FLORA OF INDIA

Introductory volume
(Part I)

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Foreword

India with over 45,000 species of flora and 75,000 species of fauna distributed in its two major biogeographic realms having 10 biogeographic zones and two biodiversity hotspot regions of the world, is justifiably recognized as one of the World's 12 magacentres of biodiversity. Such a richness of varied biomes from tropical wet evergreen forests to deserts and alpine vegetation to coastal systems understandably needed the establishment of a well organized institution like the Botanical Survey of India for undertaking detailed botanical explorations and to document systematically this natural heritage.

Since its inception in the year 1890 the BSI, now under the Ministry of Environment and Forests, has been rendering a signal service to the nation through its intensive and extensive surveys and taxonomic studies of India's floristic wealth. The survey work has also unearthed much information on less understood forest Wealth. This has augmented greatly the information base of our wild plant genetic domain so essential for research in agriculture, horticulture, economic botany, medicinal plants, ecosystem dynamics and conservation of natural resources for sustainable development. Decisions on industrial location and infrastructure development are shaped by the work of the BSI on endangered plant species, threatened habitats and fragile ecosystems.

I am glad that BSI's recently launched programme on the preparation of new 'Flora of India' volumes is progressing steadily with five volumes published since 1993 besides the 22 fascicles of the Flora of India with taxonomic revisionary studies. These studies have won international acclaim. I am confident that these two volumes will prove to be of high reference value to students, researchers and project planners and useful in evaluating the status of our flora and conservation needs.

I congratulate the Director, BSI, the authors and the editors for their efforts in bringing out these volumes.

\[N. R. Krishnan\]

Date: 4th June, 1996
Preface

Since the publication of the Flora of British India and the subsequent regional floras, several botanical explorations have been undertaken in different parts of India and publications describing the forests, vegetation types, floristic characteristics (in many cases with detailed lists of floral elements) of many botanically less understood parts in the country have been published especially after the stepping up of botanical exploratory activities by the reorganised Botanical Survey of India in the year 1954. This activity contributed vastly to our better understanding of the vegetation, forest types and floristics and has also greatly enriched the Indian herbaria with botanical specimens from several remote areas and regions of the country which were botanically poorly known in the past enabling the BSI to bring out several state and district floras or of floristically significant areas. The data collected on different aspects relating to the natural vegetation and certain man-made changes in the vegetation patterns particularly during the last one hundred years have necessitated to make suitable amendments to our knowledge on the forest types, phytogeography, endemism on one hand and on the gradual loss of pristine vegetation, habitats and certain floristic elements of significance on the other. This enriched data bank has paved the way to undertake the revision of Flora of India in a new format. Since 1978, the Botanical Survey of India has drawn up plans to bring out revisionary accounts of the flowering plant families and this effort has resulted in the publication of 22 Fascicles of Flora of India and 5 volumes of the revised National Flora till date. It is thought appropriate and necessary to describe different salient aspects pertaining to the Indian floristic richness in different phytogeographical zones in a manner more perceptible and understandable to botanists, foresters, ecologists, conservationists, ethnobotanists, and others interested in our wild plants through several suitably captioned chapters with a view to present an overall panorama of the Indian floristic estate in a book: Flora of India - Introductory Volume. In all about 30 different chapters describing the prime vegetation types in different pytogeographical and ecological systems; ecozones; endemism, centres of plant diversity and phytogeographical affinities; exotics; ethnobotanical, medicinal and plants of economic value; plant based industries; wild relatives of cultivated plants; wild plants of horticultural significance; endangered plants, habitats and their conservation; protected area network; botanic gardens, and the statistical analysis of flowering plants in Indian flora have been considered for this volume.
Accordingly, expertise for writing these chapters has been harnessed both from within the Botanical survey of India and outside organisations, and every possible effort has been made to render them coherent and readable. It is hoped that the collective knowledge in this volume being presented in two parts not only gives an overview of the flora of India but also highlights the most important aspect of action viz., conservation of plant diversity and areas needing urgent action.

In the course of preparation of this volume, the authors and the editors have received great encouragement and valuable suggestions from the Programme Advisory Committee for BSI, several senior botanists in the country and the former Directors of the Botanical Survey of India, from the Secretary, Ministry of Environment and Forests, Government of India and several scientists working in the BSI, which is deeply appreciated and placed on record.

Any suggestions for improvement of the contents of this volume are welcome.
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(G. V. S. Murthy, P. Venu & M. Sanjappa)

India lies between Latitudes 8°4' and 37°6' North and between Longitudes 68°7' and 97°25' East. It lies entirely to the north of the Equator with a greater area in the subtropical zone. The country occupies the largest Peninsula of the continent of Asia and measures 3219 km from north to south and about 2977 km from east to west. The land frontier is about 15,200 km while the coast-line is of 7516.6 km. It includes the mainland's coast-line as well as that of the Indian Islands. It is the seventh largest country in the world with an area of 32,87,263 sq. km. With regard to natural boundaries, the Great Wall of the Himalayas lies in the north. The Thar Desert of Rajasthan stretches across its north-west. In the south it narrows down to form the great Indian Peninsula which ends up in the Indian ocean with Cape Comorin (Kanyakumari) at its southern-most tip. Bay of Bengal lies in the eastern side of Peninsula wherein lie the Andaman and Nicobar Islands. On the West is the Arabian sea with another group of Islands called the Lakshadweep. (Laccadive and Minicoy Islands). These islands are parts of the Indian territory. In the east, the country is separated from Myanmar by long mountain ranges in north-south direction. The countries that touch India's border from west to east are Pakistan, Afghanistan, Nepal, Bhutan, China, Tibet Bangladesh and Myanmar (Anonymous, 1992 ; Singh, 1971).

Physiographically, India can be divided into three major divisions (a) the Peninsula, (b) the Extra Peninsula and (c) the North Indian Alluvial Plains. (Map 1)

Location-wise, the Peninsula is a triangular plateau bordered by the Vindhyan ranges in the north. The Extra-Peninsula at the northern extremity of the country constitutes the lofty Himalayan and other mountains. The third division, the Alluvial Plains exist in between the Peninsula and the Extra-Peninsula. Comprising extensive plains of Assam, West Bengal, Bihar, Uttar Pradesh and Punjab.

Stratigraphically, the Peninsula constitutes rocks of different age groups. Majorly, it is made of very ancient rocks of Archaean and Precambrian groups. Some of these Archaen rocks got metamorphosed to varying degrees. Besides, there exists the Deccan Traps and the Rajamahal lava flows of Jurassic and Eocene ages of Mesozoic and Coenozoic group. Post Cambrian sedimentary formations also occur in the Gondwana basins and occasionally along the coastal tracts of the Peninsular Shield. On the other hand, in the Extra-Peninsular division, granitic
Map 1. India - Physiography.
(Source: Based upon Survey of India map with permission from Surveyor General of India. Territorial waters of India extend in the sea to a distance of twelve nautical miles measured from the appropriate base line. Copyright Government of India, 1991).
rocks of Tertiary age occur in the core of Himalaya. Feldspar and quartz are essential minerals. The Indo-Gangetic alluvial plains formed in the quaternary era and are made of sand, clay and peat beds.

From the Physiographic point of view, the Peninsula represents ancient tableland and the major part of it was eroded since its formation. The mountains in the eastern and western coasts are the remnants of the ancient plateau. Sahyadris (The Western Ghats) are the major ranges in the Western coast. The Eastern Ghats are composed of a series of disconnected ranges all along the Eastern coast from Orissa down to the Nilgiris where they meet the Western Ghats (Mukerjee, 1990).

The Peninsula

The Peninsular Plateau is highest in the south and west and slopes eastwards. Large areas in the south exceed 600 m in elevation and sometimes even 900 m. The Western Ghats rise abruptly from the coastal plains to an average height of 1200 m, and run parallel to the sea coast so they are known as Sahyadri meaning "facing the sea." In the northern half of the Western Ghats stand two high peaks - Kalsubai 1646 m and Salher 1567 m. Mahabaleshwar, a hill station in Maharashtra lies at a height of 1438 m. There are many gaps and passes in the Western Ghats, the most important are the Thalghat and the Bhorghat. They connect the interior of the Deccan with Bombay (now Mumbai). The railway lines proceeding from Bombay to Nasik and Pune go via the Thalghat and the Bhorghat respectively.

The Eastern edge is much broken and is known the Eastern Ghats. The Eastern Ghats stretch from the Mahanadi river valley up to the Nilgiris and form the eastern fringe of the dissected plateau. They have an average height of 450 m and rarely exceed 1200 m. Mahendragiri Peak in Orissa is 1500 m high. They disappear for about 150 km between Godavari and the Krishna Valleys. Near the southern end and to the east of the Eastern Ghats are some isolated hills: Billigirirangan Hills, the 'Shevaroy' (Sherevruyans) and the Javadi Hills.

