UNIT 9 INDIAN STRATIGRAPHY

Structure

9.1 INTRODUCTION

The literal meaning of the word stratigraphy (stratum= a layer, *graphien* = to describe) is description of layers. Sedimentary rocks are truely layered rocks and therefore, strictly speaking, stratigraphy would mean description of sedimentary rocks. In the early days of the development of geological science, the word stratigraphy was indeed used in its literal sense. The science of stratigraphy is, however, not such a simple science giving merely detailed description of rocks. It collates many aspects of geological study and helps in bringing about history of the crust of the planet Earth. Therefore, stratigraphy occupies the central place within the entire scope of geology.

It is not possible for everybody to study the details of stratigraphy of the entire earth and hence, stratigraphy is studied region-wise vis-a-vis global context. Therefore, Indian Stratigraphy is the histroy of the part of the crust occurring in the Indian subcontinent.

Objectives

After studying this unit, you should be able to

- describe the types of rocks occur in any region of Indian Subcontinent,
- elaborate field relationships of various rocks occurring in a region,
- decipher geological period during which a particular rock or a particular rock sequence was formed,
- gather all historical aspects of a rock from the geologists viewpoint, such as palaeoclimates, palaeogeography,
- detail the distribution of geological resources of economic importance in the subcontinent, and
- state the material and geological structure of a place where an engineering project is to be undertaken.

8.2 GEOLOGICAL TIME SCALE

9.2.1 Concept of Time *and* its *Division*

Geologists believe that the earth is at least 4600 million years old. It has been the endeavour of the geologists to reconstruct the history of the earth right from the time when it was in the gaseous state. Several types of events have taken place in this long history, which must have left their marks on the rocks.

Such events include episodes of structural disturbances responsible for creating chief mountain chains of the world. Some other episodes were related to major and minor igneous intrusions. The earth experienced glaciation. There had been redistribution of continents and oceans. The fragments of continents drifted thousands of kilometers away to occupy their present positions. There had been varieties of life dominating different time peirods of the earth's history. All these events have been taking place incredibly in past and are continuing even today.

These episodes constitute different chapters in the chronicles of the earth. In reality, the periods during which they took place are artificial divisions of time, which in fact is an abstract continuum and never ceases to flow.

It is for the convenience of man that time is artificially divided into different units on the basis of events taking place either at definite intervals or with a uniform speed. Thus, swinging of pendulum, flow of sand in an hour-glass, rotation of earth around itself and around the sun are utilised as the means to recognise different types of time units.

9.2.2 Fossils and Palaeontology

The term **fossil** has its origin in a latin word, *Fossilis*. The latin word *fodere* means to *dig*. Therefore, a fossil is anything recovered from the earth's crust by digging. Thus, all the minerals, rocks, ores, petroleum and groundwater, etc. become fossils if the term is taken by its dictionary meaning. All these objects were once indeed referred as fossils. Now, however, the term fossils has conventionally been restricted to those objects which indicate life of ancient time preserved in rocks.

Though, the scientific community has understood what a fossil is, it has become difficult to coin a precise definition of fossils which would escape criticism. For our purpose here, we may adopt the definition of the term' fossil' given by Henry Woods, a noted British palaeontologist, in his famous text-book, His definition is : **remains of animals and plants of past ages, preserved in rocks.**

This definition might give a **fairly** accurate idea about what fossils are, but all the connotation meant by the term are not included in it. Therefore, it will be worthwhile discussing here the attributes of fossils.

A fossil is organic in origin. But that does not mean all the objects of organic origin are fossils. For example, coal and petroleum, though of organic origin, are not considered fossils. They do not reflect the morphology of organism from which they were produced. On the other hand, burrows, foot tracks and other markings, created by organic activity and preserved in sedimentary rocks, are considered as fossils.

A fossil is obviously an object which has some antiquity. The remains of organisms that existed in recent past do not constitute fossils. However, to what extent this antiquity should be is a matter of controversy. A general agreement seems that life represented by fossils should atleast *be* of prehistoric time. However, that does not mean that the genus or species must be extinct. The fossils of the genus *Lingula,* a marine animal belonging to the phylum Brachiopoda, are found in the rocks of all the ages from 500 million years. The genus also exists in the present day oceans. Incidentally, such forms are called as living fossils because they have a very log range without any remarkable evolutionary changes.

In most of the cases fossils are preserved in rocks, but this should not be an essential prerequisite for an object to be called a fossil. Scientists have discovered the remains of life in some tar-pools of Trinidad or in the ice and frozen muds of Siberia. Such remains are also called as fossils.

It was known for centuries that objects similar to marine shells and other organisms are found in rocks. But, the human being took quite a long time to recognise the exact nature of such objects. Funny ideas existed about them. They were considered as the constructions by the Devil or jokes of nature. They were also imagined to be sports of nature produced by some plastic force.

There were, of course, a few who recognised that fossils were the remains of organisms of past and the places where they occurred were once upon a time under marine waters. However, their views went unheeded. The human race is superstitious and many a time guided by religious scriptures. Rational thinking becomes implausible. It was not untill the

time when *Leonardo da Vinci* suggested that so many objects taken out from the construction-site of a canal in Europe were the remains of some ancient organisms, their true nature was realised.

This was the first attempt to stress the correct meaning of fossils emphatically which gave the impetus to study fossils systematically. The branch of science which deals with them is termed palaeontology *(Palaios* = ancient, Ontology = Biology). Therefore, a definition of palaeontology may be given as that branch of science which deals with the systematic study of past life. However, the life of past is represented by fossils alone and therefore, palaeontology is also defined as the interpretative study of fossils.

Palaeontology deals with all questions concerning the organic structure, biological classification, relationship between different groups of organisms, organic evolution, condition of existence and distribution in lime and space of the ancient inhabitants of the globe.

Leonardo da *Vinci* is called the father of palaeontology.

It goes wilhout saying that palaeontology is related to both geology and biology.

9.2.3 Basis for Dividing Geological Time

In order to divide the span of 4500 million years into suitable divisions and subdivisons, rocks are looked upon as the reliable means. The students of stratigraphy have to appreciate that flow of time, accumulation of sediments and evolution of life have taken place hand in hand. The sedimentary rocks are deposited in a pile of layers arranged in a chronological order. Each layer was formed in a definite time period of the earth's history and life characteristic to that period was preserved in that layer in the form of fossils. As more and more information was gathered, it was established that the different perjods were characterised by different stages of organic evolution. Therefore, the life, particularly the stage of evolution attained, was found the most suitable criterion for dividing the geological time. Older the rocks, more primitive is the life. Newer the rocks, more modem is the life.

9.2.4 Division of the Geological Time Scale

In the oldest period, life was nlicroscopic consisting mostly of microscopic organisms lacking exoskeleton. Some lower invertebrates were probably present, but their preservation in the rocks is very obscure due to lack of hard parts. Hence, their identity is not convincingly established. This division of the earth's history is called 'Cryptozoic', meaning a period, the life that existed during it, is obscurely preserved.

In later rocks, identifiable remains of life are found. The life hail evolved to such an extent that animals possessed hard parts like shells, bones, teeth, elc. Therefore, their preservation in recognisable fossils was possible. The major geological division during which these rocks were formed is called 'Phanerozic', meaning a period, the life which existed during it is preserved in well identifiable forms.

Cryptozoic and Phanerozoic are the grand divisions or 'Eons' of the geological time. However, they are highly unequal in their durations. The Cryptozoic Eon is of 3900 million years duration, while the Phanerozic Eon is of only 600 million years duration. Bath the Eons are further subdivided into Eras.

As regards the Cryptozoic Eon, two Eras are recognised. The former Era, when either there was probably no life or the life that existed was highly undeveloped, primitive and microscopic, is called Azoic or Archaeozoic Era. The latter, when evolution gave rise to proliferation of slightly advanced life which served as the stalk of further biotic developlopment, is called Proterozic Era.

The divisions of Phanerozioc Eon are comparatively well recognised since the rocks deposited during this Eon contain well preserved fossils. Three main Eras are recognised. The oldest is Palaeozoic Era (meaning Era with ancient life), the middle is Mesozoic Era (meaning Era with intermediate life) and the youngest is Cenozoic Era (meaning Era with modern life).

Within Eras there were some smaller periods during which a certain group of organisms was more abundant than the others. Similarly, at certain specific times some groups of organisms appeared on the earth for first time, while at certain specific time certain group of organisms became extinct. Depending upon these criteria, reflected in the fossils assemblages recovered from sedimentary rocks, the Eras are subdivided into ages (see Table 9.1). Very fine subdivisions are recognised with the help of fossils of those organisms having very limited distribution in time, known as index or guide fossils and zone fossils.

Index fossils (or guide fossils) are the fossils of those organisms which had a limited time range, but their distribution in space was very wide. These organisms required to have such a distinct morphology that today their fossils are identified easily. The number of individuals belonging to them was numerous. Also, they had a tremendous power of very quick migration and a capacity to thrive in any type of environment facilitating their wide distribution in space.

Zone fossils are the fossils of those organisms which had attributes similar to those animals giving rise to index fossils, but their distribution in space was not very wide.

Table 9.1 : Geological Time Scale in a Tabular Manner

Name of the Eon	Name of the Era	Name of the Period		Name of the Epoch	Started before million years	Ended before million years	Duration million years	Fossil Groups used as Index and Zone Fossils
PHANEROZOIC*	CENOZOIC	Quaternary		Recent	0.2	present	0.2	Forminifers mainly, also molluscs and mammals
				Subrecent	2	0.2	1.8	
				Pleistocene	3	2	1	
		Tertiary	Neogene	Pliocene	12	3	9	
				Miocene	25	12	13	
			Palneogene	Oligocene	40	25	15	
				Eocene	60	40	20	
				Palaeocene	70	60	10	
	MESOZOIC	Cretaceous			135	70	65	
		Jurassic			180	135	45	Bivalves, Ammonoids
		Triassic			225	180	45	Ammonoids
		Permian			270	225	45	Brachiopods, Ammonoids
	PALAEOZOIC	Carboniferous			350	270	80	Goniatites, Pteridosperms
		Devonian			400	350	50	Goniatites
		Silurian			440	400	40	Graptolites
		Ordovician			500	440	60	Trilobites, Graptolites.
		Cambrian			600	500	100	Trilobites
CRYPTOZIC*	Proterozoic*				1500	600	900	
	Archaeozic*				?	1500	?	

Note: 1) Epoch names of only Cenozoic are recognised almost world-over. Therefore epochs of other eras are not given. It is done also to avoid unnecessary details.

2) Names with asteriks are not used very commonly.

Though, the stage of evolution of life is the major basis for division of geological time, other geological processes such as tectonic disturbances, igneous activities, breaks in sedimentation, changes in palaeoclimates, etc. are also taken into consideration. But their utility as the means for recognising geological periods is limited and found mostly of local importance.

SAQ 1

a) Give reasons

i) Though of organic origin, coal and petroleum are not considered as fossils.

ii) *Leonardo da Vinci* is considered as the father of palaeontology.

iii) Palaeontology may also be defined as the interpretative study of fossils.

b) Give answers in single sentences

i) What has been the endeavour of geologists ?

ii) What is the basis for dividing time into artificial divisions ?

iiij What are living fossils ?

c) Fill in the blanks

i) Time is an ..... which never .....

ii) ..... of time, accumulation of ..... and ..... of life have taken place hand in hand.

iii) The two Eons are highly ..... in their durations.

d) Define following terms

i) Fossils

ii) Stratigraphy and

iii) Index fossils

9.3 CONCEPTS IN STRATIGRAPHY

Unconformity : Break or hiatus in depositional time of sediments.

