Fossil Study

Definition:

- Fossils are the **remains and traces of ancient plants and animals**.
- Fossils are formed when ancient plant and animal remains **become hardened and fixed** within sedimentary rock or sometimes volcanic ash.
- **The process of formation of fossil** in the rocks is called fossilization.

Stages:

1. First of all the wind or storm borne **plant** part **come** into quiet **water** and begin to **sink**.
2. **Abundant sediment** will cause rapid accumulation and the plants will be separated from one another.
3. The **weight** of the accumulating sediments will **flatten** it. The sediments increase in thickness, compact.
4. Less resistant and more compressible plant part's flattened to a new portion of its original thickness.
5. The cylindrical plant parts are made up of hard tissues. The weight of the sediments will produce compression or impression of plant. Thus rock having compression when split open, on one surface usually bears the impressed outer part.

Types of Fossils

1. Petrifactions or Mineralized plants: In this type of plants fossil **the original cell of the plant tissue is retained by means of some minerals** like, silica etc. These **mineral has infiltrated** the tissues. In this type of fossil sometimes the material of original plant may be preserved e.g. coal balls, Silicified wood etc.

2. Cast on incrustations: In this type of plant fossil, the form of plant if preserved as a **cast.** The cast is the result of a **cavity formed by decay of tissues of plant part**. Here the **internal structures are destroyed** and carbonaceous substances of the plant are totally gone e.g. stem leaf scars, larger seeds etc.

3. Compressions: In this type of plant fossil, the **external form of plant modifies and leaves impressions** on the sediment. A **compression fossils** undergo **physical compression**. While it is **uncommon** to find animals preserved as good compression fossils, it is very **common to find plants** preserved this way. The **physical compression** of the rock often leads to **distortion** of the fossil.


Petrified logs

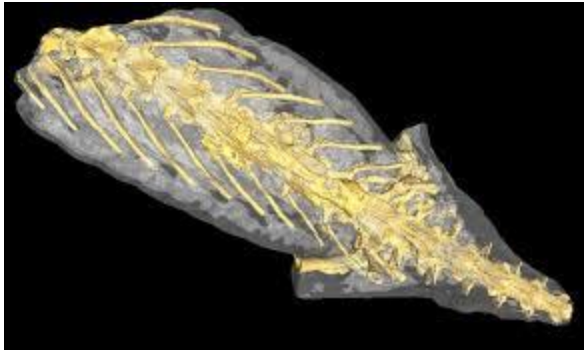
Cast Fossil


Compression

4. **Compaction or Mummified plants:** In this type of plant fossil, the **plants or their parts get compressed by vertical pressure against one another.** Coal or coal balls are the important sources of plant fossils. Coals are irregular or sub spherical mass of calcium or magnesium carbonates (or some other mineral matter).

5. **Impressions:** In this type of plants fossil, the roots, stems, leaves, fruits and seeds are preserved as impressions in such a fashion that they seem to be the **actual dried specimens** laid on the stone.

6. **Amber:** Coniferous plants exudates **resinous substance**. It drops on the floor of forests. It accumulates and hardened over ages. Insects, fragments of plants and other animals get preserved in it and become fossilized. It is called ambers.



Mummified Compaction

Impression

Amber

Modes of preservation

- The **processes of geologic preservation** are important for **understanding** the **organisms represented** by fossils.
- Some fossil **differences** are due to basic differences in **organization** of animals and plants, but the **interpretation of fossils** has also tended to be **influenced by modes of preservation**.
- ***Four modes*** of preservation generally can be distinguished:

(1) ***Cellular permineralization*** ("petrifaction") **preserves anatomical detail**, and occasionally, even cytologic structures.

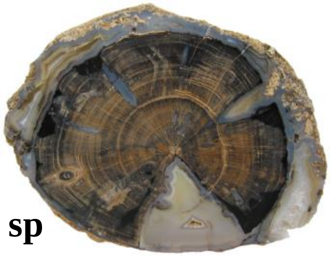
(2) ***Coalified compression***, best illustrated by structures from coal but characteristic of many plant fossils, **preserves anatomical details in distorted form and produces surface replicas** (impressions) on enclosing matrix.

(3) ***Authigenic preservation*** **replicates surface form or outline** (molds and casts) prior to distortion by compression and depending on **cementation** and timing, may integrate with fossils that have been subject to compression.

(4) ***Duripartic*** (hard part) ***preservation*** is characteristic of fossil **skeletal remains**, redominantly animal.

I. Cellular permineralization ("petrifaction")

- It **preserves anatomical** detail and occasionally, even cytological structures.
- This involves **infiltration** followed by **intracellular precipitation** of soluble materials like silicates, carbonates and iron compounds through cell walls.
- The buried plant part **undergoes** partial **disintegration** to release **free carbons** which interact with sulphides present in water and **lead to the formation of carbonates** of Ca, Mg, Fe.
- Thus the **soluble materials** like carbonates, silicates are **deposited within cell** walls through infiltration and precipitation.
- As mineral deposition continues within plant tissues, water expelled as a result of **compaction of sediments**.
- This causes the buried **plant part** within sediments **solidify** completion cellular permineralization.
- It **reveals** the **cellular details** of the plant part (cortical cells, secondary wall thickening, nature of ray cells etc.
- Rhynie chert, petrified forest of Arizona etc.



