## PHYSIOGRAPHIC REGIONS

India was part of Gondwana land, the great southern continent of the world, which broke up after the close of Palaeozoic time period into huge continental blocks. These crystal slabs gradually drifted apart to form the present day continents of Africa, Australia, Antarctica, India and South America. The Talchir Boulder Bed of glacial origin indicates that during the Permo-Carboniferous period, India must have been situated far away from the equator. When Gondwana land was fragmented, the Indian continent drifted northwards. This movement caused the Peninsular Indian block to plough into the Mediterranean Sea of Tethys causing the pile of geosynclinal sediments there to buckle up. There is evidence to show that the northern borders of the peninsular block have been overridden by the much younger mountain ranges- the Himalayas.

The doubling of the **sialic** crust is responsible for the formation of the world's most elevated table land in the Tibet, the so called "Roof of the World". The Himalayan ranges continued to be uplifted by a series of very severe convulsions. These major crust movements were responsible for the sharply demarcated three-fold structural physiographical divisions of India, each with its own characteristic features- the Peninsula, consisting mainly of Precambrian rocks in a stable shield area; the Extra-Peninsula, forms a system of folded and faulted sedimentary beds which were deposited in a Mediterranean sea; and an intermediate tectonic' **rift** valley known as the Indo-Gangetic trough which is now filled with a thick deposit of alluvium.

**Northern Mountain Range**:

High relief, snow-capped summits, deeply dissected topography, antecedent drainage and complex geological structure give a distinct character to this geomorphic unit. The average width of this series of semi parallel or converging ranges varies from 160-400 km. The length of the central axial angle is about 2500 km. The slope is steep towards the plain of India (within a horizontal distance of 150 km the vertical rise is over 8 km) and towards the north, it merges gently with the edge of the Tibetan plateau. The ranges of Arunachal Pradesh, Assam and Bhutan make up the Eastern Himalaya. The Central Himalayas covers the mountain of Nepal and the Kumaon, Punjab and Kashmir mountains are included in Western Himalayas. The north eastern ranges on the Assam-Myanmar border strikes north south through Myanmar in an arc bulging towards the west. Beyond the ranges of the Western Himalayas lie the North

western Ranges stretching over Afghanistan and Pakistan culminating in the east-west trending hills of Baluchistan in the extreme south.

The Himalayas constitute the highest mountain system of the world. They extend for a distance of about 2,500 **kms,** having a breadth of about **150** to **400 km,** and cover an area of about 500,000 sq **km.** They are typically tectonic in origin, having been uplifted during the Tertiary time period from the bed of the great Mediterranean Sea, the Tethys. The Himalayas took probably several million years to attain to their present heights. These uplifting movements of these ranges have not ceased yet, as this region is still unstable and susceptible to earthquakes. During the slow process of mountain formation, by folding and upheaval of the rock beds, the old rivers kept very much to their own channels, and hence are seen to cut across these ]nightly ranges. For example, the west-flowing river Sutlej has cut across a high range and runs through a steep-sided valley. The Himalayan chain has **an** arcual layout with the convex side facing the Indo Gangetic plain. The southern boundary is clearly demarcated by the 300 m contour line in the west, and the 150 m-contour line in the east. From the foot-hills the Himalayas rise rapidly northwards to over **8,000** m within a short distance. The heights are covered with perpetual snow which feeds the valley glaciers, but the greater **part** of the Himalayas lies below the snow-line and is dissected by fluvial erosion.

The Himalayan Mountains can be divided into three parallel or longitudinal zones, each with definite geographical features - the Great -Himalayas **(Himadri)** in the north, the Lesser Himalayas **(Himachal)** in the middle, **and** the Outer Himalayas **(Shivalik) i**n the south.

**Himadri**

The Great Himalayas or the Himadri is a majestic range of mountains which rises above the lower limit of perpetual snow. The average elevation of the range is about 6,000 m, and some of the highest peaks of the Himalayas are situated in this range - Mount Everest **(8.848** m); Kanchenjunga **(8,598** m); Dhaulagiri **(8,172** m): Nanga Parbat **(8.1** 26 m); Nanda Devi **(7,8 17 m)**and other peaks. This great mountain chain at its western and eastern ends terminates with sharp **syntaxical** bends. The northern slopes of the Great Himalayan rulge descend gradually on to some prominent river valleys which run parallel to each other for long distances.

**The Himachal**

The Lesser Himalaya or the Himachals are a massive mountainous tract, **75 km** wide. Its average elevation is 4500m .The range is divided into many parallel running ranges as Pir Panjal, Dhaula Dhar, Mussouri, Kumaon ranges.

**The Shivalik**

The Outer Himalaya or the Shivalik forms the foothills of the Himalayan system, and lies between the Lesser Himalaya and the plains of India. Its width varies from **1 0** to 50 **kms,** and the average elevation is about 600m. These ranges are composed of upper Tertiary sedimentary river deposits. They are folded and faulted **by** earth movements which mark the latest phase of the Himalayan uplift. The ranges descend northwards into flat valleys called **duns** which are intensively cultivated and densely populated

The Himalayas as a great orogenic, arcuate belt possesses strict linear parallelism in lithology, tectonism and physiography. However, in the six fold division of the Himalayas, the individual segments are transverse to the Himalayan ranges. In the northwestern part in the Kashmir Himalaya, where the width of the mountain range is close to 500 kilometers it is possible to discuss the main longitudinal ranges individually but eastwards, particularly from the Sikkim Himalaya onward, the true longitudinal ranges cannot be described separately but instead they are assembled together.

**Kashmir Himalaya**

The Himalayas are at the widest in Jammu and Kashmir province and hence its four linear ranges: the Siwalik, Lesser, Central and Trans (or Tethys)-Himalayan Ranges are discernible individually in this north-western most province of India, covering 500 kilometers in width and 700 kilometers in length. The southern ranges of the outer Himalayan Siwalik belt, which coincide with the Jammu and Poonch regions, is made up of Tertiary and early Pleistocene time molassic sediments and they present a ruggedly youthful topography with a height of not more than 1,500 meters. This sub-Himalayan zone ends in the MBT in the north, from where the Pir Panjal Range rises. In the Pir Panjal Range there exists two passes: Pir Panjal (3,640 meters) and Banihal (2,740 meters) Pass. The Lesser Himalaya (separated by the MBT) with an elevation ranging from 1,500 to 3,000 meters has a comparatively mild topography which also includes a great synclinal basin, the Vale of Kashmir, which is 135 by 40 kilometers. The latter with a floor in the Jhelum thalweg at 1,500 meters height is topographically a floodplain with intensive landuse and human occupance. The Central Himalayan Range may be taken as commencing from Zozi La (3,529 meters) Pass, beyond Sonemarg, where the Main Central Thrust, MCT, brings a plane of abrupt cataclastic change in metamorphism, strong mylonitization and schuppen structure. Topographically, the Central Himalaya, a really high ground (3,000 to 8,000 meters) is pierced into extremely rugged immature topography (Nanga Parvat, 8,126 meters) with a homoclinal structure of early Pre-cambrian metamorphics. To the north of the Central Himalaya,