Stratigraphical data are collected by fieldwork. Field observations include noting down the relationships of different rocks with each other, sedimentary structures, structural disturbances, identifying unconformities, studying degree and type of metamorphism, igneous intrusions, volcanic episodes, etc. The area under study is mapped geologically. Field work comprises not only of bringing about the basic facts but also of systematic collection of rock samples and fossils, which arc later studied in laboratory. Discovery of the phenomenon of radioactivity opened a yet another avenue in sratigraphy, since radioactive minerals help in calculating absolute age of a rock.

Information, which slratigraphy yields, is variform and manifold. One can know the sequence of geological events, evolution of life, climates of ancient geological periods (palaeoclimates) and changes therein, environment of sedimentation (depth, current direction, etc.), age of rocks, etc,

Just like any other branch of science, slratigraphy also progressed due to the efforts of certain inquisitive scientists. These scientists had a curiosity about the natural processes, an admirable ability for minute observations and a flair to interpret the observations in a rational way. The studies made by Lehmann, Grabau, Steno, Smith, Hutton, Werner, Lyell, etc. in 17th and 18th centuries laid a firm foundation for stratigraphy, Three fundamental principles of stratigraphy evolved out of their work. They are (1)Principle of order of superposition, (2) Principle of uniformitarism, and (3) Principle of faunal succession.

Nicholas Steno was first to recognise the principle of order of superposition. This principle is very easy to understand. In a pile of sediments, the sediment which occurs at the bottom was deposited first and the sediments above it come in a succession, so that the uppermost layer is the youngest. In Figure 9.1, the bed A was formed first and therefore, the oldest. Beds B, C, D and E were formed subsequently. E comes at the top and therefore, is the youngest bed.

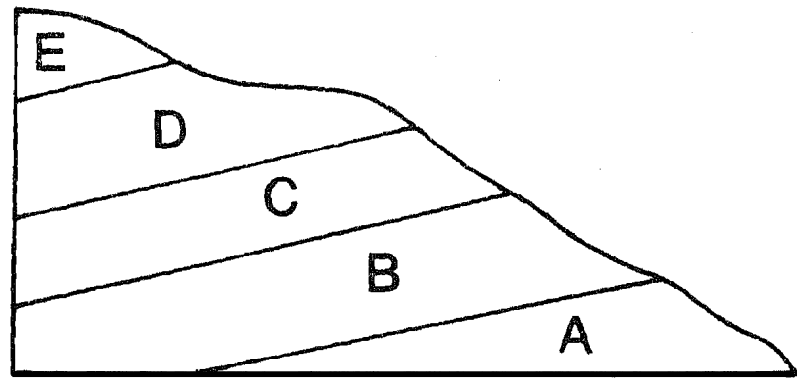

Figure 9.1 : Order of Superposition, Bed A is the Oldest and Bed E is the Youngest

Thus, the study of succession of strata indicates their chronological order. However, this is possible in case of an undisturbed sequence only. The strata that have undergone faulting or folding subsequent to their deposition must be examined with utmost care so as to avoid any possible mistake in identifying the correct order of superposition.

Principle of uniformitarism was established by James Hutton in 1788. It says that the forces at play in nature today and those during the past are uniform. Pattern of current bedding and ripple marks in the sedimentary rocks deposited millions of years ago are identical with the pattern found in the present day river channels or the present day beaches. It is therefore, reliably evidents that the processes responsible for their formation were similar. This uniformity in the geological processes becomes a handy tool at the disposal of stratigrapher and thereby, a comprehension of the present day activities of nature will help to know the events in past better. In stratigraphy, therefore, the expression 'present is the key to past' has almost become a proverb.

With the help of this principle, we can decide whether a sediment is marine, fluvial or fluvioglacial by studying its sedimentological attributes.

Stratigraphy owes the principle of faunal succession to a British engineer, William Smith. During the course of his work in a particular region of England, he became acquainted with fossils occurring in the sediments of that region. He realised that in the sequence of sediments, each layer is characterised by an assemblage of marine invertebrate fossils. Extrapolating his observations, it could be gathered that different periods were characterised by definite stages of organic evolution.

This principle gained wide acclaim since it turned to be useful so that entire geological time scale, as we have already seen in this unit, is based on this principle. Smith who recognised this principle for the first time is, therefore, called as the father of stratigraphy.

Before we start our actual study of geological history of the Indian subcontinent, it will be essential to get acquainted with the concepts of **lithostratigraphic classification** and **geological correlation.**

Different rocks which are more or less definite **units** of the earth's crust form the subject matter of the stratigraphy. According to the principle of order of superposition, their chronological relationship can be establised. It is the effort of stratigraphers to know whether the deposition of the sequence was continuous or with breaks. Continuous deposition is identified by conformable strata alternate with unconformities giving a clue as to how many episodes of sedimentation took place in a region. The smallest **unit** in a sequence is called a **member. A** few members together constitute a **group.** The two groups are separated by an unconformity. Groups taken together constitute a **supergroup** and supergroups form a **sequence,** with more and more pronounced unconformities. Such a classification is called Lithostratigraphic Classification. Once the members, groups, formations, etc. are identified, stratigrapher have to look for the geological period during which they were deposited and also for other information which can be gathered from the rocks. The aim is to know the life, climate, conditions of deposition, etc. during a given geological period.

Significance of any local sequence of rocks is often lost if its relations to sequence in other areas remain unknown. It will be of more value if the rocks of the same age in different areas are located and then chronological sequence of events is erected. The study enabling a stratigrapher to establish an equivalence in geological age of the two rocks is called

correlation. In other words, correlation means determination of the contemporanity of geological events into two areas.

Correlation is one of the most obvious and necessary functions of stratigraphy. It is with the help of correlation, that the two socks are of the same age can be conclusively proved, thereby, enabling us to view the picture of planet earth at a given time more perfectly.

When correlation for successively younger and younger rocks is taken into consideration, changes that have taken in the iace of earth can very well be visualised, in a sequential manner. Hence, correlation becomes imperative for collecting information on development of continents, distribution of land and water, evolulion of life or the vicissitudes in climates. To a student of economic geology correlation is of equal importance because some geological periods were found responsible for formation of deposits of certain ores. For example, coal deposits occur in sediments of Permo-carboniferous age, or petroleum is generally found in the Tertiary rocks.

Any proof revealing that the two rocks under consideration were formed simultaneously, becomes an evidence for correlation. Correlation should be based on any kind of pertinent evidence that is available. Generally the evidences of correlation are classified into two types: (1) physical, and (2) palaeontological.

SAQ 2

a) Give answers

i) State the three principles of stratigraphy.

ii) What is the subject-matter of stratigraphy ?

iii) Which is the most obvious and necessary function of stratigraphy ?

b) Fill in the blanks

i) .....is key to..... .

ii) Principle of .....is the basis on which entire geological column is based.

iii) Conformable strata alternate with .....giving clue as to how many .....took place in a region .

9.4 PHYSIOGRAPHIC DIVISIONS OF INDIA

Indian subcontinent can be viewed as consisting of three distinct physiographic regions:

1) Indian peninsula lying to the south of plains of Indus and Ganges river systems,

2) Indo-Gangetic alluvial plains stretching across most of norther India from Assam and Bengal on the east through Bihar and Uttar Pradesh to Panjab and Sind in the West, and

3) Extra-Peninsula comprising lofty mountain chains of Himalayas extending into Baluchistan on one hand and Myanmar on the other.

These three divisions have their own specialities about their physical, stratigraphical and structural features and, therefore, are distinct from each other. As regards physical features, the peninsula is a plateau subjected to erosion for a very long time, giving rise to mountains of the relict type. They are Comed by survival of the harder rocks, resistant to weathering, Mountains in this region are not formed because of their geological structure. The rivers in peninsula traverse more or less flat country and flow with a very low gradient. The extra-peninsula consists of tectonic mountain chains of very recent origin. The rivers in this region are actively eroding their beds with extremely steep-sided gorges. The Indo-gangetic plains are vast level expanses created due to the deposition of recent alluvium through which number of rivers flow slowly.

From stratigraphical viewpoint, the peninsula is a stable, ancient region. Old, metamorphosed, crushed, recrystallised rocks Com the basement and are exposed in most of the area of peninsula. A few basins of Proterozoic age, Palaeozoic age and Mesozoic age rest on it at some places. Almost entire Maharashtra and adjoining parts of neighbouring states exhibit occurrence of thick pile of lava sheets. The Tertiary and Quaternary rocks are

developed mostly along the coastal tracts. The extra-peninsula, barring a few exceptional occurrence of very old rocks, consist of marine sedimentary rocks of Cambrian to Early Tertiary ages, now forming the loftiest folded mountain chain of the world. The core of the mountains is made up of granitic intrusions of Tertiary age. Their southern fringe, however, consists of freshwater deposits of Miocene-Pliocene age derived largely from the rising Himalayas. The Indo-Gangetic plains are built up of layers of sands and clays of geologically very recent time.

Structurally speaking, the peninsula has remained a stable block of the earth's crust which has not witnessed any mountain building activity since practically close of the Archaean era. The later structural changes were not of very high magnitude. Exactly opposite is the case with the extra-peninsula which has recently undergone earth movements of very high magnitudes, giving rise to complex folding of the strata. These movements are still in progress, not directly perceived by the human senses. The Indo-Gangetic plains were created due to sagging in the earth's crust formed simultaneously with the uplift of the mountains. The depression was later filled by sediments derived from both sides.

SAQ 3

a) Fill in the blanks

i) The Southern fringe of extra-peninsula consists of ..... deposits of ..... age.

ii) The.....consists of ..... mountain chains of very recent.....

iii) Peninsula is a plateau subjected to ..... and for a long time, giving rise to mountains of ..... type.

b) Give reasons

i) The three physiographic divisions of India are distinct from each other

ii) The peninsula has remained a stable Block of the earth's crust.

9.5 IMPORTANT ROCK FORMATIONS OF INDIA

9.5.1 Precambrian Rock Formations

In an earlier section, we have seen that well recognisable remains of past life are found in the rocks of Cambrian period onwards. All the rocks formed before Cambrian, therefore, are many a times referred to as Precambrian rocks. We have also seen that the oldest Era is called as the Archaean Era. The rock formations formed during the Archaean Era are called Archaean rocks. Similarly, the rock formations formed after the Archaean Era but before the Cambrian period are called Proterozoic rock formations. The Archaean rocks and the Proterozoic rocks together form Cryptozoic rocks. The terms Cryptozoic and Precambrian are synonymous. However, the term precambrian is in more usage than Cryptozoic.

Archaean Formations

In many parts of the world, including Indian Peninsula, oldest rocks are seen to occur below the layers of sedimentary rocks. They are unfossiliferous, metamorphosed, faulted and complexly folded, crystalline rocks intruded by plutonic intrusions. These factors impart a complexity of field relationship and geological structure. Such rocks constitute the Archaean rocks of the world. They are often referred to as 'Basement Complex' or 'Fundamental Complex' owing to complexity of geological structure and their occurrence at the bottom of the geological column.

Some of the Archaean rocks are believed to represent portions of the first formed crust called **primordial crust,** which was formed by the consolidation from the gaseous or molten state. Further, cooling caused condensation of water vapour in the then atmosphere which caused the first rains on the earth. Water was stored in the hollows on the surface giving rise to the earliest oceans, which provided basins for collecting the oldest sediments. These sediments were later subjected to earth movements causing folding, faulting and recrystallisation due to metamorphism. Metamorphosed sediments were later intruded with plutonic igneous intrusions. The part of the Archaean rocks was formed by them. These igneous rocks too were metamorphosed in the subsequent earth movements.