***Schinoxylon* sp**

(2) Coalified compression

- Coal fossils, preserves **anatomical** details in **distorted** form and produces **surface replicas** (impressions) on enclosing matrix.
- **Un-mineralized** parts are deposited in sediment, followed by **softening** of cell walls and **collapse** of internal cell spaces.
- This leads to **loss** of gas moisture and soluble material.
- As a result of pressure exerted by accumulated sediments and water, the **residues** are **altered** and **consolidated** to form a black **coaly** deposit.
- The splitting of rocks commonly yields the **coalified compression** on **one** face and its counterpart i.e. impression on the opposite face.
- On weathering the, coaly part is lost thus an impression mat be revealed on the rock.
- They reveal leaf form, venation pattern, and epidermal characteristics ctc.
- e.g. leaves are retained in their nature but stem, root and seed become dorsiventrally flattened.

(3) Authigenic preservation

- It **replicates surface** form or outline (molds and casts) prior to distortion by compression and depending on cementation and timing, may integrate with fossils that have been subject to compression.
- It involves **early sedimentation** in **soft sediments** by iron and carbonate compounds
- The **plant material** develops an **electric charge** as soon as it starts to decay.
- It **attracts oppositely** charged **ionized** particles of sediments.
- Sediments comprising of **iron pyrite sphalerite**, **chelerite**, **agate**, **opal**, **corbonate** along with mud and sand accumulate around the plant part.
- Later the sediments become cemented and the plant part is entombed (buried) in the sediment.
- The **internal** structure is **degraded** to form **cavity** which is completely **filled up** by the surrounding sediments.
- After **lithification**, the external **surface** of the plant part is preserved as **mold** and the **replaced internal** structure of the plant part is called a **cast**.
- In this process the internal cellular details are not preserved.

(4) Duripartic (hard part) preservation:

- It preservation is characteristic of **fossil skeletal remains**, predominantly animal.
- Certain **hard part** of both **plant** and **animals** are resistant to decay and oxidation and also resistant to physical distortion.
- Preservation of such hard parts **without** being **changed** by chemical or physical factors is referred to as duripartic preservation.
- e. g. Skeletal parts of lime-precipitating algae (Characeae), coccoliths, diatom frustules (diatomite).

Geological time scale

R. Steinberg
DMC 1-12

Geologic Time Scale

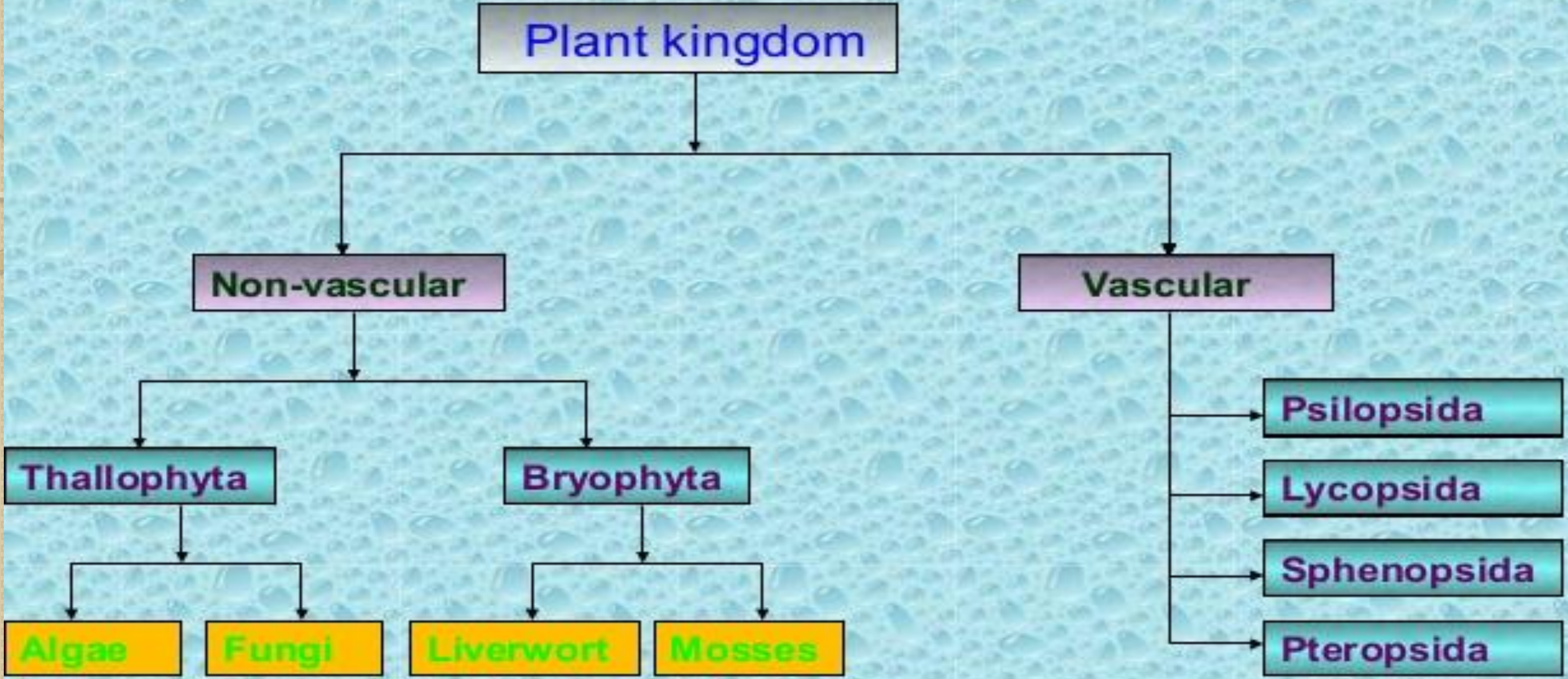
Eon	Era	Period		Epoch	Boundary Dates (Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.012
				Pleistocene	2.6
		Neogene	Tertiary	Pliocene	5.3
				Miocene	23.0
		Paleogene		Oligocene	33.9
				Eocene	55.8
				Paleocene	66
	Mesozoic	Cretaceous			146
		Jurassic			200
		Triassic			251
	Paleozoic	Permian			299
		Carboniferous	Pennsylvanian		318
			Mississippian		359
		Devonian			416
		Silurian			444
		Ordovician			488
		Cambrian			542
PRECAMBRIAN: Proterozoic	Neo-	Ediacaran			~635
	Meso-				
	Paleo-				2500
Archean					4000
Hadean		*No Rock Record on Earth*			~4600
		ORIGIN OF EARTH			

