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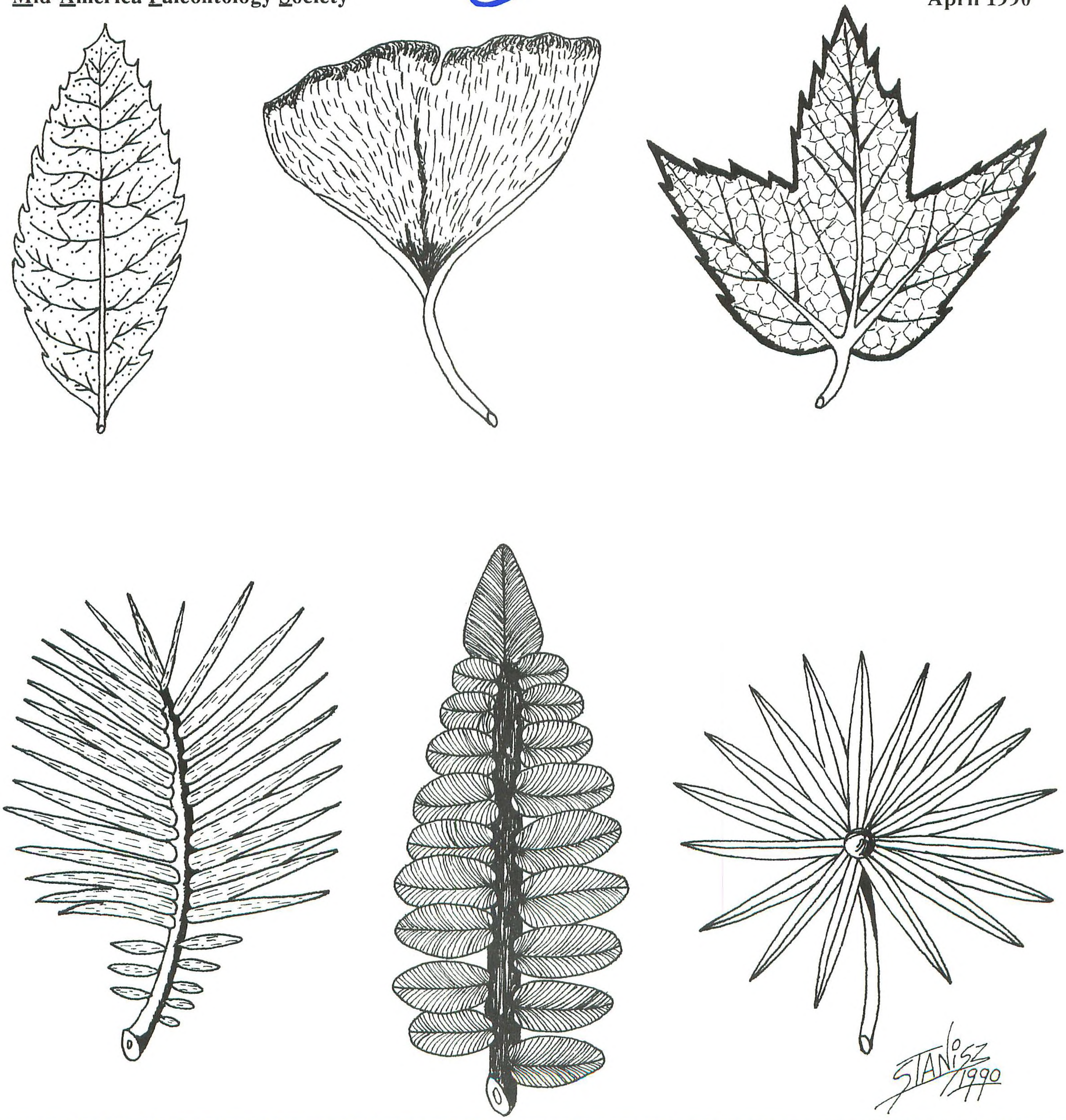
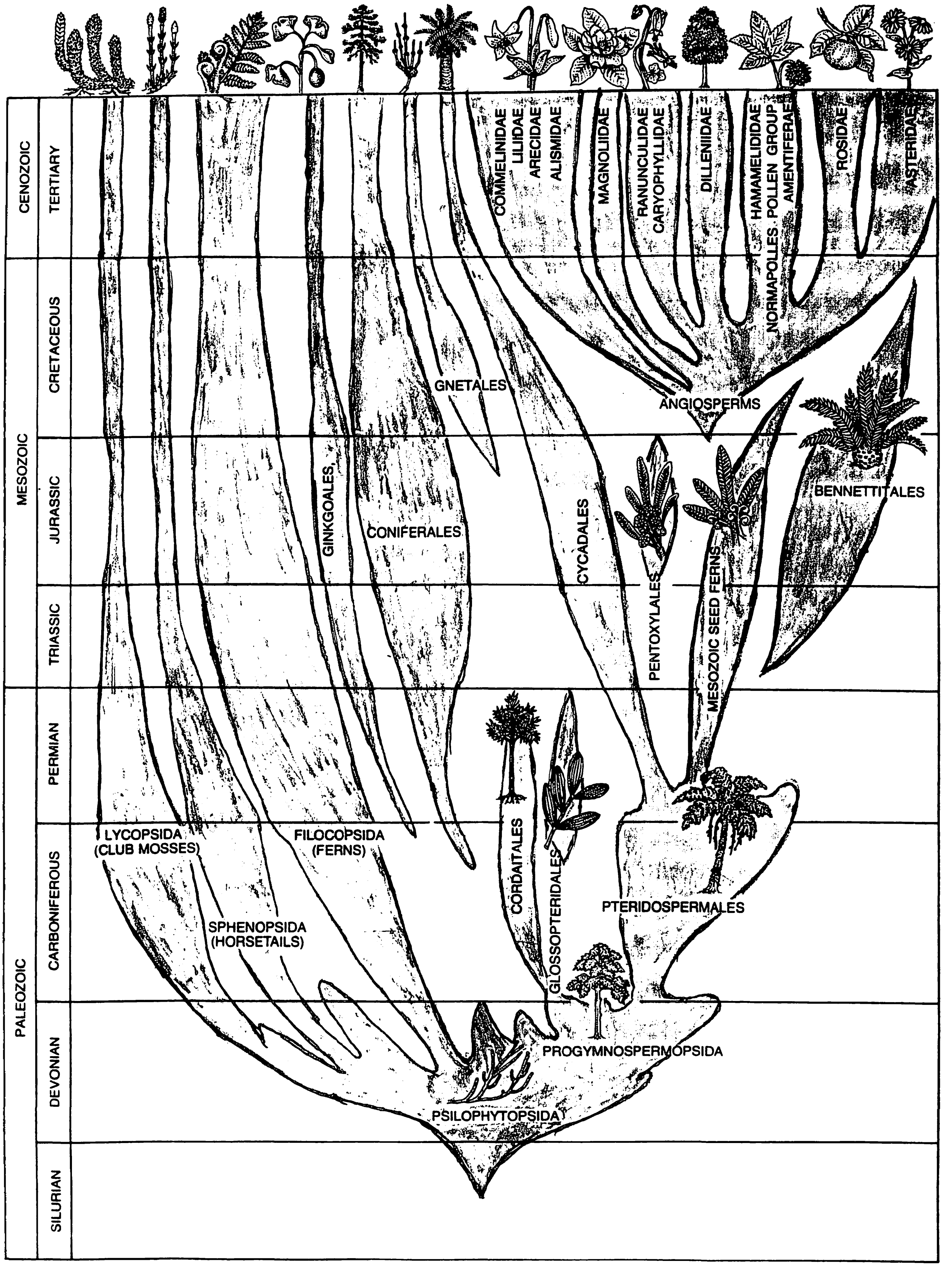