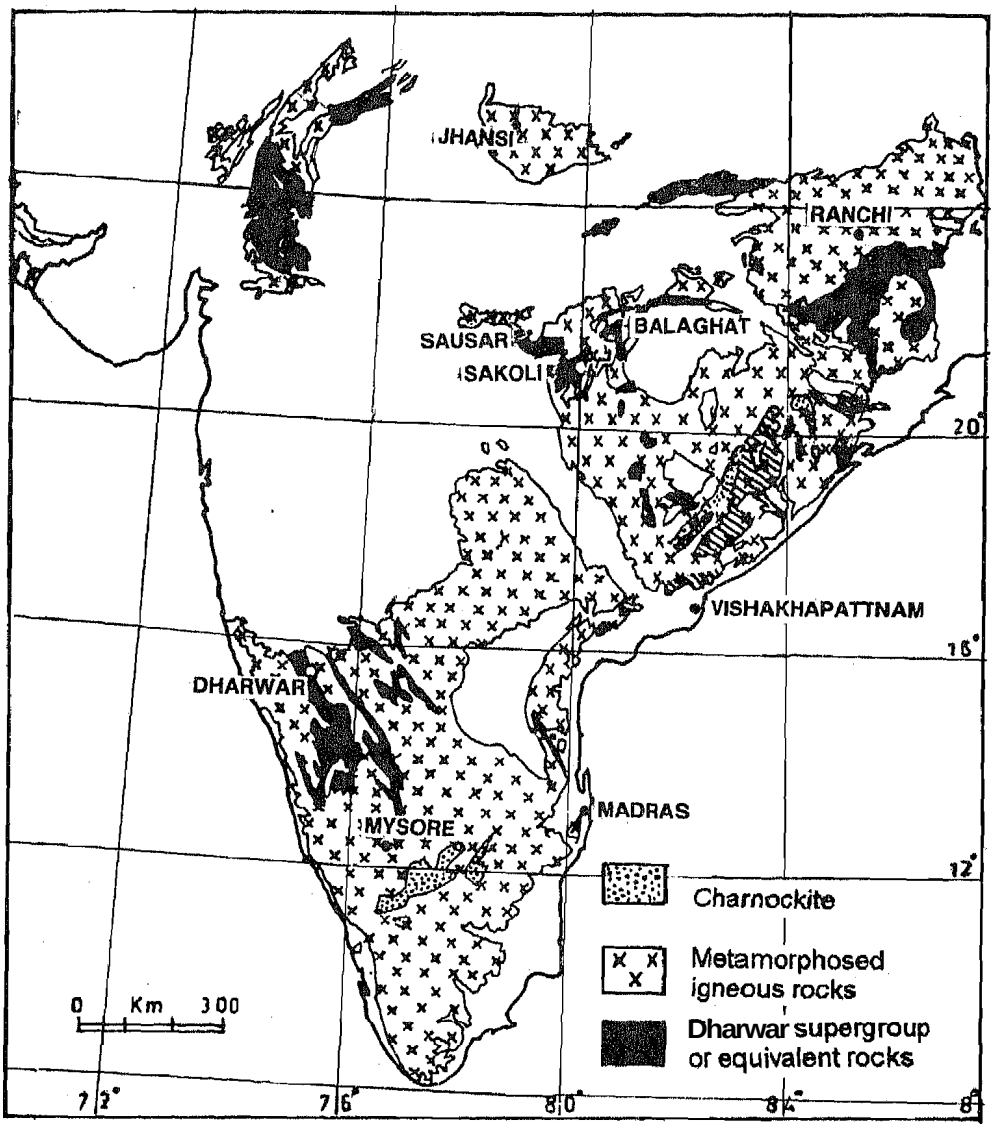

Figure 9.2 : *Distribution* of the Archaean *Rocb* in Peninsular India

The Archaean rock formations occupy a great extent of the Indian peninsula (Figure 9.2). Its southern portions are occupied by the Archaean rocks. They also occur in wide areas in Orissa, Bihar, Bundelkhand, Madhya Pradesh and North-eastern Maharashtra. They also are seen in a narrow tract extending from northern Gujarat to a portion of Rajasthan forming some part of the Aravalli range. The Archaean rocks also occur in parts of Shillong plateau and few other areas of north eastern India. Granites forming the core of extra-peninsular mountain chain were previously believed to belong to the Archaean age. Now lhey are known to be much younger.

In any of these areas, like many other areas of the world where the Archaean rocks occur, the primordial crust as such is not identified. There are two main types of rocks recognised, metamorphosed sediments and metamorphosed plutonic intrusions. Which of them are younger was a matter of controversy. If sedimentary rocks were younger then the plutonic rocks formed the large basins into which the sediments were deposited. If the sedimentary rocks were older then the igneous rocks were intruded within them. Now, the second view seems to be accepted by all.

The metamorphosed sedimentary rocks in south India are called as the **Dharwar Supergroup** of rocks. They occur as narrow belts generally trending NNW-SSE traversing the country, generally, occupied by the other Archaean rocks. The Dharwar Supergroup includes volcanic lava flows intercalated with the sediments. The volcanic rocks are also thoroughly metemorphosed. The Dharwarian rocks include **quartzites,** marbles, phyllites, mica schists, hornblends schists etc. There are certain rocks very rich in iron ores. There are also rocks rich in manganese ores.

Previously all the rocks, now identified as the Dharwarian rocks or their equivalents, were thought to be metamorphosed igneous rocks. Later detailed investigations revealed **that they** were metamorphosed sediments.

Metamorphosed sediments of the Archaean Sequence, correlated with the Dharwar Supergroup of south India occur in other parts of the country. The **Aravalli** Supergroup of Rajasthan with its southerly extension of Gujarat, called as the **Chapaner** Supergroup, are also metamorphosed sedimentary rocks of that region and are equivalent in age to Dharwar Supergroup. Similar rocks also occur in parts of Madhya Pradesh from Bilaspur to Balaghat and are called as the **Chilpi Ghat** Supergroup. Towards further west the rocks of the Chilpi Ghat Supergroup extend into two broad strips. The northern strip constitutes the **Sausar** Supergroup occupying areas in Chhindwara (Madhya Pradesh) and Nagpur (Maharashtra) districts, known for world famous manganese ore deposits, while the southern exposed in parts of Nagpur and Bhandara districts of Maharashtra is called the **Sakoli** Supergroup.

Metamorphosed sedimentary rocks also occur in the region extending from Cuttak district of Orissa to Vijaywada district of Andhra Pradesh. Along with other rocks, a different rock consisting of quartz, garnet, sillirnanite and graphite occurs in this region. This rock is named as Khondalite after the Khond tribe of Orissa. The rocks rich in iron ore occur in Bastar districts of Madhya Pradesh in association of Khondalite.

There ate many other areas where outcrops of rocks correlated with the Dharwar Supergroup occur. Such areas include parts of northeastern India (Shillong plateau), Bihar (Gaya, Hazaribagh and Ranchi districts), Orissa (Sundargarh district), Uttar Pradesh (Mirzapur district), Tamil Nadu (Salem and Coimbatore districts) and elsewhere in different states.

The rocks equivalent in age to the Dharwars also occur in the extra-peninsula. They have been variously named as **Vaikrita** Supergroup (Spiti area), Jutogh **Supergroup** (Shimla area), **Daling Supergroup** (Darjeeling, Sikkim -Bhutan area), etc.

As has been stated earlier, the rocks of the Archaean age also include metamorphosed igneous rocks, which generally have intrusive relationship with the Dharwarian metamorphosed sediments, described above. Three main types of such metamorphosed igneous rocks have been identified, viz., the Peninsular Gneiss, the Bundelkhand Gneiss and the Charnockite.

Peninsular Gneiss of Karnataka occupies about 70,000 sq. km. It consists of a heterogeneous mixture of different types of granites, intrusive into the Dharwarian rocks. It includes granite, granodoirites, gneissic granites and banded gneiss. The banded gneisses consist of white bands of quartz-feldspar alternating with the dark bands consisting of hornblende, bioltite, etc. Their nature is much complex. There is an abundance of accessory minerals. Granite gneiss occurring in Baster and Assam, the Salem Gneiss occurring in Tamil Nadu and the Bengal Gneiss occurring in parts of Bihar and Bengal are the rocks correlated with the Peninsular Gneiss.

The Bundelkhand Gneiss occurs in the type area of Bundelkhand. It is a typical pink granite without any conspicuous foliation, occupying a vast area. It has probably an intrusive relationship with the older gneisses. In contrast to the Peninsular Gneiss, association with schists causing a banded appearance is only exceptional: also there is a paucity of accessory minerals. The Bundelkhand Gneiss is extensively traversed by dykes and sills of diorite. The pegmatites and quartz veins intersecting the main granite mass occur as long, narrow, serrated walls. They intersect each others. At places they form small natural dams obstructing riverlets of the region giving rise to a lake. Numerous such lakes occur in Bundelkhand. The Berach Granite of Chittore in Rajasthan, closepet granite, Bellary granite, Hosur Granite and Arcot Granite of South India and Mylliem Granite of Assam are correlated with the Bundelkhand Gneiss.

The third group of gneissic rocks contains granitoid rocks called **Charnockite**. The mineral assemblage consists of plagioclase, ***hypersthene,*** Blue quartz and ***garnet. Hornblende, augite, enstatie*** may also be present. In the last two decades of the nineteenth century the various varieties of rocks labelled as 'Charnockite' were regarded as related igneous rocks formed due to magmatic differentiation. Later, similar rocks were reported to occur in many countries and their genesis was better understood. Some of them, the charnockites proper, are recrystallised igneous rocks. Some of them, poor in silica are pyroxene granulites and though resemble Charnockites proper have no genetic relationship, whatsoever, with them. Remaining types are hybrid rooks formed by Charnockitic magma that have assimilated some of the pyroxeme granulites, Charnockites of all these types are restricted to southern portion of peninsula and some parts near east coast.

The Archaean rocks are very rich in economic mineral deposits including metallic and nonmetallic ores, precious stones and building material. Most of the iron and manganese

ores of India come from the Archaean rocks. They also possess ores of metals like nickel, chromium, titanium, cobalt, gold, copper, zinc, lead etc. A variety of precious gemstones like sapphire, acquamarine, topaz, garnet, tourmaline, zircon, beryl, etc, come from the Archaean rocks. Many varieties of granites, charnockites, coloured and white marbles, quartzites, etc. are used as building stones. A number of historical monuments in India including palaces, forts and temples are built in stones derived from the Archaean rocks.

SAQ 4

a) Match the pairs from type of locks given in column A and peculiarity in column B.

A	B
Charnockite	Banded appearance, abundance of accessory minerals
Peninsular Gneiss	Without any conspicuous foliation, paucity of accessory minerals
Bundelkhand Gneiss	Consisting of plagioclase, hypersthenes, blue quartz and garnet

b) Give brief answers

i) What is the mineral composition of Khondalite ?

ii) What are the names of westerly extension of the Chilpi Ghat Supergroup occurring as two strips ?

iii) Why are the Archaean rocks called 'Basement Complex' ?