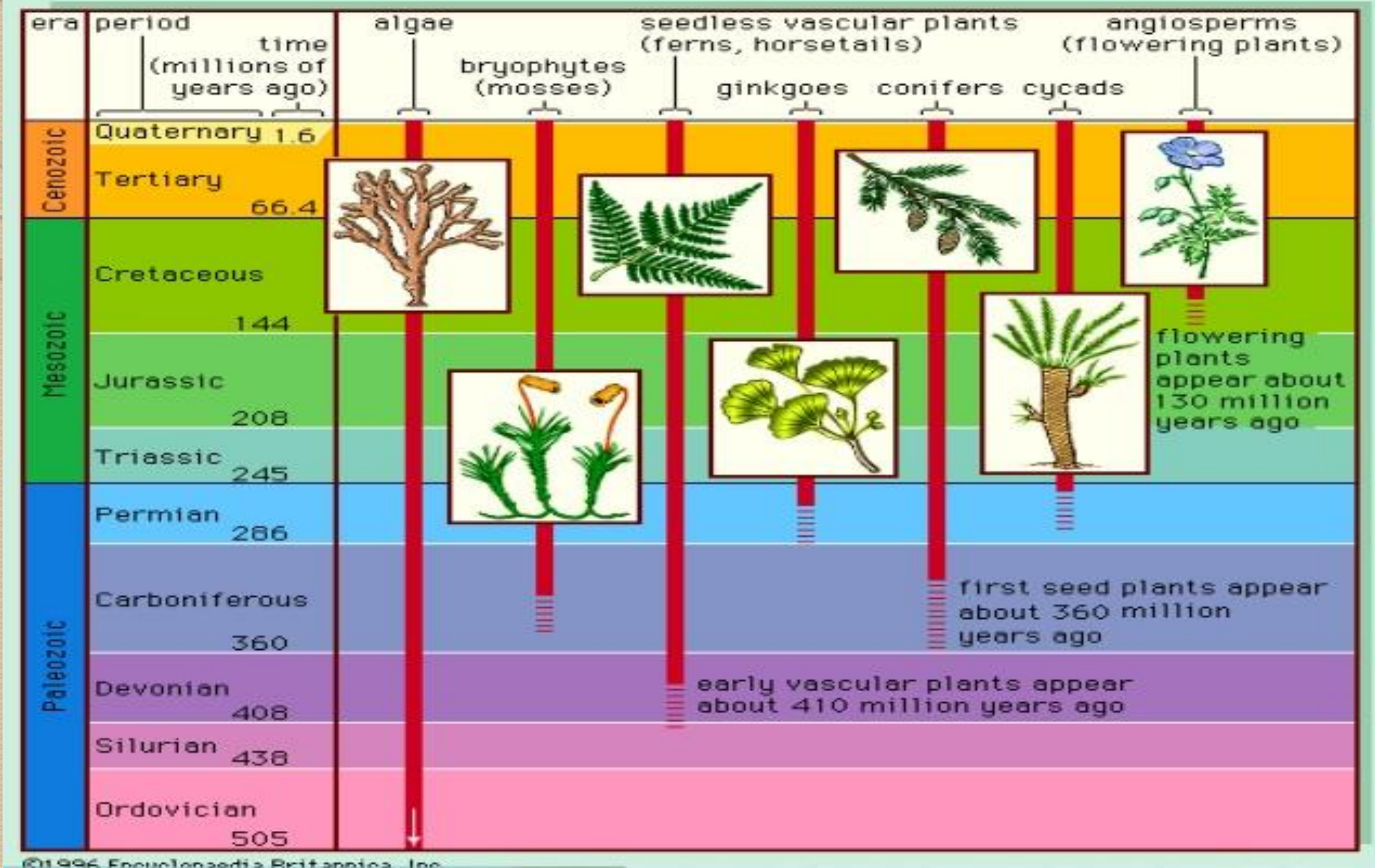
Note #1: Vertical timeline of boundary dates *is not* drawn with a uniform scale.
Note #2: Boundary dates from the International Commission on Stratigraphy 2010 Geologic Time Scale
Note #3: Carboniferous, Paleogene, and Neogene are more commonly used outside of the U.S.
Note #4: Epochs for the Mesozoic and Paleozoic are too numerous to be shown.
Note #5: The Hadean Eon is not formally recognized.

Plant life through ages

Plant life through ages:

- The study of the plant life in the geological past is called **Palaeobotany**.
- Earliest plant fossil (bacteria and BGA) occurring in precambrian rock are 3.1 billion years old.
- The earliest plants were exclusively aquatic and during evolution plants migrated towards land.
- Conditions of land is different from the water, adaptations took place (anatomical and morphological).


