

Unit- III : Palaeobotany

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3.1., Fossils:

- A fossil (latin for "*obtained by digging*") is the preserved remains or traces of organisms (plants, animals, etc) that lived in the distant past. The convention is that a fossil must predate recorded human history.
- While there is no defined date, typically something must be older than 10,000 years to be considered a fossil.
- The oldest fossils in the fossil record date from 3.5 billion years ago, however it wasn't until around 600 million years ago that complex, multi-cellular life began was first preserved in the fossil record.
- There are two main types of fossils; body and trace. Body fossils include the remains of organisms that were once living (bones, shells, teeth, eggs, etc), while trace fossils are the signs that organisms were once present (footprints, tracks, burrow, coprolites).
- Trace fossils represent a data source that reflects animal behaviors, and they do not require the preservation of hard body parts. Many traces date from significantly earlier than the body fossils of the animals suspected to have made them.
- Fossilization of an organism requires a unique set of circumstances so that it doesn't just decay without a trace.

These conditions include:

1. Rapid and permanent burial/entombment
2. Lack of oxygen that limits decay and scavenging.
3. Continued sediment accumulation
4. The absence of heat or compression which might destroy the fossil

Fossils are most often preserved within sediments that were deposited in water, such as wetlands, river basins, or the ocean.

3.2.,Types of Fossils:

(i) Sedimentary Rocks (e.g. Coal):

- Majority of plant materials are preserved as fossils in sedimentary rocks. Coal is the best known example of sedimentary rock.
- Sediments of plant origin are crushed by overlying pressure and form coal. Present coal belt in the world, therefore, represents dense forests of the world of earlier times.
- Least metamorphosed coal shows maximum details of fossilized or preserved plant material.

- Therefore, lignite's (early stage of coal formation) carry less crushed plant parts and their details can be studied easily.
- Plant parts get excessively crushed in bituminous coal and anthracite coal because they show more degree of metamorphosis than lignite coal.
- Bituminous coal is of great importance in the study of palynology because pollen grains are best preserved in this type of coal.

(ii) Amber:

- The fossilized plant resin secreted by coniferous trees that grew in very early times is called amber.
- This “very early time” in the geological past ranged from Carboniferous (i.e. about 345 million years ago) to Pleistocene (i.e. about 2.5 million years ago).
- Fungal spores, pollen grains, etc. were trapped in this resin before fossilization.
- The resin fossilized into amber and inside this were left spores, pollen grains, etc. Amber is, therefore, an example of fossils within fossil.

(iii) Diatomite:

- Diatoms are unicellular algae belonging to class Bacillariophyceae. Their walls have silicon deposits.
- The sedimentary rock formed by the remains of diatoms is called diatomite. In due course of time, diatoms keep on depositing at the base of sea, oceans or lakes and form sedimentary rock.

(iv) Pseudo-Fossils or Dendrites:

- Pseudo-fossils or dendrites are completely inorganic structures of various types. They often resemble plant organs.
- Their formation takes place by the deposition of minerals due to seepage or percolation of water in rock crevices. They superficially resemble leaves of ferns.

(v) Mummification:

- The process of the formation of fossils in ice-frozen environments in the polar regions is termed as mummification.

- The moisture of the tissue of the organism gets converted to very small or microcrystals of ice. It is almost a process similar to deep freezing.

(vi) Biochemical Fossils:

- These are the fossils which consists of chemical substances like chlorophyll, amino acids, aromatic acids, flavonoids, branched hydrocarbons and steroids.
- These have been reported to be present either in the fossilized remains of organisms or in the rocks. Niklas (1981) reported biochemical fossils of the substances related to sporopollenin, lignin, cutin, cellulose, etc.

3.3. Methods of fossilization

1. Petrification or Premineralization:

Rock like minerals seep in slowly and replace the original organic tissue. Silica calcite or pyrite, forming a rock like fossil.

This method of fossilization can preserve hard and soft parts. Most bone and wood fossils are premineralised.

2. Mold and Cast:

A replica of a plant or animal is preserved in sedimentary rocks. An organism is buried in sediment and then dissolved by underground water leaving a hollow depression is called a mold.

The mold shows only the original shape and marking of the organisms. It does not reveal the internal structure. Minerals or sediment fills the hollow depression and forms a cast.

3. Carbonization:

Fine sediments enclose a delicate matter such as leaves in an oxygen poor environment.