Proterozoic Formations

Mountain building activity and igneous intrusion towards the close of the Archaean Era induced metamorphism of extreme degree and complexity of structure in the Archaean rocks. The folded mountains thus formed, were subjected then to the agents of denudation for a vast time gap. In due course of time, some isolated basins were formed eventually which provided the place for deposition of sedimentary rocks during the Proterozoic Era. Obviously, the first Proterozoic rocks were deposited on the eroded surface of the Archaean rocks giving rise to pronounced unconformity, generally referred to as the **eparchaean unconformity**.

In entire span of the Proterozoic Era, two periods of sedimentation can be recognised, the first approximately during the Middle Proterozoic and the second during he Upper Proterozoic. The first one is typically developed in Andhra Pradesh called the **Cuddapah Supergroup.** Today the rocks of this supergroup are exposed in a vast crescent shaped area, with its concave side facing cast. The length of this area is about 340 km. Its northern extremity is situated a little south of the Singareni Collieries, while the southern end roughtly corresponds lo Nagari hills. The maximum width along east-west is about 140 km.

The total thickness of sedimentary rocks in the Cuddapah Supergroup is to the tune of 6500 m. Quartzites and slates are the chief rock types met with here. The earliest rocks have been intruded with sills and dykes of dolerites. The sedimenary rocks of the Cuddapah Supergroup show only a low grade metamorphism. The Cuddapah Supergroup is overlain by the **Kurnool Supergroup** with an unconformity.

Rocks equivalent in age occur in other isolated basins also. A series of outcrops occurring from Bundelkhand to the south of the Narmada river, comprising sandstones, quartzite and siliceous limestones, is called the **Bijawar Supergroup.** The thickness of the Bijawar rocks in type area of Bijawar south of Bundelkhand is estimated around 240 m. Some of the outcrops may actually be correlated to the Dharwar Supergroup in view of degree of metamorphism, basic sills and dykes and iron ore deposits associated with them.

The rocks occurring in an area along the Godavari river in Andhra Pradesh are also considered equivalent to the Cuddapha Supergroup in age and are termed as the **Pakhal Group.** Certain quartzites, shales and limestones occurring in the Belgaum district of

Subsequent to their formation, Vindhyan and correlated rocks were uplifted and transformed into land mass. For a very large period Indian Peninsula was a sight of weathering and denudation, practically without any substantial sedimentation, till Lower Carboniferous.

During that time a great southern continent, now named as the Gondwanaland, existed which along with Indian Peninsula included Antarctica, Australia, Africa and South America. The well-known theory of continental drift envisages that the present continents separated from each other and drifted from original places to take their present positions. During Carboniferous, glacial climate prevailed on entire Gondwanaland and it is with glacial deposits that the next episode of rock formations – Gondwana Sequence – started.

The climate slowly became warm and humid and remained so during Permian, when the fluvioglacial sedimentation gave place to fluviatile sedimentation along major rivers which existed that time. More or less linear patterns of the outcrops, presence of a number of faults within the Gondwana sediments and faulted boundaries between the Oondwana rocks and the metamorphics suggest that these Permian rivers occupied faulted troughs. The troughs probably were sinking more and more as more and more sediment was being deposited. This enabled accumulation of huge thickness of freshwater shales and sandstones.

This has also imparted a peculiar mode of geographical distribution to the rocks belonging to the Gondwana Sequence. They occur in three strips – linear tracts. One of them is along Narmada-sone-Damodar rivers alignment, second along Mahanadi river and the third along Godavari river (Figure 9.4). In addition to these, three strips some isolated outcrops also occur because towards the close of the Gondwana period around Lower Cretaceous sedimentation took place in distant isolated basins. Such outcrops occur in Kutch, Kathiawar and along our east coast.

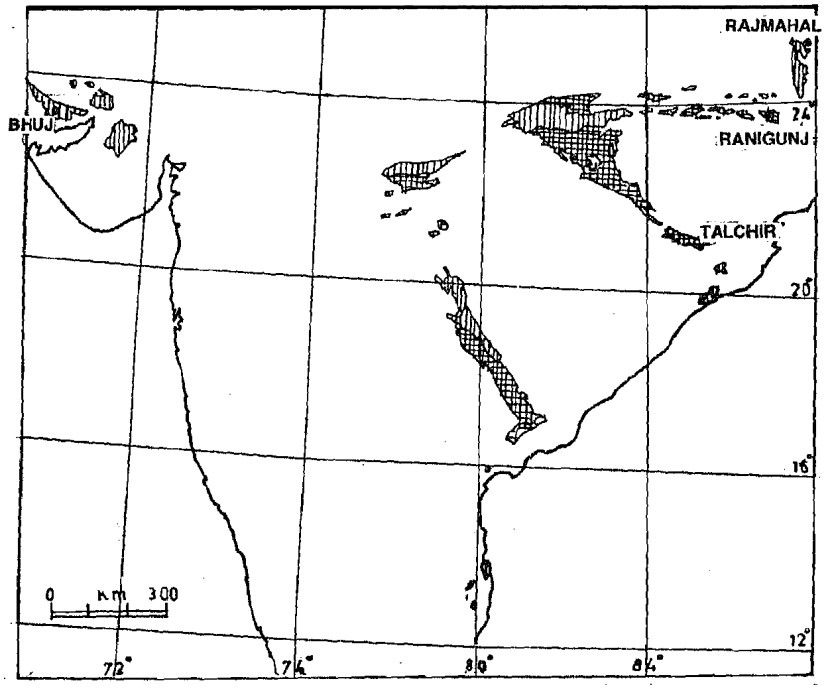

Figure 9.4 : Distribution of the Gondwana Rocks in Peninsular India

As has been stated above, the Gondwana period started with an ice age, the first rocks to be deposited were glacial boulder-beds. This horizon is referred to as Talchir **Boulder Bed** formally in Indian stratigraphy and forms an important datum line not only in Indian context, but also pertaining to all parts of the Gondwanaland. During Permian, freshwater sandstones and shales were deposited forming huge thickness. The humid and warm climate supported luxuriant growth of forests. These forests consisted mainly of *equisetales* and *pteridosperms*. Vegetable debris which accumulated as intercalations within the layers of shales and sandstones later formed coal seams.

During Triassic, the climate changed to arid, reflected by the decline in plant foossils and presence of intercalations of ferruginous shales. Fossil fish, amphibia and dinosaurians are also preserved in the Gondwana rocks deposited during Triassic. The warm and humid climate returned during Jurassic and Lower Cretaceous. Thereby, there is an increase in the plant fossils, but by Jurassic plant groups like *filicales, cycadales and coniferales* had taken the place of *equisetales* and *pteridosperms*. Development of coal is also there, but not as pronounced as during Permian.

Rocks of the Gondwana Sequence have provided very significant information. The plant fossils found in these rocks are also reported from correlated rocks of the other constituents of the Gondwanaland. Their presence in the Gondwana rocks of all these continents, despite the fact that plants do not possess locomotary organs and their migration across the oceans is obviously very difficult, is a positive proof of existence of the ancient Gondwanaland. Therefore, the fossil plants from the Gondwana Sequence, in a way, provide a direct evidence to the hypothesis of the continental drift. Along with the petrological characters of the sedimentary rocks, the plant fossils also have helped in identifying the climatic changes during the Gondwana period.

Rocks of this sequence are also known to occur in the extra-peninsula. They generally occur as narrow strips and are structurally much disturbed in comparison to their peninsular counterparts.

The Rajmahal hills were formed during the Lower Cretaceous due to volcanic activity. The eruption was of the fissure type. The lavas that were poured out at certain intervals had basaltic composition. This volcanic rock formation called the Rajmahal Trap constitutes a part of the Gondwana Sequence. It contains at certain horizons intercalations of thin sedimentary rocks called Rajamahal Intertrappean Beds. There are some excellently preserved *coniferous*, cycadean and *fern* fossils of Lower Cretaceous age in them.

From economic geology point of view, coal is the main interest of the Gondwana Sequence. Most of the coal reserves of India come from the Gondwana Sequence. Those outcrops of this sequence, containing commercially workable coal seams, are called coalfields. They occur in Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh and Orissa. The Gondwana coal of India does not belong to the best category (anthracitic). It is medium quality coal (sub-bituminous to bituminous).

Along with coal, important clay deposits occur in the Gondwana Sequence. The clay from these deposits are used in manufacturing refractory bricks, roof-tiles, pottery, china-ware and terra-cotta. A good deal of variety of sandstones is met with in the Gondwana Sequence. Some of them are useful as building stones, some for carving and some for millstones. Some sandstones provide silica sand.

SAQ 6

a) What are the evidences to deduce that Permian fluviatile sedimentation took place in rivers occupying faulted troughs ?

b) What suggests that warm and humid climate in Permian gave place to arid climate during Triassic?

c) What are the uses of clay deposits occurring in the Gondwana Sequence?

d) Fill in the blanks

i) The Gondwana period started with an ..... and the first rocks of the Gondwana Sequence to be deposited were .....

ii) The name Gondwana Sequence is derived from the .... of .... where the ..... of this sequence were first noticed.

9.5.3 Marine Mesozoic Rock Formations of Peninsular India

The drifting of continents had many impacts on the geology of India other than forming rocks of the Gondwana Sequence. The marine Mesozoic rocks of Peninsula were formed due to incursion of oceanic waters over the low lying terrestrial portions caused indirectly by the continental drift.

Such local and temporary encroachments of marine waters on coastal low land tracts are caused due to reduction in the capacity of oceans. The sediments deposited on the floor of old Mediterranean Ocean separating the Euro-American continent in the north from the Gondwanaland on south by its vast stretch, were buckled up and thrown into folded mountain chain, which we now recognise by the name Alpine-Himalayan ranges. The mountain building has taken place in definite pulses. Every pulse reduced the capacity of the

oceans forcing marine waters to spread in low lying areas in the vicinity of coasts. Records of such innudations by marine waters are known world over. These marine transgressions gave rise to some marine rocks in Indian Peninsula.

After the Vindhyan sediments were formed and uplifed, the Peninsular India did not experience any marine sedimentation during the entire Palaeozoic Era (there are a few exceptions, though) and the Triassic period of the Mesozoic Era. But during Jurassic, large areas in Kutch and Rajasthan were invaded by marine waters.

Marine Jurassic sedimentary rocks of Rajasthan occur in Jaisalmer and Bikaner districts and have thickness of about 2,000 m. They are mainly sandstones and grits, with certain horizons consisting of limestones. Some of the horizons contain gymnospermous wood fragments and ferns indicating vicinity of land. Ofcourse, the marine fossils occur in more abundance. They suggest age for the Mesozoic socks in Rajasthan from Lower Jurassic to Lower Cretaceous.

In Kutch, marine Jurassic rocks occupy a very large area. Here, also their thickness is about 2,000m. They consist of sandstones, shales and limestones. The marine fossils occurring in them have many common elements with those of marine Jurassic rocks of Rajasthan. Probably the Jurassic sea of Kutch was continuous with that of Rajasthan. The marine Jurassic rocks of these two places were continuous, now separated due to subsequent erosion. The sediinentary succession towards top shows influence of fresh water. The rocks become deltaic in origin. There are intercalations of carbonaceous shales witnin sandstones, yielding plant fossils. A few marine intercalations are also known to occur. These marine fossils collected from towards top and plant fossils in association with carbonaceous shales suggest Lower Cretacesous age. Therefore, the freshwater deltaic deposits of Lower Cretaceous age corning towards top of Jurassic Sequence are considered as belonging to the Gondwana Sequence.