Plant kingdom
Non-vascular
Vascular
Thallophyta
Bryophyta
Algae
Fungi
Liverwort
Mosses
Psilopsida
Lycopsida
Sphenopsida
Pteropsida


era
period
time (millions of years ago)
algae
bryophytes (mosses)
seedless vascular plants (ferns, horsetails)
ginkgoes
conifers
cycads
angiosperms (flowering plants)
Cenozoic
Quaternary 1.6
Tertiary 66.4
Mesozoic
Cretaceous 144
Jurassic 208
Triassic 245
Paleozoic
Permian 286
Carboniferous 360
Devonian 408
Silurian 438
Ordovician 505
flowering plants appear about 130 million years ago
first seed plants appear about 360 million years ago
early vascular plants appear about 410 million years ago
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NON-VASCULAR-PLANT :-

A plant without a vascular system and consist of soft tissue showing no differentiation in roots, stems and leaves. It can be classified into

i) Thallophyta
ii) Bryophyta

Horse Tail

Fossil Algae:

Chlorophyll present and in many algae the green of the chlorophyll is masked by the presence of red or brown pigments.

Blue-Green algae
(Precambrian to Recent)

Classification of Fossil Algae Belongs to phylum as:

– Phylum

1) Cyanophyta EX: Blue-Green algae.

2) Chlorophyta Ex: Green algae.

3) Rhodophyta Ex: Red algae.

4) Phaeophyta Ex: Brown algae.

5) Diatomaceae Ex: Diatoms.

6) Chrysophyta Ex: Yellow-Green algae.

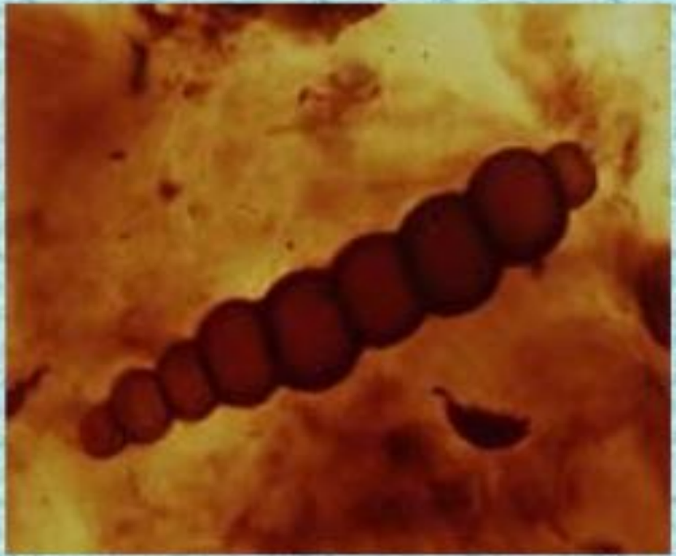
7) Euglenophyta Ex: Euglenoids.

Fossil Fungi:

Chlorophyll absent with the exception of some bacteria, which can build up their bodies from inorganic sources, all fungi are parasitic or saprophytic.

Example:

Bacteria, Slime Mould, etc.,



Fungi
(Devonian to Recent)

Classification of Fossil Fungi Belongs to phylum as:

<u>Phylum</u>

1) Schizomycophyta	Ex:Bacteria.
2) Myxomycophyta	Ex:Slime moulds
3) Euglinomycophyta	Ex: True fungi etc..,

Bryophyta:-

The plants belongs to this phylum are live on land, Preferably in marshy areas and are more developed than the thallophytes. They may have differentiated stems and leaves, but posses no true roots and no true vascular tissue.

The bryophyte possesses thallu like bodies. The fossil records are very rare. It may otherwise be described as moss-plants, and are classified broadly as

Bryophytes
(Devonian to Recent)

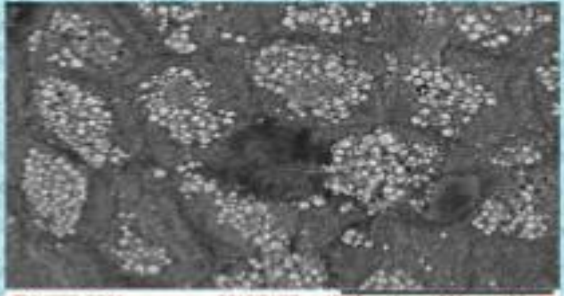
Liverwort and Mosses:-

Liverwort and mosses are the simplest land plants. They have inherited from aquatic algae, a life cycle involving a distinct alteration of sexual and asexual generation which depend on water for its completion ie.., Characteristically in damp places.

Geological age:-

Liverwort : (Mid Devonian to Recent)
Mosses : (Carboniferous to Recent) .

Liverwort



Mosses

VASCUALR PLANT :-

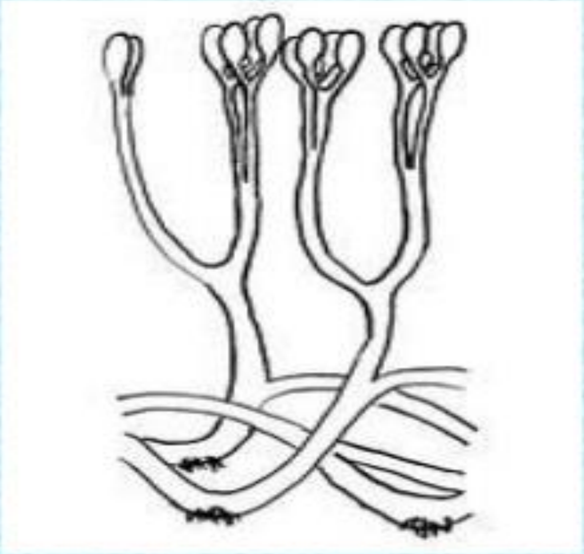
A plant having a vessels in the conducting tissues of the stele and having structural differentiation into roots, stem and leaves. Their origin, probably during the Silurian was therefore intimately associated with the move on the land and subsequent developments can be viewed as further adaptations to the terrestrial habit. The vascular plants are classified on the basis of nature and relationship of leaf and stem, vascular anatomy and position of the sporangia into four divisions. They are

Vascular plant

1)Psilopsida:-

These are earliest known seedless land plants with a simple organization. The plants often lack thick leaves, rise from a horizontal sub surface stem called rhizome.