The Eastern and Western Ghats meet in south of Mysore and form the lofty plateau of the Nilgiri. The Nilgiri have in them two of the highest peaks, Dodabetta (2637 m) and Makurti (2554 m). To the south of the Nilgiri are the Anamalai, Cardamom and Palni Hills. The Anaimudi in the Anamalai hills is the highest peak in Peninsular India, being 2695 m high. The Palghat Gap lies to the south of the Nilgiris and is about 24 km wide. It forms an easy passage across the Western Ghats. The Cardamom Hills constitute the divide between the east and west coasts. The Peninsular Plateau is flanked by a narrow coastal strip on the west and by a much broader coastal area on the east.

In the north some lines of mountains rise above the general surface of the plateau from the west to the east. It begins from the Aravalli Hills in the northwest. The Aravallis have an average height of 1500 m and are the remnants
of a much bigger mountain range. *Guru Sikhar or Mount Abu* is the highest peak in them (1722 m) and is an excellent hill station. Further south between the Aravallis and the Vindhyas lies the *Malwa Plateau*. Then follow almost parallel ranges of the *Vindhya* and the *Satpuras*. The Vindhya extend in an east-west direction for about 1000 km with an average elevation of 300 m. They form the northern boundary of the Deccan plateau. The plateau slopes northward from Vindhya Range gradually into the Indo-Gangetic Plains of North-India but in north-west, the Aravalli Range interrupts the slope.

In the north-east of the Peninsula is the Chhota Nagpur Plateau made famous for its rich mineral deposits. There are some minor ranges in the northern part of the Peninsula. They are the *Rajmahal* in Bihar, *Mahadeo Hills* and *Maikala range* in the Madhya Pradesh and the *Ajanta* and *Satmala Hills* in Maharashtra.

The Deccan Plateau is the largest plateau in India, covering an area of about 700,000 sq km. It begins from the Vindhyas and has an average height of about 600 m. It is higher in the west and south than in the east and north. The north-western part is called the "*Deccan Trap* " . The northern half forms the Plateau of Maharashtra and towards the south lies the *Mysore Plateau* with an average elevation of 600 m. Numerous streams and rivers carved deep valleys and made the Deccan plateau a dissected one.

The Peninsula is a compact natural unit of geo-morphological and biogeographical evolution. It is considered that now it is merely a relic of a much larger landmass, the major part of which now lies concealed under the alluvium of the northern plains and thrust under the high Himalaya and Tibet. Parts of the Peninsula appear also in detached blocks, both in the extreme north-east and in the north-west.

The northern boundary of the Peninsular block is generally set along an imaginary line extending from Kutch over the western flank of the Aravalli Ranges to within the environs of Delhi, and then eastwards nearly parallel to the rivers *Yamuna* and *Ganga*, as far as the Rajmahal Hills and curving south to the west of the Delta of Ganges in Bengal. The Peninsular Plateau covers 1. the Western Ghats, including Coorg; 2. the Southern Block of the Nilgiri, Anamalai and the Cardamom Hills; 3. the Deccan Lavas; 4. Karnataka or southern Bombay, Deccan and Mysore; 5. the upper Mahanadi and the adjacent basins (the Wainganga Valley, Chhatisgar, the Upper Brahmani and the Jamsheedpur Gap); 6. Telangana or the south east Hyderabad and the Madras Deccan; 7. Anantapur-Chittor Basins and 8. the Eastern Hills of Orissa and Bastar, the Cuddapah ranges and valleys (Mani, 1974).
The Extra-Peninsula

It extends for about 2500 km from the eastern extremity of Arunachal Pradesh to Kashmir with an average breadth in the west varying from 240 to 320 km. It consists of the Hindukush, the Karakoram and the Himalaya. The Himalaya can be divided into four zones. The Siwalik Zone, forming the foot hills of the Himalaya, rarely exceeds 900 m in altitude and is 3 to 48 km wide. The Lesser Himalayan Zone has an average height of 3050 m and is about 65 to 80 km in width. The Great Himalaya or the Central Himalaya comprises high snow-capped peaks rising above 4570 m. North of this is the Trans-Himalayan Zone which ultimately merges with the Tibetan plateau.

North Indian Plains

They are about 3000 km long from east to west and 240 to 320 km broad. This flat monotonous terrain is composed of unconsolidated sands, silts and clays and is drained by the three major river systems namely, the Indus, the Ganges and the Brahmaputra. It is the most fertile part of the country suited for agriculture. The Northern Plains can be divided into many sub-divisions.

The Upper Ganga region represents the states of Uttar Pradesh and Delhi. The soil is fertile but the average rainfall is less than 100 cm.

The state of Bihar represents the Middle Ganga Valley. This is an intermediate zone. The Western half has an average rainfall of 100 cm while the eastern part receives about 150 cm.

The Lower Ganga Valley forms the state of West Bengal. This is a wet region with over 200 cm rainfall.

The Brahmaputra Valley in Assam has more than 200 cm of rainfall. However in the region of Garo, Khasi and Jaintia Hills, the rainfall is far higher.

The Punjab Plain is part of Upper Indus Valley. It is nearly dry area.

The Thar desert begins roughly from southern edge of the Punjab and continues through north-western Rajasthan up to the Aravalli range. It is a fairly flat region with general elevation varying between 150 and 300 m (Charles, 1975).

RIVER SYSTEMS AND LAKES

A portion of earth's water is found to evaporate into atmosphere and returns to the earth surface in the form of rain and snow. The water that reaches the surface of the earth follow two pathways. Some portion percolates through the pore-spaces in the soils and rocks to form underground water, the remaining portion flows
down along the slopes of the hills and valleys and give rise to the streams and river systems which constitute the so called running water.

A river's source is the place at which it begins to flow. The source may be in the melt waters of a glacier or in a lake or in a spring or in a region of steady rainfall. Rivers generally have their origin in the highlands and they traverse in succession through the hilly tracts and the plains. Along the fringes of the plains the rivers usually end in the sea, sometimes in a lake. The place where the river ends is called river's mouth. The course of any river can, therefore, be broadly divided into three sections. Initially, a river flows through the hills and along the converging slopes of the valleys to reach the plains and this part is described as the upper part of the river. The flow of a river through the plains constitute the middle part and the third part of the course commences a bit off from the mouth of the river. The three sections of the course of any river may vary in length depending upon the physical features of the country and the paths followed by the river concerned.

In the upper part of a river, the process of erosion becomes very conspicuous in excavating or downcutting the valley-floor. At this stage it flows through a narrow and deep valley which is known as a gorge or canyon. Where the gradient of the valley floor is suddenly steep the waterfalls or rapids are formed. In the middle and lower portions the gradient of the valley-floor is much less, so its power of erosion and the velocity of running water is reduced and deposition now becomes active. The rivers move in zig-zag paths and form curvatures which are known as meanders or loops. During floods, the running water may cut straight through a meander and follow a short course, abandoning its previous round about tract. Such abandoned meanders containing some amount of confined water, give rise to horse-shoe or ox-bow lakes.

The products of erosion, such as boulders, pebbles, fine sand, silt, clay and soluble constituents are transported downstream alongwith the flow of the river. These constitute its load. Deposition of this load commences when it enters the plains and continues to increase as it flows towards the sea. Deposits thus formed along the course of a river are known as fluvial deposits. Such deposits form a new landmass at the mouth of the river, known as delta. Deltas commonly grow with time and gradually extend towards the sea. They are therefore, low lying land-masses and are swampy in nature.

The area drained by a river and its tributaries is known as river basin and its boundary is formed by the crest line of the surrounding highland. This boundary forms the main watershed of the basin (Mukerjee, 1990).

There are three main watersheds in India. (1) Himalayan in North India, (2) Vindhyan and Satpura ranges in Central India and (3) Sahyadri or Western Ghats in the West Coast. All the major rivers originate in one or other of these watersheds.
Map 2. India - River Systems.
There are 113 river basins (12 major river basins, 46 medium river basins and 55 minor river basins) with a total catchment area of 3.12 million sq. km. (Anonymous, 1994). These river systems run to a total length of over a 45,000 km and are estimated to carry 1,683,000 million cubic meters of water per year and in the process they do a lot of geological work. The north-Indian Plain is the creation of the Indus, the Ganga and the Brahmaputra rivers. The East Coast deltas are the handiwork of Mahanadi, Godavari, Krishna, Kauvery and Pennar rivers.

The rivers of India fall into two natural major groups viz. (1) Extra-Peninsular rivers (The Himalayan rivers), (2) The Peninsular rivers. The Himalayan rivers and the Peninsular rivers drain 70% and 30% of water discharge respectively. The perennial rivers such as the Indus, the Ganga and the Brahmaputra are fed by the mountain springs or glaciers, whereas the torrential rivers depend on the monsoon rains.

Extra-Peninsular rivers (Himalayan rivers)

Himalayas are drained by nineteen major rivers, of which the Indus, the Ganga and the Brahmaputra are the largest and most important. Of these nineteen rivers, six belong to the Indus system - Indus, Jhelum, Chenab, Ravi, Beas and Sutlej; 9 belong to Ganges system - Ganga, Yamuna, Ramganga, Kali (Sarda), Karnali, Rapti, Gandak, Bagmati and Kosi; 4 belong to Brahmaputra system - Brahmaputra (Tsangpo), Tista, Raidak and Manas. The rivers of the Indus system follow north-westerly course, while Ganges and Brahmaputra systems flow easterly course.