During Cretaceous, marine deposits due to marine incursions were formed in four regions in Peninsular India viz. Tiruchirapalli of Tamil Nadu, Narmada Valley, Kathiawar and Shillong Plateau.

The marine Cretaceous deposits developed in Tiruchirapalli district of Tamil Nadu are famous world over among geologists for the treasure of fossils occurring in them. The sediments towards the lower part are more clayey and contain phosphatic nodules. The sediments in the middle are more sandy with some horizons of shell limestones. Towards top, the sediments are argillaceous or calcareous sandstones. In some sediments petrified gymnosperm logs are preserved indicating vicinity of land during deposition . The fossils indicate Middle to Upper Cretaceous age for these rocks. The topmost beds are Palaeocene age. Isolated outcrops of smaller lateral extent also occur in Pondicherry, near Rajmahendri in Andhra Pradesh and in Thanjavur district of Tamil Nadu. The fossils occurring in these areas have distinct affinities with those occurring in sediments of Tiruchirapalli district.

Isolated outcrops of marine Cretaceous rocks of limited lateral extent occur in the valley of Narmada river mostly on the northern side. The westernmost outcrops occur in Baroda district of Gujarat, while easternmost occur near Barhwa in Madhya Pradesh. It is in these rocks that the famous Bagh Caves (Dhar district, Madhya Pradesh) are carved and hence, these deposits have been named as the Bagh Beds. The lower part of the Bagh Beds consist of sandstones, while the upper part consists of limestones. The fossils indicate Middle Cretaceous age. Affinities of the fossils are distinctly with the Alpine-Himalayan Cretaceous fossils meaning that the waters which invaded the Narmada valley during Cretaceous belonged to the Mediterranean Ocean. Cretaceous marine elements in the Tiruchirapalli Cretaceous sediments have entirely different affinities. Therefore, there was no direct connection between the Bagh estuary and the Tiruchirapalli sea.

Outliers of very small areal extent and limited thickness of marine, ferruginous sandstone occur in Surendranagar district of Kathiawar, Gujarat. Towards top , a limestone cap occurs. The limestone is very similar to that occurring in the Bagh Beds, The fossils in these rocks of Surendranagar district and the fossils from the Bagh Beds have a striking simiarlity, indicating that the Cretaceous marine sediments of Kathiawar constitute just the westerly extension of the Bagh Beds. After the township of Wadhwan, these Kathiawar Cretaceous marine rocks are called as the Wadhwan Formation. Like the Bagh beds, the Wadhwan Formation is also assigned a Middle cretaceous age.

Marine Cretaceous rocks occur in the Garo, Khasi and Jaintia hills of Meghalaya. The rocks are mostly sandstones with occasional sandy and carbonaceous shales. Towards top, some impure, sandy limestones are present. The fossils occurring in these rocks have a close relationship with the fossils from marine cretaceous sediments of Tiruchirapalli district. It means that the Assam-Meghalaya sea and the Tiruchirapalli sea were parts of the same ocean, other than the Mediterranean.

SAQ 7

a) Fill in the blanks

i) ..... and ..... encroachment of marine waters on coastal lowland tracts are caused due to ..... in the ..... of ocean.

iij Marine Jurassic sedimentary rocks of Rajasthan occur in ..... and ..... districts.

iii) Fossils occurring in marine cretaceous rocks of Garo, Khasi and Jaintia hills have a close relationship with the fossils from marine cretaceous rocks of ..... district.

iv) The waters which invaded Narmada valley during cretaceous belonged to the ..... ocean.

b) Match the pairs from the rock formations given in column A and information about them given in column B.

A	B
Marine Jurassic rocks of Kutch	Westerly extension of the Bagh beds
The Bagh beds	Deltaic sandstones towards top belong to the Gondwana sequence
The Wadhwan Formation	Famous world-over for the treasure of fossils.
Marine Cretaceous rocks of Tamil Nadu	Developed in valley of Narmada river

9.5.4 Deccan Trap

Towards the close of the Mesozoic Era, a thick pile of basaltic lava Flows was laid down in some parts of the Indian Peninsula. Numerous cracks and fissures were developed in the crust of this region from time to time during this episode of the Indian stratigraphy through which lavas welled out and formed thin lava sheets having avery wide lateral extent. A small portion of Kutch, a large tract of Kathiawar, most of the southern part of remaining Gujarat, major part of entire Maharashtra, some part of northern Karnntaka, Northwestern portion of Andhra Pradesh, a large region of Madhya Pradesh and certain areas of Rajasthan adjoining Madhya Pradesh are occupied by these lava flows covering an area of about 520,000 sq. km. The present distribution (Figure 9.5) seen in westcm, central and southern India and the outlying patches, as east as Lohardaga (Ranchi district) in Bihar and Rajmahendri in Andhra Pradesh, were probably once continuous, now separated by subsequent erosion. Thus, total original extent might have been well over 1,500,000 sq. km., because some part is submerged in the Arabian sea also.

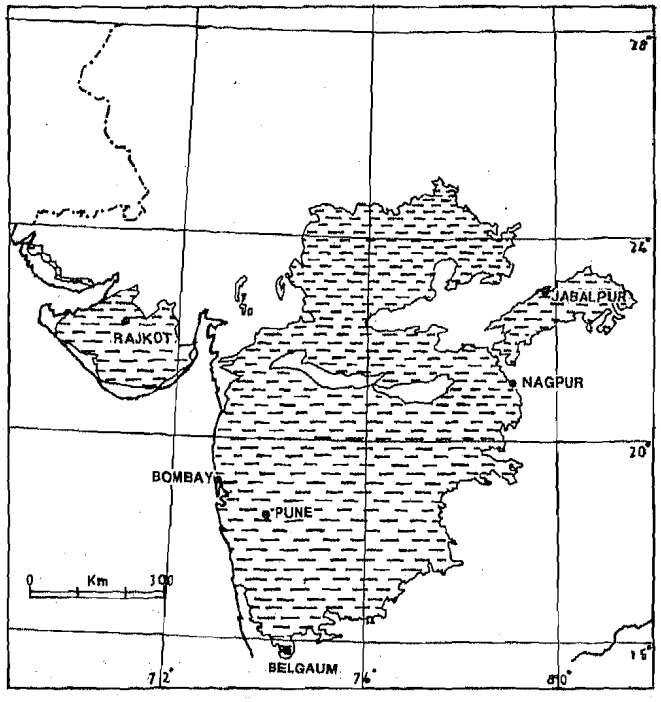

Figure 9.5 : Distribution of the Deccan Trap

This rock formation is known as **Deccan Trap.** The term 'deccan' is adopted from the Deccan plateau, a major part of which is made up of these rocks. The original urdu word is 'dakkhan' and means south. The word trap is a term of Scandinavian origin, which means a geomorphology resembling staircase like structure. The weathering of these basalts is such that they form flat topped hills with their slopes looking more or less like steps of a staircase. Hence, the term 'Deccan Trap' has been instituted.

Some of the lava flows show ropy structure, while some are blocky lavas. Many flows show vesicular structure towards top. The vesicles are mineralised by cryptocrystalline silica, rock crystals, calcile, apophyllite and certain species of zeolite family of minerals. These secondary minerals at times are of semi-precious quality and include *agates* and *amethyst.* Some of the amygdales towards top of some flows are pipe-shaped. Columnar structures are also known to occur at many places. Individual lava flows, vary in thickness from a few cm. to about 40 m. In between two lava flows, lacustrine sedimentary beds of very small areal extent with thicknesses rarely exceeding three or four metres may occur. They are called as **Deccan intertrappean beds.** They are usually fossiliferous and yield fossils of terrestrial molluscs, freshwaler algae and petrified palms. Such intertrappean beds are numerous towards the base of the Deccan Trap: They occur in Madhya Pradesh, eastern Maharashtra, northwestern Andhra Pradesh, eastern Maharashtra, etc. However, in main mass they are totally absent. Towards the top, intertrappean beds may occur rarely. Towards the top, ash beds may be intercalated with the flows.

Thickness of Deccan Trap is estimated to be more than 2,000 m. Towards east, it slowy decreases.

The basalts show porphyritic texture with *plagioclase* phenocrysts and hemicrystalline to holohyaline groundmass. Mineral augite is usually present in groundmass. *Olivine* may also occur. But there are variations in petrological and petrographical characters. For example, at places megaporyphyritic basalts occur, while holohyaline varieties occur at other places. To the north of Bombay city, rhyolite is known to occur.

The lava flows are themselves intruded by basic sills and dykes. Some sills and dykes of basic composition, belonging to the Deccan Trap episode are known to be intrusive towards the rocks of the Gondwana Sequence and the marine Jurassic rocks of Kutch.

In Vidarbha region of Maharashtra, in Madhya Pradesh and in parts of Andhra Pradesh a limestone horizon occurs just below the Deccan Trap . This formation is called as the **Lameta Beds.** Since the Lameta Beds occur just below the Deccan Trap, they are many a times referred to as **Intratrappean beds.** Dinosaurian fossils have been reported from the Lameta beds of Jabalpur district of Madhya Pradesh and Chandrapur district of Maharashtra. The fossils indicate Upper Cretaceous age for the Lameta Beds.

The Deccan Trap activity began towards the end of the Cretaceous period and continued till Lower Palaeocene, The fossils from the intratrappean beds and the intertrappean beds suggest and support this age. Also in Bharuch and Kutch districts of Gujarat state, the Deccan Trap flows are overlain by fossiliferous sediments. They also support this view.

Sebsequent to their formation, basalts of the Deccan Trap were laleritised it certain areas. In those areas, the outcrops of basalts are capped by laterites. At some places laterites contain bauxite deposits. As the bauxite is used as the ore of aluminium and as a refractory material, occurrence of bauxite is important from economic geology viewpoint. Basalts and laterites constitute durable building stones. Basalts provide material of excellent quality for road metal and for aggregate of cement concrete.

SAQ 8

a) What is the age of Deccan Trap ?

b) Which minerals are found in the vesicles of the basalts of the Deccan Trap ?

c) Why the Lameta Beds are called the intratrappean beds ?

d) What are the Deccan intertrappean beds ?

9.5.5 Tertiary and Quaternary Rocks

The Tertiary rocks occur in Peninsula as well as in Extra-Peninsula. Their development in peninsula is restricted only to the coastal belts, while the Tertiary rocks of extra-peninsula show greater development areally as well as vertically. One more pecularity of the Tertiary rocks of extra-peninsula is thal the Lower Tertiary sediments are of marine origin, whereas the Upper Tertiary sediments are of freshwater origin. The mammalian fauna preserved in them is also very important evolution point of view.

The Quaternary was a period of glaciation and we, perhaps, are still getting out of it. The impacts of the ice-age are well documented in the rocks world over and India is no exception lo that.

Tertiary Formations

In extra peninsula, as has already been alluded to, the sequence from Palaeocene to Lower Miocene is mostly marine in origin, however, the sequence from Middle Miocene to Pliocene is of freshwater origin.

Development of rocks of Palaeocene-Eocene age is seen on the southern flank of the Pi-Panjal range in Kashmir. The thickness of these rocks here, is about 500 m to 600 m. The basal rocks constituting a thickness from 100 m Io 150 m are cherty liniestones. They contain an index fossil belonging to the genus *Nummulites*, an extinct Protozoan. They are correlated with the Hill Limestone of Potwar Plateau, Pakistan. These Nummulitic Limestones are succeeddd by shales, whose thickness ranges from 150 m to 300 m. Within the shales, those towards the base are carbonaceous, while those towards top are variegated red and green sandy shales. This formation is correlated with the **Chharat Wormation** of Potwar plateau, Pakistan. To lhe south of Pir-Panjal, outcrops of Eocene rocks are seen neat Jammu. They continue south eastwards along the foothills of Shimla and Garhwal upto Nainital. The thickness, however, reduces here to 150 m to 200 m.