there stretches the vast fossiliferous sedimentary realm of the Trans (or Tethys)-Himalaya, the fourth domain of the Himalaya. This Trans-Himalaya is made up of sunclinorarily deformed huge piles of sediments deposited in the Tethys Sea and its precursor. With a floor in the Indus thalweg at Leh at 3,505 meters, the structures of folds tightened northwards from the upright isoclinal folding to vertical, strongly sheared recumbent folds and imbricating thrusts so that finally the Himalayas get separated from the Tibeto-Karakoram world of the continental block of Central Asia by a series of deep mantle-reaching faults. These truncated the Ladakh and Zaskar Ranges obliquely and formed the Indus-Tsangpo Suture Zone, ITSZ. This zone has been designated as the main mantle thrust in which the ophiolites, commonly foliated, deformed and serpentinized have been obducted and it represents the Tethys oceanic crust as well as the upper mantle material. This ITSZ sharply and dramatically separates the vast sedimentary realm of the Tethys Himalaya from the Tibeto-Karakoram world of the Eurasian continental block.

**Punjab Himalaya**

The territorial arrangement of the Punjab Himalaya is the separation from the Kishtwar area of the Kashmir Himalaya by the Chandra (or upper Chenab) Valley from which this Himalayan region stretches north eastwards for about 570 kilometers to the Satluj river. In this domain there is the usual longitudinal arrangement of the parallel Himalayan ranges. The Siwaliks here have a remarkably linear crest at 610 to 915 meters height but since this area in the northern districts of Punjab is largely deforested, the barely coherent sandstone rocks are savagely eroded into ravines particularly in the 130 kilometers long stretch of Hoshiarpur district. In this area overlying of the Siwalik rocks on the recent alluvium by the Son thrust indicates neotectonic activity. The Lesser Himalaya in this region (between the Chenab on the west and the Jammu on the east) has a tangled mass of intermediate spurs like the Kishtwar and Dhauladhar Ranges from a height of 2,155 to 4,570 meters. The former separates the long northwest to southeast extension of the Chenab (in the upper valley) from the Ravi and the latter separates the longitudinal sections of the Ravi and Beas. The topography of the Satluj and Jamuna which defiles further east is highly confused in detail with the major Jutogh-Chail thrusts that cover the complex and strongly folded anticlinorial autochthon of the Pre-cambrian sediment and now best seen in the Larji window in the Beas Valley. Finally, the Central Himalaya is on the whole much lower, the high peaks are rare in this section (with the great cleft of the Satlej cutting across the Zaskar and the Central Himalaya at 1,525 to 2,121 meters) and much more broken here than either in Kash-

mir or further east in the Kumaon Himalaya, Rohtang (3,978 meters) and Bara Lapcha (4,891 meters) are the important passes in this section.

**Kumaon Himalaya**

Broadly speaking, the Kumaon Himalaya stretches for about 320 kilometers between the Tons feeder of Yamuna and Kali rivers (the feeder of Sharda), the latter forms the western boundary of Nepal. The region thus includes the Himalayan basins of the Yamuna, Ganga, Ramganga and Sharda from west to east. The area raises abruptly from the fans of the piedmont (bhabar) belt, the junction of which is designated as the Himalayan frontal Fault, HFF. The latter cuts the folds and thrusts with steep reverse faults which gives rise to a progressively deepening depression in front of the Siwaliks with rising hills but now sedimented to develop duns, for example Dehradun Valley, one of the world's largest parabolic prisms. Further northwards, the steeply inclined Krol thrust of the Main Boundary Fault sharply cuts the youthful autochthonous Cenozoic sedimentary zone of the Siwalik from the much older Lesser Himalayan Range. Most of the Lesser Himalayan Range in the Kumaon Himalayan region consists of a maze of ridges and a highly dissected country (1,230 to 2,135 meters) of three major nappes – the Krol-Berinag-and-Almora thrust – which cover the complex, strongly folded, broadly anticlinorial autochthon of the Precambrian sediments. On the outer flanks of this region lie Chakrata, Mussoorie, Ranikhet, Almora and Nainital. The Central Himalaya in Kumaon is a huge tectonic slab rising to a magnificent series of glacier-garlanded peaks, for example Trisul (7,120 meters), Santopanth (7,084 meters), Gangotri (6,614 meters), Shivling (6,638 meters) of the Kedarnath-Badrinath group (6,614 to 7,120 meters), Nanda Kot (6,898 meters) and finally Panchuli (6,895 meters) at the extreme northwest corner of Nepal.

**Sikkim Himalaya**

The Himalayas continue from River Kali to the Singhalila Ridge on the east for more than 880 kilometers through Nepal in its most stupendous form (having the world's highest point, Mount Everest, 8,840 meters or 29,008 feet high). Between the Singhalila Ridge on the west and River Rangit is the hour-glass shaped little geographic domain of Darjeeling Hills on which the formations and metamorphosed equivalents spread of the higher ranges of Sikkim Himalayas are thrust. The mountain torrent of Tista in its descent from the Sikkim Himalayas cuts the Darjeeling Ridge (2,135 to 2,440 meters) in a narrow gorge running west of Kalimpong at Sevok bridge to spill on to the plain in a vast alluvial fan, rearmed with old courses known as the dooars (equivalent to terai in Nepal) and spread largely over Jalpaiguri district. The resting of the Pre-cambrian crystallines upon this alluvial fan of the Tista at places suggests also that the Siwaliks

in this part of the Eastern Himalayas are not developed and in their place a band of steeply thrust Gondwana rocks are observed along the whole length of the foothills of the Nepal Himalaya extending through Darjeeling and Sikkim into the frontal thrust regions of the Arunachal Himalaya. All along the foothills of the Darjeeling Himalaya these Darjeeling Damudas are overthrust in the area as tectonic relief and this thrust zone coincides with the Main Boundary Thrust, MBT. Thus the Darjeeling Hills not only show the imbricating sheets of tectonic slices leading to schuppen structure like in the Western Himalayas but they also indicate the thrusting by the Gondwana conglomerates (for example, Damuda rock) from the south. The important peaks of Darjeeling Hills are Sandakphu (3,630 meters), Phalut (3,596 meters), Saborgam (3, 543 meters) and Senchal (2,615 meters).The high hills of Darjeeling on the west form a mountain cleft which is in Sikkim and the region itself is in effect all but an enclosed basin between Singhalila and the Donkhya Ranges. This part of the Darjeeling Himalaya in Sikkim is occupied by River Lachen, the mountain torrent of the Tista along the axis of overturned anticline at the core of which lies the Kanchenjunga massif, 8,579 meters high, the third highest point in the world and the highest in India. A 50 kilometers long north-south dissected domal uplift of this massif dominates this Sikkim Himalaya. The Central Himalaya in Sikkim is simply built, being characterized by open folding rather than the intense homoclinal folding in Western Himalaya) which make it the most well known and easily accessible section of the Himalayas.

