3 Palaeontology and Stratigraphy

Introduction :

Palaeontology is the study of ancient life that is preserved in the form of fossils. 'Palaeo' means ancient, 'Ontos' means life and 'Logos' is study. Initially, the term fossil was applied to any object dug up from the ground.

Today the word fossil is used to refer only to objects associated with prehistoric life forms older tha 11,000 years. The term fossil was coined by the German mineralogist Georgius Agricola (1494 -1555). Generally fossils are found in sedimentary rocks. The term fossil is further extended to any recognizable structure in sedimentary rocks that indicates some sort of life. Life on Earth in its primitive form probably came into existence about 3500 to 3600 million years ago. Currently, we are in geological time interval known as the Holocene epoch, which began about 11,000 years ago. Therefore, any remains or evidence of ancient life forms before the Holocene Epoch i.e. before 11,000 years ago definitely counts as a fossil. Fossils can range in size. Macrofossils can be held in the hand and examined with good hand lens. They can be several meters long and weigh several tons like logs of petrified wood and dinosaur bones. Microfossils are very small and require a microscope to study them. Their size can be in micrometres, e.g. fossilised pollen and spores.

Palaeontological studies deals with taxonomy, morphology of hard parts, their nature, inter - relationship, environmental implications, distribution, age and evolution of ancient life.

Two major branches of palaeontology are recognized, viz. Palaeozoology and Palaeobotany. Palaeobotany deals with study of plant fossils and palaeozoology with vertebrate and invertebrate animal fossils. Micropalaeontology is a specialized branch that deals with the study of microfossils. Paleoichnology comprises the study of Ichnofossils and/or Trace fossils. Palynology or Palaeopalynology is yet another branch, which deals with the study of organic walled microfossils like pollen, spores, seeds, seed coats etc.

Do you know?

1) Aristotle, the Greek philosopher was one of the first to classify living things into either plants or animals.
2) Leonardo da Vinci (1452-1519) stressed that fossils were organic in nature and natural in origin.
3) William Smith (1789-1839) a British engineer was the first to note that there is an intimate relation between the fossils and sedimentary rocks containing them. He realized the importance of fossils and further, described and defined sedimentary rock units on the basis of fossils contained in them. William Smith's observation was the beginning of a new era as integrated approach was significant in the study of palaeontology and stratigraphy.

Prerequisites of fossilisation :

When an organism is buried quickly, there is less decay and a better chance for it to be preserved as it does not come in contact with oxygen. Hard parts of organisms, such as bones, shells and teeth have a better chance of being fossilised. Number of prehistoric organisms living in geologic past exceeds many billions. It has been estimated that only one out of every

10,000 organisms leaves behind fossil record. So far only about 91,000 species of fossils are known.

If an organism is to be preserved in the form of a fossil there are a set of certain prerequisites like :

1) It is necessary that the organism possesses a skeleton of hard parts that can withstand decomposition.
2) Composition and structure of its hard parts should be suitable for preservation.
3) Further, it should be covered or buried quickly by some sediment (deposits), so that dispersal and disintegration of hard parts of skeleton is prevented.

Possession of a skeleton or hard parts and quick burial are the two most important prerequisites for preservation that are most commonly fulfilled in case of aquatic organisms. After the death of an aquatic organism, its body sinks to bottom of the water body. Later, it is quickly buried by sediment, preventing destruction and dispersal. Chances of burial and preservation of terrestrial or land animals are higher when they die on the banks of lakes or rivers. Rarely land animals may be covered by volcanic ash and instantaneously preserved. The probability of an animal being preserved as a fossil is further governed by the composition and structure of its hard parts. If the skeleton consists of thin fragile shell, it can easily broken and chances of preservation diminish; whereas tough and strong skeletons are more likely to be preserved. It is not only the nature of skeleton, but its composition which determines the degree of fossilization. If the skeleton is composed of siliceous matter, and calcium carbonate (invertebrates), chances of fossilization are high whereas, phosphatic vertebrate skeletons and chitinous skeletons of insects have maximum chances of preservation, as they dissolve with difficulties.

Modes of preservation of organisms for fossilisation :

1) **Entire organism preserved :** Rarely, the organisms are preserved in a virtually unaltered state. Ice, amber, and tar can preserve entire organisms e.g. Woolly mammoth preserved in ice from Siberia, insects preserved in amber from Baltic countries (fig. 3.1), Dominican Republic, fossils from tar pits of Rancho La Brea, California, USA.

Fig. 3.1: Insect preserved in amber

2) **Entire skeleton preserved :** Most of the vertebrate skeletons are entirely preserved due to differential solubility. Such skeletons and shells once buried remain unaltered e.g. entire skeletons of the giant reptiles of the Mesozoic era such as Mesosaurus braziliansis (fig. 3.2).

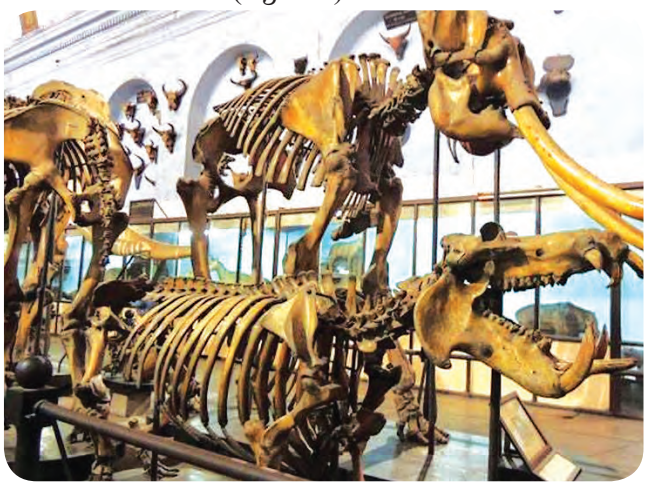

Fig. 3.2 : Entire skeleton of Mesosaurus braziliansis

3) **Petrification :** The process of removal and replacement of organic matter by inorganic minerals thereby converting the material

into rock is known as petrification. In this process, the replacement takes place molecule by molecule. Such fossils show internal and external details permitting the study of anatomy and morphology in detail. A variety of minerals are known to cause petrification. The most common replacing material is silica, calcite, dolomite, pyrite and accordingly, petrification may be a result of silicification, calcification, pyritization. e.g. Petrified wood fossils from Akal wood fossil park, Rajasthan, National fossil wood park, Thiruvakkarai T.N., National fossil wood park, Sathanur, T.N, and petrified woods near Chandrapur, Maharashtra (fig. 3.3).