The river Indus (Sanskrit Sindhu) is one of the great rivers of the world and is about 3000 km long. Historically, it is from this river that India gets its name and also the land of Hindus (river Hindu a Persian version for Sindhu). The Indus rises about 100 km north of Manasarowar at an elevation of 5182 m in Tibet Plateau and flows north-west through Tibet before entering Kashmir. After flowing for about 290 km parallel to the north of Ladakh range, it turns south through this range and flows for about 480 km along southern flank of the range. Then it flows through the Sind province of Pakistan and forms a delta before entering the Arabian sea. It has five main tributaries on its left bank (eastern side), namely Jhelum (Sanskrit Vitasta), Chenab (Sanskrit Askini), Ravi (Sanskrit Irawati), Beas (Sanskrit Vipasha) and Sutlej (Sanskrit Satadru). Between each of the tributaries there is a fertile plain.

The river Sutlej has its source deep in the Himalayas at an elevation of 4630 m in the springs near Dulchu Gompa in the Tibet. First it flows in a northwesterly course along the southern slopes of the Kailas Range, then turns southwest and enters the plains of North India near Rupar in Punjab. It flows through Indian territory for a large part of its course, gathers many tributaries and then flows
into Pakistan. The river Beas traverses through Kulu and Kangra Valleys and joins the Sutlej. The Jhelum rises in the Verinag Spring, at the bottom of the Pir Panjal Range in Kashmir. It is joined by the river Chenab, formed by the confluence of the Chandra and Bagha, rises in Lahul-Spiti and flows through Jammu and Kashmir. It joins the river Sutlej after receiving the water of Ravi.

The Ganga is the most important river and is about 2480 km long. Its basin drains one fourths of the country’s area. The Ganga originates in the Himalaya at a height of 6000 m in the Gangotri glacier from a little ice cave, Gomukhin. Thereafter, it flows in a westerly direction for about 30 km before turning southwards. There are five streams as the source of the river Ganga viz., the Bhagirathi, Alaknanda, Mandakini, Dhauli-Ganga and the Pindari. The Bhagirathi is considered as the main source stream of the Ganga. The main tributary, Alaknanda rises from the glaciers Bhagirath Kharak and Santopanth of the Chaukhamba Massif and flows along the Bardinath. The Mandakini rises from the Chorbari Glacier near Kedarnath and joins the Alaknanda at Rudraprayag. The Dhauli-Ganga joins Alaknanda at Vishnuprayag. The Pindari rises in the Pindari Glacier and joins Alaknanda at Karnaprayag. The river Bhagirathi and the combined waters of Alaknanda and its tributaries join at Devprayag to form the river Ganga. Then the river Ganga passes through the Siwalik mountains and enters the plains at Haridwar. Then it broadens out and flows southeast. Many tributaries join the Ganga on its course through the plain. The Yamuna, and Son join the Ganga on its right bank, while the Ramganga, Gomti, Ghaghara, Gandak, and Kosi are joining on the left bank. All these tributaries rise on the slopes of the Himalayas. However, the Chambal and Betwa, the tributaries of Yamuna and Son rise in the hills on the edge of the plateau. Near Bhagalpur, the Ganga bends round the Rajmahal hills and flows south. Before joining the Bay of Bengal it divides itself into many distributaries forming a large delta. The Hooghly is a famous distributary which forms the western river mouth. The rivers Damodar, and Rupnarain joins Hooghly before it flows into sea. The main channel flows in a southeasterly direction through Bangladesh where it meets the Brahmaputra (Jamuna). The combined Ganga-Brahmaputra river is known as Padma till it joins the tributary Meghna. After that it is known as Meghna and flows into Bay of Bengal. The northern part of Ganga delta is rich and fertile, where as the southern part is swampy, saline and covered by Marshy forests known as Sunderbans.

The river Yamuna originates from Yamunotri Glacier on the Western slopes of the mount Bandarpunch (6387 m). After traversing a distance of 172 km, it enters the plains near Tajewala in Haryana and travelling further 1200 km up to the confluence with Ganga at Allahabad. It is fed by Peninsular rivers viz., Chambal, Betwa, Sind and Ken.

The river Brahmaputra rises in a glacier about 100 km south-east of Manasarowar. It runs eastward for about 1250 km through Tibet, where it is known as Tsangpo. Then it turns southward and flows into India cutting through the
deep gorges in the Himalayas in Arunachal Pradesh; this part of the river is known as *Dihang* or *Siang*. It enters the Assam Valley at Saudiya where it is joined by the rivers *Dibang* (or *Sikang*) and *Lohit* to become Brahmaputra and courses down the Assam Valley. The main tributaries on the right bank are *Subansiri*, *Baroli*, *Manas* and *North Dhansiri*, while on the left bank there are *Buri*, *Dibang*, *Lohit*, *South Dhansiri* and *Teesta*. The Brahmaputra flows through Assam for about 800 km, then turns towards south and enters Bangladesh to join the Ganga. In Bangladesh it is known by many names during its course towards sea. In the upper reaches, from Dhubri (India) to Goalundo (Bangladesh) it is known as the *Jamuna*; near Goalundo it joins the *Ganga* and the combined river is known as the *Padma* up to the confluence of the river *Meghna*. Finally, the combined waters of Ganga Brahmaputra Meghna flow into the Bay of Bengal as Meghna.

**The Peninsular Rivers**

These are three systems of drainage in the Peninsular plateau:

(1) The rivers *Chambal*, *Sind*, *Betwa* and *Son* rise to the north of Vindhya mountains and flow north to join Ganga (2) The rivers *Mahanadi*, *Godavari*, *Krishna*, *Kauvery*, *Penner*, *Palar* and *Vaigai* flow eastward into the Bay of Bengal (3) The *Luni*, *Sabarmati*, *Mahi*, *Narmada* and *Tapti* rivers flow westward into the Arabian sea. The Central India has a typical radial drainage pattern: it has north flowing rivers the *Chambal*, *Betwa* and *Son*, the east flowing *Damodar*, *Ajay*, *Subarnarekha*, and *Mahanadi* and its tributaries, the south flowing *Wainganga*, *Wardha* (tributaries of the Godavari) and the west flowing *Narmada* and *Tapti*. The south Indian rivers and their tributaries rise on the slopes of the Western Ghats.

The Peninsular rivers are entirely fed by monsoon and often more or less dry in summer. Two groups of Peninsular rivers are recognised. 1) the coastal rivers and 2) the inland rivers. The coastal rivers are relatively small streams hardly 80 km in length, and there are over six hundred on the west coast from Gujarat in the north to Kanyakumari in the south. They drain the western side of the Western Ghats, pass through narrow plains and flow into the Arabian sea. The inland rivers include the west flowing *Narmada* and *Tapti* the east flowing *Mahanadi*, *Godavari*, *Krishna* and *Kauvery*. The east-flowing inland rivers have wide and fan-shaped catchment areas and have extensive deltaic deposits. The western rivers flow between the mountain ridges, hence their catchment areas are elongate and narrow and lack delta formation at their mouths.

(1) **Rivers flowing towards west**:

The river *Luni* originates at Ana Sagar at Ajmer and flows through Rajasthan towards the south west into Arabian sea. It is a seasonal river which receives
a tributary from Pushkar Valley and from the Western slope of Aravalli range. The river Sabarmati is one of the major rivers flowing westward, originating from Aravalli hills in Rajasthan. It enters Gujarat traversing a distance of 372 km and finally flows into the Gulf of Cambay. Its tributaries are Hatmati and Mesha. The river Mahi originates in the Madhya Pradesh and flows through Rajasthan and Gujarat and drains into Gulf of Cambay. Its tributary the river Aras also rises in Madhya Pradesh.

The river Narmada is the longest west flowing river and the fifth largest river in India. It traverses a distance of about 1300 km. It rises on the Amarkantak Plateau from a spring at a height of about 1060 m on the Maikal Hills. At Bheraghat it falls down from a height of 15 m forming the Marble Falls. Its basin in Madhya Pradesh is one of the most fertile areas of the country. After the Marble Falls it flows through a gorge and finally enters the Gulf of Cambay.

The river Tapti rises on the Satpura range at Multai of Betul district of Madhya Pradesh and flows between the Satpura and Ajantha hills, from north to south, near Bhushawal it turns towards west and flows into the Arabian sea, west of Surat. The Purna, Girna and the Panjhara are its tributaries. The Tapti basin covers a large area in Madhya Pradesh, Maharashtra and Gujarat. It is the second largest river draining westward of the Peninsula.

The river Sharavati in Karnataka though small, is famous for the Gersoppa or Jog Falls in the Western Ghats. During the monsoon these falls could be considered one of the world's greatest waterfalls. But like all other rivers of the Deccan, it has very little water in the dry season.

There are more than 40 rivers with their tributaries originating from the western slopes of the Western Ghats and cutting across Kerala plains to join the Arabian sea. Bharathapuzha (Ponnani) river the longest originates from Anamalai Hills The river Periyar the second longest in Kerala originates from Sabarimala Hills.

2. Rivers flowing towards east :

The river Subarnarekha originates from a place near south east of Ranchi in Bihar. It traverses about 450 kms through Bihar, Orissa and West Bengal and finally to join Bay of Bengal.