A LOVE OF FOSSILS BRINGS US TOGETHER



VASCULAR LAND PLANTS probably evolved according to the pattern indicated in this diagram. In the Devonian period the primitive assemblage of horsetails, club mosses and ferns dominated the flora. Those forms reproduce by spores and prefer humid conditions. Seed- and pollen-bearing plants developed by Devonian times, and by the Permian the conifers had begun an expansion that made them dominant in the Mesozoic era. Late in the Cretaceous period the angiosperms (flowering plants) spread explosively and became dominant.

LEAVES and GRASSES

M A P S Digest

EXPO XII EDITION

Mid - American Plaeontology Society

A Love Of Fossils Brings Us Together

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1990

Acknowledgement

Dear Hearts and Gentle People, to you the contributors of EXPO XII Edition. I stand in awe at the wonder of it all. To each one I only needed to ask.

Leaves and Grasses are subjects we can all associate with, because they are things most of us live with each day, and when we see specimens that were here eons ago we can't help but compare them with similar looking Leaves and Grasses of today.

When Peggy Wallace called to ask if I would assume this responsibility, I replied, "I did not know the first thing about editing the EXPO Edition", but I would gather the articles for someone else to edit; then after I called some of you and the response was so overwhelming, I called her two days later and told her I would try. I thought about how our dear friend Madelynne has been so instrumental in building this organization into what it is today, through the Digest and the EXPO Edition; and this year she was not able to do it. How could I refuse? Knowing at that moment that with the help of so many of you I could probably carry it out.

Time! Time! Did I have it? It was short, instead of a year of planning we only had three months to put it together. Maybe that was the best, because I had to devote all my time to it, except of course for the update of the Directory, as they both came at the same time. So if I have leaves and grasses mixed in with the Paleontological Societies, and on exhibit at the Shows around the world; you will need to consider the source, and take solace in the fact that everyone needs leaves and grasses.

Several of the contributors to this issue are newcomers to MAPS and to the concepts of the EXPO Edition, but not new when it comes to sharing their knowledge and enthusiasm of the impressions of the past, and how the past is a window to the future.

It was exciting talking to these authors. Contacts were made by phone, then with letters to follow, because time was short.

I owe a debt of gratitude to **Dr. N. Gary Lane** and **Dr. Steven R. Manchester** of Indiana University, and to **Dennis Kingery** of Rock Springs, Wyoming for helping with the list of people to contact. To them and to you, the generous contributors, you have my **THANKS**. I will always be so very grateful to you. **"WONDERFUL PEOPLE"**

This issue, EXPO XII Edition of the Digest is lovingly dedicated to our friend **Madelynne Lillybeck**.

The Mid - America Paleontology Society (MAPS) was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation, and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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COVER STORY

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The cover drawing was done by Raymond Stanisz, Jr. who has also done the art work for the Indiana state fossil Cyathocrinites multibrachiatus which has been submitted for the state fossil. The fossil plants illustrated on this cover were taken from private collections and museum specimens.

First row left to right Anthophyta (Angiosperm) Castaenea, Ginkgphyta (Ginkgos), Anthophyta (Angiosperms) Acer. Second row, Cycadophyta (Cycads), Neuropteridaceae (Brongniart) Sternberg, Stenophyta (Annularia).

Anthophyta (Angiosperms) Castanea (Chestnut). These leaves are simple and oblong lanceolate, and they have coursely serrate margins with sharp, large teeth venation consist of a generally straight midvein giving rise to 13 to 15 pairs of secondaries. Each secondary terminates in a tooth. These have been found in Tertiary and Miocene flora.

Ginkgphyta (Ginkgo) origins was possibly the Late Paleozoic. They became widespread by the Jurassic period and then declined during the Tertiary. Ginkgos have been reported in the fossil record of the western United States until the Miocene epoch when they finally disappeared from this region.

Anthophyta (Angiosperms) Acer (Maple) This genus has an extensive geological past dating from Cretaceous to the present.

Cycadophta (Cycads) Zamites Is a widespread genus for Cycadeoid leaves. These are often pinnate with pinnae attached at right angles to the rachis. The overall compound leaf is lanceolate with a single terminal pinna. In the western United States Zamites occur commonly in Triassic strata. In France it occurs in Jurassic strata.

Neuropteridaceae (Neuropteris) gigantea In spite of its name, it has medium sized pinnules oblong in shape with nearly parallel sides and obtusely rounded apexes. They are usually spaced quite closely together and nearly at right angles to the rachis so as to cause overlapping upon one another. These were distributed during the Pennsylvanian period from the Pottsville to the Conemaugh formation.

Sphenophyta (Annularia) radiata has the whorles of leaves showing great variation in size, and number of leaves will vary from 12 to 36. The leaves are long, linear sharply pointed leaves which have their widest point near the middle. Sometimes the leaves will overlap each other, the leaves are all about equal length. the Annularia was widely distributed during the Pennsylvanian coal forming period.

REFERENCES

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MAPS DIGEST EXPO XII EDITION - LEAVES and GRASSES

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*Denotes MAPS Member

LEAVES: Their Origin and Nature

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The organization of the leaf is a wonder. There is the intricacy of the veins, from the major ribs to the finely connected network within the blade. The thin, green tissue forming the photosynthetic lattice. The stalk of the leaf holding it in space so that it can intercept the light from the sun. The processes within the leaf enabling it to utilize sunlight to process carbon dioxide and water into sugars. These sugars are metabolized to release useful energy for work, or are converted into other useful organic molecules, or are converted into storage compounds such as starch.

The leaf is a marvel of design and engineering. It is found in all flowering plants, gymnosperms, ferns, horsetails, and clubmosses. Yet not all leaves are alike. Some are very small and simple such as we see in the leaf of the horsetail or clubmoss. Some are very large and complex such as we see in the tree fern and palm. Some are simple, such as a dogwood leaf; while others are compound (composed of many leaflets), such as the walnut leaf.