Eocene rocks also occur in the upper Indus valley in Ladakh from Kargil to Leh and a little further. They comprise shales, grits and limestones and contain *Nummulites* in certain zones. They form a part of a sequence here, cretaceous lo oligocene in age. This sequence is much disturhcd in subsequent mountain building.

The Eocene rocks are well developed in Assam-Mizoram belt of northeastern India. They are represented by different facies in different regions and are stratigraphically designated by different formal nomenclatures. Splintery, dark grey shales intercalated with sandstones constitute the **Disang Formation** and occur in Naga Hills area. Lower part of the Disangs extends down in Cretaceous. Total thickness of the Disangs is well above 3000 m. This entire thickness is devoid of fossils. The Palaeocene-Eocene rocks occurring in Assam-Meghalaya belt arc called the **Jaintia Group** of rocks. It has a thickness ranging from 400 m to 550 m. Jaintia Group of rocks mainly consists of alternating limestones with sandstones. The rocks are fossiliferous. The sandstones possess intercalations of coal seams.

The Eocene rocks of Kashmir are overlain by the Lower Miocene rocks. However, some rocks towards the base might be Oligocene in age. The basal zone is called the **Fatehjang Zone.** It consists of brown and grey sandstones and contains mammalian fossils. Fatehjang zone passess upwards into another succession of sandstones making a thickness of about 2,400 m. The lower 1500 m arc believed to have been deposited in brackish water, while remaining 900 m in freshwater. These rocks arc correlated with the rocks of the **Murree Series** of Salt range, Western Punjab and Pakistan.

In Shimla and Kumaon Himalayas, the **Subathu rocks** are overlain directly by Lower Miocene rocks, the Oligocene element probably being totally absent. The lower part of the Lower Miocene here, is called the **Dagshai Beds,** consisting of hard, fine grained grey or purplish quartzites. However, towards their base, development of red clays is seen. The Dagshai Beds are unfossiliferous. The upper part of the Lower Miocene in Shimla-Kumaon region is called the **Kasauli Beds.** They lie over the Dagshai Beds conformably. The Kasauli Beds consist essentially of sandstones with minor argilaceous bands, Fossils of palm and freshwater molluscs occur in the Kasauli Beds,

In Northeastern India, rocks of Lower Oligocene are missing. Upper Oligocene and Lower Miocene rocks are developed in two regions, upper Assam (the water-divide separating Brahmputra valley from Surma valley) and Surma valley, north Kachar and the Khanshi-Jaintia hills. The Upper Oligocene rocks are called the Barail Formation. Its

lower portion of about 2400 m thickness consists of sandstones in both the regions. The upper portion is differently developed in the two regions. In upper Assam it is mainly a shaly facies containing some coal seams, while it is more or less a sandstone facies in the Surma valley, north Kachar and the Khasi and Jaintia hills. Rocks of the Lower Miocene age here arc called the **Surma formation.** This is a sequence of alternating shales and sandstones. In upper Assam, the thickness of the Surma Formation is not more than 600 m while in Surma valley it is about 3000 m.

We have already seen that the Upper Tertiary rocks of extra-peninsula are of fresh water origin. By Lower Miocene, the lifting up of Himalayas had almost been accomplished due to earth movements. Accompanying the fonnalionof Himalayas a long, narrow depression in front of Himalayas, to their south, also came into being. This depression is called the fore-deep. Newly built mountains helped in establishing the monsoon climate. The mountains also became a major waler divide. Many rivers originated on their southern slopes. Their valleys ultimately joined the fore-deep, which itself became a major river. The speed of rivers was checked after meeting the fore-deep due to change in their gradient, a fact which enabled accumulation of freshwater sediments during Middle Miocene, Upper Miocene, Pliocene and ranging into Lower Pleistocene. The accumulated sediments constitute the Siwalik **Supergroup.**

The name Siwalik comes from the Siwalik hills near Haradwar, a portion of foothills of the Himalayas between the Jamuna and the Ganges valley. The supergroup, in fact, is developed continuously on the southern side of the extra-peninsula in Pakistan, India and Myanmar. In different regions it is formally recogniscd by different names. In India the term Siwalik Supergroup is restricted to the outer Himalayan region, while in Assam it is called the Dihing Supergroups.

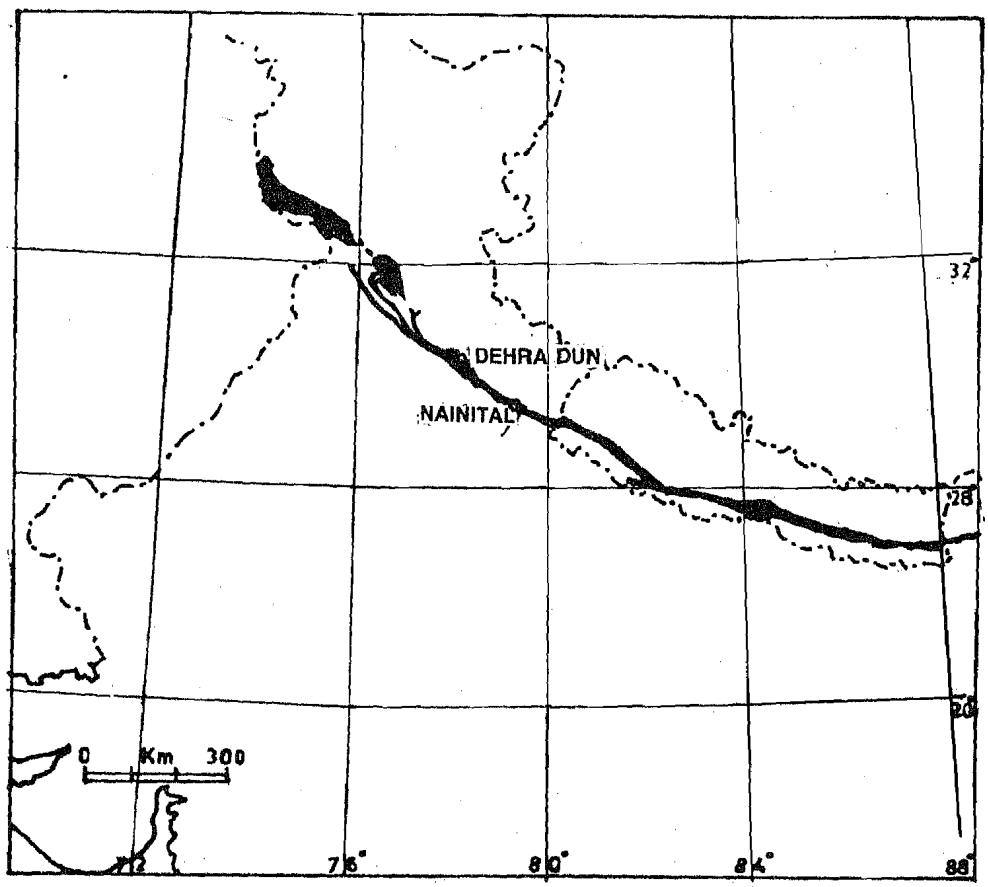

Figure 9.6 : Distribution of the Siwalik Rocks

The total thickness of the sediments of the Siwalik supergroup is more than 6,000 m. They consist mostly of coarse grained, gritty sandstones with subordinate shales. They were deposited in torrential streams and floods in shallow freshwater basins. The climate during the Siwalik period was warm and humid. There had been some changes in the nature of sediments temporarily produced due to changes in conditions of deposition as the impacts of

intermittent phases of mountain building movements. The uppermost sediments show indication of deposition by glaciers.

Certain horizone of the Siwalik Supergroup are richly fossiliferous. The Upper Tertiary biola had attained many characters sufficiently to relate it to the modern life, which is reflected in the fossil contents. A variety of huge mammals, now extinct, whose skeletons are found buried in the rocks of Siwalik Supergroup, is a special feature of the Upper Tertiary period of India. Remains of angiosperm plants are also known from these sediments.

The Siwalik rocks were involved in the subsequent mountain building activities, and like other extra-peninsular rock formations, are structurally much disturbed.

The development of the Tertiary sediments is found in many places along coast. Delta of the Ganges river, Orissa coast, Rajmahendri coast of Andhra Pradesh, part of Malabar coast, part of Konkan coast, part of Gujarat coast, gulf of Cambay and coastal tracts of Kathiawar and Cutch are the regions where Tertiary rocks had been deposited. The Terliary rocks are also known from the Andaman Islands and off-shore regions in the Arabian Sea.

The Tertiary rocks are very important, because in Gujarat, Cambay and Assam as well as in the off-shore regions in Arabian Sea, they contain reserves of petroleurn, In other areas, they hold a promise for additional petroleum reserves. Also in extra-peninsular region, there are workable coal seems in them. In tlie peninsular Tertiary rocks, lignite occurs. Therefore, the Terliary rocks help solve our fuel problem.

Quaternary Formations

Quaternary period is divided into two Epochs, Pleistocene and Recent. Pleistocene was an ice-age. Five glacial and four inter-glacial periods are recognised within it. During glacial period, a huge quantity of water remained locked in ice-sheets, depleting oceans and rivers. During inter-glacials, the ice got melted increasing the levels of seas and replenishing rivers. This phenomenon indirectly conrolled sedimentation. Oscillalions of strand line along coasts and changes in the quantity of water flowing in rivers are recorded by coastal deposits and terraces along valleys of major rivers of the world, There are direct evidences of glaciations in different parts of the world. They are in the form of glacial sedimenlary deposits, erratic boulders, roche moutonnees, etc.

One more speciality of the Quaternary period is the evolution of the man, the wisest animal of the world, one of the best creative experiments of mother nature. The ice-age also brought a severe change in the global environnient that destroyed many huge mammals which thrived during Siwalik times. The Mammalian fauna today is a small heritage of the rich and varied fauna of the Miocene-Pliocene Epochs.

In valley of Kashmir, older alluvium occupies fifty percent area, restricted to peripheral parts. They occur as flat mounds consisting of fine silty clays with sand and bouldcry gravels. These deposits are known as Karewas in kashmiri language and the same term is adopted in stratigraphy. I1 is believed lhat Karewas are lacustrine in origin, deposited in tlie lakes which came into existence during interglacials. The oldest part was probably fluviatile. In some portions between Baramula and Banihal, glacial morains deposited during ice-age have been identified within the Karewas.

Part of the western Rajasthan and part of Sind (Pakistan) constitute the **Thar Deserts.** The land is covered by several metres thick sands, which are constantly being shifted by winds blowing from southwest. The sands get piled up in dunes. The ridges of older rocks lying below rise above this sandy accumulalion. The desert conditions grew only during last 4,000 years or so, before which this part had a climate suitable for the growth of jungles.

In the Himalayan foot hill region, accumulation of fragments eroded from the slopes of mountains accumulate. Such accumulations are called **tallus.** In local language they are called **'Bhabar'** and 'Terai'. The Bhabar has a vertical extent of less than 300 m. It constitutes upper portion of the tallus and consists of rock fragments, gravel and soil. It supports forests. Immediately below the Bhabars, Terai is developed constituting lower portion of lallus. It consists of gravel and soil. It forms marshy belt with grass and thick jungles. It is a zone not suitable for human inhabitations.