As time passes, pressure squeezes out the liquid and gaseous components of the organism leaving behind a thin residue of carbon. Other elements like oxygen, hydrogen and nitrogen are removed.

4. Trace Fossils:

Fossils are formed by the traces left in the rock by an animal such as:

(i) Tracks:

Animal foot print made in soft sediment that later formed solid sedimentary rock.

(ii) Burrows:

Animal trails made in soft sediment that later formed solid sedimentary rock.

5. Coprolites:

Fossil dung (feces) and stomach contents in soft sediment that later form solid sedimentary rocks. Fossilized drooping, can give an insight into the feeding behavior of animals and can therefore be of great importance.

6. Preservation:

Original remains can be preserved in ice or in amber (tree sap). Both ice and amber protect the organisms from decay (oxygen free environment). The entire animal has been preserved, even the soft parts when usually decay and disappear.

7. Compression:

When organism dies, the hard parts of their bodies settle at the bottom of the sea floors and are covered by sediment. The process of sedimentation goes on continually and fossils are formed.

8. Natural Molds:

Organisms make impressions on mud or on sand. These impressions harden and transform into stone. These solidified impressions are known as natural molds.

9. Mummified Plants:

Plants or plant fragments are compressed by means of vertical pressure. These are called mummified plants.

10. Infiltration or Replacement:

The precipitation of minerals take place which later on infiltrate the cell wall. The process is brought about by several mineral elements such as silica, calcium carbonate and magnesium carbonate. Hard parts are dissolved and replaced by these minerals.

3.4., Geologic Time Scale

The geological time scale relates stratigraphy (layers of rock) to periods of time. The time scale is used by geologists, palaeontologists and many other Earth scientists to date certain historical events on Earth.

As we have already seen in other pages in this section, the Earth is approximately 4.6 billion years old. This age is estimated by radiometric dating. Earth's past has been split into different sections based on events that happened during this time. An example is the boundary between the Cretaceous period and the Palaeogene period

(formerly the Tertiary period) which are separated by an extinction event, where the dinosaurs and many other species went extinct.

The scale is split into different units; An **Eon** is a period of time greater than half a billion years. Eons are split into smaller units called **Eras** which last several hundreds of millions of years. Eras are split into smaller again units known as **Periods** which are again split into smaller units called **Epochs**.

Eons

Eons are the largest intervals of geologic time and are hundreds of millions of years in duration. In the time scale above you can see the Phanerozoic Eon is the most recent eon and began more than 500 million years ago.

Eras

Eons are divided into smaller time intervals known as **eras**. In the time scale above you can see that the Phanerozoic is divided into three eras: Cenozoic, Mesozoic and Paleozoic. Very significant events in Earth's history are used to determine the boundaries of the eras.