**Arunachal Himalaya**

East of the Kanchenjunga, there is a gap in the Central Himalaya and little is known about the high Himalaya further east in Bhutan and Arunachal where the crest barely reaches 6,400 meters. Arunachal is the easternmost part of the Himachal where upto Dihang-Dibong-Lohit confluence, a little beyond Sadiya, the Himalayas maintain their west to east strike but mountains in the form of ridges curve around the Sino-Indian-Burma Plateau to turn north-south. The Lohit river basin forms the southeastern boundary of the Arunachal Himalaya. At this eastern end of the Central Himalaya is Namche Barwa (7,757 meters), the highest peak east of Kanchenjunga. The wild Dihang cuts a gorge, some 5,500 meters deep, in hair-pin shaped bends below Namche Barwa to link the Tibetan Tsangpo with the Indian Brahmaputra River. Like the Daling series in the Darjeeling Himalayan region, the Lesser Himalayan nappes in the Arunachal are also involved in very severe deformation of the Pre-cambrian Gondwana rocks, resulting in the spectacular shuppens, for example the Aka, Daphla, Miri, Abor and Mishmi hills in the foothill zone. Again, like in other parts of the Eastern Himalayas, here also the central Himalayan range is characterized by open folding and much less relief.

Since this easternmost Himalaya as a rampart overlooks the 640 kilometers long Brahmaputra Valley closely, the spread of the alluvial cone is restricted because of the progressively deepening Subansiri basin which appears to be sinking parri passu.

**Purvanchal Himalaya**

In the northeastern margin of the Arunachal province, the mountain ranges of the Himalayas bend topographically (but not structurally) in the form of a spectacularly sharp V-shaped re-entrant by the north-northwest to south-southeast trending Lohit thrust (which is the Main Boundary Thrust, MBT in the area) wrapping the tightly packed parallel ridges and valleys of the Patkai-Naga. They extend beyond the region as Arakan Ranges in a linear north-northeast to south-southwest trending belt of 240 kilometers width. This trend of the ridges and valleys have apparently given a mild bulge to this region towards the west. This belt, formed of the upper Cretaceous to Eocene flysch and molasses sediments of sandstones, limestones and shales, has severe deformation leading to the Tertiary successions and into multiple thrust sheets of schuppen character in the northern part (Nagaland-Manipur). In the southern part, in Tripura and Mizoram, the folded structure is a synclinorium consisting of broad synclines and tight-faulted anticlines. This structural characteristic makes the region tight-packed with north-south aligned ranges defined by knife-edged parallel valleys. The drainage system in this Purbachal Himalaya, particularly in Mizoram, shows an extraordinary trellis pattern of the Jura type. Topographically, the Purbachal Himalaya is the lowest among all the six Himalayan regions discussed here since the ridges in this region rarely exceed 2,135 meters though Saramati in the Naga Hills on the Indo-Burma border attains (3,826 meters) height, carrying snow at the summit occasionally. Starting from the north, Dapha Bum of the Mishmi Hills is the highest peak (4,579 meters high) not only of the Lohit district but of this Purbachal Himalaya also. (Consider to be part of Himadri) Again, in Nagaland, the Barail Range piercing from the southwest via the Cachal Hills, runs upto Kohima with its highest peak, Japavo (2,995 meters) lying to the south of the town. The general elevation of the Purbachal Himalaya increases towards the northeast and the altitudinal range of 900 to 2,100 meters covers a large part of Nagaland and Manipur. The Manipur Hills make an oval rim enclosing the Imphal Valley which is an oblong shallow saucer stretching for 57 kilometers north-south and 32 kilometers east-west with the Loktak Lake occupying its lowest part. The region ends in the south with the Luchai (or the Mizo) Hills which in Mizoram exhibit an alternate arrangement of parallel ridges and valleys within a height range of 150 and 900 meters though peaks of over 1,500 meters elevation are not rare. A series of long-drawn sharp edged spurs from the Mizo Hills pierce the Tripura and

Cachar region – the latter is a low lying plain at 150 meters height. This area is virtually a part of the Surma Valley (downstream in Bangladesh), built up by detrital materials. Due to the lack of sufficient slope, the surface is dotted with a number of swamps and marshy tracts.

**Plateau:**

It is in the shape of an inverted triangle occupies the greater part of central India and the Deccan with typical landscape of extensive flat or rolling plains at altitudes from 300 m to 1000 m. In central India, the Malwa and Vindhya plateau (scarp land) on the Vindhyan Mountain range on the south and decline gently northwards. The topography of Eastern plateau is diversified, ranging from low lying Mahanadi basin to undulating plateau of Baghelkhand, Chotanagpur, Dandakarnaya. The Maharashtra plateau is formed entirely of basalt and the plateau of Karnataka, Telengana are composed of Archean gneises. The hills in India are either remnants of worn down mountains as Aravallis, Satpura, Eastern Ghats or dissected plateau excarpment as Vindhyan hills or Sahyadri along west coast.

Peninsular plateau is recognized to be the part of ancient Gondwanaland. It thus represents one of the significant examples of shield of the world. Developed in Azoic, it incorporates Paleozoic reconstruction and Cenozoic modifications. The triple tectonic characteristics of India is individually justified in this relief thereby. As per the present relief profile in general, this shield has reached old stage of cycle of erosion. Its general configuration is that of a rolling Plateau with isolated relict hills in the central part and chain of hills surrounding it. Physiographically, this relief is divided on the basis of both location as well as geological structure. The central highlands include the Aravallis range, the Vindhyans and the Satpuras. These relief features belongs to the Paleozoic era. Aravallis are majorly made up of limestone, dolomite deposited in the geosyncline. It also incorporates metalliferous minerals as the reference of Azoic construct. Extending for 800 km, this range registers an increase in height towards south. It is Gurushikhar that represents the highest peak of range. As water divide, it demarcates inland seasonal drainage Banas to its east. The Vindhyan range though represents limestone dominated construct as Aravalli, it is Paleozoic block. Like Aravallis, it has Cenozoic basaltic modification towards its west covering considerable stretch in central India with average elevation of 300 m. The main features of the region are scarps of Vindhyan sandstone. The range also includes Bandher plateau, Kaimur hills and Baghelkland as its physiographic constituents. It slopes gently towards the north and abruptly towards south. The Panna hills forms the diamond bearing horizon. This entire belt structurally belongs to Archean and Purana, Upper