The river Mahanadi basin is the third biggest basin in the Peninsula and fourth in India. It has its source in the Maikal Hills in Madhya Pradesh and flows east, through the state of Orissa. The river flows through the Eastern Ghats in a gorge 65 km and enters the Bay of Bengal east of Cuttack, forming an enormous delta in Orissa. The important tributaries are Tel and Seonath rise in the Chhota Nagpur region.
The Godavari is the largest river of the Deccan and second largest river basin in India. Its basin covers 10% of the total area of India. It has its source near Trimbak in the Nasik district of Maharashtra. It flows through a deep gorge in the Western Ghats before reaching Nasik City. It crosses Maharashtra, then enters the Telangana region in Andhra Pradesh. Its tributaries are Darna, Pravara, Manjira, Purna, Pranhita, Penganga, Sabari, Indiravati and Wainganga. The river Godavari cuts across the Eastern Ghats in a gorge and reaches the Bay of Bengal forming a large delta, east of Rajamundry in Andhra Pradesh. The tributaries Indiravati, Kodab and Sileru drain the districts Ganjam and Koraput of Orissa. The Wainganga rises near Seoni town in Madhya Pradesh and flows a distance of about 240 km to join the Godavari in Maharashtra.

The river Krishna is the third largest in India and second largest in the Peninsula. It rises in the Mahabaleshwar Hills in Maharashtra and flows south and southeast. Its main tributaries are Koyna, Bhima, Tungabhadra, Varna, Panchaganga, Dudhganga and Vedavati. After traversing a length of 1400 km through the states of Maharashtra, North Karnataka, and Andhra Pradesh, it drains into the Bay of Bengal forming a large delta near Vijayawada in Andhra Pradesh.

The river Kauvery originates at 1320 m on the eastern edge of the Western Ghats near Mercura in Karnataka. It flows East crossing the Ghats. There are several rapids and water falls in its course. At Shivasamudram it plunges from a height of 100 m forming the famous Shivasamudram Falls. Then it enters Tamil Nadu and reaches the Bay of Bengal by way of a large delta. The river travels 710 km of which 310 km are in Karnataka and 460 km in Tamil Nadu. It starts dividing near Srirangam. The river Kollidam is a well known distributary.

There are many other smaller rivers along the East coast. The well known are Rushikulya, Burabalonga, Brahmani and Vaitarni in the north, in Orissa; in the far south the Ponnaiyar, Palar, Vaigai, Chittar and Tamraparini in Tamil Nadu. The river Chittar and its tributaries traversing the Courtallum region joins the Thambraparni river northeast of Tirunelveli. It takes southeasterly course of about 115 km to empty itself into Gulf of Mannar. The Chittar has several ‘falls’ at the descent to the plains of Tenkasi, known as Courtallum Falls.

Lakes and Swamps

Some depressions on the land surface which, when filled up with water, are described as lakes. Lakes commonly occur above the mean sea level and the basins always have their bottoms below the water table.

Fluvial erosion and deposition often cause the formation of lakes along river valleys. There are a number of such small lakes in the Gangetic delta of West Bengal and in Kashmir. In hilly tracts, some lakes are formed due to landslides
along or across the course of rivers. Such lakes are known as rock-fall basins. Some smaller lakes in Central India and the Golna lake in Garhwal are said to have been formed due to landslides. Deposition of sand away from the seashore, some times cuts off a portion of the sea to form saline lakes. The lakes Pulicat and Chilka, along the eastern coast of India, are of such origin. Lakes are also formed due to glacial erosion and deposition. The moving ice masses often excavate the floor of their valleys and form a lake there during the postglacial period. Some of the lakes in Kashmir viz, Alipuiher, Sheshnag, Kounsernag, Vishnusar, Tarsar and Gangabaler are of glacial origin.

The comparatively smaller lakes are usually fed by underground water alone. The larger lakes are also fed by streams and rivers which drain in them.

In the humid climatic regions, lakes with inlet and outlet can maintain a regular circulation of water and continue to remain fresh all through. Such lakes are known as freshwater lakes. In warm and dry regions, the process of evaporation on the surface of water bodies may lead to complete or partial desiccation of the lakes and also brings about concentration of the dissolved minerals occurring within the water bodies. Such lakes become saline in nature and depending on the salts present are described as salt lakes, alkaline lakes, bitter lakes, borax lakes etc. Salt lakes contain a greater proportion of Sodium Chloride while alkaline lakes have a greater concentration of carbonates of Sodium and Potassium. Bitter lakes contain more Sodium sulphate.

Those lakes lying along the river valleys act as natural reservoirs and effectively control the discharge of water further downstream and floods. Comparatively larger lakes play some role in controlling the local climatic conditions and provide ideal habitat for some specific groups of plants and their remains are preserved as fossils in the lake sediments.

India by its unique geographical position with varied terrain and climatic conditions ranging from the cold arid of Ladakh to the warm arid of Rajasthan has many lakes in addition to major river systems. Some important lakes of India are: Pangong Tso, Tso Morari (Ladakh); Dal lake, Wullar (Jammu & Kashmir); Harke, Kanjli (Punjab); Sambhar, Pichola, Pachpadra, Lunkaransar (Rajasthan); Nalsarover (Gujarat); Renuka (Himachal Pradesh); Nainital, Bhim Tal (Uttar Pradesh); Kabartal (Bihar); Bhuj (Madhya Pradesh); Lonar, Ujni (Maharashtra); Chilka (Orissa); Kolleru, Pulicat (Andhra Pradesh); Asthamudi Sasthamkotta, Vembanad (Kerala); chho Lhamo, Gurudongmar Chho (Sikkim) and Loktak (Manipur). (Chatrath, 1992; W.W.F. India, 1992). Physical features of some important lakes are given below.

Wullar lake is the largest and deepest fresh water lake in the Jhelum Valley in Kashmir. It absorbs the flood waters of the river Jhelum. Its area is 173 sq
km. Dal lake is another fresh water lake in Kashmir situated near Srinagar. It is about 12 sq km and has a catchment area of about 300 sq km. It is fed by Dachigam and Telbal streams.

Harike lake is a shallow reservoir located at the confluence of Beas and Sutlej rivers. It has an area of 28 sq km. The lake was developed (man made) due to construction of Harike barrage in Punjab.

Sambhar lake is the most important salt lake in Rajasthan. It has an area of 234 sq km. during rainy season with a depth of about 1 meter.

Lunar lake in Maharashtra is a saline deep crater lake in the district Buldana. The lake is about 100 meter depth and 2 km in diameter.

Vembannad lake in Alleppey is the largest brakish - water lake in Kerala. While Asthamudi lake is the deepest one. The Sashthamkotta lake is the only natural fresh water body in Kerala.

Chilka lake in Orissa is a salt water lake separated from sea by sand banks and is the largest salt water lake in India. Its maximum length is 64 kms and width 80 km. It is connected to the Bay of Bengal. It receives flood waters from river Daya and other rivulets.

Kolleru lake is a large fresh water lake situated near Gudivada in Andhra Pradesh. It extends over 900 sq km. It has a catchment area of about 4700 sq km. A number of rivulets flow in. The outlet into sea is called Upputeru.

Loktak lake is the largest natural lake in eastern India with an area of 289 sq km and occupies the southern part of Manipur Valley. Impal river and its tributaries flow water directly into Loktak.

Swamps are low lying lands where the water table has just reached the land surface. In swamps the land surface is always saturated with water. The depressions, actually contain water only during the rainy seasons, when the water table rises to some extent. Swamps commonly occur along flood - plains of rivers and in lowlying sea shores. The salt lake swampy areas in West Bengal lie within the flood - plain and delta of the Ganges. The vast tract of low land, lying along the western coast of India known as the Rann of Kutch in Gujarat and Vedaranayam salt swamp in Tamil Nadu constitute the best examples of coastal swamps. In swamps, vegetation grows in abundance and these are in the long run, converted into layers of partcally carbonised plant remains known as Peat. Peat beds occur in swamps lying in the Gangetic delta are of low-land Peat, while those occurring in the Nilgiri hills (Western Ghats) are of high land.
Tidal marshes are shallow depressions along seashores, within which a thin sheet of saline water enters during the high tides. As soon as low tide sets in, sea water completely recedes from such depressions. The tidal marshes differ from coastal swamps since no inrush or recession of seawater takes place in coastal swamps, during high and low tides respectively. The best examples of the tidal marshes are Sunderbuns in West Bengal, Bitrakanika in Orissa, Coringa in Andhra Pradesh, Pichavaram and Point Calimere in Tamil Nadu, Rann of Kutch in Gujarat and some along the coast of Andaman and Nicobar Islands.

REFERENCES


2. GEOLOGY

(P. Venu, G. V. S. Murthy & M. Sanjappa)

In general geological history is mainly construed based on the study of interrelationships between different groups of rocks and the conditions responsible for their formation. Studies on the sedimentary rock formations include the order of the strata, lithology, fossil content and structural characters. While in igneous and metamorphic rocks, structural element, petrogenesis and geochronology form the important guidelines.

The rock formations constituting the earth crust are of three types and their basic features including origin are summarised before actual description of the geology of the country.

