhārata* (XII. 207. 43). The *Śrimad-Bhāgavatagītā* (II. 4. 18) mentions them as living outside the Aryan fold.

1. *Kumārasaṃbhaba.*, 1. 6.
2. *Ibid.*, 1. 10.
3. *Jātaka*, III, p. 16.
4. *Mahāvastu*, III, 130.
5. *Buddhavamsa*, II, v. 29.
6. *Apadāna*, p. 342.
7. *Ibid.*, 162. 12.
8. *Ibid.*, p. 382.
9. *Ibid.*, p. 451.

The Himalayan region abounds in such reptiles as pythons, cobras, lizards and frogs in various kinds, and snakes divided into four families of *virūpakkha, erāpatha, chavyāputta* and *kaṇha* (black). There are water snakes feeding on green frogs and iguanas, porpoises, crocodiles and alligators. The Himalayan rivers are full of fish e.g., *pāṭhina, muñjarohita* and *maggura.* There are small and big crabs. The birds are numerous, such as ruddy geese, swans, blue swans, sweet voiced cuckoos, cranes, herons, owls, birds of ill omen, crows, doves, pigeons, kites, eagles, vultures, *phasianus jallus,* partridges, and peacocks.

There were various kinds of trees and plants such as banyan, peepul, fig, mango, rose-apple, jackfruit, *shorea robusta, mesua ferrea,*[1] *haritaka*[2] (*terminalia chebula, phyllanthus emblica*), *vibhītaka*[3] (*terminalia belerica*), *mādhavilatā,*[4] banana, citron, campaka, ketaka (*pandanus odoratissimus*),[5] lilies—white, red and blue, lotus having 100 petals and lotus having 1,000 petals.[6]

Of the mountains of the trans-Himalayan Zone, three have been described in the ancient literature of India : the Hindu Kush, Karakoram, and Kailās Mountain. The Hindu Kush mountain which was known as the Malyavat mountain to early geographers starts from the north-western extremity of the Himalaya and extends south-westwards, first dividing India from Afghanistan, and then through North-Eastern Afghanistan. The Karakoram was known to the ancient geographers as the Kriṣṇagiri (Kanhagiri, Kanheri—Luders' List No. 1123) or the Black mountain.[7]

The *Kailāsa range* : This range is called a king of mountains. It contains a number of groups of giant peaks. One such group stands near Mānasasarovara, the highest of the groups being the *Kailāsa* (6,714m). It is also known as Kaviḷāsa. It is the abode of Siva.[8] The Kailāsa may be identified with the *Vaidyūtaparvata.* It is the Kangrinpoche of the Tibetans, situated about 40 kilometres to the north of Mānasasarovara. Badarikāśrama is said to be situated on this mountain. It is also called Hemakūṭa.[9]

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1. *Naga, Nāgakeśara, Nāgarukkha* (*Apadāna,* I, 18 ; *Buddhavaṃsa,* II, v. 51).
2. Its fruit acts as a good purgative.
3. *Baheḍā.* Cf. *Apadāna,* II, 346.
4. *Hiptage Mādhabilatā* (Gaertn).
5. Male flowers are sweet-scented. Cf. *Jāt.,* IV, 482 ; *Buddhav.* II, 51.
6. *J. B. B. R. A. S.,* xiii, 1937, p. 236.
7. *Vāyupurāṇa,* Ch. 36.
8. Siṅgur Inscription of Yādava Mahādeva-raya—*E.I.,* XXIII, Pt. V, 194.
9. *Mbh.,* Bhīṣmaparva, Ch. 6 ; Cf. Kālidāsa's *Abhijñānaśakuntalam,* p. 237.

It is also known as the Bhūteśagiri surrounded by the river Nanda also called the Gaṅgā[1] and the Śaṁkaragiri according to the *Daśakumāra-caritaṃ* (p.54), which was visited by Vīraśekhara, son of Mānasavega, and grandson of Vegavat, a king of Ikṣvāku's line. This mountain is mentioned in the *Yoginītantra* (1/1, 1/12). The Puruṣottama plates of Rāmacandra refer to this mountain. The *Kālikāpurāṇa* refers to this mountain (Vaṅgabāsī Ed., Ch. 13.23). It was visited by Śiva and Pārvatī.[2] Śāntanu lived on this mountain and also on the Gandhamādana (Ch. 82.7). The Mahābhārata (Vanaparva, Chs. 144, 156) includes the Kumaun and Garhwal mountains in the Kailāsa range. To the Jains it is known as the Aṣṭāpada mountain, where many sages attained perfection including the sons of Riṣabha.[3]

In the north-west of India, a lofty range runs dividing the Indus Valley from the hills of Baluchistan and extending from the west of *Dera Ismail Khan* to the sea-coast. The northern portion of this range is called the Sulaiman mountain, known to the ancient geographers as Añjana.[4] It is mentioned in the Rāmāyaṇa (Kiṣkindhyākāṇḍa, 37.5), in the *Mārkaṇḍeyapurāṇa* (58. ii) and in the Jaina *Āvaśyakacūrṇī* (p.516). According to the *Skandapurāṇa* (Ch. I, śl. 36-48) it was made up of gold.

Manor Avasarpana is a mountain mentioned in the *Śatapatha Brāhmaṇa* (1, 8.1, 8) on which the vessel of Manu rested. The epic name is Naubandhana. The view that it is alluded to as Nāvaprabhaṃsana in the *Atharvaveda* (xix, 39, 8) is abandoned.[5] *Trikakud* or *Trikakubh* meaning three peaks is a mountain mentioned in the *Atharvaveda* (iv, 9.8).[6] It is modern Trikoṭa in the Himalaya. From it came the salve (*āñjana*) which tradition made out to be derived from Vritra's eye.[7] It is better to refer to Ludwig's *Translation of the Rigveda* (3.198).

Krauñca is the name of a mountain mentioned in the *Taittirīya Āraṇyaka* (I, 31.2) In the *Kūrmavibhāga* section of the *Mārkaṇḍeyapurāṇa* it occurs among the countries and peoples placed on the tortoise's left flank. It must be a mountain in northern India. Pargiter points out that this mountain appers to have been a portion of the Maināka mountain in the Great Hima-

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1. *Bhāgavata Purāṇa*, IV, 5. 22 ; V, 16. 27.
2. *Ibid.*, Ch. 14. 31.
3. Law, *Some Jaina canonical Sūtras*, p. 174.
4. Jātaka, V, p. 133.
5. Vide Macdonell, *Vedic Mythology*, p. 139 ; *JRAS.*, 1907, 1107 ; Whitney, *Indische studien*, I, 162 ; *Vedic Index*, II, p. 130 ; Cf. Brahmāṇḍap. 43. 2.
6. Cf. *Satapatha Br.*, iii, 1. 3. 12 ; *Maitrāyanīsaṃhitā*, iii, 6. 3 ; *Pañcavimśa Br.*, xxii, 14 ; *Kāṭhakasaṃhitā*, xxiii, 1 ; *Vājasaneyī sam.* xv. 4 ; *Matsyapurāṇa*, 121, 15.
7. Cf. *Atharvaveda*, iv, 9. 9. 10 ; xix, 44. 6 etc. Cf. *Matsyapurāṇa*, 121. 15.

layan mountain system.[1] It is the portion of the Himalayan chain bounding Nepal at the extreme north-west.[2] The *Rāmāyaṇa* (Kiṣkindhyākāṇḍa, Ch. 44) says that the Krauñca mountain is that part of the Kailāsa mountain where the lake Mānasasarovara exists. The Krauñcarandhra mentioned in the *Meghadūta* (I, v. 58) and included in the *Krauñcaparvata* supplies a passage to Tibet from India. According to Megasthenes and Arrian *Mount Abu* is identified with the Capitalia which, attaining an elevation of 1,722 m, rises far above any other summit of the Aravalli range. The *Capitalia* is the loftiest of the Indian mountains. The mount *Caucasus* is called the *Paropamisos* (*Parapamisos*) which denotes the great mountain range called the Hindu Kush. The mount Paros or Aparasin of the *Zendavesta* corresponds with the Paropamisos of the Greeks. According to Pliny the Skythians called the mount Caucasus, Graucasis, a word representing the Indian name of the Paropamisos.[3]

The *Meru* is identified with Rudra-Himalaya in Garhwal,[4] where the Ganga takes its rise.[5] It is also known as Hemādri or Svarṇācala.[6] It is near the Badarikāśrama and is probably the Mount Meros of Arrian. The Karṇikācala is one of the names of this mountain. On the western side of this mountain stand Niṣadha and Pāripātra ; on the southern side stand the Kailāsa and Himavanta and on the northern side stand Śriṅgavān and Jarudhi.[7] The Mount Meru stands in the middle of Ilāvṛta. It was visited by Vaiśampāyana, and the sage Śālaṅkāyana meditated here.[8]

The *Sumeru* (Pali Sineru) is bounded on the north by Uttarakuru, in the south by Bhāratavarṣa, on the west by Ketumālā and on the east by Bhadrāśvavarṣa. Some hold that the mount Meru is situated to the north of Almora district.[9] The *Padmapurāṇa* (Uttarakhaṇḍa vs. 35-38) and the *Kālikāpurāṇa* (Ch. 13. 23 ; Ch. 19.92) refer to it. Śiva saw its summit.[10] The Jambu river flows from this mountain.[11] Mahendra, Malaya etc. are treated as the great knots of the Mount Meru.[12] The Buddhist texts and commentaries refer to

1. Cf. *Harivaṃśa*, xviii, 941-42.
2. *Mārkaṇḍeyapurāṇa Tr.*, p. 376 n.
3. Ptolemy's *Ancient India*, pp. 247, 143, 186 f.n.
4. *Therīgāthā Commy.*, p. 15.
5. Law, *Geo. of Early Buddhism*, p. 42.
6. Hultzsch, *S. I. I.*, I, p. 166.
7. *Mārkaṇḍeyap.*, Vaṅgavāsi, Ed. 240.
8. *Bhāgavatapurāṇa*, V, 16 ; 20. 2 ; *Brahmāṇḍapurāṇa*, II, 23. 108 ; *Matsyapurāṇa*, 10. 26 ; 11. 38 ; *Kurmapurāṇa*, 144. 10.
9. Sherring, *Western Tibet*, 90.
10. *Kālikāpurāṇa*, Ch. 17. 10.
11. *Ibid.*, Ch. 19. 32.
12. Alberuni, *India*, Chs. 23. 25.

Sineru.[1] This mountain was 68,000 leagues in height[2]. The highest of the mountain peaks of the continent of India is the *Sineru* which sinks 84,000 yojanas in the great deep and ascends to the same height. It is accompanied by seven celestial ranges.[3] The Mount Meru or the Sineru contains gold deposits. The temple at Chidambaram appears to have been looked upon as the southern Meru, as it contained a large amount of gold deposited on the roof of its golden hall.[4] The Mount Meru is near the Badarikāśrama.[5] It is identical with the Rudra Himalaya in Garhwal. It is probably the Mt. Meros of Arrian. It is called Mahāmeru in the *Taittirīya Āraṇyaka* (I, 7.1.3).[6] The Meros mountain is known as Maer-Koh near Jalalabad in Pakistan which was visited by Alexander the Great.

The *Rudra-Himalaya* has five peaks and so it is called *Pañcaparvata.* Patangiri near Gaṅgotrī is said to be the place where the five Pāṇḍavas lived for 12 years worshipping Mahādeva and where Draupadī and four of the Pāṇḍavas died. [7]

The *Phalika* and *Rajata* mountains are in the Himalayan region. They are the names of its different peaks.[8] The *Maṇiparvata*, *Mahākāla*, *Suvarṇaparvata* and *Sānuparvata* are also in the Himalayan region.[9] The *Śvetaparvata* is in the Himalaya to the east of Tibet.[10]

The *Kāñcana* mountain is in the Uttara Himalaya.[11] The *Niṣadha* mountain is not far off from the *Himavanta.*[12] It is the mountain which lies to the west of the *Gandhamādana* and north of the Kabul called by the Greeks Paropanisos, now called the Hindu Kush. The *Anoma*, *Aśoka* and *Cāvala* are the mountains not far from the Himalaya.[13] The *Uśīradvaja* may be said identical with the Uśīragiri, a mountain to the north of Kaṅkhal.[14] It is the Siwalik range or the hills at Hardwar (Haridvāra) through which the Ganga passes to the plains.

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1. *Dhammapada Commy.*, I, 107 ; *Jātaka*, I, 202.
2. *Dhammapada Commy.*, I, p. 107.
3. Law, *Geography of Early Buddhism*, xvi.
4. Hultzsch, *S. I. I.*, p. 166 ; II, p. 235.
5. *Mahābhārata*, Śāntiparva, Ch. 335-36.
6. Weber, *Indische Studien*, I, 78. 3. 123.
7. *Mahābhārata*, Mahāprasthānikaparva, Ch. 2.
8. *Jātaka*, II, 6 ; V, 415.
9. *Ibid.*, II, 92. 38 & 415.
10. *Samyutta Nikāya*, I, 67 ; Cf. *Agnipurāṇa*, 107. 7.
11. *Jātaka*, II, 396, 397, 399 ; VI, 101.
12. *Apadāna*, 67.
13. *Ibid.*, 342, 345, 451.
14. *I. A.*, 1905, 179.

The *Hingula mountain* is in the Himalayan region[1]. Hinglāj is situated at the extremity of the range of mountains in Baluchistan, called by the name of Hingul or Hingulā, about 30 kilometres or a day's journey from the sea-coast on the bank of the Aghor or the Hingulā or Hingol river near its mouth.

Aruṇācala or *Śoṇācala*—This mountain is situated on the west of the Kailāsa range. In the *Skandapurāṇa* (Ch.iii, 59-61 ; iv, 9.13, 21, 37) it stands on the river Kampā flowing past Kāñcī.

Daṇḍakahiraññā[2]—This mountain seems to have been situated in the Himalayan region.

Gandhamādana—A part of the Rudra Himalaya and a part of the Kailāsa range. It is also said to be watered by the Mandākinī. Kālidāsa mentions it in the *Kumārasambhava* (Nirṇayasāgara Ed. viii, 23, 24, 29, 59). The *Vikramorvaśīya* and the *Yoginītantra* (p. 87 ; 1.15), also mention it. Brahmā descended on this mountain[3] The *Jātaka* (VI. 519) describes it as a rocky mountain which was visited by King Vessantara, his wife and children. According to the *Harivaṃśa* (Ch XXVI. 5-7) King Pururava lived with Urvaśī for 10 years at the foot of this mountain. The *Padmapurāṇa* (Ch. 133) says that there was a holy place here called the Sugandha. Bāṇabhaṭṭa describes it as one of the summits of the Himalaya.[4] There existed a cave in this mountain known as the Nandamūla inhabited by the saints.[5] This mountain had a big Śivaliṅga[6]. The Kāmaparvata existed to the east of this mountain.[7] According to the *Divyāvadāna* (p. 157) Aśoka's tree was brought by Ratnaka, the keeper of a hermitage, and was planted at the place where the Buddha showed miracles. The Buddha visited this mountain when a brahmin used to live at its foot.[8]

Gaṇḍaparvata—It is the Gaṅgotrī mountain at the foot of which Bindu-sarovara is situated.[9]

The Nisabha mountain, which was not far off from the Himalaya, was situated to the west of the Gandhamādana and north of the Kabul river called by the Greeks Paropanisos, now called the Hindu Kush.[10]

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1. *Jātaka*, V, 415.
2. *Jātaka*, II, p. 33.
3. *Bhāgavatap.*, IV, 1. 58 ; V, 1 18 ; X, 52. 3.
4. *Kādambarī*, Kale's Ed., p. 94.
5. *Sāsanavamsa*, PTS., p. 68 ; B. C. Law, *The History of the Buddha's religion*, SBB series, p. 75.
6. *Kālikāpurāṇa*, 78. 70.
7. *Ibid.*, 79, 57.
8. *Buddhisattvāvadānakalpalatā*, 5th pallava, pp. 25. 31,
9. *Matsyapurāṇa*, Ch. 121.
10. Cf. *Apadāna*, p. 67.

Hṛṣikeśa—This mountain is situated 40 kilometres to the north of Hardwar which was the hermitage of Devadatta.[1] It is situated on the Ganga on the road from Hardwar to Badrīnāth. According to some this holy city of the Vaiṣṇavas is situated on the Gangā about 30 kilometres from Haridvāra.

Lachmanjhola—Not far from Hṛṣikeśa there exists a beautiful spot, famous for its mountain scenery. Before proceeding to Badrīnāth and Kedārnāth, pilgrims halt here. The place derives its name from a hanging bridge.[2]

Govardhana (Pali Govaḍḍhana)[3]—Thirty kilometres from Vṛndāvan in the district of Mathurā. In the village called Paitho, Krishṇa is said to have taken up the mount on his little finger and held as an umbrella over the heads of his cattle and his townsmen to protect them from rains poured upon them by Indra.[4] Kālidāsa mentions this hill in his *Raghuvaṃśa* (vi, 51).[5] This hill contains the temples of Harideva and Cakreśvara Mahādeva and also the image of Śrīnathaji,[6] formerly known as Gopāla.

Indrapura—This large and lofty mountain mentioned in the Indore Copper plate inscription of Skandagupta stands about 8 kilometres to the north-west of Dibhai, the chief town of the Dibhai Pargana in the Bulandshahr district.[7]

The *Neruparvata* also exists in the Himalayan region.[8] It is mentioned in the Jātaka as the golden mountain.[9]

The *Vindhyācala* is a hill near Mirzapur on the top of which stands the celebrated temple of Binduvāsinī. The town of Vindhyācala also known as Pampāpura lies eight km to the west of Mirzapur.[10] It is mentioned in the *Yoginītantra* (2.9.214 ff.) and in the *Kālikāpurāṇa* (Ch. 58.37).

Uśīradhvaja—This mountain may be said to be identical with the Uśīragiri a mountain to the north of Kaṅkhal.[11] The Siwalik range through which the Ganga forces her way into the plains, may be identified with the Uśīragiri. Some hold that Uśīnārā and Uśīnaragiri are doubtless identical with the

1. *Varāhapurāṇa*, Ch. 146.
2. Law, *Holy Places of India*, p. 21.
3. *Jātaka*, IV, 80.
4. *Mahābhārata*, Udyogaparva, Ch. 129.
5. *Bhāgavatap.*, V, 19. 16 ; X, 11. 36 ; 13. 29 ; *Yoginītantra*, I. 14.
6. *Harivaṃśa*, Ch. 55.
7. *C.I.I.*, Vol. III.
8. *Milinda*, p. 129.
9. *Jātaka*, III, 247.
10. *Bhaviṣyapurāṇa*, Chap. IX.
11. *I. A.*, 1905, 79.

Uśīragiri of the *Divyāvadāna* (p. 22) and Usiradhvaja of the *Vinayapiṭaka*.[1]

Citrakūṭa (Pali Cittakūṭa).—This beautiful mountain finds its place among the holy places mentioned in the *Padmapurāṇa* (Ch. 21—*Tīrtha-māhātmya*). It is known in the Jaina Bhagavatī-Ṭīkā (7.6) as Cittakuḍa. According to Kālidāsa it appears like a wild bull playfully butting against a rock or mound.[2] It stood at a distance of 30 kilometres (10 krośas) from the hermitage of the sage Bharadvāja.[3] The *Uttaracaritaṃ* (Act. I, 24) refers to the road on the bank of the Kālindī leading to the Citrakūṭa mountain. It is the modern Citrakūṭa, a famous hill, lying 100 kilometres west-south-west of Allahabad.[4] It is situated about six km from the modern Chitra-kuta railway station. It lay to the south-west of Prayāga. the *Apadāna* (p. 50) vaguely locates it to be not very far off from the Himavanta. The Gaḍhwā stone inscription refers to it.[5] The *Bhāgavatapurāṇa* mentions it as a mountain (v. 19.16). The *Lalitavistara* (p. 391) refers to it as a hill. It was a pleasant spot.[6] It was a spotless place.[7] It existed in the Himalayan region and it had a golden cave and a natural lake.[8] It was noted for its waterfalls.[9]

It has been identified with Kāmptānāthgiri in Bundelkhand. It is usually identified with the mountain of the same name in the Banda district, U.P., about 30 kilometres north-north-east of Kalinjar.[10] The Mahābhārata (III, 85, 56) associates it with Kālañjara. As regards its indentification we may also refer to *A.S.R.*, XIII and XXI and *J.R.A.S.*, 1894.

According to the *Rāmāyaṇa*,[11] Rāma dwelt on this hill situated on a river called the Payasvinī (Paisunī) or Mandākinī. He came here after crossing the Yamunā while returning from the hermitage of Bharadvāja. It was 3 yojanas distant from Bharadvāja-āśrama.[12] This beautiful mountain was an abode of many geese living in the golden cave which it contained,[13] some of which were swift and some golden.[14] A king set out for this mountain being

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1. *Vinaya Texts*, S. B. E., Pt. II, p. 39.
2. *Raghuvaṃśa*, XIII, 47.
3. *Rāmāyaṇa*, Ayodhyākāṇḍa, Sarga 54, v. 28.
4. *J. R. A. S.*, April, 1894, p. 239.
5. *C. I. I.*, Vol. III.
6. *Jātaka*, II, 176.
7. *Ibid.*, VI, 126.
8. *Jātaka*, II, 176 ; III, p. 208.
9. *Raghuvaṃśa*, XIII, 47.
10. *J. R. A. S. B.*, Vol. XV, 1949, No. 2, Letters. p. 129.
11. *Ayodhyākāṇḍa*, Ch. 55.
12. *Ayodhyākāṇḍa*, LIV, 29-30.
13. *Jātaka*, V, 337 ; II, 107 ; V, 381.
14. *Ibid.*, IV, 212, 423-24.

instructed to observe the moral law, to rule the kingdom righteously and to win the hearts of the people.[1] The *Kālikāpurāṇa* (79.143) points out that a mountain called Kajjala stands to the east of the Citrakūṭa.

There were two rivers at Citrakūṭa called the Mandākinī and Mālinī.[2] The Mandākinī is stated to have been on the north side of this hill. The forest at Citrakūṭa does not appear to have been isolated. The Nīla forest joined the forest on the hill.[3] The *Mahābhārata* (85, 58-59) refers to the *Citrakūṭaparvata*[4] and the Mandākinī river. The hermitage of the sage Atri was not far from the Citrakūṭa.

SOUTHERN INDIA

Amarakaṇṭaka—A sacred hill on the top of the Mālyavat. Here flows the river Viśalyakarṇī formerly a part of Kaliṅga.[5]

Candaka—It is a mountain near the Mahiṃsaka kingdom, where the Bodhisatta built a leaf-hut at the bend of the river Kannapeṇṇā. It is the Malaya-giri or the Malabar ghats.

Candragiri—It is a hill at Śravaṇa-Belgola, the well-known Jaina town in the Hassan district of the Mysore State and not far from Seriṅgapatam.[6] It was known to the ancients as *Deya Durgā.*

Gomukhagiri—It is the name of a hill with a temple dedicated to the Gomukhagiriśvara by king Annadeva.[7]

Khaṇḍagiri and Udayagiri—The twin hills of Khaṇḍagiri and Udayagiri were known to the authors of the Hāthigumphā Cave Inscriptions as the Kumāra and the Kumārī hills. The two hills form part of a belt of sandstone rock, which, skirting the base of the granite hills of Orissa, extends from Athgarh and Dhenkānāl in a southerly direction past Khurda and towards the Chilka lake.[8] In the north-west of the Khurda subdivision stands the Khaṇḍagiri hill at a distance of five km north-west of Bhuvaneśwar in the Puri district. The Khaṇḍagiri (broken hill) is the name applicable to three peaks, Udayagiri, Nīlagiri and the Khaṇḍagiri. The crest of the Khaṇḍagiri is the highest point being 37 m high, while the crest of the Udayagiri is 33 m high. The Udayagiri has a small Vaiṣṇava hermitage at its foot. It has fortyfour caves, the Khaṇḍagiri has nineteen and the Nīlagiri has three. In the Udayagiri the caves are divided into two groups, one higher and the other lower. In the Khaṇḍagiri all the caves except two lie along the foot track.

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1. *Ibid.*, V, 352.
2. *Rāmāyaṇa*, Ayodhyākāṇḍa, LIV, 39 ; LVI, 7. 8.
3. *Ayodhyākāṇḍa*, LVI, 1-18.
4. *Rāmāyaṇa*, ii. 117.5.
5. *Matsyapurāṇa*, 22-28 ; 186. 12-34 ; 188. 79. 82.
6. *E. I.*, III, 184.
7. E.I., XXVI pt. I.
8. *J. A. S. B.*, *Old Series*, Vol. VI, p. 1079.

Among the Udayagiri caves the Rāṇīgumphā or the Queen's Palace is the biggest. The other important caves are the Ganeshgumphā, the Jaya-Vijaya cave, the Mañcapurī, the Bāghgumphā (the Tiger cave) and the Sarpagumphā (the Snake cave). In addition to these the Hāthigumphā or the elephant cave and the Anantagumphā are noteworthy.

The crest of the Khaṇḍagiri has been levelled so as to from a terrace with stone edges. In the middle of this terrace stands a Jain temple. The main temple consists of a sanctuary and a porch. Sir John Marshall points out that the Hāthigumphā cave, which is the earliest of all these caves, is a natural cavern enlarged by artificial cutting. The next in point of time was the Mañcapurī cave which seems to have been the prototype of all the more important caves excavated on this site. Next again was the Anantagumphā. All these caves may be dated not much earlier than the middle of the first century B. C.[1] Next in chronological sequence comes the Rāṇīgumphā.[2]

Mahendrācala—The *Yoginītantra* (2.4.128 ff.) has a reference to the Mahendra mountain. The Gautamī plates of Gaṅga Indravarman mention it. It probably refers to the hills of this name in the Ganjam district.[3] The Mahendra range of mountains extended from Ganjam as far south as the Pāṇḍya country to the whole of the Eastern Ghat range. The Mahendrādri or the Mahendra mountain was situated between the Gaṅgāsāgarasaṅgama and the Sapta-Godāvarī. A portion of the Eastern Ghats near Ganjam is still called the Mahendra hill. Pargiter thinks that the name should be limited to the hills between the Mahānadī, Godāvarī and Waingaṅgā, and may perhaps comprise the portion of the Eastern Ghats north of the Godāvarī.[4] According to Bāṇa's *Harṣacarita* (Ch. VII) the Mahendra mountain joins the Malayaparvata. The *Raghuvaṃśa* (IV, 39, 43 ; VI, 54) places it in Kaliṅga. The name is principally applied to the range of hills separating Ganjam from the valley of the Mahānadī. Kālidāsa styles the king of Kaliṅga as the Lord of the Mahendra.[5]

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1. *Cambridge History of India*, Vol. I, pp. 639-40.

2. For details vide *Asiatic Researches*, Vol. XV (1824) ; Fergusson, *Illustrations of the Rock Cut Temples of India* (1845) ; R. L. Mitra, Orissa, Vol. I, Ch. I ; *A. S. I.*, Vol. XIII ; Fergusson, *History of Indian and Eastern Architecture* (1876) and *Cave Temples* (1880) ; *Cambridge History of India*, Vol. I, Ch. XXVI ; B. M. Barua, *Old Brāhmī Inscriptions in the Udayagiri and Khaṇḍagiri Caves*, 1929 ; B. C. Law, *Geographical Essays*, Ch. X ; Law, *Holy Places of India*, p. 49.

3. *E. I.*, XXIV, Pt. IV, October, 1937, p. 181.

4. *Mārkaṇḍeyapurāṇa*, p. 305 note.

5. *Raghuvaṃśa*, IV, 43 ; VI, 54.

The minor hills associated with the Mahendra mountain were the Śrīparvata, Puṣpagiri, Venkaṭādri, Aruṇācala and Ṛṣabha. The whole range of hills extending from Orissa to the district of Madurai was known as the Mahendraparvata. It included the Eastern Ghats. It joined the Malaya mountain. Paraśurāma retired to this mountain after being defeated by Rāmacandra. The Eastern Ghats must have been known to the geographers of ancient India as the Mahendragiri, as the highest peak of the Eastern Ghats is still called by that name. They run as detached hills more or less parallel to the eastern coast of India, which are known by different names in different parts of the country.[1]

Mainākaparvata—The *Rāmāyaṇa* locates it in South India. According to Aśvaghoṣa it entered the river to check the course of the ocean.[2] This legendary account is also found in the *Rāmāyaṇa*, which locates the Mainākaparvata in the *Dakṣiṇāpatha*. This mountain also known as the Malayagiri had three cavities crowded with serpents.[3]

Malayagiri—It is the name of a hill.[4] It is mentioned in the *Bṛhat-saṃhitā* (XIV, 11). A Pandya king leaving his own country sought refuge in this hill. Pargiter correctly identifies the range of hills with the portion of Western Ghats from the Nilgiri to the Cape Comorin. The hermitage of Agastya was situated on the Malayakūṭa which was also known as Śrīkhaṇḍāḍri or even as Candanādri.[5] It was visited by Balarāma. Manu performed austerities here.[6] The southern extension of the Western Ghats below the Kāverī, really forms the western side of the Malayagiri. According to some the mount Candaka mentioned in the *Jātaka* (V, 162) is the Malayāgiri or the Malabar State.

Malayācala—The Epic tradition locates it in South India. Jīmūtavāhana took shelter on this mountain after renouncing his sovereignty.[7] The *Padmapurāṇa* (Ch. 133) mentions Kalyāṇatīrtha in Malayācala. Dakṣiṇādri mentioned in the Kāvyādarśa (III, 150) by Daṇḍin is the same as the Malayācala according to the commentator.

Meru—This is a mountain which contains gold deposits, and is supposed to be situated to the north of the Jambudvīpa. The temple at Cidam-

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1. For details vide B. C. Law, *Mountains of India*, Calcutta Geographical Society Publication No. 5, p. 22.
2. *Saundaranandakāvya*, Ch. VII, verse 40.
3. *Daśakumāracarita*, p. 36.
4. *S. I. I.*, III, p. 422.
5. Cf. Dhoyi's *Pavanadūtam*.
6. *Bhāgavata*, V, 19. 16 ; 1. 8. 32 ; VI, 3. 35 ; XII, 8. 16 ; *Matsya*, 61, 37 ; 1. 12.
7. *Bodhisattvāvadāna-Kalpalatā*, 108 Pallava, p. 12.

baram seems to have been looked upon as the southern Meru, as it contained a large amount of gold on the roof of its golden hall.[1]

Nandagiri—The Indian Museum plates of Gaṅga Indravarman refers to Nandagiri, which is identical with Nandidrug, the well-known fortified hill to the west of the Kolar district, Mysore State.[2]

Pañcapāṇḍavamalai (or the hill of the five Pāṇḍavas)—About six kilometres to the south-west of the town of Arcot stands a rocky hill called the Pāncapāṇḍavamalai, which, according to the popular belief, is connected with the five Pāṇḍavas.[3]

Podiyil—It is a hill in the Tirunelveli district. It is also called the southern mountain. It is said to have been the seat of Agastya.[4]

Ratnagiri—It is an isolated hill of the Asia range, six kilometres to the north-east of Gopalpur, and stands on a small stream called Kelua, a branch of the Birupa. This hill really stands on the eastern bank of the Kelua and has a flat top. It contains the ruins of a big stūpa.[5]

Rājagambhīra hill—It is also called Rājagambhīran-malai. This hill was probably called after Rājagambhīrasaṃbuvarāyan.[6]

Ṛṣyamukha—This mountain is situated 13 kilometres from Anagandi on the bank of the river Tuṅgabhadrā. The river Pampā rises in this mountain and falls into the Tuṅgabhadrā after flowing westward. It was at this mountain that Hanumāna and Sugrīva were met for the first time by Rāmacandra.[7] The *Mārkaṇḍeya Purāṇa* (translated by Pargiter, Canto LVII, 13) refers to Ṛṣyamukha which has been identified by Pargiter with the range of hills stretching from Ahmadnagar to beyond Naldrug and Kalyāṇī dividing the Mañjira and the Bhīma rivers.[8] The *Bṛhat-Saṃhitā* mentions it as a mountain in the south. (XIV, 13).

Sahyādri—This is a mountain lying on the Western Ghats.[9] The Western Ghats were known to the ancients as the Sahyādri, which form

1. *S.I.I.*, I, p. 166 ; II, p. 235.
2. *E.I.*, XXVI, Pt. V, Oct. 1941, 167.
3. *E.I.*, IV, 136 ff.
4. *S.I.I.*, III, 144, 464.
5. For details, vide R. P. Chanda, *Exploration in Orissa, M. A. S. I.*, No. 44, pp. 12-13.
6. *S.I.I.*, I, p. 111.
7. *Rāmāyaṇa*, Ch. IV, Kiṣkindhyākāṇḍa.
8. *J. R. A. S.*, April, 1894, p. 253.
9. *S.I.I.*, I, pp. 168-69.

the western boundary of the Deccan and run continuously for a distance of about 1,600 kilometres from the Kundaibari Pass in the Dhulia district of Maharashtra down to Cape Comorin, the southernmost point of mainland of India. The Western Ghats are known by different local names. There are important passes too.[1]

Śrīparvata—The *Mārkaṇḍeya Purāṇa* (LVII, 15), the *Kurma Purāṇa* (30. 45-48 ; Cf. *Agni Purāṇa* 109), and the *Saura Purāṇa* (69. 22) refer to this mountain. It is also called Śrīśailam. According to the *Padma Purāṇa* (Ch. 21, śl. 11-12) the summit of this holy mountain is beautiful where the deity called Mallikārjuna resides. This lofty rock overhangs the river Kṛṣṇā in the Kurnool district. It is usually identified with Siriṭana of the Nasik Praśasti. It is the site of a famous temple called Mallikārjuna, one of the twelve liṅga-shrines.[2] The *Agni Purāṇa* (CXIII, 3.4) places it on the river Kāverī. According to it, it was dedicated to the goddess Śrī by Viṣṇu because she had once performed some austerities.[3] The introductory verses of Bāṇa's *Harṣacarita* mention Śrīparvata which is the name of a range of mountains in Telaṅgana.[4] As to its location it may be said that on the southern bank of the river Kṛṣṇā stands this ancient religious shrine on the Ṛṣabhagiri hill.[5]

Sūdādupārai-malai—This is the name of a mountain.[6] It must have been the old name of the Bavāji hill. It was situated in the north of Paṅgalanāḍu, a division of Poḍuvurkoṭṭam.

Tirumalai—This is the name of a hill, also called Arhasugiri and Eṇgunavirai-Tirumalaī.[7] It is in the North Arcot district, about 150 kilometres south-west of Madras.[8]

Tirumuḍukunraṃ (ancient holy mountain)—Its Sanskrit equivalent is probably Vṛddhācalaṃ, the headquarters of a taluk in the South Arcot district.[9]

Tirupati—Tirupati or Tripati or Tripadī is in the Chitoor district, 116 km north-west of Madras. On the top of a cluster of seven hills stands

1. For details, vide B. C. Law, *Mountains of India, Calcutta Geographical Society Publication*, No. 5, pp. 22-23.

2. *A. S. S. I.*, Vol. I, p. 90 ; *A. S. W. I.*, p. 223.

3. *Arch. Sur. of South India*, by Sewell, Vol. I., p. 90 ; Pargiter, *Mārkaṇḍeya Purāṇa*, p. 290.

4. *Harṣacarita*, Tr. by Cowell and Thomas, p. 3 f.n.

5. Vide B. C. Law, *Holy Places of India*, Cal. Geo. Soc. Pub. No. 3, p. 41.

6. *S. I. I.*, I, pp. 76, 77.

7. *Ibid.*, I, p. 106.

8. *E. I.*, XXVII. 24.

9. *S. I. I.*, Vol. I, p. 123.

the Tirupati temple. The seven hills are said to represent the seven heads of a serpent on which Venkaṭācalapati stands ; the centre of the serpent's body is that of Narasiṃha and the tail-end is the abode of Mallikārjuna. The beginning, middle and end, presided over by Brahmā, Viṣṇu and Śiva, form a wonderful specimen of south Indian architecture.[1]

Udayagiri—It is the most easterly peak of the Asia range, situated in the Jajpur sub-division, five kilometres north of Gopalpur on the Patamundai canal. There is a two-armed image of the Bodhisattva Avalokiteśvara bearing an inscription written in characters of the 7th or 8th century.[2] It is in the Nellore district containing also the temple of Kṛṣṇa.[3]

Vaigai—It is a mountain which is the same as Tirumalai[4]. It is also the name of a river which flows past Madurai.[5] It has been identified with the Kṛtamālā.[6]

Vallimalai—This is a hill situated about two kilometres of Melpāḍi in the Chittoor district. It was an ancient site of the Jain worship.[7] Here Jaina rock inscriptions have been found mentioning the names of two Jaina preceptors and the founder of the two images.[8]

Venkatagiri—It is the Tirumalai mountain near Tirupati in the Chittoor district, about 116 kilometres to the north-west of Madras, where Rāmānuja, the celebrated Vaiṣṇava reformer, performed the worship of Viṣṇu in the 12th century A.D.[9] It is known as the Venkaṭācala accord-to the *Skandapurāṇa* (Ch. I, śl. 36-48), which is seven yojanas in extent and one yojana in height.

EASTERN INDIA

Barabar hill (vide Khalatika)—There are some caves in these hills situated about 25 km north of Gaya. The caves known as Sātgharā (seven houses) are divided into two groups, the four southernmost in the Barabar group being more ancient. The Nyagrodha cave is hewn in the granite ridge and faces south. There is an inscription recording the gift of the cave

1. Law, *Holy Places of India*, 41-42.
2. *B. & O. Dist. Gazetteers, Cuttack* by O'Malley, 1933.
3. *A. S. I.*, Annual Report, 1919/20, p. 15.
4. *S. I. I.*, I, pp. 94-95.
5. Cf. *Caitanyacaritāmṛta*, Ch. 9, p. 141.
6. Cf. *Kurmapurāṇa*, XLVII, 35 ; *Varāhapurāṇa*, LXXXV, etc.
7. *S. I. I.*, III, p. 22.
8. *E. I.*, IV, 140.
9. Law, *Mountains of India*, p. 21.

to the Ājīvikas by Aśoka. The Lomasrishi cave is similar to this cave, but is unfinished. The side walls of the outer chamber are dressed and polished but the inside of the inner chamber is very rough. The entrance is finished and is, no doubt, the earliest example of the rockcut caitya hall. The fourth cave of the Barabar group is the Viśvajhopri. It consists of chambers, but it is unfinished. There is an inscription on the wall of the outer chamber recording the gift of the cave by Aśoka.[1]

Corapapāta—It seems to have been a hill near Rājagṛha.[2]

Gayāsīsa—Gayāsīsa which is the principal hill of Gayā[3] is the modern Brahmayoni and identical with what is called Gayāśira in the *Mahābhārata* (III. 95.9) and Gayāśira in the Purāṇas.[4] Gayāśira or Gayāśirṣa is the rugged hill to the south of Gaya town which rises some 120 metres above this town.[5] The *Agni Purāṇa* (Ch. 219, V. 64) mentions it as a place of pilgrimage. The *Yoginītantra* (2. 1. 112-13) refers to Gayāśira. The Wai-Kuo-Shih has wrongly applied the name of Dharmāraṇya hermitage to this hill. On the Gayāsīsa Devadatta lived with five hundred monks after making a dissension in the Buddhist Church.[6] While he was on this hill, he proclaimed that what the Buddha preached was not the right doctrine and that his was the right one.[7] Here he also tried to imitate the Buddha in his deeds but he was unsuccessful.[8] The fire sermon was delivered here by the Master and after listening to it one thousand Jaṭilas attained saintship.[9] Here the Master also gave a discourse on the intuitive knowledge before the monks.[10] A monastery was built by prince Ajātaśatru on this hill for Devadatta and his followers who were daily provided with food by him.[11] The early Buddhist commentators account for the origin of the name by the striking resemblance if its shape with that of the head of an elephant.[12]

Gorathagiri (Goradhagiri)—It is the modern Barabar hills.[13] It is mentioned in the *Mahābhārata* (Sabhāparva, Ch. XX, v. 30—*Goratham-*

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1. Law, *Geographical Essays*, pp. 17, 341.
2. *Dīgha*, II, p. 116.
3. *Vinaya Piṭaka*, I, 34 ff, ; II. 199, Law, *A Study of the Mahāvastu* 81.
4. Vide Barua, *Gayā and Buddha-Gayā*, I, p. 68.
5. B. M. Barua, *Gayā and Buddha-Gayā*, I, 11.
6. *Jātaka*, I, 142 ; *Vinaya Piṭaka*, II, 199 ; *Jātaka*, II, 196.
7. *Jātaka*, I, 425.
8. *Ibid.*, I, 490 ff ; II, 38.
9. *Ibid.*, IV, 180 ; *Samyutta*, IV, 19 ; *Vinaya Piṭaka*, I, 34-35.
10. *Aṅguttara*, IV, 302 ff.
11. *Jātaka*, I, 185 ff., 508.
12. *Sāratthappakāsinī*, Sinhalese ed., 4.
13. *J. B. O. R. S.*, Vol. I, Pt. II, p. 162 ; Barua, *Old Brāhmī Inscriptions on the Udayagiri and Khaṇḍagiri Caves*, p. 224.

girim āsādya dadrisur Māgadhaṃ puraṃ). The city of Magadha could be seen from the Gorathagiri. According to some, Pāsāṇakacetiya was either identical with Gorathagiri or some hill near it.[1] Gorathagiri was stormed by king Khāravela of Kaliṅga who then marched towards Magadha. The hill is known as the Goragiri in the Jaina *Nisithacūrṇī*, p. 18.

Gṛdhrakūṭaparvata (Pali Gijjhakūṭa)—It was one of the five hills that surrounded Girivraja which was the inner area of Rājagṛha. It was so called either because it had a vulture-like peak or because the vultures used to dwell on its peak. According to Fa-hien, about three *li* before reaching the top of the Gṛdhrakūṭa hill there is a cavern in the rock facing the south where the Buddha meditated. Thirty paces to the north-west stands another cavern where Ānanda sat in meditation. While he was meditating, Māra assuming the form of a large vulture took his seat in front of the cavern and frightened Ānanda. The Buddha by his supernatural power made a cleft in the rock, introduced his hand and struck Ānanda's shoulder so that his fear might pass away at once. The footprints of the bird and cleft for the Buddha's hand are still there, and hence the name of 'the Hill of Vulture Cavern' has come into vogue.[2] It stood to the south of Vepulla. According to the *Vimānavatthu Commentary* (p. 82) it was a mountain in Magadha. It could be approached from the eastern gate of the city. This mountain is also known as the Giriyek hill or the Indasīlāguha of Hiuen Tsang, situated on the southern border of the district of Patna across the river Pañcānā which is the ancient Sappinī, having its source in the Gijjhakūṭa mountain. According to Cunningham, the Gijjhakūṭa hill is a part of the Śailagiri, the Vulture Peak of Fa-hien, and lies ten km to the south-west of Rājgir. Relying on the evidence of the Chinese sources Gṛdhrakūṭa may be sought for somewhere on Ratnagiri.[3] From the top of this hill Devadatta tried to kill the Buddha by hurling a block of stone. The Kālaśilā on a side of Isigili (Ṛṣigiri, or 'Hermit hill') was situated in front of it. The Deer Park at Maddakucchī lay near about it. The Gṛdhrakūṭa hill was so called because the great sages attained the final beautitude by meditating on it. A Śiva-liṅga was installed on it. This hill bears also the footprints of Śiva. It contains a cave where the pilgrims offer oblations to the manes and a banyan tree. *Vāyu Purāṇa* (108, 61-64) refers to a sanctified boundary for offering *piṇḍas* to enable the spirits of the departed fore-fathers to go to heaven. This Gṛdhrakūṭa stood near the old city of Gayā. Dr. Barua says that it is a mistake to think that the Gṛdhrakūṭa of the *Gayāmāhātmya* was one

1. Barua, *Gayā and Buddha-Gayā*, Vol. I, p. 84.
2. Legge, *Travels of Fa-hien*, p. 83.
3. For a discussion on this point, vide L. Petech, *Northern India according to the Shui-Ching-Chu, Serie Orientale Roma*, II, pp. 45-46.

of the five hills encircling Girivraja or old Rājagṛha, the ancient capital of Magadha.[1]

Isigilipassa.—It was one of the five hills encircling Rājagṛha.[2] All the five hills except the Isigili had different names in different ages.[3] The *Mahābhārata* (II, 21. 2) refers to this mountain as Ṛṣigiri. As this mountain swallowed up the hermit teachers,[4] it got the name of the 'mount swallow-sage' [5]. By the side of this mountain, there was a black rock (*Kālaśilā*) on which Godhika and Vakkali committed suicide.[6] Monks desired to have a lodging place at the black rock on the Isigilipassa.[7] The Buddha lived on this mountain at Rājagṛha and addressed the monks.[8] His happy reminiscences of the sites at Rājagṛha are vividly recorded in the *Mahāparinibbāna suttanta*. He told Ānanda that he would dwell at Kālaśilā Isigilipassa.[9] Once the Master lived here with many monks including Mahāmoggallana who was very much praised by the revered Vaṅgīsa in the presence of the Master.[10] The Buddha came to Rājagṛha and took up his abode in the bamboo-grove as soon as he received the death-news of Sāriputta. Then an elder who attained perfection in supernatural power dwelt on the slopes of the Mount Isigili. Several attempts were made on his life by the heretics but all in vain.[11] According to the Pali *Isigilisutta*, five hundred *paccekabuddhas* (individual Buddhas) lived on this hill for ever (*ciranivāsino*). They were seen entering the mountain but not coming out. The *sutta* mentions many of them by name.[12] Dr. Barua thinks that the Mount Isigili was hallowed by the death of these hermits or holy personages.[13]

Kajaṅgala (*Kayaṅgala*).—This extensive hill tract lay to the east of Aṅga and extended from the Ganga in the north-east to the Suvarṇarekhā in the south-west. It was a Brahmin village, which was the birthplace of Nāgasena.[14] The Buddha once dwelt at Veluvana in Kajaṅgala.[15]

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1. B. M. Barua, *Gayā and Buddha-Gayā*, 13.
2. *Majjhima*, III, 68 ff. ; *Pāramatthajotikā*, II, 382 ; *Vimānavatthu-aṭṭhakathā*, p. 82.
3. *Majjhima*, III, 68 ff.
4. *Isigilatīti Isigili-Majjhima*, III, 68 ; *Papañcasūdanī*, II, P. T. S., p. 63.
5. Chalmers, *Further Dialogues of the Buddha*, II, p. 192.
6. *Samyutta*, I, 120 ff. ; III, 123-124.
7. *Vinaya*, II, p. 76.
8. *Majjhima*, III, p. 68.
9. *Dīgha*, II, 116 ff.
10. *Samyutta*, I, 194-195.
11. *Jātaka*, No. 522, Vol. V.
12. *Majjhima*, III, 68-71.
13. *Calcutta Review*, 1924, p. 61.
14. *Milindapañha*, p. 10.
15. *Aṅguttara*, V, 54.

The Master delivered the *Indriyabhāvanāsutta* during his sojourn at Mukheluvana in Kajaṅgala.[1] In the Buddha's time, food could be easily obtained here (*dabbasaṃbhārā sulabhā*).[2] In the *Mahāvagga*[3] as well as in the *Sumaṅgalavilāsinī* (II, 429), it is stated to have been the eastern limit of Madhyadeśa beyond the Brahmin village of Māhāsāla. It is the *Ka-chu-Hen-Ki-lo* of Yuan Chwang. It was 2060 *li* in circuit and was bounded on the north by the Ganga. It is to be located somewhere in the Rājmahal district.

Karaṅgarh (Karaṇāgarh)—It is a hill near Bhagalpur town in the Bhagalpur district and is said to have derived its name from the pious Hindu king Karṇa. The only objects of interest are the Śaiva temples of some celebrity, one of which is very ancient.[4]

Khalatika hills—These are the modern Barabar hills in the district of Gaya. The Barabar hill cave inscriptions of Aśoka inform us that four cave-dwellings were dedicated to the Ājīvikas by Aśoka in the Khalatika hills.[5] The Khalatika (Bald-headed) hills became known in the later inscriptions by the name of Gorathagiri (Goradhagiri), and still later by the name of Pravaragiri.[6]

Kukkuṭapādagiri (also called *Gurupādagiri*). Stein has located it on the Sobhanath hill, the highest peak in a range of hills further south-west from Kurkihār and about six kilometres distant from the village of Wazirganj.[7] Some have identified it with Gurpa hill about 100 *li* east of Bodh-Gayā.[8] Cunningham has identified it with the three peaks situated about two kilometres to the north of Kurkihar and 25 kilometres north-east of Gaya.[9] The three peaks are said to have been the scene of some of the miracles of the Buddhist saint Mahākāśyapa. According to Hiuen Tsang, the lofty peaks of the Kukkuṭapāda or the Gurupāda mountain are the endless cliffs and its deep valleys are boundless ravines. Its lower slopes have their gullies covered with tall trees, and rank vegetation clothes the steep heights. A three-fold cliff projects in isolated loftiness reaching the sky and blending with the clouds. Mahākāśyapa took up his abode on this mountain.[10]

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1. *Majjhima Nikāya*, III, 298.
2. *Jātaka*, IV, 310.
3. *Vinaya Texts*, S. B. E., II, 38.
4. Byrne, *Bhagalpur, B. D. Gazetteers*, 1911, p. 166.
5. Cf. Patañjali's *Mahābhāṣya*, I, 2. 2 ; B. C. Law, *India as described in the early texts of Buddhism & Jainism*, p. 27.
6. See B. C. Law, *Rājagṛha in Ancient Literature, M. A. S. I.*, No. 58.
7. *I. A.*, March, 1901, p. 88.
8. *J. A. S. B.*, 1906, p. 77.
9. *CAGI.*, ed. Mazumdar, p. 721.
10. Watters, *On Yuan Chwang*, II, p. 143.

Makulaparvata—Some have identified it with Kaluhā hill which is about 40 kilometres to the south of Buddha Gayā and about 25 kilometres to the north of Chatra in the district of Hazaribagh. The place abounds in Buddhist architectural remains and figures of the Buddha. The Buddha is said to have spent his sixth rainy season on this mountain.

Mallaparvata—It is the Parasnath hill in the district of Hazaribagh, three kilometres from the Isri railway station. It is a sacred hill for the Jains. It is the Mount Maleus of the Greeks.[1] It is also known as the Sametśikhara, Samidagiri and Samādhigiri.

Mahādeva—This hill as described by Hiuen Tsang was a small solitary double-peaked one. Here the Buddha overcame the Yakkha Vakula. According to some it was situated on the western frontier of Hiraṇyaparvata. To the west of it were some hot springs.[2]

Mandāra hills (also known as Mandāragiri and Mandarācalaṃ)—The *Kālikā Purāṇa* mentions this parvata (Ch. 13. 23). It was sacred to Śiva. Here Prithu died.[3] It is situated in the Banka sub-division of the district of Bhagalpur, 50 kilometres to the south of Bhagalpur, and five kilometres to the north of Bansi. This hill is about 200 metres high. The oldest buildings are the two temples, now in ruins. The Sītākuṇḍ tank is the largest.

Nāgārjuni hill—The Nagarjuni hill cave inscription of Anantavarman mentions the Nāgārjuni hill which is a part of the Vindhya range. It is situated about two kilometres away on the northern side of the village of Japhra which is about 25 kilometres to the north by east of Gayā.[4]

Patibhāṇakūṭa—It was a peak with a fearful precipice in the neighbourhood of the Gijjhakūṭa.[5] According to the Pali commentator Buddhaghosa it was a boundary rock which looked like a large mountain.[6]

Pāṇḍavaparvata—It may be identified with the modern Vipulagiri, north-north-east of Rājagṛha.[7]

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1. McCrindle, *Megasthenes and Arrian*, pp. 63, 139.
2. *J. A. S. B.*, Vol. LXI, Pt. I, 1892.
3. *Bhāgavatap.*, IV, 23-24.
4. *C. I. I.*, Vol. III, vide also *Khalatika hills*.
5. *Samyutta*, V, 448.
6. *Sāratthappakāsinī*, III, 301.
7. B. C. Law, *Rājagṛha in Ancient Literature, M.A.S.I.*, No. 58, pp. 3-(, 28-30.

Pāpahāriṇī—Name of a hill in Bihar. There is a beautiful tank at the foot of this hill, which is frequented by the people on the last day of the month of Paus, when the image of Madhusūdana is brought to a temple at the foot of the hill from Baṃśī. This tank was caused to be excavated by Konadevī, the wife of Ādityasena, who became the independent sovereign of Magadha in the 7th century, after the kingdom of Kanauj was broken up on the death of Harṣavardhana.[1]

Pārśvanātha—It is in the district of Hazaribagh, which is very frequently visited by the Jains. The height of this hill is 1,366 metres. It is a remarkably handsome mountain, sufficiently lofty to be imposing, rising out of an elevated country.[2] There is a Digambara Jaina temple on its top and some Śvetāmbara temples are found at its foot. This hill, also known as Sametśikhara, stands in a dense forest infested with wild animals. Pārśvanātha before his passing away came to the foot of this hill and attained salvation.[3]

The Buddhist and Jain remains exist on Kuluha hill in the Dantara pargana and a temple and tank to the west of the hill dedicated to Kuleśwarī, the goddess of the hill are visited by Hindu pilgrims in large number. The four rock-cut temples on Mahudi hill are worthy of mention. The ruins of temples on Mahudi hill are worthy of mention. The ruins of temples at Satgawan and an old fort at Kunda may be mentioned.

Pātharghāṭā—This hill is in the Bhagalpur district situated oh the bank of the Ganga. On the north of this hill there are some ancient rock sculptures. This hill also contains some caves. Some have identified it with Vikramaśilā.[4]

Pravaragiri—The Barabar hill cave inscription of Anantavarman refers to ancient Pravaragiri, situated on the northern side of the village of Panāri, about 22 kilometres to the north by east of Gayā, the chief town of the Gayā district.[5]

Rājmahaḷ Hills—These hills belong to the Santal Parganas in Bihar, inhabited by the Antargiryas, mentioned in the Bhīṣmaparva list of the *Mahābhārata*. The Antargiryas were the people dwelling on the outskirts of the hills of the Bhagalpur and Monghyr regions. It is also known as Kālakavana according to Patañjali.[6]

1. *C.I.I.*, III, 211.
2. For details—*B. and O. District Gazetteers*, Hazaribagh, 202 ff.
3. B. C. Law, *Geographical Essays*, p. 213.
4. *Bhagalpur*, by Byrne. *B. D. Gazetteers*, p. 171.
5. *C.I.I.*, Vol. III.
6. *Mahābhāṣya*, II, 4. 10 ; Cf. *Baudhāyana*, I, 1. 2.

Rohitāgiri—The Rohtāsgaḍh stone seal matrix of Mahāsāmanta Śaśāṅkadeva mentions the hill fort of Rohitāsgaḍh, 40 kilometres south by west of Sahasrām, the chief town of the Sahasrām sub-division of the Shāhābād district.[1] According to Rampal copper plate of Śrīcandra, the Candras were the rulers of Rohitāgiri, which may be identified with Rohtāsgaḍh in the Shāhābād district of Bihar.[2] Rohtāsgaḍh, the ancient hill fort of Rohtās, is named after Prince Rohitāśva the son of Hariścandra of the Solar dynasty.[3] It is also mentioned in the copperplates discovered from Orissa relating to a Tuṅga family. Both the Tuṅgas of Orissa and the Candras of East Bengal came from Rohitāgiri.[4] According to some Rohtās hill is a spur of the Kaimur range, a branch of the Vindhya mountain.[5]

Ṛṣigiri (Pali Isigili)—It is near Rājagṛha. It is one of the five hills encircling Girivraja, the ancient name of Rājagṛha.[6]

Śilā-saṅgama (or *Vikramaśilā-saṅghārāma*)—This hill contains seven rock-cut caves of a very ancient date with niches for the images of the deities mentioned by Hiuen Tsang, when he visited Campā in the 7th century A.D. Some have identified it with the Pātharghāṭā hill (vide *Vikramaśilā*).

Śuktimat range—It is identified by Cunningham with the hills south of Sehoa and Kanker separating Chattisgarh from Bastar.[7] Beglar places this range in the north of the Hazaribagh district.[8] Pargiter identifies it with Garo, Khasi and Tripura hills.[9] C. V. Vaidya locates it in Western India and identifies it with Kathiawar[10] range. Others have identified the Śuktimat with the Sulaiman range.[11] Some have applied the name to the chain of hills extending from Śakti in Raigarh, Madhya Pradesh, to the Dalma hills in Manbhum drained by the Kumārī river and perhaps even to the hills in the Santal Parganas washed by the afluents of the Bāblā.[12]

Vaibhāragiri (Pali Vebhāra ; Sans. Vyavahāra)—It is in Magadha. It is one of the five hills encircling the ancient city of Girivraja, 'a hill-

1. *C. I. I.*, Vol. III.
2. N. G. Majumdar, *Incs. of Bengal*, Vol. III, pp. 2 ff.
3. *Harivaṃśa*, Ch. 13.
4. *I. H. Q.*, II, 655-56.
5. N. L. Dey, *Geographical Dictionary*, p. 170 ; For further details vide *B. and O. District Gazetteers, Shahabad*, by O'Malley, pp. 174 ff.
6. *Vimānavatthu Commy.*, P. T. S., p. 82.
7. *A. S. R.*, XVII, pp. 24, 26.
8. *Ibid.*, VIII, pp. 124-25.
9. *Mārkaṇḍeyap.*, 285, 306 notes.
10. *Epic India*, p. 276.
11. *Z. D. M. G.*, 1922, p. 281 note.
12. H. C. Raychaudhuri, *Studies in Indian Antiquities*, pp. 113-20.

girt city'.[1] It extends southwards and westwards ultimately to form the western entrance of Rājgir with the Soṇagiri. In the Jaina *Vividhatīrthakalpa* the Vaibhāragiri is described as a sacred hill affording possibility of the formation of *kuṇḍas* of tepid and cold water (*taptaśilāmbukuṇḍam*). Buddhaghosa associates the hot springs giving rise to the Tapodā river with Mount Vebhāra. It is the same mountain as Vaihāra described in the *Mahābhārata* as a *Vipulaśila* or massive rock. The city of Rājagṛha shone forth in the valley of Vaibhāragiri with Trikūṭa, Khaṇḍika and the rest as its bright peaks. Some dark caves existed in this hill. Close to this hill were the Sarasvatī and many other streams flowing with pleasant waters with properties to heal diseases. The Buddhists built *Vihāras* on this hill, and the Jainas installed the images of the elect in the shrines built upon it. The Vebhāra and the Pāṇḍava appear to have been the two hills that stood on the north side of Girivraja and were noted for their rocky caves.[2] The Vaibhrāj is undoubtedly the Vaibhāragiri of Rājagṛha.

The Jains relying on a much later tradition thus locate the seven hills encircling Rājagṛha : If one enters Rājgir from the north the hill lying to the right is the Vaibhāragiri ; that lying to the left is the Vipulagiri ; the one standing at right angles to the Vipula and running southwards parallel to the Vaibhāra is the Ratnagiri ; the one forming the eastern extension of Ratnagiri is the Chaṭhāgiri and the hill standing next to the Chaṭhāgiri is the Śailagiri. The one opposite to the Chaṭhāgiri is the Udayagiri ; that lying to the south of Ratnagiri and the west of the Udayagiri is the Soṇagiri.[3]

Vaṃka—It was a mountain near Rājagṛha. Its older name was Vepulla.[4] It is mentioned in the *Jātaka* (VI, 491, 513, 520, 524-25, 580, 592).

Vebhāra—This hill is in the Magadha country. It is one of the five hills encircling Girivraja.[5]

Vediyaka—This hill is identified by Cunningham with the Giriyek. It contains the famous cave called Indasālaguhā.[6]

Vepulla—It is a mountain in Magadha. It was known in a very remote age by the name of Pācīnavaṃsa, which was later changed to Vaṅkaka.

1. Cf. *Vimānavatthu Commy.*, p. 82.
2. *Theragāthā*, XLI, v. 1.
3. Law, *Rājagṛha in Ancient Lit.*, *M. A. S. I.*, No. 68, p. 3.
4. See *Annals of the Bhandarkar Oriental Research Institute*, VIII, 164 ; Cf. *Samyutta*, II, 191-92.
5. *Vimānavatthu Commy.*, p. 82.
6. *Dīgha*, II, 263 ; *Sumaṅgalavilāsinī* III, 697 ; B. C. Law, *India as described in the Early Texts of Buddhism & Jainism*, p. 29.

It then received the name of Supassa, and afterwards it became known as Vepulla[1] and the people of the locality by the name of Magadhas.[2] It was one of the five hills encircling Rājagṛha. King Vessantara was banished to this hill. It took him three days to reach its summit.[3] The Vipula mountain runs for some length towards the south-east leading to the northern range of hills extending up to the village called Giriyek on the Bihar-sharif-Nawada road. Hiuen Tsang has definitely represented the mountain as *Pi-pu-lo*, which verbally equates with Vipula. He tells us that to the west of the north gate of the mountain-city was the Vipula mountain. He further points out that on the north side of the south-west declivity there had once been five hundred hot springs of which there remained at his time several, some cold and some tepid. The source of the streams was the Anavatapta Lake. The water was clear and the people used to come from various lands to bathe in the water which was beneficial to the people suffering from old maladies. On the Vipula mountain there was a tope where the Buddha once preached. This mountain is frequently visited by Digambara Jains.[4] The Vipula mountain is described as the best among the mountains of Rājagṛha.[5] It lay to the north of the Gijjhakūṭa and stood in the midst of the girdle of the Magadhan hills.

WESTERN INDIA

Brahmagiri—It is a mountain in the Nasik district near the Tryambaka in which the Godāvarī has its source.

Raivataka Hill—Raivata or Raivataka was near Dvārakā. It is mentioned in the *Mahābhārata* (Ādiparva, CCXIX, 7906-17) that a festival was held on this hill in which the citizens of Dvārakā took part. Pargiter is inclined to identify it with the Baradā hills in Jamnagar District.[6] In the Junāgaḍh Inscription of Skandagupta occurs the Raivataka hill which is opposite to Ūrjayat.[7] The Jaunpur stone inscription of Iśvaravarman Maukhari mentions it along with the Vindhya mountains.[8] Fleet has identified Raivataka with one of the two hills of Girnar

1. *Samyutta*, II, 190 ff.
2. Cf. B. C. Law, *India as described in the Early Texts of Buddhism & Jainism*, pp. 29-30.
3. *Vinaya Piṭaka*, II, 191-92.
4. Watters, *On Yuan Chwang*, II, pp. 153-54.
5. *Samyutta*, I, 67.
6. *Mārkaṇḍeyap*, p. 289.
7. See *Dohad Stone Inscription of Mahamuda in E. I.*, XXIV, Pt. V, Jany., 1938, p. 216.
8. *C. I. I.*, Vol. III.

and not with Girnar proper.[1] The *Bṛhatsaṃhitā* (XIV, 19) mentions it as situated in the south-west division. In early times Raivata and Urjayanta might have been names of two different hills at Girnar; but in later times they came to be regarded as identical.[2] The Raivataka in the *Dohat Stone Inscription of Mahamuda* refers to the hill on which there are temples and which is now known as Girnar.[3] Close to Junagadh in Gujarat stands the Raivataka hill or Girnar, which is considered to be the birthplace of Nemināth, the religious preceptor of king Dattātreya. The river Suvarṇarekhā flows at the foot of this hill. There is a foot-print on the Girnar hill known as the *Gurudattacaraṇa*. The temples of Nemināth and Pārśvanāth are found here. The name of Girinagara occurs in the *Bṛhatsaṃhitā* (XIV, 11). Girnar is famous in the inscriptions of Aśoka, Skandagupta and Rudradāman. To the east of Junāgaḍh there is a number of Buddhist caves. The Inscriptions of Rudradāman and Skandagupta inform us that at Girnar the provincial governors of Candragupta, Aśoka, and the Imperial Guptas lived. There is the Svayamvara lake near it. Here stands a high pinnacled temple of Neminātha on the summit of the Raivataka hill in Surāṣṭra.[4]

Ūrjayat—Ūrjyat (Ujjanta) of the Junāgaḍh Inscriptions of Rudradāman and Skandagupta may be identified with the Girnar hill near Junāgaḍh. This mountain is mentioned in the *Mahābhārata* (iii, 88, 23). The Kap Copperplate of Keḷadi Sadāśiva-Nāyaka refers to Ujjantagiri which is Girnar.[5] It is also known as Ūrjayatgiri.[6] In Luders' List No. 965 it is called Ūrjayat. This mountain which is sanctified by Śrīnemi is known as Raivataka, Ūrjayanta, etc. This mountain is situated at Surāṣṭra. Vastupāla built three temples here for the good of the world. In the temple of Satruñjaya built by Vastupāla there are images of Ṛṣabha, Puṇḍarika and Aṣṭāpada.[7]

Vaidūryaparvata—It is the Satpura range situated in Gujarat. the hermitage of the sage Agastya was on this hill.[8] It is so called because the costly stone of *lapis luzuli* is found here. The most important minor mountain associated with the Sahya is the Vaidūrya, which is generally identified with the Oroudian mountain of Ptolemy. It included

1. *Ibid.*, III, p. 64 n. 11 ; *I. A.*, VI, p. 239.
2. *Bombay Gazetteer*, Vol. VIII, p. 441.
3. *E. I.*, XXIV, Pt. V, p. 222.
4. For further details, vide B. C. Law, *Some Jaina Canonical Sūtras*, pp. 181-82.
5. *E. I.*, XXIV, Pt. V, Jany., 1938 ; Cf. Fleet, *Gupta Inscriptions*, *C. I. I.*, Vol. III, p. 60.
6. Cf. Junāgaḍh Inscription of Rudradāman.
7. B. C. Law, *Some Jaina Canonical Sūtras*, p. 180.
8. *Mahābhārata*, Vanaparva, Ch. 88.

the northernmost part of the Western Ghats, but the Mahābhārata suggests that it included also a portion of the southern Vindhya and the Satpura ranges.

Vindhyapādaparvata—The *Mahābhārata* refers to it as Vindhyaparvata (Ch. 104, 1-15). The *Padma Purāṇa* (Uttarakhaṇḍa, vv. 35-38) mentions it. The Vindhya forest attached to the mountain is described in the *Daśakumāracaritaṃ* (p. 18) as a wild wood full of terror, fit habitation for beasts and remote from the haunts of men. It is known as Quindon to Ptolemy. It forms the boundary between Northern and Southern India. The Ṛkṣa, the Vindhya and the Pāripātra are parts of the whole range of mountains now known as the Vindhya.[1] This mountain had a beautiful grotto (*kandara*) watered by the river Revā.[2] It occurs in Luders' List No. 1123.

This mountain, otherwise known as Vijha, may be identified with the Satpura range. On a spur of this range there is a colossal rock-cut Jaina image called Bawangaj.

Satruñjaya or Siddhācala—It is the holiest among the five hills in Kathiawar according to the Jains. To the east of it stands the city of Palitana, 110 kilometres north-west of Surat. The Satruñjaya temple was repaired by Bāghbhaṭṭadeva, an officer of king Kumārapāla in Gujarat. Of all Jain temples situated on the top of the Satruñjaya hill, Caumukha temple is the highest. Some inscriptions were found in the Jaina temples situated on the Satruñjaya hill.[3] Satruñjaya, also known as Siddhakṣetra, was visited by a large number of accomplished sages, such as Ṛṣabhasena. Many saints and kings attained the bliss of perfection. Here the five Pāṇḍavas with Kunti also attained perfection. This sacred place of the Jains is adorned with five summits (kūṭas). The cave lying to north of Śrimad-Ṛṣabha, set up by the Pāṇḍavas, still exists. Close to the Ajitacaitya lies the Anupama lake. Near Marudevī stands the magnificent caitya of Śānti. King Meghadhoṣa built two temples here. Śatruñjaya was under his rule and that of his father, Dharmadatta.[4]

CENTRAL INDIA.

Acāvaḍa (Accāvaṭa)—It is the Ṛkṣavat mountain where lived the banker Nāgapiya, a native of Kurara. It occurs in Luders' List Nos. 339, 348, 581 and 1123). The Ṛkṣavat is the Ouxenton of Ptolemy. It is a

1. Law, *Geographical Essays*, 107 ff.
2. *Mārakaṇḍeya Purāṇa*, Vaṅgavāsī Edition, p. 19.
3. *E. I.*, II, 34 ff.
4. For further details, vide Law, *Some Jaina Canonical Sūtras*, 179-80.

part of the whole range of mountains now known by the common name Vindhya. Ptolemy describes the Ṛkṣavat as the source of the Toundis, the Dosaron, the Adamas, the Ouindon, the Namados, and the Nanagouna. By the Ṛkṣavat or the Ṛkṣavant Ptolemy meant the central region of the modern Vindhya range, north of the Narmada.[1]

Amarakaṇṭaka—This hill is a part of the Mekhala hills in Gondwana in the territory of Nagpur in which the rivers Narmada and Son take their rise. Hence the Narmada is called the Mekhalasutā.[2] It is in Madhya Pradesh on the easternmost extremity of the Maikala range, 100 kilometres by country road from Sahdol railway station, 1,000 metres above sea-level. It is one of the sacred places of the Hindus.[3] The Amarakaṇṭaka is the Āmrakūṭa of Kālidāsa's *Meghadūta* (I, 17). It is also known as the Somaparvata and the Surathādri.[4] According to the *Matsyapurāṇa*, this sacred hill was superior to Kurukṣetra (22, 28 ; 186. 12-34 ; 188. 79, 82 ; 191, 25). The *Padma Purāṇa* (Ch. 133, v. 21) mentions a holy place named Caṇḍikātīrtha at Amarakaṇṭaka.

Arañjara—It is a chain of mountains in the Majjhimadesa. It is described here as existing in a great forest[5].

Aravalli—Some have identified this range with the Apokopa. It is perhaps the oldest tectonic mountain of India. It divides the sandy desert of western Rajasthan from the more fertile tracts of eastern Rajasthan.The range can be traced from Delhi to Jaipur as a low hill. Farther south the range becomes more prominent. Beyond Ajmer the height increases farther, the highest peak attaining the height of 1,732 m. The main range terminates south-west of the Sirohi district. The Aravalli range is pre-Vindhyan in age. The Arbuda (Mount Abu) which is separated from the Aravall range by a narrow valley is also pre-Vindhyan in age.[6]

Arbuda (Abu)—It is also called Ar-bu "the hill of wisdom" identified as the Mount Capitalia of Pliny. It is the Mount Abu in the Aravalli range in the Sirohi district of Rajasthan, 30 kilometres north-west of Abu Road on the Western Railway and 710 kilometres north of Bombay. It contains the hermitage of the sage Vaśiṣṭha and the famous shrine of Ambā Bhavānī. According to Megasthenes and Arrian the sacred Arbuda or Mount Abu is identical with Capitalia which attaining an elevation of 1,732 m rises far above any other summit of the Aravalli Range.[7] The river called

1. Law, Mountains of India, p. 17 ; Law, Geo. Essays, pp. 107 ff.
2. *Padma Purāṇa*, Ch. VI.
3. For details, vide B. C. Law, *Holy Places of India*, p. 34.
4. *Mārkaṇḍeya Purāṇa*, Ch. 57.
5. *Jātaka*, V, 134.
6. For details, vide *Imperial Gazetteers of India*, by W. W. Hunter, pp. 214-215.
7. McCrindle, *Ancient India as described by Megasthenes and Arrian*, p. 147.

Sābhramatī has its source in the Arbudaparvata.[1] There are many Jain temples here *e.g.*, the temple of Vimala Sah, dedicated to Ādinātha, the first of the 24 *Tīrthaṅkaras* of the Jains, the temple of Vastupāla and Tejapāla dedicated to Neminātha, the 22nd *Tīrthaṅkara*. The famous Jain temples dedicated to Riṣabhadeva and Neminātha on the Mount Abu deserve mention.[2]

Ābuyagrama[3]—It may be identified with Abu.

Bhawangajā Hill—Eight kilometres from the town of Barwani. A place of great sanctity among the Jains. Its name is derived from the popular idea of the height of the gigantic figure of Gomateśvara, a Jain teacher. It is visited by many pilgrims on the full moon of the month of Pauṣa (January).

Citrakūta—It has been identified by some with Citrakūṭa near Kālañjara in the Banda district. It is the modern Citrakoṭ or Caturkoṭ hill near Kampla in Bundelkhand. It is mentioned in the *Bṛhat-saṃhitā* (XIV, 13). It is also identified with Chitoor, the famous fort of which was captured from the Gurjara-Pratihāras by Kṛṣṇa III.[4] According to the Jaina *Padma Purāṇa* (summarized in Bengali by Chintaharan Chakravorti, p. 20), Rāma and Lakṣmaṇa came at the foot of the Citra-kūṭa hill in the Mālava country. Here the forest was so very thick that it was difficult to find out any trace of human habitation.

Harṣa—It is a hill on the top of which are found the ruins of an ancient temple. It is also called Uñchāpahar, which is near the village of Harṣanātha in the Shaikhāvatī region of Sikar district of Rajasthan about ten kilometres south of Sikar and 100 km north-west of Jaipur, where a stone inscription of Cāhamānā Vigraharāja of the Vikrama year 1930 was discovered.[5]

Kuraragharaparvata—It was in Avanti, Mahākaccāya once dwelt here. A lay female disciple named Kālī came to him and asked him to explain in detail the meaning of a stanza. He did so to her satisfaction.[6]

Mayūragiri—In the Barhut votive label (No. 28) occurs Mayūragiri, which is the Mayūraparvata referred to in the *Caraṇavyūhabhāṣya*. In

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1. *Padma Purāṇa*, Ch. 136. For further details, vide Law, *Some Jaina Canonical Sūtras*, pp. 184-85 ; *Rajputana Gazetteers*, Vol. III-A compiled by Erskine pp. 284 ff. ; *The Imperial Gazetteers of India*, by W. W. Hunter, Vol. I, pp. 2 ff.
2. For further details, vide Law, *Holy Places of India*, pp. 52-53.
3. *E. I.*, VIII, 222.
4. Vide *J. B. O. R. S.*, 1928, p. 481 ; H. C. Ray, *Dynastic History of Northern India*, Vol. I, p. 589, for epigraphic references.
5. *E. I.*, II, 116 ff.
6. *Aṅguttara*, V, pp. 46-47.

Luder's List (Nos. 778, 796, 798, 808, 860) occurs the name of a place called Moragiri (Mayūragiri). Some have placed it in Madhya Pradeśa.

Pāripātra Mountains—It is, according to Baudhāyana's *Dharmasūtra* (i. 1. 25), the southern limit of Āryāvarta. According to the *Skanda Purāṇa*, it is the farthest limit of Kumārīkhaṇḍa, the centre of Bhāratavarṣa. The mountain seems to have lent its name to the country with which it was associated. Pargiter identifies the Pāripātra mountain with that portion of the modern Vindhya range, which is situated west of Bhopal together with the Aravalli mountains.[1]

Ṛkṣavat—Ṛkṣavat is the ancient name of the modern Vindhya mountain. It is called by Ptolemy Ouxenton. Ptolemy describes this mountain as the source of the Toundis, the Dosāran and the Adamas. According to Ptolemy, the Dosaran is said to have issued from the Ṛkṣa. By the Ṛkṣa he meant the central region of the modern Vindhya range north of the Narmadā.[2]

Udayagiri—It is noted for the rock cut temples excavated in an isolated sandstone hill. The Udayagiri cave inscription of Candragupta II mentions this well-known hill with a small village of the same name on the eastern side about three kilometres to the north-west of Vidisha.[3] According to some, this hill stands 7 kilometres north-west of the Vidisha railway station. This ancient site is situated between the Betwā and the Besh rivers. It contains caves which are twenty in number. The region in which this hill is situated, was formerly known as Daśārṇa or Dasaṇṇa of the early Buddhist canon. Dasaṇṇa is generally identified with the region round modern Vidisha. The hill of Udayagiri is about 2 kilometres in length, its general direction being from south-west to north-east. Vedisagiri where Mahendra, son of Aśoka, stayed with his mother in a monastery before his departure for Ceylon, might probably be the same as this Udayagiri hill. The Cave No. 5 is the most important of the Udayagiri caves from the sculptural point of view. It contains the scene of Varāha inscription. The Cave No. 6 contains the sculptural representations of the two Dvārapālas, Viṣṇu, Mahiṣamardinī, and Gaṇeśa. The Udayagiri caves contain twelve inscriptions of which the four are the most important. The inscription in the Cave No. 6 discloses that the Sanakānikas occupied this region.[4]

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1. Law, *Mountains of India*, pp. 17-18 ; Law, *Geographical Essays*, 115 ff.
2. Law, *Mountains of India*, p. 17.
3. *C.I.I.*, Vol. III.
4. Vide D. R. Patil, *The Monuments of the Udayagiri hills*, published in the Vikrama Volume, ed. by Dr. R. K. Mookerji, 1948, pp. 377 ff. ; Luard, *Gwalior State Gazetteer*, I, p. 296.

Vediśagiri—It was a mountain on which the Vediśagiri-mahā-vihāra was built by Mahinda's mother. According to the *Samanta-pāsādikā* (p. 70) Mahinda stayed here and from this place he went to Tam-bapaṇṇi.

CHAPTER II

THE HIMALAYA MOUNTAIN : ITS ORIGIN AND GEOGRAPHICAL RELATIONS*

One of the most clearly established facts of geological science tells us of a sea which girdled India along its north face through vast aeons of time—a true mediterranean sea, which divided the northern continent of Eurasia (known as Angaraland) from a southern continent of more or less uncertain borders, but which united within its compass the present disjointed peninsulas of Africa, Arabia, India and Australia (known as Gondwanaland).

THE RISE OF THE HIMALAYA :

The rise of the Himalaya from the floor of this mediterranean sea, the Tethys, is an epic of the geological history of Asia. All the relevant facts of this event are well dated and documented in the rock-records of these mountains. The thousands of metres of marine sediments laid down on the bed of this sea, from the Upper Carboniferous to the Eocene with their characteristic entombed fossils indicative of the successive ages of deposits, were subjected to protracted compression during later Tertiary ages, as in a vice, between the two stable continental blocks of peninsular India to the south and the tableland of Tibet to the north. The uplifting of the Tethys floor resulting from this compression, its exposure to atmospheric agents and the sculpturing of time have produced the youngest, largest and highest chain of mountains in the world, a chain that is probably still growing in altitude.

The rise of the Himalaya from the mediterranean sea-bed was not a single event but there were three distinct and widely separated phases of uplift. The earliest phase was post-Eocene. A few patches of the Eocene nummulitic limestone, a highly certain landmark in geological history, are found at Kashmir, Hundes and several parts of Eastern Tibet, capping the pile of marine sediments that had been growing on the ocean floor since the Upper Carboniferous. This is the last record left by the Himalayan sea before it vanished. These Eocene rocks now occur at elevations from 4,500 to 6,000 m. The next upheavals took place at the

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end of the Miocene epoch, which also involved and lifted the sediments laid down by rivers in estuaries along the flanks of the embryonic mountain chain ; these today form the Middle or Lesser Himalaya ranges. The last movement did not commence till after the very end of the Tertiary and involved the foothills zone of Siwalik deposits, a system of strata as new as the Middle Pleistocene and containing within its tilted beds some relics of early man in India. There is a body of competent evidence, both physical and biological, to indicate that parts of the Himalaya have risen at least 1,500 m since the Middle Pleistocene. Early man thus witnessed the growth of this northern barrier interfering more and more with his migrations and intercourse across the steppes of Asia. A great ethnic watershed thus came into being early in human history.

Let us try to realise the geographic significance of this earth-feature that for 26 degrees of meridian presents a wall of 6,000 m mean elevation. Standing in the path of the prevalent equatorial wind currents, one can easily imagine what dominating influence this chain must have on the water and air circulations of Asia, on its climate and physiography, and through these on the distribution of life on the continent.

GEOGRAPHICAL RELATIONS :

This mighty range, 2,400 kilometres long and 250-400 km wide, with a mean elevation of the central axial range of 6,000 m forms by far the largest feature in the geography of Asia, if not of the world. The Himalaya is not a single continuous chain or range of mountains, but a series of more or less parallel or converging ranges intersected by enormous valleys and extensive plateaus. Connecting the Himalaya with the other ranges of High Asia, and acting like girders in the structural framework of the continent, are the Hindu Kush, the Karakoram, the Kun Lun, the Tien Shan and the trans-Alai ranges, bound in the knot of the Pamir (Persian *Pa-i-Mir*, Foot of the Eminences). From the Pamir, 'the roof of the world', to the borders of China, Tibet and Burma, the Himalaya extends as an unbroken wall of snow-clad ranges, pierced by passes only a few of which are less than 5,000 m in height. To the north is the block of High Asia, the biggest and most elevated land-mass on the earth's surface, of which the plateau of Tibet (4,500 m mean altitude), the highest inhabited region of the world, is only a part. Sinkiang, the Gobi and Mongolia are the other parts.

For geographical purposes, the long alignment of the Himalayan system has been divided into : the Punjab Himalaya from the Indus to the Sutlej, 560 km long ; Kumaun Himalaya from the Sutlej to the Kali, 320 km ; Nepal Himalaya from the Kali to the Tista, 800 km ; and the Assam Himalaya from the Tista to the Brahmaputra, 720 km long. Longitudinally, the system is classified into three parallel zones differing from one another in well marked orographical, hydrographical as well as vegetational features ; (i) the Great Himalaya, composing the innermost line of high ranges of perpetual snow; their average height is 6,000m carrying the peaks Everest (8,848 m), Kanchenjunga (8,598 m), Nanga Parbat (8,126 m), Nanda Devi (7,817 m), Namcha Barwa (7,756 m), etc. (ii) the Middle Himalaya—a series of ranges closely related to or bifurcating from the former, of mean elevation of 3,700-4,500 m ; their average width is about 80 km ; and (iii) the Outer Himalaya or the Siwalik ranges, which intervene between the Middle Himalaya and the plains of the Indus and Ganga ; they are of varying width from 10-50 km, and form a system of foothills of average height 900-1,200 m.

RIVER SYSTEMS :

The drainage system of the Himalaya, composed of rivers and glaciers, is of a eomplex nature. The most important fact to be realised regarding the drainage is that it is not, in a large measure, a consequent drainage, that is, its formation was not consequent upon the relief of the mountains, but there is clear evidence to show that the principal rivers of this area were of an age anterior to them. In other words, many of the great Himalayan rivers, the Indus, the Sutlej, the Bhagirathi, the Alaknanda with the other tributaries of the Ganga system, and the Brahmaputra are older than the mountains they traverse. During the slow process of mountain-formation by the folding and upheaval of the rock-beds, the old rivers kept very much to their own channels although working at an accelerated rate. The great momentum acquired by this upheaval was expended in eroding their channels at a faster rate. Thus the elevation of the mountains and the erosion of the valleys proceeding *pari passu*, the mountain-chains emerged with a completely developed valley system, cutting it in very deep transverse gorges. These deep gorges of the Himalaya are a highly characteristic feature of these mountains. This circumstance of antecedent drainage of the Himalaya explains the peculiarity that the great rivers drain not only the southern slopes of these mountains but to a large extent the northern Tibetan slopes as well, the watershed of the chain being not along its highest peaks but a great distance to the north of it. This drainage of the northern slopes flows for a time in longitudinal valleys through Tibet, parallel to the mountain chain, *e.g.*, the Indus, the Sutlej and the Brahmaputra. But these rivers invariably take an acute bend and descend to the plains of India by cutting across the mountains in the manner described above. These transverse gorges of the Himalaya are often thousands of metres (3,000-5,000 m) in depth from the crest of the bordering precipices to the beds of the rivers.

GLACIERS :

The snow-line, the lowest limit of perpetual snow, on the southern slopes of the Himalaya facing the plains of India, varies from 4,300 m in the eastern Himalaya to about 5,800 m in the western. On the opposite Tibetan side the snow-line is about 900 m higher, owing to the desiccations of that regions caused by the absence of moisture-bearing winds. The Great Himalaya Range is the gathering ground of snow, nourishing a multitude of glaciers, some of which are among the largest in the world outside the Polar Circles.

Though a majority of the Himalayan glaciers are three to five kilometres in length, there are giant ice-streams 30 km and upwards, such as the Milam and the Gangotri glaciers of Kumaun, and Zemu draining the Kanchenjunga in Sikkim. The largest glaciers of the Indian region are those of the southern face of the Karakoram, discharging into the Indus —the Hispar and the Batura, 58-61 km long—while the Biafo and the Baltoro glaciers of the Shigar, a tributary of the Indus, are about 60 km in length. The lowest limit of descent of the glaciers is very variable ; while in the eastern part of Assam and Nepal the glaciers move hardly below the level of 4,000 m, those of Kumaun and Kashmir Himalaya descend to 3,600 m in the former and 2,500 m in the latter.

GEOGRAPHICAL LIMITS :

The exact topographical limits of the Himalaya outside the bounds of India proper are yet undefined and are a subject of controversy. According to general belief, the Himalaya terminates to the north-west at the great bend of the Indus near Gilgit, and at the other end in the south-east at a similar bend of the Brahmaputra in Upper Assam. Both geographers and geologists have refused to accept this limitation of the Himalaya because, to them, this theory ignores the essential physical and structural unity of the ranges beyond the Indus and Brahmaputra rivers.

The convex arcuate trend-line of the Himalayan chain has a great bearing on the mode of origin and formation of this mountain system. For 2,400 kilometres from Assam to Kashmir, the chain follows a southwest-east-west-northwest direction and then appears to terminate suddenly at one of the greatest eminence on its axis—Nanga Parbat (8,126 m). Detailed geological studies of the structure and stratigraphy of this area have shown that just at this point there is a great acute bend of the axis of the whole mountain system, which turns sharply to the south and then to the south-west, passing through Chilas and Hazara instead of pursuing its north-west trend through Chitral towards Afghanistan. This extraordinary bend (called syntaxis) affects the whole breadth of the mountains from the foothills of Jamnu to the Pamirs. At the eastern limit of the Himalaya beyond Assam there is a similar deep knee-bend from an easterly to an abrupt south-westerly trend, away from China. As stated above, these remarkable inflections as well as the arcuate shape of the mountain with their convexities facing India are significant and throw light on the mechanism of mountain-building. It is interpreted as a consequence of the reaction of the weakened and overloaded Tethyan zone of sedimentation, compressed between the two stable crust-blocks of Tibet to the north and the Deccan to the south. As the mountain-building pressures from the north impinged on the recently elevated pliable mass of Tethyan sediments and thrust them over and against the triangular resistant block of the Deccan, they acquired this curvilinear arcuate form. The system of earth-waves and folds as they emerged from the Tethyan sea had to mould themselves on the capes and projections of the triangle of the Deccan shield acting like a nail or pivot in the earth's crust.

METEOROLOGICAL INFLUENCE :

The Himalaya exercises as dominating an influence on the meteorologic conditions of the Indian sub-continent as over its physical geography, vitally affecting its air and water circulation system and, through these the distribution of life on the sub-continent, its migrations and intercourse. The high snowy ranges have moderating influence on the temperature and humidity of Northern India. By reason of its altitude and situation directly in the path of the monsoons, it is most favourably conditioned for the precipitation of all their contained moisture either as rain or snow. Snow-fields and glaciers of enormous magnitude are nourished on the higher ranges which, together with rainfall in the Middle Himalaya feed a number of noble perennial rivers which course down to the plains in hundreds of fertilizing tributaries. In this manner the Himalaya has been a contributing factor in the desiccation which is overspreading Central Asia and the desertic conditions that inevitably follow continental desiccation. The most significant recent instance of this effect is the vast desert tract of Tibet and the Tarim basin to its north, the latter occupying an area as large as the Indo-Gangetic plain ; these are some of the most desolate regions of the world today. It is a well-known fact that these deserts are all recent ; in the case of the Takla Makan, in the Tarim depression, of late historic growth. These once fertile and well-forested regions have been fighting against adverse climatic conditions since the end of the Glacial period, and though they succeeded in preserving the remnants of their forests and cultivation even to such a late age as the early centuries of the Christian era, they have since steadily succumbed. The increasing desiccation of this area, generally admitted to be in a material way connected with the rise and interposition of the lofty mountains on their mouth, has had its full toll on the river system which, once extensive and well-developed, has decayed and withered to such an extent that the few existing rivers lose themselves entirely in the growing sands and surface debris which they are wholly powerless to sweep away. The Kun Lun glaciers are wasting away and their vast reservoirs of ice are retreating. The perennial north-flowing rivers which they once supported and disappear near the foot of the mountains, either in the piedmont gravels or in the shifting dunes of Takla Makan, the immense waterless waste of sand that has replaced the once fertile, lowland stretch of Khotan and Sinkiang. The water brought by the monsoon winds is turned back to India by the Himalayan and trans-Himalayan affluents of the Indus, Ganga and Brahmaputra systems. Thus Northern India is saved from the gradual desiccation that has overspread Central Asia since early historic times.

FORESTS :

In the physiography of the Himalaya, forests form an important element. The zonal distribution of forest vegetation from the outer foot-hills, through the Middle Himalaya to the central ranges, is determined wholly by the altitudinal factor but bed-rock, soil and other edaphic factors exert quite a considerable influence. The altitude determines the sub-tropical, temperate and alpine zones of vegetation as one moves from the submontane tracts to the snowy ranges. The highest limit of forest growth in the more humid eastern Himalaya of Sikkim, Bhutan and Assam is 4,600 to 4,900 m and in the drier Kumaun and Kashmir Himalaya the highest limit of tree growth is 4,000 to 4,200 m. Beyond this altitude trees and shrubs disappear and the mountains assume a rugged wind-swept and frost-bitten character. They present an aspect of desolate snow-bound altitudes and long dreary wastes of valleys, depressed lands and plateaus, totally different from the soft, soil-clad harmony of the middle ranges, green with their cover of forest and cultivation. The rainfall steadily diminishes to almost total absence of any rain in the districts lying at the back of the Kashmir and Nepal high ranges, which in their bleakness and barrenness partake of the character of Tibet.

MINERAL PRODUCTS :

Though a great extent of the inner Himalaya has yet remained unexplored and is *terra incognita* to geologists, from what has been known so far of the surveyed areas of these mountains it is apparent that over wide stretches there are few deposits of minerals and ores of any commercial value. Productive mineral occurrences so far located are on a moderate scale in Kashmir, Nepal and Sikkim. The best-known of these are three Tertiary coalfields, bauxite deposits and some zinc in the Jammu sub-Himalaya, lignite in the Kashmir Valley, copper ore in Sikkim and hitherto imperfectly known cobalt and nickel ore occurrences in Nepal. Some antimony deposits in Lahul and fairly extensive magnesite occurrences in the Kumaun Himalaya have been mapped. Exploration for petroleum in the outer Tertiary fringe has met with some success in Western Punjab, and Assam has two or three productive coalfields. Of late, radiation surveys have revealed significant patches of uranium mineralization in the ancient crystalline rocks of the Kulu and Garhwal Himalaya.

CHAPTER III

THE PHYSIOGRAPHICAL AND STRUCTURAL EVOLUTION OF THE HIMALAYA.

Physiographically, the Himalaya can be divided into four well marked orographic units :

1. Sub-Himalaya or the Outer Himalaya of the Siwalik range,
2. Lesser or Middle Himalaya,
3. Great or Inner Himalaya,
4. Trans-or Tibetan Himalaya.

The Sub-Himalayan zone of the Siwalik ranges lies in between the Indo-Gangetic plains and the Lesser Himalaya. These are chiefly composed of Tertiary sediments and are related to the latest phase of the Alpine-Himalayan Orogeny. The Siwalik range makes almost a continuous chain and is spread for more than 2,400 km from the Indus gorge in the NW to the river Brahmaputra in the NE of Assam, parallel to the Himalayan arc. A small gap of 80-90 km between the rivers Tista and Raidak of the Assam Himalaya cuts through the Siwalik or the outer Himalayan range. The Siwalik zone is of varying width from 10 to 50 km, and its heights seldom exceed 1,300 metres. This belt is generally marked by an abrupt lowering of heights from the Lesser Himalaya, except in the eastern part where it has no physiographic individuality but forms the foothill zone of the Lesser Himalaya. A large portion of the Siwaliks or the Sub-Himalaya is at places separated from the Lesser Himalaya by flat bottomed valleys, termed *duns*, which are covered by thick gravels and alluvium. The best example of such valleys is furnished by the Dehra Dun valley lying in between the rivers Yamuna and Ganga and many others like Kota, Patli, Kiarda and other duns, mainly in Nepal.

The Lesser Himalaya is approximately 60 to 80 km in width. It forms the southern boundary of the Great Himalaya range. The heights range between 2,000 metres and 3,300 metres. The zone mainly comprises the unfossiliferous Purana, Palaeozoic and Mesozoic formations and "consists chiefly of four branches issuing obliquely from the Great Range" to quote Pascoe (1964). The Pir Panjal and the Dhaola Dhar ranges of the Kashmir-Punjab Himalaya are parallel but in the Garhwal-Kumaun region these are irregularly scattered and do not show any alignment. These oblique branches generally decrease in heights from their proximal end, and consist of (i) Nag Tibba, given off from Dhaulagiri ; (ii) Dhaola Dhar from the neighbourhood of Badrinath ; (iii) the Pir Panjal (the largest of the lesser ranges), from the Sutlej gorge ; and (iv) North-Kashmir range from the Zoji La, which separates the Jhelum and the Kishenganga rivers. In the Nepal region, the outer three parallel ranges stretching from Kanchenjunga to W. Nepal form the Mahabharat range. The Mussoorie range between the Ganga and the Sutlej and the Rattan Pir in the south-western Kashmir are also important.

The Great Himalaya—the highest range, forms a single mountainous chain generally covered with snowy peaks. Mostly it is composed of granites and gneisses with some sedimentary horizons in between. Some of the highest peaks of the Himalaya, *i.e.*, the Kula Kangri (7, 539 m) and and Chomo Lhari (7,314 m) of Bhutan, Mt. Everest (8,848 m), Kanchenjunga (8,598 m), Makalu (8,481 m), and Dhaulagiri (8,172 m), of Nepal, Nanda Devi (7,817 m) and Bunderpunch (6,315 m) of Kumaun and the Nanga Parbat (8,126 m) of Kashmir lie in this zone.

The Tibetan Himalaya or the Trans-Himalayan zone is approximately 40 km in width. It lies behind the Great Himalaya and is at places cut by the south flowing rivers with their basins at an altitude varying between 3,000 to 4,300 metres. This zone is made up of highly fossiliferous sedimentary formations ranging from Palaeozoic to the Eocene times.

Glaciation and Glaciers :

The Himalayan glaciers are not constant in length but are considered to be gradually receeding, and the rate of decrease in their sizes is so irregular that no general rule can be applied to them. The study of the diurnal motions of different glaciers has revealed that their velocity per day varies from 8 cm to 13 cm on the sides to between 20 and 30 cm in the middle. According to Wadia, Professor K. Mason studied the Himalayan and the Karakoram glaciers in detail who concluded that the climate does not govern the velocity of glaciers which is controlled mainly by the topography of the region. Mason further observes that the velocity varies from three cm to several cm per day, and observes that not a single glacier either of the Himalaya or of the Karakoram show any definite cyclic or periodic variations in their velocities. On the basis of their nature and the extent of glacial activity, as indicated by the movement of the snouts, Wadia (1961) concludes that "these glacial movements may be due to causes which are in distinct cases, secular, periodic, seasonal, or accidental".

The Karakoram glaciers are larger than the Himalayan glaciers even though the present day snowfall is insufficient to feed them. On this basis and on the basis of the indications of the Palaeo-glaciers, left over the areas now devoid of ice, it is thought that the present day numerous glaciers, snow fields and ice sheets of the Himalaya can be considered as the "withered remnants of an older and much more extensive system of ice-flows and snow-fields which once covered Tibet and the Himalaya".

The occurrence of ancient glacial moraines at low levels and the smooth plained or grooved surfaces on the tops and sides of some of the Middle Himalayan ranges are significant at an altitude of about 2,160 metres in the Pir Panjal. In addition, (a) the terminal moraines, (b) U-shaped valleys at the heads of cirques around Everest, Makalu and Trisuli regions in Nepal, Badrinath and Kedarnath regions in Garhwal, Tirichmir and Mt. K_2 in Gilgit, (c) typical cirque like amphitheatres with steep cliff faces at low levels in Punch, (d) high level river terraces and the old silted up lakes in Kashmir and (e) the presence of fluvio-glacial drifts at much lower levels in Punjab and Garhwal-Kumaun regions, again lead one to conclude that the Himalayan region has been affected by at least one glacial age and spasms of upheavals probably during the Pleistocene times.

Fluvio-Glacial Terraces : All through the Himalaya and particularly in the river valleys many deposits of gravels and sands at different levels are common feature. Some of these are considered comparable to the Siwalik boulder formations while others are of Pleistocene and recent times. In 1890 Middlemiss studied several boulder terraces above the Ramganga valley in the Kumaun-Garhwal region and reported that the recent gravels, cut by the river, lie inclined over the slightly elevated river banks of the older gravels, covered with thick vegetation. He further added that the still older terraces are also seen above the younger terraces in the form of long flat steps one over the other and most of the level portions of the 'Dun gravels' which in turn lie over the northerly gently dipping Upper Siwalik conglomerates and gravels, which again flatten out beneath the younger gravels. To this feature he pointed out that the present Ramganga has cut its valley through several stages and each of the older terraces were a fore-runner of the present river. Later he and other workers have described many more terraces of gravels at varying altitudes in the valleys of the river Indus, Sutlej, Yamuna, Ganga, Kosi and many others.

In the Kashmir-Punjab Himalaya, the Kulu Valley, the Beas and the Spiti valleys are characterised by very well developed river terraces. In the Spiti valley often a series of five river terraces are observed.

Similarly at Balwakot in Kumaun, the terraces of the Kali river are well developed. Here the lower terrace occurs at 15 metres above the river and is dissected in the form of a vertical wall. This is followed by another terrace at about 60 metres above the river, while a third is supposed to be at about 300 metres above the river level.

Similarly, east of the Tista river five gravel beds rising to a height of 92 metres have been noted by Heim and Gansser (1939). Of these, the upper most and the middle terraces are fairly well developed. Similar terraces have also been marked east of the Jaldhaka river with high cliffs towards the west. Here the original southern slope has tilted to develop a level platform at least 350 metres high and the river has made a down cutting of at least 137 metres through the Nagrakata terrace. Further west, along the Murti river, a tributary of the Jaldhaka at Sam Sing the slope of the river bed rises rapidly towards the mountain side normally at 5° and at times even upto 10° while a terrace occurs at a height of 130 metres above the river. This has been compared with the middle terrace of Nagrakata and considered that these terraces of river Murti are either the continuation of the Nagrakata plateau or they are slightly higher stratigraphically (Heim and Gansser, 1939). Many other terraces of the Tehri-Garhwal and Joshimath regions in Upper Garhwal are a common feature of the Ganga-Yamuna system. The river terraces are not only limited to the Himalaya but are common features all through even in their extension in Hindu Kush, Sulaiman Range of Baluchistan and Assam regions. In the western regions the series of terraces lie one over the other and are a dominant feature along the rivers of Hazara District, filling broad valleys, *e.g.* the Haripur plain, the Dori valley, the Abbottabad plain, to a depth of 90 metres or even more.

It has been already stated that there are good evidences of extensive glaciation during the pleistocene period of which some of the present glaciers are the remnants. Enormous heaps of ground and terminal moraines with striated and polished boulders embedded in glacial clays, tills and gravels of heterogeneous composition have been noted in various parts of the Himalaya, *e.g.*, in the Haramukh mountain in Kashmir at the height of 1,680 metres, in the Sind and Lidar valleys at a height of 2,280 metres, in the Pir Panjal at a height of 1,980 metres, and on the southern faces of the Dhaola Dhar range at a height of 1,430 metres. In the Kangra valley, the famous Kangra fans composed of huge boulders of the Dhaola Dhar granites are laid at levels as low as 910 metres. It is believed, though not fully confirmed, that these huge granitic masses have been laid by glacial action. Besides these, as discussed later, many lakes of Kashmir, Ladakh, Kumaun and Garhwal regions occurring at differant heights are due to glacial origin and are indirect evidences of large scale glaciations and upheavals. The sudden extinction of most of the Siwalik mammals after the Pleistocene times gives an additional evidence of an 'Ice age' in this part of the Indian sub-continent.

As recorded by de Terra, at least four inter-glacial periods can be recognised in the Pleistocene deposits of the upper Sind and Lidar valleys of Kashmir. These glacial moraines are indicated by the oscillations of the glacial and inter-glacial sediments characterised by carbonaceous beds, cross bedded and varved clays with erratic boulders and fossils comparable to the lower Karewa beds of Kashmir and sometimes the boulder conglomerates with the river terraces of the Kashmir valley. Similar characters have also been noted recently by many workers in the upper reaches of the rivers Sutlej, Alaknanda, Bhagirathi and their tributaries in the Garhwal region. Krishnaswamy (1965) and Kaushic (1965) have concluded that the Himalaya has gone through four to six upheavals. Similarly, Bordet (1961) thinks that the Kathmandu valley has been affected by several upheavals and upwarpings. The occurrences of such widespread features with intermittent characters are indicative of upheavals during Pleistocene and Pliocene periods. These features are summarised by Wadia (1961) and is reproduced in Table I.

TABLE I
(Modified after Wadia, 1961)

Period		Glacial Stages in Siwaliks	Glacial Cycle in Kashmir
PLEISTOCENE	Upper	Re-deposited silt	4th ice advance. Terminal moraine at 2,400 to 3,000 metres.
		Erosion	3rd Interglacial erosion.
	Middle	Potwar; yellow, loose-like silt and gravel.	3rd ice advance : 3-4 recessional moraines Terminal moraines at 2,000 metres.
		Erosion	Long 2nd Interglacial Upper Karewa beds erosion.
	Lower	Boulder conglomerate stage	2nd ice advance : boulder clay and gravel in Karewa beds.
		Pinjor Stage	1st Interglacial ; lower Karewa beds, birch ; oaks, pine-forest.
		Tatrot Stage	1st ice advance. Terminal moraine at 1,700 metres.
Pliocene		Dhok Pathan Stage	

The Significance of the Karewa beds : The Karewa series of the Kashmir valley, as described by de Terra (1939), Middlemiss and Wadia (1941 and 1961), is a very significant unit and may be helpful in deciphering the physiography and the stratigraphy of Kashmir Himalaya. The Karewa beds extend for about 80 km in length and vary from 5 to about 25 km in width.

Lithologically, the series is made up of blue, grey and buff silts, compact sands and conglomerates. At least four embedded glacial moraines can be recognised in the Pir Panjal between Banihal and Baramula at different levels, the height being at 3,800 metres from the sea level. The beds are separated by an erosive unconformity in two series, the Lower and the Upper Karewa beds. The Lower Karewa beds are folded and denuded on tops of two anticlines. Though the total thickness of the series exceeds 2,330 metres, the true thickness is difficult to estimate owing to their folding and denudation. The Upper Karewas are generally horizontal beds of fine blue sandy clays, loams and sands with lenticles of conglomerate. The occurrence of varved clays of the glacial moraine even at the height of upto 3,800 metres above sea level and of the local dips even to 40° with monoclinal bends, all point to oscillations even in the glacial times. Further, the workable seems of lignite at a few locations in the top beds allow one to infer that the Pir Panjal has been elevated through upheavals after the deposition of the Karewas.

During the Pleistocene and Recent times the base level of the river systems have gone down as a result of glaciation and spasms of uplifts—thus causing an increase of gradients in their courses. The increase in gradients have also resulted in an increase of the erosive capacity of the rivers resulting in a rapid dissection of the ancient valley bottoms. Further the reported moraines and the terraces all along the valleys of Kali at Malpa in Kumaun at a height of 2,150 metres, on the Goriganga at a height of 2,000 metres and on the Alaknanda at a height of 2,030 metres above sea level indicate the movements of the past glaciations during the Pleistocene glaciation.

Himalayan Rivers :

The drainage and the development of the watershed in the Himalaya are not simple. It can be imagined that initially the drainage system should have originated in the Great Himalaya, but the main drainage arises either in the northern plateau of the Tibetan Himalaya or originates at the southern faces of the Lesser or the Great Himalaya. This phenomenon has been attributed to the popularly known "antecedent drainage" or the simultaneous development of river systems along with the orogenic processes *i.e.*, the rise of the Himalayan chains. Another hypothesis used to explain the phenomenon is headward erosion or 'river piracy'.

Antecedent Drainage : According to this view, the rivers were already in existence before the rise of the Himalayan mountain chains and flowed from the higher Tibetan plateau to the Indo-Gangetic plain. This trend continued through the orogenic processes forming the ranges of the Himalaya and deep transverse gorges were cut in these ranges *pari passu* with the upheavals of the land masses, and the building of the mountain chains. Rivers like Indus, Sutlej and Brahmaputra are accepted as the best examples of this process.

Of the rivers of the Ganga Syetem only a few have their sources in Tibet, which may be considered as antecedent. River Arun of Nepal is cited as an example of antecedent drainage in this region. This river rises at a height of about 7,400 metres, and after dropping at 4,650 metres, it becomes a "braided river" flowing eastward through a valley flanked with terraces of gravels. At about 4,340 metres, it abruptly cuts through the schists in the small Yori gorge. After flowing for a short distance in a valley it runs again through the long and deep gorges lying between Mt. Everest and Kanchenjunga, and emerges at an altitude of about 1,335 metres. Some of the Indian Geologists believe that the Arun gorge is an antecedent one, but Wager (1937), based on his observations in 1933 concluded that the course of the rivers was established long ago on a "mountain slope which formed the descent from the Tibetan plateau to the Ganges plain" or the sea. On the basis of the dips of 15° at the higher terraces and 5° at the lower, Bordet (1961) suggests that the mountains are probably still rising against the down cutting of the river Arun and believes that the movements are "still in progress".

Holmes (1964) however considers that these antecedent rivers have not maintained their courses continually against the rise of the mountain chains, a few of which are "anteposed". This was probably attained irregularly and at times, when the "uparching" of the Himalayan branches was fairly active in order to check the flow and thus "pond-back the rivers" until they overflowed and resumed their downward erosion.

An example of this type can also be considered to be the Kathmandu Valley. This valley is floored with sediments similar to the infillings of a lake and the region has the form of "an amphitheatre surrounded by spurs" of Middle Himalaya and the Mahabharata range in the south. The upper Baghmati and its tributaries show a notable example of centripetal drainage and there is only one exit for the Baghmati (lower), that is, through a deep gorge cut across the Mahabharat range.

River Piracy : The other view on the development of drainage and the shifting of the water divide takes note of the varying amount of rainfall in the different regions of Himalaya. Due to the direct showers of the monsoons, there is much more rainfall on the southern faces of the

Himalaya as compared to the northern side of the massif or the Tibetan highlands. Also the rainfall is far greater in the eastern parts than the western Himalaya. As such, the rainfall is maximum in the Assam and NEFA regions and gradually decreases to the west and north. In the Tibet, Kashmir, Hazara, Gilgit and Baluchistan the rainfall is scanty, and the erosion due to rain or running waters is less significant here than on the southern slopes of Great Himalaya.

As a result of this, it is argued that the north flowing rivers in Tibet and Sinkiang have little chance of cutting the Great Himalaya by headward erosion than the south flowing rivers, and the latter therefore capture the north flowing ones due to their rapid headward erosion, *i.e.* "River Capture or Piracy". According to Pascoe (1964) the Lachen river to the east of Kanchenjunga, for instance, is thought to have captured much of what was formerly the watershed between the northern and southern systems of drainage. This deduction follows from the presence of erratic blocks of granite originally derived from the Kanchenjunga massif which now lie scattered on the hills above the surrounding Yaru Plain, proving that the drainage from Kanchenjunga and its neighbourhood must, at one time, have had a northerly trend.

River Sutlej is another outstanding example of river piracy. Pascoe (1964) writes that Gen. Strachey observed "the Sub-Recent deposits in the Sutlej valley in Hundes extend southwards to the crest of Niti Pass and that a detached portion of these, is even seen two or three miles to the south of the crest" indicating that the "original watershed" of the river must have run further south which is another proof of "encroachment on the northern drainage area". The valleys of the rivers Bhagirathi, and Tista are other notable examples of river piracy.

River Valleys and their configuration : It has already been indicated that the Himalayan rivers are antecedent and have consequently eroded deep gorges through the Himalayan chains and ranges. The characters and nature of their valleys is rather complicated with immature and youthful valley profiles that have undergone rejuvenation due to later upheavals. The drainage of the northern slopes is longitudinal and sometimes with meanders and wide basins and troughs parallel to the mountain chains. However, after a while all the rivers invariably make an acute bend and cut across deep transverse gorges sometimes hundreds of metres in depth. The valleys are generally 'V' shaped but 'U' shaped valleys along the same river courses are not uncommon. These rivers show marked meanders in flat wide valleys which are anomalous at such high gradients. These are sometimes alternated with straight alignments and deep gorges, which are generally not controlled by the prevalent NW-SE Himalayan structure. The other common features in these valleys are the river-terraces, rock-terraces, knick points, slip-off slopes, hanging valleys, faceted spurs, rock islands, multi-storeyed valleys and other characters of rejuvenation due to intermittent upheavals or spasms.

The peculiar configuration of the Himalayan river valleys is chiefly due to (i) the transverse gorges, (ii) the nature of rocks and (iii) the amount of rainfall in a region. In the western and central regions the broad 'V' shaped valleys in softer rocks are always present above the deep 'U' shaped narrow gorges or canyons, which are sometimes more than 50 km in length, *e.g.* the Gilgit gorge. In the eastern Assam and NEFA regions the valleys are comparatively broad and much shorter with straight gentle slopes, and river-erosion is the main cause of denudation.

With the mountain building processes, the valleys have been upheaved and rejuvenated again and again, and because of the different rock characters and structures affecting their surfaces rapids, cataracts, cascades and waterfalls are common throughout the Himalayan chains. In addition, another important geomorphic development is the predominant network of rectangular or trapezoid topographic features in between the valleys or the ranges particularly in the central zone or at the syntaxial bends. These may be due to a series of tear faults affecting these regions. Most of these are also characterised with glacial markings, pockets of gravel terraces and unusual sediments resting at steep slopes.

From the foregoing it is evident that the peculiar configuration of the major Himalayan valleys is chiefly due to a series of narrow neck-like transverse ravines and gorges alternated with oblong and wide valleys similar to a lengthwise chain of long necked bottles. The morphology of these valleys or narrow defiles may have further been modified due to the avalanche debris and/or glacial moraines or landslides. In the course of a river such places are clearly marked by a sudden widening of the valleys—indicating a damming of the river and the creation of a natural reservoir in the recent past. Other important evidences of such morphological changes are the occurrences of 'pot holes', rock and river terraces, cusps and alluvial deposits at higher levels of a valley, and formation of epigenetic gorges with steep convex slopes, so common in the Western and Central Himalaya.

4, Lakes :

As compared to the Alps or the other important mountain systems of the world, lakes are not very common in the Himalaya. Thus they play an insignificant role in the physiography or geomorphology or the drainage system of the Himalayan region. Amongst many lake basins of the Tibetan plateau the important ones are the Manasarowar (350 sq km) and Rakas (260 sq km). These are sweet water lakes situated at an altitude of 4,540 m on the south side of the Kailas, while others contain mostly saline water as they do not have any outlets.

In Kumaun, the lakes like Khurpa Tal, Naini Tal, Bhim Tal, Naukachia Tal, Malwa Tal are comparatively small and are described by Thomas (1952) to be lying in a belt 25 km long and 32 km broad near the border of the sub-Himalayan zone, "a naturally dissected peneplain", 50 km wide, and at an altitude of 2,400 metres between the Siwaliks on the south and the main Himalayan ranges on the north. Ball in 1878 considered the Kumaun lakes to be of landslip origin. Theobald (1888) like Blanford, supported a glacial origin, while Medlicott (1881) considered these to be due to hypogene groundwater movements. In 1890 Middlemiss suggested a differential uplift and subsidence, along groups of fractures aided by the dissolution of local limestones. Based on the study of the geological structures and the geology of the area by Heim and Gansser (1939) and Auden (1942), Thomas (1952) discussed the origin of Kumaun lakes in detail. Thomas believed that the recent earth movements and diversified lithology were the two main factors responsible for their origin. He states that "frequency of lakes in the small region at this time may be connected with the recent movements. The irregularly eroded surface of Siwaliks over which the Krol Nappe has moved must have contributed to the formation of surface irregularities consequent upon the breaking up of the thrust mass".

In the Kashmir—Ladakh region the fresh water Dal and Wular lakes of the valley, the Tso Morari (120 sq km) at an altitude of 4,600 metres in Rupshu, the Pangong and the Salt lakes ofLingzi Tang at 4,250 metres height in Ladakh are the important ones. In the Sub-Himalayan region of the Jammu province two small lakes, Surum and Mansar, lie at the crest of an eroded anticline. According to Oldham, the fresh water lakes of Kashmir valley are the "inundated hollows" in the Jhelum alluvium, similar to the ox-bow lakes, meanders and *jhils* of the Ganga plains. In the case of the lakes of the higher regions, the presence of old terraces, beach marks and varved clays at higher levels indicate that these lakes are due to the uplift of the region or the blockage of streams by large blocks of more resistant rocks probably of glacial origin or might even have been produced by landslips at different stages of their geological history.

Origin of Himalayan Lakes : Three different views have been prevalent amongst the Geologists and the Geographers regarding the origin of the lakes. According to F. Drew (1875), lakes characterised by long and narrow valleys, have been formed by the damming of the side valleys of their tributaries by alluvial fans. Oldham (1880) considered that the development of the Tibetan and Kumaun lakes was caused by the blockage of the river channels brought about by the comparatively faster tectonic uplift of a portion of the river beds compared to the erosional action of these rivers. Huntington (1906) attributed the Tibetan lakes to be the erosional hollows, scooped out by glaciers. Some lakes of this type have also been reported in other parts of the world, but there are no evidence to support this hypothesis as far as the origin of the Tibetan lakes is concerned. Notwithstanding the divergent views presented for their origin, from what has been said above and the nature of their occurrence, the lakes of the different Himalayan regions could be considered as owing to any or a combination of several of the following processes :—

(a) Damming up of the main river-valleys by the alluvial fans of the side valleys ; (b) The Partial blockage of river beds due to the faster uplift of a portion of the river bed compared to the cutting of the streams ; (c) Scooping of hollows by glaciers ; (d) Blockage of streams by differential earth movements ; (e) Blockage of streams by landslips, glaciers etc. ; (f) Processes such as those which produced the *jhils* and meanders of the Gangetic plains.

Two particular features of the Tibetan and the Ladakh lakes are : (i) their increasing salinity, and (ii) the diminution of their volumes in recent geological times. The first of these is due to the absence of any outlets and regular accummulation of salts caused by perennial evaporation of waters from their basins, while the decrease in volume may be the result of recent uplifts of their basins.

5. Structure of the Himalaya :

Like all great mountain chains of the world the Himalaya is of the "folded" type. Thus the relief of the ground is closely related to the axis of the uplift and the strike of the trend of the mountain system. Since the last century and particularly during recent years considerable interest has been shown by travellers, geologists and geographers in the study and evaluation of the Himalayan structures. The greater part of the mountain is yet to be explored and almost all present knowledge about the Himalaya has come from the mountain expeditions and from geologists who have done pioneering work, noted among whom are Medlicott (1864-87) Middlemiss (1885-1913), Oldham (1883-1917), Hayden (1904-15) Burrard (1907), Pilgrim (1928), West (1928), Wadia (1927), Wager (1937), Auden (1932-53) Heim (1934 and 1956), Gansser (1934 and 1964), Hagen (1951-60), Bordet (1955 and 1961) and several others. Studies of the Himalayan structures by these authors have led them to the conclusion that a crustal shortening of approximately 400 km has taken place, and the major structures of the Himalaya are comparable to those of the Alps in many respects.

The structure of the outer or sub-Himalaya is comparatively simple, it is made up of a series of normal anticlines and synclines of Jura type structures. On the south side, the outer Himalaya shows a series of steep escarpments and dip slopes separated by longitudinal depressions, the *duns* and other tectonic valleys. In between these, the reversed Main Boundary Fault or the Krol thrusts are characteristic of the tectonic framework in these ranges. The Main Boundary Fault extends all along the foot-hills

TABLE II

CORRELATION OF DIFFERENT HIMALAYAN TECTONIC SUBDIVISIONS FROM WEST TO EAST

(Modified after Krishnaswamy and Swami Nath, 1964)

West — East

Tectonic Subdivisions.	Kashmir.	Punjab.	Garhwal.	Kumaun.	Nepal.	Darjeeling.	Assam.
Tethyan Himalayan Zone	Tethyan Facies with Ultrabasics	Tethyan Facies with Ultrabasics	Exotic Blocks Tethyan Facies	Tethyan Facies with thrust in the zone	Tethyan and Tibetan facies	Tethyan Facies	
AUTOCHTHONOUS ZONE: Crystalline belt of Central Himalaya and the Root zone	Crystallines	Crystallines with Rampur and Mashnu windows (Berthelsen)	Crystalline with Ghuttu window (Tiwari)	Crystalline Central zone	Crystallines	Crystallines	
	————	MAIN	HIMALAYAN	THRUST	————		
Kashmir Nappe System (Valdiya)	**Kashmir Nappes**	Chail/Jutogh Nappes	Garhwal Nappes	**Almora Nappe and crystalline zone of Askot and**	**Katmandu and Khumbu Nappe**	**Daling Nappes with Rangit valley window of Gondwana**	**Metamorphics**
Krol nappe system (Valdiya)	..	**Krol nappe** (including three thrusts —Krol thrusts bordering sub-Himalaya, Giri thrust parallel to Krol thrust and Tons thrust of Chakrata)	**Krol Nappe** with windows of early Tertiaries and Chandpurs. (includes Krol thrust)	**Krol nappe** syncline of Naini Tal and window of Sedimentary zone of Pithoragarh (Valdiya)	**Nuwakot** nappe		**Permo-**Carboniferous sediments ?
Para-autochthonous zone	Murrees (Post Nummulitics)	Dagshai, Kasauli Dharmsala	Subathu, Dagshai and Kasauli				
	Main Boundary Fault	Main Boundary Fault	Main Boundary Fault	Main Boundary Fault	Main Boundary Fault	Main Boundary Fault	Main Boundary Fault
		(Nahan thrust)	(Merges with Krol thrust at places)	(Merges with Krol thrust at places)	Merges with Nuwakot thrust)		
Autochthonous zone	Siwaliks	Siwaliks	Siwaliks	Siwaliks	Dharan Series	Siwaliks	Siwaliks

from Assam to Punjab (Fig. 1) while others are of smaller dimensions. From south to north in the Kashmir, Punjab and Garhwal regions there are the Murrees and Nahan thrusts followed by the Panjal and Krol thrusts which in turn are followed by the Zaskar, Giri and the Garhwal thrusts towards the central ranges (see Figs. 2, 3 and 4). The width of the *duns* and the Siwalik zone is thus affected by the outer thrusts. In some regions *e.g.*, near Dehra Dun it is fairly wide whereas in others it is completely missing as in south of Darjeeling where the thrusts sheets have overridden the whole of the Tertiary zone including the Siwaliks and lies at the edge of the Bengal—Assam plains, *e.g.*, the Buxa series.

Considering the tectonics, Wadia (1957) has classified the NW Himalaya into the following structural zones :

Structural zones :

Foreland

1. Siwalik belt characterised by Jura type of open simple folds and reverse strike faults.
2. Sirmur belt—comprises more tight folding and steep strike faults.

Autochthonous Fold zone :

3. Carboniferous—Eocene belt includes Carboniferous—Triassic cores within the recumbent folds of Eocene.

Nappe Zone :

4. Purana slate belt consisting of unfossiliferous Palaeozoic and Mesozoic formations.
5. Crystalline belt of Metamorphic rock intruded by granites.
6. Tibetan belt, includes marine sediments from Cambrian to Eocene.

Valdiya (1964) has divided the Himalaya from Indus to Brahmaputra into five tectonic sub-divisions : (i) the autochthonous Siwalik zone (ii) the Para-autochthonous Lesser Himalayan zone, (iii) the Krol Nappe, (iv) the Kashmir *nappe* system and (v) the Tethys Himalaya. For purposes of comparison a correlation of the different Himalayan tectonic subdivisions from west to east has been proposed in Table II.