Pre-Cambrian construct. South of Vindhyans, lies narrow valley of Narmada, the example of rift valley. The river flows westwards forming several waterfalls as Dhuandhar falls near Jabalpur. The Satpura range also forms the example of Paleozoic block. More extensive and high elevation, this block is incorporating Cenozoic basalt construct. Generally, this range has elevation between 600-900mts extending between Narmada and Tapi rift valleys. It extends from Rajpipla in Gujarat to Maikala range in Chhattisgarh. The Gwaligarh range, Betul Plateau, Mahadeo hills are the other physiographic constituents. Dhupgarh in Panchmarhi is the highest elevation. Amarkantak represents the radial drainage of Narmada, Hasdo and Johilla rivers. South of river Tapi, Satmala and Ajanta ranges are identified. Majorly made up of Upper Precambrian construct, it has significant basaltic construct of Cenozoic. The Azoic relief includes crystalline plateau with major structural and relief features. The Deccan plateau is a triangular plateau extending between Eastern and Western Ghats, south of river Tapi. The relief is dominated with denuded hills and dissected plateaus. The Maharashtra plateau and Malnads of Karnataka has major basaltic construct developed over Archean Gnesis and Schist as well as Dharwar series. The plateaus of Telengana and Dandkarnya are majorly the Archean structure with Dharwar/Cuddappah structure. The gradient of these tablelands are generally towards east. Western Ghats demarcates the western boundary. Also called Sahyadris, these mountain escarpments represents continuous profile barring Thalghat, Bhorghat gaps. Acting as water divide between Sahyadri basin and rest of peninsular basin; it is physiographically extending till Nilgiris. The Phalghat gap and Shenkotta gaps further forms the divides. Though considerably narrow, Sahyadris have Balaghat and Harishchandra ranges in Maharashtra along with Baba Budan, Melagiri, Schechacalam hills and Bangalore-Mysore Tableland as extensive parts in Karnataka. The structural characteristics of the Sahyadris are similar to that of peninsular plateau with Archean, Dharwar and basaltic Cenozoic construct. The Eastern Ghats are more low-lying and dissected owing to riverine deposits. Mahendragiri, Nallamalla, Palkonda are the significant constituents. Tikarpara, Nayagarh forms the discontiguous and Mahendragiri due to Brahmani, Mahanadi and Rushkuliya rivers. It is delta deposits of Godavari and Krishna that demarcates Nallamalla and Mahendragiri. The Penneru river incorporates the tributary network that forms the cause of Erramalla, Velikonda, Palkonda and Nagari hills. The southern hills as Javadi, Sheveroy and Panchimalai hills demarcate the plains of Tamil Nadu. Structurally it though has Azoic built, it has Cuddappah structure. The Malwa–Bundelkhand tableland has the similar geological construct to that of Deccan trap. It however has flat topped feature and it is majorly dissected by peninsular tribu-

taries of Yamuna. The Chottanagpur plateau though is the extension of shield; it represents lack of Cenozoic construct. The Hazaribagh Plateau, Garjat hills, Ramgarh hills and Rajmahal hills are the physiographic units. The far eastern uplands are discontiguous extension of Chottanagpur plateau. It however is distinguished on the grounds of more lateritic construct. On to the extreme west is the Kathiawar upland, known for its basaltic construct. It has Gir range, Girnal hills, Barda and Mandvi hills as its physiographic subdivides. Radial drainage forms its characteristics also with Bhader, Shetrunji, Bhogawa and Machhu rivers.

**Plains**

Plains are relatively low lands moderately undulating or flat. Plains occurring on continental borders are known as coastal plains. Interior plains are those which are situated in the interior of a continent. The plains of India are of great importance from historical point of view, as they have been the craddles of ancient cultures. Almost all the different types of plains are found in the vast Indian subcontinent, which are briefly described as following

**Great Plain of India**

Between the Himalayan Range in north and plateau to south, lays the Great Plain of India. These are aggradational plains, formed by the work of river systems, Indus, Ganges and Brahmaputra. The **arcuate plain** extends for the length of 3200 km (in India it is 2400km). Its average width varies between 150-300 km. Covering about 7.8 lakh km$^2$, its northern boundary is much specified by Shiwalik though the southern boundary is quiet irregular. Geologically, these plains were deep depression and were filled up by the both alluvium of peninsular and Himalayan Rivers. These plains are categorized on the basis of the **soil structure**. The **Bhaber** is a narrow belt of about 8-16 km of width at the foot of Shiwalik with continuity from **Rabi** to **Tista** Rivers. These are riverine deposits, mainly of gravel and unsorted sediments. These are thus, the northern boundary of the plain and is lacking in cultivation potentiality. The **Tarai** is 15-30 km wide marshy land running parallel to Bhaber. As the braided streams dominates the landscape, thick stand of deciduous trees are typical feature of the plain. Towards east, wet climatic conditions and towards west, large streams descend makes the Tarai belt homogenous in its characteristics. The **Bhanger** is an old alluvium of these plain, deprived by annual renewal. To the arid west land, it reveals calcareous structure called **Kankar**. These mark universal presence in the alluvial terraces. The **Khader** on the contrary are composed of new alluvium. These are thus confined to the present flood prone river basins. It is Khader that avails the most fertile characteristics, as per the annual renewal of soil and spatially mix up with coastal delta deposits

in West Bengal. On the basis of **climatic conditions** and **riverine** course, the great plains are divided into several **regional units**. The units reveal the characteristic details of the Great Plains.

**The Trans Gangetic plains** are confined to north – western extents of the plain where the arid, semi arid climatic conditions prevails. Physiographically, it thus includes the arid plains of **Thar Desert** and **Rajasthan bagar** to west and Sutlej – Yamuna plains in east. The Thar desert – **Maruasthali**, is typically recognized with the shifting sand dunes – **Dharians**. The temporary playa lakes **Dhands** and the temporary furrows **Dharos** forms the other characteristic features. Comparatively towards Aravalli range **bagar**, sandy alluvium of luni river network avail **rohi**, the fertile land. The luni basin is characterized also with the saline lakes availing inland drainage – Didwana, Sambhar are the prominent examples.