1. Igneous rocks:

Igneous rocks are the products of consolidation of magmas, the molten silicates which underlie the solid crust of the earth. The underlying magma after the formation of the crust tries to penetrate into the thin solid crust and thus enter the surface of the earth. In its effort to come out on the earth surface, some of the magma-masses may be stopped during their upward journey. The igneous rock-masses which were produced due to the consolidation of the magma upon the surface of the earth are known as extrusive bodies and the others which remain as injections within the country-rocks underneath the surface are known as intrusive bodies. Intrusive rock masses may consolidate either at very great or at moderate depths underneath the surface. They are classified into Plutonic rock bodies of deep seated origin and Hyp-abyssal rocks formed at shallow depths.

2. Metamorphic rocks:

A change in physico-chemical and tectonic conditions commonly upsets the stability of the pre-existing country rocks and the latter tend to reform themselves into new rocks stable under the new set of conditions. The change or reformation may be either in mineral composition or in texture or in both and under appropriate conditions, in chemical composition as well. The process which brings about this change is known as metamorphism and the ultimate products, formed due to operation of such processes are defined as the metamorphic rocks. Metamorphic rocks are, therefore, the products of metamorphism of pre-existing igneous,
sedimentary or even metamorphic rocks which had lost their stability and hence reformed themselves in keeping with the new environment.

3. Sedimentary rocks:

The surface of the earth has evolved through natural agencies and these changes involved withering and erosion of high lands and consequent deposition of the resulting sediments in depressions of the earth surface. These natural agencies deposited enormous quantities of sediments giving rise to sedimentary rocks. These constitute nearly three fourths of the surface of the existing continents. These thick columns of sediments were built over years and sometimes these columns constitute entire height of the lofty mountains. In each column of these sedimentary rocks, the lower beds were deposited first and the overlying ones in a later stage following a definite chronological order. The fossils contained in different layers of these rocks indicate the nature of the organisms existed during that period.

The lithological sequence also gives some information on the nature of environment and climate existed during that period. The entire investigation tries to read the detailed geological history of the earth from the study of rock belts. The smallest lithological unit is termed bed and beds of similar characteristics constitute formation. Sometimes sedimentary columns get subjected to very severe diastrophism. In any column of sediments, constituent formations may be conformable with one another. Each formation should pass imperceptibly into the overlying and the underlying ones. In many cases the successive formations are found to be related unconformably.

Strateographic Units

Different rock formations constituting the earth's crust may be classified into six major groups. a) Archaean or Azoic, b) Precambrian or Proterozoic or Algonkian, c) Primary or Palaeozoic, d) Secondary or Mesozoic, e) Tertiary or Cenozoic/Cainozoic, f) Quarternary or Recent. Of these, Archean group is the most ancient one and the Quarternary is the youngest.

The major groups are divided into systems; each system into series; each series into stages and each stage into zones. Corresponding to these divisions of formations, there are divisions of geological time:

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All the stratigraphic groups and systems have been traced and studied from India and are given in Map 3.
Map 3. India - Geology.

(Source: India - A Regional Geography, R. L. Singh, 1971)
ARCHAEOAN GROUP

The Archaean group refers to gneisses, schists and granites, which constitute the platform on which all sedimentary formations lie. The maximum age determined is about 3000 million years. The schists and gneisses were formed due to the metamorphism of pre-existing igneous and sedimentary rocks and are found to have been traversed by intrusive igneous bodies of acidic to ultrabasic composition. In some regions, the Archaean is made up only of sedimentary metamorphites or of mixture of para or ortho schists. Such rocks are commonly described as Dharwarian rocks. The Archaean rocks are very complex and are devoid of fossils. In fact no life existed during the Archaean rock formation.

Occurrence and distribution:

The Archaean rocks are well developed in South India, Rajasthan, Madhya Pradesh, and in the Eastern India in Singhbhum - Gangpur area of Bihar and Orissa. This group of rocks also occurs in Eastern Ghat ranges. In the Extra Peninsular, the Archaean rocks occur along the whole length of Himalayan mountains.

In South India the Archaean rocks are best developed in Karnataka (carstwhile Mysore) and Maharashtra. Here they are commonly described as Dharwar System. It is made up mainly of schists, gneisses and granites. The metamorphosed sediments are older in age than the gneisses and granites of igneous origin. In South Maharashtra and parts of northern Karnataka these rocks exhibit the lower grade of metamorphism compared to those of southern Karnataka.

The rocks known as Champion gneiss developed along the eastern border of the Kolar Schist belt and are characterised by opalascent quartz grains with greyish tint. The rocks known as Peninsular gneiss are widely distributed in Karnataka and in other parts of South India. They are made of gneisses, granite, and granodiorites of varying composition, texture and structure. The Charnockites are widely distributed in parts of both Eastern and Western Ghat ranges. They exhibit the characters of both igneous and metamorphic rocks.

The Colsepet granites (Bellary gneiss) are younger in age than the Charnockites. They exhibit intrusive relationship with the pre-existing country rocks. These granites are coarse-grained with por-phryritic texture and are occasionally foliated.

In Central India, the Archaean rocks are developed in Bastar, Rajpur, Sambalpur, Bilaspur, Balaghat, Nagpur, Bhandara, Chhindwara, Jabalpur and adjacent areas. In Bastar, the Archaean rocks were made of schists and gneisses of both igneous and sedimentary origin and these were intruded by igneous bodies
of acidic and basic composition. Mica schists quartzites, phyllites and banded haematitic quartzites and the associated masses of granites and gneisses occupy a vast area in Rajpur.

In Sambalpur area, hornblende and biotite-schists and gneisses, quartz-schists, quartzites and igneous bodies of granite composition constitute the Archaean rocks.

In northern Balaghat area, the oldest rocks are described as the *Sonawani series*. This series is made up of manganese ores, calc. gneisses, crystalline limestones, quartzites and schists. The *Sonawani series* is overlaid by the *Chilpi ghat series*. It is made of trap rocks, grits, conglomerates, green stones etc. Either of these contains manganese bearing horizons.

In Bilaspur-Balaghat area, the *Sonawani* and the *Chilpi ghat series* are associated with granatic rock belonging to three distinct groups. They are made of schistose biotite gneisses, porphyritic and augen gneisses and granites respectively.

In Nagpur-Chhindwara area, the Archaean rocks are highly metamorphosed and are known as *Sausar series*. The rocks of this series are granulites, marbles, schists etc., which exhibit a regional dip towards south of south-south east. The whole sequence of rock beds had undergone folding, faulting and shearing and contain important manganese deposits.

In Nagpur-Bhandara area, the metamorphic rocks of Archaean age are made up of quartzites, dolomites, amphibolites, schists, phyllites, conglomerates, ferruginous and manganiferous ores and dolerites of igneous origin.

In Jabalpur, the Archaean rocks are made up of marbles, mica-schists, phyllites, conglomerates and ferruginous and manganiferous ore bodies. In addition, there are some basic igneous rocks which are altered to a great extent.

The Archaean rocks of northern Singhbhum are separated from those of southern Singhbhum by a distinct thrust zone which is 125 km in length and runs approximately east-west. Towards the south of this thrust zone, there occurs a group of unmetamorphosed rocks like conglomerates, sandstones, limestones, shales, banded-haematite-quartzites etc., which are underlain by the older metamorphic rocks. The unmetamorphosed group of rocks is associated with basic lavas. The whole sequence of rocks in southern Singhbhum is traversed by younger igneous bodies of ultrabasic, basic and acidic composition. In the northern Singhbhum, the Archaean rocks are made of mica schists, chloriteschists and hornblende schists which contain minerals like garnet, staurolite and kyanite. The metamorphic rocks of northern Singhbhum are known as the *Ironore series* and are associated with younger granites and gneisses known as *Chota Nagpur granite gneiss*. 
The Archaean rocks harbour major metalliferous deposits in India. The Kolar gold occurs within the Dharwarian schists; important copper deposits occur in Bihar, Rajasthan and Tamil Nadu; high grade iron enriched in the banded hematite quartzites of Bihar, Orissa and Madhya Pradesh; other deposits include those of manganese, chromite, lead-zinc, nickel and numerous metalliferous ores. Mica occurs within the pegmatites of Rajasthan, Bihar and Andhra Pradesh. Gem stones of Kashmir, Rajasthan and Tamil Nadu constitute a minor part of the mineral wealth of the Archaean group of rocks in India.

**PRECAMBRIAN GROUP**

The Archaean rocks after their formation were subjected to diastrophism, erosion and denudation resulting in what is known as *Eparchaean Unconformity*. The Precambrian rocks lie above this unconformity and are well represented in the Peninsula. In India, the Precambrian rocks have given rise to two distinct formations known as the *Cuddapah* and the *Vindhyan systems* of which the former is older in age and complicated in structure. These rocks are practically devoid of fossils.