Fig. 3.3 : Petrified wood

4) **Carbonization :** Process of carbonisation forms carbonized fossils. It is a process of incomplete chemical decomposition of organic matter, reducing it to a carbon residue or a thin film. Parts of plants are usually preserved with this mode. Buried broken parts of stems, leaves etc., undergo dehydration and decomposition loosing nitrogen, oxygen and hydrogen. Carbon contained within the remains of a soft-bodied animal or plant forms a stamp-like impression on the sediment Organisms like graptolites and plant fossils from Gondwana are preserved as carbonized fossils (fig. 3.4).

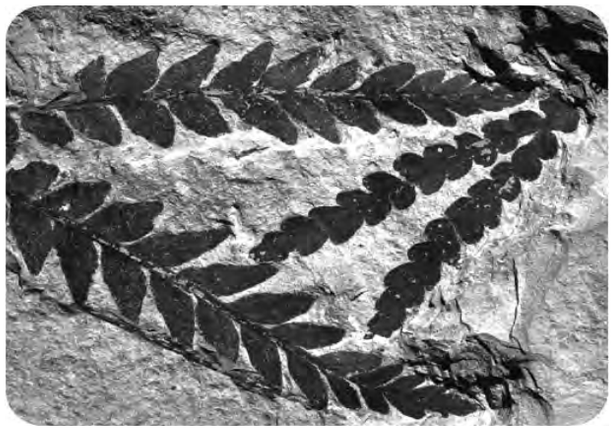

Fig. 3.4 : impression of carbonised plant fossils

5) **Imprints :** Imprint as a mode of preservation is more common in case of soft bodied organisms like jelly fish (fig. 3.5). They leave behind their impression on the surface of fine grained sediments. These preserved impression are indicative of many morphological features.

Fig. 3.5 : Imprint of jelly fish

6) **Cast and Mould :** Sometimes, open pores in the rock let water and air reach the organism or part of it, causing it to decay or dissolve, leaving behind a cavity in the sediment. This empty cavity is called a mould. A mould shows the original shape and the external morphology of the organism. Later, sand or mud may fill the mould and harden, forming a cast of the original organism. A cast is a replica of the original organism. This is the most common mode of preservation of invertebrate fossils e.g. shells from Cretaceous of Tiruchirappalli (TN), Bagh Beds (MP) and Jurassic of Kutch (Gujarat) (fig. 3.6)

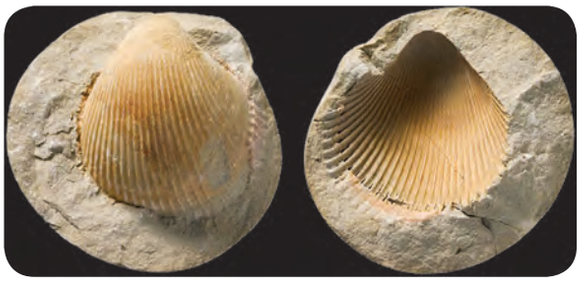

Fig 3.6: Cast and Mould of bivalve

Types of fossils :

Broadly speaking, paleontologists divide fossils into two main groups :

1) Body fossils 2) Trace fossils

1) Body fossils : Body fossils are remains of body parts of ancient animals, plants and other life forms. They may be preserved intact or fragmented (fig. 3.7a).

Fig. 3.7. a) Body fossil

2) Trace fossils : Trace fossils (sometimes also called ichnofossils) provide evidence about the movements and/or activities of ancient organisms, but not necessarily about their appearance. Tracks, trails, burrows, footprints, nests, worm burrows, gizzard stones, and coprolites are considered to be trace fossils. They range in size from worm burrows to dinosaur footprints (fig. 3.7 b).

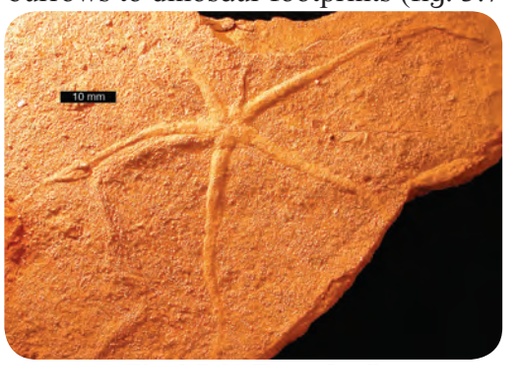

Fig. 3.7. b) Trace fossil

Do you know?

Various kinds of trace fossils : Track : an impression made by a single foot.

Trackway : a number of tracks made during a single trip.

Trail : an impression made by an animal without legs.

Burrows : a hole dug by a life form in loose sediment (like mud).

Borings : a hole dug by a life form into a hard substrate (like wood or rock).

Coprolites : animal faecal pellets that have fossilized.

Uses of fossils :

Fossil records have facilitated palaeontologists, stratigraphers and biologists to unravel the geological events. Many uses of fossils are known. Some important uses are as follows :

1) **Determination of the geological age of strata :** Geological age of the fossils is the geological age of the rocks they are contained in.

2) **Information of Palaeo- environment and history of deposition :** Characters of animals and plants from different environments vary. Presence of vertebrate fossils and plant fossils indicate terrestrial environments like lakes, ponds, rivers, flood plains, etc. Marine environments are indicated by th exclusive presence of fossils of corals, trilobites, brachiopods, ammonoids, nautiloids etc.

3) **Determination of palaeo-climate :** Terrestrial plants thrive in specific climatic conditions. The occurrence of fossils of such plants is evidence of the existence of climatic conditions in the geologic past. For example occurrence of palm fossils indicate tropical climate.

4) **Correlation of widely separated strata :** Fossils are frequently used to determine relative or comparative ages of sedimentary rocks. Similarity of fossils in widely separated rocks indicates equality in their age. So by associating similar fossils among such rocks, they can be correlated.

