Plant Fossils and Effects of Geological Changes

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Abstract : This article provides an overview of the type of plant fossils with a detailed overview of the climatic and environmental changes those can be understood with the help of these fossils. It further illustrates the relation of concentrations of carbon dioxide with several structural and morphological changes in the plants.

Contents

Introduction
Fossils are the earliest and most detailed records of the organisms that occurred in the prehistoric times. They are the only direct evidence that can help scientists understand the phenomenon that occurred in history. Plant fossils have been the focus of scientists for centuries because of their ability to predict land and climatic conditions of the particular era in which they lived along with their own evolutionary pattern. They have been particularly divided into microfossils and macrofossils.

Macrofossils
Macrofossils are made of the larger plant parts such as leaves and stem, which are visible to the naked eye and can be manipulated by hand [4]. As some of these parts are fragile, macrofossils can be fragmented and often occur less in number. Most of them are limited to space where they grow, macrofossils are a good source to interpret the climatic and environmental conditions of the land where they grew [7].

Some of the evidence that can be collected with the help of macrofossils are discussed below:-

1 Dendrochronology, the technique of dating using tree rings, is a widely known practice. The density of the wood is indicative of the rainfall precipitation as less dense wood is formed during summer rainfall season. Moreover, stressful conditions such as frost, defoliation or a dry spell are indicated by anomalies in the tree rings. Furthermore, tree rings mostly predict the region where a specific plant grew because rings are usually absent in the trees which grow in humid environments [8].

2 Leaves embedded in the form of fossils are an excellent way to predict the historic climates by assessing and identifying the nearest current relative. For example, by examining the fossils of Nyssa and Taxodium from the Miocene era (5 million to 23 million years ago) of the Rhine area of Germany, it can be inferred that the climate of Germany was different than it is today. This is because the modern relatives of these fossils are found in warm and humid environments contrary to the cold temperatures that prevail in Germany today [9]. US paleontologist Jack Wolfe studied the physical appearance of leaves and compared them with the climatic condition around the world. Wolfe illustrated that the shape of the leave’s margin and its edge varies with mean annual temperature such that in higher temperatures, most plants have full smooth margins of the leaves whereas toothed edges are mostly found in colder environments. Moreover, leaf size also varies with temperature variations across environment because leaf size is directly proportional to water loss [8].

3 The protective surface called cuticle and pores called stomata on the surface of the leaves can also infer about the environmental conditions of the obtained fossils. For example, plant leaves with thick cuticles and fewer stomata on the leaves reveal that they were growing in a hot and dry climate and thus fewer stomata to avoid excessive water loss [15].

4 In a study, pollen-based temperature reconstructions of the summer temperatures from Northern Europe revealed that the temperature rose in that area 9000 years ago. The evidence is obtained from sedimentary pollen records. These records differ with the type of tree taxa. When the tree pollen taxa of the plants such as spruce (*Picea abies*) in North Eastern European Russia, pine (*Pinus sylvestris*) in Northern Fennoscandia and *Alnus incana*, *Alnus glutinosa*, *Ulmus glabra*, *Corylus avellana*, *Tilia cordata* and *Quercus robur* rose, the rises in temperature occurred simultaneously. This study has also shown that aquatic plant macrofossil records can provide additional information about the early-Holocene temperature evolution in Northernmost Europe. Moreover, it can further suggest the development of post-glacial climatic condition using multi-proxy data [13].

5 Two depositional episodes of interstadial (ca. 26,000-22,000 yr B.P.) and mid-to-late Holocene (<3600 yrs. B.P.) age were identified in a study using pollen and plant macrofossil data from the Piedmont region of North Eastern Georgia. Most of the pollens are of Pinus, Quercus, Carya, Picea, and Abies. Interstadial macrofossils included two needle morphotypes of Pinus subgenus Pinus and one needle morphotype of *Pinus banksiana* [9].

6 Very few fossils records of the largest plant family *Orchidaceae* exists which makes the plants present in this family difficult to classify. However, fossils leaves of two plants, Dendrobium and Earina, were obtained from New Zealand. The finding of these two orchid leaves is a major breakthrough in the field of botany. It will not only reveal the diversification of the epiphytic orchids but it will also leave clues about their biogeography [4]. The fossils obtained from Maar Lake sediments consists of leaves of 10 different monocots from the early Miocene period and indicate a diverse subtropical rainforest. The fossil leaves from Earina shows distinctive, raised tetra-to cyclocytic stomatal subsidiary cells and those from Dendrobium revealed characteristic papilla-like absorbing glands and “ringed” guard cells. These characteristics support that fact that they belong to Orchidaceae. These are therefore the oldest fossils which show cuticular preservation [4].

7 The use of plant macrofossils to study Quaternary vegetational history was a widely known practice for centuries which faded after the discovery of quantitative pollen analysis. However, a study has revealed that the use of data obtained from macrofossils can really be helpful if studied along the pollen analysis. One reason is that plant macrofossils can even be obtained in treeless situations. Moreover, they are much more locally distributed from their source and are more precise taxonomically. Macrofossils records for plants which produce little or no pollen can also be obtained and thus they have the ability to infer more information about paleoclimatic conditions. Some limitations to the use of macrofossils include that they are not as abundantly produced as pollen and they require large volumes of sediments to study them. However, their reconstruction at an ecological site can interpret vegetation changes and its dynamics [2]

8 The importance of plant macrofossils in the reconstruction of late-glacial climates have been demonstrated by a study in which assumed local occurrence of tree Betula (B. pubescens) at Blomøy, and the presence of pollen of thermophilous taxa at Utsira are under consideration. When modern vegetation analogues are compared with the late-glacial macrofossils, long-distance dispersal, facilitated by the strong winds during the late-glacial are indicated by the pollen of Betula and thermophilous. Thus local and ecologically sound macrofossils are a valuable record for vegetational and climatic reconstructions [3].