**The Cuddapah System:**

The name of this system was derived from the Cuddapah basin in Andhra Pradesh, where it is best developed. In this area, the Cuddapah system is overlain by the *Kurnool system* of Vindhyan age. The huge Cuddapah basin is more or less crescentic in shape. This crescent is convex towards the west and concave in the east. The Western side of the basin exhibits an undisturbed sequence of Cuddapah rocks, made up of quartzites and shales. In the eastern half of the basin, the same rocks have been folded and slightly metamorphosed. The effect of diastrophism is most conspicuous along the concave eastern margin of the crescent, where the rock beds have been remarkably folded and even faulted.

Structurally, the Cuddapah system shows alternating layers of quartzites and shales and an unconformity between any two successive series of the system. Of the four series constituting the Cuddapah system, the oldest one is known as *Papaghi series* and is about 1500 m thick and lies unconformably upon the Archaean rocks. The *Cheyair series* is over 3300 m in thickness and its lower part (*Nagari or Pulivendra stage*) is made up of quartzites, sandstones, conglomerates which have been crushed along the eastern margin of Cuddapah basin. The upper part of the series (i.e. *Pullampet or Tadpatri stage*) is composed of shale beds which have become slaty due to metamorphism. There are some siliceous and calcareous bands and basic sills within the rocks of this stage. The *Nallamalai series* is over 1000 m in thickness and forms the Nallamalai hills. The Bairenkonda quartzites and Cumbum shales are two stages that constitute this series. The youngest series, named after *Kistna* overlaps all the older series and
lies right over the Archaean rocks. It is made up of three distinct stages which constitute a total thickness of about 600 m.

The rocks of Cuddapah system also occur in different parts of the Peninsula and the Extra-Peninsula. Towards the southern side of Maharashtra, rocks of Cuddapah age are described as *Kaladgi series*, which is made up of quartzites, conglomerates, limestones and shales.

In Singhbhum the *Kolhan series* lies above the iron ore series and is made up of basal conglomerates, sandstones, shales and limestones which exhibit some amount of folding in them. This series is considered equivalent to Cuddapah system.

In Madhya Pradesh, the arenaceous rocks belonging to the *Chandrapur series* and the argillaceous calcareous rocks of the *Rajpur series* and the *Delhi system* of Rajasthan are equivalent in age to the Cuddapah system of Andhra Pradesh.

The rocks of Cuddapah age contain a number of important economic mineral deposits. In Andhra Pradesh, deposits of talc and asbestos occur at the contact of Vempalle limestone and the intrusive sills. Deposits of cobalt and copper ores are associated with the black slates of the *Delhi system* in Rajasthan. Veins of barites occur in *Vempalle limestones* of Andhra Pradesh and in the *Alwar quartzites* of Rajasthan.

The Vindhyan System:

The Vindhyan system (named after Vindhyan range) lies unconformably above the older formations and constitutes an unmetamorphosed column of calcareous, arenaceous and argillaceous sediments. These cover 52,000 sq km in area with a maximum thickness of 4600 m. This group extends from the Eparchaean terrestrial period to a part of Cambrian. From the point of view of lithology and structure of constituent beds, the Vindhyan system has been divided into lower and upper subdivisions. The lower part is made of calcareous and argillaceous sediments, which were deposed under marine environment. The upper Vindhysans are made of undisturbed and more or less horizontal layers of arenaceous rocks, of esturine or fluviatile origin. They exhibit no sign of diastrophism and are devoid of fossils. The Vindhyan system is composed mainly of limestones, shales and conglomerates. This is a source of limestones and also some pyrite and diamond deposits.

**PALAEOZOIC GROUP**

Palaeozoic era includes rocks of Cambrian to Permian. The geological formations developed during this era contain some fossils. In this respect, these rocks radically differ from the unfossiliferous formations of Precambrian and Archaean ages. Palaeozoic rocks formed under marine environment contain distinct
remains of organisms and are developed characteristically in the Extra-Peninsula. Those were studied especially in Spiti and Kashmir. In the Peninsula, the Palaeozoic group is represented by (a) Talchir and Damuda series of Permo-carboniferous age. (b) The marine Lower Permian rocks near Umaria in Madhya Pradesh. (c) A portion of the upper Vindhyan sequence which is possibly of Cambrian age. A brief account of Palaeozoic sequence developed in Spiti, Kashmir, Kumaon and other Extra-Peninsular region is given below.

**Spiti:**

In the Spiti Valley and adjoining areas, a complete succession of folded marine Palaeozoic rocks exist in a large synclinal depression which has its axis running north-west to south-east.

In Spiti, the *Haimanta system* of Cambrian age is 1500 m thick with quartzites, slates and shales. It is underlain by highly metamorphosed rocks of *Vaikrita system*. This is followed by rocks of *Ordovician* age which are highly fossiliferous and contain quartzites, grits and sandstones of shallow water facies. The Ordovician rocks are overlain conformably by limestones and marls and included within the *Silurian system*. These are further overlain by an unfossiliferous column of quartzites and range in age from Upper Silurian to Devonian. This is followed by *Kanwar system* of carboniferous age, which is composed of quartzites, shales and limestones rich in fossil fauna belonging to *Lipak* and *Po series*. Over these, there is a thick boulder of conglomerate horizon and it represents the Permo-Carboniferous break. This is overlain by *Kuling system* consisting of shales and calcareous sandstones of the Permian age.

**Kashmir:**

*Hundwara system* of rocks, mainly composed of slates, greywackes and quartzites of early Cambrian age overlie the Dogra slates in many parts of Kashmir and Liddar valleys. The upper part of the Cambrian sequence is composed of blue clays with thin limestone bands and rich Trilobite fossils. As the arenaceous slates and limestones of Ordovician-Silurian part of Palaeozoic era is poorly developed in Eish makam and few other areas with restricted outcrops, muth quartzite of Devonian age is found to rest directly over the Cambrian sequence all over the Kashmir region. However, the succeeding Carboniferous system is well represented by *Syringothyris limestone* and *Fenestella shales*. During the Hercynian movement of Permo-Carboniferous time, land conditions prevailed in Kashmir region when the Panjal volcanics were erupted. The pyroclastics of Panjal volcanics including intercalated beds containing plant fossils and vertebrate remains are known as *Gangamopteris* and *Zewan beds*. Unfossiliferous Palaeozoic rocks made of quartzites, phyllites and quartz-schists occur in some parts of Kashmir. These rocks form *Tanawal series*. 
Kumaon:

In the Kumaon Himalayas, Garbyang series comprising slaty calcareous sandstones and metamorphosed volcanic tuffs of about 5000 m thick contain fossils of Cambrian age. Shiala series contain characteristic Ordovician fossils in its calcareous rocks. The overlying conspicuous red and green shales with thin limestone bands, known as Variegated series represent Silurian system. The lower 800 – 1000 m part of muth quartzite containing dolomitic limestone bands is also included within the Silurian. The rest of the muth quartzite represents Devonian system which is composed of limestones rich in fossil fauna. Over these, the Kuling series of Permian age lie unconformably.

In the eastern Himalayan region the Permian system is represented by marine deposits. The Productus shales continue eastwards up to Assam, known as Subansiri beds.

The fossil fauna of palaeozoic era are invertebrates like Brachiopods, Trilobites, Gratolites, Corals, Crinoids etc.

Gondwana sequence:

After the uplift of the Vindhyan rocks, the Peninsula during the Precambrian era witnessed no further deposition of sediments for a long time. During the Upper Carboniferous period, there is a new phase of deposition of sediments within the continental block, which continued up to the end of Jurassic period. The sediments exhibit all characters of having been formed under a shallow stretch of water in river and lake basins and constitute a total thickness of the order of 6 to 10,000 m. The enormous thickness of the sedimentary column may be ascribed to the gradual sinking of the basin along with the deposition of more of sediments. The aforesaid inland sediments of Upper Carboniferous to Jurassic age occupy a vast tract in the Peninsula and together constitute the Gondwana group. The Gondwana sediments contain enough of remains of plants and animals and are characterised by the presence of large number of coal seams.

During the period of deposition of Gondwana sediments, the configuration of the surface of the globe was quite different from what is now. The southern continents namely Australia, Southern part of Africa, Madagascar, South America, Antarctica and India were united together to form one continuous stretch of land known as Gondwana land. Thus the fluvialite and lacustrine deposits of Gondwana age occur not only in India but also in all the southern continents of the present day. The Gondwana rocks of India and of southern continents have similarities in lithological, floral and faunal characteristics.

On the basis of their floral content, Gondwana has been subdivided into two parts. The lower Gondwana rocks ranging in age from Upper Carboniferous to
Lower Triassic and are characterised by the presence of *Glossopteris* flora in which *Pteridosperms, Corditales, Equisetales* and *Sphenophyllales* are the dominating elements. The upper Gondwana rocks are marked by the advent of *Rajmahal* flora (*Ptilophyllum* flora) which exhibit the dominance of more advanced flora such as ferns, cycads and conifers.

The Gondwana rocks occur in a series of narrow faulted troughs which lie along the Damodar, Sone, Narmada, Godavari and Mahanadi valleys. In the Damodar, Sone and Narmada valleys, the trend of the troughs is approximately east-west. In the Godavari valley this trend changes over to north-west to south-east. They also occur in certain foot hill portions of Himalayas. In the eastern coast, the Gondwana rocks occur near Cuttack, Rajmundry, Vijayawada, Guntur, Madras, Trichirapalli and Ramanathapuram.