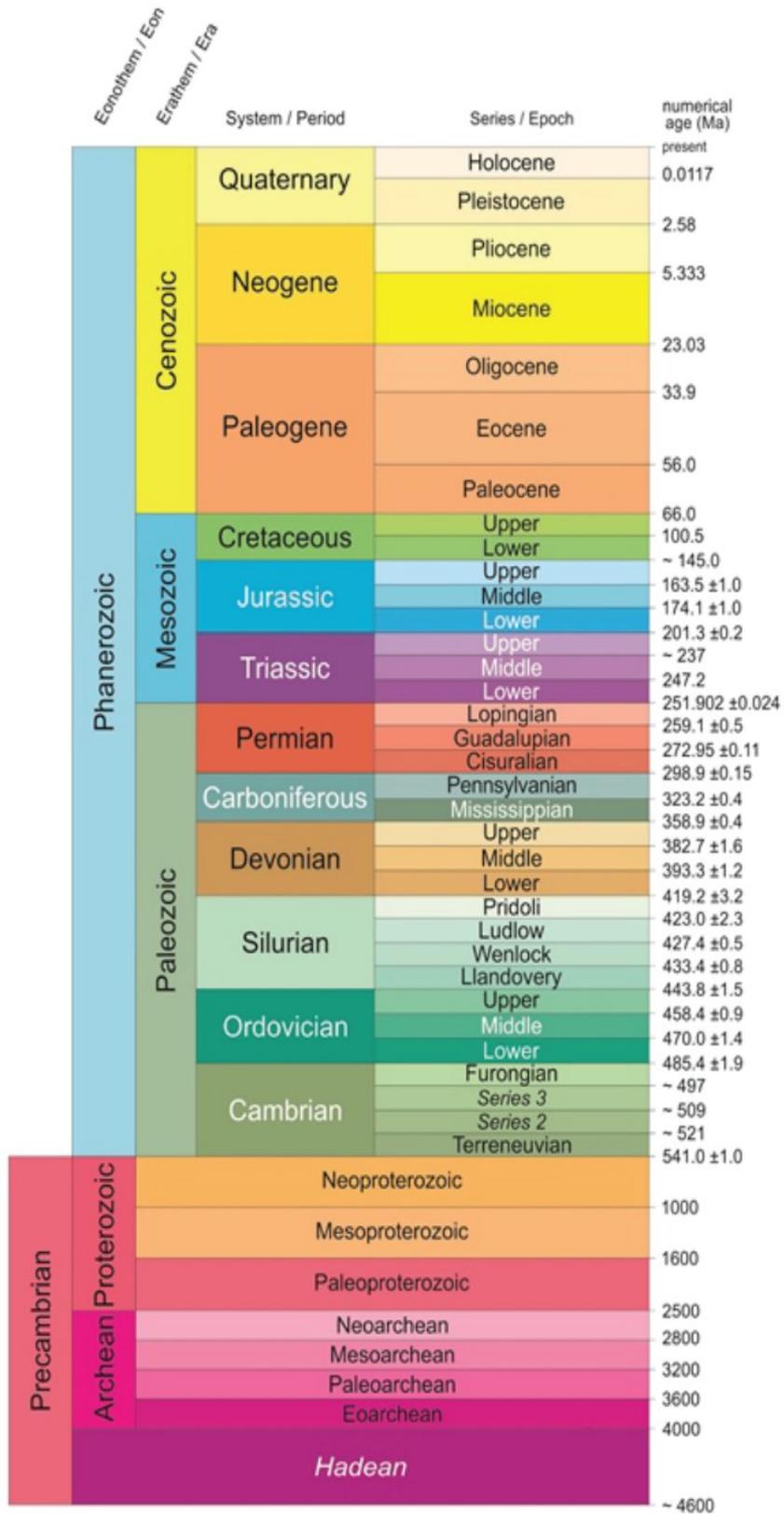
Periods

Eras are subdivided into **periods**. The events that bound the periods are widespread in their extent but are not as significant as those which bound the eras. In the time scale above you can see that the Paleozoic is subdivided into the Permian, Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician and Cambrian periods.

Epochs

Finer subdivisions of time are possible, and the periods of the Cenozoic are frequently subdivided into **epochs**. Subdivision of periods into epochs can be done only for the most recent portion of the geologic time scale. This is because older rocks have been buried deeply, intensely deformed and severely modified by long-term earth processes. As a result, the history contained within these rocks cannot be as clearly interpreted.

Our geologic time scale was constructed to visually show the duration of each time unit. This was done by making a linear time line on the left side of the time columns. Thicker units such as the Proterozoic were longer in duration than thinner units such as the Cenozoic.



3.5. Carbon Dating

- Radiocarbon dating is a method that provides objective age estimates for carbon-based materials that originated from living organisms.
- An age could be estimated by measuring the amount of carbon-14 present in the sample and comparing this against an internationally used reference standard.
- The impact of the radiocarbon dating technique on modern man has made it one of the most significant discoveries of the 20th century.
- Archaeology and other human sciences use radiocarbon dating to prove or disprove theories. Over the years, carbon 14 dating has also found applications in geology, hydrology, geophysics, atmospheric science, oceanography, paleoclimatology and even biomedicine.

Basic Principles of Carbon Dating

- Radiocarbon (carbon 14) is an isotope of the element carbon that is unstable and weakly radioactive. The stable isotopes are carbon 12 and carbon 13.
- Carbon 14 is continually being formed in the upper atmosphere by the effect of cosmic ray neutrons on nitrogen 14 atoms. It is rapidly oxidized in air to form carbon dioxide and enters the global carbon cycle.
- Plants and animals assimilate carbon 14 from carbon dioxide throughout their lifetimes. When they die, they stop exchanging carbon with the biosphere and their carbon 14 content then starts to decrease at a rate determined by the law of radioactive decay.
- Radiocarbon dating is essentially a method designed to measure residual radioactivity.