9 In another study done on microfossils, it has been shown that the oldest known Eucalyptus macrofossils are those obtained from South America. Some impressions of flower buds, a flower, individual fruits, and leaves are the plant parts that were obtained from that particular fossil. Since they are repeatedly found on the same stratigraphic levels and quarry sites, it has been concluded that they belong to the same plant taxon [7].

Microfossils

Microscopic parts of the plant such as small seeds, grains, and spores are called microfossils. They are not visible to the naked eye and usually, an electron microscope is needed to study them. Several fields and laboratory techniques are required for obtaining a precise sample that can be studied in the laboratory [1].They are more preferred than the macrofossil records because they are present in large amounts in a vast number of environments and provide the earliest evidence of bryophytes and bryophytes like plants. Their history dates back to the Llanvirn (Mid-Ordovician) period in which their first evidence has been found. A period of relative stasis of about 40 Myr from the Llanvirn (Mid-Ordovician) to the late Llandovery (Early Silurian) is also evident from microfossil record [14].

1 One form of plant microfossils are the dispersed spores which are usually referred to as crypto spores because of their unclear morphology. Cryptospores are divided into monads and permanently united dyads and tetrads. They may be naked or enclosed within an envelope. Data from the Ordovician Early Silurian spores revealed that they are geographically widespread and their composition is remarkably constant throughout this period. This revealed that they were large in number but were not diverse for over a period of 40 Myr in duration. In the late Llandovery, major changes in the composition of spores are reported [14].

2 The occurrence of early land plant spores is evident of their current and historical distribution and abundances. The presence of these spores in continental and nearshore marine deposits show that they are sub aerially released spores of land plants which are transported through water and wind to their deposition areas [14].

3 The size, gross morphology and the thick spore wall of the bryophyte spore and extant land plants are compared and similarities have been found. One of the many functions of Sporopollenin walls is to protect propagules during transport following subaerial release. Thus the presence of such walls in early higher land plant spores is evident of the fact that they are functionally similar to their modern counterparts [14].

4 A direct link between the dispersed spore and plant megafossil records can be found in the in situ spores that are preserved in the fossil plants [14].
The study of the spore wall ultrastructure is particularly important in assessing the development of spore wall in early land plants. It also provides valuable information about the phylogenetic relationships of extant land plants [14]

5 Along with spores, dispersed phytodebris extracted from the Ordovician/Early Devonian period can interpret early ecosystems. They are usually obtained from embryophytes and fungi and contribute to the understanding of early plant life [14]

6 Evidence of the early bryophytes has been obtained from Silurian and Devonian coalfield mesofossils in a study done by Edwards, D. [5].

7 The assessment about the composition of the plant diet of the population of people living in Bronze Age site of Shilinggang in Yunnan Province, southwestern China, has been made by the microfossils embedded in the dental calculus of the ancient teeth. Along with microfossils, the discovery of storage organs such as roots, bulbs, and rhizomes in plant macrofossils revealed that they used to consume a variety of plant-based food [11].

CO2 Concentration and Plant Fossils

The concentration of atmospheric carbon dioxide fluctuated along with the tectonic activity that occurred over a period of time. During the period of active volcanic activity, the increased concentration of carbon dioxide accounted for the production of the greenhouse effect that resulted in several adaptations in plant structure at that time. Similar is true when a decrease in carbon dioxide concentrations resulted in ice ages. It has been indicated that these megacycles of carbon dioxide concentrations over a period of several hundred years resulted in the evolution of vascular plants. This is due to the fact that plants undergo a variety of functional and structural changes when they are exposed to any stressful condition [6]. For example, it is evident that the fossil leaves exhibit numerous, smaller stomata in those geological intervals when carbon dioxide concentration was low. The opposite occurred when concentrations were higher. This is because under low concentrations, leaves adapted for higher average maximum leaf diffusive conductance to CO_2 and vice versa [10].

As the guard cell size of the stomata changed, it has been demonstrated that the genome size of the nucleus also changed. So, in a way, these megacycles of carbon dioxide concentration changed the size of the genome size as well. The mechanisms underlying this phenomenon are still uncertain but it is established that these changes can be a result of changing CO_2 concentrations but do not entirely depend on it [15].

The long-term biogeochemical carbon cycle also helps us to predict about the timeline of the evolution of organisms from simple microbes to multicellular vascular plants. This is due to the fact that carbon dioxide concentrations depend upon two processes namely photosynthesis and weathering of calcium and magnesium silicates in surface rocks and soils. Both of these processes are directly linked with the evolution of terrestrial ecosystems [6].

Conclusion

Plant fossils are the most proximate source for evaluating the origin and development of terrestrial plants on earth. Among them, microfossils provide the evidence of earliest land plants which are not otherwise available in the form of macrofossils. Along with the functional and morphological development of plants, these fossils have left the evidence of environmental changes that occurred through the centuries.

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