Yet, when we look back to the time of the origin of the land flora (Late Silurian-Early Devonian), we see that the first land plants lacked leaves. In fact these primitive vascular plants lacked leaves as well. They consisted of a branching stem that served in an anchorage, absorptive, photosynthetic, storage function. These primitive plants consisting of stems only were called Rhyniophytes. They are considered to be the ancestors for the major groups of vascular plants we see today.

So, how did the leaf appear? When? What does it represent? The answers to these questions are found in the fossil plant record and in the scientific models and hypotheses proposed by paleobotanists over the course of the past century. Much credit must go to the German paleobotanist, Walter Zimmermann who assembled a number of observations into a unified concept called the Telome Theory. Zimmermann looked at these primitive Rhyniophytes with their leafless, rootless organization. He noted that their stems forked equally and at successive right angles to each other so as to form a bushy appearance. Using this pattern as a basis for evolutionary events, Zimmermann proposed that five different basic developmental processes could account for the variation in form that we see today among members of the plant kingdom. These processes were termed: overtopping, planation, webbing, reduction, and recurvation (figure 1).

The process of overtopping occurs when one half of a forked branch grows more vigorously than the other. This results in a larger major branch and a smaller, lateral branch. The process of planation occurs when portions of a branching system fork in the same plane forming a somewhat flattened structure. The process of webbing occurs when tissue proliferates between adjacent branches therefor connecting them into a single unit. The process of reduction occurs when portions of a branching system do not develop to their former potential. In essence, reduction is involved with suppression of growth and development resulting in smaller and fewer branches in a branching system. The process of recurvation occurs when portions of a branching system curve back upon themselves forming a hook at their point of curvature.

According to Zimmermann, the leaf represents a branching system that has become lateral (due to overtopping), flattened (due to planatin of the banching units), and webbed (due to proliferation of tissue between the planated branch units). Furthermore, leaves in different groups of plants may represent different segments of a lateral branch system. The small leaves of the conifers may represent a small, lateral branch system; the large leaves of the cycads and ferns represent much larger portions of a branching system.

If Zimmermann is correct, then the Telome theory can be tested using the fossil record. The theory leads us to predict that fossils should be found that show dynamic evidence of overtopping, planation, and webbing. This is indeed the case. Instead of documenting volumes of detail regarding evidence for the processes of the Telome theory in the fossil record, I will describe a few instances that I have examined personally during my research career.

Aneurophyte Branch Systems

The Aneurophytales represents a group of Devonian plants that appear to be ancestral to the seed plants (pines, cycads, ginkgos, and flowering plants). I have examined the external form and internal structure of all members of this group. The stem branches many times, producing successively smaller branch units (figure 2). The internal anatomy of these branching systems is relatively constant. That is, the anatomy of the stem is repeated successively in each order of branching (figure 3). As would be expected the size and compexity of the internal tissues would decrease proportionately with the decreasing size of the more distal branch units. All members of the Aneurophytales bear small, dichotomously-branching units as their terminal or ultimate units. These units fork in three-dimensions in some species and appear to be planated in other species. In addition, the anatomy of these ultimate units is very different from that of the stems and branches that bear them. Here then are the beginnings of early leaf evolution. The ultimate units have been overtopped. Most have been non-planated, although some appear to be moving in this direction. None of these units are webbed. The change in internal anatomy of these ultimate units sets them up as being different - perhaps the precursors of leaves.

Leaves of Archaeopteridales

A second group of Devonian plants thought to be ancestral to early seed plants is the Archaeopteridales. Members of this group show a range in simple leaf morphology from three-dimensional, unwebbed simple units, to planated unwebbed units, to planated webbed units. The simplest and most primitive organization can be found in the Middle Devonian Actinoxylon banksii that I described from New York (figure 4). It can be seen that the leaf is a non-planated, unwebbed, lateral unit on a branch system. The remaining variation in this group of early plants can be seen among species of one genus, Archaeopteris (figure 5). The most primitive form, Archaeopteris fissilis, is most similar to Actinoxylon. The leaves of the most specialized forms are entire and non-dissected leaves and are most similar to modern leaves.

Lateral branch system of an early seed plant from Ireland

The previous two examples show stages in the evolution of simple leaves on lateral branching systems. The evolution of large compound fronds would develop in a similar fashion. One such example of a stage in the development of a large compound frond can be found in my collections of early seed plants from Ireland. Many early seed plants are assigned to the group called the seed ferns. These seed ferns are characterized by large compound leaves bearing many small photosynthetic leaflets (= pinnules). If the Zimmermann Telome Theory model is correct, then one should find evidence that some of these large fronds are modified lateral branch systems. In addition, one should predict that some of these early fronds were not completely planated. The anatomy of these early fronds should be very similar to that of the stems that bear them.

My students and I found such an example of a primitive, non-planated frond with anatomy similar to the stem (figure 6). If one examines the figure provided he/she can note that the water-conducting tissue (in the internal anatomy) of the stem bearing the frond is essentially three-ridged (in 3-dimensions). As one examines the internal anatomy of the frond axis, one can note that the three-ridged appearance is reconstituted. At this level, the frond anatomy is indistinguishable from that of the stem. If one follows the attachment of the lateral parts of the frond, one can note that they are attached in a spiral pattern and are displaced in space in a three-dimensional configuration. That is, the frond is not planated. The evidence of the terminal units (pinnules) indicates that they were also non-webbed. The frond in this plant still has many stem-like characters.

I have just indicated in a few brief paragraphs, the types of evidence that is found in the plant fossil recond to help support the Telome Theory model for the evolution of the leaf. There are hundreds of additional stories that can be cited and documentd. Let it suffice that the leaf has a long history and that its ancient heritage is that of a lateral branching system. The wonders of its structure go back almost 375 million years to the Early Devonian. During the ensuing 375 million years, the many variations that we recognize in the world around us have evolved using a few basic processes encapsulated in the Telome Theory and responding to the forces of nature that we term natural selectionl.