Kashmir Himalaya : In the Kashmir region Wadia's view (1939, 1933) has been generally accepted. As stated earlier he has classified the Kashmir Himalaya into three broad tectonic zones (Fig. 2) :

1. Foreland—which is almost a peneplain containing mostly Tertiary sediments of *Molasse* facies,

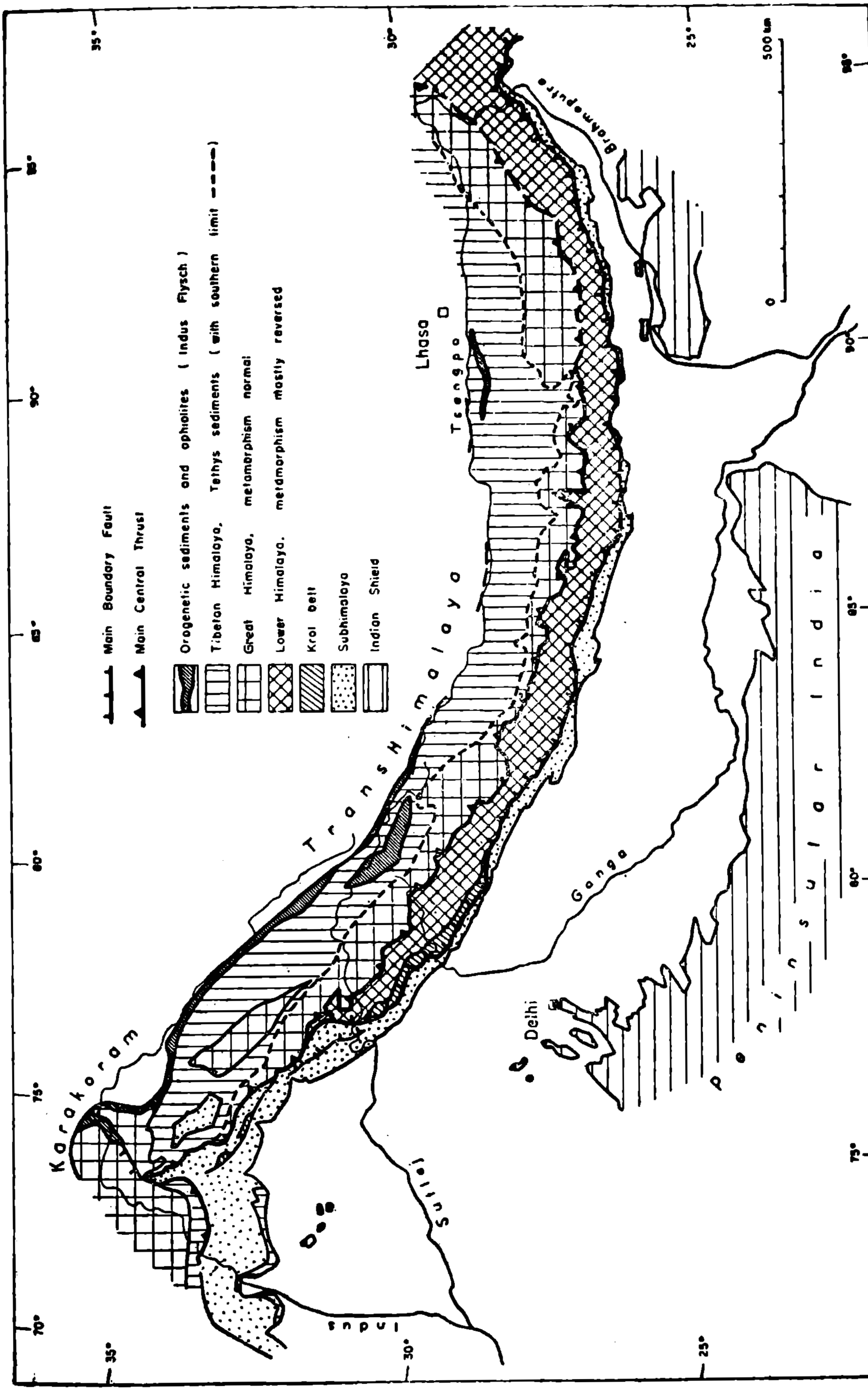

Fig-1

After A. Ganser

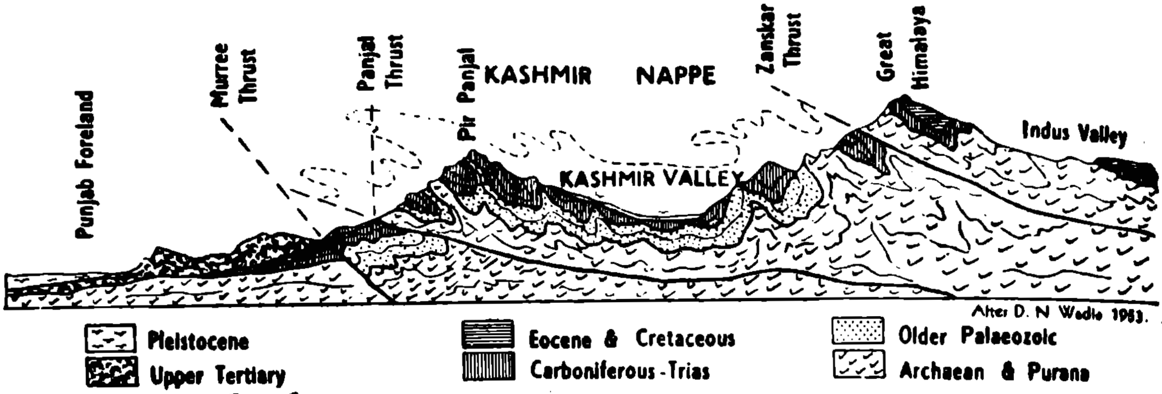

Fig-2 NAPPE STRUCTURE OF THE KASHMIR HIMALAYA

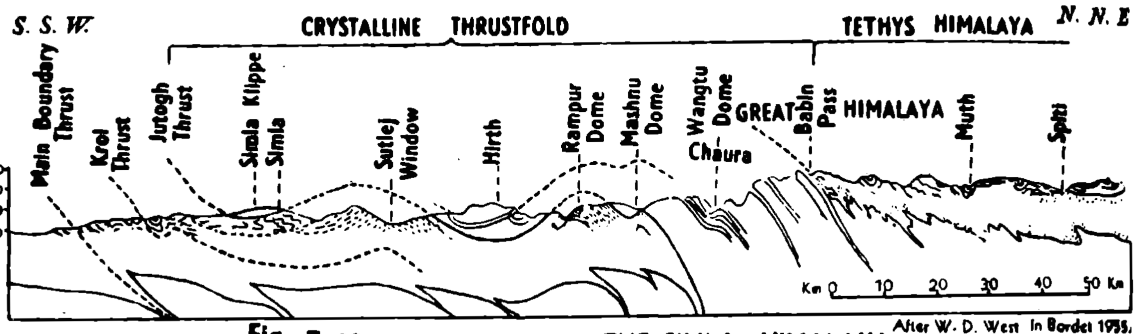

Fig-3 SECTION THROUGH THE SIMLA HIMALAYA

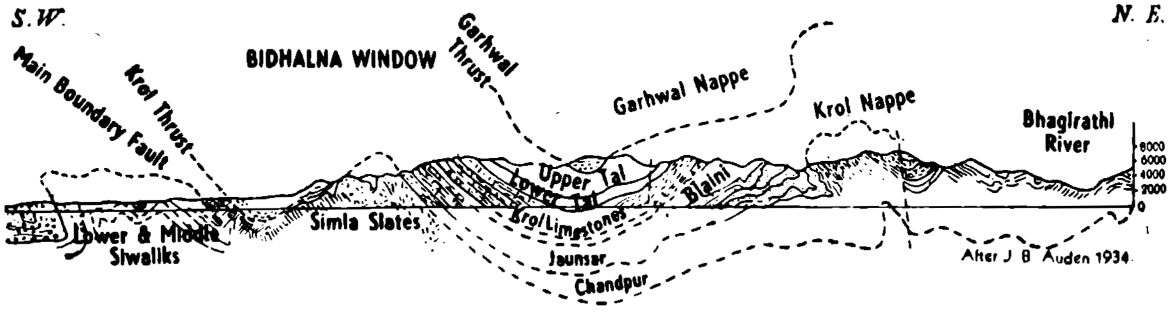

Fig-4 SECTION ACROSS THE GARHWAL HIMALAYA

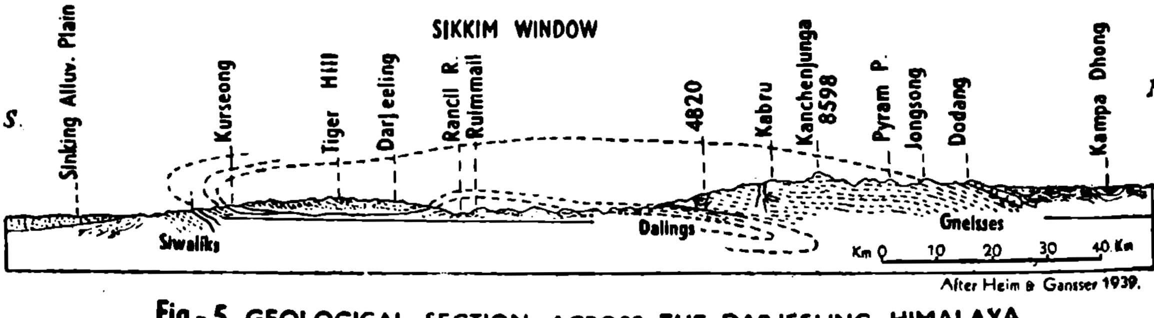

Fig-5 GEOLOGICAL SECTION ACROSS THE DARJEELING HIMALAYA

2. Autochthonous belt—It includes the rocks mainly ranging from Carboniferous to Eocene in age and are characterised by recumbent types of folds. The autochthonous belt has been thrusted over the foreland which underlies the Murree series. The Murree thrust shows a greater vertical displacement and is much more steep compared to the Panjal and the Zaskar thrusts.

3. Nappe zone—The Kashmir *nappe* is mainly composed of the pre-Cambrian Salkhala series overlain by the Dogra slates forming the floor of the great geosyncline that has moved forwards along the Panjal thrust in a horizontal sheet. In various parts of the Kashmir region the Salkhala series and the Dogra slates are overlain by the Palaeozoic and Triassic deposits. The root zone of the Kashmir *nappe* is formed of another tectonic unit in the great Himalayan range, which is the principal geanticline within the main Himalayan geosyncline. It is composed mainly of the Archaean and pre-Cambrian formations which have been intruded by several granitic masses and epidioritic bodies. The different phases of the Himalayan uplift must have been associated with various phases of the granitic activity a few of which are recognised as post-Cretaceous.

Simla Himalaya : The detailed study and mapping of the Simla rocks have been made by Pilgrim and West (1928) and by West (1939). Their interpretations of the geology and structure of the Simla region have revolutionized the previous concepts though a slight modification has been made by Berthelsen (1951). According to West, four major sheets Krol, Giri, Chail and Jutogh occur in the form of great recumbent folds (Fig. 3) along which the strata have moved bodily from NE towards SW in the autochthonous belt, while the Carboniferous and the Permian rocks have been pushed along the Krol thrust over the Tertiaries and the older Jutogh, and Chails have been piled up over the Blaini and the massive Krol limestones. Structural and the metamorphic investigations made in other similar areas also show that the highly metamorphosed pre-Cambrian Jutogh schists and the Chails form the mountain top and overlie the younger Krols and the Blaini boulder beds. The latter groups are less altered and develop a *klippe* structure. The *nappe* zone of the Simla formations starting from Solon are separated from the Krols by the Jutogh and Chail thrust, which are considered equivalent to the Panjal thrust of Kashmir (Wadia, 1961). In the Krols the tectonic sequence, given by West, indicates that two *nappes*, the Krol and the Garhwal of the Palaeozoic and the older rocks, override the autochthonous fold belt of the Tertiaries of the outer Himalaya.

North of Simla, the Shali Tertiary formations occur in a window exposed due to the denudation of the overlying older formations. Similarly, the cropping out of the Nummulitic limestones and Dagshai beds near Solan and Subathu from beneath the Krol *nappe* reveal the window structures of the younger beds (Fig. 3).

Garhwal Himalaya : Meddlicott (1864), Middlemiss (1887) and Greisback (1891), studied the Garhwal Himalaya as early as in the nineteenth century and the lithology and stratigraphy given by them have formed the basis of all later studies though no satisfactory explanations were offered to explain the complex structure of the area. Middlemiss was puzzled to note the occurrence of highly crystalline schists and gneisses (*Klippe*) on the tops of the mountains surrounded on all sides by the less altered unmetamorphosed arenaceous and argillaceous sediments with Nummulitic limestone dipping towards the older formations. Some fifty years later, Auden (1934, 1937), discussing in greater detail the tectonics of the Garhwal Himalaya in two of his papers, divided the regions into six structural sub-divisions (Fig. 4).

1. The autochthonous belt, the base of which is supposed to have been formed of the Simla slates, overlain by Nummulitic limestones, Dagshais, Kasaulis, and other Siwalik formations. The rocks are slightly folded and faulted. Auden considers that this autochthonous belt starting from the *duns* might be extending even upto 30 km into the Himalaya.

2. Krol Nappe : This unit is composed of the Jaunsar and the Krol formations thrusted over the Tertiaries of the autochthonous belt. Recently Ranga Rao (1963) has discussed the possibility of the Krol belt being a part of the autochthonous unit. However, his views cannot be generalised at the present stage without further detailed work. East of Katri and Chakrata, the Krol belt formations occur in a major syncline—the Mussoorie synclinal hills, on top of which are the '*Klippe*' of the metamorphosed equivalents of the Jutogh—Chail series of the Simla area.

3. Garhwal Nappe : It is considered to have been thrusted over the Krol *Nappe* zones with its root zone in the Great Himalaya and includes the crystalline rocks of the Garhwal series.

4. Main Himalayan Zone : It is the root zone of the Garhwal *Nappe* and is composed of para-gneisses and schists, sometimes with well developed kyanite, garnet and other minerals.

5. Central Autochthonous zone : This zone lies further in the north of the Main Himalayan zone and is composed mainly of the granites intruding within the para-gneisses and schists.

6. Tibetan zone : It consists mainly of the Tethyan fossiliferous sediments ranging from Cambrian to Cretaceous and Eocene times. The rocks are considered to have upheaved by the late orogenic movements. Later in 1939, Heim and Gansser, have shown the structural relations of *Nappes* and Thrust sheet movements in the Garhwal, Kumaun and Tibet regions.

Nepal Himalaya : During recent years the Nepal Himalaya have attracted much attention and several investigators have studied it, but much is yet to be done. The early works of Hooker (1848) and Meddlicott (1875) are notable. In the later part of the last century and the beginning of the present, several others have visited the Nepal Himalaya but the accounts of Auden in 1935 can be taken as important contribution on the geology and structure of this region based on a few traverses in connection with 1934 Nepal-Bihar earthquake. Later in 1939, Heim and Gansser also studied a part of NW Nepal and described the structure along R. Kali. During the fifties Hagen carried out intensive field studies for eight years on behalf of the Government of Nepal (much of which is still unpublished). In the course of the Swiss Everest Expedition in 1958 Lombard (1958) and Bordet (1955, 1959, 1961) gave a good account of the geology of Everest based on the field studies during the French Makalu Expedition. The three workers : Hagen (1959), Lombard (1958) and Bordet (1961). studied almost the same sections from Everest to the Ganga but have differed in their interpretations.

Starting from south to north, Bordet (1961) observes that the contact between the Upper Dharan Series (U. Siwaliks) and the Gangetic plain is covered under thick alluvium and suggests that this may be due to the existence of a fault or an overthrust. However, the Siwalik belt of Nepal is better differentiated as compared to their western extensions in Kumaun. At the foot of the Upper Dharan formation, the occurrence of thick fluvio-glacial deposits with progressively inclined dips 5°—15° from the younger to the older terraces occurring towards the Main Boundary Fault and certain local thrusts in the Recent and Sub-recent deposits indicate of the later epirogenic movements. (Hagen 1956, 59).

Geologically and tectonically Hagen has divided the lower Nepal Himalaya into two units, i.e. (i) Nuwakot—Pyuthan unit and (ii) Katmandu unit. The former mainly comprises the sedimentary formations in belts or zones while the latter consists of the crystallines. He has correlated the Nuwakot unit and the Katmandu unit with the Krol *nappe* and the Garhwal *nappe* of Auden and the Almora thrust sheet of Heim and Gansser (1939). The Nuwakot unit has been further divided into four *nappes*. Lombard (1959) described the crystalline zone of Eastern Nepal as Khumbu *Nappe*, equivalent to Katmandu unit No. 5 of Hagen. However, Hagen accepts the terms of Lombard but has divided the Khumbu *nappe* zone into three sub-zones and the No. 3 zone into three smaller units.

Bordet does not agree to the idea of multiple *nappes* in the lower Nepal Himalaya, which has been shown by Hagen because comparatively fewer *nappe* zones have been marked by other authors in the eastern (Bordet and Lombard) as well as in the western parts of the Nepal Himalaya. While describing the Arun river sections he has marked seven units, the migmatites, the mica schists, the lower quartzites, the lower phyllites, the upper quartzites, the calc-schists and the upper phyllites within the Lower Himalaya. These can be summarised as :—

The Ganga Plain	Dharan series (L. Siwalik)
The Border Unit	Sanguri series
The Lower Himalayan Unit (From border zone to the high peaks)	(a) The migmatites (b) The mica schists (c) The lower quartzites (d) The lower phyllites (e) The upper quartzites (f) The calc-schists (g) The upper phyllites
The Higher Himalayan Unit	(a) The gneisses of Barun (b) The migmatites of Barun (c) The black gneisses (d) The Makalu granite (e) The Everest series

Darjeeling, Sikkim and Bhutan Himalaya : In 1854 Hooker, published some geological reports of his traverses in many parts of Sikkim. Later, a part of the Darjeeling as well as of the Sikkim Himalaya was studied by Mallet (1875) who has given an excellent account of the foothill regions. The inner contact of the Siwaliks has been found to be a thrust plane against the Gondwana formations, which is the Main Boundary Fault. In this region at the Tindharia Railway station the Gondwana formations lie underneath the highly metamorphosed rocks on the top of the steep slope. The schists and gneisses in the cuttings show a higher degree of metamorphism than the rocks below which are of lower grade. Auden (1935) has shown the existence of a distinct thrust between the Darjeeling gneisses and the Gondwana formations. Heim and Gansser (1939) confirm the observations of Auden and conclude that the Darjeeling gneisses and their continuation in the Kanchenjunga massif belong to a huge recumbent anticlinal thrust from north to south of more than 80 kilometres (Fig. 5), and have given the following sequence. From south to north the tectonics can be given as :—

Siwaliks

Main Boundary Fault

Gondwana—(Damuda series as Tectonic windows)

Nappe zone

Daling series	i.	Slates
	ii.	Schists
Darjeeling series		
Darjeeling gneiss		

In common with the tectonics of the Darjeeling Himalaya, Nautiyal and others (1964) consider the highly metamorphosed Thimphu series in Bhutan equivalent to the Darjeeling series. The high grade garnet, kyanite, sillimanite rich schists, gneisses and the calc silicate rocks like as a thrust sheet over the less metamorphosed pelitic and psammitic rocks which constitute the Sanchi and the Chekka series comparable to the Daling series of Sikkim. To the south, the Sanchi series is overlain by isolated and disconnected outcrops of the Buxa series, which are considered equivalent to the Krol—Tal formations of the Kumaun Himalaya.

Assam Himalaya : The Assam Himalaya includes hills like the Aka hills, the Daphla hills, the Miri hills, the Abor hills and the Mishmi hills. A few of these were first studied by Godwin Austen (1875) followed by La Touche (1883), Maclaren (1903) and Ghosh (1905). Besides these, some minor accounts are also available in a few papers from the Burmah Shell oil geologists, e.g. Evans (1932, 1959, 1964) ; but no detailed studies appear to have been made regarding the structure of this part of the Himalaya. The Siwalik belts exposed in Sikkim and Bhutan continue in Assam and NEFA regions which are separated from the Gondwana formations by the Main Boundary Fault and the underlying Gondwanas are bordered with high grade micaceous slates, schists and gneiss. The Gondwana rocks in this region are interbedded and covered by a thick sequence of volcanics consisting of reddish to dark green lava flows, called the Abor volcanics. Towards the north they are followed by sericite schists quartzites, brecciated dolomitic limestones and still higher grade rocks. These can be compared to the 'Buxas' and 'Dalings' of the Darjeeling Himalaya while the Abor traps on the basis of their lithology may be considered equivalent to the Panjal traps of Kashmir.

Syntaxial Bends :

(i) *North-West Himalayan Syntaxis :* It has already been noted that the Himalayas terminate both in the East and the West in sharp acute syntaxial bends caused by the north-westward and north-eastward spurs of the Indian Peninsular shield which extend below the Indo-Gangetic plain. Around both these bends the mountain ranges swing southwards into Baluchistan in the west and the Burmese arc in the east. The north-western bend is known as the N.W. syntaxis of Kashmir and Hazara districts, and the north-eastern as the Assam syntaxis. Geologically, the former is much better known as compared to that of the latter.

The syntaxis of Kashmir—Hazara region has been treated in detail by Wadia (1931). In this region the Salt Range is off-set by the Sulaiman range, while west of the R. Indus the Hazara range of the main Himalaya makes a loop southwards around Nanga Parbat into the Sulaiman and again the swerves around into the Kirthar ranges near Quetta. Along with the bending of the mountain ranges the strikes and the structures of the rocks also swing and are continued in these southward extensions, preserving the individual fold axes, and the stratigraphy of the rocks. While discussing the N.W. syntaxis Wadia and West (1964) explain the origin of these bends due to a reversal of the N.E. Hazara strike to SW in the Sulaiman which in turn might have been caused by the "moulding of the Himalayan orogeny as it merged from the Tethys round a tongue-like projection of Gondwana massif—the Punjab wedge. On meeting this obstruction the northerly earth-pressures resolved into two components, one acting from the north-east and the other from the north-west against the shoulder of this triangular promontory". He further observes that the Hazara region is similar to the Kashmir Himalaya both in structure and in physiography.

West of the Indus and immediately north of the Salt Range a narrow belt of ophiolitic rocks is found to continue underneath the Hindu Kush. On the other hand the Sulaiman range "develops into a well marked system of folds arching garland-like and joining the southern Baluchistan ranges at Quetta" into the Kirthar and the Baluchistan ranges which also continue southwards and have "produced some garland folding on a smaller scale similar to the Sulaiman arching". All these formations of the Western Himalayan extensions show a large virgation towards the west with east-west directed steeply folded ranges in *Flysch* type lower Tertiary formations. According to Gansser (1964) these archings, virgations and garland-like syntaxial folds of the Sulaiman and Baluchistan arcs may have been caused, "by basement influence of the Indian Shield similar to, but smaller in magnitude than the Himalayan Syntaxis".

Syntaxial Bend of NE Himalaya : The eastern extremity of the Himalaya range, like the Kashmir—Hazara syntaxis, also terminates in the Upper Assam syntaxial bend where the Himalayan arc joins the Assam and the Burmese arcs. The evidences point to the strike of the rocks also taking knee-bend towards the south western and then southern directions. Gansser further adds that the Assam wedge with its large granite pluton has acted as a pivot and instead of pursuing its course towards China, as was once presumed, the entire Himalayan chain turns sharply on itself near the peak of Namcha Barwa (7,756 m) and takes at first a south-western and then a southern course". On flying over the regions of Assam where the two ranges meet, Lees (1952) expressed his visual impressions that "Naga (Patkai front) structures strike into the Himalayan front and are overridden by it. There seemed no indication of a swing of strike from one system into the other but rather that the Himalayas were dominant over their weaker neighbour" and the country between the Himalayan and the Burmese arcs (Arakan Yoma) has been "sliced by cross-faults into blocks that have pushed southwards *en-echalon*". Gansser (1964) is also lends his weight to the latter view when he writes that the Himalayan strikes "do not turn around the Eastern Himalayan Syntaxis but are cut off by crystalline thrust masses which continue southwards to join the crystalline masses of Shan plateau of Central Burma". In view of the above, the ranges of Arakan Yoma are problematic as the *Flysch* type Cretaceous sediments with their intrusives lie along a fault zone in contrast to the rocks of the Sulaiman range of the Western Extra Peninsular region.

The occurrence of such anomalous syntaxial bends do not seem to be very uncommon along the Himalayan mountain chain system. Based on the present day knowledge of the various Himalayan zones, which has been already discussed, minor syntaxial bends can be easily recognised on large scale topographical and geological maps. Near Dalhousie the NW-SE strike takes a southern trend ; in Simla-Bilaspur region the *Flysch* and *Molasse* formations are arched and affected by strike thrusts and faults and again in Mussoorie-Rishikesh region the rocks swing almost north-south and are affected by the prominent Yamuna and Ganga tear faults. Similarly the N-S asymmetrical folds in various parts of Nepal particularly those of Arun and Honggoan, and the existence of fragments of the older thrust sheets on the younger rocks as found in the Darjeeling-Sikkim Himalaya are noteworthy.

Also, the occurrences of shield massifs in Assam, in the Ambala-Delhi ridge, in the pre-Cambrian and pre-Aravalli formations of the Shahpur ridge in the Indus-Sutlej basin of Pakistan plains and also in the deep wells drilled for oil explorations in the Indo-Gangetic plain and the foothill zone of the Siwaliks, tempt one to compare the loops and swings of strikes around the oblique strikes of older orogenies as well as the transverse faults or tear faults which are also recognised on the aerial photographs with the syntaxial bends of the Himalayan systems. These minor syntaxial flexures or 'festoons' might as well be the result of the ramifications of the Indian Peninsular shield extending underneath the alluvial plains and the Siwalik *molasse* facies.

6. Geological History of the Himalaya

The history of the Himalaya can reasonably be traced as far back as to the Archaean times and it is considered that the rock formations of that era form the basement for these mighty mountain chains.

Pre-Cambrian and early Cambrian History : The orogeny responsible for the rise of the Aravalli range has left a profound mark on the Himalayan tectonics (Auden, 1935). From the geological or physiographic map of India it is evident that the Aravalli strikes almost at right angles to the Himalayan arc and perhaps extend beneath the Punjab, Garhwal and Kumaun Himalaya. The older Archaeans forming the basement of the Himalaya have despite several diastrophic movements retained many of their original characters. Thus, the gneisses, migmatites, crystalline schists, thick quartzites and tectonized granite intrusions which constitute the basement of the main Himalayan thrust zone compare very well with the Archaean rocks. The marble, limestone, amphibolites, psammitic gneisses and the schists of the Main Thrust Zone are comparable to the Algonkian (Purana) formations of the Peninsular shield as they underlie the rocks exhibiting Cambrian fauna such as has been noted in Kashmir.

The thick argillaceous formations with limestones and quartzites all along the Lesser Himalaya may be envisaged as the marine equivalents of the peninsular Vindhyans having characteristic terrestrial deposits. This view is further supported by the recent discoveries of stromatolitic horizons of late pre-Cambrian or Cambrian age in the Lesser Himalaya. Here the evaporities must have resulted in a transition zone from the marine to continental environments and are perhaps represented by the Saline series and the purple sandstone of Salt Range. Gansser (1964) assumes a saline belt, bordering the Peninsular India along its northern edges which is now covered by the frontal Himalayan thrust. The enormously thick limestones and quartzites of the Lesser Himalaya suggest quiet sedimentation in a shallow sinking basin, in the further north deeper from the peninsular shield. The great thickne s of the quartzites is, however, difficult to accoun for. These seem to be the reworked sediments and not the derived types from the older crystallines, as a few important conglomerate horizons in them do not contain any igneous or metamorphic pebbles. On the basis of their lithology these sediments may be the equivalents of the Vindhyans.

In the higher reaches of Kumaun Himalaya, a complete succession is exposed and no marked unconformity exists in between the older crystallines and the over-lying sedimentary formations. The older metamorphic series is seen gradually passing through the zones of phyllitic schists to the phyllitic calcareous sediments with rich fossils of pre-Ordovician age in the upper horizons (Garbyang formations).

Palaeozoic and Mesozoic History : The most remarkable feature of the Himalaya is the existence of two major geosynclines parallel to and separated by the present crystalline axis (West, 1935). In the northern geosyncline of the Tibetan Himalaya, fossiliferous formations from the lower Palaeozoic to early Tertiary were deposited. In contrast, the southern or the Lesser Himalayan geosyncline formations are generally unfossiliferous upto the Mesozoic times. There are, of course, indications of connections between the two geosynclines as shown by the presence of fossiliferous horizons in the Lesser Himalaya of Kashmir, Nepal, Sikkim and in the Eastern Himalaya.

During the Palaeozoic era the environmental conditions of the Himalayan regions varied considerably from the outer zone to the inner zone. The Purana formations of the northern shield mass were followed by a long period of emergence possibly lasting upto the Mississippians. During Palaeozoic times the conditions in the Lesser Himalaya were similar to those of the northern Peninsula ; with the exception of Punjab and Kashmir Himalaya, where the Tethys sediments of the Inner Himalaya transgressed southwards over the central crystallines. Besides, Pulchuki beds of Nepal are Silurian and the Tangcha beds in Bhutan may be Devonian.

After the Puranas, the Gondwana sedimentation is marked by the tillites in Salt range and Blaini boulder beds of Garhwal and Simla regions, which are the equivalents of the Talchir boulder beds of the Gondwana formations. These are frequently inter-calated with pyroclastics and volcanics, i.e. the Panjal Traps in the west and the Abor volcanics in the east.

The post Blaini—Krol formations, constituting the outer belt of the Lesser Himalaya extends roughly from Simla to Naini Tal. These may be the representatives of the upper most Palaeozoic and perhaps the early Mesozoic formations. The rocks are generally devoid of any recognizable fossil forms ; though very often, elliptical pallets of microscopic sizes and deceptive appearances of coral or foraminifera or other micro-organisms including algal structures in the massive limestones suggest a depositional environment similar to those of the pre-Cambrian times.

Auden (1943 and 1951) mentions that the dolomitic and calcareous rocks "were originally deposited in contrasted positions in the basin of sedimentation and that the para-autochthonous rocks were possibly laid down close to the shore line, while the Krol rocks may have been laid down further from the shore. The relative palaeogeographical positions of the contrasted types of sediments are thought to have been reversed by the great thrust movements which followed in the Miocene".

After the erosion of the Krol beds and the exposure of the underlying rocks for a long time as indicated by the bauxite horizons of Kashmir, the Eocene transgression extended in a wedge like belt from Kashmir-Punjab to Naini Tal in the Lesser Himalaya (Subathus and the intermediate Salt range). In the Tibetan and the Great Himalayan regions continuous deposits from Cambrian to upper Cretaceous or even lower Eocene of fossiliferous beds mark the environments as completely different from that of the Lesser Himalaya. This view clearly supports the large displacements recorded in the main central thrust, which have narrowed the gap between the original depositional areas by more than 100 km. Lithologically, the sediments from the Palaeozoic to the Upper Cretaceous are well differentiated and interrupted locally by epeirogenic movements and show characters of *flysch* deposits.

Tertiary and Recent History: During this period the conditions of deposition changed very markedly from Cretaceous to Eocene and the sediments reflect an incipient Himalayan orogeny. In the outer Himalaya, the quiescent phases between the subsequent orogenic impulses are marked by three successive periods of sedimentation (Krishnan, 1961). The principal sedimentary facies are the "black shale" facies of Eocene, followed by the *flysch* facies of the lower parts of the Lower Miocene and finally replaced by the *Molasse* facies (Siwaliks) during the Middle Miocene to Pliocene times. The transgressive Upper Cretaceous conglomerates of Karakoram indicate that the movements started from the north. The problematic occurrence of exotic blocks of Johar and southern Tibet thrusted over the upper Cretaceous *flysch* deposits indicate the culmination of Eocene sedimentation. This also saw the rising of Tibetan platform and the end of marine condition in the Tethys region north of the Himalaya. Only in the NW Himalaya, Eocene deposition was followed by fresh to brackish water Miocene deposits (Murrees), which were mostly derived from the peninsular shield and only a part of the sediments were derived from the emerging Himalaya. Large consequent drainage and rivers must have begun flowing to the north as well as to the south before the main Himalayan orogeny. Concomitant with the long Himalayan orogeny probably the southern shield mass also drifted northwards and a fore-deep with two arms of rift zones, i.e. the Indus-Sutlej and Ganga-Brahmaputra were produced in between the rising Himalayan chains and the peninsular shield, running parallel to the incipient Himalayan ranges. A considerable amount of detritus filled in this gap from the Himalaya as well as the southern peninsular shield. The final and the main phase of the Himalayan orogeny produced the Siwalik conglomerates and sand rocks in the form of alluvial fans. These formations are comparable to the *molasse* formations.

The world-wide Pleistocene glaciation has also been recorded in the Himalaya and has specially been well studied in Kashmir (de Terra, 1937). According to him the overthrusting of S waliks was followed by fluvio-glacial depositions. The boulders of which persist in the recent gravel terraces and fans. It is also shown that the Karewas of Kashmir with Palaeolithic implements would have been uplifted by about 2,000 metres. Evidences of uplift and tilting of Quaternary terrace deposits from Kashmir to Nepal have also been recorded by many workers and this uplift is still far from complete.

7. Sequence of Tectonic Events :

Two views have been expressed for the origin of the compressive forces : (a) forces came from the north, north-west and north-east, thrusting extensively the soft rocks over and against the Indian Peninsular shield and (b) the other more recent view holds that the mainland of India itself moved north and was thrust under the softer sedimentary formations around its northern borders. Geological and geodetic data also appear to support the latter view though the former has the advantage of offering explanation for the large scale horizontal translations of the thrust sheets.

From the evidences discussed in the earlier pages, the 'uplift' of the Himalayan chain was initiated during the Cretaceous and continued into the Pleistocene. Concomitant with these, 'downwarpings at the foot of the Himalayan thrusts gave rise to the Indo-Gangetic foredeep now occupied by the Punjab and the Ganga-Brahmaputra plains. The Himalaya together with its north-western and the Burmese arcs have been uplifted in four or five successive stages :—

First Stage	..	Upper Cretaceous
Second Stage	..	Upper Eocene
Third Stage	..	Middle Miocene
Fourth Stage	..	Upper Pliocene to Lower Pleistocene
Fifth Stage	..	Late Pleistocene to Sub-Recent (Feeble movements alternated with widespread glaciation till and terrace deposits.)

The structural units of *Nappes*, recumbent folds and reversed faults discussed earlier and the sequence given above, are separated by large tectonic features—the boundary faults trending approximately in NW-SE in the Kashmir-Punjab and Garhwal, E-W in the Nepal, Sikkim and Bhutan and NE-SW in the Assam and NEFA regions.

Coming to the sequence of chief events of the Himalayan orogeny, the close of the Mesozoic witnessed the drama of large scale earth movements and diastrophism. The breaking of the Gondwanaland had already begun earlier during the upper Carboniferous times and had given rise to the present day continents. In the first Laramide phase of the Upper Cretaceous the Himalayan geosyncline, a continuation of the '*Anti-Medi-Him*' rift zone or the Tethys was subjected to intense compressional forces. As a result of these lateral movements, the Himalayan chains were folded and uplifted in four or five successive phases in the Miocene times. The Siwaliks came into existence only at the end of the second or the early third phases of Himalayan orogeny. During these phases was formed a narrow trough subsequently filled by fluviatile and fluvio-glacial deposits derived from the Himalaya in front of the Himalayan chain. In the fourth phase of the orogeny, the mountains were again uplifted and gave rise to the Siwaliks, extending from Jammu to Assam. Simultaneously a fore-deep or frontal trough—the Indo-Gangetic basin—was formed and extended from Kutch to Naini Tal through western Rajasthan and Punjab and was conjoined with the 'Indo-Brahm' (river of Pascoe) itself a result of sinking of the Ganga-Brahmaputra rift (Mithal and Srivastava 1959, and Mithal, 1963).

In addition to the NW-SE primary folds axes and boundary faults, large scale N-S folds and faults exist affecting the *Nappes* and other structures, throughout the Himalayan region and sometimes even the Siwaliks. These are generally perpendicular to the general strike of the Himalayan formations or ranges. Some of these structures extend transversely for more than 50 km, affecting the Lesser Himalaya to the central zone in Tibet. The Arun trans-anticline, Everest-Lhotse synclinal ridge, the Karnali and other transverse anticlines of Mahabharat range etc. (Bordet, 1961) may have been caused subsequent to the formation of *Nappes*, Many tear faults (including the well known Ganga and Yamuna Tears) recently mapped in detail in the Lesser Himalaya and the Siwalik formations of Garhwal and Punjab are other examples as may be due to the post-Siwalik phases of the Himalayan orogeny.

8. Relationship of the Indo-Gangetic Trough with Himalaya :

Structurally, the Indo-Gangetic trough marks the culmination of the Himalayan orogeny. From its geographical shape and configuration and also from the data available the Gangetic trough points out a possible relationship between the southern peninsular shield and the Himalayan mountain chains. A study of the basement rocks below the Gangetic alluvium suggests a northerly slope with a thickening of sediments in the same direction. On the basis of the aeromagnetic, gravity, seismic and other geophysical and geodetic data, the floor of the Indo-Gangetic plain is found to be uneven and the thickest sediments lie below the Outer Himalaya. According to Ghosh (1959) the sediments attain a total thickness of more than 6,670—10,000 metres in a narrow belt of the foothill zone while in certain other sections the basement is met at shallow depth even at 1,635 metres.

Mithal and Srivastava (1959) consider this narrow belt of indeterminate depths as the "Ganga-Brahmaputra rift" lying parallel to sub-parallel with the main Himalayan arc at the fringes of the foredeep. In the light of recent investigations in Punjab, Dehra Dun, Hardwar and Naini Tal regions, the foothills of Nepal and Raxaul (Bihar) it is believed that the Siwalik formations are deformed with high dips and are traversed with steep faults and thrusts lying in juxtaposition with the sub-Recent and Pleistocene deposits of the plains.

On the basis of recent geophysical surveys by the Oil and Natural Gas Commission working in the Indo-Gangetic plains, Aithel and others (1964) observe that "in Punjab the trend of gravity *highs* falls approximately on the Delhi-Shahpur ridge while the trend of the magnetic contours follow the general trend of the Himalayas. The zone of the *higher* and *lower* anomalies continue almost upto Ambala, east of which the anomalies get broader in width and smaller in intensity", i.e. underneath the shallow alluvium lie the basement rocks of the Delhi—Ambala ridge.

A. N. Dutta and others, (1964) based on the seismic survey in the Punjab plains, concluded that the southern limit of the Punjab platform is separated from the Rajasthan platform "by an approximately NW-SE striking basement arch along the Sirsa—Bhatinda—Ferozepore axis". They also consider that "North of the arch, the basement gently slopes down towards the Himalayas". Further, on the basis of the test wells a Hoshiarpur, Zira and Adampur in the foothill Tarai zone, they conclude "that in greater part of the Punjab plains, particularly in the south, the basement is directly overlain by the Siwaliks (continental, middle Miocene to Pliocene) and Recent sediments".

Again Mool Chand and others (1964), based on seismic surveys in Uttar Pradesh, conclude that these investigations prove "the existence of a pronounced unconformity associated with a short velocity contrast across it". In addition they also suggest that, "the post-unconformity sediments follow the Himalayan trend and are characterised by low dips with hardly any recognisable features. The pre-unconformity sediments ....show strong deformation...........and seem to follow the Aravalli trend". As noted in the deep well at Ujhani in the Budaun region of Uttar Pradesh the unconformity forms the base of Tertiaries.

Similarly, S. Ray and others (1964) while reporting on the results of seismic prospecting of the Brahmaputra valley of upper Assam, assert "the presence of gentle anticlinal folds and a multitude of interesting faults". The former seems to have been due to "the movements of fault blocks at different geological times. The dominant trend is NE-SW, second E-W and a few faults in WNW-ESE".

The Assam, the crystalline rocks of Mikir hills and the Shillong plateau form the shelf of the Brahmaputra basin, which is gradually sloping towards the Himalayan foothills (Evans, 1958, 64) similar to those of the Punjab and the Ganga basin. He has also pointed out that the floor of the upper Assam basin is down faulted from the main shield area to a few thousand metres underneath Jorhat and the main valley is filled with at least 6,670 metres of sediments which are also affected by several transverse faults. Mithal and Srivastava (1959) consider this down faulted basin of the western Brahmaputra valley to be the eastern extensions of the Ganga-Brahmaputra rift zone.

Therefore, as a result of the geophysical studies quoted above it can be concluded that the Indo-Gangetic plains do not form a single unit of sediments, but appears to be made up of several smaller basins separated by several ridges and other structures and ramifications of the peninsular shield. The basement of these basins is also affected by block faultings and is thus studded with horsts and grabens, which can be traced further to the formations of the peninsular shield, particularly at the hinge platforms and the southern boundaries of the Siwaliks and even the Indo-Gangetic plains.

9. Recent Tectonic Activity :

The Indo-Gangetic plain lies at the southern foothill margins of the Outer Himalaya or the Siwalik range. Since the Siwalik formations are considerably folded and dislocated it is evident that the northern limits of the trough and even the plain are also affected by foldings and faultings due to Himalayan orogeny. This is further confirmed by the appreciable dips in the upper boulder terraces, the reported occurrences of the Upper Siwalik sand rocks and boulder conglomerates at depths between 30—100 metres in the Bhabar region, artesian conditions between 50—120 metres depths in the Tarai—Bhabar belt of Punjab and Gangetic plains. It is, therefore, clear that these terraces etc. are of tectonic origin and the "northern rim of the great trough is under considerable strain due to the progressive downwarping, with the greater subsidence where it merges into the foot of the mountains" (Wadia, 1961).

In Jammu and Kashmir and the western parts of the Himachal Pradesh, three major thrust faults involving the Tertiary formations have recently been mapped. These are the Hoshiarpur, Satlitta and Riasi thrusts. Similarly major thrust faults affecting the pre-Tertiary rocks are the Murree thrust, the Panjal thrust and the Zaskar thrust. In Uttar Pradesh and eastern parts of the Himachal Pradesh the major thrust fault involving the Tertiaries is the Main Boundary fault (Nahan thrust) and that involving the pre-Tertiaries is the Krol Thrust.

According to Jalote (1962), the Satlitta thrust in the vicinity of the Beas dam site in Punjab clearly indicates at least three different periods of movements. Of these, the first movement seems to have taken place in the Middle Pliestocene times with a minimum throw of 1,432 metres. During the second movement which seems to have taken place in the Sub-recent times, the minimum vertical throw has been of the order of 137 metres and the last movement in Recent times produced a minimum throw of 2 metres. Later Krishnaswamy in 1962 concluded that the Satlitta thrust was possibly the most likely tectonic features responsible for the origin of the Kangra shock of 1905 thus corroborating the Recent activity along the Satlitta thrust. Again, Krishnaswamy (1966) suggested an active seismic status to the Satlitta and the Riasi thrusts and a probable "active status" to the Panjal and the Zaskar thrusts. The activity of these thrusts has been attributed to the nearness of the major Kashmir-Hazara syntaxis.

Near Dehra Dun in the Kalsi area the Krol and the Nahan thrusts have been recognised as distinctly separate. East and south-east of Kalsi upto Rishikesh the two thrusts appear to have coalesced together, thus bring the pre-Tertiaries over the Middle Siwaliks and the *duns* even over the recent gravels. Based on his field studies P. M. Jalote (1966) has established that there were different stages of movements in this region also. They continued upto the Recent times along the Krol thrust in the Dehru Dun—Rishikesh valley. As a result of the Kangra earthqauakes the Krol thrust seems to have shown the most recent activity due to which Dehru Dun is reported to have risen by 12.5 cm in relation to Mussoorie (Middlemiss, 1910) indicating that the Krol thrust is s.ill active and is one of the important features to bring about a change in the physiography of the area.

Occurrence of gravel beds at higher levels near the foothills e.g., at Samba in the Jammu and Kashmir and in the cutting of river Ghaggar near Anantpur Sahib over the Simla road, as well as on the left bank of the river Ganga at Rishikesh, along the Ramganga near Kalagarh and along the rivers at the foothills of Nepal and NEFA regions indicate that the Pleistocene or the Recent deposits of the Indo-Gangetic plain have been affected by Tectonic (Epi-orogenic) movements (Ahmad, 1963) during historical times. These have thus brought physiographic changes which may be responsible for the rapid erosion at the foothill zones and the present abrupt rise along the Siwaliks and the Outer Himalaya.

At many localities in the interior of the Himalayan chains, it is frequently observed that the rivers have filled or are filling in their valleys and are sometimes eroding the terrace or similar alluvial deposits in their present course, e.g. R. Arun in higher Himalaya of Nepal, R. Alaknanda near Badrinath, R. Dhauliganga near Tapoban in Garhwal etc. Likewise, the Katmandu and Kashmir valleys are due to the infilling of ancient lakes of tectonic origin. Similarly, the present filling up of the channel bed by the R. Sun Kosi at Dolaghat in Nepal Himalaya, the occurrence of water features similar to "ox-bow lakes" and minor "incised meanders" on tops of flat hills close to the Tons valley (west of Dehra Dun) in the Lesser Himalaya further indicate that the Himalaya as a whole has suffered some recent tectonic movements.

Further, the peculiar morphological features particularly the 'U' shaped glaciated valleys with alluvial fillings, occurrence of rectangular or trapezoid h ll features, and lakes at great heights lead one to believe that the mountains are still rising. Lastly, the periodic violent earthquakes in Baluchistan, Kashmir, Kangra, Kumaun, Nepal and Assam regions indicate a profound instability of this region. Thus we find that the foothill Himalayas are affected by the orogenic as well as epeirogenic activity at different times and continued upto the recent times. Minor shocks with occasional big earthquakes all along it indicate that the activity has beeen going on during historical recent times also.

HIMALAYAN OROGENY AND SCULPTURE

In the foregoing pages, an account of the geomorphological and tectonic features as developed in the Himalaya has been given, on the basis of which it is evident that there are infinite varieties and a numerous types of landforms present in the region. The occurrences of peculiar and extra-environmental litho units at horizons other than they are normally expected also suggest that due to the periodic risings and heavings of the earth's crust during the geological past, the sediments of the Tethys geosyncline have been uplifted folded and thrusted over or have submerged parts of Himalayan regions from time to time. These movements have also been localised around the margins of the shield structures, i.e. the Indian Peninsular shield mass of the Gondwanaland and the Tibetan shield of the Laurasia.

King (1962) believes that "the belt of Palaeozoic orogeny may be expected in the roots of the Himalayan mountain system and in Tibet, united now with the Palaeozoic mountain systems of Central Asia". The evidences are the small inliers from beneath the later Himalayan geosynclinal formations. He further expresses that, "the Alpine-Himalayan geosyncline........was extent from Carboniferous till nearly Cainozoic time" and later in the Middle Eocene, "the geosynclinal floor and its contents are subjected to orogenic spasms" due to which "the contents are crumpled, thrusted and finally uplifted" and formed the lofty mountain chains. During Cretaceous period, the Gondwana planation survived but an incursion of the Tethys extended from Salt Range through Baluchistan into Kutch, in which the sediments from the old lands were accummulated, which are now found as fossiliferous marine beds.

According to Wadia (*op. cit.*) the Tertiary or the Cainozoic era is the most important period in the geological history of the Indian sub-continent. During the late Cretaceous, consequent to the Mesozoic fragmentation of Gondwanaland and Laurasia, the submergence of large blocks of land masses and the upheaval of the Tethyan geosyncline, probably resulted due to the great diastrophic movements and period of volcanicity.

As a result of these earth movements, the sediments of the Tethys geosyncline have been deformed due to lateral compressional forces and vertical movements generally resulting into dislocations, elevations and tilting of the rock masses. While discussing Himalaya and Pamir R. D. Oldham (1918) stated that, "the broad features of the major relief, as well as the determination of the more restricted zones of greater uplift are not the result of processes apparent in the structures visible at the surface, but of more deeply seated and possibly quite independent processes which are not accessible to surface observation". These perhaps occurred locally in phases. The phenomena has given rise to an extremely complicated system of mountain chains. Essentially, they consist of a number of great recumbent folds thrusts and *nappes*, one over the other, which in turn are thrusted over a core of older crystalline rocks. Due to these large scale deformations and structural convolutions, the massive limestones or quartzites bend into large folds or fracture blocks, while the softer intermediate shaly beds are changed into slates, phyllites or schists. When a *nappe* has slid along a fault plane, the under surfaces are marked by thin stretched or entirely pinched beds or the closely packed isoclinal anticlines and synclines. However, beneath all types of rock formations is a crystalline base which is highly jointed and broken by minor faults.

On erosion, these Himalayan folds give rise to usually varied and peculiar topography. In the areas where the *nappes* have been completely eroded, the irregular jagged high peaks e.g. Everest, Makalu, Trisuli, Badrinath, etc. or sharp edged granite ridges e.g. Lohtse, Dhaulagiri, Dhaola Dhar etc. are common in the Himalaya. On the south side of the crystallines, the limestone ranges form plateaus but more often ridges and peaks of all shapes are fully developed.

Wager (1937) suggests that "the great peaks of the Himalaya owe part of their additional elevation over the average height of Tibetan plateau to the effect of isostatic readjustment" and the uplift has followed the relief of load where deep valleys have been eroded". Holmes (1964), however, believes that in addition to isostasy, "some other process or processes must be responsible for the exceptional heights of Everest, Kanchenjunga, Karakoram, Nanda Devi etc." and adds that the youthful mountain ranges and plateaus "descend steeply to the neighbouring lowlands, generally, but not always bounded by eroded fault scarps". In the Simla, Garhwal and Nepal-Darjeeling regions the younger formations are exposed as windows generally at the bottom of the valleys. Similarly *klippe* of higher and older *nappes* are commonly recognised at the tops of peaks or plateaus in all regions of Outer Himalaya.

The Tertiary history of Himalaya reveals alternating episodes of sedimentation and orogenesis. Throughout Himalayan belt Palaeocene is marked by marine formations, the Middle Eocene of northern parts is mainly *flysch* type and the Upper Eocene is gypsiferous. This is then followed by another orogeny breaking up the Tethyan geosyncline into shallow basins responsible for the brackish water Murree or Dharmsala formations along the southern faces of the Lesser Himalaya and Zaskar formations of Ladakh.

The important Middle Miocene orogeny gave rise to the major structures and threw the older formations in thrust sheets and *nappes* towards south, due to which the central axial zone was intruded with granites and the main southern Himalayan chains were built up with huge recumbent folds. The Baluchistan zone and the Burmese sector did not suffer much but the sediments were thrusted comparatively mildly over the shield wedges or ramifications of the main Indian Peninsula, near Quetta. In the case of the Burmese Himalaya, the sediments were thrusted over the Naga hills.

At the end of the Mid-Miocene orogeny, coarse fluviatile and glacial *molasse* formations were deposited in the sinking basins all along the southern faces of Himalaya. Towards the end of Pliocene, the Cainozoic Himalayan chains were eroded deeply. These were uplifted and upheaved again in the Plio-Pleistocene which gave rise to the more elevated, faulted and folded Himalayan system of mountain chains and the Siwalik foothills. The deformation due to orogenesis may be from simple anticlinal and synclinal structures to complex over folds and flow structures. Most of which are due to gliding under the force of gravity, and sometimes the *flysch nappes* of the major Himalaya have flowed into the river gorges through the frontal Siwalik hills, e.g. the schistose Dalings east of R. Tista and the Disangs in NE Assam. These have since been denuded to the present form and represent the last phase of orogeny, mainly of post-Pliocene to middle Pleistocene period.

Morphologically, the middle and outer ranges are orthoclinal in which the folds are dissected into south facing steep escarpments and the northward gentle dip slopes, separate the longitudinal narrow valleys. In the middle zone the anticlines are generally faulted in their southern limbs and the rocks of the steep faulted escarpments lie "in juxtaposition with much younger rock zones". The outer zone is comparatively a simpler structure with a series of broad anticlines and synclines. But here also, the south facing steep fault scarps due to a series of reversed strike faults or thrusts affecting the anticlinal axes are a characteristic feature of these ranges. The longitudinal tectonic valley, filled with gravels and glaciated boulders form the *duns*.

The occurrence of titled and elevated glacial and fossiliferous lacustrine deposits in the Karewa beds in Kashmir valley, the sediments of the

Katmandu valley and other smaller similar formations in the "Gauchar plains" in the Great and Middle Himalayan valleys are important evidences of Quaternary uplifts and even overthrusting in these regions.

Though de Terra has reported many broad floored ancient valleys at heights between 3,300 and 3,600 metres in Kashmir, still evidences of late Cainozoic or Tertiary movements are lacking. However, the antecedent drainage of the rivers Sutlej, Indus and Brahmaputra etc. with their headward erosion, deep gorges and wide valleys in the Himalaya are indicative of the recent vertical movements.

Concomitant with these late upheavals and slidings of modern Himalaya developed the Indo-Gangetic foredeep or depression and is formed of separate troughs due to transverse ridge like ramifications or extensions of the Peninsular shield. The closely spaced streams from the mountainous region discharge the load and make piedmont alluvial plain. The vast Indo-Gangetic plain extending from the delta of Indus to that of the Ganga-Brahmaputra is made up of boulder beds, gravels, sand, silt and clays.

CONCLUSION

The arcuate Himalaya mountain chains have risen against the older established river courses of the Indus, Sutlej and Brahmaputra. Emerging from the northern ranges and flowing longitudinally for several hundred kilometres north of this barrier, these rivers now pass through deep antecedent gorges to the Indo-Gangetic plains. Due to long intense forces of Alpine-Himalayan orogeny the old land surfaces have been changed completely. Simultaneously, the intermittent emergence and submergence of the land masses throughout the orogeny, the extent and configuration of the Tethys also changed but continued to be a zone of accumulation and sedimentation almost till late Cretaceous. It is certain, during the intervening periods of tectonic episodes a series of cyclic landscapes were carved out. However due to intense thrust movements, *nappe* structures, steep fault scarps and the present jagged terrain it is difficult to establish the cyclic evolution of the landscape development. Nevertheless, from the shapes of the hills, plateaus and the configuration of the valleys, presence of lakes and their lacustrine deposits at higher levels etc. it is evident that the Himalayan region has experienced several mountain building episodes during the late Cainozoic period. The intermittent Pleistocene glacial activity and deep carvings due to river action are notable features of the Quaternary times. Summing up, the modern Himalaya is a result of thrusts and vertical upheavals (cymatogenic activity) of the late Tertiary times. The thrust sheets and overfolds are overridden by relicts of earlier "smoother planation" of mid-Tertiary age. The anticlines, synclines and other isoclinal folds so created have been carved and denuded by the now receding glaciers and large scale river erosion in the sub-Recent and Recent times. The phenomena of uplifts is still in progress and is marked by the frequent earthquakes. The lofty Himalayan system have thus been sculptured and present the beautiful scenery through a process of complicated phenomenon.

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CHAPTER IV

INTRODUCTION TO MOUNTAINS OF THE INDIAN PENINSULA

The Indian Peninsular shield is the most ancient and stable landmass unaffected by later fold movements. The mountains that we see over the Peninsula are not fold mountains like the Himalaya, but represent the erosional remnants of former surfaces uplifted and subjected to more than one cycle of erosion. The drainage of the Peninsula is asymmetrical. Almost all the principal rivers take their origin at the western edge almost within sight of the Arabian Sea but flow eastwards traversing the full width of the continent. The explanation offered is that the present Peninsula represents only a part of a larger landmass, the western half of which either drifted away or foundered beneath the Arabian Sea. The more prominent of the mountain ranges of the Peninsula are the Aravalli, the Vindhya, the Satpura, the Western Ghats, and the isolated mountain ranges parallelling the east coast collectively called the Eastern Ghats.

THE ARAVALLI RANGE

The oldest mountain range in India is the Aravalli. It is a typical tectonic mountain which was uplifted and folded during the late pre-Cambrian period. Erosion during the ages reduced what was once a lofty range into a peneplain almost at sea level. In the late Mesozoic, the region was once again uplifted by at least 1,200 m near Udaipur city, and 300 m at its present terminals near Delhi and Ahmadabad. During the erosion which followed, the resistant quartzites formed bold ridges. The trend of the range is NE-SW extending from Gujarat to Delhi. The range is mostly made up of schistose rocks of pre-Cambrian age.

The Aravalli extends from Delhi southwestward to near Ahmadabad for a distance of about 800 km. The highest point in the range is Mt. Abu in the SW which rises to 1,158 m. Near Delhi it has been reduced almost to the level of the alluvial plain, though the strong quartzites, still outcrop in blocky masses and known locally as the Delhi ridge. At the southern end the range has been much more dissected with the result that only a few scattered buttes, hardly over 60 m in height, are the remnants of the mighty Aravalli.

South of Delhi, a long narrow hogback extends for about 70 km from Sohna to Ramgarh, rising to a maximum height of 400 m. South of Beawar, the Aravalli runs for about 100 km as a tightly compressed synclinal range, 600 to 900 m high. It then divides into a number of parallel folded ridges which enclose between them elevated plateaus.

THE VINDHYA RANGE

The Vindhya range traverses nearly the whole width of Peninsular India, a distance of about 1,050 km in a E-W direction. It has an average elevation of about 300 m. The range overlooks the valleys of the Narmada and the Son on the south, and slopes gently northwards to the Ganga valley. The range is formed mainly of massive sandstones.

The Vindhya mountain forms one of India's main watersheds, and along with the Satpura range, has often been considered as the dividing line between the Deccan and North India. Though there is no clear geological evidence to support it, topographical features such as truncated and faceted spurs suggest that the western part of the Vindhya range is a fault escarpment.

The Gomanpur peak (554 m) in the Dhar district of Madhya Pradesh marks the western end of the Vindhya range. For the first 100 km from this point, the range runs in a curve, the convex side facing the Narmada valley, and following a 300 m contour line in Deccan Trap country. For the next 160 km there is a prominent escarpment still formed of basalt. Near Hoshangabad the rock type changes—the Vindhya mountain approaches the Narmada river in a series of terraced slopes composed of hard sandstones alternating with shales. The Kaimur range, which is the eastern portion of the Vindhya mountain is one of the most pronounced scarps in India ; it is composed of quartzites and marbles, and is nowhere cut across by any large stream.

THE SATPURA RANGE

South of the Vindhya range and more or less parallel to it rises the Satpura, separating the Narmada and Tapti. It extends from Ratanpur on the west to Amarkantak on the east, a distance of 900 km. Several of its peaks rise above 1,000 m, and only a small part of this range lies below the 500 m contour line. In shape it is somewhat triangular, with its base along the north-south Maikala range, its apex at Ratanpur, and two of its sides parallel to the Narmada and Tapti-Purna rivers. It consists of a number of parallel ranges which enclose in between them extensive, flat-topped, lava plateaus.

Three distinct parts of the Satpura can be recognised, each rising to a height of about 900 m, and being connected with each other by lowlying plateaus. The westernmost part is locally known as the Rajpipla hills. A high, craggy, sharp-crested ridge formed of basalt dominates this western part of the Satpura and almost overhangs the Narmada valley between the two north-flowing tributaries of the Narmada—the Goi and Devganga.

The Satpura broadens considerably in the central part and has a radial drainage. This part is bordered on the north by the Mahadeo hills and on the south by the Gawilgarh hills. The Mahadeo hills are formed of resistant Gondwana quartzites which slope steeply southwards, the southern slope falling abruptly from a height of 1,200 to below 300 m, and the cliffs running ENE for a long stretch. The rectilinear trend of the scarp indicates that faulting was probably responsible for the steep scarp. The highest peak of the Satpura, Dhupgarh (1,350 m), is near the Pachmarhi hill station.

The eastern part of the Satpura is known as the Maikala plateau. It is bordered on the east by a line of east-facing escarpment, the Maikala range. This range runs in a northeastern direction from Raj Nandgaon to the Amarkantak knot and then turns northwest, meeting the Vindhya range to the north of Jabalpur. It is probable that the Maikala range marks the site of an ancient shore line to the east of which sediments were deposited in a Cuddapah sea, and that it may have prevented the flow of lava during the Deccan Trap period.

THE WESTERN GHATS

The Western Ghats (Sahyadri in Sanskrit) runs for about 1,600 km along the western border of the Deccan from near the mouth of the river Tapti to Cape Comorin. The average elevation is 1,200 m. Viewed from the west coast, the Ghats look like an ancient sea-cliff rising almost perpendicularly from the coastal plain up to 1,000 m in some places. Some have considered this to be a fault scarp. The Western Ghats are not true mountains, but form the faulted edge of an upraised plateau. The *ghat* landscape presents a youthful aspect composed of steep-sided valleys, narrow gorges and waterfalls of great magnitude. The west-flowing rivers are seen rapidly eroding headward and capturing the mature drainage on the upraised plateau. These facts indicate that the elevation of the *ghats* to the present level is recent more or less coincident with the time of uplift of the Himalaya. The consequence of this uplift is that all the important rivers of Peninsular India except the Narmada and the Tapti flow eastwards into the Bay of Bengal though they have their sources on the crest of the Western Ghats, which is only 50 to 80 km from Arabian Sea coast, The northern 650 km of the Western Ghats are formed of horizontal sheets of lava, and exhibit the characteristic Deccan Trap landscape. The crest line of the range runs in broad curves, forming two re-entrants at Trimbak and Tamhini, carved by the headwaters of the Godavari and Bhima rivers respectively, and two easterly bulges marked by Harischandragarh (1,424 m) and Mahabaleshwar peaks (1,438 m). Two other peaks rise higher, Kalsubai (1,646 m) near Igatpuri, and Salher (1,567 m) 90 km to the north of Nasik.

For the next 650 km south of 16° N latitude, the basalt gives place to granitoid gneiss. In this section the Western Ghats run very close to the coast, till they join the Nilgiri mountain near Gudalur. Vavul Mala (2,339 m) is the highest peak. North of the Nilgiri plateau, the eastern flank of the range merges somewhat gradually into the high plateau of Mysore, but its western slopes rise suddenly and boldly from the low coast.

The Palghat Gap along which the river Ponnani flows, trends east-west, and is a prominent break in the continuity of the range along the western border of the Deccan plateau. It is about 24 km wide at its narrowest point and lies at an elevation of 145 m, whereas the bordering range rise from 1,500 to 2,000 m.

South of the Palghat Gap both the eastern and western slopes of the Ghats are steep and rugged. In Kerala, the range is flanked by picturesque terraces of laterite which shelve gradually down towards the coast. In elevation it varies from 1,000 to 2,500 m above the sea. Anai Mudi (2,695 m), the highest peak in the Peninsula, is a nodal point from which three ranges radiate in three different directions—the Anaimalai in the north, the Palni in the northeast, and the Cardamom hills in the south. Kodaikanal, an important hill station, is located in the Palni hills. The Anaimalais are perhaps the most striking ranges in south India. They are divided into a lower and a higher range. The latter consists of a series of plateaus about 2,000 m in elevation running up into peaks of over 2,500 m. These are covered with rolling downs and dark ever-green forests, and are cut off from one another by deep valleys containing some magnificent scenery.

The Palnis consist of two well-marked divisions, the more eastern of which averages from 900 to 1,200 m in height and is known as the Lower Palnis, while the western has a mean elevation of 2,000 m, and in one place rises to 2,506 m. The favourite hill station Kodaikanal, which stands on the southern edge of the central portion of the ranges is about 2,195 m in elevation. In the southern side the Palnis often end in steep sheer precipices, but on the north they slope more gradually down to the plains,

THE EASTERN GHATS

The Peninsular plateaus are bordered on the east by the Eastern Ghats. These are not really ranges in the same way as the Western Ghats, but appear as uplifted plateaus abruptly demarcated from the surrounding plains. The Eastern Ghats run in fragmentary spurs and ranges down the east side of the Peninsula, receding inland and leaving broad plains between their base and the coast. The Eastern Ghats belong to no one geological formation, and the rocks which they consist of vary in structure and origin with the country through which they pass. The range is cut into discontinuous blocks of hills by several large rivers. Between the Godavari and the Mahanadi, the range which trends northeast to south-west, is prominent with several peaks above 1,000 m in height. North of the Godavari, the Eastern Ghats are locally known as Mahendragiri. South of the Krishna, there is a series of parallel ranges and valleys which constitute the Nallamala hills.

The northern portion of the Eastern Ghats borders the Dandakaranya —a rugged terrain south of the Chhattisgarh basin, and lies in Orissa and Andhra Pradesh. Nowhere do the Eastern Ghats exhibit their mountainous character more clearly than in the region between the Godavari and the Mahanadi. The ancient name of the Eastern Ghats, Mahendragiri, was given after a peak of that name (1,501 m), which stands conspicuously above the coastal plain, about 80 km southwest of Berhampur in Orissa. This mountainous tract is chiefly composed of charnockites and khondalites. The ranges form the watershed between the west-flowing streams like the Machkund and Sileru, and the east-flowing streams like the Linguliya and Vamsadhara.

The Shevaroy hills constitute a detached range which is divided into an eastern and western section by a deep valley. The western portion consists of three elevated plateaus ; at the southern extremity of the eastern portion at an elevation of 1,400 m, stands the hill station Yercaud.

Further north occur north-south trending parallel ranges and valleys of the Eastern Ghats, cut transversely by the Penner river in the south, and the Krishna in the north. The most prominent range of this section, the Nallamala, runs parallel to the Coromandel coast. Its southern part, the Palkonda range, is higher. From the tip of the northernmost point in the Palnad basin to the Tirupati hill on the south, the length of the Nallamala is 430 km, the average width 30 km, and the elevation ranges from 900 to 1,100 m.

The Nilgiri or Blue mountain is one of the most picturesque spots in south India. Its northeast-southwest trend conforms to the alignment of the Eastern Ghats. The Nilgiri is the meeting point of both the Western and Eastern Ghats and the two enclose within them the Mysore plateau. It forms a level plateau 2,600 km^2 in extent and is abruptly cut off on all sides. Two of the highest peaks are Doda Betta (2,637 m) and Makurti (2,554 m). The southwestern part, named Kundah, is more hilly and is traversed by bold ranges and intersected by deep valleys. It has a steep cliff towards the Malabar plains on the west. There is probably no landscape in south India that surpasses this gigantic escarpment in grandeur. The rest of the Nilgiri presents a different topography. Its surface is extremely undulating and the streams meander through rounded grassy hills and patches of forests.

CHAPTER V

PHYSIOGRAPHIC CHARACTERISTICS OF PENINSULAR RANGES

The triangular shape of Peninsular India is an expression of the structure of the region, which is determined in part by the Eastern and Western Ghats. Though the Eastern Ghats turn towards the interior near the city of Madras, their trend is continued farther south by submerged ridges which influence the delineation of the coast. The northwestern border is roughly parallel to the Aravalli ranges, while the northern border under its cover of Recent alluvium, is merely the undefined limit of the Vindhyan and Ranchi plateaus. The Shillong plateau and the Mikir hills constitute a promontory or prolongation of a wedge of the Peninsula towards the northeastern corner of the country. The interior of the Peninsula is occupied by a series of plateaus having a general easterly slope as a result of the uplift and tilting of the Peninsula in comparatively recent geological times. The important mountain ranges of the Peninsula are described below.

THE ARAVALLI RANGE

These mountains run across the State of Rajasthan in a NE-SW direction and are composed of a central range of ancient gneisses and schists of the Aravalli Syetem of rocks, associated with a synclinorium of the Delhi System which form parallel ranges. These mountains constitute a true orogen of folded rocks. They form a compact series of parallel ranges in the northern part but spread out in southern Rajasthan, turning gradually to the southeast and east, as they approach the Narmada valley.

Near the northern end, in the region of Delhi, the mountains are quite insignificant, marked out by a few low ridges of hard quartzites. The Delhi ridge traversing the Union Territory of Delhi is a part of this feature, which when followed to the northeast, disappears under the alluvium of the Yamuna river. These ridges can be followed to the southwest into Alwar and Jaipur where they become fairly prominent and also show zones of intercalated schists and gneisses. The Aravalli ranges may be said to commence only near Khetri (28° N, 75° 47′E) where they proceed to the southwest becoming gradually higher as well as wider.

The central range is formed of gneisses and schists as well as of quartzite belonging to the Aravalli System. These rocks form rugged hills with rounded surfaces but the quartzites stand out as jagged hills exposing scarps facing northwest. Here are the comparatively low peaks of Babai (791 m), Kho (979 m), Raghunathgarh (1,109 m), and Harasnath (903 m). Near Ajmer, they separate out into a number of parallel ridges occupying a width of 11 to 16 kilometres, skirting the Sambhar lake which lies on their west. Ajmer itself stands on high ground amidst the ranges and is overlooked by the Taragarh hill fort (870 m). There is a break in the ranges south of Ajmer for about 16 kilometres, after which two prominent ridges appear near Beawar. These two ridges continue almost unbroken for nearly 110 kilometres, separating the territory of Mewar (Udaipur) on the east from that of Marwar (Jodhpur) on the west. In this region the mountainous terrain is 25 to 30 kilometres wide and quite wild, consisting of a series of ridges of quartzites and of gneisses and granite. The well defined hill range called the Mewar hills near Udaipur and that near Indargarh present a steep scarp on the western side for a distance of nearly 40 kilometres. This ridge is unbroken except for one or two rugged passes. Farther to the southwest, the country becomes a rather confused mass of hills occupying a width of 40 kilometres, though the general trend of the mountains can be made out clearly. In this region are the Nathji peak (937 m), southwest of Todgarh. The main range may be said to culminate at Jargo (24° 58′ N, 73° 32′ E) which attains an elevation 1,315 m. The hills become lower thereafter, although the mountainous character persists, and there is a definite veering of the trend to the south and southeast. Mt. Abu in the Sirohi district stands slightly off the trend of the range, being composed of a boss of granite which rises suddenly out of the plains. The rugged cluster of peaks on this mountain is topped by the eminence called Guru Sikhar which reaches a height of 1,722 m, this being the highest point in the Aravalli ranges.

These mountains expose various types of rocks—mica-schists, amphibolites, granites, gneisses, quartzites and crystalline marbles. The quartzites constitute well marked ridges with serrated outlines, and steep scarps on the western side. The crystalline limestones form rough ridges with numerous crags and well jointed blocks marking the outcrops. Some of the prominent exposures of marble, especially those near Raialo, Makrana, Nathdwara, Raj Samand, Kankroli, Jahazpura and in the Sabalpura hills are being worked to yield building and ornamental stones. The granites, gneisses and amphibolites are marked by more rounded topography. Granites are prominent particularly in the southwest, where they can be recognised by the presence of characteristic tors.

The country to the southeast of the ranges descends down to the valley of the Chambal river which for about 800 kilometres follows an important fault line and is therefore straight. From this valley the ground rises gradually and almost imperceptibly towards the Aravalli mountains

12

of Ajmer and Udaipur, but, once the top is reached, there is a steep fall on the northwestern side. The Aravalli also forms a sort of boundary between the semi-desert to desert country on the west and the more normal country on the east.

In eastern Rajasthan are the Mukandwara hills which run from Chambal to Jhalrapatan as a double range. The southernmost part, in Dungarpur and Banswara, is quite rugged country, broken by numerous hills and valleys. East of this region we come to the area occupied by the Deccan Trap lavas with its distinct topographic expression.

THE VINDHYA MOUNTAIN

In complete contrast to the Aravalli mountain, the Vindhya is constituted of relict structures due to the sculpturing of a basin of sedimentary rocks in which a series of hard sandstones play an important part. These mountains extend between Rohtasgarh in Bihar in the east to Ganurgarh in Bhopal in the west, over a distance of nearly 725 kilometres. The whole of this region exhibits SSE facing scarps formed of the major subdivisions of the Upper Vindhyan System. The shaly formations between the sandstones form the slopes and terraces, some of large area. The Vindhya mountains really form a plateau which has a gentle northerly slope drained by numerous rivers which finally join the Ganga system. The rivers rise in the upper part of the plateau and flow north or northeast and their courses are marked by gorges and cascades when they cross the sandstone formations. The Son river flows, in part, along the foot of the Kaimur scarp which forms a near-vertical wall over 60 m high. The course of the southern Tons is marked by several waterfalls the best known of which is the Behar falls which, when in flood, is a solid sheet of water 180 m wide and 110 m high. The Vindhyan formations terminate westwards at Ganurgarh and turn to the north, but the mountains continue farther west for 325 kilometres more, but are composed of Deccan Trap lavas. In this area, the southern foot of the mountains is occupied by the valley of the Narmada river bordered by steep sides. The top of the mountains here partakes of the character of a plateau, but devoid of the sandstone scarps. Instead, it is occupied by flat-topped hillocks of lava flows with terraced appearance.

THE SATPURA MOUNTAINS

These occupy the country between the Narmada and Tapti rivers in Peninsular India. They are considered to commence in eastern Gujarat. From here they run east, separating Khandesh from Indore. The mountains are fairly rugged, forming an elevated plateau 760 m above sea level. They are composed mainly of the lavas of the Deccan Traps. Farther to the east, they rise above 1,000 m in elevation the plateau being covered by rather stunted trees. In the east the Gondwana formations replace the Deccan lavas. A prominent landmark here is the Mahadeo hills, a rugged mountain rising abruptly from the plains of Chhattisgarh basin, its top occupied by the hill station of Pachmarhi. The Mahadeo hills present a strong contrast to the rest of the Satpuras as they consist of pink and brown sandstones very different from the sombre black of the Deccan lavas. The easternmost part of the Satpuras is of varied character consisting of a medley of hills and valleys reflecting the heterogeneous character of the geological formations therein.

THE ASSAM RANGES

The Assam ranges together constitute the Meghalaya or Shillong plateau. They include the Garo, Khasi and Jaintia hills, which occupy the southern part and run roughly in an E-W direction. The average elevation of the plateau is about 1,830 m. The top of the plateau consists of rolling downs interspersed with ridges in the southern part and more rounded and rugged hills in the northern part. The southern flank is a steep scarp which constitutes the southern limb of a large monocline plunging steeply into the Bengal plains. It exposes thick beds of the Sylhet Limestone and other Tertiary rocks. The northern part is composed mainly of ancient granites, gneisses, schists and quartzites. The plateau decreases in height northwards through a series of steps into the valley of the Brahmaputra. Near the western end are the Garo hills, carrying the Nokrak peak (1,402 m). Being formed of prominent sandstones, they show a serrated outline. Near Shillong, in the gneissic terrain, is the Shillong peak (1,961 m) standing prominently above the plateau. The level falls towards the south and southeast towards the Jaintia hills. Cherrapunji in this region is celebrated as the wettest place in the world, receiving a rainfall of 10,869 mm per year on an average, and much more in some years. In the southeast, close to the southern margin, are the Barail range which continues to the east and rapidly rises in elevation. The Barail range finally merges into the Lushai hills which are part of the Indo-Burma border ranges.

The southern border of the plateau, along the axis of the monoclinal structure, is marked by the prominent Dauki fault along which the whole plateau is believed to have been moved eastward over a distance of about 250 km from its original position north of the Rajmahal hills and across the present Garo-Rajmahal gap at the head of the Ganga delta. The transcurrent movement occurred during the late Miocene or Pliocene. Followed eastward, this fault merges into the Haflong-Disang thrust which runs to the northeast from the northeastern end of the Shillong plateau into Upper Assam for a distance of some 400 km parallel to the Naga thrust which borders the Brahmaputra plains of Upper Assam.

The Shillong plateau is intersected by a criss-cross pattern of faults developed as a result of the southward directed pressure from the Himalayan side and the NW-directed pressure from the side of Burma. The faults are conspicuous by the fact of their being occupied by stream courses.

THE EASTERN GHATS

On geological and tectonic grounds, the Eastern Ghats may be considered to consist of four sections. The northernmost, is the part occupying Mayurbhanj and adjoining territory north of the Mahanadi river ; the second lies between the Mahanadi and Krishna rivers running NE-SW parallel to the eastern coast ; the third lies between the Krishna and the city of Madras along the arcuate eastern margin of the Cuddapah basin ; the last is the region between Madras and the Nilgiri hills where they meet the Western Ghats.

The first unit is formed of an intrusive igneous mass flanked by gneissic rocks on the north and east and by banded iron formations on the west. The hill ranges run N-S or NNE-SSW with prominent ridges and heavily forested deep valleys. The topography varies according to the nature of the geological formations. In this region are the peaks Meghasani (1,165 m). In Mayurbhanj, Thakurani (785 m) and Gandhamadan (1,060 m) in Keonjhar, and Malayagiri (1,187 m) near Pal Lahara.

From south of the Mahanadi, the Ghats run parallel to and 25 to 40 kilometres west of the coast ; but they come to the coast at Vishakhapatnam. They are composed of the khondalite-charnockite suite of rocks occupying a belt 15 to 25 kilometres wide. The khondalites are metamorphosed sedimentaries, giving rise to smooth, rounded hummocky hills capped by laterite cover, and with more or less level tops. The charnockites and associated intrusive granites form more rugged hills with their surfaces covered with large blocks and tors. This part of the Eastern Ghats is a true mountain range of the Alpine type formed in the early pre-Cambrian times and uplifted in the late pre-Cambrian. The western margin, at least in part, shows a faulted junction against the gneissic country, as evidenced by the straight course of the Machkund river. It is likely that the other parts of the margins are similarly faulted. In Jeypore (Koraput) and Kalahandi, there are extensive plateau-like expanses of laterite known as "*pats*". The average elevation of the Ghats is about 1,100 m one of the highest points being Mahendragiri (1,501 m) in Ganjam. They form an important water-shed from which rise the Machkund, Sabari, Sileru, Bhaskel, Indravati and several lesser streams which flow west and ultimately join the Godavari. Those rising on the eastern flanks are smaller and shorter, like the Nagavalli and the Vamsadhara, the former rising from a cluster of hills known as Nimgiri at an elevation of 1,515 m. There are a few caverns in the limestone formations in the Ghats, the ones of Borra near Vishakhapatnam and of Gupteswar on the western side being well known. The Ghats become narrower and less prominent as they reach the Krishna valley.

The Godavari, like the Mahanadi and Nagavalli, cuts across the Ghats and flows through a narrow but not very steep gorge. The Khondalite-charnockite rocks terminate at the Kondavidu hills near Guntur just south of the Krishna river, and run into the sea nearby. The continuity of the Ghats is, however, taken up by the eastern margin of the Cuddapah basin along which the gneissic rocks on the east are thrust against the sedimentary rocks of the basin. The ranges in this part are called the Nallamala, Palkonda and Velikonda hills whose average elevation is about 760 m. These form an extremely rugged and broken hilly country with jagged peaks and steep slopes. The well known Tirupati hills and the Nagari hills some 120 km and 56 km respectively to the north of Madras are formed of quartzites constituting picturesque landmarks. This part of the Ghats has an arcuate shape with concavity to the east, and terminates at the Nagari hills.

The Eastern Ghats commence again near Madras city but take a WSW direction, and proceed through Chingleput, North and South Arcot, Salem and Coimbatore, to the Nilgiri mountains. Throughout this stretch, they are composed of massifs of charnockite associated with gneisses and a varied metamorphic suite including crystalline limestones, banded magnetite quartzites, mica schists and amphibolites. For some distance west of Madras city they form straggling hills but become prominent in the Javadi hills of North Arcot. The other units of the chain are called the Gingee hills in South Arcot, Kollaimalai and Pachaimalai in Tiruchchirappalli, Shevaroys, Godumalai etc. in Salem and Biligiri Rangan hills in Coimbatore. The last named occupy a width of 25 km with several peaks, the highest of which attains a height of 1,279 m. The charnockite massifs are the most prominent amongst these, constituting bold and steep sided mountains with a comparatively flat and rolling topography on the top.

THE WESTERN GHATS

The Western Ghats are not, in any sense, a mountain range, as they are mainly the uplifted western border of the Peninsula formed of different geological formations of varied origin and structure. The northern part, in Maharashtra State, is the edge of the Deccan plateau occupied by the flatlying Deccan Trap lava flows. In fact, the term *Ghats* expresses the terraced appearance of the mountains, the steps of the terrace being successive lava flows. Ancient gneisses and metamorphics appear farther south in Ratnagiri and Kanara, the iron formations in Kadur and Shimoga, and charnockites farther south. The total length is about 1,600 km and there is a great variety of scenery and topography.

The Western Ghats commence in Khandesh just south of the Tapti valley. They are 50 to 60 km from the coast, and have an average elevation of 550 m, with a few peaks rising to 1,000 m. From Khandesh to Trimbak, the source of the Godavari River, the trend is S. by W. and thereafter almost due south in Maharashtra. In the Bombay-Surat region the Deccan Traps show a monoclinal fold whose western limb dips gently towards the sea at about 8 to 10 degrees. The axis of the monocline, running through Panvel and Kalyan toward the Gulf of Cambay, is fractured and shows numerous hot springs. Throughout Maharashtra the Ghats present steep and abrupt slopes towards the coast, but a gentle slope towards the east. Though there is no well defined range, several spurs take off from near the coast and run to the east. The general elevation south of Bombay is about 1,400 m the more important eminences being Kalsubai (1,646 m) and Mahabaleshwar (1,438 m),the latter being the source of the Krishna river.

Between Ratnagiri and Coorg the rocks are a heterogeneous assemblage of gneisses and metamorphics including green-schists and prominent ridges of iron formations. The famous Gersoppa (Jog) falls of the west-flowing Sharavati river at the southern border of Kanara is remarkable for its sheer drop of 250 m. In Coorg, farther south, the Ghats recede to a distance of 60 to 80 km from the coast, but in Sagar, between the Govardhanagiri and Devakonda, they are only 15 km from the sea. The peaks of Kudremukh (1,894 m) in Kadur and Pushpagiri or Subrahmanya (1,714 m) in Coorg occur in this region. Between Pushpagiri in the north and Brahmagiri in the south, there is a great range of charnockite rocks for a length of 100 km. Several ridges run eastwards from here through Coorg, the one carrying the double peak of Kotebetta (1,638 m) near Mercara being noteworthy.

The Coorg belt of charnockite is really the northwestern prolongation of the Nilgiri mountains which carry the peaks of Dodda Betta (2,637 m) and Makurti (2,562 m). The latter presents a spectacular vertical sided flank with a drop of several hundred metres. The Nilgiri mountain on which the well known hill station of Ootacamund stands, has a steep western face but merges gradually into the Mysore plateau on the north.

South of the Nilgiri is the extraordinary Palghat Gap, which is the only wide and low pass of any size in the Ghats. This Gap is a smooth saddle, about 25 kilometres wide, at an elevation of only 300 m. For a long time it was the only easy line of communication between the plains of Madras and the coastal plains of Kerala. It is probably the valley of a large river which flowed west in pre-Pleistocene times.

The Anaimalai rises abruptly south of the Palghat Gap, occupying the area between 10° 15′ to 10° 30′ N and 76° 51′ to 77° 20′ E, throwing off an easterly branch which forms the Palni hills. The Anaimalai constitutes a series of plateaus with rolling topography, intersected by deep glens and valleys, clothed with dense forests of large timber trees including teak, ebony, rose-wood, etc. These as well as the other charnockite ranges of Coorg, Kerala and Madras (Shevaroys, Palni hills), support large coffee plantations while rubber trees are grown in the lower hills of Kerala. The plateaus of the Anaimalai are 1,800 to 2,000 m above sea level, with several peaks rising above 2,400 m. The highest, and indeed the highest in the whole of the Peninsula, is the Anaimudi (10° 10′ N, 77° 4′ E) which is 2,695 m above sea level. In these mountains is also a cluster of peaks in the shape of a horse-shoe, opening into a valley to the northeast.

The Western Ghats continue south, forming the border between the Madras and Kerala States, but the elevation of the hills falls gradually to about 1,200 m. The high rainfall on these mountains, averaging 5,000 mm per year, is conducive to the growth of thick forests which form an abundant source of excellent timber. The Ghats give off several easterly spurs, of which the Varshanad and Andipatti hills are of large size to the south of the Palni hills. From Quilon south to Nagercoil, which is about 20 km north of Cape Comorin, the Ghats lose their identity and only a few low hills are present.

It will be noticed that the main watershed of the Peninsula south of the Tapti valley is the western Ghats, though it is so close to the western coast. This is believed to be due to the faulting down of a strip of country west of the Western Ghats into the Arabian Sea, as it is known that the edge of the continental shelf on the west is a fault line of late Pliocene age. It is also believed that there were two periods of uplift of the western side of the Peninsula one post-Miocene and the other probably Pleistocene. The Mysore, plateau and the Cuddapah basin show two erosion surfaces which can be related to these uplifts. There is also some evidence that the chief charnockite massifs in the south under went uplift in the late Tertiary as a result of isostatic adjustments in the crust.

CHAPTER VI

ZOOGEOGRAPHY OF THE MOUNTAINS OF INDIA

An attempt is made here to present a brief outline of the outstanding characters of the zoogeography of the principal mountains of India. The account is necessarily sketchy and avoids detailed evaluations of evidence and discussions of problems and conflicting views. The salient features of the ecology, faunal characters, patterns of distribution, centres of origin and faunal radiation and other peculiarities of the biogeography of these mountains are discussed in considerable detail elsewhere.*

LIMITING FACTORS

The general ecology of the "hills" and "mountains" of India, in correlation with their biogeography, does not conform to our experience in other parts of the world. It is known, for example, that on nearly all the important mountain ranges in the world, the atmospheric temperature is the dominant, if not the most decisive limiting factor in animal distribution. While this is perhaps partly true above the forest-line on the Himalaya, it would, however, seem at first sight that within the forest zone on the Himalaya and at least on the Peninsular mountains, it is the amount and distribution of annual rainfall that is dominant as a biogeographical factor. The close agreement between the patterns of distribution of rainfall and distribution of plants and animals in India would indeed seem to be convincing evidence of such a view. It must, however, be pointed out that while not in complete disharmony with the rainfall patterns and other climatic conditions, the general composition and distributional patterns of the character fauna of the mountains of India are not primarily the result of these conditions. These conditions do not even give any clues to the origin of the distributional peculiarities. The present-day climate of practically the whole country is determined largely by the mountains themselves, and particularly by the Himalaya, so that the dominant limiting factors in the distribution of animals are, therefore, largely historical, rather than climatic. The Himalaya orogeny, the geological stability of the

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*Mani, M. S. 1962. Introduction to High Altitude Entomology. London: Methuen & Co. pp. 302, fig. 80, pl. xvii.

Mani, M. S. 1967. Ecology and Biogeography of High Altitude Insects. The Hague : Dr. W. Junk Publishers. p. 700.

Mani, M. S. Biogeography in India (In Press).

Peninsular Block and the intense pressure of influx of Extra-Peninsular faunas, mainly from the east, have determined the general composition and biogeographical affinities of the mountain faunas. The peculiarities of distributional patterns of the faunas of the Peninsular mountains and of the Himalaya and other Tertiary mountains are largely the results of the Pleistocene glaciations on the Himalaya. Pleistocene glaciations have influenced animal distribution in a great diversity of ways in Europe and North America and in India this influence has been quite different from those regions.

The patterns of distribution on the Peninsular mountains and within the forest zone on the Himalaya have been very profoundly influenced by the pressure of human settlements and expansion and spread of civilization. Deforestation, intensive and shifting cultivation, overgrazing and wars are major decisive factors, which have determined the distributional patterns on the Peninsular mountains. Commencing from the lowlands, deforestation has extended up the hills and mountains, till eventually little of the original climax forest now remains as mere relicts, in the extreme southwest corner of the Peninsula. Areas deforested, but subsequently abandoned by man, did not regain the original forest-cover, but turned into open grassland savannahs, so that the ecological and biogeographical effects of deforestation have been far more intense in India than perhaps anywhere else in the world. Destruction of forests affected the distribution not only of the forest-specialized forms, but as a chain reaction more or less profoundly influenced every other dependant habitat, so that even the distribution of fresh-water stream species was altered.

Climatically, the mountains of the extreme southwest of the Peninsula are largely comparable with those of Assam-Burma in the northeast, where deforestation has not, however, been so colossal as in the rest of India. The eastern Himalaya and the Burmese Arc are humid-tropical in their general ecology and also form an integral part of the ecological and biogeographical unit of south China, Indo-China, Thailand, Assam and north Burma. As we proceed westward along the Himalaya, the general ecology, both within the forest zone and above the forest-line, is progressively dominated by increasing continentality of climate and the Baluchistan Arc is indeed characterized by its general high aridity. The transition between the ecological and distributional conditions prevailing in the eastern Himalaya and in the extreme northwest Himalaya in Kashmir occurs in the area of the great defile of the Sutlej through the Himalaya.

The outstanding peculiarities of the ecology of the Himalaya, with special reference to animal distribution, may be attributed to its massiveness, the stupendous elevations of the mountain ranges, their trendlines, their location in the middle of a vast continental mass, their Tertiary orogeny, the Pleistocene glaciations and the continuing post-Pleistocene uplift movements. South of the crestline of the Great Himalaya, the lower hills are covered by the broad-leaved wet or lower monsoon-forests up to elevations of 900-1,000 m. Above this succeed the middle and the upper montane evergreen-forests, and at elevations between 2,450 and 3,100 m there is the broad-leaved sclereophyll *Quercus-Rhododendron* forest. This is really a mischwald, with conifers in the east. This gives place to the *Betula-Juniperus* zone at elevations of 3,000-3,600 m in the extreme west and a shrub zone of *Abies spectabilis*, with thickets of *Rhododendron campanulatum*, succeeded by dwarf *Rhododendron anthopogon* and *Rhododendron setosum* at elevations of 4,260-4,575 m in the east, where this belt may, however, ascend up to 5,180 m. In the western parts of the Himalaya, the *Betula-Juniperus* zone marks the upper limits of the forest and gives place to open vegetation of plant cushions, reaching up to 6,150 m. In the east the forest-line is at an elevation of about 4,100 m.

THE PENINSULAR MOUNTAINS

The Peninsular mountains are, from the zoogeographical point of view, refugial areas of survival of relicts of a complex, but at the same time greatly impoverished fauna, characterized at present by their pronounced regression. These mountains are indeed progressively diminishing theatres of concentrations of relicts of a fast vanishing faunal complex. The concentration of the typical Peninsular faunal elements on the mountains, observed at present, is no proof that these mountains were the centres of differentiation and faunal radiation. It does not also indicate approaching climax conditions and ecological and faunal stabilities.

The dominant character forms, found at present on the high mountains of the Peninsula, like the Nilgiri, Anaimalai, Palni and Cardamom Hills, were formerly widely and continuously distributed over the whole of the Peninsular Block and many of them even transgressed extensively and often deeply into the Extra-Peninsular areas, particularly on the mountains of Assam-Burma and south China. A part of the faunas of south China, Indo-China and Malayan subregions transgressed and was continuously distributed from Assam-Burma to the extreme southwest corner of the Peninsula. The climatic changes in the Indo-Gangetic Plains and in the northern and northeastern parts of the Peninsular Block, brought about by the Pleistocene glaciations on the Himalaya, represent perhaps an initial phase in the origin of the marked discontinuity of distribution prevailing today. Though there seems to have been a partial restoration of continuity and re-establishment of faunal exchanges between the mountainous areas in the northeast and the Peninsular high areas by the end of the Pleistocene conditions, increasing human interference, especially within historical times, interrupted these processes. The regressive changes in the faunal range of the Peninsula seem to have reached a critical stage, beyond which even a partial recovery of the ground lost became impossible, some time soon after the Mahabharata war. The fauna that was thus once common to the Peninsula as a whole and even to the contiguous Extra-Peninsular mountains in the northeast, has thus been pushed up to the refugial niches of the higher levels, viz. the so called mountains, of the Peninsula by the destruction of habitats elsewhere.

The fauna of these mountains cannot, therefore, be strictly speaking described as composed of mountain animals—these are indeed no mountain-autochthonous elements on the Peninsular mountains, but only tropical-forest autochthonous forms of plateau and of a strictly relict character. The distribution of animals on the Peninsular mountains, despite the high elevations at least in the south, is not also characterized by perceptible altitudinal zonation. We find on the other hand a striking gradient in the density of species, in other words an increasing poverty of species from the mountains, to the north, northeast and east. This peculiar inversion in abundance of species is fundamentally different from the conditions observed on mountains in other parts of the world, The gradient, which we observe, reflects merely the concentration of relicts on the refugial forested hills and the fall in their abundance with increasing distance and with vanishing habitats. The heavy concentration of genera and species and the high degree of isolation on the high hills of the southern block of the Peninsula are really symptoms of faunal regression, within historical times. While intense isolation ordinarily favours rapid speciation, there is, however, a striking evolutionary stagnation on the Peninsular mountains.

From the biogeographical point of view, the fauna of the Peninsular mountains, especially of the Western Ghats, are therefore composed almost exclusively of phylogenetic and geographical relicts. They represent essentially impoverished remnants of a vanished fauna of the whole Peninsular plateau.

The original fauna of the Peninsular Mass, the impoverished relicts of which are now restricted to the forests on the mountains, was characterized by the following component elements : i. the derivatives of relatively older faunas, differentiated in a southern landmass, viz. the Gondwana faunas and ii. the derivatives of the relatively younger faunas differentiated in the northern landmass of Asia, mostly during Tertiary times. There was a complex admixture of these derivatives of essentially forest faunas in the Peninsula. Ethiopian and Mediterranean faunal elements constituted minor components.

The derivatives of the Gondwana faunas represent perhaps the oldest component elements and are thus true phylogenetic relicts. The most important of these derivatives are the Peninsular autochthonous elements, which differentiated from the common ancestral stock of Lemuria (Africa-Madagascar-Indian Peninsula), after the Peninsula became separated from Madagascar. They represent the dominant types of the original fauna of the Peninsula, before the intrusion of the younger Tertiary faunal elements from the northeast. The fresh-water sponges *Gecarcinucus* and *Pectispongilla*, the fresh-water hydroid *Limnocnida indica*, the Oligochaeta *Comarodrilus*, *Ochtochaetus* and *Eudichogaster*, the Mollusca *Ariophanta*, *Mariaella*, *Pseudaustenia*, etc. are some of the more interesting relicts of this ancient fauna, now restricted to small patches on the Western Ghats. The Lamellibranch-Mollusc *Mülleria* is represented by a single species *Mülleria dalyi* in mountain streams, feeding the Krishna on the Western Ghats. The family Aetheriidae, to which *Mülleria* belongs, is of great antiquity and the next congeners of this species are found only in South America. Another Mollusc *Mariaella* is at present confined only to the Western Ghats, for Mahabaleshwar in the north to Malabar in the south, but was formerly more widely distributed in the Peninsula. Two other Mollusc *Pseudaustenia* restricted to the Nilgiri and Cardamom Hills and *Ratnadvipa* restricted to hills of Ceylon (which are detached portions of the Peninsular Block) are also relicts belonging to this group.

There are some interesting Peninsular-autochthonous fishes like *Sisor*, *Jerdonia*, *Nemachilichthys*, numerous species of *Mystus*, *Batasia*, *Glypto-thorax*, *Silnopangasius*, etc. The South Indian hills are the home of several interesting relict Amphibia like *Micrixulus*, *Nyctibatrachus*, *Nannobatrachus*, *Cacophis*, *Nannophrys*, *Melanobatrachus*, *Gegenophis*, etc. The relict reptiles on these mountains include the snakes Uropeltidae, *Xylophis*, *Haplocercus*, *Aspidura*, etc. The mammals *Platacanthomys*, *Loris*, *Melursus* and *Tetraceros* must also be considered as such relicts. All these autochthonous forms are essentially humid tropical forest elements and it was this high ecological specialization that led to their relict status on the mountains by the disappearance of the forest habitat below.

A great many of the Peninsular forms are common to the Peninsula and Madagascar and sometimes also tropical and South Africa or have their closest relatives in these areas. Some of these Madagascan and tropical African relatives transgress eastwards to the Melanesian and Polynesian subregions and even to the Australian and Neotropical regions. The genera and species with Madagascan and tropical African affinities are also essentially forest-specialized forms. The genera and species with Madagascan affinities are more numerous on the South Indian mountains than those with tropical African affinities. The fresh-water sponges *Corvospongilla* and *Spongilla* (*Stratospongilla*) *bombayensis*, occurring in the drainage area of the Godavari on the Western Ghats up to Mysore, are known from South Africa. The fresh-water hydroid *Limnocnida* and the fresh-water Bryozoa *Plumatella* (*Afrindella*) *tanganyikae* and *Lophopodella*, occuring in the Western Ghats, are tropical African forms. The Oligochaeta of the Peninsular hills, with Madagascan-Tropical African affinities, include *Howascolex*, *Curgia*, *Gordiodrilus*, *Glyphidrilus*, etc. The East African scorpion *Iomachus* occurs on the Shevaroy and Nilgiri Hills. The Tropical African spider *Heliogmomerus* occurs on the Kodaikanal and Palni Hills and on the hills of Ceylon. The fishes with African affinities, occuring on the Western Ghats, include *Notopterus*, *Barilius*, *Rasbora*, *Gobius*, *Mastacembelus*, *Garra*, etc. *Eutropiichthys*, a Schilbaeid fish with three species in the Peninsula, is closely related to the African *Eutropius*. Of the reptiles common to Africa and South Indian mountains, mention may be made of *Cnemaspis* and *Riopa* and the birds include the yellow-throated *Gymnornis* and *Salpornis*. The Cercopithecine monkeys of the South Indian hills are closely related to the African forms.

The derivatives of the younger faunas, differentiated on Tertiary mountains of Yunnan-Assam-Burma area or the Indo-Chinese Subregion and from the Malayan Subregion, belong to Recent and phylogenetically higher groups like Lepidoptera, snakes, higher mammals and birds. The greatest bulk of the butterflies found on Peninsular mountains, even as far as the extreme southwest, are, for example, localized endemic races and subspecies of species and genera which arose in the northeast and in Malaya, or they are wholly identical with them. All these butterflies, now restricted to the mountains, were formerly continuously and widely distributed in the Peninsula. The butterfly *Graphium agamemnon*, which has extended from South China southwards to the Solomon Islands and westwards on the Himalaya up to Kumaun, is represented, for example, on the Nilgiri Hills and on the hills of Ceylon by *Graphium agamemnon menides*. The Homalopterid fishes like *Balitora*, *Bhavania*, *Travancoria*, etc., numerous lizards and snakes are other examples with such eastern affinities. The Malayan elements are illustrated by the Oligochaeta *Megascolex*, *Woodwardia*, etc., scorpion *Chaerilus*, Uropygi *Thelyphonus* and *Trithyreus* and fishes like *Thynnichthys*.

A small number of Ethiopian and Palaearctic forms also occur on the Western Ghats. The Palaearctic elements are mostly derived from the Mediterranean Subregion, but isolated examples of the Turkmenian forms from the Himalaya are also discontinuously found on the South Indian mountains and represent Pleistocene relicts. Most of these elements have intruded from the northwest, during perhaps the late Pleistocene and also to some extent during the early post-Pleistocene times and are mostly confined to the northern parts of the Western Ghats, although extremely few species have spread further south. The Mediterranean elements are illustrated by the scorpions *Buthus* and *Buthueolus* and the Himalayan forms include the Carabid beetles *Harpalus* and others. The mammals like *Hemitragus hylocrius* occur on the Western Ghats, from Nilgiri to south, but all the other species of the genus are found on the Himalaya. The

Mediterranean and Ethiopian elements are ecologically specialized for open habitats and steppes and not forest forms and are thus habitat-foreign elements that have largely not transgressed beyond the Deccan Lava areas of the northern parts of the Western Ghats.

THE EXTRA-PENINSULAR MOUNTAINS

The biogeographical peculiarities of the Himalaya are correlated with the topographic youthfulness and persistence of the uplift movements to the present times, the highly transitional conditions that prevailed after the retreat of the Pleistocene glaciers, the repeated faunal intrusions from the east, the wide ecological differences introduced by the enormous elevations and great lengths of the mountain ranges and the far-reaching ecological changes affecting animal distribution in the Indo-Gangetic Plain brought about by man within historical times. In marked contrast to the Peninsular mountains, the Himalaya is extremely rich in relatively young and phylogenetically highly plastic forms. The distributional pattern is also fundamentally different and is characterized not only by marked altitudinal zonation but also by a very pronounced east-west limitation and gradation of the faunal component elements.

There is a pronounced concentration of typical mountain-autochthonous and endemic elements at higher elevations, above the forest-line, with a corresponding poverty below. There is also a marked westward enrichment of the mountain-autochthonous and endemic elements, so that the extreme eastern end of the Himalaya is biogeographically very different from its extreme western end. In the extreme east, the dominant component elements of the fauna of the Himalaya, both within the forest and above the forest-line, are derived largely from the South Chinese, Indo-Chinese and Malayan Subregions of the Oriental Realm. In the west the fauna is, however, almost completely Palaearctic and the dominant elements are derived from the Turkmenian Subregion (Middle Asia*) and the eastern extension of the Mediterranean Subregion. Although there is no sharp boundary between the predominantly Oriental fauna of the Eastern Himalaya and the Palaearctic fauna of the Northwest Himalaya, the biogeographical transition occurs about the defile of the Sutlej, where there is also a sharp change in the Himalayan syntaxis. Here the already attenuated Chinese and Malayan tropical forms seem to have been not

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* In English language, there is considerable confusion about the areas included here. Middle Asia includes the Republics of Turkmenistan, Uzbekistan, Tadjikstan and Kirghisia (former Southern Turkestan and North Afghanistan). Central Asia includes strictly the Mongolian People's Republic, Western China (Sinkiang, Tsinghai), Tibet and Inner Mongolia.

only halted but also partly deflected southwards along the Aravalli trend to the Peninsula.

The boundary altitude between the tropical elements of the Oriental (forest) fauna and the cold-adapted Palaearctic (steppes) fauna is in the ecologically transitional zone of the forest-line. The wooded slopes of the Himalaya form a belt of very variable width, between the Indo-Gangetic Plains on the one hand and the Palaearctic area on the other hand. The forested area is not, however, easily defined biogeographically north-south, as a number of genera that really belong to the tropical lowlands penetrate up the valleys deep often beyond the Oriental-Palaearctic transition and similarly some of the Turkmenian and Tibetan types descend in great tongues on the cold slopes, well within the forest.

1. THE FAUNA OF THE HIMALAYAN FORESTS

The animal life of the forest zone on the Himalaya is essentially a tropical forest fauna, secondarily adapted to subtropical, montane and even temperate conditions in the upper reaches of the forest and partly also towards the west. This fauna is derived largely from the South Chinese and Indo-Chinese faunal differentiation centre and to some extent from the Malayan centre. The tropical faunal elements have even spread round the eastern end of the Himalaya to Eastern Tibet and some of the outliers of these elements are indeed detected even in the Manchurian Subregion of the Palaearctic. Genera and species, which were differentiated in the areas to the east, spread on the Himalaya much further westwards on the forested Indian side than on the Tibetan side. North of the Great Himalaya, the tropical forest fauna reaches only Eastern Tibet, but south of the Great Himalaya as far west as Kashmir. The genera and species, now restricted to the forest zone on the Himalaya were, however, formerly more widely distributed even in parts of the Indo-Gangetic Plains and Peninsula. In most groups of animals derived from these centres, there have risen on the Himalaya a graded series of local subspecies, varieties and races, with increasing distance from its eastern end. This is an important difference between the fauna of the Himalaya and of the Peninsular mountains—speciation is far more intense in each group and also frequent in many more groups than on the Peninsular mountains. The greatest majority of the Himalayan butterflies, distributed in the forest zone, belong to genera and species which have their centres of origin and dispersal in South China, Indo-China, Thailand, and Burma, but are represented by an almost complete graded series of local mountain-autochthonous subspecies and races, from the Eastern Himalaya through Nepal and Kumaun-Garhwal nearly to Kashmir.

The Indo-Chinese genus of butterflies *Chilasa* is largely confined to the Eastern Himalaya, but extends sparsely even up to Kashmir. *Chilasa* *agestor agestor* occurs, for example, from Tonkin to Sikkim in the Eastern Himalaya, but *Chilasa agestor govindra* extends from Kumaun to Kashmir and *Chilasa agestor chiraghshai* occurs in West Kashmir. We observe in this case, for example, the East Himalaya and South and Indo-China have the typical subspecies, but further westwards on the Himalaya the subspecies are increasingly localized developments. *Papilio bootes* extends from west China through Assam and Eastern Himalaya to Garhwal. *Papilio rhetentor*, from China and Hainan, occurs on North Burmese mountains and extends westwards along the Himalaya to Kumaun. *Papilio protentor*, from Formosa, Hainan, China, Tonkin and Burma, extends through the Eastern Himalaya up to Kashmir and *Papilio polycitor* even up to Chitral. The beautiful butterflies of the genus *Troides* (=*Ornithoptera*), from the Malayan and Malaysian areas, are represented by *Troides helena cerberus* in the Eastern Himalaya (and also parts of the Orissa Hills of the Eastern Ghats) and *Troides aeacus aeacus* extending from Formosa across North Burma to Garhwal Himalaya. The Indo-Chinese Papuan *Valeria* occurs on the Eastern Himalaya. *Polydorus philoxenus*, from China, Tonkin, Formosa and Annam and Burma, extends across the Himalaya to Kashmir. A number of Coleoptera like *Jumnos*, and the butterfly *Teinoplapus imperialis* are common to the Eastern Himalaya and the Assam-Burma mountains.

Mention must be made here of the Onychophora *Typhloperipatus williamsoni* found on the Abor Hills of the Eastern Himalaya. This is related to the Malayan *Eoperipatus*. The distribution of the Onychophora includes Malaysia, tropical Africa, tropical America and Australia. The occurrence of this Gondwana group on the Eastern Himalaya shows again biogeographical affinities of this part of the Himalaya to the Oriental Region.

The fish *Glyptothorax*, found in the Himalayan streams and rivers, is represented by a single species which is common to the Eastern Himalaya, Eastern Tibet and South China. Many fishes like *Psilorhynchus balitora*, *Balitora brucei brucei*, *Nemachilus beavani*, *Nemachilus savona*, *Nemachilus scaturgina*, etc. are confined to the Eastern Himalaya, and others like *Tor progenius*, *Schizothorax progastus*, *Batasio batasio*, etc. are endemic to the extreme east of the Himalaya. The amphibian *Tylototriton* extends from Yunnan to Nepal. Among the reptiles, we find numerous examples. *Japalura*, from south-west China and extending to Formosa and Sumatra-Borneo, is represented by *Japalura variegata* on the Eastern Himalaya, *Japalura tricarinata* from Sikkim to Nepal, *Japalura major* from Garhwal to Northwest Himalaya and *Japalura kumaonensis* in the Kumaun Himalaya. The snake *Typhlops jerdoni* is common to the Eastern Himalaya and Assam-Burma mountains and *Typhlops oligolepis* is confined to the Eastern Himalaya. Another snake *Elaphe radiata* extends from South and Indo-China to the Eastern Himalaya and occurs also on the Orissa Hills of the Eastern Ghats. *Elaphe porphyracea* extends from Yunnan across Assam-Burma mountains to the Eastern Himalaya (and south to Malaya-Sumatra and *Elaphe cantoris* is confined to the Assam-Burma mountains and Eastern Himalaya. *Zaocys nigromarginatus* extends from Yunnan to the Eastern Himalaya. *Natrix parallela*, from Yunnan-Tonkin, extends across Assam-North Burma mountains to the Eastern Himalaya and *Natrix himalayana* is confined to the Eastern Himalaya and Assam-Burma mountains, but *Natrix platyceps* extends from the Eastern Himalaya nearly up to Kashmir. While *Boiga ochracea* and *Boiga* gokool are confined to Assam and Eastern Himalaya, *Boiga cyanea* is common to Indo-China and Assam-Burma and Eastern Himalaya and *Boiga multifasciata* has spread up to Kumaun on the Himalaya.

Some of the common birds of the Eastern Himalaya include the black-rumped magpie *Pica bottanensis*, the blue magpie *Urocissa*, the racket-tailed magpie *Cry irhina* ; titmouse *Aegithaliscus*, *Lophophanes* and *Silva parus*, etc. *Paradoxiornis* and *Suthora* are common to the mountains of South China, North Burma and the Eastern Himalaya and others like *Liothrix*, *Cutia*, *Peruthius*, *Mesia* and *Minla* are confined to the Assam-Burma mountains and Eastern Himalaya. The Eastern Himalaya is richer in birds than the Western and Northwest Himalaya.

Among Mammals *Macacus assamensis* occurs throughout the Himalaya. *Felis nebulosa*, *Felis marmorata* and *Felis temnicki* occur in the Eastern Himalaya, Burma and Malaya. *Linsang* (*Prionodon*) *pardicolor* is common to Burma and the Eastern Himalaya, but *Mustela flaviguda* extends from the Eastern Himalaya to Malaya. *Arctonyx* is represented by two species in the Eastern Himalaya, Assam-Burma and Indo-China. *Lutra cinerea* extends from South China across Assam-Burma to Malaya in the south and westwards to the Eastern Himalaya (discontinuously also on the Nilgiri Hills in the Peninsula). Other Mammals in the east include *Talpa murina* (only Himalaya), *Talpa leucura* and *Chimarrogale himalaica* (Himalaya and Burmese mountains). Though formerly distributed up to the Northwest Himalaya, *Rhinoceros unicornis* is now confined to the base of the foothills up to Nepal only.

In its western end, forest zone of the Himalaya has a relatively small fauna. Even the forest is here different from that in the Eastern Himalaya and most genera and species of animals, which are characteristic of the east, are absent. We have here the meeting of the Mediterranean, Ethiopian and Turkmenian elements, with the greatly attenuated Oriental outliers. While the Eastern Himalaya has, for example, a rich and diversified assemblage of Oligochaeta, the western end of the Himalaya is strikingly poor, but we have here *Perionyx* and the endemic *Eutyphoeus*. The Mediterranean Carabid beetle *Calosoma* occurs here. The butterflies of the Holarctic *Pieris* and *Colias* are abundant in the west and have spread eastwards across the Himalaya, with diminishing abundance even to Burmese mountains. The Satyridae, which are largely concentrated in the Eastern Himalaya within the forest zone, rise above these limits in the western parts of the Himalaya. The genus *Pararge* is mostly confined to the upper reaches of forest in the Northwest Himalaya and *Coenonympha* is restricted wholly to the Northwest Himalaya. *Schizopygopsis* is confined to the western parts of the Himalaya. There are about ten species of *Schizothorax* in Afghanistan and eight species in the Northwest and Western Himalaya. The Malayan element in the western parts of the Himalaya is very small and is illustrated by *Microhyla* Amphibia).

The Ethiopian *Gymnodactylus* has spread eastwards across the Northwest Himalaya to Burmese mountains. *Gymnodactylus lawderanus* extends, for example, from the Northwest to Kumaun Himalaya. *Agama himalayana* is common to Middle Asia and Northwest Himalaya and *Agama tuberculata* extends from Afghanistan eastwards to Nepal. *Phrynocephalus* occurs in Middle Asia, Northwest Himalaya and Baluchistan. Though found in the Northwest Himalaya, the birds *Urocissa flavirostris, Garrulax albigularis, Trochaloperum lineatum, Stachyridopsis pyrrhops, Hodgsonius phoenicuroides,* etc. do not extend east beyond Kumaun. Among mammals *Vulpes leuopus* and the polecat *Putorius larvatus* are confined to the Northwest Himalaya. The Himalaya black-bear *Ursus torquatus* extends from Afghanistan and Baluchistan across the Himalaya to Assam-Burma and South Chinese mountains.

2. FAUNA OF THE HIMALAYA ABOVE THE FOREST-LINE.

The fauna of the elevated regions above the forest-line on the Himalaya is very different from that of the forest zone. This fauna is relatively sparse, characteristically lacking in tropical Indian, South Chinese, Indo-Chinese and Malayan derivatives, but is composed almost exclusively of mountain-autochthonous, cold-adapted Palaearctic elements, the greatest bulk of which are strictly endemics that arose *in situ* and *pari passu* with the Himalayan uplift from an essentially steppes fauna. The main faunal affinities of the biotic zones above the forest-line on the Himalaya are with the Turkmenian Subregion of the Palaearctic, but there are also some Mediterranean and Manchurian elements. The greatest bulk of the Invertebrates found above the forest-line are typically terricole and also mostly endogeous, predatory species, but many species occur also in the glacial lakes, ponds, streams and thermal and chemical springs. The Vertebrata are remarkable for the absence of fishes and amphibians and the striking poverty of reptiles. Birds and mammals are, however, sparsely found.

Corvus corax is represented, for example, by a large race at higher elevations. The snow-partridge *Lerwa nivicola* and the Cornish cough are common at elevations of 6,200 m. The snow-leopard *Felis uncia* and other Carnivora like *Felis lynx* and *Felis manul* are also typical of the high elevations. The European beech-marten *Mustela foina*, extending from Afghanistan to Kumaun Himalaya, may also be found above the forest-line in the Northwest Himalaya. A variety of the European *Ursus arctus* usually occurs above the forest-line. *Arctomys himalayanus*, *Arctomys hodgsoni* and *Arctomys caudatus* occur in North Kashmir and Tibet. A number of voles occur in the Northwest Himalaya. *Lagomys* is confined to the higher elevations of the Northwest Himalaya, Baluchistan and Tibet. *Bos grunnius*, the Tibetan yak, may be found sparsely at higher elevations on the Northwest Himalaya. *Ovis hodgsoni* the Tibetan sheep, *Ovis poli* the Pamir sheep, and *Ovis vignei* are typical high altitude mammals from the Northwest Himalaya and *Ovis nahura* occurs at high elevations throughout the Himalaya. *Capra sibirica* the ibex, *Capra falconeri* the markhor and *Capra aegagrus* the Persian wild-goat are also characteristic of the higher elevations above the forest-line on the Northwest Himalaya. *Nemorhaedus bubalinus* occurs from Kashmir to Assam-Burma mountains. *Moschus moschiferus* is characteristic of the elevated regions above the forest throughout the Himalaya. *Nectogale*, *Eupetaurus* and *Pantholops* are Tibetan animals, occasionally found at high elevations on the Himalaya.

The animals *par excellence* of the high altitudes above the forest-line on the Himalaya are, however, diverse insects, spiders and mites. The highest elevation at which insects and mites exist in the world is 6,900 m. on the Himalaya.

The high altitude insect life of the Himalaya is remarkable for the very high species-endemism in all groups. Over 70 per cent of the species occurring above the forest-line are strictly endemic. There are, besides, a large proportion of species which are endemic to the vast elevated region of the northwest Himalaya and the Pamirs-Alai. The greatest bulk of the endemic species have risen during the Pliocene times, but many are also of Pleistocene and post-Pleistocene origin. The Pliocene endemic species have survived the Pleistocene glaciations on high *nunataks* (ice-free rocks above the glaciers) and have since the end of the Pleistocene glaciations given rise to numerous subspecies. Essentially thermophile lowland steppes forms were lifted up, in the course of the Himalayan orogeny, to high elevations by the rise of the ground they inhabited and simultaneously came to be modified into cryophile and cryobiont, mountain-autochthonous types. While the evolutionary changes during the Pliocene times largely involved the modification of relatively few species into true high altitude types, there is at present a very pronounced tendency towards an increase in the number of species through rapid subspeciation and isolation high massifs.

Mayflies, stoneflies and caddisflies abound in the melt-water torrents, nearly right up to the permanent snowline (5,200 m). The stonefly *Rhabdiopteryx lunata* occurs, for example, at an elevation of 5,000 m. A remarkable number of curious grasshoppers like *Bryodema* and *Gomphomastax* endemic to the Northwest Himalaya, Karakoram and the Middle Asiatic mountains, the interesting apterous *Conophyma* also endemic to the Northwest Himalaya, the Middle Asiatic high steppes and the Pamirs, the Himalayan endemic genus *Dicranophyma* and the Mediterranean genus *Sphingonotus* are typical of the higher elevations above the forest on the Himalaya. The tettigonid grasshopper *Hypsinomus fasciata* occurs at elevations between 4,57. and 4,875 m. Certain earwigs like *Anechura*, with close affinity to the species found in the Alai-Pamirs, also occur above the forest-line on the Northwest Himalaya. Among the bugs there are two interesting endemic genera, viz. *Dolmacoris* and *Tibetocoris* at elevations of 4,000-5,000 m. *Nysius ericae* is also represented by certain endemic subspecies at 5,200 m. Coleoptera are the dominant high altitude insects and represent almost one half of the total number of high altitude species so far known from the Himalaya. The dominant families of Coleoptera include Carabidae, Staphylinidae, Tenebrionidae and Curculionidae. The interesting aquatic beetle *Amphizoa* occurs in glacial lakes at very high elevations on the Northwest Himalaya. These beetles are also known from Tibet and North America. The Carabidae include *Amara, Bembidion, Carabus, Calosoma, Cymindis, Nebria, Harpalus, Trechus, Anchomenus, Phaeropsophus, Calathus, Bradytus, Clivina, Broscus, Chaetobroscus, Dyschirius, Leistus, Tachys*, etc. *Amara brucei* and *Bembidion nivicola* occur at elevations of 5,050 m. The Staphylinidae include *Atheta, Aleochara, Geodromicus, Lesteva, Ocyusa, Oxypoda, Philonthus, Tachinus*, etc. The highest altitude record of permanent existence of Coleoptera in the world is held by the remarkable Staphylinid *Atheta* (*Dimetrota*) *hutchinsoni*, which occurs at an elevation of 5,600 m on the Northwest Himalaya. Many Tenebrionidae like *Bioramix* and *Chianalus* are endemic to the Northwest Himalaya and there are besides endemic species of genera like *Blaps, Cyphogenia, Laena*, etc. *Laena alticola* occurs at an elevation of 5,020 m. *Ascelosodis* occurs at 5,180 m in the area of Mt. Everest. A number of ants like *Formica* (*Serviformica*) *picea* and bumble-bees like *Subterraneobombus melanurus subdistinctus* and *Lapidariobombus saparandus* are also found. The most dominant butterflies of the Himalaya, above the forest-line, are species of Holarctic *Colias, Argynnis* and *Parnassius*. Several species and subspecies of *Parnassius* habitually occur only at elevations of about 5,800 m. The Diptera include the interesting family Deuterophlebiidae found on the Northwest Himalaya, Tien Shan, Altai Mountains, Canada and many parts of the United States of America. *Deuterophlebia* are peculiar mayfly-like delicate flies, the larvae of which breed in glacial torrents and cling to submerged stones by means of powerful hooks at the tips of their numerous appendages. There are besides a number of species of Simuliidae, Blepharoceridae, Syrphidae, Anthomyiidae, Tachinidae and Sarcophagidae even up to elevations of 6,000 m. A number of Collembola (snow-fleas) like *Entomobrya*, *Isotoma*, *Proisotoma*, *Hypogastrura*, *Isotomurus*, *Tomocerus*, *Onychiurus*, etc. occur on ice and snow even at above the snowline, at elevations of 6,900 m.

To summarize, it may be stated that the Peninsular mountains are refugial areas of phylogenetic and geographical relicts, which are not also essentially mountain forms, but typically lowland tropical forest types. The fauna of the Himalaya is, however, composed of mountain-autochthonous endemic Palaearctic elements only above the forest-line. The fauna of the forest-covered mountain ranges south of the Great Himalaya is composed of Oriental forest elements, which have become secondarily adapted to montane conditions. The eastern parts of the Himalaya are nearly completely Oriental, but the western end has Turkmenian and Mediterranean faunas. The effect of isolation on Peninsular Mountains is to preserve phylogenetic and geographical relicts, but on the Himalaya to intensify speciation.

CHAPTER VII

VEGETATION OF THE HIMALAYA

The present author published in 1957 the first comprehensive account of the vegetation of the Himalaya, which was accompanied by a map—on scale 1 : 2,000,000—based upon careful evaluation of the material available upto and including 1956. To avoid any guess work all those areas within the mountain world of the Himalaya, of which there did not exist any reliable data concerning the vegetation, were deliberately left 'white' on the map as still 'botanically unexplored' country such as parts of the Northwest, Nepal, Bhutan, and Assam Himalaya.

Although 10 years have passed not much substantial additions have since been made to the areas concerned, except some minor gains in western Nepal and western Bhutan, which however do not yet justify the publication of a new edition of the map. On the other hand, the author feels particularly grateful that—besides the many communications he received in the meantime—there was none so far pointing to a mistake or major alteration within the frame work of the basic concept. The summaries attached to the original work[1] included one in English—otherwise there has been no translation yet into a foreign language. The author therefore gratefully accepts the opportunity offered to contribute here a short account of the work, originally published in 1957, hoping that this more extensive 'summary' in English may attract attention of a wider circle of people interested in the Himalaya and in particular direct interest into those areas of the mountain world, which are still botanically little known or unknown. For any further detail and in particular the reference literature, the author likes to draw attention to the original work, cited above. It may be added, that the map was originally prepared on a scale of 1 : 1,000,000, subsequently for the purpose of publication reduced to a scale of 1 : 2,000,000.

For an area, in which so much emphasis lies on the vertical arrangement and change of the vegetation, it seemed to be of prime importance to present together with the map a series of cross-sections through the mountain ranges. In fact because of the very nature of the Himalayan region, these cross-sections proved to be the 'guiding lines' for the research contemplated. Topographically the work includes the Tarai region along the foot of the ranges in the North Indian plains and the southern fringe of the Tibetan plateau on the north. It follows the so called

'Himalayan forests' to the west into Afghanistan and includes in the east a portion of the great north-south running river gorges. This is obvious if one considers the edge of the Central Asian plateau—whether Himalayan ranges or river gorges in the east—as something which is worthwhile to be looked into under an overall view point occasionally The framework for the research conducted was therefore naturally wide. It actually developed with the progress of the work itself and freely transgresses all political boundaries.

It was not earlier than the middle of the 19th century that scientifically reliable reports on the vegetation of the Himalaya, mainly by British explorers and scientists, among which Thomas Thomson for the Western Himalaya (1847-1848) and Sir Joseph Dalton Hooker, a little later, for the Eastern Himalaya deserve to be quoted. Amongst the many, who followed, the contribution of one man was outstanding—by sheer quantity and quality of his observations, derived from more than four decades of a more or less 'exploring existence' in the most difficult parts of the mountain world concerned, namely the east from Bhutan to northern Burma and the Chinese borderlands. This was Francis Kingdom Ward. When the Indian Forest Service was established, a new form of research into the Himalayan vegetation came into being, to which we owe a multitude of contributions on various aspects of equal interest to the forester, ecologist and scientist in general. But the work, which provided the original stimulus for the basic concept of the vegetation map of the Himalaya was Carl Troll's map of the vegetation of Nanga Parbat, published in 1939, shortly before the outbreak of the Second World War[2].

In the original work (1957) there is a detailed regional appreciation covering the entire area indicated above. A procedure of this length does not lie within the scope of this contribution. The present author will, therefore, proceed to discuss in short the various types of vegetation, he was able to distinguish during his work, and will continue later on with some summarising remarks concerning the vegetation of the Himalaya as a whole.

The various types of vegetation have been conceived on the basis of the general character of the vegetation met with, with special reference to the physiognomic appearance. The regional arrangement of the types distinguished as easily demonstrated on the map, leads one to the conclusion that the vegetation types are primarily dependent upon the climate and in particular upon the rainfall and humidity. This may very well be so, but as there are also types distinguished mainly upon their floristic composition and without any climatological basis whatsoever, it seems more advisable to avoid to deal with 'climatic' vegetation types, until further data are available. The work done by Champion 1936[3] and Troll 1939[4] —has been basic in this attempt to establish types for the vegetation of the Himalaya.

SUBTROPICAL SEMI-DESERT

These are steppes of shrubs, mainly of central Asian proven ınce, occurring in a sort of semi-desert, covering the area by some 20-25 per cent only, leaving much bare ground in between. During summer the shrubs experience a dormant stage. The type occurs in the dry valleys of the bigger rivers in the north-west of the Himalayan world, as for instance in the valleys of the Kabul and Kunar, the Indus and its tributaries Hunza, Shigar and Shyok. At the foot of Nanga Parbat, the type appears up to 2,000 m. The records of Jalalabad, Gilgit, and Skardu may offer some climatic substance. Rainfall varies in between 130-160 mm per year, but there is no rainy season and summer drought tends to be excessive. Strong, hot winds are prominent. Floristically the following species must be mentioned : *Capparis aphylla, C. spinosa, Peganum harmala, Calotropis procera, Ephedra prshewalskii, Haplophyllum criffithianum.*

There are a number of well-defined habitats as pointed out by Troll 1939, as for instance : rocks, screes, dry river valleys, and the surface of river terraces ; a highly specialised site is offered by sand dunes distinguished by *Cymbopogon iwarancusa, Ephedra prshewalskii, Stipa Sp.*

Man interferes with this vegetation type mainly in so far as his settlements within the area of the type are by necessity oases and have to rely on irrigation and an irrigation channel in a (semi-) desert usually influences its immediate surroundings.

SUBTROPICAL THORN-STEPPE

This type displays all sorts of transitions to the desert proper. Of particular importance are Acacies, 5—10 m high, usually occurring in clumps leaving considerable expenses of bare ground in between, in general woody growth from tree-height down to dwarfed shrubs. After rain a thin grass cover makes its appearance. The distribution of this type ranges along the foothills of the Himalaya, where they rise out of the Punjab plains, and towards east as far as Hoshiarpur and Ambala. The records of Rawalpindi may help to understand the climatic conditions. The precipitation amount to 250-270 mm, mainly resulting from the monsoon in July and August ; further north there may be some rain during winter as well. Great variations during the years are experienced.

Floristically, mention must be made of *Acacia modesta, A. arabica, Prosopis spicigera, Capparis aphylla, Zizyphus jujuba.* Acacia is more frequent in the moist parts towards east. The type is particularly prominent in the area of heavy erosion amongst the foothills. The local occurrence of salts has a pronounced influence on the composition of the vegetation, *Salsola kali*, and *Suaeda* being characteristic for such localities.

Man's influence is exercised in the cultivation of large areas, wherever irrigation is possible.

SUBTROPICAL EVERGREEN SCLEROPHYLLOUS FOREST

A comparatively low sort of forest of trees and shrubs, with small and evergreen leaves, also thorn shrubs—these last ones prominent in the transition to the semi-desert. During the monsoon, grass and herbs appear. Regionally, this forest follows further up the slopes of the northwest Himalaya, where the semi-desert gives way, and ranges as far as the Sutlej towards east. It is quite prominent in certain river valleys in the northwest as for instance Jhelum and Chenab. The altitudinal range lies between 500 and 1,500 m.

Rawalpindi is the station which may serve as a clue to the climatic conditions. A long, hot, dry season and a cold winter with frost are characteristic ; about 800 mm rainfall is experienced, mostly during July and August.

In the floristic composition *Olea cuspidata, Dodonaea viscosa, Punica granatum, Adhatoda vasica, Pistacia integerrima, Carissa Spinarum, Acacia modesta* are widespread.

There is one very conspicuous subtype to be seen seasonally in dry valleys, the mediterranean 'torrente', in which *Nerium odorum*—Oleander flourishes.

The influence experienced by men and his animals is pronounced. The trees are frequently lopped and the forest grazed all over. In Hazara, there is occassionally *Dodonaea viscosa* virtually the only survivor being not liked by the grazing animals.