Carbon-14 Datable Materials

- Not all materials can be radiocarbon dated. Most, if not all, organic compounds can be dated. Some inorganic matter, like a shell's aragonite component, can also be dated as long as the mineral's formation involved assimilation of carbon 14 in equilibrium with the atmosphere.
- Samples that have been radiocarbon dated since the inception of the method include charcoal, wood, twigs, seeds, bones, shells, leather, peat, lake mud, soil, hair, pottery, pollen, wall paintings, corals, blood residues, fabrics, paper or parchment, resins, and water, among others.

- Physical and chemical pretreatments are done on these materials to remove possible contaminants before they are analyzed for their radiocarbon content.

Carbon Dating Standards

- The radiocarbon age of a certain sample of unknown age can be determined by measuring its carbon 14 content and comparing the result to the carbon 14 activity in modern and background samples.
- The principal modern standard used by radiocarbon dating labs was the Oxalic Acid I obtained from the National Institute of Standards and Technology in Maryland.
- This oxalic acid came from sugar beets in 1955. Around 95% of the radiocarbon activity of Oxalic Acid I is equal to the measured radiocarbon activity of the absolute radiocarbon standard—a wood in 1890 unaffected by fossil fuel effects.
- When the stocks of Oxalic Acid I were almost fully consumed, another standard was made from a crop of 1977 French beet molasses. The new standard, Oxalic Acid II, was proven to have only a slight difference with Oxalic Acid I in terms of radiocarbon content. Over the years, other secondary radiocarbon standards have been made.
- Radiocarbon activity of materials in the background is also determined to remove its contribution from results obtained during a sample analysis.
- Background radiocarbon activity is measured, and the values obtained are deducted from the sample's radiocarbon dating results. Background samples analyzed are usually geological in origin of infinite age such as coal, lignite, and limestone.

Carbon 14 Dating Measurements

A radiocarbon measurement is termed a conventional radiocarbon age (CRA). The CRA conventions include

- (a) usage of the Libby half-life,
- (b) usage of Oxalic Acid I or II or any appropriate secondary standard as the modern radiocarbon standard,
- (c) correction for sample isotopic fractionation to a normalized or base value of -25.0 per mille relative to the ratio of carbon 12/carbon 13 in the carbonate standard VPDB – Cretaceous belemnite formation at Peedee in South Carolina,
- (d) zero BP (Before Present) is defined as AD 1950, and
- (e) the assumption that global radiocarbon levels are constant.

3.6., A brief study of *Rhynia*

External Structure of *Rhynia*:

- The plants of *Rhynia* were herbaceous. *R. major* was 50 cm. in height and 1.5 to 6 mm in diameter whereas *R. gwynne-vaughani* was only about 20 cm. in height and 1 to 3 mm in diameter.

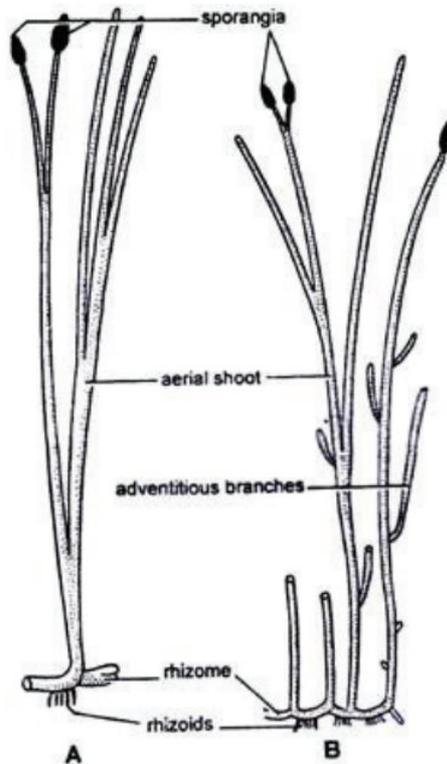


Fig. 3.1 A-B *Rhynia*, External features. A- *R. major*, B- *R. gwynne-vaughani*

- The plant body was differentiated into a subterranean rhizome with an abruptly turned upright photosynthetic aerial shoots. Roots were absent but at places rhizome was provided with tufts of unicellular rhizoids (Fig. 1 A, B). The aerial shoots were cylindrical and leafless with a tapering dichotomously branched system.
- In *R. major* the aerial shoots were smooth (Fig 1 A) but in case of *R. gwynne-vaughani* many adventitious branches were present on the aerial shoots as well as rhizome (Fig. 1 B). These branches perhaps help in vegetative propagation.
- The tip of the aerial branch usually bears a solitary terminal sporangium which was about 12 mm in length and about 4 mm in diameter.

