Fossils and Fossilization

The term fossil originally referred to anything dug out of the ground. The root Latin word is *fossilis* meaning 'dug up' and therefore minerals as well as the remains of animals and plants were called fossils. But the term soon came to be restricted to the remains of animals and plants found is rocks.

"Fossils are remains of organisms, both plants and animals which has been preserved within the sedimentary rock beds, under favourable geologic conditions."

The study of plant fossils is also helpful in locating the occurrence of coal, oil and gas deposits in the earth. Fossils have served as tools to provide record of plant life in geologic ages and documents of past distribution of plants.

A. Scopes of Fossils

The study of fossil includes two aspects, botanical and geological. The botanical aspects are concerned with morphology of fossil plants, their distribution, evidence of early plant life, past climate etc. The geological aspects of palaeobotany centre around calculation of age of rocks through correlative studies of plant vestiges retained in them as fossils. There are many scopes of fossils.

Fossils as index

Fossils indicate the geographic history of the earth i.e. the distribution of seas, the mountains or the continental areas of the past. They also give out incomplete information about the animals and plants, which inhabited those continents and seas from the beginning of life on earth over billion years ago to the present. Fossils indicate the age of rock in which they are found.

Fossils as climatic indicators

Fossil plants also indicate the variation of temperature and degree of moisture and it is also supported by the fossil organism. For example, fossil ferns found in Antarctica and the fossil magnolias reported from Greenland indicate a much warmer climate for these areas in those times.

Fossils as evidence of organic evolution

Palaeontology is the science of the past life of the earth. It indicates definite lines of ancestry for living plant and animals. Botanists and zoologists are able to collect information about the ancestors of the present-day plants and animals.

Fossils as economic tools

Many of our important resources are associated with fossils. Coal deposits are associated with fossil plants. Valuable deposits of radioactive minerals have been discovered in sedimentary rock. Uranium was found in same specimens of fossil wood and bones of certain fossil reptiles and mammals. Same fossiliferous limestones and sandstones are useful as building stones. The Trigonia stone of the lower cretaceous of Texas is an example of such stone. It contains a large number of casts and moulds of marine clams and snails. Petroleum is a fossil fuel, which is always found trapped between two impervious rocks (non-porous rocks).

B. Conditions for fossilization

The process of the formation of fossils i.e. conversion of plants, animals or their parts into fossils is called fossilization. The plant fossils are usually preserved in sedimentary rocks deposited in water.

The fossils are preserved only in sedimentary rocks, but it is not necessary that fossils will occur wherever sedimentary rocks have been formed. In nature, there are abundant places where sedimentary rocks do not contain any fossil. This indicated that the process of fossilization requires certain special conditions and if these conditions are not existing, the fossils will not be formed. Some of these conditions are:

(a) **Burial:** The initial stage of fossilization is the burial of dead plants or animals or their detached parts which sink into the mud or sand of the water body. The plants growing on land are carried by the running streams of rivers to the large water bodies like lakes or ocean where they settle down into the bottom and get buried. The plant growing near the sea shores get buried easily in soft mud of the shores. Thus, the aqueous or semi-aqueous condition is required.

(b) **Prevalence of aseptic condition:** Under normal conditions the dead bodies of plants and animals are attacked by decomposers i.e. aerobic bacteria and fungi. Thus, the perfect preservation of plant and animal's parts is difficult under septic conditions. It is possible only if the deposition takes place under aseptic conditions. Some of the aseptic conditions prevailing at the site of fossilization are as follows:

(i) Sudden deep burial of plant or animal remains in the protected water bodies such as swamps, where fine-grained sediments are continuously deposited at faster rate. This creates anaerobic conditions around the organic remains, which prevents the activity of aerobic microorganisms responsible for decay. Thus the plant parts are preserved unaltered for many years.

(ii) The chemical nature of the preserving rocks should be such that the growth of decomposers is prevented. For example lowering of pH (increased acidity) in the surrounding medium favouring the deposition of insoluble SiO_2 or evaporation of water from the swamps results in precipitation of super saturated solutions. Thus sedimentary minerals retard the growth of tissue degrading microorganisms and create aseptic conditions.