The semi arid trans-Gangetic plain are characterized by the **doab** soil. **Bist** and **Bari** doabs, coarser alluvium are the most significant characteristics. The **chos** are the braided streams descended from Shiwalik. **Betlands** and **Dhayas** are the flood plains and bluffs known for their agricultural value. Being semi arid, these alluviums are influenced by calcification and thus are kankar rich. The **Bhiwani Bagar** forms the inland drainage basin of Ghaggar in Haryana. Dry for most part of the year, this river basin incorporates saline tracks also.

**The Gangetic plains** are the largest constituent of the northern plains of India. It stretches from river Yamuna to river Hooghly. Apart from Himalayan Rivers, it includes the deposition of peninsular streams also. The over all gradient of the plain is from NW to SE. It is on the basis of **riverine course** and **climatic conditions** that these plains are categorized into three, physiographic units. The **upper Gangetic plains** are sub-humid plains politically confined in Uttar Pradesh. Generally, these plains are doabs, divided into Rohilkhand and **Awadh** plains. Mainly these plains are characterized by sandy alluvium, **bhurs** and **kols**. The Rohilkhand plain is dominated by Ganges – Yamuna doab and the low lying Awadh plain has Ghaghra, the principal stream. The **mid-Gangetic plains** are humid plains of silty alluvium. These plains are divided into two parts, demarcated by Ganges flow. The northern plains are **Mithila** drained by Gandak, and Kosi and southern plains are **Magadh** drained by river Son, Punpon and Badna. The Magadh plains are dotted by azoic shield thus **chaurs**, fresh water lakes represents the prominent characteristics. For the Rajmahal hills, these lakes are called **Kavartals**. The **lower Gangetic plains**, have clayey alluvium with par moist conditions. The **barinds** and the coastal delta thus are the two most important physi-

ographic divides. The sub-Himalayan plains however incorporates **duars**, the alluvial cone and the plateau, plain have developed **Rahr** plains.

**The Brahmaputra plain**s are 720 km long narrow plains between Dhubri and Sadiya. Large number of tributaries of Brahmaputra makes the plain characterized with meanders, Oxbow lakes. The majuli riverine island forms the important feature at the confluence of Disang and Subansiri. The Indian plains, with renewed soil makes the fertile lowlands, sustaining the food requirement of the country. Its year-round cultivation is also favoured by Himalayan barrier restricting polar winds.

The **coastal plains** are the alluvial plains of varying width. East plain is broader with deltas of all the major peninsular river whereas west is narrower excepting for its northern extension, where it has broader delta deposits of Sabarmati and Mahi. These plains are referred to have attained their narrow characteristics due to subsidence during Paleozoic.

The Indian Ocean was formed when Gondwanaland broke up and the different parts moved apart. Breakup of Gondwanaland started in the Africa-Tasmania-Victoria land region according to F. Ahmad. India-Australia-Antarctica started sundering apart from Africa in the Cretaceous Period and the Carlsberg Ridge was formed. Soon after, however, India-Australia-Antarctica started rotating in an anti-clockwise sense independent of the Carlsberg Ridge. Widespread faulting occurred in peninsular India and it extended to Western Australia. Thereafter, Antarctica-Australia drifted away from India by crustal sliding and after that Antarctica broke away from Australia in the Oligocene time and moved into its present frigid zone. All the waters between these land masses formed the various parts of the Indian Ocean. With the breakup of Gondwanaland during the later Mesozoic era the Indian Peninsula seems to have acquired its main outline only about the beginning of the Cretaceous, except for its northwestern part which already had a coastline in the Permo-Carboniferous. India probably separated from Madagascar in the Upper Cretaceous when the western coastline developed. The east coast went straight up to Upper Assam during the Upper Mesozoic and Lower Cenozoic. The truncation of this long coastline to give it the present reduced length occurred in the late Tertiary when the Bengal Bain started to develop and separated the Shillong Plateau from the main mass of the Peninsula. It thus appears that the two coasts of India evolved at different times in geological history. The coasts that surround the Indian Peninsula are of the longitudinal Pacific type which border mountain chains. The major portions of the Indian coasts are either stable or advancing, being built into the sea by deltas or estuaries. However, an example of the retreating type of coast is found near Rameswaram where the land surface

connecting the southern tip of India with Sri Lanka was drowned during the Quaternary times. The submerged link is not more than 13 m deep, and a narrow land bridge between the two countries is now represented by the Pamban Island and the Mannar Island connected by the Adam's Bridge lying midway between the two islands. The Adam's Bridge is a drowned ridge whose crests are exposed during low tides.

The east coast is much broader than the west coast; the former presents a more smooth outline than the latter, though the indentations in the west coast are not prominent.

**The East Coast**

The east coast of India starts from the edge of the Ganga delta and extends right through to the southernmost tip of the Peninsula at Kanyakumari (Cape Comorin) facing the Bay of Bengal. The coast is mostly of the emergent type, that is, it is regular in outline and is characterized by offshore bars, fine sea beaches, sand ridges and lagoons. Most of the great rivers of India, barring a few notable exceptions, have their mouths on this coast. The coastal plain on the east is much wider than that on the west. Here the narrow strip of beaches is fronted by rows of sand dunes, broken by a number of lagoons. The surfaces of the **Kanthi Coastal Plain** of West Bengal and the **Balasore Coastal Plain** of Orissa are more or less terraced, and the **Mayurbhanj Plain** on their hinterland is partly aggradational and partly erosional. The **Nadhra Plain** is much narrower and is flanked by outlying spurs of the Eastern Ghats. South of the Krishna delta, the coastal plains broaden again and are successively designated as the **Nellore**, **Tamil Nadu** and **Tuticorin Coastal Plains**. They are mostly alluvial plains with belts of sand dunes in between.

The low level and the smooth contours of the tract of country which lies in front of the east coast below the Mahanadi suggest that it was a submarine plain which has emerged from the waters at a comparatively late date. Behind this coastal belt are the gneissic highlands of the mainland, the Eastern Ghats, which are marked by a more varied relief and rugged topography. Between these lies the old shoreline.

The east coast is marked by several lagoons and deltas. The most prominent lagoon is the **Chilka Lake** on the Orissa coast. It is about 70 km long and its maximum width on the northeast is about 22 km narrowing to some seven kilometers on its southwestern end. It is barred by two spits (a long, narrow sandback extending from the shore) from opposing directions, leaving a narrow opening through which sea water enters into it during high tide. These spits were formed probably by accretion, like some of the islands that occur in the lake. Another remarkable lagoon is the **Pulicat**, which has been barred by a long sand spit, now known as Sriharikota Island, on which

stands the satellite launching station of the Indian Space Research Organization. The lagoon is about 60 km long and about 15 km in the widest part. It is dotted with several large islands, and its northern portion is emerging as a swamp. There are some smaller lagoons on the east coast but many of them now lie far inland having been completely closed by the advancing coastline.