5) **Reconstruction organic evolution :** Fossil record is invaluable for reconstruction of organic evolution because change in characters of animals and plants is gradual. This change is recorded in the fossils found in successively younger strata. For example, the earliest horse of Eocene age was the size of a dog with five toes. It was succeeded by forms with lesser number of toes and increased height. Finally, modern day horse has evolved. This is the evidence of the evolution of modern day horse.

6) **Exploration of Petroleum and Coal Reserves :** Some microfossils like Foraminifera and Ostracoda are very sensitive to the environment. Therefore, they are indicators of environments. Marine reducing environment with rapid deposition, good compaction ratio, low current index and ideal temperature condition are essential for the generation of hydrocarbons. All these factors can be inferred with the help or microfossils. For exploration of petroleum, deep drilling is required. Such drilling must have stratigraphic control. For this purpose, accurate correlation of subsurface rocks is essential. Such correlation can be established by using microfossils, especially Foraminifers and Ostracods. Plant fossils are useful in the study of coal deposits.

Do you know?

Geo Parks aim to protect geodiversity (rocks, minerals, landforms and fossils) and promote geological heritage within the general public as well as support sustainable economic development of the area, primarily through the development of geological tourism.

It is interesting to know that the first stamp on fossils was issued by India. This stamp was issued to commemorate the Centenary of Geological Survey of India in 1951. The stamp features a fossil elephant: Stegodon ganesa", which was the probable direct ancestor of our modern day elephant. Such fossils were reported from Siwalik Hills of Himalayas.

Terminologies used in palaeontology :

1) **Index fossil :** These are fossils which are easily recognisable, distinctive, widely distributed and abundant. They existed for a limited life span. (e.g Ammonites from Mesozoic, trilobites from Palaeozoic). Index fossils are used as stratigraphic markers.

2) **Chemical fossils :** When some organisms decompose they leave a characteristic chemical signature. Such chemical traces provide indirect evidence for the existence of past life.

3) **Pseudo fossils :** These are visual patterns in rocks that are produced by naturally occurring geological processes rather than biologic processes. They can easily be mistaken for real fossils, for e.g. dendritic markings formed by filling of fissures in a rock by manganese oxide, which are tree like.

4) **Living fossils :** Living fossils are present day forms which also exists as fossils. (e.g.

cyanobacteria, horseshoe crabs, ginkgo biloba, cycads).

5) **Reworked fossil :** Reworking can happen to any fossil. It simply means that the fossil may have been removed from its original sedimentary layer and redeposited in a younger layer. A reworked fossil can mislead a geologists about age of the rock in which it was found

Do you know?

Lagerstatten Unique windows into the past

These spectacular fossil deposits represent an amazing 'snapshot' in time. These extraordinary fossil deposits, where organisms are so well preserved that even their soft parts remain as carbon films, are referred to as Lagerstätten, a German word meaning 'deposit places'.

Do you know?

Fossil parks in India

The Geological Survey of India (GSI) currently maintains the following fossil parks:

- Siwalik Fossil Park, near Saketi, Himachal Pradesh is notable for its life-size models of the vertebrates that might have roamed the Sivalik Hills 1.5-2.5 million years ago.
- Mandla Plant Fossils National Park, near Dindori, Madhya Pradesh is a park that attempts to preserve the fossil remains of a primordial forest that covered the region 40—150 million years ago.
- National Fossil Wood Park, Tiruvakkarai in Tamil Nadu.
- National Fossil Wood Park, Sathanur, in Tamil Nadu.

Other fossil parks in India include :

- Indroda Dinosaur and Fossil Park, Gujarat
- Ghughua Fossil Park, Madhya Pradesh
- Salkhan Fossils Park, Uttar Pradesh
- Akal Wood Fossil Park, Rajasthan
- Amkhoi fossil park, West Bengal
- Raiyoli dinosaur fossil park, Gujarat

Do you know?

Narmada human

On December 5, 1982, the geologist Arun Sonakia discovered the only known fossil of a human ancestor from South Asia on the banks of the Narmada, at a place called Hathnora village in Sehore district, nearly 35 kilometres east of Hoshangabad in Madhya Pradesh.

Fossil skull of Narmada human, belongs to the ancestor category of Homo erectus, who inhabited the Earth from 1.8 million to 200,000 years ago and preceded Homo sapiens.

Activity 1 :

Recreation of Fossil Moulds and Fossil Casts

Expected duration : Two, thirty minute sessions on separate days.

Instructions :

1) Place some clay at the bottom of a small container. This clay represents the bottom of the ocean.
2) Press a shell or bone into the clay. This is a hard part of organism that was buried in the clay.
3) Remove the shell or bone, and observe the imprint in the clay. This imprint is a mould of the shell/ bone.
4) In a second container, prepare some plaster of paris by adding water and mixing until it is creamy.
5) Pour the Plaster of Paris into the mould that has been created.

6) Next day, gently tap and remove the fossil cast.

7) Examine the fossil specimens from the first investigation. Identify the fossils as moulds, casts, or other.

Activity 2 :

Simulation of process of petrification :

Expected duration: Thirty minutes session for initial set up, several days for observations and thirty minutes session for conclusion and discussion.

We will model a process whereby the remains of a buried organism or part of an organism are replaced by minerals.

1) Cut two pieces of white sponge into a bone shape. One piece will be used to simulate fossil formation and the other will be used for comparison.
2) Fill a cup with hot water. Prepare a saturated solution of Epsom salts ($MgSO_4$) and add a few drops of food colouring.
3) Pour the solution into a pan.
4) Immerse one bone shaped sponge into the pan and observe the movement of water through the holes of the sponge.
5) Leave the pan untouched for several days until the sponge is dry.
6) Examine the dry sponge.

STRATIGRAPHY

It is a branch of geology that deals with the study of stratified and sedimentary rocks with reference to their description, identification, content, correlation and extent, both horizontal and vertical. 'Stratum' means a layer and 'graphy' means description. Therefore, stratigraphy is a descriptive study of layered or stratified (generally sedimentary) rocks.

The basic idea of stratigraphy is to arrange the rock units in chronological sequence, so that continuous history of the Earth can emerge. This is essential because rocks of different ages are found at different places.