(iii) Temperature, hot or cold, may also prevent the action of bacteria and fungi. The high temperature and low humidity of the desert environment favours fossilization. Refrigeration of trapped plant parts in snow and ice field has been found to be good site for the preservation.

(c) **The kinds of tissues composing the plants:** Plants are usually composed of soft as well as hard tissues. Soft tissues such as parenchyma, collenchyma, phloem, meristematic tissue etc. distributed mainly in the cortex, pith, ground tissues, delicate leaves, flowers are prone to disintegration much faster as compared to hard tissue. Hard tissues including sclerenchyma, cork, xylem tracheids, vessels, calcareous parts of some algae, extensive cutinized layers, hard seed coats are usually preserved with less destruction and retain their identity.

(d) **Forest fires:** Forest fires sometimes play a major role in the process of fossilization. Fossils can be preserved after forest fire in the form of fossil charcoal or fusain or structured fusinite.

C. Kinds of fossils and modes of their preservation

Depending on the various ways of fossilization the fossils are grouped into following main categories:

(i) Compressions

(ii) Surface preservation by cementation

(a) Impressions
(b) Moulds
(c) Casts

(iii) Infiltrated cellular preservations
(a) Petrifactions
(b) Mummifications

(iv) Hard part preservations

(v) Structured fusinites

(vi) Chemical fossil

(i) Compression: -

Compression is the most common kind of fossil that contains compressed remains of plants usually in the form of black carbonaceous film in the rock. The compressions retain the original outline of the plant parts. They usually contain unrecognizable mass of coal enclosed within a cuticularized bag. Cellular details are never observed in compression. They range in size from spores, pollen grains and fragments of leaf cuticle (microfossil) to large leaves, branches, flowers, seeds or cones. One of the most significant example of complex kind of compression is the coal.

Coal was formed when huge forest areas got buried under the surface of the earth having very high temperature and pressure. Different varieties of coal are formed depending for how long and at what temperature and pressure the coal is buried under the surface of the earth:

(i) Peat: Youngest variety of coal, light brown in colour and contain 50% to 60% of carbon.

(ii) Lignite: Next stage of carbonization of peat and contains 60% to 70% of carbon.

(iii) Bituminous: It is the common variety of coal and contains 75% to 80% of carbon. It is best for household work.

(iv) Anthracite: It is the oldest variety of coal and contains 90% to 95% of carbon.

Fossilization process: -

At first the plants or plant parts are carried into basins where they become water-logged and buried in sediments. The sedimentary particles such as mud and sand continue to settle down. Burial of plant parts is followed by hydrolysis and softening of cell walls and tissues. The pressure exerted by accumulated sediments and water results in compression and

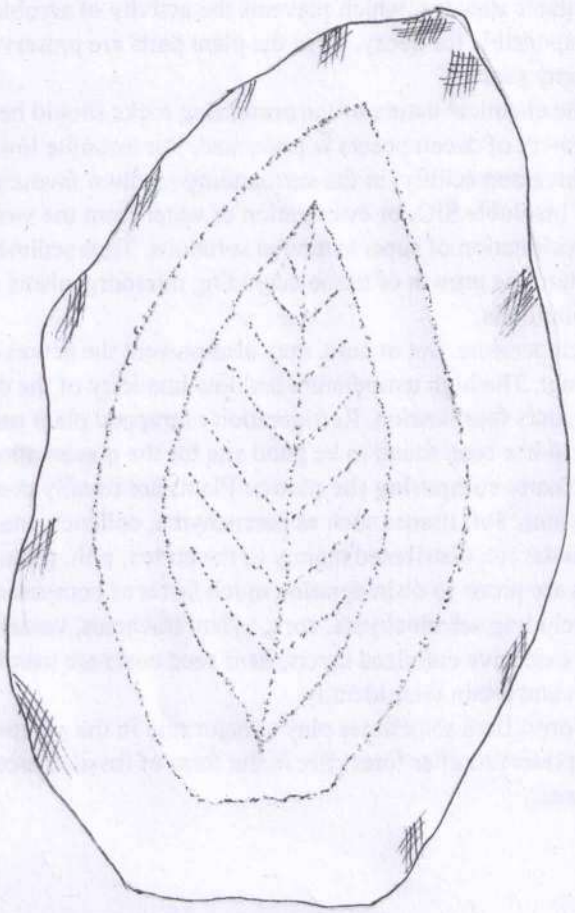
collapse of internal cell space. It results a loss of gas, moisture and other soluble materials of the tissues. The residues of plant parts are altered and consolidated to form a black coaly deposit and undergo varying degree of mineralization.