The division includes two orders. They are the living psilotales and the extinct psilophylates.



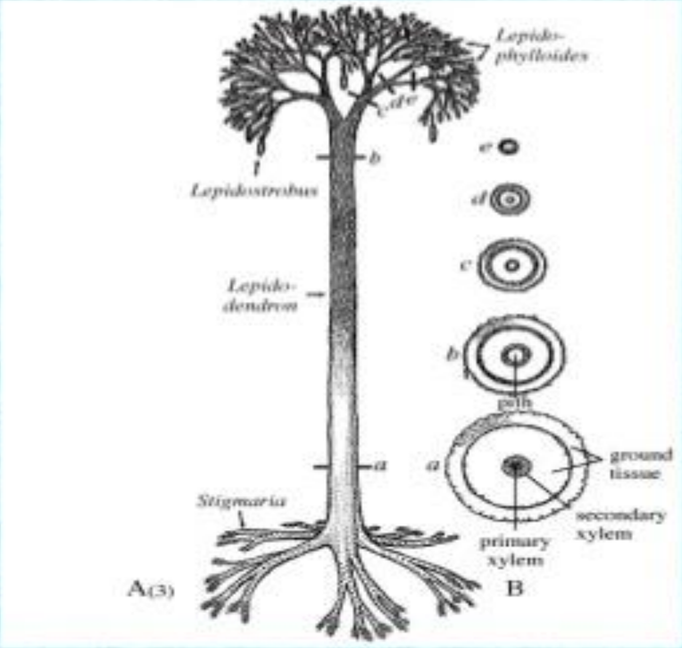
Polysporangiophyte
(Upper Silurian to Recent)

2)Lycopsida

Lycopods are plants of modest dimensions with simple, small spirally arranged leaves and provided with vascular system.

Reports:

Ancient lycopods include Baragwanathia longifolia of Silurian reported in Australia. Drepanophyces of lower Devonian reported in Europe and Canada, and protolepidodendron of middle Devonian reported in Germany.



Lepidodendron
(Silurian and Lower Devonian)

3)Sphenopsida:-

Plants of this division are also called articulates. The stems are jointed and bear whorls of leaves at the nodes. The leaves are attached by a narrow base but sometimes broadened. They were very important in the carboniferous.

Sphenopsida
(Lower Devonian to Recent)

4)Pteropsida:-

The division includes fern, seed- fern, pteridospermae, Gymnospermae and Angiospermae. The members are predominantly megaphyllous and leaf gaps are present in the primary vascular cylinder of all except protostelic form and a few of the very ancient Gymnosperms.

Pteropsida is divided into three classes . They are

1.Filicineae

2Gymnospermae

3.Angiosopermae

Pteropsida (Devonian to Recent)

a)Filicineae:-

The class includes ferms which posses frond (a leaf which bears sporangia). They manage from Devonian to recent. The typical fern has an underground stem from which roots grow down into soil.

Examples:

Rhacopteris, Cladophlebis etc..,

Rhacopteris
(Cretaceous)

b) Gymnospermae

These are woody plants increase in birth by secondary growth. The embryo is sporophyte and the seed is naked. It can be further sub class into three types they are ….

1. pteridospermae
2. cycadophyta
3. coniferophyta

Ginkgoales
(Devonian to recent)

C) Angiospermae

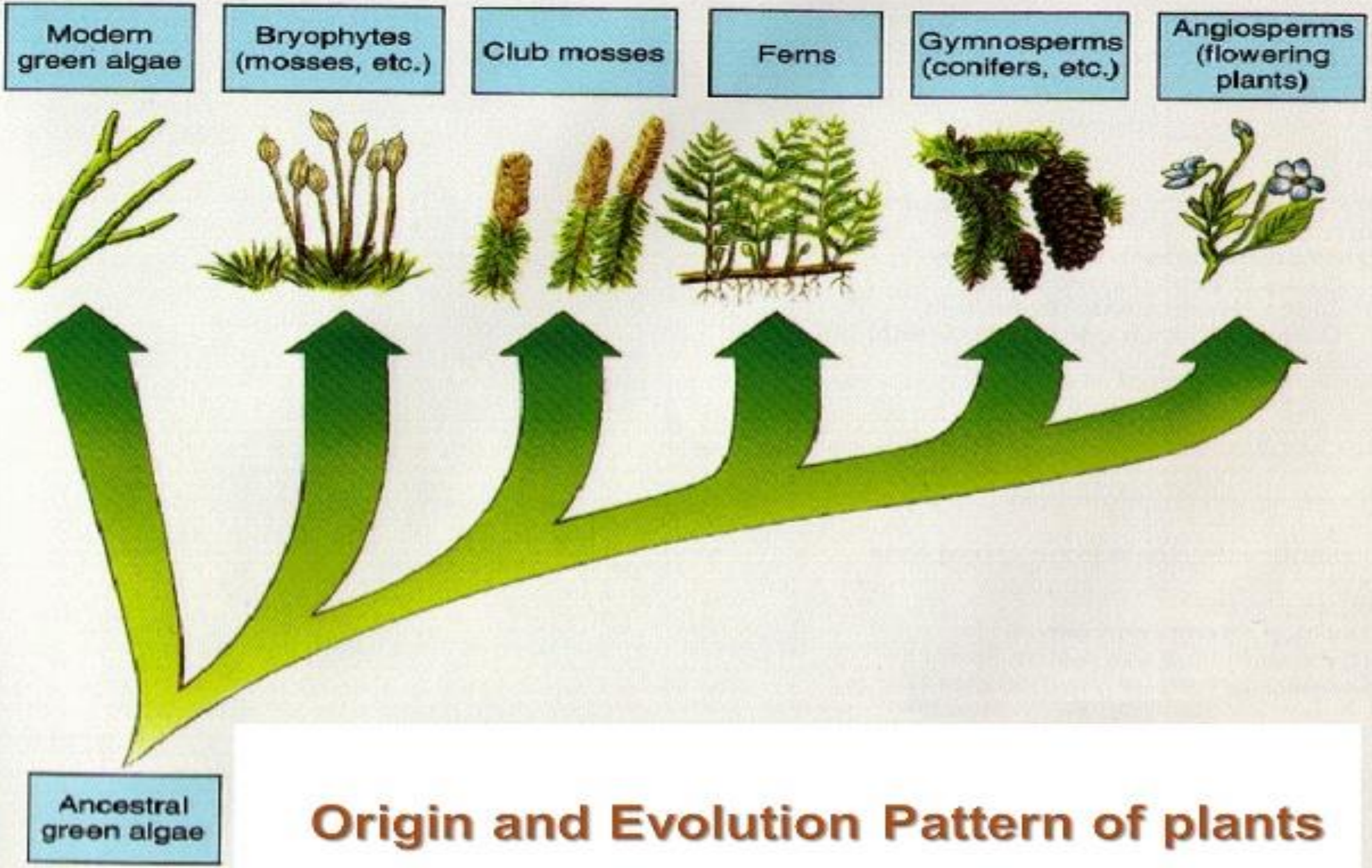
The flowering plants or angiosporms appeared during jurassic and became dominant throughout late mesozoic to present day. These plant bear whorls which become seeds. The seeds are enclosed in a seed care, fruit wall, leaves, trunk, flowers, fruits, seeds and pollens are preserved as fossils. It is sub devided into two types