Accumulation of alluvium occurs in the valleys of many rivers. That developed in Narmada and Tapi are particularly notable. Also, there are deltaic deposits at the mouths of all the major rivers on east coast. Raised beaches occur along coast. They consist of beach sands with sea shells, found a few metres above the present coast line.

Extensively developed marine limestone on the coast of Kathiawar is called the **milliolitic limestone** becasue it consists mainly of the minute shells of the micro-organism belonging to the genus *Milliolite*. This limestone is also called as the Porbandar limestone.

In Pleistocene, **Rann** of Cutch was a shallow arm of sea, which now is silted up. During the dry seasons, it forms an extensive and desolate salt marsh and, on the other hand, a tidal flat during monsoon.

Laterites of the Quaternary age occur in many parts of the country. Their formation requires tropical climate with monsoon. Therefore, the laterites were formed after the conditions became suitable. Indian subcontinent began to receive monsoon rains only after the birth of northern mountain chains. Laterite forms a blanket like layer on the rocks, from which they have originated. It is a ferruginous, porous, pitted or pisolitic rock.

Various soils occurring in different regions of the country were formed during the Quaternary Epoch.

Indogangetic alluvium formed during the Quaternary Epoch are dealt with somewhat details in section 9.5.7

SAQ 9

a) From the descriptions given below, identify the rock formations

i) Shales of thickness of 150 m to 300 m, carbonaceous towards base and variegated towards top.

ii) Splintery dark grey shales intercalated with sandstones occurring in Naga Hills area.

iii) Hard, fine grained grey or purplish quartzites, development of red clay towards their base.

iv) Deposited in torrential streams and floods in shallow freshwater basins.

v) Deposited in lakes which came into existence during interglacials.

vi) Marine limestone, developed extensively on the coast of Kathiawar.

b) Fill in the blanks.

i) Development of the Tertiary rock formations in peninsula is restricted only to the .....

ii) The lower Tertiary sediments of extra-peninsula are of ..... origin, while the Upper Tertiary sediments are of .....**origin.**

iii) Pleistocene was an ..... five ..... and four ..... periods are recognised within it.

iv) In Pleistocene, Rann of Kutch was a .....

v) Indian subcontinent started receiving the monsoon rains only after the birth of .....

9.5.6 Stratigraphy of Extra-peninsula

The Himalayas can be divided into thrde broad stratigraphical zones: The northern or Tibetan zone, the central or Himalayan zone and the outer or Subhimalayan zone. The northern zone consists of a continuous series of marine fossiliferous sedimentary rocks, ranging in age from Cambrian to Eocene. The central zone is made up of granites, gneisses and schists with unfossiliferous sedimentary deposits of Proterozoic age. The outer Himalayas consist of Cenozoic rocks including, as we have seen, rocks of the Siwalik Supergroup of freshwater origin.

Geology of extra-peninsula is indeed very interesting from both stratigraphical and structural points of view. However, it is extremely inaccessible for exploration and as such our knowledge about the geology of extra-peninsulais far from perfect.

As a representative case from extra-peninsula, we will study the stratigraphy of the Spiti basin. This basin is identified and selected for this purpose on the basis of two reasons. Primarily it is one of the difficult terrains, whose stratigraphy is studied at least to some extent as compared to other areas. Secondly, an almost complete sequence from Cambrian to Eocene exists there.

Stratigraphy of the Spiti Valley

The Spiti valley is located in the northeastern ranges of the Kangra district, Himachal Pradesh and in some adjoining parts. River Spiti is a tributary of Sutlej. A great geosynclinal basin with its axis trending NW - SE is exposed beyond the crystalline axis of Himalayas in this region.

The Cambrian strata found in this region are lcrmed the **Maimanta Formation.** They rest over the **Vaikrita Supergroup** of Proterozoic age. The Haimanta Formation is 1200 mm to 1600 m thick and contains mostly slates and quartzites. Towards the top some dolomitic bands are known to occur. Certain horizons contain fossils. The Haimanta Formalion is overlain by a thick series of shallow water deposits consisting of conglomerates, quartzites and grits of Ordovician age. Thickness of the Ordovician strata is about400 m. The Ordovician rocks are overlain by shales and limestones of the Silurian age. Thickness of the Silurian rocks of the Spiti basin is about 70 m. Like Cambrian rocks of the Spiti Valley area, these Ordovician and Silurian rocks are also fossiliferous.

White, hard, unfossiliferousquartzites called the **Muth Quartzites** overlie the Silurian rocks. Their thickness is abour 155 m. They are underlain by fossiliferous Silurian sediments and overlain by fossilifcrous Lower Carboniferous rocks, hence they surely are of Devonian age.

The fossiliferous Lower Carboniferous rocks which succeed the Muth Quartzites in the Spiti area have been termed as the **Kanawar Formation** and have a total thickness of about 600 m. The Kanawar Formation contains limestones, quartzites and shales, All of them are fossilferous.

After deposition of the Kanawar formation, there was a short break in the process of sedimentation. Next rock to be deposited was a conglomerate. Its age is Upper Carbnonifrous. This conglomerate is followed by the Permian rocks varying in thickness from 0 to 100 m. The Permian rocks of the Spiti basin are identified by the formal name the **Kuling Pormation.** Rocks of the Kuling formation are fossiliferous. The lower members consist of grits, quartzites and calcareous sandstone and have a thickness of ranging from 30 to 50 m, while the upper members consist of brown or black carbonaceous and siliceous shales, ranging in thickness from 30 to 60 m.

The Permian rocks pass upwards into the Triassic rocks without any break. The Triassic rocks are exposed in the Spiti-Kumaon belt, north of the main axis of Himalayas. They form huge scarpments making up a height of more than 3,000 m. The Triassic rocks are formally called as the **Lilang Formation.** Total thickness of the Lilang formation is well over 1200 m. However, the lower Triassic. is represented by only 12 m thick strata, middle Triassic by 120 m, while the Upper Triassic is represented by much thicker strata, about 1100 m. The formation comprises mainly black limestomes with intercalations of shales. The strata included are entirely of marine character. The Triassic rocks of Spiti basin are richly fossiliferous except the topmost division, about 250 m thick, which is also called the **Para Limestone Member.** Along with the lower 450 to 500 m thick strata of the Jurassic rocks are called the **Tagling Member,** the para Limestone Member constitutes a conspicuous scarp made up of limestone. This limestone is called the **Kioto Limestone.** In other words, the lower 200 to 250 m portion of the Kioto Limestone is Upper Triassic in age and is named as Para Limestone Member, while the upper 450 to 500 m portion of the Kioto Limestone is Lower Jurassic in age and is named the **Tagling Member. Though,** the para Limestone Member is mostly unfossiliferous, the Tagling Member contains a few fossiliferoushorizones. The Kioto Limestone is succeeded by shales, called the Spiti shales of the upper Jurassic age. The thickness of Spiti shales is about 150 m. They are grey to black, soft, friable shales with a few thin intercalations of limestone. They have yielded a rich fauna. They pass upwards into a sndstone, called the **Giumal sandstone.** This sandstone is Lower Cretaceous in age, yellow and brown in colour with intercalations of slaty quartzites. It contains fossils of the Lower Cretaceous age, Conformably above it comes the **Chikkim Formation** of about 75 m thickness. The lower 30 m thick portion comprises limestone called the Chikkim limestone and is fossiliferous. The upper 45 m thick strata comprises shales called the **Chikkim shales** and are unfossiliferous. Chikkim shales are overlain by a group of unfossiliferous sandstones and arenaceous shales ranging in age from Upper Cretaceous to perhaps Lower Eocene. These sandstones and arenaceous shales belong to flysch facies.

SAQ 10

a) Complete the following table

Sl.No.	Name of the formation	Age	Thickness
1)	Chikkim Formation	–	–
2)	Spiti Shales	–	–
3)	Kioto Limestone	–	–
4)	Lilang Formation	–	–
5)	Kanawar Formation	–	–
6)	Muth Quartzite	–	–
7)	Haimanta Formation	–	–

b) **Fill** in the blanks

i) Geology of extra-peninsula is interesting from both ..... and ..... **Point:,** of view.

ii) River spiti is a tributary of river .....

iii) ..... of the Upper Triassic age and the .... of the Lower Jurassic age together constitute the .....

9.5.7 Indogangetic Alluvium

The portion of the land occupied by the alluvium deposited by the rivers Ganges, Brahmaputra and Indus is called as the **Indogangetic** alluvium. It separates peninsula from extra-peninsula and as we have seen in the Section 9.4, constitutes a separate physiographic division of India. It covers an area of about 650,000 sq. km.

This region is believed to be formed as a sag in the earth's crust when geosynclinal sediments accumulated in the Tethys were lifted up due to northward drift of the Indian continent. The deepest portion of the sag is only a few miles south of the mountainous region. Towards peninsula, it gradually shelves up. The **maximum** depth is estimated to be of the order of 2,000 m.

The sediments that have filled this depression in the earth's crust are silts, sands and clays. Occasionally beds of gravel and lenses of peaty organic matter are found to occur. The alluvium is classified into two parts, the older alluvium and the newer alluvium.

The older alluvium forms slightly elevated river terraces. It is Middle to Upper Pleistocene in age. The older alluvium is dark coloured and often contains impure concretions or nodules of calcium carbonate.

The newer alluvium is light coloured and poor in calcareous matter. It contains lenticular beds of sand, gravel or peat. Its age is Upper Pleistocene.

The older alluvium is locally called Bhangar and contains the remains of extinct species of mammals. The newer alluvium is locally called Khadar. Fossils contained in the Khadar are those of extinct mammals.

SAQ 11

a) Compare the Lower Indogangetic alluvium with the Upper Indogangetic alluvium.

b) How the region of Indogangetic alluvium was formed ?

c) Fill in the blanks :

i) The Indogangetic alluvium covers an area of about .....

ii) The maximum depth of the Indogangetic alluvium is estimated around .....

9.6 SUMMARY

Stratigraphy is that branch of geology which collates various aspects of geological study in order to build history of the earth's crust. For the sake of convenience, stratigraphy is studied regionwise vis-a-vis global context. Indian stratigraphy is the history of that part of the crust which is now occupied by the Indian subcontinent.

Flow of time, accumulation of sediments and evolution of life have taken place hand in hand. Therefore, evolutionary status of life serves as a convenient tool for dividing and subdividing the geological time. Hence, the remains of life in the rocks by way of fossils and their study, which constitutes the subject matter of the science of yalaeontology, give significant information to a stratigrapher.

As regards Indian subcontinent, the three physiographic divisions, viz., peninsula, extra-peninsula and the Indo-gangetic alluvium plain are separate stratigraphical entities, because their stratigraphical histories are totally different from one another.

The peninsula is an old shield, made up principally of ancient metamorphic, crystalline complex. Metamorphosed sedimentary rocks, the Dharwar Supergroup and their equivalent formalions are the oldest rocks of peninsula. These were intruded from time to time with igneous intrusions complicating the already folded crystalline metamorphosed sediments. These igneous rocks too were subsequently metamorphosed due lo subsequent earth movements. Three phases of igneous activities are recognised and are formally called the Peninsular Gneiss, the Bundelkhand Gneiss and the Charnockite. They have their equivalents in different areas. The Archaean rocks are very important from economic geology point of view.

During the Proterozoic era, sedimentary rocks were deposited in isolated basins. They contain remains of very primitive life. The Cuddappah Supergroup and the Vindhyan Supergroup represent two types of rock formations, the Cuddapah Supergroup being older of the two. Their correlated rock formations occur in various regions and have different formal names.