The great east-flowing rivers of the Peninsula have formed large deltas. The deltas of the Godavari and the Krishna Rivers have merged with each other, and have advanced their faces towards the sea for at least 30 km during recent years. This is clear from the present position of the **Kolleru Lake**, which was once a lagoon on the shore but now lies far inland. This lake is now connected with the Goyyeru lagoon by a channel. Some of the smaller east-flowing rivers, like the Subarnarekha, Pennar, Palar and the Coleroon have formed small estuaries.

**The West Coast**

The west coast of India also culminates at Kanyakumari. It was also formed due to faulting. This straight-looking coast is however quite jagged marked by a large number of coves (small, sheltered recesses in the coast) and creeks (small tidal inlets or estuaries of small streams). A large number of very small streams descend from the precipitous Sahyadri Range and flow through the narrow coastal plain to open into the Arabian Sea. Although the streams are very small, some of them have formed spectacular waterfalls.

The **Gujarat Plains** are built up mainly of the alluvium of the Sabarmati, Mahi, Narmada and the Tapti Rivers, all of which have formed large estuaries. The **Konkan Coastal Plain** to the south is cliffy and there are several shoals, reefs and islands in the Arabian Sea. Bombay was a large island but parts of the sea have been reclaimed in recent years to connect it with the mainland. There is a submerged forest near Bombay which suggests that the sea level rose on the Konkan coast not long ago. This coastal plain is dotted with flat-topped low hills. Transverse, flat-looped spurs come down almost to the shoreline from the edge of the plateau in the northern part of Karnataka; these appear to be abrasional platforms, now dissected by the west-flowing streams. It is only on the Malabar coast that there are seen a number of lakes, lagoons or backwaters which form a noteworthy feature of the coast. These backwaters, locally called kayals, are shallow lagoons or inlets of the sea, lying parallel to the coastline. The largest among these in the **Vemband Lake**, which is about 75 km long and 5-10 km wide; it gives rise to a 55 km long spit. Cochin harbor is situated on its opening into the sea. These backwaters form an important physical as well as economic feature of the Malabar coast, affording facilities for inland water communication.

The silt brought by the recurring monsoon floods supports large forests and plantations along their shores. At some places, especially along the tidal estuaries, deltaic fronts, or salt marshes, there are remarkable mangrove swamps lining the coasts.
Some unique mud banks have been located between Cochin and Alleppey in the continental shelf off the Vemband Lake. They occur in shallow water, about 10 m deep, and are 25 sq km or more in area. They are possibly the modern analogues of an ancient hydrocarbon generating environment. They are characterized by rapidly accumulating fine-grained silty clay, high organic matter, oxygen-deficient bottom waters, and dense mud suspensions. The environment is suitable for gas generation within the sediments.

**Sea Level Fluctuations**

The Bay of Bengal and the Arabian Sea came into existence only during the Cretaceous or early Tertiary period as prolongations of the original ocean after the foundering and breakup of Gondwanaland. After that the configuration of the Indian coast more or less assumed the present form, though during the late Pleistocene and early Holocene the shape underwent modifications with fluctuations in the sea level. There is plenty of evidence to show that marine transgressions have taken place since then, some in historical times.
The most well-known example of subsidence or transgression in recent times is the existence of a submerged forest at depths of 6-12 m below the present sea level on the eastern side of the island of Bombay. Marine archaeologists have recently discovered the ancient city of Dwarka lying under shallow waters off the coast of Saurashtra.
Good examples of eustatic changes of the sea level are provided by the shores of Kathiawar and the Gulf of Kutch. Here, there are raised coral reefs and oyster beds extending inland up to the high level, indicating either that the land has been elevated slightly or the sea level has fallen. Similar littoral concrete of pure reef or calcareous beds of well-cemented shells and corals is also found in many places on the west coast, especially in the city of Bombay. Similar raised oyster beds near Kolkata have also been reported.
The Rann of Kutch is the best example of repeated falls in sea level, giving rise to the present day extensive marshland. Striking proofs of the eustatic change are furnished by coastal dunes along the northern edge, islands in the Gulf with typical sea cliffs, sea caves within the plains, and raised beaches of littoral concrete on the fringes of the islands. The total fall in the sea level has been measured at 26 m. Before the Rann became dry, the Luni River used to enter the Arabian Sea through the Kori estuary crossing the entire length of the Great Rann, and the Western Banas flowed over the

Little Rann to discharge into the Gulf of Kutch. The Andaman and Nicobar Islands also afford evidence of eustatic rise and fall of the sea level. Raised coral beaches, marine conglomerates and sea caves in uplifted platforms much above the high water mark provide proofs of this. Another evidence of submergence is the existence of drowned valleys of several coastal rivers flowing transverse to the coast.

Some islands off the western shore along the Arabian Sea are believed to be mesas and buttes on coastal plains which were isolated to form islands because of submergence of the low-lying areas around them. The land bridge and shallow platform of Palk Strait connecting the southern tip of India with Sri Lanka has already been mentioned.

**Islands**

India has a number of islands both is Bay of Bengal and Arabian Sea. The Andaman Nicobar islands represent the elevated portions of submarine mountains. The Andaman group incorporates North, Middle, South and little Andamans. Mount Marriet (460 m) is the highest point in the archipelago located in South Andaman. The Nicobar group of islands includes Great Car, little islands Barren and Narcondam are the islands parallel to the main chain and are volcanic in their origin. In Arabian Sea, Amindivi, Cannanoore and Minicoy forms the major group of coral islands. These are collectively Lakshadweep. These islands have fringing reef very close to their shore.

This archipelago forms a north-south trending arcuate chain, convex to the west, and is composed of some 265 islands, from tiny inhospitable rocky projections above the sea level to large islands several hundreds of square kilometers in area. This part of the Bay of Bengal is called the Andaman Sea. The islands cover a cumulative area computed at 8,090 sq km. they stretch from latitude 14° N to 6° 302 N in two distinct groups: the Andaman chain to the north, which is separated by the Ten Degree Channel from the Nicobar group on the south. The distance between the southernmost island in the Andaman chain, the Little Andaman, and the northernmost island of the Nicobar group, the Car Nicobar, is 140 km. The Andaman is a close knit group of 203 islands, covering a total area of 6,496 sq km. The main part, collectively called the Great Andamans – composed of North Andaman, Middle Andaman, South Andaman, Baratang and Rutland Islands along with numerous small islets – forms a compact cluster; it spreads roughly for a length of 260 km and width of 30 km. Separated from it by the Duncan Passage, a 50 km wide open stretch of sea, lies the **Little Andaman**, about 43 km long and 23 km wide. To the east of the South Andaman, paralleling some 12-25 km away for nearly 600 km, is the Ritchie's Archipelago.