Internal Structure of *Rhynia*:

T.S. of Aerial shoot

Anatomically, the aerial shoots and rhizome are almost similar. T. S. of aerial shoot can be differentiated into three parts: epidermis, cortex and stele (Fig. 2 A).

(a) Epidermis:

It was the outer-most surrounding layer. It was one cell thick and covered by thin cuticle. In aerial shoots it was interrupted at certain places by stomata but stomata (Fig. 2 B) were absent in rhizome.

(b) Cortex:

Epidermis was followed by cortex. It is differentiated into outer cortex and inner cortex. The outer cortex was only 1-4 cells thick, thin walled and without intercellular spaces. The inner cortex had large intercellular spaces and its cells had chloroplast. It is thought that this was the chief photosynthetic region of the plant. The endodermis and pericycle layers were absent.

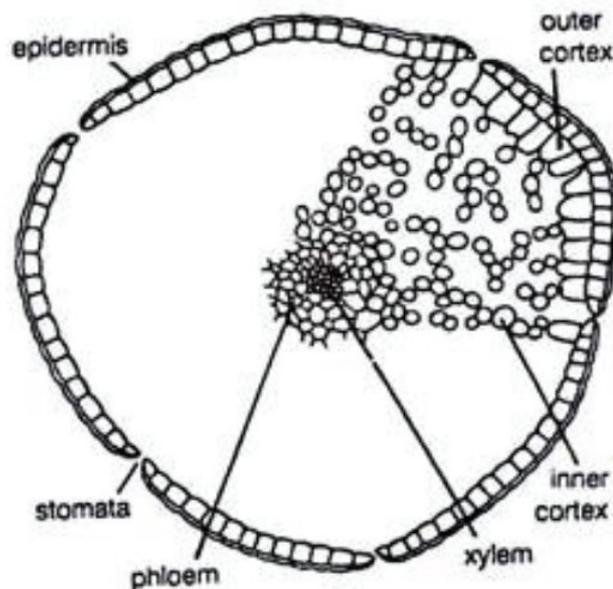


Fig.3.2 T.S. of aerial shoot

Stele:

The centre of the aerial shoot/rhizome was occupied by stele. The stele was a protostele (haplostele). The xylem was made up of annular tracheids and there were no sieve plates in phloem.

Reproductive Structures of *Rhynia*

- The sporangia were borne singly on the apices of some aerial branches, each sporangium being oval or slightly cylindrical structure with a little greater diameter than that of aerial branch on which it is developed.
- They were 12 mm long and 4 mm in breadth in *R. major* and 4 mm long and 1 mm broad in *R. gwynne-vaughani*.
- A longitudinal section (L.S.) of sporangium shows that it had a five cells thick wall. The outermost layer was 1 cell thick cuticularized epidermis. It was followed by 3 cells thick middle layers of thin walled cells.
- The inner-most layer was 1 cell thick tapetum. The wall was surrounding a spacious sporangial cavity which was without columella and contained large number of spores. The spores were of same size and measured upto 60 μ in diameter.
- It means that *Rhynia* was homosporous. In many specimens the sporangium contained tetrahedral tetrads of spores which suggest that they were formed by reduction division and the plant bearing them represented the sporophytic generation.
- There was no special mechanism of sporangium dehiscence. The liberation of spores seems to have taken place by disintegration of the sporangial wall. Nothing definite about the gametophyte of *Rhynia* is known.