STEPPE OF ARTEMISIA

Shrubs occur in fair density, 50-70 per cent of the surface are covered ; conspicuous are *Artemisia maritima, Eurotia ceratoides* and *Kochia.* From the distance, slopes under this type appear to be sprinkled all over with the shrubs, locally there is some steppe forest. The type thrives mainly under dry conditions, but tolerates moisture, once higher up the slopes. Above 2,700 m on Nanga Parbat, there is a considerable amount of snow during winter. The vegetation comes into prominence late in spring (May-June), but in July it may already be too dry. The type is mainly distributed in the northwest parts of the Himalaya, where transition into the alpine steppe is widespread. On the slopes exposed to the south, the Artemisia steppe penetrates far into the realm of the moist coniferous forest, as for instance in the valleys of Kaghan, Kishengaga, and Indus. The vertical range of the type depends on the exposition of the slopes ; Troll (1939) observed the type on Nanga Parbat on the northern aspects upto 3,000 m, but upto 4,200 m on the southern aspects, where Artemisia steppe merges with the moist alpine belt.

The records of Dras and Chitral stations will suitably indicate climatic conditions for this type ; precipitation ranges between 400-500 mm and occurs mainly during winter ; the effect of the monsoon is negligible.

Artemisia maritima, *Eurotia ceratoides*, *Kochia*, *Daphne oleoides*, *Lonicera persica*, *Sophora*, and *Berberis* deserve special mention.

A number of subtypes have been described as for instance along water courses : Salix, Populus—or on shingle banks : *Hippophae rhamnoides*, *Myricaria germanica*.

The influence of man is prominent, especially on the slopes of Nanga Parbat, where this belt is the region of permanent settlement and also of the cultivated land ; irrigation channels invariably produce local variations. Also *Artemisia maritima* is widespread as a secondary growth on abandoned patches.

STEPPE-FOREST

Steppe-forest occurs in various compositions in a transitional belt between the steppes, predominantly those of Artemisia, and the forest proper. The steppe-forests are mainly composed of Juniperus sp., Pinus sp. and Quercus sp. It is significant to note that this transitional belt of steppe-forests is met with in particular in those parts of the mountain world of the Himalaya, where river valleys cut through the main range, as for instance Indus, Sutlej, Kali Gandak, Tsangpo and the great river gorges in the east, also where the forests peter out towards the dry steppe country, as for instance in Afghanistan (Hindu Kush and elsewhere). It is tempting to compare the two prominent situations—Indus valley in the northwest and Tsangpo valley in the southeast. Similarly there are Juniperus, Pinus, and Quercus prominent, but there are different species met with in the northwest compared with those in the southeast, about the latter we do not know much yet. Steppe-forest therefore constitutes the outer fringe of forest country towards the drier interior of the continent, i.e. the lower continental tree-line, which, however, may coincide with the upper tree-line, where both the tree-lines verge towards the interior of the continent.

The steppe-forests are light and open communities. Here and there, at sheltered places, northern slopes, denser stands may occur. There is some shrubbery, often aromatic, a thin grass-cover, too, but the soil surface may also be bare as well for considerable stretches.

Floristically, various species of Juniperus are common, *Pinus gerardiana*, *P. excelsa*, *P. sinensis*, *Quercus ilex* (syn. Q. *baloot*), *Q. aff. ilex*, *Hippophae rhamnoides*, *Artemisia maritima*, *Caragana*, *Astragalus*, and *Rosa webbiana*.

There is a considerable difference in the floristic composition of steppe-forests to the west and to the east of the Himalayan ranges. The forests of the west are best described by Troll (1939) from the slopes of Nanga Parbat where they occur from 2,000—3,000 m on northern slopes, 4,000 or even 4,200 m on southern slopes, but the data vary for other parts of the mountains considerably. Our knowledge about the steppe-forest in the valleys of the east, beginning with the valley of the Tsangpo, is scanty ; also much more information about the steppe-forests of Afghanistan would be of particular interest as befits a forest-type of such an ecologically interesting position. The records of the stations at Dras, Chitral, and Kilba in the Sutlej valley may be representative. There are no stations situated within the boundaries of the steppe-forest of the east, as far as we know.

There is an interesting interplay between steppe-forest on southern slopes, and northern slopes already occupied by moist coniferous forest within the transitional belt on Nanga Parbat.

Man shows great interest in these forests being first of all the only ones available ; the cones of *Pinus gerardiana* in the northwest are collected for human fuel ; the wood of Quercus Ilex is in high esteem for tool-making. In the river gorges in the east fire is of periodical occurrence. In the Luhit valley Ward (1949),[5]—regards the steppe-forest of Pinus Khasya as a man-made association, not a true climax ; from this valley the practice of periodical burning is well-known.

FOREST OF PINUS ROXBURGHII

The forests of Pinus roxburghii are amongst the most conspicuous in the Himalaya. The species is endemic for the region ; furthermore, the species practically dominates the type to the exclusion of any other significant associate. The type constitutes a light and open forest, 20-30 m high. Fires are frequent and of strong influence, so much so that some authors regard the type as to be a fire climax. There are only a few shrubs in the undergrowth ; during the monsoon a luxuriant grass cover appears, whereas dryness dominates the situation during winter. Just before the rainy season, the ground is covered with the long needles (syn. P. longifolia), very slippery to walk on, especially when on steep slopes. Winter is the season of fires.

The type is dominated by Pinus roxburghii (syn. P. longifolia). There are some *Quercus incana*, *Rhododendron arboreum*, *Pieris ovalifolia*, and others. The type occurs in the outer Himalayan ranges from the northwest to the Manas in the east. In Sikkim there are only very few localities with this species, but otherwise Pinus roxburghii ascends far up in the valleys, as for instance the Sutlej and Ganga, also in Nepal, in the Burhi Gandak and Trisuli valleys. The altitudinal range is 900-1,800 m. In the inner valleys the type may occur as high as 2,100 m.

Almora and Ranikhet may be taken as indicator stations ; precipitation amounts to 1,000-1,400 mm. The rainfall during the monsoon is particularly important. There are some striking differences according to the topography of the localities : the type is generally found on slopes, Pinus roxburghii, preferring the dry well-drained sites, ridges, cliffs, whereas the gullies are filled with *Quercus incana*, or the monsoon forest to be discussed later ; on hot, dry cliffs, *Euphorbia royleana* is common.

The density of settlements within the area of this type explains its reduction and complete replacement. Furthermore, the wood of the species is valued for building purposes. Fire is of outstanding importance ; Pinus roxburghii has much higher fire resisting qualities than all competitors, which may serve as an explanation to the pureness of the stands. *Quercus incana* is further handicapped by heavy loppings. On the other hand, only the clearing of the forest floor by fire, i.e. the periodical burning of the needles, opens up a chance for regeneration. There is also strong pressure effected by grazing animals.

FOREST OF CEDRUS DEODARA

Cedrus deodara is another species endemic to the Himalayan region. It occurs in the northwestern parts of the ranges. But there are reports about its occurrence as far east as Nepal. The tree is widely distributed in other forest types as well, though bound to certain site requirements. Here are dealt with only those forests predominantly composed of *Cedrus deodara.* Well-known are the forests of the upper Ganga and the Sutlej. The tree experiences a complete change in its association within its range from the monsoon drenched outer Himalaya towards the continental tree-line, which is occassionally represented by *Cedrus deodara.* As the species tolerates long lying snowcover, it is found also in the interior of the mountain world in special habitats. The further inland, which means "mountainwards", the more the species tends to constitute pure forests. It displays a gregarious habit. The individual trees may attain up to 20 m height.

Generally, there is a shrubby undergrowth : *Artemisia maritima* usually present, amongst the trees *Pinus excelsa* frequently met with, also *Pinus gerardiana* in the northwest. According to the wide range of association there may be a fair number of deciduous species as well.

Pure forests of *Cedrus deodara* have been reported from Nuristan, the valley of the Chenab and Sutlej, the upper regions of the Ganga, also the Alaknanda (Garhwal) and central Nepal. The pure stands occur between 2,100 and 3,000 m with a strong tendency towards higher localities further inland.

The climatic records of Kilba and Pu (Sutlej valley) may be representative. Precipitation ranges from 250 to 1,000 mm, but the pure Deodara forest depends mainly on precipitation during winter, areas with heavy monsoon rain are avoided—indeed, pure Deodara forest are represented even there, where they are sustained by precipitation during winter only (upper Sutlej) : the summer may be dry, but the effect of the drought is balanced by the melting of the snow.

Dudgeon-Kenoyer[6] regards the pure Deodar a forest as an edaphic climax ; the species occurs as a pioneer on screes, on rocky and steep slopes. Pure forests prefer southern aspects (upper Ganga), where it faces moist coniferous forest on the opposite northern aspects.

MIXED DECIDUOUS AND CONIFEROUS FORESTS OF ASSAM HIMALAYA

These are open light forests with only thin undergrowth. During the rainy season there is a fine herb cover. If protected from fire, natural regeneration is fairly good.

The most prominent representatives are *Pinus excelsa. Quercus griffithi-Q. Incana*, further *Rhododendron arboreum*, *Prunus puddum*, *Photinia griffithii.* So far the type is described only from the Tenga valley and known from the Apa Tani region as well. But this is no doubt depending on our scant knowledge of the Assam Himalaya in general and there is good reason to expect this particular type in similar localities which are not yet botanically explored. In altitude the type ranges between 1,600 and 2,800 m as far as we know today. These seem to have no more than 1,250 mm precipitation, mainly during May to September, and some snow in December ; fog is frequent, and the valleys represent frost hollows. Compared with the conditions in the Assam Himalaya in general, these inner valleys offer relatively dry habitats.

Some interesting local differentiation should be noted : on limestone outcrops, with only thin soil cover, pure stands of *Cupressus torrulosa* occur. The individual trees attain upto 45 m height. In the gullies, *Alnus nepalensis* and *Populus ciliata,* both upto 35 m height, are prominent with a dense layer of ferns. Southern aspects display Pinus just 15 m high, whereas at the foot of the slopes it reaches double size. Quercus on thin soil barely attains 10 m, but, where the soil is deep and moist, 25 m.

In the Tenga valley, shifting cultivation is practised by the Sherdukpen, which includes annual use of fire to clear the ground of dry grass.[7]

MIXED DECIDUOUS CONIFEROUS FOREST OF SOUTHEASTERN TIBET

This is another type, of which our knowledge so far is very poor, because the area of its distribution is still an unexplored country. But, what we know so far, seems to justify to regard these forests as a distinct type between the dry steppe-forests and the moist coniferous forests. There are some links with the moist coniferous forests of the inner valleys of the Eastern Himalaya, and the further we go east, the more prominent will become species, which do not belong to the Himalayan region sensu stricto. The following species are important within this type : *Picea likiangensis, P. spinulosa, Larix Griffithiana, Pinus sp., Tsuga dumosa, Betula, Quercus, Populus, Salix, Acer* and *Rhododendron.*

The type occurs in the upper Tsangpo gorge and has been observed in similar country in the valleys of its tributaries ; also further east in the gorges of Salween, Mekong, and Yangtze. The altitudinal range seems to be 3,000—3,300 m and higher up. Climatically, the country where the type occurs may be called 'fairly moist', with sufficient rain in summer, but dry and long winters. No climatic records are available.

The observations of F. Kingdon Ward are our chief source of knowledge for this type.

TEMPERATE MIXED OAK AND CONIFEROUS FOREST

These are evergreen forests of oaks and conifers. The number of the dominant species is small. There is a distinct differentiation according to altitude—resulting in 3 subtypes—and also according to aspect : conifers avoid southern slopes. The oaks, generally, do not attain great size. There is always abundant undergrowth of deciduous shrubs, the density depends on the state of the canopy of the forest and on the pressure exercised by grazing. The 3 dominant oaks are : *Quercus incana, Q. dilatata, Q. semecarpifolia*—all evergreen with stiff, leathery, serrated leaves, higher up and farther east the forest tends to become richer. Epiphytes, lichens, mosses, ferns, orchids etc., are common.

Three distinct subtypes can be distinguished : *Quercus incana* with *Cedrus deodara* : 1,800—2,400 m on southern aspects, on northern aspects

200—300 m lower ; *Quercus dilatata* with *Abies, Picea, Cedrus* : 2,100—2,400 m ; *Q. semecarpifolia* with *Abies* 2,400—3,300 m.

These forests bear, because of their prominent distribution over large parts of the western Himalaya, great importance for the water supply of the main rivers and therefore for the agriculture in the north Indian plains.

Lower belt : *Q. incana*, predominant upto 70 per cent ; this subtype depends on rain and is not favoured by snow. This explains why it does not occur round the Kashmir basin. The two prominent associates of the oak are *Rhododendron arboreum* (20—30 per cent) and *Pieris ovalifolila* (5—10 per cent) both are not liked by the browsing animals, and man is not interested in them as well.

Middle belt : *Q. dilatata* predominant ; this is a narrow belt only, 2,100—2,400 m., and at its lower levels *Q. incana* still occupies the drier localities, whereas the *Q. dilatata* belt comes into prominence in the moisture habitats (gullies, ravines). Snowfall is here of annual occurrence, the snow lies for several weeks. This middle belt displays the most luxuriant strata of the mixed forests, *Q. dilatata* herself being the mightiest of the three dominant oaks of the type, attaining 20—30 m height. There are a good number of deciduous species represented in the canopy, whereas the lower storey is composed of broad-leaved species (Rhododendron, Lauraceae). Besides the leading oaks mention must be made of *Cedrus deodara, Abies denseflora, Taxus baccata, Carpinus viminea, Betula alnoides, Acercaesium*. Bamboos-*Arundinaria falconeri, A. jaunsarensis, A. falcata, A. spathiflora*—occur in dense thickets in wet localities and grow several metres high.

Upper belt : *Q. semecarpifolia* is predominant ; on the southern aspects Quercus, on the northern aspects Abies is leading. The vertical range is from 2,400—2,700 m. This is typical mountain cloud forest (Nebelwald). The summers are short, characterised by the monsoon. During winter, there is heavy snowfall. *Q. semecarpifolia* dominates the belt to 75 per cent. The belt bears a rather monotonous appearance and is described as rather gloomy. The canopy consists of *Q. semecarpifolia* more or less entirely, about 15—25 m high. The undergrowth is less dense, but there is a lot of dark green and brown moss swaying from the branches. At its lower levels still a mixed oak and coniferous forest, the belt is dominated by Abies higher up. There is no under-storey of trees, but we find dense and luxuriant thickets of ringal-bamboo (*Arundinaria spathiflora*) highly characteristic for the forest in these altitudes. The abies forest often heralds the transition into the subalpine belt.

These temperate mixed oak and coniferous forests have their westernmost outpost on the hills above Murree ; from there they stretch to the east, prominent on the outer slopes of Pir Panjal, but they do not occur on the slopes round the Kashmir basin. These forests, indeed, are typical for the outer Himalayan ranges. The western central Himalaya shows this type at its best ; we expect this type in west Nepal as well, but the transition to the more eastern influenced types becomes gradually apparent.

The records of Murree, Simla, and Chakrata stations may indicate the climatic conditions to a certain degree, but the stations are all situated lower down, being therefore representative for the type only upto a certain point. Precipitation is within the range of 1,400—2,000 mm, of which 70—80 per cent are experienced within the monsoon period ; fogs are also frequent during this time ; in higher altitudes snow falls during several months. Topography exercises its influence : southern aspects are favoured by the oaks, northern aspects by the conifers ; likewise crests and ridges by the oaks, depressions by the conifers ; on especially warm and dry localities we find *Quercus incana* and grass underneath.

The influence of man and his animals is strong. As far as the lower belt of *Q. incana* is concerned, this being the altitude favourable for settlements and cultivation, the forest is reduced to a large extent. Furthermore, the lower levels suffer from frequent fires ranging up out of the *Pinus roxburghii* belt. Lopping for fodder is common practice with *Quercus incana* and *Q. dilatata*, which is supposed to supply the best fodder. *Q. incana* displays all stages of degradation, unlopped and ungrazed areas are indeed a rare sight within the lower levels. As a result of intensive grazing and lopping a curious vegetation of grass with only one tree species :—*Rhododendron arboreum* is left, this being of no interest to the animals and this of very little use for firewood. At higher altitudes, the type suffers from shifting cultivation in certain areas and the establishment of temporary (summer) camps, causing further destruction.

This type is of such outstanding practical importance for forestry and river management that it has been well studied, especially by the Indian Forest Service.

WESTERN HIMALAYAN CONIFEROUS FOREST

The moist coniferous forests of the inner western Himalaya are dominated by *Avies webbiana, Picea morinda, Pinus excelsa, Cedrus deodara.* To a varying extent there is an admixture of deciduous and broad-leaved trees. Around the Kashmir basin, deciduous trees are still important association ; in the area of Nanga Parbat their presence is negligible, but the number of conifer species is also decreasing from south to north. The general trend is towards light *Pinus excelsa* forests, until finally, in the Hunza valley (Karakoram), only *Juniperus sp.* remain as the sole component of a rather poor moist coniferous forest.

In these western Himalayan coniferous forests we find frequently meadows alive with flowers, usually a result of grazing. At the upper fringe the type gradually gives way to the subalpine birch belt, which locally descends far down into the coniferous belt, wherever there are avalanche paths. Besides the leading species already mentioned there must be quoted : *Acer caesium*, *Ulmus wallichiana*, *Juglans regia*, *Celtis australis*, *Carpinus viminea*, *Cory us colurna* ; ferns are rare and mosses and lichens decrease further into the mountains.

This type is best developed round the Kashmir basin ; towards northwest, it represents a sort of high altitude forest-belt above the steppe-belt : as far as Nuristan on the southern slopes of the Hindu Kush ; similarly the type extends towards north as a forest-belt above the Artemisia steppe ; towards east, the type finds itself confined to the inner valleys of the high massifs of the main range, until we notice further east the transition into what we call 'Eastern Himalayan temperate coniferous forest.' In altitude, the type ranges in Nuristan from 2,000 to 3,500 m, on Nanga Parbat 3,000 to 3,600 m.

The records of Gurais and Sonamarg station seem to represent the condition for the type fairly well ; precipitation is about 1,000—1,800 mm, mainly during winter ; snow lies for several weeks. It seems, that the transition towards the 'temperate mixed oak and coniferous forest' must have something to do with the changing proportion of the precipitation during summer and/or winter ; higher humidity seem to favour Abies (northern aspects).

There are a number of important local variations, as for instance, avalanche paths, which offer conditions suitable for *Betula utilis* far down within the conifer belt ; or the differentiation exercised by northern and southern aspects in as much as northern aspects are favoured by deciduous trees, whereas round Nanga Parbat southern aspects may be bare of any forest whatsoever, and the northern aspects carrying forest only, here of conifers ; there is also a differentiation according to the species : southern aspect Pinus ; northern aspect Abies.

The outposts of this type appear as another sort of steppe-forest, composed of *Pinus excelsa* and Juniperus in light open stands and a ground cover of Stipa (Kali Gandak valley, Manangbhot).

Settlements in the coniferous belt are temporarily only, but there may be some cultivation in the clearings, and with the demand for fire-wood, grazing etc. even the temporary settlement initiates wholesale destruction of the forest. Nitrophilous vegetation is characteristic near the camping sites with Rumex, *Urtica parviflora* etc. On abandoned fields, *Pinus excelsa* and *Cedrus deodara* appear as pioneers.

TROPICAL DECIDUOUS FOREST

Shorea robusta is the most important species of the type, a gregarious species which occurs in practically pure stands from 32°N, 76°E to 93°E in a belt of varying breadth along the foot of the mountains. There is a gradual transition from west to east, from dry to moist and wet 'sal'. It is convenient to distinguish the tropical deciduous forests in 'sal' forest and 'others'. The dominance of 'sal' is accentuated by man, i.e., by fire and grazing, which do not prevent the regeneration of 'sal' at all. The young plants quickly develop large leaves which obstruct any competition by more light demanding young plants. Scientific forest management has focussed largely on the development of 'sal' in India.

'Sal' forest is a typical high forest. The trees attain upto 25 m., occasionally upto 35 m. The trees shed their leaves with the beginning of the dry season, a procedure which is performed in the east within 5 to 15 days, but takes 2 months in the west (February to April).

Within the 'sal' belt there are savannah-like patches interspersed. The grass cover of the ground becomes more important towards the drier country in the west. This may be in connection with the longer period—2 months—without protection by leaves during which the direct influence of the sun can be exercised. There is also a sequence from south to north within the 'sal' belt : Tarai sal, Bhabar sal, Hill sal. In the valleys, the 'sal' forest penetrates far into the mountains.

Floristically, besides *Shorea robusta*, the following species are important : *Dalbergia sissoo*, *Bombax malabaricum*, *Terminalia tormentosa*, *Anogeissus latifolia*, *Lagerstroemia parviflora*.

As mentioned above, this type is characteristic along the foot of the hills save the dry northwest and the wet east ; dry and moist sal range from Kangra Beas towards (Gorakhpur), where the wet sal sets in, and into the mountains upto 900—1,000 m or in the case of dry sal 1,500 m. The upper limit is the lower limit of snowfall. The climatic data of Dehra Dun are representative for the type. Precipitation is in the environment of 1,000 to 2,000 mm, distributed over a rainy season in summer and a dry winter. The far northwest with 7 months below 1,500 mm is too dry for sal ; the east (Assam) with less than 4 months of a dry season is too wet.

Topography and soils exercise some influence : *Shorea robusta* is at its best at the high level plateaus, whereas on the alluvial soils in between *Dalbergia sissoo* (always a pioneer) together with *Acacia catechu* ; in wet localities, swamps (Tarai) the forest is predominantly evergreen with *Eugenia jambolana*, *Albizzia procera*, *Cedrela toona*.

Also aspect is of some influence : in the duns, northern aspects display a tendency towards pure 'sal' forest, southern aspects towards mixed forest.

The impact of man is strong. The area of 'sal' forest is one of dense settlement. And in winter there is the additional influx of people coming down from the hills exercising additional pressure on natural resources. The tarai is well-known for providing suitable grazing for cattle from the plains and from the hills after the rains. Also in the valleys within the hills, there is very heavy pressure by cultivation and settlement to destroy this forest belt entirely—and it is only at the edges of the cultivated terraces that we may find the last remains of the original forest cover. The 'sal' forest in Nepal, being in many parts still virgin forest, presents a striking contrast to the well-known and, in general, well managed 'sal' forest within the boundaries of the Indian Union.

TROPICAL DECIDUOUS FOREST

The transition form the moist parts of the former type is very gradual indeed ; *Shorea robusta* remains the most prominent species, the undergrowth is becoming denser ; *Shorea robusta* attains upto 20—30 m height. Towards east, the leaveless period is gradually reduced ; but the higher density of the undergrowth, the competition by the evergreen species reduce the chances of regeneration of *Shorea robusta* to a point, where the dominance of 'sal' can only be achieved by forest management.

Besides *Shorea robusta*, floristically are important *Terminalia belerica*, *Lagerstramia parviflora*, *Cedrela toona*, *Dalbergia sissoo.*

Taking into consideration the difficulties just outlined, the area of distribution may be defined as from the foothills of central Nepal towards east into western Assam. North of Charduar, there are still pure 'sal' forests, but BOR (1938) regarded them as outliers. This type ascends in the valleys as high up as 1,500 m, but presents difficulties of a proper delimitation to the tropical evergreen lower montane forest.

The records of Jalpaiguri station may provide some clues : precipitation is 2,000 mm at the minimum, near 4,000 m we observe the transition towards the evergreen rain forest, but for 'sal' a clearly defined dry season is a necessity : *Shorea robusta* thrives even under heavy precipitation as long as there is a dry season, but the species does not thrive under moderate precipitation all the year round without a dry season. Topography is of importance in so far as the higher the rainfall, the more important is drainage. The impact of man leads to (secondary) savannahs, but man exercises deliberate influence to propagate the dominance of *Shorea robusta* and therefore more or less pure forests in checking its associates by periodical burning.

TROPICAL EVERGREEN RAIN FOREST

Evergreen trees, also deciduous, huge dipterocarps high above the other components, single or in clumps, these are some characteristics of the type. The number of species is very high indeed in a complete mixture, only a few represent something in the order of an association. There are palms and climbers, and epiphytes in great numbers. The undergrowth is evergreen and dense, denser in the plains, less so on the slopes. The ground cover consists of evergreen shrubs. There are few herbs, practically no grass. The evergreen dipterocarps—*Dipterocarpacure, Meliacea, Anacardiaceae, Lauraceae, Magnoliaceae* are conspicuous ; the dominant trees reach 30 m height. In the hills, grass does not even appear in clearings, herbs come first, shrubs soon after, but very soon there are the trees again to bring back the evergreen rain forest, the unavoidable climax ; only where there are steep slopes there may be dense clumps of *Dendrocalamus*. There is no distinct dry season. To classify this type as 'tropical' rain forest is open to discussion, inspite of a close relationship to the true equatorial rain forest of Malaya ; for floristical reasons, however, a distinction towards the tropical evergreen lower montane forest has to be made. A few chief components may be mentioned : *Dipterocarpus pillosus, D. alatus, Shorea assamica, Altingia excelsa, Mesua ferrea, Michelia champaca, Terminalia ;* ferns are abundant ; where there is no closed canopy. *Selaginella* is often the only ground cover ; there are many *Hymenophyllaceae.*

The area covered by this type ranges from the Manas towards, the transition to the montane forest is difficult to define : above Diwangiri 1,200 m is given, for the Aka hills 1,000 m.

The records of Dibrugarh station may be taken as representative for this type. Precipitation at this station is recorded as about 3,000 mm, the total for the type may be less high, but then there must be an even distribution throughout the year provided for.

There are a number of local edaphic and topographical variations, as for instance the 'khadar', an inundated, flooded area, where the trees are often uprooted by the floods with *Terminalia myriocarpa, Bombax malabaricum,* or *Terminalia myriocarpa* in pure stands on gravel and shingle—the daily slips and repeated inundations offer excellent conditions for this particular species ; on sandstones : *Quercus* and *Castanopsis* appear ; on very steep slopes : bamboos ; on porous soils : *Nesua ferrea* in 200—800 m to mention only a few examples.

The savannah-like tracts in the plains are the result of the destruction of the forest by frequent changes of river courses and human interference (fire and animals) : only regular burning keeps those areas under grass ;

cultivation of rice and the propagation of the tea garden in Assam have added to the replacement of the forest. Within the hills, shifting cultivation is practised upto 1,200 m and often bamboo thickets as secondary growth are the results, however temporary.

TROPICAL EVERGREEN LOWER MONTANE FOREST

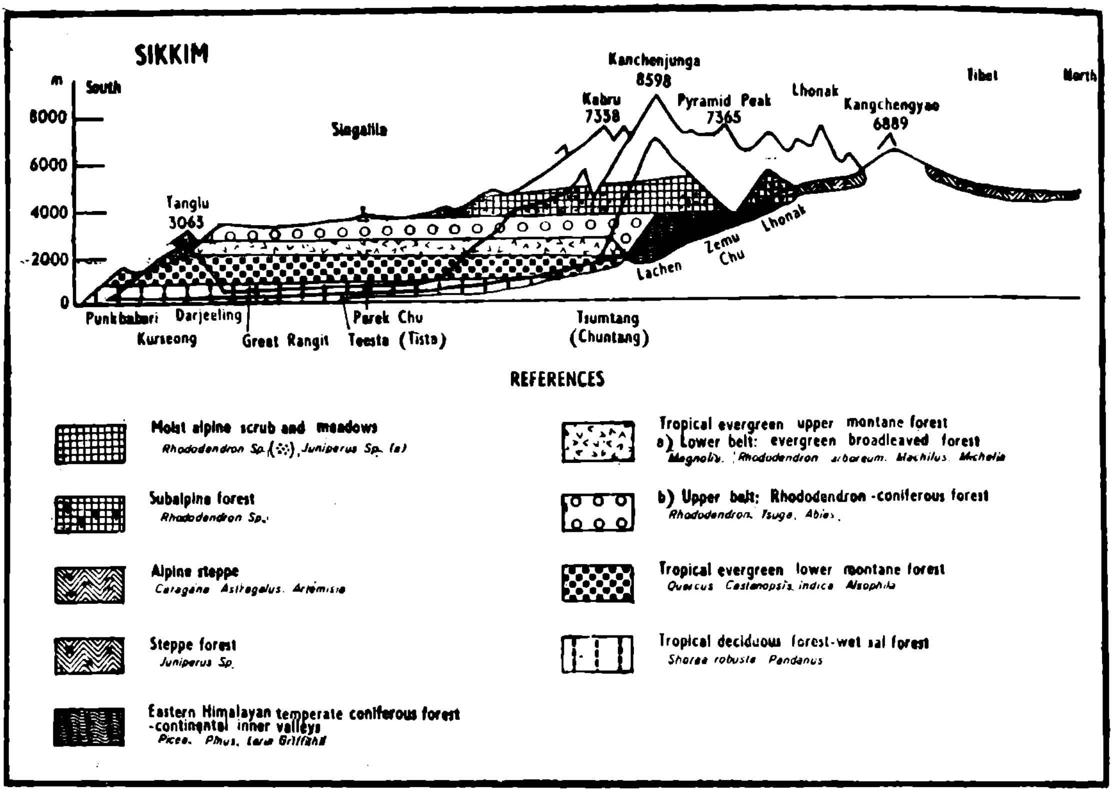
This type is a true montane forest, the dominant species mainly evergreen, but there are also some deciduous ; a highly mixed forest, but distinctly different from the tropical rain forest below. Under favourable conditions, the forest attains upto 50 m height, generally between 20-30 m. The canopy normally is much less closed, compared with the tropical rain forest, the outstandingly high trees usually do not appear next to each other. There is a well developed middle storey and also undergrowth of shrubs. Occasionally, there are thickets of bamboos, climbers and numerous epiphytes, including orchids and shrubs. Tree-ferns are well represented. The dominance of *Quercus* and *Castanopsis* is a striking characteristic conifers—*Podocarpus*—are only locally met with. The transition towards this montane forest is always indicated, where *Castanopsis* appears above *Shorea robusta.*

Amongst the floristic composition the following deserve mention : *Quercus, Castanopsis indica, C. tribuloides, Schima wallichi, Beilschmidia roxburghiana, Engelhardtia spicata, Betula cylindrostachys, Alnus nepalensis, Aesculus assamicus, Rhododendron arboreum, Lithocarpus, Machilus edulis, Pieris ovalifolia.* The type has been observed from central Nepal to the east, it penetrates far up into the valleys like the Dihang. Tsangpo gorge, but differs somewhat in its altitudinal range : Nepal 1,200—1,900 m, Sikkim 1,000—1,800 m, Aka hills 1,200—2,000 m The climatic records of Kurseong are surely well representative to explain the climatic conditions of this type ; precipitation amounts to from 1,500—5,000 mm ; there is no distinct dry season ; during winter there is frequently heavy dew instead of rain (November to April 50 mm.), there are dense fogs in winter as well. Humidity is always high and temperatures even. Owing to the almost everywhere steep slopes the montane forest covers, there is everywhere good drainage. Along the water courses *Alnus nepalensis* is typical, on steep crests *Pandanus furcatus* prominent.

The impact of man is conspicuous in so far, as within the range of this type are tea and cinchona plantations ; highly locally also the cultivation of potatoes is important. On abandoned sites, a secondary growth of *Maesa chisia, Rhus semialata, Alnus nepalensis, Pteridium acquilinum, Sohima wallichii* is wide-spread.

TROPICAL EVERGREEN UPPER MONTANE FOREST

A dense evergreen forest, upto 30 m high, usually with closed canopy ; branches and trunks are thickly wrapped into moss, an astonishing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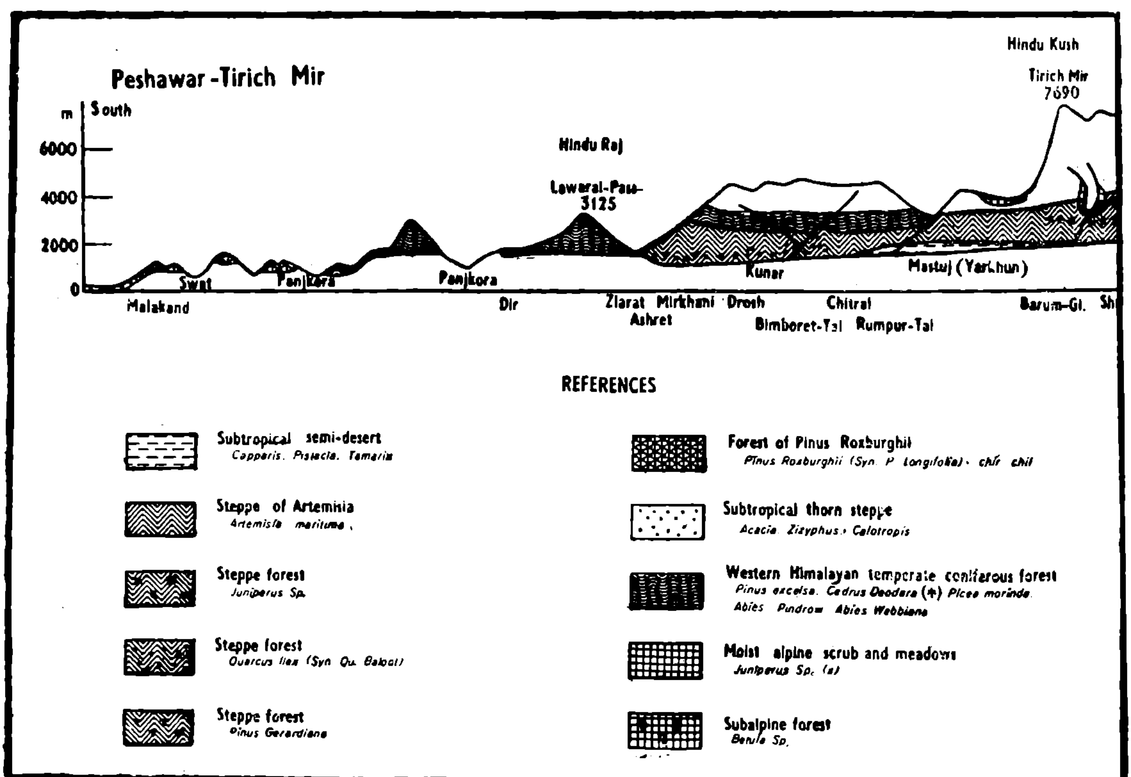
Lachen
Zemu Chu
Lhonak
Punkbabari
Darjeeling
Kurseong
Great Rangit
Parek Chu
Teesta (Tista)
Tsumtang (Chuntang)
REFERENCES
Moist alpine scrub and meadows
Rhododendron Sp. (∴), Juniperus Sp. (a)
Subalpine forest
Rhododendron Sp.
Alpine steppe
Caragana Astragalus Artemisia
Steppe forest
Juniperus Sp.
Eastern Himalayan temperate coniferous forest -continental inner valleys
Picea, Pinus, Larix Griffithii
Tropical evergreen upper montane forest
a) Lower belt: evergreen broadleaved forest
Magnolia, Rhododendron arboreum, Machilus, Michelia
b) Upper belt: Rhododendron -coniferous forest
Rhododendron, Tsuga, Abies.
Tropical evergreen lower montane forest
Quercus Castanopsis indica Alsophila
Tropical deciduous forest-wet sal forest
Shorea robusta Pandanus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Tirich Mir 7690
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Mastuj (Yarkhun)
Malakand
Dir
Ziarat Mirkhani
Ashret
Drosh
Chitral
Bimboret-Tal
Rumpur-Tal
Barum-Gl.
REFERENCES
Subtropical semi-desert
Capparis. Pistacia. Tamarix
Steppe of Artemisia
Artemisia maritima
Steppe forest
Juniperus Sp.
Steppe forest
Quercus ilex (Syn Qu. Baloot)
Steppe forest
Pinus Gerardiana
Forest of Pinus Roxburghii
Pinus Roxburghii (Syn. P. longifolia) - chir chil
Subtropical thorn steppe
Acacia Zizyphus Calotropis
Western Himalayan temperate coniferous forest
Pinus excelsa. Cedrus Deodara (+) Picea morinda.
Abies Pindrow Abies Webbiana
Moist alpine scrub and meadows
Juniperus Sp. (a)
Subalpine forest
Betula Sp.

number of epiphytes find suitable living conditions here, the swaying mosses and lichen garlands, together with the ever present veils of mist and fog (Nebelwald) land to these forest, a rather eerie appearance [('amongst the darkest and gloomiest in India' Champion 1936)] There is a small number of deciduous trees as well. Usually the stands are mixed, but there is always a strong tendency to the prominence of a few : *Quercus* and *Lauraceae* from 1,800—2,100 m high up almost pure stands of Rhododendron in between 2,500—2,800 m. A great sight are the magnolias, when in blossom, though numerically they are of minor importance. *Engelhardtia*, *Schima*, and *Castanopsis* are the links with the lower montane forest ; Rhododendron, *Prunus*, *Acer* those with the coniferous belt above. Evergreen undergrowth is typical, at least where the canopy is less dense. At the higher levels, dense bamboo thickets occur. Filmy ferns are abundant, and also unfortunately, leeches ever present.

Amongst *Quercus* must be mentioned : *Q. pachyphylla*, *Q. lamellosa*, *Q. lineata*, *Q. spicata*, *Q. fenestrata*, *Q. semiserrata*, *Q. semecarpifolia*, *Q. dilatata*, *Q. acutissima*, *Q. glauca*, further on *Magnolia rostrata*, *M. nitida*, *M. campbelli*, *Manglietina*, *Michelia cathcartii*, *Acer sp.*, *Rhododendron arboreum*, *Tsuga dumosa*, *Pinus excelsa*, *Taxus baccata*, *Podocarpus neriifolia*, *Pieris ovalifolia* ; amongst the epiphytes : *Vaccinium venulosum*, *Hydrangea altissima*. The type can be identified clearly on the southern slopes of the Annapurna and ranges from there towards east, well represented in northern Burma ; in the Tsangpo gorge, it occurs also north of the main range, likewise in the vicinity of Kyerong and the upper Arun. The altitudinal range is 1,800—3,000 m. But in the east Assam and Burma, the type can be distinguished already at lower altitudes.

The climatic records of Darjeeling are representative ; there is precipitation all the year round, heavy during the monsoon (July), comparatively less in November to March (heavy dew) ; the overall precipitation may be as high as 5,000 mm. Humidity is high all the year round and dense fog characteristic, consequently there is not much of direct sunshine. The lower limit of this type is the level down to which frost occurs, the upper limit the level, where on the southern aspects snow begins to lie for longer periods.

Bor (1938) : 'The soil rock makes no difference to the climax vegetation in view of the very high rainfall', may suitably be quoted here. On slips, *Alnus nepalensis* appears as a pioneer ; open steep ridges are frequented by Rhododendron and bamboo thickets.

Tea and cinchona plantations and the cultivation of potatoes are still met with at the lower levels of this type, but here also shifting cultivation exercises some destructive influence. Clearings and fire help to the expansion of bamboo thickets (*Arundinaria, Dendrocalamus*).

A dense evergreen forest which at its lower levels has still a large component of broad-leaved trees ; at about 2,500-3,000 m *Tsuga dumosa* chiefly represents the conifers ; from 300 m upwards it is *Abies*, which quickly attains dominance at the higher levels. Rhododendron is ever present in the undergrowth : lower down as a tree, 12—18 m high, with rather larger leaves, higher up with smaller species, gradually merging into the belt of subalpine forest. Dense undergrowth of bamboo and evergreen shrubs are widespread and epiphytes—mosses, lichens etc. are well represented.

The forests at higher levels are disrupted by screes and avalanche paths. Fog occurs frequently (Nebelwald !).

Floristically the following conifers are important : *Abies denseflora, Tsuga dumosa, Pinus excelsa, Picea complanata, P. morinda, Larix griffithiana, Taxus baccata, Juniperus recurva ;* amongst the broad-leaved trees : *Quercus pachyphylla, Q. lineata, Magnolia campbelli, Acer campbelli, Prunus nepalensis, Rhododendron barbatum, Rh. falconeri, Betula utilis, Sorbus foliolosa, Pieris ovalifolia ;* amongst the epiphytes there are most conspicuous Rhododendron, mosses, lichens ; Rhododendron trees themselves are free from epiphytes as they shed their bark. Bamboos (*Arundinaria sp.*) are everywhere present, so are ferns. The distribution of the type ranges from the southern slope of the Chakhure Lekh (West Nepal) towards east, the type is well represented in the Tsangpo gorge, Zayul, and northern Burma too : the altitudinal limits are 2,800—3,600/4,000 m.

Climatically, high precipitation—upto 3,500 mm seems to be a fair estimate—is of basic importance, the seasonal distribution may be indicated by the records of Darjeeling station. Monsoonal precipitation starts early and lasts long. The winter is comparatively 'dry', snow-falls occur from November/December until March, but there is less snow experienced here than in similar altitudes in the western Himalaya. Humidity is always high, and fogs are dense and frequent ; temperature data relevant to the type do not exist—it is, however, clear, that they will be moderate to low.

On poor soils and steep slopes *Pinus excelsa* is frequent (central Nepal, Tsangpo gorge, north Burma) ; along water courses : *Taxus baccata ;* on crests and ridges : thickets of bamboos and Rhododendron.

The impact of man is feasible only within the lower levels of the type, where there may be still shifting cultivation practised.

EASTERN HIMALAYAN TEMPERATE CONIFEROUS FOREST

A mixed coniferous forest, of which the occurrence of *Larix, Picea* and *Tsuga* is characteristic. There is a varying amount of *Pinus, Abies,* and *Juniperus* too. Tree-Rhododendron constitute the undergrowth. In many ways, this type is a counter-part to the western Himalayan coniferous forest. There are also some floristic relations to the mixed deciduous and coniferous forests of the southeast Tibet.

The prominent species are *Larix griffithiana, Picea spinulose, Tsuga brunoniana, Pinus excelsa, Abies densa, Juniperus* ; furthermore, there are Rhododendron, *Acer, Pyrus, Betula, Alnus, Corylus, Gaultheria, Rosa, Ribes.*

The type occurs in the inner valleys of the eastern Himalaya, the westernmost outposts seems to be in the upper reaches of the Burhi Gandak system. The type is well represented in upper Sikkim, Chumbi, Bhutan, Monyul. The altitudinal range is from 2,700/3,000 m upwards ; in the Shiar Khola valley *Larix griffithiana* constitutes the timber-line in 3,800 m.

The climatic situation cannot be based on records it will be summed up fairly correctly as 'moist'. There are striking contrasts according to aspect, for instance in upper Sikkim, where southern aspects are practically of devoid of forest. *Larix griffithina* is frequently met with on moraines.

SUB-ALPINE FOREST : BETULA UTILIS

There are two types of subalpine forest : the one dominated by *Betula utilis* is the 'western facies'—a dense growth of small, also dwarfed trees or shrubs with bent branches, here and there clumps of conifers, raising above the birch ; the conifers are predominantly *Abies*, which display condensed growth habits. *Betula utilis* is usually bent at its base by the pressure of snow. There is some undergrowth ferns and alpins herbs. The conifers are rarely higher than 20 m, the birches and other broad leaved trees 6—10 m. Within the confines of avalanche paths this belt descends far down into the conifer belt mentioned above. Higher up there is an easy transition into alpine scrub.

Three components are of importance : the birches which constitute the main body of the type. Rhododendron sp. being the undergrowth and locally, *Abies* raising above the mass of the forest proper. Vegetation season is June to September. The floristic components are *Betula utilis, Abies Webbiana, Juniperus recurva, Pinus excelsa* (locally), *Rhododendron barbatum, Salix.*

The type occurs as the upper belt of forest growth on the outer Himalaya as well as in the inner Himalaya everywhere it represents at its uppermost level the tree-line (Nanga Parbat 3,900 m, locally 4,150 m, Langtang, central Nepal 4,200 m). Climatically, this type is less dependent on the monsoon much more so on the melting of snow. During the short season in these altitudes, it thrives therefore also where the annual precipitation is low, 250 mm is about the smallest amount indicated, but there are no relevant climatic records. The winter is cold at these altitudes. Avalanches frequently occur ; the birches display a high degree of adaptation to it, but the air currents connected with the avalanches, are harmful to tree growth. With increasing winter precipitation, i.e., snow, the belt does not range as high up as elsewhere.

Betula utilis is also a pioneer species. A distinct influence of aspect is noticeable northern aspects favoured by *Betula utilis*, southern aspects by *Juniperus*.

The impact of man and his animals is pronounced as this type borders at the alpine meadows ; the bark of the birch is used for roofing of temporary sheds and also for the packing of butter.

SUBALPINE FOREST : RHODODENDRON SP.

A dense low evergreen forest of small, often dwarfed trees, practically Rhododendron only, here and there some *Betula*, virtually impenetrable, especially if one is on the way up, as due to the pressure of snow, trees and branches are pressed down. The trunks are smooth and short. Besides mosses, ferns, and some herbs, it is Rhododendron in all sizes and shapes, from trees to low scrub which constitutes this type. In 3,600—3,800 m the type represents the tree-line.

Betula utilis, Pyrus, Salix, Juniperus and occasionally, *Abies dense flora, Larix griffithiana* deserve note.

The type ranges from the Shiar Khola valley towards east ; Rhododendron gradually replaces the birch, until it dominates the type completely. It is best developed in the wetter areas (Assam Himalaya).

The climate is characterised by heavy precipitation with a high percentage in the form of snow. No relevant records are available. The soil is wet and peaty.

The impact of man derives from man's activities on the alpine meadows higher up which are frequented during summer.

MOIST ALPINE SCRUB AND MEADOWS

This type comprises all the 'wet' and 'moist' alpine vegetation above the tree-line towards the upper limit of the vegetation. There is a gradual transition into the alpine steppe representing the dry alpine vegetation in the northwest, where the dry type seems to be more prominent and the moist type and exception bound to the vicinity of the glaciers, whereas in the southeast the wet type penetrates into the interior of the continent on the Tibetan plateau.

It may be stated generally that the similarities within the alpine belt from west to east all along the Himalayan ranges are greater than in any other type, perhaps, because the climatic contrasts within the alpine belt are less pronounced from west to east. On the other hand, from south to north the wet alpine vegetation is quickly replaced by alpine steppe. Scrub and meadows have to be distinguished ; the extreme outpost of plant life can be summed up as 'high alpine belt' proper. Scrub and meadows are intrinsically inter-woven, they often change with aspect, northern aspect : scrub ; southern aspect : meadow.

Scrub : low evergreen shrubs, ½ to 1 m high, single or in carpets lie over large patches of alpine country. *Juniperus* is widely distributed, but in the wetter parts in the east completely dominated by Rhododendron. *Juniperus* prefers sunny sites, steep and rocky slopes and is everywhere present towards the drier areas, on Nanga Parbat as high as 4,250 m. Rododendron is ever present in the alpine belt in the Himalaya, especially in the east ; its dominance decreases from east to west, until in northeast Afghanistan there is only *Rh. campanulatum* occurring. The wettest parts of the Himalaya display the greatest variety of Rhododendron. In central Nepal, where there seems to be a certain balance struck between *Juniperus* and Rhododendron, it is interesting to find the two genera separated according to aspect, *Juniperus* on southern slopes, Rhododendron on northern both are common between 3,900 and 4,200 m. *Salix* : *S. hastata* on Nanga Parbat (Troll, 1939) attains 20—30 cm height and occurs as undergrowth under birch forest, also in the avalanche paths.

Besides enthusiastic praise with regard to the colourful display of flowers, there is so far not much detailed ecological work done on the alpine meadows of the Himalaya. Grasses are a major constituent of the alpine meadows. Amongst the herbs are a good number of very well-known genera represented : *Gentiana*, *Primula*, *Iris*, *Saxifraga*, *Androsace Pedicularis*, *Aconitum*, *Delphinium*, *Anemone*, *Ranunculus*, *Potentilla*, *Pulsatilla*, *Meconopsis*, *Corydalis*, *Allium*, *Myosotis*, *Aster*, *Leontopodium*, *Thymus*, *Geranium*, *Viola*, *Senecio*, *Rheum*, *Campanula*, *Fritillaria*, *Epilobium*.

In the broad sense as understood in this context the moist/wet alpine belt ranges from the far northwest to the east. Within this frame work there is, of course, a change within the floristic composition. In the dry northwest, there is a larger admixture of species of alpine steppe. From Kashmir towards east, we can distinguish on the southern slopes of the main range clearly between a scrub belt and the alpine meadows as well as the alpine steppe north of the main range. The limits of the alpine vegetation vary ; it begins above the tree-line, i.e., in between 3,500—3,900 m and ranges as far up as 4,500—4,900 m above this there may even be a high alpine belt discernible. There exists no moss or lichen belt in the Himalaya, but phanerogamic plants may occur high above the snow line (Nanga Parbat, Mt. Everest). There are no climatic records available.

Exposition often is an obstacle to a clear definition of the belt. Southern and northern aspects present striking contrasts ; on Nanga Parbat southern aspects carry *Artemisia maritima* and *Juniperus.* The wet alpine country as prominent in the eastern Himalaya favours *Primula* and *Pedicularis.* Snow beds offer distinct habitats and are well distinguished by certain species : *Primula nivalis, Carex nivalis, Oxyria digyna, Sibbaldia cuneata.*

On Nanga Parbat (Troll, 1939), the unbroken vegetation cover does not reach higher up than 4,500 m above this only a few high alpine plants occur on special sites.

The impact of man and his animals is profound. The alpine country is an area of intense seasonal activity. The transport of goods across the passes by means of large flocks of sheep and goats is well-known and has influenced the alpine country along the paths. Some species are much sought after and collected for various purposes. But on a much larger scale are the striking concentrations of a few species over large expanses of the wet alpine country as observed by Ward[8] in the Assam Himalaya, these meadows of *Primula Dickieana* owe their existence to the selective grazing of animals, especially the yaks, concentrated up here during the summer in large numbers, also clearings made in the Assam Himalaya to extend the grazing country quickly turn to a cover of *Primula* as resulting waterlogged conditions of the soil, are not easily tolerated by other species. Many other examples are known indicating that the wet alpine belt with its great variety of species represents a particular interesting field for ecological studies.

ALPINE STEPPE

This is the vegetation type of the Tibetan plateau. It is often difficult to state exactly, where this type sets in. There are all sorts of transitions from the wet alpine type and also out of the Artemisia steppe. The chief characteristic of the alpine steppe is the mixture of the components of the alpine zone and of the steppe often xerophytic : thin grass cover, thorny shrubs, succulents, cushion and rosette plants ; on the wind-swept, exposed plateaus, cushion and tussock plants are widespread. But there are also wide expanses of bare ground in between. With a general rising of the vegetation limits towards the interior of the continent, there is starting from such strikingly different conditions as can be found in the gorges of the Indus in the northwest and the Tsangpo in the east a very noticeable trend towards a highly uniform type of vegetation as exemplified on the Tibetan Changstang.

The period of vegetation is short, June to September. The vegetation is exposed to severe, indeed extreme condition. The dryness of the air, and the duration of the winter seem to be limiting the period available for the vegetation. There is an important contrast in the landscape : the valleys may be able to produce a close vegetation cover, the slopes above are more often desert-like.

Floristically, the following species and genera are of importance : *Caragana pygmaea, C. tibetica, Artemisia maritima, Astragalus, Eurotia ceratoides, Oxytropis, Juniperus, Rosa, Cotoneaster microphylla, Lonicera microphylla, Ribes orientale, Sophora, moorcroftiana, Berberis, Ephedra, Thymus serpyllum, Polygorum affine, Tanacetum, Rhododendron, Potentilla, Ran unculus, Rheum, Daphne, Buddleia tsetangensis, Meconopsis, Epilobium, Arenaria, Gentiana, Kochia, Salsola kali, Atriplex, Chenopodium, Saussurea, Stipa, Juncus, Scirpus, Festuca, Hippophae, Myricaria, Salix, Elaeagnus, Betula, Populus.*

The alpine steppe is the vegetation of the Tibetan plateau. Locally the type occurs in the inner valleys of the main range, preferably, on the southern aspects. The records of Leh, Lhasa, and Pu (Sutlej) may help to gain an idea about the climatic conditions of this type. Precipitation during winter comes more from the west, during the summer more from the east, but the three stations mentioned are peripherally situated, when viewed from the plateau proper. There are tremendous differences in temperature between day and night, summer and winter. Wind is almost constant, of particular importance are the winds of local occurrence. Along water courses, also along artificial water courses, i.e., irrigation channels, there is a luxuriant vegetation and only here trees are found : *Myricaria germanica, Hippophae rhamnoides, Tamarix, Elaeagnus, Populus, Ulmus, Betula, Salix babylonica*—in striking contrast to the open landscape round about. On salt bearing soils, halophytic plants are prominent : *Triglochin maritima, Glaux maritima, Salsola kali, Statice, Chenopodium*. Sand dunes as met within the valley of the Tsangpo offer another special habitat.

Perhaps because the vegetation is so scanty, the impact of man and his animals in all the more conspicuous. The settlements represent cases with irrigation. The irrigation channels are in contrast to the country round about. Some of the highest altitudes for such cases seem to be Pede 4,520 m and Tuna 4,540 m.

In conclusion after so much detail, it is perhaps worthwhile to concentrate again on the Himalayan world in the whole as a stage of display for the vegetation.

A glance on the vegetation map immediately shows the 'colourful' southern slopes of the main range as against the grand uniformity to the north of it. This striking contrast first of all underline the effect of the relief. The main range of the Himalaya is an effective barrier between the moist and wet southern slopes and the dry plateau to the north, but only in its central part, i.e., from Kashmir to Bhutan (75°—93°E). Within this central portion the passes connect, indeed, two different worlds. But in the northwest and in the southeast, we recognise different conditions : in the northwest, the colours of the dry vegetation types mingle, it is obvious—inspite of our restricted knowledge—that the mountains here rise out of the great dry zone connecting near and Middle East with central Asia, but higher up the slopes the mountain ranges carry forest : the moist coniferous forest of the western Himalaya ; however, where conditions are no longer suitable for forest growth, the vertical arrangement of the vegetation displays dry types only.

Also the southeast is prominent in showing contrasts to the rule but if we may say so in quite the opposite direction, east of 93°E, the main range does no longer serve as an effective barrier, far from that at certain passes across the Assam Himalaya, it does not even carry the timber-line, i.e., forests on the south and on the north slopes of the main range are virtually connected across certain passes of the Assam Himalaya, most prominent, the big gap, which the Tsangpo has cut through the main range, opens up the mountain world in this southeast part of the influences from the south, which as indicated by the moist and wet vegetation types penetrate out of the Tsangpo gorge high up towards the Tibetan plateau.

The barrier effect of the central part of the mountain ranges, the variation in the southeast, all this is easily recognisable on the vegetation map and this means first of all in the distribution of precipitation and humidity which means the influence of the monsoon. The monsoon on its way from the Bay of Bengal, hits the mountains in Sikkim and then turns to west and east. In the east, the air masses can not easily find an outlet, closed in by the Assam hills until they find their way up the Tsangpo gorge, penetrating into the continent. The branch towards west follows along the southern slopes of the mountains, gradually losing its force. The horizontal zonation of the vegetation along the foot of the hills from east to west reflects the conditions clearly, from tropical rain forest in Assam to subtropical thorn-steppe in the Punjab and subtropical semi-desert in the major valleys of the northwest. Wherever we leave the plains and ascend up the hills, we find that a typical vertical sequence of vegetation can be observed and we find that everywhere to the zonation in the plains a specific vertical sequence belongs. If we follow up all the available evidence closely, we discover that there is a belt of highest precipitation and humidity ranging from about 2,000 m in the east, a bit higher up towards west, that this particular belt is represented by a broad leaved facies in the east, further to the west by mixed oak and coniferous forest, until it is represented in the west by the western Himalayan conifer forest. This belt clearly rises in altitude towards the dry country in the northwest and in doing so, it appears in the northwest as a moist vegetation (forest) belt high above the dry vegetation types. This peculiar phenomenon can only be explained as an influence effected by the mountains on the whole. It is worthy of note that in contrast to the zonation along the foot of the mountains, this belt of highest precipitation and humidity shows a tendency towards greater uniformity from east to west, and the higher we climb, the more marked this tendency becomes.

The changes occurring from south to north within the mountain world of the Himalaya are depending on the force of the moisture carrying winds and in connection with this, on altitude, the arrangement of the various ranges, and of course, on the direction of the valleys, whether they provide easy access. In the northwest where the mountains show a much broader development, the vegetation easily displays by the colour of the various types the 'Outer Himalaya' carrying the monsoon vegetation, the 'Inner Himalaya', best developed round the Kashmir basin, where the influence of winter rain is pronounced, and further to the north the dry 'Tibetan Himalaya', the fringe of the Tibetan plateau. The southnorth arrangement of the three types of landscape so broadly developed in the northwest, can be followed up further to the east, where the three types are gradually more and more 'compressed' into the less broadly developed ranges, until in Bhutan the character of what I call the 'Inner Himalaya' undergoes a profound change under the accentuated power of the moisture bearing winds, this less humid inner part of the mountain world is dissolved, the 'Outer (wet) Himalaya' border without transitional zone immediatly on the dry Tibetan Himalaya (Subansiri). And if we follow the mountain ranges further to the east, an entirely new arrangement in the types of landscape distinguished becomes apparent as examplified best in the Tsangpo valley : the monsoon drenched lower gorge country, the less humid upper gorge country and, as before, the dry Tibetan Himalaya.

These rather complex conditions have been revealed by careful evaluation of the material available and painstaking care in compiling the map, which proves the point that no single other factor provides us with such a meaningful appreciation of the former largely unknown area than the vegetation by now an easy access is offered to understand the enormous complexities of the various landscape within the Himalayan world and to understand the profound importance of this region, representing the border area between south and central Asia.

In this short summary and a summary only it will be, it is impossible to mention all the other phenomena which serve to make the Himalaya an area of such abiding interest as for instance the peculiar dry river valleys or the highly complex problem of the tree-line to mention only a few, the interested reader is once again invited to consult the original work (1957).

The present author feels confident that the basic principle proved its worth but he feels all the more urged to direct attention to those parts of the Himalayan world still unexplored—in the northwest, in western Nepal, in Bhutan, and the Assam Himalaya. It is deplorable that most of these areas are at present inaccessible for political reasons, the author, however, wishes to express his hope that conditions may change to the better soon to enable him to complete the vegetation map of the entire Himalayan mountain world in not too distant future.

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CHAPTER VIII

DISTRIBUTION OF THE FLORA OF THE EASTERN HIMALAYA

The floristic composition of the flora of the eastern Himalaya particularly the plants of the Darjeeling and Sikkim Himalaya is unique of its kind even within the geographical boundary of India. The phyto-geographical composition of the plant communities in this part of the Himalaya in the proper order of altitudinal, succession all over the ranges of the hills in the east, the west, the north and the south varies according to the geological stratification, edaphic conditions and last but not least to the climatic and ecological specially microecological and biotic factors influencing the growth and general features and consequently synecological associations, consociation, associes, consocies and ecads etc. of the vegetation of this one of the most interesting regions of the Himalaya ranging from Afghanistan to the hills of Assam and northern Burma merging into Tibet and beyond extending to south China in Szechuan in the north. From geological aspect, "The Eastern Himalaya, like its western counterpart," according to A. M. N. Ghose (1956) "is roughly divisible into four zones from south to north, viz. (1) the Sub-Himalaya, (2) the Lesser Himalaya, (3) the Great Himalaya, and (4) the Tibetan zone."

The Sub-Himalaya forms an autochthonous zone consisting of folded unfossiliferous tertiary sandstones and shales fringing the foothills of the border zone throughout its entire length, except for a gap of about 80 kilometres in North Bengal lying between the Chel, Jaldhaka and Torsa rivers. Here the Gondwanas and Daling phyllites abut against the *tarai* plains.

The tertiaries are overridden, on a thrust plane, in an inverted sequence by older rocks, namely, the Gondwanas, Buxas, and Dalings in the order mentioned. The thrust plane is known as the Main Boundary Fault of the Sub-Himalaya. At places it is warped and folded.

The Lesser Himalaya forms a para-autochthonous unit consisting mainly of unfossiliferous dolomites and limestones (Buxa) and low grade metamorphosed sediments (Daling) and their granitised members and gneissose granites. All these rocks are considered pre-Cambrian in age. The metamorphic rocks overlie the Gondwanas in juxtaposition with the basal pebble beds of the latter suggesting that the normal order of superposition has been reversed. Everywhere in the Lesser Himalaya high grade metamorphic rocks overlie less metamorphosed ones. As a result of the erosion of the upper limb of a gigantic recumbent fold, the median limb of which forms the para-autochthonous zone with the root lying in the Central or Great Himalaya, the less metamorphosed rocks have been exposed in the lesser elevations the upper reaches of which are occupied by the high grade metamorphic rocks. The para-autochthon represents the overturned northern border of the Gondwana land lying at the southern margin of the Tethyan Geosyncline.

The para-autochthonous zone extends into the Great Himalaya, which consists mostly of gneisses and granites of different ages. Between Mount Everest and Lhonak country in northern Sikkim a normal succession of various grades of metamorphic rocks are found to underlie undisturbed sedimentaries of Permo-Carboniferous age. They represent the northern limb of the gigantic recumbent fold.

North of Mount Everest these rocks have gentle northerly dips and underlie gently dipping marine sediments of the Tibetan zone ranging in age from Permian to Eocene at elevations of 4,500 metres or more.

The high grade gneissic rocks of the Great Himalaya support the unaltered younger sediments of Tibet and are themselves supported by the low grade meta-sediments followed downward by still less or almost unmetamorphosed Permo-Carboniferous rocks of the Lesser Himalaya.

The Great Himalaya Range, aligned eastwest in northern Sikkim, supplies the waters of the Tista river and forms the Kanchenjunga-Pauhuri massif. Two arms, one from the western and the other from the eastern ends of the massif, project southwards and gradually descend on the *bhabar* land lying at the northern end of the North Bengal plains. The Singalila range forms the western arm and the Dongkya range comprises the eastern zone. Arch-shaped spurs having a southerly sweep but of a much smaller magnitude are thrown out in the Sikkim and Darjeeling Himalaya from the two main northsouth arms mentioned earlier. The most conspicuous of the former is an offshoot of the Singalila range which supports the town of Darjeeling.

Towards the north, the spurs of long tortuous ranges run north to south throughout the entire length of Sikkim dividing the deep wooded gorges, ravines and valleys which form the lands of mountain torrents, watershed and large rivers. The snowy peaks extend from east to west at a distance of about 48 to 64 kilometres from the outer range of Darjeeling. The rivers oozing out from the snowy source as trickling streams from the Tibet border increase in volume and size as they flow down to the valleys and emerge into the plains and finally discharge into the Bay of Bengal. Even in higher elevation the low temperature with the atmosphere charged with humidity sustains luxuriant growth of vegetation characteristic of the temperate rain forest with dominating rhododendrons. "The source of this humidity", according to Hooker (1849), "is the southerly or sea wind, which blows steadily from May till October in Sikkim and prevails throughout the rest of the year, if not as the monsoon properly so-called as a current from the moist atmosphere over the Ganga Delta. This rushes north to the rarefied regions of Sikkim, up the great valleys, and does not appear materially disturbed by the northwest wind, which blows during the afternoon of the winter months over the plains, and along the flanks of the outer range, and is a dry surface current, due to the diurnal heating of the soil. When it is considered that this wind, after passing lofty mountains on the outer range, has to traverse 130 to 160 kilometers of Alps before it has watered all the rhododendron region, it will be evident that its moisture must be expended before it reaches Tibet".

The studies by F. Kingdon Ward (1930, 1942) and Biswas (1943, 1967) on the vegetation of the hill ranges of this part of the Eastern Himalaya lead them to think that the Sikkim and Bhutan mountains lie in that part of Asia where the three great areas, China, India and Tibet, are very close together. Geographical factors seem to have resulted not so much in comparative isolation, but in lack of opportunities for interpenetration, since the huge mountainous range of the Himalaya separates India from Tibet, and the sheer gorges of the Irrawaddy, Salween and Mekong rivers, with their well-nigh impassable divides, effectively bar communication for man at any rate between India and southwest China. Even so, these three areas have distinctive divides, effectively bar communication for man at any rate between and southwest China. Even so, these three areas have distinctive peoples, climates, plants and animals but types appear in common and tend to intermingle occasionally where the boundaries of the areas merge together. The Eastern Himalaya are roughl bounded by Nepal on its west flank, Tibet on the east and north and Assam and Bengal on the south.

Part of the main Himalayan range, the "Indo-Tibetan divide" forms the northern boundary of the country, and its big snow-covered groups of peaks reach, at their highest points, elevations of 6,000—7,000 metres. From this main range a series of ridges run southwards, decreasing in elevation until they reach the plains of India ; but where they cross the line of 27°30′ N latitude there is a noticeable tendency for many of these ridges to throw up their crests in peaks varying from 4,000 metres to nearly 5,000 metres in altitude. Lateral spurs project with an easy slope into the valleys, but sometimes the slopes make an abrupt descent to the bottoms of the valleys from shoulders at elevations of 2,400—2,700 metres.

Eastward from the line of 91°E longitude the configuration of the Himalayan chain alters. No longer do the secondary ranges trend southward from the main divide. This itself shows signs of disintegration, and the secondary ranges begin to stretch from broken sections of it in other directions. The observable tendency is a swinging to the northeast and south-west a changing of direction which culminates in the direct north and south trend of the divides of the big Assam and Burmese gorges.

The character of the vegetation is influenced by the strong moisture-laden monsoon winds from the south. The ramifying outer spurs have a heavy rainfall, and are densely clad by moist forest of tropical and sub-temperate genera. The central portions of the gorges and valleys have a lesser rainfall and tend to bear a drier type of forest. The moisture-laden breezes of the upper layers of the atmosphere pass unscathed over the outer spurs, only to be arrested by the summits of the ridges in the interior, where in consequence they deposit their moisture and a moist temperate flora develops. This is made up of moss-clad and lichen-draped oaks, rhododendrons, Maple, poplars and birches, *Magnolia cambalii Michelia excelsa, Tsuga brunonniana, Taxus baccuta, Pinus roxburghii, Pinus excelsa, Picea morinda, Cedrus deodara, Larix griffithiana, Abies webbiana, Juniperus recurva, J. psendo-sobina, Cryptomeria joponica* (introduced). The general features of the vegetation of this part of the temperate rain forest are well illustrated between altitude 2,400 metres and higher upto 3,000 metres. Between 3,000 and 4,000 metres is seen the most common characteristic association of *A. densiflora—Rhododendron campanulatum—Betula utilis—Berberis—Cotoneaster microphylla* and *Rosa sericia* association.

Trees range up the slopes to a upper limit of approximately 3,900—4,500 metres where an undergrowth of shrubs and bushes are replaced by dwarf scattered patches of plants. There are, however, many open glades containing herbaceous plants only. Above 3,300 metres—the altidudinal limit of taller pine—spruce and juniper trees are found, mainly on moist and dry slopes respectively and range to the limit of tree growth. Some interesting insectivorous plants—*Drosera peltata, var. lanata, Penguicula alpina* with bright yellow flowers, *Utricularia nepalensis* are found. *Penguicula* is common along the route from Lachen to Thangu at about 3,000 metres and above.

Above tree-level, where the slopes are moist, they bear a rich moisture loving flora of biennial and perennial dwarfish herbaceous plants. Those uplands, which are robbed of moisture by intervening peaks and ridges, are consequently drier and have a less profuse herbage, all forms showing adaptations to drought, and also response to the effects of high altitudes. These areas are free from snow only from April to September, and this short season, during which alone growth is possible seems to generate a definite type of plant which produces flower spikes at the first awakening of growth, the leaves following immediately after. The climatic conditions of the drier upland valleys are coincident with those prevailing on the north side of the main chain (*i.e.* in Tibet) and plant forms range accordingly across the chain into that country. The general altitudinal successions of vegetation is shown in the following diagram (See altitudinal succession of vegetation).

As regards the composition of the flora at different elevation from the foot of the hills to the snows at an elevation of even above 5,500 m where *Rhododendron nivale* is found to grow along with other dwarf alpines in the bleak and barren alpine snows is of considerable interest with regard to the distribution of the alpine scree vegetation in the eastern Himalaya. The occurrence of Rhododendraous in this region may be summarised as follows : "There are nearly 850 species recorded from the different parts of the world. Of these India claims about 86 species and of these again 84 species are in the Eastern Himalaya 5 of which extending upto Northwestern Himalaya, and Ceylon and Nilgiris have only one species each.

Field investigations reveal that there exists considerable confusion in the systematic position of some of the common species such as *R. campanulatum*, *R. fulgens*, *R. camelliaeflorum*, *R. cinnabarium* and *R. Roylei* and other allied species.

The chief reason for such a confusion is wide range of variations in the size of the plant, leaves and other morphological structures, number of flowers in each bunch, colour and texture of the flowers in each species, mainly due to their adaptation and acclimatisation to different habitat conditions and other ecological factors to which this genus is highly sensitive. Light, rainfall, snow-fall, hail-storm, stormy wind in higher altitudes, shade, particular spot of the hill side having favourable edaphic conditions, association with particular plant community, such as, *Viburnum* association, *Betula-Salix-Juniperus* association, *Abies densiflora* association and similar other association have definite effects on foliar and floral morphological variations of the species of this genus particularly those growing in the Darjeeling Sikkim-Himalaya. Detailed study clearly indicates that there exists many lacunae and sufficient scope to modify Hooker's description and observation as recorded in some of his monumental publications in the light of more intensive field study of the Rhododendrons of the Eastern Himalaya.

Hooker recorded his observations with detailed data and valuable information in his masterly treatment of the *Genus Rhododendrons* Many voluminous literature—both past and recent on the subject although made comments on the systematic position of some of the species, it appears the field-notes of Hooker are indisputable. The variations in the colour of flowers of *R. capmasnulatum*, the habit of trees under different microclimatic conditions, so also of *R. cinabrinum*, to which Hooker is inclined to include *R. royall*, *R. maddeni*, *R. campylocarpum* and many other species puzzle botanists when these are seen in their natural habitat in the forests at different elevations growing in nature under different microecological and edaphic conditions. Nevertheless, Biswas (1967) also records his observations based on field notes which future workers alone can check and modify the conclusions made and add further notes and thereby throw more light on this most fascinating genus of the flowering plants.

There is, however, much controversy about the distribution and different elements composing the flora of the phytogeographical region of these mountain ranges of the Himalaya. Field study of the vegetation of these Himalayan ranges leads the author to conclude that, as Hemsley says, "No arguments are required to prove that the Tibetan is a derived flora ; that is to say, derived since tertiary period ; and its composition is so largely Himalayan that there can be little doubt as to its origin". This would seem to imply that Tibet was bare at some time when the Himalaya was covered with vegetation. The high altitude of Tibet takes this very improbable. The upheaval of the Himalaya and Tibet must have been simultaneous and the vegetation also must have developed simultaneously. Marquand very recently has remarked. "Material available now makes it quite clear that one homogeneous flora extends from Sikkim to Eastern Tibet and the whole of the Eastern Himalaya, South Eastern Tibet and Western Szechuan as well as upper portions of Yunnan should be considered as one botanical area". Central Tibet is not sharply marked off from Eastern Tibet with its more luxuriant vegetation on the one hand and from the higher and wilder Western Tibet with its scanty vegetation but it cannot be said that the flora of Western Tibet has had a different origin. It possesses a smaller number of plants, more highly adapted to more unfavourable conditions than their eastern relative. The flora of Western Tibet must naturally be poorer as fewer plants can be expected to adapt themselves to extreme conditions.

Considering all the data it would be more in accordance with facts to say that the floras of the Himalaya and Tibet and Western China have a common origin and differentiation gradually took place as the Himalaya and the Tibetan plateau gradually rose from the sea-level to become the highest region in the world.

Kingdom Ward (1942), however, holds that "the present flora of Tibet is not an indigenous flora ; it has been almost entirely derived from the surrounding regions. The arrangement of the mountain ranges which completely encircle the plateau, and the former great extension of the

Himalayan, Chinese and Eastern Tibetan glaciers prove that during the Pleistocene glaciation the plateau was surrounded by a belt of ice which must have almost completely sterilized any preglacial flora it possessed. Whatever that pre-glacial flora may have been, little, if any, of it survived the Ice age. Since the restocking of Tibet, the flora has probably undergone little modification".

David Prain (1891), on the other hand, admits that a detailed review, so far as concerned the Northwestern Himalaya and Sikkim, is likely to prove incomplete owing to our rather partial acquaintance with the flora of the region between Garhwal and Sikkim and our most imperfect acquaintance with that of the region between Sikkim and Mishmi country.

'It seems to me therefore', adds Sir David Prain in a letter to the author, that the time can hardly yet be ripe for a discussion on the origins of the flora as a whole ; one must, I think, say origins in the plural number because we do know already that there are links between the Himalaya and Peninsular India, between the Himalaya and Persia, between the Himalaya and Central Asia, between the Himalaya and China even between the Himalaya and Japan, also that it is point which has been in dispute as to the boundary between the Himalaya and Tibet'.

W. W. Smith (1913) is of opinion that the distribution of the flora is too wide a theme to bring it down to a few general statements. In the extreme northwest is an undoubted connection with the flora of the Orient especially with Persia. At the other end there is a marked relationship, especially as regards genera, with the mountains of Western China, and to a much lesser extent with Burma. The association with Burma is really an explanation of the Chinese association. As for the intermediate region, its genera are in the main members of what may be called the palaeoarctic group. This would be true of most of the flora above 2,100 metres.

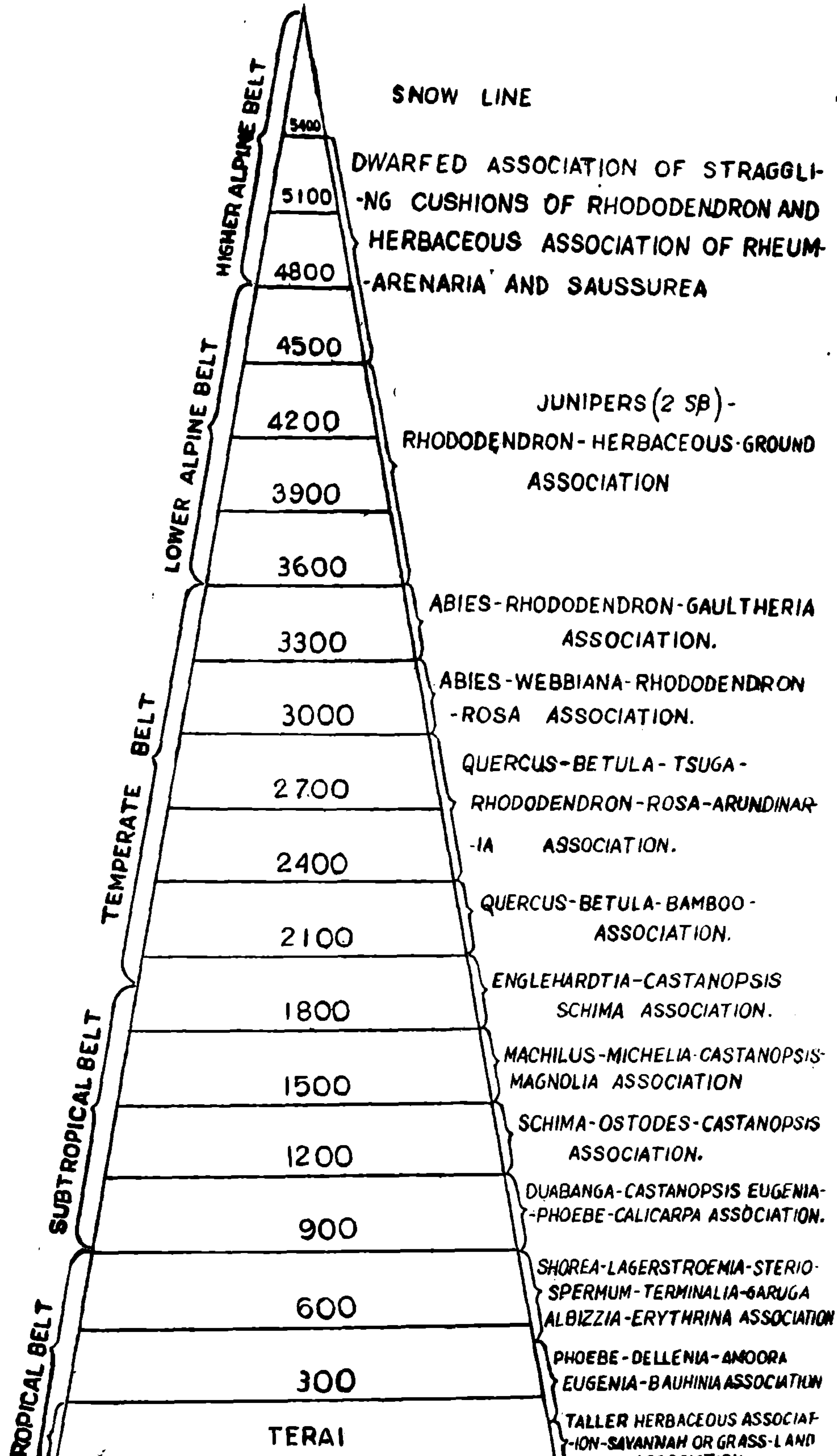
Bor (1934), in his observations on the flora of the Naga and Khasi Hills, remarks that the discovery by Hooker of terminal moraines in Sikkim at an altitude of 2,300 m where at the present day no glaciers are found below 4,600 m suggests that during the glacial epoch the mountains of the Himalaya which are now forest–clad, must have been covered with snow. The Naga Hills may very well have been in the same condition. The Bhabar tract in Goalpara and Darrang consists of enormous boulder deposits of Pleistocene age which indicate that even the plain may have been too cold to support such a flora as is now found in the Eastern Himalaya at high altitudes.

The immediate result of the glacial epoch would have been to eject the pre-glacial flora of the Himalaya to the south where there was sufficient warmth for it to exist. The retreat of the ice would see the return of an Indo-Malayan flora, the advance of which was facilitated by the mountainous country which lay to the south and southeast. If this theory be correct one would expect to find a general resemblance in the floras to be true to a certain extent also with regard to the flora covering the top of the ridges of the Parasnath Hills, the highest mountain in the Santal Parganas along the border of Bengal and Bihar. Here at an elevation of 1,200 metres the flora is, as observed by the author and indicated by Anderson (1857) almost similar to that of the Eastern Himalaya as found particularly in the region of Kurseong in the Darjeeling district.

There are numerous works of the botanists particularly since J. D. Hooker (1848-49) M. G. Berkeley (1871). Nevertheless, Hooker's records on geographical, edaphic and climatic factors and accurate descriptions of vegetation of the Sikkim Himalaya based on his field study in 1849 is the most valuable contribution towards our knowledge of the flora of this part of the Himalaya for all time to come.

In the publications on the explorations of the Japanese the ecology of the vegetation of Central Nepal Himalaya has very briefly been outlined by Kitamura (1955). The vegetation of this part of Nepal Himalaya does not vary much from the Singalila, Jongri and Guicha-La ranges of the Darjeeling Himalaya. Although the vegetation bears general affinity to that of Nepal at different elevations, the composition of the flora varies in detail presumably due to local micro-climatic, edaphic, biotic and other environmental conditions prevailing in these two parts, one more Central and the other more Eastern Himalaya. These observations are mentioned in order to enable the future investigators to compare the general features of the vegetation of these two sections of the Eastern Himalaya and work out detailed analysis of the Nepal and Sikkim floras. Dr. K. Imanishi, Mr. S. Nakao and Mr. J. Kawakita summarise the zones of the vegetation as follows :—

600—1,000 m	Zone	of *Shorea robusta*	Subtropical zone.
1,000—1,200 m	"	of *Castanopsis indica.*	
1,200—2,000 m	"	of *Myrica, photinia,* etc.	Warm temperate zone.
2,000—2,500 m	"	of evergreen trees (*Quercus glauca,* etc.)	
2,500—3,200 m	"	of Conifers (*Tsuga Picea*), and deciduous trees.	Cold temperate zone.



Figures are in metres

ALTITUDINAL SUCCESSION OF VEGETATION

3,200—4,000 m	"	of Conifers trees (*Abies, Betula*).	
4,000—5,200 m	"	of Alpine shrubs and herbs.	Arctic zone.
5,200 m and above	Permanent ice and snow.		

Accoring to A. Engler, the subtropical flora of the Himalaya belongs to the monsoon region. There are many species common to Ryukyu and Formosa. Some Japanese botanists who have been studying the flora of the Ryukyu and Formosa are interested in the identification of subtropical plants of the monsoon region.

According to Engler, the province of the temperate region of Western China, Eastern Tibet and Himalaya belongs to temperate Eastern Asia. This province corresponds to R. Good's province of Sino-Himalayan-Tibetan mountains which belongs to the Sino-Japanese region.

According to R. Good, the western boundary of the Sino-Japanese region is in Kashmir. According to Hooker's Flora of British India, many plants described primarily from Himalaya have been discovered also in Western China, namely Yunnan, Szechuan and Kuichau.

Most of these common plants are now believed to have migrated westward from Western China, the older land to Himalaya, the younger land which has been rising since the Cretaceous period.

The long mountain range of Himalaya is considered to constitute a unique corridor between East and West Asia, which has been available for the migration of the temperate plants, since in the south of the Himalaya the climate is tropical, while in the north there is the high Tibetan plateau and the deserts of Chinese, Turkestan and Mongolia.

The Mediterranean elements become more numerous westward from Sikkim, Kunawar to Kashmir through Nepal, Kumaun, Garhwal, while the Sino-Japanese elements become more numerous eastward. We can find no abrupt change between Western and Eastern Himalaya. This is because the Himalayan corridor of migration was formed rather recently.

These valuable observations will enable future floristic workers on the vegetation of the West and East Himalaya and the phyto-geographers to find out in detail and more accurately, the different elements present in the flora of the East Himalaya.

Chatterjee (1939), in his investigation after a thorough survey of the Dicotyledonous species of India and neighbouring areas points out clearly that the number of endemic species common generally in India is 533, in the Himalaya 3,165, in Continental India 2,045 and in Burma 1,076. According to Chatterjee's estimate 61.5 per cent of the plants are endemic. "This figure", he adds, "is definitely very high for a continental area with land connection in three directions—east, north and west. In India there are three regions containing a specially high percentage for the whole country. These regions are (i) the Himalaya, (ii) the Indian Peninsula forming "Continental India", and (iii) Burma. The rest of India—the Indo-Gangetic plains and the desert regions of Sind, Rajputana and the dry regions of Baluchistan—form an area which is extremely poor in endemic content". The variation of the intensity of the endemic population is delineated in his map.

Chatterjee further explains that 'it is clear from the map that the northern part of India is completely occupied by the lofty mountains of the Himalayan range. The effective nature of this as a barrer to plant-migration has already been pointed out. This barrier is separated from continental India by a broad and dry plain which has cut off that region from close contact with the northern flora, thus affording a large independent area with a high endemic population. The Deccan Peninsula contains no less than 2,045 endemic species and is thus not far behind the Himalaya with 3,169 endemic species. How far land connections between Malaysia, India and Africa have influenced the present flora of the Deccan Peninsula is difficult to indicate with any degree of precision'.

A rough analysis of the flora of the Sikkim Himalaya in and about the town of Darjeeling, both wild and cultivated species, shows that nearly 50 per cent of the total number are indigenous to the Himalaya. The rest of the plants under cultivation in Darjeeling are composed of foreign species of which Japan represents about 14, North American 7, Australia 6, China 6, Malaya 4, Europe 4, South America 3, Tropical Asia 3, Central America, 2, Burma 1 and Africa 0.5 per cents.

The results of the study of the Phanerogamic flora of Eastern India, a brief sketch of which has been given above, definitely establishes a high degree of endemicity in the flora of India as far as can be judged from living flora. The analysis of the various classes of the Cryptogamic flora shows, however, slight variation in the endemic values as outlined by Chatterjee. Of the Filicales, out of the total number of about 8,200 species known to science only about 580 species and 40 species of fern allies are so far recorded from India. A census of these 580 species of ferns reveals that about 240 species are Himalayan, 190 South Indian and 150 Malayan. Thus from the analysis of the fern flora it is clear that the results fully tally with the analysis of Phanerogamic Dicotyledonous flora made by Chatterjee. Bruhl's and Dixon's researches show that out of approximately 3,000 true mosses hitherto recorded from India about

32 per cent are endemic to the Himalaya, 28 per cent belong to Indo-Gangetic plains, Peninsular India, Ceylon and Malaya and about 40 per cent are foreign immigrants. As regards the moss flora the endemic value is just lower than that of the Palaearetic element.

H. N. Dixon, the well-known bryologist, states that the summary of the publications on the moss flora of India gives results which no doubt confirm rather closely those derived from the study of higher plants. They show the following elements of the bryophytic flora probably roughly in a decreasing order of frequency, as follows :—

(1) Palaearctic element, including a considerable number of Arctic, Alpine, European, Asiatic, and North American species.

(2) Endemic.

(3) Indian Peninsula generally. The number of species common to the Himalayan range and the southern part of the Indian Continent is much smaller than either of the two previous categories.

(4) Burmese, Chinese Malayan affinities. A considerable number, chiefly in the Eastern ranges, and especially marked in the Assam moss flora.

(5) Affinities with Western Asia, Caucasus, etc. A small number principally, as is natural, in the western part of the range, and particularly shown in the Hindu Kush (of Herzog, 1938).

There are, of course, in addition to the above, smaller elements of cosmopolitan species, and a few others of a disjunct distribution. Of the latter, one of the most remarkable is *Aongstroemia julacea* (Hook.) Mitt., which was collected by Somervell on Mt. Everest at 6,000 m, the highest altitude of any moss so far recorded ; a species only known elsewhere from the summit of Giant's castle, Natal, and from one or two of the highest summits of the Andes. [For a wider study of this geographical distribution, Herzog's Geographic der Moose (Jena, 1926) may be consulted].

It is a well-known fact that an alpine flora at a given level is richer in proportion to the height of the ground above it. Thus an alpine flora of an altitude from 3,000—4,000 m will be richer than the summit flora of a range of about that altitude.

Analysis of thallose and foliose liverworts discloses that 70 thallose and 108 foliose (total 178) species have hitherto been reported to occur in India. Of the thallose, 50 are indigenous to India. Thus thallose liverworts represent 71.4 per cent endemic to India particularly to the Himlayan region.

A census of fresh water and brackish water algal flora of India does not, however, lead to any definite conclusion with regard to the different elements in the algal flora of India. More intense systematic work on the algal flora requires to be done before anything with sufficient accuracy can be stated. Careful examination of the habitats of the algae, so far recorded from India, indicates that there is a great predominance of the Malayan elements. The total number of species of marine algae and varieties known in the western coast of India is 255, representing 5 species of *Myxophyceae*, 81 of *Chlorophyceae*, 38 of *Phaeophyceae* and 131 of *Florideae*. Endemic species, varieties and forms are only 45, thus representing only 17.6 per cent of the algae recorded from this area of the seashore of Peninsular India. Nelle Carter (1926) indicates them quite a good number of Himalayan algae particularly of North East Frontier, Sikkim and Abor Himalaya upto 3,000 m are endemic. Contributions include those of Bruhl and Biswas (1926) on Manipur algae and algae of Khasi and Jaintia Hills. The freshwater algae of Nepal Himalaya and Afghanistan have been studied by the Japanese algologist—Minoru Hirano (1955, 1964). The nature and trend of distribution of the algal flora also more or less tally with those of the flowering plants.

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CHAPTER IX

NATURAL VEGETATION OF THE EASTERN GHATS

The Eastern Ghats which form the eastern border of the Peninsular Plateau of India, are discontinuous blocks of mountains. With its northern end lying in Orissa it extends to the south through Andhra Pradesh and ends in the Biligirirangan Hills and in the steep Shevaroy Hills in the Salem district of Madras State.

The northern section of the Eastern Ghats which lies in Orissa and Andhra Pradesh, covering 75,000 km^2 with an average width of 200 km in the north and 100 km in the south, shows its characteristic features clearly between Godavari and Mahanadi rivers. The Eastern Ghats were in ancient times known as Mahendragiri, after a peak of that name which is about 1,501 m high and about 80 km southwest of Berhampur in the Ganjam district of Orissa. (Gazetteer of India, 1965).

The southern section of the Eastern Ghats lies in the Deccan proper and forms detached low hills. But when it reaches Cuddapah and Kurnool ranges of Andhra Pradesh it becomes high mountain. The Biligirirangan Hills form the southern end of these mountain ranges. Further north the Cauvery river cuts the range transversely, forms the Hogenakal waterfalls and supplies water for the Mettur reservoir. The Eastern Ghats also extend to two other groups of hills viz., the Javadi Hills and the Shevaroy Hills.

They are uniform in their character in Orissa and in the northern part of Andhra Pradesh down to the valley of Krishna river, their average elevation being 762 metres. But there are a few points which rise to considerable heights of which mention may be made of the following : Korlaput 1,213 m, Banksoma 1,275 m, Nimgiri 1,516 m, Malaygiri 1,187 m, Megasini 1,165 m, Mankarnacha 1,109 m and Mahendragiri 1,499 m. The Shevaroys rise to 1,646 m.

GEOLOGY AND SOILS

According to Krishnan (1956) the Eastern Ghats region lying between Vijayawada and Cuttack which attains the greatest width in the Ganjam-Cuttack tract is composed of ridges, ending in a north-east to south-west direction. The mountains are made up of gneisses, charnockites and khnodalites. To their west there is the gneissic tract of Cuddapah rocks. Puri (1960) reports that the laterite and lateritic soils are developed on the summit of the hills of the Eastern Ghats. They are deficient in potash, phosphoric acid and lime and contain hydrated oxides of aluminium and iron with small amounts of manganese, titanium etc. In the Mahendragiri region the hilly plateau is formed by large crystals of feldspar but the higher peaks are of granitic gneiss in huge prismatic block. The Ghumsur Forest division in the Ganjam district shows a mass of plutonic rock—granite, granite-gneiss. The soil here is good for plant growth. In Vishakhapatnam region of the Eastern Ghats, Ghate (1938) described the soil as loose boulders of quartzite and extensive sheet rocks on the slopes of the mountain and also on the top. Cornwell (1937) reports that the Godavari region of these mountains consists of gneiss, Kamthi and Barakar sandstones, Rajahmundry sandstones and alluvial soil. In the hill reserves the under-lying rock is gneiss, generally well-bedded, massive and granitoid. They contain a high percentage of quartz and can be located by a surface layer of small quartzite stones. The soils commonly found are sand, light sandy soil, dry shallow stony soil, red lateritic soil, light loam, heavy loam, heavy alluvium, black cotton soil and broken ground.

Venkataramanan (1934) while describing the Guntur upland forests records that the formation of rocks in this region is of the sedimentary type consisting of shale, slates and limestones. Mahammad Amir Padsha Sahib Bahadur (1932) observes that in the Kurnool section of the Eastern Ghats the underlying rock is limestones in some reserves while in others it is shale and sandstone with the result the surface soil varies in different localities.

In the Cuddapah region the forests occur on formations of quartzite, sandstones, slates, shales, limestones and volcanic rock. The soil is generally a red ferrugineous loam, shallow and generally poor with loose boulders of varying sizes. In the Nallamalai area of this region the soil is comparatively greater in depth and hence the growth of vegetation is better than in the other regions.

Wilson (1916) states that the Javadi Hills and the Yelagiri Hills or the Eastern Ghats which lie in the North Arcot district show the underlying rock formation a granitic gneiss. The soil here is fertile with red clayey loam of sufficient depth to support the growth of timber trees. There are also places where the soil is hard and stony of a whitish colour and in such places no growth flourishes. According to Dorairaj (1963) the Shevaroys is a compact block where the soil is highly red and sandy loam. Black soil is exceptional. This region contains a few flat top peaks on which bauxite deposit occurs.

CLIMATE AND RAINFALL

The Eastern Ghats show varying degrees of temperature and rainfall throughout the extensive ranges. Mahendragiri, which lies in the northern section, receives 100—150 cm of rainfall. In the Ghumsur region extremes of cold and heat are considerable but frost is unknown. The Southwest monsoon bursts about the middle of June and lasts until the month of September or later. The Northeast monsoon is expected to break about October but is variable and usually cyclonic. The climate becomes cold by the end of November. In March the nights are cold but the days are hot. Thunder showers occur in the beginning of April. The average rainfall in the forest tracts here is about 152.4 cm.

In the regions of Vishakhapatnam district the temperature is varying from 15.6° to 37.8°C. The hot months are from March to June. Both the Southwest and Northeast monsoons give rain in this area. The bulk of the rainfall is from the Southwest monsoon during the months of June, July and August and ends by the middle of September. Here also the North-east monsoon which is very light begins at the end of October. The average annual rainfall in these hills is about 114.3 cm.

The lower Godavari areas have clear seasons of the year. Cornwell (1937) reports 3 seasons, the cold weather, the hot weather and the rainy weather. The cold weather is during December, January and February. During these 3 months the mean total rainfall is below 2.5 cm. The average maximum temperature is 26.7° C and the minimum falls below 15.6° C. The days are cool, bright and dry. The hot weather starts at the beginning of March and continues until the rains break about the middle of June. The mean annual rainfall is 108.5 cm.

In the Guntur regions of the Eastern Ghats, it is very hot from April to the middle of June. May being the hottest month in the year. The temperature goes up to 47.8° C in the shade and hot winds blow over this area. The monsoon begins in June and extends up to the middle of November. The highest rainfall is in September and the mean annual rainfall is below 63.5 cm.

The Eastern Ghats in the Kurnool section have temperature varying between 10° C in December to 43.3° C in May. The hot weather begins here in March and lasts till the middle of June and it is severe. The Southwest monsoon is the chief source of rain. The cold season is from October to February when the nights are cold. The average rainfall is 58 cm.

In the Cuddapah areas the climate is very hot from the middle of February to June. The coolest period is from the middle of November to the middle of January. The average maximum temperature in the shade is about 41.1°C and the minimum is about 27.8°C. This region does not lie in the region of either of the monsoons. Little showers occur between the Southwest and Northeast monsoons by precipitations from June to November. The annual rainfall of this area is 66 to 162.6 cm, the bulk of which is from the Southwest monsoon. In the Seshachalam hills the annual rainfall is about 74.7 cm.

In Javadi and Yelagiri hills the climate is cool with a very fair rainfall. In the Shevaroys both the monsoons are active, the annual rainfall being about 160 cm.

VEGETATION

Gamble (1915) records 2 distinct regions in the Eastern Ghats based on vegetation. 1. The Sal region in the north comprising the districts of Ganjam and the hill tracts of the agencies of that district, and Vishakhapatnam and Godavari. This region is characterised by abundance of *Shorea robusta* Gaertn., which species does not occur south of the Godavari river and hence the name of the region. 2. The Deccan region comprising the lower Godavari, Krishna, Guntur, Kurnool, Cuddapah, Chittoor, Nellore, North Arcot and Salem districts where the forest growth is mainly deciduous and more or less follows the same pattern.

The characteristic features of these deciduous forests are the presence of large populations of species such as *Adina cordifolia* (Roxb.) Hook. f.ex Brandis, *Albizia amara* Boiv., *A. lebbeck* (Linn.) Benth., *A. marginata* Merr., *A. odoratissima* (Linn.f.) Benth., *Anogeissus latifolia* Wall., *Bauhinia racemosa* Lam., *Bombax ceiba* Linn., *Cassia fistula* Linn., *Chloroxylon swietenia* DC., *Cochlospermum religiosum* (Linn.) Alston, *Dalbergia paniculata* Roxb., *Dichrostachys cinerea* (Linn.) Wt. & Arn., *Emblica officinalis* Gaertn., *Gmelina asiatica* Linn., *Grewia tiliaefolia* Vahl, *Kydia calycina* Roxb., *Lagerstroemia parviflora* Roxb., *Madhuca indica* Gmel., *Protium serratum* Engl., *Pterocarpus marsupium* Roxb., *Tectona grandis* Linn.f., *Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn., *T. chebula* Retz. *T. tomentosa* Wt. & Arn., *Xylia xylocarpa* Taub. and *Zizyphus xylopyra* (Retz.) Willd. These forests include in some places both dry-deciduous forests between 400—900 m and moist deciduous forests from 900 m upwards. *Xylia—Terminalia—Anogeissus—Dendrocalamus* association predominates.

Ganjam District.

Gamble (1884) states that in the Ganjam district, particularly Ghumsur taluk and including Surada, there are large Sal (*Shorea robusta* Gaertn.) forests, the best portion of which lies at the foot of the

Ghat range in the valleys of the Gullery and Mahanadi rivers and on the boundary of the Puri district in the Kriyamba valley. The Sal tree chiefly occurs on level lands and in valleys and slopes of hills, the upper slopes being covered, where dry, with forests of bamboo and deciduous trees. In the ravines occur evergreen and large specimens of *Mangifera indica* Linn. The chief allies of Sal in the plains are *Adina cordifolia* (Roxb.) Hook. f. ex Brandis, *Anogeissus latifolia* Wall., *Chloroxylon swietenia* DC. and *Diospyros exsculpta* Buch.—Ham. *Terminalia tomentosa* Wt. & Arn. also is met with occasionally, while in the poor 'Kankar' lands which here and there alternate with higher Sal producing soils, *Soymida febrifuga* A. Juss. grows to a large size. The slopes of the Eastern Ghats which surround Ghumsur on the southwest are clothed with a better vegetation and here the Sal may be seen ascending from 610 m to 914 m in altitude. Large and lofty forest trees cover the slopes and in wetter places are especially found *Tooná ciliata* Roem. and *Xylia xylocarpa* Taub.

Minchin (1921) gave a more detailed idea of the vegetation of Ghumsur forests under these main heads : 1. Sal forests of the plains, pure or nearly pure. 2. Forests of the main hills, valuable mixed deciduous forests. 3. Forests on the broken ground in the plain, mixed growth and stunted and poor quality. 4. Forests of the lower hill ranges, containing bamboo and inferior deciduous growth. 5. Forests on isolated out-lying hills, scrub jungles and bamboo growth.

The main hill ranges contain scrub jungles on broken ground and pure Sal forests in the plains. The vegetation of this region is characterised by the presence of *Adina cordifolia* (Roxb.) Hook.f. ex Brandis, *Anogeissus latifolia* wall., *Bombax ceiba* Linn., *Bridelia retusa* Spr., *Buchanania lanzan* Spr., *Chloroxylon swietenia* DC., *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Dalbergia latifolia* Roxb., *Dillenia pentagyna* Roxb., *Ficus religiosa* Linn., *Garuga pinnata* Roxb., *Gmelina arborea* Roxb., *Grewia tiliaefolia* Vahl, *Lagerstroemia parviflora* Roxb., *Lannea coromandelica* (Houtt.) Merr., *Madhuca indica* Linn., *Mangifera indica* Linn., *Mitragyna parvifolia* (Roxb.) Korth., *Protium serratum* (Wall. ex Colebr.) Engl., *Pterocarpus marsupium* Roxb., *Schleichera oleosa* (Lour.) Oken., *Semecarpus anacardium* Linn.f., *Shorea robusta* Gaertn., *Sterculia urens* Roxb., *Syzygium cumini* (Linn.) Skeels, *Tamarindus indica* Linn., *Terminalia bellirica* (Gaertn.) Roxb., *T. chebula* Retz., *T. tomentosa* Wt. & Arn. and *Toona ciliata* Roem. There are two species of bamboos, namely *Dendrocalamus strictus* Nees on dry rocky ground and *Bambusa arundinacea* Willd. beside water courses. Bamboos are abundant but not over crowded in the forests. The vegetation of a forest varies according to the configuration of the hills. The southern slopes are generally steeper than the other slopes and the soil is more shallow and arid. Here the white and grey barked species that are adapted to withstanding heat predominate. Most common among them are *Anogeissus latifolia* Wall., *Sterculia urens* Roxb. and *Adina cordifolia* (Roxb.) Hook.f.ex Brandis.

The scrub jungle consists of thorny shrubs with *Dendrocalamus strictus* Nees scattered all over.

Climbers such as *Bauhinia vahlii* Wt. & Arn., *Calycopteris floribunda* (Roxb.) Lamk. and *Millettia auriculata* Baker are quite common in this area.

The upper parts of Mahendragiri are covered with sholas as in the Nilgiris and the lower parts with forests. The principal tree here is *Xylia xylocarpa* Taub.

Kapoor (1964) mentions that the families of flowering plants represented in this region by more than 10 species are in order of dominance as follows : *Leguminosae*, *Compositae*, *Acanthaceae*, *Euphorbiaceae*, *Rubiaceae* and *Cyperaceae*. The family *Orchidaceae*, according to him, does not find any important place in the Mahendragiri flora.

The vegetation shows a characteristic mixture of the temperate, tropical and sub-tropical flora. The important species are *Acacia catechu* Willd., *Ajuga macrosperma* Wall., *Alstonia venenata* R.Br., *Alysicarpus racemosus* Benth., *Anaphalis lawii* Gamb., *Andrographis ovata* Benth., *Anotis calycina* Hook.f., *Barleria gibsoni* Dalz., *Bauhinia vahlii* Wt. & Arn., *Blumea jacquemontii* Hk.f., *Bupleurum mucronatum* Wt. & Arn., *Callicarpa arborea* Roxb., *Carex baccans* Nees, *Carmona microphylla* (Lamk.) Don, *Cinnamomum caudatum* Nees, *Cipadessa baccifera* (Roth) Miq., *Clematis roylei* Rehdr., *C. wightiana* Wall., *Crotalaria alata* Ham., *Cyrtococcum trigonum* (Retz.) Camus, *Dendrobium bicameratum* Lindl., *Dimeria avenacea* (Retz.) Fisch., *Dioscorea glabra* Roxb., *Diospyros candolleana* Wt., *Ecbolium viride* (Forsk.) Alston, *Eranthenum capense* Linn., *Eria bambusifolia* Lindl., *Eriocaulon conicum* Fisch., *Exacum perrottetii* Gris., *Euphorbia rothiana* Spr., *Gelonium lanceolatum* Willd., *Gynura lycopersifolia* DC., *Gymnema sylvestre* (Retz.) R. Br., *Gymnosporia emarginata* Laws., *Homalium nepalense* Benth., *Ipomaea diversifolia* R. Br., *Knoxia linearis* Gamb., *Leucas montana* Spr., *Lindenbergia grandiflora* Benth., *Linociera ramiflora* (Roxb.) Wall. ex G. Don, *Litsea laeta* Wall., *L. monopetala* (Roxb.) Pers., *Macaranga peltata* (Roxb.) Muell.—Arg., *Melasma avense* (Benth.) Pennell, *Memycelon umbellatum* Burm.f., *Millettia auriculata* Baker, *Molineria finlaysoniana* Baker, *Osbeckia hispidissima* Wt, *Pavetta breviflora* DC., *Phlebophyllum jeyporense* (Bedd.) Brem., *Pimpinella heyneana* Wall., *Pouzolzia bennettiana* Wt. var. *gardneri* Hook.f., *Pseudarthria viscida* Wt. & Arn., *Pterospermum xylocarpum* (Gaertn.) Sant. & Wagh, *Rungia parviflora* Nees var. *monticola* Gamb., *Santalum album* Linn., *Senecio* *candicans* DC., *S. corymbosus* Wall., *S. nudicaulis* Buch.—Ham., *Sophora glauca* Lesch., *Tephrosia roxburghiana* Drumm., *Thunbergia fragrans* Roxb. var. *hispida* Gamb., *Thunbergia fragrans* Roxb. var. *vestita* Cl., *Vernonia divergens* (Roxb.) Edg., *Viburnum acuminatum* Wall., *Viola patrinii* DC. and *Wendlandia gamblei* Cowan.

The Parlakimedi hills of this region present a vegetation that is different from that of the Mahendragiri. Srinivasan and Subba Rao (1961) state that the general aspect of the vegetation bears great similarity to that of the Deccan, but with this difference that in Parlakimedi and its neighbourhood it is interspersed with Sal. They describe the vegetation of the hills under three heads : 1. The vegetation of the low hill jungles. 2. The vegetation of the dry broken jungles. 3. The vegetation of the rocky hills.

The vegetation of the low hill jungles presents the following features. *Ailanthus excelsa* Roxb. and *Crotalaria albida* Heyne are common at the foot of the hills in certain areas. On barren grounds in such hill jungles *Gonotheca ovatifolia* (Cav.) Sant. & Wagh is plenty. In jungles where the substratum is more sandy, *Hugonia mystax* Linn., *Maba buxifolia* Pers. and *Murraya paniculata* (Linn.) Jack. are the characteristic species. Among the various other species of the low hill jungles are *Aspidopterys indica* (Roxb.) Hochreut., *Bridelia retusa* Spr., *Ceropegia tuberosa* Roxb., *Cissampelos pareira* Linn., *Cryptolepsis grandiflora* Wt., *Erycibe paniculata* Roxb., *Flacourtia indica* (Burm.f.) Merr., *Holarrhena antidysenterica* (Linn.) Wall.,. *Justicia glauca* Rottl., *Leucas mollissima* Wall., *Morinda tinctoria* Roxb., *Oldenlandia nitida* Gamb., *Pavonia odorata* Willd., and *Tarenna asiatica* (Linn.) Sant. & Merch. Bamboos also form large populations at certain places. Amidst the bamboos *Thespesia lampas* (Cav.) Dalz. & Gibs. grows in some localities. On steep hills *Litsea glutinosa* (Lour.) C. B. Robin. occurs. *Bidens biternata* (Lour.) Merr. & Sherff. is characteristic on the top of the hills.

In the dry broken jungles the characteristic species are *Adina cordifolia* (Roxb.) Hook.f. ex Brandis, *Antidesma diandrum* (Roxb.) Roth and *Hybanthus enneaspermus* (Linn.) F. V. Muell. Among rocks *Derris scandens* (Roxb.) Benth., *Knoxia sumetrensis* (Retz.) DC., *Mimosa rubicaulis* Lam. and *Pseudarthria viscida* Wt. & Arn. are very common.

The vegetation of the rocky hill slopes shows the following species. *Blepharis maderaspatensis* (Linn.) Heyne ex. Roth. *Helicteres isora* L., and *Trichosanthes cucumerina* Linn. Where it is stony and dry *Blepharis molluginifolia* Pers., *Caralluma adscendens* R. Br., and *Phyllanthus maderaspatensis* Linn. are very common. *Flacourtia indica* (Burm. f.) Merr., *Hibiscus micranthus* Linn.f. and *Indigofera glandulosa* Roxb. ex Willd. are also found.

The vegetation of the valleys shows *Alysicarpus vaginalis* (Linn.) DC. and *Atylosia scarabaeoides* Benth., the latter climbing on shrubs and trees. In the interior of the jungles in the valleys, *Aegle marmelos* (Linn.) Corr., *Butsa monosperma* (Lamk.) Taub. *Diospyros exsculpta* Buch.—Ham., *Madhura indica* Gmel., and *Shorea robusta* Gaertn. are found widely spread in the jungle parts. In the valleys *Argyreia choisyana* Wt. is seen climbing high on trees in Sal forests. *Bridelia tomentosa* Bl., *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Datura metel* Linn., *Pergularia daemia* (Forsk.) Chiov., *Rauvolfia tetraphylla* Linn., and *Vitex pinnata* Linn. are the other species occurring in the valleys.

Vishakhapatnam District.

The forests of Palkonda in the north. Velikonda hills in the south-west, and forests of Jeypore in this region have according to Gamble (1884), large areas of *Chloroxylon swietenia* DC., *Xylia xylocarpa* Taub., and *Terminalia tomentosa* Wt. & Arn.

Ghate (1938) reports in the working plan he prepared that the forests in this region are almost entirely deciduous. *Shorea robusta* Gaertn. occurs in scattered patches in the northern parts of the Palkonda range near the Ganjam frontier, along with its associates as mentioned above.

Here also bamboo forests consisting of *Dendrocalamus strictus* Nees exist all over. But *Bambusa arundinacea* Willd. occurs only in small patches on the banks of the streams in Caraca, Dharakonda and Sanivaram ranges.

Godavari District.

The Godavari region consists of a large portion of the Eastern Ghats. The forests are mostly mixed deciduous. The hill side, particularly in the region of Peddapur and Gokavaram ranges, shows *Dendrocalamus strictus* Ness in large population, associated with *Anogeissus latifolia* Wall., *Bombax ceiba* Linn., *Chloroxylon swietenia* DC., *Cochlospermum religiosum* (Linn.) Alston and other allied species. On the hill sides where there are no bamboos the same general type of the growth prevails.

Forests in the lateritic soils in this region support a great variety of species such as *Albizia amara* Boiv., *Bauhinia racemosa* Lam., *Cassia fistula* Lam., *Erythroxylon monogynum* Roxb., *Wrightia tinctoria* R.Br., *Zizyphus xylopyra* (Retz.) Willd. and other allied species. The height of the trees in this region is rather poor averaging to about 3 m. There are open grasslands with a few scattered trees chiefly *Dillenia pentagyna* Roxb., *Pterocarpus marsupium* Roxb., *Terminalia chebula* Retz. and *Xylia xylocarpa* Taub. Cornwell (1937) reports that the forests of this region in areas of Beddanole and Marlagudem reserves of Polavaram range and Devancheruvu blocks of the Rajahmundry range show the vegetation having a greater variety of species including *Acacia ferruginea* DC., *A. leucophloea* (Roxb.) Willd., *Albizia amara* Boiv., *Azadirachta indica* A. Juss., *Bauhinia racemosa* Lam., *Caesalpinia coriaria* Willd., *Casearia elliptica* Willd., *Emblica officinalis* Gaertn., *Erythroxylon monogynum* Roxb., *Gmelina asiatica* Linn. and *Zizyphus mauritiana* Lamk. Climbers are plentiful and they combine with the low trees and the undergrowth to form a dark tangle. The more common climbers are *Abrus precatorius* Linn., *Acacia caesia* Willd., *Pterolobium hexapetalum* (Roth) Sant. and Wagh and *Zizyphus oenoplia* (Linn.) Mill. In this area evergreen species such as *Maba buxifolia* Pers., *Manilkara hexandra* (Roxb.) Dub. and *Memecylon umbellatum* Burm. associated with *Acacia chundra* (Roxb.) Willd., *Bauhinia racemosa* Lam., *Bridelia montana* Willd. and *Diospyros sylvatica* Roxb. occur.

In the valleys where the soil is deep loam, the deciduous forest trees grow in abundance often to a height of 21 m. There are also forests of *Tectona grandis* Linn.f. in the Ravigudem valley, in the Addakonda-Pothanakonda valley and also along the slopes of the Chilukalur, associated with *Pterocarpus marsupium* Roxb. In the Ravigudem region *Terminalia tomentosa* Wt. & Arn. grows to a height of 31 m and a girth of 2 m which is quite noteworthy. In the Rampa and Gudem areas, Seshagiri Rao (1958) mentions two major vegetational zones—mixture of thorny scrub and dry deciduous type.

Guntur District.

Venkataramanan (1934) enumerates the following species in the Guntur upland forests. Besides, the common deciduous species already *Acacia* Willd., *A. chundra* (Roxb.) Willd., *A. farnesiana* (Linn.) Willd., *A. horrida* (Linn.) Willd., *A. leucophloea* (Roxb.) Willd., *Adina cordifolia* (Roxb.) Hook.f. ex Brandis, *Aegle marmelos* (Linn.) Corr., *Alangium salvifolium* (Linn.f.) Wang., *Atalantia monophylla* (Roxb.) DC., *Azadirachta indica* A. Juss., *Balanites aegyptiaca* (Linn.) Delile, *Bridelia montana* Willd., *Calotropis gigantea* R. Br., *Canthium dicoccum* (Gaertn.) Merr., *Carissa carandas* Linn., *Cassia auriculata* Linn., *C. tora* Linn., *Tarenna asiatica* (Linn.) Sant. & Merch., *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Commiphora caudata* (Wt. & Arn.) Engl., *Cordia gharaf* (Forsk.) Ehrent. & Asch., *Diospyros chloroxylon* Roxb., *D. melanoxylon* Roxb., *Dolichandrone falcata* Seem., *Drypetes sepiaria* (Wt. & Arn.) Pax & Hoffm., *Erythroxylon monogynum* Roxb., *Euphorbia antiquorum* Linn., *Ficus glomerata* Roxb., *Gardenia latifolia* Ait., *Gyrocarpus americanus* Jacq., *Hardwickia binata* Roxb., *Helicteres isora* Linn., *Ixora arborea* Roxb. ex Sm., *Lannea coromandelica* (Houtt.) Merr., *Maba buxifolia* Pers., *Mangifera indica* Linn., *Manilkara hexandra* (Roxb.) Dub., *Mitragyna parvifolia* (Roxb.) Korth., *Morinda citrifolia* Linn., *Phoenix sylvestris* Roxb., *Pongamia pinnata* (Linn.) Pierre, *Dremna tomentosa* Willd., *Prosopis spicigera* Linn., *Pterolobium hexapetalum* (Roth.)

Sant. & Wagh., *Sapindus emarginatus* Vahl, *Soymida febrifuga* A. Juss., *Streblus asper* Lour., *Strychnos nux-vomica* Linn., *Syzygium cumini* (Linn.) Skeels, *Tamarindus indica* Linn., *Ventilago maderaspatana* Gaertn., *Vitex altissima* Linn.f., *Wrightia tinctoria* R. Br., *Xeromphis spinosa* (Thumb.) Keay and *Zizyphus mauritiana* Lamk. are also common. The important grasses in this region are *Andropogon pumilus* Roxb., *Apluda mutica* Linn., *Arthraxon lanceolatus* (Roxb.) Hochst., *Brachiaria ramosa* (Linn.) Stapf, *Chloris barbata* Sw., *Dactyloctenium aegyptium* (Linn.) P. Beauv., *Eragrostis tremula* Hochst. ex Steud., *Heteropogon contortus* (Linn.) P. Beauv. ex Roem. et Schult., *Sehima nervosum* Stapf and *Setaria pallidefusoa* (Schumach.) Stapf et Hubbard.

Kurnool District.

In the Kurnool section of the Eastern Ghats, Muhammad Amir Padhsa (1932) reports that *Hardwickia binata* Roxb. is the most important specis throughout the hills, *Anogeissus latifolia* Wall., *Tectona grandis* Linn.f., and *Terminalia tomentosa* Wt. & Arn. also occur in special localities and are either gregarious or mixed with other species. Often they are stunted in growth.

In the Nallamalai hills the characteristic deciduous trees occur besides *Garuga pinnata* Roxb., *Givotia rottleriformis* Griff., *Hardwickia binata* Roxb., *Lannea coromandelica* (Houtt.) Merr., *Millusa velutina* Hook.f. & Thoms. and *Phoenix sylvestris* (Linn.) Roxb.

The important climbers are *Bauhinia vahlii* Wt. & Arn. and *Butea parviflora* Roxb.

Generally, the Nallamalais show varying types of vegetation from scrub type to patches of evergreen with intermediary vegetation well represented in different regions. The dry deciduous is generally represented in most of the places whereas moist deciduous is confined to higher elevations having heavier rainfall.

Scrub vegetation is seen in Srisailam, where the typical representatives abound and they are *Atalantia monophylla* (Roxb.) DC., *Dichrostachys cinerea* (Linn.) Wt. & Arn., *Plectronia parviflora* Bedd., *Zizyphus oenoplia* Mill., and *Z. rugosa* Lam. There are some moist deciduous species common in Gundlabrahmeswaram and they are *Clerodendrum serratum* (Linn.) Moon, *Costus speciosus* (Koem. ex Retz.) Smith, *Glochidion velutinum* Wt., *Tacca leontopetaloides* (Linn.) O. Kuntze, *Thunbergia laevis* Nees and giant lianas like *Bauhinia vahlii* Wt. & Arn. and *Entada pursaetha* DC.

Cuddapah District.

In the Cuddapah region the vegetation is of the mixed deciduous type. The growth of trees is poor in height and girth. *Hardwickia* *binata* Roxb. appears in large numbers along with *Anogeissus latifolia* Wall. and *Pterocarpus santalinus* Linn.f. The thorny scrub jungle is found at the edges of the forests all over the lower plains. This is characterised by *Acacia chundra* (Roxb) Willd., *A. horrida* (Linn.) Willd., *Albizia amara* Boiv., *Carissa carandas* Linn., *C. spinarum* Linn., *Dichrostachys cinerea* (Linn.) Wt. & Arn., *Diospyros chloroxylon* Roxb., *D. montana* Roxb., *Euphorbia antiquorum* Linn., *Flacourtia indica* (Burm.f.) Merr., *Maytenus emarginata* (Willd.) Ding Hou, *Mimosa polyancistra* Benth., *M. rubicaulis* Lam., *Prosopis spicigera* Linn., *Securinega leucepyrus* (Willd.) Muell. Arg., *Xeromphis malabarica* (Lam.) Raju, *X. spinosa* (Thumb.) Keay, *Zizyphus mauritiana* Lamk., and *Z. xylopyra* (Retz.) Willd. Above the scrub jungles deciduous forests occur presenting all the characteristic species mentioned before. Here the most common climbing or straggling plants are *Acacia caesia* Willd., *A. pennata* (Linn.) Willd., *Ampelocissus tomentosa* Planch., *Cissus pallida* (Wt. & Arn.) Planch, *Jacquemontia paniculata* (Burm.f.) Hall.f., *Merremia hederacea* (Burm.f.), Hall.f., *Mimosa polyancistra* Benth., *Operculina turpethum* (Linn.) Silva-Manso, *Pterolobium hexapetalum* (Roth) Sant. & Wagh and *Rivea hypocrateriformis* Choisy. Other climbers include *Cansjera rheedii* Gmel., *Opilia amentacea* Roxb., *Pachygone zeylanica* (Gaertn.) Sant. & Wagh, *Ventilago calyculata* Tul. and various taxa of *Dioscorea*.

After the rains in September—October, grasses such as *Chionachne koenigii* (Spr.) Thw., *Dichanthium annulatum* (Forsk.) Stapf, *Eragrostiella bifaria* (Vahl) Bor, *Mnesithea laevis* (Retz.) Kunth and a few other taxa practically cover the ground. *Eriocaulon quinquangulare* Linn. and *E. sieboldianum* Sieb & Zucc. are commonly seen in partially inundated regions. In February—March *Isoetes coromandeliana* Linn. comes up in abundance in puddles.

Besides these, Seshagiri Rao (1960) reports that there is a Red Sanders (*Pterocarpus santalinus* Linn. f.) zone from 250 metres to 600 metres and a *Shorea tumbaggaia* Roxb., and *Syzygium alternifolium* (Wt.) Walp. zone above 600 metres. These occur in association with the other prominent deciduous forest trees.

North Arcot District.

The Javadi Hills are famous for the growth of *Santalum album* Linn., the Sandalwood trees. The sandal is spreading rapidly in this region. The tree grows in patches of varying size and density form a few hectare to several hundred hectares. The most interesting feature about this tree is the fact that it is a root parasite. The host plant is not quite clearly known, but it grows in association with large number of species and perhaps all these associates serve it as host. Wilson (1916) lists 81 species as associates and which proved to some extent as hosts to *Santalum album* Linn.

The rest of the forest follows the same pattern of vegetation characteristic of deciduous forest mentioned earlier.

Salem District.

Shevaroys.

Dorai Raj (1964), following Champion's classification, describes three types of forest vegetation in the Shevaroys.

I. **Southern Kutch Thorn Forest :** This is the most widely spread form, occurring throughout the tract upto 457 m. The species most commonly seen are *Acacia chundra* (Roxb.) Willd., *A. ferruginea* DC., *A. horrida* (Linn.) Willd., *A. leocophloea* (Roxb.) Willd., *Ailanthes excelsa* Roxb., *Albizia amara* Boiv., *Azadirachta indica* A. Juss., *Canthium dicoccum* (Gaertn.) Merr., *Carissa carandas* Linn., *Chloroxylon swietenia* DC., *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Dichrostachys cinerea* (Linn—) Wt. & Arn., *Dodonaea viscosa* (Linn.) Jacq., *Erythroxylon monogynum* Roxb., *Gyrocarpus americanus* Jacq., *Strychnos nux-vomica* Linn., *S. potatorum* Linn.f., *Tamarindus indica* Linn., *Wrightia tinctoria* R.Br., *Xeromphis spinosa* (Thunb.) Keay, *Zizyphus mauritiana* Lamk. and fleshy *Euphorbias*. *Dendrocalamus strictus* Nees is commonly found occurring extensively on slopes often forming a gregarious stands of pure bamboo. *Lantana camara* Linn. var. *aculeata* (Linn.) Moldenke appears to be spreading. *Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn. occurs along stream banks and attain considerable size. *Hardwickia binata* Roxb. is found in some reserves.

II. **South Indian Tropical Dry Deciduous Type :** The major portion of the forests between 457—1,067 m of the division fall in this category. The species found in this type are not very different from those found in the lower thorn forest, but the density of the forest is distinctly better, and the growth in general is more luxuriant. Although the division as a whole is deficient in timber species, there are several patches of forest where valuable species such as *Dalbergia latifolia* Roxb., *Pterocarpus marsupium* Roxb. and *Tectona grandis* Linn.f. occur in some profusion. These patches, however, are of limited size and the tree growth in them is generally stunted. Besides the species already mentioned the following are also found : *Albizia lebbeck* (Linn.) Benth., *A. odoratissima* (Linn.f.) Benth., *Anogeissus latifolia* Wall., *Bauhinia racemosa* Lam., *Cassia fistula* Linn., *Dalbergia paniculata* Roxb., *Diospyros montana* Roxb., *Hardwickia binata* Roxb., *Mangifera indica* Linn., *Shorea roxburghii* G. Don, *Syzygium cumini* (Linn.) Skeels, *Terminalia arjuna* (Roxb. ex DC.) Wt. & Arn., *T. chebula* Retz., *T. paniculata* Roth and *T. tomentosa* Wt. & Arn. The predominance of *Anogeissus latifolia* Wall., is a noteworthy feature of this zone. Thorny Acacias and fleshy Euphorbias are gradually replaced as one goes higher up. Sandal is widespread in this region.

III. **Sub tropical Evergreen Forest** : This occurs above 1,067 m and is akin to the sub-tropical evergreen forests on the slopes of the Nilgiris, Palnis and Anaimalais. This type is found in Sanyasimalai reserved forest on the Yercaud plateau. The trees are smaller and with less shapely boles and are often festooned with herbaceous epiphytic orchids such as *Dendrobium aquem* Lindl., *Diplocentrum recurvum* Lindl., *Luisia tenuifolia* Bl., *Saccolabium pulchellum* (Hook.f.) Fischer and *Vanda testacea* (Lindl.) Reichb.f. The species commonly met with are *Alseodaphne semecarpifolia* Nees, *Artocarpus lakoocha* Roxb., *Chukrsaia tabularis* A. Juss., *Machilus macrantha* Nees, *Mangifera indica* Linn., *Syzygium cumini* (Linn.) Skeels and *Toona ciliata* Roem. Besides, the terrestrial orchid, *Acanthophippium bicolor* Lindl. is very common.

The Shevaroys also present a rich fern flora, and Subramanyam *et. al.* (1960) enumerated 51 species from this region of which the most common ones are *Actiniopteris dichotoma* (Forsk.) Kuhn, *Adiantum cuneatum* Lang. & Fisch., *Asplenium althiopicum* (Burm.) Bech., *Botrychium lanuginosum* Wall., *Dicranopteris linearis* (Burm.) Underwood, *Dryopteris sparsa* (Don) Kuntze, *Lepisorus nudus* (Hook.) Ching,. *Nephrolepis cordifolia* (Linn.) Presl., *Pellaea concolor* Lang. & Fisch., *Pyrrosia porosa* Wall. and *Sphenomeris chusana* (Linn.) Copeland.

The vegetation of the Eastern Ghats shows variations presenting certain remarkable species of trees like *Pterocarpus santalinus* Linn.f., *Santalum album* Linn., *Shorea robusta* Gaertn. and *Tectona grandis* Linn.f. restricted to definite regions. However, in general it faithfully represents the characteristic species of plants forming deciduous forests and scrub jungles throughout its extensive range of forests starting from Orissa to Madras. In the hill top over 1,067 m the vegetation shows the presence of certain temperate elements and ferns besides a few evergreen species. The evergreen trees are also met with in the ravines on the slopes and valleys.

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CHAPTER X

THE HABITAT AND CULTURE OF PRIMITIVE HILL PEOPLES OF INDIA.