The advent of Gondwana period during the early Permian time was characterised by prolonged cold climate, as evidenced by glacial and fluvioglacial deposits of the *Talchir formation*. In most of the basins these deposits overlie, at places with intercalated marine sediments with marine Permian fauna, the basement complex with profound unconformity as the basal part of the Lower Gondwana sequence. Over these lie the thick sequence of sandstones, siltstones, shales and coal seams. Workable coal seams are restricted to two main horizons of which the lower coal measure is known as the *Barakar formation* and *Karharbari formation* (being developed in restricted fields) and the Upper one as *Raniganj formation* with a barren zone in between designated as the *Barren measures*. These two coal measures contain the major coal reserves of the country. Fire-clay, another economic mineral, is associated with these rocks. The coal measures roughly represent the middle and upper part of Permian and are rich in *Glossopteris* flora.

**MESOZOIC GROUP**

In India, the Mesozoic group of rocks generally lies conformably above the rocks of Palaeozoic age. This group occurs in the Extra-Peninsula as well as in some parts of the Peninsula. The era includes Triassic, Jurassic and Cretaceous. In the Extra-Peninsular region, the Triassic rocks are well developed in Spiti, Kumaon and Kashmir areas of the Himalaya. The rocks of Jurassic age developed in Kutch, Rajasthan, Kumaon, Spiti and Kashmir. The Cretaceous rocks occur in the eastern coast of South India.

**Spiti**:

In Spiti area, the Triassic is represented by *Lilang system* composed of limestone and shale interbands of about 1,200 m thickness. This is overlaid by the *Jurassic system* consisting of upper part of *Kioto limestone, Sulcactus beds* and *Spiti shales* in order of succession. The Spiti shales are famous for Saligrams (with
Ammonite) and gradually pass upward into Cretaceous sequence consisting of Giumal series and Chikkim series. The former series is made up of sandstones and quartzites while the later is of fossiliferous grey and white limestone and folded unfossiliferous shales.

Kashmir:

A more or less complete sequence of Triassic is represented in Srinagar which is composed of limestones and shales of about 1000 m thickness. Jurassic is represented by Kiotu (Megalodon) limestones. White limestones of Cretaceous age are found in Ladakh.

Kumaon:

Well developed sections of Triassic sequence are seen in Bambanag, Shalshal Cliffs, Painkhanda and Byans. In this region also the lower part of Megalodon limestone is included within the Upper Triassic and the rest in Jurassic. Rocks of this age are also developed in Mt. Everest region.

In Kumaon, Cretaceous rocks are represented by Giumal sandstone and volcanic breccia associated with exotic blocks. Kampa system in north Darjeeling is represented by rocks of Cretaceous and early Tertiary age.

Kutch:

Mesozoic rocks, from middle Jurassic to Lower Cretaceous are particularly well developed in Kutch, where they exhibit a complete succession with a total thickness of over 2000 m. The Jurassic succession in Kutch commences with Patcham series which is principally made up of limestone, sandstones and shales with about 300 m thickness. The series as a whole is rich in limestones. The lower beds are, however, somewhat arenaceous while the upper beds contain some shaly horizons. The Patcham basal limestones contain some shaly horizons and the characteristic fossil Megateuthis. The overlying shell limestones contain Pelecypods (Trigonia and Corbula) and ammonites (Macrocephalites triangularis). The Patcham coral beds are characterised by the presence of remains of corals (Stylna, Montlivaltia, etc.) and ammonites (Sivajiceras and Macrocephalites).

The Chari series, made up of five distinct stages, lies above the Patcham series and constitutes a thickness of about 400 m. The oldest stage of this series, known as the Macrocephalus beds, is made up of shales, calcareous bands and is characterised by the presence of Macrocephalites macrocephalus and a few other forms of ammonites. The overlying Rehmanni beds are composed of yellow limestones and contain remains of a number of ammonites (Reinckekea rehmannii, Sivajiceras, etc.). The Anciaes beds lie above the Rehmanni beds and are made up of limestones and shales. This horizon contains Perispinctes aniceps and a few
other remains of ammonites. The marls and gypseous shales occurring above the Anceps beds are known as the Athleta beds. These beds are characterised by the presence of fossils namely Peltoceras athleta (ammonite). The Dhosara oolites, made up of green and brown oolitic limestones, form the uppermost stage of the Chari series. This horizon is characterised by the presence of Mayaites maya, Epimayaites polyphemus and other important fossils.

The Katrol series lies above the Chari series and is made up of three stages with a total thickness of about 330 m. The Katrol stage has been found to contain a few plant remains. The Gajansar beds form the uppermost horizon of the Katrol series and are characterised by the presence of important fossils like Belemnopsis gerardi and Phyllocera sp.

The Umia series, which lies above the Katrol series is made up mainly of shales and sandstones and constitutes a total thickness of about 1000 m. This series has been subdivided into six stages which include (1) Zamia shales, (2) Ammonite beds, (3) Trigonia beds, (4) Ukra beds, (5) Umia plant beds, and (6) Marine Sandstones. These beds are characterised by different fossil members.

The Jurassic and Lower Cretaceous rocks in Kutch are overlain in some places by the Deccan Trap lava-flows. In certain regions, they are overlain unconformably by younger rocks of Tertiary age.

**South India**:

In the Peninsula after the Vindhyan period, only a few patches of sedimentary rocks were deposited along the coastal tracts. However, there occurs no complete succession of mesozoic rocks along the eastern coast and exist only three patches of rocks of Cretaceous age. These patches rest upon a basement of Archaean gneisses and Charnockites and are sometimes fringed, along their western margins by the strips of rocks of Upper Gondwana age. Of these three patches the largest patch occurs in the Trichinopoly district (Tamil Nadu) while the smallest one is located near Pondicherry. The other patch exists near Cuddalore and Vriddhachalam.

The Cretaceous succession in Trichinopoly commences with the Uttattur stage which is made up of limestones, clays and arenaceous rocks. In general, the rock-beds of this stage exhibit an average seaward dip of about 10°. The Uttattur stage constitutes a thickness of about 600 m and its upper part appears to have been deposited during a period of desiccation of the Cretaceous sea.

The Uttattur stage is overlain by sandstones, grits, clays and shell limestones belonging to the Trichinopoly stage. Its constituent rock-beds appear to have been deposited under a shallow stretch of marine water.
The overlying Ariyalur stage is composed of grey, light brown and white sandstones and argillaceous horizons with a thickness of about 330 m. The white sandstones forming the upper beds are unfossiliferous. The Ariyalur beds exhibit a gentle seaward dip of about 3° to 5°, and are overlain by brown and grey sandstones, shales and arenaceous limestones, which together constitute the Ninjyur stage. This stage is characterised by the absence of remains of ammonites in its constituent rock-beds.

The Deccan Traps:

In the Peninsula, the end of the Mesozoic era was characterised by the pouring out of extensive lava-flows, which were erupted mostly through fissures and occupy a major portion of the Deccan plateau. These lava-flows generally occur in the form of horizontal sheets, ranging in thickness up to 30 m and cover an area of about 3,38,000 sq km. The successive lava-flows are separated from one another by sedimentary beds formed under water and are known as the intertrappeans. The total thickness of the column of lava-flows and intertrappeans varies, in different localities from 60 to 2300 m. Although most of the flows were erupted through fissures, there are a few areas like the Girmar Hill and some other localities in Gujarat and Maharashtra where they appear to have been poured out through localised vents. These extensive lava-flows gave rise to flat topped mountains and plateaus with step-like terraces. They are described appropriately as the trap rocks and the formation as a whole is known as the Deccan Traps.

The Deccan Traps occur in Maharashtra, Gujarat (Kutch, Kathiawar), Madhya Pradesh and in some parts of southern India. In the geologic past these rocks occupied a much larger area and in course of time, the constant erosion through natural agencies totally removed them from many localities. Some portion of the lava-flows appears to have been faulted down the Arabian sea in Western Coast. The Deccan Trap formation has been classified broadly into three parts. Upper flows 500 m thick; Middle flows 1330 m thick; and Lower flows 160 m thick.

The upper flows are developed characteristically in Bombay and Kathiawar. They are about 500 m thick and contain intertrappean horizons and ash beds. The middle flows are well developed in Madhya Pradesh and are associated with some ash beds. Intertrappean horizons are extremely rare. The lower flows occur in Madhya Pradesh and further eastwards. They are about 160 m thick and contain a number of intertrappean horizons. Layers of volcanic ash occur rarely in association with the lower flows.

The Deccan Traps are made up principally of basic volcanic rocks of basaltic composition. In few localities, however, there occur a few other rock-types which were formed as a result of localised differentiation of the basaltic magma.
The Deccan Traps are used commonly as excellent road metals. Those of lighter colour are sometimes utilised as building stones. The lateritised tops of the lava yielded workable deposits of high grade bauxite in Belgaum, Jabalpur, Katni and other areas. The iron rich laterites are used as building stones. The vesicular traps contain enough of agate, chalcedony, amethyst and other semiprecious stones that are used in the manufacture of ring stones, beads etc. The black soil of the Deccan suited for cotton cultivation was derived from the trap-rocks. The vesicular and highly jointed lava-flows serve as suitable aquifers from which a steady supply of ground water can be obtained in some parts of the Deccan Trap country.