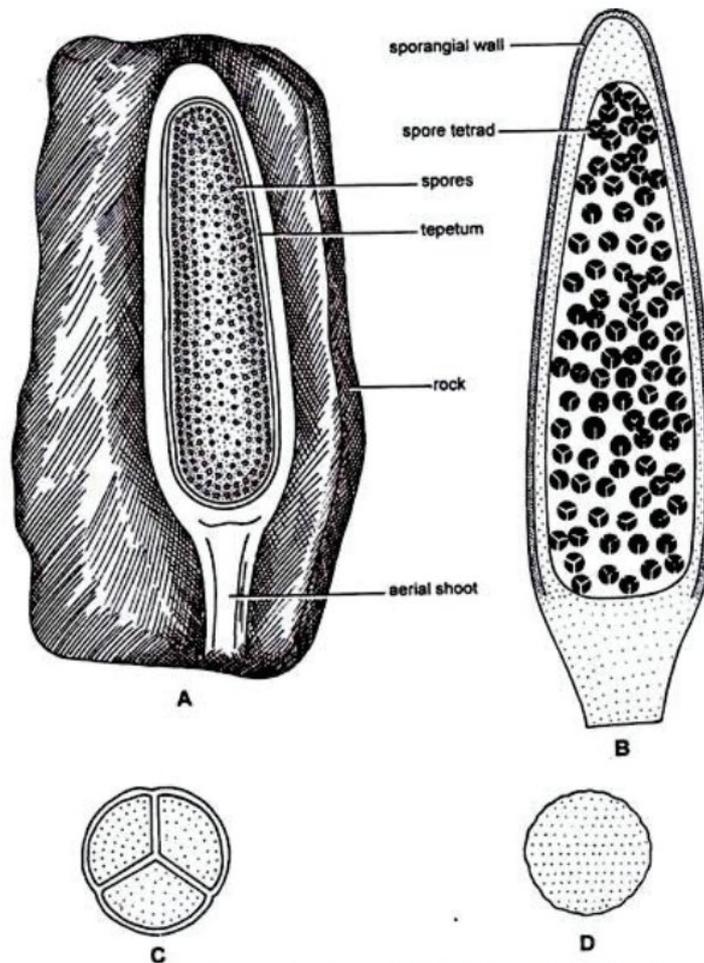


Fig.3.3: (A-D) *Rhynia*. Sporangia and spores A. L.S. of sporangium of *R. major*, B. L.S. of sporangium of *R. gwynne-vaughani*, C. Sporetetrad, D. Spore

3.7., A brief study of *Lepidodendron*

Habit

- Like other ancient lycopods, *Lepidodendron* was also tree like in habit. In general appearance it was not unlike that of present day *Lycopodium*.
- But in size the genus enormously exceeded the herbaceous *Lycopodium*.
- The petrified trunks were sometimes as long as 100 feet. Judging from this it may be safely assumed that the plant reached a height of over 120 feet.



Fig, 3.4 Lepidodendron: Reconstruction of *L. obovatum*

- The stem was erect and did not branch up to some distance from the ground. The branching of the stem was typically dichotomous. The ultimate dichotomies produced the leaves. The branches and the foliage formed a sort of crown at the apex of the stem.
- The leaves which clad the young stems and branches were acicular or linear in shape having a length of 5-9 inches. The arrangement of the leaves was spiral or very rarely they showed a whorled arrangement. The leaves were ligulate.
- Each leaf had a single vein with the stomata situated in two bands on the ventral surface. The leaves were deciduous. Upon abscission a flat rhomboidal scar persisted on the stem resembling a small cushion. The base of the stem had a stigmarian type of root system.

Internal Structure of *Lepidodendron*:

1. Stem:

- In majority of the species, secondary growth is characteristic. But some species seem to lack a cambium. A transverse section of the trunk, of *L. vasculare* shows three regions, stele, cortex and a periderm.
- In the primary structure there was an epidermis but soon i.e. even before the initiation of secondary growth in the vasculature, it was replaced by the periderm.
- The periderm was produced by a phellogen which produced phellogen towards the interior and phellem towards the exterior. The outline of the bark was wavy due to the presence of leaf bases.