1. monocotyledon
2. palmoxylon

Angiospermae
(Early Cretaceous to Recent)

Monocotyledoneae
(Early Cretaceous to Recent)

Palmoxylon
(Early Cretaceous to Recent)



Origin and Evolution Pattern of plants

CONCLUSION

- Plant Fossils are significant in the Reconstruction of Plant Life
  Ex: Lepidodendron, Calamites, Sigillaria etc.,

- Plant Fossils helps in Reconstruction of Paleoclimate,
  Ex: Paleoecological studies.

- Correlation between Continents to Continents.

- High Resolution Sequence Analysis .
  Ex: Small cycles of environmental changes could be studied.

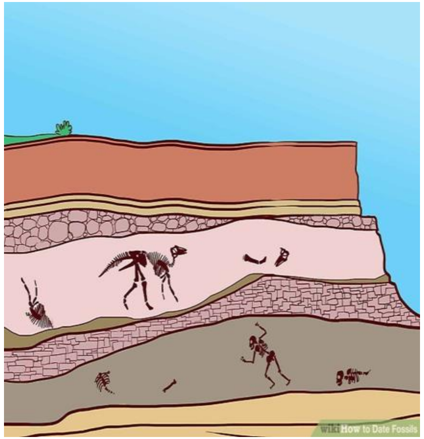
- Plant evolutions record is yet to complete.

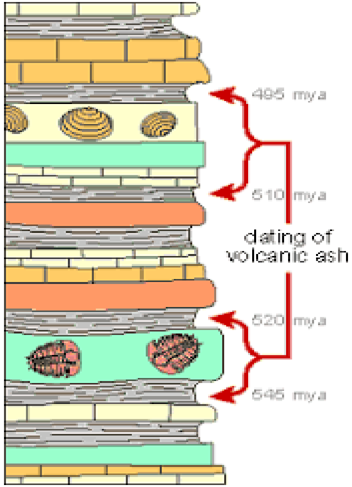
- Paleoecological studies through plant remains.

Dating methods

How Are Fossils Dated?

- Two main methods determining a fossil's age, relative dating and absolute dating.
    - **Relative dating** is used to determine a fossils approximate age by **comparing it to similar rocks** and **fossils** of known ages.
    - **Absolute dating** is used to determine a precise age of a fossil by using **radiometric dating** to measure the **decay of isotopes**, either within the fossil or more often the rocks associated with it.





Relative Dating

- The **majority** of the time fossils are dated using relative dating techniques.
- The **fossil is compared to something for which is already known**.
- Scientists can use certain types of **fossils referred** to as **index fossils** to assist in relative dating via correlation.
- **Index fossils** are fossils that are known to **only occur within a very specific age range**.
- Fossils that had a widespread geographic distribution such as brachiopods, trilobites, and ammonites work best as index fossils.
- **Multiple index fossils** can be used.
  - ✓ A rock formation contains fossils of a type of **brachiopod** (known to occur between 410 and 420 million years) and also contains a type of **trilobite** (known to live 415 to 425 million years ago).
  - ✓ The age of the rock formation, must be in the overlapping date range of 410 to 420 million years.
- Studying the layers of rock or strata can also be useful. **Layers** of rock are **deposited sequentially**. If a layer of rock containing the fossil is **higher** up in the sequence that another layer, you know that layer must be **younger** in age. This can often be complicated by the fact that geological forces can cause faulting and tilting of rocks.