What strikes one readily is India's diversity. Diversity is everywhere in India in her nature, physical features and even in the people who live in the vast country. But what is surprising is the unmistakeable tone of unity lying behind all this diversity and integrating it into a composite whole. The vast stretch lying between the Himalaya and the cape shows all shades of physical variety including snow clad—mountains, high table land, dense tropical forests, fertile river valleys as well as barren desert. In the same way people living in the vast area show different racial strains along with a range of cultural and behavioural pattern. racial strains along with a range of cultural and behavioural pattern. These different cultures like different flowers composing a colourful bunch, have merged to one single entity namely the Indian civilisation.

Culture in Anthropological sense includes the material traits ; production of food, building of houses, method of cooking, clothing etc., the units and institutions of social organisation as well as moral and religious norms.

Culture composing the civilization of India is no doubt greatly influenced by the opportunities and limitations offered by the physical environment of the country. One may at once discover the different modes of cultural behaviour between the people living in hills and those living in plains. The modes of living in the plains may seem further varying in different types of terrestrial environment as river valley, desert and so on.

Of course, man has been trying to mould the opportunities offered to him by nature in his favour and as a result has been shifted considerably from the natural environment. Yet among some of the primitive communities the relation between man, his culture and geography is conspicuous. This relation is however, more evident among the hill communities.

The present article will cover an outline of the cultural life of the Indian primitive communities living in the hills.

It is to be noted that in this article the term 'tribe' has been avoided instead of which the term 'primitive community' has been used. This has been done mainly for the following reasons. It was the British government for the convenience of colonial administration labelled one group of people as 'tribe' basing on some general physical and cultural facts in 1872. Since then controversies are raging to ascertain where actually the 'tribe' pole ends and the caste pole begins. So on such uncertain grounds, a group of people over 29 million should not be isolated from the main stream of the country for it is only erroneous but also detrimental for the integration of the country as a whole.

PRIMITIVE COMMUNITIES OF THE ASSAM HILLS

The primitive communities living in hills of Assam are the Garos, the Khasis, the Mikirs, the Kacharis, the Mizos, the Kukis, the Naga groups of people and the communities of NEFA.

The Kuki tribes chiefly inhabiting the Manipur and Cachar hills are : the Purums, the Vaipheis, the Aimols the Anals, the Koms, the Thados and a dozen of such. According to 1931 census Kuki population of Manipur is 78,346 and that of Cachar is 8,767.

The Mizo district (Lushai hills) is populated by different ethnic groups of Kuki-Chin stock. The main groups are : the Mizo Ralte, Hmar, Pawi, Paihte, Reang, Mara (Lakher) Chakma, Panek, Bong, Pang, Tipra etc. Bulk of the Mizo group of people migrated in the area from Burma in the 17th century and established as isolated almost self-sufficient small communities. According to 1961 census the number of the Mizo is 2,13,061, Chakma 19,337 Mara (Lakher) 8,780, Pawi (Lai) 4,515 and Hmar 3,118.

The Kacharis belong to the Boro linguistic group. They inhabit Cachar hills and also part of Mikir hills.

The Mikiris are the inhabitants of Mikir hills. Total Mikir population according to 1931 census is 1,29,797.

The total Naga population is about 3,57,000 (Nagaland : Verrier Elwin : 1961 p. 5). They are divided into several groups, viz., Angamis, Aos, Chakhesangs, Changs, Khienmungans, Konyaks, Lothas, Phoms, Rengmas, Sangtams, Semas, Yimchungrs and Zeliangs. Approximate number of these groups are 30,000, 50,000, 31,000, 17,000, 17,000, 63,000, 23,500, 13,000, 5,000, 20,700, 48,000, 17,500 and 15,250 respectively.

The chief communities of the NEFA hills are the Abors or Adis, the Aka, the Apatani, the Dafla, the Galong, the Khampti, the Khowa, the Mishmi, the Momba, the Miri and the Singho. Population of all these people are not available. According to 1931 census, the population of Daflas is 3,288, Adis is 14,042 and Miri is 85,038.

The Khasi and Jaintia hill is populated principally by the Matriarchate Khasis, Syntengs or Pnars, Wars, Bhois and Lyngams. Number of Khasis according to 1951 census is 292,923.

The Garo hill range is chiefly peopled by the Garos and the Koches. The Koches are minor in numerical strength. According to 1961 census the Koch language formed 1·9 per cent of the total Garo hill population. The Garo population according to 1951 census is 242,075 of which only 190,901 recorded Garo as their mother tongue. The hill range lies between 25°9′ and 26°1′ of north latitude and between 89°49′ and 91°2′ of east longitude. It is bounded by the Goalpara district on the north and west, on the south by Mymensingh district, East Pakistan and on the east by the Khasi hill, Assam. It contains an area of 8,132 km.[2] Average height of the hill is 600 m. The highest peak, Nokrek is about 1,400 m high. Rainfall in the entire Garo hill range is very heavy. The moist hills are densely wooded mainly by 'Sal', bamboos and other trees.

The Garos who live in the hill are known as 'Pahris' or 'the hill Garos' and those who live in the plains are known as 'Lamdani' or 'the plain Garos'. This dichotomy is associated with certain cultural practices too. The Garo speech belongs to the 'Boro' group of the Assam-Burmese branch of Tibeto-Burman family of languages. The topographical influence is detected in the speeches as considerable number of the Garos in the plains of Mymensingh, East Pakistan talk in the local Bengali tongue. Generally, the Garos are short people with marked Mongoloid traits. In the material traits also sharp differences are observed between the Paharis and Lamdanis. In the plains, they practice wet cultivation where as in the hills the Garos practise slash and burn cultivation. In the Garo hills three seasons are felt—rainy, summer and winter. Winter begins from November and lasts till February. The summer begins from March. From the middle of April to first week of May showers begin. The record of rainfall is about 350 cm per year. This pronounced rainy season influences the cultivation. The crops are planted at the beginning of the rains. From December to February jungles of the selected piece of land in the hill slope are cut down. In the March these are burnt. In April and May with the first showers crops are sown with the help of a digging stick. In the first year a number of crops are sown in the same field and these are harvested from July to December. Millet is harvested first and last of all, cotton. These fields are weeded at least two to three times. During harvesting, only the ears of the plants are grasped and the grains are dragged in and are collected in baskets one on the back another fastened to the waist in the front. Implements are very simple as hoe, short rake made of bamboo and scraper also made of bamboo.

Most of the domestic utensils, the mortar and pestle for poundering grains etc. are made of local woods. For winnowing the rice a flat tray of bamboo splits is used. Sieves, spoons and drinking cups are made of bamboo. Plantain leaves serve for plates. For carrying water bamboo pieces as well as dry gourds are used. For carrying other goods baskets made of bamboo splits are used. The earthen wares for boiling rice are traded in from the traders in the plain. The Garos in the hill district produce paddy, millet, spices and vegetables. In the orchards orange, melon and pineapple etc. are grown. Jackfruit trees grow normally in the forests.

In the hills, the Garos produce sufficient cotton in their fields. Every housewife possesses a loom. The principal garment of the Garo males is the 'Gando' a strip of cloth 15 cm wide and about 1·8 to 2·1 m long. The dress of Garo females consists of a piece of cloth 46 cm long and just broad enough to meet round the waist as a petticoat. Actually short garments facilitate the movement of these people in the hills. Use of bark clothes in the interior Garo villages was not rare till the recent period.

For the slopes, as well as heavy downpour, the houses in the hills are built on piles. Posts, cross-beams etc. are made of bamboos. The floor is also made of bamboo matting. The walls are made of the same matting and the roof is covered by thatching grass which grows locally in abundance. The hunting and fishing implements, the musical instruments etc. are made either of wood or of bamboo.

The Garo villages are found in valleys, near streams. The market occupies an important place in their life. Markets are found wherever roads penetrate the hills. The Garos carry mostly agricultural products, fruits and handloom products and purchase salt, earthen wares and sundry articles. Cotton is the chief cash crop and the others are the spices and fruits.

Socially, the Garos are matrilineal people divided into 5 exogamous units, Sangma, Marak, Momin etc. These units are divided into matrilineal clans (Ma-chong) which are again divided into sub-clans—Chatchi or Mahari, members of which trace descent from a common woman (mother). Mother is the owner of the family property which is transmitted to one of the daughters known as 'Nokna'. The marriage distance is controlled by the scopes of communication in the hills. Polygyny and cross cousin marriages are found among the Garos. The 'Nokpante' or bachelor's or bachelor's quarter for the young unmarried men which is situated at the centre of the village plays an important role in imparting the social, educational and recreational norms among its inhabitants. These people have a set of very definite rules of inheritance. One of the daughters is selected as 'Nokna' (heiress) and with certain rights and duties she inherits the property. In the Garo hills, still the village government is found in action. The Garo district is divided into fifty-five administrative

'Elekas', each including about twenty villages. A petty magistrate with the title of 'Loskor' is appointed in each 'Eleka'. In a village at least one man is referred by the term 'Nokma' who is generally known as the headman and recognised by the government. The villagers also elect a man as 'Loskor' who often appoints one or more assistance or 'Sardars' for administrating respective 'Eleka'.

In religious practices once again the close relation between man and nature is obvious. With the ancestor worship the Garos worship the thunder, lightning, rains, wind, earthquakes, shooting stars and offer sacrifices to these forces. They prepare certain sacrificial erections of bamboo which represent the spirits before whom offering is made. Number of stones of different sizes are worshipped by the Garos for their magical potency. Each stage of the cultivation is associated with rituals and sacrifices towards the spirits ruling over the seasons. Better crops and fertility of the soil is prayed to the deities.

THE BHOTIYAS OF THE NORTHWESTERN MOUNTAINS

The geographical situation controls the subsistence pattern which again exert influences upon the cultural life of the people. This may further be seen in the cultural life of the Bhotiyas. The Bhotiyas are the representatives of northwestern mountains.

The vegetation varies according to the altitude. In the foot hills upto 1,200 m height Sal and Haldu (*Adina cordifolia*) are the chief woods. Pine is found from 1,500 m and Oak, from 2,400 m. Grassy slopes begin from 3,000 m but above 3,300 m grassy slopes are common, along with silver fir, birch and blue pine. Vegetation ceases above 3,900 m of height. This area is inhabited by the Bhot or Bhotiyas. The people bear Mongoloid traits in the physical features. Settlements follow the river valleys. The communication is checked by the mountains hence the villages are practically self-supporting. The people inhabiting the area below 3,000 m practise cultivation. It is practised in the terraces made in the mountain slopes and alluvial cones. Period of cultivation is from middle of May to the middle of October. The chief implement is the hoe (Kutla) used both by men and women. The plough is seldom used. The plough when used is usually drawn by the men and also by the 'Jibu'—a hybrid of the yak and the cow. When man pulls the plough, a rope is tied to the beam and tied round the waist of the man and then dragged. A stick is held in the hand which assists his forward movement. The plough share is guided by another man. A couple of men also draw the plough. Normally the rotation of crops is not found. Irrigation is practised in some of the oases. Only the fields near the homestead are heavily manured. The dung of sheep and goats is used as manure. Harvesting begins from the middle of September. Sickle is not used for the purpose, The ears of the plants are nipped with the help of two bamboo stick and kept in the bell shaped basket (Doka) at the back of the reaper. These ears are either threshed by hand with the help of a club (Dabla) made of oak wood or the goats or sheep are allowed to move on the stalks as a result of which the grains and stalks are separated. Madua (*Eleusine coracana*), wheat and barley are the chief crops. This type of cultivation is practised in the upper terraces or "Upraon' region.

In the oases or 'Talaon' lands, situated near rivers, wet cultivation is practised. The lands are irrigated from nearby streams. Plough is used for cultivation. The first class irrigated lands are known as 'Sera'. The methods of agriculture in these lands are similar to the Indo-Gangetic plain. Here also the chief crops are Madua and paddy. In the valleys and in the foothills ginger, cabbage, potato, are grown during winter. These are their cash crops.

The Bhotiyas above 3,000 m are pastoral nomads. The grassy slopes are used as pastures (Bugyal or Payar). These peoples change their residence twice a year. The summer dwellings are situated in the cold valleys towards the Tibetan frontier and in winter they come down. These two residences of them are equipped with two sets of beddings and utensils. There are three varieties of migrations. In the first case the carrier flocks and traders move, in the second case the families accompany the traders and their flocks and in the third case herds of cattle are moved in charge of three or more drovers. Sheep and goats are the chief animal stocks.

Wool is the chief article of their industry. The yarn spun is of two types. Single ply for coarse textures and two ply for fine texture. In every primitive looms mainly in the sunshine the people (normally the women) use to weave. They are reputed blanket makers. Coarse woollen serge, small pile carpets etc. are also produced by the Bhotiya woman. Small industry of making wooden vessels is also found among them. Marketing in these hill tracts is a problem. The people purchase articles from fairs or 'Melas' held in towns and store them for the rest of the period. These people are patrilineal and often polygynous.

The environment is reflected in the religious beliefs of the Bhotiyas. They worship the peaks of the mountains. Peak 'Trisul' is worshipped as the seat of Mahadev and Nandadevi, the consort of Mahadeva as guiding goddess. Rain god 'Gabla' is worshipped with the offerings—goats and corns. The shepherds worship the god 'Sidhuwa' and 'Bidhwa' the protector of their cattle from ailing beasts. Each village possesses its own presiding deity.

PRIMITIVE COMMUNITIES OF THE CENTRAL PLATEAU

The Central plateau is mainly inhabited by the Mundas, the Kols, the Santals, the Bhumijas, the Oraons, the Kharias, the Juangs, the

Savaras, the Khonds, the Gonds, the Korkus and the Bhils. Total number of them according to 1931 census are : 5,49,764 ; 5,23,158 ; 17,12,133 ; 37,974 ; 6,37,111 ; 1,46,037 ; 15,024 ; 2,44,670 ; 3,15,709 ; 25,16,890 ; 1,76,615 and 7,76,975 respectively.

The Munda languages are spoken in Chotanagpur. The Kherwari is commonly spoken by them. The Santal, Bhumij, Kol speak in their own dialects under Mundari group. Juang and Kharia languages are very old and dying. Kurukh language is spoken by the Oraons which is related to the ancient Tamil language. Kui is spoken by the Khonds. The Savara dialect is nearer to that of Juang and Oriya. The Korku dialect is allied to Kherwari. The dialect of the Bhils is more Aryanised. The Gonds speak in Gondi language which is an intermediate form between the Dravida and the Andhra language. Most of these people are bilingual.

All these people are patrilineal, possessing totemic or ancestral clans and a sub-clans with smallest unit, the simple family. The Mundas, the Kols, the Santals, the Bhumijas, the Oraons, the Bhils and the Korkus are expert agriculturists. The Kharias are dibblers and collectors. The hill Kharias are semi-nomadic by nature and move in small groups. The Savara, the Juang and the Khonds are also horticulturists. In some areas they have taken up agriculture.

The Gonds are the most numerous of the primitive communities in India. They occupy a vast region from Central plateau to the heart of the Peninsular India. Russel finds the following divisions among the Gonds : Agarias, Ojhas, Pardhans, Parjas, Koyas, Bhatras, Marias and Murias. Among these groups who live in hills as Hill Marias, are dibblers the others live in the valleys and are settled agriculturists.

The Gonds occupy the areas between 17° 46′ and 20° 14′ north and 80° 13′ and 82° 1′ east. It is an area of about 35,000 km.[3] The river Indrawati divides this Central plateau into two geographical regions : Northern and Southern. The hills are from 90 m to 1,200 m in height. The entire region is characterised by red lateritic soil, innumerable streams, beautiful falls and wild rapids, high cliff ramparts, green valleys and forests. Sal is the chief wood in the forest.

The great northeastern plateau stretches from the Telinghat hills to the south of the northern border to the Tangridongri and Tulsidongri ranges. The height of the northeastern plateau varies from 500 m to above 700 m. It is a region of evergreen forests, with a temperature 5° C in the winter and 40° C in the summer. Abujhmar mountain mass is the other section of this plateau. Height of the peaks of Abujhmar vary from 600 m to 1,000 m. The great southern plain varies from 90 m to 180 m in height according to the proximity of the Godavari river. In this physical setting the Gonds live. The Hill Marias live only in the Abujhmar hills in the north of the Indrawati and Kutru-Bijapur plateau. They differ from the Bison Marias and represent an isolated section of the Gonds. They inhabit the most interior hill tracts of the Central plateau. They occupy an area of about 3,900 km^2. But Grigson found only 150 to 160 villages in the entire area.

The Hill Maria villages are situated in the hill slopes surrounded by the horticultural fields. The huts are arranged in a linear fashion by the sides of the streets and the streets end in the 'Gotul-lon' or village dormitory which is situated in the hill top. The huts are constructed of bamboos and thatches. The villages are often shifted for superstitious or economic reasons.

The Hills Marias are dependent on hunting, fishing, gathering and shifting cultivation. They practise slash and burn cultivation which is known as 'Penda'. For 'Penda' the entire village work as one unit.The method of cultivation is same as in the 'Jhum'. They cultivate 'Sawa', (*Panikum frumentaceum*), 'Kodon' (*Paspalum scroblculahum*), 'Mandia' (*Elensine coracana*), paddy, cucumbers, marrows and gourds but no pulses. For cultivation the digging sticks, hoes and small iron sickles are used.

The men and women in the periods after cultivation, collect honey from the forests. The fruits collected are : 'Achar' (*Buchanania latifolia*), 'Tendu' (*Diospyros melanoxylon*), 'Seona' (*Gmelina arborea*), 'Jamun' (*Eugenia jambolana*), 'Aonla' (*Phyllathus emblica*), wild mangoes etc. Liquor is prepared of the 'Mahua' flowers. The woman collect green vegetable, edible roots and tubers.

The Hill Marias are omnivorous. All types of bird and animals are trapped or caught and eaten up. Among animals, hare and deer are much favourite. They have traps for catching these animals.

For fishing they use rod and lines and traps. They also poison water for the purpose.

Bullock, cows, goats, pigs and fowls are the domestic beasts. These are used only for the sacrificial purpose.

The Hill Maria villages are mostly uniclan. The clans are divided into phratries. Clan organization is the chief feature in the social structure of the Hill Maria. Clan is also the political unit. Two types of cross-cousin marriage are conspicuous among these peoples.

The earth, clan god and village mother are worshipped by the people. These deities are represented in stones, bamboo pieces, and pieces of woods of particular tree. In each step of the 'Penda' cultivation these deities are worshipped. Each village has its own clan priest (Penwadda) who perform the worships in the village.

PRIMITIVE COMMUNITIES OF THE SOUTHERN PLATEAU

Main stocks of the primitive communities living in the southern plateau are the Chenchu, the Kadar, the Paniyan, the Urali, the Kota, the Badaga, the Toda and the Kurumba. The Kadars, the Paniyan, the Urali live in Kerala and the rest in the Nilgiri Hills. The Kadar and the Paniyan tribes are very primitive, still in collecting and wandering stage. They move in the jungles in small bands. Veddid element is traced among them. The Toda are the pastoral and polyandrous people. The Kotas are expert horticulturists and the Badagas are the chief business community of the area. Physical built-up of these people are akin to the North Indians. The Kurumbas are small in numbers. They are food collectors and known for their musical exponency and witchcraft. All these people speak in Dravidian dialect.

The Chenchus are one of the most primitive food gathering tribes living in the hilly tracts of Hyderabad, north of the river Krishna, at the northern part of the Nallamalai hills. It lies within 16° and 16° 30′ north latitude and 78° 30′ and 79° 15′ east longitude. The height of the pleateau varies from 250 m to 850 m. The entire tract is hilly. Type of soil is very poor. In the foothills rainfall is scarce the vegetation is thin. The main species are *Hardwickia pinata, Anogeissus latifolia* and *Acacia leucophloea* etc. On the higher areas the rainfall is heavier and the forest is also denser. The chief flora is *Tectonia grandis, Terminalia tomentosa, Pterocarpus marsupium* etc. Bamboo grows near water sources. Tiger, bear, deer etc. are found in these forests. Peacocks, jungle fowl etc. also are plentiful in number. Varieties of snakes are seen in the rains.

Climate of the area is similar to that of the central Deccan. The hot season lasts upto May. The rains start from June and continue till September. Average rainfall is 50 cm. Winter begins from October and lasts till February.

Total number of these Veddid people is 3,280 according to 1941 census. These people live in jungles in scattered villages. In the fringe, the Chenchus live in permanent villages and have been influenced by Hindu culture. In the hills their mode of life is totally different. The whole area inhabited by the Chenchus is divided into well defined tracts belonging to different groups among them. In hills, the Chenchus are migratory in habit. Normally they establish village in the top of the ridge near the water source and the fruit bearing trees. They shift the village sites within 3 to 10 years. Six to seven houses compose a village. They move in small local groups as greater number may eat up all the food available in the district soon. They construct conical huts with circular wattle wall with a thatched roof. Rock shelters are also used by them.

The Chenchus in the hills are hunters and food collectors. Hunting is a man's job. In collecting roots, fruits and tubers both men and women share. Digging stick is used for the purpose. The bow is made of bamboo stave and deer sinew string. Collection of honey is a traditional occupation of the Chenchus. They use varieties of ropes and appliances made of bamboo for the purpose.

The houses are constructed by the wood available in the local forests. The utensils are made of bamboo fibre and wood. The plates, spoons are made of wood. Iron is a precious metal among them which is procured from the nearest locality in exchange of honey and other jungle products. The size as well as the duration of the settlement is governed by the environment. These primitives strikingly lack concerted economic action. The individual family is such an independent entity that at any time it may sever its relation with the village group. This may be also a result of the physical environment. The food habit is chiefly governed by the seasons. In the month of January they collect the pods of *Ballhinia Vahlii* which is taken after boiling. The months of February and March are very bad for these collectors. They try to depend upon fresh food of any variety during the period. At the end of March the fruits of *Ficus infectoria* and *Ficus glomerata* are ripen. 'Mahua' flowers also bloom and they depend upon these. Liquor from 'Mahua' flowers is also prepared at this time. This condition prevails till May when wild mangoes, jackfruits etc. come into season. During monsoon, figs and black berries are available in plenty. After monsoons numerous herbs grow in the forest which satisfy the hunger of these intimates of nature. In the monsoon the Chenchus also practise fishing in the streams. The people come at the localities only at dire necessities. Socially the Chenchus are patrilineal. They have 12 exogamous clans. The smallest unit is the simple family.

The insecurity of the material traits no doubt casts some impact upon their religious ideas as no rigid theological system is traced among them. Some vague modes of soul worship and cult of dead are the chief forms of Chenchu religion.

CONCLUSION.

Life and culture of the people do not in all cases obey the 'sovereign influence of environment'. Each people has altered its environment to some extent. The urban situations aided by the superior knowledge, science and advanced technology have harnessed and changed the physical environment to a great degree. Still, in underdeveloped conditions a relation between the cultural habit of the people and the physical environment is observed. This is however, eminent in the life and culture of the primitive communities inhabiting the hills in India.

It is seen that among these primitives, outline of the basic economy depends for its continuance on the physical conditions. The tools, utensils, houses and other material equipments show a direct relation to the given resources. Leaving aside the social traits, which is rather independent of the physical setting, influence of environment is once more conspicuous in the structure of supernatural beliefs and practices.

It may be said in the conclusion that among these primitive communities the physical conditions enter to great extent into the cultural patterns not as determinants but as one category of the raw material of cultural elaboration. So, towards understanding of the cultures at the basic level, study of the space or the geographical environment is not only essential but vital.

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CHAPTER XI

MOUNTAINEERING IN THE HIMALAYA

It has been said that most of us are geographers at heart. How many times have we in our childhood made mountains from sand, dug tunnels through them, dammed the waters and carved out rivers. I suppose as many times as we had the opportunities. Many a time a child's imagination runs wild, and he wants to follow the stream to its source the only thing which prevents him is his inability to do so. Very few children can resist the temptation of knowing what is behind a watershed. This geographical tendency in the child reappears when he grows up and he wants to satisfy the curiosity to get to the source of the river to see the unexplored areas and discover new heights. Therefore I am sure that the geographers of the world would be interested in this article which deals with the Himalaya.

The Himalayan Range which is 2,400 km long, from east to west, is the longest, the largest, and the tallest mountain range in the world though the youngest. Obviously it is a paradise for geographers. There are unlimited areas of unexplored valleys, rivers and mountain tops.

MAPPING AND EXPLORATION

Perhaps the first Himalayan sketch map of any accuracy was drawn by Father Monserreti, the Spanish Missionary to Akbar's court in 1590. In 1777, Lt. N. S. Welsh was to explore the source of Ganga. His observations led him to believe that contrary to earlier belief Ganga did not start from Manasarowar lake but south of the main watershed of the Himalaya. He also worked out the height of Dhaulagiri. According to his estimates it rose to 8,166 m above sea level. Till then western geographers firmly believed that Chimborazo (6,314 m) in the Andes was the highest mountain. No wonder till 1845 Dhaulagiri was not considered the highest mountain in the world. Very soon it lost the privilege of being the highest mountain as Kanchenjunga was proved to be higher than Dhaulagiri. Finally it was George Everest who was mainly responsible for putting the Himalaya on the map. Between 1823 and 1847, he completed the 'Great Meridional Arc' from South India to the Himalaya which served as the backbone for the Great Trigonometrical Survey. Heights of many peaks were found out by trigonometrical survey. It was only in 1852 that Everest got its rightful place.

Though this survey had marked Peak XV on its map much earlier, the computation of various readings was only done in 1852 when they discovered that hitherto Peak XV on their charts was the highest peak in the world. Peak XV was given the name Mount Everest in 1865, when all efforts to find its local name had failed. This does not mean it has no local names. In fact too many of them. Chomolungma—the Mother Goddess of the World, is one of its Tibetan names. Sagar Matha (Highest of Snows) is its Nepalese name.

By 1862 more than 40 peaks of 6,096 m and above had been climbed for the sake of taking observations from them. K_2 (8,616 m) was recognised as the second highest peak after the survey of Kashmir was completed.

By 1864 the surveys of the Himalaya came to an end as the surveyors came to the northern borders of India. The foreigners were not allowed in Nepal, Tibet, Sikkim, and Bhutan. The trans-frontier maps were blank. The Survey of India decided to train some of the border inhabitants to take some readings which could be useful in making maps of the forbidden lands.

These so called surveyors, who were sent to forbidden lands disguised as traders, priests and pilgrims were called Pundits. They counted their steps with beads, found direction by stars, altitude by mercury carried in cocoanuts and kept their notes in the prayer wheels. Some of them reached Lhasa, some went beyond, to the border, of Mongolia and China and Burma. Sikkim, Bhutan and Nepal were also extensively though secretly explored.

Apart from geographical expeditions there were many other type of expeditions which were attracted to the Himalaya. There were religious expeditions. Millions of Hindu devotees went to Holy Shrines which were instituted in the interior of the Himalaya. Some of these shrines were situated on altitudes higher than the highest mountains in many countries. Some of the Hindu Yogis who were not satisfied by just the visit to shrines went still higher in the remote corners of the Himalaya for meditation. Apart from Hindus there were Jesuit Missionaries who crossed into Tibet and Bhutan for the sake of religion. One of the Fathers from Goa went right upto Caucasus mountains to spread the Gospel. Then there have been military expeditions across the Himalaya—like Alexander crossing Khowak pass in Hindu Kush and Zorawar Singh's expedition to Tibet. Chinese army expedition in 1792 to the doors of Katmandu and the British expeditions to Tibet, Nepal and Bhutan. Most of the above military expeditions followed the trade routes.

EARLIER MOUNTAINEERING EXPEDITIONS

With all the activities in the Himalaya and across, it was still the age of exploration. It was only in March 1883 that W. W. Graham set the pace for mountaineering as a sport. He was the first one, to come to the Himalaya to climb mountains for the sake of mountaineering and not advancement of scientific knowledge. In Nepal, he climbed a peak of 6,096 m and in Sikkim he claimed to have climbed Kabru (7,315 m). Then he went to Central Himalaya where he failed to force a way through Rishi gorge to the foot of Nanda Devi (the then highest mountain in the British Empire). He then attempted Dunagiri (7,077 m) He claimed to have climbed Changehang (6,865 m) in the Central Himalaya and Kabru in the Western Himalaya. Though both these claims were not accepted on technical grounds, the beginning had been made. More Himalayan mountaineering expeditions were organised in due course. The first major expedition was led by Martin Conway in 1892 in the Karakoram. Pioneer Peak (6,889 m) was climbed and reconnaissance was done of the routes up Baltora Kangri, Gasherbrum I and Broad Peak. In 1895 A. F. Mummery and two Gurkhas disappeared while surveying the north face of Nanga Parbat. Seven years later Oscar Eckenstien led the first expedition to K_2 and in 1905 Crawley's team attempted Kanchenjunga where five men were killed in an avalanche.

First expedition to Mt. Everest was thought of in 1907 by Bruce but was given up due to political reasons. The same year Longstaff climbed Trisul (7,120 m). This remained the highest mountain climbed for over 20 years. Duke of Abruzzi attempted K_2 in 1909. On this expedition they got upto the height of 7,498 m on Chogolisa, the highest point reached till then. Then the first world war came and there were no expeditions.

MOUNTAINEERING BETWEEN THE TWO WORLD WARS

After the war was over the struggle against the highest of points started. Various nations chose their mountains, British—Mt. Everest, Americans and Italians—K_2, Germans—Nanga Parbat etc.

Attempts on Mt. Everest

Col. Howard Bury led the first British expedition in 1921. It was following by Bruces expedition in 1922 when seven Sherpas were carried away by an avalanche. Two years later another tragedy happened on Mt. Everest. Two of the climbers (Mallory and Irwin) of British expedition were lost. They were last seen at 8,387 m, they never returned to tell the tale. Dalai Lama was sad, that so many lives had been lost on Mt. Everest. He refused to give permission to further expeditions on humanitarian grounds. It was only after eight years that he was persuaded to grant permission again. In 1933 Norton and Somervell reached the highest point so far been reached by any human being. They got to within 274 m of the summit. Four more expeditions followed before the Second World War, but none of them could do well. Worthy of note is that of Maurice Wilson who made a solo attempt on empty stomach and was frozen to death while he slept in his tent. His body was found in fully preserved condition a year later in 1935.

Attempts on Nanga Parvat

While Britishers were on the northeast face of Mt. Everest, Germans were busy on the treacherous slopes of Nanga Parbat which was considered the most dangerous mountain. The Germans attempted Nanga Parbat in 1932 but could not go beyond 6,960 m as they did not have the resources. In 1934 a very strong German team came back. They established Camp VIII at the height of 7,491 m but due to bad weather further attempt was thwarted. The retreat was unfortunate. Three Germans including the leader and six Sherpas were killed in their struggle to get to the base camp. Ang Tsering, the only member of the team could survive.

The Germans came back to the killer mountain in 1937. On June 14th they established Camp IV at the height of 6,096 m. Seven Germans and nine Sherpas were in the camp when they were killed again in this venture.To avenge the death of 11 Germans and fifteen porters which lay dead on the slopes of Nanga Parbat, another German expedition went in 1938. The weather was bad and Bauer the leader led with caution and withdrew his team in time. In 1939 the Germans reconnoitred a new route to the summit of Nanga Parbat.

Attempts on Kanchenjunga

In 1929 a German expedition attempted Kanchenjunga from the Zemu glacier but had to give up due to heavy snowfall. In 1930 an international expedition tried the same mountain from the northwest without success. In 1931 the German expedition returned from Zemu glacier on 9th August. In this venture one German and one porter died when the snow under their feet gave way.

Attempt on K_2

Americans carried out a reconnaissance in 1938. A party under Weisner went to the mountain in 1939. Three Sherpas and a member were killed.

Other Attempts

The years between the wars were full of tragedies for mountaineers. Many lives had been lost on Mt. Everest, Kanchenjunga, K_2

and Nanga Parbat. However, there were two major successes ; viz., the climb of Kamet (7,761 m) by Smythes' party in 1931 and the ascent of Nanda Devi (7,822 m). For over 50 years people had tried to reach the base of Nanda Devi but had failed. It was only in 1934 when Tilman and Shipton could force a way through the Rishi Gorge one of the most treacherous gorges in the world. The mountain was climbed in 1936 by an Anglo-American team. W. H. Tilman and N. E. Odell got to the top. The Second World War put an end to all mountaineering expeditions.

GOLDEN AGE OF HIMALAYAN MOUNTAINEERING

The period during the two world war was a dark one for the mountaineers, but the post-war period was a golden era, due to three factors, viz., opening of Nepal, better equipment and more experience. In 1950, the French who had only once climbed in the Himalaya stole the show from the other Himalayan going countries. They were the first to climb Annapurna I, a peak about 8,000 m in western Nepal. The expedition was led by Maurice Herzog. No sooner did they get to the summit, the storm started and the party "started the race with death". Maurice Herzog and two Sherpas were thrown down several hundred metres by an avalanche but survived miraculously. Several members were severely frost bitten, Maurice Herzog lost his toes and fingers.

Mt. Everest Climbed

In 1951, Shipton carried out detailed reconnaissance of southern approaches of the Mt. Everest. In 1952 the Swiss entered the 'race for Everest' and two members Lambert and Tenzing reached the height of 8,540 m before they gave up the pre-monsoon attempt. They returned after the monsoons but due to wintery cold they could not go beyond 7,930 m. In 1953 the British brought their 9th expedition and with it came the success when Tenzing and Hillary got to the summit at 11-30 a.m. on 29th May. Expedition was led by John Hunt. In 1956 the Swiss put four people on the top. In 1960 Indians went for the first time but had to give up 214 m below the summit, because of bad weather, (author was one of the summit party which consisted of three members). Chinese claim to have climbed Mt. Everest in 1960. This claim is not accepted by Western climbing nations due to technical flaws. The Indians went back in 1962 to be beaten again by the weather when they were only 122 m below the summit. In 1963 six Americans climbed it. Two of them climbed it from the western ridge. They were Hornbein and Unsoeld. In 1965 Indians put nine people on the top. At present the expeditions to Mt. Everest are banned due to political reasons.

Nanga Parbat Climbed

Nanga Parbat was climbed in 1953. This success was hailed by the mountaineers all over the world. The Killer Mountain was climbed by an Austro-German expedition. Herman Buhl left his ocmpanion at Camp V and started at 2 a.m. on July 3. After seventeen hours of Herculean task he got to the summit. On the way down he had to bivouac at 8,006 m without food or sleeping bag. He reached Camp V at 6 p.m. Three years later he climbed Broad Peak (8,056 m) in Karakoram. A few days later while he was on Chogolisa he stepped on a cornice. The cornice broke and there were no signs of Buhl.

K_2 Climbed

In 1954 K_2 was climbed by Italians. Achille Compagnon and Livo Lacedelli got to the top on July 1931. The last bit was done without oxygen. On the way back the climbers had to find their way in the dark. They were indeed very lucky to escape accident. Apart from K_2 many other peaks were climbed in the Karakoram in the golden era.

Other Karakoram Peaks Climbed

Muztag Tower (7,259 m) though not very high, is one of the most difficult peaks in the Karakoram. This impregnable mountain situated in the basin of Baltoro glacier was climbed in July 1956 by a British and French expedition from entirely two different routes.

Gasherbrum II (8,068 m) in the Baltoro glacier region was climbed by Austrians on 7th July 1956.

Gasherbrum I or the Hidden Peak which had defied American attempt in 1933 and the French attempt in 1936 was at last climbed by Americans in 1957. It was the last peak above 8,000 metres which was left unclimbed.

Rakaposhi (7,788 m) high was climbed by All Services British expedition in 1958.

Disteghill Sar (7,885 m) the highest peak in the Karakoram west of K_2 was climbed by Austrians in 1960 and Trivor (7,737 m) in the same area by British in the same year.

Kanchenjunga Yielded

In 1955 Kanchenjunga which was considered the most difficult mountain, technically yielded to British team. Charles Evans was the leader. To respect the sentiments of the Sikkimese the team did not tread on the summit but remained few metres below. George Baird, when asked if there was not the great temptation to go those last few metres said "No for one thing I was too tired to want to take another step. But apart from that, I am glad we left no foot marks on the top. Had it not been for the promise, we should have gone to the top". The promise was to the Sikkimese Government who objected to climb as they consider it a God and as well as a protector.

Nepal Himalayan Peaks Climbed

Though Nepal was the last to open its doors to the mountaineers, the first 8,000 metre peak to be climbed was in its Himalaya. During the golden age of Himalayan mountaineering many major peaks were climbed in Nepal.

In 1954 French climbed Chomolongo (7,820 m) and in 1955 they climbed Makalu (8,481 m). The entire team of 9 members got to the summit. The team was lead by Jean Franco. Seven years later in 1962 French climbed Jannu (7,715 m) one of the most difficult peaks in the Himalaya. The team was led by famous French climber Lionel Terray. Eight members and two Sherpas got to the summit.

In 1954 the Austrian team climbed Cho Oyu (8,153 m). In a race against Franco-Swiss party who had gate crashed on Cho Oyu after they failed to climb Gauri Sankar. Cho Oyu was later climbed by Indians in 1958. Lhotse (8,506 m) was climbed by Swiss in 1956 when they climbed Mt. Everest. One of the 2 members (Fritz Luchsinger) who climbed Lhotse had been operated for removal of appendix only six weeks before. An international expedition had failed to climb it earlier in 1955. Nuptse (7,884 m), the third peak of Everest massif was climbed by the British in 1961.

In 1960 the Swiss climbed Dhaulagiri (8,172 m). This mountain had earlier thwarted the Swiss attempt in 1953. In the successful attempt Swiss used a Bi-plane called 'Yeti' to carry their supplies to the base camp. In one of the trips the plane crashed. No one was hurt.

The Japanese climbed Mansalu in 1956 in their fourth attempt. Three members and Sherpa Gyalzen Norby got to the top. In 1960 Japanese climbed Himalchuli (7,869 m) and in 1964 Japanese also climbed Gyachung Kang (7,903 m). There were many other expedition which were successful in Nepal in the golden era.

At last the golden era came to an end in 1965 when Nepal closed its doors to the mountaineers once again. So did India, Pakistan and Tibet.

PART TWO

CHAPTER XII

RIVERS OF INDIA AS IN ANCIENT LITERATURE

So far as India is concerned, many of her rivers became sacred in the eye of the people, numerous religious shrines and hermitages adorning their banks and several of them being fitted with bathing ghats. Many of them still bear the living associations of the history and civilization of the country. 'All the rivers', says the Mārkaṇḍeya Purāṇa,[1] 'are sacred, all flow towards the sea. All are like mothers to the world, all purge away sins.'

From the days of the Vedas it became a convention in the religious literature of India to denote the gradually widening Aryandom by the seven rivers called *sindhus*, *sarasvatīs*, *gaṅgās* or *nadīs*. The most ancient Aryandom has been described in the Ṛg Veda (X. 75. 4) as the sacred land watered by the seven *sindhus* (*Sapta-sindhavah*),[2] namely, the five rivers of the Punjab together with the Sindhu (Indus) and another river, whether it be the Sarasvatī, or the Kubhā (Kābul) or even the Oxus. When Aryandom was spread over the whole of India, it came to be represented by the seven rivers called Gaṅgā, Yamunā, Godāvarī, Sarasvatī, Narmadā, Sindhu, and Kāverī.[3] The Seven sacred rivers of the Buddhist Midland are differently enumerated either as Bāhukā (Bāhudā), Adhikakkā, Gayā (Phalgu), Sundarikā, Sarassatī, Payāgā (confluence of the Gaṅgā and the Yamunā), and Bāhumatī,[4] or as the Gaṅgā, Yamunā, Sarabhū (Sarayū), Sarassatī, Aciravatī, Mahī, and Mahānadī.[5]

The Greek astronomer and geographer Ptolemy, like the Epic and Puranic writers, groups the rivers of India according to the moun-

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1. *Mārkaṇḍeya Purāṇa*, LVII, 30.
2. *Vedic Index*, ii, *sub voce*, *sapta sindhavaḥ*.
3. Gaṅgā ca Yamunā caiva Godāvarī Sarasvatī Narmadā Sindhu Kāverī-jale'smin sannidhiṃ kuru.
4. *Majjhima Nikāya*, i, p. 39 :
   Bāhukam Adhikakkaṃ ca Gayā Sundarikaṃ api
   Sarassatim Payāgañ ca atha Bāhumatiṃ nadim.
5. *Visuddhimagga*, i, p. 10 :
   Na Gaṅgā Yamunā cāpi Sarabhū vā Sarassatī
   ninnagāvā'ciravatī Mahī vāpi Mahānadī.

The Gaṅgās, noted in the Ājīvika tradition, comprise (Rockhill's *Life of the Buddha*, p. 253) Mahā-Gaṅgā, Sādīṇa-Gaṅgā, Lohiya-Gaṅgā (Lauhitya), Avatī-Gaṅgā, Paramāvatī-Gaṅgā, Maḍu-Gaṅgā.

tain and hill ranges out of which they arose. In fact, he seems to have before him some old traditional list of Indian rivers which he made use of in his geography. The accounts of rivers in different Purāṇas are, more or less, the same. The Tīrthayātrā and Digvijaya sections of the Mahābhārata, the Jambukhaṇḍavinirmāṇa section of the same Epic, the Kiṣkindhā-Kāṇḍa of the Rāmāyaṇa, the Bhuvanakoṣa, Jambudvīpavarṇanā and Kūrmavibhāga sections of the Purāṇas, the Bṛhatsaṃhitā of Varāhamihira, the Parāśaratantra, and the Atharvapariśiṣṭa contain useful information regarding the rivers of India. Equally important from this point of view are the Buddhist and Jain literature, particularly the Jambudiva-paṇṇattī, the Jaina work called Vividhatīrthakalpa, the Indika of Megasthenes, and the writings of Arrian, Strabo, Diodorus, Plutarch, and Pliny based, more or less, on the work of Megasthenes and the itineraries of Fa-Hien and Hiuen-Tsang. The information derivable from these sources is substantially correct. The later foreign accounts, such as those of Alberuni, Marco Polo, and Buchanon Hamilton, and the Imperial and District Gazetteers of India will be very helpful in the study of the subject in question.

It is said in the Bhāgavata Purāṇa, 'All the *nadas* and *nadīs* (of India), whose number is legion, issue from the prominent parts of the mountains'.[1] The pivot of the legendary account of the rivers in India is undoubtedly the mountain system of the country. The principal rivers of the land have been invariably grouped in the Great Epic, the Purāṇas, as well as the Jaina and Buddhist books, according to the mountain ranges out of which they are said to have emanated. Of the mountain ranges, the *Himavat*, *Himādri* or Himālaya is rightly recognized as the Varṣa-parvata forming, as it does, the northern boundary of Bhāratavarṣa. This is said to have stretched from sea to sea like the string of a bow (*Kārmukasya yathā guṇah*). In the Jaina Jambudiva-paṇṇatti, the Himalayan range is divided into two, its eastern extension being distinguished as the Mahā-Himavanta (Greater Himalaya) from its western extension, called Culla-Himavanta (Lesser Himalaya). This is distinguished in the Purāṇas from the seven Kulācalas or internal ranges called Mahendra (Eastern Ghats), Malaya (southern extension of the Western Ghats), Sahya (Western Ghats), Śuktimat of doubtful identity, Ṛkṣavat, Vindhya, and Pāripātra (or Pāriyātra). It would seem that the Ṛkṣavat, the Pāripātra, and the Śuktimat were somehow or other the offshoots and extensions of the Vindhya range. In the opinion of the Varāha Purāṇa, the rivers that take their rise from the Kula-parvatas and by implication, also from the Varṣaparvata, enjoy predominance, the rest being the rivers of minor importance.[2] According to the Mārkaṇḍeya Purāṇa, the

1. *Bhāgavata Purāṇa*, V, 19.

2. *Varāha Purāṇa* : *etāḥ prādhānyena kulaparvata-nadyah, śeṣāḥ kṣudranadyaḥ.*

lesser rivers of India, whether having a flow only during the rains or throughout the year, are to be counted by thousands.[1]

In the Rājanirghaṇṭa, the river-waters are generally characterized as having the properties of being transparent, light, stimulating, tasteful, appetizing, sweet, and lukeworm. The waters of the rivers that flow towards the east tend to be heavy and those that flow towards the west, light. Their properties, however, vary according to the localities through which they flow. The waters of the rivers that are sluggish are found to be heavy and those of the rivers with rapid flow tend to be light. The waters of the rivers with rocky or sandy beds are pure. The waters of the rivers that issue from the Himalaya are like nectar. The waters of the rivers that flow east from the Vindhyas tend to produce rheumatism, those of the rivers that flow east and west tend to cure phlegm and bile, those of the rivers that flow west tend to excite bile and those of the rivers that flow north possess the digestive property. The waters of the rivers that issue from the Pāripātra and other offshoots of the Vindhya tend to cause headache, heart disease, leprosy, and elephantiasis. The waters of the Godāvarī are praised as possessing the property of quenching thirst and destroying the causes of such diseases as leprosy, tuberculosis, and blood-pressure and as being stimulating and highly digestive. It characterizes the waters of the Tuṅgabhadrā as being refreshing, pure, tasteful, rather heavy, tending to produce itching and increase bile, self-complacence, and brains. The Kṛṣṇā is praised as the river of which the waters are transparent, tasteful, stimulating, and appetizing.

The principal rivers of India may be classified either in terms of the mountains or hill ranges or in those of the territorial or administrative divisions with which they are connected. They may also be broadly distinguished into two classes, viz. (1) those which belong to distinct groups or systems, and (2) those which flow down independently either to disappear in a desert or to empty themselves into a sea.

Here we should like to deal with the rivers of the Northern, Western, Eastern, Central, and Southern India.

NORTHERN INDIA

The rivers that issue forth from the Himalayas or have their origin in the Himalayan region belong to the northern part of Northern India. The Pali work called Milindapañha (p. 114) speaks of 500 rivers that flow down from the Himalayas, out of which only ten are said to have been important, to wit, Gaṅgā, Yamunā, Candabhāgā, Aciravatī, Sarabhū, Mahī, Sindhu, Sarassatī, Vettavatī, and Vitaṃsā (Vitastā). The Ṛg Veda (X. 75) mentions the Sindhu, the Gaṅgā, the Yamunā, the Śutudrī, the Paruṣṇī, the Sarasvatī, the Asiknī, the Vitastā, the Marudvṛdhā,

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1. *Mārkaṇḍeya Purāṇa*, LVII, 31.

the Ārjikīyā the Suṣomā the Triṣṭāmā the Rasā the Susartu, the Śvetyā, the Kubhā, the Mehatnū, the Krumu, and the Gomatī as the typical rivers from the Himalaya. The typical Himalayan rivers (Himavatprabhavā)[1] as enumerated in the Mārkaṇḍeya Purāṇa (LXVII) consist of the Gaṅgā, Sarasvatī, Sindhu, Candrabhāgā, Āpagā, Yamunā, Śatadru, Vitastā, Airāvatī, Kuhū, Gomatī, Dhūtapāpā, Bāhudā, Dṛṣadvatī, Vipāśā, Devikā, Vaṅkṣu, Viśālā, Gaṇḍakī, and Kauśikā. As enumerated in the Varāha Purāṇa, these consist of the Gaṅgā, Sindhu, Sarasvatī, Śatadru, Vitastā, Vipāśā, Candrabhāgā, Sarayū, Yamunā, Irāvatī, Devikā, Kuhu, Gomatī, Dhūtapāpā, Bāhudā, Dṛṣadvatī, Kauśikī, Nisvīrā, Gaṇḍakī, Cakṣusmatī, and Lohita (Brahmaputra). It is better to say with Megasthenes that the Himalayan rivers of northern India belong to two main river groups or systems, viz. the Indus and the Gaṅgā, the former being connected with the northern northwestern division (Uttarāpatha) and the latter with the Midland (Madhyadeśa). The continuation of the Gaṅgā system is traceable through Bengal, west and east. From its connection with the Brahmaputra and the Meghnā, the Gaṅgā system may be shown to include also the rivers of Assam. In other words, the Gaṅgā system may be considered as much in connection with the Buddhist Midland as with the eastern (Prācya) division.

The Sindhu System

The Sindhu is a Trans-Himalayan river. The Himalayan area included in the catchment basin of the Sindhu is 268 800 km.[2] Another 16,800 km[2] of Himalayan area are included in the catchment basin of the principal tributaries of the Sindhu. According to Sven Hedin the source of the Sindhu is situated in southern Tibet at Singi Katal (latitude 31° 15′ and longitude 81° 40′). This river is locally known as Sengge Khabab near its source. It flows first north-west parallel to the Ladakh range, pierces the latter at two places, Chang La and Skardu, before turning southward.

The Sindhu is fed by a number of glaciers. There are five glaciers, ranging in length from 60 to 70 kilometres—Siachen, Hispar, Biafo, Baltoro, and Batura.

The Sindhu, also known by the name of Sambheda and Sangama, both meaning 'the confluent', is counted among the seven streams of the Divyagaṅgā or Celestial Gaṅgā. The seven streams that are popularly known as Divyagaṅgās or Divyanadīs are somewhat differently enumerated in the Great Epic and the Matsya Purāṇa (Ch. 101). The Great Epic names them as Nalinī, Pāvanī, Sarasvatī, Jambu, Sītā, Gaṅgā, and Sindhu. The Padma Purāṇa[2] mentions Vasvokāsā as another name of the Nalinī. According to the Matsya Purāṇa, on the other hand, they

1. Same as Himavatpādānirgatā, Himavatpādaniḥsṛtā.
2. *Bhūmikhaṇḍa*, Ch. 131.

consist of the Nalinī, Hrādinī, and Pāvanī—the three streams that flow eastwards, the Sītā, Vaṅku, and Sindhu—the three streams that flow westwards, and the seventh the Bhāgīrathī which flows southwards. The source of all is traced to a lake called Bindusara and situated between the three Himalayan peaks, namely, the Kailāsa, the Maināka, and the Hiraṇyaśṛṅga. The Divyagaṅgā is called *tripathagā* apparently for the reason that its seven streams, as noted above, flow in three different directions.

Of the seven streams, the Sindhu is the well-known Indus. The Gaṅgā, which is known also by various other names, such as Viṣṇupadī, Jāhnavī, Mandākinī, and Bhāgīrathī, is no other than the Ganga of great fame. The Sarasvatī is the sacred river of the Haryāna and Punjab which is too well known to need further comment. The Sītā is identified by some with the Jaxartes, also called Sir Darya, and by others with the river Yarkhand on which the town of Yarkhand stands. The Vankṣu or Vakṣu is probably the modern Oxus. The Jambu or Jāmbunada, traditionally famous for its gold, is known as a river, which takes its rise from a side of Mount Meru. The Nalinī or Vasvokasā is identified with the Padmā. Nando Lal Dey identifies the Pāvanī with the Ghaggar in Kurukṣetra (District Ambala), better with the united stream of the Sarasvatī and the Ghaggar, which is doubtful.

According to the Matsya Purāṇa, the seven celestial rivers water the land which is mostly inhabited by the Mlecchas. The river Śailodakā flowing from the lake Śailodā at the foot of the Himalayan mountain, on the western side of Mt. Kailāsa, is said to flow between the Vankṣu and the Sītā. The Vankṣu or Vakṣu is mentioned as the river which watered the tracts of the Cīnamarus, Kālakas, Cūlakas, Tuṣāras, Barbaras, Kāras, Pahlavas, Pārdas (Parthians), and Śakas (Scythians). The tracts watered by the Sindhu are said to comprise those of the Varadas, Kūtajas, Gāndhāras, Aurasas (Auragas), Kuhus, Sindhus, and Raurorkas (Sauvīras). The tracts hallowed by the Gaṅgā are those associated with the Gandharvas, Kinnaras, Yakṣas, Ṛakṣas, Vidyādharas, Auragas, Kalāpagrāmakas, Kimpuruṣas, Kirātas, Pulindas, Kurus, Pāñcālas, Kauśikas, Matsyas, Māgadhas, Aṅgas, Brahmottaras, Vaṅgas, and Tāmraliptas. The tracts watered by the Hrādinī consist of those connected with the Āpakas, Niṣādas, Dhīvaras, Ṛṣikas, Līnamukhas, Kekaras, different classes of the Kirātas, Kālandaras, Vivarṇas, Kuśikas, and Svargabhūmikas (Tibetans), the river evidently being the Brahmaputra. The Pāvanī of doubtful identity is said to flow eastwards piercing several mountain ranges and flowing through such places as the Kharapatha, the Vetrapatha, the Śaṅkapatha, and the Ujjānakamaru which are to be connected rather with the trade-route connecting Eastern India with Further India and China. The source of the Sarasvatī is traced to a ridge of the Hemakūṭa range.

The Sindhu group, as known to Pliny, was constituted of the Sindhu (Indus) and nineteen other rivers of which the most famous were the Hydaspes with its four tributaries, the Cantabra fed by three tributaries, the Acesines and the Hypasis both of which were navigable in spite of having no very great supply of water. The Sindhu, now know as the Indus, skirted the frontiers of the Prasii whose mountain tracts were said to have been inhabited by a race of pygmies (*kimpuruṣas*). It was generally regarded as the western boundary of India,[1] though some writers viewed the river Cophes (Kābul) as its furthest limit.[2] It was nowhere broader than fifty stadia, or deeper than fifteen paces. It formed a large island, called Prasiane, and a smaller island, known as Patale (*Prasthala*.) Its stream, which was navigable, by the lowest estimates, for 2,000 kilometres, turned westward as if following more or less closely the course of the sun, and then falling into the sea.[3]

The Sindhu was known to Arrian as the great river which, like the Gaṅgā, its only rival, spread out in many places into lakes, with the result that where the country happened to be flat, its shores appeared far apart. The main tributaries of the Indus are said to be the Hydraotes, the Akesines, the Hypasis, the Hydaspes, the Kophen, the Parenos the Saparnos, and the Soanos. The Hydraotes, which is no other than the Airāvatī or Irāvatī of the Purāṇas (modern Rāvi), was known as a river which, flowing from Kambistholi (Kapisthala), fell into the Akesines (Pliny's Acesines, Vedic Asikṇī, Candrabhāgā of the Purāṇas, and Pali Apadāna, modern Chenāb), after receiving the Hyphasis (Pliny's Hypasis, Hypanis and Bibasis of other classical writers, Sk. Vipāśā) in its passage through the country of the Astrybai, as well as the Saranges from the Kekians (Kekaya country in the Northern Punjab), and the Nendros from the country of the Attakenoi (Aṣṭagaṇas, Aśvakas). The Hydaspes (Bidaspes of Ptolemy, Sk. Vitastā, modern Bidastā, Behut, Jhelum) was the river which, rising from the country of the Oxydrakai (Kṣudrakas) and bringing with it the Sinaros, received in the dominions of the Arispai, fell itself into the Akesines (Chenāb). The Akesines itself joined the Indus in the country of the Malloi, though not until it had received into it the waters of a great tributary, the Toutapos (lower stream of the Śatadru, modern Sutlej ?). Augmented by all these confluents, the Akesines (Chenāb) succeeded in imposing its name on the combined waters and in retaining it till it united with the Indus. The river Kophen or Kophes (Vedic Kubhā, modern Kābul), too, fell into the Indus, having risen in Peukelaitis (Puṣkalāvatī) and brought with it the Malantos (Kameh, Khonar, identified by some with Arrian's Choes), the Soastos

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1. McCrindle, *Ancient India*, pp. 28, 43.
2. *Ibid.*, p. 156.
3. *Ibid*, pp. 143-4.

(Choaspes, Sk. Suvāstu, modern Suvād, Swāt), and the Garroia (Garaea, Sk. Gaurī). Higher up than these, the Parenos (Burindu ?) and the Saparnos (Abbasin ?), flowing at no great distance from each other, emptied themselves into the Indus, as did also the Soanos (modern Soan), flowing down without a tributary from the hill-country of the Abissareans (Sk. Abhisāras). Most of these were known to Megasthenes as navigable.[1]

As may be gathered from the Nadī-stuti hymn of the Ṛg Veda, the fourteen (seven and seven) rivers that were known to the Vedic Aryans during the closing period of this great Veda comprised even the Gaṅgā and the Yamunā, the two Himalayan rivers, which belonged to the Gaṅgā group. Among the remaining rivers, all of which belonged apparently to Uttarāpatha, the Sarasvatī was not to be included in the Indus Group, and so also the Aśmanvatī of the Ṛg. Veda, which is identified with the Dṛṣadvati of the Manu-saṃhitā fame. The Sindhu which figures in it as the main river is the well-known Indus. The Asikṇī is evidently the Akesines of Arrian and the Candrabhāgā (Chenāb) of the Purānas. The Vitastā is no other than the Hydaspes of Arrian and the Bidastā or Jhelum of today. The Śuturdī can be easily identified with the Śatadru of the Purāṇas and the modern Sutlej. Similarly, it is to identify the Kubhā with Kophen or Kophes of the classical writers, the Kuhu of the Purāṇas, the Koa of Ptolemy (VII. i. 26), or the modern Kābul. The Paruṣṇī is identified with the Irāvatī, modern Rāvi. Yaska identifies the Ārījikiyā with the Vipāśā, modern Beas, while Hillebrandt thinks that it was either the upper Indus, or the Vitastā (Jhelum), or some other stream. That it could not be the Vitastā is evident from the Vedic hymn itself, where both find mention as two different rivers. The Marudvṛdhā (?) Suṣomā is taken to be another name of the Sindhu itself in its course through the Punjab. The Tṛṣtāmā (?), the Rasā (identified with the Jaxartes), the Susartu (?) and the Śvetyā (?) appear all to have been the tributaries of the Indus above the Kubhā or Kābul. Similarly, the Mehatnu, the Krumu (Kurram), and the Gomatī (Gomal) may be regarded as the three tributaries of the same river below the Kubhā. Though still of doubtful identity, one may be inclined to think with Ludwig that the Silamāvatī (?) and the Urṇāvatī were but two affluents of the Indus, both flowing in that part of the country which was noted for woollen cloth and rich in precious stones. The river called Āpagā in the Ṛg Veda (III. 23. 4) is conveniently identified with the modern Āpayā, a small tributary of the Sarasvatī, which is situated between the Sarasvatī and the Dṛṣadvatī and flows past Thaneswar. It may even be the modern Indramatī farther west, though Pischel would prefer to assign it to the

1. McCrindle, *Ancient India*, pp. 196-7.

Kurukṣetra, of which the Āpayā is mentioned as a famous river in the Mahābhārata.[1]

The Sindhu is the greatest known river of Uttarāpatha after which the Indus group is named. To the Vedic Aryans, this was known as the river which stood unsurpassed, while, in the opinion of Megasthenes and other classical writers, it was rivalled by no other river than the Gaṅgā. As described in the Ṛg. Veda (X. 75), the Sindhu in might surpassed all the flowing streams. Varuṇa cut the channels for it when it ran on to win the race. It speeded over the precipituous ridges of the earth, and was the 'lord and leader of the moving floods'. Its roar was lifted upto heaven above the earth. It put forth endless vigour with a flash of light. Like the floods of rain that fell in thunder from the cloud, it rushed on bellowing like a bull. Like mothers to their calves, like milch-kine with their silk, the roaring rivers ran unto it. It led as a warrior king its army's wings and came in the van of those swift streams.[2]

According to Alberuni, however, only the upper course of the Indus, above the junction with the Chenāb (Candrabhāgā), was known as Sindhu ; lower that point to Aror, it was known by the name of Pañcnād, while its course from Aror down to the sea was called Mihran (India, i, p. 260). In the Behistun inscription of Darius, it is referred to as Hindu, and in the Vendidad, as Hendu. It goes without saying that the Sindhu lent its name to the country through which it flowed.[3] Its upper course, together with its important tributaries, is accountable for the name of the country across which it lay as 'the land of the five rivers' (Pañcnād), the modern Punjab. Its lower course gave to the country around the name of Sind (JASB, 1886, ii, p. 323, for the ancient course of the Sindhu through Sind).

The Jaina work called Jambudīva-paṇṇatti traces the source of the four rivers called Gaṅgā, Rohitā (i.e. Lauhitya or Brahmaputra), Sindhu (Indus), and Harikānta to the twin lotus lakes (Padmahrada), one on the side of the Lesser and the other on that of the Greater Himalayan range. Each of the four rivers is said to have channelled out through one of the four outlets of the twin lakes. The Jaina lotus lake is no other than what is called Bindusara in the Great Epic, Anotatta in Pali literature and Mānas Sarovar in popular parlance. The Pali scholar Buddhaghosa provides the Anotatta Lake, situated in the enclosure of the

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1. Vide *Vedic Index*, i, p. 58.
2. The summary is based on Griffith's metrical translation of the Ṛg Veda.
3. Cf. Beal, *Buddhist Records of the Western World*, i, p. 69 : '*On examination*', says Hiuen Tsang, 'we find that the names of India (Tien-chu) are various and perplexing as to their authority. It was anciently called Shin-tu, also Hien-tau ; but now, according to the right pronunciation, it is called In-tu.

Kelāsakūṭa, the Citrakūṭa, and another Himalayan peak, with four outlets called Sihamukha (the Lion or East Face), Hatthimukha (the Elephant or South Face), Assamukha (the Horse or West Face), and Usabhamukha (the Bull or North Face). The Great Epic Traces the source of the Gaṅgā to Bindusara. The channel of the Sindhu is connected evidently with the west outlet of the western lotus lake. The sources of the two rivers of Uttarāpatha, namely, the Śatadru and the Sindhu, may be traced to the western and northern regions of the Mānas Sarovar. It is interesting to note that the above Jaina work speaks of thousands of other rivers that fall into the Sindhu and flow together into the Western or Arabian Sea.

The Sindhu or Indus at the start is a united flow of two streams, one flowing north-west from the north-west side of the Kailās-parvat and the other in a north-westerly and then in a south-westerly direction from a lake situated to the north-east of Kailās. Beginning from this confluence it flows north-west over a long distance to turn south below the Kara koram range. From this point it follows a slightly serpentine and south-westerly course till it falls into the Arabian Sea forming two well-known deltas at its mouth below Karachi, the larger one called Prasiane by Arrian and the smaller one Patale (Sk. Prasthala). It finds its way through the Jaina Lesser or Western Himalayan range midway between Gilgit and the Nanga-parvat. It receives on its left side at a place called Panjnad (Pañcnād) the joint flow of the five other main rivers of the Punjab under the name of the Chenāb.

THE DESERT RIVER SYSTEM

Sarasvatī : This and the Dṛṣadvatī are the two historical rivers of Uttarāpatha that flow down independently without belonging to the Indus Group. Manu locates the region of Brahmāvarta between these two sacred streams. The Sarasvatī is described in the Milindapañha as a Himalayan river and its source is traceable to the Himalayan range above the Simla hills. It flows southwards through the Simla and Sirmur States forming a bulge. It flows down past Patiala to lose itself in the northern part of the desert of Rajputana at some distance from Sirsā. Manu applies the name of Vinasana to the place where it disappears from view. In the Siddhānta-śiromani (Golādhyāya, Bhuvanakoṣa), the Sarasvatī is correctly described as a river, which is visible in one place and invisible in another.[1] It disappears for a time in the sand near the village of Chalaur and reappears at Bhavānīpur. At Bālchhāpar it again disappears, but appears again at Bara Khera ; at Urnai near Pehoa, it is joined by the Mārkaṇḍa and the united stream bearing still the

1. *Dṛśyādṛśyā ca bhavati tatra tatra Sarasvatī.* See *Śabdakalpadruma, sub voce, Bhūgola.*

name of Sarasvatī ultimately joins the Ghaggar or Gharghar which was evidently the lower part of the Sarasvatī..........The Mahābhārata also says that after disappearing, the river reappears again at three places, namely, at Chāmasodbheda,[1] Śirodbheda, and Nāgodbheda.'[2] This river, which still survives, flows between the Śatadru (Sutlej) and the Yamunā. It is not improbable that the Sarasvatī, as known to the Vedic Aryans, was a mighty river, which flowed into the sea.[3]

Dṛṣadvatī : Nearer the Yamunā is the sacred river called Dṛṣadvatī of which the origin may be traced to the hills of Sirmur. Upto Nahan it has a westerly course, after which its course changes towards south and lies through the district of Ambala past Shahabad. It tends to meet the Sarasvatī at Sirsā, the place below which both the stream disappear. The town of Pehoā (Sk. Pṛthudaka) is situated on the Dṛṣadvatī. According to Manu (II. 17), this river formed the eastern and southern boundary of the Brahmāvarta, while its western boundary was the Sarasvatī. In the Mahābhārata (Vanaparva), the confluence of the Dṛṣadvatī and the Kauśikī is regarded as of peculiar sanctity. The Vāmana Purāṇa (34), on the other hand, takes the Kauśikī to be a branch of the Dṛṣadvatī which is identified by Cunningham with the modern Rakshi that flows by the southwest of Thaneswar, by Elphinstone and Todd with the Ghaggar flowing through Ambala and Sind, and by Rapson with the Citrang, Chantang or Citang running paralled to the Sarasvatī.

THE GANGA YAMUNA SYSTEM

Just as the rivers of Uttarāpatha belong, with the exception of the Sarasvatī and the Dṛṣadvatī, to the Indus system, so those of Madhyadeśa or Midland, as known to early Buddhists, go to constitute the Gaṅgā system. The classical writers differ as to the number of tributaries of the Indus, it being fifteen according to Arrian[4] and nineteen according to Pliny,[5] while in the case of the Gaṅgā, the number of its tributaries was known to them as nineteen.[6] Though the Gaṅgā and the Indus were known to them as the two largest rivers in India, the former was taken as the greater of the two rivals. As Pliny observes, 'This river (i.e. the Gaṅgā), according to some, rises from uncertain sources, like the Nile, and inundates similarly the countries lying along its course ; others say that it rises on the Skythian mountains, and has nineteen tribu-

1. N. L. Dey, *Geographical Dictionary*, p. 180f. ; *Punjab Gazetteer*, Ambala Dt., Ch. I.
2. *Vanaparva*, 8.
3. Max Muller, *Ṛg Veda-Saṃhitā*, p. 4?.
4. McCrindle, *Ancient India*, p. 45.
5. *Ibid*, p. 143.
6. *Ibid*, p. 137.

taries, of which, besides those already mentioned (i.e. the Prinas and the Cainas),[1] the Condochates, Erannoboas (Yamunā), Cosoagus (Kauśikī), and Sonus (Sona) are navigable. Others again assert that it issues forth at once with loud roar from its fountain, and after tumbling down a steep and rocky channel is received immediately on reaching the level plains into a lake, where it flows out with a gentle current, being at the narrowest 13 km, and on the average a hundred stadia, in breadth, and never of less depth than twenty paces (30 metres) in the final part of its course, which is through the country of the Gangarides.[2]

More useful information is supplied by Arrian regarding the Gaṅgā and its tributaries when he observes : 'Megasthenes states that of the two (i.e. the Gaṅgā and the Indus) the Gaṅgā is much the larger and other writers who mention the Gaṅgā agree with him ; for, besides being of ample volume even where it issues from its springs, it receives as tributaries the river Kaīnas, and the Erannoboas, and the Kossoanos, which are all navigable. It receives besides the river Sonos and the Sittokatis, and the Solomatis, which are also navigable, and also the Kondochatoo, and the Sambos, and the Magon, and the Agoranis, and the Omalis. Moreover there fall into it the Kommenases, a great river and the Kakouthis, and the Andomatis, which flows from the dominions of the Madyandinoi, an Indian tribe. In addition to all these, the Amystis, which flows past the city Katadupa, and the Oxymagis from the dominions of a tribe called the Pazalai, and the Errenysis from the Mathai, an Indian tribe, unite with the Gaṅga.'[3]

With regard to the Gaṅgā and its tributaries, the Jambudīva-paṇṇatti tells us that the Gaṅgā flowing eastwards with the fourteen thousand other streams joining it and inundating the earth in its downward course, falls into the eastern sea. The Great Epic traces the source of the Gaṅgā to the Bindusara, the Jambudīva-paṇṇatti to the Padmahrada, and the Pali works to the southern face of the Anotatta lake, all in other words, to the Mānas Sarovar. The Pali commentaries give the following description of the manner in which this river channels out through the southern outlet of the Anotatta Lake.

The south channel 'circles the lake three times under the name of Āvaṭṭagaṅgā, then as Kaṇhagaṅgā flows straight for 60 leagues along the surface of a rock, comes into violent contact with a vertical rock, and is thrown upwards as a column of water three gāvutas in circumference ; this column, known as Ākāsagaṅgā, flows through the air for 60 leagues, falls on

1. *Ibid.*, pp. 62, 135.
2. McCrindle, *op. cit.*, p. 137 ; cf. *Ibid.*, pp. 45, 62, 63, 159, 190-95.
3 McCrindle, *op. cit.*, pp. 190-91.

to the rock Tiyaggala, excavating it to a depth of 50 leagues, thus forming a lake ; then the river under the name of Bahalagaṅgā, flows through a chasm in the rock for 60 leagues, then under the name of Ummaggagaṅgā, through a tunnel for a further 60 leagues, and finally coming upon the oblique rock Vijjha, divides into five streams forming the five rivers, viz. Gaṅgā, Yamunā, Acīravatī, Sarabhū, and Mahī'.[1]

Yamunā : The Yamunā rises on the slopes of Bandarpūnch, a peak situated on the watershed between the Yamunā and the Gaṅgā. The shrine of Yamunotri stands at the base of the Bandarpūnch. The Himalayan area included in the catchment basin of this river is about 12,000 km². The first and great western tributary of the Gaṅgā is the Yamunā proper, which, like the Sindhu and the Gaṅgā, retains its Vedic name. She cuts a valley through the Siwalik range and Garhwal before she enters the plains of Northern India to flow south parallel to the Gaṅgā ; from Mathurā downwards she follows a south-eastern course till she meets the Gaṅgā forming the famous confluence at Prayāga or Allahabad. In the district of Dehra Dun she receives two tributaries on the west side, the upper one of which is known at Northern Tons. Between Agra and Allahabad, she is joined on the right side by four tributaries, called Carmaṇvatī (modern Chambal), Sindh (Sandhyā ?) Vetravatī (modern Betwā), and Ken (Cainas), and Payaṣṇī (modern Paisuni). Many holy places of India are situated on this river, e.g. Mathurā, Vrindāban, Gokul, Prayāga, etc. The Mughal cities of Delhi, and Agra, too, are situated on it. Sarabhaṅga, a disciple of Kāśyapa, was present at a great sacrifice held at a place between the Gaṅgā and Yamunā.[2] The Yamunā is known to the Chinese as Yen-mou-na. It is one of the five great rivers according to the Buddhists.[3] The Yamunā served as a boundary between Śūrasena and Kośala and further down between Kośala and Vaṃśa ; Madura, capital of Śūrasena, and Kosambī, capital of the Vaṃsas standing on its right bank. Kauśāmbī the capital of the Vatsas, was situated on its north bank. Kālindī is another familiar name by which it is known. The Yamunotrī which is 13 km from Kursoli is considered to be the source of the river Yamunā. It is identical with the Greek Erannaboas (Hiraṇyavāha or Hiraṇyabāhu). The Skanda Purāṇa mentions the Vāluvāninī as a tributary of this very river.

Alaknandā : This represents the upper course of the Gaṅgā. Its upper tributary is constituted of the Piṇḍā and another stream, at the confluence of which is situated Śrīnagar in Garhwal. Another tributary of

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1. Malalasekera, *Dictionary of Pali Proper Names*, i, pp. 733-34.
2. *Mahāvastu*, p. 160.
3. *Aṅguttara Nikāya*, IV, p. 101 ; *Dīgha Nikāya*, II, p. 135 ; V, pp. 401, 460, and 461.

the Alaknandā is the Mandākinī which may be identified with the Kāligaṅgā or Mandāgni rising in the mountains of Kedāra in Garhwal. The Gaṅgā may be supposed to have assumed the name of the Gaṅgā-Bhāgīrathī from the point where it is met by the Mandākinī.

Sarayū : Though a tributary on the left side, Pali literature assigns to the river Sarabhū (Sarayū) the same important as to Gaṅgā itself. The main stream of this great historical river is now known as Ghargharā (Ghāghara). It joins the Gaṅgā in the district of Chāprā of which it appears as its western natural boundary. The Ghargharā above Chandanchauki in Nepal receives no less than five tributaries, one below another, some of which represent the united stream of a few rivulets, all having their origin in the Himalayan range. At the north-west corner of the district of Bahraich, it receives a tributary from the north-east, which goes now by the name of Sarayū (Sarju). The ancient city of Ayodhyā stood on the Sarayū of which Devikā or Devā is just another name.

Hiraṇyavati : This river, otherwise known as Ajitavatī, is no other than the Little Gaṇḍak. It flows through the district of Gorakhpur about 13 km west of the Great Gaṇḍak and falls into the Ghāghara (Sarayū). It was on the banks of this river that the Sālavana of the Mallas of Kuśīnārā stood.[1] Yuan Chwang calls it Shi-la-na-fa-ti (the river with gold).

Aciravatī : This great tributary of the Sarayū has its origin in the Himalayan range. It flows through the district of Bahraich, Gonda and Basti, and joins the Sarayū or Ghargharā west of Burhaj in the district of Gorakhpur. It is fed by no less than three tributaries on the left side, all in the district of Gorakhpur, and by a small tributary on the right in the same district. It is the modern Rāpti on which stood the city of Śrāvastī. It is also called Ajiravatī[2] and its shortened form is Airāvatī. According to I-Tsing (p. 156) Ajiravatī means the river of the Aji (dragon). Kapila was born here as a golden fish as a result of his evil deeds.[3] According to the Chinese pilgrim Yuan Chwang, this river is called A-chi-lo which flows south-eastwards past the city of Śrāvastī.[4] During the hot season it ran dry, leaving a bed of sand.[5] It could be seen from the terrace of Pasenadi's palace.[6] The Tevijja sutta was preached here. The river was crossed in rafts[7] ; it sometimes became so full[8] that disastrous floods occurred, in one of which Viḍūḍabha and his army

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1. *Dīgha*, II, 137.
2. *Avadāna Śataka*, I, 63 ; II, 60.
3. *Dham. Comm.*, IV, 41.
4. Watters, *On Yuan Chwang*, I, 398-9.
5. *Aṅguttara Nikāya*, IV, 101.
6. *Vinaya* P., IV, 111-12 ; *Sutta N. Comm.*, I, 19.
7. *Vinaya*, III, 63.
8. *Dīgha* N., I, 244-5 ; *Jataka*, IV, 167.

were swept into the sea.[1] The people on the banks were in the habit of casting nets for fish.[2] Near the river was Daṇḍakappa, a Kosalan village.[3] It was on the bank of this river that Viḍūḍabha, son of Pasenadi, met the Śakyas in battle and completely defeated them. In vain did the Buddha try to save the Śākyas. But Viḍūḍabha and his army also met with destruction. This river overflowed and carried all into the sea.[4] The Buddha dwelt at Ambavana on the bank of this river to the north of Manasākaṭa.[5]

Gaṅḍaka : The next great tributary of the Gaṅgā is the river Gaṅḍaki (modern Gaṅḍak), the origin of which may be traced to the hills in South Tibet. In passing through Nepal, it receives four tributaries on the left side and two on the right. Those on the left side comprise the Buriā Gaṅḍak, the Mādī, the Setī, and the Kāli, among which the Mādī itself represents a united flow of three streams, and the Kāli of seven. The Gaṅḍaka with all these tributaries in Nepal appears on the map like the born of a Bārāsing stag. It enters India just between the districts of Gorakhpur and Campāran, from that point it begins to flow down though the latter district, and further down it forms a natural boundary between the two districts of Sāran and Muzaffarpur. Its main stream flows into the Gaṅgā between Sonpur in the Sāran district and Hājipur in the district of Muzaffarpur, while its lesser stream bifurcating at Basarh flows down into another river which rising near Ararāj in the Campāran joins the Gaṅgā near Sonāriaghāt in the district of Monghyr. The seven rivers that form it consist of the Barigar, the Nārāyaṇī, the Śvetagaṇḍakī, the Gaṇḍi, the Triśulā, the Daraṇḍī, and the Marsiaṇḍī.[6]

Sadānīrā : This formed the boundary between Kośala and Videha.[7] It has been identified by some with Karatoyā. The Sadānīrā of the Satapatha Brāhmaṇa has been sought to be identified with the Gaṇḍak[8] by some and with the Tāpti by others. On the west of Videha or Tirabhukti flows the river Sadānīrā.[9] According to the Mahābhārata, it has been placed between the Gaṇḍakī and the Sarayū. Pargiter identifies it with Rāpti.[10]

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1. *Dham. Comm.*, I, 360.
2. *Udāna Comm.*, 366.
3. *Aṅguttara Nikāya*, III, 402.
4. *Dham. Comm.*, 359-360.
5. *Dīgha Nikāya*, I, 235.
6. *J. A. S. B.*, XVIII, p. 762.
7. *Śatapatha Br.*, I, 4. 1.
8. Eggeling's *Introduction to the Śatapatha Brāhmaṇa*, S. B. E., Vol. XII, 104.
9. *J. R. A. S.*, 1907, p. 644.
10. *Mārkaṇḍeya Purāṇa*, p. 294.

Bāhumatī : This is identified with Bāgmatī, a sacred river of the Buddhist in Nepal, which is also called Bachmatī as it was created by the Buddha Krakucchanda by the word of his mouth during his visit to Nepal. Its junction with the rivers Ratnāvatī, Prabhāvatī, Cārumatī, Triveṇī, Maradārika, Rājamañjari, and Mamsrohi goes to form the tīrthas called Śānta, Śaṅkara, Rājamañjari, Gokarṇa, etc.[1]

Kauśikī : The Kauśikī (modern Kośī) appears to view under this name in the southern part of eastern Nepal as the united flow of four rivers, the three of which have their origin in Tibet. The second river on the west side, called Sun Kośī, is a united flow of five streams. The next river, called Arun, is a united flow of two streams. The fourth river is called Tamar. In its course through India, the Kauśikī flows through the districts of Bhagalpur and Purnea, and meets the Gaṅgā west of Manihāri, in the district of Purnea. Near its mouth, the Kauśikī receives a small tributary, called Saura. According to Pargiter the river seems to have largely shifted its course.[2]

Tamasā : This is the historical river of the Rāmāyana fame, the modern South Tons which flows northeast from the Rkṣa mountains to fall into the Gaṅgā below Allahābād. It is fed by two tributaries on the left and by two on the right.

Sona : The greatest known lower tributary of the Gaṅgā is the Sona, Arrian's Sonos, the modern Son, which takes its rise in the Maikala (Mekala) range in the district of Bilaspur and flowing northeast through Bāghelkhaṅḍ, Mirzāpur, and Shāhābād districts, joins the Gaṅgā at Patna. The Purāṇas count it as one of the important rivers that rise from the Rkṣa range. Its course past Rājagṛha (Rājgir) in Magadha (south Bihar) was probably known as Sumāgadhā or Sumāgadhī. The Yatirathā of doubtful identity finds mention in the Great Epic, Vanaparva, as a tributary of the Son.

Phalgu : The southern tributary, called Phalgu, joins the Gaṅgā in the district of Monghyr, north-east of Kakhisarai. The Phalgu is but a united flow of the two hill-streams called the Nairanjana (modern Nīlājān) and Mahānada (modern Mohānā) which meet together above Bodhgayā. The Phalgu receives two tributaries, one in the district of Patna, and the other, called Kiul, in the district of Monghyr.

Sakulī : Pargiter identifies this river with Sakri which flows into the Ganga between Patna and Monghyr.

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1. *Svayambhū P.*, Ch. V ; *Varāha Purāṇa*, Ch. 215.
2. *Mārkaṇḍeya Purāṇa*, p. 292 f.n.

Campā : This river forms the boundary between Aṅgi in the east and Magadha in the west.[1] It is probably the same river as one to the west of Campānagar and Nāthnagar in the suburb of the town of Bhāgalpur. It was formerly known by the name of Mālinī.[2]

THE BRAHMAPUTRA-MEGHNĀ SYSTEM

The two principal rivers of Assam are the Brahmaputra and the Surmā, and its remaining rivers go to form the tributaries of either of them, the lower courses of both of which lie in and through East Bengal.[3]

Brahmaputra : The source of the Brahmaputra, otherwise known as Lauhitya (Rohita), is traced in the Jambudīva-paṇṇatti to the stream which channels out through the eastern outlet of the eastern Lotus lake, that is to say, the eastern one of the Mānasa Sarovar pair of lakes. Modern geographical exploration, too, goes to show that its origin is really traceable to the eastern region of the Mānasa Sarovar. It maintains its easterly course between the Himalayan and the Nyanchenthangla ranges, from the Mānasa Sarovar to Namcha Barwa, and at the latter place it turns south and flows down before it forces its way through the eastern extremity of the Himalayan range to enter the valley of Assam. It flows in a southwesterly direction from Sadiyā down to the place above the Garo hills, with a slight deflection here and there, to turn and flow south again to meet the Gaṅgā at a little above the Goalundo.

The course of the Brahmaputra through the tableland of southern Tibet is known by the name of Tsangpo, just as its course through East Bengal is known by the name of Jamunā. This Jamunā is nothing but the main stream of the Brahmaputra as it flows through East Bengal, while its minor stream flows past the town of Mymensingh to meet the Meghnā representing the united stream of the three Assam rivers called Surmā, Barāk, and Puinī. The meeting of the minor stream (formerly the main stream) of the Brahmaputra with the Meghnā takes place a little below Bhairab Bazar in Kishoreganj sub-division of the district of Mymensingh. The combined waters of the Meghnā and the Brahmaputra flow together under the name of Meghnā.

1. *Jātaka*, IV, 454.

2. *Mahābhārata*, XII, 5, 6-7 ; *Matsya*, 48, 97 ; *Vāyu*, 99. 105 and *Harivaṃśa*, 31. 49.

3. *East Bengal District Gazetteers*, Dacca, p. 7.

RIVERS OF WESTERN INDIA

The Pāripātra of Pāriyātra mountains represent just a western branch of the Vindhya range, which formed the western boundary of the ancient kingdom of Avantī and may be taken to extend northeast through Rajputana under the modern name of Aravalli. The rivers that are traditionally associated with this Kulācala consist, according to the Mārkaṇḍeya Purāṇa, of the Vedasmṛti, the Vedavatī (Vedasinī, Vetasinī), the Vṛtragnī (Rātrighnī), the Sindhu, the Veṇvā (Veṇā), the Syandanī (Sānandinī), the Sadānīrā, the Mahī, the Pārā, the Carmaṇvatī, the Lūpī (Nūpī Lopamudrā), the Vidiśā, the Vetravatī, the Siprā, and the Avantī. The Syandanā is called Candanā, Bandhanā, and Sabandhanā in other Purāṇas. The Vāyu Purāṇa (XLV. 97) reads Satīrā and Sadātīrā instead of Sadānīrā. The Vāyu (XLV. 97) and Kūrma (XLVII. 29) Purāṇas add the name of Varṇāśā or Parṇāśā. Among them, the Sindhu, the Siprā, and the Mahī have retained their ancient identity. The Carmaṇvatī is the modern Chambal, the Varṇāśā is no other than the modern Banāśī. The Vetravatī is easily identifiable with the modern Betwā. The rest are not identified ; they are of doubtful identity. The rivers of this region mostly belong to the two river systems, namely, the Carmaṇvatī or Chambal and the Luni. There are a few local rivers in Gujarat and Kutch that flow independently into the Arabian Sea.

Pārvatī : This is a local river of Indore which flows north northwest to join the Chambal on the right, northwest of Sheopur. Cunningham identifies it with the Para of the Pārā of the Purāṇas.

Berach : The next tributary on the left is the Berach which takes its rise in the Aravalli range and is joined by the tributaries, called Bena (Veṇā of the Purāṇas), Koyārī, Khārī, Mashī and Bandī, Dhund, and Morel. The Moshi and Bandī unite together before they flow into the Berach near Tonk. From the point where the Berach receives the Dhund, it becomes known as the Banas (Sk. Varṇāśā). As Banas, the Berach is joined by the river Morel and meets the Chambal, north of Sheopur.

Vetravatī : The next tributary, called Vetravatī, the modern Betwā, issues, according to the Purāṇas, from the Pāripātra mountains. In its course towards the Yamunā, it is joined by several tributaries, the most important of which is the Jamnī.

Ken : This important tributary of the Yamunā below the Vetravatī was known to Arrian as the river Cainas. It flows in a zigzag course towards the Yamunā from a place in Madhya Pradesh to the west of Murwāra.

Vihalā, Vegavatī : The Jaina tradition associates the two rivers, called Vihalā and Vegavatī, with Mount Ujjayanta in Surāshṭra. Their modern identity is unknown.

Nirbindhyā : As specified by Kālidāsa in his Meghadūta, this river lay between Vidisā and Ujjayinī that is to say, between the Daśārṇā (Dhasan) and the Siprā. It is identified with the modern Kalisindh which forms a tributory to the Carmaṇvatī (Chambal).

Siprā : This has been immortalized by Kālidāsa as the historical river on which the city of Ujjayinī (modern Ujjain) was situated. This is a local river of the Madhya Pradesh, which flows into the Chambal a little below Sitamau. It is fed by two tributaries.

RIVERS OF CENTRAL INDIA

The Śoṇa, the Mahānada, the Narmadā, the Surathā, the Adrijā, the Mandākinī, the Daśārṇā, the Citrakūṭā, the Citrotpalā, the Tamasā, the Karamodā, the Piśācikā, the Pippaliśroṇī, the Vipāśā, the Vañjulā, the Sumerujā, the Śuktimatī, the Śakuli, and the Tridivā are the rivers that are connected in the Mārkaṇḍeya Purāṇa, with the Rkṣa or Ṛkṣavat mountains. The Varāha Purāṇa list replaces the Mahānada by the Jyotirathā and omits Adrijā, which finds mention in the Mahābhārata (Anuśāsanaparva, CLXV). The Surathā is called Surasā, the Pippalaśroṇī Pippalā, the Vañjulā Vañjukā, the Karamodā Karatouā, the Śuktimatī Bhuktimatī, the Sumerujā Virajā, and the Śakuli Vālukāvāhinī. Instead of the Tridivā, the Varāha list has the Paṅkinī and the Rivī. These rivers are referred to the Ṛkṣa mountains also in the Kūrma, Matsya, Brahmāṇḍa, and Vāyu Purāṇas. The Viṣṇu and Brahma Purāṇas, on the other hand, mention the Vindhya as their source.

The rivers that issued from the Vindhya Mountains consist, according to the Mārkaṇḍeya Purāṇa, of such rivers as the Siprā, the Payoṣṇī, the Nirbindhyā, the Tāpī, the Nisadhāvatī, the Veṇvā, The Vaitaraṇī, the Sinivālī, the Kumudvatī, the Karatoyā, the Mahāgaurī, the Durgā, and the Antaḥśirā. In the Varāha list the Antaḥśirā is called Antyāgirā, the Karatoyā Toyā, the Veṇvā Veṣṇā. It mentions the Maṇijāla, the Subhā, the Śighrodā and the Pālā, of which the corresponding names are not to be found in the Mārkaṇḍeya Purāṇa. Some of the rivers in the Mārkaṇḍeya list are absent from the Varāha. Evidently the rivers that are connected in the Mārkaṇḍeya, Varāha, and other Purāṇas with the Vindhya are referred in the Viṣṇu and Brahma Purāṇas to the Rkṣa as their source. Ptolemy agrees with the Mārkaṇḍeya and other Purāṇas when he describes the Ouxenton (Ṛkṣavant) as the source of the Dosaran (Daśārṇa), but he differs at the same time from them in connecting the Namados (Narmadā) with the Onindon (Vindhya). This confusion is really due to the fact that the Revā is usually connected with the Vindhya and the Narmadā with the Rkṣa, they being regarded as two separate rivers in the Bhāgavata and the Vāmana Purāṇas, and one and the same river in the Revākhaṇḍa. The fact, however, is that the main river of the Narmadā which issues from the Rkṣa is joined by the Revā which flows northwest from the Vindhya, and the course of the Narmadā or Revā below this juncture represents but a united flow of the two streams. Going by the Mārkaṇḍeya tradition as regards the connection of the Narmadā with the Rkṣa, we may regard the Rkṣa and the Pāripātra as two upper horns of the Vindhya in central and western India, the former being the eastern and the latter the western. The Rkṣa and Vindhya rivers in central India either go to form tributaries to the Yamunā, the Gaṅgā, and the Son or belong to the three systems of the Chambal, the Narmadā, and the Tāpti. The modern identity of many of them is either unknown or doubtful.

Narmadā : The most important river of central and western India is the Narmadā which rises from the Maikala range and flowing, more or less, in a south-westerly direction The river runs through Indore and flows past Rewa Kantha of Gujarat and meets the sea at Broach. As the river takes its course in between the two great mountain ranges of the Vindhya and the Satpurā, it is fed by a very large number of small tributaries issuing from one or the other of the mountain ranges. Before the river enters Indore, it is joined by not less than thirteen tributaries on the left and seven on the right. The river is further fed by seven tributaries, four on the left and three on the right as if flows through Indore. The river receives no more tributary in the rest of its course upto the sea. The Narmadā (Namados of Ptolemy) is otherwise known as Revā, Somodbhavā, and Mekalasutā. The last name is important as indicating its source, namely, the modern Maikala range preserving the name of the ancient territory of Mekala. The Maikala range, evidently a portion of the Rkṣa, is also the source of the great river Son. The source of the Revā is traceable to the Amarakaṇṭaka hills adjoining the Vindhya range. The Narmadā and the Revā form a confluence, a little above Māndlā to flow down under either name. According to the Mahābhārata, the Narmadā formed the southern boundary of the ancient kingdom of Avantī.

Tāptī : The Tāpti or Tāpī has its source in the Multai plateau to the west of the Mahadeo hills and flows westward. Thereafter the river passes through Burhanpur and crossing the boundary of the Madhya Pradesh, enters the Maharashtra to meet the sea at Surāt. Within the Madhya Pradesh it is met on the left by four unimportant tributaries, all flowing from the Mahadeo hills. In Jālgaon the river is met by a very important river called the Pūrṇa. Six more rivers including the Girnā meet the Tāpī on the left before it empties itself into the sea. It takes only two tributaries on the right and both of them in Khandesh. The Pūrṇa which retains its ancient identity, mentioned in the Padma Purāṇa (Ch. XLI), rises from the Satpurā range and meets the Tāpī a little below Burhanpur.

RIVERS OF EASTERN INDIA

East-flowing rivers having their sources either in the Madhya Pradesh or Orissa : The principal rivers in Orissa are the Vaitaraṇī, the Brāhmaṇī, the Mahānadī, the Chotamahānadī, the Vaṃśadharā, and the Lāṅgulinī. All of them flow independently into the Bay of Bengal, and none but the Mahānadī may be regarded as the river which forms a system. The first is connected in the Mārkaṇḍeya Purāṇa with the Vindhya range, and the last two with the Mahendragiri or Eastern Ghats. It is not unlikely that the Vindhya rivers in the Mārkaṇḍeya list, from the Vaitaraṇī to Antaḥsirā or Antyāgirā, were all rivers belonging to the ancient kingdom of Kaliṅga or the modern province of Orissa.

Vaitaraṇī : The Vaitaraṇī which is one of the most sacred rivers of India formed the northern boundary of the kingdom of Kaliṅga. She rises in the hills in the southern part of the district of Singhbhum and a little below the point where she enters Orissa, she receives two tributaries that flow from the foot of the Malayagiri to the west of Keonjhar. She follows a course from northwest to southeast through the district of Balasore and reaches the Bay at Dhāmrā.

Brāhmaṇī : The next river Brāhmaṇī is equally sacred in the eye of the Hindu people and flows, like the Vaitaraṇī, through the district of Balasore from northwest to southeast. By the name of Brāhmaṇī is really meant the united flow of two hill-streams called Sankh and south Koel, both of which rise in the hills of Chotanagpur. The Brāhmaṇī is joined east of Angul by an important tributary, called Tikkirā, which flows from northwest to southeast, having its origin in the Mandar hills of Sambalpur. The Tikkirā may be identified with the Antaḥśirā or Antyāgirā.

Mahānadī : The river is identified with the Mahāgaurī of the Purāṇas. The Devī and the Prochi are two affluents of the Mahānadī on its right side that form two deltaic rivers in the district of Purī.

Lāṅgulinī : The Lāṅgulinī or Lāṅguli (modern Lāṅguliyā) rises in the hills at Kalahandi and flows south through the district of Ganjam to empty itself into the Bay.

Trisāmā and Ṛṣikulyā : The most northern river in the district of Ganjam which flows into the Bay past the town of Ganjam is now known as Ṛṣikulyā, evidently retaining its ancient name. Though the Trisāmā, otherwise called Triyāmā, Tribhāgā or Pitṛsomā, and the Ṛṣikulyā are mentioned in the Purāṇas as two separate rivers, it would seem that they were one and the same river, the Ṛṣikulyā bearing the descriptive name of Trisāmā Ṛṣikulyā, signifying that the name Ṛṣikulyā was applicable to the united flow of three upper streams. Between this river and the Vaṃśadharā below, one may notice three small rivers in the district of Ganjam, the two of which might be identified with the two remaining rivers in the traditional list.

There is wide divergence of opinion among the Indologists concerning the identification of the Śuktimat range and its rivers. The best suggestion, hitherto offered, is that from Dr. Raychaudhuri who identifies the Śuktimat range with the chain of hills that extends from Śakti in Raigarh district in Madhya Pradesh, to the Dalma hills in Singhbhum drained by the Kumārī and perhaps even to the hills in the Santal Parganas washed by the affluents of the Bāblā. The Ṛṣikulyā, the Kumārī, the Mandagā, the Mandavāhinī, the Kṛpā and the Palāsinī are the six streams that are said to have issued, according to the Mārkaṇḍeya Purāṇa, from this range.

Kumārī : This is convincingly identified by Dr. Raychaudhuri with the modern Kumārī which waters the Dalma hills in Singhbhum.

Kṛpā (*Kūpā*) : This is similarly identified with the modern Kopā, a tributary of the Bāblā in eastern India.

Palāsinī : Dr. Raychaudhuri seems to identify this rivers with the modern Parās, a tributary of the Koel in Chotanāgpur.

The Pitṛsomā (otherwise known as Trisāmā, Triyāmā, Tribhāgā), the Ṛṣikulyā, the Ikṣukā (Ikṣulā, Ikṣudā), the Tridivā, the Lāṅgulinī, and the Vaṃśadharā (Vaṃśakarā) are the six notable rivers that are connected in the Mārkaṇḍeya Purāṇa with the Mahendragiri, now identified with the Eastern Ghats. These were evidently all local rivers belonging to the southern division of the ancient kingdom of Kaliṅga, and should as such be identified with the main rivers that flow into the Bay of Bengal through the district of Ganjam, now included in the State of Orissa. In the Kūrma Purāṇa (XLVII.36) these rivers are referred to the Ṛkṣa mountains.

The Mārkaṇḍeya Purāṇa restricts evidently the name of the Mahendragiri to the northern extension of the Eastern Ghats in the district of Ganjam. If we agree to apply the name even to the southern extension of the Eastern Ghats, there are several small coastal rivers in the Andhra Pradesh that issue from the Mahendra mountains and flow independently into the Bay of Bengal. These rivers do not unfortunately find mention in the Purāṇas.

RIVERS OF SOUTH INDIA

The Sahyagiri or Sahyādri is correctly identified by Pargiter with 'the northern portion of the Western Ghats....from the river Tāptī down to the Nilgiris'.[1] The main rivers, of which the sources are mentioned in Mārkaṇḍeya Purāṇa, are the Godāvarī, the Bhīmarathā (Bhīmarathī), the Kṛṣṇaveṇvā, the Veṇvā, the Tuṅgabhadrā, the Suprayogā, the Vāhyā (Varadā, Agni Purāṇa), andt he Kāverī. The Sahya rivers that flow east to fall into the Bay of Bengal may be shown to belong to the four river systems of the Godāvarī, the Kṛṣṇā, the Pennār, and the Kāverī. Several Vindhyā and Mahendra rivers, too, form the tributaries of the Godāvarī.

Godāvarī System : The largest and the longest river in south India is the Godāvarī of which the source is traceable to the Western Ghats. The river assumes this name from the point where the Kadvā and the combined waters of the Pravarā and the Mūlā meet and begin to flow together below Gaṅgāpur in Aurangābād, Hyderābād. The Kadvā itself receives on its right bank a tributary, called Darnā, southeast of Nāsik. The Godāvarī flows in a southeasterly direction below the Vindhya range cutting a valley through the Eastern Ghats. It falls in three main streams into the Bay of Bengal in the district of Godāvarī forming a large delta at its mouth. In its course through Maharashtra and Andhra Pradesh it is joined by ten tributaries on the left and by eleven on the right, the important among which are the Pūrṇa, the Ḳadam, the Pranhitā, the Indravatī, the Sabarī-Sileru on the left, and the Sindphanā, the Mañjirā, the Maner, and the Kinarsani on the right.

Pranhitā : This is one of the two most upper tributaries of the Godāvarī, which represents the united flow of the Waingaṅgā (Veṇvā) and the combined waters of the Wardhā (Varadā) and the Pengaṅgā (Peṇṇā). The Waingaṅgā is a Vindhyan river which has its source in the hills in the district of Seoni, M.P., and flows south forming a bulge and being joined by seven tributaries on the left and by four on the right. The Pengaṅgā rises from the Sahyādri-parvat and before its confluence with the Wardhā it is joined by four tributaries on the left and by one on the right, the Pus, the Aran, and the Kuni being among the well-known. The Wardhā rises from the Mahādeo hills and is fed by several small streams.

Mañjirā : The next important lower tributary is the Mañjirā (Vañjula of the Purāṇas ?) which, rising from the Bālāghāt range, flows southeast and north to join the Godāvarī east of Kandalwādi.

1. Pargiter, *Mārkaṇḍeya Purāṇa*, P. 285.

This is no other than the famous river in South India, called Kṛṣṇaveṇā in the Purāṇas, Kaṇhapeṇṇa in the Jātakas, and Kaṇhapemṇa in the Hāthi-gumphā inscription of Khāravela. It has its source in the Western Ghats ; flowing east through the Deccan plateau and breaking through the Eastern Ghats in a gorge, it falls into the Bay of Bengal. Its course lies through the Maharashtra, Mysore and Andhra Pradesh.

Bhīmā : The Bhīmā (Bhīmarathā) which figures prominently as a Sahya river in the Purāṇas appears to view in the northwestern portion of the district of Poona, from which place it takes a southeasterly course and flows into the Kṛṣṇā north of the district of Raichur, Mysore. It is fed by five streams on the left and by seven on the right, among which the most noteworthy are the Ghod, the Sinā, and the Benathorā on the left bank and the Nirā and the Mān on the right.

Tuṅgabhadrā : This is the most important among the lower tributaries of the Kṛṣṇā. The two streams, called Tuṅga and Bhadrā, both having their origin in the Western Ghats on the western border of Mysore, combine to flow together under the name of Tuṅgabhadrā. The Tuṅgabhadrā which retains its ancient name meets the Kṛṣṇā north of Nandikotkur in the district of Kurnool, Andhra Pradesh, is fed by seven streams on the left and by six on the right, the most important among which are the Varadā on the left and the Hagarī and the Hindrī on the right. Within the belt of the Kṛṣṇā and the Tuṅgabhadrā are to be found the four sets of Aśoka's edicts.

Kāverī : This famous river in South India rises in the Western Ghats hills of Coorg, flows southeast through Mysore and falls into the Bay of Bengal in the district of Thanjāvūr, Madras. It forms a large delta at its mouth where several deltaic rivers are to be seen. As it flows down, it receives ten streams on the left and eight on the right, the noteworthy among them being the Shimsā on the left bank and the Kābbāni-Nugu, the Moyār-Bhavānī, the Noyil, and Amrāvatī on the right. In ancient times the Kāverī, noted for pearl-fishery, flowed down into the sea through the southern portion of the ancient kingdom of Coḷa. Uragapura, the ancient capital of Coḷa, modern Uraiyur, was situated on the southern bank of the Kāverī.

The Malaya range of hills is no other than what is called Bettigo by Ptolemy and Podigei or Podigai in Tamil. Pargiter identifies it with the portion of the Western Ghats from the Nilgiris to Cape Comorin. The Mārkaṇḍeya Purāṇa connects with it the four important rivers, called Kṛtamālā (Ṛtumālā in the Kūrma Purāṇa, Śatamālā in the Varāha), Tāmraparṇī (Tāmravarṇā in the Brahma Purāṇa), Puṣpajā, and Sūtpalāvatī (Utpalāvatī). In the Arthaśāstra and the Rāmāyaṇa we have mention of the Pāṇḍyakapāṭa and the Tāmraparṇī as the two rivers noted for pearl-fishery. In the Rāmāyaṇa the latter is described as a large Malaya river which went to meet the sea forming a row of islands covered with sandal woods. In modern atlas one may notice eight rivers flowing east and eleven flowing west from the Malaya range. The three upper rivers on the east are known as the Vaigai, the Gundur which flows in two streams into the sea, the Vaippar, and one upper river on the west is called Periyār.

Kṛtamālā : This is identified with the Vaigai which flows past the town of Madurai (ancient Madhurā, the capital of the kingdom of Pāṇḍya).

Tāmraparṇī : This must have flowed below the southern boundary of the kingdom of Pāṇḍya and may be identified with the modern Tāmbrāvarī or with the combined stream of this river and the Chittar. The port of Korkai (modern Kilakarai) was situated, according to Ptolemy, at the mouth of this river. This may justify us in identifying it with the Gundur, the name under which the combined waters of three streams flow in two streams into the sea.

CHAPTER XIII

MAJOR CHANGES IN RIVER COURSES IN RECENT HISTORY

Introduction

The oscillations and avulsions of the courses of rivers in recent history have significant contributions in laying the foundation of the alluvial morphology. The regime conditions accelerating the southward shifting of the Brahmaputra, the eastward diversions of the river Tista, the frolicsome shift of the Kosi's courses, the flood-flow-transfer of the Adhwara rivers, the swinging behaviour of the Damodar courses and the meandering habits of the Bhagirathi river have positive influences in determining the nature and the shape of the relief of the flood plain. The changes in the courses of these rivers aggravate many physical problems including flood and drainage.

The Brahmaputra

The Brahmaputra river is shifting laterally from Pasighat to Goalpara. The operation of the erosive factors and the increasing silt change in the river initiates the change that takes place in the migration of the river curves following flood problems. The river bank erosion is maximum during the falling flood stages. The channel section from Deshangmukh to Dibrugarh has deteriorated considerably since the earthquake of 1950. But the southward shifting of the Brahmaputra river, particularly the stretch between Dibrugarh to Palasbari, is active since 1954 due to erosion. Palasbari town has completely disappeared from the map, and about one-tenth of the Goalpara town and a considerable portion of the Dibrugarh town have been encroached by the river Brahmaputra. The shifting of river banks is gradual and it is less in the eastern part than the western sector of the town (Fig. 1). Dibrugarh town was located by the side of the river Dibru, a tributary to Brahmaputra. It merged with the Brahmaputra in 1950.

The heavy silt charge accompanied by the flashfloods of the north bank tributaries are pushing the bank of the Brahmaputra southward. The sand shoals have also been formed in many places, e.g., Banaria, Bengamati, Kurwa, Kholabanda, etc., resulting in channel shifting.

The Tista

The word Tista derived from sanskrit "Trisrota" means three flowing channels. Originally the flowing channels were the Purnabhaba, the Atrai and the Karatoya (Fig. 2). The combined flood discharges of the Karatoya and Atrai poured into Ganga near Goalundo. One branch Purnabhaba went on its course and joined the river Mahananda during the 18th century, finally discharging into the Ganga river. The mention of the "Trisrota" has been made by Rennell (1784-77).

The base of the Tista delta is Padma. The land was rising progressively since the diversion of the Bhagirathi flood water to the river Padma. The outfalls of these channels falling into Padma have been choked up by silt and as a result of it a series of depressions have been formed.

An unusual flood occurred in the Tista river in 1787[1], and flood discharges caused the diversion to an old abandoned course which joined the Brahmaputra. Thus, the courses of the river Tista have changed very frequently in the plains.

The Kosi

The Kosi is an antecedent river. It is tumbling down the Himalaya flowing through the transverse gorges, winding its way down through the vast monotonous plains and depositing sediments on the channel profile later on and finally falling into the Ganga near Kursela. The catchment area of about 42,000 km^2 of which 28,000 km^2 is subjected to erosion and the remaining area lies above the snowline. These eroded slopes of about 28,000 km^2 stretching from Tribeni to Chatra belongs to thrust zone. The area has frequent siesmic disturbances also. The gradient is steep. The disintegrated rock fragments and debris are deposited in the downstream of the river in stages. The oscillation of the Kosi due to excessive silt has been attributed by many experts engineers.[2,3]

The Kosi oscillates between two fixed points. The one is located between Chatra and the Belka hills and the other point is near Kursela where Kosi meets Ganga. The Kosi has shifted about 112 km westward in the last 200 years (Fig. 2). The rate of movement has been calcu-

1. W. W. Hunter : Statistical Account of Bengal, Vol. VII, p. 165.
2. P. C. Ghosh (1938) : A comprehensive treatise on North Bihar flood problems.
3. C. C. Inglis : Report on factors affecting the westerly movement of Kosi river with further suggestion.

lated by Aich and Mukherjee[1] measured in a line passing through Bhelaki and Purnea since 1736.

TABLE I

Year	Period of movement in years	Approximate distance moved in km	Approximate distance moved in km per year
1736-70	34	10.78	0.32
1770-1823	53	9.33	0.16
1823-56	23	6.12	0.16
1856-83	27	12.88	0.48
1883-1907	24	18.52	0.81
1907-22	15	14.17	0.72
1922-33	11	28.98	2.58
1933-50	17	17.71	1.05

Aich and Mukherjee also observe that "the coarse sediment is being deposited between Hanumannagar and Karsara and the bulk of medium sediments are deposited between Kahara and Basua."

The westward movement of the river curves were slow and marked in stages and then the eastward oscillation has probably been possible in one great swing.

The Adhwara rivers

The group of rivers lying east of the Burhi Gandak and the flowing Kosi are called Adhwara rivers. These rivers have a small catchment in the Himalaya. The special feature of the Adhwara rivers, especially Bagmati and Kamla, are spill prevention in the middle reaches. The result of this is flood transfer from one river basin to another river basin, for example, the flood discharges of Bagmati are flowing to the Burhi Gandak river. The above mentioned factors are the cause of avulsion in the Adhwara rivers. The Kamla and the Bagmati are good examples of river avulsions leaving their former courses to meet Kosi in recent times.

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1. B. N. Aich and D. Mukherjee : Sedimentation in the Kosi. A Unique Problem. Journal of C. B. I. & P. July 1963, p. 266.

The Bhagirathi

The Bhagirathi is a very old river. Wilcox thought that this river was a man made canal.[1] But this view was not accepted by many scientists and engineers. The diversion of the Ganga from Bhagirathi to Padma was probably complete by 1564. This diversion considerably reduced the flood discharge of the Bhagirathi river channel. After diversion the seasonal flood discharge during the monsoon reduced due to the closing and shifting of the Bhagirathi offtakes.

Gaur, the ancient capital of Bengal, stood on the left bank of the Bhagirathi, and it started deteriorating before 15th century. Probably Ganga left its course past Gaur and moved southwards since the earthquake 1515 A.D. Since Ganga's diversion the Bhagirathi offtakes are shifting and they have the natural tendency to move downstream until it becomes backwater.[2] The flow of the Bhagirathi river is continuous only when the discharge is sufficient at the head depending upon favourable and unfavourable conditions of these changing offtakes.

The formation of the present Bhagirathi meander plain was probably complete before the diversion. Only minor alterations take place during the flood season. The fluctuating flood discharge depending upon the intensity and the amount of rainfall during the monsoon season plus the factors like physiography, soil, ground water etc. together with man's interference are responsible for the shifting of the meander curves.

The magnitude and wave length of the meander curve was normal during 14th to 16th century and this was probably due to discharge volume flowing this stretch. The deformities or breaking up of a single curve or curves shifting after 16th century was entirely due to a sudden increase in discharge and silt charge. The human interference to the normal flow condition in a channel i.e., by river control works and embankments etc. restricts the normal growth of meander curve in the floodplain. The meander curve at Purbasthali (Fig. 3) has migrated towards concave side about 105 m in 47 years i.e., 2·25 m approximately annual rate of migration.[3]

The Damodar

The changing pattern of the river courses in the lower reach of the Damodar from 1550 to 1850 A.D. reveals the swinging type depend-

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1. Wilcox, W. (1930) : Ancient irrigation system of Bengal, C. U. Publication.
2. Report on the Headwaters of the river Hooghly, Vol. I, Govt. of Bengal Publications (1919).
3. S. Sen (1967) : River curves and their forms.

ing upon the nature of the flood volume and intensities (Fig. 4). Since 1850 the change of the river course was due to man's interference. In 1550 De Barros showed the river Damodar on his map. At that time the main flow of this channel was passing through the Kana Damodar.[1] In 1640 a large amount of water was flowing through the present Gangur and Behula rivers finally falling into the Bhagirathi river near Kalna.[2] Of course, this branch existed for a short period. In 1660 the flood water of the Damodar river was flowing through the Amta branch and it fell into Hooghly river opposite Falta. At that time this was known as Mondalghat river. It was a creek no bigger than ordinary canal.

A navigation chart of 1690 shows that Kana Damodar was a big channel in 1550 and it was deteriorating very rapidly. The charts of 1720 and 1730 represented it is a narrow channel.[3] In Ritchie and Lacam's chart of 1758 the Kana Damodar was shown as an insignificant creek, meanwhile "changes had been taking in the upper branch of the Damodar or Kana and Kunti Nadi".[4] During Rennell's time (1760) the bed level of the Kana Damodar had risen, and he has shown this river as the old bed of the Damodar river. In 1823 and 1840, the big floods, having discharge of more than 12,600 cubic metres per second at Raniganj, used to flow through this Amta channel of Damodar. This evidently shows that between 1700 and 1850 A.D. the Damodar flood water had alternately been operating between the Damodar (Amta section), the Kana Damodar and Kana or Kunti Nadi.

An attempt was made for constructing a temporary dam on the Damodar at Muchihana in 1851 to divert the flood waters of Damodar from the Hooghly river to the Rupnarayan river. The purpose was to lengthen the life of Calcutta port from sedimentation. The last big change occurred with the opening of Begua channel some 6 km below Jamalpur in 1865.[5] Since then most of the Damodar flood water is flowing through this channel which is known as Kaki river below Muchihana and then it flows through the Mundeswari river finally falling into the Rupnarayan river.

These changes in river courses are the normal phenomenon in the deltaic conditions. The behaviour of the river in the past confirms the irre-

1. R. K. Mukherjee : The changing face of Bengal.
2. Kshemandanda Das : Monshar Bhasan (In Bengali).
3. Reports on the Headwaters of Hooghly (1919) : Govt. of W. Bengal Publications.
4. Alex Hamilton : East Indies, Vol. II, p. 3.
5. Capt., J. P. Beadle's Diary (1956).

gular nature of the sedimentation and the formation of profiles. The following results have been obtained from the study of the subsoil geology.[1]

(a) there are no continuous layers of sand, silt and clay in the inland delta of Damodar,

(b) The detritus brought down by the two rivers. Damodar and Bhagirathi are found to be intermixed at all places. The boring stations close to Damodar (Baneswarpur and Kotalpur) show Bhagirathi detritus while the stations close to Bhagirathi (Denur and Radhanagar) indicate the presence of Damodar sand, and

(c) scattered clay pans of varying thicknesses are found to infiltrate beds of sand or silt over the lower reach of Damodar.

The above mentioned results confirm the swinging nature and erratic behaviour of the Damodar river in its lower reaches.

S. Sen (1962) : Drainage study of lower Damodar Valley.

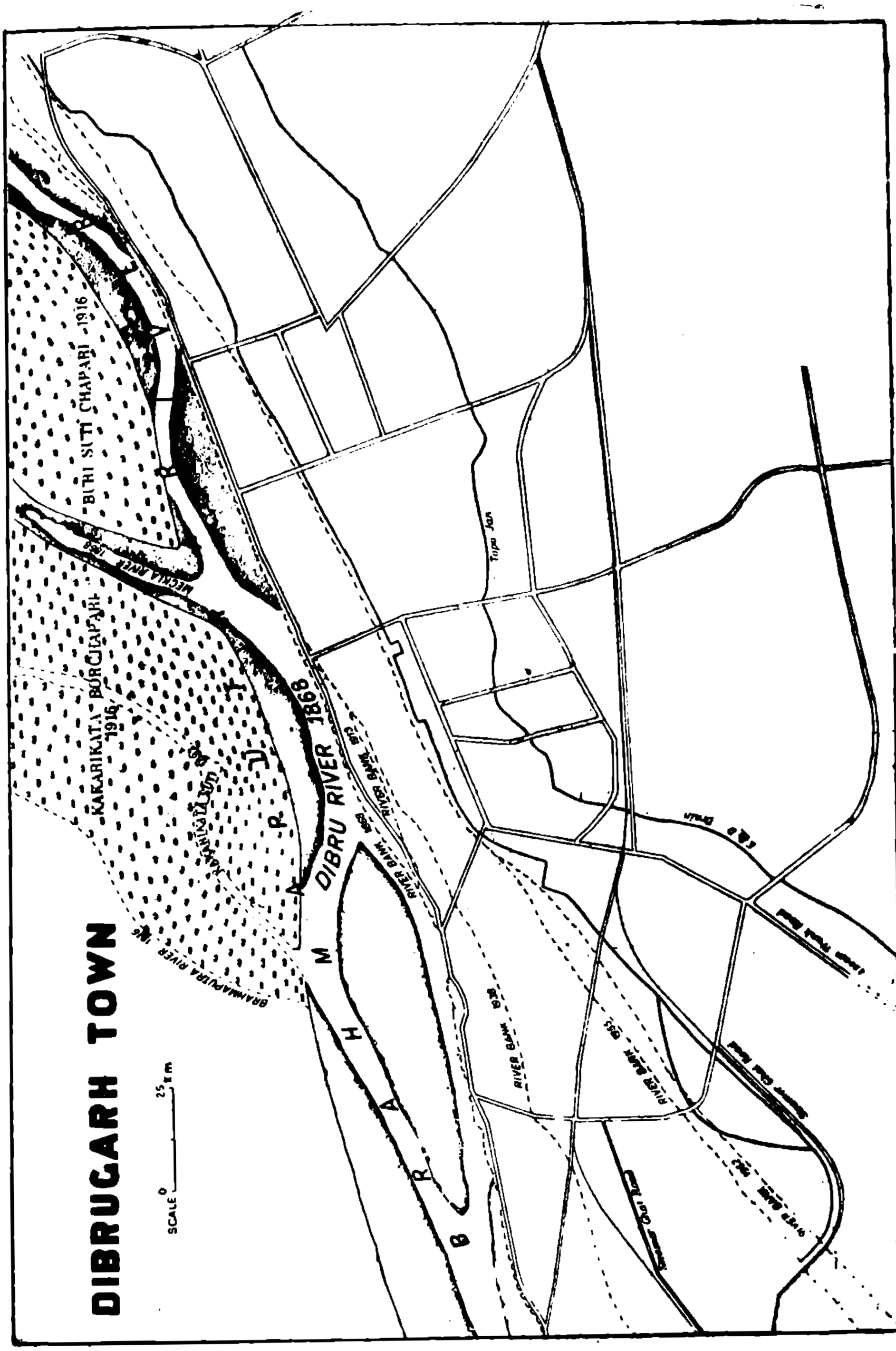
DIBRUGARH TOWN
SCALE
DIBRU RIVER 1868
KAKARIKATA BORCHAPARI 1916
BURHI SUTI CHAPARI 1916
B R A H M A P U T R A
RIVER BANK
Tipa Jan

Figure 1.

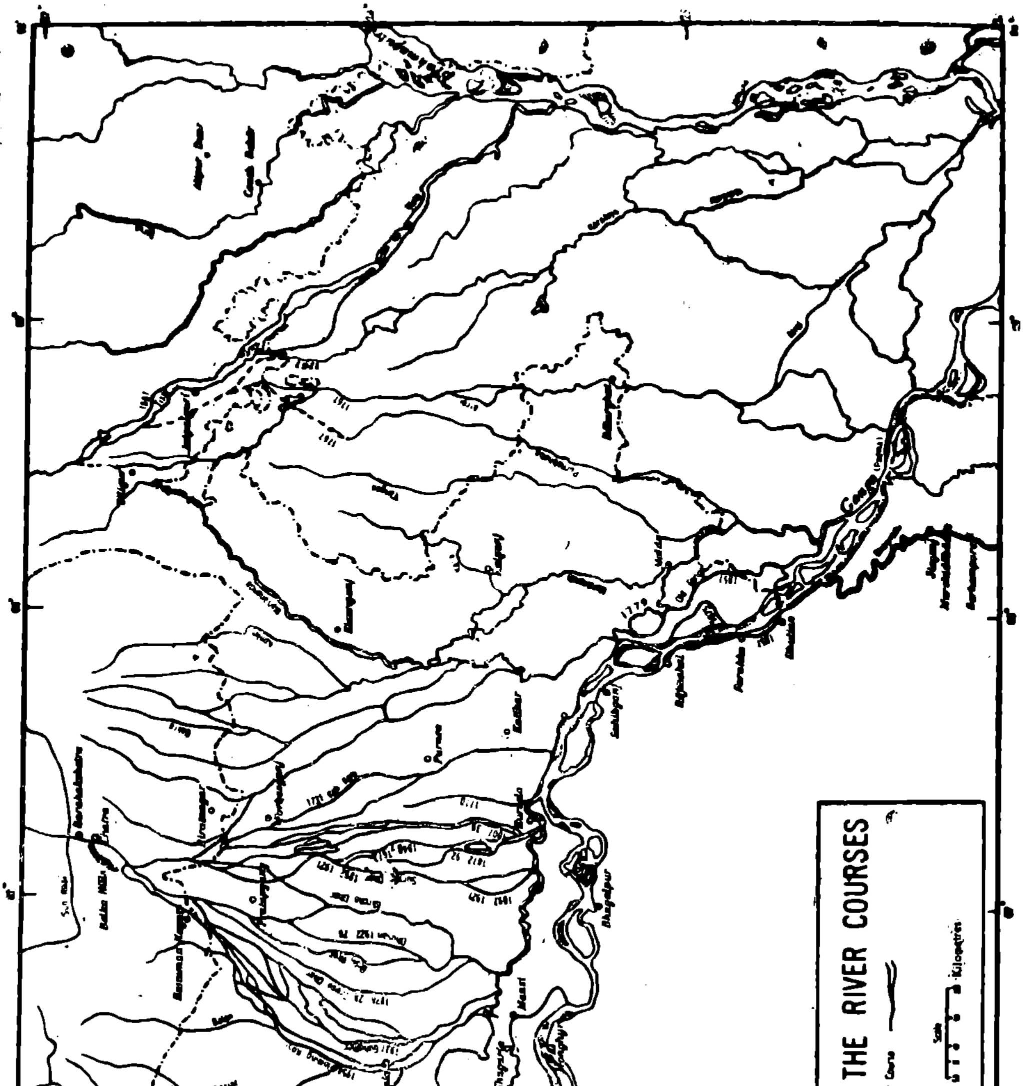

Figure 2

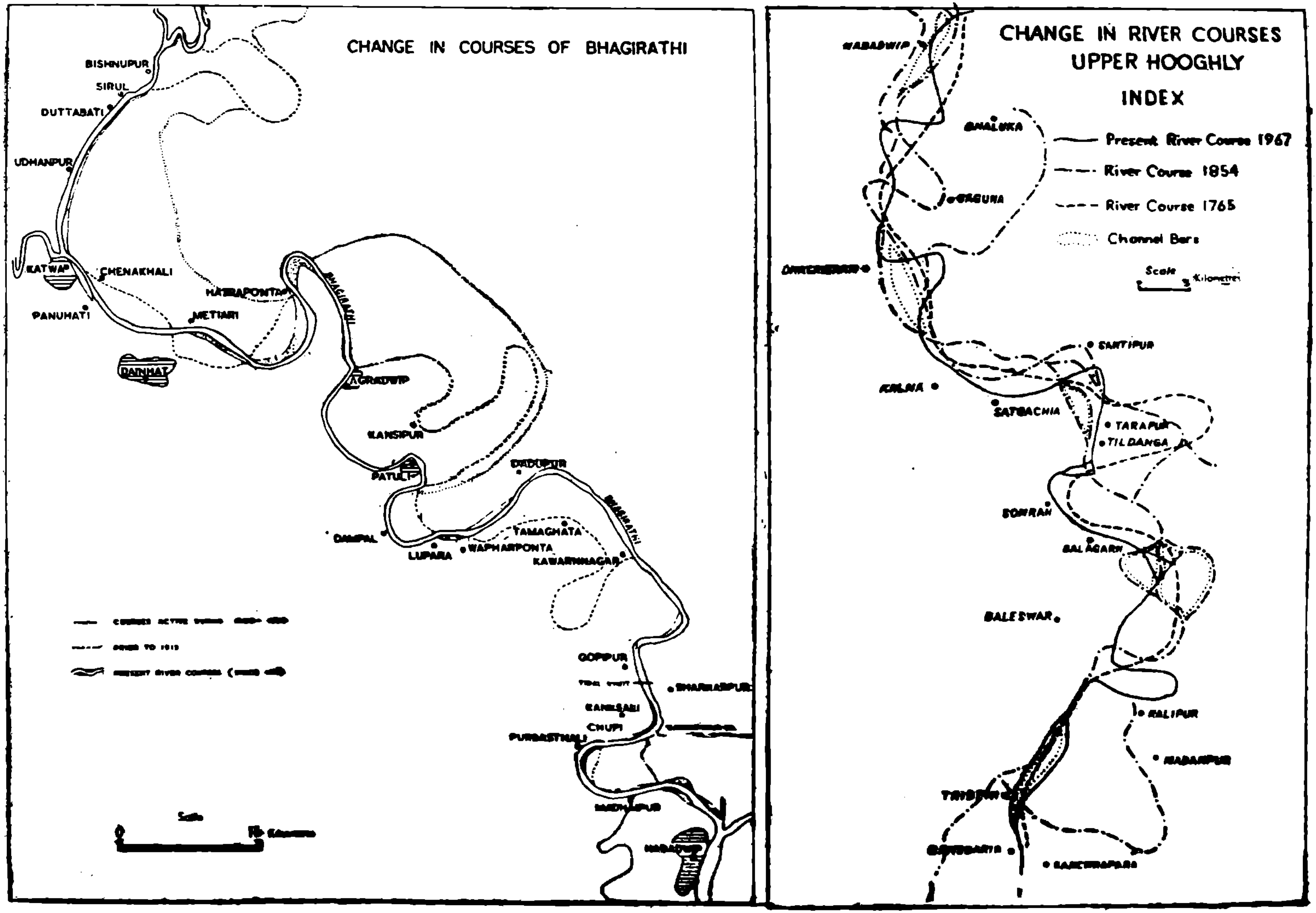
CHANGE IN COURSES OF BHAGIRATHI
BISHNUPUR
SIRUL
DUTTABATI
UDHANPUR
KATWA
CHENAKHALI
PANUHATI
METIARI
DAINHAT
AGRADWIP
KANSIPUR
PATULI
DADUPUR
BHAGIRATHI
TAMAGHATA
LUPARA
GOPIPUR
CHUPI
PURBASTHALI
CHANGE IN RIVER COURSES
UPPER HOOGHLY
INDEX
Present River Course 1967
River Course 1854
River Course 1765
Channel Bars
Scale
SANTIPUR
KALNA
SATGACHIA
TARAPUR
TILDANGA
SOMRAH
BALAGARH
BALESWAR
KALIPUR

Figure 3.