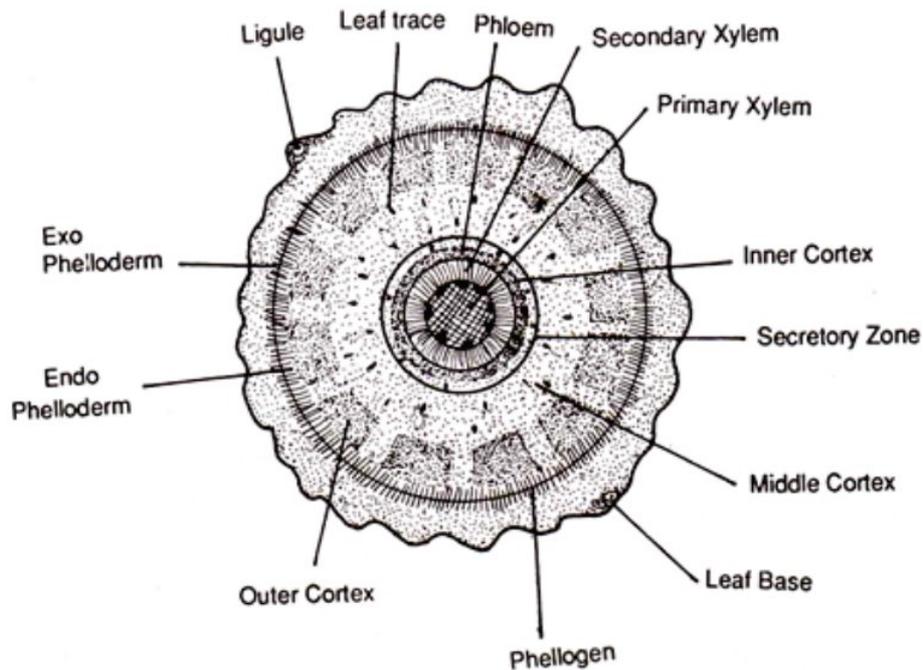


Fig.3.5 *Lepidodendron*: T.S. of Stem of *L. vasculare*

It consisted of four regions viz.:

- (1) Outer cortex consisting of alternating bands of sclerotic and parenchymatous cells,

3.8., A brief study of *Calamites*

External Features

- The calamitean fossils range from pith casts, stems, twigs and leaves to strobili. The stem is known as *Calamities*, leafy twigs are called nularia, and fructification is known as Calamostachys.
- The plant body of *Calamites* was a tall tree growing to a height of 20-30 metres.
- The plant had an underground prostrate rhizome.
- The rhizome was differentiated into nodes and internodes and had a whorl of adventitious roots at each node. From the upper surface of the rhizome arose a number of aerial shoots.

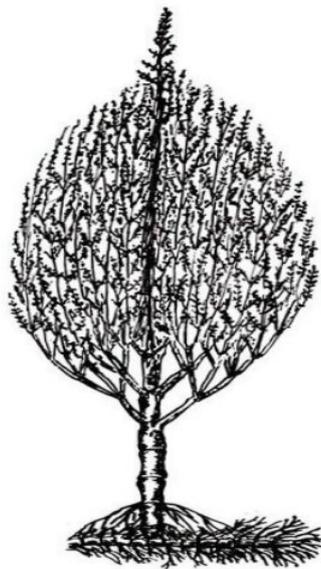


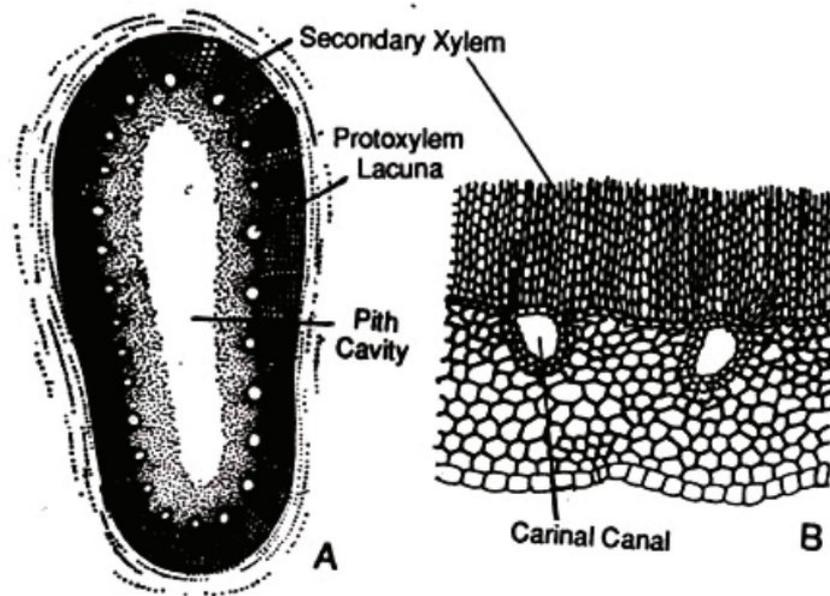
Fig.3.6. *Calamites*: Reconstruction of plant body

- Some of these aerial shoots produced roots at some of the lower nodes, indicating that rhizome grew at some distance below the surface of the soil.
- Erect shoots were constricted at the point of their junction to the rhizome. The branching was conspicuous in the aerial shoots which had whorls of branches at the nodal region.