Absolute Dating

- Used to determine a precise age of a rock or fossil through **radiometric dating methods**.
- This uses r**adioactive minerals** that occur in rocks and fossils like a geological clock.
- It's often much **easier** to date **volcanic rocks** than the fossils themselves or the sedimentary rocks.
- Layers of **volcanic rocks above and below** the layers containing **fossils** can be **dated** to provide a date range for the fossil containing rocks.
- The atoms in some chemical elements have different forms (**isotopes**). These isotopes break down at a **constant rate over time** through **radioactive decay**.
- By measuring the **ratio of the amount of the original (parent) isotope to the amount of the (daughter) isotopes** that it breaks down into an age can be determined.
- While people are most familiar with carbon dating, carbon dating is rarely applicable to fossils.
- **Carbon-14,** the radioactive isotope of carbon used in carbon dating has a **half-life of 5730 years**, so it decays too **fast**. It can only be used to date fossils **younger than about 75,000 years**.
- **Potassium-40** on the other hand has a half life of **1.25 billion** years and is common in rocks and minerals. This makes it ideal for dating much older rocks and fossils.

Importance of plant fossil study

1. **Basic Aspect of Studying Fossil Plants:** To understand the past vegetation, climate and palaeoecology including the history of plant evolution, biostratigraphy, etc.

(a) To Decipher Palaeovegetation and Palaeoclimate:

- Plants face death and decay. Sometimes, they **escape** from final **destruction** and **survive** as **fossils**. Thus, plant fossils serve as **tool for past vegetational studies**.

- A correlation exists between fossil plants and their surrounding environments which serve as an index for **palaeoclimate**. The fossil plants are used for interpretation of the past climate, because the present-day living plants are well understood for their integral association with the idea "present is the key to the past".

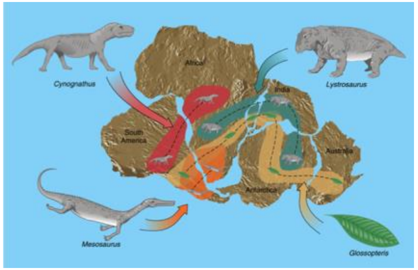
- Palaeoclimate factors, are assessed on the basis of modern-day plants, showing their morphological and anatomical characteristics commensurate with climatic condition including adaptive factors.

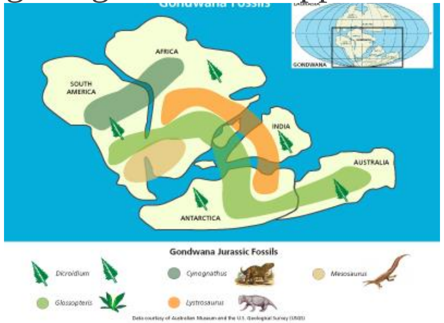
(b) Provide Evidence for Origin and Evolution of Plants:

- Important in understanding the ***origin*** and ***evolution*** of different plant groups through ages.
- In support of the origin of land plants: **The evolution of land plants during Silurian period**.
- To acquire **terrestrial** habit leaving their **aquatic** habitat the plants needed to be **self-supportive** and they had to be able to **withstand the drying effect** of the atmosphere leading to a series of adaptations, such as **development of cuticle in their outer surface** to check desiccation, f**ormation of roots as anchoring** and **absorptive organ, stomata** for gaseous exchange, **vascular tissue for conduction**.
- During Silurian-Devonian periods more and increasingly complex fossil plants represented by Rhyniopsida appeared with such adaptive features. Gymnosperms became more successful than the pteridophytes by having selective advantage of seed formation.

(c) To Ascertain Palaeo-phytogeography:

The most astonishing example of such aspect is the concept of **Gondwanaland**, which consisted of a single landmass formed by the union of the faraway continents of the **Southern Hemisphere**,
such as South America, South Africa, Madagascar, Australia, New Zealand, Antarctica and India.
The fossil evidence shows a clear **floral continuity** ranging in age from the Upper Carboniferous to the beginning of the Cretaceous.





(d) To Make Biostratigraphic Correlation:

- The applied significance: in understanding the **bio-stratigraphical sequence** which provides evidence to **trace the plant evolution through ages**.

- **There are two aspects to be considered:**

(i) Correlation of the data showing **quantitative and qualitative value** of retrieved fossil data,

(ii) Use of fossils for comparison to get the empirical value in terms of **appearance**, **duration** of **dominance** and then **gradual disappearance** through migration or extermination due to climatic and other factors establishing a biostratigraphic scale.

- For example, in the coal bearing strata of the Middle Carboniferous of West Europe, seven successive vegetational sequences were established using plant megafossils. Thus, an analysis of plant fossils of a given stratigraphic zone, provides the needed data to interpret its floristic composition and evolutionary sequence.

(e) Calculation of Age of the Rocks:

Radioactive elements are generally used for **dating the rocks**. But sometimes, **index fossils** are used to date a rock of unknown origin. Any index fossil the rock contains must be carefully studied with precise information about its systematics and age. Using of such index fossils the age of an unknown rock can be determined.

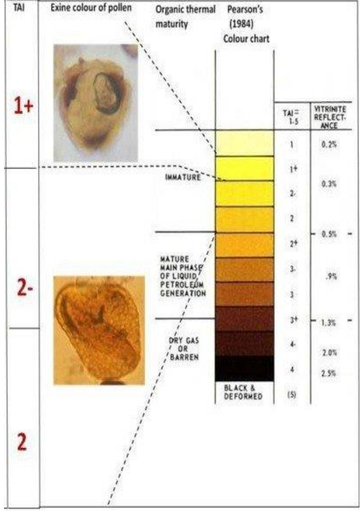
2. Applied Aspect of Studying Fossil Plants:

- To provide useful information in the exploration of **fossil fuel like coal and oil**.
- The plant inhabitants of **Palaeozoic- Mesozoic swamps:** a source of **coal and formed coal seams**.
- Accumulation of **plant materials** with a variety of minerals coupled with mud, silt and other organic materials constitute a **coal bed**.
- A **stratified scale** based on **fossils** can be made to establish the **age of coal deposits** and their position in the succession of rocks.
- A **tool to ascertain age of coal layers**, their lateral extent and quality of coal deposits.
- In India, the palaeobotanical study has helped to demarcate the nature and quality of **Raniganj coal** (**Permian Age**) from that of **Rajmahal coal** (**Jurassic Age**).