FIGURE LEGENDS

figure 1. Illustration of processes of the Telome Theory. I = overtopping; II = planation; IIIa = webbing in a leaf; IIIb = webbing in a stem; IV = reduction; V = recurvation. (after W. Zimmermann, 1959. Die Phylogenie der Pflanzen, Fischer Verlag, Stuttgart)

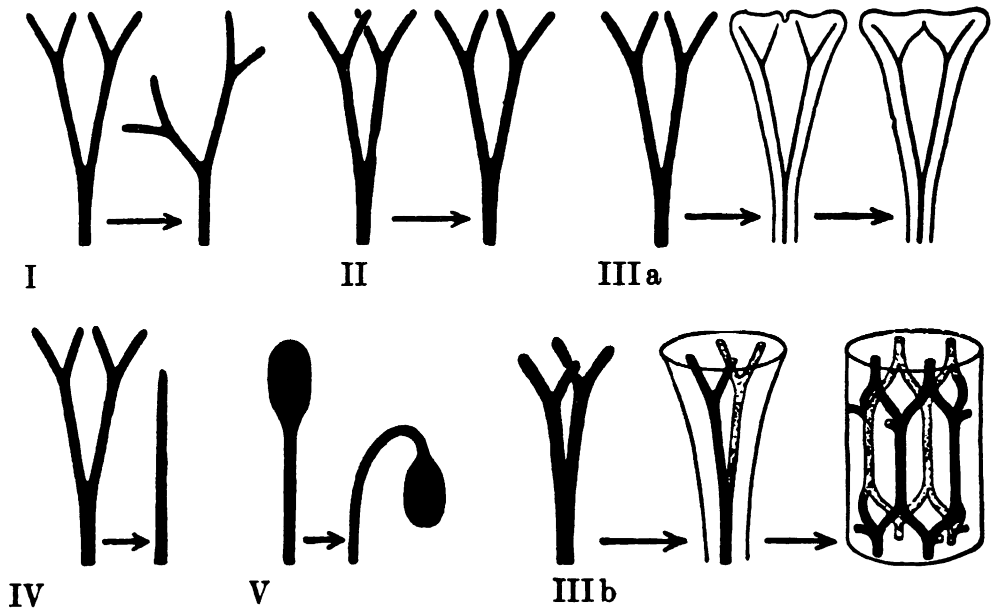
figure 2. Partial reconstruction of Protopteridium, a member of the Aneurophytales showing the branching system with the smaller, leaf-like ultimate units. (after Schweitzer and Matten, 1982. Palaeontographica 184B: 65-106)

figure 3. Reconstruction of Tetraxylopters, a member of the Aneurophytales showing the branching system and its accompanying anatomy. (after Beck, 1957. American Journal of Botany 44: 350-367)

figure 4. Reconstruction of Actinoxylon, a member of the Archaeopteridales showing the 3-dimensional leaves on the branches. (after Matten, 1968, American Journal of Botany 55: 773-782)

figure 5. Reconstructions of three species of Archaeopteris, Archaeopteridales showing the variation from naked, non-webbed leaves (A. fissilis on the left) to dissected leaves (A. macilenta in the middle) to almost entire leaves (A. halliana on the right). (after Phillips et al. 1972. Palaeontographica 139B: 47-71 and Andrews et al. 1965. Canadian Journal of Botany 43: 545-556)

figure 6. Reconstruction of a new seed fern from the Upper Devonian of Ireland (currently being studied in the author's laboratory). The stem is disposed horizontally in the drawing and the major portion of a frond is shown. The lower right cross section shows the internal anatomy of the stem with the vascular connection (7 O'clock position) going to a frond. If one follows the vertical series of drawings on the right, one can see three lateral pinnae being produced in a non-planated fashion. The three-ridged vascular system of the internal anatomy is a typical stem configuration.



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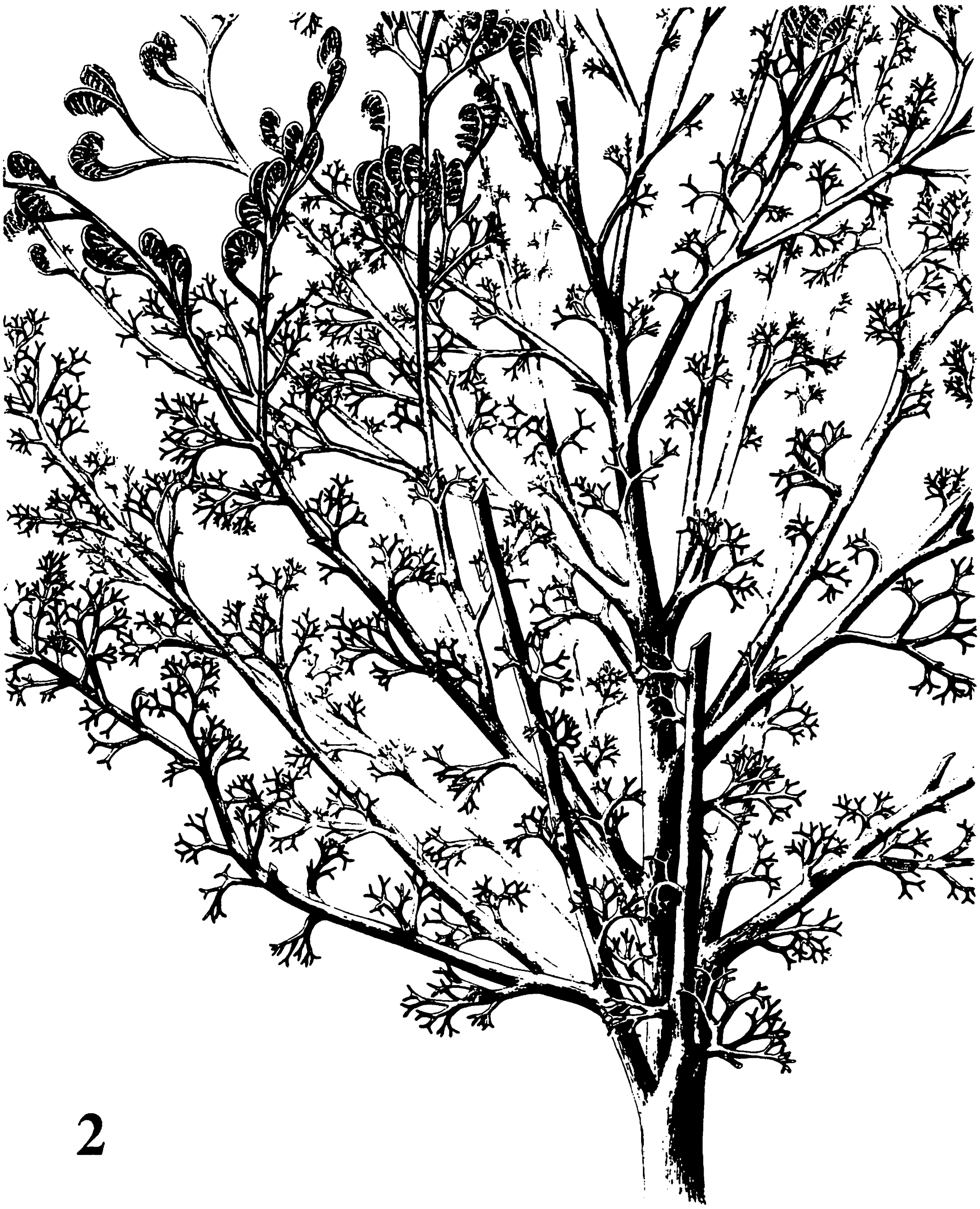