Principles of stratigraphy :

Stratigraphy is based upon three fundamental principles :

1) **Principle of Uniformitarianism :** The concept of uniformitarianism was given by a Scottish geologist, James Hutton (1726-1799). In its simplest form, it states that the processes which have acted in the past, are essentially the same as those in operation on the Earth today. It can be summarized in the statement 'present holds the key to the past'. By actual observation, we can see that layering and variation of grain size seen in the sediments, on the banks of the modern stream, are the result of fluctuations in the velocity of the stream. Hence, we can summarize that the same phenomenon was responsible for the layering in ancient fluvial sediments. Likewise, we know that the ripple marks observed on beaches is a product of wave action. It is, therefore, logical to conclude that ripple marks present in sedimentary rocks were formed by the same process.

Do you know?

James Hutton FRSE (Edinburgh 1797) was a Scottish physician, geologist, naturalist, chemical manufacturer and experimental agriculturalist. His work helped to establish the basis of modern geology. His theories of geology and geologic time, also called deep time, came to be included in theories which were called plutonism and uniformitarianism.

2) **Order of Superposition :** In 1669 Danish physician Steno on the basis of observation along the walls of the Arno Valley in Italy suggested the concept of Order of Superposition. He pointed out that in any series of sedimentary layers, lying in a normal disposition; the rocks at the bottom of a sequence are older than the rocks at the top of the sequence. However, where the rocks are over folded and thrusted or faulted, it is first necessary to determine whether the rocks are in their normal position or if are overturned.

3) **Faunal Succession :** The British surveyor, William Smith (1769-1839), is regarded as the father of modern stratigraphy and was the first to recognize the fact, that fossils could be used to correlate and date the strata in which they were found. During the course of his work, he noticed that the same assemblage of fossils always occurred in the same rock layers. Fossil species in layers above and below these layers were distinctly different. The fossils occurred in the same order in widely separated localities. This discovery of William Smith led to the establishment of the 'Law of Faunal Succession'.

Stratigraphic Correlation : Correlation is a method of finding equivalence in geological age or stratigraphic position between two rock units that are widely separated. Correlation may be local, regional, intra or inter basinal, short range or long range.

Methods of Stratigraphic correlation :

There are two methods of Stratigraphic correlation i) Lithological correlation and ii) Palaeontological correlation. It can be achieved by a) Physical/ lateral continuity and b) presence of marker horizon or key beds.

Most simple way of correlating strata on local scale is by ascertaining, if there is a physical continuity of strata. If one can walk physically from one locality to another on the same rock type, then correlation is established by the principle of continuity of strata (fig.3.8).

i) Lithological correlation :

If succession of lithological units is similar at different localities then there is every possibility that corresponding rock units are of the same age and can be correlated (fig. 3.9).

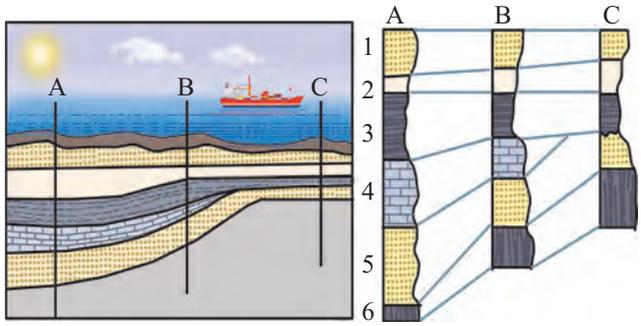

Fig. 3.9 : Correlation based on lithological succession

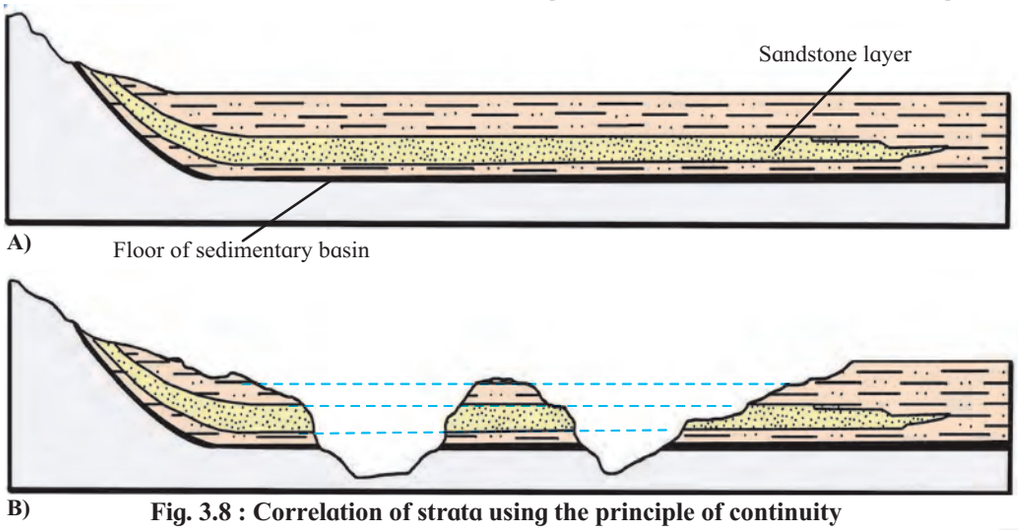

Fig. 3.8 : Correlation of strata using the principle of continuity

In the lower part the lithological succession is similar and the beds of shale and sandstone can be correlated in section A , B and C. It may be noted that, there is a slight variation in the thickness of these beds, at different localities. As we move upwards the limestone bed is missing in section c but correlated in Section A and B. If in a particular exposure only a small part of the succession is seen, then there can be difficulty in correlation.When the horizons pinch or die out, the presence of a Marker Horizon or Key Horizon is extremely useful. This bed is relatively thin but persistent bed having distinctive lithological or structural characters, which permit its identification without any difficulty.

From the above discussion, it is evident that lithological characters are useful only to limited extent. In areas where there is repetition of beds of identical composition and where marker horizons are missing, other methods like Palaeontological correlation are more useful.

ii) Palaeontological correlation :

It is entirely based on fossils or fossil assemblages. Organisms evolve with age and it is possible to differentiate between beds having the same lithology but with fossils of different age (fig. 3.10). Moreover a given species is likely to be present at widely separated localities during a particular period. This enables palaeontological correlation on a regional scale.