The **Nicobar** is a group of widely scattered islands, spread over 262 km length and the extreme width of 58 km in the sea, covering a total area of 1,647 sq. km. It is made up of seven large and 12 small islands together with several tiny islets. The Car Nicobar, Teressa, Camorta, Katchall, Nancowry, Little Nicobar and the Great Nicobar are the main islands of this group. The last named is the largest, as the name suggests, 50 km long by 25 km wide. It is the southernmost island of the archipelago, and is only 147 km away from the Indonesian island of Sumatra – the two separated by the Great Channel. Most of the islands in the archipelago are made up of hard rocks, mainly fossiliferous Tertiaries resting on basic and ultra basic volcanics. Some of the islands are fringed with coral reefs, and some coral banks also occur. The topography of these islands is mountainous and rugged, and some of the summits reach considerable heights. A central range of hills is recognized in the Great Andamans. Some peaks worth mentioning are: the Saddle Peak in North Andaman, 738 m; Mount Diavolo in Middle Andaman, 515 m; Mount Koyob in South Andaman, 460 m; Mount Ford in Rutland Island, 435 m; Mount Deoban in Little Nicobar, 435 m; Mount Thuiller in Great Nicobar, 642 m. The coastal zone of these islands is generally sloping but in some parts cliffs of sandstone and limestone directly overlook the sea. The coasts themselves are highly indented. The streams are small and swift-flowing. This group of islands is an assemblage of 25 small islands, the named Lakshadweep, the islands are widely scattered in the Arabian Sea 200-500 km off the coast of Malabar, between the North latitudes of 11° 45 and 8°°. Two subgroups can be recognized. The islands north of the eleventh parallel are collectively known as Amindivi Islands; included in it are Chetlat, Bitra, Keltan, Kadmat, Amini and a few tiny atolls. The ones south of this parallel are Androth, Pitti, Agatti, Kalpatti, Kavaratti, Cheriyam, Kalpeni, and several small islets designated together as the Cannanoore Islands. Minicoy is an isolated island situated 250 km south of Kavaratti, which is the administrative headquarters of the Lakshadweep territory. The size of these islands is variable: Bilara, for example, is only a fraction of one sq km. in area; and Minicoy is the largest with an area of 453 sq km.

The islands are made up of corals and rise less than five meters above the sea. Their topography is flat with hardly any natural features, like hills or streams, breaking the monotony of their surface. Shallow lagoons occur on the windward (western) side of the islands, while on the eastern seaboard the slopes are steeper. The gradually sloping western coral bank, less than one kilometer wide, under shallow sea, ends abruptly from a depth of about 35 m to a precipitous 1,000-1,600 m. Coral sand forms the top surface. A compact crust of fine conglomerate, which appears like a coarse oolitic

limestone with embedded shell fragments, occurs under it. These deposits are of Recent to sub-recent age. The age of the dead corals forming the reef is not known with certainty. Most islands in this archipelago have storm beaches consisting of unconsolidated pebbles, shingles, cobbles and boulders on the eastern seaboard. Besides, there are some reefs and banks to the north of the Aminidivi group. A cluster of coral atolls between Agatti and Bitra islands is known as Perumulappara. Two clusters of atolls northwest of Bitra are the Byramgore Reef and the Cherbaniani or Beleapani Reef. Further north in the Arabian Sea, some 225 to 300 km from the Karnataka coast, lie three large submarine platforms rising from a depth of about 1,500 m to within 100 m of the sea level, known as the Sesostris Bank. This chain consists of continental islands atop the Chagos-Lakshadweep ridge, which is made up of Neogene and Paleogene sediments deposited on a basaltic basement that evidently is an extension of the older part of the Indian shield. The tops of the peaks surmounting the ridge have been built up by corals to form atolls and coral islands. The sediments seem to have been derived from altered basic rocks and may be related to the Deccan Trap volcanic activity. The end of this volcanic activity was followed by subsidence of the ridge to about 2,000 m starting from the Eocene time. After the eruption of the Deccan Trap extensive faulting took place on the western continental margin, resulting in the formation of the Khambhat-Lakshadweep graben. This faulting and the subsequent Tertiary uplift of the Western Ghats formed an eastern slope which deprived this graven of large quantities of terrigenous sediments from the Peninsula and is believed to have resulted in the deposition of biogenic and calcareous sediments till recent times.

**Continental Margin Feature**

The whole sea board is surrounded by a submarine ledge: the continental margin, that is, the floor of the ocean which lies between the shoreline and the abyssal or great depths of the ocean floor. This margin is of much greater breadth on the west than on the east. The western margin broadens progressively northwards from the southern tip of the Indian mainland to the Kathiawar Peninsula. From the shelving margin the sea suddenly plunges to depths of more than 1,500 m. The Arabian Sea is much deeper than the Bay of Bengal. The continental shelf, the part of the continental margin which is very gently sloping and lies between the shoreline and the continental slope, generally at 200 m depth, is similarly wider on the west than on the east. While the eastern shelf is more or less free of incongruities, there are a number of shoals, reefs and tiny islands in the Arabian Sea making coastal navigation somewhat hazardous. On the Coromandel Coast the shelf is much narrower. It is certain that the island of Sri

Lanka was a part of the southern Indian mainland, severed only in recent times. It is separated by a submerged platform, the Adam's Bridge, which is barely three metres deep. Outside the Indo-Sri Lanka strait the coastal shelf plunges to 100-2,000 fathoms. This part of the Indian coast has been invaded by the sea again and again from the Jurassic to mid-Pliocene times, but the broad outlines of the coasts were determined in the Cretaceous. The coastal shelf broadens considerably and shallows to the south of the Ganga delta, because of the heavy alluvium deposits of the Ganga and the Brahmaputra.

Beyond the shelf lies the continental slope, which is a part of the continental margin extending up to the continental rise (or oceanic trench) and as a rule has a steeper slope, of 3° – 6°. Where there are ridges and basins between the shorelines and the continental slope and the topography is more complex than that of the slope, this part of the margin is called the continental borderland. The part that is situated between the slope and the abyssal plain (except in areas of oceanic trenches) is known as the continental rise; it has a gentle slope of 1-in-40 to 1-in-2,000, but it may contain submarine canyons.

The near shore region of the shelf, up to the depth of 15 m, is composed of quartz and heavy mineral sands. Recent terrigenous silts and clays, low in calcium carbonate and high in organic matter, form the floor between 15 and 60 m depths. The outer shelf beyond 60 m and up to 200 m is made up of relict carbonate sands and carbonate rocks as algal and oolitic limestone of Holocene age.