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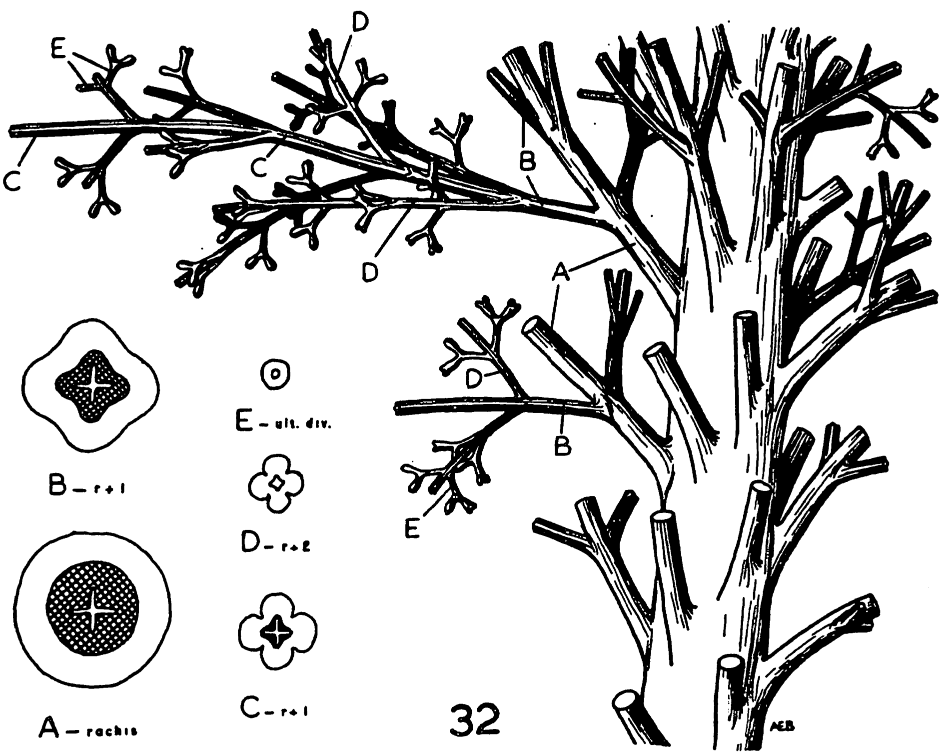

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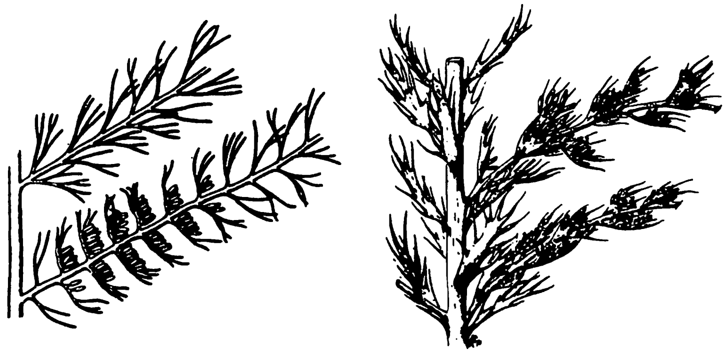

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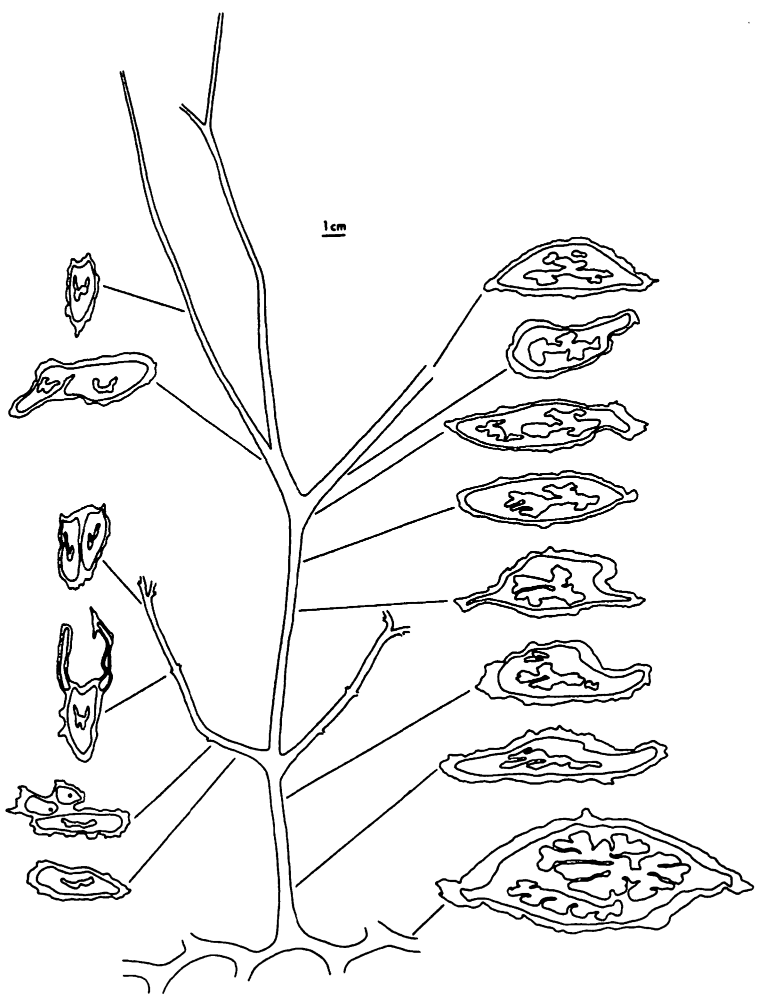

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CENTRAL OREGON FOSSIL LEAVES: THEIR IMPLICATIONS ABOUT PALEOCLIMATE AND THE GROWTH OF THE CENTRAL PORTION OF THE OREGON HIGH CASCADE MOUNTAINS

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ABSTRACT:
Parts of Oregon older than the Cretaceous period are generally thought to be accreted terranes The Pennsylvanian Spotted Ridge flora and the Jurassic floras of Douglas and Curry counties thus were not in ancient Oregon while living. They represent island floras rafted to the continental margin of North America from some unknown distance west or south of Oregon.

When most of the state was raised above sea level in Eocene time, the climate was tropical, as shown by palms and other tropical plants found in Eocene fossil floras.

A major change from tropical to temperate vegetation during earliest Oligocene time is documented in five successive fossil floras found at Gray Butte, Jefferson County, Oregon.

An abrupt change from somewhat dry-temperate to semi-arid-temperate conditions took place about 7ma in central Oregon, and is reflected in fossil plants found near the Deschutes River. The change to ariditiy is believed to be the result of mountain building in the High Cascade Mountains of central Oregon as well as general region-wide crustal uplift.

INTRODUCTION.

Ever since someone gazed in astonishment at the first fossil palm leaf to be found in rocks in the arctic, it has been obvious that fossil plants have a lot to tell us regarding past climates. The rich fossil plant beds of Oregon have provided raw material that has given us much significant information about tertiary plant communities.