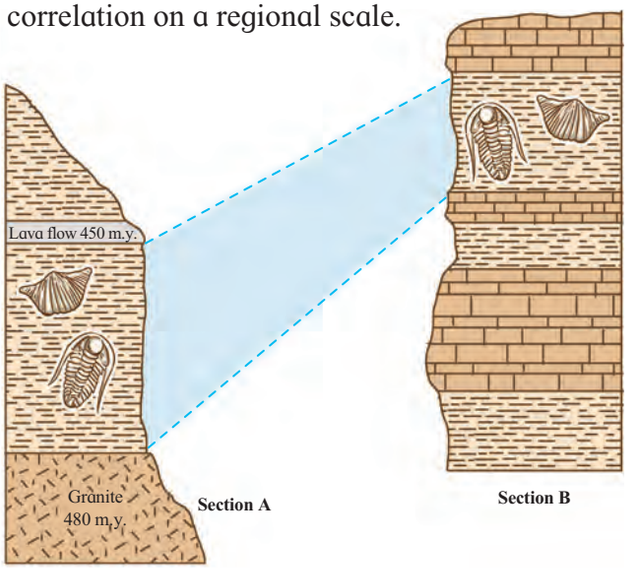

Fig. 3.10 : Palaeontological Correlation

Do you know?

Nicolas Steno (1638, 1686)

A scientist and a pioneer in both anatomy and geology. Steno was trained in the classical texts on science. However, by 1659 he seriously questioned accepted knowledge of the natural world. Importantly he questioned explanations for tear production, the idea that fossils grew in the ground and explanations of rock formation. His investigations and his subsequent conclusions on fossils and rock formation have led scholars to consider him one of the founders of modern stratigraphy and modern geology.

Standard Geological Time Scale :

Age of the Earth is about 4600 million years. This enormous geological time is divided into different durations. The successive sequential arrangement of geological time units for global reference is called as Standard Geological Time Scale (fig. 3.11). It is based on the following criteria. The periods of non-deposition (and consequently of erosion) are called as unconformities, that are related to widespread tectonic activities. The regional unconformities provide the natural boundaries for subdivisions of geological time into different units. Fossils are also of great importance in recognition of particular space of geological time. Radiometric age analysis of older rocks formed before biogenesis is also useful in this respect. The Geological Time Scale is also based on principles of stratigraphy that are discussed earlier.

The time units are Eons, Eras, Periods and Epochs. The largest time unit is known as Eon. It is successively divided into Eras, Periods and Epochs.

Most commonly two Eons Precambrian and Phanerozoic are recognized. The former indicates the time during which life was either absent,

obscure or very primitive and the latter suggests the time when evolved life was in existence.

Precambrian Era is further sub divided into Hadean, Archean and Proterozoic.

The second Eon Phanerozoic is subdivided into three Eras viz. Palaeozoic Era containing ancient life, Mesozoic of middle life and Cenozoic contains modern/recent life. The life (animals/ plants) of these eras (organic evolution) is shown in (fig. 3.11).

The Palaeozoic Era is further subdivided into (from older to younger) six Periods viz. Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian. Carboniferous is again subdivided into Missisippian and Pennsylvanian.

Mesozoic Era is further subdivided into three Periods, viz. Triassic, Jurassic and Cretaceous.

Cenozoic Era is subdivided into three Periods, viz. Paleogene, Neogene and Quaternary. Palaeogene Period consists of Palaeocene, Eocene, and Oligocene Epochs and Neogene Period consists of Miocene and Pliocene Epochs. Quaternary Period is subdivided into Pleistocene and Holocene Epochs.