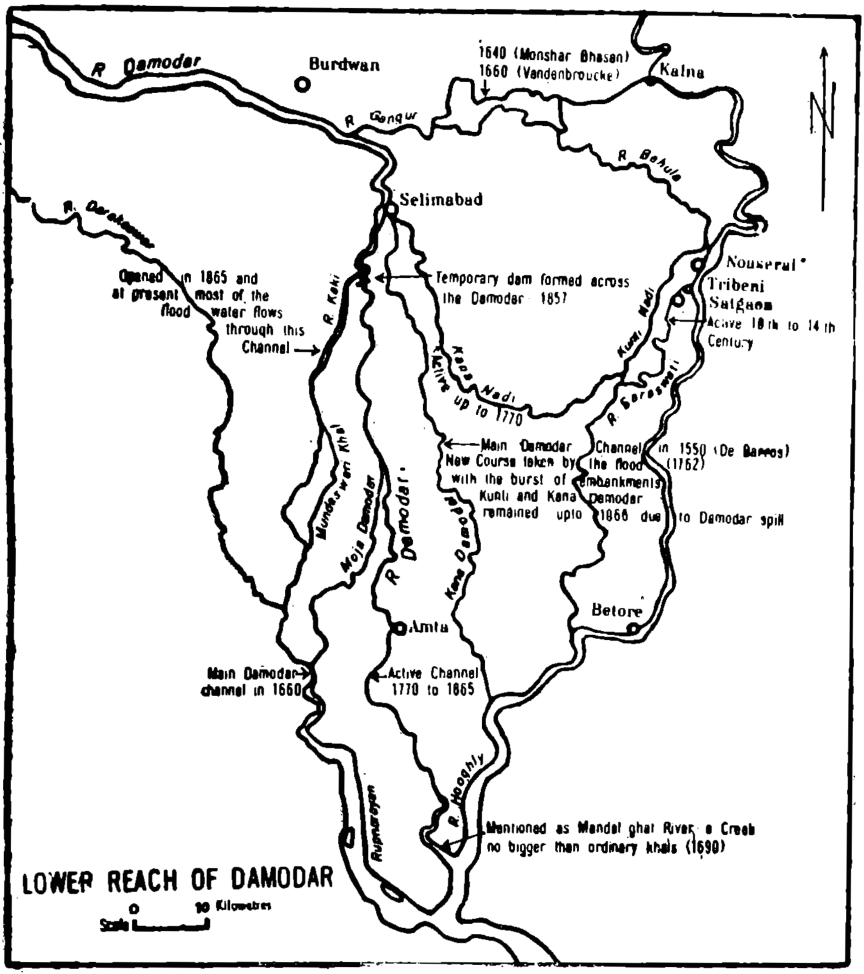
R Damodar
Burdwan
1640 (Monshar Bhasan)
1660 (Vandenbroucke)
Kalna
R Gangur
R Bahula
Selimabad
Opened in 1865 and at present most of the flood water flows through this Channel
Temporary dam formed across the Damodar 1857
Kunti Nadi
Kana Nadi
Active up to 1770
Tribeni
Satgaon
Active 10th to 14th Century
R Saraswati
Main Damodar Channel in 1550 (De Barros) (1762)
New Course taken by the flood with the burst of embankments Kunti and Kana Damodar remained upto 1866 due to Damodar spill
Mundeswari Khal
Moja Damodar
R Damodar
Kana Damodar
Betore
Amta
Main Damodar channel in 1660
Active Channel 1770 to 1865
R Hooghly
Rupnarayan
Mentioned as Mandal ghat River, a Creek no bigger than ordinary khals (1690)
LOWER REACH OF DAMODAR
0 10 Kilometres
Scale

Figure 4.

CHAPTER XIV

NEW LIGHT ON THE SOURCES OF THE FOUR GREAT RIVERS OF THE HOLY KAILAS AND MANASAROWAR

"No Pundit had succeeded in penetrating to the source and the one who advanced nearest to it, namely, to a point 48 km from it had been attacked by robbers and forced to turn back........Thanks to those admirable robbers, the discovery of the Indus source was reserved for me and my five Ladakhis..........".

"I revelled in the consciousness that except the Tibetans themselves, no other human beings but myself had penetrated to this spot........ Not without pride but still with a feelings of humble thankfulness. I stood there, conscious that I was the first white man who has ever penetrated to the source of the Indus and Brahmaputra"[1]. Thus declared Dr. Sven Hedin in 1908 in his "*Trans-Himalaya*". Since then, every geographer had believed that Hedin's was the last word on the subject of 'The sources of the Four Great Rivers of the Holy Kailas and Manasarowar'. Thirty years had elapsed before it fell to the lot of an humble Indian Swami, in the person of the author, to find out certain serious discrepancies and errors in the findings of Sven Hedin. Herein lies the explanation for the present paper.

The Kangri Karchhak—the Tibetan *Kailasa Purana* (literally guide) says that the Ganga had at first descended from Kailas to the spring Chhu-mik-thungtol and that four rivers emerged out of this spring and entered copper pipes to pass through the Lake Manas. Of these : (1) the Ganga went first eastwards and thence came out of the elephant-mouth (Langchhen Khambab[2], the Elephant-mouthed river, or the Sutlej) near Dulchu Gompa on the west and proceeded to Chhemo Ganga Gyagar (India) ; (2) the Sindu went northwards at first and came out of the peacock-mouth (Mapcha or Mapjya Khambab, the peacock-mouthed river or the Karnali) at Mapcha-Chaungo on the south in Lankapuring and proceeded westwards to Sinduyul ; (3) the Pakshu or Vakshu went westwards in the beginning and thence came out of the horse-mouth (Tamchok or Tachhog Khambab, horse-mouthed river, or the Brahmaputra) from a mountain in Chema-yungdung on the east, going to Chang (Tashi-Lhunpo) and thence to Kamarupa in India, where it is called Lohita ; and (4) the Sita went southwards at first and thence emerged from the lion-mouth (Sengge Khambab, lion-mouthed river, or the Indus) from a mountain called Senge, situated on the north of Kailas going to Baltichen and Changhor.

According to Tibetan traditions and scriptures, the source of the Sutlej is in the springs near Dulchu or Dunchu Gompa, about 48 km west of Manasarowar, or in the Rakas Tal, for all practical purposes from a layman's point of view. The genetic source is in the Kanglung glaciers, about 48 km east of Manasarowar. The source of the Indus is in the springs of Sengge Khambab, northeast of Kailas, about 100 km from Manasarowar ; of the Brahmaputra, in the Chema-yungdung glaciers, about 150 km southeast of Manasarowar ; and of the Karnali, in the springs of Mapcha-Chungo, about 48 km southeast of Manasarowar, the genetic source being in the Lampiya pass. The sources of these four rivers are within a distance of about 72 km (as the crow flies) from the shores of the Holy Lake.

There had long been a controversy over the sources of these rivers till matters were taken to have been set at rest by Dr. Sven Hedin's verdict in 1907-1908. I had the good fortune of travelling in western Tibet 33 times on a visit to the Holy Kailas and Manasarowar or, where the sources of these rivers are situated, by various routes in different seasons of the year.

At the very outset, I would like to raise the important question as to how the source of a particular river is to be fixed. If the river in question happens to have more than one headstream, which of them is to be considered the main river ? Is it decided by the volume of water that it brings down or by the length of the particular headstream, or is the source to be located according to the traditions of the local people ? If all the three factors are simultaneously to be taken into consideration, it would be impossible to locate the sources of these and other Himalayan rivers, inasmuch as none of the headstreams fulfils all the three conditions. If all the three conditions are not fulfilled, which of them should be given the greatest weight and why ?

SOURCE OF THE BRAHMAPUTRA

According to Tibetan traditions, the source of the Brahmaputra lies not in the Kubi glaciers, as claimed by Sven Hedin, but in the Chema-yungdung glaciers. While locating the sources of the Indus and the Sutlej, he tries to refer to Tibetan traditions in support of his findings, although he had not faithfully adhered to them even in finally fixing the source of the Sutlej. But, unfortunately, all the quotations which he cites are from Chinese geographers and not even a single direct reference is made to any Tibetan work. Inspite of the fact that none of the Chinese geographers has even mentioned the name of Kubi, Sven Hedin persists in making the Kubi the principal branch of the Tamchok Khambab or Brahmaputra.

We ought not to attach greater significance to the Chinese geographers than to the Tibetans themselves on matters of Tibetan geography. Some of of the Chinese geographers themselves placed the source of the Brahmaputra in the Chema-yungdung.

Sven Hedin's own remarks are : "We have seen that some of the Chinese writers make the Chema the principal branch, coming from Tamchok-Kabab ; others say that Chema is only a tributary joining Kubi. In all instances, both western and eastern, the Kubi-Tsangpo has, however, been almost ignored. The Chinese authorities do not mention its name".[3] Sven Hedin gives a vague quotation from the '*Elements of Hydrography*', by the Chinese Professor Chi Chao Nan (1762), which runs thus : "Langchen-Kabab (mountain) lies southeast of Kailas. On the east of this mountain stands the Tamchok-Kabab mountain which is the source of Tamchok-Kabab or the Brahmaputra."[4] Even this single quotation gives more support to my own findings than to those of Sven Hedin, because the Chema-yungdung glaciers are east of, and nearer to, the Kanglung Kangri glaciers (the source of the Tag), whereas the Kubi Kangri glaciers (where Sven Hedin places the sources of the Brahmaputra) are on the southeast of Kanglung glaciers, and not on the east), as has been mentioned by the Chinese Professor, whose authority Sven Hedin cites in his support. A monument (called Tamchok Khambab Chhorten) at the source of the Brahmaputra near the Chema-yungdung glaciers, was shown to me by my Tibetan guide, and this agrees with the Tibetan tradition about the source of this river.

Regarding the source of the Brahmaputra, Sven Hedin writes : "No other traveller had ever been in this region, and I would on no account miss the opportunity of penetrating the actual source of the Brahmaputra and fixing its position definitely. First of all, I must, of course, gauge the quantities of water in the source streams."[5] He thought he would be able to investigate the sources of the Sutlej and the Indus also on the same basis by measuring the quantities of water, as in the case of the Brahmaputra, but in this he failed and was forced to fall back on the Tibetan tradition to support his findings. He had neither time nor choice to fix the sources of the Indus and the Sutlej after duly measuring the quantities of water which the different headwaters discharge and then to proceed to the head of the biggest of them.

Sven Hedin would have served the cause of truth better if he had frankly admitted the difficulties of deciding upon suitable and consistent criteria for fixing the sources of these rivers instead of struggling desperately for achieving the covetted honour of being their first discoverer. By giving preference to the quantity of water in the case of the Brahmaputra, to tradition in the case of the Indus, and length (combined with far-fetched tradition again) in the case of Sutlej, he did not hesitate to discard a consistent, reasonable, and uniform procedure.

The following lines, from Sven Hedin, will speak for themselves regarding the hollowness of his arguments and the way in which he begs the question : "I cannot, however, judge in this case, as I never went up to the sources of the Chema-yungdung-chu..........This problem will have to be solved in future and the very source of the Chema-yungdung, even if well known by certain Tibetan tribes, has not yet been discovered."[6] "The Chema-yungdung seems to be a few miles longer than the Kubi. So in length and absolute height, the western branch (Chema-yungdung) is no doubt more distinguished than the eastern (Kubi). But the volume of water is overwhelming in the latter.........."[7]. However, in fixing the sources of the Sutlej and the Indus, he gives no place or consideration to volume of water. Can anybody pronounce such findings to be scientific ?

The Chinese geographer Chi Chao Nan (1762), the Chinese maps of the Ta-ch'ing (1744), the Chinese Civil Officer Kloproth (1840), D'Anville (1733), Lloyd Gerard, Henry Strachey (1846), Nain Singh (1866), Graham Sandberg (1964), Major Ryder (1904), and others located the source of the Brahmaputra in the Chema-yungdung (from the information obtained through the Tibetans) and made the Kubi a tributary to the Chema. In spite of the fact that the Chema-yungdung is the traditional source of the Brahmaputra and is better distinguished by its length and absolute height than the Kubi. Sven Hedin overlooked all these points and gave preference to the test of volume of water and put the source in the Kubi glaciers. As opposed to this, in fixing the sources of the Sutlej and the Indus he paid no heed to the volume of water.

It may be interesting to note here that the lower course of the river Chema-yungdung is also called Nartsang Tsangpo or the Tamchok Khambab even much above Shamsang, where the Kubi joins the Chema. This goes to prove that the Chema-yungdung is traditionally the principal headstream of the Brahmaputra.

On a close observation of Sven Hedin's map we note that he gives the Tibetan names of only three sub-glaciers of the Kubi Kangri group but not of the Brahmaputra glacier itself. Brahmaputra is the Indian name and not the Tibetan. Why should he omit to give the Tibetan name of Brahmaputra glacier when he does so in the case of the Sutlej and the Indus ? The Tibetan name would have given us a clue as to whether the Tibetans really consider that to be the source of the Tamchok Khambab *Ta*-horse, *amchok*-ears, *khambab*-coming from the mouth of. So, the meaning of the word 'Tamchok Khambab', is 'horse-ears-mouthed or 'celestial horse-mouthed'[8] river. The sources of the four great rivers are located by the Tibetans in certain springs to which they attribute the appearance of the mouths of various animals just as the Hindus call the source of the Ganga, Gaumukh or 'cow-mouth'. There are two glaciers called Chema-yungdung-pu and the Tamchok Khambab Kangri with a broad-faced peak separating them. The monument or the shrine is situated on the left bank of the Brahmaputra (where it is called Chema-yungdung Chhu) between these two glaciers, opposite the broad faced peak. There is a dry spring nearby, which is said to contain water in summer and in the rainy season. The two glaciers are the two ears, and the spring near the boulder is the mouth. Both these glaciers together go by the general name Chema-yungdung-pu, or simply Chema-yungdung. The distance between these two glaciers is about two to three kilometres.

SOURCE OF THE SUTLEJ

About 8 km down Tirthapuri, at Palkya, a river called Langchhen Tsangpo (the same name as that of the Tirthapuri branch coming from the Rakas Tal) joins the Sutlej. The Chhinaku, Guni-yankti, Darma-yankti, and the Gyanima branch join together to form the river Langchhen Tsangpo. The Guni-yankti and the Darma-yankti taken individually, carry more water than the Tag Tsangpo where it falls into the Manasarowar ; of these two rivers, the Darma-yankti, taken individually, also often carries more water than the Tirthapuri branch. So if the quantity of water is taken into account, the source of the Darma-yankti should be the source of the Sutlej ; that is, it is in the Zaskar range near Darma pass.

Sven Hedin says : "But if we are to move the source from one point to another according to the volume of either streams we may as well give up the problem as unsolvable. Reckoned from the source of the Tag Tsangpo the Tirthapuri branch is the longest."[9] Here he brings into consideration the length of the river and local traditions, which points he overlooked in the case of the Brahmaputra, where he lays the whole stress on the quantity of water. If the quantity of water is taken into consideration, the source of the famous Ganga cannot be placed at Gaumukh but should be located at the Mana pass, inasmuch as the river Alaknanda, which takes its rise there, is twice as big as the Bhagirathi at Devaprayag, where these two rivers meet. Dr. Longstaff also says that the volume of water in the Langchhen Tsangpo is greater than in the Tirthapuri branch.

Going further up Tirthapuri, we have the stream Trokposhar which carried 27 cubic metres of water per second whereas the Dulchu branch (Sutlej) carried only 18 cubic metres of water in the year 1908. If we take the quantity of water into consideration, the source of the Sutlej could as well be located at the head of the stream Trokposhar. In fixing the sources of the Brahmaputra, Sven Hedin gives preference to the Kubi over the Chema-yungdung as the Kubi happened to be 3·5 times as large as the Chema when he took the measurements ; but in the case of the

Sutlej he rejects this consideration, even though the affluent Chukta was 50 times as large as the sourcestream of the Sutlej.

Sven Hedin further writes : "If we compare the two branches (Tirthapuri and Langchhen Tsangpo) and ask which of them should be reckoned as the original source of the Sutlej, I would give this honour to the one which has the longest course and comes from the highest and most extensive glaciers,"[10] From this, one can very well judge how Sven Hedin loses all sense of proportion in applying a uniform procedure in fixing the source of these rivers belonging to the same region.

SOURCE OF THE INDUS

About the source of the Indus, Sven Hedin writes : "At this point the situation which has been discussed and searched for during some two thousand years, the famous Singi Kamba or Indus is born. But the infant river which is a mere brook, is much shorter than both the Lungdep and the Munjam........in fact and strictly hydrographically the Singi Kamba is only a right or northern tributary to the Bokhar Tsangpo, which itself is only a very insignificant brook. Compared with the latter, both Lungdep and Munjam have a greater quantity of water and may be somewhat larger than Bokhar. From a hydrographic point of view it may be said to be a matter of taste which of these different brooks should be regarded as the principal source of the Indus. The question is of no great consequence, for whichever branch should be chosen, its source is situated at a short day's march from the Singi Kabab. The problem cannot be settled in any more satisfactory way than to accept Tibetan view and regard the Singi Kabab as the source of the Indus, inspite of its being the shortest and one of the smallest of the several source branches."[11]

So, Sven Hedin had neither choice nor time to fix the source of the Indus after duly measuring the quantity of water which the different headstreams discharged and than proceed to the head of the biggest of them. Besides other things, he did not like to spend much time at the Sengge Khambab in measuring the water in the different headstreams, because he was not certain as to which of the streams—the Sengge or the Gartong—would carry more water, since he had yet to make the actual measurements. Instead of first measuring the velocity of the two rivers, the Sengge Khambab and the Gartong at their confluence, and then going up the Sengge Khambab to find out the sources of the Indus. Sven Hedin first fixed the sources of the Indus in the Singge Khambab springs and then went down to measure the quantity of water in the Gartong. It was an accidental coincidence that the Sengge Khambab carried more water than the Gartong at that time, namely early winter. But as a matter of fact the Gartong oftentimes carries greater quantity of water for greater part of the year than the Sengge Khambab itself.

Sven Hedin himself writes : "The spring floods consequent on the melting of snow is also greater in Gartong..........we may consider it probable that the Gartong carries during the whole year more water than the Singi-Kamba but we have at least discovered that the Singi-Kamba is a large stream, when no disturbing influences are at work, when there is no precipitation and when the temperature in the two river basins may be considered identical,"[12] but the conditions mentioned in the above passage are very rarely fulfilled.

So, if the quantity of water be taken into account, the source of the Indus should be at the head of Gartong river. Coming back to the Sengge Khambab, of the different sourcestreams of the Indus—the Tsethi chhu, the Lungdhep chhu, the Munjam chhu, and the Bokhar chhu, into which the tiny brook of the Sengge Khambab springs flow, the Lungdhep chhu carries most water and is the longest of all the streams and as such its source, which is in the Topchhen la, should be considered the source of the Indus, on the basis of the quantity of water. But if the Tibetan traditions are taken into account, the source of the Indus would be in the springs of the Sengge Khambab, which Sven Hedin also accepted.

SOURCE OF THE KARNALI

The source of the Mapchu Khambab, the fourth of the series of the four great rivers, is at the Mapcha-Chungo springs, 37 km—west of Taklakot, and the genetic source is near the Lampiya pass. Some explorers have placed the source of the Karnali in the Rakas Tal, because one of its headstreams, the Gurla chhu, has its source in the glaciers on the northwestern slopes of the Gurla Mandhata peak, southeast of the Gurla pass. This Gurla chhu flows into the Karnali, a little more than a kilometre down near the village of Kardung. Those who go to Kailas by the Lipu Lekh pass and Taklakot cross this stream at the southern foot of the Gurla pass. There is another small stream which has its source on the southeastern side of the Gurla pass (not very far from where Gurla chhu takes its rise) but flows to the northern side of the Gurla pass into Rakas Tal. The Gurla chhu is a big stream, whereas the other stream is a very small one. Those who did not trace the courses of the two streams closely, confused them and placed the source of the Karnali (Mapcha Khambab) either in Rakas Tal or in the Gurla Mandhata. The Gurla chhu is much smaller than the Map chhu proper. Moreover, the traditional spring—source Mapcha-Chungo is on the Map chhu, which is the longest as well as the biggest headwater of the Karnali ; so the glacial source of the Karnali is near the Lampiya pass in the Zaskar range.

It may be noted that the combined river of the Kali, coming from the Lipu Lekh pass and the Saraju coming from the Nandakot, is called Sarda from Tanakpur downwards. The Karnali coming from Mapcha-Chungo, after its mountainous course in Manasa Khanda and

Nepal, is called Ghaghara, which receives the Sarda at Chouka Ghat. From Chouka Ghat till it falls into the Ganga, down Chapra, the combined river is known by both the names, Ghaghara and Saraju. I make a mention of this fact here, because some people believe that the river Saraju takes its rise from Manasarowar.

CONCLUSIONS

TRADITIONAL SOURCES

If Tibetan traditions are taken into account in fixing the sources of the rivers under discussion, the source of the Sutlej (Langchhen Khambab) is in the springs near Dulchu gompa, about 35 km west of Parkha ; that of the Indus (Sengge Khambab) is in the springs of Sengge Khambab north-east of Kailas, 85 km from Parkha ; the source of the Brahmaputra (Tamchok Khambab) is at the head of the Chema-yungdung at the Tamchok Khambab Chhorten, 148 km from Parkha ; and that of the Karnali (Mapeh Khambab) is in the spring Mapcha-Chungo, about 36 km northwest of Taklakot.

It will not be out of place if I quote here a few lines from the Journal of the Royal Geographical Society, London, February, 1939, from the pen of Dr. T. G. Longstaff. "I am in full agreement with Swami Pranavananda in accepting the traditional sources of the four rivers...... it savours of impertinence for Europeans to assert their views against the usage of other civilizations."

One cannot object to the genetic sources of these rivers being traced with our 'dislocating' the traditional places of tampering with the religious, susceptibilities and usages of the local people concerned. Thus, without 'dislocating' the traditional sources, we can trace the genetic source of the Sutlej either to the Lhe la or Tsethi la (48 km from Parkha), the head of the Lha chhu (according to the quantity of water), or to the Kanglung Kangri glaciers (about 104 km from Parkha) at the head of the Tag Tsangpo (according to length). So also the genetic source of the Brahmaputra can be taken to the Chema-yungdung Kangri glaciers (or Tamchok Khambab Kangri glaciers), about 2 km up the Tamchok Khambab Chhorten ; and the genetic source of the Karnali to the Lampiya pass (two short days' journey from the traditional source, Mapcha-Chungo), both in respect of length and volume of water. Then, in the case of all these three rivers—the Sutlej. Brahmaputra, and Karnali—the sources would be glacial. But, in the case of the Indus, if we want to go to the genetic source, without disturbing the traditional source, it would be at the head of Bokhar Chhu or near the Lama la (a short day's march from the springs of the Sengge Khambab) neither of which is glacial. Moreover, the Bokhar chhu is neither the biggest nor the longest of the headstreams of the Sengge.

SOURCES ACCORDING TO QUANTITY OF WATER

Should the quantity of water be the criterion, then the source of the Sutlej is near the Darma pass (four days' journey from Dulchu gompa) at the head of the river Darma-yankti ; the source of the Indus is near the Topchhan la (42 km from Parkha) at the head of the Lungdhep chhu or at the head of Gartong ; the source of the Brahmaputra is in the Kubi glaciers ; at the head of the Kubi river (three or four short days' march from the Chema-yungdung glaciers) ; and the source of the Karnali is near the Lampiya pass (two short days' march from the spring, Mapcha-Chungo). When volume is taken into consideration, the sources are all glacial. Except in the case of the Karnali, the traditional sources of all the other three rivers are dislodged. According to volume, the source of the Sutlej may also be either at the head of the Trokpo-shar chhu. or at the head of the Chukta chhu or at the head of the Lha chhu, as already discussed.

SOURCES ACCORDING TO LENGTH

Should length be the test, the source of the Sutlej would be in the Kanglung Kangri but the Samo Tsangpo might be given due consideration. The source of the Indus would be near the Topchhan la at the head of the Lungdhep chhu ; the source of the Brahmaputra in the Chema-yungdung or Tamchok Khambab Kangri glaciers at the head of the river Chema-yungdung or at the head of the Angsi chhu in Angsi glacier, and the source of the Karnali, near the Lampiya pass. When length is taken as the test, the traditional sources of three rivers—the Sutlej, Brahmaputra and Karnali—remain intact and that of the Indus alone is disturbed ; but the sources of all the rivers remain glacial.

Sven Hedin's source of the Sutlej, in the Kanglung Kangri, of the Indus in the springs of the Sengge Khambab, and of the Brahmaputra in the Kubi glaciers, would not satisfy any one of the above three criteria (tradition, volume, or length, in its entirety), a position which assails his claims of being "the first white man and European" to discover the sources of these rivers finally.

SOURCE OF THE GANGA

For several generations the Ganga was confused with the river Sutlej and described as taking its rise from Manasarowar and Kailas—which is far from the truth. Hindu *Puranas*, Isbrants Ides (1704), Desideri (1715), Father Gaubil (1729), D'Anville (1732), Anquetil du Perron (1770), Tieffanthler, Purangir (1773), Major Rennel (1782), Puranpuri (1792), Captain Wilford (1800), Webber (1866), Ekai Kawaguchi (1903), Holdich (1904), Sarat Chandra Das and a host of other tourists and Hindu pilgrims had either confounded the river Ganga with the river Sutlej or described the Ganga taking its rise from Manasarowar and Kailas. The said confusion and the wrong findings were due to :

(i) the Indian name of the Sutlej as given in the Tibetan *Purana* is "Ganga" ; (ii) that the outlet of the Manasarowar into Rakas Tal is called "Ganga Chhu" (Ganga river) in Tibetan ; (iii) pilgrims to Kailas and Manasarowar cross the Ganga chhu and think that it is the famous river Ganga ; (iv) one of the headstreams of the Ganga, the Alaknanda, is supposed to take its rise in the two small glacial lakelets Rakas Tal and Deo Tal at the Mana pass. But the actual source of the Ganga is at Gaumukh, about 21 km beyond Gangotri ; and Manasarowar is about 225 km from Gaumukh, as the crow flies."[13]

SELECTED BIBLOGRAPHY.

1. Sven Hedin, 'Trans-Himalaya' vol. II, pp. 212-214.
2. '*Bab*' in Tibetan means descend from and *Kha* means the mouth of ; hence *Khabab* or *Khambab* means descending from or coming from out of the mouth of.
3. Sven Hedin, 'Southern Tibet' Vol. I, p. 118.
4. 'Trans-Himalaya', Vol. II, p. 183.
5. 'Southern Tibet', Vol. II, p. 140.
6. 'Op. cit., Vol. II, p. 248.
7. Op. cit., p. 264.
8. The word *Tamchok* or *Tachhog* also means best or celestial horse.
9. 'Trans-Himalaya', Vol. III, p. 221.
10. 'Southern Tibet, 'Vol. II, p. 77.
11. Op. cit. Vol. II, p. 213.
12. 'Trans-Himalaya', Vol. III, pp. 45, 46.
13. Swami Pranavananda, 'Exploration in Tibet', published by the University of Calcutta.

CHAPTER XV

MONSOON AND RAINFALL PATTERN IN THE INDIAN SUB-CONTINENT

INTRODUCTION

The Indian sub-continent* is indeed unique in having for its northern boundary the tallest and most extensive mountain system of the world, viz., the Himalaya. This formidable mountain barrier obstructs the moisture laden winds from the south causing them to shed their moisture as copious rain along the sub-montane regions to the north of the Indo-Gangetic plains and as snowfall in the mountain ranges. The Himalaya also protects India from the entry of the extremely cold winds from the north temperate and the polar regions. Again, peninsular India, flanked by the Arabian sea on the west and by the Bay of Bengal on the east and abutting into the vast Indian Ocean to the south, has the Western Ghats along its west coast and the less conspicuous Eastern Ghats along the east coast. Fig. 1, brings out strikingly these orographic features as well as the resulting river systems watering and draining the country and finding their way into the adjoining seas.

The Indus and the Gangetic river systems are perennial, fed as they are both by the intense rainfall in their lower catchments and by the melting snows over their upper catchment areas in the Himalaya. The rivers of the Peninsula are, on the other hand, are rainfed and so are seasonal in their flow, tending to dry up during the rainless months of the year.

NORMAL RAINFALL OVER THE SUB-CONTINENT

Fig. 2, shows the distribution of the normal (i.e. average of large number of years) rainfall over the Indian sub-continent. The areas of very heavy rainfall up to 2,500 mm or more annually are to the windward side of the Western Ghats and the hills of Assam, while along the sub-Himalayan ranges the precipitation may go up to 1,875 mm or so. These are the watersheds from which originate the major river systems of the sub-continent. Elsewhere, in the plateau of the Deccan, in the Ganga plain of North India and the plains of Madras State the effect of orography are less pronounced or are completely absent and the annual rainfall is only moderate. The Northwest, the desert regions of Rajasthan and adjoining areas in Pakistan constitute the driest areas of the sub-continent.

* As past climatic data are readily available as a uniform series for the sub-divisions of undivided India, we shall discuss the rainfall pattern of the entire Indian sub-continent.

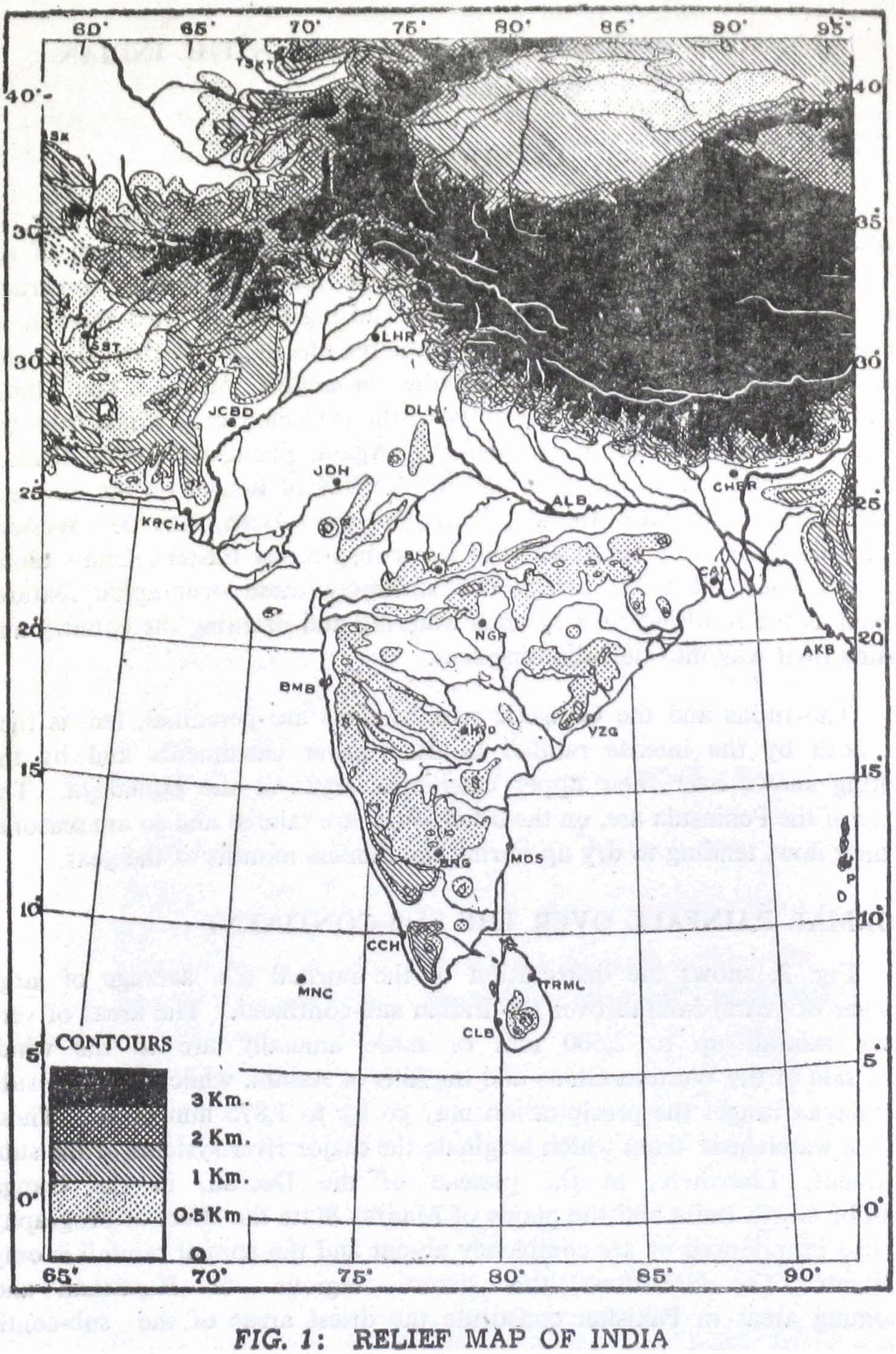

FIG. 1: RELIEF MAP OF INDIA

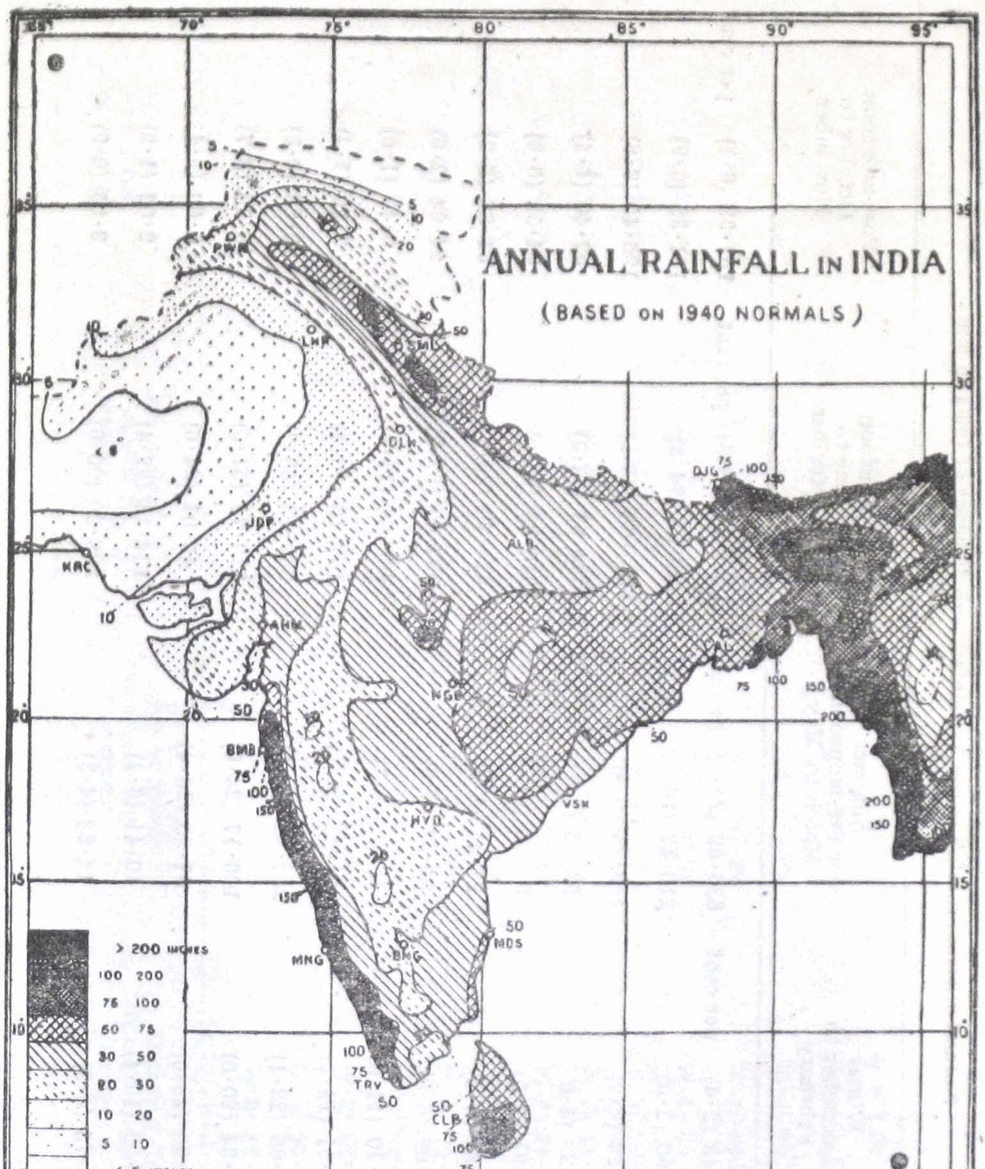
ANNUAL RAINFALL IN INDIA
(BASED ON 1940 NORMALS)
> 200 INCHES
100 200
75 100
50 75
30 50
20 30
10 20
5 10
< 5 INCHES
PWR
LHR
SML
DLH
JDP
KRC
AHM
BMB
NGP
ALD
DJG
VSK
HYD
MDS
BNG
MNG
TRV
CLB
65°
70°
75°
80°
85°
90°
95°

Figure 2

TABLE 1

Normal seasonal rainfall in the 30 rainfall sub-divisions of India in mm

Sub-division	Winter December to February	Summer or Pre-monsoon March to May	Monsoon June to September	Post-monsoon October to November	Annual
1. Assam ..	60·45 (2·4) per cent	636·52 (25·7) per cent	1632·20 (65·8) per cent	151·38 (6·1) per cent	2480·55
2. Bengal ..	38·86 (2·0)	315·47 (16·5)	1422·65 (74·5)	131·32 (6·9)	1908·30
3. Orissa ..	46·23 (3·2)	142·75 (9·9)	1130·05 (78·2)	126·49 (8·8)	1445·52
4. Chotanagpur ..	65·28 (5·0)	92·46 (7·1)	1084·83 (83·4)	57·40 (4·4)	1299·98
5. Bihar ..	35·81 (2·9)	83·82 (6·8)	1040·38 (85·0)	64·52 (5·3)	1224·53
6. U. P. East ..	38·86 (3·9)	28·45 (2·9)	874·78 (88·0)	51·82 (5·2)	993·91
7. U. P. West ..	57·66 (6·0)	34·54 (3·6)	837·69 (87·8)	24·64 (2·6)	954·53
8. Punjab, E. & N.	70·10 (11·9)	48·01 (8·1)	463·04 (78·4)	9·40 (1·6)	590·55
9. Punjab, SW ..	32·51 (13·7)	34·54 (14·5)	167·13 (70·4)	3·30 (1·4)	237·48
10. Kashmir ..	231·65 (22·1)	230·89 (22·0)	563·63 (53·7)	23·88 (2·3)	1050·05
11. N. W. F. P. ..	85·34 (20·0)	106·17 (24·9)	219·71 (51·5)	15·75 (3·7)	426·96
12. Baluchistan ..	88·90 (45·6)	51·56 (26·4)	48·01 (24·6)	6·60 (3·4)	195·07
13. Sind ..	17·02 (10·4)	10·41 (6·4)	134·11 (82·4)	2·03 (1·2)	163·57
14. Rajputana, W. ..	15·75 (4·8)	14·22 (4·3)	298·20 (90·0)	3·05 (0·9)	331·22

	Sub-division	Winter December to February	Summer or Pre-monsoon March to May	Monsoon June to September	Post-monsoon October to November	Annual
15.	Rajputana, E. ..	24·38 (3·8)	19·81 (3·1)	581·91 (90·9)	13·97 (2·2)	640·07
16.	Gujarat ..	5·59 (0·7)	6·10 (0·7)	799·08 (96·2)	19·56 (2·4)	830·33
17.	C. India, West ..	21·59 (2·5)	11·94 (1·4)	801·62 (93·8)	19·05 (2·2)	854·20
18.	C. India, East ..	36·58 (3·7)	20·07 (2·0)	890·27 (90·9)	33·02 (3·4)	979·94
19.	Berar ..	25·65 (3·1)	24·38 (3·0)	713·74 (87·4)	52·58 (6·4)	816·35
20.	C. P. West ..	37·34 (3·2)	28·96(2·5)	1042·42 (90·4)	44·70 (3·9)	1153·42
21.	C. P. East ..	40·13 (3·0)	53·34 (4·0)	1177·80 (89·1)	50·55 (3·8)	1321·82
22.	Konkan ..	7·11 (0·3)	46·99 (1·7)	2602·23 (93·7)	120·65 (4·3)	2776·97
23.	Bombay Deccan	12·95 (1·7)	54·10 (6·9)	620·01 (79·1)	97·03 (12·4)	784·10
24.	Hyderabad, N. ..	17·02 (1·9)	38·86 (4·4)	749·55 (84·5)	81·28 (9·2)	886·71
25.	Hyderabad, S. ..	14·48 (1·9)	53·34 (7·0)	593·85 (78·1)	98·55 (13·0)	760·22
26.	Mysore ..	18·54 (2·0)	138·94 (15·2)	565·66 (61·8)	37·72 (20·9)	914·66
27.	Malabar ..	69·34 (2·6)	320·29 (12·2)	1815·34 (68·9)	430·02 (16·3)	2634·99
28.	Madras, SE. ..	120·90 (13·6)	115·06 (12·9)	305·05 (34·2)	350·52 (39·3)	891·53
29.	Madras, Deccan	18·80 (3·0)	61·47 (9·9)	387·86 (62·3)	2·29 (24·8)	622·82
30.	Madras, Coast N.	42·93 (4·2)	87·38 (8·9)	635·76 (62·3)	254·00 (24·9)	1020·07

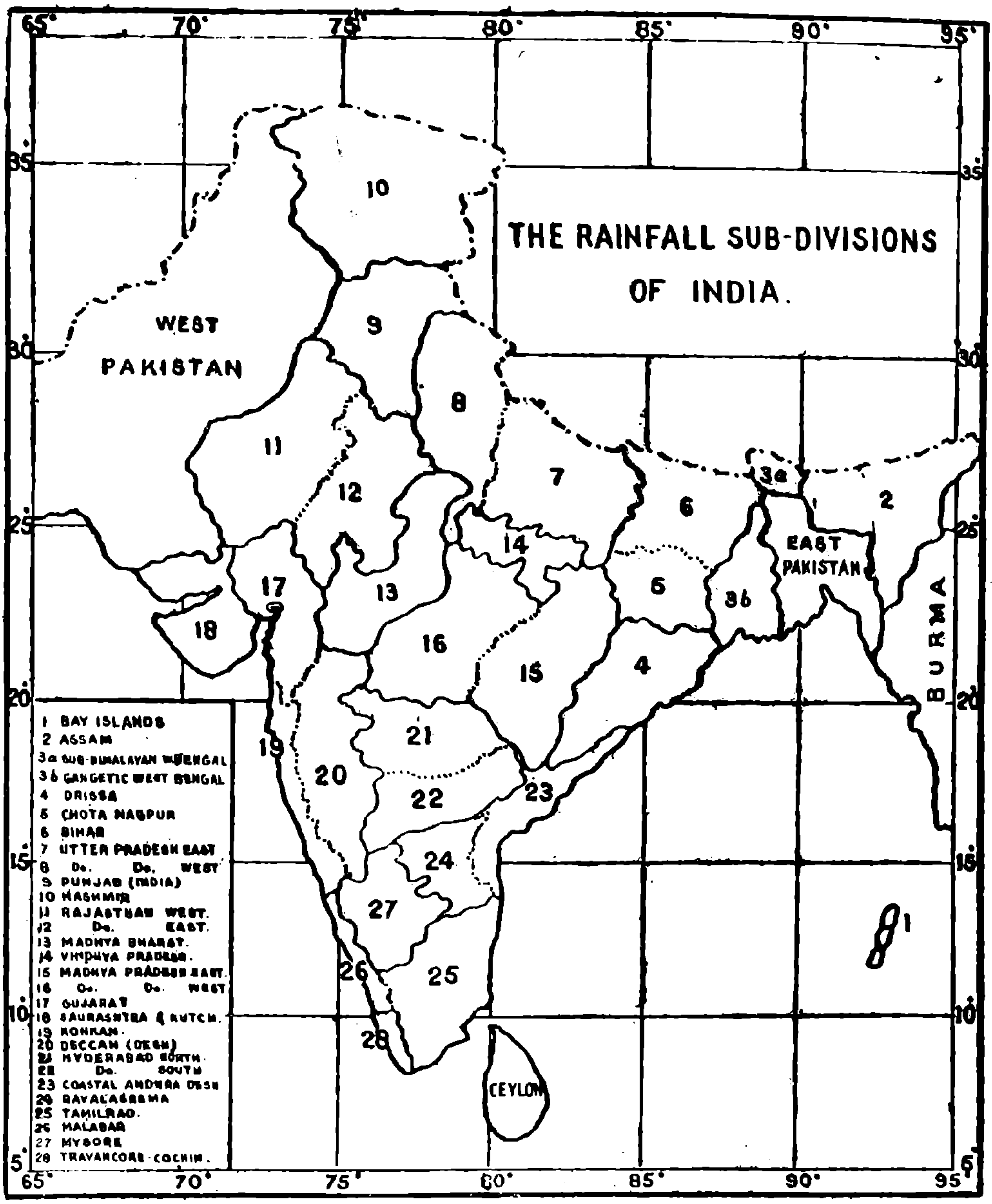
THE RAINFALL SUB-DIVISIONS OF INDIA.
WEST PAKISTAN
EAST PAKISTAN
BURMA
CEYLON
65° 70° 75° 80° 85° 90° 95°
35 30 25 20 15 10 5
1 BAY ISLANDS
2 ASSAM
3a SUB-HIMALAYAN W. BENGAL
3b GANGETIC WEST BENGAL
4 ORISSA
5 CHOTA NAGPUR
6 BIHAR
7 UTTER PRADESH EAST
8 Do. Do. WEST
9 PUNJAB (INDIA)
10 KASHMIR
11 RAJASTHAN WEST.
12 Do. EAST.
13 MADHYA BHARAT.
15 MADHYA PRADESH EAST.
16 Do. Do. WEST
17 GUJARAT
18 SAURASHTRA & KUTCH.
19 KONKAN.
20 DECCAN (DESH)
21 HYDERABAD NORTH.
22 Do. SOUTH
23 COASTAL ANDHRA DESH
25 TAMILNAD.
26 MALABAR
27 MYSORE
28 TRAVANCORE-COCHIN.

Figure 3.

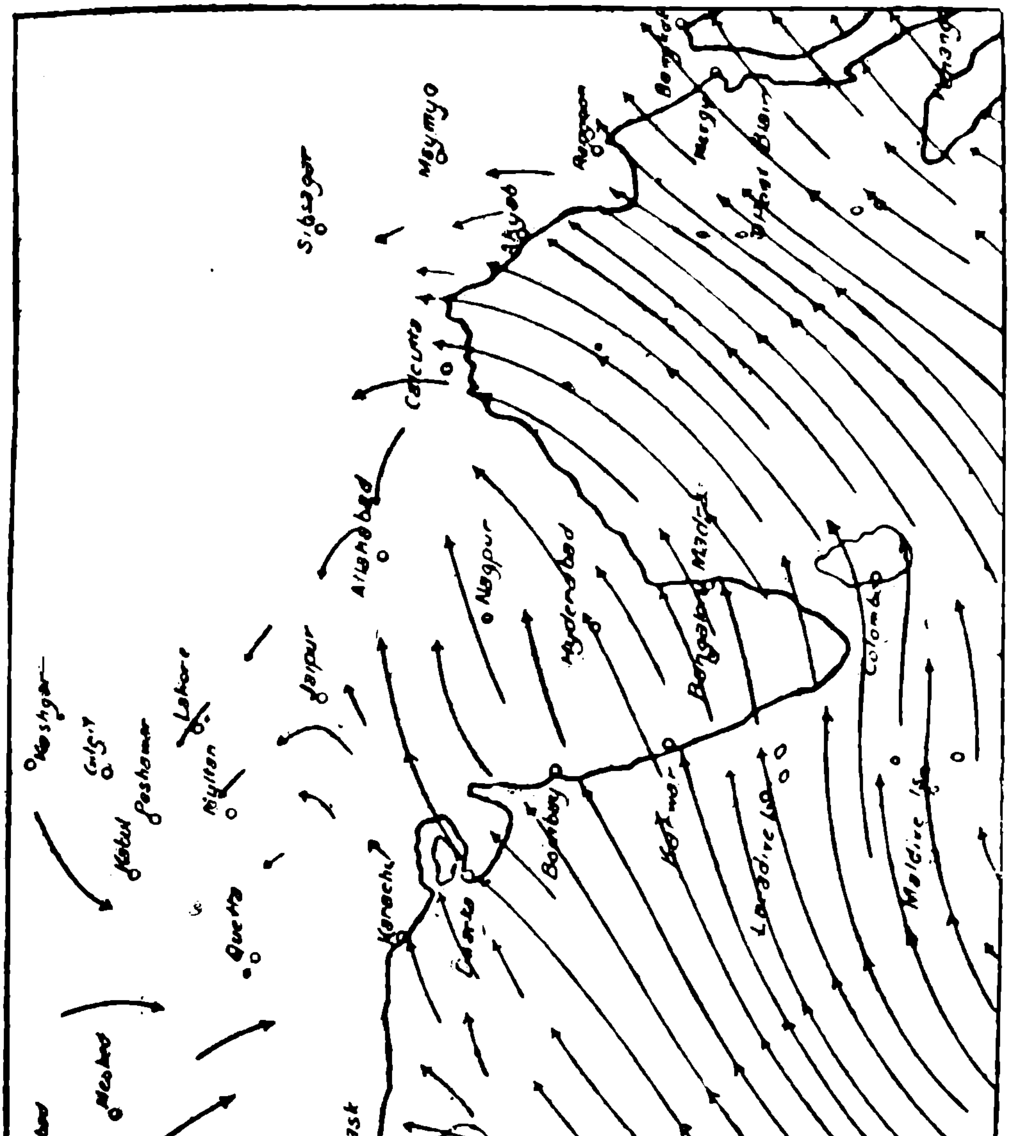
Calcutta
Nagpur
Bombay
Karachi
Jaipur
Lahore
Multan
Kabul
Peshawar
Quetta
Maymyo
Colombo
Maldive Is.
Jask
Muscat

Figure 4.

Table 1, gives the normal rainfall in different seasons of the year, and during the year as a whole in the 30 rainfall sub-divisions of the sub-continent, as they existed during the period before the partition of the country (Fig. 3). The four seasons are as below.

Winter	..	.. December to February
Summer or pre-monsoon		.. March to May
S. W. monsoon	..	.. June to September
Post-monsoon	..	.. October to November

In columns (2) to (5) the figures within brackets are the seasonal amounts expressed as percentages of the annual rainfall.

The information presented in table 1 reveals at once that India is truly the land of the monsoons, for, with the exception of Kashmir, Baluchistan, the North West Frontier Province in the north and southeast Madras in the south, a very large percentage of the annual rainfall over the sub-continent occurs during the southwest monsoon season (June to September). In the extreme north a good part of the annual rainfall occurs during the winter, while in southeast Madras nearly half the annual rainfall occurs during the post southwest monsoon or the northeast monsoon period, i.e., after September.

Besides the major monsoon phenomenon which grips the entire country from June to September, we have also to consider other weather phenomena of relatively shorter duration, but often quite violent in their nature, like the cyclonic storms and depressions which help to bring about an equitable distribution of rainfall (non-orographic) in the interior of the sub-continent. We shall refer to these after looking more closely into the vagaries of the monsoon which plays such a major role in determining the annual prosperity of the Indian sub-continent.

THE SOUTH WEST MONSOON

For a brief summary of the dynamics of the Indian monsoon, reference may be made to the classical article on the subject by G. C. Simpson (Quarterly Journal of the Royal Meteorological Society, Vol. XLVII, No. 199, July 1921). The vast amount of upper air data collected since the publication of the above article and the recent survey conducted by the International Indian Ocean expedition have only confirmed the main conclusions of Simpson. These emphasizes the supreme role played by the favourable distribution of the mountains over the country in shaping the pattern of the wind circulation over the country (see Fig. 4, which shows the mean air flow during July). The important role played by (i) the general pressure distribution over Asia in summer ; and (ii) the building up of the main monsoon current from the southeasterly trades crossing over the equator and turning into the southwesterlies over the southeast Arabian Sea and the Bay of Bengal has been stressed by Simpson. The intense precipitation due to the uplifting of these moist air currents when they meet the Western Ghats of Peninsular India, the Arakan Yomas of the Burmese coast and when, after further deflection eastwards, these currents ultimately meet the Himalaya of North India, is another important feature of the monsoon. We shall now examine some of the important characteristics of the rainfall during this season.

DATE OF ESTABLISHMENT

As is well known, the success of agriculture in the sub-continent depends mainly on the timeliness and the seasonal and geographical distribution of the monsoon rains. The farmers most anxiously look forward to the onset of the monsoon. The characteristics of the monson rainfall have been discussed in various publications of the Indian Meteorological Department. Fig. 5 and 6, show the normal dates of onset and withdrawal, respectively, of the monsoon in different parts of the subcontinent. Fig. 5, shows how, after its onset along the west coasts of Peninsular India and Arakan coasts by the 1st of June, the monsoon normally enters inland rapidly and has the whole country right up to North Western India in its grip by the middle of July. By the beginning of September the monsoon begins to retreat from the Indus valley and is well out of North India by the middle of October. Its further retreat southwards through the southern regions of the peninsula during the months of November and December is associated with what is known as the "retreating monsoon" or the "northeast monsoon" which gives the major rainfall of the year to these southern regions.

While Figures 5 and 6 shows only the normal dates of onset and withdrawal, it must be realised that the normal duration of the monsoon as well as the distribution in time and space, of the monsoon precipitation vary from year to year. Table 2 gives the actual dates of establishment of the southwest monsoon in four areas along the west coast of the peninsula for the years 1891 to 1943. It will be seen from Table 2, that there is considerable variation not only as regards the dates of establishment but also in the speed with which the monsoon current moves from the Kerala area in the south towards Kolaba to the north near Bombay. Table 3, summarises the main features of the previous table. During the series of more than 50 years considered the monsoon has been as early as May 7 in the disastrous year of 1918 and as late as June 10 in the year 1935 in arriving at Kerala. The over-all variability is indicated by the standard deviations given in the 3rd column of Table 3, which is of the order 7 days in above area decreasing to about 5 days in Kolaba.

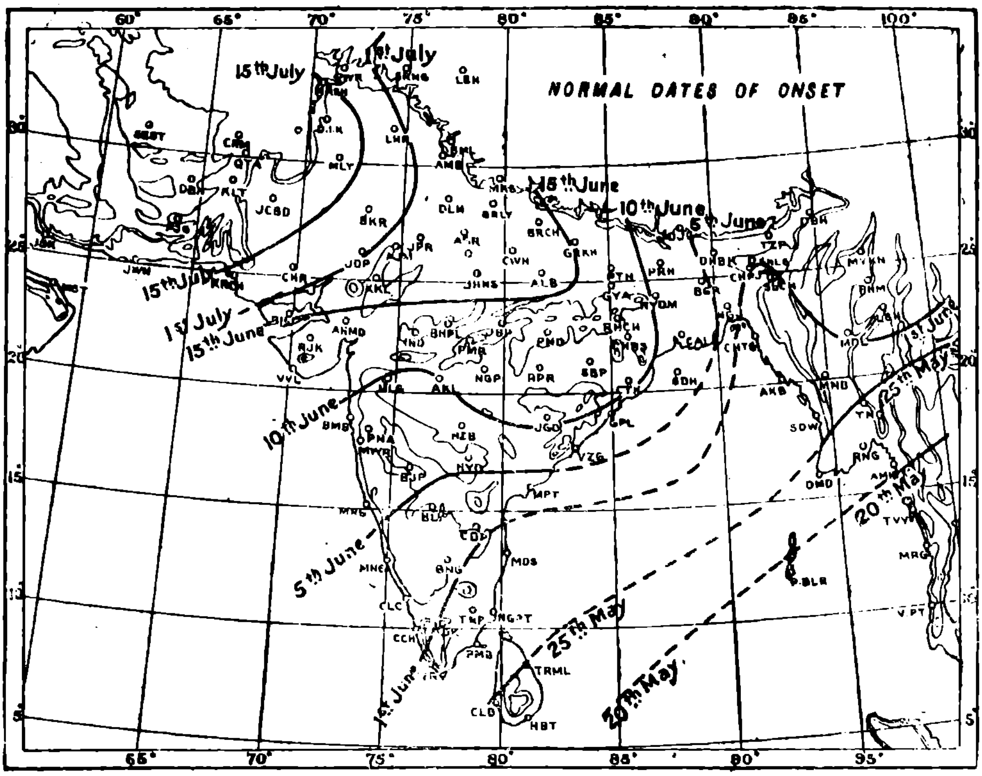

Figure 5.

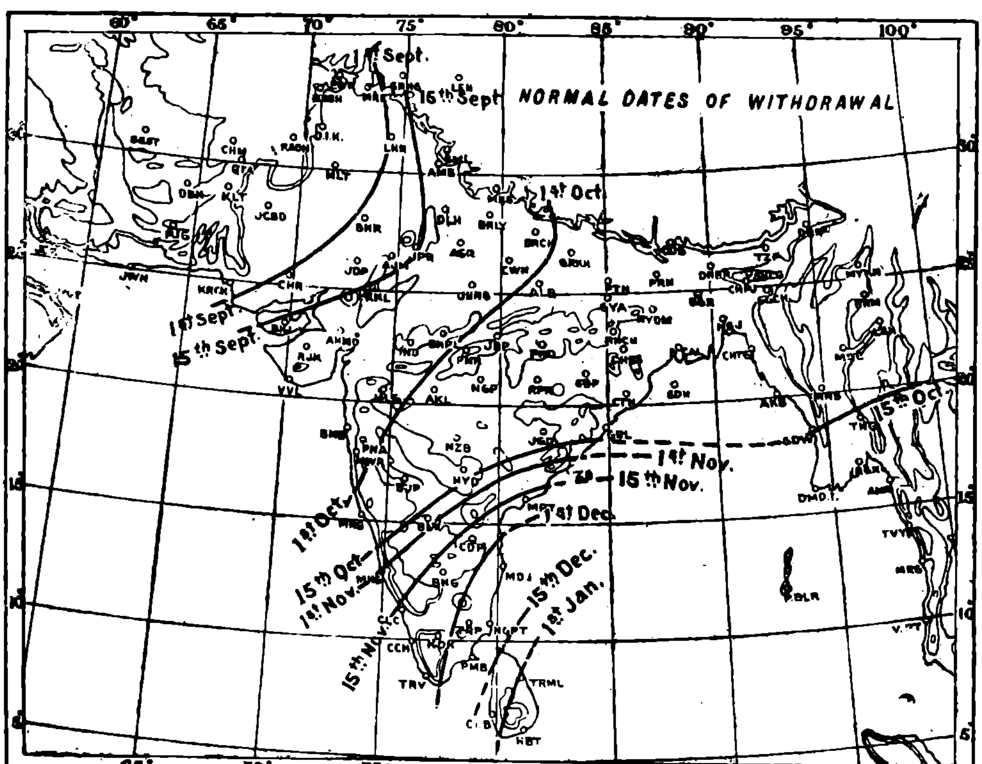

Figure 6.

TABLE 2

Date of establishment of the S. W. monsoon along the West Coast of India

Year	Travancore-Cochin	S. Kanara	Ratanagiri	Kolaba
1891	May 27	June 3	June 19	June 21
1892	May 22	May 24	May 29	May 31
1893	May 22	June 4	June 10	June 10
1894	June 1	June 2	June 7	June 7
1895	June 8	June 12	June 14	June 15
1896	May 30	May 31	June 1	June 1
1897	May 30	June 5	June 7	June 7
1898	June 2	June 3	June 8	June 8
1899	May 23	June 7	June 9	June 10
1900	June 6	June 8	June 9	June 9
1901	June 1	June 4	June 7	June 7
1902	May 31	June 6	June 7	June 12
1903	June 8	June 11	June 12	June 12
1904	May 29	June 1	June 7	June 8
1905	June 6	June 8	June 9	June 10
1906	June 3	June 6	June 7	June 8
1907	May 31	June 5	June 11	June 11
1908	June 8	June 10	June 11	June 11
1909	June 1	June 2	June 3	June 3
1910	May 28	June 2	June 3	June 3
1911	June 1	June 2	June 4	June 4
1912	June 4	June 6	June 12	June 12
1913	May 24	June 1	June 6	June 7
1914	May 28	June 5	June 13	June 13
1915	June 3	June 12	June 17	June 18
1916	May 26	May 27	May 31	June 1
1917	May 26	May 29	June 4	June 5

Table 2—Contd.

Year	Travancore-Cochin	S. Kanara	Ratanagiri	Kolaba
1918	May 7	May 15	May 22	May 25
1919	May 16	May 26	June 4	June 6
1920	May 27	June 2	June 6	June 6
1921	June 1	June 3	June 10	June 12
1922	May 25	May 31	June 10	June 12
1923	June 4	June 11	June 12	June 13
1924	May 31	June 3	June 10	June 12
1925	May 27	May 28	May 29	May 29
1926	May 28	June 5	June 9	June 10
1927	May 23	May 27	June 10	June 10
1928	May 31	May 31	June 5	June 7
1929	May 29	May 30	June 1	June 6
1930	May 21	June 7	June 8	June 9
1931	May 23	May 29	June 14	June 14
1932	May 14	June 2	June 3	June 3
1933	May 22	May 28	June 1	June 1
1934	June 6	June 6	June 10	June 10
1935	June 10	June 10	June 12	June 14
1936	May 20	May 22	May 29	June 1
1937	June 3	June 10	June 11	June 12
1938	June 1	June 2	June 2	June 4
1939	June 6	June 6	June 7	June 9
1940	June 7	June 13	June 16	June 18
1941	May 23	June 3	June 14	June 16
1942	June 4	June 8	June 12	June 13
1943	May 12	May 14	May 21	May 21

TABLE 3

Mean features of the dates of establishment of the S. W. Monsoon along the west coast of the Peninsula

Area	Mean date	Standard deviation in days	Earliest date	Latest date
Kerala	May 29	7·0	May 7	June 10
South Kanara	June 3	5·7	May 15	June 12
Ratnagiri	June 7	5·4	May 22	June 19
Kolaba	June 8	5·2	May 25	June 21

HOW THE SOUTH-WEST MONSOON HAS BEHAVED DURING THE YEAR 1875—1951

Fig. 7, has been prepared to show at a glance how the monsoon has actually behaved in a series of 77 years, from 1875 to 1951 in each of the 30 rainfall sub-divisions of the Indian sub-continent. The diagram brings out vividly, the major abnormalities and the areas and years of their occurrence, while suppressing all details.

In preparing the above diagram, we have considered the total monsoon rainfall during June to September in each of the 30 rainfall sub-divisions for each of the years under review. If the actual rainfall in a year and for a particular sub-division is in excess of the normal by more than twice the mean deviation, that year is defined as a year of Flood (solid circle). If on the other hand the actual rainfall happens to be below the normal by more than twice the mean deviation, that year is defined as a year of drought (open circle). In fig. 7, the series of years from 1875 to 1951 are given vertically, while horizontally we have indicated the 30 rainfall sub-divisions. The blank spaces in the diagram represent the years and the sub-divisions when the actual rainfall has been more or less normal, that is within the limits for abnormality (twice the mean deviation) referred to above. A careful study of this diagram will reveal many valuable view point for guidance in future planning.

Taking the diagram as a whole, one finds that the largest number of abnormalities of floods and droughts occurs in areas of scanty rainfall, like northwest India, and Rajasthan. Areas of heavy rainfall like Malabar, Konkan, West Bengal and Assam have the least number of abnormalities.

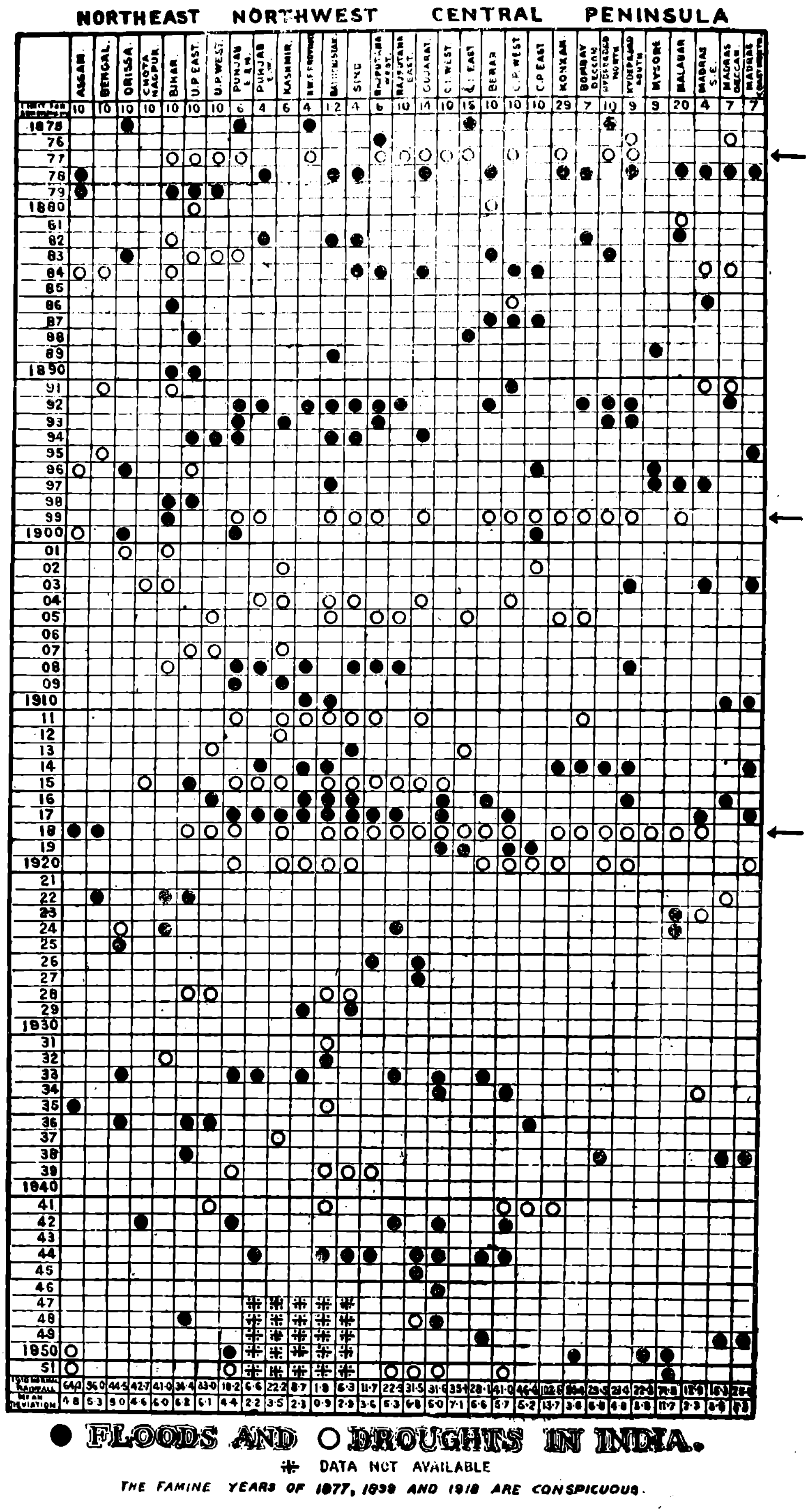
NORTHEAST NORTHWEST CENTRAL PENINSULA
ASSAM
BENGAL
ORISSA
CHOTA NAGPUR
BIHAR
U.P. EAST
U.P. WEST
PUNJAB E & N.
PUNJAB S.W.
KASHMIR
N.W.F. PROVINCE
BALUCHISTAN
SIND
RAJPUTANA WEST
RAJPUTANA EAST
GUJARAT
C.I. WEST
C.I. EAST
BERAR
C.P. WEST
C.P. EAST
KONKAN
BOMBAY DECCAN
HYDERABAD NORTH
HYDERABAD SOUTH
MYSORE
MALABAR
MADRAS S.E.
MADRAS DECCAN
MADRAS COAST NORTH
FLOODS AND DROUGHTS IN INDIA.
DATA NOT AVAILABLE
THE FAMINE YEARS OF 1877, 1899 AND 1918 ARE CONSPICUOUS.

Figure 7

DROUGHTS

Looking more carefully year by year one finds that droughts have occurred over the largest number of sub-divisions in the years 1877, 1899 and 1918. Such countrywide droughts were indeed the years when the country was struck by unprecedented famines. Such nationwide calamity may be expected to occur once every twenty years.

Years when only some zones of the sub-continent were affected by droughts, as in 1920, may occur more frequently, say 4 or 5 times in a spell of 20 years. The rest of the years may be having 1, 2 or 3 sub-divisions only affected by droughts and may be reckoned as more or less normal. There have been nearly 38 years out of 77, when the entire sub-continent was free from drought as defined in the present paper.

FLOODS

Almost countrywide floods have occurred in the years 1878, 1892 and 1917. Here again there is a likelihood of such wide-spread floods, only once in twenty years. There may be 6 to 7 years out of 20, when only parts of the country are affected by excessive rains.

The remaining 12 to 13 years out of every 20, will therefore be almost or entirely free from floods. From fig. 7, it will be seen that 23 years out of 77 have been entirely free from floods, as defined in the present paper.

It may be mentioned that in regard to the sequence of severe flood and drought years there is no kind of regular periodicity and so predictions of their country-wide occurrence cannot be made long in advance. It is extremely unlikely that one year of country-wide drought will be succeeded by a similar year, though as in 1965 and 1966 the monsoon rains failed badly in sub-divisions like eastern U. P. and Bihar, causing the present intense scarcity of food in those areas.

However, in two instances at least,, as in 1877 and 1878 and later in 1917 and 1918, one year of general drought and another of general flood have occured in adjacent years.

In many years, while some parts of the country have been suffering from drought some other areas have had floods. There have been very few years indeed when the whole sub-continent was entirely free from abnormality, i.e., with neither flood nor drought. Such years are the 1885, 1906, 1921, 1930, 1940, 1943 and 1947, i.e., seven in a series of 77 years.

In concluding this section on floods and droughts, referring to the entire monsoon rainfall of the year, it seems obvious that areas of good rainfall and successful crop production will have to come to the aid of the less fortunate zones of the sub-continent. Also, the large number of good years should make possible the saving of some part of the crop out-turn for use in the famine years. Indeed, modern facilities for quick transport enable parts of the world where food production is in excess in a year to rush aid to nations which suffer from crop failure.

RAINFALL IN INDIA WEEK BY WEEK DURING THE YEAR

We may now turn to the problem of rainfall distribution week by week during the year. For this purpose we use the rainfall data published regularly in the weekly weather reports of the India Meteorological Department. The present author has devised a method for presenting the normal and the actual weekly rainfall week by week for all the 30 rainfall sub-divisions of the sub-continent of India in a single chart. Against each sub-division for each week two entries are made. The upper figure gives the actual while the lower figure gives the normal weekly rainfall. As the rainfall of a week has a highly skew frequency distribution, for making out the abnormalities, the following criteria were found useful. Weeks with the actual rainfall equal to or more than twice the normal weekly rainfall have been defined as floods, while weeks with the actual rainfall equal to or less than half the normal have been defined as droughts.

The ideal year will be one in which there are no droughts or floods. Successful crop production depends not only on the total seasonal rainfall, but also on the proper distribution of the rainfall in time and space. Even a sub-normal rainfall may, if well distributed, produce a good yield. The incidence of some spells of drought and of flood is expected in most years. In many years only short spells of drought and flood alternate without materially affecting the total rainfall of the season. Once in about 5, 10, or 20 years, however, depending on the area concerned, the drought or flood spell extends over a number of consecutive weeks ; such prolonged spells, particularly at the critical stages of crops cause wide-spread damage.

Charts thus prepared for a series of 42 years (1908 to 1950) confirm that the method of presentation adopted by the present writer does bring out satisfactorily the major rainfall abnormalities in each year. From these 42 charts diagrams have been prepared showing the normal, drought and flood spells in respect of each sub-division for all years. As examples of such sub-division-wise charts, we reproduce here the charts for Assam (Fig. 8) and for Gujarat (Fig. 9). These are typical, respectively, of N.E. India where the wet season is longest and the rains are most dependable and of the arid zone of India where the rains are most erratic and the

RAINFALL OF ASSAM WEEK BY WEEK.

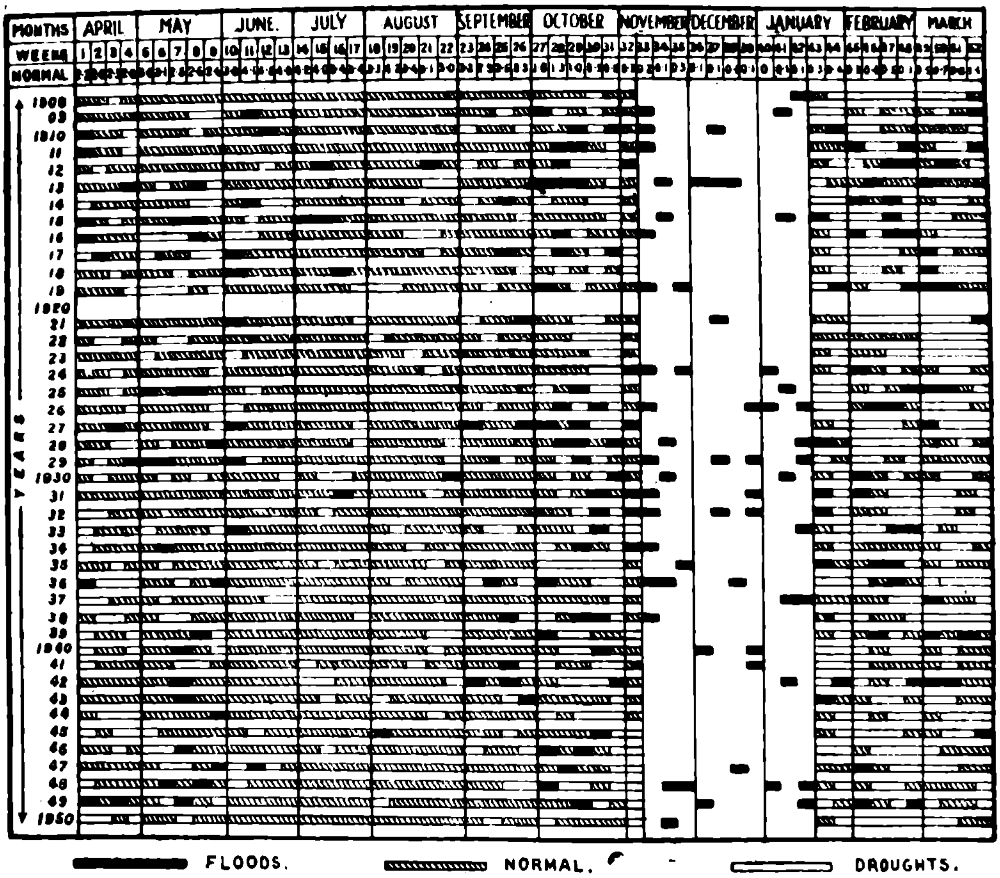

Figure 8.

RAINFALL OF GUJARAT WEEK BY WEEK.

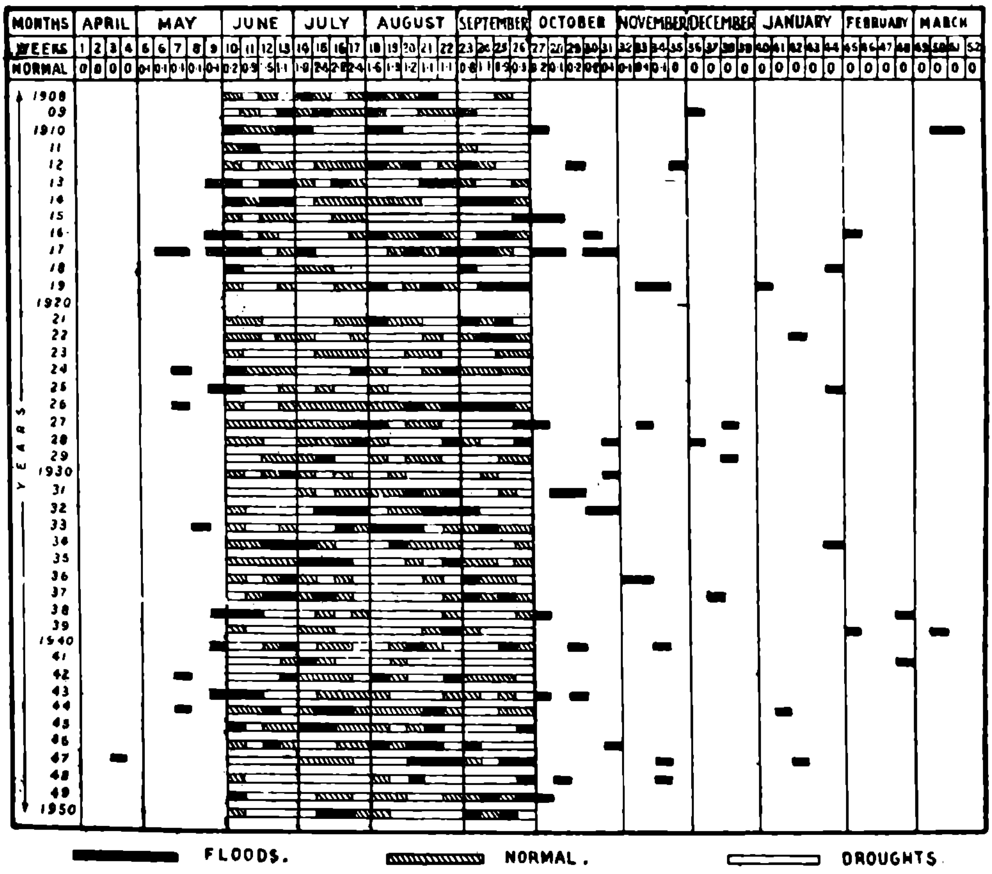

Figure 9.

normal wet season is also short. The entire set of 30 diagrams have been published and discussed in a paper by T.S. Govindaswamy (Irrigation & Power Journal) Vol. X, Nos. 2 & 3, April & July, 1953). The main features shown by these charts are summarised in Table : 4. A study of Table 4 reveals the following general conclusions regarding the week by week rainfall, year by year, in the different sub-divisions of the Indian sub-continent :—

(a) The duration of the wet season in any area (column 4) generally increases with the normal annual rainfall (column 2).

(b) The percentage of normal spells (column 5) also has a tendency to increase in areas of higher normal annual rainfall (column 2) ; these spells are longer and more frequent in wet areas like N.E. India and Malabar.

(c) The percentage of flood spells (column 8) appears to decrease with the annual rainfall. In other words, flood, as we have defined it, appears to occur more frequently in areas of sporadic and small normal rainfall.

(d) Similarly, the percentage of drought spells, as defined (i.e., actual rainfall $< \frac{1}{2}$ the normal rainfall), also decreases with increase of the normal annual rainfall. That is, the frequency as well as the duration of drought spells is likely to be greater in areas of low rainfall than in areas of high rainfall.

(e) In columns (6) and (7), the occasions of exceptionally long normal spells have been mentioned. Thus, in Assam, in the year 1908, an unusually long spell of normal rainfall lasted as long as 26 consecutive weeks.

Continuous spells of flood seldom exceed 5 weeks anywhere on the sub-continent. Occasions when they were 3, 4 or 5 weeks continuously have been mentioned in columns (9) and (10).

Continuous spells of drought rarely extend over more than 9 weeks. Occasions when they were as long as 5, 6, 7, 8, 9 or 10 weeks, depending on the sub-division concerned, are mentioned in columns (12) and (13).

In concluding this section on week by week rainfall during each year, it may be noted that the general features referred to above are generally consistent with the indications of abnormality in the total monsoon rainfall already referred to in Fig. 7. The detailed picture week by week is also helpful in judging the integrated effect of the weather up to any particular date during the agricultural growing season and for planning for the rest of the season. Those interestetd in long term planning will also find such charts extremely useful in estimating the liability to abnormal spells of each of the subdivisions of the country.

TABLE 4 : **Main features revealed by the 30 sub-divisional charts of rainfall abnormalities of week by week rainfall during the year 1908-1950**

Sub-division	Normal Annual Rainfall in mm	Duration of wet season : weeks with normal rainfall > 5 mm	No. of weeks of wet season	Percentage of Normal weeks, irrespective of duration of spell	Normal Spells: Exceptional spells of long duration — Year	Normal Spells: Exceptional spells of long duration — Duration in weeks	Percentage of Flood weeks, irrespective of duration of spell	Flood Spells: Exceptional spells of long duration — Year	Flood Spells: Exceptional spells of long duration — Duration in weeks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Assam	2540	3rd week of January to 1st week of November.	42	66·5	1908 .. .. 1911, 1937, 1950 ..	26 > 15	9·7	Never exceeded 3 weeks	..
2. Bengal	1778	2nd week of February to 1st week of November.	39	61·0	1916, 1921, 1937 ..	> 15	10·0	1912, 1937, 1949 ..	4
3. Orissa	1473	1st week of February to 3rd week of November.	42	48·0	1911, 1921, 1936, 1948	> 9	14·1	1936 ..	6
4. Chotanagpur ..	1372	(i) May to October .. (ii) February to mid-March ..	27 6	50·5	1919, 1936, 1939, 1949	> 10	13·3	1912, 1917 1930, ..	4 to 5
5. Bihar	1245	Last week of April to 4th week of October.	27	53·7	1916, 1924, 1934, 1946	> 8	10·5	1916, 1946 ..	3
6. Uttar Pradesh-E ..	1016	Last week of May to 4th week of October.	22	53·6	1916, 1924, 1926, 1939	7 to 10	12·0	1916, 1938 ..	3
7. Uttar Pradesh-W ..	965	(i) 1st week of June to 2nd week of October. (ii) 3rd week of January to 3rd of February	19 6	44·1	13 times in 42 years ..	> 7	15·0	1916, 1947 ..	4
8. Punjab E & N ..	584	(i) 2nd week of June to 1st week of October. (ii) 1st week of January to mid-March.	18 11	37·6	Never exceeded 8 weeks	..	16·1	Twice in 1947 ..	4
9. Punjab S-W ..	254	2nd week of June to 3rd week of September.	15	39·9	Never exceeded 6 weeks	..	17·1	1908 ..	4
10. Kashmir	1016	1st week of December to 3rd week of September.	41	45·6	1934	10	14·6	1908, 1941 ..	4
11. N. W. Frontier Province	381	(i) July-August .. .. (ii) 3rd week of January to 3rd week of April.	9 14	34·5	1925	6	17·0	1910, 1922, 1932, 1942	4
12. Baluchistan	178	(i) 2nd week of July to 3rd week of August. (ii) 2nd week of January to end of March.	6 12	51·3	13 times in 41 years ..	6	18·5	1913 ..	4
13. Sind	152	3rd week of June to 4th week of August.	10	31·9	1909, 1943, 1944 ..	4	16·2	1910, 1934, 1944 ..	3

TABLE 4 : Main features revealed by the 30 sub-divisional charts of rainfall abnormalities of week by week rainfall during the year 1908-1950

Normal Annual Rainfall in mm	Duration of wet season : weeks with normal rainfall > 5 mm	No. of weeks of wet season	Percentage of Normal weeks, irrespective of duration of spell	Normal Spells — Exceptional spells of long duration: Year	Normal Spells — Exceptional spells of long duration: Duration in weeks	Percentage of Flood weeks, irrespective of duration of spell	Flood Spells — Exceptional spells of long duration: Year	Flood Spells — Exceptional spells of long duration: Duration in weeks	Percentage of Drought weeks, irrespective of duration of spell	Drought Spells — Exceptional spells of long duration: Year	Drought Spells — Exceptional spells of long duration: Duration in weeks
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
2540	3rd week of January to 1st week of November.	42	66·5	1908 .. .. 1911, 1937, 1950 ..	26 > 15	9·7	Never exceeded 3 weeks	..	23·8	1908, 1921, 1923, 1950	> 5
1778	2nd week of February to 1st week of November.	39	61·0	1916, 1921, 1937 ..	> 15	10·0	1912, 1937, 1949 ..	4	29·0	1908, 1921, 1937 ..	> 5
1473	1st week of February to 3rd week of November.	42	48·0	1911, 1921, 1936, 1948	> 9	14·1	1936 ..	6	37·9	1914, 1918, 1926, 1927, 1935, 1937.	> 6
1372	(i) May to October .. (ii) February to mid-March ..	27 6	50·5	1919, 1936, 1939, 1949	> 10	13·3	1912, 1917 1930, ..	4 to 5	36·2	1918, 1924, 1926, 1930, 1950.	> 5
1245	Last week of April to 4th week of October.	27	53·7	1916, 1924, 1934, 1946	> 8	10·5	1916, 1946 ..	3	35·8	1914, 1925, 1931, 1935	> 5
1016	Last week of May to 4th week of October.	22	53·6	1916, 1924, 1926, 1939	7 to 10	12·0	1916, 1938 ..	3	34·4	1913, 1918 ..	> 5
965	(i) 1st week of June to 2nd week of October. (ii) 3rd week of January to 3rd of February	19 6	44·1	13 times in 42 years ..	> 7	15·0	1916, 1947 ..	4	40·9	1911, 1913 ..	6 to 8
584	(i) 2nd week of June to 1st week of October. (ii) 1st week of January to mid-March.	18 11	37·6	Never exceeded 8 weeks	..	16·1	Twice in 1947 ..	4	46·3	14 times in 41 years ..	> 5
254	2nd week of June to 3rd week of September.	15	39·9	Never exceeded 6 weeks	..	17·1	1908 ..	4	43·0	1939 ..	7
1016	1st week of December to 3rd week of September.	41	45·6	1934	10	14·6	1908, 1941 ..	4	39·8	1909, 1939, 1945, 1946	> 6
381	(i) July-August .. .. (ii) 3rd week of January to 3rd week of April.	9 14	34·5	1925	6	17·0	1910, 1922, 1932, 1942	4	48·5	1911, 1915, 1946, 1947, 1949.	> 6
178	(i) 2nd week of July to 3rd week of August. (ii) 2nd week of January to end of March.	6 12	51·3	13 times in 41 years ..	6	18·5	1913 ..	4	30·2	1944, 1947, 1948 ..	> 5
152	3rd week of June to 4th week of August.	10	31·9	1909, 1943, 1944 ..	4	16·2	1910, 1934, 1944 ..	3	51·9	1947 13 times in 41 years ..	8 > 3

[Continued

Sub-division		Normal Annual Rainfall in mm	Duration of wet season : weeks with normal rainfall> 5 mm	No. of weeks of wet season	Normal Spells			Floods Spell			Percentag of Drough weeks, irr pective o duration spell
					Percentage of Normal-weeks, irrespective of duration of spell	Exceptional spells of long duration		Percentage of weeks, irrespective of duration of spell	Exceptional spells of long duration		
						Year	Duration in weeks		Year	Duration in weeks	
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
14.	Rajasthan-W ..	279	2nd week of June to end of September.	16	26·9	1946 1914 ..	6 5	20·0	1917, 1944 ..	4	53·1
15.	Rajasthan-E	686	June to September ..	17	44·3	1926, 1944, 1948 ..	> 5	18·2	5 times in 42 years ..	3	37·5
16.	Gujarat	838	June to September ..	17	34·2	1926, 1927, 1914 ..	6 to 7	21·0	1917, 1926, 1932 ..	> 3	44·8
17.	Central India-W ..	965	Last week of May to 2nd week of October.	20	46·6	1913, 1921, 1922 ..	> 6	18·1	1916, 1917, 1946 ..	4	35·3
18.	Central India-E ..	1118	2nd week of June to 4th week of October.	20	46·8	1917, 1921 ..	7	11·5	Never exceeded ..	2	41·7
19.	Berar	889	Last week of May to 4th week of October.	22	36·4	1942	7	15·8	Never exceeded ..	3	47·8
20.	Central Provinces-W ..	1219	Last week of May to end of October.	23	52·7	20 times in 42 years ..	> 5	13·6	1917, 1931, 1936 ..	4	33·7
21.	Central Provinces-E ..	1422	2nd week of May to 1st week of November.	27	57·5	24 times in 42 years .. 1921	> 6 11	11·8	1925 ..	4	30·7
22.	Konkan	1820	4th week of May to 2nd week of November.	26	47·9	19 times in 42 years ..	6 to 10	14·6	1916 ..	4	37·5
23.	Bombay Deccan ..	838	4th week of May to 2nd week November.	26	44·2	11 times in 42 years ..	> 5	15·1	1952 .. 1916 ..	4 5	40·7
24.	Hyderabad-N ..	991	Last week of May to 1st week of November.	24	42·8	1931, 1948 ..	11	16·5	1927, 1928, 1934, 1943	4	40·7
25.	Hyderabad-S ..	787	2nd week of May to 2nd week of November.	28	47·4	1910, 1932	10	13·7	Never exceeded ..	3	38·9
26.	Mysore	914	2nd week of April to end of November.	34	43·9	14 times in 42 years ..	7	16·3	1932 ..	4	39·8
27.	Malabar	2743	April to December ..	39	51·8	14 times in 42 years .. 1912	8 14	15·7	1911, 1917, 1931 .. 1944	4 5	32·5
28.	Madras-S.E	940	3rd week of April to 2nd week of January.	39	46·3	1929 1939	18 10	13·2	1917, 1929, 1933, 1940	4	40·5
29.	Madras Deccan ..	610	2nd week of May to end of October.	30	35·2	5 times in 42 years ..	6	16·1	5 times in 42 years ..	4	48·7
30.	Madras Coast-N ..	991	2nd week of May to 2nd week of December.	32	48·1	1908, 1917, 1938 ..	8 to 12	13·7	1946 ..	4	38·2

Duration of wet season : weeks with normal rainfall> 5 mm	No. of weeks of wet season	Normal Spells: Percentage of Normal-weeks, irrespective of duration of spell	Normal Spells: Exceptional spells of long duration — Year	Normal Spells: Exceptional spells of long duration — Duration in weeks	Floods Spell: Percentage of weeks, irrespective of duration of spell	Floods Spell: Exceptional spells of long duration — Year	Floods Spell: Exceptional spells of long duration — Duration in weeks	Drought Spells: Percentage of Drought weeks, irrespective of duration of spell	Drought Spells: Exceptional spells of long duration — Year	Drought Spells: Exceptional spells of long duration — Duration in weeks
(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1 week of June to end of September.	16	26·9	1946 1914 ..	6 5	20·0	1917, 1944 ..	4	53·1	1911, 1915, 1918, 1925, 1939, 1947.	> 6
ie to September ..	17	44·3	1926, 1944, 1948 ..	> 5	18·2	5 times in 42 years ..	3	37·5	1918, 1930 ..	6 7
ie to September ..	17	34·2	1926, 1927, 1914 ..	6 to 7	21·0	1917, 1926, 1932 ..	> 3	44·8	1910, 1911, 1915, 1918, 1925, 1941, 1948.	> 7
st week of May to 2nd week of October.	20	46·6	1913, 1921, 1922 ..	> 6	18·1	1916, 1917, 1946 ..	4	35·3	4 times in 42 years in 1913	> 4 6
l week of June to 4th week of October.	20	46·8	1917, 1921 ..	7	11·5	Never exceeded ..	2	41·7	1913, 1918, 1929 ..	> 5
st week of May to 4th week of October.	22	36·4	1942	7	15·8	Never exceeded ..	3	47·8	8 times in 42 years in 1913.	> 5 8
st week of May to end of October.	23	52·7	20 times in 42 years ..	> 5	13·6	1917, 1931, 1936 ..	4	33·7	9 times in 42 years in 1912, 1939.	5 6
l week of May to 1st week of November.	27	57·5	24 times in 42 years .. 1921	> 6 11	11·8	1925 ..	4	30·7	1918 ..	7
week of May to 2nd week of November.	26	47·9	19 times in 42 years ..	6 to 10	14·6	1916 ..	4	37·5	1908, 1923, 1946, 1947	6
week of May to 2nd week November.	26	44·2	11 times in 42 years ..	> 5	15·1	1952 .. 1916 ..	4 5	40·7	1923, 1926, 1937, 1943	6
t week of May to 1st week November.	24	42·8	1931, 1948 ..	11	16·5	1927, 1928, 1934, 1943	4	40·7	1908, 1942 ..	6
week of May to 2nd week November.	28	47·4	1910, 1932	10	13·7	Never exceeded ..	3	38·9	1908, 1918, 1945 ..	6
week of April to end of ovember.	34	43·9	14 times in 42 years ..	7	16·3	1932 ..	4	39·8	1913 ..	8
il to December ..	39	51·8	14 times in 42 years .. 1912	8 14	15·7	1911, 1917, 1931 .. 1944	4 5	32·5	1917, 1923 .. 1947 ..	6 7
week of April to 2nd week January.	39	46·3	1929 1939	18 10	13·2	1917, 1929, 1933, 1940	4	40·5	1910, 1918, 1921, 1935, 1945 twice ..	1939 6 6 & 8
week of May to end of ctober.	30	35·2	5 times in 42 years ..	6	16·1	5 times in 42 years ..	4	48·7	1947 twice 8 times in 42 years 1913 ..	6 & 7 6 to 10 9
week of May to 2nd week December.	32	48·1	1908, 1917, 1938 ..	8 to 12	13·7	1946 ..	4	38·2	8 times in 42 years .. 1926 ..	6 to 10 10

Duration of wet season : weeks with normal rainfall> 5 mm	No. of weeks of wet season	Normal Spells			Floods Spell			Drought Spells		
		Percentage of Normal-weeks, irrespective of duration of spell	Exceptional spells of long duration		Percentage of weeks, irrespective of duration of spell	Exceptional spells of long duration		Percentage of Drought weeks, irrespective of duration of spell	Exceptional spells of long duration	
			Year	Duration in weeks		Year	Duration in weeks		Year	Duration in weeks
(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1 week of June to end of September.	16	26·9	1946 1914	6 5	20·0	1917, 1944	4	53·1	1911, 1915, 1918, 1925, 1939, 1947.	> 6
ne to September	17	44·3	1926, 1944, 1948	> 5	18·2	5 times in 42 years	3	37·5	1918, 1930	6 7
ne to September	17	34·2	1926, 1927, 1914	6 to 7	21·0	1917, 1926, 1932	> 3	44·8	1910, 1911, 1915, 1918, 1925, 1941, 1948.	> 7
st week of May to 2nd week of October.	20	46·6	1913, 1921, 1922	> 6	18·1	1916, 1917, 1946	4	35·3	4 times in 42 years in 1913	> 4 6
l week of June to 4th week of October.	20	46·8	1917, 1921	7	11·5	Never exceeded	2	41·7	1913, 1918, 1929	> 5
st week of May to 4th week of October.	22	36·4	1942	7	15·8	Never exceeded	3	47·8	8 times in 42 years in 1913.	> 5 8
st week of May to end of October.	23	52·7	20 times in 42 years	> 5	13·6	1917, 1931, 1936	4	33·7	9 times in 42 years in 1912, 1939.	5 6
l week of May to 1st week of November.	27	57·5	24 times in 42 years 1921	> 6 11	11·8	1925	4	30·7	1918	7
week of May to 2nd week of November.	26	47·9	19 times in 42 years	6 to 10	14·6	1916	4	37·5	1908, 1923, 1946, 1947	6
week of May to 2nd week November.	26	44·2	11 times in 42 years	> 5	15·1	1952 1916	4 5	40·7	1923, 1926, 1937, 1943	6
t week of May to 1st week November.	24	42·8	1931, 1948	11	16·5	1927, 1928, 1934, 1943	4	40·7	1908, 1942	6
week of May to 2nd week November.	28	47·4	1910, 1932	10	13·7	Never exceeded	3	38·9	1908, 1918, 1945	6
week of April to end of ovember.	34	43·9	14 times in 42 years	7	16·3	1932	4	39·8	1913	8
il to December	39	51·8	14 times in 42 years 1912	8 14	15·7	1911, 1917, 1931 1944	4 5	32·5	1917, 1923 1947	6 7
week of April to 2nd week January.	39	46·3	1929 1939	18 10	13·2	1917, 1929, 1933, 1940	4	40·5	1910, 1918, 1921, 1935, 1945 twice 1947 twice	1939 6 6 & 8 6 & 7
week of May to end of ctober.	30	35·2	5 times in 42 years	6	16·1	5 times in 42 years	4	48·7	8 times in 42 years 1913	6 to 10 9
week of May to 2nd week December.	32	48·1	1908, 1917, 1938	8 to 12	13·7	1946	4	38·2	8 times in 42 years 1926	6 to 10 10

Important Weather Phenomena (other than the monsoon) which also bring about spells of rainfall particularly in the non-orographic areas of the sub-continent.

Eastern Depressions

The fluctuations in the intensity of the monsoon itself are, to a significant extent, associated with a series of depressions which mostly originate (or, when they are coming from further east as remnants of the disturbances originating in the Pacific or the China Sea revive and strengthen) at the head of the Bay of Bengal and travel in a northwesterly direction across north or central India towards N.W. India, causing heavy precipitation along their track. The frequency of such depressions is 3 or 4 per month during the monsoon months (June to September). But for these depressions the monsoon precipitation may tend to be orographic or localised along the hills and mountains. They help to bring about a more equitable distribution of rainfall during the monsoon season in the interior of the country than would be the case otherwise.

Western Depressions

During the period November to May a series of western depressions enter India through Baluchistan and the N.W. Frontier and travel eastwards across north India towards N.E. India (Assam-Bengal). These depressions (some of which come from as far west as the Mediterranean Sea or even from the Atlantic Ocean) cause cloudy weather and light rains in the plains and snowfall in the Himalaya and are followed by cold waves. Their frequency is, on the average, 2 in November, 4 or 5 per month during December to April and about 2 in May. The rabi crops of north and central India are benefited immensely from timely winter rains.

Cyclonic Storms

The more severe cyclonic storms usually form in the Bay of Bengal and in the Arabian Sea in the transition months of April to June and October to December. They enter inland and cause considerable precipitation and damage due to high winds and, occasionally, tidal waves in the coastal districts. The mode of occurrence of these storms and their favourite tracks have been discussed in several publications of the India Meteorological Department. On an average one or two severe cyclones may be expected in the pre-monsoon period and two or three in the post-monsoon period.

Thunderstorms and Hailstorms

These are comparatively local and sporadic in character, lasting only for a few hours, and may also sometimes be associated with depres-

TABLE 5

Monsoon rainfall June to September. Inter-correlations between pairs of divisions. Period 1875-1918

(vide Table E, Memoirs of the Ind. Met. Dept., Vol. 25, Part ii, p. 23)

Division	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I Burma ..	−0·47	−0·14	−0·05	−0·01	−0·09	−0·21	+0·29	−0·07	−0·26	+0·01	−0·01	−0·32	−0·15	−0·33
II Assam ..	..	+0·45	+0·27	+0·01	−0·16	−0·10	−0·13	−0·17	−0·24	−0·27	−0·40	−0·01	−0·11	+0·14
III Bengal ..	..	..	+0·56	−0·07	−0·07	−0·05	+0·04	−0·24	−0·31	−0·22	−0·45	−0·18	−0·15	−0·12
IV Bihar & Orissa ..	..	..	..	+0·31	+0·13	+0·06	+0·06	+0·05	−0·10	+0·04	−0·27	−0·01	−0·07	−0·16
V United Provinces	..	..	..	..	+0·49	+0·31	+0·06	+0·55	+0·30	+0·68	+0·33	+0·37	+0·07	+0·22
VI Punjab ..	..	..	..	..	..	+0·82	+0·56	+0·87	+0·59	+0·79	+0·59	+0·61	+0·11	+0·35
VII N. W. F. P. ..	..	..	..	..	..	..	+0·65	+0·73	+0·59	+0·64	+0·46	+0·63	+0·22	+0·45
VIII Sind ..	..	..	..	..	..	..	..	+0·50	+0·65	+0·34	+0·34	+0·40	+0·24	+0·40
IX Rajputana ..	..	..	..	..	..	..	..	..	+0·57	+0·81	+0·54	+0·57	+0·21	+0·40
X Bombay ..	..	..	..	..	..	..	..	..	..	+0·46	+0·58	+0·72	+0·53	+0·66
XI Central India ..	..	..	..	..	..	..	..	..	..	..	+0·61	+0·40	+0·50	+0·21
XII Central Provinces	..	..	..	..	..	..	..	..	..	..	..	+0·55	+0·07	+0·18
XIII Hyderabad ..	..	..	..	..	..	..	..	..	..	..	..	..	+0·38	+0·61
XIV Mysore ..	..	..	..	..	..	..	..	..	..	..	..	..	..	+0·80
XV Madras ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

sions and storms. Thunderstorms usually occur before the onset and after the withdrawal of the monsoon. In their mode of occurrence there are points of similarity between thunderstorms, duststorms and hailstorms. In the absence of sufficient moisture in the atmosphere only a duststorm occurs. When enough moisture is present we get a thunderstorm. A hailstorm is just a particularly violent thunderstorm with the formation of hailstones. Though short in duration, the precipitation and associated squalls are often very intense. Squalls up to 128 or 160 km per hour in short spells of a few minutes' duration may sometimes occur. In many parts of the country, e.g., the Deccan and adjoining areas, pre-and post-monsoon thundershowers are the main source of soil moisture for growing crops.

Contemporary relationships of monsoon rainfall in fifteen divisions of India and Burma (which was a part of India before it was separated).

It is of great interest to know whether a deficiency in the monsoon rainfall in one part of the country is likely to be compensated by excess in some other part of the country. Table 5 expresses the relation between the monsoon rainfall in each of the 15 divisions and the remaining divisions of India and Burma in the form of contemporary correlation coefficients. A positive coefficient in this table indicates that the two areas concerned are likely to be affected similarly, i.e., an increase of rain in one area is associated with an increase in the other area also. A negative coefficient would indicate that a decrease in one is likely to be associated with an increase in the other area. Looking at the correlation coefficients in each row in Table 5, one notices that a vigorous monsoon in Burma tends to be associated with a weak or sub-normal monsoon over India and vice versa. To a smaller extent, excess of rainfall over N.E. India tends to be associated with a defect elsewhere. Over the rest of India, i.e., N.W. India, Central India and the Peninsula the correlation coefficients are generally positive, indicating that departures from normal are likely to be similar over the greater part of India, as indeed the dot diagram of Fig. 7 suggest from the tendency for a number of adjoining sub-divisions to have the same type of abnormality in particularly abnormal years.

Is India's Climate Changing ? Are there secular (long term) variations or periodities in India's rainfall ?

The longest meteorological records in India are of rainfall at the three presidency towns of Madras (from 1813), Bombay (from 1847) and Calcutta (from 1829). Even these do not show any significant long term or secular variations, apart from the usual random variations about a steady normal. These data as well as shorter time series in the case of

10 stations of Bihar were examined for periodicity. In some cases in Bihar these was indication of some periodicity in the data. But, considering that even neighbouring stations do not indicate similar periods, not much significance can be attached to these results. Evidence so far available does not support the possibility of any regular periodicity in Indian rainfall.

Unusually Heavy Rainfall

The frequency of heavy rainfall over India has been discussed in a note by Doraiswamy and Mohamad Zafar (Sci. Notes, Ind. Met. Dept., 7, No. 77). With reference to the heaviest fall in a day they find that :—

(a) Falls exceeding 125 mm in 24 hours have occurred over the whole of the sub-continent excluding N.E. Baluchistan and parts of N.W. Frontier.

(b) Falls have not exceeded 250 mm in 24 hours over most of the interior of the Peninsula and of Burma and in a few districts of the central parts of the country.

(c) Falls of 375 to 500 mm in 24 hours have occurred all along the west coast including Gujarat, on the Coromandel Coast, in south Assam, in Bengal and the foot of the Himalaya.

(d) A few isolated falls of 500 mm and over have occurred in the plains.

(e) The greatest fall of over 1,000 mm in 24 hours has occurred at Cherrapunji in the Khasi Hills.

When heavy rainfall occurs consecutively on a number of days and particularly over the catchment areas of rivers, the magnitude of the ensuing floods may well be imagined. Ramakrishnan (Sci. Notes, Ind. Met. Dept., 7, No. 74) has estimated the total volume of water precipitated over certain areas in South India on days when they were under the grip of storms coming from the Bay of Bengal. The values given by him for one of these storms are quoted in Table 6. Increasing forest cover, checking erosion, delaying flood-peaks, training the major rivers, etc., are problems which have begun to demand increasing attention of many countries of the world.

TABLE 6

Total Volume of water precipitated over certain areas in South India during a storm which prevailed from 21-10-30 to 27-10-30

Date	Area of land which had rain of 12 mm or more in km²	Volume of water precipitated on land in cubic km
21-10-30	60,150	1.9
22-10-30	53,730	1.6
23-10-30	71,540	4.9
24-10-30	103,660	8.0
25-10-30	133,740	6.5
26-10-30	141,620	7.1
27-10-30	342,520	11.9

Regional Peculiarities in the distribution of Rainfall

We may divide the country into climatically homogeneous zones on the basis of the normal rainfall. However, there will be many local peculiarities when we go into the variability in time and space, from station to station and over a number of consecutive days in different sub-divisions. The variability of rainfall in the month of July 1942 has been analysed for a number of representative areas in India, taking 20 stations selected at random from each of these areas. Table 6 gives the analysis of variance between stations, days of the month and 'residual' (due to random variability) for the Punjab, the Uttar Pradesh, the Madhya Pradesh, Bengal, Rajasthan and Kerala. Column (5) gives the standard deviation of the variability 'between stations', 'between days' and the 'residual' representing 'error' or random variability. The next column gives the ratios of the variances which are given already in column (4). These ratios are :—

$$\frac{\text{Variance between stations}}{\text{Residual Variance}} \quad \text{and} \quad \frac{\text{Variance between days}}{\text{Residual Variance}}$$

If the variability 'between stations', 'between days' and the 'residual' are all of the same order of magnitude the ratio F will not be significant.

In the Punjab, West Bengal and, in particular, Rajasthan and Kerala the variability between stations is very significantly larger than that attributable to random variability. In Malabar this variability between stations is due to orography, while in Rajasthan it represents a real climatic non-homogeneity. The variability between days is significant in all areas. In places like Rajasthan it is indeed difficult to indicate where exactly rain would fall during a rain spell. The engineer would be well advised to construct a wide network of small reservoirs in preference to a single large reservoir, in such areas.

Conservation and Efficient Utilisation of our Water Resources

Wherever the precipitation falling over a wide catchment is drained into large river systems like the Indus and the Ganga and other major rivers of the country, it is obvious that irrigation projects based from large bunds, barrages, and big reservoirs will be successful, as has indeed happened in the Punjab, Sind and other river valleys of the sub-continent. In areas like the Uttar Pradesh, besides canal irrigation, tube wells have also been sunk on a large scale.

It may be pointed out that the large semi-arid tracts of the Deccan which are away from the big rivers like the Godavari and the Krishna can get adequate supplies of water for agriculture if the necessary irrigation projects are set up at favourable localities in the catchment areas of the Western Ghats which receive sufficient rains for this purpose even in years with weak monsoon. Much of this water is now drained by rapids flowing into the Arabian Sea. If large reservoirs are built up on the Ghats over elevated areas, taking advantage of natural facilities for impounding the rain water, the water so collected can be fed into the plains to the east of the Ghats through canal systems. This problem is indeed being tackled vigorously in recent times.

Artificial Stimulation of Rain

By seeding carefully selected clouds in some seasons with nuclei of silver iodide and other seeding agents, attempts are being made to stimulate the rapid development of these clouds into rain yielding ones. This technique is full of promise and considerable active researches are in progress in many laboratories of the world on the subject of Cloud Physics. The subject is receiving considerable attention in India also and we may look forward to useful developments in this attempt to supplement natural rainfall by artificially induced precipitation, when the present development stage is over.

TABLE 7 : Analysis of variance of rainfall in July 1942

Area	Due to	Degree of freedom	Sum of squares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability
1. Punjab	Stations	19	21·1334	1·1123	1·55	3·73S		680
	Days	30	19·8421	0·6614	0·81	2·72S	5·79 mm	356
	Residue	570	160·8981	0·2981	0·55			241
	Total	619	210·8736	0·3407				
2. United Provinces	Stations	19	16·1105	0·8479	0·92	1·55		197
	Days	30	114·5280	3·8143	1·95	6·97S	11·84 mm	418
	Residue	570	312·1042	0·5475	0·74			159
	Total	619	442·7427					
3. Central Provinces	Stations	19	45·5754	2·3987	1·55	1·35	17·70 mm	222
	Days	30	270·4394	9·1465	3·02	5·16S		433
	Residue	570	613·9953	1·7715	1·33			191
	Total	619	929·9901	1·5024				

(Continued)

Area	Due to	Degree of freedom	Sum of squares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability
4. Bengal	Stations	19	41·4545	2·1818	1·48	3·62S	10·72 mm	350
	Days	30	43·2902	1·4430	1·20	2·39S		284
	Residue	570	343·4197	0·6025	0·78			185
	Total	619	428·1644	0·6917				
5. Rajputana	Stations	19	108·8973	5·7314	2·39	6·92S	10·59 mm	573
	Days	30	46·2551	1·5418	1·24	1·86		297
	Residue	570	471·9398	0·8280	0·91			218
	Total	619	627·0922	1·0131				
6. Malabar	Stations	19	85·4648	4·4981	2·12	5·53S		159
	Days	30	382·1749	12·7392	3·57	15·68S		268
	Residue	570	463·1872	0·8126	0·90		33·81 mm	68
	Total	619	930·8269	1·5038				

S Mean significant at 1 per cent level.

Reduction of Evaporation Losses from exposed surfaces of water in lakes, reservoirs, ponds etc.

Here one takes advantage of the laboratory finding that, if a free surface of water is covered with a mono-molecular of a long chain compound like cetyl or stearyl alcohol, the evaporation can be reduced up to 60 per cent. Field trials carried out in India and other countries like Australia, USA, USSR, Israel, etc. in very recent years do show that even under open air conditions when the film is disturbed or destroyed by sunshine, wind, bio-chemical action and so on, the saving can be of the order of 25 to 30 percent. Even under moderate to strong wind of the extra dosage of the film forming material called for so as to maintain maximum film coverage does not raise the cost of the saved water above the rates at which most municipalities supply water to the citizen. The subject is receiving considerable attention in many countries, and in India the many aspects of water evaporation control were discussed at an International Symposium held under the joint auspices of UNESCO and the Council of Industrial Research, at Poona in 1962. The problems of the bigger reservoirs as well as that of manufacturing the material for mono-molecular spreading from indigenous sources are awaiting solution.

Concluding Remarks

The subject we have dealt with in this article is so vast and of such national importance that it would need a big volume to discuss all the aspects adequately. We have just taken a bird's eye view of it in these few pages.

CHAPTER XVI

HYDROLOGY OF INDIAN RIVERS

Rivers, as sources of water have attracted mankind to their banks through the ages. Big cities grew on the banks of rivers and civilization flourished in these cities. The benefits accruing due to the vicinity of the river and the fertility of the valley on either side are mainly the reasons for people to migrate and settle as near the river as possible. Indians' love and respect for rivers go a step further. Here the rivers are considered sacred and are worshipped. Each of the rivers bears name of a Goddess and carries some myth behind it.

As people became interested in the utilization of a river, they tried to know more and more particulars about it. They went into details and examined the source of a river, its course, its drainage area, its slope, the velocity of its currents, the extent of flow in different seasons, the amount of sediment it carried and so on. In short, they tried to probe and attempted to know the hydrology of the river.

In spite of vast resources of water in this country, the pace of hydrology has been rather slow in India. This is because the people tried to take the path of least resistance. In the northern region, the rivers being perennial and, the land having flat slopes, they were satisfied with utilising only the seasonal flow of the river for irrigation and water supply. By constructing low weirs and barrages, they were able to command vast areas in the plains for irrigation. Similar is the case in the deltaic areas of the peninsular rivers. Therefore, long term data of the flow of rivers in India exist mostly at these diversion works.

As years passed by, the pressure of population increased and more and more need for storages and reservoirs of multiple purpose was felt. Therefore, dams and reservoirs are being built and proposed in all parts of the country. To design these big structures long term hydrological data of rivers are necessary. The States, who were empowered to look after the hydrology of the rivers have not taken seriously to the gauging of the rivers till now. In fact, hydrology has not been attended to systematically except in very few States. Nobody had thought of establishing basic and secondary network of hydrological sites. The States who were mainly concerned with projects had carried out some observations at project sites for a few years and then discontinued.

This was the state of affairs in the pre-plan period. As planned development was thought of, some States desired assistance from the Centre to develop the hydrology of their rivers as early as possible. The Central Water and Power Commission gave a helping hand and they were responsible for the setting up of sites and starting of observations on many of the important rivers such as the Brahmaputra, the Tapi, the Narmada, the Sabarmati and the Mahanadi rivers. Recently, they have been gauging on these two rivers also.

As early as 1948 an attempt was made by the C.B.I. & P. to collect call the discharge data in the country and publish them basinwise. For this purpose they even standardised the forms for publishing the data and the Central Water and Power Commission was asked to undertake the work. With the best of efforts they have been able so far to collect and publish data in the form of Water Year Books for a few basins only.

As already stated there has been some improvement in the installation and observation of hydrological sites on rivers since the starting of the plan projects. But the improvement is not adequate. In all there are about 1,790 sites of which 930 are discharge sites where gauges as well as discharges are observed. The remaining are gauge sites to record only river levels.

The observations carried out by different States have to be accurate and comparable. For this purpose standardisation of methods of observation and of equipment is necessary. In this regard the Indian Standards Institution in consultation with the C. W. & P. Commission and other agencies connected with river valley projects have formulated standards for the measurement of river flow and sediment in Indian rivers and also land standards for their equipment.

Hydrologically, the country's river systems fall into two broad groups viz., the rivers of Himalayan origin and those flowing in the peninsula. It is well-known that the entire ranges of the Himalaya form one typical structure geologically and are snow-clad, much different from other ranges in the central and southern India. The plains adjoining the Himalayan ranges are also of more alluvial type. On account of extensive snow over the Himalaya, the rivers are perennial in nature. The geologically unstable conditions of the mountain formations and the friable nature of the terrain cause considerable meandering and uncertainty in the behaviour of these rivers. The high seismic influence prevalent in these ranges often cause land slides which make them meander and sometimes change their course and become problem rivers.

In sharp contrast, the peninsular rivers, originating at comparatively lower altitudes, drain areas which are comparatively more stable geologically and do not therefore meander so much. The rainfall densities in the peninsular zones except in the small western coastal strip of Kerala are also comparatively less intense ; and this feature and the smaller temperature variation obtaining, contribute to well-defined and rigid channels and smaller sediment loads in these rivers.

The Himalayan river system comprises three major rivers namely, the Indus, the Ganga and the Brahmaputra.

The Indus basin is subjected to seasonal changes. The mean temperature generally decreases with increase in latitude as well as elevation. In its hilly regions seasonal variation of temperature is roughly from −10°C in January to about 18°C in July. The plains region of the basin are very hot in summer and the diurnal variation is also quite appreciable. The annual rainfall in this region ranges from 3,000 mm to 1,000 mm.

The Ganga basin is also characterised by large seasonal and diurnal variations in temperature. The mean temperatures decrease with higher latitudes and elevations. In the plain the highest temperatures recorded are of the order of 48°C and the lowest of the order of 2°C. The hilly regions of the basin record minimum temperatures below freezing point in winter. The annual rainfall in the basin varies from 2,000 mm to 800 mm.

The Brahmaputra basin has comparatively a more temperate climate than the Ganga but is more humid. The basin experiences heavy rainfall. The adjoining watershed of the Barak around the Jaintia hills has experienced an average annual rainfall of 1,150 mm at Mawsynram. Some of the wettest spots in the world are situated in between the watersheds of the Brahmaputra and this river. The heavy rainfalls are due to the monsoon depressions travelling from the Bay of Bengal. The annual rainfall in the basin varies from 10,000 mm to 4,000 mm.

Indus River

The Indus is one of the large rivers of the world. It rises in the snowy ranges of the Himalaya at an altitude of 5,000 m in Tibet. It is 709 km long within India and drains an area of 117,844 km^2. It flows for nearly 320 km in a northwesterly direction when it crosses the southeastern boundary of Kashmir at an elevation of 4,500 m. Flowing in the same direction it falls to 3,500 m at Leh. 19 km below Leh the Zanskar joins on the left. Continuing for 240 km in the same direction it is joined by the Shyok on the right. Near Skardu the Shigar joins on the right. Gilglt river joins on the right further down. Here the river bed is 1,220 m above sea level. The river then flows west, crosses the Kashmir border and turns south ; southwest into Pakistan.

The main tributaries of river Indus in India are briefly described below.

The Jhelum rises in the Kashmir valley and flows through Srinagar and Wular Lake. The river slope is small and the river is navigable or about 160 km. The flat reach ends at Baramula where the elevation is 1,550 m. The river then falls through narrow gorges and enters Pakistan. In India it is 400 km long and drains 28,490 km^2.

The Chenab is the largest of the five tributaries. At the source the river is in two streams, the Chandra and the Bhaga at an elevation of 4,900 m in Punjab. After the confluence, the river flows between the Himalaya and the Pir Panjal range and then takes a turn to the south through a gorge crossing Pir Panjal. It flows south between rocky mountains till it enters the plains near Akhnoor.

The Chenab in India is 1,180 km long and its basin in India is 26,755 km^2.

The Ravi has a catchment of 5,957 km^2 in India. It rises in the Kulu hills of Himachal Pradesh and enters the plains near Madhopur. It is 725 km long from source to Shadara in Pakistan near Indo-Pakistan border.

The Beas rises in Kulu at an elevation of 4,000 m. In the first 120 km from its source the slope average 1 in 40 and then it decreases rapidly. It is 1 in 500 in the valleys of the outer Himalaya and 1 in 5,000 in the plains. It is 470 km long and drains 25,900 km^2.

The Sutlej rises at an elevation of 5,000 m in Tibet and has the largest catchment area among the tributaries of the Indus. After flowing for 400 km from its source more or less parallel to the Indus, through rugged mountainous terrain, it enters the Indian border and then flows west through the uplands of the Punjab. It emerges from the mountains at the Bhakra gorge where the Bhakra dam has now been constructed. It flows for another 16 km in a narrow deep channel with low hills on either side before it widens into an alluvial river. The bed material changes from boulders at Bhakra to sand at Rupar. At Harike the Beas joins the Sutlej. The Sutlej is 1,050 km long in Indian territory and drains 24,087 km^2. The river slope is 1 in 150 to 1 in 175 from source to Bilaspur, where the bed level is 488 m. The slope flattens to 1 in 5,000 below Rupar.

Rainfall and Run-off

Rainfall variation in the Indus basin is very great. The precipitation inclusive of snow is much heavier in the hills than in the plains. The precipitation varies with elevation also. It is of the order of 3,000 mm over the hilly regions near Dharamsala and decreases to 1,000 mm near the

Kashmir valley. The southern plains of the basin are mostly semi-arid where rainfall ranges from 800 to 400 mm.

In the plains the rainfall occurs mostly in summer. In the upper sub-basins of Indus and Jhelum the winter precipitation is nearly equal to that in the summer.

The flows in Indus are subject to extreme variations. The maximum flow is in summer. The low winter flows are mainly from the ground storage built up during summer. Thus a drought in winter can follow a flood in summer.

The following table gives the maximum and minimum discharges recorded at certain gauging stations on the tributaries of Indus river.

River	Site	Maximum	Minimum
Jhelum	Near Indo-Pak. border.	29,600 m^3	112 m^3
Chenab	Near Indo-Pak. border.	24,700 m^3	102 m^3
Ravi	Near Indo-Pak. border.	15,400 m^3	34 m^3
Beas	Mandi Plain	9,800 m^3	60 m^3
Sutlej	Near Indo-Pak. border.	12,000 m^3	78 m^3

RIVER GANGA

The Ganga is the most important river of India. It flows through the populous alluvial Ganga Plains and has a very fertile valley. It has been considered as a very holy and sacred river by the Hindus from time immemorial.

Rising from the snow bound Himalaya the river is 2,071 km long in India and drains an area of 951,600 $km.^2$ Its two head streams Alaknanda and Bhagirathi meet at Devaprayag. After their confluence the river is known as Ganga. The source of Alaknanda is near the Garhwal-Tibet border at an elevation of 7,800 m. The Bhagirathi rises near Gangotri peak at an elevation of 6,600 m. From Devaprayag the Ganga flows west and southwest through the Himalaya up to Hardwar. The river, then, enters the plains and proceeds south and southeast till it receives the Ramganga on the left. It flows then in a southeasterly direction through the alluvial plain up to Allahabad where Yamuna the major tributary of Ganga meets on the right. From Allahabad the Ganga flows eastward and receives the Tons on the right. After passing Varanasi it receives the Gomati on the left. At Chapra a large tributary, the Ghaghara, joins the Ganga from the north. A short distance after that it receives the Son from the south. Further to the east the Gandak meets the Ganga opposite Patna. From here the Ganga flows in a wide and deep channel passing the towns of Monghyr and Bhagalpur. Three more large tributaries the Buhri Gandak, the Baghmati and the Kosi join from the north. The Ganga then skirts the Rajmahal hills and flows southeastwardly to Farakka which may be said to be the apex of the delta. The Ganga has a large number of spill channels running north-south to the Bay of Bengal. The largest and most westerly is the Bhagirathi-Hooghly. The others are the Jalangi, Bhairab, Mathabhanga and Gorai. River Damodar with a catchment of 22,000 km^2 joins the Hooghly estuary 48 km below Calcutta. The Mahananda which is the eastern most tributary of the Ganga joins on the left in the reach where the Ganga is the common frontier between India and Pakistan. The maximum flood discharge of Ganga at Farakka is of the order of 59,500 m^3/sec. The major tributaries of the Ganga are briefly described below :—

The Yamuna is one of the important tributaries of the Ganga. It is a major river by itself. It rises in the Himalaya west of Ganga with its source very near to that of Ganga. It flows almost parallel to Ganga all its length. It is 1,300 km long. Its drainage area which is 359,000 km^2 includes the Central Indian Plateau from which its tributaries the Chambal, Betwa and Ken rise. During floods the river spreads to a width of 1 to 2 km. Its maximum flood discharge is 14,158 m^3/sec as gauged at Tajewala.

The Ramganga rises near Naini Tal in the lower Himalaya. It is 690 km long and has a drainage area of 32,800 km^2. It joins the Ganga below Farrukhabad. During floods it overflows its banks for a distance of 160 km near its confluence with Ganga.

The Ghaghara rises in the snow covered foot hills of the Himalaya east of Ganga and runs southeasterly parallel to the course of the Ganga till it joins at Chapra. It is 1,080 km long and drains an area of 127,500 km^2. The Ghaghara has two main tributaries the Rapti on the left and the Sarda on the right. The slope of the river in the plains is about 1 in 9700 and the river and its tributaries spill in several reaches. It is said that the Ghaghara used to join the Ganga at a point 27 km west of Chapra about 170 years ago. The point of confluence has gradually been shifting to its present location.

The Son is a southern tributary of Ganga. It originates in the Chotanagpur hills and flows east and northeast before it meets the Ganga above Patna. It is 780 km long and drains an area of 71,900 km^2.

The Gandak rises at an elevation of 7,600 m in the Central Himalaya in five branches in the head reaches. In Nepal the river is known as Narayani and flows southwards through a series of rapids and pools. It enters the plains in India and flows in a southeasterly direction to join the Ganga opposite Patna. The Gandak is 425 km long and and drains 45,800 km^2 out of which the catchment in India is 9,540 km^2. There is extensive bank erosion in the reach forming the U. P. Bihar border. The upper reaches over-flow in Nepal territory during floods and also escape to adjoining river basins like the Rapti. The river slope varies from 1 in 3,500 in the first half to 1 in 8,000 near the confluence.

The Burhi Gandak rises in the western slopes of Sumesar hills. It flows in a southeasterly direction for 610 km to join the Ganga below Monghyr. It drains an area of 12,200 km^2. During the rains it rises very fast and floods a large area of land to a depth of 1 to 1.5 m.

The Kosi has its source in the snow covered mountain ranges of Tibet, Nepal and Sikkim. It flows in three branches in the head reaches. The three streams Kosi, Arun and Tamur meet to form the Kosi. The river is 730 km long and drains 86,900 km^2 out of which the catchment in India is 21,500 km^2.