Quantitative measurement of morphological features of leaves has given science the tools to make considered estimates of the ecological condition that prevailed when plants at a given fossil site once were alive. Such characters as leaf size, texture, presence of drip-tips, margins (whether toothed or entire) plus the relationship of fossil genera and species to climates where their modern counterparts live give important clues to the past. From such evidence, deductions can be made concerning approximate mean annual temperature, temperature extremes, seasonality and approximate abundance of rainfall at the fossil site during the time of deposition. A comparison of the fossil plant community at a locality with modern plant communities can sometimes give clues to the altitude of the site at the time fossilization occurred Careful scholars do not use these criteria alone, but crosscheck and correlate with paleoecological data from the fields of archaeology, glaciology, geology, vertebrate and invertebrate paleontology, paleopedology (the study of fossil soils) and others.

GEOGRAPHIC SETTING OF THE STUDY AREA:

As is shown on the map (Fig. 1), the central Oregon area lies just to the east of the Cascade Mountains. The effect that this mountain range has on the weather of Oregon is extraordinary. The popular conception of the state is that it is a wet, green area. The residents even call themselves "webfoot". The heavy annual rainfall west of the Cascade Mountains makes this appropriate there. In rising to surmount the Cascade Mountains, however, most of the moisture in the air is condensed and falls as rain or snow. When the dry air descends into central and eastern Oregon, the effect is dramatic. Except in very high elevations, this vast part of the state is semi-arid. Large portions of it are considered to be desert. At Madras, Oregon, for instance, the annual rainfall is only about eight inches. The area is largely mountainous. The canyon bottoms along the lower reaches of the Deschutes and John Day rivers are at elevations of around 300m above sea level. Most of the agricultural areas, however, lie from 450m to 1,000m above sea level. Plants not only have to deal with the aridity of the region, but a very short frost-free season due to the elevation and latitude. What little precipitation that falls there is very seasonal and plants that cannot survive prolonged dry periods have difficulty living. Native vegetation, often described as "sage and juniper" also includes grasses, bulbous and tuberous herbs and a few species of shrubs. Exceptions are large irrigated plots where crops are bountiful, elevations above 900m, where pine forests are common, and streamsides.

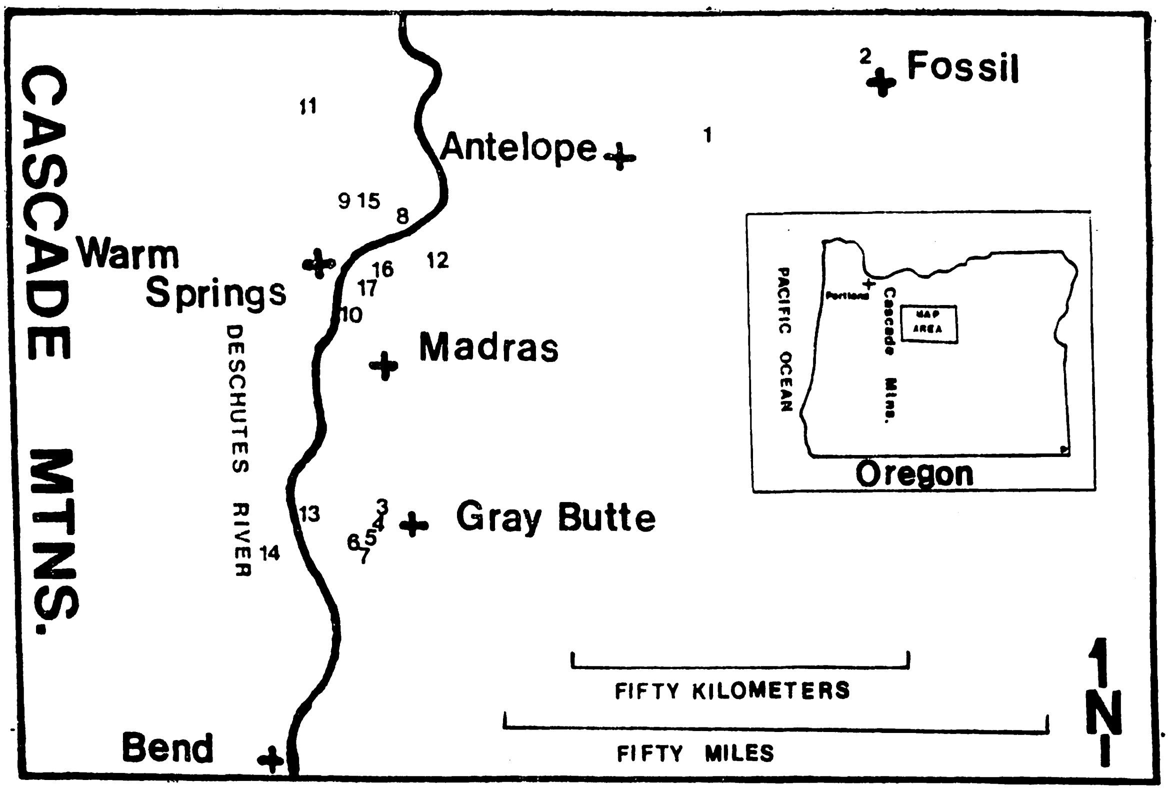
REGIONAL GEOLOGY:

For the past approximately two hundred million years, the North American continent has been drifting slowly northwest. It is believed that at the outset of this journey, the Oregon we know existed only as a patch of ocean off North America's western shore. Geologists have evidence to indicate that large and small chunks of ocean floor have become attached to the continental edge as North America has plowed through and over the Pacific Ocean floor. This process has served to extend the shoreline westward. It has also left a veritable jigsaw puzzle of a geologic record that is not yet completely worked out by researchers.

In Oregon, there is one Carboniferous age fossil flora called the Spotted Ridge flora (Mamay and Read, 1956), and several from the Jurassic age known as the Riddle and Elk River floras (Fontaine, 1905). Since the rocks at these sites are considered to be "exotic terranes" rafted to the shores of Oregon from some remote site, it is likely that the plants found in these deposits grew on some seamount (island) rather than an Oregon mainland.

FIG. 1

LOCATION of fossil floras.



1-Hancock Field Station flora. 2-Fossil, Oregon flora. 3-Kings Gap flora. 4-Sumner Spring Flora. 5-Nichols Spring flora. 6- Canal Flora. 7-Trail Crossing flora. 8-Heath Ranch flora. 9-Horse Trap flora. 10-Pelton flora. 11-Foreman Point flora. 12-Vibbert flora. 13-Round Butte Dam flora. 14-Juniper Canyon flora. 15-Kahneeta flora. 16-Deschutes flora. 17-Rehermann flora.