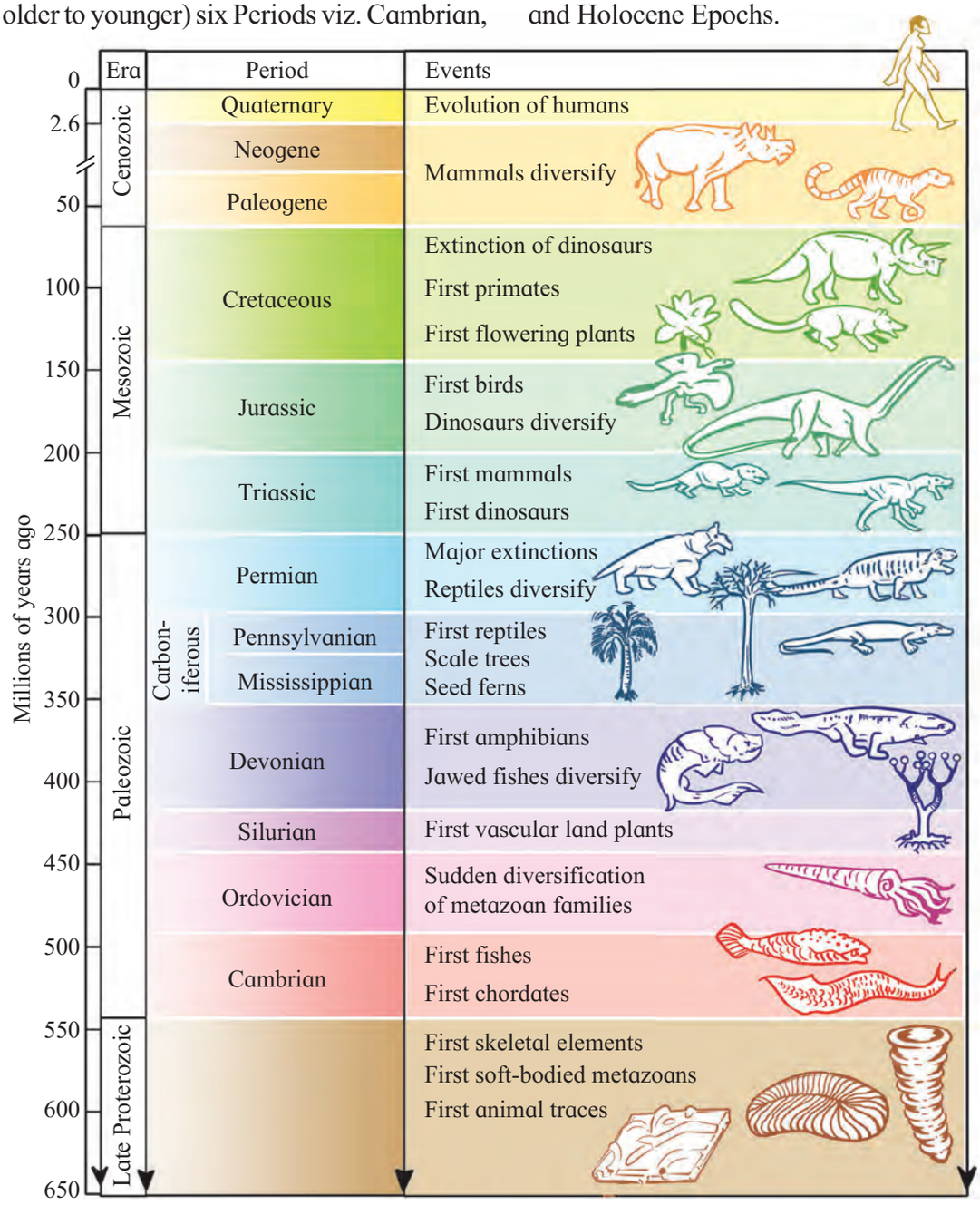

Fig 3.11 : Geologic time scale, 650 million years ago to the present

Do you know? **Major Events in Geological Past do you know**

Era	Period	Geological Events	Life (Animals-Plants)
Cenozoic	Quaternary	Early period known for ice age formation of Laterites	Ape like man appeared in Pleistocene, Aves, Fish, Important Age of man. Dicot-Monocot dominated.
	Paleogene and Neogene	Most of the Continents and oceans occupied their present positions, India collided with Asia, Alpine-Himalayan orogeny, Himalaya-Alps formed, Red Sea opened.	Age of mammals placental. marsupials, elephants, horses, pigs, dear, cows, primates, flowering plants dominated.
Mesozoic	Cretaceous	Few phases of marine transgression General elevation of land, fragments of Gondwanaland and Laurasia separated Andes and Rockys mountains formed.	Great extinction of ammonites, dinosaurs. Abundance of plants, extinction of cycades plants Mammals evolved.
	Jurassic	Fragmentation of Gondwanaland and Laurasia started, Atlantic ocean formed, Continental drift continued.	Age of dinosaurs Flying reptiles first bird Archaeopterix. True mammals appeared Gymnosperms dominated.
	Triassic	Pangea broke into Gondwanaland and Laurasia, Period of marine regression and salinity crisis	General recession in marine fauna Early dinosaurs came into existence Egg laying mammals, primitive flowering plants Angiosperms appeared.
Paleozoic	Permian	Siberia joined Laurassia-Gondwana, Formation of Pangaea, Ancient Atlantic closed.	Reptiles diversified, brachiopod declined, trilobites extinct. New land plants appeared
	Carboniferous	Gondwana was on South pole and covered by ice sheets, Gondwana collided with Laurassia, Hercynian orogeny began, Appalachian mountains formed.	Early reptiles evolved from amphibians. Amphibians were important. Luxuriant growth of bearing (gymnosperms) Spermatophytic plants Major Coal seams formed.
	Devonian	Formation of Laurassia, Mountain building activities on peak, Caledonian mountains formed, Old Red Sandstaones of Europe formed.	Golden age of fish. Arrival of amphibians. Vascular seedless pteridophytic plants abundant Graptolites become extinct.
	Silurian	Caledonian orogeny. Baltica-Laurentia collided, Formation of Caledonian mountains began, Siberia drifted to North.	Graptolites important, many trilobites declined in number Jawless fish appeared. First land Appeared.
	Ordovician	Main continents converged-diverged, Gondwana moved towards South pole, Baltica to South and Siberia to North	Bush like graptolites are index fossils. Cambrian invertebrates continued Probably by the end of Ordovician, first land plants appeared
	Cambrian	Six to Seven continents lying 60º N and 60º S, Present Antarctica was on Equator, there existed Panthalassic and echinoides, lapetus oceans. They were shallow	All major groups of invertebrate protozoans, mollusca, trilobites, graptolites, sponges, corals, brachiopods, bryozoans present Trilobites are index fossils. Calcareous blue-green Algae present.
Proterozoic		Ancient supercontinent Rodinia split and fragmented, fragments reunited to form another supercontinent Pannotia, Panthalassic ocean present. A chunk of Pannotia tore into fragments. Era began with tectonic zonation with formation of geosynclinal and platformal types of basins. Atmosphere-Hydrosphere purified.	Ediacara fauna of Australia is important Unicelluar life thrived. Stromatolites (biosedimentary structures) important. Burrows of soft bodied worms and termites.
Archean		Older shield areas formed. Extensive volcanism and plutonism. Highest degree metamorphism. Earth attained present shape. Ancient continents and oceans formed. Differentiation of Earth into crust, mantle and core. Accretion of Earth complete.	Probably no life.

Do you know?

William Smith (1769 –1839) was an English geologist, credited with creating the first detailed, nationwide geological map of U.K. It was only late in his life that Smith received recognition for his accomplishments, and became known as the "Father of English Geology".

Brief outline of stratigraphy of Peninsular India :

Lithostratigraphy is one of the elements of stratigraphy. It deals with organization of strata into sequential successive rock units arranged in a chronological order, entirely based on lithological characters. It has its own lithostratigraphic units, like; Supergroup, Group, Formation, Member and Bed. Many comparable mutually related rock layers form a Bed. Numerous Beds constitute a Member, several such Members give rise to Formation. Formation is the fundamental unit recognizable and mapable in the field and can be distinguished locally in a small area. Many such formations make still larger units, covering larger area called Group. An association of similar mutually related Groups constitutes a Supergroup that spreads over a very larger time span of the order of an Era.

Study of the Indian lithostratigraphic units with reference to their origin, distribution, content, age relationship and correlation is known as Indian stratigraphy. Important lithostratigraphic units of peninsula India, according to their age and correlation are depicted in table 3.1.

The important lithostratigraphic units of Peninsular India are described, in brief, with reference to their distribution, age, lithological characters, fossils and economic importance.

Table 3.1 Major Lithostratigraphic units of Peninsular India.