Cambrian to Lower Carboniferous periods are not represented in peninsula. During Upper Carboniferous, sedimentation resumed after a long hiatus with glacial deposit, which forms an important datum line in Indian stratigraphy. This episode of deposition under terrestrial condition continued till Lower Cretaceous. The rocks formed are recognised by the formal name the Gondwana Sequence. They were mostly deposiled in the rift valleys. The Gondwana Sequence contains coal deposits. The fossil flora of this sequence is very interesting for it provides a reliable proof to the theory of continental drift The climatic changes that have occurred from the Upper Carboniferous to the Lower Cretaceous are also well documented in the rocks of the Gondwana Sequence, both sedimentologically and palaeontologically.

Besides the Gondwana sequence, Mesozoic Era is represented in peninsular India by temporary and local encroachments of sea over land called the marine incursions. Jurassic rocks of Kutch and Rajasthan, crelaceous rocks of Tamil Nadu and hilly region of Assam, Meghalaya, the Bagh Beds and the Wadhwan Formation are the examples.

Towards the close of the Mesozoic Era pouring of basaltic lavas through numerous cracks gave rise to a thick pile of volcanic lava flows called the Deccan Trap. The volcanic activity continued till Palaeocene.

Development of Tertiary and Quaternary rocks is restricted mostly to the coastal belts. In areas other than coastal belt, river alluvium of Tapi and Narmada is particularly notable. Palaeocene Epoch of the Quaternary was a period of ice-age.

As regards exlra-peninsula three broad stratigraphical zones are seen. Northern or Tibetan zone consists of an almost continuous series of Cambrian to Eocene sediments. The Central or Himalayan zone is made up of granites, gneisses and schists of probably Proterozoic age. The outer Himalayas consist of Cenozoic rocks, the younger part of which is freshwater origin.

As an example of rocks occurring as a series from Cambrian to Eocene, Spiti basin can be cited. The rocks, barring a few exceptions, arc fossiliferous.

Cenozoic rucks are seen in the outer Himalayas. From Eocene to Lower Miocene are marine while Middle Miocene onwards the rocks are of freshwater origin. The freshwater rocks are of particular interest because they contain fossils of the mammals. These freshwater sediments of Upper Tertiary age are termed the Siwalik Supergroup.

In the Himalayan foot hill region, tallus was accumulated during Quaternary. It is locally called Bhabar and Terai.

As regards the Indo-gangetic alluvium, these are the geologically uninteresting accumulations of the material brought by rivers Ganges, Indus and Brahmaputra. They are deposited in Subrecent times in the sag which was formed in the earth's crust simultaneously with the uplifting of Himalayas.

9.7 KEY WORDS

Archaeozolc : that era of the geological time scale when these was either no life or if at all life existed it was too undeveloped to be preserved.

Azoic : same as Archaeozoic

Cenozoic : that era of the geological time scale during which life had become modem.

Cryptozoic that Eon or principal division of the geological time scale during which life was imperfectly developed and hence, obscurely preserved in rocks.

Flysch arenaceous rocks deposited in an environment not suitable for existence of life and therefore, unfossiliferous.

Fossil remain of any ancient organism preseved in a sedimentary rock.

Geosynclinal Deposit : sedimentary deposit formed in a geosyncline.

Geosyncline : a very large depression in the earth's crust sinking and receiving sediments simultaneously and hence, accommodating a huge pile of sedimentary rocks.

Guide Fossil : same as index fossil

Hiatus : a break in sedimentation indicated by an unconformity.

Index fossil : fossils of organisms which had a limited time range but a very wide distribution in space.

Mesozoic that Era of the geological time scale during which evolutionary status of life was intermediate.

Palaeontology that branch of science which deals with the study of past life, also defined as that branch of science which deals with the study of fossils.

Palaeozoic : that Era of the geological time scale during which the evolutionary status of the life was ancient.

Phanerozoic : that Eon or principal division of geological time scale during which life had sufficiently evolved to be preserved as fossils in rocks.

Primordial Crust : first formed crust of the earth, when it cooled from a gaseous or liquid state.

Shield : that region of the crust which has attained a stuctural stability.

Stratigraphy : that branch of geology which collates many aspects of geological study in order to construct the history of the earth's crust.

Zone Fossil	fossils of those organisms which has a limited time range and whose distribution in space was limited to particular geographical zone.

9.8 FURTHER READINGS

1) Krishnan, M.S., *Geologies of India and* Burma, Higginbothams, Madras.

2) Wadia, D.N., *Geology of India,* Oxford, London.

9.9 ANSWERS TO SAQs

SAQ 1

a) i) All objects of organic origin are not fossils, if they do not reflect the morphology of the organisms from which they were produced. Therefore, coal and petroleum are not considerd as fossils.

ii) Leonardo da Vinci is called 'the father of palaeontology'.

iii) Palaeontology means study of ancient life, However, the ancient life is represented by fossils alone. Therefore, palaeontology is also defined as the study of fossils.

b) i) To reconstruct the history of the earth right from the time when it was in the gaseous state, has been the endeavour of the geologists.

ii) The events such as swinging of a pendulum, flow of sand in an hour-glass, rotation of earth around itself and the sun take place either with uniform speed or at definite intervals. Such events are utilised as the means to divide time into artificial units.

iii) The organism still living today and whose fossils are also found in the rocks of different ages, have a very long range without any remarkable evolutionary changes, are called as the living fossils.

c) i) abstract continuum, ceases to flow

ii) Flow, sediments, evolution

iii) inequal

d) i) Fossils : remains of animals and plants of past ages preserved in rocks.

ii) Stratigraphy : A branch of geology that collates all the aspects of geological study in order to build the history of the crust of the earth.

iii) Index fossil : Fossils of organisms which had a limited time range but a very wide distribution in space.

SAQ 2

a) i) Principle of order of superposition, uniformitarianism and Principle of faunal succession are the three principles of stratigraphy.

ii) Different rocks which are more or less definite units of the earth's crust form the subject matter of the stratigraphy.

iii) Correlation is the most obvious and necessary function of stratigraphy.

(b) i) Present, the past.

ii) faunal succession.

iii), unconformities, episodes of sedimentations,

SAQ 3

a) i) , freshwater, Miocene - Pliocene.

ii) extra-peninsula, tectonic, origin.

iii) weathering and denudation, relict.

b) i) The three physiographic divisions have their own specialities about their physical, stratigraphical and structural features and are, therefore, distinct from each other.

ii) The peninsula has not practically witnessed any mountain building activity since the close of Archaean era, therefore, it has remained a stable block of the earth's crusl.

SAQ 4

a) Charnockites – consisting of plagioclase, hypersthene, blue quartz and garnet.

Peninsular Gneiss – banded appearance, abundance of accessory minerals.

Bundelkhand Gneiss – without any conspicuous foliation, paucity of accessory minerals.

b) i) Khondalite consists *of* quartz, garnet, sillimanite and graphite

ii) Sausar Supergroup and Sakoli Supergroup are the names of westerly extension of the Chilpi Ghat Supergroup.

iii) The Archaean rocks are uiossiliferous, metamorphosed, faulted, complexly folded, cystalliie rocks intruded by plutonic intrusions. These factors impart a complexity of field relationship and geological structure. Besides, they are the oldest rocks and occur below the layers of sedimentary rocks. Hence, they are called as 'Basement complex'.

SAQ 5

a) The pronounced unconformity with which the first Proterozoic rocks overlie the Archaean rocks is called the 'Eparchaean Unconformity'.

b) The rocks of the Cuddapah Supergroup are exposed in a vast crescent shaped area in Andhra Pradesh. The concave side of the crescent shape faces east. Its north-south length is about 340 km. Its northern extremity is situated a little south of Singareni Collieries, while the southern end roughly corresponds to Nagari hills. The maximum width along east-west is about 240 km.

c) The township of Abu rests over the Erinpura Granite.

d) The Kurnool Supergroup is correlated with the Vindhyan Supergroup. It rests over the Cuddapah Supergroup with an unconformity.

e) Out of the four groups constituting the Vindhyan Supergroup, the two upper groups have diamondiferous conglomerate at their bases. The lowermost sandstone in the Kumool Supergroup also contains diamonds.

SAQ 6

a) More or less linear patterns of the outcrops, presence of a number of faults within the Gondwana sediments and faulted boundaries between the Gondwana rocks and the metamorphics are the evidences to deduce that Permian fluviatile sedimentation took place in rivers occupying faulted troughs.

b) Decline in plant fossils and presence of ferruginous shales in place of carbonaceous shales suggest that warm and humid climate in Permian gave place to **arid** climate during Triassic.

c) The clay from the Gondwana Supergroup is used in manufacturing refractory bricks, roof-tiles, pottery, china-ware and terra-cotta.

d) i) ice age, glacial boulder bed.

ii) Gond community, Madhya Pradesh , rocks

SAQ 7

a) i) Temporary, local, reduction, capacity

ii) Jaisalmer, Bikaner

iii) Tiruchirapalli

iv) Mediterranean

b) Marine Jurassic rocks of Kutch - Deltaic sandstones towards top belong to the Gondwana Sequence

The Bagh Beds - Developed in valley of Narmada river

The Wadhwan Foimation -Westerly extension of the Bagh Beds

Marine Cretaceous rocks of Tamil Nadu - Famous world-over for the treasure of fossils.

SAQ 8

a) The Deccan Trap has an age from the Upper Cretaceous to the Lower Palaeocene.

b) Cryptocrystalline varieties of silica, rock crystals, calcite, apophyllite and certain species of the zeolite family of minerals are found in the vesicles of the basalts of the Deccan Trap.

c) The Lameta Beds occur just below the Deccan Trap, they are called as Infratrappean Beds..

d) In between two lava flows, lacustrine sedimentary beds of very small areal extent with thicknesses rarely exceeding 3 or 4 m may occur. They are called Deccan intertrappean beds.

SAQ 9

a) i) Shales occurring in Pir Panjal, equivalent to the Chharat Formation

ii) The Disang Formation

iii) The Dagshai Beds

iv) The Siwalik Supergroup

v) The Karewas of Kashmir

vi) Milliolitic Limestone

b) i) coastal belt

ii) marine, freshwater

iii) ice age, glacial, interglacial

iv) shallow arm of sea

v) northern mountain chains

SAQ 10

a)

Sl.No.	Name of the Formation	Age	Thickness
1)	Chikkim Formation	Cretaceous	75 m
2)	Spiti Shales	U. Jurassic	150 m
3)	Kioto Limestone	U. Triassic	650 m
		to L. Jurassic	750 m
4)	Lilang Formation	Triassic	1200 m
5)	Kanawar Formation	L. Carboniferous	600 m
6)	Muth Quartzite	Devonian	155 m
7)	Haimanta Formation	Cambrian	1200 m - 1600 m

b) i) Structural and stratigraphical

ii) Sutlej

iii) Para Limestone Member, Tagling Member, Kioto Limestone

SAQ 11

a) The Older Indogangetic alluvium, locally called Bhangar is Middle to Upper Pleistocene in age. It is dark in colour and often contains nodules and concretions of impure calcium carbonate. The new Indogangetic alluvium, locally called Khadar, is upper Pleistocene in age. It is light coloured and contains lenticular beds of peat.

b) The region is believed to be formed as a sag in the earth's crust when geosynclinal sediments accumulated in the Tethys were lifted up due to northward drift of the Indian continent,

c) i) 650,000 sq. km

ii) 2,000 m.