It is not until we look at the record of Cretaceous time that we see marine strata that represent the rocks of near and offshore seas in situ. Fragmented leaves of Cretaceous age are found along with marine invertebrate fossils at some localities in the state.

No terrestrial fossils of uncontested Paleocene age have been so far found in Oregon. Indeed, rocks of this age are almost completely missing from the geologic record here. Since the dinosaurs died out at the end of the Cretaceous era, the above information explains why, with the exception of flying and marine serpents, no dinosaur remains have been recovered in Oregon.

Geologic formations from which central Oregon tertiary plant fossils are recovered include the Clarno Formation, largely Eocene in age, the John Day Formation, Oligocene and Miocene in age, the Columbia River Basalt Group, Miocene in age, the Miocene Simtustus and Mascall Formations, and the late Miocene-early Pliocene Deschutes Formation (some maps refer to it as the Madras Formation or the The Dalles Formation). All of these formations are made up mostly of erupted volcanic materials, and include large quantities of ash, tuff, lava, mudflows, clays and sandstone. Material making up sedimentary units are mostly derived from volcanic rocks. Volcanics of the Clarno and John Day Formations are mostly silicic (andesites and rhyolites), while those of the other formations are mainly basaltic.

By far, most fossil leaf beds in central Oregon are found in tuffaceous siltstones from fossil lake or pond sediments. A signifiacant number of fossil leaf beds do occur, however, in rocks that represent ancient mudflows. Fossil leaves from the mudflow beds typically are to some degree rolled and curled, while those from quiet water sediments are usually flat-lying.

PAST WORK IN CENTRAL OREGON:

Thomas Condon, a pioneer preacher and naturalist, made the first noteworthy collection of fossil leaves in the area. This was in the last half of the 19th centrury. However, the most comprehensive early studies of Oregon fossil floras began in 1916. That was the year that young Ralph Works Chaney, a botany student in Chicago, took a suggestion that he look at some fossil leaves in the gorge of the Columbia River. The experience not only led to a life as a paleobotanist for him but to a series of monumental studies of fossil floras of the state of Oregon (Chaney, 1924, 1927, 1938, 1956, 1959). Although Chaney collected leaf fossils from China, Mongolia, Japan and much of the western half of the United States, he returned to Oregon over and over throughout the rest of his life. His last trip to the state was a sentimental journey with some of his past students in 1969, just two years before he died. Chaney collected from more than twenty major sites in Oregon (Ashwill, 1987).

Most paleobotanists presently working in America have collected in the area at least once. Four of these have made significant collections in central Oregon. Jack A. Wolfe of the United States Geological Survey, Gregory J. Retallack of the University of Oregon, Herbert W. Meyer of Salem, Oregon, and Steven R. Manchester of Indiana University together have added extensively to our knowledge of Oregon paleobotany.

SEVENTEEN SELECTED FOSSIL FLORAS FROM CENTRAL OREGON:

From the more than fifty fossil leaf localities known in central Oregon, the following seventeen have been chosen for discussion in this paper. Together, these floras illuminate what types of vegetation flourished in the region from Eocene time to Pliocene time. We as yet have found no significant fossil floras of late Pliocene nor Pleistocene time locally.

The ages of three of the localities studied have been measured. Ages of seven are estimates based on radiometric dating of overlying or underlying strata, and the remainder are based on stratigraphic position and correlation of floral components with those of other fossil floras in the western United States representing similar plant communities. When ages have not been confirmed by direct radiometric dating, a question mark is placed after age estimates.

HANCOCK FIELD STATION FOSSIL FLORA: LOCALITY MSA/F-38.

About forty four million years ago, at a place now known as Hancock Field Station, a remarkable assemblage of leaves, nuts, seeds and wood were entombed in sediments and became fossilized. The leaves remained impressions, but the nuts, seeds and wood were replaced by minerals. Thus they lend themselves to detailed study involving cross sectioning and microscopic examination (Bones, 1979; Manchester, 1981). Today, the spot is a paleobotanist's dream, and is usually the place first sought out when one arrives in Oregon. Collecting is restricted, and the field station is administered by the Oregon Museum of Science and Industry, Portland, Oregon. Situated in a little valley just off Oregon highway 218 between the towns of Antelope and Fossil, this rustic research and education center is unique, and has an impressive history.

The fossil flora at Hancock Field Station (table 1) includes lianas and a high proportion of trees that today grow mosty in tropical areas (Manchester, 1981). Retallack notes that red, highly weathered fossil soils associated with the nut beds are compatible with a warm, wet tropical paleoenvironment (Retallack, 1981). The climate at the time of deposition was tropical, and temperatures were warm, humidity high (Retallack, 1981, 1987). It is an astonishing experience to view the harsh landscape at Hancock Field Station today and envision the same place as a tropical jungle with palms, lianas and bananas growing there.

In addition to the presence of tropical genera, the morphology of the fossil leaves

Table 1

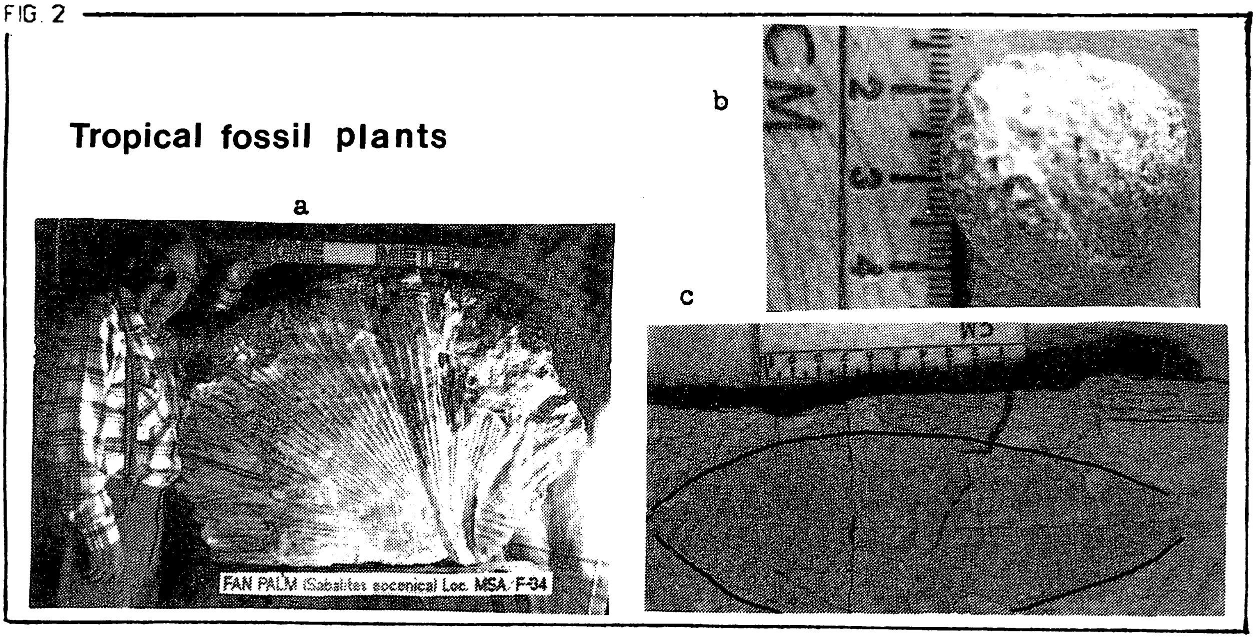
COMPARATIVE PLANTS LISTS FROM SEVENTEEN SELECTED FOSSIL FLORAS IN CENTRAL OREGON