Below the confluence of the three tributaries the Kosi flows through narrow gorges for 9 km before emerging into the plains at Chatra. The river then runs southwardly through sandy alluvium exhibiting the features of a deltaic stream. The Kosi has been notorious for changing its course. During the last 200 years it has moved 112 km towards the west turning large tracts of cultivable lands into waste lands. These are estimated to be about 5,000 to 8,000 km^2 in Bihar and about a 1,000 km^2 in Nepal. That is why it is known as "the river of sorrow". The slope of the river varies from 1 in 1,050 near Chatra to 1 in 23,000 to 18,000 near the confluence.

The Mahananda is the easternmost tributary and is 290 km long and drains an area of 25,100 km^2.

The Damodar rises in the hills of Chotanagpur at an elevation of 1,366 m and flows in a generally southeasterly direction for 290 km before entering the deltaic plains before Raniganj. In the upper reach the topography is hilly. In the lower reach, it is flat. Damodar joins the Hooghly, an estuary of the Ganga, 48 km below Calcutta. The total length of the Damodar is 541 km. It drains an area of 22,000 km^2. The river slope is 1.86 m per km for the first 241 km, 0.57 m per km in the next 161 km and 0.16 m per km in the last reach. The river floods the area in the lower reaches. The maximum flood discharge so far observed is stated to be 18,410 m^3 per sec.

Rainfall and Run-off

The precipitation over the Ganga basin is due to the southwest monsoon as well as cyclones originating in the Bay of Bengal. The average annual rainfall varies from 1,500 mm (with 2,000 mm over the hilly region) at the western end of the basin to 1,000 mm in the middle and from 750 to 2,120 mm near the eastern end in the delta portion. Most of the rainfall occurs mainly during the months of June to October.

The slope of the river from Allahabad to Varanasi is 1 in 10,550 and it is even flatter below Farakka being about 1 in 18,700.

The average annual flow at Farakka is of the order of 12,500 m^3 per sec and the low water mean discharge 1,568 m^3 per sec.

The upper reaches of some of the tributaries of the Ganga viz. Ghaghara, Son and Kosi contain sites suitable for developing considerable hydro power.

During floods the Ganga overflows its banks in some reaches. Near Kanpur the left bank is flooded to a width of about 8 km. Above Chapra the river floods both banks up to a distance of 130 km along the river. The flood at times spreads to a width of 26 km.

BRAHMAPUTRA

The Brahmaputra drains a smaller catchment than the Ganga or the Indus. Its drainage area is about 580,000 km^2 out of which 293,000 km^2 lies in Tibet and 47,000 km^2 in East Pakistan. It rises in Tibet and flows through Tibet, India and East Pakistan. Its total length is 2,580 km out of which 885 km is in India. Its valley is comparatively thinly populated. In sharp contrast to the Ganga, the turbulent nature of Brahmaputra and the wayward nature of its various tributaries were not conducive to the settlement and growth of vast populations. It is practically untamed and untapped.

Rising at an elevation of 5,150 m in the Himalaya, it flows east in southern Tibet parallel to the main Himalaya for 1,100 km. In Tibet it is known as the Tsangpo. The tributary Raja Tsangpo joins on the left near Lhatse Dzong. Ngang Chu joins on the right near Shigatse the second town of Tibet.

Kyi Chu which passes close to Lhasa joins on the left further down. The river is said to be navigable for about 640 km downstream from Lhatse Dzong. It is one of the most unique inland waterways of the world being 3,650 m above mean sea level.

At Tsela Dzong the Giamda Chu joins on the left. The river here is 3 km wide., Further east the river falls to 3,000 m at Pe and the river is 600 m wide and flows placidly. It then flows northeast through a number of gorges in a series of cascades and rapids. It then flows south and southwest. It is called Dihang when it emerges from the foot-hills and enters India. Near Sadiya two important tributaries, Dibang and Luhit join the main river. From this junction onwards the river is known as the Brahmaputra.

Brahmaputra which is by then several kilometres wide flows through Assam valley for 725 km. It receives several large tributaries. The Subansiri, Kameng and Manas join on the right and the Burhi Dihing, Disang, Kopili and Dhansiri join on the left.

River Brahmaputra brings down a large quantity of silt, is braided and forms numerous islands. The largest of these islands called Majuli has an area of 1,250 km^2. Downstream of Goalpara near about Dhubri the river enters the plains of East Pakistan and flows south till it joins the Ganga at Goalundo.

Upto Shigatse the river slope is approximately 0.93 m per km. The slope is nearly double this at the commencement of the gorge. In the gorge portion the river has a fall from 3,658 m to 305 m. A noteworthy feature is that that there is no drop more than 9 m and the river flows in a series of cascades, the average slope varying from 4.3 to 16.8 m per km.

As soon as it leaves the gorge its slope becomes as low as 0.27 m per km. Near Dibrugarh it is practically flat, the gradient varying from 0.17 to 0.09 m per km.

The tributaries from the eastern and southern sides behave differently from those of the north. The eastern and southern tributaries are of the meandering type. Many tributaries have undergone considerable changes in their courses and slopes etc. after the 1950 earthquake. The northern tributaries have tortuous and serpentine courses while the southern tributaries are more stable.

The tributaries of Brahmaputra are briefly described below.

The eastern group of rivers comprises the Dibang, Sessari and the Luhit. The first two drain the hills of Mishmi and Migan with a total catchment area of 13,237 km² and are noted for several inter-linking channels in the plains. The changes sustained during the 1950 earthquake are still seen over the slopes of the Dibang Valley which is steeper than the Dibang. The Sessari, however is now reduced in its capacity and looks more a spill channel like a spent force after a very active period before 1950. The other important river namely, Luhit has a course of 253 km with an average gradient fall of 38 m per km in the deep gorge. The upper portion of the river lies in the snow-clad Kangri, Karpla peak of the Tibet and it breaks into several channels in the plains of Sadiya.

To the southern group belong the important rivers Burhidihing (8,539 km²), Dhansiri (south) (12,344 km²) and Kopili (14,538 km²). While the Burhidihing is noted for steep gorges running in many directions with very little vegetations in the upper reaches, the distinctive feature of the upper reaches in the Dhansiri is a thick growth of tropical vegetation. Also the lower reaches of the Dhansiri and of the Kopilli afford cultivation of rice and sugar-cane on account of somewhat flatter slopes. At the same time, there continues the danger of visitations of floods.

The Subansiri, Dhansiri (north), Jaibhorelli, Manas and Tista are the major rivers belonging to the northern group. All these rivers are subjected to considerable undulations in their courses. Actually they form a kind of patternless cobweb over the northern plains of Assam.

The 525 km long Subansiri originates in Tibet at an elevation of 4,481 m and descends to a height of 107 m in the course of 338 km before entering the plains which gives an average slope of 13 m per km in the hilly reaches. The Jaibhorelli which has also its origin in Tibet has a much steeper slope. Its bed fall in the lower zone is 81 m in a reach of 76 km.

The Manas and the Tista join the Brahmaputra in its lower reach. The 34,480 km² basin of the Manas has a triangular catchment and most of its area is spread over rocky and precipitous mountains. The Tista has however a comparatively elongated catchment and has steep slopes and high velocity in the gorges and widens out considerably in the plains. Prior to 1787 it was a tributary of the Ganga. Its affiliation to the Brahmaputra was reported to have been caused by the disastrous flood in that year. The river along with its companion, the Torsa, brings enormous quantity of silt and their bed slopes vary from 4.73 m per km to 0.38 m per km.

Rainfall and Run-off

The Brahmaputra basin receives copious rainfall in Tibet the precipitation which is in the form of snow commences to melt in March. The central basin of Assam receives 2,125 mm annually. The average annual rainfall of the whole basin is 2,125 mm.

The maximum flood discharge of Brahmaputra at Pandu, where the catchment area is 424,309 km^2 was 72,460 m^3 per sec and the minimum 2,680 m^3 per sec. The maximum, average and the minimum annual run-offs at Pandu based on the data available during 1955-62 are 571,514 and 460 billion m^3 respectively.

PENINSULAR RIVERS

Peninsular rivers can be considered under two categories viz., Inland and Coastal.

The Coastal rivers consist of a number of comparatively small streams all along the west coast from Saurashtra to Cape Comorin and a few on the east coast near delta areas. The western rivers which number as many as six hundred drain the western side of the Western Ghats and have very narrow plains to cut across before they join the Arabian sea. They are known for their steep slopes draining quickly the abundant rainfall experienced in their catchment areas.

Climatologically the entire coastal strip covered by the west coast rivers forms one belt. The rainfall in this area increases as we travel from Kutch down towards south to Kerala. The orographic effects of the Western Ghats have marked influence on rainfall variations of the region. Broadly, the entire belt can be divided into three sections namely the (1) Gujarat, Saurashtra and Kutch area (2) Maharashtra and Konkan districts of Mysore (3) Malabar districts of Mysore and Kerala.

The normal annual rainfall of the first section ranges from 600 to 1,500 mm, most of which occurs during the period May to September. Apart from the Arabian sea current of southwest monsoon, cyclonic storms from the Bay of Bengal entering inland in a series of depressions move in westnorthwest direction, causing considerable rainfall in these areas. As we come down to the second section viz. ; the Maharashtra and Mysore coast the rainfall is found to increase double fold, with a normal annual value varying between 2,000 to 3,000 mm. Here, the rainfall is mostly due to the southwest monsoons. The third section experiences much higher rainfall of the order of 3,500 to 5,000 mm on the average. The rainfall pattern is generally governed by the influx of southwest monsoon current associated with surface and upper area cyclonic system. However, in the southern most districts of Kerala the rainfall extends even to October-November.

Though the catchment areas drained by these coastal rivers of the west measure just 3 per cent of all the basin areas in the country put together, in view of the uniformly heavy rainfall experienced, the total potential in this narrow belt is as much as 14 per cent of the country's water resources. This is a very significant point worthnoting. Unfortunately, there is comparatively little plain area which can be irrigated. In these areas, salt water intrusion from the sea poses a big problem. The considerable water potential available has given rise to development of plantations in the southern portion of the western ranges and offers scope for better exploitation in the form of power and water supply.

The inland rivers of the peninsula comprise of Narmada and the Tapi flowing towards the west and the Mahanadi Brahmani, Baitarani, Subarnarekha, Godavari, Krishna and Cauvery which are all east flowing. The peninsula is very old and has been inactive since ages. It represents the survival of the harder masses of rock which have escaped weathering and removal. The greater part of the peninsula is constituted by the Deccan Plateau, a table l and rising to about 610 m from the sea and enclosed on all sides by hill ranges. Hence the river systems in this region are of great antiquity and have well-defined and stable courses. Their characteristics are generally similar. There is no braiding, aggrading or degrading behaviour as commonly met with on many of the rivers belonging to the Ganga-Brahmaputra system. They more or less stretch over the width of the peninsula. There are some contrasting features between the west flowing and the east flowing rivers. The former generally flow between two mountain ridges with the result that their catchments are more elongated and narrow ; while the latter are wide and fanshaped. Secondly the western rivers are conspicuous by the absence of delta formation at their mouths. On the other hand considerable deltaic deposits are the distinguishing characteristics of the eastern rivers.

Hydrometeorologically they are in a belt which receives rainfall mostly during the southwest monsoon season, though the southern rivers are affected by the northeast monsoon also. The rainfall in these regions is high near the Western Ghats varying from 800 mm to 600 mm. The central areas get low rainfall forming a semi-arid region. Again along the Eastern Ghats the rainfall is higher and varies from 1,000 mm to 1,200 mm. The flow patterns also vary similarly. Most of the flow occurs during May to October except for the southern most rivers like Cauvery, Vaigai and Tambraparni which receive supplies in November and December also, due to the North Eastern Monsoon.

The hydrological aspects of some of the important rivers forming the inland group given below in a general way would provide a closer picture.

NARMADA RIVER

Narmada is the largest among the west flowing inland rivers of the Peninsular river system. It is 1,312 km long and drains an area of about 93,180 km^2, Rising from a tank at an elevation of 1,057 metres in Amarkantak plateau in Madhya Pradesh, the river flows west between the Vindhya range of hills on the north and the Satpuras on the south.

There are a number of falls in the head reaches the most famous among them being the 23 metre falls at Kapildhara. From source up to Handia the hills are far apart and the basin is a fertile plain. In the reach from source to Handia, a large number of important tributaries join Narmada. Burhner, Banjar, Sher, Shakkar, Dudhi and Tawa join on the left. Those joining on the right are Hiran, Tendoni, Barna and Kolar.

Between Handia and Mandhata the hills have come nearer and river Narmada flows amidst steep hills and thick jungles. Below Mandhata the hills recede and the valley is an alluvial basin. At Harinphal the hills have again closed in and the river flows through a narrow gorge with a number of rapids up to Rangan. Below this the course of the river is smooth. After the confluence of Karjan the river flows through the Gujarat plains. The stream is wide and deep and the flow of water slow enough for navigation. The only important tributary joining river Narmada in the reach between Handia and its outfall, is Chota Tawa joining on the left bank. There are a number of smaller tributaries. Those joining on the left are Anjal, Machak, Kundi, Goi and Karjan. Those joining on the right are Kanar, Uri and Orsang.

River slope

Source to Marble rocks	..	1.6 metre per km
Marble rocks to Mandhata	..	0.26 metre per km
Mandhata to Harinphal	..	0.40 metre per km
Harinphal to confluence of Karjan.	..	0.70 metre per km
Confluence of Karjan to sea.	..	0.40 metre per km

The tidal effect is felt for 40 km above Broach. The spring tides have a height of 7.5 to 9 metres at the mouth and 2.75 metres at Broach.

Rainfall and Run-off

Rainfall in the Narmada catchment near the sea is 1,016 mm but increases in 1,270 mm near Gora. Thereafter the rainfall decreases towards the east to 762 mm upto Punasa. It rises again to about 1,270 mm at Jabalpur. Beyond Jabalpur upto the source the rainfall is of the order of 1,575 mm. The average annual rainfall in the entire catchment is 1,212 mm. The rainfall occurs mostly during monsoon season from June to October. Of these five months, July and August get the major part of the precipitation.

The river has been gauged at a number of important sites namely, Garudeshwar, Mortakka, Manote, Hoshangabad and Jamtara. A number of tributaries have also gauges and discharge sites on them. The normal annual run-off of the Narmada is 40,800 million m^3.

Its vast water resources are practically untapped and offer scope for spectacular development of the irrigation and power potential of the basin.

River Narmada has carved for itself a deep and well defined channel and seldom overflows its banks. The flood problem is confined to certain reaches only. Mandla town and Jabalpur city in the upper reaches and Broach and Ankleshwar taluks in the Gujarat plains are subject to occasional floods. The 1837 flood is said to be the greatest on record when the waters of Narmada, Tapi and Kim are said to have formed one continuous stretch, 64 km wide. Since 1926, there have been a few major floods in the valley. The maximum discharge at Garudeshwar during 1944 has been estimated to be of the order of 65,100 m^3 per sec.

TAPI RIVER

Tapi is the second largest among the west flowing inland rivers of the peninsular region. It is 724 km long and drains an area of 64,750 km^2. The average annual run-off is 8,634 million m^3.

River Tapi (Tapti) derives its name from the word "Tap" in Sanskrit meaning heat. It rises near Multai in in Betul district at an elevation of 762 metres. It flows in a westward direction between the Satpura hills on the north and Gawilgarh hills on the south. Purna which is the principal tributary of Tapi takes its birth on the southern slopes of the Gawilgarh hills and flows in a westerly direction till it joins Tapi. The Purna is 338 km long and drains an area of 18,311 km^2. After the confluence of Purna, the Tapi is bounded on the north side by the Satpura ranges and on the southern side by the Ajanta range of hills. At a distance of about 587 km from source the river enters the rapids reach of 40 km. It enters the Gujarat plains at Kakrapar.

Before the confluence with the Purna a number of small tributaries join river Tapi on both banks. Betul, Lavda, Patki, Ganjal, Dathranj and Bokad join on the right while Ambhora, Khursi, Khandu, Kapra, Sipra, Garja, Khokri, Utaoli and Mona join on the left.

Tributaries joining the Tapi on the right after the confluence of Purna are Bhokar, Suki, Mor, Harki, Manki, Guli, Aner, Arunavati, Gomai and the Valer. These originate in the Satpura hills and flow south to join the main river. The tributaries joining on the left are Vaghur, Gurna, Bori, Panjna, Buray and Amaravati. Except for the Vaghur which has its source in the Ajanta range of hills and flows northwards, the other tributaries originate on the eastern slopes of the Western Ghats and flow eastwards. All of them take a turn to the north before joining the Tapi.

River slope (Main Tapi)

First	226 km	2.09 m per km
Next	121 km	0.77 m per km
Next	241 km	0.51 m per km
Next	40 km	0.75 m per km
Next	97 km	0.47 m per km

The tidal influence is felt for a distance of 49 km from the mouth.

Rainfall and Run-off

As in the case of Narmada the rainfall occurs mostly during monsoon month. The rainfall increases eastwards from 1,016 mm at Surat to 1,143 mm at Kathor. It remains steady at that level till Vajpur and decreases thereafter to 483 mm at Sakiri (Panjora). Then there is a gradual rise to 762 mm near Jalgaon and a further rise to 1,143 mm at source. The mean annual rainfall is 780 mm the maximum and the minimum being 1,191 mm and 271 mm respectively.

Even though the area drained by Tapi is about 68 per cent of that of Narmada the normal annual runoff is only about 18 per cent of the latter. The run-off has been as high as 49,340 million m^3 and as low as 480 million m^3. The average run-off is computed as 8,635 million m^3.

Occasional floods have occurred in Tapi in Khandesh region and also on the major tributary Purna. The lower reaches near Surat have experienced floods fairly frequently. During the period 1882 onwards for which flood gauges are available at the Hope Bridge near Surat, very high floods (i.e. above R.L. 100) have occurred thrice in 1883, 1944 and 1945 and high floods (i.e. above R.L. 95) have occurred 11 times during a period of 70 years. The maximum flood so far observed is 36,000 m^3per sec.

SABARMATI RIVER

The Sabarmati is the third largest west flowing inland river. It is 416 km long and drains an area of 54,610 km^2.

It rises in the Aravalli hills in Rajasthan and passes through Rajasthan and Gujarat States before falling into the Gulf of Cambay. Its principal tributaries are Wakal, Harrow, Hathmathi, Meshwa and Watrak. About a quarter of the drainage area lies in Rajasthan and the rest in Gujarat.

Ahmadabad, the most important town of Gujarat, is situated on the banks of Sabarmati river. In the initial reaches of about 130 km the river bed is steep and the river runs between high banks in a hilly area. From Dharoi to Ahmadabad the river flows in a broad sandy bed with a fairly flat slope. From Ahmadabad to its outfall the river is wide, tortuous and sluggish.

Rainfall and Run-off

The mean annual rainfall in the catchment is of the order of 737 mm. The recorded maximum flood discharge is 10,874 m^3 per sec in 1950 at Dharoi. The minimum flow is practically nil at Dharoi. The average annual run-off is 1,233 million m^3.

MAHANADI RIVER

The Mahanadi, even though not the biggest river of India as its name would imply, is however big in terms of its water potentialities and flood producing capacity. The river is 858 km long, and its catchment up to Cuttack at the head of the delta is 132,090 km^2.

Mahanadi rises near Sihawa in Raipur district of Madhya Pradesh at an elevation of 442 metres. It flows northwards 263 km till a major tributary Seonath joins from the left. It then moves more or less eastwards but for a sharp bend near Sambalpur. By the time the river reaches Sambalpur three more important tributaries viz., the Hasde, Mand and Ib from the north and Jonk from the south have enriched the flows and the river is as wide as 1·6 km. At Hirakud the river bed level has fallen to 140 m. From Sambalpur the river flows south upto the confluence with Tel, its most important tributary which joins from the right. In this reach the Ong joins on the right some distance upstream of the confluence of Tel. Then it takes a right angled turn and flows east till it meets the Bay of Bengal.

From Baudraj to Mundali weir the river flows through a series of rapids. At Cuttack the river branches out and flows through the delta. The general river slope is varying from 1 m per km in the head reach to 0·46 m per km below Hirakud Dam.

The annual rainfall over the Mahanadi catchment varies considerably. The heaviest rainfall of the order of 1,524 mm is confined to a small area between Sambalpur and Sonepur. The northeastern part of the basin receives the next heaviest and the central and southern portions receive about 1,140 mm to 1,270 mm which decreases to the east and south. The months of July and August register conspicuously heavy rainfall.

The water potential in the Mahanadi is fairly high. On an average it carries 67,000 million m^3 of water every year. Of this about 47,000 million m^3 are received even at the Hirakud Dam which is the first major project in the area for the development of the resources of the Mahanadi river.

The maximum flow is of the order of 46,000 m^3/sec and the minimum flow 6 m^3 per sec.

The Mahanadi has a large delta which is very fertile. Floods in the Mahanadi cause serious damage and vast inundation in the delta area. The tide height at the mouth of river Mahanadi is between 1·07 metres to 2·59 metres. The silt brought down by the river is spread in the shape of a long bar at the mouth of the river by a littoral drift which moves the sediment along the shore in a northeasterly direction. This results in higher flood heights in the delta till the bar breaches. Study of survey maps prepared in 1889 and 1928 showed that a bar 26 km long and 5 km away from the original shore had formed during this period. Thus on the Mahanadi there is the phenomenon of increasing flood heights over a period of year (when the bar builds up followed by a period of relief when the bar breaches).

BRAHMANI, BAITARANI AND SUBARNAREKHA RIVERS

These sister rivers of Mahanadi have similar topographical features and pattern of behaviour. Their catchment areas are of similar shape with comparable rainfall and drainage conditions.

The Brahmani is 705 km long and has a catchment area of 36,000 km^2. The mean annual rainfall in the catchment is 1,470 mm. The mean annual run-off is about 27,137 million m^3.

The Baitarani is 333 km long and has a catchment area of 10,500 km^2. The mean annual rainfall is 1,360 mm, and the mean annual run-off 7,278 million m^3.

The Subarnarekha is 433 km long and has a catchment area of 19,500 km^2. The mean annual rainfall is 1,400 mm, and the mean annual run-off is 7,400 million m^3.

GODAVARI RIVER SYSTEM

River Godavari is the biggest of the east flowing rivers of Peninsular India. It flows east across the Deccan Plateau from the Western Ghats. It rises in the Nasik district of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m. After flowing for about 1,465 km in a generally southeasterly direction through Maharashtra and Andhra Pradesh, it falls into the Bay of Bengal about 97 km below Rajahmundry. It has a catchment area of about 313,389 km^2.

About 64 km from its source, the Godavari receives the waters of Darna and at a short distance lower down the river, it gets out of the high rainfall zone of the Western Ghats and there is no further significant contribution to the river flow until about 150 km below when it receives the combined waters of the Pravara and Mula rivers. About 483 km lower down, Manjra joins from the south. At this point, the Godavari runs at an elevation of about 329 m and has again entered a rainfall zone of about 1,020 mm and more. The river Pranhita conveying the united waters of the Penganga, the Wardha and the Wainganga falls into the Godavari about 306 km below the Manjra confluence. About 48 km lower, the Godavari receives the water of the Indravati river. Both Pranhita and Indravati are major rivers in their own right. Sabari is the last major tributary which falls into the Godavari 100 km above Rajahmundry.

The slope of the river from its source to 100 km distance is 2·7 m per km and 0·3 m per km in the next 700 km ; 1·19 m per km in the next 160 km upto the confluence of Godavari with Pranhita. In the next reach upto the sea, the slope is 0·23 m per km.

The river Manjra rises in the Balaghat range in the Bir district of Maharashtra at an altitude of about 823 m. The river flows in a generally east and southeasterly direction for 515 km. The total length of the river from the source to its confluence with the Godavari, at an altitude of 323 m is about 724 km. The Manjra and its tributaries have a total catchment area of about 30,821 km^2, nearly one tenth of the Godavari catchment.

The Pranhita with its three principal branches, the Penganga, the Wardha and the Wainganga is by far the most important tributary of the Godavari. The Penganga rises at an altitude of about 686 m in the Buldana range in Maharashtra and after flowing for a length of 676 km in a generally southeasterly and easterly direction joins river Wardha at an elevation of 174 m. Except in its upper most reach of about 161 km which is mostly barren and hilly, the river passes through dense forests of Yeotmal and Nanded districts and is then joined by several tributaries. The catchment area of the Penganga river with all its tributaries is 23,898 km^2.

The Wardha rises at an altitude of 777 m in the Betul district of Madhya Pradesh and enters Maharashtra about 32 km from its source. After flowing further for a distance of 483 km in a generally southeasterly direction it joins the Wainganga at an elevation of 145 m for the last 42 km of its course it forms the boundary between Maharashtra and Andhra Pradesh. The catchment area of Wardha is 24,087 km^2 lying mostly in Maharashtra. Throughout its course, river flows through dense forests, River Wainganga rises at an altitude of 640 m in Seoni district of Madhya Pradesh and after flowing for a short length, it takes a turn towards east and then south forming a great loop. After flowing for a total length of 274 km in Madhya Pradesh, it forms the boundary between Madhya Pradesh and Maharashtra for about 32 km. It then continues to flow due south for another 188 km to join the Wardha.

The combined waters of the Wainganga and the Wardha, now called Pranhita flow for 113 km along the border between Maharashtra and Andhra Pradesh before falling into the Godavari at an elevation of 107 m. The catchment area of Wainganga is 61,093 km^2 lying partly in Madhya Pradesh and partly in Maharashtra. The river passes through the thick forests of Madhya Pradesh.

The catchment area of the Pranhita and all its branches is 109,077 km^2, a little more than ohe third of the entire Godavari river system.

The Indravati rises at an altitude of 914 m in the Kalahandi district of Orissa on the western slopes of the Eastern Ghats. It flows westward through Koraput and Bastar districts, turns south and about 531 km from its source joins the Godavari at an elevation of about 82 m. The important tributaries of the Indravati are the Narangi, Boardhig, Kotri and Bandia from its right and Nandira from its left. The total catchment area of the Indravati is 41,665 km^2, lying in Orissa and Madhya Pradesh.

The Sabari also known as the Kolab is one of the important tributaries of the Godavari. The Sabari rises at an altitude of 1,372 m in the Sinkaram hill range of the Eastern Ghats. After flowing for a short distance in northwesterly and westerly direction, it turns south and joins Godavari about 418 km from its source at an altitude of 25 m about 97 km upstream of Rajahmundry. The Sileru (also known as Machkund river) is the important tributary of Sabari river. The Sileru rises at an elevation of 1,219 m and flows for a length of about 306 km before joining the Sabari at an elevation of 4,134 km above the Sabari confluence with Godavari. The total catchment area of the Sabari and of its tributaries is 20,427 km^2.

RAINFALL AND RUN-OFF

The principal source of water supply in the Godavari basin lies in its upper reaches from the relatively small catchment in the Western Ghats, and in its lower end from the Mahadeo hills, the Maikala range and the hills in the south Orissa. About 128 km length of the Western Ghats constitutes the heavy rainfall zone with an annual rainfall of about 3,000 to 1,000 mm. Maximum rainfall occurs during June to September when the southwest monsoon occurs. The northeast part of the Godavari basin receives also some rain in association with monsoon depressions which move west-northwest across the Orissa coast. Quite a large area of the basin receives less than 600 mm of normal annual rainfall. The weighted average annual rainfall of the Godavari basin is 1,130 mm. About 8·6 per cent of the annual rainfall occurs during the months October to December in the lower Godavari and Sabari basins. The Manjra basin lies in the medium rainfall zone from 800 mm at its west end 1,000 mm in its north eastern part. The Penganga sub-basin receives about 800 to 1,000 mm, the Wardha sub-basin 900 to 1,300 mm and the Pranhita 1,100 to 1,600 mm of annual rainfall. The Indravati sub-basin lies in a fairly heavy rainfall zone 1,400 to 1,600 mm ; so also the Sabari sub-basin which receives 1,200 mm to 1,600 mm. The Godavari and its tributaries receive run-off contributed at different times because the date of on-set of monsoon is different in the different reaches of the basin. Due to paucity of observed discharge data, the correct assessment of the run-off of the Godavari river system has not been possible. However, the Krishna Godavari Commission (1962) have assessed the approximate average annual yields as follows :—

Manjra	7,650	million m^3
Penganga	5,100	"
Wardha	6,800	"
Pranhita	36,810	"
Indravati	32,850	"
Sabari	13,590	"
And the rest of the Godavari basin including the free catchment ..	15,200	"
The average annual yield of the entire Godavari basin is estimated as ..	48,000	"

Heavy floods in the river Godavari occur in the lower reach below Polavaram down to the sea. In the year 1953, the Godavari rose to its maximum height of about 6 m at the Dowlaishwaram Anicut and there were serious breaches upstream due to over-topping of the embankments. Whenever the river is in very high spate, breaches occur and result in large scale inundation. The silt brought down by the Godavari is deposited due to strong littoral drift at the mouth. The delt has extended on the northern side. The river is maintaing a straight course into the sea. Flood heights have not shown any particular increase in the Godavari delta.

KRISHNA RIVER SYSTEM

The Krishna which is the second largest of the east-flowing inland rivers of Peninsular India rises in the Western Ghats at an altitude of 1,337 m just north of Mahabaleswar about 60 km from the Arabian Sea and flows for a length of about 1,400 km from west to east through the States of Maharashtra, Mysore and Andhra Pradesh before falling into the Bay of Bengal. It drains a catchment area of about 2,59,000 km^2. Its main tributaries are the Koyna, Yerla, Varna, Panchganga, Dudhganga, Ghataprabha, Malaprabha, Bhima, Tungabhadra and Musi. These rivers like the main river run in deep channels and swell into brimming torrents during the rainy season while during the remaining months of the year, they become streams of insignificant flow. Near its confluence with the Dudhganga, the Krishna river has an altitude of about 533 m and at this point it has emerged from the heavy rainfall zone along the Western Ghats. A short distance below the junction of the Malaprabha, the Krishna drops from the table-land of the Deccan proper, by about 122 m to the level lands of Raichur. Both the Bhima and Tungabhadra drain very large areas of the Western Ghats and each is a major river in its own right. From a short distance below its confluence with the Tungabhadra, the Krishna runs in a deep gorge through a series of hills for nearly 290 km before emerging into the coastal belt at an elevation of about 37 m above sea level. Beyond Vijayawada, the river continues in a single channel of great width for another 64 km through alluvial delta and from there it sends off to the left a branch known as Puligada, which forms the island of Divi, and after a course of 30 km it enters the sea at Divi. The main stream continues for another 24 km and breaks up into three branches separated from one and another by two small islands covered by dense jungles more or less submerged during spring tides and high floods.

The bed slope of the river Krishna from its source to its confluence with Bhima is 1·43 m per km ; from Bhima confluence to the confluence with Tungabhadra is 0·55 m per km and from confluence of Tungabhadra to the mouth of Krishna river is 0·58 m per km.

Bhima and its tributaries drain 69,114 km^2 of the Krishna basin, contributing the major part of the water potential of the Krishna basin. Bhima rises in the Western Ghats at an elevation of 975 m near the village Bhimashankar in Poona district of Maharashtra. It flows for a distance of about 568 km in Maharashtra and 299 km in Mysore before joining Krishna. Ghad, Nira, Kagna and Sina are its tributaries. Their initial reaches are hilly and they mostly flow in plains.

River Tungabhadra like Bhima is a major tributary of river Krishna with considerable water resources. In all, it drains a catchment area of 69, 562 km^2. Its tributaries are Tunga, Bhadra and Hagari. Both Tunga and Bhadra rise in the Gangamula peak of the Western Ghats in Chikmagalur district of Mysore State at an altitude of about 1,200 m. Most of their catchments lie in the hilly Ghat region full of semi-deciduous forests and bamboo groves. Flowing down the Ghats, the Tunga river passes through deep valleys between broken chains of hills for a distance of 177 km before joining river Bhadra at Kudli to form the Tungabhadra river. Bhadra loses much of its rapidity soon after descending from the ghat region and flows through rocky bed and well defined banks for 145 km before flowing in a comparatively flat country and joining Tunga. River Bhadra is 193 km long. Hagari (also called Vedavati) which is 360 km long flows mostly in comparatively plain country. It joins Tungabhadra about 160 km upstream of confluence of Tungabhadra with Krishna. Tungabhadra after the union of the twin rivers Tunga and Bhadra at Kudli flows through high banks of red-loamy soils and it is joined by many small streams before it falls into Krishna after traversing 528 km from Kudli.

RAINFALL AND RUN-OFF

The chief source of the waters of the Krishna is the 708 km stretch of the Western Ghats which receives very heavy rainfall. Therefore, the Krishna river system gets maximum rainfall during June to September when the southwest monsoon occurs. The monsoon winds strike the west coast of the Indian Peninsula from the west-southwest and meet the western coast of the Indian Peninsula from the westsouthwest and meet the Western Ghats or the Sahyadri range which present an almost uninterrupted barrier ranging from 610 to 2,134 m high.

The amount of rainfall on the Ghats, at any place, is governed largely by the orographic features there. This factor introduces considerable spatial variation in the rainfall amounts. The conditions in the interior are somewhat unfavourable for heavy precipitation except in association with the depression from the Bay of Bengal. In the high rainfall zone of the basin which extends a few kilometres from the Ghats, the annual rainfall varies from 3,000 to 1,000 mm. January and February are the dry months with less than 15 mm of rainfall. Less than 150 mm occur during the months October to December. About 800 mm is the annual rainfall in the Krishna basin.

The upper reaches of the Bhima basin, lying in the Western Ghats, receive very heavy rainfall upto 5,080 mm per annum while the plains receive about 510 mm. In Tunga basin, the maximum rainfall occurs in the month of July and a large part of catchment gets more than 2,920 mm per annum. In particular, Agumbe records an average annual rainfall of over 8,130 mm as it is situated in the thick forest tract of the Western Ghats. The rainfall decreases steeply towards the plains where it is about 760 mm. In Bhadra basin, the rainfall on an average varies from about 3,300 mm in the hill region to about 760 mm in the plains. The catchment of Hagari is a dry tract with an average rainfall of about

640 mm annum. Except in the hill regions where there is heavy rainfall varying from about 1,520 mm to 3,050 mm a year, the rainfall in the free catchment of Tungabhadra varies from about 380 to 1,020 mm.

As in the Godavari, a feature of the flow in the Krishna river system is the fact that different parts of the catchment contribute to river flow at different times during the rainy season. There is not enough recorded data about the river flows of the Krishna river and its tributaries and this hinders a proper assessment of the run-off. However from the data available the approximate average annual yield have been assessed by the Krishna Godavari Commission (1962) which are as follows :—

Ghataprabha	5,380	million m^3
Malaprabha	1,980	"
Bhima	12,890	"
Tungabhadra	16,140	"
Musi	1,420	"
And the rest of Krishna basin including the free catchment ..	24,970	"
The total average annual yield for the entire Krishna basin is	62,780	"

The problem of floods fortunately does not loom large when compared to that in the Indo-Gangetic plain and other flood affected regions of India. With heavy downpour of rain in their catchments, the rivers spill over the banks in the lower reaches of their course causing floods, particularly, in the delta areas. A very heavy flood in the river Krishna occurred in 1949 which almost reached the previous maximum of 1903 when a Flood discharge of 34,000 m^3/sec was recorded at Vijayawada. A comparative study of survey carried out from 1786 to 1800 and those carried out during 1927 to 1930, shows that the delta of this river has extended into the sea by about 3 km over a sea-face of 22 km. The effect of this rise was demonstrated by higher gauges and more extensive damage during the 1949 flood compared with that which had occurred in 1903. Tides from the sea 0·60 to 1·25 m high travel up the river for about 48 km bringing considerable quantity of silt with them. During low floods the river gets silted up in its lower reaches and it is cleared when heavy floods wash down the deposited silt. The storage reservoirs like Tungabhadra and Nagarjunasagar on the river system, considerably moderate the floods in the river.

CAUVERY RIVER

The Cauvery which is the fourth largest of the east-flowing rivers is famous in that its potential has been largely utilized. It rises in the Bramhagiri hills near Mercara in Coorg district of Mysore high up amid the Western Ghats at an elevation of 1,341 m above sea level. The course of the river in Coorg is tortuous, its bed is rocky and its banks are high and covered with luxuriant vegetation. In this portion of its course, it is joined by many tributaries. The river passes through a fall of 18 to 24 m in the rapids of Chunchankatte. After this it widens to an average width of 274 to 366 m till it receives the Kabbani, from which point it swells to a much broader stream. The main tributaries which join Cauvery in the Mysore State are the Hemavati, Lokpavani, Shimsha and Arkavati in the north and the Lakshmanatirtha, Kabbani and Suvaranavati in the south. The tributaries originate on the Western Ghats which are hilly and thickly wooded. For a length of 64 km at the lower end of its course in Mysore the river forms the boundary between the States of Mysore and Madras. It is in this reach that the celebrated falls of the Cauvery at Sivasamudram, unrivalled for scenic beauty, bring the river from the Mysore plateau on to the plains of Madras. The river, here running northeast, branches into two channels, each of which makes a descent of more than 91 m in a succession of rapids and broken cascades.

After it enters Madras State it forms the boundary between Coimbatore and Salem districts till it enters the Mettur reservoir. Below Mettur dam, Bhavani river meets the Cauvery. Thereafter, it follows a southern course till it reaches the Noyil and Amaravati tributaries. Here the river becomes wide with a sandy bed and flows in an easterly direction. In Madras the river covers a length of 321 km and drains an area of 46,384 km^2.

The Cauvery breaks at the island of Srirangam into two channels. The Cauvery delta extends from a point 16 km west of Tiruchchirappalli to the sea. The delta is a gently sloping alluvial plain with vast stretches of rice fields interspersed with coconut and other fruit trees. Its area is about 3,200 km^2. The northern channel takes the name of Coleroon while the southern one retains that of Cauvery. The Coleroon is really the main channel of the river and carries the bulk of the flood waters to the Bay of Bengal. The southern branch of the Cauvery is utilised as the main channel for the supply of irrigation waters to the fields of the delta. It divides and subdivides into innumerable branches which form a network of distributaries all over the delta. Some of these find their way ultimately into the sea while others are lost in the wide expanse of fields. The one which retains the name of Cauvery throughout, reduces to an insignificant stream, enters the sea at Cauveripatnam, north of Tranquebar. In all, the river covers a length of 805 km and has a drainage area of 80,290 km^2. The sea-board of the delta is over 161 km long and extends from point Calimere in the south to Porto Novo in the north. This has shown no signs of extension for almost a century as is apparent from a comparative study of surveys made in 1791-1855 and 1929-31.

RAINFALL AND RUN-OFF

The highest rainfall usually occurs in July or in early August. The Mysore plateau which drains into the middle reaches of the river is subject to the fluctuating rains during the months of August to October. Upto the point where the Mettur dam is constructed, the area comes under the influence of southwest, monsoon and from this point downwards the catchment is within the influence of the northeast monsoon rains and the high floods due to this monsoon usually occur in November. This sequence of rainfall is conducive to a fairly high flow during the irrigation season from June to January except for a short period of about six weeks when there is a break in the monsoon. While the southwest monsoon supply is copious and dependable, the northeast monsoon supply is irregular and fails frequently. In the Cauvery basin, upstream of Krishnarajasagara dam, the rainfall varies from 760 to 2,720 mm.

The annual run-off of Cauvery basin at the gauging sites are given below :—

Serial No.	Discharge gauging stations	Catchment area in km^2.	Annual run-off in cubic metres
1.	Krishnarajasagara Dam ..	10,360	68,400
2.	Mettur Dam ..	42,217	97,100
3.	Bhavani Bridge ..	44,512	87,400
4.	Aghanda Cauvery at the upper Anicut ..	67,547	144,300

The highest floods usually occur during July and August though on rare occasions they have been as late as November. It was in 1924 that the highest flood in the living memory occurred in the river. During a period of 24 years prior to that occurrence the highest flood was in 1896 when 5,861 m^3 per sec passed at the site of Mettur Dam but the great flood of 1924 had recorded an estimated flood of 12,912 m^3 per sec at Mettur nearly two and half times as great as the highest flood previously recorded. The construction of the Mettur Dam has a large moderating effect in the Cauvery and the devastation caused by the 1924 flood in the Cauvery valley below Mettur will not recur though moderate floods of longer duration will be probable.

Below the Grand Anicut the old beds of the river, except the Coleroon, which are being used as the main canals for the distribution of water for the vast irrigation in the area are often sanded up. The fact is that the flow in the river is restricted to the Coleroon branch only owing to the heavy siltation of the other branches. The Coleroon is really the flood carrier while the Cauvery distributes the waters for irrigation.

The above pages give briefly the general hydrology of the main rivers of the country. India has a large system of rivers fairly well distributed all over the country. They constitute a potential source of wealth if properly harnessed and used. A good knowledge of hydrology of these rivers is essential for the purpose. It is perhaps the first step necessary in the planning and development of water resources of the country.

CHAPTER XVII

USABILITY OF INDIAN RIVERS

India is fortunate in having several large rivers with numerous tributaries spread over the whole country. The tributaries of the Indus in the northwest drain the western Himalaya and flow westward towards Pakistan. The Ganga originates in the central Himalayan range, and with its tributaries, traverses a vast alluvial plain, on its way to the sea. Towards the east are the plains of the mighty Brahmaputra with its several large tributaries. The two long parallel rivers, the Narmada and the Tapi lie in the dividing ranges of the Vindhya and the Satpura and drain into the Arabian Sea. Towards the east coast, the Mahanadi flows from the highlands of Madhya Pradesh into the Bay of Bengal. The southern Deccan Plateau is traversed by the three big rivers i.e., the Godavari, the Krishna and the Cauvery, which flow from west to east into the Bay of Bengal.

These great river systems comprise the large water wealth of the country. The volume of annual precipitation in the country has been estimated at about 3,700,440 million cubic metres of which a substantial part seeps into the ground, and, is lost by evaporation and transpiration. The mean annual river flow is estimated at about 1,677,532 million cubic metres.

India has also a large population to support. The population assessed at 428 millions in the 1961 census, has crossed the 500 million mark by the end of 1966 ; it may increase to 900 million by the end of the century. Besides being a basic need for human existence, water is the primary input into most of the measures that go towards improving the living conditions, and, standards of human society.

Towards this end, the rivers of India are put to use for purposes of irrigation, domestic and industrial water supply, hydel generation, and navigation.

Irrigation

India is a vast country with a wide variety of climate. Of of the total area of about 334 million hectares, about 192 million hectares are cultivated. Of these, about 136 million hectares are under cropping at present. Agriculture is the most important industry in the country. which sustains about 70 per cent of the population.

The continuing rise in population demands increasing food production, which cannot be assured only on the rain, with its vagaries from year to year. Irrigation, therefore, becomes a necessary tool for successful agriculture. Most of the irrigation depends upon the surface water resources, which are provided by the Indian rivers. The rivers are well spread over the whole sub-continent, but their flows vary in quantity from season to season, and year to year.

The southwest monsoon is the main sources of precipitation and lasts about June to September over the whole sub-continent. The northeast monsoon is usually active from October to February. In the States of Madras, Jammu and Kashmir, Andhra Pradesh and Kerala, the winter rainfall accounts for 53 per cent, 28 per cent, 28 per cent and 20 per cent respectively of the total annual ; in other States, the percentage varies from 4 to 14.

The annual average rainfall over the country has been worked out to be 1,170 mm, with considerable variations in space and time. For example, Cherrapunji in the northeast receives an annual average rainfall of about 10,600 mm, which is, perhaps, the highest in the world, while the Rajasthan desert in the northwest receives only about 126 mm at an average.

The seasonal and annual variations in rainfall make the Indian economy and planning a gamble on the monsoons. This underlines the need for properly harnessing and utilising the rivers of India by suitable irrigation works so as to supply assured waters for agriculture.

The rivers of India fall in two broad categories, viz., those in the north, which originate in the snow-clad Himalaya, and which carry perennial flows, varying according to the season of the year. The other category is the rivers in the central and south India, which depend upon the monsoon rainfall. Therefore, during the monsoon season they carry very heavy flows, which dwindle down to negligible quantities in the fair weather.

While, therefore, some kind of assured flows for irrigation can be provided from the northern rivers, successful agriculture in the rest of the country depends more upon controlled storages. The history of irrigation in India has been conditioned by these characteristics of its rivers.

Irrigation during the ancient time

Civilizations in the world have grown around sources of water ; India is no exception. Early population settled along the country's rivers, and developed irrigated agriculture, as well as cities and towns. The famous Indus civilization was highly developed, and there are clear indications that some sort of irrigation system had also been developed on which food crops and cotton were grown. Old scriptures like the Rig Veda, Atharva Veda, and mythological books like the Mahabharata, written centuries before the Christian era, contain indications about the practice of irrigation from wells, canals, reservoirs etc. Similarly, historians like Megasthenese, while recording his impressions in the fourth century B.C., also mentioned about irrigation facilities.

Another famous example of old irrigation works is the Grand Anicut across the Cauvery river in south India. This was constructed in the 2nd century A.D., and proves the talent of the local engineers, which must be considered as of extremely high order. Similarly, there are a large number of tanks in the southern peninsula of the sub-continent.

Irrigation development also received great attention during the pre-Mughal and the Mughal periods in the 14th to 17th centuries A.D. Notable examples are the Yamuna Canal near Delhi, constructed in the 14th century. This was later named Western Yamuna Canal, which is even today successfully serving a substantial area near Delhi. The Eastern Yamuna Canal followed the Western Yamuna Canal during the reign of the Mughal King, Mohammed Shah (1719-1748). Other small systems of old are also in existence in the country.

The science of drainage was not so well known of advanced, and there are indications that on account of water-logging and drainage congestion, conditions sometimes became unhealthy, and villages and cultivated lands had to be abandoned.

Development during the British Period

The British inherited a tradition of irrigation in India. The Indian Irrigation Commission of 1901-1903 recorded "Be this as it may, it is certain that it was the existence of the Grand Anicut in Madras, and the remains of old Mohammedan channels in the Punjab and United Provinces, which suggested and led to the construction of the earliest works carried out under British rule. India, therefore, in a great measure owes to her former rulers the first inception of the present unrivalled system of irrigation works".

The initial step taken by the British was to undertake the renovation and re-modelling of the Western Yamuna and the Eastern Yamuna Canal systems. The other important work taken at the time was the Cauvery Delta Canal system in conjunction with the Grand Anicut, which was renovated and reconstructed.

Another notable example of irrigation works was the construction, by Sir Arthur Cotton, of a masonry weir across the Coleroon, a branch of the Cauvery river, which ushered the age of irrigation works from the year 1836 to the end of the century. The Upper Ganga Canal in U.P. was commenced in 1842 and completed in 1854 by Cautley. This was followed by other canals like the Lower Ganga, the Agra and the Betwa Canals in U.P., Sirhind Canal in the Punjab, Mutha Canal in Bombay (now Maharashtra), and the Periyar Canal in south India. Other notable works were the weirs across the river Godavari near Rajahmundry, and across the river Krishna near Vijayawada, along with their canal syetems, which led to the irrigation of the fertile Godavari-Krishna deltas.

Occurrence of very serious famines towards the latter part of the 19th century led to the appointment of the Indian Irrigation Commission in 1901, to report on irrigation as a protection against famines in India. The Commission submitted their report in 1903, and most of their recommendations were accepted by the Government of India. This gave further impetus to irrigation projects, and led to a number of important projects like the Triple-Canal Project in the Punjab, the Godavari Canals in Maharashtra and the Tribeni Canal in Bihar.

Further works were taken up after the First World War, notable examples being the Mettur and the Krishnarajasagara Projects in the south and the Ganga and the Sarda canals in the north. Besides these major syetems, a large number of medium and small irrigation works like tanks and canals were also constructed all over the country. This led to substantial increase in irrigation and food production.

Post-Independence period

During the depression of the 1930s and the Second World War, there was little addition to irrigation development. With the attainment of Independence in 1947, however, the need for food production and raising the standards of the country's population, led to post-war reconstruction programmes, including irrigation works. The establishment of the Planning Commission in 1950 resulted in an all round development, and a large number of irrigation projects were planned and undertaken.

The partition of the country in 1947 resulted in major irrigated areas going to Pakistan. Of the total volume of water carried by the canals in undivided India, the canals in Pakistan received 81,400 million cubic metres of water, against 11,100 million cubic metres of water used by India in the Indus basin. In terms of irrigated area, about 8 million hectares of land went to the share of Pakistan, against only about 2 million hectares left in India. This, further, necessitated the rapid planning and growth of irrigation potential, if India was to meet the needs of food for its population. It was under these circumstances that active measures were taken from 1951 onwards towards planning of irrigation from the Indian rivers.

The total average precipitation in India is estimated as equivalent to about 3,700,440 million cubic metres of which a substantial amount seeps into the ground and is lost to the atmosphere. Further, limitations to beneficial use are imposed by topography, flow characteristics, and other factors. Thus, only about 555,166 million cubic metres of water can is assessed to be utilised for irrigation.

It has been estimated that, of this about 93,734 million cubic metres were being utilised for irrigation upto the end of 1951, which was the beginning of the First Five Year Plan. By the end of the Second Five-Year Plan (1960-61), the utilisation had risen to 148,017 million cubic metres, thus raising the percentage from 17 to 27 in 10 years. At the end of the Third Five-Year Plan (1965-66) the total utilisation has risen to about 185,022 million cubic metres, i.e., about 33·33 per cent of the total utilisable flows. There is still scope for utilising about 370,044 million cubic metres of water for irrigation projects in the future.

The irrigation projects in the country fall into two main categories, viz.,

(i) Major and Medium ; and

(ii) Minor Irrigation Schemes.

The categories have been fixed on the basis of cost, i.e. schemes costing upto Rs. 15 lakhs are termed Minor, between Rs. 15 lakhs and Rs. 5 crores, as Medium, and above Rs. 5 crores, as Major. The major and medium irrigation schemes fall within the purview of the Irrigation Ministry, and are usually treated as a single unit. The minor schemes are within the purview of the Agricultural Ministry. By and large, the major and medium schemes comprise storages and diversion weirs across rivers and streams, while the minor schemes consist mainly of small storage works and development of underground water resources by tubewells and dug-wells.

The pre-Plan irrigation from major and medium irrigation projects was of the order of 9·6 million hectares. In the First Plan (1951-56) 250 major-medium schemes were visualised of which 237 schemes were undertaken for execution, with an outlay of Rs. 380 crores (including Rs. 80 crores on schemes taken up prior to the commencement of the Plan). During the Second Plan (1956-61), 188 new schemes were added and the total outlay during the Plan was Rs. 380 crores. In the Third Plan (1961-66), 103 new schemes were included and the outlay during the Plan was Rs. 572 crores. The outlay on major-medium schemes in the Fourth Plan is visualised at about Rs. 825 crores.

The total ultimate irrigation potential under major-medium irrition schemes is assessed at 44·8 million hectares, of which about 16.4 million hectares would have been developed by the end of the Third Plan.

The total potential of the major-medium schemes undertaken during the three Plans is expected to be 16 million hectares, in addition to the 9·6 million hectares pre-Plan. Future planning would, therefore, cover the balance of about 19·2 million hectares in this sector.

The total irrigation potential added during the three Plans amounts to about 6·8 million hectares, of which about 5·6 million hectares had been brought under actual irrigation. Thus, under the major-medium irrigation projects, a total of about 15·2 million hectares have been brought under irrigation upto the end of the Third Plan.

The area irrigated under minor schemes at the beginning of the Plan period was about 12·8 million hectares. This has been raised to 20 million hectares by the end of the Third Plan, the total outlay being about Rs. 6,000 million in the three Plans.

The total ultimate irrigation potential from minor irrigation schemes is estimated at 30 million hectares, of which about 12 million hectares would be from surface water resources and about 18 million hectares from the underground resources. Further development of minor irrigation would add 10 million hectares of irrigated area.

The total investment on irrigation works during the years 1800-1950 was of the order of Rs. 1,560 million, against which the total outlay during the 15 years of the three Plans is about Rs. 18,500 million, on both major-medium and minor works. Even with the depreciation of money values, this fact alone would indicate the intensive efforts that are being made in the country to increase its irrigation development, towards self-sufficiency in food, and providing the rural population with gainful employment.

Irrigation Management

According to the Indian Constitution, irrigation is a State subject. Since, however, the start of the Five-Year Plan in 1951, the planning and co-ordination of all sectors is achieved by the Planning Commission. Therefore, no major-medium scheme is taken up for execution without the approval and technical clearance from the Planning Commission. The process of planning involves Central assistance by way of grants and loans; this assistance is contingent on proper sanctions by the Planning Commission.

By and large, the schemes are investigated, planned, prepared and constructed by the States. The Central Water & Power Commission renders technical help in this regard, when required. The Central Water &

Power Commission also helps the Planning Commission in scrutinising irrigation schemes and assessing their merits, etc.

As has already been mentioned, the total cultivable area in the country is of the order of 192 million hectares, while the total area that can be irrigated by all categories of irrigation projects is of the order of 75 million hectares. Therefore, the water resources fall short of the land resources. This underlines the need of proper irrigation and water management, so that maximum benefits may accrue from the irrigation schemes.

Sound water management has to begin at the very start of an irrigation project, and requires that construction of canals, distributaries and field channels should be synchronised with the construction of the diversion works or the storages, so that water is put to beneficial use as soon as it is made available.

While the major installations for storage and supply of water are the responsibility of the Irrigation Department, the other departments of the Government, like the Revenue, Cooperation, Agriculture, etc., have to coordinate activities in the matter of getting water to the field, and its proper utilisation. It is these departments that are responsible for looking after the supply of the needed finances, seeds, fertilizers, land-levelling, equipment, etc., to the irrigators, before the water can be utilised with the maximum benefit.

There are many other measures which are adopted for economising the irrigation water, and for assuring its most beneficial use. These involve items like lining of canals in highly pervious zones, soil surveys for deciding the best cropping patterns, agriculture research and trials in regional soil-climate complexes and extension services by way of demonstrations on Government farms and irrigators' plots.

In a country where irrigation waters are not available in a plentiful measure, the provision of irrigation facilities to only a part of the community gives them special benefits, which are financed by the general community. It, therefore, becomes incumbent on such beneficiaries to pay for this facility, at least up to their full capacity, if not to the full cost of the works. This is achieved by levying water rates which are generally charged on crop-area basis.

The water rate structure in most States has not been modernised to keep pace with the increasing prices and returns to the irrigator. There is need for an upward revision of water rates on almost all crops in most of the States. The best method suggested for this purpose is to levy a water charge on a two-part tariff system. This visualises a compulsory charge per hectare on the total area commanded by the irrigation system and an additional charge on the crop area basis.

The provision of irrigation facilities in an area leads to increased agricultural production, and, appreciation of land values. It is considered reasonable that a part of such unearned gains should revert to the general community. This can be done in various ways, the most favoured being in the form of betterment levy. This connotes the recovery of a charge per hectare in equated instalments over a period of time. Attempts at recovery of such a levy have not succeeded in any large measure so far. The matter is under review in most States.

For long time past, irrigation had been considered a commercial proposition, and irrigation projects were sanctioned on the basis of direct financial returns, which aimed at recovery of the servicing charges on the capital invested by way of interest, depreciation and maintenance. Since, the costs of construction have risen steeply while the returns to the farmer have not appreciated to the same degree, the matter was reviewed. It is not felt that irrigation provides not only direct, but also, indirect benefits to the community which are not quite susceptible of accurate assessment. Therefore, the yard-stick for acceptance of irrigation projects is now based on the benefit-cost ratio, only direct benefits being taken into account for the purpose. The criterion will, no doubt be under continuing review and refinement, in the light of the experience gained.

Generation of power

With a large base of rural population, dependant on agriculture, it was but natural that irrigation should have the first priority on the utilisation of Indian rivers. Industry was slow in developing for various reasons, and, the need for electric power was confined mainly to large urban centres. After Independence, however, there was a general urge towards improving the living standards of the population. This meant industrialisation, and cheap electric power.

The total installed capacity of electrical installations in 1947 was about 1·36 million kW, generating about 4,000 million kW per year. This averaged 16 kW per capita of the country's population, and was one of the lowest in the world. It was, therefore, necessary to look for cheap sources of electric power, if the country was to develop as it planned to do.

The relief of India—a large country with high mountain ranges and several major river systems would immediately suggest the possibility of cheaply developing its large waterpower resources. Topographically, the Himalayan ranges in the north, the Vindhya, the Satpura ranges, the Aravalli in the west, and the Maikala and Chota Nagpur in the east, rising from the Peninsular Plateau, the Garo, Khasi and Jaintia hills constituting the Shillong Plateau and the Western and Eastern Ghats of Deccan Plateau, offer possibilities of large scale hydro power development.

In regard to water resources, the Indian rivers drain at an average approximately 1,677,532 million cubic metres of water every year, of which 60 percent represents the contribution from the Himalayan rivers, viz., the Indus, the Ganga and the Brahmaputra, 16 per cent from the Central Indian rivers mainly the Narmada, the Mahanadi and the Tapi and the west from the rivers draining the Deccan Plateau, the important of which are the Godavari, the Krishna, and the Cauvery.

The practical harnessing of these vast resources, however, is governed by numerous factors which impose limitations both in the regulation of the fluctuating river flows and in the development of "Head" for power generation.

The basic pattern of the river flow is similar all over the country, and is characterised by a short spell of heavy discharge during the monsoon period followed by a long period of lean flow. The dry weather discharges of the Peninsular rivers which are derived mainly from ground water storage, dwindle down to a trickle during the summer months, just preceding the monsoons. Variations of the order of 1 to 3,000 in the mean monthly flows of these rivers are not uncommon. The range of variation in the flows of the Himalayan rivers is, however, not so great due to the fact that the extensive glacier and snow-fields which are drained by these rivers function as vast natural reservoirs and contribute significantly to the dry weather flows during the pre-monsoon months. With the above pattern of inflows, provision of regulating storages to even out the wide, seasonal fluctuations, becomes the key factor in hydro-electric development in this country.

Dependable power generation particularly on the rivers of the Peninsula and Deccan Plateau would not be possible at all without substantial facilities for impounding the water during the monsoon months. In the case of the Himalayan rivers, although the problem is not so serious due to the fact that even during the critical winter months, the river flows are appreciable, thereby providing some scope for hydro power development on the run-of-the-river basis, even small storages afford substantial increase in the dependable flows and a higher degree of utilisation for firm power generation.

Limitations in providing adequate storage are set by topography and economics. In the uppermost reaches of the valleys where economic "high head" schemes can be planned, the valley characteristics are generally unfavourable for substantial storages. In the middle and lower reaches, more amenable to large storages, only a few sites are available, where economic regulating structures can be constructed, these being usually the well settled areas of river valleys where problems of submergence of cultivated lands and habitations are most serious.

Regional factors also impose limitations in development. For example, in the Himalaya, although the topography presents scope for development of large drops for power generation, the narrow valley configurations generally preclude provision of large storages for regulation. The high seismicity of the region does not permit construction of very high structures. Similarly, the Decccan Plateau with the prominent mountain ranges of the Western and the Eastern Ghats presents topographically a vast potential for hydro power development, but its actual exploitation is greatly limited by the over-riding priorities of irrigation. The Indo-Ganga Plain, a vast stretch of flat alluvium, exhibits practically no variation in relief and therefore is of little significance from the point of view of hydro power generation, although the Ganga and its tributaries drain large quantities of water.

Such limitations have to be taken into account while making any realistic assessment of the usability of Indian rivers for purposes of hydro-power generation.

The common approach of assessing the power potential is on the basis of the "theoretical limit" representing integration of the products of "average flow" and "head" and deriving therefrom the "technical limits" and the "economic limits" by proper surveys and studies. Accordingly, a systematic survey of the hydro-electric resources of the country, based on specific schemes of development evolved from available topographical and hydrological data, and taking into account the various limitations indicated above was undertaken by the Central Water & Power Commission during 1953-60. On the basis of about 240 existing and possible schemes pinpointed by this survey, the economically exploitable hydro potential of the river basins within the territories of the Indian Union aggregates to about 41 million kW at 60 percent load factor, corresponding to about 216,000 million kW of firm energy output annually.

For purposes of the survey, the country was divided into six regions based on contiguity and similarity in geographic characteristics. The problems and results of the assessment in each of these regions is discussed in the following paragraphs.

The Indus basin

The water of the Indus basin (Indus and its five tributaries, the Jhelum, Chenab, Ravi, Beas and Sutlej) are being used extensively for irrigation and power in India and Pakistan under the Indus Water Treaty, The Indus Basin with the restrictions on storage and its water uses has a total potential of about 6·582 million kW at 60 per cent load factor, corresponding to 34,500 million kW of annual firm output.

The Ganga basin.

The Ganga basin constitutes the largest river system in the country and comprises the rivers which drain the great Himalayan range in the north, viz., the Ganga, Yamuna, the Ghaghara, the Gandak, and the Kosi, and those that drain the northern part of the Central Plateau, viz., the Chambal, the Betwa, the Ken, the Tons and the Son. The hydro potential of the southern tributaries are concentrated in their upper reaches before they emerge from the Peninsular Plateaus into the plains, the most important ones being in the Son Valley.

As already pointed out, firm power generation in the case of the Himalayan rivers, depends upon the extent of regulation of the river flows possible with storages, though possibilities of run-of-the-river developments also exist in view of their relatively large unregulated discharges. Apart from a few sites in the foothills of the Himalayan range such as the Bhakra site which is one of the most favourable sites from the point of view of storage, the general topography excludes possibilities of very large storages, the valleys being steep and narrow. However, the large snow-fed catchments ensure high run-off in all except the winter months and consequently, wherever storage developments appear feasible, even comparatively small storages could increase the power draft considerably above the minimum winter discharges. Not only do these discharges constitute large power potential at the dam sites, but they invariably also enable better utilisation of the drops below the point of regulation.

The hydro potential of the Ganga basin has been estimated at about 4·828 million kW (25,400 million kW annual output).

The Brahmaputra basin.

The Brahmaputra enters the Indian territory from the northeastern side under the name of Dihang and joined subsequently by several tributaries draining the Himalaya and the northern face of the Shillong Plateau. There are practically no possibilities of providing storages on the Himalayan tributaries of the Brahmaputra. However, the large dependable discharges of the Dihang and its two major tributaries, the Luhit and the Dibang contributed by the snow-covered catchments that they drain, and the steep course that these rivers traverse through the Himalaya, constitute some of the major possibilities of run-of-the-river developments in the world.

The southern tributaries of the Brahmaputra drain the northern face of the Shillong Plateau which slopes gently with intermittent steep stretches towards the Brahmaputra valley. There are attractive possibilities of high and medium head hydro developments on these rivers.

The southern face of the Shillong Plateau is drained by rivers which form tributaries of the Surma. These have a flat course in their upper reaches providing facilities for storages. In their middle reaches, they flow into the Surma in a series of rapids and falls, sharply dropping by about 1,200 m in elevation. Though the catchment areas above the level stretches of these rivers in their upper reaches are small, they receive very high rainfall (highest in the world), and have possibilities of developing high heads with short stretches of water conductor systems. These are factors favourable to major hydro-electric development in these rivers.

The Barak and the Manipur rivers in Manipur State also have important possibilities of hydro-electric development. The irrigation possibilities in these regions are practically negligible and, therefore, the water resources can be utilised mainly in the interest of hydro power generation. The survey has located a number of schemes in this region with a total potential of 12·486 million kW corresponding to 65,600 million kW of annual power output.

The Central Indian rivers.

The most important of the Central India rivers are the Baitarani, the Brahmani and the Mahanadi which have their origin in the Central Plateau and drain eastward to the Bay of Bengal while the Narmada and the Tapi which have also their origin in the Central Plateau but drain westwards to the Arabian Sea. Like the east-flowing rivers in the south, these rivers are characterised by gentle gradients, their water courses having no sharp drops, and irrigation has a high claim over their water resources. Development of these rivers for power generation has necessarily to be coordinated with irrigation and they depend mainly on the storage capacity that would be available after allowing for requirements of irrigation and flood control.

In the Baitarani and the Brahmani basins, the power potential is concentrated in the upper reaches, where the irrigation possibilities are negligible, thereby enabling utilisation of the flows entirely in the interests of power generation, although the regulated discharges resulting therefrom can be utilised for irrigating large commands in the lower reaches.

The Mahanadi, on the other hand, runs through a relatively flat area in its upper reaches which affords practically no site for major power development. In its middle and lower reaches, it flows through the Eastern Ghats where construction of dams for storages and multipurpose development for irrigation, power and flood control is possible. The 270 MW

Hirakud Project, completed a few years ago, marks the beginning of such a unified development.

By far the greatest concentration of hydro power in this group is the middle and lower reaches of the Narmada where the river flows alternately through plains and narrow gorges in a trough between the Vindhya and the Satpura ranges. Here, with the main regulation provided at a dam site near Punasa and at a few upstream sites, it would be possible to generate 1·6 million kW at 60 per cent load factor.

West flowing rivers of the Western Ghats.

The western face of the Western Ghats rises steeply from the narrow coastal plains to elevations upto about 2,100 m and intercepts the rain bearing winds of the southwest monsoon, causing heavy precipitation ranging from 2,000 m to over 7,000 m, in the general neighbourhood of the dividing range. The bulk of the precipitation, north of Goa, drains eastward ; south of Goa, the drainage is westwards by a number of rivers in the States of Mysore and Kerala. These rivers have sizeable catchment areas situated at elevations between 600 m to 1,800 m above sea level with storage possibilities for impounding the heavy monsoon flows. These areas being situated in close proximity to the coastal plains, the stored waters can be utilised for power generation at drops ranging from 300 m to 750 m, constituting some of the country's most valued assets of cheap hydro power. The precipitous topography of these river basins precludes irrigation development, except in the narrow coastal plains in the lower reaches.

The major rivers on which economic schemes could be evolved are the Kalinadi, Bedti-Sonda, Sharavati, Varahi, Barapole, Kuttiyadi, Kundipula, Chalakudi, Periyar and the Pambiar. The total power potential has been estimated at 4·345 million kW at 60 per cent load factor, corresponding to about 22,800 million kW of firm annual energy output.

East flowing Rivers of Southern India

The most important east-flowing rivers of Southern India from the point of view of water resources development are the Godavari, the Krishna and the Cauveri. These rivers except some of the tributaries of the Godavari rise in the Western Ghats and traverse almost the full width of the Deccan Plateau with very gentle gradients before draining into the Bay of Bengal. Along their courses, there are several possibilities for large scale irrigation development which claims priority and sets serious limitations on practical development of firm hydro power.

The Godavari has a catchment of 301,217 km^2 and drains about 70,920 million cubic metres of water (dependable flow) to the Bay of

Bengal. The tributaries of the Godavari have limited irrigation potential in their valleys, their enormous flow being in excess of what can be economically used for irrigation, thereby making it possible to utilise these flow for development of hydro-power on a large scale with an estimated potential of 6.15 million kW at 60 percent load factor (32,300 million kWh of firm energy output annually.

The sources of the Krishna river and its numerous affluents lie along the ridge of the Western Ghats extending over a distance of about 950 kilometres, subject to heavy precipitation from the southwest monsoon. The water of some of the tributaries of the Krishna in the upper reaches in Maharashtra which are capable of utilisation with drops of about 600 m along the western face through trans-basin diversion have been exploited by the Tatas at their Bhira Bhivpuri and Khopoli stations. The Koyna Project, undertaken by the Maharashtra Government is a similar scheme with an ultimate installed capacity of 900 MW, of which an installation of 540 MW is already in operation. Except for the stretches near Jaldrug in its middle reaches, and near Srisailam in the lower reaches where a 500 MW project is under construction, the gentle easterly course of the main Krishna river offers very little scope for hydro power development.

The water resources of the Cauvery also are required for irrigation, in Madras and Mysore, and, therefore, development of firm power along the course of the river is limited. The Nilgiri range which is important source for hydel power generation is drained in the north by the Pykara river and in the south by the Kundah and the Upper Bhawani. These have already been exploited by the State of Madras for affording a total potential of about 420 MW at 60 percent load factor. The total potential of the east-flowing rivers has been estimated at 8.626 million kW at 60 percent load factor (45,300 m kWh of firm annual energy output).

Of the total possibilities of developing about 41 million kW of hydro potential at 60 percent load factor in the country, the hydro potential actually developed by the end of the Third Plan was 3.25 million kW, at 60 percent load factor which is expected to rise to about 6 million kW at 60 percent load factor by the end of the Fourth Plan. There is thus still a very large amount of hydro-potential awaiting development.

NAVIGATION

Navigation in the early days

Inland waterways by and large constitute an important and economical means of transport in the various parts of the world. The Ganga and the Brahmaputra river systems in the north and the northeastern part of the country, the Mahanadi in Orissa, the Godavari and the Krishna in Andhra Pradesh, the Narmada and the Tapi in Gujarat, the lakes and tidal creeks of Kerala, Orissa and West Bengal, possesses some of the very important and useful natural waterways in India. The trade by country boats on these waterways flourished in the olden days. Yuktikalpataru, an ancient work in Sanskrit, which describes the art and science of building sailing craft is an evidence of the importance attached to inland navigation in ancient times. Inland navigation, suffered a set back with the advent of rail and road communications.

The earliest recorded observation on navigation in India is by Megasthenes, the Greek traveller, who toured India more than two thousand years ago. According to him, the Ganga, the Indus and their tributaries and other fifty eight rivers were navigable in India.

Even in the 14th century, navigation along rivers and other water courses was flourishing. Very authentic description of the various canals and rivers in this era, and the territories covered by them are given by Rennell in his book "Man of Hindoostan of the Mogul Empire". Of the Ganga and Brahmaputra Rennell says.

"The Ganga and Burrampooter rivers, together with their numerous branches and adjuncts, intersect the country of Bengal in such a variety of directions, as to form the most complete and easy inland navigation that can be conceived. So equally and admirably diffused are those natural canals over a country that approaches nearly to a perfect plain, that, after excepting the lands contiguous to Burdwan, Birbhoom, etc., we may safely pronounce that every other part of the country, has even in the dry season, some navigable stream within 25 miles (40 km) farthest ; and more commonly within a third part of that distance. From Hurdwar, in latitude 30 degree, where it (i.e. the Ganga) gushes through an opening in the mountains, it flows with a smooth navigable stream through delightful plains, during the remainder of its course to the sea (which is about 2,160 km), diffusing plenty immediately by means of its living production ; and secondarily by enriching the adjacent lands, and affording an easy means of transport for the production of its borders".

In the 19th century, the irrigation-cum-navigatign canals formed the main arteries of the transport system in the country. The introduction of steam vessels in the northeast of India during the early part of this century completely revolutionised inland water transport and assisted in the growth and development of the indigo industry in Bihar, the jute industry in Bengal and the tea industry in Assam.

Rise and decay

Steam power propelled the first water craft in India in 1823, when the 81 metric tons "Diana" sailed with passengers from Kulpi road to Calcutta on the Hooghly, a distance of 80 kilometres. This turned out at first to be a mere novelty, but by 1834, steam asserted its superiority and a regular monthly steamer service between Calcutta and stations on the Ganga was established and steamers plied on the Ganga as far as Garhmukteshwar, 640 kilometres above Allahabad. In 1842, a regular fortnightly service was functioning between Calcutta and Agra on the Yamuna. About the same time, two British companies started service on the Ganga, and later on, on the Brahmaputra. These services covered 8,000 kilometres of the water-ways (in India and East Pakistan). Incredible as it may seem, until 50 years ago, steamers plied as far as Ajodhya on the Ghaghara river in Uttar Pradesh a distance of 320 kilometres above its confluence with the Ganga.

Steam navigation, however, never at any time amounted to more than a comparatively small part of the total navigation on the Ganga and the Brahmaputra river systems. A great bulk of the traffic was carried in country boats plying from Delhi and Nepal border up to Assam. At its peak in 1876-77, the country-boat traffic registered at Calcutta 1,78,627 cargo boats, at Hooghly 1,24,357, and at Patna 61,571.

The decline of water transport began with the construction of the railways during the middle of the nineteenth century. The Government gave preference to the development of railways and the water transport was neglected. As a result, the traffic by country boats as well as by steamers declined.

The next factor contributing to the decline was the withdrawal of large quantities of water for irrigation, resulting in the decrease of water depths in the upper reaches of the Ganga and the consequent suspension of steamer services above Allahabad.

Whatever navigation still remained on the Ganga was further affected by the partition of the country, which completely altered the trade pattern between northeast India and East Pakistan. Consequently, the steamer companies incurred losses on the Calcutta-Bihar services and had to curtail the frequency of the services on the Ganga from Calcutta upto Patna and Buxar and on the Ghaghara upto Barhaj. A skeleton service, however, continued till it was finally withdrawn in January, 1958.

Before the termination of the Calcutta-Assam service, about 93 percent of the jute and 90 per cent of the tea trade of Assam as well as about 10 percent of the 10 million tons of cargo handled by the Calcutta Port used to be carried by the inland water transport.

Important waterways.

The total length of important navigable waterways in the country is about 10,600 km comprising :

(i)	rivers navigable by steamers and large country boats— ..	2,480 km
(ii)	rivers navigable by medium size country boats—	3,920 km
(iii)	canals and back waters navigable by country boats—	4,200 km

These exclude small tidal creeks on the coast which are not connected to any waterway system. Besides these, some stretches of a few rivers have been covered by the reservoirs of storage dams and have also become navigable.

The most important navigable rivers are the Ganga (and its major tributaries the Yamuna, the Ghaghara and the Gandak), the Brahmaputra and the Mahanadi. Navigation for short distances from their mouths, is also carried on other rivers, such as the Godavari, the Krishna, the Narmada and the Tapi.

There is extensive navigation in the coastal areas and in the backwaters of Kerala, Orissa and Bengal. The Orissa coast canal connecting Cuttack with Calcutta, was constructed exclusively for navigation. This canal was later on neglected due to the construction of railways and a portion of it was abandoned in 1928. The Buckingham canal the Vedaranyan canal and the west-coast canal are other important canals constructed solely for navigation.

There are also irrigation-cum-navigation canals, such as the Krishna and the Godavari delta canals in Andhra Pradesh, the Mahanadi delta canals in Orissa, the Ganga canal from Hardwar to Kanpur, the Yamuna canal in Uttar Pradesh and the Son canal in Bihar. Some of these canals still serve the navigational needs of the local people.

Progress since Independence

The Government of India has been considering ways and means of restoring inland water transport to its rightful place since Independence and an inter-State conference of the States in northeast India was held to consider suitable measures to establish inland water transport on a firm and economic footing in this region. In 1948, information was collected from the State Governments on various points connected with the development of inland water borne traffic construction of craft, training of marine personnel, and the number of registered companies operating inland water transport, etc.

Among the river valley development projects, taken up since Independence, the Damodar Valley Project in Bihar and West Bengal provides navigation facilities in the Left Bank Main Canal taking off from the Durgapur Barrage. This connects the lower Raniganj coalfields with Calcutta by a navigable waterway. Navigation on this canal has been started since 1965.

Ganga Brahmaputra Water Transport Board

A conference amongst the representatives of the States of Bihar, Uttar Pradesh, West Bengal and Assam, held in April, 1951, resulted in the formation of the Ganga Brahmaputra Water Transport Board in 1952. This Board deals with problems relating to navigation on the Ganga and the Brahmaputra and their tributaries, besides running pilot projects with shallow draft tugs and barges on the Ganga.

Inland Water Transport Committee

In 1956, the Central Board of Transport had recommended the formation of a committee to examine the part played by inland water transport on an all India basis and to make recommendations for further improvement. Consequently, the Government of India, set up the Inland Water Transport Committee in 1957. The members of the Committee visited important waterways in the country and held discussions with State Government officials and private bodies interested in the development of navigation. The Committee submitted a report in June 1959 and on its recommendations the Government of India are continuing effort for the development of navigation in the country. One of the important recommendations of the committee is to keep navigational aspects in view while planning the development of river valleys and while executing the river valley projects. The Committee also recommended various navigational improvements and developments to be undertaken by the different State Governments in their regions. Besides, it studied the aspects of classification of waterways, organisation of country boats, operation of ferries and craft building in the country. A strong centrally administered organisation for development of inland water transport in the country was suggested by the Committee. Accordingly, a Directorate of Inland Water Transport has been formed in the Union Ministry of Transport, under a Chief Engineer, to deal with all matters related to inland navigation. The Central Water and Power Commission under the Union Ministry of Irrigation and Power has been entrusted with the task of planning of navigational aspects of river valley projects, and the formulation of design features of the navigation works in consultation with the Ministry of Transport.

Other benefits

While irrigation, hydel power generation and navigation are very important uses of Indian rivers, the water resources in these rivers, though utilised in smaller measures at any one place, are of great important for industrial and domestic water supply. Almost all big cities and towns of the country and a very large number of rural areas derive their water supply from the streams ; so also all big industrial installations. In this connection, amongst others, mention may be made of big industrial complexes at Durgapur which depend upon the D.V.C., and of the complexes in Bombay-Poona area where the local streams serve the large tracts of concentrated industries.

The Port of Calcutta is deteriorating on account of silting and salinity due to the intrusion of saline sea water. In order to stem this deteriotion and to improve the conditions of the Calcutta city and port, substantial quantities of fresh upland water supplies are proposed to be brought from the Farakka Barrage, which is now under construction on the Ganga. The supplies will be carried through a large-sized long canal, and let into the Bhagirathi river, which joins the Hooghly river lower down.

The total usability of Indian rivers is also sought to be improved by interconnecting them, in the form of a grid, at suitable locations. This has been done in a big way in the Punjab by interlinking the Ravi, the Beas and the Sutlej rivers. Similarly, the possibility of linking of the Godavari with the Krishna, in order to transfer supplies from the former to the latter, is under investigation.

Conclusion.

Like other places in the world, civilizations in India have grown around its rivers and reliable sources of water. Development, even in the modern world, depends upon the country's water resources, which unless properly used and harnessed would not serve the demands of growing population, and the needs of industry and modern civilization. The rivers of India have large usable resources, susceptible of beneficial development.

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CHAPTER XVIII

HYDRO POWER IN INDIA

Water power has been an important source of electricity ever since public supply began in India at the turn of the present century. Despite the fact that the demands for power were small and generally in distant urban areas, hydro-electric power predominated during the first two decades through private entrepreneurship and in princely States. Its contribution declined thereafter. By 1930 the aggregate capacity of hydro stations in the country constituted roughly half of the total installed capacity of 577 MW. Hydro power has since maintained this place of importance. In 1966 with an aggregate installed capacity of 4,320 MW, it made up 40 percent of the total, and supplied nearly half the nation's electrical energy. The main factors that have contributed to the crucial role of water power in India are the availability of resources, their fairly even geographic distribution and, most important, its overall economy. The country's economically expolitable hydro power resources have been estimated at 41 million kW, with an annual assured energy potential of 216,000 million kWh, of which only 8 percent is utilised at present. Hydro power constitutes the cheapest source of electricity production in the country today, with the cost of generation ranging from 1.5 to 3.0 paise per unit compared to a minimum of 4.5 paise per unit of coal-based thermal power at large pit-head thermal stations at normal system load factors. Apart from this economic consideration, development of river valleys for irrigation and other multi-purpose benefits has also contributed to the steady tempo of development of hydro resources of India. Fortunately there are few areas of the country which lie more than 500 km away from the main concentrations of hydro resources. This is in sharp contrast to the occurrence of coal, the only other conventional source of energy for electricity production in India, which is confined to a few regions. The poor quality of the country's coal resources makes its transportation over long distance uneconomic. In areas far removed from coal bearing regions hydro power is the obvious choice. It has been found justifiable an overall economic considerations, even in areas close to collieries in Andhra Pradesh, Orissa and Madhya Pradesh. In areas where coal based thermal stations and nuclear power stations justify themselves on economic considerations and have to be runtas "base load" stations, hydro power would have to be developed in fuure at an even faster pace to meet peak demands. The relatively new field of "pumped storage" hydro developments is particularly important in this context. Consequent on devaluation, capital outlays on schemes of thermal/nuclear generation have increased considerably with the result, even on the consideration of investments alone, hydro schemes are at a decided advantage. In India, hydro power is therefore expected to be even more important in the future.

India covers an area of about 3.27 million km². It has high mountain ranges and numerous large river systems. The country falls into three well-defined geomorphological regions—the Himalayan range and their associated mountains, peninsular India, and the Indo-Gangetic plain. The Himalaya comprises three parallel ranges—the Greater Himalaya, the Lesser Himalaya and the Siwaliks—interspersed with plateaus and valleys. The Greater and Lesser Himalaya are extensively covered with glaciers and snow fields which function as vast natural reservoirs and feed practically every major Himalayan river. The region thus abounds with possibilities of large scale economic water power development. The Indo-Gangetic plain, 2,400 km long and 250 to 300 km broad, is a vast stretch of flat alluviam, south of the Himalaya, exhibiting practically no variation in relief and consequently of little interest from the point of view of power generation. The central Indian portion of the peninsular plateau is characterised by a number of hill ranges running across it west to east. These hill ranges, varying in height from 500 to 1,300 m, are well defined in the western half and get diffused to the east, the most important of them being the Vindhya and the Satpura with their western extensions, the Aravalli and easterly extensions, Maikala and Chotanagpur. The Garo, Khasi and Jaintia hills, constituting the Shillong plateau and the other hills of Central Assam in the north-eastern part of India, or an eastern extension of the Central Indian topography. The southern part of the subcontinent, the "Deccan Plateau", is enclosed by hill ranges all round and rimmed by strips of coastal plains. The Western Ghats—a prominent escarpment rising sharply from the western coast to elevations of 1,000—1,300m, and in places to over 2,400m, and running all along the western coast—form the main mountain feature of the Deccan Plateau. The less prominent Eastern Ghats, running along the east coast of the plateau, is an irregular and a discontinuous chain of hills. It is most prominent just north of the estuary of the Godavari river where it rises to elevations of 800 to 1,000 m. Topographically this entire region has vast potential resources, whose actual exploitation is, however, greatly limited by overriding priorities for irrigation development.

In regard to rainfall, the country may be broadly divided into four main regions. northeastern Assam and NEFA, Manipur, Tripura and Nagaland, and the west coast of India are areas of very heavy rainfall (2,500 mm and above). In contrast the Rajasthan desert and the high Ladakh plateau of Kashmir are regions of low precipitation (250 mm and below). The eastern part of the peninsula and the north Indian plains are subject to moderately heavy rainfall (1,000 to 2,500 mm). The

Punjab plains, the Central Indian mountains and the western part of the Deccan get low rainfall (250 to 1,000 mm). The period from mid-June to September, generally known as the monsoon period, is the most important from the point of view of general precipitation when the southwest monsoon is most active. In practically all areas of the country, the rainfall in this period accounts for more than 75 per ment of the total annual precipitation. Only the southeast coast of peninsular India gets a major share of its precipitation during November and December from the northeast monsoon.

The main river systems of India are the Indus, the Ganga and the Brahmaputra flowing through the Indo-Gangetic plains, and the Narmada, the Tapi, the Baitarani, the Brahmani, the Mahanadi, the Godavari, the Krishna and the Cauvery traversing the peninsular plateau. They carry approximately 1,670 billion cu m (1,356 million acre ft) of water annually on an average to the Arabian sea and the Bay of Bengal. The Indus, the Ganga and the Brahmaputra river systems alone carry nearly 60 percent of the total. The Narmada, the Mahanadi, the Godavari and the Krishna account for the bulk of the drainage of the peninsula.

The basic pattern of the country's river flows follows that of rainfall and is similar all over the country, characterised by a short spell of heavy discharges during the monsoon period followed by a long period of lean flows. The dry weather river flows of the peninsular rivers, derived from ground water storage, follow the usual decrement pattern of ground water flows, the discharges dwindling down to a trickle during the summer months just before the monsoon. Variations of the order of 1 to 300 in the mean monthly inflows of these rivers are common. The pattern of river flows of the Himalayan rivers differs in that the glaciers and snow contribute significantly to the dry weather flows during the pre-monsoon months The period of minimum flows for the major Himalayan rivers is during winter and they do not reach the low levels of the peninsular river. With the above pattern of inflows, provision of regulating storages to even out the wide seasonal fluctuations becomes the key factor in hydro-electric development. Dependable power generation along the peninsular rivers is just not possible without substantial facilities for storing the water during the periods of high inflows. Thus the courses of these rivers through the hilly regions in their upper reaches, where possibilities of construction of storage dams exist, are important for hydro-electric development.

In the case of the Himalayan rivers, though the unregulated discharges are appreciable even during critical winter months, providing some scope for hydro-electric development on a run-of-the river basis, even small storages contribute to substantial increases in dependable flows and enable a tangibly higher degree of firm power generation. Possibilities of providing storage facilities in these river basins exist mainly along their courses through the Siwaliks and these stretches are of maximum interest for hydro power generation. The river courses through the Greater and Lesser Himalaya are generally too steep for construction of storage dams except at a few sites in the Sarda and Karnali valleys. However, they offer attractive possibilities for run-of-the river developments.

The entire potential for medium and major schemes of hydro development in the country have been systematically surveyed by the Central Water and Power Commission from 1953-60. For the assessment to be realistic and provide the necessary data for forward planning, it had to be based on specific schemes of development taking into account the various limitations imposed by other priority uses of river waters, technology and economic considerations. Topographical, hydrological and other data required for such a study was available. Fortunately topographic maps on the scale of 1 : 63,360 and 1 : 26,720 with contours at intervals of 50 ft (15 m) and 100 ft (30 m) respectively were available for good many areas of the country. These maps have proved to be of reliable accuracy for preliminary studies and were used to select potential sites for construction of storage dams and development of drops for power generation. On the hydrological side, actual run-off data were, no doubt, meagre for most of the sites in the upper reaches. However, fairly good rainfall data were available for most of the areas and thanks to the early start which the country had in initiating river valley projects for irrigation and power, some run-off data were available either lower down the basins or in similarly situated neighbouring river valleys. With those data hydrological studies of sufficient accuracy were possible. On the basis of these data, specific schemes for power development were evolved for developing the resources of each basin taking into account requirements of irrigation and other priority uses. All possibilities of development in each basin were examined and the most economic alternatives chosen from considerations of the physical proportions of the civil works required in relation to the benefits assured, after ensuring that they were within limitations imposed by current technology. The results of the assessment for the following six regions based on contiguity and similarity in geographic characteristics : the west flowing rivers of southern India, (ii) the east flowing rivers of southern India, (iii) the rivers of Central India, (iv) the Ganga basin, (v) the Brahmaputra and adjoining basins and (vi) the Indus basin, are given below :

West flowing rivers of southern India

The western face of the Western Ghats is drained by numerous river systems fed by the heavy south-west monsoons, into the Arabian sea. The steep courses of the west flowing rivers offer possibilities for very economic, high head hydro-electric development. The catchments of streams north of Goa do not offer facilities for any storage. Consequently, development of these rivers for generation of electricity on a dependable basis is not possible. The major rivers south of Goa flow fairly level at a general elevation of 450 to 600 metres in their upper reaches, where it is possible to provide adequate regulating storages with relatively small dams. They then follow a steep course to the sea, enabling development of high heads with short water conductor systems. These topographical features enable large scale hydro-electric development, most of which constitute the cheapest source of electricity production in the country. These include the 891 MW Sharavati and the 300 MW Sabarigiri (Pamba) projects nearing completion, the major 780 MW Idikki project under construction and the Kalinadi project with a potential of over 1,000 MW at 60 percent load factor currently under investigation. The potential of these rivers on the basis of 34 schemes has been estimated at 4,345 million kW at 60 percent load factor, corresponding to about 22,800 million kWh of firm annual energy output.

East flowing rivers of southern India.

Proposals for power development of east flowing rivers of southern India have to be formulated taking into account the possibilities and requirements for irrigation and their impact both on the available waters and the limited storage facilities. Many of the tributaries of these rivers in their upper reaches provide attractive possibilities for power development by diversion away from their natural courses. Some of these possibilities have already been developed in Maharashtra. However, the Central Water and Power Commission did not consider further possibilities of diversion away from the natural courses of these rivers in view of the fact that plans for utilisation of the entire waters of those rivers for irrigation along their natural courses were, by then, under active consideration.

The important possibilities of hydro-electric development in the Godavari basin are along the course of its three important tributaries—the Pranhita, the Indravati, and the Sabari, which join it before the river enters the narrow gorge stretch through which it traverses the Eastern Ghats. The development of these rivers could be considered mainly from the point of view of power generation. The regulated discharges from the possible developments along these rivers can be used for power generation along the course of the Godavari downstream of their confluence and later on for irrigation in the deltaic region. These possibilities with a potential of 6·15 million kW at 60 percent load factor (32,300 million kWh annual output) constitute one of the biggest and most important concentrations of hydro-power in the country. Development of these resources commenced with 114 MW Machkund project in the Sabari basin which has been followed up by the 360 MW Balimela and the 840 MW Upper and Lower Sileru schemes which are currently under construction.

The gentle slope of the eastern face of the Western Ghats near the upper reaches of the Krishna and its tributaries is conducive to construction of storage dams and the sharp drop of about 600 metres available along the western face provides a setting for economical hydro-electric projects. Bhira (132 MW), Bhivpuri (70 MW), and Khopoli (70 MW)—completed by the Tatas during the early part of this century through transbasin diversion of east flowing waters to west and the 860 MW Koyna hydro-electric project nearing completion are developments falling under this category. As explained earlier, there are possibilities of utilising the entire inflows of the Krishna along its natural course for irrigation. Therefore, no further possibility of westward diversion for power generation has been considered in the present survey. Though the theoretical potentialities of the Krishna river along its natural course, below its confluence with the Tungabhadra have been estimated at about eight million kilowatts, continuous, it is of interest to note that the priority irrigation requirements for its waters, at high levels, to meet a predominantly seasonal pattern of irrigation reduces the potential capable of development on a firm basis to only about 500 MW at 60 percent load factor. The 770 MW Srisailam project, currently under construction is one of the major projects in this stretch, with its large installed capacity specifically designed for peak load operation.

The most important sites for hydro-electric development in the Cauvery basin lie in the Nilgiri hills, which rise sharply to elevation of 1,800 metres and above. The possibilities of storing waters from small streams at these high altitudes and utilising them at high heads, totalling about 1,600 metres, have enabled the State of Madras to exploit them rapidly to meet their demands. The 550 MW Kundah hydel project is the most impressive of these.

The Central Water and Power Commission's survey envisages 61 schemes in this region with a total potential of 8·626 million kW at 60 percent load factor, or 45,300 million kWh of firm annual energy output.

Rivers of Central India

The Baitarani and the Brahmani basins have attractive possibities for major hydro-electric development in their upper reaches and the rivers can be developed mainly in the interest of power. The regulated discharge from these power schemes can conceivably be used in the lower reaches of these river basins for irrigation along the coastal plains, which would improve the economics of power development in these basins.

The Mahanadi runs through relatively flat country in its upper reaches and there are hardly any suitable dam sites for major power development. In its middle reaches, it flows through gorges before emerging into the coastal plains, and construction in this reach for storage to regulate its large inflows and utilising them for irrigation and power generation is possible. The 270 MW Hirakud project marked the beginning of the unified development of this river valley for irrigation, power generation and flood control. Further possibilities downstreams of Hirakud under investigation and the magnitude of benefits that can be derived from these projects depend on the submergence that would be justifiable on economic and other considerations. For the purposes of the survey, submergence was assumed at the minimum possible level, which would economically justify power generation at these sites. The Narmada river which flows in a trough between the Vindhya and the Satpura ranges towards the Arabian Sea, constitutes an important source of hydro-electric power. With the main regulating storage provided by the construction of a dam at Punasa in the middle reaches of the river, it would be possible to generate a firm power output of about 1·6 million kW at 60 percent load factor (8,400 million kWh annual output) at the Punasa dam and a cascade of two or three power stations downstream.

The total power potential of the Central Indian rivers has been estimated on the basis of 39 schemes, at about 4.287 million kW at 60 percent load factor or about 22,500 million kWh of firm annual energy output. These are largely untapped so far.

The Ganga basin

The upper reaches of the southern tributaries of the Ganga have several possibilities of hydro-electric development, the most important ones being in the Son valley. These developments can be taken up on a unified basis for power generation and to provide irrigation benefits down-stream in the vast Ganga plains. The 381 MW Chambal valley development and hydro electric development of Rihand river (400 MW) constitute the initial phase of harnessing these resources.

The upper reaches of the Himalayan tributaries of the Ganga do not offer suitable sites for providing storages in view of the steep nature of their courses. However, the topographical and hydrological features in these reaches are conducive to development of hydro-electric projects on run-of-the-river basis. Some of the northern tributaries offer storage possibilities along their courses through the foot-hills of the Himalaya, though dams of the order of 160 to 200 metres above bed level have to be envisaged to provide storages to an appreciable extent. As the large snow-fed catchment areas, drained by these rivers ensure high run-off in all except the worst winter months, even those comparatively small storages contribute to substantial increases in the dependable power draft and enable large scale power developments at the dam sites and the drops lower down. Several of the Himalayan tributaries of the Ganga have their origin and entire course through the Himalaya in Nepal, For the sake of completeness, the Central Water and Power Commission's study included some of these rivers, viz. ; the Sarda, which forms the boundary between Nepal and India, the Karnali and the Kosi, for which topographical and other data were available. The hydro potential of the Ganga basin has been estimated on the basis of 58 schemes at about 13.08 million kW at 60 percent load factor or about 68,800 million kWh of firm annual energy output of which about 4·0:9 mK (21,3C0 mKh annual output) lies within India and 1.54 million kW (8,000 million kWh output) on the border between Nepal and India and the rest in Nepal.

Brahmaputra, basin and other rivers of Assam, Manipur and Tripura.

Possibilities of providing storages on the Himalayan tributaries of the Brahmaputra do not appear to exist. In view of this, the development of these tributaries for power generation had to be considered on a run-of-the river basis. The Tista, the Kameng, the Dihang, the Luhit and the Dibang, have substantial dependable discharges and drop rapidly as they descend down the Himalaya to enter the Brahmaputra plains, offering attractive possibilities of hydro-electric development, the potential afforded by some of them being colossal in magnitude. While the rivers that drain the gently sloping northern face of the Shillong plateau to join the Brahmaputra, have several possibilities of high and medium head hydro-electric development, the rivers that drain the southern face of the plateau to join the Surma are more attractive for power development on a large scale. These rivers drain catchments which are subject to the highest rainfall in the world, with storage possibilities in their upper reaches and steep courses which drop about 1,200 metres in elevation offering possibilities of major high head hydro-electric developments which are conducive to economic exploitation. The Barak and the Manipur rivers in the Manipur State also have such important possibilities.

The survey envisages 41 schemes in this region with a total potential of about 13.43 million kW at 60 percent load factor (about 70,100 million kWh annual output) of which 21.486 million kW (65600 million kWh output) is in India. The irrigation possibilities in this region are practically negligible and these hydro-electric schemes are of the single purpose type to be developed in the interests of power generation. These water power resources, again, are largely untapped at present.

The Indus basin

The question of development of the water resources of the Indus Basin has been settled between India and Pakistan under the Indus Water Treaty. The power potentials of the rivers of this basin have therefore been studied on the basis of the allocation of waters and storages permitted under this treaty, taking into account the present and future patterns of irrigation.

The upper reaches of the Indus river are remote and relatively inaccessible. Possibilities of major hydro development in these mountainous and snow-bound ranges have not been considered in this assessment of our utilisable hydropower potential. The most important tributary of the Indus from the point of view of power development is the Chenab which drops by about 2,500 metres in its middle stretch of 300 km. Its minimum discharge augmented by storage reservoirs in its upper reaches can be utilised at a total head of about 1,800 metres to generate about 3·256 million kW at 60 percent load factor, or about 17,000 million kWh of firm annual energy production. Unified development of the Beas and the Sutlej, of which the 1,204 MW Bhakra-Nangal Project marks the beginning, is estimated to yield about 2.358 million kW at 60 percent load factor (12,400 million kWh annual output), besides providing waters for irrigating extensive areas in Punjab and Rajasthan. There are important possibilities on the Jhelum river also which can contribute about 810,500 kW at 60 percent load factor (4,260 million kWh annual output) to the potential of the Indus Basin.

Thus the Indus Basin with the restriction on storage and its water uses has a total potential of about 6.582 million kW at 60 percent load factor, corresponding to 34,500 million kWh of firm annual energy output.

The total economically exploitable hydro-electric potential of the river basins covered by the Central Water and Power Commission's preliminary hydro-electric survey has been estimated at 50·35 million kW at 60 percent load factor (corresponding to a firm annual energy output of 264,000 million kWh) on the basis of about 260 existing and possible schemes. As already explained, the survey included the Sarda, which forms the boundary between India and Nepal, the Karnali and the Kosi, the upper and middle reaches of which lie in Nepal and the Tista which takes its rise and flows through Sikkim. The potential of these river basins is estimated at 9·962 million kW at 60 percent load factor (52,000 million kWh annual output). Of this, 1.542 million kW (8,000 million kWh output) constitutes the potential of schemes on the Sarda river along the boundary between Nepal and India and the rest lies beyond the boundaries of India in Nepal and Sikkim. Assuming that half of the potential of the schemes on the Sarda along the border between India and Nepal would be available to India, the economically exploitable hydro-electric potential of India is 41.155 million kW at 60 percent load factor (corresponding to an assured annual output of 216,000 million kWh). This region is one of the areas where there are possibilities of obtaining large quantities of power from neighbouring countries. The attached map indicates the concentrations of the hydro-electric resources of India and their magnitudes.


HYDRO-ELECTRIC RESOURCES
LEGEND
NOTE:- THE EXTERNAL BOUNDARY OF INDIA ON THE MAP AGREES WITH THE RECORD COPY CERTIFIED BY THE SURVEY OF INDIA
W. PAKISTAN
TIBET (CHINA)
NEPAL
BHUTAN
RAJASTHAN
UTTAR PRADESH
GUJARAT
MADHYA PRADESH
MAHARASHTRA
ORISSA
BIHAR
ANDHRA
MYSORE
MADRAS
ARABIAN SEA
BAY OF BENGAL
BURMA
JAMMU
KASHMIR
PUNJAB
HARYANA
DELHI
BOMBAY
HYDERABAD
BHUBANESWAR
CALCUTTA
TRIVANDRUM

Ref. No.	Hydel Resources	Firm Power in MW at 60 per-cent L.F.
	I IN INDIAN UNION	
1	Pambiyar, Papanasam ..	297·0
2	Periyar	931·5
3	Chalakudi	297·0
4	Nilgiri	498·5
5	Barapole & Oorakuzhi	267·7
6	Sharavati Aghanashni, Varahi, Chakranadi, Bhadra	1,406·3
7	Kalinadi, Bedti, etc. ..	1,114·0
8	Cauvery	338·0
9	Tata Group ..	270·0
10	Koyna	474·0
11	Upper Krishna ..	507·0
12	Lower Krishna } Srisailam ..	200·0
	Nagarjuna Sagar ..	160·0
13	Sileru	723·0
14	Indravati & Kolab ..	2,458·3
15	Pranhita	1,023·6
16	Upper Godavari ..	19·5
17	Manjra	43·0
18	Lower Godavari ..	1,943·0
19	Mahi	33·0
20	Upper Narmada ..	328·0
21	Middle Narmada ..	666·0
22	Lower Narmada ..	1,033·0
23	Tapi	90·0
24	Upper Mahanadi ..	389·5
25	Lower Mahanadi ..	558·0
26	Upper Brahmani ..	531·5
27	Lower Brahmani ..	255·0
28	Baitarani	368·0
29	Subarnarekha ..	35·0
30	Chambal	232·0
31	Betwa	295·0
32	Ken	150·0
33	Tons & Son ..	804·0
34	Damodar	20·0
35	Yamuna	559·0
36	Alaknanda ..	446·5
37	Bhagirathi ..	105·0
38	Upper Ganga & Ram-ganga	1,094·0
39	Sarda	1,071·0*
40	Gandak	35·5
41	Kosi-Canal ..	16·7
42	Jaldhaka	22·0
43	Kameng	605·0
44	Subansiri	166·0
45	Dihang	4,055·0
46	Dibang	930·0
47	Luhit	3,270·0
48	K & J Hills (North) ..	946·4
49	K & J Hills (South) ..	1,064·0
50	Barak & Manipur ..	1,030·0
51	Tyao	378·0
52	Upper Jhelum ..	305·0
53	Lower Jhelum ..	505·5
54	Upper Chenab ..	555·0
55	Middle Chenab ..	1,025·0
56	Marusudar ..	813·0
57	Lower Chenab ..	863·0
58	Ravi & Lower Beas ..	286·0
56	Beas Sutlej Link, Bhakra Nangal & Uhl. ..	2,229·5
	Total ..	41,155·5

* Includes half the potential of Schemes in the Indo-Nepal border.

Ref. No.	Hydel Resources	Firm Power in MW at 60 per-cent L.F.
	II IN NEPAL & SIKKIM	
39	Sarda	771·00‡
60	Karnali (Nepal) ..	2,745·0
61	Gandak (Nepal) ..	10·0
62	Sun Kosi (Nepal) ..	2,360·0
63	Arun (Nepal) ..	2,365·0
64	Tista (Sikkim) ..	940·0
	Total ..	9,191·0
	III IN TIBET (CHINA)	
63	Brahmaputra ..	30,000·0

‡ Half the potential of Schemes on the Indo-Nepal Border.

A comparison of hydro resources of various countries in the world is difficult since the assessment of resources themselves have not been made on a uniform basis. Some give their theoretical potentials, others some fractions thereof which are described as "technical" or "economic limits". Few have built up estimates based on specific sites and detailed assessments, unlike in India. Further many countries have not yet initiated systematic assessment of their hydro-electric resources. However, it is interesting to note from Table I attached, which gives the energy resources recently indicated by member countries of the ECAFE Region that hydro-electric energy is one of the major sources of energy in the region and that India has one of the largest untapped reserves.

Of the country's total power potential, about 10.3 million kW (54,000 million kWh) represents the potential of simple "run-of-the-river type projects" in the Himalayan ranges and the rest of "storage projects". Again, the "high head" type projects—utilising drops over 300 m account for about 13.63 million kW (71,000 million kWh) the "medium head" projects—in a head range from 30 to 300 m account for 23·86 million kW (126,000 million kWh) the bulk of the total, and the "low head" Projects, utilising heads ranging from 8 to 30 m form the smallest category with a total potential of about 3·66 million kW (10,000 million kWh).

The hydro-electric resources, as would be observed from the attached map ; are fairly evenly distributed within the country. The northeastern part of India has the largest concentration of hydro-electric resources with an aggregate potential of 12.5 million kW at 60 percent load factor. The other important concentrations are :

6·6 million kW located in northwestern part of India in the Indus Basin.

3·26 million kW located in the Himalayan tributaries of the Ganga.

1·6 million kW along the middle and lower reaches of the Narmada.

6·15 million kW located in the Western Ghats along the tributaries of the Godavari.

2·7 million kW located in the northwestern part of Mysore along the west flowing rivers of the Western Ghats, and

2.1 million kW located in the Nilgiri and Angimalai hill ranges.

It is interesting to observe that very few parts of the country are situated beyond the economic reach of these major concentrations of hydroelectric power. Further, these concentrations are favourably located to serve the needs of those parts of the country which are far removed from the coal bearing areas. There are also important sources of hydroelectric power located in the midst of coal bearing regions of the country, which can be developed as peaking stations.

The survey has also revealed that the bulk of the hydro-electric potential is situated in the hilly regions along the upper and middle reaches of various river systems. The topographical features in these reaches are seldom favourable for development of irrigation. Consequently, development of the important hydro-electric sites in the country would not clash with other priority uses of water. Most of the hydro-electric schemes that would be taken up for implementation in the future would be of single purpose type and priorities for implementing them would primarily be determined by their power benefits though incidental benefits of irrigation, flood control, water supply, etc. would accrue to areas downstreams.

Out of the hydro-schemes mentioned earlier, 41 with a total potential of about 2·36 million kW at 60 percent load factor have been fully developed and are now in operation. Eight schemes with a potential of 2.10 million kW at 60 percent load factor have been partially developed and are under completion. Besides the above, 31 schemes with a total potential of about 2·9 million kW at 60 percent load factor are currently in various stages of implementation. Thus schemes with a potential of 34 million kW at 60 percent load factor are available for future development.

It is interesting to note that out of the stations so far completed only one (Rihand, U.P.—300 MW) has an installed capacity over 250 MW. Out of those partially developed or under completion four have capacities less than 250 MW, one (Sabarigiri, Kerala—300 MW) in the range 250-500 MW, two (Sharavati, Mysore—891 MW Koyna, Maharashtra—540 MW) in the range 500 to 1,000 MW and one (Bhakra Dam, Punjab/Rajasthan—1,050 MW) over 1,000 MW. Out of the 30 stations, which are currently in various stages of implementation, four stations (Idikki, Kerala—780 MW ; Lower Sileru—600 MW and Srisailam—770 MW, Andhra Pradesh ; Dehar, Punjab/Rajasthan—660 MW) will have capacities between 500 and 1,000 MW, five stations (Koyna Tailrace, Maharashtra—320 MW ; Pong, Punjab/Rajasthan—360 MW ; Ukai,—Gujarat—300 MW ; Balimela, Orissa—360 MW ; Nagarjunasagar, Andhra Pradesh—400 MW) in the range of 250 to 500 MW and the rest below 250 MW. Installed capacities at the future hydel sites will be influenced mainly by the load factors for which they would be designed. The importance of hydro schemes for peaking purposes has already been recognised in the country and it is likely that most of the schemes will be designed for operation at very low load factors of the order of 30 percent eventually. On this basis out of the stations yet to be developed 13 stations will have capacities of over a million kW, 26 stations in the range of 500 and 1,000 MW, 27 stations between 250 to 500 MW and 92 stations less than 250 MW.

Hydro-power has contributed substantially to economic power development in India. Unlike in advanced countries of Europe and America, the capital outlay on hydro schemes compare favourably with the thermal alternatives. There are many hydro schemes where the capital investments are lower than that required for equivalent thermal development. The cost of generation from new hydro stations varies from about 2 paise to about 3 paise per unit, the average being around 2·25 paise per unit. This is relatively low compared to the cost of electrical energy from thermal sources using coal which is about 4.5 paise per unit at the stations located even at mine mouths.

There are some areas in the country where either available hydro-resources have been almost fully developed or the load centres are far removed from the untapped hydro-resources, and where future power development will be predominantly from thermal and nuclear resources. Consideration would have to be given in these areas to construction of pumped storage schemes for peaking purposes. The comparatively recent development of pumped storage schemes with capacities of the order of 300 MW in the U.K. and 1,800 MW in the U.S.A., are now being implemented. There are a number of places in India where such schemes can be implemented with direct economic advantages in addition to the main source of hydro-electric energy described earlier. A systematic survey of possible pumped storage sites close to load centres in such areas has therefore to be initiated so that they can be investigated and taken up for implementation depending on the needs.

Development of river valleys opens up important avenues for international and inter-regional cooperation. These possibilities occur where the rivers traverse more than one country and also where large resources especially of water power exist, which could be utilised for the benefit of countries within their economic reach.

The hydro-electric survey conducted by the Central Water and Power Commission has brought out immense possibilities for international cooperation in the field of power development. The survey covered the rivers of adjoining Nepal and Sikkim for which sufficient data were available and discovered large sources of hydro-power capable of economical development. In addition, spectacular possibilities of power development utilising a drop of about 2,200 m, exist in the sharp U-bend of the Brahmaputra in Tibet just across the Indian border. Estimated to yield about 30 million kW at 60 percent load factor on the basis of minimum discharge, this represents one of the greatest concentrations of hydro-potential in the World. Provision of regulating storages upstream would increase the potential considerably and valley characteristics upstream of the U-bend appear attractive for this purpose. All these possibilities can conceivably be developed for mutual benefit of all.

TABLE I.

Known energy resources and current production of the ECAFE Region.

Country	Petroleum		Natural Gas		Coal (including lignite)		WATER POWER		
	Reserves (10^3 barrels)	Production (annual '63, 10^3 barrels)	Reserves (10^6 m^3)	Production (annual '63, 10^6 m^3)	Reserves (proven & indicate (10^6 tonnes)	Production (annual '62, 10^6 tonnes)	Potential (10^3 kW.)	Installed capacity (annual '63, 10^3 kW)	Others.
Taiwan ..	100	19	14,788	38·4	673	4·55	5,145	539·4	
India ..	675,000	12,904	20,370	176·6	123,000	61·58	41,000	3,170	
Iran ..	3,2000,000	538,558	2,000,000	9,125·0	..	0·16	9,000	..	
Australia ..	50,000	..	..	..	61,000	42·28	..	1,859	
Japan ..	60,000	5,486	32,000	1,209	20,948	55·51	36,734	15,109	
Indonesia ..	8,500,000	166,878	150,000	3,492	465	0·47	2,860	187·9	
Pakistan ..	27,000	3,631	485,000	1,198·6	168	0·69	10,400	347·2	
Brunei ..	360,000	25,942	40,000	1,279·6	..	..	..	..	
Burma ..	50,000	4,735	3,080	18·9	265	..	2,000	84·5	
Afghanistan ..	..	..	30,000	..	..	0·07	2,500	47·0	
Thailand ..	150	45	..	..	80	0·04	3,293	..	
New Zealand ..	..	..	..	..	1,108	1·38	..	1,500	
Malaysia ..	..	373	..	..	98	..	..	81·0	
Korea (Republic of) ..	..	..	..	..	1,425	7·44	1,810	143·5	
Laos ..	..	..	..	..	..	..	12,445	..	
Nepal ..	..	..	..	..	..	..	8,000	..	
Cambodia ..	..	..	..	..	..	..	5,400	..	
Philippines ..	..	..	..	..	42	..	2,271	291·1	
Ceylon ..	..	..	..	..	..	..	1,400	63·5	
Viet Nam (Republic of) ..	..	..	..	..	..	..	1,100	83·9	
W. Samoa ..	..	..	..	..	..	..	6·4	1·3	

CHAPTER XIX

WATER CONSERVATION IN INDIA

Ancient India

India is a Fairly ancient country with one of the earliest civilisations that mankind has inherited. The heritage is both material spiritual. Among the former is a sound technology, which can be defined as principles and devices aimed at reducing human effort or raising productivity or both. Literature from the dateless past, like the Vedas, said to be more than 3,000 years old, refer among others to *avata* or water wells, *kulya* or canal, and *sarsi* or dam, in a casual manner, indicating that the devices were already known for a long time. Artificial water storages, *tataka*, are mentioned by Manu, the law-giver. Sage Narada inquiries of Emperor Yudhisthira in the Mahabharata (c. 3150 B.C.) : Are the dams full of water and large enough and distributed evenly in different parts of the kingdom ? Does agriculture depend on rain only ? Kautilya of Artha Sastra fame who lived in the third century before Christ anticipates modern polity, if not suggest a model, when he observes : If privately managed dams are neglected for five years, their charge is taken over by the State. If they are constructed by public contribution, revenue is to be remitted for five years. If only repairs are carried out by public effort, revenue is to be remitted for four years.

Classical Sanskrit literature is replete with nicely categorised water courses—*pranali, kulya, nala, nalika, tilamaka* and so on. A differentiation is even made—yet to be introduced in modern engineering—of channels based on the speed of the current in the water course.

Lands being taxed in certain kingdom of ancient India according to the amount of rainfall received during the year, a rain-gauge had been devised, the specifications of which are available today. Irrigation was a separate department of Government, *vari gripa karana,* which was in charge of a specialist, *jala sutrada* or Water Director. These were men who had studied treatises on dam and canal construction, though the treatises appear to have been lost. Brahmins learned in hydrology (*pathas shastra*) are noted in old inscriptions.

Artificial lakes and canals dot the country in hundreds, most of them in service today. All of them are centuries old, and some have served for more than a thousand years.

The Greek traveller, Megasthenes, who was the ambassador of Saleukos Nikator at the Court of Chandragupta near Patna, in his description of India 300 years before Christ wrote : "the whole country is under irrigation", and very prosperous because of the double harvests, which they were able to reap each year because of irrigation.

Storages and their water courses are common in south, central and eastern India. The size and complexity of many of the old hydraulic structures would do credit to a modern engineer.

The most notable of the ancient works in the South, extent and functioning, is the grand Anicut across the Cauvery. The first structure, a weir built in stone and clay, was probably laid in the second century A.D., with additions and alterations during the succeeding period. The The Grand Anicut is a solid mass. of stone masonry about 330 m long, 12 to 18 m wide and 4·6 to 5·5 m high. The anicut has served irrigaton and withstood the annual Cauvery floods for more than sixteen hundred years.

The Bhojpur (Bhopal) Lake, covering an area of 650 km^2 was built in the 11th century A.D. 'The great Bhojpur Lake', says the well known historican, W. C. Kinciad, "was without doubt the largest and most beautiful sheet of fresh water....... Though it is so extensive, only two breaks occur in its walls of hills—one a little more than one hundred yards, and the other about five hundred yards wide. Both of them were spanned by very remarkable dams, consisting of an earthen central band faced on both sides, outer and inner, with immense blocks of stone laid one on the other without mortar, but fitting so truly as to be watertight". Continuing, Kinciad says, ..A study of the local topography and the remains of the works, clearly proves that the engineers of those days undoubtedly understood that the drainage area of the Betwa and its tributaries was insufficient for their purpose, and that they skilfully supplied the deficiency by turning into the Betwa valley the waters of another river...... This was accomplished by the creation of the magnificient cyclopean dam on which stands the old fort of Bhopal.

"......To test the tradition as to the lake's unusual size......a line of levels was run from the waste weir or ancient outfall to the Bhopal railway levels and thence other lines were projected. These, when plotted......proved that the ancient lake covered the valley to the extent of 250 sq miles (650 km^2)........and must have formed the largest, as it did the most beautiful, lake in the peninsula of India........ It was in places of a hundred feet deep........".

"Its (the waste weir's) position, so far from the dam, affords another proof of the practical ability of the Hindu engineers of the time ; for, any error in levels would have quickly destroyed the dam...... There are signs on its rocky and unbroken sides which show that the high water mark was within six feet (about 2 m) of the top".

Medieval time.

The Ganga plain in north India also witnessed memorable feats of irrigation engineering during the medieval period. The Jumna (Yamuna) canal of Firoze Shah Tughlaque brought water to Delhi from the Jumna river as early as at the end of the 13th century. It also served as an irrigation canal in the tract it traversed. It was subsequently and extended during the reigns of Akbar and Shahjahan. The present Bari Doab Canal in the Punjab incorporates a canal from the Ravi river executed by Ali Mardan Khan in the middle of the 17th century.

The Sirhind canal in the Punjab is another piece of Indian engineering which has evoked considerable professional interest all over the World. "It has the greatest width, if not the greatest length, or supply", wrote Alfred Deakin, an Australian engineer, at the end of the last century, ..and it represents the largest investment of capital in any single undertaking......and rivals even the Ganges canal in the magnificence of its structures and the greatness of the difficulties which it has surmounted".

British period

The Sirhind and Ganga canals carry forward, as it were, the tradition and skill of ancient irrigation engineering in India. Built on a larger scale by British engineers, who acknowledge their admiration and debt to indigenous experience and craftsmanship, the works obviously incorporate the tried techniques and practices called from old works. In addition, British engineers brought in the well classified, well developed technology of engineering, based on rational laws and verifiable principles of nature.

The more outstanding among British engineers who built the old and brought in the new technology are Sir Arthur Cotton who was responsible for planning and executing the Dowlaiswaram Anicut on the Godavari, the Buckingham Canal, and the Upper Anicut in the Cauvery delta; Sir Probyn Cautley of Ganges Canal fame; Col. Dyas, designer of the Bari Doab canal; Col. Gulliver and Col. Hume builders of the Sirhind canal.

Systematic technology, transplanted from the West, found a fertile soil in Indian heritage in the same field. In less than a few decades, engineering colleges, started in Bombay, Calcutta, Madras and one or two other cities, began to pour out modern engineers. Major engineering works, comparable with the largest and most complex anywhere in the world, began to be planned and executed independently by Indian engineers. The

Krishnarajasagara in Mysore State was designed and built by Sir M. Visveswaraya in the twenties of the present century. It was the highest stone masonry dam in the world at that time. The crest gates for the dam were designed and fabricated in the State Iron Works and installed by Indian technicians.

After Independence

The National Planning Committee which functioned under the leadership of the late Pandit Jawaharlal Nehru before India gained Independence pointed out in its 1947 report : "the forces and effects of these vagaries (of rainfall) were recognised from the earliest times and to guard against them had become the principal pre-occupation of the rulers ever since public consciousness had developed. From the earliest times it has been among the most sacred duties of the powers that were to construct artificial water supply so as to make up for the deficit of rains for the raining and nourishment of crops".

Translating this basic national policy after assumption of power, Jawaharlal Nehru said in 1948, "the development of river valleys in India is of the most basic and fundamental importance. For a number of years past I have been very greatly interested in this matter not as an engineer, because I am not an engineer, but in its wider public aspect of being in a sense, the foundation of very large scale planning in India. I have been interested in planning, because it seems such an extra-ordinary and such an unfortunate fact that with all the potential resources available in India—and in a way it applies to the whole world that all these enormous resources—have not been utilised to raise the standard of living of our people and nation".

Pandit Nehru said later in 1953, addressing the Central Board of Irrigation and Power ; "You are building or making a river valley scheme. See the fine things that flow from it, not only in the shape of canals and irrigation and hydro-electric works and industry and all that. Certainly it is important but something even more than that, the progress of humanity in a particular direction".

In that direction India has travelled far during the last 15 years, and can look back with some satisfaction the ground covered in water and power resources development.

Natural resources

The total water wealth of India is estimated at 1,677,500 million cubic metres, almost the same as that of the U. S. A., which has about three times the land area of India. In the pre-Independence period, only 94,700 million cubic metres or about 6 percent of the gross water wealth was utilised for productive purposes. More recent studies put the quantity that can ultimately be exploited, consistent with technological limitations at 555,000 million cubic metres. As a result of a determined bid to accelerate the development of water resources during the last decade and a half, 185,000 million cubic metres of water have been exploited up to the end of the Third Plan. This represents a two-fold increase over the figure of exploitation in the pre-Plan period. Further, a number of projects are under construction which on completion will utilise another 123,300 million cubic metres, bringing the total to 308,300 million cubic metres of water. An index, useful in estimating the degree of exploitation of water resources, is given by the extent of storage capacity. When India launched upon planned development in 1951, the storage capacity of all the reservoirs in India at that time was 12,334 million cubic metres. Today it is 61,670 million cubic metres—a five-fold rise.

During the same period, 12·1 million hectares of irrigated area have been added. The irrigated area which was 22·6 million hectares, in 1951 has increased to 35·6 million hectares at the end of March, 1966, giving an annual growth rate of 0·8 million hectares per year, perhaps the highest for any country during the same span of time.

Similarly, in the field of power, from 2.3 million kW of installed capacity around 1951, the total installed capacity has increased to over 10 million kW, by March, 1966 i. e., a four-fold increase.

These are gigantic advances—gigantic in relation to what was done in India earlier and in relation to what is being done elsewhere in the world ; although, in relation to her own needs, they are not adequate.

Irrigation development

For administrative convenience, irrigation projects in India are divided into three categories, major, medium and minor. Major projects are those costing more than Rs. 50 million each ; medium those costing between Rs. 1·5 million and Rs. 50 million each ; and minor, costing up to Rs. 1·5 million each.

Pre-Plan development

The area irrigated in India up to 1950 from major and medium projects is estimated at 9·7 million hectares, out of a total irrigated area of 2·26 million hectares. In this area are included the areas irrigated by projects which existed before Independence like the Upper and Lower Ganga Canals and the Agra Canal in U. P., the Upper Bari Doab Canal and the Sirhind Canal in the Punjab ; the Godavari and the Krishna Systems in Andhra Pradesh, the Cauvery System in Madras ; Mutha Canals in Maharashtra ; the Mahanadi Canals in Orissa, etc.

Development in the three plans

During the last 15 years, an irrigation potential of 7·3 million hectares has been created by various major and medium irrigation projects. The achievement during this interval is 75 percent of the achievement during the preceding one hundred years. A number of mammoth projects have been undertaken and completed, like the Bhakra Project in the Punjab, the Damodar Valley Project in Bihar and West Bengal, Hirakud Dam in Orissa, Matatila in U.P., the Tungabhadra in Mysore and Andhra Pradesh the Kosi in Bihar, the Malampuzha in Kerala, etc.

In addition, a number of gigantic projects are in varying stages of progress. Very recently, water has been let into the canal system from the Nagarjunasagar Dam across the Krishna. For the first time in history, some of the endemic famine areas in Andhra Pradesh would be enjoying the benefits of irrigation. The Gandak Project is under contruction which, on completion, will benefit about 1·2 million hectares in Bihar and U. P. The Rajasthan Canal Project in Rajasthan, the Yamuna Irrigation Scheme in U.P., the Parambikulam-Aliyar in Madras and Kerala, the Kallada in Kerala, Bhadra in Mysore, the Mahanadi Delta Project in Orissa, the Beas Project in Punjab, the Ramganga in U. P. and Kangsabati in West Bengal and several others are fast reaching completion. When all the irrigation projects in progress are completed, they would be irrigating an area of 17·8 million hectares.

Completed and continuing schemes

In all, 500 irrigation projects have been taken up in the major and medium sector since Independence. Three hundred schemes have so far been created in the course of the Third Plan, giving irrigation benefits to 4·4 million hectares. Two hundred schemes, which are in varying stages of construction and which have so far yielded a benefit of only 2·8 million hectares of irrigation potential, would continue into the Fourth Plan.

Out of 500 plan schemes, 74 major schemes with an ultimate potential of 14·5 million hectares have so far yielded an irrigation potential of 5·2 million hectaress. The 426 midium schemes which have an ultimate potential of 3·2 million hectares have so far yielded an irrigation potential of about 2 million hectares. Schemes under construction in the current plan will receive the highest priority so that the benefits of irrigation to 17·8 million hectares will begin to accrue from the earliest possible date.

Utilisation of potential

Potential created under these projects has been utilised at a steadily accelerating pace. At the end of the First Plan, only half the potential created was actually utilised. At the end of the Second Plan, the percentage of utilisation rose to 77 and at the end of the Third Plan it touched 87. While the utilisation or the national scale is very high, comparable to any standard, there are individual projects where utilisation is not satisfactory, on account of a variety of reasons. In order to step up the pace of utilisation in these specific projects, and also, in general, in the country, efforts are being made to give assistance to farmers by way of provision of better seeds, manure, fertilisers, marketing and credit facilities, to enable them to take advantage of the irrigation water and increase agricultural production.

Minor Schemes

The "minor" scheme included a variety of schemes involving surface and subsurface extractions like tanks, small diversion schemes, lift irrigation schemes from streams and canals, tubewells, ordinary wells and small schemes of local drainage, flood protection as well as works intended to prevent intrusion of salt water. There are nearly 6 million wells in the country, and over 0·5 million small tanks. During the last 20 years, an area of 5·6 million hectares has been benefited by all these schemes, bringing the total area irrigated by minor sources to about 20·2 million hectares in March 1966. Out of this, an area as large as 9·6 million hectares is irrigated by small tanks and diversion schemes and an area of 8·7 million hectares by ordinary wells, with or without pumping. Minor irrigation schemes are of great importance to large number of people. Renovation of existing works and construction of new ones have been receiving continuous Government attention. According to present estimates, the total area which can ultimately be brought under irrigation by minor schemes, both surface and sub-surface, is 30 million hectares.

Flood Protection and Drainage Schemes

India is a tropical country with a large number of rivers and is, therefore, subject to floods every year almost in some parts of the country or other. The total direct and indirect damage caused by floods to urban and rural property is estimated at Rs. 1,000 million a year. A greater part of this damage occurs in the States of Assam, Bihar, Punjab, Uttar Pradesh and West Bengal. Practically nothing had been done, before India attained Independence to counteract this recurring menace. During the last 15 years, attention has been paid to this problem of affording protection against flood damage on a scale never before witnessed in this country. Organisationally and technically, the extent of work done has been much more than in all the preceding period. Prior to Independence, a total length of 4,800 kilometres of embankments existed mainly along the banks of the Gandak, Damodar, Mahanadi, Godavari, Krishna and Cauvery rivers. During the last 15 years, the length of additional embankments constructed was 7,200 kilometres and 8,000 kilometres of drainage channels were excavated. Over 4,500 villages have been raised above high flood level. About 80 town protection schemes were completed. In addition, existing embankments were raised and strengthened wherever necessary. As a result of the work done up to the end of the Third Plan, more than 4 million hectares, usually subject to flood damage, now enjoy reasonable protection.