On the India-Pakistan continental margin facing the Arabian Sea the fine fraction of the sediments has been separated and deposited on the uppermost part of the continental slope, where recent sedimentation reaches its maximum. Only coarse material has been deposited on the outer shelf; it is rich in oolites, which formed when the sea was at its lowest level at the end of the Pleistocene.

Geochemical investigations of the margin sediments have revealed phosphatic content along Kerala, Mangalore and Bombay coasts. Iron, manganese, nickel, cobalt and copper concentrations in the fine-grained sediments of the inner shelf are higher than in the sediments of the outer shelf and the slope.

**The Eastern Continental Margin**

This margin is of narrow width, only 30 to 60 km wide between the deltas of the Mahanadi and the Kaveri. Calculations have shows that this shelf is advancing seaward at the rate of one kilometer in 25 years because of the sediments brought to it by the great rivers of India. The shelf is a zone of carbonate deposition amid terrigenous muds of the continental slope and the coastal sands and clays. The calcareous matter

is mainly in the form of oolites and foraminiferal tests. They were probably formed at a time of lower sea levels during the Pleistocene glaciation.

**The Western Continental Margin**

This margin is much broader than that fronting the eastern seaboard of India. From only 40 km on the southern end it gradually widens to almost 330 km south of the Kathiawar Peninsula. A large platform rises on the shelf some 125 km out into the sea fronting the Ratnagiri coast. This bank ascends vertically over 150 m from depths greater than 200 m. Situated south of the Indus Canyon is the Darshak Sea Mount which soars nearly 1,100 m from a depth of about 1,500 m to roughly 450 m below the sea surface. Some other submarine hills have also been charted in this region. These are probably undersea volcanoes related to Deccan Trap activity.

The shelf here is floored by three types of sediments gradually passing from one into the other. The near shore zone is of quartz sand (with such heavy minerals as ilmenite and magnetite) extending to a depth of 5-10 m. Clay and silt occur to a depth of 60-70 m, and farther seaward are found calcareous sediments composed of shells, oolites and algae. The inner shelf sediments were contributed by the present-day rivers of the west coast, while the carbonates were deposited during the late Pleistocene when the sea level was much lower than at present.

There are two important submarine platforms or “banks” on the western continental margin. The bank, some 65 to 250 km west of Bombay, is the Bombay High, which has become famous as a petroleum production field. It consists of several structures spread over an area of roughly 25,000 sq km, and rises steeply within 20-80 km of the sea level from a depth of about 300 m. Paleocene to Miocene sediments sit on top of the basement in this off-shore area. The second, the Angaria Bank, is some 125 km out into the sea fronting the Ratnagiri coast. A small platform here rises very steeply from depths greater than 2,000 m to within 50 m of the sea surface.

**Submarine Canyons**

The steep-sides, elongated trenches and valleys, often V-shaped that indent the continental slopes are known as submarine canyons. Oceanographers believe that they are formed by turbidity currents which cut deep troughs in the continental shelf down to the deep sea. Turbidity currents are bottom-flowing streams laden with suspended sediments moving swiftly down subaqueous slopes in bodies of water like lakes and seas; the suspended sediments give them greater density than the surrounding clear water and hence considerable erosive power. According to another view, submarine canyons are formed by faulting and diastrophism. Probably turbidity currents and faulting both play parts in the origin and subsequent deepening of these canyons. Turbidity

currents flush down large quantities of sediments along the canyons and accumulate them all along the slope and spread them on the floor of the sea.

A well-known canyon off the coast of India is the trench in front of the Ganga delta called the "Swatch of No Ground". It forms a unique feature of the Bay of Bengal as it notches the continental margin as a narrow, steep-walled depression, at least 150 km long and 12-15 km wide through most of its length but opening out to about 30 km towards its mouth in the Bay. At its head it is only 20-55 m deep but plunges to more than 900 m within a short distance. In general, its bottom is fairly flat. At its head the canyon runs nearly SW but changes direction gradually until some 80 km down it runs nearly south. The earlier view was that the Swatch may have been formed by faulting aided by scouring of the continental margin, but recent oceanographic investigations have shown that it was most probably carved out by turbidity currents. This view is supported by the vast submarine fan that covers the floor of the Bay of Bengal in front of the canyon. The designation "Swatch of No Ground" is also applied to another canyon in front of the Indus delta, and to avoid confusion between the two, it should more appropriately be called the Ganga Canyon. The Indus Canyon in front of the Indus delta is about 115 km long and 8-10 km wide. At the delta margin its floor is 120 m below the sea level, and at the shelf margin it is 1,130 m deep. It has been traced seaward to a depth of more than 1,800 m, where it appears to end; it has a great fan as a seaward extension. The fan indicates that it may have been scoured by turbidity currents. Both the Swatchs have steep walls and a broad, flat floor instead of the V-shape of the typical submarine canyon. Rock walls or tributaries have not been found in either of them.

Oceanographic research in recent years has brought to light several small submarine canyons on the eastern continental margins. Those discovered east-northeast of Vishakhapatnam have been named the Andhra, Mahadevan and Krishnan canyons. They are small and cut into the continental slope. Other such canyons along this coast are the Cuddalore, Puducherry, Palar, Swarnaukhi group, Pennar group, Nagarjuna group, Godavari group, Gautami group, and some others. Most of them are found in the vicinity of the mouths of both major and minor rivers. Their investigations are still at a preliminary stage, and so the exact causes of their origin are not known for certain, but it is surmised that they probably resulted from subaerial erosion by rivers during the Pleistocene and probably much earlier, for the east coast of India acquired its present configuration during the Upper Jurassic time.

A canyon cuts through the Precambrian gneisses and quartzite in the shelf off Trincomalee on the east coast of Sri Lanka. It is an extension of the estuary of the

Mahaweli River through the Koddiyar Bay. Its walls are precipitous and its average gradient is 7.3° from the vertical, which makes it among the steepest in the world. It was excavated by stream erosion in the geological past and modified thereafter by marine processes. Some other smaller canyons off the straight coast of Sri Lanka have also been surveyed.

It may be noted that submarine canyons have been reported only from the east coast of India. No major rivers pour into the sea through the narrow coast in front of the Sahyadri Mountains and thus the sediment transport is inadequate for the generation of turbidity currents in the Arabian Sea. Moreover, the continental margin off the western seaboard is so wide that the feeble currents that may be generated tend to lose their erosive power within very short distances. These factors appear to be responsible for the absence of submarine canyons on the continental shelf in front of the west coast of India.