Era	Period	Litho. Unit
Cenozoic	Quaternary	Laterite-Bauxite
	Tertiary	Tertiary of Assam, Gujarat, Rajasthan, Maharashtra and East Coast.
Mesozoic	Cretaceous	Deccan Basalts.
	Jurassic	Upper Gondwana
	Triassic	Midde Gondwana
Paleozoic	Permian	Lower Gondwana
	Carboniferous	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Precambrian – Proterozoic		Vindhyan Supergroup
		Cuddapah Supergroup
Precambrian – Archean		Dharwar Supergroup
		Peninsular Gneisses
Precambrian		Basement complex of South India-Karnataka-Sargur Schist complex.

Do you know?

Sir Thomas Henry Holland KCSI KCIE FRS FRSE (22 November 1868 – 15 May 1947) was a British geologist who worked in India with the Geological Survey of India, serving as its director from 1903 to 1910. He later worked as an educational administrator at Edinburgh University.

Dharwar Supergroup :

Dharwar Supergroup is named after Dharwar district of Karnataka, where it is best exposed. The term Dharwar system was coined by R. Bruce Foote in1888.

Distribution : They occur in Dharwar-Mysore region. Older Dharwars are developed in Bababudan Hills in Chikmagular region. Younger Dharwars are observed at Chitradurga and Ranibenur regions.

Age : Archean.

Lithology : It is divided into three divisions as lower, middle and upper Dharwars. The Lower Dharwar contains rhyolites, schists and gneisses. The Middle Dharwar comprises of the granite porphyries, basic and ultrabasic intrusive igneous rocks, volcanic products and banded ironstones. The Upper Dharwar contains cherts, ferruginous silts, clay, conglomerates and quartzites.

Fossils : No evidence of life.

Economic importance : They are known to contain largest iron ore and manganese deposits. The associated granitic rocks supply best quality of granites for decorative purpose as well as building material. Gold and chromite deposits are also believed to belong to Dharwars. The other minerals include copper, lead, zinc, mica, asbestos and kyanite.

Cuddapah Supergroup :

Cuddapah Supergroup has been named after the Cuddapah district of Andhra Pradesh, where it is best exposed in the form of crescent- shaped outcrop, covering about 42,000 Sq km. area. These rocks are separated from the underlying Archean rocks by the Eparchean unconformity.

Distribution : The Cuddapah Basin of Andhra Pradesh has an east-west width of about 140 km. from Tadpatri to Nellore and is over 300 km. north-south in length from Ongole to Tirupati Nagari Hills. The Cuddapah rocks are largely undisturbed except along the eastern margin, where they are folded and faulted. The thickness of the Cuddapahs is about 6100 m.

Age : Lower Proterozoic.

Lithology : The Cuddapah Supergroup consists of quartzites, limestones, sandstones and slates without any fossils.

Fossils : These rocks are mostly non- fossiliferous

Economic importance : Economic resources of the Cuddapah system include limestone, iron, manganese, copper, cobalt, nickel, barites, asbestos, steatite, diamonds and other minerals.

Vindhyan Supergroup :

Vindhyan Supergroup of India is one of the largest and thickest sedimentary successions of the world. Vindhyan Supergroup has been named after great Vindhyan Mountain in Central India, where these rocks are well exposed. It can be separated into Lower and Upper divisions on the basis of an unconformity marked at various places.

Distribution : These rocks cover an area of about 1,00,000 sq. km. in Central India and are well exposed in the Son valley.

Age : Upper Proterozoic.

Lithology : This group consists of sedimentary rocks such as sandstones, shales and limestones with thickness often over 4000 m. to 6000 m.

Fossils : In the evolution of Peninsular India, for the first time some structures indicative of primitive organisms have been reported.

Economic importance : Shales from the Vindhyan Supergroup contain workable pyrite mineralization. All types of limestone, sandstone and shale are used as building materials. Huge limestone deposits supply basic raw material to cement industries. Most of the Indian diamonds are obtained from Vindhyan Supergroup. They are recovered either from Kimberlite pipes (volcanic necks) or from the diamond bearing conglomerate horizons. Excellent quality of glass sand is obtained from the weathered sandstone found in Vindhyans.

Gondwana Supergroup :

Gondwana rocks are named after the Gond tribe in Madhya Pradesh where these rocks are best exposed. Subsequent to the deposition of the

Vindhyan, there was a break in sedimentation in Peninsular India, till Carboniferous times. It was followed by the deposition, of thick sequence of fluviatile sediments constituting Gondwana sediments.

Distribution : Gondwana rocks mostly occur in the states of Madhya Pradesh, W. Bengal, Chattisgarh, Odisha, Jharkhand, Telangana and Maharashtra. Isolated outcrops occur in Gujarat and Rajasthan. Gondwana Supergroup is today exposed in linear tracts largely corresponding to the valleys of the river Narmada, Damodar, Mahanadi and Godavari.

Age : Permo-Carboniferous to Jurassic.

Lithology : They consist of alternation of sandstones, green sandstones, gritty sandstones, shales, limestones and coal.

Fossils : Plant fossils such as glossopteris, gangamopteris, conifers, cycades, and animal fossils such as crustaceans, fish, insects, reptiles, dinosaur (bones and eggs), coproliths and amphibians are found.

Economic importance : Gondwanas contain thick coal seams which contribute practically all of India's coal output. Gondwana Supergroup is well known for its good steam and gas quality of coal. Beds of oxides of iron ore products have been worked out for blast furnace. Clay for terracotta, pottery. Sandstone is extensively used as building material.

Deccan Volcanic Province (DVP) :

Deccan Volcanic Province cover an area of over 500,000 sq. km. in western India, with flat-topped hills, hence also known as plateau basalts. They also show step-like terrace form and consist of sub- horizontal flows.

Distribution : They occur almost in all parts of Maharashtra and extend to cover parts of adjacent states of Gujarat, Madhya Pradesh, Telangana and Karnataka. Maximum thickness of Deccan Basalts, (> 3500 m), is towards west. They thin out towards east.

Age : Cretaceous- Eocene.

Lithology : The volcanic rock type generally called as basalt is a fine grained, dark grey to porphyritic rock with vesicular to amygdaloidal structures. They contain a rich assemblage of secondary minerals, like; quartz and zeolites. Acidic and intermediate differentiates occur along the west coast of India. In the lower part, the basalt flows are sometimes separated by fluvial sedimentary beds, called the intertrappeans. The intertrappean beds show fresh water lacustrine deposit. Best examples of such sandwiched intertrappeans are in Malabar hills of Mumbai.