Some of the important protection schemes completed are the Budameru diversion scheme in Andhra Pradesh, Dibrugarh Town Protection scheme in Assam, the Kosi and the Bagmati flood embankments in Bihar, the Dalaighai Protection Scheme in Orissa and the Ghaggar Diversion scheme in Rajasthan. These are in addition to the flood protection assured by multi-purpose reservoirs like those in the Damodar Valley, on the Mahanadi etc. Work has also been taken up on the protection of coastal erosion in Kerala. Anti-waterlogging and drainage schemes have been taken up in a big way in the Punjab and West Bengal.

Development of Hydro-Power

Development of power is vital to the economic growth of a nation. It is not infrequent that criteria like the generation and consumption of power are taken as indices of national economic advancement. Power supplies the motive force for transforming the industrial economy of a country, and also effecting a qualitative change in agricultural production. From this point of view, schemes for power development have occupied a place of pride after Independence in the Three Five Year Plans. Hydro-power has contributed remarkably to the transformation taking place in India today.

Hydro-Power resources

India is fortunate in having immense potentialities of hydro-power development. The hydro-electric potential of the country is estimated at 41 million kW at 60 percent load factor. In addition, there is a vast potential in the Himalayan rivers in territories outside Indian boundaries which can be utilised for the common benefits of these countries and India.

Development Projects

After the advent of Independence, schemes for the generation of power utilising, among others, hydro-power resources have been taken up, some of which have already been completed.

A number of multipurpose and single purpose hydel projects were taken up for the development of hydro-power, some of the major ones being Bhakra Nangal in Punjab, Hirakud in Orissa, Chambal in Rajasthan and Madhya Pradesh, Tungabhadra in Mysore and Andhra Pradesh. Major single purpose Hydel projects were Machkund in Andhra Pradesh and Orissa, Rihand and Yamuna Valley Development Scheme in U. P., Periyar and Kundah in Madras, Koyna in Maharashtra, Sharavati in Mysore, Sabarigiri in Kerala and Umiam in Assam. The installed hydro-power capacity, which was 0·6 million kW in 1951 has risen to about four million kW at the end of the Third Plan. During the period the percentage of the total hydro-power capacity to the total generating capacity has risen from 33 to 40 percent.

Rural Electrification

Extension of electricity supply facilities to the villages as a policy is another fruit of political freedom. It holds revolutionary possibilities for the future economy of India. The output and productivity of the Indian villages today are probably the lowest in the world, and, soon after Independence, it was recognised that rural electrification would promote the growth of agriculture and industries in rural areas. Supplying electricity to the 573,000 villages, which make up the major portion of India, is no doubt, a herculean task ; but a beginning has been made and the aim of taking electricity to every village at the earliest possible date has also been accepted. Against hardly 2,000 villages electrified during the long British rule, 27 times as many villages enjoy electricity in less than 20 years of Independence.

With the electrification of the vast number of villages, it is hoped that the release of the creative energy of the teeming millions, which was dormant for centuries, will transform the face of the entire country with a tremendous rise of agricultural as well as industrial production.

In order to comprehend the impact of this achievement in the sphere of rural electrification, it will be necessary to bear in mind the distribution of population in India's villages. The number of villages with a population of 500 and less is the largest, being as much as 350,000. Ninety million people live in such villages. Then there is the second group each with a population between 500 and 1,000, numbering in all about 120,000. Ninety million live in this group. Then there is the third group, 100,000 with a population between 1,000 and 10.000. In this group live 210 millions.

The extension of rural electrification so far achieved has covered a sizeable number of villages in the third group. Thus, while the progress of rural electrification, reckoned in terms of number of villages in India may look small, its real impact has been on one-third of the country's rural population. In the Fourth Plan, it is programmed to electrify another 58,000 villages covering the balance of the people in the third group and half the number of people in the second group. This would mean that, by the end of the Fourth Plan, two-thirds of the rural population of the country would be enjoying the benefits of electricity. It has been the experience that the limitation on extension of rural electrification has been, not the availability of power, but of the necessary transmission system to carry the power to isolated and widely scattered load centres. Special attention is therefore being paid to improve and extend the transmission system to carry power to the villages.

For this purpose, Rs. 112.1 million were allocated during the last two years of the Third Plan over and above the outlay on normal rural electrification programme. During the Fourth Plan, the normal programme of rural electrification has been re-oriented to sub-serve the purpose of increasing food production in the country. Due to food shortages, particularly the drought conditions the country is now facing, the State Governments in pursuance of policy decisions taken by the Union Government, have given priority to electrification of groups of villages where clusters of irrigation wells are available. The rural electrification programme is now being coordinated with the programme of energisation of pumpsets. At the end of Third Plan period, about 0.51 million pumpsets were energised. A big programme of energising tube-wells/pumpsets has been taken up during 1966-67 (first year of the Fourth Plan). With the normal allocation of Rs. 400 million it was possible for the States to energise 99,800 pumpsets in addition to meeting other connected loads in the area. Due to severe drought conditions prevailing in Uttar Pradesh and Bihar, it was decided to give these States an additional Central assistance of Rs. 60 million each. This has enabled these States to energise respectively 7,000 and 8,000 pumpsets/tube-wells more during 1966-67. The demand of additional energisation of tube-wells was also persistent from other States as well. Taking into consideration their capacity and the availability of materials and power, additional Central assistance of Rs. 111.73 million was allocated to nine States. With this additional assistance, these States had to energise 32,200 tube-wells/pumpsets during 1966-67. Although actual figures of pumpsets energised during 1966-67 are not still available, it is expected that in all some 150,000 pumpsets would have been energised by State Governments during 1966-67. In Bihar alone, 14,000 pumpsets have been energised up to April 1967 which is more than the number which the State had done during the last 16 years. Madras tops the list where about 85 000 pumpsets have been energised in the same period.

The tempo of electrification has already been built-up sufficiently in all the States and a big programme of energising tube-wells and pumpsets has been taken up.

Regional and National Grids

In view of the uneven distribution of the available resources, it has become increasingly clear that power development has to be on a regional basis rather on a statewise basis. In view of the need for integrated power development in the country, five regional electricity boards have been constituted for effective coordinated operation for northern, southern, western, eastern and northeastern regions. With suitable high voltage inter-connections, existing State power generating systems are being constituted into regional grids, the formation of an all-India grid being the goal towards which progress is to be made. India has nearly 38,400 kilometres of transmission lines of 132 kV and above for power distribution. But in view of the large size of the country, this would not be enough. To ensure immediate inter-State and inter-regional grid formation, another 4,000 kilometres of high tension lines are being laid.

Prospect

The achievement of India during the last fifteen years in the fields of water conservation and utilisation have been tangible, but it is recognised that much more remains to be done to make up the leeway caused by enforced economic backwardness. In the field of irrigation, more area will have to be brought under irrigation in the coming years than the total area under irrigation at the end of the Third Plan. While the irrigated area in India at the end of the Third Plan was 35 million hectares, an additional area of 40 million hectares has yet to be provided with irrigation facilities. In the field of power development the installed capacity around 1980 may have to go up to 60 million kW as against the present 10.2 million kW. Hydro-power will come to make a sizeable contribution to total power generation in the country. Similarly, in respect of flood protection, about 3 times the present achievement remains to be accomplished in future Plans. India is, therefore, attaching great importance to the primary need for the development of water and power resources of the country.

IMPORTANT RIVER VALLEY PROJECTS

Nagarjunasagar Project

The Project consists of a masonry dam across the river Krishna and two canals, one on each side of the river. The Right Bank Canal will be 216 km long and the left Bank Canal 173 km. It is expected that an area of 0·834 million hectares will be irrigated by the end of the Fourth Plan. The Dam is of stone masonry, with an average height of 90·6 metres above the foundation level. The sanctioned estimate of the Project is Rs. 911·2 million.

Gandak Project

The Gandak Project is primarily an irrigation project, though a small quantum of power will also be generated. It is an inter-State Project in which Bihar and Uttar Pradesh are participating. Pursuant to the agree-

ment signed with His Majesty's Government of Nepal on 4th December
Nepal would also derive irrigation and power benefits from the project.
1959.

The Project comprises :

(i) A 743 metre long barrage with a road-bridge across the Gandak at Bhaisalotan in Bihar.

(ii) Main Western Canal to irrigate 484,000 hectares in the Saran district of Bihar and about 344,000 hectares in the Gorakhpur and Deoria districts of Uttar Pradesh. A separate canal taking off from the Western bank to irrigate 16,600 hectares in the Bhairwa district of Western Nepal.

(iii) Main Eastern Canal to irrigate 603,000 hectares in the Champaran, Muzaffarpur and Darbhanga districts of Bihar and 42,000 hectares in Parasa, Bara and Rautuhat districts of Nepal.

(iv) A power house with an installed capacity of 15 MW at the 14th km of the Main Western Canal in Nepal territory.
This power house will be handed over to Nepal as a gift when the connected load in Nepal has developed to a firm potential of 10 MW at 60 percent load factor).

The work, including the excavation of all the four canals, is in progress. The estimated cost of the project is about 1,113·8 million.

Kosi Project

The Kosi Project is a multipurpose project with emphasis on irrigation and flood control. It consists of the following :—

Unit I : Kosi Barrage and Headworks.

Unit II : Flood embankments of 240 km long and other protective works.

Unit III : Eastern Kosi Canal System.

The Barrage has been completed in all respects. The flood embankments have freed an area of about 20,720 km^2 in Bihar and Nepal from the ravages of the Kosi and afforded direct protection to about 60,000 hectares of cultivable land in Nepal and 200,000 hectares of land in Bihar from recurring submergence.

Earthwork on the entire Eastern Kosi Canal System has almost been completed. The project provides annual irrigation to 519,200 hectares of land in the districts of Purnea and Saharsa.

Extension of Eastern Kosi Canal

This scheme is estimated to cost about Rs. 46.7 million and comprises a canal system taking off from the Eastern Kosi Main Canal to irrigate an area of 160,400 hectares in the Saharsa and Monghyr districts of Bihar. This scheme is expected to be completed in 1969-70.

In addition, State II of the project, which consists of the 20,000 kW Kosi Power House, the Western Kosi Canal, the extension of the Eastern Kosi Canal and the extension of flood embankments is also under execution.

Western Kosi Canal

This scheme, approved for Rs. 134·9 million, comprises the contruction of a main canal 112 km long taking off from the right flank of the Kosi Barrage and will irrigate 312·300 hectares of land in Darbhanga district of Bihar and an area of 12, 120 hectares of land in the Saptari district of Nepal.

Extension of Flood Embankments

The Eastern Flood Embankment is being extended in a length of 25·76 km from Maina to Koparia.

Ukai Project

The Ukai multipurpose Project of Gujarat State envisages a 70·8 m high Dam on the river Tapi near village Ukai in Surat District, creating a reservoir of 8,511 million cu m capacity. A part of the impounded waters will irrigate annually 85,000 hectares from the Left Bank Canal taking off directly from the reservoir. The rest of the water, after driving the turbines, would run along the river to Kakrapar Weir, 88 km downstream, to be picked up and delivered through the Right Bank Canal to irrigate land in Surat and Broach district. This will firm up the irrigation of 227,300 hectares under the Kakrapar canals and extend irrigation facilities to a new area of 73,511 hectares coming under the command of the Kakrapar Right Bank Canal. The scheme also envisages the installation of 4 units of 40/45 MW each. The Project estimated to cost Rs. 582·1 million is to be completed in the Fifth Plan period.

Lower Jhelum Hydro-electric Project

The project, run-of-the-river schemes, is located in Baramula district on the river Jhelum and envisages the generation of power by utilising the waters of the river Jhelum and the natural storages available from Wular lake supplemented by waters from the upstream tributaries. The estimated cost of the scheme is Rs. 174·5 million for 112 MW installed capacity.

Idikki Project—State I

The Project, rec iving Canadian aid in the form of loans, envisages the installation of three generating units of 130 MW each at a total estimated cost of Rs. 580 million in Stage I, with an ultimate potential of 800 MW hydro-power capacity.

Tawa Project

The Project envisages a reservoir across the Tawa (river a tributary of the Narmada river) about a kilometre downstream of its confluence with its tributary Denwa in Hoshangabad district and canal system on both banks. The project is expected to irrigate a total area of 0·31 million hectares and have an installed capacity of 42 MW. The project, estimated to cost Rs. 480 million is scheduled for completion during the Fifth Plan period.

Kundah Hydro-electric Project—Stage III

The scheme provides for the installation of the third generating unit of 20 MW in the existing Power House No. 1 and a 5th unit of 35 MW in Power House No. II which were commissioned in the Second Plan period and one unit of 20 MW, 2 units of 60 MW and one unit of 20 MW were commissioned in the first quarter of 1964 and another unit of 20 MW was commissioned in October 1964. Two more units of 60 MW each were commissioned in March 1965 and July 1965. One unit of 50 MW was commissioned in February 1966.

The revised estimated cost of the Project is Rs. 375·8 million.

Koyna Hydro-Electric Project—Stage II

Work on four generating units of 75 MW each, is simultaneously in progress. The estimated cost of Stage II of the project is Rs. 146·1 million the total for Stages I and II being Rs. 528·9 million.

Jayakwadi Project

The Jayakwadi Project across the river Godavari consists of a dam 36·5 metres high near Paithan and a left bank canal 185 km long. This will irrigate an area of 142,000 hectares. The scheme, estimated to cost Rs. 384·6 million, is expected to be completed during the Fifth Plan period.

Tungabhadra Project

The Project consists of a masonry dam across the Tungabhadra, a 203 km long canal called the Left Bank Canal with a Power House on the left side, a 347 km long canal called the Low Level Canal with two Power Houses on the right side and a 195 km High Level Canal also on the right side. On completion, the Project will irrigate 4,08,669 hectares of land in the two States of Andhra Pradesh and Mysore and generate 1,08,000 kW of power.

Under the Low Level Canal, irrigation potential has been created and utilised in full. The total area to be irrigated under the Left Bank Canal is 234,000 hectares.

The total installed capacity of the Tungabhadra Hydro-electric System is 99 MW at present—72 MW from the two Power Houses under the Tungabhadra Board and 27 MW from the Left Bank House under the Government of Mysore. The estimated cost is likely to be Rs. 203·1 million.

Sharavati Hydro-Electric Project

The first stage of this Project has been completed. Two units of 89,100 kW each have been commissioned.

The second stage of the Project provides for the installation of six additional units of 89,100 kW each. The third and final stage of the project will and two more units of 89,100 kW each during the Fourth Five Year Plan. The generating units for both Stage I and II have been supplied by U. S. A. under US AID assistance and the turbines by France.

Hirakud Dam Project

Stage I of the Hirakud Dam Project has been completed providing irrigation for the entire ayacut of 155,000 hectares. The actual utilisation so far has gone up to 131,000 hectares during Kharif season and 73,000 hectares during Rabi season.

Stage II of the Hirakud Dam Project comprises the augmentation of Hirakud Main Power House at Burla by installation of two more generating units of 37·5 MW each (units 5 and 6) and construction of Chiplima Power House with 3 generating units of 24 MW each.

The total installed capacity at the Main Power House is 198 MW and at Chiplima Power House is 72 MW. The cost of the project is estimated at Rs. 820 million.

Mahanadi Delta Irrigation Scheme

The Mahanadi Delta Irrigation Scheme, an adjunct to Stage I of the Hirakud Dam Project consists of a diversion weir at Mundali to pick up the regulated releases from Hirakud and remodelling of the existing canal system and weirs on the Mahanadi and Birupa rivers. On completion, it will irrigate a gross area of 650,000 hectares of land (including the existing area of 82,000 hectares) in the Cuttack and Puri districts. The Project is likely to be completed in all respects by 1969-70. It is expected to cost Rs. 34·34 million.

Beas Project

A joint venture of the Governments of the Punjab and Rajasthan, the Projects consists of two units, viz., Beas-Sutlej Link and Beas Dam at Pong.

The Beas Sutlej Link envisages the diversion of the Beas water into the Sutlej to avail of the 305 metre fall en route at Dehar (tail of the Link) and another 122 metre fall at Bhakra for generation of hydro-power and to enable extension of irrigation to the arid tracts in south and southwest Punjab. Dehar Power Plant, to be located near Dehar village. all have 4 units of 165 MW capacity each, giving a total installed capacity of 660 MW. The total installed capacity under the whole Beas Project complex would be 1,019 MW.

Two more units of 165 MW at Dehar Power House and another 2 units of 60 MW each at Pong Dam Power House will be added later under separate project.

The project will provide irrigation to a cultural commanded area of 525,000 hectares and the annual irrigation will be of the order of 324,000 hectares. The scheme, at a total estimated cost of Rs. 96·67 million, is likely to be completed by the end of 1971-72.

The Pong Dam located near Pong village about 38 kilometres from Mukerian will be an earth-cum-rockfill dam rising 116 metres above the river bed. It will ensure extension of perennial irrigation in the Punjab and Rajasthan. A power plant with an installed capacity of 240 MW will also constructed here, giving firm power of 75 MW at 100 percent load factor. The Unit is expected to cost about Rs. 1,110 million.

The foreign exchange requirements of the Project are planned to be met partly from a loan of 33 million from US AID and partly from another loan of 23 million from the International Bank of Reconstruction and Development.

Bhakra Nangal Project

The 226 metres high Bhakra Dam completed in 1963 has an installed capacity of 604 MW, shared between Punjab and Rajasthan in the ratio of 84·78 : 15·22 after meeting the requirements of Delhi, Nangal Fertiliser Factory and Himachal Pradesh.

Bhakra Right Bank Power Project

The Bhakra Right Bank Power project, an adjunct of the Main Bhakra-Nangal Project, will have an ultimate installed capacity of 600 MW, and will meet the requirements of the Punjab and Rajasthan as also of Delhi, Jammu and Kashmir and Himachal Pradesh.

The cost of the project is likely to be Rs. 593·2 million.

The plant and equipment for the Power House is being imported from U. S. S. R. under an agreement between the Government of India and the Government of U. S. S. R. The main civil works on this Project have been completed.

Chambal Project

The multipurpose Chambal Project is being jointly executed by the Madhya Pradesh and Rajasthan Governments, who share its benefits and cost equally. On completion, the Project will produce 2,30,000 kW of power at 60 percent load factor and irrigate 566,000 hectares of land. The Project will be completed in three stages.

Stage I of the Project consists of the Gandhi Sagar Dam, a Power House at the foot of the dam with 5 units of 23,000 kW each (4 units in Stage I and the 5th in Stage II), transmission lines, Kotah Barrage, and irrigation canal system in both the States. It will produce 80,000 kW of power at 60 percent load factor and irrigate 444,000 hectares of land in both the participating States.

The Gandhi Sagar Dam and the Kotah Barrage have been completed, and four units of 23,000 kW each have been installed. Full irrigation potential to the extent of 282,000 hectares is expected to be created by December, 1967. In Rajasthan, the main canals on both sides have been completed.

The estimates are currently under revision and are likely to go up to Rs. 704.6 million.

Stage II of the Project envisages a masonry dam on the main river (Rana Pratap Sagar Dam), a Saddle Dam across Padajhar Valley on the left flank and a power station with 4 units of 43,000 kW each below the Rana Pratap Sagar Dam, with suitable transmission lines and Grid Sub-Station. On completion of this stage, 90,000 kW of power at 60 percent factor would be generated and irrigation facilities to an area of 121,000 hectares would be provided.

Stage III includes the Kotah Dam (renamed as Jawahar Sagar Dam) and a power station at its toe, situated about 24 kilometres below the Rana Pratap Sagar Dam. The Power station will have 3 units of 33,000 kW each with provision for the installation of a Fourth unit a later date. It will produce 60,000 kW of power at 60 percent load factor.

Rajasthan Canal Project

The Rajasthan Canal comprises Stage I (Rajasthan Feeder, Rajasthan Main Canal up to 196·42 km and branches and distributaries taking off in this reach) to be completed by 1969-70, and Stage II Main Canal below 196·42 km and all its off-taking channels to be completed after 1977.

The Rajasthan Canal Project, on completion of both the phases, will provide irrigation facilities to an area of 1·16 million hectares annually in the districts of Ganganagar, Bikaner and Jaisalmer in Rajasthan. The total cost of the Project is estimated to be Rs. 1,840 million of which, works in the First State of the Project are estimated to cost Rs. 750 million and in the Second Stage Rs. 640 million. The share debitable to the Project towards the cost of Pong Dam, Madhopur Beas Link and Harike Barrage is estimated to be Rs. 450 million.

Ramganga Project

The multipurpose Ramganga River Project in Uttar Pradesh comprises the following items of works :—

Unit I : Dams and appurtenant works

There will be a 123·6 metre high earth and rockfill dam across the river Ramganga near Kalagarh in Garhwal district and a 75·6 metre high saddle dam across the Chuisot stream with connected works, There will also be two diversion tunnels of 10·6 metre diameter each, for diverting the flow of the river during construction period. One of the tunnels will be used, later on as spillway tunnel and the other one as power tunnel.

Unit II : Irrigation and Drainage works

These consist of :—

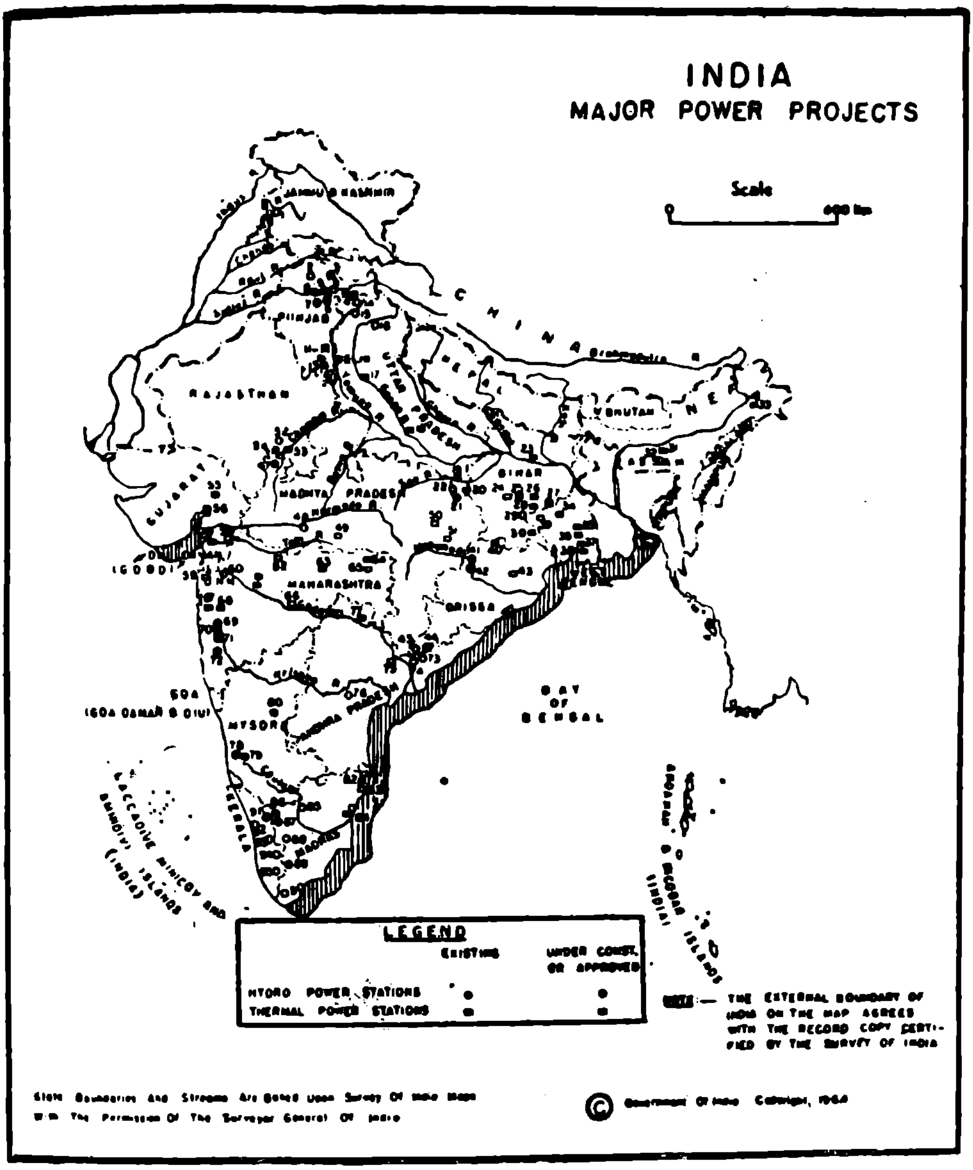
(i) a 546 metre long weir across the river Ramganga at Hareoli and connected works ; and

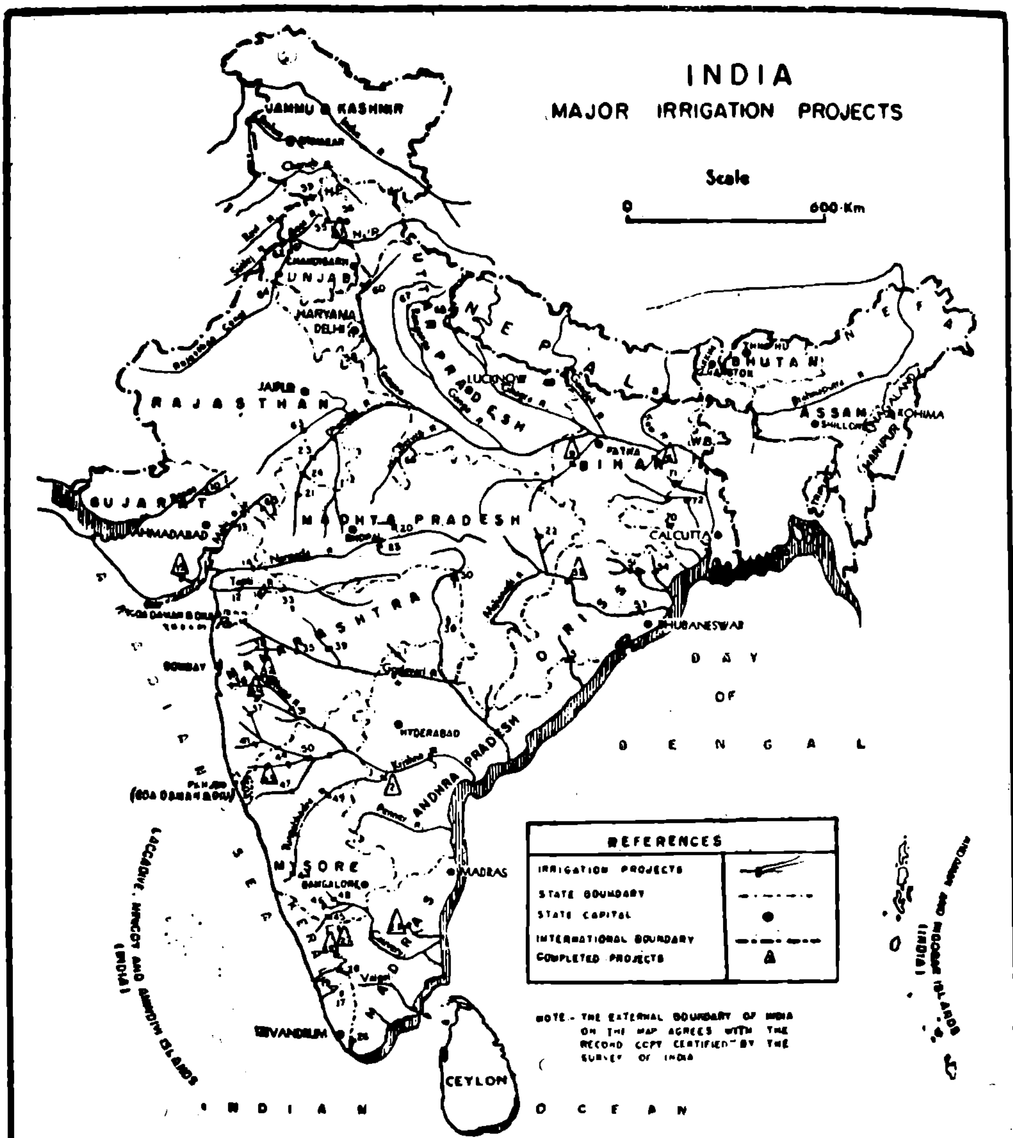
(ii) remodelling and extension of irrigation channels of the Lower Ganga Canal, the Agra Canal, the Upper Ganga Canal and the Ramganga Canal System.

Unit III : Power Generation works

The scheme provides for a power house on the right bank of the river at the toe of the main dam, having 3 units of 60 MW each.

The Project is expected to be completed by March 1972 at an estimated cost of Rs. 920 million. On completion, the Project will irrigate an additional area of 690,000 hectares, generate 165 MW of power and reduce the intensity of floods in central Uttar Pradesh.


INDIA
MAJOR POWER PROJECTS
Scale
RAJASTHAN
GUJARAT
MADHYA PRADESH
MAHARASHTRA
ORISSA
BIHAR
BHUTAN
MYSORE
KERALA
BAY OF BENGAL
LEGEND
EXISTING
UNDER CONST. OR APPROVED
HYDRO POWER STATIONS
THERMAL POWER STATIONS


INDIA
MAJOR IRRIGATION PROJECTS
Scale
0
600 Km
JAMMU & KASHMIR
H.P.
PUNJAB
CHANDIGARH
HARYANA
DELHI
RAJASTHAN
JAIPUR
GUJARAT
AHMADABAD
UTTAR PRADESH
LUCKNOW
NEPAL
BHUTAN
ASSAM
SHILLONG
KOHIMA
NAGALAND
MANIPUR
PATNA
BIHAR
W.B.
CALCUTTA
MADHYA PRADESH
BHOPAL
MAHARASHTRA
BOMBAY
ORISSA
BHUBANESWAR
HYDERABAD
ANDHRA PRADESH
MYSORE
BANGALORE
MADRAS
KERALA
TRIVANDRUM
CEYLON
BAY
OF
BENGAL
INDIAN OCEAN
REFERENCES
IRRIGATION PROJECTS
STATE BOUNDARY
STATE CAPITAL
INTERNATIONAL BOUNDARY
COMPLETED PROJECTS

Kangsabati Project

The Project envisages two independent earthen dams on the river Kangsabati and on Kumari river (a tributary of Kangsabati river). respectively, about a kilometre upstream of their confluence near Ambikana- gar in the Bankura district of West Bengal. The length of the Dam and dykes is 10·4 km and maximum height of the dam above the river bed is 41·15 m. The live storage capacity of the reservoir created will be 986·8 million cu m. Two canals are proposed from the Right and Left Bank Head Regulators to irrigate 323,000 hectares of kharif and 60,000 hectares of rabi annually.

The estimated cost of the Project is Rs. 252·6 million.

Delhi Rural Drainage Scheme

The work on the Najafgarh Drainage Scheme is in progress. The dismantling of the old bridges across the Najafgarh drain has been completed. The important bridges at Basaidhara, Bharat Nagar, Delhi Tail Distributary aqueduct, Roop Nagar, Vijay Nagar, Rajpur Road and Rohtak Road have been completed and work on G. T. Road bridge is in progress. The regulators at Dhasa Bund and Kakraula have been completed.

Farakka Barrage Project

The Farakka Barrage Project is primarily intended to improve the navigability of the Port of Calcutta. The principal components to secure this objective are :—

(i) Construction of a Barrage across the Ganga at Farakka with a rail-cum-road bridge ;

(ii) a barrage across the Bhagirathi ; and

(iii) a feeder canal tailing into Bhagirathi.

Keeping in view the limitations in regard to the resources for this project during the Fourth Plan period vis-a-vis the main objective to be achieved, the project works have been phased as under :—

Unit I—Farakka Barrage with road-cum-rail bridge over it. Head Regulator, Right Afflux Bund, 40 percent of Right Guide Bundh, Left Guide Bundh, 66 percent of Left Afflux Bundh, Feeder Canal Jangipur Barrage, Navigation Lock and Bye-Pass Channel at Jangipur Barrage Bagmari Syphon, Kanoli inlet and other diversion works, Road Bridges over Feeder Canal 2 Nos. (Work on Upstream Lock at Farrakka which has already been started has to be suspended after bringing it to a safe stage and the balance works to be taken up under Unit II). These works are to be completed by 1970-71.

Unit II—34 percent of Left Afflux Bundh, 60 percent of Right Guide Bundh, Tail Regulator on Bye-Pass Channel, Bye-Pass Channel, Additional bridges over Feeder Canal.

Unit II work is to be taken up after 1970-71, if funds are not available during the Fourth Plan.

Unit III includes the work required for navigation, viz., navigation locks, shelter basins, etc. This would be taken up in the Fifth Plan after completion of work on Unit I.

Trisuli Project (Nepal) under Indian Aid Programme

The first stage of the scheme comprises construction of a diversion weir across the Trisuli river, water conductor system and a power station with the installation of three generating units of 3 MW each. The total cost of the first stage is Rs. 86·4 million.

The second stage of the scheme provides for completion of the balance civil works for the ultimate development and installation of the fourth generating unit of 3 MW. The estimated cost of the second stage is Rs. 7·02 million.

Under the third stage of the Project, 3 additional generating units of 3 MW each are proposed to be installed in the Power Station at an estimated cost of Rs. 3·75 million.

The entire cost of the Project is borne by the Government of India, but the foreign exchange required for the project is being made available by the Government of Nepal, and equivalent amount in Rupees against it, is paid to the Government of Nepal by the Government of India. After completion, the project is to be handed over to the Government of Nepal.

APPENDIX I

DEVELOPMENT AT A GLANCE

IRRIGATION AND POWER SECTOR

	1951	1966
IRRIGATION		
Irrigation Potential created from Major and Medium Schemes (million hectares)	9·71	17·00
Area Irrigated from Major and Medium Schemes (million hectares)	9·71	15·38
Gross Irrigated Area from all sources (million hectares)	22·66	35·61
POWER		
Installed Capacity (million kW)	2·3	10·2
Total generation (million kW)	6,573	38,400
Villages and Towns electrified (number)	3,687	54,780
Per capita generation (kWh)	18	82
FLOOD CONTROL		
Embankments (length in Kilometres)	4,828	12,070

APPENDIX II

MAJOR IRRIGATION PROJECTS IN INDIA AFTER INDEPENDENCE

Serial No.	Name of Project	Estimated cost in Million Rupees	Ultimate Potential in 000 hectares	Remarks
	ANDHRA PRADESH			
1.	Tungabhadra H.L.C. ..	128·128	60·18	
2.	Nagarjuna Sagar	1645·00	833·25	
3.	Tungabhadra H.L.C. (St. I) ..	177·80	48·16	
4.	Kadam	83·80	34·40	
5.	Karnool-Cuddapah canal ..	75·72	122·22	completed.
6.	Pochampad	40·10	230·67	
7.	Vamsadhara	139·74	111·43	

Serial No.	Name of Project	Estimated cost in Million Rupees	Ultimate Potential in 000 hectares	Remarks
	BIHAR			
8.	Son H.L.C.	59·10	171·99	
9.	Kosi	436·70	568·58	
10.	Gandak	949·19	1,151·33	
11.	Son	163·93	124·24	completed.
12.	Badua	62·80	42·49	-do-
13.	Kosi Western Canal ..	196·90	324·96	
14.	Rajpur Canal	64·78	160·66	
15.	Chandan Reservoir ..	92·56	54·63	
16.	Ajoy	56·46	40·47	
	GUJARAT			
17.	Kakrapar	185·70	227·53	
18.	Mahi Stage. I	249·28	186·16	
19.	Shetrunji	77·50	34·80	completed.
20.	Banas	108·80	44·52	
21.	Narmada (scope under examination)	414·00	403·67	
22.	Ukai (including Power) ..	963·30	158·50	
23.	Mahi Stage. II	162·68	16·56	
	KERALA			
24.	Kallad	132·80	105·22	
25.	Malampuzha	58·00	38·53	completed.
26.	Pamba	64·00	33·99	
27.	Periyar Valley	64·00	40·99	
	JAMMU & KASHMIR			
28.	Ujh	140·00	30·76	
29.	Liddar	120·00	2·42	
	MADHYA PRADESH			
30.	Chambal Stage I ..	369·40	222·58	
31.	Ranapartap sagar	59·10	60·70	
32.	Barna	70·00	66·45	

Serial No.	Name of Project	Estimated cost in Million Rupees	Ultimate Potential in 000 hectares	Remarks
33.	Tawa	341·40	303·51	
34.	Hasdeo Stage I	90·00	..	Water supply to Korba Thermal Station.
	MADRAS			
35.	Lower Bhawani	102·08	78·91	completed.
36.	Manimuthar	51·60	41·68	-do-
37.	Parambikulam	378·70	97·12	
38.	Chittar Pattanamkal	73·30	19·02	
	MAHARASHTRA			
39.	Ghod	57·76	25·25	completed.
40.	Vir	54·11	26·71	-do-
41.	Purna	153·41	61·51	
		134·60	57·20	
43.	Khadakwasla St. I	160·72	17·28	
44.	Mula	161·60	65·70	
45.	Bagh	58·43	24·69	
46.	Itiadoh	73·40	28·94	
47.	Warna	320·55	90·45	
48.	Krishna Irrigation	305·05	70·25	
49.	Bhima	425·80	116·55	
50.	Jayakwadi St. I	384·60	141·64	
	MYSORE			
51.	Tungabhadra Left side	355·20	234·72	
52.	-do- Right side	14·50	37·37	
53.	Ghataprabha St. I	57·60	19·42	completed.
54.	Bhadra	342·70	99·03	
55.	Ghataprabha St. II	420·00	101·17	
56.	Kabini	170·40	51·88	
57.	Malaprabha	200·00	121·41	
58.	Harangi	110·00	30·35	
59.	Upper Krishna	5·90	242·81	
60.	Hemavathi	163·00	40·47	
61.	Tungabhadra H.L.C. St. I	44·00	40·47	
62.	-do- St. II	30·00	37·64	

Serial No.	Name of Project	Estimated cost in Million Rupees	Ultimate Potential in 000 hectares	Remarks
	ORISSA			
63.	Hirakud	678·19	242·81	completed.
64.	Mahanadi Delta	343·40	638·19	
65.	Salandi	130·77	61·92	
	PUNJAB			
66.	Bhakra Nangal	553·88	1,227·77	completed.
67.	Beas Project Unit I ..	22·54	323·75	
68.	-do- Unit II ..	133·26		
69.	W. J. C. Remodelling ..	95·20	247·95	
70.	Gurgaon Canal	78·95	101·58	
71.	Harike Project (Makhu Canal)	91·45	13·80	
72.	Sirhind Feeder	67·00	..	No direct benefits.
	RAJASTHAN			
73.	Chambal Stage I	222·80	222·58	
74.	Ranapratap Sagar ..	59·10	60·70	
75.	Rajasthan Canal—St. I ..	801·20	526·09	
76.	Mahi	49·50	30·76	
77.	Gurgaon Canal	30·20	25·09	
78.	Beas Unit I	18·00	..	Under Rajasthan Canal.
79.	-do- Unit II	676·30	..	-do-
80.	Bhakra	224·74	230·67	completed.
	UTTAR PRADESH			
81.	Matatila	78·98	165·76	completed.
82.	Sardasagar Stage II ..	73·23	74·93	-do-
83.	Western Gandak Canal (Share)	422·90	264·17	
84.	Ramganga Project ..	646·00	690·43	
	WEST BENGAL			
85.	D.V.C. Project	425·00	364·22	
86.	Mayurakshi	204·60	246·86	
87.	Kangsabati	318·40	384·45	

APPENDIX III

MAJOR POWER PROJECTS IN INDIA AFTER INDEPENDENCE

PROJECTS				INSTALLED CAPACITY	
				Already commissioned kW	On completion kW
ANDHRA PRADESH					
Machkund Project	..	(Hydro)	Joint Project with Orissa.	1,14,750	1,14,750
Upper Sileru	..	(do)		..	1,20,000
Lower Sileru	..	(do)		..	4,00,000
Srisailam	..	(do)		..	4,40,000
Kothagudem	..	(Thermal)		1,20,000	4,20,000
Ramagundam	..	(do)		37,500	1,00,000
ASSAM					
Naharkatiya	..	(Thermal)		69,000	69,000
Gauhati	..	(do)		12,500	72,500
Umiam-Umtru	..	(Hydro)		44,400	65,200
BIHAR					
Maithon	..	(Hydro)		60,000	60,000
Subarnarekha	..	(do)		..	1,20,000
Sindri	..	(Thermal)		80,000	80,000
Bokaro	..	(do)		2,55,000	2,55,000
Chandrapura	..	(do)		2,80,000	6,60,000
Barauni	..	(do)		45,000	1,45,000
Pathratu	..	(do)		50,000	6,00,000
GUJARAT					
Ukai	..	(Hydro)		—	3,00,000
Uttran	..	(Thermal)		67,500	67,500
Dhuvaran	..	(do)		2,50,000	5,00,000
JAMMU & KASHMIR					
Lower Jhelum	..	(Hydro)		—	1,12,000

PROJECTS			INSTALLED CAPACITY Already commissioned kW	On completion kW
KERALA				
Sabarigiri	..	..	1,00,000	3,00,000
Idikki	..	..	..	7,80,000
Kuttiadi	..	..	..	75,000
Sholayar	..	..	18,000	54,000
MADHYA PRADESH				
Korba	..	.. (Thermal)	1,50,000	3,00,000
Amarkantak	..	.. (Thermal)	60,000	60,000
Satpura	..	.. (do)	..	3,12,500
Gandhi Sagar	..	.. (Hydro)	1,15,000	1,15,000
MADRAS				
Mettur Tunnel	..	.. (Hydro)	2,00,000	2,00,000
Periyar	..	.. (do)	1,40,000	1,40,000
Kundah St. I to IV		.. (do)	4,39,000	5,49,000
Kodayar	..	.. (do)	..	1,00,000
Parambikulam Aliyar		.. (do)	30,000	1,85,000
Ennore		.. (Thermal)	..	3,30,000
Neyveli	..	.. (do)	3,00,000	6,00,000
Kalapakkam	..	.. (Atomic)	..	4,00,000
MAHARASHTRA				
Trombay	..	.. (Thermal)	3,27,500	3,27,500
Khaper-Kheda	..	.. (do)	1,20,000	1,20,000
Paras	..	.. (do)	30,000	92,500
Bhusaval	..	.. (do)	..	62,500
Nasik	..	.. (do)	..	2,80,000
Nagpur	..	.. (do)	..	4,90,000
Koyna St. I & II & III		.. (Hydro)	3,90,000	8,60,000
Vaitarna	..	.. (do)	..	60,000
Tarapore	..	.. (Atomic)	..	3,80,000
MYSORE				
Mahatma Gandhi Station		.. (Hydro)	1,20,000	1,20,000
Sharavati	..	.. (do)	1,78,200	8,91,000
Tungabhadra (3 power stations)		(Hydro)	99,000	99,000

PROJECTS			INSTALLED CAPACITY	
			Already commissioned kW	On completion kW
ORISSA				
Hirakud St. I & II	..	(Hydro)	2,70,000	2,70,000
Balimela	.. ..	(do)	..	3,60,000
Talcher	.. ..	(Thermal)	..	2,50,000
PUNJAB				
Bhakra Nangal ..	..	(Hydro)	6,04,000	6,04,000
Bhakra Right Bank	..	(do)	1,02,000	5,10,000
Beas-Sutlej St. I & II	..	(do)	..	9,00,000
RAJASTHAN				
Ranapratap Sagar	..	(Hydro)	..	1,72,000
Jawahar Sagar ..	..	(do)	..	1,00,000
Ranapratap Sagar	..	(Atomic)	..	4,00,000
UTTAR PRADESH				
Rihand	.. ..	(Hydro)	3,00,000	3,00,000
Obra	.. ..	(do)	..	1,00,000
Yamuna St. I & II	..	(do)	56,000	4,24,000
Obra	.. ..	(Thermal)	..	5,50,000
Harduaganj	.. ..	(do)	1,10,000	3,20,000
Renukot	.. ..		..	1,25,000
WEST BENGAL				
Durgapur	.. ..	(Thermal)	2,85,000	4,35,000
Bandel (D.V.C.)	..	(do)	3,30,000	3,30,000
Durgapur (D.V.C.)	..	(do)	1,65,000	3,05,000
Santaldih	.. ..	(do)	..	4,80,000
DELHI				
Delhi 'C' Station	..	(Thermal)	36,000	2,78,500
Badarpur	.. ..	(do)	..	3,00,000
HIMACHAL PRADESH				
Giribata	.. ..	(Hydro)	..	60,000

CHAPTER XX

THE INDUS AND ITS TRIBUTARIES

General

Indus is one of the great rivers of the world. From its source to the sea, it is 2,880 kilometres long ; its principal tributaries, the Kabul and the Swat on its right, and the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej, on its left, have a total length of 5,600 kilometres. Geographically, it is the river of northwest India and of West Pakistan. Historically, from this river India got her name.

In terms of dependent agriculture and food supply, the Indus, with its tributaries, is easily the most important river of the world. Not including the area to be developed from projects under execution and those still to be taken up, the waters of the Indus system of rivers have already been harnessed and put on the land to irrigate, every year, more than 12 million hectares of arid land, to produce wheat and rice, cotton, oil-seeds and citrus. This irrigated area is by far the largest in the world on any one river system, larger even than the total irrigated area in any country outside the Indian sub-continent, China main land and the U. S. A.

The Indus is the largest river of the world, subject to an international treaty (between India and Pakistan) for the diversion of most of its waters for use in irrigation.

In terms of volume of water carried annually, the Indus ranks with the Columbia in Canada and United States. The annual flow of the Indus is about 209,691.6 million cubic metres, twice that of the Nile, three times that of the Tigris and Euphrates combined.

The Indus has a drainage area of 1,165,500 km^2, an area larger than Egypt and almost equal to the aggregate area of France, Italy, and undivided Germany, taken together. The mighty Indus and its eastern-most tributary, the Sutlej, rise in the Tibetan plateau near the Manasarowar lake, another tributary, the Kabul rises in Afghanistan. Most of the Indus basin, however, lies in India and Pakistan, the catchment in Tibet and Afghanistan being only about 13 percent of the total area of the basin.

Out of the total drainage area of 1,165,500 km^2, about 453,250 km^2 lie in the Himalayan mountains and foot-hills, the source of water supply ; the rest lies in the arid plains of India and Pakistan, mostly desert but for the waters of the Indus.

Brief description of the rivers*

The Indus (Sanskrit, *Sindhu* ; Greek, *Sinthos* ; Latin, *Sindus*) rises in Tibet (32°N and 81°E) behind the great mountain wall of the Himalaya, at an elevation of 5,182 metres. Issuing from the lofty mountains around Manasarowar, it flows northwest under the name of Singge-Khabab until it is joined, about 257 kilometres from its source, by the Ghar. A short distance lower down, it enters the southeastern corner of Kashmir at an elevation of 4,206 metres, and flows over a long flat of alluvium. It skirts Leh at 3,200 metres and is joined by the Zaskar river near the crossing of the great trade route into Central Asia *via* the Karakoram pass. Still flowing north, but more westerly, the Indus passes near Skardu and reaches the Haramosh mountain (7,407 metres). Here it takes a turn southwards at an acute angle and passing beneath the Hattu Pir enters Kohistan. After flowing through the wilds of Kohistan and about 1,448 kilometres from its source, the Indus is joined opposite Attock (West Pakistan) by the Kabul river from Afghanistan. At this point the river has fallen to an elevation of about 610 metres. After leaving Attock, the Indus flows southwards, parallel to the Sulaiman range. Just above Mithankot, about 805 kilometres from the sea, and at an elevation of 79 metres, the Indus receives, from the Panjnad, the accumulated waters of the five eastern tributaries. The river finally empties itself by many mouths into the Arabian Sea, near Karachi. Its delta covers an area of 7,770 km^2 and extends along the coast line for about 201 kilometres.

The Jhelum (Sanskrit, *Vitasta* ; Greek, *Hydaspes*, *Bidaspes*) is known in Kashmir as *Veth*. The river has its source in Verinag, a spring at the bottom of a high scarp of a mountain spur, at the upper end of the famous Kashmir valley. The river has several tributaries in the valley ; many of these come from the everlasting snows of the Liddar valley. Below Srinagar, it receives the Sind and beyond the Wular Lake, which is in fact a delta of the river, the Pohru stream from the Lolab valley. Below Baramula, the Jhelum leaves the fertile banks of the valley and rushes headlong down a deep gorge between lofty mountains. At Muzaffarabad. the Kishanganga joins the Jhelum from its right. Lower down, the river skirts the outlying spurs of the Salt Range and finally debouches upon the plains near the city of Jhelum in West Pakistan, about 402 kilometres from its source. About 322 kilometres lower, it joins the Chenab at Trimmu.

* Based to the extent applicable on the Imperial Gazetteer of India (1908).

The Chenab (*Asikni* of the Vedas and *Acesines* of the Greeks) rises in the Himalayan canton of Lahul in the Himachal Pradesh in two streams —the Chandra and the Bhaga. The united stream, known as the Chandra-bhaga or Chenab, flows through the Pangi valley and enters Kashmir at an elevation of 1,828 metres. It flows for 290 kilometres between steep cliffs of high mountains and then for 40 kilometres through the lower hills to Akhnur where it enters West Pakistan near the Merala weir, below the junction of the Tawi. In Pakistan, the Chenab flows for more than 644 kilometres to Panjnad, where it joins the Sutlej, having received the waters of the Jhelum about halfway at Trimmu and of the Ravi a little lower down.

The Ravi (Sanskrit, *Iravati*) rises near Kulu and emerges into the plains near Madhopur, the headworks of the Upper Bari Doab canal. For some distance, it flows on the boundary between India and Pakistan and then enters Pakistan near Lahore.

The Beas (Sanskrit, *Vipasa ;* Greek, *Hyphasis*) rises on the southern face of the Rohtang Pass, 4,062 metres above sea level. Fairly steep in its upper portion (24 metres per kilometre), it meanders lower down in a westerly course through hilly country. On meeting the Siwalik hills in Hoshiarpur, the river sweeps sharply northward, then bending round the base of the hills, it takes a southerly direction. In this portion of its course, through the uplands of the Punjab plains, a strip of low alluvial soils fringes its banks, subject in flood-time to inundation from the central streams. Lower down, the river shifts from year to year through the alluvial valley and finally joins the Sutlej at Harike after a total course of 460 kilometres, wholly in India.

The Sutlej (*Sutudri* or *Satadru* of the Vedas) rising at a height of 4,630 metres near the more westerly of the Manasarowar lake, flows in a northwesterly direction along the southern slopes of the Kailas mountain, then turns southwest and enters the Punjab plains near Rupar. About 160 kilometres, from below Ferozepore, it forms the boundary between India and Pakistan and enters Pakistan near Suleimanke. About 1,440 kilometres from its source, it joins the Chenab at Panjnad.

There is evidence to show that the Chenab, the Ravi, the Beas, and the Sutlej have changed their courses in historical times. The Chenab flowed east of Multan as late as 1245, the Beas then occupied its old bed near Dipalpur and the Jhelum, the Chenab and the Ravi met northeast of Multan and joined the Beas 45 kilometres south of Multan. At one time, the Sutlej found an independent outlet into the Rann of Kutch. In the year 1000, it was a tributary of the Hakra and flowed in the Eastern Nara. By 1245 the river had taken a more northerly course, the Hakra had dried up, and a great migration took place of the people of the desert—as it thus became—to the Indus valley. About 1593, the Sutlej changed its course once more. Since 1796, there has been little further change.

Hydrological features

The principal rivers of the Indus system, being snow-fed, are all perennial but the flow in them varies enormously during the year. The discharge is a minimum during the winter, floods occur in the rainy season—July to September ; occasionally there are freshets during the winter. Unlike many other rivers of the world, the Indus and its tributaries receive all their waters in the upper hilly part of their catchments. Accordingly, their flow is maximum where they emerge from the foot-hills. There is little surface flow that is added from the relatively large but arid part of the catchment in the plains. On the other hand, because of the long length of the rivers in the plains, there are large losses on account of evaporation, percolation, etc. In the post-monsoon months, however, there is some gain from seepage into the river bed from the wet river margins and from irrigated fields on the banks.

The flow characteristics vary from one river to the other. In the main Indus, the discharges are lowest from mid-December to mid-February. The river then starts rising, slowly at first, but more rapidly after mid-March ; peaks usually occur between mid-July and mid-August. The river then falls rapidly until the beginning of October after which the decline is more gradual.

The Jhelum and the Chenab have a winter minimum from mid-November to mid-January. The Jhelum rises slowly until mid-February, then more rapidly till end of May ; the peak is rather flat and extends to early July. The river then falls steadily till the end of September ; the subsequent decline is slower. The Chenab rises much slower than the Jhelum ; however, from May to end of July, the rate of rise is much higher than in the Jhelum. The post-monsoon fall is fairly sharp and somewhat similar to that on the Indus.

The Ravi behaves like the Chenab ; the overall quantum of supplies is, however, much lower. The Beas and the Sutlej have a winter minimum from mid-November to mid-February. The subsequent rise is relatively slow until April on the Sutlej and end of June on the Beas. The peaks are reached between mid-July and mid-August, the subsequent fall is relatively sharp.

Over the year, the main Indus carries about one-half of the total supply of the Indus system of rivers. The Jhelum and the Chenab each carry about one-fourth as much as the Indus ; and the Ravi, the Beas and the Sutlej, taken together, carry about one-fifth of the total supply of the system. The annual flow of each river at the place when it emerges from the foot-hills* and the seasonal variations are shown in the following table :

Seasonal variations in flow

Name of river	Annual mean flow (million cubic metres)	Percentage of the annual mean flow during			
		April-June	July-September	October-December	January-March
Indus ..	110,396.46	31	54	8	7
Jhelum ..	27,876.65	44	36	8	12
Chenab ..	28,986.78	28	56	7	9
Ravi ..	7,894.26	30	51	8	11
Beas ..	15,665.20	15	67	10	8
Sutlej ..	16,775.33	23	62	9	6
All rivers together	207,594·68	30	54	8	8

Apart from the seasonal variations described above, the annual volume of flow in every river fluctuates from year to year. Also, the seasonal variations, though following the same general pattern, differ considerably in magnitude and time. For example, on the main Indus, the ratio of the actual total flow in any one year to the mean lies between a relatively narrow range, from 1·3 to 0·77 but for the month of May alone, this range is much bigger, from 1·57 to 0·43. Again, in September, the river supply may be unusually low in the early part of the month in any year. Similarly, during May 11-20, the supply in the Beas may be more than 500 cubic metres per second in one year and less than 100 cubic metres per sec in another, or, in the last ten days of September, the supply in the Beas may be as high as 2,000 cubic metres per sec or as low as 300 cubic metres per sec.

Development of irrigation

No other comparable area in the world is as well adapted to irrigation as the flat and arid plains of the Indus basin with six perennial

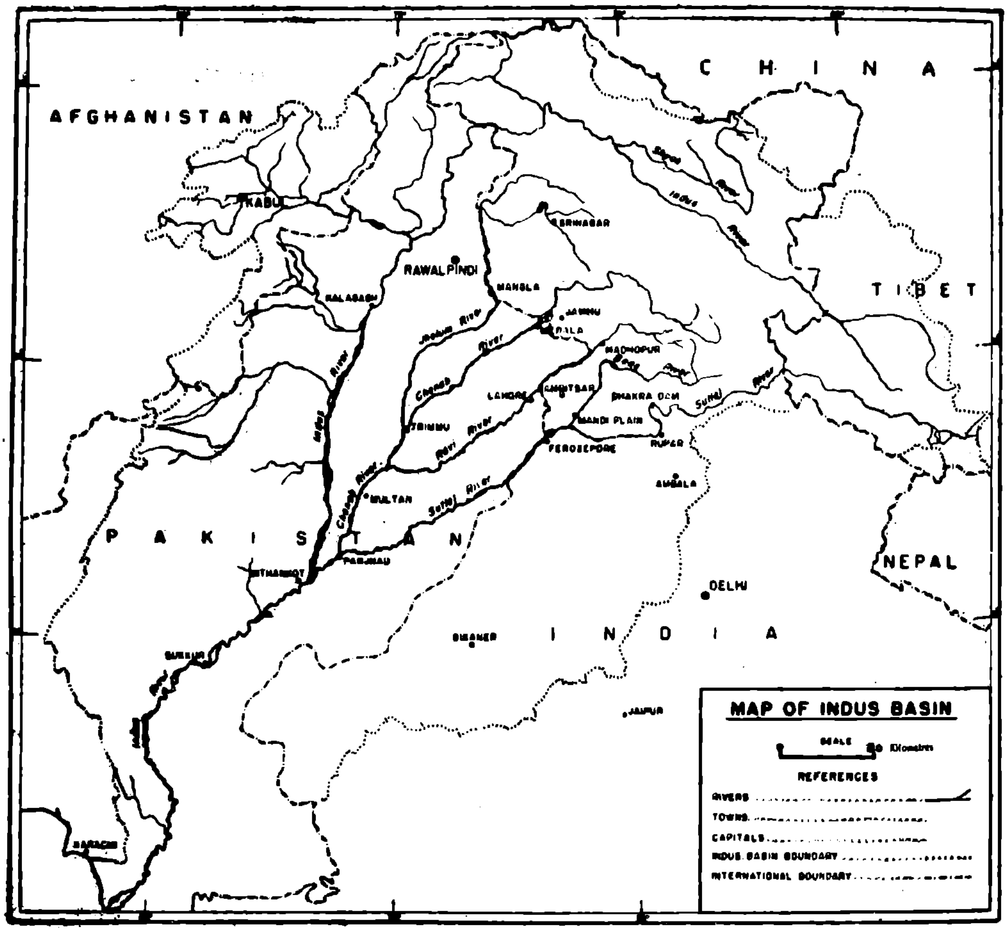
* Kalabagh for the Indus, Mangla for the Jhelum. Merala for the Chenab, Modhopur for the Ravi, Mandi plain for the Beas and Rupar for the Sutlej.

rivers flowing through them. The annual rainfall in these plains decreases rapidly from northeast to southwest, from about 75 cm in the upper part, to 25 cm below in the down. Most of the annual rainfall is confined to a period of less than three months, July to to September. Thus, in large parts of the Indus basin no cultivation is possible without irrigation.

Irrigation has been practised in the Indus basin from prehistoric times but the developments in this field since the middle of the nineteenth century are remarkable not only for the extent of the area developed but also for the impetus they gave to the evolution of modern irrigation engineering. Until about 1850, relatively narrow fringes along the Indus, the lower Chenab, the Panjnad and the Sutlej were enjoying the benefits of irrigation from inundation canals, depending on the annual rise of river levels. Such irrigation was obviously non-perennial, somewhat insecure and confined to the lowlands along the rivers. In the upper mountainous reaches also, there were numerous small irrigation channels, more particularly in the Kashmir valley and on the Beas, called Kuhls.

From the middle of the nineteenth century, for the next hundred years, several large canal systems were constructed, one after another, for the irrigation of the uplands between the rivers. In addition, most of the earlier inundation canals were provided with headworks and secured supplies or were otherwise improved upon and extended. A description of these activities, the problems that had to be faced and the ultimate success of the efforts made is outside the scope of this publication. It would be sufficient to state here that, with the independence of India in 1947, when a new international boundary was simultaneously imposed to cut across the Indus system of rivers and two of the thirty canal systems, as many as 10·5 million hectares were being irrigated, annually, in the Indus basin. This area was larger at that time than the total irrigated area in any other country of the world, except China mainland. The United States of America, the next most irrigated country in the world had, at that time, only 9·3 million irrigated hectares. The pre-1947 canal systems included some of the biggest irrigation achievements in the world, like the Lower Chenab Canal and the Triple Canals Project in the former Punjab and the then largest irrigation work in the world, the Sukkur Barrage Canals in former Sind. These works now lie in West Pakistan. The Upper Bari Doab Canal was split between India and the Pakistan but the Sirhind Canal (now 100 years old) came to lie in India. With the partition of the Indus basin between India and Pakistan, 8·5 out of the 10·5 million hectares of irrigated land came to lie in Pakistan and only 2 million hectares in India.

Surprising as it may seem today, the enormous development described above had been brought about without the construction of a single


AFGHANISTAN
KABUL
RAWALPINDI
KALABAGH
MANGLA
JAMMU
CHINA
TIBET
Indus River
Jhelum River
Chenab River
Ravi River
Sutlej River
LAHORE
AMRITSAR
MADHOPUR
BHAKRA DAM
MANDI PLAIN
FEROZEPORE
RUPAR
AMBALA
MULTAN
PAKISTAN
NEPAL
DELHI
INDIA
MAP OF INDUS BASIN
REFERENCES
RIVERS
TOWNS
CAPITALS
INDUS BASIN BOUNDARY
INTERNATIONAL BOUNDARY

storage reservoir. It depended entirely on river flow and such natural storage as is provided by the snows and glaciers in the Himalaya. Obviously this was possible only by adopting a pattern of development closely following the pattern of available river supplies, which, for 7 to 9 months in the year, were almost fully diverted into the canals. It had, however, become clear that any further development in the Indus basin would be possible only with conservation of flood waters by storage dams.

After Independence, because of the food shortage, the large-scale migration to India from the canal-colonies that came to lie in Pakistan and the urgency of rehabilitation of these refugees, irrigation activity in the Indus basin in India received a new stimulus. Apart from several smaller works, the Bhakra dam and Canal system has been built to bring under irrigation about 1·2 million hectares of land and the Rajasthan canal is now under construction for the development of another 1·2 million hectares in the Rajasthan desert.

Development of power

The rivers of the Indus system, falling from the Himalayan heights to the plains have a large hydro-electric potential. Unfortunately, apart from a small hydro-electric project on a tributary of the Beas, which was developed about 1930, no effort had been made to develop this potential until just before Independence when two relatively small hydro-electric projects were undertaken, one from the Upper Jhelum canal near Rasul (now in Pakistan) and another on the Nangal canal, ex-Sutlej (now in India).

After Independence, the Bhakra multi-purpose project has been completed in India, to furnish inter-alia, a large block of power, and work is in progress for developing another large block of power from the Beas. There is still a large potential remaining to be developed in India in the upper reaches of the Indus, the Jhelum, the Chenab and the Ravi.

Inter-State and international relations

The Indus system of rivers provide an interesting and instructive study of the use of their waters, for irrigation, first between different States in India and, after Independence, between India and Pakistan. The technical, legal and constitutional aspects of the arrangements evolved first between different States in the same country and later between two neighbouring countries are outside the scope of this publication. It may, however, be stated that these arrangements are based on a remarkable spirit of co-operation between the parties concerned and the use of engineering techniques rather than legal attitudes for the settlement of inter-State and international problems relating to the economic use of river waters, for the benefit of the people of the Indus basin as a whole.

CHAPTER XXI

THE GANGA

Introduction :

River valleys, specially of perennial and snowfed rivers, have been the cradles of human civilizations from early days. Besides water which is so essential for human life, they provide facilities for sanitation, irrigation and navigation. With the growth of civilization their uses have increased and diversified. The river Ganga draining vast plains of northern India between the Himalaya on the north and the Vindhya hills on the south has nurtured and given shelter to many races and civilizations. In the course of these developments religious centres like Hardwar, Allahabad, Varanasi and Calcutta (Kalighat), educational centres like Delhi, Roorkee, Varanasi, Allahabad and Calcutta, and imperial cities like Delhi, Agra, Gour, Mursidabad and Calcutta have flourished. The river during its long journey from the Himalaya to the sea with its numerous tributaries and distributaries has attracted from very ancient days, human settlements on its banks with the attendant growth of different civilizations.

Uttar Pradesh

The Ganga emerges from the Himalaya at Hardwar. In the hill areas it is joined by two important tributaries, one passing through Kedarnath and another by Nandadevi. Beyond Hardwar it passes through the sub-montane tracts of the Himalaya where it is joined by numerous hill streams. Then running through the fertile plains of Uttar Pradesh it is joined on the right bank by the river Yamuna at Allahabad. Upto this ancient city, the Ganga receives a number of small local streams on the left bank. The catchment area up to this city is 97,902 km^2 with an average rainfall of 100-200 centimetres in a stretch of 100 km from the foot-hills and 60-100 centimetres in the Doab between the Yamuna and the Ganga. Up to Allahabad there are a number of important trading centres of which Kanpur is wellknown for varied industries.

The Yamuna river is the first principal tributary that meets the Ganga on the right bank at Allahabad. It has a catchment area of 371,871 km^2 with an average rainfall of 40-60 centimetres on the right bank and 60-80 centimetres on the left bank. Two modern cities of Delhi and Agra with their ruins and old traditions are situated on the right bank of the river. The Ganga-Yamuna Doab (land between two rivers) is a fertile plain stretching from the foot-hills of the Himalaya. On the right bank of Yamuna lies the hilly tracts of Central India with the Chambal and the Betwa as the principal streams flowing into the Yamuna.

The Ghaghara river flowing from the Himalaya runs along the left bank of Ganga and joins it at Chapra. The average rainfall on the left bank between the foot-hills and the river is heavy—100-200 centimetres and causes extensive flooding frequently. The Doab between the Ganga and Ghaghara is a fertile plain containing important centres of learning like Roorkee, Lucknow, Allahabad and Varanasi. The rainfall distribution is between 80-100 centimetres.

The three main streams, Yamuna, Ganga and Ghaghara running parallel from northwest to southeast carry the drainage of the vast fertile plains of the Uttar Pradesh between the foot-hills of the Himalaya and the Vindhya. The tract is a part of the Indo-Ganga alluvium. It ranges from north to south for about 160-400 km and has a maximum length of 650 km west to east. The land is thickly populated and is one of the most prosperous part of India.

Irrigation, waterlogging & tubewells

To augment the irrigation supply of this stretch of land and to counteract the menace of water-logging that follows in the wake of double irrigation in tropical countries, batteries of tubewells have been sunk in the Doab between the three principles streams. These batteries are operated by electrically driven pumping sets that derive their power supply from the electric generators situated on the falls of the irrigation canals that obtain their water supply from the three main rivers. These batteries of tubewells have successfully tackled the problem of water-logging and provide at the same time sources of water supply for the irrigation of the fertile fields. As the land is well drained by the Ganga with the help of the tributaries of the Yamuna and the Ghaghara, there is very little natural water-logging excepting on the left bank of the Ghaghara and in the foothills of the Himalaya. The land slopes from the Himalaya and the Vindhya towards the main stream Ganga that flows through well-formed river channels with very few meanders and loops almost all produced by the local terrain. All the three rivers are snow-fed and carry considerable dry season discharges.

The city of Allahabad which is situated at the juncture of the Ganga and the Yamuna, is a very ancient city mentioned in Hindu mythology. The city of Varanasi which is also a very old place of pilgrimage of the Hindus, lies on the Ganga which hugs the ghats (bathing steps) of the ancient city that is mentioned in Hindu mythology also. Between Allahabad and Varanasi the river has maintained its course more or less steady. The main changes have taken place after it is joined by the Ghaghara at Chapra.

Bihar

Between Chapra and Patna, where the river is joined by the Ghaghara on the left bank and the Son on the right bank, the character of the river channel changes considerably. In this reach the river is also joined by the Gandak which is also a mighty stream snow-fed from the Himalaya. Though the two rivers Ghaghara and Gandak join the Ganga within a short distance, their take-off points being quite apart, the debris brought down by them to the Ganga are very different in character and have several effect on the course of the river Ganga beyond Patna. Between Patna and Maniharighat the river is joined by a number of streams that flow from the southern slopes of the Himalaya of which the main one is the Kosi, joining the Ganga on the left bank, a few kilometres upstream of Maniharighat. Between Chapra and Manihari-ghat the Ganga is joined by two mighty streams on the left bank Gandak and Kosi and one mighty stream on the right bank the Son. Volumes of water brought down by these rivers, specially when they are in spate during the rainy season, are heavy and the nature of the detritus brought in by them is considerably different from those brought down by the Ganga itself. This fact together with the nature of the country through which the main stream flows here has introduced the problem of flooding as a great menace to the people of this reach of North Bihar. Beyond Maniharighat the river Ganga enters the famous Ganga delta that lies between its two arms—Bhagirathi-Hooghly on the right and Padma-Meghna on the left.

After the Kosi the only stream that joins Ganga on the left bank is Mahananda which is mainly rain-fed, snow-melt contributing only a small dry weather flow. The river Kosi due to its very nature of fluctuating discharge and siltcharge has been gradually shifting its course from the east to the west, laying vast waste tracts of North Bihar. This has now been successfully stopped by the construction of a controlling barrage at a point few kilometres down-stream of the foothills where the river emerges from the Himalaya. The land between the present course of the Kosi and the Mahanada which is interspersed with numerous old courses of the river Kosi is now being successfully irrigated by the canals taken off from the Kosi barrage. The problem of the Kosi has been successfully solved. A vast tract of fertile land well served by rainfall varying between 200-300 centimetres laid waste periodically by Kosi floods, has thus been rendered safe for cultivation and habitation by this project.

Delta

Beyond the outfall of the Kosi, the river Ganga turns into the plains of Bengal round the outcrops of the Rajmahal hills receiving only a few local drainage channels on the left bank. A few kilometres below Farakka the river starts throwing off distributaries that join into the right hand channel of Bhagirathi (Ganga) which formed once the main arm of the Ganga. Through this channel it used to flow all the low water discharges of the river into the Bay of Bengal, whereas during the flood stages the overflow used to take place through the left arm Padma (Ganga) which after throwing off distributaries like Jalangi, Mathabhanga-Ichamati-Bhairab, Nabaganga and Gorai, is joined by the Brahmaputra, and later on meets the Bay of Bengal as the Meghna. The delta between the two arms Bhagirathi-Hooghly and Padma-Meghna is well known as the delta of the Ganga from very ancient days. The area covers roughly 58,752.80 km^2, i.e. a little over one fourth of Bengal (undivided). On its right arm can be seen the ruins of a number of very ancient localities once prosperous and famous as centres of cultures, art and industries. The cities of Gour, Murshidabad and Berhampore—the centres of acticitie of muslim satraps of Bengal, Katwa and Nabadwip—the cities of ancient Hindu cultural revivals and latest, though not the last, the industrial complex stretching for kilometres on both banks of the river Bhagirathi-Hooghly the metropolitan city of Calcutta. All this array of ancient and modern centres of art, culture and industries indicates that the the right arm of the delta was the main channel of the river Ganga before the left arm Padma-Meghna started drawing more and more discharges towards the end of the 18th century. As the left arm improved, the right deteriorated rapidly. Towards the end of the 19th century and in early twenties, when Calcutta had developed into a centre of trade and commerce for the whole of eastern and northeastern India with the hinterland of Nepal, Bhutan, Sikkim and Tibet, the river Hooghly showed signs of deterioration that appeared to be fatal for the development of the city and the port of Calcutta. Extensive dredging of the river channel was resorted to by the Port Commissioners of Calcutta that appeared to be successful in the early days, but with the rapid deterioration of the navigability of the river channel, it was quite apparent that other methods besides dredging had to be resorted to if the port and city of Calcutta was to be kept functioning satisfactorily. A number of experts were consulted and Commissions were constituted to study the problem and suggest remedial measures. The main factors that were considered to be responsible for the rapid deterioration of the navigability of the river are :—

(1) The duration and intensity of upland supply from the main stream Ganga into the Bhagirathi channel was limited to the months of mid-June to mid-November and the volume of supply diminished from about less than 2,830 cu m per sec to nil.

(2) As against this, the arm Bhagirathi-Hooghly receives a strong tidal inflow from the Bay of Bengal throughout the year.

To counteract the effect of these two unequal flows and thereby to prevent a rapid deterioration of the navigability of the river channel from the Calcutta port to the sea, a proposal has been made to introduce from the main river channel Ganga regulated discharges into the Bhagirathi channel with the help of a barrage at Farakka across the river Ganga, and to lead the discharge into the Bhagirathi with the help of a canal that will meet Bhagirathi some distance downstream of its offtake point from the Ganga. A detailed plan has been drawn up and the project has been undertaken to implement the schemes. It is expected that with the scheme in full operation, the fate of the international port of Calcutta and its extensive industrial complex will be assured for the future. The port deals not only with almost half the import and export trade of India but it is also the only trade route between the outside world and the hinterland of eastern and northeastern India, Tibet, Nepal, Bhutan and Sikkim. As such the importance of keeping the river Hooghly navigable upto the sea cannot be over emphasized.

Concluding remarks :

The Indo-Ganga plains have been the homes of numerous races and civilizations from very early days. The ruins of Mahenjodaro, Harappa and Taxila bear evidence to those glorious days. Of the various streams that flow through this sub-continent, the river Ganga with its numerous tributaries and the extensive delta have given shelter to many races that have come into India from the outside world. The fertile nature of the plains, plentiful rainfall and sunshine, have contributed largely to the prosperity of the land and welded the races into one Indian nation. The nature has been kind and bountiful, and the river Ganga running through the different states like a band of unity will continue the glory of the past to the prosperity of the future.

CHAPTER XXII

SOURCE RIVERS OF THE GANGA

The five source rivers of the Ganga, namely, Bhagirathi, Mandakini, Alaknanda, Dhauli Ganga and Pindar are found in Uttarakhand division of Uttar Pradesh. They join at Devaprayag to form the Ganga. Five zones of occupance may be recognised, according to altitude, in this region.

The highest zone is approximately above 4,000 metres. Some Himalayan giant peaks, such as Kamet and Nanda Devi are situated here. Shivling and Nilkantha are examples of awe-inspiring horned peaks surpassing Matterhorn in grandeur. The peaks are generally surrounded by steep rock cliffs flanking glaciers between them. They resulted from truncation by Pleistocene giant glaciers. Frost action is supreme all over the region. The present glaciers ride over the ground moraines of the past giants. Today they are shrinking and decaying. This zone is not inhabited by men. Occasionally shepherds visit some places with flocks of sheep. There are a few difficult routes.

Between 4,000 and 3,000 metres the valleys and amphitheatres are chocked by Pleistocene glacial till which is being slowly removed by rivers. Alpine meadows provide pastures for semi-nomadic tribes. Barley, 'Phabar' and wheat are cultivated. Holy shrines situated in this zone attract thousands of pilgrims, who are a source of income to the people.

Between 3,000 and 2,000 metres occur tremendous gorges. Truncated spurs rise steeply to dizzy heights. Over them descend waterfalls from hanging valleys. The present rivers are digging a V in the past U-form. Habitations and communication lines are along valley bottoms. Potatoes, paddy, wheat, 'Madua' and 'Chua' are cultivated. There are dense temperate forests of oak and pine. The topography is extremely rugged.

Between 2,000 and 1,000 metres river terraces are very well developed. The valleys are open. Terraces provide land for intensive cultivation of paddy, wheat, 'Madua' maize and potatoes. This zone has an optimum density of population.

Below 1,000 metres the valleys again form deep gorges among tropical rain forests. Habitations are scattered and few. The climate is moist, warm and unhealthy. Wild animals inhabit the jungles.

Source rivers

Below Devaprayag where the Bhagirathi and the Alaknanda meet and the river acquires name Ganga, which emerges from the mountains at Rishikesh, flows through the Dun and cuts across the Siwalik range at Hardwar.

Alaknanda is the main tributary of Bhagirathi. Another source river of the Ganga is Mandakini which rises near Kedarnath temples and joins Alaknanda at Rudraprayag. The fourth source river, Pindar Ganga rises from Pindari Glacier and joins the Alaknanda at Karna Prayag. The fifth source river may be taken as Dhauli Ganga, which joins Alaknanda at Vishnuprayag below Joshimath. There are numerous other source rivers, all rising in the snowy ranges of Uttarakhand, such as, Jadh Ganga or Jahnavi rising in Nilang tract, and the Saraswati which rises near Mana pass and joins Alaknanda at Keshavprayag below Mana village. Two other tributaries of Alaknanda are the Bhyundar Ganga or the valley of flowers and Birehiganga.

Morpho-ecology of the upper Bhagirathi valley

River Bhagirathi is considered to be the main source of the river Ganga. Between Tehri and Bhatwari the river generally flows in a comparatively broad open form except above Dharasu, where it cuts a deep gorge through quartzites.

Near Tehri it forms extensive river terraces, which are well cultivated and fairly well populated. The location of Tehri, the capital of the past mountain kingdom is based upon the occurence of these terraces. Four sets of terrace levels are clearly visible. But sometimes there are more.

A feature of the valley is the meandering course of the river which are clearly incised. A beautiful incised meander, complete with a meander core occurs at Kalidewal. Even in the core there are three terrace levels. These clearly indicate the intermittent rise in the Himalaya. The terraces are widely developed up the river. There are large expanses of terraces at Dharasu and Uttarkashi, and are responsible for the location of these localities. Uttarkashi is situated on a wide terrace.

The higher slopes forming the interfluve between Bhagirathi and Yamuna are usually forested above 2,000 metres. Among these forest and above them live nomadic Gujars with herds of buffaloes. In winter they migrate to the forests around Rishikesh and come down with their herds in September and October.

Paddy grows extensively as a summer crop on the terraced fields. Other crops are maize and oil seeds. Late winter and early summer crops are wheat and barley. Millets are grown in summer.

The last expanse of natural terraces occurs near Bhatwari, where gorge scenery is also evident at places.

But a few kilometres beyond Bhatwari, a deep gorge is fouud through which the river rushes down, very often in rapids. On both sides rise stupendous truncated spurs. The rocks are usually gneisses. Waterfalls cascade down into the gorge from hanging valleys, which alternate with truncated spurs. Gangnani is situated inside this gorge. The various features of the glaciated valley mentioned prove the extension of glaciers below Gangnani, that is, about 3,500 metres. The features are now being obliterated by active normal erosion.

Beyond Suki the scene suddenly changes. There is a broad flat basin below Jhala about three kilometres broad. It is filled with sand and gravel over which the river flows in a braided course. This is definitely a rock basin excavated by the past glacier. There is a neck with a bridge near Harshil, followed by another flat basin at Dharali. The length of the two basins is about 15 km.

The open aspect of this part of the valley has lead to the development of agriculture. Apples were introduced at Harshil by a British ex-soldier settler and now there are many flourishing apple gardens. Large apricot trees grow wild. There are wild walnuts also. The altitude is about 3,000 metres. Horticulture could be developed here much more. Cabbages and beans are also grown. Curiously they supply "Phalahar" for the Gods, and perhaps this is the incentive. Otherwise the dwellers of Garhwal hills do not bother much about growing fruits and vegetables. Harshil and its neighbouring settlement Bagori is also serving as a staging ground for the semi-nomadic "Jadhs" of the Jadh Ganga valley. Their main wealth consists of flocks of sheep with some mountain goats.

There is a sudden change of scenery at Jangla beyond which the Bhagirathi cuts an awe-inspiring gorge through tourmaline granites constituting the central axis of the Himalaya. Here the blue waters of Jadh Ganga meet the Bhagirathi, amidst the most spectacular granite scenery. Both the rivers are in all probability antecedent to the rise of the Himalaya.

Bhagirathi flows towards the northwest from Gaumukh. It then suddenly turns at right angles towards the south and cuts across the Himalayan axis in the granite gorge. It again turns at right angles and flows towards the southeast just opposite in direction to its upper course.

Beyond Gangotri the valley opens out again. The interfluve consists of serrated, razor-sharp ridges and pinnacles covered by eternal snow. The valley is broad and choked with glacial till. It is a fantastic landscape of boulders. The clay has been mainly washed away. Patterns of long wall like features of boulders indicate skeletal, lateral and medial moraines of the past. There is a huge platform of boulders near Chirbas which is a portion of an old terminal moraine. The enclosing rock walls of the valley are often polished and striated.

A peculiar feature is the clusters of gigantic boulder clay pillars topped by big boulders, clinging to the side walls. They are the fast disappearing remnants of the old moraines, a clear sign of the recent shrinkage of the past giant glacier. The end of the Bhagirathi valley is blocked by two kilometres wide front of the 30 km long Gangotri glacier. Over it rise the glistening snowy pyramids of Bhagirath Parvat and Shivling. The later is a perfect example of a horned peaks.

Geomorphology and occupance in Alaknanda valley

River Alaknanda, a major tributary of the Ganga, rises from the twin glaciers Bhagirath Kharak and Satopanth, which take their rise from the eastern slopes of the Chaukhamba massif and its satellite peaks, forming the snowparting between the Gangotri group of glaciers to the west and the Bhagirath group to the east. The young river skirting the Nilkantha and Narayan Parvat from the north and east flows past the holy shrine of Badrinath, and collecting the waters of Khira Ganga, Bhyundar Ganga (Valley of Flowers), Dhauli Ganga, Mandakini, Pindar Ganga and joins the Bhagirathi at Devaprayag to form the Ganga, which emerges out of the ranges of the Himalaya at Rishikesh.

This portion of the river from Rishikesh to Devaprayag passes all along through dense tropical forests covering steep slopes on both sides of the valley. Foaming over boulders, the river meanders through interlocking spurs in a gorge cut deep in the towering ranges.

This condition continues above Devaprayag in the Alaknanda valley upto a few kilometres below Kirtinagar. Further up the valley broadens out. Large terraces are developed on both sides of the river which are covered by cultivated fields and dotted by farm houses and dwellings concentrated into villages here and there. This is in marked contrast to the patchy habitations in forest clearings in the gorge below Kirtinagar around Vyasi.

The terraces spread from here to Pipalkothi, 16 km beyond Chamoli, the district headquarters. The terraces occur very often at three or more levels. At places there are paired terraces at the same level on both sides of the river. They are a clear proof of the intermittent rise of the Himalaya in recent past.

Higher up, now and then, are seen levelled spur tops, which are actually very old terrace remnants. It seems very probable that the levelled surfaces were formed at a lower level and were raised later on. At places there are cultivated alluvial cones. Schist and slate slabs are used for making house top.

The terraces open out into a big intermontane plain at Srinagar. Alaknanda is incised in the plain some 30 metres. Srinagar has grown into a big route centre where buses and trucks have to stop at night due to the prevailing gate system and one way passage. About 13 kilometres above Srinagar are well marked incised meanders with flat terraces in the cores.

In this sector of the river boulders are often seen flanking the roads. They are mostly water rounded boulders, which formed the bed of the river in the past. At a few places the boulders are sharp and angular. They are found when the road cuts through screes and talus cones made up of frost shattered rocks, which roll down from above. Conglomerate boulder beds formed in Miocene and Pliocene should not also be ruled out.

Beyond Rudraprayag quartzites form stable and hard rocky walls of the gorge. Terrace development is very common. Three terrace levels are seen very often. They are sliced at times by deep gorges cut by tributaries through them.

Another very large terrace is found at Ganchar which is so big that an air-strip has been constructed on it. There are a number of villages situated on this flat piece of land.

Seven kilometres further up from Chamoli a road leads up the Birehiganga to Gohna Tal, formed by the blocking of the river valley by a big landslide in 1890. It is now a lovely tourist spot.

Below Joshimath the Dhauli Ganga joins Alaknanda at Vishnuprayag. Glacial topography is discernible clearly from this point onwards. The river is now busy in cutting a V inside the glacial U-form. The shoulders of U can be easily seen. At places, however, two or even three shoulders are noted. This proves the phenomena of multiple glaciation.

At Govind Ghat Bhyundarganga meets Alaknanda from the north. Its glaciated scenery is no less enchanting than the yellow-stone or Yosmite National Parks. Bhyundar itself is a hanging valley and the waterfall has broken down into a number of steps. Other obsequent hanging valleys discharge into Bhyundar itself in silvery cascades. Upper Bhyundar drains the eastern slope of Nar Parvat and the western slopes of Gauri and Hathi Parvats. A beautiful tarn named Lokpal lies at a height of 4,800 metres between two spurs culminating in Sapt Shring and Bandarpata peaks both above 5,000 metres high.

From Govind Ghat to Pandukeshwar and Vinayak Chatti the valley bottom is somewhat broad and strips of arable land are available, which give good crops of potatoes. But the enclosing rock walls of quartzite are steep and look formidable. Rock debris shed from these form large talus cones. Detrital fans are formed where steeply descending mountain streams debouch into the main valley.

While chirpine '*Pinus longifolia*' is very common from Rudraprayag to Joshimath along the road level, higher up grow dark green deodars. There are oaks '*Quercus incana*' here and there. But beyond Pandukeshwar the pines disappear. There are more deodars and also various kinds of oaks. The Indian oak is very common. There are a good number of horse-chestnuts or "Pangar". Rhododendrons are also seen.

Just before Hanuman Chatti Khira Ganga joins the Alaknanda. From this point the source of Alaknanda in the snouts of the Satopanth and Bhagirath Kharak glaciers is hardly 20 km. Khira Ganga rises from the snout of Panpatia glacier hardly 10 km away. The valleys above this junction of the rivers are choked with immense quantities of glacial debris resulting from Pleistocene glaciation and also present glacial and frost erosion. It is a well known fact in the high Himalaya that glacial eroded material is much more than the amount of the transport agents can move down. The triangular level area is a common geomorphological feature at river junction in such places.

Above Hamuman Chatti large amounts of glacial debris of the past are found clinging to the sides of the gorge at many places, and they increase as one goes up. Just near Hanuman Chatti there is a large deposit of glacial till which has made road making rather hazardous as the unstable boulder beds slide down very easily.

Two kilometres from Badrinath, the valley opens out into a circular undulating plain made up of glacial till. Just below this point occurs a very important evidence of double glaciation. On the opposite side of the gorge is seen a bed made of outwash material wedged in between two beds of boulder clay.

The bowl of Badrinath surrounded by steep rocky cliffs and filled up with boulder clay is an ancient gigantic amphitheatre or cirque. The glacial ice must have filled the bowl up to some 400 metres depth up to the tops of the present cliffs. Later on this bowl must have been covered by forests of birch (*Bhurja Patra*), juniper and rhododendron. The occurence of a hot spring called Tapta Kund decided the site of the temple of Badrinath. The rolling landscape and the forests were ideal for the congregation of pilgrims. The forests have disappeared here for supply of fuel. They should be replanted.

The settlement of Badrinath has grown up on the western bank between the river bank and the rock cliffs surrounding Narayan Parvat (6,500 metres), spreading down up to the junction with Rishi Ganga which descends from the dazzling silvery and near perfect horned peak Nilakantha (7,200 metres) often called the Queen of Garhwal. The settlement is now and then damaged by avalanches falling down the cliffs of Narayan Parvat.

On the eastern side of Badrinath rise rock cliffs facing the western slopes of Nar Parvat (6,500 metres). From it descends the hanging glacier—Kuber, which is cut by many transverse crevasses with longitudinal crevasses along its flanks. To its south is an ice fall broken into blocks of blue ice and discharging waterfalls dropping over the cliffs.

Wheat, barley and a kind of similar crop called "Phabar" are cultivated in patches here and there. Cultivation increases further towards Mana, the last village situated in another bowl. It is a large village on a stabilized talus slope above the river north and east of it and is inhabited by semi-nomadic Marchyas. The houses are strong and well built and made up of stone and straw. Some timber is also used. The Marchyas menfolk are essentially shepherds and tend flocks of sheep, goats and black coloured cattle. There are a few yaks and some cross-breeds. During summers the Marchya menfolk go over to the high alps near the snow line with their flocks to feed on nutritious grass. As winter comes they move down to Joshimath and Chamoli. The sheep and goats are used for transporting wool and grain in small woollen bags.

The Marchyas have, however, cultivated the glacial terraces all round the Mana bowl and the ripe, golden grain spreads all around the place. Potato is a very important crop. The women mainly are engaged in cultivation. In October they are seen with their children in the fields, harvesting the crop.

The Saraswati valley is a broad glaciated valley, choked with boulder beds and moraines. Numerous glaciers, some of them conspicuously hanging, join it from the east. They come down from the slopes of giant peaks like Kamet. From the west another large system of glaciers form the river Arwa, which joins the Saraswati at the triangular land of Ghastoli at 4,500 metres. The Saraswati drops as a hanging valley into the Alaknanda beyond Mana.

Higher up the Alaknanda takes a turn at right angles towards the east. Here it acquires a true U-shape. The river bed is filled up with deep beds of moraines, through which it cuts a gorge, leaving glacial terraces on both sides, but hugs the southern edge, due to much eroded debris being dropped from the quartzite cliffs to the north, parallel to the river. The northern flank of Narayan Parvat rises south of the river from which descend a number of corrie glaciers. On the north stands the Bangneu and Pawegarh peaks. The 150 metres cascade of swaying Vasudhara falls drop as a hanging valley between them. The tremendous amount of rock shattering by frost action is seen in the huge talus cones accumulated below the cliffs and the jagged peaks above, stabbing into the sky in gigantic rock spires.

Across the valley near Vasudhara one again sees a 200 metres high moraine ridge blocking the valley through which the young Alaknanda cuts a gorge hardly 2 km from the snouts of Satopanth and Bhagirath Kharak glaciers. This is a 100 years old terminal moraine now grassed. Beyond this morainic ridge about 100 metres below spreads the outwash plain below the snouts. This proves that the glacier has retreated 2 km and it has also dug slightly deeper in this period.

Beyond the large U-section here one sees the two glaciers coming from two sides of Balakun peak (7,100 m.) which dominates the middle of the scene. Lateral moraines about 100 or more metres high flank both the glaciers. They form regular conical shaped ridges. The glacial surface is covered completely by moraines, which are oxidised into a brownish colour. The double snout consists of a grey wall about a kilometre long and 20 metres high.

Aspect is a very important factor in micro-climates in the glaciated areas. The duration of sunny hours at a spot depends upon the direction of the slope. The southern faces of ridges and cliffs get more sun. The northern slopes of Nilkantha and Balakun are cold and shady. Places where the high peaks cast their shadows are also cold. The sunny spots also support some vegetation, such as, junipers and small bushes. Sweet, nutritious grasses and a variety of alpine vegetation including low bushes are also found in these places. "Guggul", which is burnt for producing scented smoke covers the upper sunny slopes, growing upto 5,500 metres. "Guggul" is found extensively on the slopes of Narayan and Nilkantha above the cliffs.

A series of talus cones lie at the bottom edge of the cliffs. They are results of tremendous frost shattering in the high peaks and arete slopes. They provide material for the formation of lateral and other moraines. Here sometimes the movement of the glacier is too slow to shape them into lateral moraines, and they often obliterate themselves. Erosion being very intense on the sunny slopes, there is a very well marked contrast between the northern and southern flanks of Bhagirath Kharak glacier.

In October the snow over the glaciers is minimum. The moraines covering the glaciers is subsiding all the time at various places producing a continuous rubbling noise. It is quite probable that for about a kilometre both the glaciers are in their last stages of disintegration.

For about five kilometres there runs a high glacial terrace parallel to Bhagirathi along its northern bank. It is sliced here and there by streams descending from above which disappear into the glacier.

Below the terrace appear multiple lateral moraine walls. Parallel depressions are seen running between the outer moraines and the rock cliffs. Here one often finds little streams running in braided courses or forming small lakes here and there. Furrows between two lateral moraines are often at a higher level. The outer depressions are even lower than the glacier. It is so because the glacier is riding at a higher level over the ground moraines deposited by the past giant glacier. This view is supported by Gansser and Heim who visited this area in 1935.

The upper Bhagirath Kharak extends to the northwest and smaller tributaries fan out towards the snowy Ganga-Alaknanda watershed. The glacial surface is marked by moraines and circular depressions, now and then filled by water, often frozen. At places there are glacial tables, often of gigantic dimensions. They are huge pieces of rock supported by transparent glassy ice pedestals. A cirque at the bottom of two peaks in the watershed is the starting point of the glacier.

To the southwest rise the vast snow slopes fllanking Chaukhamba (7,138 metres). The four peaks of Chaukhamba dominate the watershed.

The higher reaches of Narayan, Nilkantha, Balakun and Chaukhamba abound in sharply cut up aretes, ice steps, ice falls, yawning crevasses, gigantic walls of solid blue-green ice, overhangs and cornices. Prohibitive solid ice walls guard the spire of Nilakantha made up of white granite with tourmaline and mica. Avalanches thunder down the cliffs below it. Balakun rises like a tower of ice. It has been nicknamed avalanche peak very aptly. The higher slopes of Chaukhamba are also very unstable. They crack and thunder down as big avalanches at slight notice, perhaps a chill night, a bright sun or a fresh snow fall may press the trigger.

Mandakini valley

The Mandakini rises from the Chorabari glacier descending from the slopes of Kedarnath peak (6,940 metres) while the Alaknanda is a much bigger river collecting its water from a large number of glaciers. The two rivers rise at a height of approximately, 4,000 metres and flowing down less than 100 km, join in a deep gorge at Rudraprayag at a height of 1,000 metres.

An interesting point to note about the Mandakini is the break in its thalweg at Sonprayag where it first meets its major tributary Basuki Ganga. The waterfall is about 100 metres high. Possibly, it is a rock step in the longitudinal profile of previously glaciated valley, occurring, as it should, at the junction of a tributary.

Morphology of Kedar-Badri region.

Kedarnath temple stands on a platform of loose and unconsolidated glacial till material. The platform is roughly 5 km long and 2 to 3 km broad. The Mandakini cuts a deep gorge into it being 200 metres deep on the average. The steep lower face of the deposit is seen from Rambara 5 km below Kedarnath. The patch zigzags over its face, climbs up to the top of the platform and then follows the river. The flanks of the Mandakini gorge reveal the nature of the loose material. Waterfalls and melting water from snow disappear into the ground above the valley and pour out through holes in the flanks of the valley. Some of these openings are dry and pour out water when there is large supply.

Dhauli Ganga valley

This valley is much similar to the Mandakini valley as it has also a large portion of its upper reaches cradled between the snowy 'Himal' portion of Kamet group of peaks in the west and Nanda Devi 'Himal' in the east. Though the Dhauli Ganga rises near the Niti pass on the Indo-China border it receives much more water from East Kamet and Raikana glaciers, via the Raikana Nullah. After a flow of about 100 km, at first in a southerly and then in a western direction, through narrow gorges it joins the Alaknanda near Vishnuprayag below Joshimath.

The Dhauli Ganga lies wholly north of the Great Himalayan Range which in this region contains the Kedarnath-Chaukhamba group of peaks and Trisul-Nanda Devi massif. This forms a mighty barrier against the spread of the monsoon. Naturally, the strength of the monsoon is very much weakened in the Dhauli Ganga valley in comparison with the southern side of the Great Himalayan Range. It becomes feebler and feebler as it approaches the Kamet glacier in the Zaskar mountain. Though precipitation varies within the valley itself, yet the average annual is only 50 centimetres.

The Dhauli Ganga valley may be divided into three distinct geographical units based on physiography and climate. The lower valley stretches from the confluence of the Dhauli-Alaknanda (Vishnuprayag) to the confluence of Dhauli-Rishi Ganga (Reni). The altitude of the valley bottom is 2,000 metres on the average. The length of the stretch is about 20 km. The gradient of the river is gentle and the valley is also wide.

Below Suraithota village the Dhauli is joined by Rishi Ganga or Reni, which pours out from inside the Nanda Devi Sanctuary through a tremendous gorge, which does not allow him to enter the sacred Sanctuary.

The sanctuary itself is a huge amphitheatre perhaps the biggest and the most majestic in the world. It is surrounded by an array of gigantic pyramids of snow, which influde Nanda Devi, Dunagiri, Nanda-ghunti, Trisul and many other giant peaks. It is surrounded by impenetrable rock and snow ramparts which did not allow man to enter the sanctuary for a long time. It was ultimately pierced by man from a high above Latakharak.

From Reni to Malari, a distance of about 40 km is the middle stretch of the valley. The altitude of the valley bottom is about 2,500 metres. Occasionally, the river has widened out to give rise to a broad plain in which the stream is braided. A lake, about a kilometre in length, has been formed at the confluence of the Dhauli and the Dunagiri Nullahs. is believed by local people to have originated from a depression caused by a recent earthquake.

The upper valley starts from Malari onwards. The height of this valley bottom is 3,000 metres and above. Unlike the first to stretches, the river here takes a meandering course and passes alternately through wide and narrow valley profiles. The valley from Malari onwards is wide and is particularly so near Reolcho, where the stream is braided.

The gorge between the second and third sections is deep and runs for several kilometres. The valley is typically U-shaped with snow-clad peaks and corrie glaciers on the heights by its side. There are several hanging valleys on both sides. In winter the seasonal glaciers come down to the valley bottom and avalanches are also frequent. Rainfall is very scanty. Almost barren topography is visible in consequence of low temperature and low rainfall and enormously heaped up boulders from the typical scene of this area.

Just south of the Tibetan border lies the northernmost pair of glaciers of the area, Raikana and Purbi-Kamet. In front of their snouts lies the scared place called "Vasudhara *Tal*". The Rainka river that originates here is an important tributary to the Dhauli Ganga, the sacred river of the Hindus. The nearest village is the Niti village (3,500 metres) only about 16 km from the present snout. According to the local villagers the journey to the sacred place was difficult even about five decades ago because of the presence of the glacier. But no such glacier has to be crossed today to reach the sacred place. Also it is stated that the snouts of the two glaciers were united even 20 years ago. But at present the snouts are separated by at least 1,000 metres. Heaps of fresh moraines on the outer shore of the terminal lake of the Purbi-Kamet glacier also indicate recent recession of the glacier. Niti, the last village in this valley, is at a height of nearly 4,000 metres. The village site is above the river bed and well protected from avalanches by ranges and spurs on all sides.

Pindar Ganga.

This is the easternmost tributary of the Alaknanda which joins at Karnaprayag. The river rises from the snout of Pindari glacier which lies in the shadow of Nanda Devi, the towering snow spire (7,817 metres) of Garhwal Himalaya and on the eastern edge of the stupendous outer face of the rock and ice wall of the sanctuary surrounding it. The glacier though small in size is fed by tremendous slopes and flanks of peak which stand to its right as well as left. These include Nanda Khat (6,811 metres) and Nanda Kot (6,861 metres) to its seat.

Pindari glacier can be easily reached from Almora. It was a favourite place for British tourists, for whose convenience a series of staging Dak Bungalows had been erected roughly 15 to 10 kilometres apart. Coming to greater details of Pindari glacier, Coggin Brown and Cotter who visited the glacier in 1906 said that the glacier was fed by two ice flows, the larger originating from the neves on the slopes of Nanda Kot and the other descending in a cascade from between 6,322 metres peak locally called Bankhatia, or Chhanguch and an unnamed peak (6,591 metres). The snout of the glacier is at present 8 km away from the last Dak Bungalow at Phurkia (3,202 m) situated below a steep cliff rising above the Pindar gorge, hidden amidst large boulders which must have resulted from rock bursts higher up due to frost action.

A study of the valley forms below Phurkia shows that the Pindari glacier and its tributary glacier Kafni, which joined it at Dwali (Dak Bungalow below Phurkia at 2,563 metres) proceeded further down upto about 4 km above Khati, the last potato growing village on the route.

Hanging valleys represented by waterfalls cascading over precipitious cliffs enclosing the Pindar river appear above Khati and continue beyond Phurkia. Some such cliffs are formed by truncated spurs. The cliffs facing Dwali Dak Bungalow rises more than 1,000 metres above it. Sprays of water descend over it into the valley below.

The ground moraine of the glacier which has now retreated seems to have been completely eroded upto very near Phurkia. Its remnants appear as small platforms standing above the valley which gradually opens out above Phurkia. Huge talus slopes produced by materials tumbling down after rock bursts, frost erosion and avalanches are common features here. They rest upon the edges of the old ground moraine platforms. At Phurkia, it seems, that the flat ground moraine, which is being gradually eaten away by the enlarging gorge of Pindar river, has been removed very recently right upto the bungalow. Further up, the V-shaped gorge out by Pindar into the thick mantle of the ground moraine of the past glacier becomes narrower and narrower, leaving broad belts of flat land between its edge and the towering ramparts of rocks. They are covered by lush green grass during summer. They are the Bugiyals visited by shepherds of Garhwal and Kumaon. The nutritive value of the grass is well known in the region. On the right side of Pindar are the Bugiyals of Rata, Chhier and Martoli, where a few temporary huts of stone, built by shepherds can be seen. Further up, the morain platform broadens out and is strewn by boulders. Such platforms of past moraine are also noticed at Kedarnath. A similar platform was noticed by Fritz Muller at Thyang-boche.

Waterfalls cascading over the cliff thunder down during the day but become silent as night advances, as they freeze. Talus cones and fans by streams lie in a line at the base of the cliff wall.

Coming nearer to the glacier one is confronted by a large old lateral moraine lying to the left (west) of the glacier and the Pindar river. It is a gigantic wall of loose morainic material over-grown by grass and moulded by erosion to its present knife edge form. It is locally called Chhuri Dhar.

The erosion is more pronounced inwards where it presents a nearly vertical face of loose material descending into the valley. It is about 2 km long and 200 metres high. Its large size proves that it was formed in the Pleistocene period, when the present glacier was very large. A similar gigantic moraine is seen alongside the Hispar glacier in the Karakoram range and also along the famous Khumbu glacier at the base of Mt. Everest.

The main glacier from Traill's Pass to the snout is only 2 km long and this descends from 6,000 metres to 4,500 metres, i.e., the slope on the average is 1 : 4. The glacier has three falls, the top-most being just below Traill's Pass, the middle being below Chhanguch between two rock exposure, near a nunatak-like rock on the right. The last drop is steepest just above the snout. It is more or less an ice-fall. Inspite of such a steep fall, crevasses and pinncles are not quite so prominent in the Pindari glacier as in other Garhwal glaciers. This is, in all probability due to the very slow movement of ice.

Tail Chhanguch and Shel Chhauguch tributary glaciers have shrunk very considerably than as shown in the topographical sheet based on surveys in 1936-38.

Coming further down from its glaciated gorge between Phurkia and Khati, the Pindar river flows nearly eastwards upto Gwaldam situated across a massive limestone ridge just south of the river. It is joined by snow-fed streams descending from snowy ramparts to the north, on which stands the silvery pyramid of Trisul, a conspicuous landmark in the ranges visible even from Naini Tal. On these slopes are a number of beautiful

Bugiyals including Baidini Bugiyal, through which a difficult route ascends to the mysterious Rupkund tarn, where skeletons, skulls and many other remains of groups of people have been found, who perished here by being buried in avalanches.

In its last stages the Pindar runs in a V-shaped valley to the north-west where river terraces are well developed. This part of the valley has many good villages and cultivated fields. Forests are being developed. *Pinus longifolia* has been planted and timber is being extracted.

The combined waters of Alaknanda, Dhauli Ganga, Pindar and Mandakini finally join the Bhagirathi at Devaprayag to form the sacred Ganga, which emerges from its mountain fastness at Rishikesh and flows down to Hardwar and to the northern plains of India, till it empties its waters in the Bay of Bengal near Sagar Island, where the legendary Bhagirath brought the Ganga from Gaumukh to pour upon the ashes of the thousand sons of King Sagar who were burnt by the wrath of Kapil Muni, to send them back to 'Swarga'.

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CHAPTER XXIII

MIDDLE GANGA

The Ganga having its catchment area in the snowy Himalaya flows with an average gradient of 9·5 cm per km from west to east. It has been thwarted by the plateau offshoots towards the south. At places the projected spurs and outlines are visible in the districts of Mirzapur, Monghyr, Bhagalpur and Santhal Parganas.

The right bank of the Ganga is generally steep and 8 to 15 metres high during dry months. The left bank is generally flat and low but at places where it is formed of hard gravel exposures, rises even 10 to 12 metres high from the river bed during dry months.

The Ganga enters the middle Ganga Plain heavily loaded with detritus brought down from its vast catchment area and supplemented by the tributaries of the upper Ganga plain. Most of the notable tributaries of the Ganga in this section belong to the Ghaghara system, the Gandak system, the Kosi system and the Son system.

The Ghaghara system consists of four main rivers i.e. the Ghaghara and its three main left hand tributaries—the Kuwana, the Rapti and the little Gandak. As the area to the south of the Ghaghara slopes towards southeast it does not receive any large tributary from its right. Most of the rivers of this system have been shifting channels and are notorious for dangerous floods. The Gandak, formed by the confluence of seven streams and having a maximum flood discharge (15,730 cubic metre per sec) has a higher gradient than that of the Ganga or the Ghaghara. The plain formed by this system appears like a cone which Geddes calls the Gandak Cone. Kosi system, like the Gandak forms another cone known as the Kosi Cone. The main river of this system is the Kosi with its various distributaries. Despite a flood discharge of about 5,660 cubic metre per sec, the Kosi has no permanent deep channel. The flood of the Kosi is often very disastrous, and the affected area becomes barren, being overlain with unproductive sands. The Son is the lonely river of its system without any significant tributary. During the rains it flows with a considerable amount of water, but in the dry months the bed presents a wide stretch of drifting sand with narrow and lean stream of water.

Some major and minor changes in the course of the Ganga are observed through out its course which is evident from the existence of the old high

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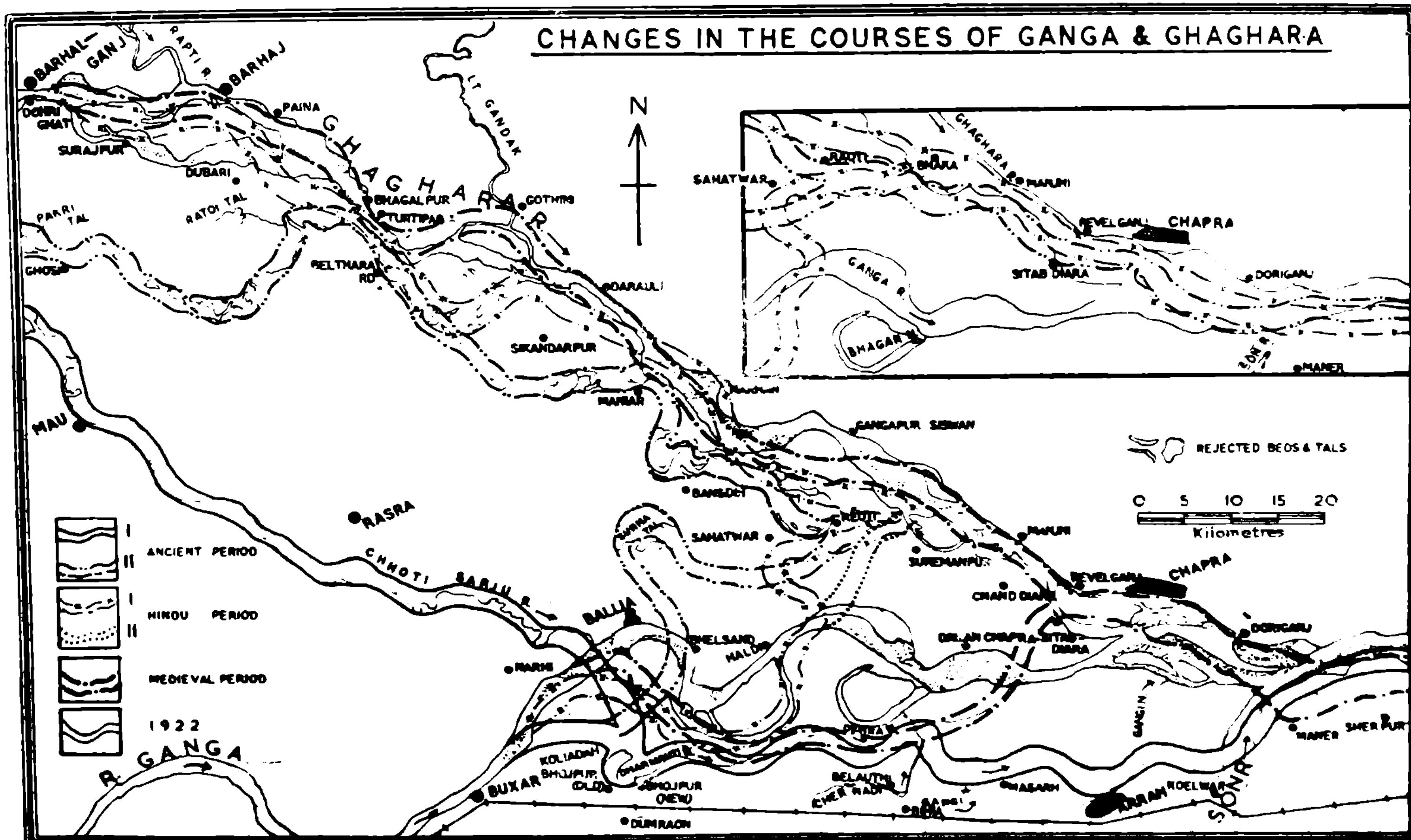
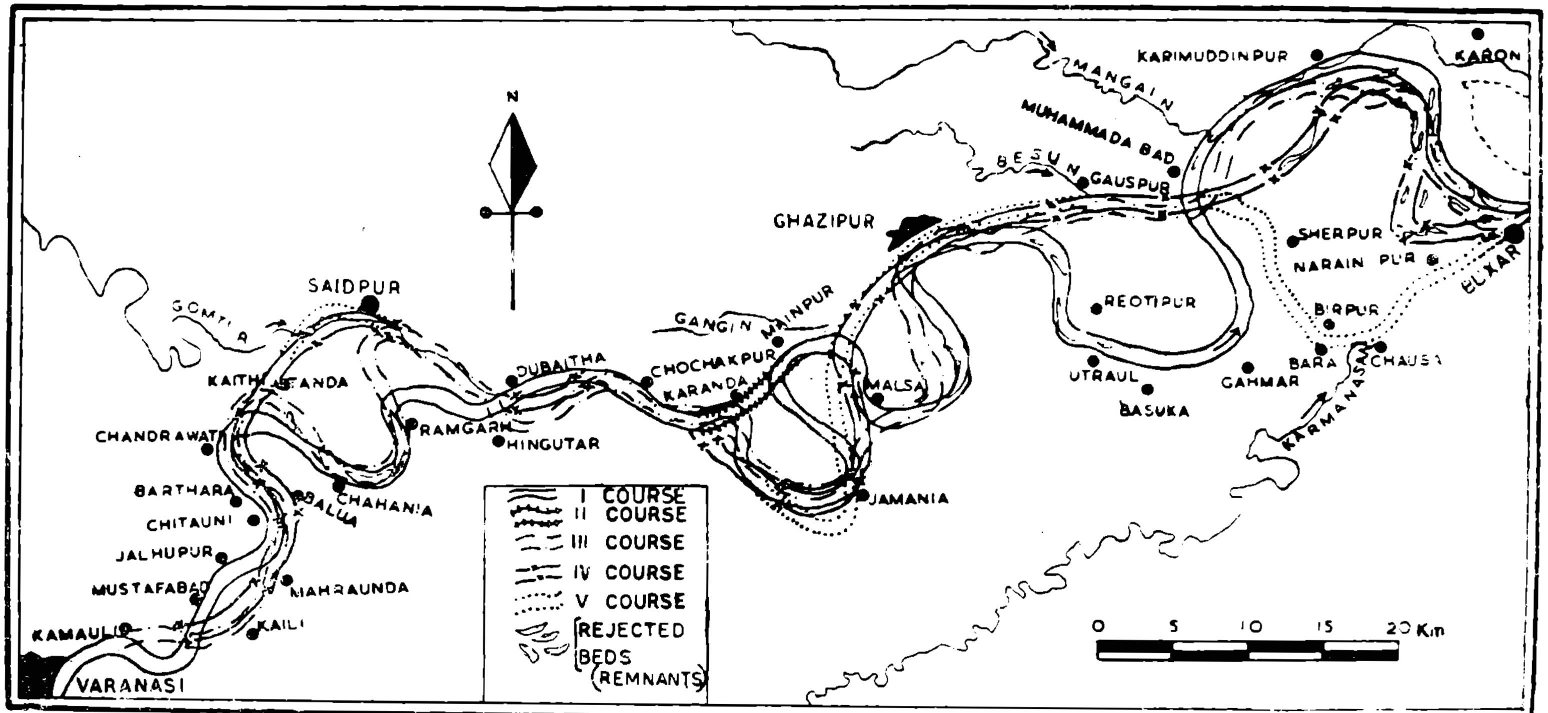


Note: Details From Sahatwar To Doriganj In The Inset.

EARLY CHANGES IN THE COURSE OF GANGA

VARANASI TO BUXAR



bank along the river at the junction of the older and newer alluviums. The course of the middle Ganga may conveniently be divided in 5 sections—(i) Allahabad to Varanasi, (ii) Varanasi to Buxar, (iii) Buxar to Patna, (iv) Patna to Colgong and (v) Colgong to Sakrigali.

CHANGES BETWEEN ALLAHABAD AND VARANASI

Some major changes in the course of the river have taken place at its confluence with other rivers, such as the Yamuna and the Tons. At Allahabad the confluence has been oscillating between the fort and Jhusi. The confluence which in 1908 lay just by the side of the fort, shifted to a distance of 400 metres eastward in 1924 and again receded nearer to the fort in 1958.[1] But the major changes have occurred between Mirzapur and Chunar where the Ganga has shifted about 6 to 8 km to the south. It is supposed that during Mahabharat times (1400 B.C.) the Ganga was flowing through Chunar hills[2] and it has been eating away the bank on the Mirzapur side ; now its erosive action is obstructed by the presence of the Vindhyan rocks in the south. Lower down, the Chunar hill and the Ramnagar fort are the controlling points that have thwarted the Ganga in its southerly march.

CHANGES BETWEEN BUXAR AND PATNA

In this tract, the changes in the course of the Ganga are most frequent and extensive because of its junction with several larger rivers. The Ganga has been changing its course at first towards the north, then to the south and finally to the north. It is not known when the river started shifting to the south, but by the first century B.C. the Ganga appears to have shifted through Bhojpur Kadi (old) when Raja Bhoj, son of Vikramaditya of Ujjain selected this site for his residence. In the 7th century A.D. when Hieun Thsang visited India, the river flowed due east from Buxar via Bhojpur and Arrah.[3] When Fahien visited India in the 4th century A.D. the Ganga appears to have flowed through this southerly direction.[4] But by 1582 A.D. it had moved to the north from Arrah leaving a feeble channel to the south. The river abandoned this channel probably about 1820.

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CHANGES IN THE NEIGHBOURHOOD OF PATNA

About 750 A.D. when the Son shifted to the west and joined the Ganga at Maner, the confluence point of the Son and Ganga, the latter river pushed to the north as far as Dighwara, where from it took turn to the south dashing its right bank from Patna to Fatwa. Formerly, the effects caused by the Gandak were neutralized by the Son. But after 750 A.D. both the tributaries, the Son and the Gandak jointly pushed the Ganga to the south below Hajipur. Thus the Ganga with increased discharge flowed directly from Dighwara to Fatwa in a straight course. It resulted in the gradual erosion of the right bank and till 12th century a large part of Patna was brought within the river bed. Owing to the southerly march of the Ganga towards Patna, the confluence with the Gandak also moved to the southeast, about 6 km southeast of Sonpur.

Owing to the changes in the courses of the Ganga and the Ghaghara, their confluence also moved accordingly. With the gradual shift in the course of the Ghaghara to the left and the Ganga to the right the confluence moved to Bhaka, and by 7th century A.D. it further reached to the east of Chapra. Since then owing to the retreat of both the rivers the junction also moved to the west and by 1582 (during Akbar's regime) the junction moved to Revelganj.[1]

In, 1840, the confluence of the Ghaghara was 43·2 km east of Ballia and 4·4 km west of Chapra. By 1852, it came just south of Chapra and by 1863-64 it moved to 12·8 km southeast of Chapra. A swing back in 1875 brought it again near Chapra and by 1895 it moved rapidly to the east a distance of 22·4 km from Chapra. Thus in all the easterly progression had taken place for about 37 km in 55 years.

CHANGES BETWEEN PATNA AND MONGHYR

All through from Patna to Monghyr the course of the Ganga appears to have moved gradually to the south and has widened its bed.

The major changes which took place in this stretch probably occurred from ancient to early medieval periods when the original sites of Fatwa, Bakhtiarpur, Surajgarh[2] and Abgel[3] were embedded by it in its southerly march.

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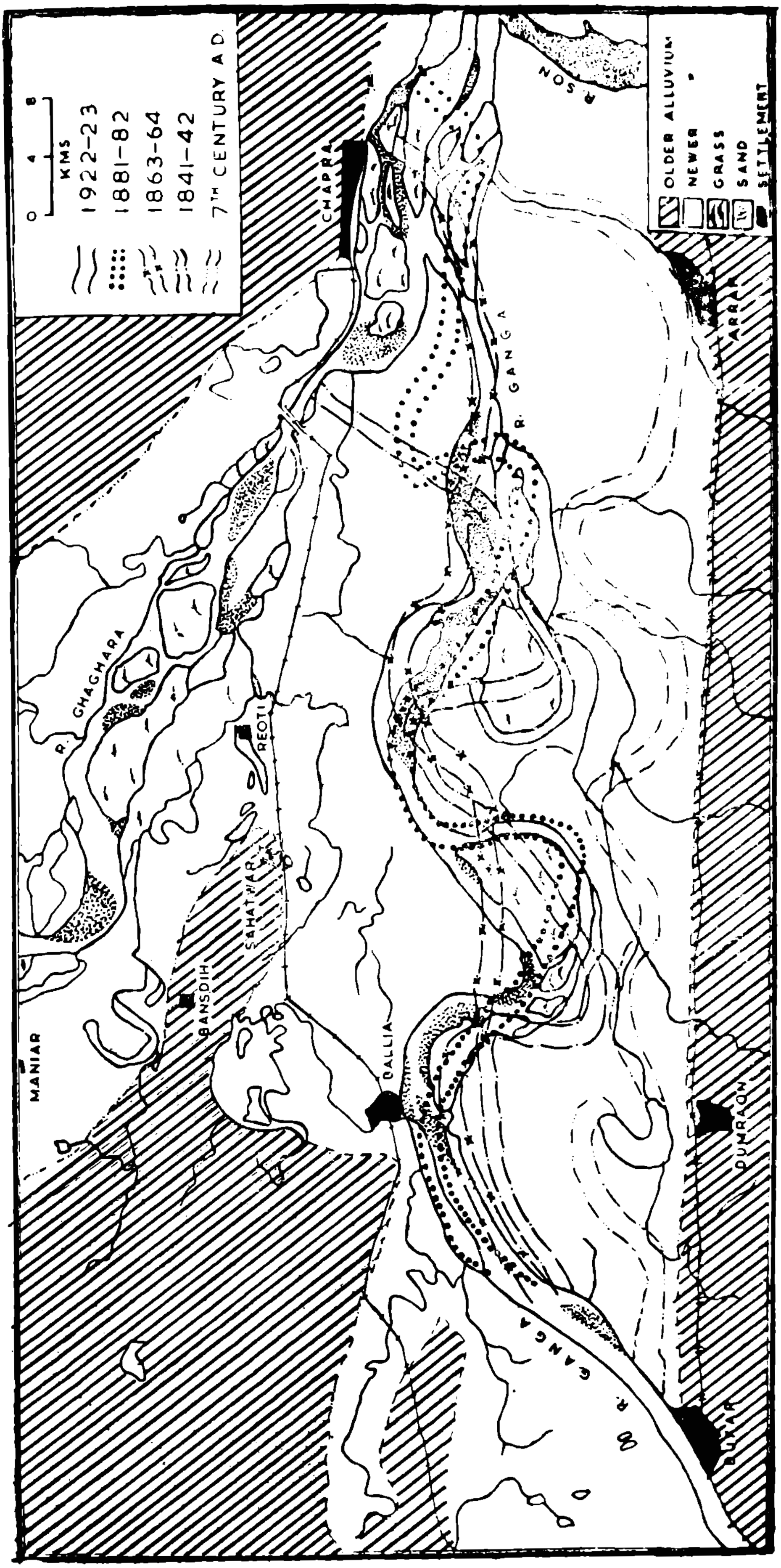
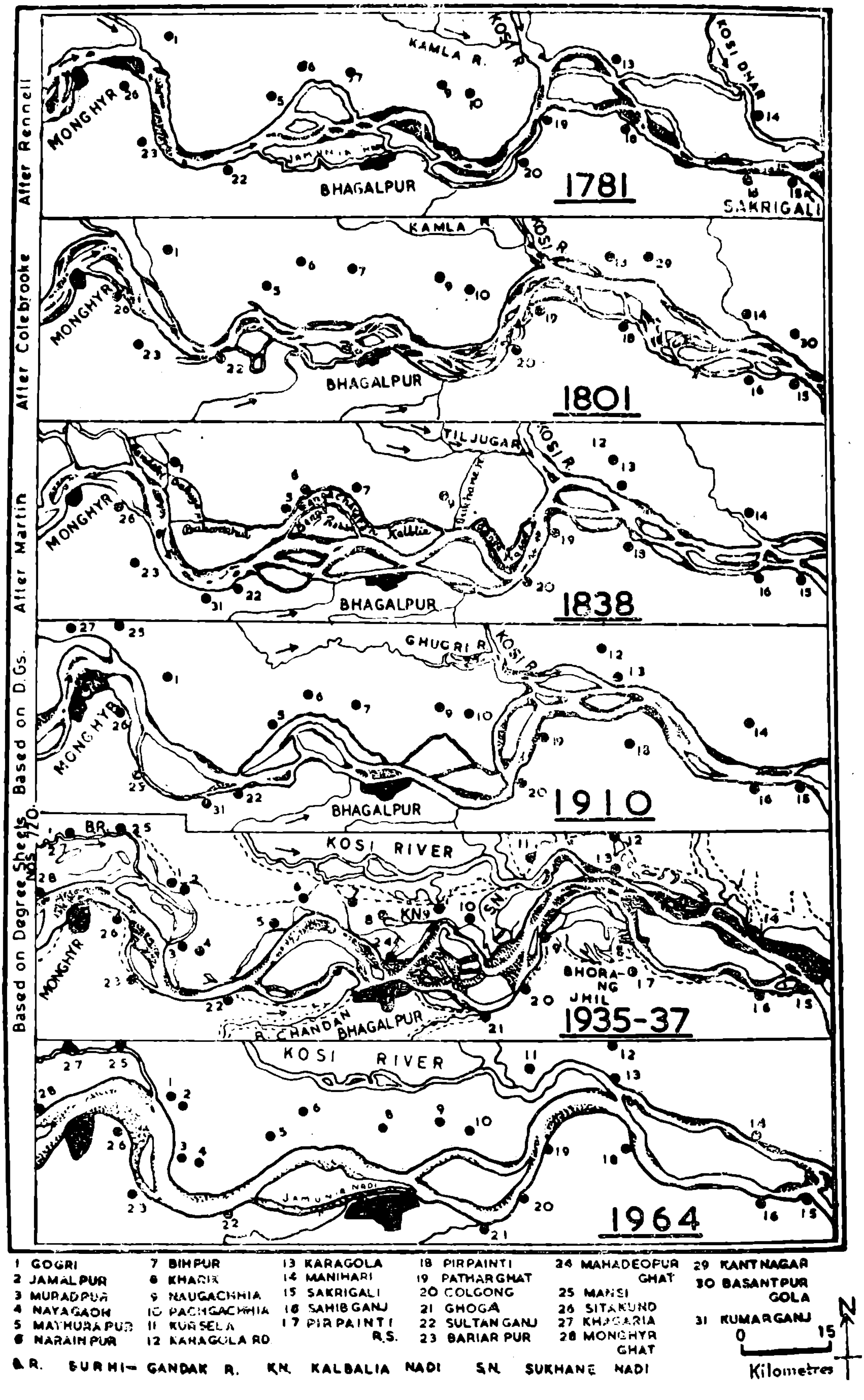


CHANGES IN THE COURSE OF GANGA (BUXAR TO PATNA)

CHANGES IN THE COURSE OF RIVER GANGA

MONGHYR TO SAKRIGALI



1 GOGRI
2 JAMALPUR
3 MURADPUR
4 NAYAGAON
5 MATHURAPUR
6 NARAINPUR
7 BIHPUR
8 KHARIK
9 NAUGACHHIA
10 PACHGACHHIA
11 KURSELA
12 KARAGOLA RD
13 KARAGOLA
14 MANIHARI
15 SAKRIGALI
16 SAHIBGANJ
17 PIRPAINTI R.S.
18 PIRPAINTI
19 PATHARGHAT
20 COLGONG
21 GHOGA
22 SULTANGANJ
23 BARIARPUR
24 MAHADEOPUR GHAT
25 MANSI
26 SITAKUND
27 KHAGARIA
28 MONGHYR GHAT
29 KANTNAGAR
30 BASANTPUR GOLA
31 KUMARGANJ

B.R. BURHI-GANDAK R. KN. KALBALIA NADI S.N. SUKHANE NADI

CHANGES BETWEEN MONGHYR AND COLGONG

Between Monghyr and Colgong the Ganga has again continuously eroded the southern bank leaving its former courses in the north in the form of numerous discarded channels and depressions known as Marganga (dead Ganga), Ganga Prasad (refuse of the Ganga), Ganga Chharan (deserted channel of the Ganga), etc. all of them receiving spill waters during rains.