TERTIARY GROUP

The Tertiary (or Cainozoic) era witnessed some significant changes in the physiographic, environmental, faunal and floral characteristics on the surface of the globe. The ancient Gondwana land was broken down into a number of fragments and these drifted gradually to form the modern southern continents. The great orogenic movement was in operation during the Tertiary era and the Himalaya mountains attained their present configuration in a series of five remarkable phases of uplift. Along with the rise of the Himalaya, the geosynclinal basin (i.e. the Tethys) became progressively shallower. As a consequence, the initial marine environment of the Tethyan sea gradually changed over to estuarine and, after the principal phase of the Himalayan upheaval in Middle-Miocene, fresh water environment prevailed in the resulting inland basins. Along with the aforesaid changes in physiography and environment, the older life forms failed to adapt themselves to the new set up and in their place new plants and animals were brought into being and these continued to develop and flourish during the Tertiary era. Ferns, Cycads and Conifers which dominated during the Mesozoic era became much less important and were replaced by the angiosperms. The mighty reptiles of the Mesozoic era became extinct and, in their place the mammals grew as dominating group. The ammonites which occurred in abundance in the Mesozoic seas disappeared just before the advent of the Tertiary era.

In India, Tertiary rocks are particularly well developed in the Extra-Peninsula where they occur practically all along the length of the Himalayan ranges. Characteristic geological successions of Tertiary rocks have been studied in Jammu and the Himachal Pradesh Himalayas, Assam and the Andaman & Nicobar Islands in the south. In the Peninsula, small patches of Tertiary rocks occur in Rajasthan, Gujarat (Kutch) and along the eastern coast in West Bengal, Orissa, and Tamil Nadu. In the early stage, it is marked by rocks of marine facies which in the later periods, through estuarine condition, became a fresh water one in the Siwalik time. It is also the major constituent of the Indo-Gangetic plains including the Bengal Basin.

In Gujarat and Rajasthan, the Lower and Middle Eocene are well represented by equivalents of Ranikot and Laki series. Over these the Murree series of
Lower Miocene age lie unconformably which again is overlain by the Siwalik system of rocks composed of limestones, shales and sandstones ranging in age from Miocene to Pliocene. In other parts of Himalaya, Hill limestone and Chharat Stage represent the Eocene rocks over which the Murrees and Siwaliks rest unconformably. In the eastern extremity the Tertiary rocks are well developed in the Assam region by Jaintia series of Eocene age. Over this the Barail series were deposited during the Oligocene time. Surma, Tipam, Dupitila and Dihing series were laid successively up to the Plio-Pleistocene. These are rich in oil and coal. The Siwaliks are famous for their spectacular vertebrate fossil wealth.

QUATERNARY GROUP

With the advent of Quaternary Period, the Northern Hemisphere witnessed a widespread glaciation. Throughout this period cold climate recurred five times interspacing with four interglacial warmer periods. Spells of Ice-age caused extinction of the major parts of the previous flora and fauna. However, some of the existing life migrated to other parts.

In the Extra-Peninsula in the Himalayan region, it is marked by glacial tillites. Bain boulder beds of Trans-Indus region are an example. Karewa deposits of Kashmir composed of sands, clays, loams, breccian beds were laid down in large lakes in the Himalayan region. Fossil assemblages of land plants and animals were reported from these deposits.

In the Peninsular region warmer climatic condition prevailed during this time. The vast Indo-Gangetic plain constituting the thick deposits of sands, clays, gravels, pebbles and peat beds formed during this period. The older alluvium contains remains of Pleistocene mammals. The younger beds consisting of sands and gravels, known as the newer alluvium, merges into the recent alluvial deposits. The fluviatile and deltaic deposits of Bengal and of other major rivers are included within this. The Pleistocene deposits are found in Narmada, Godavari, and Krishna valleys. Some of these contain fossils of Palaeolithic and Neolithic implements of ancient man. Rajasthan desert, coastal beach sands and limestone deposits of the Eastern and Western Coasts of the Peninsula, and lacustrine deposits of Kodaikanal, and Chilka were formed during this time.

SOILS

Soils that sustain the vegetation are actually the altered product of rocks of a particular area. Composition of soil is governed by the mineralogical components of the parent rocks. As there exists a great variety of rocks in India in different parts, an equal diversity in the soil types are observed.

Soil is defined as the part of earth crust in which humus is present. According to Daubenmire (1968) soil is a weathered superficial layer of earth crust with which
are mingled living organisms and products of their decay. According to Wadia (1953), soil is the topmost layer of earth crust capping the rock. The soil is made up of five components which include mineral particles, dead organic matter, soil atmosphere, soil water and biological system or soil micro-organisms.

Depending upon the mode of origin, soils are classified into two main groups: Sedimentary soils and Transported soils. Sedimentary soils formed from the disintegrated rocky material and remains at the same place where they are formed. Transported soils are brought from the place of their origin to another by various agencies. They are different types basing on the transporting agency. Illuvial soils are moved due to gravitational influence. While alluvial soils are transported by river courses. Glacial soils are shifted by glaciers and aeolian soils by wind.

Geographically soils of India are divided into three groups (i) Mature soils of Peninsular India (Red, Black and Lateritic soils), (ii) Alluvial soils of Indo-Gangetic Plains, (iii) Scanty soils of Himalayas. Some generalised soil maps were prepared under the auspices of International Society of Soil Science, Geological Survey of India and Indian Agricultural Research Institute. The soil types of India are presented in Map 4.


1. Laterite or Lateritic soils

Lateritic soils are generally reddish or yellowish-red and turn black on exposure to sun. This group of soils occurs in parts of Rajasthan, Madhya Pradesh, Bihar, West Bengal, Assam, Orissa, Tamil Nadu and in Eastern and Western Ghats. These cover an area of 2,48,000 sq km and are majorly composed of hydrated oxides of aluminium and iron with minor quantities of manganese and titanium oxides. The rocks rich in aluminium such as gneisses, sandstone, basaltic rocks and granites produce lateritic soils. These soils are formed in regions having alternate wet and dry seasons. Alkali and silica are lost in the leaching process and the residual compounds of rocks rich in aluminium and iron oxides form such soils. Laterites are well developed on hill tops and are characterised by low levels of lime, magnesia and nitrogen. There is higher content of humus.

In Tamil Nadu, laterites occur at different altitudes from a variety of rock materials under specific climatic and weather conditions. They occur along the West coast and in some parts of the East coast. Paddy is grown on the laterites at lower elevation while those at higher elevation support plantations of tea, cinchona, rubber and coffee. The soils are rich in nutrients and contain 10 to 20 per cent
Map 4. India - Soil Types.
(Source: *India - A Regional Geography*, R. L. Singh, 1971)
organic matter. The pH is generally low around 4.0 in the soils under tea plantations and at higher elevations.

In Kerala, at lower elevations the laterites show poor nutrient status and paddy is grown. Laterites at higher altitudes support plantation crops such as tea, rubber, cinchona, arecanut etc. The soils are generally poor in nitrogen, phosphorus, potassium and organic matter with pH ranging between 4.5 and 6.0.

The laterite soils in Karnataka occur in the western parts of the districts of Shimoga, Hassan, Chikkamagalur and Mysore. These soils are comparable to the laterites found in Tamil Nadu. In Kodagu (Coorg), laterites appear sporadically almost all over the country.

The soils of Uttara Kannada and Dakshina Kannada districts (North & South Kanara districts) are coarse, poor in lime and phosphorus but fairly good in organic matter. Laterites are found only in Ratnagiri and Konkan in Maharashtra. In the soils of Ratnagiri, coarse materials are found in large quantities.

In West Bengal, the area between the Damodar and the Bhagirathi is interspersed with some basaltic and granitic hills with laterite capping.

In Bihar, laterite occurs principally as a cap on the higher plateaus but is also found in fair thickness in some valleys.

The laterites of Orissa are found largely capping hills and plateaus occasionally in considerable thickness. Large areas in Khurda are occupied by laterites.

2. Black cotton soils or Regur (Regada = Black)

These are black soils and best suited for cotton cultivation. Black soils are locally known as ‘regur’ in some states and are distributed in Tamil Nadu (Ramanad and Tirunelveli (Tinnavelly) districts), parts of Karnataka, Andhra Pradesh, southern districts of Orissa, Maharashtra, Bundelkhand region of Uttar Pradesh, Western Madhya Pradesh, some districts of Rajasthan and Gujarat. It covers a total area of 5,46,000 sq km.

The black soils are derived by the decomposition of trap rocks and its black colour is due to presence of superficial iron in the rocks. The surface fraction consists of small transparent or semitransparent grains cemented together by dark coloured matrix which is a double hydrated ferrous and aluminium silicate.

The colour of black soil varies from place to place. Regur soils are mostly dark grey to black in colour. The soil is clayey (clay content 40 - 60%) or loamy. They are highly argillaceous, fine grained and contain a high proportion of calcium and magnesium carbonates. They are very tenacious to moisture and exceedingly