(ii) Surface preservation by cementation: -

It is a kind of fossil in which the surface layer of plant or plant part is preserved by the process of cementation. Except the surface outline, no other organic material of plant parts is preserved in this category of fossil and they are used to study the surface details of the fossilized plant parts. The kind of fossils included in this category are:

(a) Impression
(b) Moulds
(c) Casts

(a) Impression: It is a kind of fossil, usually formed from the flat, dorsiventral or two-dimensional plant body (such as leaves, sporoplylls etc) in which the remains of plant decays completely leaving its impression on the rock. They are usually darker in colour than the surface of rock and regarded as negative imprint of the flat organ or organism.



A LEAF IMPRESSION WITH NO ORGANIC MATTER

(b) Mould: It is a kind of fossil usually formed from voluminous remains of an organism or from a three dimensional organ (such as tree trunk, flower or fruit) in which the entire organic matter is lost leaving a cavity or hollow space in which it was buried. These hollows retains the exact form of the original. These are known as moulds and used to study the surface details of fossilized plant parts.

(c) Cast: The mould, once it is formed, becomes filled with a mineral deposit or a elastic sediment (consisting of lime, silica, clay, sand or other substances) so that a perfect positive three dimensional replica is created. Cast of whole plants, stump and seeds are frequently formed. Cast retain only external configuration of the hard part of the organism and lack original organic material. Casts are of great significance as they help in reconstructing external appearance of plants of past vegetation.

Fossilization Process: -

The formation of impression, mould and cast is similar. At first the plant parts get buried in the sediment of soft clay. During fossilization, these plant parts undergo a peculiar physico-chemical change. In fact, the two process occur simultaneously-

(i) decay of internal organic material of the plant part and
(ii) cementation of the surface layer by the cementing material.

As soon as the plant material start to decay in the depositional environment, they develop an electric charge and attracts colloidal and other small ionized particles from the surrounding medium (matrix) that have an opposite charge. The organic remains liberate decomposing products into the surrounding matrix producing a peculiar geo-chemical situation around themselves. In the meantime, sedimentary material that possess iron and carbonate minerals, accumulate and become cemented around the plant parts. The decay and loss of original organic matter leads complete disappearance of internal tissues of plant parts while surface layer is preserved by the process of cementation. The flat and dorsiventral parts (e.g. leaves) print as impression while three-dimensional plant parts disintegrate to create a hollow in the rock, called a mould, the hollow mould gradually gets filled with sediments or a deposit of mineral matters. This produces a cast of perfect replica of the original specimen.

(iii) Infiltrated cellular preservation: -

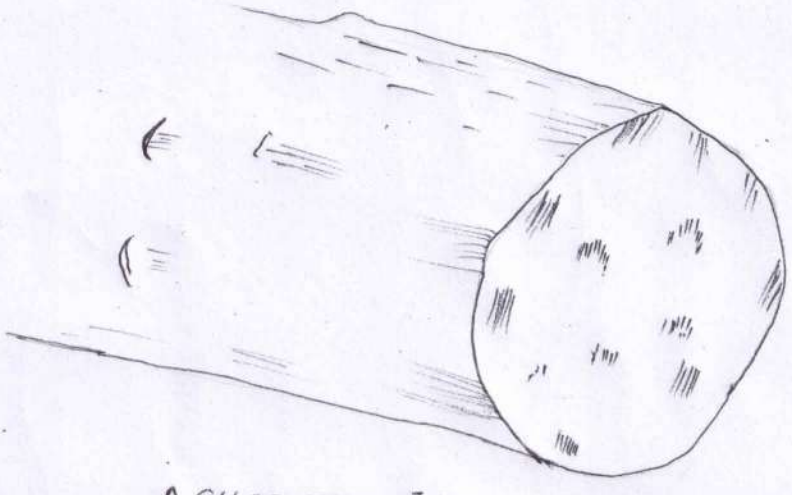
This category includes the kind of fossils in which the cells or cell structure of plants or plant parts are preserved and considered best for detailed study of their internal organisation. The infiltrated cellular preservations include:

(a) Petrification
(b) Mummification

(a) Petrification (True fossils): These are the kinds of fossils in which the tissues are fully or partially replaced or infiltrated by mineral matter with preservation of their cellular structure. The mineral matter infiltrates into the cell lumen and intercellular spaces perfectly preserving the cell wall and cell contents of the plant parts. These are in fact the true fossils which preserve every cell of the plant. Petrified fossils show all the details of internal structure and even components of cell wall and cell components such as nuclei, nucleoli, chromosomes, pyrenoid like bodies, mitochondria, lamellae of chloroplasts etc. and therefore, considered as best specimens for the study of internal organisation of fossilized plants under the microscope.

The most common mineral substances which infiltrate into the cell lumen and intercellular spaces to form petrification are silicon dioxide, calcium carbonate, magnesium carbonate, iron sulphide, phosphate etc.

Callixylon logs in Upper Devonian bland shales in East Central United States, *Lepidodendron* trunk of lower Pennsylvanian age may be cited for petrification.



A SILICIFIED LOG

Coal ball is more or less petrified spherical specimens. Coal balls have been recorded from England, Belgium, Russia, Spain, China etc.

Fossilization Process: -

At first the plant or plants parts are carried into the water basins where they become water-logged and buried in sediments. In due course of time, the process of fossilization begins when the soluble silicates, carbonates and iron compounds etc. infiltrate the cells and the space between them. It is followed by intracellular or intercellular polymerization of siloxane bonds and the elimination of water. As the polymer grows continuously the amorphous or microcrystalline silica gets deposited from the outer solution and the water moves out from the plant tissues. Ultimately opaline silica is formed which gets transformed, after millions of year, to low quartz. The result is conversion of plants parts into petrified fossils.

(b) Mummification: In this form the entire organism or some parts of the body is preserved in some special preserving materials so that all its soft parts i.e. blood, flesh, soft tissue remains intact. Such organisms have undergone little or no change. The mummifications are of the following type: -

(a) **Ice embedded fossils:** It is well known that the living organism usually contain 70-80% water in their cells. Such organisms, when get buried in snow and ice field, the water gets converted into ice and the organisms get frozen. Refrigeration of organism preserves their tissues unaltered for thousands of years.

(b) **Preservation in oil saturated environment:** Organisms trapped in oil remain unaltered for millions of years and their soft parts get preserved. The tree trunks are so well preserved that it is possible to cut them with a saw and drive nails into them.

(c) **Resin embedded fossils:** During the previous geologic epochs when coniferous forests flourished, a large number of spiders, millipeds, ants, flower parts, pollen grains etc. were entangled into sticky resin exuded by coniferous trees. During fossilization the resin have undergone some chemical changes and converted into soft amber. The amber is fossilized resin containing preserved mummified bodies with almost every detail and their internal organization.

(iv) Hard part preservation

Some plants possess resistant hard parts which are preserved as such without being transformed by oxidation or any factor. Such preservation is called duripartic.

(v) Structured Fusinites

The remains of plants that are fossilized after forest-fires are called structured fusinites. They are black in colour, opaque and undergo little degradation in water or these fossils show cellular structures although the cell walls are generally empty.

(vi) Chemical fossil

Some chemical organic substances such as chlorophyll molecules, various types of proteins, amino acids etc. are found preserved in the rocks. These are called chemical fossils.

Petroleum is a fossil fuel. It is dark colored crude oil. It is always found trapped between two impervious rocks (non-porous rocks). Petroleum is formed by the anaerobic decomposition of extremely small sea animal and plants which got buried in the seabed millions of year ago.

.....