- The mode of branching is varied and it is used as a criterion in classifying the genus. Based on the branching pattern three sub-genera have been founded.
- In Stylocalamites the branches are few and scattered (e.g. *C. suckowi*). In *Calamitina*, whorls of branches are present only at certain nodes, (e.g. *C. undulatus*). In Eucalamities, branches are borne at every node (e.g. *C. cerinatus* and *C. cruciatus*).
- The lateral branches of the aerial shoots in some cases persisted for a long time and were as thick as the main axis giving the familiar appearance of the present day Equisetum, but much larger in size.
- The surface of the stem had longitudinal ribs alternating with the grooves. But in some instances the ribs of the successive internodes were directly above instead of alternating with one another.

Internal Structure of stem

- Anatomically the stem of Calamites showed an epidermis, cortex and stele.
- In the young stems the cortex had an outer sclerotic zone and an inner thin walled parenchymatous zone.
- There were no Vallecular canals as in Equisetum. The stele was siphonostelic.
- In the central region there was a parenchymatous pith at the nodes, but represented by a central cavity at the internodes.
- The vascular bundles had collaterally arranged xylem and phloem.
- The xylem was endarch.
- The tracheids had scalariform thickenings in metaxylem but annular and spiral thickenings in the protoxylem.
- In each vascular bundle there was a carinal canal formed by the dissolution of the protoxylem elements.



**Fig.3.7. *Calamites*: Anatomy of stem (after secondary growth) A. Ground plan of cross Section,
B. A Sector enlarged**

- Secondary growth in the stem took place by the activity of a cambium. The cylinder attained a thickness of 6 cm. or more due to the secondary growth. The secondary wood did not show the differentiation of annual rings.
- These point out that the plant had an evergreen foliage and there was probably no seasonal variation in a year which is responsible for the annual ring formation.
- Secondary xylem had scalariform and pitted tracheids. Secondary growth also took place in the cortex producing periderm of several centimeters in thickness.

3. Strobili:

The strobili associated with the Calamitean stem are given the name Calamostachys. In this, the strobilus had a central axis bearing whorls of sporangiophores. Alternating with the whorls of sporangiophores were whorls of sterile appendages called bracts. The sporangiophores had cruciately branched apices.

The tip of each branch recurved towards the strobilar axis and had a sporangium at the tip. The genus Calamostachys had both homosporous and heterosporous species. The strobilus had both the types of sporangia in heterosporous forms.

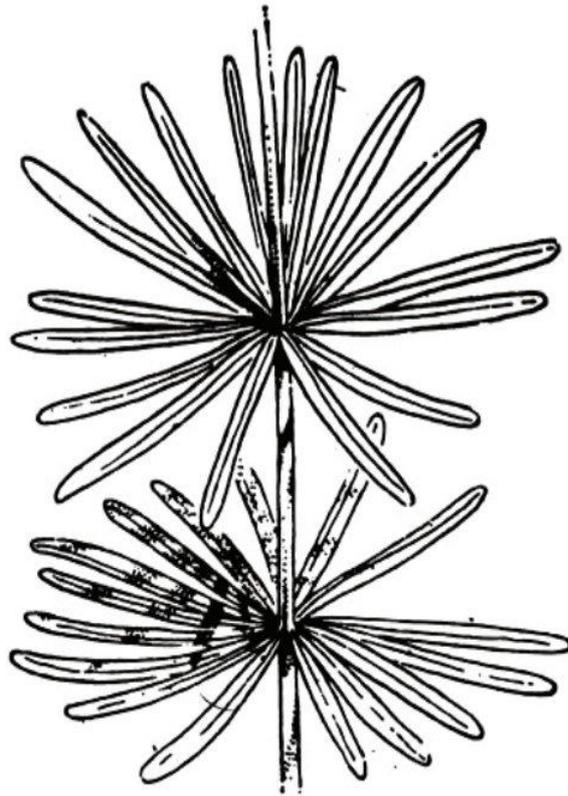


Fig.3.8. *Calamites*: Leaves of *Annularia*

Questions

1. Briefly describe the salient features of *Rhynia*.
2. Write a brief account of *Calamites*
3. Write a brief note on contribution of Birbal Sahni
4. Give an account of fossil nomenclature.
5. Describe the morphology and structure of *Lepidodendron*
6. Write an essay on radiocarbon dating.
7. Write a brief note on Fossilization methods
8. Give an account of Geological time scale,