Fossils : Fossils of turtle, frogs, molluscs and some plant remains are reported from the intertrappean beds.

Economic importance : Compact basalt is extensively used for building constructions. Old temples, forts and buildings are built with basalt. Deccan basalts host amazing zeolites and silica bearing minerals (amethyst, quartz, chalcedony, agates) as secondary minerals in the cavities within the deccan basalts. A thin capping of bauxite is used as an ore of aluminium. Along the coastal Konkan area of Maharashtra, the laterite blocks are used as building material.

Cenozoic rocks :

In Peninsular India, Cenozoic sedimentary rocks of marine origin are found in Rajasthan, along the onshore and offshore regions of Gujarat and offshore regions of Maharashtra. These rocks are also developed along the east coast in Krishna-Godavari and Cauvery basins. These are important because they form reservoir rocks for oil and natural gas.

Distribution : These rocks occur in Rajasthan, Maharashtra, Andhra Pradesh, Tamil Nadu and Gujarat

Age : Eocene to Pliocene.

Lithology : Majority of the rocks are conglomerates, sandstones, limestones and shales.

Fossils : foraminifera and ostracoda.

Economic importance : Some of the Tertiary rocks contain huge lignite (Neyvelli) deposits, Oil and gas reserves and hydrocarbons (Bombay High, Cambay, K-G Basin).

Do you know?

Birbal Sahni FRS (14 November 1891 – 10 April 1949) was an Indian palaeobotanist who studied the fossils of the Indian subcontinent, was also a geologist who took an interest in archaeology. He founded the Birbal Sahni Institute of Palaeobotany in Lucknow, India. His greatest contributions lie in the study of fossil plants of India. Apart from writing numerous papers on these topics he also served as the President, National Academy of Sciences, India (1937-39 and 1943-44)and as an Honorary President of the International Botanical Congress, Stockholm in 1950.

Summary :

Palaeontology is the scientific and systematic study of fossils. It includes classification of organisms and study interactions with each other and their environments. There are different modes of preservation of organisms depending upon the presence or absence of hard parts, conditions of preservations and depositional environments. Fossils are useful in finding geological ages and correlation of the strata. . Stratigraphy works as a basic source of all geological information, about probable sites of oil and gas, coal reserves, metals (ore) and non-metallic deposits etc. Stratigraphy acts as an agent of identifying geological events. It unites the global information of rocks.

EXERCISE

Q. 1. Fill in the blanks :

1) Cenozoic era is age of ..... .
(Fishes, Trilobites, Reptiles, Mammals)

2) The principle of uniformitarianism was given by ..... .
(James Hutton, Steno, William Smith, Wadia)

3) Any evidence of ancient life before ..... epoch is considered.
(Holocene, Pliocene, Miocene, Eocene)

4) The branch of geology dealing with study of trace fossils is known as ..... .
(Paleobotany, Paleoichnology, Palynology, Paleozoology)

5) Insect preserved in amber is an example of ..... .
(Imprint, Petrification, Entire organism preserved, Carbonization)

6) Paleozoic Era is subdivided into ..... periods.
(4, 5, 6, 7)

7) The largest time unit is known as ..... .
(Eon, Era, Epoch, Period)

8) The Dharwar Supergroup of rocks have ..... .
(Evidence of life, Evidence of no life, Fishes, Trilobite, Mammals, Reptiles)

Q. 2. True or False :

1) In petrification only soft parts of an organism are preserved

2) Index fossils are useful in correlation.

3) The age of trilobite is Devonian.

4) Age of deccan basalts is Carboniferous.

5) The principle of faunal succession was given by William Smith.

6) Track and trails are the examples of body fossils/ Trace fossils.

7) The study of growth rings in a tree trunk is known as Ichnology.

8) A method of finding equivalence in geological age or stratigraphic position between two rock units is known as correlation.

9) Dharwar Supergroup rocks do not have any evidence of life.

10) The rocks of Vindhyan Supergroup are Upper Proterozoic in age.

11) The rocks of Gondwana Supergroup are of Permo-Carboniferous to Jurrassic age.

12) Gondwana Super group is well known for good quality of coal, plant fossils, reptiles and other fossils.

Q. 3 Choose the correct alternative :

1) The process of carbonisation takes place in case of …
   a) Plants
   b) Animals
   c) Both Plants and Animals
   d) All of the above

2) The diamond bearing beds are found in …
   i) Sandstones of Vindhyans
   ii) Conglomerates of Vindhyans
   iii) Limestones of Vindhyans
   iv) Shales of Vindhyans

Q. 4 Match the following :

i)

	A	**B**
a)	Devonian	i) Dinosaurs
b)	Cenozoic	ii) Mammals
c)	Jurassic	iii) Fish
d)	Cambrian	iv) Trilobites

1) a-iii b-ii c-i d-iv
2) a-iv b-i c-ii d-iii
3) a-i b-iii c-iii d-ii
4) a-i b-iv c-iv d-i

ii)

	A	**B**
a)	Dharwars	i) Coal
b)	Cuddapah	ii) Gold
c)	Gondwana	iii) Limestone
d)	Deccan Trap	iv) Basalt

1) a-ii b-iii c-i d-iv
2) a-i b-ii c-iv d-iii
3) a-iii b-i c-ii d-ii
4) a-iv b-iv c-iii d-iii

Q. 5 Write short notes on :

1) Uniformitarianism
2) Lithological Correlation
3) Carbonisation
4) Economic importance of Gondwana rocks
5) Branches of Paleontology
6) Imprints

Q. 6 Answer in brief :

1) Uses of fossils in organic evolution
2) Tertiary rocks of India
3) Economics of Deccan Volcanic Province
4) Stratigraphy of India

Q. 7 Answer in detail :

1) Differentiate between Imprint and Trace fossil.
2) Describe the uses of fossils.
3) Discuss the various methods of correlation.
4) Describe in detail different modes of preservation of fossils.
5) Describe Dharwar Super Group.
6) Describe Conditions necessary for fossilisation
7) Describe the Geological Time Scale
8) Describe Lithology of Vindhyan Super Group