To the north and east of Monghyr fort, the Ganga has many times changed its course resulting in the shift of its confluence with the Burhi Gandak.

Major changes in the course of the Ganga have also occurred in the neighbourhood of Bhagalpur—by 1781, the main current had shifted to the south and flowed in two channels known as 'Ganga Chharan' and Jamunia Nadi. About 1864, when the main current passed through the city of Bhagalpur,[1] "the streamers anchored close under the houses of the residents". The Ganga at present flows about 2·5 km north of the city of Bhagalpur separated from the Jamunia (along which the city stands) by vast stretch of sandy area.

CHANGES BETWEEN COLGONG AND SAKRIGALI

From Colgong to Sakrigali, the changes in the course of the Ganga are due to the combined work of the Ganga and the Kosi. Between Colgong and Pirpainti, the river gradually shifted to the north truncating the lower course of the Kosi while the latter was continuously shifting to the west. The Ganga during its northerly march to the west of Colgong flowed through the Sukhane Nadi when the Kosi flowed much to the east of the present course. This northerly march of the Ganga below Colgong has many times led to the change in its confluence with the Kosi. Below Pirpainti, the Ganga was flowing at a greater distance from the southern hills which it has gradually approached.

CONCLUSION :—

The Ganga in its middle course flows with regular sinuosity and modest number of bifurcations. The changes in its courses are gradual and slow. From Allahabad to Buxar or Chapra, it has changed its course like a true meandering channel. Below Chapra it has mainly widened its course by gradually eroding the southern bank which has now been considerably checked at places by the plateau spurs. These spurs have forced the river to bend northward. Below Chapra, it has taken southward shift due to excessive discharge and fan formations by its large tributaries. The most conspicuous changes are observed at the confluence points of its tributaries.

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CHAPTER XXIV

BHAGIRATHI-HOOGHLY BASIN

Introduction

The river Bhagirathi flowing through the heart of West Bengal has been deteriorating since its diversion to the river Padma. The reduced discharge of the Bhagirathi from its Ganga offtake and the increased volume of siltladen waters from its tributaries, e.g. Mayurakshi, Ajoy, Damodar, Kangsabati etc. during flood season introduces the flood problems by decreasing the sectional discharge capacity. The oscillation of the meander curves of the Bhagirathi during bankful stage also invites the problem of navigability.

The tributaries of the Bhagirathi-Hooghly (Ajoy, Mayurakshi, Damodar etc.) are flashy streams. They rise from the Chotanagpur plateau and flow through the old metamorphic terrain which has undergone peneplanation. The traces of recent rejuvenation can be marked in the upper catchment of these streams. The abnormal silting and scouring are the characteristic features of the flashy streams.

The stream-flow and the rain-storm blow are opposite in direction. The result is that the run-off from the upper catchment is being impeded by the flood waters of the lower valley resulting into flood plain inundation by overtopping the banks.

RAINFALL CHARACTERISTICS

The Bhagirathi-Hooghly basin receives its water from the inter-play of currents near and around the monsoon trough and in most cases the heavy shower is associated to the passage of depression and storms from the Bay of Bengal. The rainfall amount is maximum in the period from June to October and the distribution is not uniform throughout the catchment. In many areas the amount required is less from the agricultural point of view and in this part of the catchment irrigation is essential for agricultural production. The analysis of the last fifty years reveals that the rainfall does not show any upward or downward trend and so far the amount of annual precipitation is concerned, it is neither regular nor periodic.

The Bhagirathi-Hooghly basin is under the tropical monsoon precipitation regime and the normal rainfall lies between 110 and 150 cm.

The rainfall decreases from the southeast to the northwest. The distribution of the seasonal rainfall is normal. In the upper catchments of the Mayurakshi, the Ajoy, the Damodar and the Kangsabati the rainfall is less than 125 cm. The lower reaches of these catchments receive higher rainfall probably because of their location near the moisture source and influence of local storms. In May or early June the rainfall occurs due to the Nor'westers or 'Kalbaishakhi'. The study of the storm track line shows that the tracklines change in the direction with the approach of the monsoon especially about the middle and the end of the monsoon.

The frequency of flood occurrences are high during June to September. The abnormal activity of the monsoon caused by some specific meteorological conditions are responsible for high rainfall intensity and heavy concentration in the vicinity of depression.

EVAPORATION

The evaporation graph in the Bhagirathi-Hooghly catchment basin shows a rising trend during the pre-monsoon period (March to mid-June) and then there is a sudden drop during the rainy season when humidity is comparitively high. The evaporation is low from August to September. From October to December the evaporation curve rises but daily fluctuation is small. The smaller magnitude of evaporation during this period is probably because the soil remains wet after the rains. The evaporation study reveals that the altitude is apparently not the predominant factor in the distribuation of evaporation. The evaporation increases as one proceeds towards the west.

RIVER REGIME

The streams are seasonal and flashy type and the flow characteristics in the upper catchments are intermittent depending upon rainfall characteristics. The surface run-off is greater than the storage amount in the steeper slopes of the upper catchment particularly when the rainfall is heavier. Thus a high intensity of flow of short duration rushes down the middle and the lower valley enhancing the destructive potentialities in the flood plain.

In recent times the floods particularly in the Damodar basin as recorded in 1913, 1935, 1943 and 1959 were of high magnitude causing disaster in the lower reaches. The flood of 1913 accounts for a high peak discharge at Rhondia (18,400 cubic metres per sec and is recorded as the heaviest flood in volume and intensity. The flood intensity of the daily average flood flow of 1959 was less than 1913 and 1935 floods. The peak discharge and the flow pattern in 1959 flood was lesser in magnitude than in 1913 flood and this reduction was probably due to the construction of storage reservoirs.

About 80 percent of the total discharge flows during the period beginning from June to August. The maximum volume of discharge in Damodar flows in the month of August. The waterlevel in the stream usually records a very rapid rise and fall in the upper catchment particularly at Ramgarh. The rise of water level is rapid also at Aiyar, Barhi and Giridih but the rate of fall is slower than that at Ramgarh. The intensity of the flood crest velocity recorded in the upper catchment is 5 to 6 km per hour on the average.

The monsoon flood discharges of about 60 percent of the total discharge of the Mayurakshi, passes through Massanjor during the months of July and August. The maximum volume of flood discharge in Dwarka and Brahmani is in August and September. The maximum volume of flood discharge flows during August in Dwarakeswar. The peak discharge of 850 cubic metre per sec is recorded in September. In Selya a maximum volume of flood discharge and peak discharge of 370 cubic metres per sec occurs in September. On many occasions one flood overlaps another during the period from June to August and the peak discharge of the latter flood is higher than the first one. It is to be noted that the flood intensities are not the same each year.

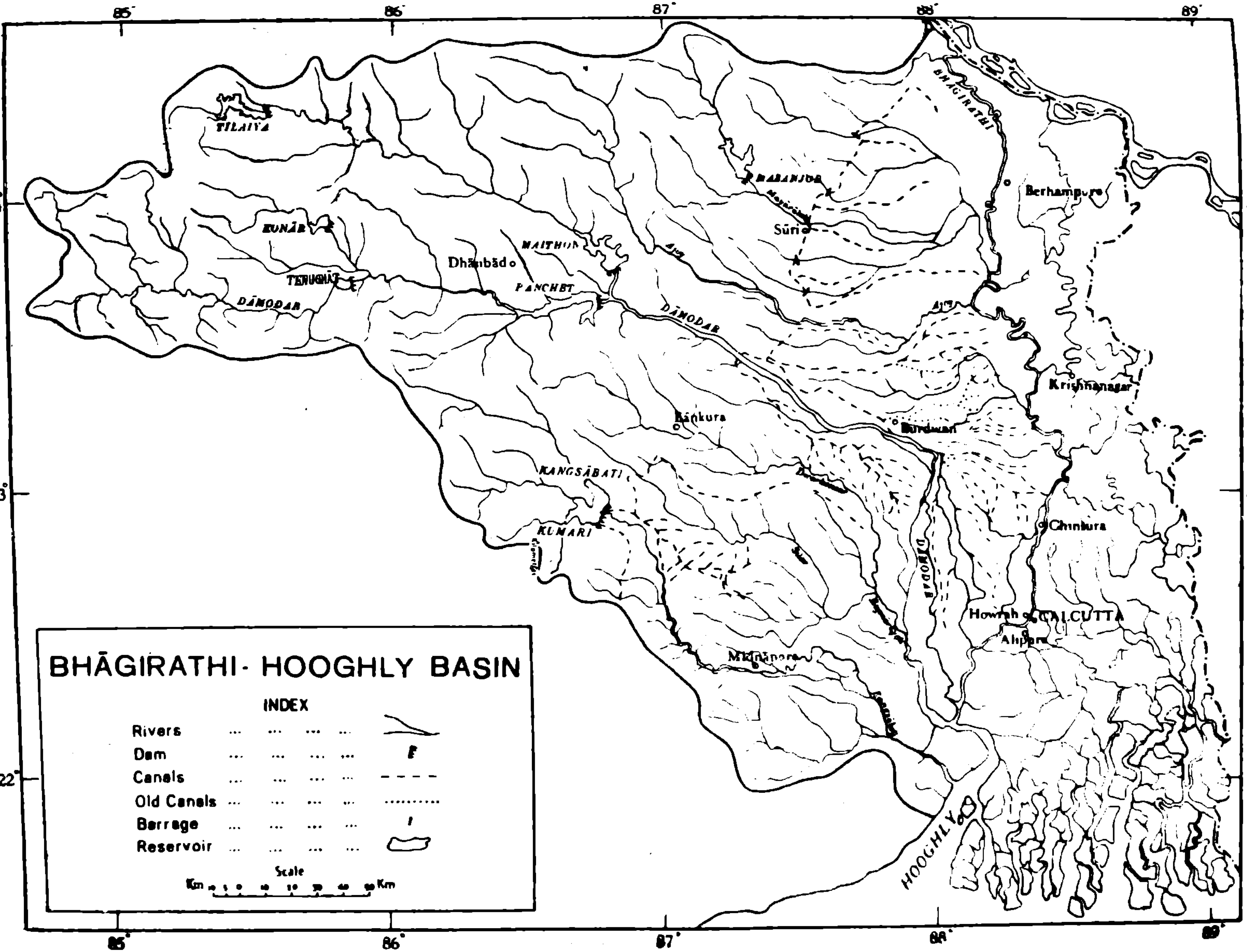
SUSPENDED LOAD

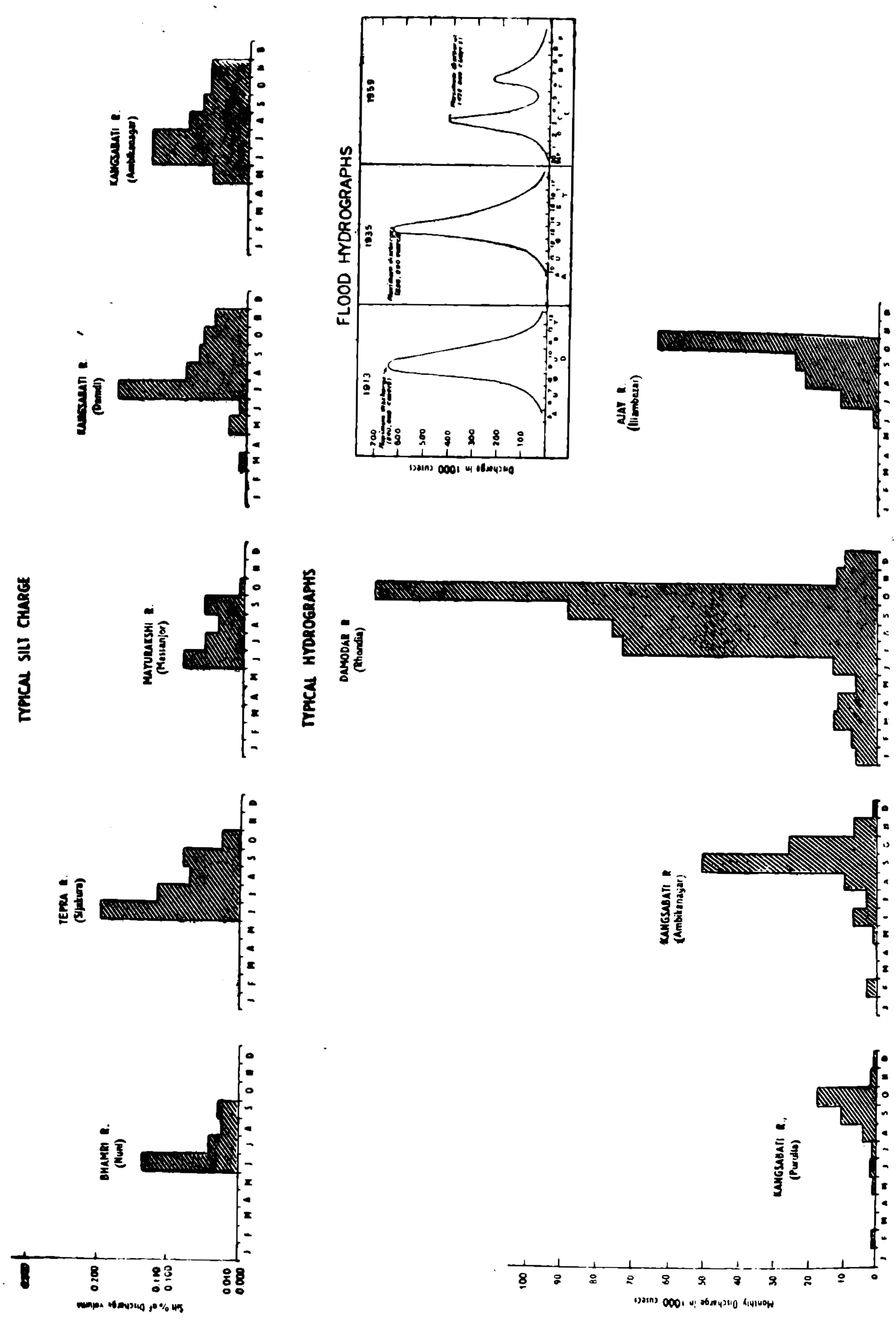
The sediments carried by the main stream itself are being added by those of the tributary streams. Thus the combined volume of a stream and its tributaries should be able to carry more than the combined total of the constituent loads.

Careful examination of air photographs and recent survey maps reveals that the Chotanagpur plateau is dotted with alarming preponderance of gully erosion. The flash flood of the denuded catchment and the increase of primeter of eroding bank caused by the rapid widening of the trough, along recently cut gully, is also prevalent. The main causes of soil erosion in the Chotanagpur plateau have been deforestation, overgrazing, forest fires, unscientific cultivation and mining.

The sediment of upper valley invades the lower valley with rushing torrents during the monsoon season. Most of the bedload of coarser type falls early but the finer particles as the suspension load are deposited in the lower reach.

Silt charge stations are few in number. The statements available are only for the monsoon months. In pre-and post-monsoon seasons the river channel becomes dry. The surface currents are feeble and free of silt which is sometimes nil, practically non-existent. The suspended load was found to consist of a high amount between June and October and the amount varies with the discharge, velocity and the intensity of flood.


BHĀGIRATHI- HOOGHLY BASIN
INDEX
Rivers
Dam
Canals
Old Canals
Barrage
Reservoir
Scale
Km
Km
85°
86°
87°
88°
89°
24°
23°
22°
TILAIYA
KONĀR
TENUGHAT
DĀMODAR
Dhānbād
MAITHON
PANCHET
DĀMODAR
BHAGIRATHI
Sūri
Berhampur
Krishnanagar
Bānkura
Burdwan
KANGSĀBATI
KUMARI
Chinsura
Howrah
CALCUTTA
Alipore
HOOGHLY


TYPICAL SILT CHARGE
BHAMRI R. (Nuni)
TEPRA R. (Sijakura)
MAYURAKSHI R. (Messanjor)
KANGSABATI R. (Dandi)
KANGSABATI R. (Ambikanagar)
Silt % of Discharge volume
TYPICAL HYDROGRAPHS
KANGSABATI R. (Purulia)
KANGSABATI R. (Ambikanagar)
DAMODAR R (Rhondia)
AJAY R. (Illambazar)
Monthly Discharge in 1000 cusecs
FLOOD HYDROGRAPHS
1913
1935
1959
Discharge in 1000 cusecs
J F M A M J J A S O N D

FLOODS AND FLOOD AFFECTED AREAS

The size, shape and the area of the catchments like the Mayurakshi, the Ajoy, the Kangsabati etc. varies from basin to basin. These catchments receive heavy rainfall caused by the passage of a depression resulting into high floods. The run-off percentage is higher during flash floods in the upper catchment because the slope is steeper and eventually sheet erosion takes place. The eroded materials are carried downstream and deposited in the river bed. This river bed aggradation plus heavy rainfall invites the flood plains of the lower reaches of the catchment. The channel water movement is sluggish in the lower reaches and the breaches in the embankments also accentuate floods. A large number of breaches occurred in 1959 floods.

A heavy and concentrated rainfall occurs in the Bhagirathi-Hooghly catchment. The rainfall amount is high as the storm approaches the coastal areas and then penetrates inward. The amount of rain is greater when the storm moves slowly.

The water absorbing capacity of the soil has deteriorated and still deteriorating due to deforestation in the upper catchment. The sediment is thus deposited when the slope flattens.

The lower reaches of all the catchments of the Bhagirathi-Hooghly basin adjacent to the Bhagirathi-Hooghly river is under the influence of heavy rain during the latter half of the monsoon causing floods which is synchronised with high tide levels of Hooghly and Rupnarayan river resulting into drainage obstruction and finally congestion.

The coverage of flood affected areas in the Bhagirathi-Hooghly basin is about 5,960 km^2. The depth of floodwater is high in the depressions The average depth of flood water from the Bansloi outfall to the Bhagirathi-Jalangi confluence is about 2 to 2·5 m sometimes above 3 m. The flood is intense and spreads widely near the outfalls of the tributaries of the Bhagirathi-Hooghly river. In this zone the main problem is drainage congestion. The flood intensity increases due to the choking of outfalls by sediments on account of backwash from the Bhagirathi.

The floods of the Kandi areas and the Bhagirathi flood plain occur almost every year. The combined flood waters of the Brahmani, the Bakreswar, the Dwarka and the Mayurakshi accumulate and are ultimately drained by the Babla and its tributaries. The mouth of the Babla is silted up and actually causes about flood catastrophe in this area.

The flood inundation in the Katwa-Purbasthali-Nabadwip area is also due to heavy shower along with high Bhagirathi water level. The meander floodplain configuration is also responsible for the flooding in the sloughs and depressions of the newly built alluvial floor of the wandering river. The inadequate provision of escapes and negligence in the maintenance of the old zamindari embankments are also the cause of drainage congestion.

The flood occurrences in the Damodar-Hooghly are frequent in the topographic depressions and also in the Moribund drainage channels. The tide lockage at the outfalls of the drainage channels and the lack of drainage facilities in the waterlogged areas result in a stagnation of flood water in this zone.

The tidal lockage and the silting up of the Rupnarayan, Hooghly and the Haldi river cause floods in Tamluk. The flood inundation of the Sonamukhi (Bankura district) is due to the silting up of river bed.

FLOOD CONTROL DAMS AND FLOOD MODERATION

The magnitude of flood after the construction of dams was high in 1959. Many experts were of the opinion that the release of the reservoir water enhanced the problem. But as far as the Massanjor dam is concerned it was constructed for irrigation purposes and practically has no provision for flood moderation. Actually speaking the release of water from Massanjor dam did not aggravate the flood condition in its lower reaches, particularly it has less contribution on the floods in Kandi area.

The space for flood moderation is limited in the Konar and Tilaiya. The provision is extensive in the Maithon and the Panchet. The waterlevels of these two reservoirs rose high on 2. 10. 59 due to high intensity of rainfall. The rainfall was heavy also in the lower reach of the Damodar particularly below the two dams sites mentioned above. The sudden rise of waterlevel in the reservoirs due to high intensity of rainfall and the accumulated heavy surface run-off was flowing to the river and these together formed the cause of drainage congestion in 1959. Hence, the reduction of flood discharges from the DVC reservoirs in 1959 probably contributed much in reducing the flood distress in the lower reach of the Damodar.

WATERLOGGING PROBLEMS

When the balance between inflow and outflow of subsoil water is being disturbed, the waterlogging occurs. The site of groundwater table often leads to waterlogging and this problem makes lowlying agricultural tracts uncultivable. The construction of canals, embankments and irrigation field bunds aggravate this problem. The waterlogging sites are mainly found in the topographical depressions.

In the lower reach of Damodar the waterlogging chances are high to the south of Khari river and particularly in the lower portions of the Damodar-Hooghly interfluve. The watertable fluctuation between pre- and post-monsoon period is little. The ground watertable to the west of Burdwan town is located well below the surface. The range of watertable becomes high with the rise of relief. The watertable is usually near the river.

The watertable fluctuation is very sensitive to rainfall. It rises and reaches its peak in the early part of October and in the post-monsoon it drops steadily. The amount of water causing the rise of watertable adds more than the accumulated rainfall. This is probably due to seepage flow from outside the area concerned.[1]

The study of watertable maps from 1955 to 1962 shows that there is no appreciable change in the trend of watertable fluctuations. But after the commencement of irrigation system in DVC since 1958 the watertable zones ranging from 0 to 1·5 m below the surface has become very important for agricultural practices. The field survey reveals that some portion of the lower reaches of the DVC commanded irrigated area remained waterlogged since the commencement of irrigation in 1957.

Another important waterlogging area is near the Babla outfall. There are many depressions including Hijole covering about 130 km^2 in area. This area is wholly covered with flood water and sometimes act as detention reservoir basins.

NAVIGATION

The hydrological conditions, that is, the seasonal discharge fluctuations, meander pattern, channel stability, river bank erosion, sedimentation problems etc. are important in solving the navigational problems of the Bhagirathi-Hooghly basin.

The river Ganga experience severe bank erosion during falling flood stages at certain sections. The fluctuating meander curves of the Bhagirathi depending upon hydrological conditions hinder navigation. The Bhagirathi river channel reduced considerably after the diversion of the Ganga to Padma and this reduction of upland discharge heralded the decay of the channel width and depth.

The river is navigable throughout the year from Calcutta to Nabadwip. Of course, the navigable depths reduce considerably during the dry season. The navigation is extremely difficult from Calcutta to Sandheads because of the pressure of numerous bars, shoals and crossings.

1. S. Sen (1958)—Drainage Study of Lower Damodar Valley.

The complicated situation of the river bed, topography and its relationship with sedimentation develops at the confluence of the Damodar, Rupnarayan and Hooghly. The Rupnarayan is navigable upto Kolaghat and above Kolaghat the river is shallow during dry season and the boats can ply upto Gopiganj.

AGRICULTURE

The intensity of agriculture is high in the lower reaches of the river basins. In West Bengal particularly due to high population density and and high demand for rice, the irrigated waters are chiefly used for the increasing yield of paddy. The yield of irrigated paddy is high provided the rice fields are watered thrice during transplantation, growth and maturing. The storage reservoir waters are utilised for increasing the paddy yield and the waters are distributed in the field by some of flooding methods. Many irrigation engineers are of opinion that the increase of the yield of 'Aman' paddy by irrigation agriculture by utilising storage reservoir waters will not help in maximising agricultural production because there is a natural tendency to destroy natural drainage ultimately affecting the recently watered irrigated land.

In the upper catchments the surface run-off drains rapidly into gutters finally to drainage channels and thereby forming numerous gullies and ravines. The total area under gully and ravines is about 0·8 million hectares.

In the middle reaches the alluvial deposits are covered by thin veneer of colluvial materials. Irrigation is a necessity in the porous area and it will act as a catalytic agent in receiving food for the plant from the soil. The layout of irrigation system thus should be adjusted to different physico-chemical properties of the soil.

The irrigation water requirements are high in the red soil area. The soil particles are removed by the surface run-off during flood irrigation. top soil removed by scouring activity is a problem. Hence it is suggested that the irrigation water should move slowly in red soils.

The soils of the flood plains of the Mayurakshi, the Damodar and the Kangsabati are permeable and consists of coarse sand and thick clay with sodium. The clay with sodium in the lowlying packets particularly above watertable are harmful from agricultural point of view. Thus the control in the rise of watertable in the irrigated areas are of prime necessity.

The water retentive capacity is high and the demand for irrigation is low in alluvial soils. The drainage congestion is a problem. The yield in this region will increase only by introducing pumps.

STORAGE RESERVOIR PROJECTS

The Mayurakshi reservoir aims at irrigating 250,900 hectares of land during kharif season and 48,600 hectares during rabi season and in this project area the rice is the predominant crop grown extensively in terraced fields. In addition to irrigation about 4,000 kW of electric power is generated from Massanjor dam. The storage reservoir has already been constructed at Massanjor. About 32 km below the dam site a barrage (at Tilpara near Suri) has been constructed across the Mayurakshi river wherefrom two main canals are drawn. The barrages are also constructed on the Brahmani, Dwarka and Kopai to utilise the monsoon discharges from these rivulets to main canals. The project consists of 1,280 km of canals with 1,480 canal structures. There is an acute water shortage in the commanded area of the Mayurakshi basin. The main purpose of this irrigation project is to increase the agricultural yield by proper water conservancy rather than expansion of cultivable lands.

In 1843 the embankments of the lower Damodar were taken over by the Government from the local landlords with a view to keep the riverflow within the bounds of the two marginal lines of embankments. The history of the lower Damodar Valley from 1843 to 1863 was thus the history of the continued struggle between the river and engineers. Embank-bankments were breached every year at one place or another resulting in heavy economic loss. The important object of the measures taken is to control floods in the lower reach of the Damodar. The idea of flood control by means of reservoir was considered as early as sixties of the last century. From 1864 to 1944 surveys of the Damodar basin often carried out with the purpose of locating the storage reservoir sites. The Damodar Valley Corporation came into existence on the 7th July 1948. In the First Five Year Plan 4 storage reservoirs (Maithon, Konar, Tilaiya and Panchet) were proposed and now all are functioning. The three hydel stations were constructed according to the First Five Year Plan. The project aims at irrigating 422,500 hectares including 74,900 hectares of kharif irrigation for an existing system with weir across the Damodar. The project has also constructed 136 km long irrigation-cum-navigation canal with adequate locks, loading and unloading facilities. In addition, this multipurpose scheme aims at draining 1,810 km^2 of waterlogged land in the lower valley and numerous headwater dams for soil conservation and irrigation in the upper catchment and miscellaneous development works. Recently blue print for another dam has been prepared by authorities across the Damodar at Tenughat and the construction of this earthen dam is mainly to supply industrial and domestic water for the use in the Bokaro-Sindri region. The site is located 13 km southwest of Bokaro thermal station.

The Kangsabati reservoir project aims at minimising the flood intensity and also irrigating 324,000 hectares of kharif land and about

60,700 hectares of rabi land. The two dams are complementary to each other and has already been constructed one across Kangsabati and the other across Kumari river. The two reservoirs have a common spillway across the saddle near Gorabari.

EFFECT OF RIVER REGULATIONS

The embankments were constructed in the lower reaches in many places as flood control measures but they do not solve the problem in the long run. The embankment restricts the flow movement and eventually siltation raises the river bed thereby reducing the sectional discharge-capacity of the channel.

The construction of storage reservoir on the alternative situation to control the unregulated discharges from the upper catchment. These dams will reduce the peak flood discharges and increase the flood duration. The river-flow will be controlled considerably after the construction of dams. The effect of the DVC dam regulations have been studied in details.[1,2]

In the lower Damodar Valley the flood-flow will be confined to the gutters. The gutterful stage discharge at different points of the river is below 2,830 cubic metres per sec. This reduction of flood days in post-dam conditions will favour the growth of vegetation. The trans-Damodar area, under the pre-dam conditions, gets overflooded every year and often from a number of floods, the duration on an average being about 2·5 hours per hour. But under post-dam condition this duration of spill from right bank would come to be about 3 hours per year only. Flood flushing through the spill channels would be stopped. The flood discharge amount of Damodar flowing through the Mundeswari has also reduced considerably. The lower Damodar channel passing through Amta may die due to the reduction in the flood-flow in the main Damodar. The reduced Damodar discharge which will overflow into the Rupnarayan will affect the tide absorbing capacity of the river. The reduced discharge will also create operation difficulties of the sluices. The lower Damodar Valley, particularly the Damodar-Hooghly interfluve, has got possibilities of waterlogging in the lowlying pockets. It has been observed in 1959 flood that the discharge intensity and duration has been decreased.

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1. S. Sen (1958)—Drainage Study of Lower Damodar Valley.
2. B. Maitra and A. C. Chatterjee (1966)—Bed deformation in the Damodar and the Rupnarayan due to construction of multipurpose reservoirs in the upper valley C.B.I. Journal, Vol. 23, No. 1.

Moitra and Chatterjee observes the post-dam conditions and stages that "the reduction in the run-off by over 40 percent from the pre-dam to the post-dam period has not been due to any reduction in the rainfall. There is a withdrawal of about 50 percent of the average river-flows during July to August months. The frequency and duration of moderately high discharges down the lower valley have decreased considerably and this has affected the capacity of the river". For the withdrawal of water from the storage reservoir for distribution, needs careful planning of the present water resources.

CHAPTER XXV

THE YAMUNA

Origin

The Yamuna is a Great Himalayan river with its source in the Yamunotri glacier lying on the western slope of the Bandarpunch peak. This peak is 6,387 metres high. The river originated in the post-mid-Miocene age, consequent on the second phase (main phase) of the upheaval of the axial range. Its headwaters are formed by several melt-streams, the chief of them gushing out of the morainic snout at an altitude of 3,255 meters, 8 km northwest of the Yamunotri hot springs, at 31° 2′ 12″ N and 78° 26′ 10″ E.

Rishiganga streamlet rises 3 km further northwest and joins the Yamunotri stream on its right bank near Banas, while two streamlets Unta and Hanu manganga rising from Jakhal glacier and Chhaian Bamak glacier on the south of Bandarpunch meet the Yamunotri stream on its left below Kharsali. Further southwest, Yamuna receives several tributaries from the Lesser Himalayan ranges and ridges.

Tons, the biggest Himalayan tributary of the Yamuna, takes its rise from the northeastern slope of Bandarpunch, and flowing in a valley northwest of the Yamuna confluences with the latter below Kalsi, on the southwest fringe of the Mussoorie range. Tons brings nearly double the volume of water of the Yamuna. Another important tributary, Giri, comes from further northwest of the Tons, bringing waters from southeast Himachal Pradesh.

The length of the Yamuna from its source to the debouch from the Himalaya is 152 km and from source to its confluence with the Ganga at Allahabad is 1,376 km.

Physiographic divisions of Yamuna basin

There are two main physiographic divisions of the Yamuna basin—

1. Himalayan Yamuna basin : it has undergone very minor changes in the direction of drainage and courses of streams, since the origin to present day. The changes have been those of relief and slope morphology.

2. Plain Yamuna basin : changes have taken great strides in this part of the river basin. Originally the Yamuna was a member of the Indus

system and sent its waters to the Arabian Sea from mid-Miocene to the Recent ages ; but, in the sub-Recent age it has become a tributary of the Ganga, due to subsidence in the Ganga delta and a tilting uplift of the Sutlej-Yamuna divide.

Himalayan Yamuna basin drains the districts of Uttarkashi, Tehri and Dehra Dun in Uttar Pradesh and the districts of Mahasu and Sirmur of Himachal Pradesh. Plain Yamuna basin serves the states of Haryana, Delhi, Uttar Pradesh, Rajasthan (Chambal basin) and Madhya Pradesh.

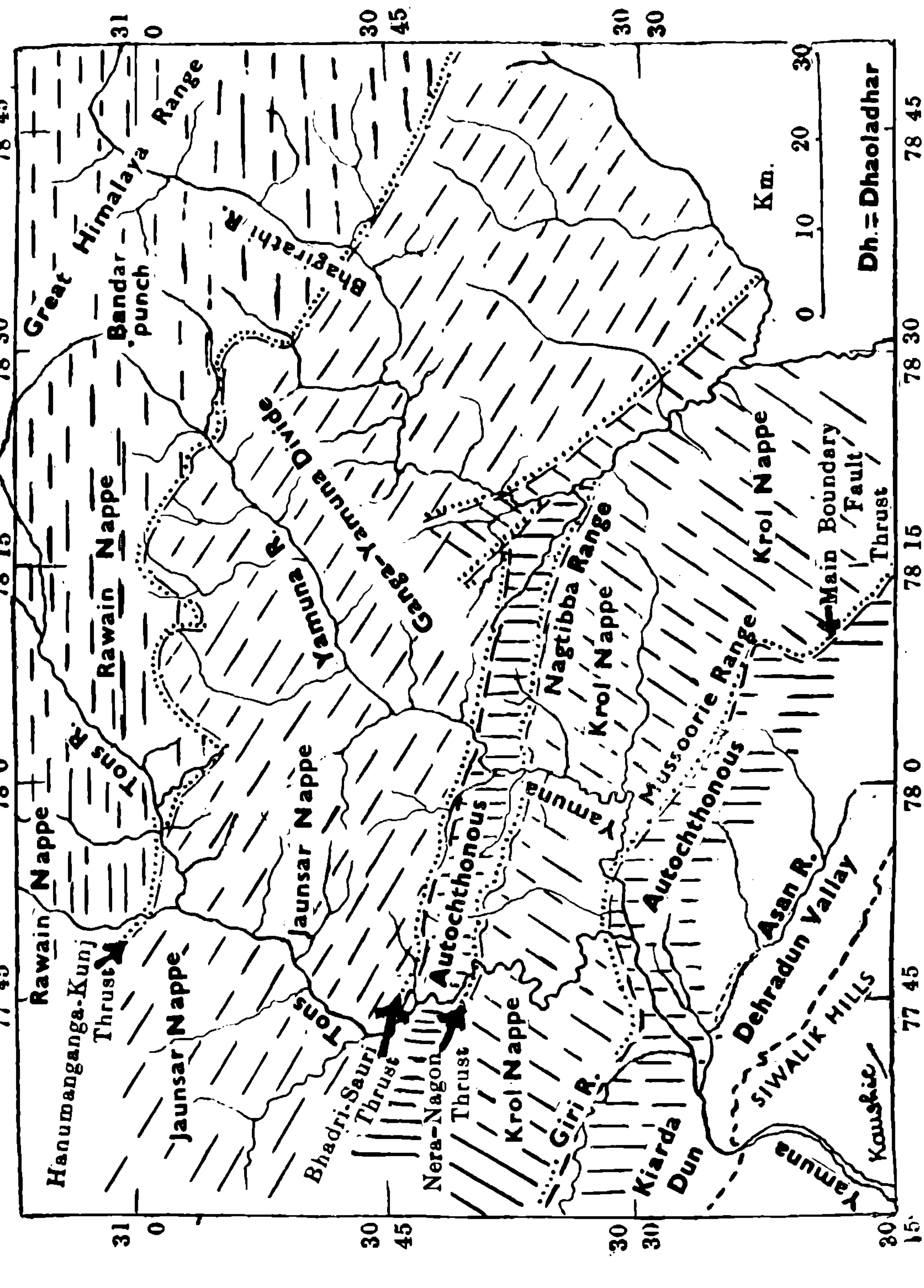
HIMALAYAN YAMUNA BASIN

Structural zones

The Himalayan Yamuna basin has a catchment area of about 8,280 km^2. On the east, a transverse spur extending southwards from the Main Himalayan Range to Chhaian Bamak, Darwa, Thadol and Nag Tibba separates the Yamuna basin from Bhagirathi basin. In its north and west the Yamuna basin is juxtaposed to the Sutlej basin. The area consists of rugged relief, formed by longitudinal ranges, transverse ridges, spurs and dales of the Lesser Himalaya, while its southern part is a tectonic syncline of longitudinal Dun trough. North of the Dun, it is a highly dissected region consisting of several anticlines of normal and fan-shaped types, and a labyrinth of criss-cross valleys.

The basin extends over six structural zones, which lie almost longitudinally parallel to the Great Himalayan range, from north to south, as—

1. Main Himalaya, in which the source region (Bandarpunch) has its roots.
2. Dhaola Dhar zone existing in the northwestern part of the basin.
3. Nag Tibba range crosses the middle part of the basin, from southeast to northwest upto Chakrata in Jaunsar and further on to the Tons. It is the biggest structural zone having northsouth extension of about 60 km and eastwest extension of about 80 km.
4. Mussoorie range, about 16 km south of the Nag Tibba range.
5. Dun valley exists between the Mussoorie range and the Siwalik range. It is a flat-bottomed canoe-shaped tectonic synclinal trough, about 30 km wide and 80 km long. Its western part is Kiarda Dun (in Himachal Pradesh) and eastern part is Dehra Dun (in U.P.)
6. Siwalik hills of the Outer Himalayan range, with a width of about 6 km.



Sketch map of the tectonic features.

Tectonic features of the Himalayan Yamuna basin

From mid-Miocene to post-Pleistocene, this anticlinorium has experienced severe tectonic movements, resulting in extensive thrust-faulting with twisted strikes and mass dislocations causing the transport of great nappes.

There are twelve structural divisions of the Himalayan Yamuna basin, from north to south :—

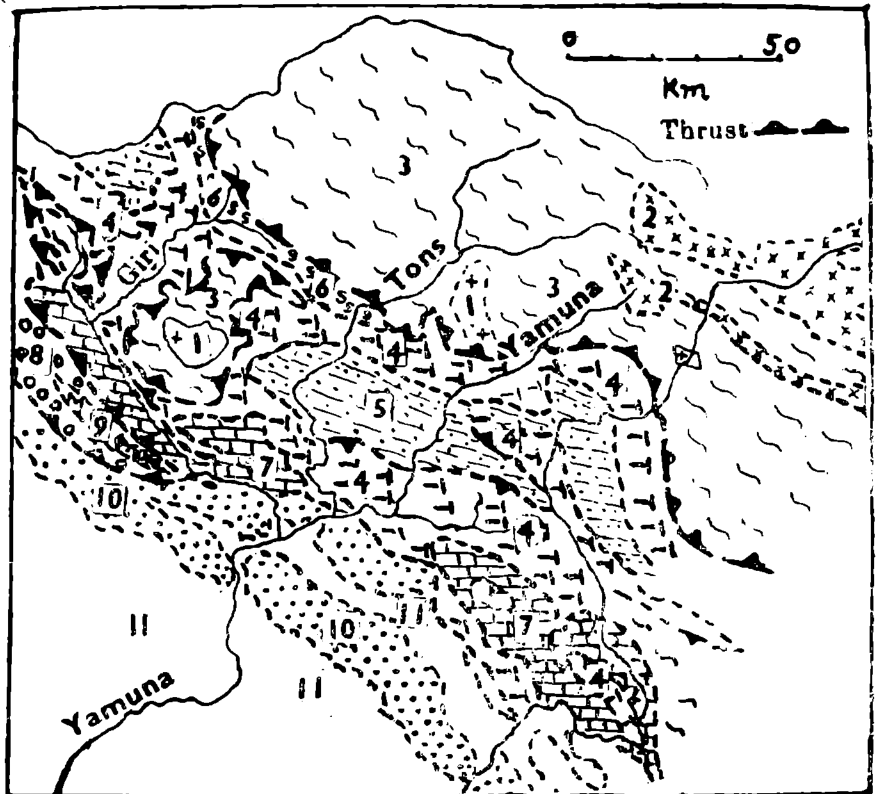
1. Intrusive belt of the Bandarpunch granites.
2. Rawain nappe : it has its roots in the Main Axial Range, and its northwest extension has the root in Dhaola Dhar.
3. Hanumanganga-Kunj thrust.
4. Jaunsar nappe : highly compressed recumbent double anticlines ; Chaur granite area is a syncline.
5. Bhadri-Sauri thrust.
6. Autochthonous zone.
7. Nara-Nagon thrust.
8. Krol nappe.
9. Giri thrust Main Boundary Fault.
10. Autochthonous zone.
11. Dun valley trough.
12. Siwalik hills.

Lithology of the Himalayan Yamuna basin

The sources of the Yamuna and Tons (the largest tributary) lie in the tourmaline granite belt of post-Miocene age, while pre-Miocene granites exist in two important localities (i) in a part of the Rawain nappe between the Yamuna and Tons and (ii) the Chaur peak zone.

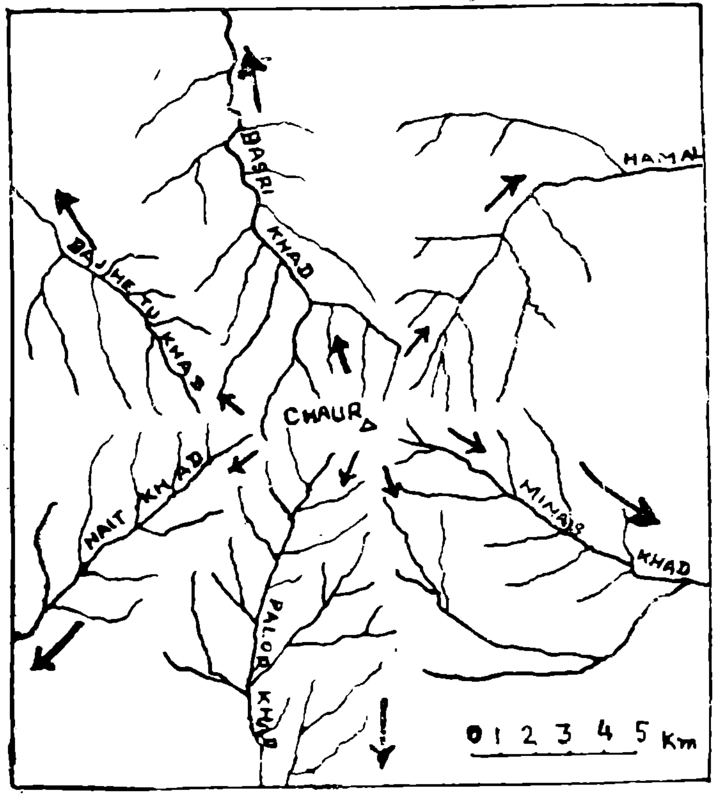
The Yamuna and the Tons flow across the zone of gnesis-migmatites and quartzites upto the Hanumanganga thrust. then, the Rawain nappe consists of highly metamorphosed pre-Cambrian gneisses and schists. Granitic material has been transported from the Main Axial Range and Dhaola Dhar range.

Jaunsar nappe has three sub-sections : (a) Jutogh quartzites, slates mica schists and limestone. (b) Chaur granite exists in the core of a syncline, and its metamorphic oreole has produced different minerals. (c) Quartzites, slates, phyllites and conglomerates of Jaunsar series, Chandpur schists, Manahali slates and Deoban limestones.



1	Granites (Pre-Miocene)	7	Krols
2	Granites (Post-Miocene)	8	Nummulitics
3	Gneisses, migmat.	9	Murrees
4	Jutoghs	10	Siwaliks
5	Jaunsars	11	Alluvia
6	Blaini		

Lithology of the Himalayan Yamuna Basin.



Sketch map of radial drainage.

Krol nappe consits of sandstone, shales, limestones and quartzites. Southwards exist the Tertiaries of the Mussoorie range, and then the Main Bounday Fault.

The Dun valley has alluvial deposits of gravel, sand, silt, and clays. Further south are the Siwalik hills composed of sandstones, shales, clay and conglomerates.

Tributaries and drainage patterns

From Yamunotri the main stream flows south and then southwestwards upto its confluence with the Rikhnargad (30° 45′ N 75° 5′ E), further southwards upto the confluence of Bhadrigad (30° 34′ N 78° 1′ E). Here it makes a sharp bend and turns westwards upto the confluence of the Tons (30° 30′ N 77° 50′ E). Now the Yamuna enters the Dun valley and flowing southwestwards debouches from the Siwalik range near Kalesar, 6 km below. Paonta of Himachal Pradesh. The basin of tributary Tons lies almost parallel to that of the Yamuna in the west of the latter. Giri brings its waters from Himachal Pradesh in northwest and joins the Yamuna in Kiarda Dun valley ; is important affluents take their rise from Chaur peak. Western Dehra Dun valley sends its waters to the Yamuna through the Asan.

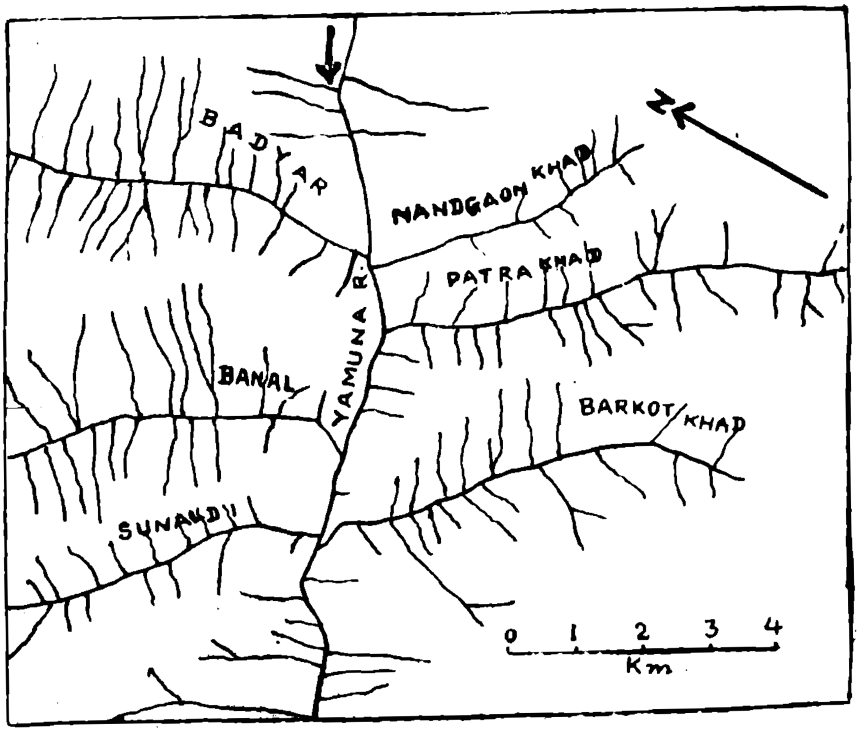
Influenced by the geological structure, nature of rocks, degree of slope and volume of water, the drainage of upper Yamuna basin presents four patterns :—

1. Dendritic drainage is the most common form developed by the main stream, its tributaries and their affluents in the mountains above the Dun valley zone.

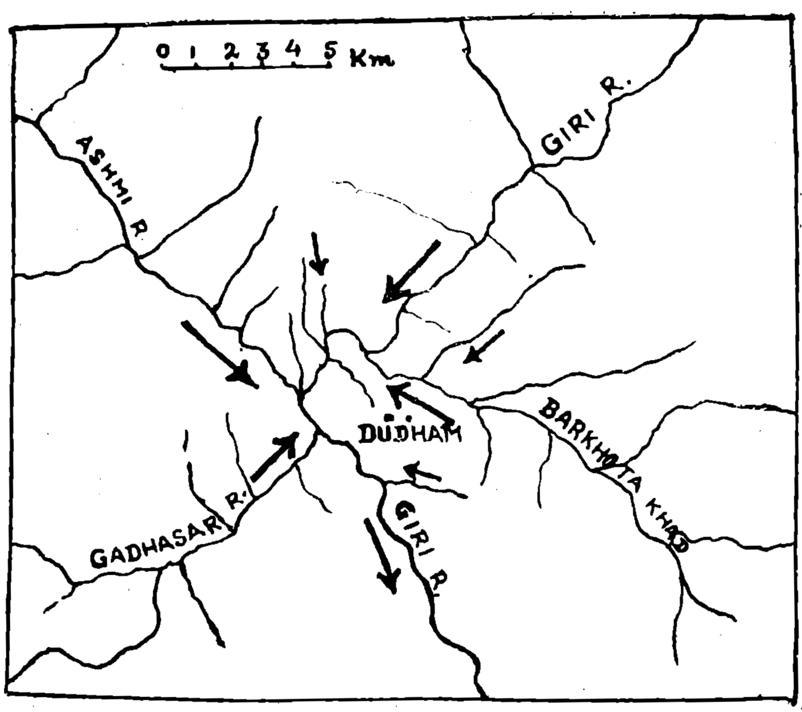
2. Radial drainage has developed in the areas of peaks ; e.g. from the Bandarpunch group of peaks, the Yamuna, the Tons, and affluents of the Bhagirathi flow out to all directions. In Jaunsar area, between the Yamuna and the Tons, the streams of Dharagad, Banal, Khutnugad, Khetwa and Beshairgad flow radially from Kharamba peak. In Giri basin, the streams of Basri, Bajheta, Pervi, Naitkhad, Palorkhad, Sainj (Minas) and Hamalkhad (Shalwi) flow down radially from the Chaur peak.

3. Trellis drainage in the areas of thrusts and local faults is exemplified by Banal Gad, lower Badyar Gad, Patra Gad and lower Pali Gad affluents of the Yamuna. These consequent streams have their subsequent affluents at right angles, and also further their obsequent streams in the opposite directions of the consequent streams.

4. Centripetal drainage exists in those localities where streams from all the four different directions flow into one central valley, for example in the Dudhan valley of Giri basin, in Sirmur district of Himachal Pradesh.



Sketch map of trellis drainage.



Sketch map of centripetal drainage

Rapid streams and braided streams

In the upper reaches of the the Yamuna and the Tons, the streams are torrentially rapid, with almost invariably escarp gradients. Moderate rapid flow exists in the area south of the Hanumanganga thrust upto the Mussoorie range, above the confluence of the Yamuna and the Tons. Below Kalsi, the Yamuna emerges out of the Lesser Himalaya and forms a braided stream on account of the very gentle slope gradient. It enters the Dun valley, and in Dun all rivers form braids. Giri forms vast braids before pouring its waters into the Yamuna in Kiarda Dun. Asan of west Dehra Dun valley not only forms braids, but also sinks underground in many localities and reappears after 4 or 5 km.

Rejuvenation of the upper Yamuna basin, and early stage of development

The Yamuna and the Tons valleys have undergone intermittent upheavals 3 or 4 times, and each upheaval has caused a rejuvenation of the valleys. The fact is clear from the following features :—(i) Paired terraces and single terraces of the Yamuna near Kharsali, Bagasu, Tirkhli, Phuldhar, etc.

(ii) Intrenched meanders and slip-off slopes of the Yamuna near Mungra, Kishna, Barkot and Tirkhli.

(iii) Knickpunkte in the valley profile of the Yamuna near Rana, Banas, Kharsali, etc.

(iv) Two-storeyed valleys in the upper reaches of the Yamuna and the Tons, in the ablated zone.

On account of these rejuvenations, the Himalayan Yamuna valley is yet in its early stage of development.

Retreat of thc Yamunotri and Tons glaciers

The Yamunotri and Tons glaciers have retreated during the Recent and Sub-Recent ages ; it is evident from the glacial deposits of morainic boulder conglomerate upto Kharsali in the Yamuna valley and upto Harki Dun in the Tons valley. The present valleys upto Kharsali and Harki Dun are newly carved V within old U shaped glacial trough. The glacial retreat has been at least 12 km in each valley.

The Yamunotri hot springs

5 km below the Yamunotri snout, there are hot springs in the eastern side of the Yamuna valley. They lie on the pilgrimage route to the Yamunotri shrine. Two of them are low gysers. For the use of pilgrims, they are made into stone walled tanks. Water of the bigger spring near the temple gave a thermometer reading of 90·4°C. Pilg rims boil their rice, potato, pulses, etc. in the hot water. For bathing purposes, extremely cold water of the stream and hot water of the spring are mixed together in bathing tanks.

THE YAMUNA BASIN IN THE PLAIN

Shift of the Yamuna from Indus drainage to the Ganga drainage in Sub-Recent age

As pointed out above, the Yamuna belonged to the Indus basin not only in the Tertiary age but also in the Pleistocene and Recent ages.[1] It was a twin stream with another stream named Saraswati, which had its catchment between those of the Yamuna and the Sutlej and debouched from the Siwalik hills near Nahan east of Ambala. Both the Yamuna and the Saraswati flowed southwestwards to combine near Suratgarh, north of Bikaner. This combined stream continued to flow as Ghaggar (Hakra) through Bahawalpur to join the Indus. The dry bed of Ghaggar is still existing. In the areas of Bikaner and Bahawalpur the flat bed is 3 to 6 wide, bordered on either side by steep aeolian dunes covered with bushes and thorny scrubs.

One strong opinion favours the view that the Saraswati was not a tributary to the Indus, but it flowed as an independent river to the Rann of Kutch.[2] R. D. Oldham[3] and C. F. Oldham[4] have discussed the history of the Saraswati in detail. The former believed that the Yamuna either "flowed into what was the Saraswati or atleast shared much of its waters with that river". This view is supported by M. S. Krishnan.[5]

Due to a subsidence in the Ganga delta, a pre-Yamuna tributary of the Ganga began working headward actively to catch the stream of the Yamuna ; and subsequently the drama was completed by a later uplift in the Aravalli-Delhi axis as well as the gradual rise of the Eocene Sea floor of the Rajasthan desert. Thus, the Yamuna became a tributary of Ganga and confluenced with the later at Prayag (Allahabad). As the combined stream of the Yamuna and the Saraswati had been flowing into one bed (Saraswati or Ghaggar), which lies almost dry now, it has given rise to a mythological belief that Saraswati waters have also gone with the Yamuna into the Ganga. The confluence at Allahabad is called 'Triveni Sungam' (confluence of three streams), which is considered to be a holy

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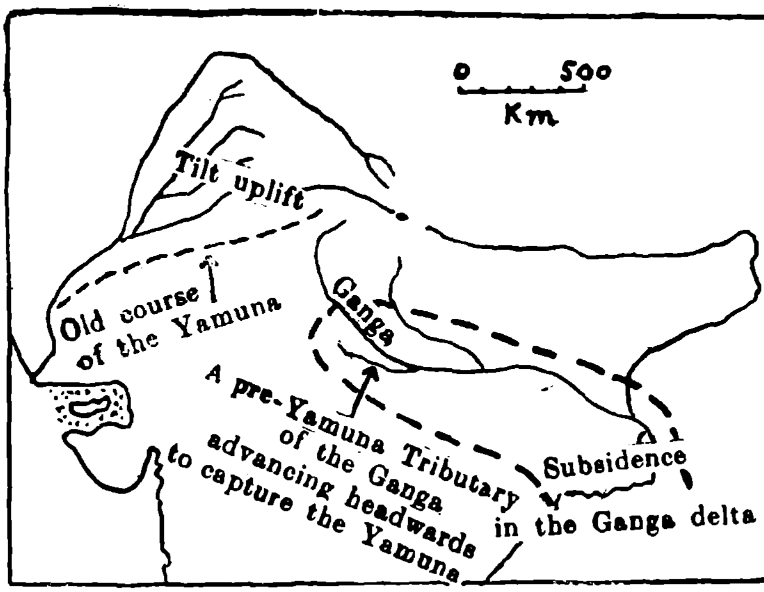
1. D. N. Wadia— Geology of India, London, 1953, 3rd edn., pp. 55-56.
2. Rig Veda— "Eka· Chetal Saraswati Nadinam.... Girlbhyo Asamudrat." 95-7-2.
3. R. D. Oldham— (1886) On probable changes in the Geography of the Punjab and its Rivers—an historico-geographical study. Jour. Asso. Soc. 55.
4. C. F. Oldham— (1893)—The Saraswati and the 'lost' river of the Indian Desert. Jour. Roy. Asso. Soc. N.S. 25, 49-76.
5. M. S. Krishnan— Geological History of Rajasthan, Proceeding of the Symposium on the Rajputana Desert, N.I.S., New Delhi, 1952, 27-29.

place for bathing and homage by the pilgrims, and the 'Pandas' of the Triveni Sangam tell the pilgrims that the third stream is that of Saraswati, which comes up from below at the confluence of the Yamuna and the Ganga.

C. S. Fox, once Director Geological Survey of India, supports the view of the shift of the Yamuna from Indus basin to the Ganga basin, "No great change of watershed has taken place in this region since the Jumna was captured by the Ganges."[1] D. N. Wadia confirms this whole geological change in clear words, "There are both physical and historical grounds for the belief that Jumna during early historic times discharged into the Indus system though now neglected bed of Saraswati river of Hindu tradition, its present courses to Prayag being of late acquisition."[2]



From Post-mid-Miocene to Recent Age, the Yamuna belonged to the Indus Drainage System.
In the Sub-Recent Age, it has become a member of the Ganga Drainage system.

The present valley of the Yamuna in the plains

The present basin of the Yamuna in the plains has five sub-sections :—

1. From the debouch near Kalesar (30° 22′ N 77° 35′ E) to Bidauli in Muzaffarnagar district, 118 km, southwesterly direction. Its upper part exists in 'Chos' belt, which is a longitudinal strip lying south of the Siwalik hills. A 'Cho' is a rainy-season streamlet flowing a broad shallow valley of sand. Hardly a few of these Chos carry their water

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1. C. S. Fox— Physical Geography for Indian Students, Macmillan, London, 1942, pp. 319-20.
2. D. N. Wadia— Op. Cit., pp. 55-56.

upto the Yamuna, e.g. Somb and Boli Nadi in Chhachhowli on the right bank, and Maskara on the left bank.

Two irrigation canals, the eastern Yamuna canal and the western Yamuna canal, are taken out from the Yamuna near Tajwala (Faizabad) in Saharanpur district, about 25 km below the debouch.

2. From Bidauli to Delhi, 128 km, southward direction. This part of the Yamuna basin has a great politico-cultural importance, as given in the sequel. Kurukshetra, Thaneshwar, Karnal, Panipat and Delhi have been the cockpits of colossal warfares, right from Epic Mahabharat to Prithvi Raj, Mohammed Ghori, Mughals, Marahattas and the British. Agra canal is taken off from the Yamuna near Okhla (New Delhi).

3. From Delhi to Mathura, 170 km, southerly direction. Tributary Hindan pours its waters into the Yamuna on the left bank near Dankaur. This portion is also of great politico-cultural importance.

4. Mathura to Agra 64 km, southsoutheasterly direction. It does not have so much of physical importance as political and cultural importance of Mathura and Agra.

5. Agra to Mau in Banda district, 696 km, southeasterly direction. The river passes the towns of Firozabad, Etawah, Auriya and Hamirpur. On its left bank it receives two small tributaries Karwan and Sengar, while the right bank tributaries are Banganga, Chambal (the largest tributary 1,040 km, Sind, Betwa and Ken, which have their sources in the Vindhya hills and Bhanrer hills. Irrigation canals are taken out from Chambal, Betwa and Ken.

6. Mau (Banda) to Allahabad, 72 km, northeasterly direction. Yamuna confluences with the Ganga at 25° 25′ N, 81° 54′ E.

Morphometry of the Yamuna valley

Excluding the details of the tributary valleys, a brief account of the morphometric study of the Yamuna valley is presented here. Although the altitude of the Bandarpunch group of peaks is above 6,000 meters the average altitude of the Himalayan Yamuna drainage, including those of Tons and Giri tributaries, ranges from 2,000 to 350 metres from northeast to southwest.

Rate of fall (Vertical interval) in the valley profile of the Yamuna

In the Himalayan area, the Yamuna valley has a very steep profile, but in the plains it is very gently graded and gradually it becomes almost flat. The altitude of the source is 3,255 metres and the altitude of confluence at Allahabad is 94 metres.

The total length of the Yamuna is 1,376 km. The horizontal equivalents and the rate of fall per km in the different important sections of the valley are given below :—

Sub-section of the valley				Horizontal equivalent in km	Total fall vertical interval in meters	Rate of fall per km
Higher Point.	altitude in meters	Lower Point.	altitude in meters			
(a) In the Himalayan area						
Source	3255	Pali Gad	1785	25 km	1470	59 m
Pali Gad	1785	Debouch near Kalesar	348	127 km	1437	11.3 m
(b) In the Plain area						
Kalesar	348	Delhi	236	398 km	112	0·3 m
Delhi	236	Mathura	168	170 km	68	0·4 m
Mathura	168	Agra	154	64 km	14	0·22 m
Agra	154	Allahabad	94	768 km	60	0·08 m

The above figure clearly present the great difference in the rate of fall in the valley profile in the Himalayan basin and the plain basin. In the first 25 km the valley falls at the rate of 59 metres per km while in the long section from Agra to Allahabad in 768 km the rate of fall is only 0·08 metres per km.

Averages :

Total Himalayan valley—152 km—rate of fall 19·1 metres per km.
Total Plain valley—1,224 km—rate of fall 0·2 metres per km.

Relative relief

Himalayan valley
30 percent High (RH)—240 metres and above.
35 percent Moderate high—120 to 240 metres.
20 percent Moderate—60 to 120 metres.
15 percent Low—30 to 40 metres—(In Dun valley).

Plain valley
18 percent Low—30 to 60 metres (In Ravine lands).
82 percent Extremely low—Below 30 metres.

Dissection index :

Himalayan Yamuna valley
38 percent High (DH) above 0·3
52 percent Moderate (DM) 0·1-0·3
10 percent Low—Less than 0·1

Plain Yamuna valley

22 percent Moderate (DM) 0·1-0·3— (Mainly in Ravine areas)

78 percent Low (DL) Below 0·1

Drainage texture :

Himalayan Yamuna basin :—

25 percent very fine (TVF)
60 percent fine (TF)
15 percent moderate (Most of this degree in the Dun valley).

Plain Yamuna basin :—

70 percent moderate (TM)
30 percent coarse (TC)

Slope

Himalayan Yamuna basin :—

9 percent escarp steep (In Bandarpunch peak zone ; (Chaur peak zone, etc.)

30 percent very steep— 40°-60°

32 percent steep— 25°-40°

29 percent moderate steep 10°-25°.

Plain Yamuna basin :—

28 percent gentle 2°-5°

72 percent level—below 2°

The plain basin of Yamuna is composed of alluvia. The newer alluvium lying along the river bed is called 'Khadar', while the older alluvial deposits lie away from the beds, and they are called 'Bangar'. The deposits are composed of sand and silt, containing a good proportion of lime concretions.

Water potential of the Yamuna

The Yamuna basin has a much larger catchment area in the plains than that in the mountains, yet the water potential of the Himalayan Yamuna basin is much greater than that of the plain basin.

Himalayan basin catchment area	8,280 km²
Plain basin catchment area	297,300 km²
Total catchment area	305,580 km²

The average annual rainfall in the Himalayan Yamuna basin is about 150 cm, while that in the plain basin is about 75 cm.

Water brought by the Yamuna from the Himalaya is mostly given away to the irrigation canals below the debouch near Faizabad ; and rainfall in the plains is not adequate for any perennial canals (except the Agra canal) from the Yamuna. Of course, canals have been out off from the tributary streams of the Chambal, Betwa and Ken.

In the Himalayan area small irrigation channels, called 'Kuls' are taken off the affluents to irrigate field-terraces, around scattered hamlets or villages. Area irrigated by the Himalayan basin is about 41,000 hectares, including the area irrigated by the Doon canal.

In the plains, there are three irrigation canals of the Yamuna :—

1. Eastern Yamuna canal } both are taken off at Tajwala near
2. Western Yamuna canal } Faizabad (Saharanpur dist.)
3. Agra canal, taken away near Okhla (New Delhi).

In mid-historic period, the first canal from the Yamuna was dug in the reign of Firoz Shah Tughlak, for a length of about 160 km into the district of Hisar in Haryana. In the 16th century it was restored by Akbar ; and one branch was brought to Delhi. In the 19th century British engineers reconstructed this Western Yamuna canal, which has been fully developed now for more than 600 km length.

Eastern Yamuna canal, length 206 km

Discharge of the canal at head—63 cm m per sec ;
Culturable commanded area 476,600 hectares ;
Gross area irrigated per year 200,000 hectares ;
Average annual rainfall in the area 80 cm.

Western Yamuna canal, length 646 km.

Discharge of the canal at head—218 cu m per sec ;
Culturable commanded area 1045,700 hectares ;
Gross area irrigated per year 532,600 hectares ;
Average annual rainfall in the area 70 cm.

Agra canal, length 267 km ;

Discharge of the canal at head—54 cu m per sec ;
Culturable commanded area 496,560 hectares ;
Gross area irrigated per year 167,450 hectares ;
Average annual rainfall in the area 62 cm.

Doon canal from the Yamuna, the Tons and the Song, length 35 km ;

Culturable commanded area 18,360 hectares ;
Gross area irrigated per year 11,280 hectares ;
Rainfall in the area 212 cm.

Hydro-electric power

Stage I—Yamuna Hydro-electric scheme in district Dehra Dun, at Dakpathar 2 km down the confluence of the Yamuna and the Tons. Installed capacity 56,000 kW.

Stage II—Diversion dam at Ichari across the Tons. Height of the dam 48 m ; circular lined tunnel diameter 7 m and 6 km long ; firm discharge available for power generation 52 cu m per sec ; storage 14,308,000 m^3 ;

Chambal Project (for Madhya Pradesh and Rajasthan)

On Chambal, the biggest tributary of the Yamuna in the plain basin. Chambal rises in the northern slopes of the Vindhyas at an altitude of 840 metres. After traversing a course of about 960 km it confluences with the Yamuna near Etawah. The catchment area of Chambal is 143,225 km^2. From its source to its confluence, the river has a descent of about 720 metres ; of this 240 metres are in the first few km and further 120 metres upto Kota. Chambal carries a consider able volume of water in the monsoons, but is reduced to a trickle in dry months. Therefore, to assure irrigation and power, water has been stored by dams and a barrage.

Three dams : Gandhi Sagar dam, 8 km downstreams of Chowrasiagarh ; capacity 8,449 million m^3 ; power 92,000 kW.

Rana Pratap Sagar dam, 32 km down Gandhi Sagar dam ; capacity 2,899 million m^3 power 128,000 kW.

Kota dam, 16 km upstream of the town of Kota, power 81,000 kW.

Kota barrage will divert water through two canals—

Left Main canal will irrigate 104,000 hectares ;
Right Main canal will irrigate 320,000 hectares ;

On completion, the Chambal Valley Project will irrigate annually 0·45 million hectares of land, adding 5 lakh tons of foodgrains annually, and will generate 301,000 kilowatts of power.

Politico-Cultural importance of the Yamuna

Amongst the holy waters of India, the name of the Yamuna is often linked with that of the sacred Ganga. The area existing to the west and east of the Yamuna has been a region of perennial cultural evolution throughout the historic times. Great empires, since the very age of Mahabharata, have flourished on this land. Golden ages of the Mauryas, Guptas and Harshas and afterwards the rules of Muslims, Moghals, Marathas, and the British have had their day in this region. Places between Thaneshwar and Agra—Kurukshetra, Thaneshwar, Karnal, Panipat, Delhi, Mathura, Bharatpur and Agra—belong to the vast cockpit, in which the battles between the Kauravas and Pandavas, Mohammad Ghori and Rajputs, Sultans and Rajputs, Sultans and Moghuls, Afghans and Moghals, Marathas and Moghals, Marathas and the British, and the British and Sikhs were fought for power.

The famous cities of Delhi, Mathura, Agra and Allahabad exist on the bank of the Yamuna.

Delhi has been the administrative seat of India. The old fort of Delhi and Indraprastha denote the golden rule of the Pandavas during the period of Mahabharata. Afterwards, Delhi has been shifting to nine different spots during the successive reigns of Prithvi Raj, Sultans and Moghals. The British rulers made New Delhi the seat of their administration. Thus, the actual location of the fort of ruling throne has been shifting in the same locality, west of the Yamuna. Delhi is also a seat of learning, commerce, small industries, crafts and fine arts.

Mathura, at least as old as Delhi, might be older. It is a pre-Buddhistic town ; and it flourished fully during the days of Buddha. Cunningham writes, "The holy city of Mathura is one of the most ancient places of India."[1] Excavations from an old mound[2] prove that it is the remains of at least of two large Buddhist monasteries of as early a date as the beginning of the Christian era." Fa Hien mentions Mathura as a centre of Buddhism ; Hsiuan Tsang writes that it contained 20 Buddhist monasteries, 5 Brahmanical temples. It is famous as the holy place of Lord Krishna. Mathura is 'Modura' of Ptolemy and 'Methoras' of Pliny. Thus, it has been a seat of learning and religious culture. At present Mathura is a famous pilgrimage centre of Hindus, and pilgrims

1. A. Cunningham— The Ancient Geography of India, I, 1871, p. 315.

2. A. Cunningham— Op. cit.

come from all parts of India to pay their visits to Mathura and its neighbouring area, called Braj-Mandal.

Agra has shared as administrative seat with Delhi, during the rule of Moghul kings. Original town was on the right bank of the Yamuna. Present city was developed as a capital during the Moghul period. It is famous for Taj Mahal built by Shahjahan. It is a commercial town with cotton textiles, gins, flour mills, carpet industry and stone-carving craft.

Allahabad is situated on the confluence of Yamuna and Ganga. Its old name is Prayag. The fort of Asoka the Great was built about 235 B.C. ; it was reconstructed in the 16th century by Akbar, who renamed the city as Allahabad. Prayag has been a seat of learning (from Buddhist monasteries to present day University), Culture and pilgrimage. Millions of Hindus take their sacred bath at the Triveni Sangam (confluence), where every sixth year there is held a great Kumbha fair.

Of the Himalayan Yamuna basin, two important places must be mentioned : Kalsi and Yamunotri.

Kalsi is situated near the confluence of the Tons and the Yamuna. There was a Buddhist monastery here, during the period of Asoka, whose pillar inscriptions are preserved in a monument even today, although the monastery was flooded away by the Yamuna in a deluge. It exists on the route to Kashmir, Himachal Pradesh and further to Tibet.

Yamunotri, the source of the Yamuna, is also a sacred place of pilgrimage, and every summer about 400,000 pilgrims from all parts of India go to pay their homage at the shrine.

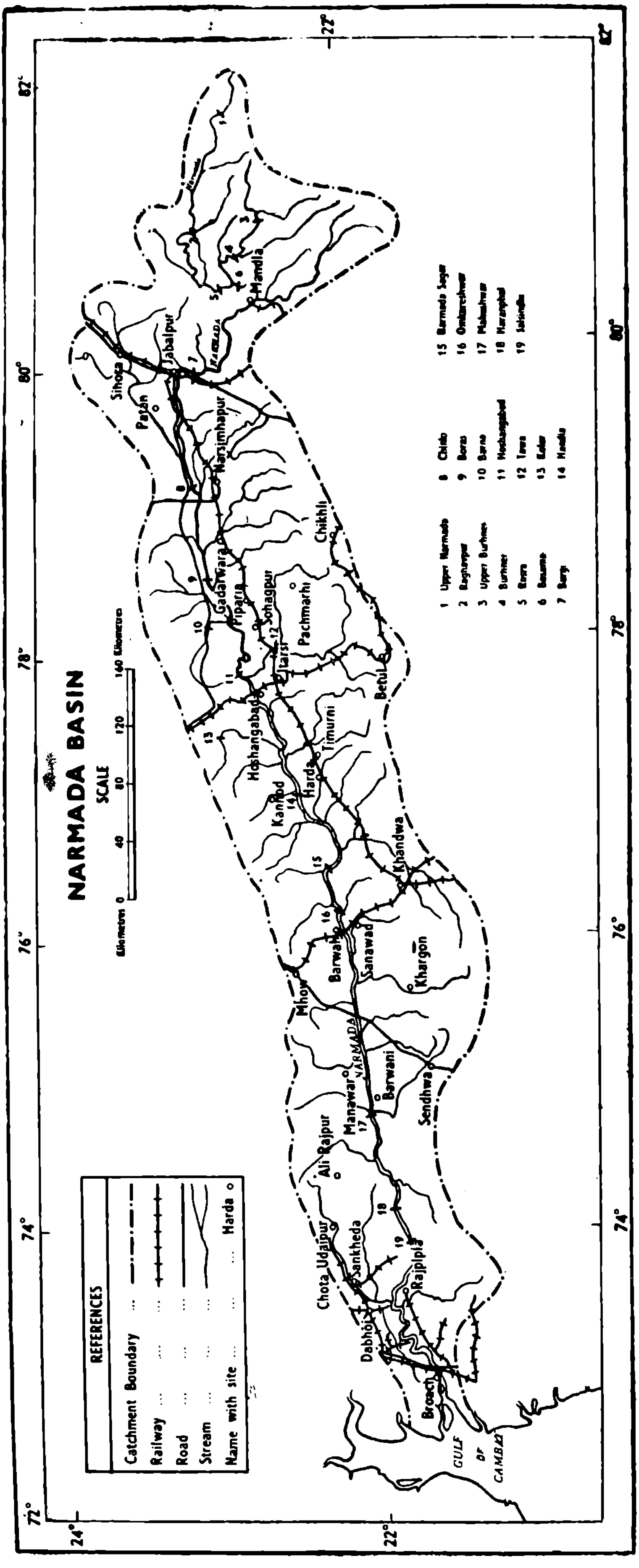
CHAPTER XXVI

THE NARMADA

The Narmada is one of the twin rivers of Central India which though drains part of the peninsular India, flows against its general slope i.e., from east to west. For about 1,078 km it flows through Madhya Pradesh and its valley lies in Mandla, Jabalpur, Narsimhapur, Hoshangabad, East Nimar and West Nimar districts. For next 32 kilometres it makes the boundary between Madhya Pradesh and Maharashtra and for another 40 kilometres between Maharashtra and Gujarat. The lower reaches of about 160 km are in the State of Gujarat. Thus the total length of Narmada is about 1,310 km and the total area of the basin is approximately 98,420 km^2.

According to the conventional concept the Narmada—Son axis is taken as the physical boundary between northern India and Deccan Tableland. Narmada takes rise in the east central highland which is the source region or many other rivers like Son, Mahanadi, Wainganga and Tapi. This highland is marked by its elevation, hilly nature and high rainfall. To be precise the source of the Narmada is in Amarkantak (1,057 m), one of the highest spots of Maikala range.

Upper hilly tract : In the upper section Narmada and its tributaries have a fan-shaped hilly basin where the general slope is towards north and northwest. Here the river valleys are narrow and deep and the river course winding. At place, the Narmada takes pin-head turns and at a similar turn the town of Mandla is situated. Between Mandla and Jabalpur the valley is comparatively open. Only near Jabalpur, Narmada emerges from the narrow valley and the termination is marked by the famous Dhuandhar falls and by a very narrow deep gorge cut in white marble. Though the fall is only 15 m high, the youthful condition of the river is very well evident by rapid-like descent, rocky narrow bed, dissected banks and 3 kilometres long gorge in front of the fall. These outcrops containing marble belongs to Chilpi series of Dharwar system and are perfectly crystalline dolomite limestone. The river cuts its gorge into this marble and Deccan traps which at places is only 6 m wide. The slopes are just wall life precipice of white marble into which flows Narmada with its deep blue waters. Here the gradient and depth is considerable hence approach to Marble Rocks is possible only after monsoons are over. In this upper basin the average descent is 7—9 m per km.


NARMADA BASIN
SCALE
Kilometres 0 40 80 120 160 Kilometres
REFERENCES
Catchment Boundary
Railway
Road
Stream
Name with site ... Harda
NARMADA
GULF OF CAMBAY
Jabalpur
Sihora
Patan
Narsimhapur
Mandla
Gadarwara
Piparia
Sohagpur
Pachmarhi
Chikhli
Itarsi
Hoshangabad
Timurni
Harda
Kanod
Betul
Khandwa
Barwaha
Sanawad
Khargon
Mhow
Manawar
Barwani
Sendhwa
Ali Rajpur
Chota Udaipur
Sankheda
Rajpipla
Dabhoi
Broach
72°
74°
76°
78°
80°
82°
22°
24°

The plain : Below Jabalpur the Narmada enters a rather open fertile plain. But the basin is narrow and elongated with well defined northern and southern natural boundaries. In the north the Vindhyan and Bhanrer ranges rise with wall-like escarpments of sandstones which are remarkably continuous and may be crossed only at a few places. From the crest of these ranges, there is a gentle slope northwards and the watershed runs along this crest hence the tributaries of Narmada drain only the scarp face. The fact explains the short and insignificant northern tributaries of the river. The only exception is the Hiran (catchment area 4,791 km^2) which flows parallel to the Bhanrer range in Jabalpur district for quite some distance. Other right-hand tributaries which need a reference are Barna, Kolar and Orsang (catchment areas being 787, and 4,079 km^2 respectively). The southern margin of the basin is made by the Satpura range, the highest in it are the Mahadeo hills. These ranges themselves are elongated and narrow. A number of tributaries of the Narmada drain the northern slopes of these ranges, the important amongst them are Tawa, Chota Tawa and Kundi river (catchment areas 6,333, 5,050 and 3,820 km^2).

Near the confluence of Chota Tawa low hills again approach Narmada and at Mandhar and Dardi are two waterfalls of 12 m each. About 34 kilometres before Mandhar fall is the Punasa dam site. This narrow section separates the upper and the lower Narmada plain. The latter extends upto Barwani, located on the northern bank of the river. In the middle of this plain near Maheshwar, the river again descends from another small fall of 8 m called Sahasradhara falls.

The Narmada enters the last gorge near Haringpal and emerges in the Gujarat plain east of Rajpipla. In this section it has almost a straight course and adjacent tract is hilly and dissected and clothed with dense forests. In this gorge the average descent is about 0·71 m per km.

In the Gujarat plain the Narmada flows through an open terrain and has a meandering channel. It is this lower plain which from time to time experiences serious floods. Below the city of Broach the river widens out and meets the Arabian Sea in the form of an estuary. At the confluence the mouth is about 28 km wide.

Tectonic characteristics and geology : The analysis of the physical features and the drainage give ample evidence that the basin of Narmada is distinctly different from other rivers of adjoining areas and has a pronounced narrow and elongated shape. In contrast to other major rivers of peninsular India, it has not attained mature stage and still has well-defined ungraded sections marked by water-falls, very steep descent and narrow gorges. These features have been attributed to the recent tectonic disturbances and the valley has been designated as a rift valley with bounding uplifted blocks viz., Vindhyans and Satpuras.

The Narmada basin has exposures of Archaean, Purana and Aryan groups. However, for practical purposes it may safely be said that the river flows through Deccan traps along two third of its course, while in its middle and lower courses there are thick alluvial deposits in which the river has entrenched. Only for 3 kilometres in the middle it runs through granites and gneisses, the Bijawar series and the Vindhyan system. The same formations again appear in the extreme upper part of the basin, south of Mandla. Another extensive exposure of granites and gneisses is again found in the upper Tawa basin and in the form of scattered small outcrops of the Kolhan and Bijawar series north of Jabalpur. An elongated narrow belt of the Vindhya formations is found north of the river in its middle valley. The other major representative is of Lower and Middle Gondwana system belonging to Upper Carboniferous to Upper Cretaceous in age. The extensive exposures of these are in the Mahadeo hills. These are a great thickness of massive red and yellow course sandstones, conglomerates, grits and shales. The coal deposits belong to Jabalpur, Bijori and Barakar series. The formations are intensively dissected and steep scarpments and deep gorges are a frequent phenomena. This Gondwana basin has faulted margins both in the north and the south.

Water resources : Narmada river basin receives a reasonably high rainfall. Average annual rainfall is highest in the upper hilly track of Maikala range and Satpura range in the south. The former is encircled by the isohyet of 140 cm while the latter has rainfall above 114 cm to 127 cm. The rainfall decreases in the lower plain and drops down to 64 cm to 76 cm. However, on account of the nearness of the sea, it further increase to 102 cm to 127 cm in the Gujarat plain.

Having a perfect system of drainage, the Narmada and its tributaries bring a very large amount of water which practically goes waste to the Arabian Sea. The magnitude of the water resources may be realized by the fact that the Narmada brings water almost equal to Sutlej and Beas combined and the average annual flow at Gardeshwar, the lower most discharge site, is 38,670 million cubic metres. The figures for other sites are as follows :

Average flow of Narmada

(in million cubic metres)

		Jamatra	Tawa	Mortakka	Gardeshwar
July to Oct	..	8,918·06	345·37	29,739·20	35,400·88
Nov. to June	..	493·39	197·36	2,676·65	3,268·72
Annual	..	9,411·45	3,651·10	26,248·45	38,669·60

Though the figures for maximum and minimum flow vary considerably and annual average may give a rather bright picture yet for development purpose 75 percent as dependable figures have been taken into account.

Before 1947, practically no efforts were made to utilize these water resources, either for irrigation and power or for navigation. Inspite of the fact that the region was far away from the major sources of coal in Bengal and Bihar, this state of affair continued. The basin contained fertile black soil which could be utilized intensively, had mineral resources like iron, manganese, dolomite and lime stone and it had an outlet towards west which had its own advantages for entry into the interior of the country. The Narmada, without any development is navigable for 112 kilometres from its mouth. In fact on account of steep, narrow and interrupted longitudinal profile, forest-clad surrounding hilly tract, the Narmada never remained a line of assembly and attraction for the people but a line of demarcation of the boundary and a barrier for passage across the country. The basin thus remained one of the relatively under-developed areas of the country.

Land use in the Narmada basin in Madhya Pradesh

(*in thousand hectares*)

Gross area	Area under forest	Cultivable area	Net sown area	Area irrigated
8,593	2,836	5,189	3,328	89

These figures by themselves explain that all the cultivable area has not been intensively utilized. The production of both food crops and industrial crops may be increased by providing reliable supply of water through irrigation. The present irrigated land is only 2·5 percent of the net sown area. The above facts further show that one third of the basin is still under forests and out of that 1·7 million hectares are of reserved forests. But this resource is also awaiting a proper development and utilization for want of power, means of transport and market in the form of industries using forest products.

A close study reveals the fact that amongst the food crops rice and millets are important in the hilly tract, wheat and jowar predominate in the upper plain. In the lower plain and the hilly tract they are replaced by cotton, oil seeds and jowar. All these crops may be benefited if irrigation facilities are made available.

Development of water resources : The preliminary investigations in 1947 onwards done by the Central Water and Power Commission proved that besides irrigation, the Narmada and its tributaries have potentials of hydro-electricity of about 1·3 million kW and it could be generated on 16 sites. This may be made possible if the river and its tributaries are regulated through a comprehensive multipurpose valley project. During the first plan only pilot projects to irrigate 36,400 hectares were taken up. During the second plan two major projects, Tawa and Barna with one medium and five minor schemes to irrigate 404,700 hectares were sanctioned but out of the total estimated cost of 33 crores, only 3 crores were allotted to these schemes.

The Tawa multi-purpose project is located in Hoshangabad district. This river drains most of the Mahadeo range and the total catchment fall and the river brings a very large amount of water and the average annual flow is 3,651·10 million cubic metres when the river enters the Narmada valley, it opens out and from time to time causes serious floods. The Tawa project aims at utilizing the water resources both for irrigation and power and for control of floods. The project when complete will comprise 1,654 m long dam and two masonry dykes of 235 m and 238 m long. The length of the canals will be 145 km on the left and 76 km on the right bank. These canals will irrigate 3·0 lakh hectares of land and will help in yielding 207,000 tonnes of additional food grains and 4,12,000 tonnes of cash crops annually. The two stations will produce 20,000 kW of power at 60 percent load factor.

Now a comprehensive plan is being prepared for the development of the water resources of the Narmada basin. The outline of the master plan is already under consideration. Meanwhile intensive investigations are going on for the Bargi and the Narmada (Punasa) Project by the Central Water and Power Commission. Apart from six minor dams and reservoirs in the upper hilly tracts of the Narmada basin there are six proposed dam sites viz., Bargi, Haringpal, Punasa, Barwaha, Jalsindhi and Navagaon. The project when complete will provide irrigation facilities to an area of 2·556 million hectares. The project also aims at power generation of 575,000 kW. The first phase of the development which is expected to start soon would include Narmadasagar (Punasa), both for irrigation and power and Bargi project, power only in the first instance. The Tawa and Barna projects, already under execution, will also be pushed through.

As mentioned before, Narmada is of great significance for navigation since it is one of the twin rivers of peninsular India flowing towards west. And if made navigable upto Hoshangabad, cheap media of transport may be provided upto the heart of the country. Even without any improvement Narmada is navigable in its tidal compartment, upto Broach (48 km from the mouth) by vessels of 70 to 80 tonnes and thereafter by small country crafts upto Chandod (about 64 km upstreams). The port of Broach on this river handles about 85,000 tons annually. But if the Narmada is developed as a navigable waterway, landlocked state of Madhya Pradesh will be opened to sea and that too towards the west.

With the construction of dams and reservoirs navigation possibilities will definitely increase but further improvement will be required in sections of steep drop and of silting in the Gujarat plain. The Master Plan for the Narmada basin has a ambitious scheme to connect the river to Ganga through Son, Chambal via Karma river and to the Yamuna via Bearma and Ken rivers. But these schemes seem too ambitious at this stage.

It may be realized that with vast resources of the Narmada basin for power, irrigation and navigation, a sound base for economic development will be created. It will intensify agricultural landuse, would help the exploitation of mineral and forest resources, and with these and the agricultural products development of industries would be possible, not only in the basin but also in the adjoining areas too.

CHAPTER XXVII

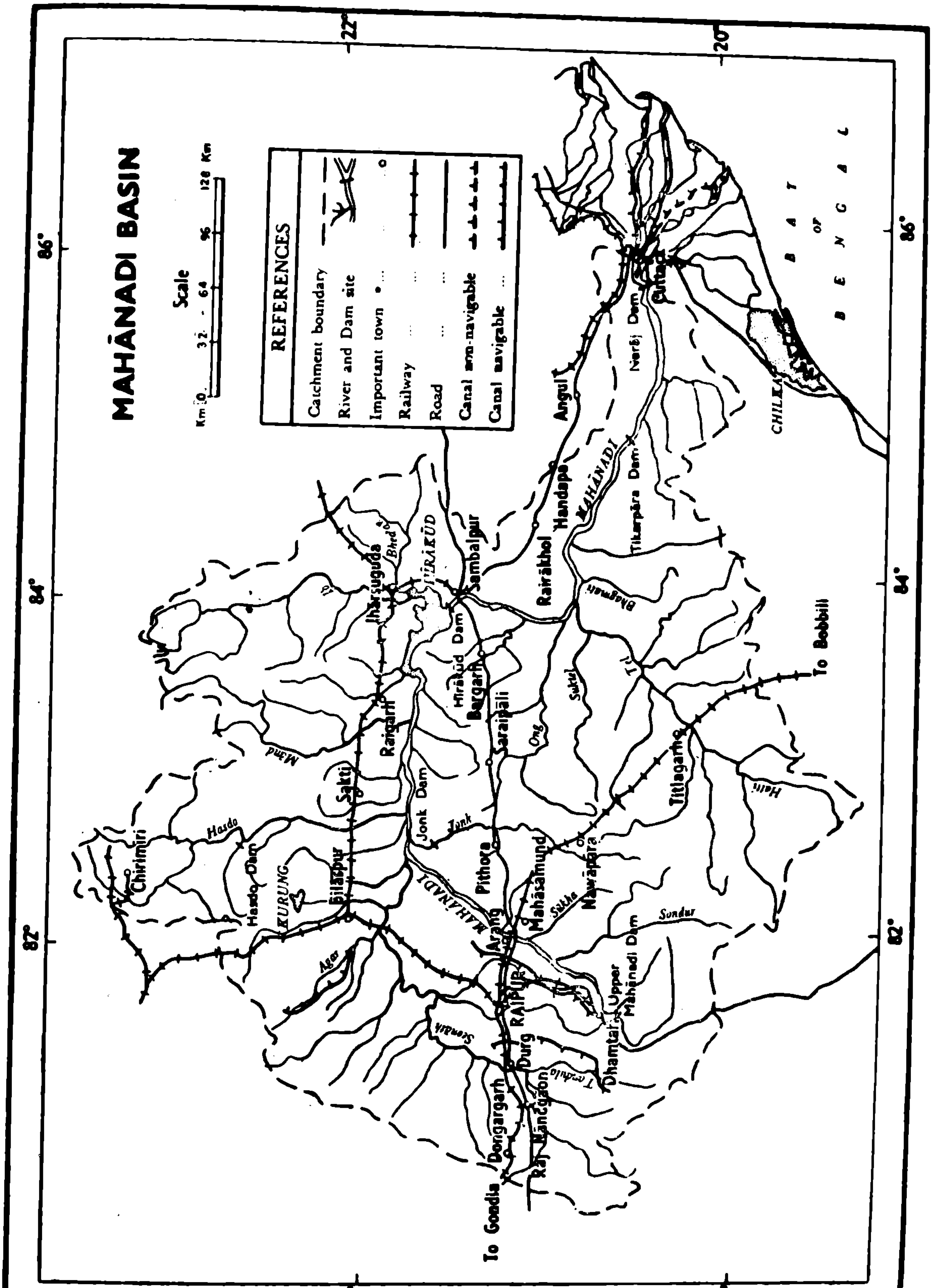
THE MAHANADI

The Mahanadi is one of the major rivers of northern peninsular India which drains to the Bay of Bengal. Its total drainage area is 132,100 km^2 and the total length is 842 km. The upper basin is a saucer-shaped depression, called the Chhattisgarh and is bound in the north by Chotanagpur plateau, in the northwest by the Maikala range and in the south by the highlands of Bastar and the Eastern Ghats. The Mahanadi takes its rise in the Bastar hills near a place called Sihawa in the extreme southwestern part of Raipur district and takes a northeasterly course. In the middle of the Chhattisgarh basin it turns towards east but below Sambalpur the river takes a circutous route around the hills of the Eastern Ghats and cuts through them below Dholpur. In this section the valley as well as the basin narrows down. It is here that the Mahanadi has carved out Satkosia gorge through which it descends down the rapids. Near Naraj, Mahanadi debouches in the coastal plains and below Cuttack it throws off a number of distributaries which combined make a sizeable delta.

Only in the upper basin the Mahanadi receives water of a number of large tributaries which come from north, west and south. Amongst them the important ones with their drainage areas are Ib (12,310 km^2), Mand (5,198 km^2), Hasdo (9,821 km^2), Seonath (184.855 km^2), from the left hand side and Ong (5,887 km^2) Tel (22,800 km^2) from the right hand side. These combined drain practically whole of the southeastern Madhya Pradesh comprising of Raipur, Bilaspur, Raigarh and part of Bastar district. The inter-state boundary between Madhya Pradesh and Orissa passes through the middle of the basin. In Orissa districts of Sambalpur, Bolangir, Phulbani, Kalahandi, Dhenkanal, Puri and Cuttack wholly or partly fall in this basin.

Geological characteristics of the Mahanadi basin : The upper Mahanadi basin comprises of Cuddapah formations and are surrounded by gneisses and granites. The former are compact and unfossiliferrous shales, grits, quartzites, slates and limestones. Since these have not suffered any serious tectonic disturbance in the later period neither the signs of metamorphosis are well-marked nor are the structural disturbances common. These formations dip at a rather gentle angle.

Only on the northern margin i.e. between the Mahanadi and the Brahmani lie the coal deposits of the Gondwana period and on the


MAHĀNADI BASIN
Scale
Km 0 32 64 96 128 Km
REFERENCES
Catchment boundary
River and Dam site
Important town
Railway
Road
Canal non-navigable
Canal navigable
BAY OF BENGAL
CHILKA
Cuttack
Naraj Dam
Angul
Handapa
MAHĀNADI
Tikarpāra Dam
Rairākhol
Sambalpur
HIRĀKUD
Jharsuguda
Bhedo
Ib
Hirākud Dam
Bargarh
Saraipāli
Ong
Sukel
Tel
Bhagmati
To Bobbili
Raigarh
Sakti
Mānd
Titlagarh
Hatti
Jonk Dam
Jonk
Pithora
Hasdo
Chirimiri
Hasdo Dam
Bilāspur
KURUNG
Mahāsamund
Nawāpāra
Sukhe
Sondur
Arang
MAHANADI
Agar
RAIPUR
Upper Mahānadi Dam
Dhamtari
Seonath
Durg
Tandula
Nāndgaon
Dongargarh
Raj
To Goādia
86°
84°
82°
22°
20°

western and southwestern margins are the Dharwar formations which contain extensive and rich deposits of iron ore and manganese. It is these resources which are providing the basis for industrialisation in the upper Mahanadi basin.

The hill mass south of the Mahanadi constitute of Khondalites and Charnockites which are some of the oldest formations.

Water resources : The average annual rainfall of the Mahanadi basin is 137 cm but is much above this average in the adjoining hills. The perfect drainage brings this water to the river and during the rainy season it swells into a gigantic mass of water. In Sambalpur after the confluence of the Jonk, Hasdo, Ib, Ong and Tel, the Mahanadi becomes more than a kilometre in width during the floods. The respective mean minimum and maximum run-off near Sambalpur have been calculated as 61,674·00, 30,294.27 and 78,794.70 cubic metres. Following are the hydographic records of the Mahanadi :

Barnaul : 209 km down-stream from Hirakud.

Average annual

run-off (pre-Hirakud)	.. 53,779·73	million cubic metres
run-off (post Hirakud)	.. 68,976·20	,, ,, ,,
Minimum flow (1954)	.. 34,389·42	,, ,, ,,
Maximum flow (1961)	.. 119,918·93	,, ,, ,,

The Mahanadi is navigable in its lower reaches. In the hilly tract boats shoot the rapids at a great pace and on their return journey they have to be dragged up from the bank with immense labour. During the rainy season the water is enough in this section but in the dry season its course is broken at several places by rocky outcrops which make the navigation difficult. Boats however, can ascend from its mouth as far as Arang in Raipur district.

In the Chhattisgarh basin and the coastal plain, including the delta, the Mahanadi from time to time causes serious floods and damages the crops, means of transport and communication and the human settlements. Even in the recent years, for example in 1961, 192 villages of Durg, Bilaspur and Raigarh districts were adversely affected by floods and the total damage was upto Rs. 17·87 lakhs. Paddy crop in 3,055 hectares of land were damaged. Similarly, in Orissa in 1927, 1933 and 1937 very high floods occurred and standing crops in extensive areas were completely washed away. In the delta area at such times the Brahmani and the Mahanadi join and they cause great havoc and disaster.

The above statements give an idea that the Mahanadi has ample water resources awaiting development for irrigation and power. But in pre-

Independence days the utilization has been rather meagre. There was no utilization for power and no improvement was made to provide an easily navigable water-way. However, water of the Mahanadi was utilized both in the Chhattisgarh basin and in the delta for irrigation. In the former there were three canal systems : Mahanadi main canal, Tandula canal and Kurung canal. Mahanadi canal has a total length of 221·94 km with four canals viz., Baloda, Mandar, Lavan and Bhata sana. These have a capacity to irrigate 144,829 hectares. Tandula canal has been taken out from the Tandula reservoir which has been errected by damming a tributary of the Seonath. The canal irrigated the agricultural land between the Seonath and the Kharun. Kruang tank impounds the water of the Arpa and the canal taken out from this tank irrigates the land between the Arpa and the Lilagar.

Efforts were also made to utilize the vast water resources in the delta. All the three branches in which the Mahanadi splits, have been regulated by a weir and four canals have been taken out, two from Birupa weir and one with its branch, from Mahanadi weir. These combined had been designed to irrigate 118,200 hectares.

Besides canals, in the Mahanadi basin, small tanks have been a very common source of irrigation. In many villages there are more than one tank and adjoining agricultural lands receive water from them. But the system is neither reliable nor efficient and may be replaced by perennial canals.

Landuse in the Mahanadi basin : Except in the Chhattisgarh and the coastal plain, the Mahanadi basin has an extensive area under forests. It is mainly on account of the hilly nature of the terrain and lack of transport facilities. The Chhattisgarh basin and the coastal plain are the regions of red and yellow soil. Combined with high incidence of rainfall, these are predominantly rice growing areas. Other important crops are pulses, linseed and wheat. The double cropped area is rather limited and the main hindrance is the seasonal rainfall and limited irrigation facilities. The landuse in the Mahanadi basin shows that the land resources are not put to intensive use :

	In lakh hectares
Basin drainage area	77.4
Net cultivated area	32.2
Fallow and uncultivated land	12.76
Forest	27.11
Area not available for cultivation	5.38

Water resource development : Only after Independence attention has been given to the water resources of the Mahanadi basin, their meagre utilization and the serious damage by floods. Thus the systematic investigations have been made regarding the water resource potentials and the possibilities of their development. The following table gives a clear idea of the water resources of the Mahanadi basin and the possibilities of its utilization.

Average annual run-off ..	35,524	million cubic metres
Utilizable run-off ..	18,502	" " "
Total cultivable area ..	81	lakh hectares
Total that can be irrigated ..	22	" "

Estimates have also been made on the basis of many medium schemes, both multipurpose and exclusively for irrigation.

Number of schemes		Probable utilization: Irrigation in lakh hectares	Probable utilization: Power (MW)
Multi-purpose	12	5·05	171·2
Irrigation	39	4·21	..

These schemes are essentially for the utilization of the water of various tributaries of the Mahanadi. The only exception is Mahanadi hydel canal. The other schemes through which more than 40,450 hectares of land will be irrigated are Jonk (40,450), Pairi (59,500), Mahanadi (40,450), Hasdo-Mand (46,500), (schemes only for irrigation) Mongra (48,500), Arpa (85,000) and Hap (40,500). These schemes will be helpful in increasing the area under irrigation in the three districts of upper Mahanadi basin. Following is the data of the existing irrigated land of the districts in the Mahanadi basin :

Districts	Total irrigated land in hectares	Area irrigated by canals in hectares	Percentage of total irrigated land by canals	Area irrigated by other sources in hectares	Percentage of the total irrigated land by other sources
Bilaspur	87,560	69,325	79·4	18,219	20·6
Raipur	147,675	111,565	75·5	36,110	24·5
Raigarh	4,492	..	..	4,492	100·0

Mahanadi multipurpose project : Mahanadi project is parallel to, but much larger than Damodar valley project. It is one of those comprehensive schemes which were taken up in the First Five Year Plan and still are not complete because of the gigantic task and the is to regulate the Mahanadi itself by the construction of three dams across the river viz., Hirakud, Tikarpara and Naraj. So far, Hirakud project has been completed and the work at Tikarpara has started recently. Even the former has been divided into two stages, the first being the Hirakud dam in Sambalpur district, Orissa, with its power house having an installed capacity of 123,000 kW. This work was completed in 1957. The dam is 49 m high and 4,800 m long and the reservoir impounds 81,410 lakh cubic metres of water. Three canals have been taken out viz., Sambalpur canal (19 m), Bargarh canal (24 km) and Sason canal (23 km). This irrigated 230,700 hectares of agricultural land in Sambalpur and Bolangir districts of Orissa. The dam and the reservoir also moderate the peak floods in the delta of the river to a safe limit of 0.25 lakh cubic metres per sec. The flood moderation has been done since 1957 yet only in 1964 the actual target has been attained.

The second stage of Hirakud project envisages addition of two more generating units of 37·5 MW each and the construction of Chiplima power house and the installation of three units there of 24 MW each. This work is also complete and now the total installed capacity in this project is 270,000 kW. The power is being supplied to Indian Aluminium Co., Hirakud ; Ferro-magnesium factory, Joda ; Cement Works, Rajgangpur ; Orient Paper Mills, Brajrajnagar ; and to many other industries in the districts of Cuttack, Puri, Sambalpur, Dhenkanal, Sundargarh, Keonjhar, Mayurbhanj, Balasore and Bolangir. The estimated cost of the first and second stages are Rs. 71 crores, and Rs. 15 crores respectively.

The project also includes Mahanadi delta irrigation scheme which was taken up by the Government of Orissa as adjunct to the first stage of the Hirakud project. The scheme consists of a diversion weir at Mundali, to pick up the regulated release of water from Hirakud and remodelling of the existing canal system and weirs on the Mahanadi and the Birupa rivers. On completion, these canals will irrigate a gross area of 6·51 lakh hectares(including the existing area of 80,937 hectares) in Cuttack and Puri districts. By the end of 1962-63, an additional 19,788 hectares of Kharif and 37,722 hectares of Rabi crops have been irrigated by these remodelled canals and their distributaries. The estimated cost of the project is Rs. 27 crores and is expected to be completed in all respects by 1969-70. The immediate benefit of the first stage of Hirakud project is an additional production of 5·6 lakh tons of food grains and 2·4 lakh tons of other agricultural commodities.

A distance of 117 km from Dholpur to Cuttack, has been considerably improved for navigation due to the regulated flow of the Mahanadi.

Recent investigations reveal that the navigation would be possible by shallow-draft power-crafts.

The second dam has been sited across the Mahanadi at Tikarpara. The project as envisaged, comprises the construction of a 1,271 m long dam across the river and a power station with 16 generating units of 125 MW each and a number of sub-stations. The water resources available will include the discharge from Hirakud and 41,440 km^2 of the basin between Hirakud and Tikarpara.

This multipurpose project combined with other small schemes has not only increased the agricultural production but has made it more reliable. It has, at the same time, provided a sound power base for varied and rich mineral wealth, forest and agricultural resources which are awaiting development. They now are being utilized for innumerable primary and secondary industries. The navigable waterway may in future will give a helping hand to the economic development and last but not the least, the regulated flow of the Mahanadi will save a considerable section of the basin from devastating floods.

CHAPTER XXVIII

THE CAUVERY

The Cauvery which is the principal river flowing through Mysore and Madras States is held in great veneration in South India. It is designated as the Dakshina Ganga or the Ganga of the South and local legend says that even the holy Ganga resorts underground once a year to the source of Cauvery to purge herself from the pollution contracted from the crowd of sinners who bathe in her waters. No other river of equal magnitude has brought such untold benefits as the Cauvery to the country through which it flows. The industrial and agricultural prosperity of the States of Mysore and Madras is in no small measure due to this noble river Cauvery. It is no wonder the people consider the land through which it flows as holy ground.

The reputed source of the river is at Talakaveri on the Bramhagiri range of hills (12° 25′ N 75° 34′ E) forming part of the lofty Western Ghats in the district of Coorg. From the geomorphological point of view it is of interest to note that the river originates almost at the very edge of the Western Ghats within sight of the Arabian Sea, but flows eastwards, crossing the mountain barrier. It thus drains a portion of the mountainous country lying to the west of the crest line of the Ghats. The hilly region in Coorg is subject to heavy rainfall during the months of June to September and it is during these months, the river discharges a large volume of water to the thirsty plains below.

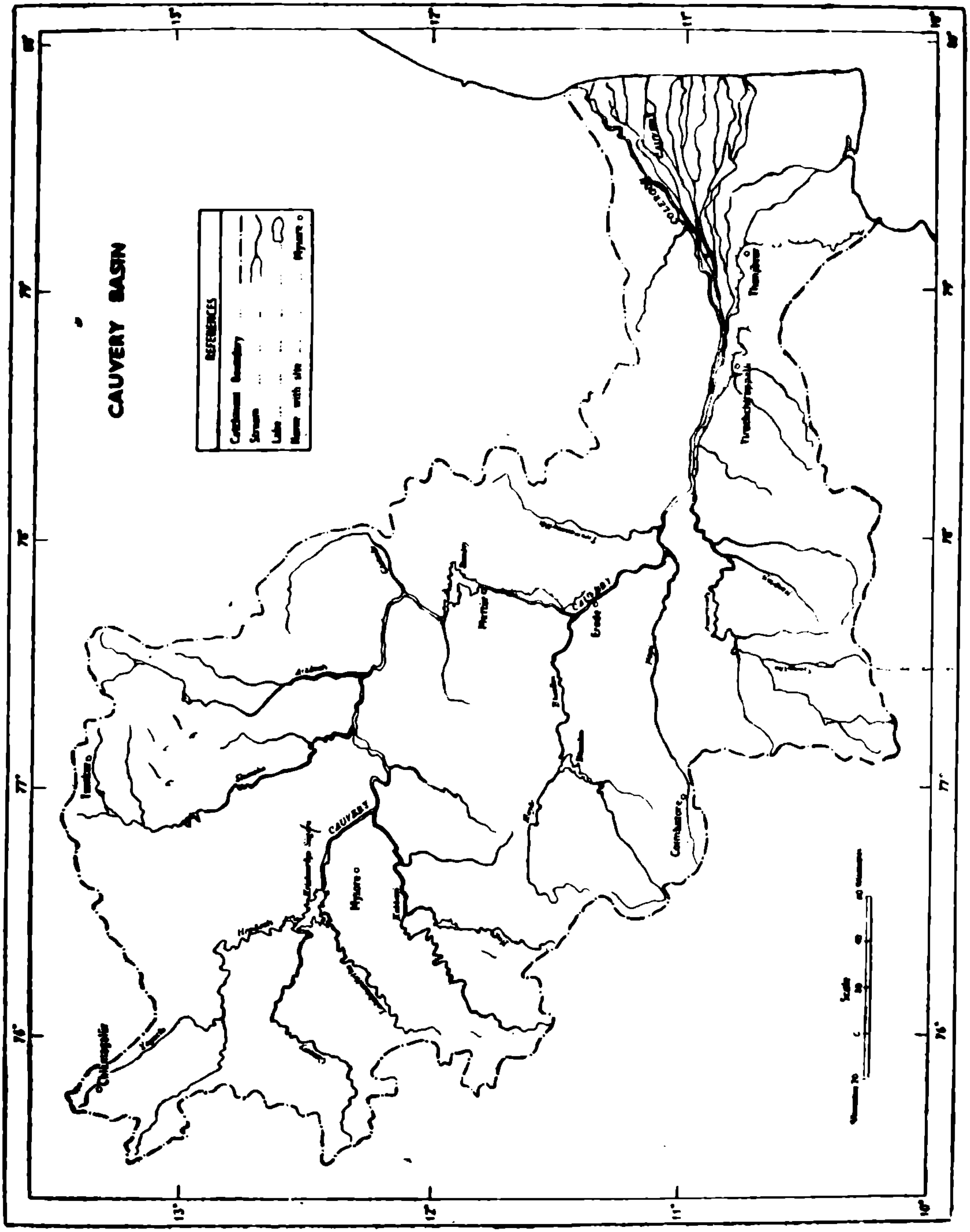
The river, coursing down its place of birth loses height rapidly, falling 450 m within a course of eight kilometres. After Bhagamandala, the river presents all the characters of a mature stream, although still in its initial stages flowing through a mountainous country, and presenting steep banks. The fall in gradient is very gradual and the river cuts across the strike direction of the country rocks, the underlying rock structure exercising little or no control over the course of the river. It gives the impression of an ancient river whose meandering course has been superimposed on a topography which has become youthful as a result of recent uplift.

The middle course of the river over the table land of Mysore with an an average elevation of 750 m above sea level is characterised by broad and sweeping meanders. The country is gently sloping with rich alluvial flats fashioned in the form of terraces to facilitate growing rice. Numerous anicuts (small dams) thrown across its course store and discharge the river water into canals which run for several kilometres on either side. The total length of these canals is upward of 1,900 kilometres over the plateau of Mysore. These dams are of great antiquity some of them constructed over a thousand years ago.

About 19 kilometres northwest of Mysore city is built the celebrated Krishnarajasagara dam across the Cauvery. The dam is 38 m high above the bed level, is 1,996 m long and is capable of storing 1,175 million m^3 of water. The main object with which the dam was built was to ensure steady supply of water to the hydroelectric power station at Shivasamudram lower down and also to bring a large area in parts of Mysore and Mandya districts under cultivation. The river keeps on an easterly course gaining in volume and growing bigger and moving sluggishly in broad meanders. In this section it presents the character of old age suggestive of the ultimate stages of river development.

This feature is very significant for within a few kilometres to the east, the old river suddenly leaps down a precipice cutting its way through a wild and narrow gorge and galloping its way down the ghats. The river which was nearly more than a kilometre wide above the Shivasamudram falls, narrows down considerably and within a distance of 80 kilometres loses height by. nearly 300 m. The river literally leaps down the Mysore plateau in a series of rapids and broken cascades. The waterfalls on the two branches of the river are known as the Gagan Chukki and Bhar Chukki. The huge column of water descends over the rocky ledge raising clouds of foam ascending skyward giving the name Gagan Chukki (Sky spray). The fall of the river has been utilised for the generation of hydro electric power. Constructed in 1902, Shivasamudram station is one of the earliest hydro-electric power installations in the whole of Asia. The two branches after the descent join together and flow in a wild narrow gorge. The flow of the river in this middle section is in marked contrast with the sluggish meandering path it followed before the fall. The new channel is too narrow to accommodate the fury of the flood waters. The hardest rocks have been cut and incised as though they were made of clay. Giant pot holes measuring several metres across and 12 to 15 m deep testify to the enormous erosive power of the mighty river. At one point the channel is so narrow that it is said a goat can leap across. The place is known as Mekedatu (Goat's leap).

The abrupt changes in the course of the river are marked only at points where a tributary comes and joins the main river. The flow gives the impression that the river coming down the ghats has usurped and occupied for short distances the courses of pre-existing streams. These changes have been too recent and the river has not yet had time to adjust itself.


CAUVERY BASIN
REFERENCES
Catchment Boundary
Stream
Lake
Name with site
CAUVERY
Mysore
Erode
Coimbatore
Thanjavur
Scale

At Mettur, just after one more of the right angled bends and capture of the river Palar coming from the east another reservoir has been constructed. Once again the waters of the Cauvery get stored to generate hydroelectric power and also to assure a regular supply of water to the vast delta in Thanjavur district. From Mettur the river follows a straight southerly course upto Bhavani where it joins the Bhavani river coming from the west.

After its sudden leap into youth in the middle section, which ends near Bhavani the river once again picks up its former easterly course and flows majestically to the sea, becoming very wide and spreading its beneficial effects on both the banks. Prosperous towns line the banks of the river. At the upper anicut, the river divides, the northern branch being called the Coleroon, and the southern branch retaining the name of the parent river. The two branches unite again 16 kilometres below Tiruchchirappalli to form the island of Srirangam. The grand anicut is constructed at this junction. It forms the head of the great irrigation system in the Thanjavur district. The irrigation of the delta dating from second century A.D. is one of the most ancient in India. The river waters are entirely regulated and utilised for irrigation. The whole of the taluks of Kumbakonam, Mayuram, Sirkazhi, Nannilam and parts of Thanjavur, Mannargudi, Tirutturaippundi and Nagappattinam are irrigated through the waters of the Cauvery. The lands of these taluks are the best irrigated and the richest lands in Tamilnad. The delta forms one long uninterrupted stretch of rice fields. The surplus water not required for irrigation in the (Thanjavur) delta is diverted to the Coleroon (Kolladam) by means of regulators and the river detours in a northeasterly direction until it discharges to the sea south of Porto-novo. The southern branch is called the Vennar. Both the branches the Kolladam flowing northeast and Vennar flowing southeast bifurs cate and split up into numerous channels and form a vast network irrigating the delta. The Cauvery is acclaimed as one of the best regulated rivers utilising 90 to 95 per cent of the flow. About 0.8 million hectares are irrigated through its waters.

Born as an insignificant streamlet in the mountainous region of Coorg, it starts from its early youth to confer its beneficial effects, bringing wealth and prosperity to the land through which it flows. Even its abrupt leap into youth at Shivasamudram has enabled generation of vast stores of electrical energy enabling its bounty to reach far off corners of the country through which it flows. After conferring such untold benefits in an ever increasing measure till its very end, it merges and becomes one with the sea. It thus exemplifies in its course through Mysore plateau and the plains of Tamilnad, a life of dedicated service. No wonder the people worship it as their divine mother and consider that a dip in its holy waters washes away all their sins.

CHAPTER XXIX

THE BRAHMAPUTRA

Introduction

Brahmaputra meaning the son of Brahma, the creator, is one of the largest rivers of the world traversing a distance of about 2,900 km through Tibet (China), India and Pakistan and draining an area of nearly 580,000 km^2.

In Tibet (China), the river is known as Tsangpo, meaning "the purifier". In India, it has the unique privilege of being called in masculine gender, though all the other Indian rivers are named in feminine gender. Its mighty and turbulent behaviour seems to justify such differential treatment.

Source of river

The Brahmaputra rises in the Great glacier in the northern most chain of the Himalaya in the Kailas range at an elevation of about 5,150 m at a latitude of 30° 31′N, longitude of 82° 10′ E; just south of lake called Konggyu Tsho. It belongs to the family of east flowing rivers of the Himalaya, namely Hwang Ho, Yangtze-Kiang, and Mekong and shares with them most of their riverine characteristics. Many tributaries merge in the infant river from near the Mariam La pass which separates its basin from the Manasarowar lake, in which two other great Indian rivers, the Indus and the Sutlej, have their origin. It is rather remarkable that the two great Indian rivers having their sources almost at the same place on either sides of a divide, traverse in opposite directions east and west of the subcontinent.

Course of the river and the tributaries

The river under its Tibetan name of Tsangpo flows through the southern Tibet for about 1,100 m eastwards, keeping a course roughly parallel to the main range of the Himalaya, meets the first main tributary from north, Raga Tsangpo near Lhatse Dzong ; river Ngang Chu which flows by the large trade centre of Gyantse joins it from south near Shigatse, the second town of Tibet. The river is then replenished by waters of Kyichu from the north. It is an important tributary, on which stands the sacred town of Lhasa, the capital of Tibet.

From Lhatse Dzong, Tsangpo has a wide navigable channel for about 640 km downstream. It is one of the most remarkable navigable waterways of the world with boats sailing at an altitude of 3,650 m and more above mean-sea level.

At Tselha Dzong, the river is joined from the north by the Griamda Chu. Beyond Pe altitude 3,000 m the river abruptly turns to the northeast and north and then traverses in a succession of rapids between high mountains of Gyala Peri, and Namcha Barwa (7,756 m) and turns to the south and southwest to emerge from the foot hills under the name, the Siang and then the Dihang. It enters India across Sadiya frontier tract, west of Sadiya town into the Assam valley. Here it is joined by two more tributaries viz. the Dibang and the Luhit. From here onwards the river is known as the Brahmaputra.

This mighty river then rolls down the Assam valley east to west for a distance of about 720 m with its channels oscillating from side to side and forming many islands. One of these islands is Majuli covering an area of 1,250 km^2. During its course the river receives many more tributaries both from north and south. Some of them are trans-Himalayan rivers with considerable discharges. In the north the principal tributaries are the Subansiri, the Kameng, the Dhansiri, the Manas, the Champamati, the Saralbhanga and the Sankosh. On the south bank the main tributaries are the Noa Dihing, the Buri Dihing, the Disang, the Dikhu and the Kopili.

Traversing round the spurs of the Garo hills, near Goalpara, the river enters Pakistan and flows for a distance of about 270 km across the alluvial plains of East Pakistan before joining the Ganga at Goalundo. The united stream of the Brahmaputra and the Ganga flows under the name of Padma. About 105 km below Goalundo, the main stream is joined on the left bank by another large river, the Meghna, having its source in high mountains in Assam. From the confluence southward, the river now known as Meghna, makes a very broad estuary before its exit into the Bay of Bengal.

The average gradient of the entire river is about 1 : 11400, but there is considerable variation in actual slopes in different reaches. During first 450 km of its journey, the slope is 1 : 1000. In the upper reaches in Assam between Kobo and Dibrugarh it maintains slope of 1 : 3600. The slope between Dibrugarh and Nanmati is 1 : 5500 and between Nunmati and Gauhati is 1 : 7000 and between Gauhati and Dhubri it is 1 : 10000.

Rainfall

The geographical features considerably influence the rainfall distribution in the basin. The upper reach in Tibet is surrounded by high mountains, which do not allow most of the rain clouds to pass. There is is hardly 250 to 500 mm of rainfall, in this trans-Himalayan region. The precipitation in this region is in the form of snow which melts in March.

The Abor and Mishmi hills receive very heavy rainfall of the order of 5,100 to 6,400 mm. annually, brought about by the southwest monsoon.

While the Brahmaputra plain receives about 2,500 to 5,100 mm of annual rainfall. Generally the rainy season extends from May to September. The rainfall is maximum in the months of June and July but sufficient precipitation is experienced in the months of August and September.

Hydrological data

The records of discharge data of the river are scanty. It was only after heavy floods of 1954 that work of gauge discharge observations at some sites in the Brahmaputra basin was started. Earlier, only water levels were being observed on the main river at few points like, Dibrugarh, Gauhati, Tezpur and Dhubri in Assam. Gauge records at these points from 1931 to 1966, indicate some interesting features of the channel regime. While there is a gradual rise in the minimum levels at the three places, Dhubri, Gauhati and Tezpur, the levels at Dibrugarh show a sudden upheaval of the order of 2·44 metres after 1950. It is supposed to bring out the effect of 1950 earthquake which, probably caused a sudden rise of the bed level of the river at Dibrugarh by bringing down large mass of debris to that place. The more gradual rise in the lower sites shows the effect of the debris moving down slowly over years. Similar feature is also seen though not so markedly in the trend of the maximum levels.

The limited data available shows that volume of flow in the Tibetan reach is comparatively small. A study of the maximum discharges at the various sites for the years 1956-61 shows that while Pandu records a peak discharge varying from 50,000 to 70,000 cubic metres per sec, the maximum recorded being 72,460 cubic metres per sec in 1962, while the maximum flow at Tselha Dzong is of the order of 14,000 cubic metres per sec.

Silt data :

The water in the upper reach i.e. in the Tibetan portion is clear and there is not much silt carried by the water. But on entry in India the silt charge is heavy. In winter the Dihang is calm and clear but during floods, it brings down more of sand and boulders. Because of more friable nature of the outer hills, the silt charge in the north bank tributaries is generally greater than tributaries from south. It is noted that while the northern tributaries Subansiri, Rangannadi, and Manas give out average silt yield of the order of 666·7 m^3 per km^2 the silt charge from the south ranges from 95·2 to 666·7 m^3 per km^2. The monthly volume of silt flow in the Brahmaputra at Pandu is given in the following Table :—

Monthly discharge and silt load in Brahmaputra at Pandu

Month	Sediment load (cubic metres).	Discharge volume (Million cubic metres per second).	Percent of silt by volume of discharge.
January	986,784	0·12	0·0093
February	616,740	0·10	0·0074
March	1,480,176	0·14	0·0120
April	1,973,568	0·10	0·0120
May	8,387,664	0·42	0·0230
June	46,255,500	1·06	0·0500
July	118,167,384	1·37	0·0990
August	99,295,140	1·29	0·0900
September	35,770,920	0·68	0·0620
October	9,867,840	0·45	0·0250
November	2,837,004	0·25	0·0130
December	1,110,132	0·16	0·0080
Total	326,748,852		

It is seen that of the annual volume of 326·7 million m^3 of silt about two thirds is carried only in the two months of July and August, and the percentage of silt per unit volume of discharge is maxium in July.

Floods in the Brahmaputra basin

The Brahmaputra has a braided channel in most of its length in Assam. There is constant movement in shifting of these channels and the sandy shoals. The flood discharge and silt charge brought in by various major tributaries at different points also influence the formation of these channels. The deep channel of the Brahmaputra hugs more on the southern bank than on the northern bank. This tendency is apparently enforced by the northern tributaries from the Himalaya which bring copoius discharge and heavy silt charge during the flood season. The northern bank tributaries tend to push the river towards the south.

The rainfall is also concentrated during monsoon months and floods discharges are generally higher than the dominant discharge. Moreover, it is seen that only 27 percent of area in Assam is covered by valleys and 73 percent comprises hill ranges enclosing the valleys from north, east and south.

Under these conditions typical rivers carrying heavy silt charge cannot normally maintain a channel which is capable of carrying the flood discharge within its banks, specially where rainfall is copious in monsoon months.

This results in frequent heavy floods in Assam. The earthquake of 1950 led to numerous landslides in the mountain ranges extending for many kilometres parallel to the right bank of the Brahmaputra. As a result, the charge of material washed into the river increased enormously. This, in turn caused sudden rise in the flow water level which otherwise had been rising gradually every year. This has greatly aggravated the flood situation in Assam.

Spilling over the banks during high floods is therefore a normal feature. In the course of 17 years viz. 1950-1966 the river was in floods during all the years, except 1951, 1952 and 1958.

The floods in Assam affect on an average an area of 8·10 lakh hectares of which about 1·20 lakh heactares are cropped area. The maximum area affected during the period 1953-66 was about 25·10 lakh hectares including about 4·65 lakh hectares of cropped area.

Measures for flood control protection

The River Brahmaputra is turbulent river and has been causing lot of damage to the neighbouring areas and towns along its course. Specially after the earthquake of 1950 the southern channel of the Brahmaputra became violently active, probably on account of aggradation of the north channel due to heavy silt from the landslides. The problem of erosion and flood damage therefore became more acute after heavy floods of 1954.

Though flood protection works in Assam were started long before floods of 1954, the problem had to be tackled as national flood control policy afterwards. Before 1954 protection works consisted of construction of about 170 kilometres of embankments on the Brahmaputra and about 210 kilometres of embankments along the tributaries. After the re-orientation of policy of flood protection however number of schemes were formulated for execution. The works executed so far include construction of embankments on the Brahmaputra and its tributaries, raising and strengthening of existing embankments, improvement of drainage, town protection, and river training works.

Upto the end of Third Five Your Plan the following works were implemented in Brahmaputra basin in Assam :

1.	(a) Total length of embankments along the Brahmaputra.	=	810 km
	(b) Total length of embankments along tributaries of the Brahmaputra.	=	2160 km
2.	Town protection schemes (in number)	=	26
3.	Drainage channels	=	350 km

The Brahmaputra has been one of the most important inland waterways in India since long. Country craft plied between the Ganga and Brahmaputra and there had been the main mode of transport between northern and eastern parts of the country. The comparatively uniform flat slope below Dibrugarh makes the river navigable upto that town. During the British rule steam navigation companies had regular transport services between Bihar, Bengal and Assam. Since the partition of India however the services have been curtailed.

Inland water route on the Brahmaputra is a very important commercial route between Calcutta, East Pakistan and Assam. It is only after the outbreak of hostilities between India and Pakistan during September 1965 that water transport by this route was suspended.

Water resources development

Potential of the river Brahmaputra is indeed very great, but there are practically no possibilities of providing storages on Himalayan tributaries of the Brahmaputra. The southern tributaries of Brahmaputra draining northern Shillong plateau, with intermittent steep stretches, and series of rapids and falls are suitable for hydro-power development. Though the catchment areas above the level stretches of these rivers in upper reaches are small, but the heavy rainfall along the course favours the development of major hydro-electric power on these rivers.

The Barak and the Manipur rivers in Manipur State also have important possibilities of hydro-electric development. Surveys and investigation have been carried out for water resource development in the region. Studies reveal that 49 schemes are technically feasible. Out of these 26 are for irrigation development with irrigation potential of 2·3 million hectares and 23 for power development with estimated power potential of about 10 million kW at 60 percent load factor.

The following are some of the important schemes under construction and or contemplation :

Sl. No.	Name of project	Annual benefits/Power output at 60 percent load factor
1.	Karatoa Talma project	8,800 hectares
2.	Jamuna project	3,4100 hectares
3.	Tista (multipurpose) barrage project.	923,000 hectares
4.	Rikor power project.	2·5 million kW
5.	Pang-I	1·55 million kW
6.	Subansiri	1·00 million kW
7.	Kopili	0·25 million kW (Releases from this project are likely to be used for irrigation)