Exploration of oil is done by:

(i) *Determining the Thermal Alteration Index*:

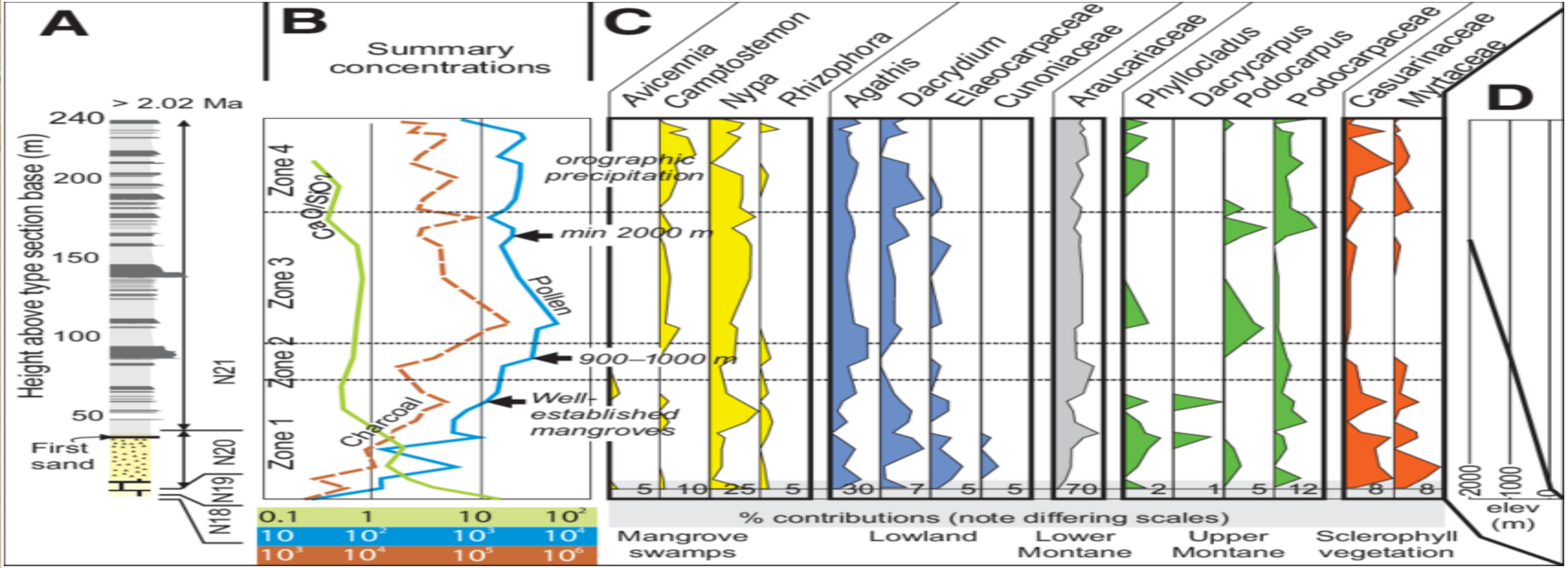
- The sporopollenin present in the walls of pollen and spores undergo post depositional thermal changes in course of the geological ages.
- These **thermal changes** brought about **carbonisation** resulting in **changes** in **exine colour** of fossil pollen and spores in transmitted light.
- The basic idea involved is the usage of the variation in the **exine colour as an indicator of the degree of carbonisation** in the rocks to predict their changes of bearing reservoir.
- ***Pearson's colour chart*** directly relates exine colour to a numerical index called **Thermal Alteration Index** (TAI) which is a measure of the d**egree of carbonisation**.
- TAI having a range of 2+-3+ and exinite flourescence colour white-yellow, dark yellow-brown indicates the possibility of exinite containing rock to possess liquid petroleum and natural gas.



Organic thermal maturity	Spores/ Pollen colour	Correlation to other scales		
		TAI 1-5	Vitrinite reflectance	Fluorescence
Immature		1	0.2%	Blue
		1+		Green
		2-	0.3%	Greenish yellow
		2		
Mature main phase of liquid petroleum generation		2+	0.5%	Golden yellow
		3-		Orange
		3	0.9%	
				Red
Dry gas or Barren		3+	1.3%	Nonfluorescence
		4-	2.0%	
		4	2.5%	
	Deformed	5		

(ii) *Palynostratigraphy:*

- To avoid **unnecessary and costly drilling** the **determination of oil zone** is made by comparing the biostratigraphic data of one to those of the others.



Palynostratigraphy and zonation

A: Stratigraphic column showing carbonate base overlain by marls then interbedded turbidites (dark gray) and hemipelagic muds (light gray).

B: Per-gram concentrations of pollen (blue) and charcoal (brown). CaO/SiO 2 (green) refl ect increasing terriginous sediment. Black arrows represent estimated elevation in meters above sea level of proto-Timor at the respective points in the stratigraphy.

C: Pollen diagram for taxa that defi ne elevation zones. D: Plot showing upsection increase in paleoelevation.

iii) Defining of Ancient Shorelines:

- The sediments parallel to sea shore are rich in oil. The density of pollen and spores decreases in the seaward direction.
- Sedimentary environment with pollen assemblages are limited to near shore marine or lacustrine waters.
- Thus by the study of microfossils along with marine microfossils if presents, one can determine the distance and direction of ancient shore lines, possibly bearing oil deposits.