	EOCENE	OLIGOCENE						MIOCENE							PLIOCENE		
GENUS OR FAMILY	Hancock Field Station Loc. NSA/7-38	Fossil, Oregon Loc. NSA/7-33	Kings Gap Loc. NSA/7-64	Sumner Spring Loc. NSA/7-1	Nichols Spring Loc. NSA/7-5	Canal Loc. NSA/7-8	Trail Crossing Loc. NSA/7-6	Bath Ranch Loc. NSA/7-16	Horsetrap Loc. NSA/7-69	Fulton Loc. NSA/7-15	Foreman Point Loc. NSA/7-17	Filbert Loc. NSA/7-72	Round Butte Dam Loc. NSA/7-49	Juniper Canyon Loc. NSA/7-7	Lamonta Loc. NSA/7-68	Deschutes Loc. NSA/7-14	[illegible] Loc. NSA/7-24
Isoetes (quillwort)								●									
Equisetum (horsetail rush)	●			●							●						
Dennstaedtiopsis (tree fern)	●																
Aristostichum (fern)	●																
Polypodium (fern)		●				●		●									
Salvinia (floating fern)					●												
Dioon (cycad)	●																
Ginkgo (maiden hair tree)	●		●								●						
Juniperus (juniper)												●					
Abies (fir)		●															
Picea (spruce)				●								●					
Pinus (pine)	●	●		●								●					
Metasequoia (dawn redwood)		●			●	●											
Taxodium (swamp cypress)								●			●						
Sequoia (redwood)				●				●			●						
Torreya (California nutmeg)				●	●												
Magnolia (magnolia)	●																
Anonaspermum (custard apple fmy.)	●																
Laurocarpum (laurel fmy.)	●																
Persea (avacado)											●						
Cinnamomophyllum (cinnamon)	●				●												
Ulminium (laurel fmy.)	●																
Litseaphyllum (laurel fmy.)			●		●												
Chandleria (moonseed)	●																
Odontocaryoidea (moonseed)	●																
Diploclisia (moonseed fmy.)	●																
Tinospora (moonseed fmy.)	●																
Cocculus (moonseed)											●						
Calkinsia (moonseed fmy.)			●														
Mahonia (Oregon grape)		●			●			●				●			●		
Cercidiphyllum (katsura tree)	●	●						●									
Liquidambar (sweet gum)								●		●	●						
Platanus (sycamore)	●	●		●	●		●	●	●			●					
MacGinitiea (ancestral sycamore)				●							●						
Ulmaceae (elm fmy.)		●		●	●	●		●	●	●	●	●					
Ulmus (elm)		●		●		●		●	●	●	●	●					
Celtis (hackberry)									●								
Zelkova (keaki tree)				●	●			●			●						
Chaetoptelea (elm fmy.)					●												
Morus (mulberry)		●															
Ficoxylon (fig fmy.)	●																
Castilla (fig fmy.)	●																
Fagopsis (beech fmy.)					●												
Castanea (chestnut)	●			●	●	●	●					●					
Quercus (oak)	●	●		●	●		●	●	●	●	●	●		●		●	
Betula (birch)					●	●	●	●									
Alnus (alder)		●	●		●	●	●				●	●		●			●
Ostrya (hop hornbeam)					●	●	●										
Paracarpinus (birch fmy.)		●			●	●	●	●			●						
Juglans (walnut)	●	●															
Carya (hickory)					●					●							
Pterocarya (wingnut)	●	●															
Engelhardia (walnut fmy.)	●	●		●													
Triplochitioxylon (ext. tree)	●																
Salix (willow)					●						●		●		●	●	
Populus (poplar, cottonwood, aspen)												●	●		●	●	●
Chaetomya (ext. tree)	●																
Hydrangea (hydrangea)	●	●															
Ribes (currant fmy.)												●			●		
Prunus (cherry fmy.)												●	●				
Holodiscus (ocean spray)												●					
Rosa (rose)						●				●		●			●		
Sorbus (mountain ash)		●						●									
Crataegus (hawthorn)		●			●	●		●		●		●		●			
Robinia (locust)										●		●					
Ptelea (hoptree)				●		●									●		●
Ailanthus (tree of heaven)				●		●											
Cedrela (chinese cedar)		●				●											
Bursericarpum (torchwood fmy.)	●																
Tapirira (cashew fmy.)	●																
Astronium (tropical tree)	●																
Dracontomelon (tropical tree)	●																
Tapiscia (bladdernut fmy.)	●																
Sapindaceae (soapberry fmy.)																	
Sapindus (soapberry)						●											
Dipteronia (maple fmy.)				●													
Acer (maple)		●		●	●	●	●	●	●	●	●	●	●			●	
Meliosma (agustilla)	●																
[illegible]	●																
Alangium (alangium)	●																
Mastixioidiocarpum (ext. genus)	●																
Langtonia (ext. genus)	●																
Paleophytocrene (tropical vine)	●				●												
Vitis (grape)	●																
Parthenocissus (vine)	●																
Berhamniphyllum (buckthorn fmy.)	●																
Musaceae (banana)	●																
Sabalites (fan palm)	●																
Typha (cattail)												●					

provide evidence supporting the temperature estimates.

Modern tropical deciduous trees typically have leaves that are large and with entire margins (no teeth on the edges). Trees growing in temperate areas usually have smaller leaves with toothed margins (Bailey and Sinnott, 1916). Pioneering studies correlating toothed/entire leaf margins with climate done by Bailey and Sinnott were largely unused for decades. Recently, Jack A. Wolfe and others have seen the validity of their concept (Wolfe, 1978) and are currently doing field work to establish further data bases by studying this phenomenon in several tropical and temperate localities.

FIG. 2



a-Large fan palm (Sabalites eocenica) b-Tropical liana seed (Paleophytocrene sp.) c-Avocado leaf (Persea sp.) approximately eight inches long.

Several fossil floras in central Oregon, including the Clarno Formation flora at Hancock Field Station, support the observation that the climate there in mid to late Eocene time was tropical (Chaney, 1956).

FOSSIL, OREGON FLORA: LOCALITY MSA/F-33.

The fossil plant association found at Fossil, Oregon documents the typical assemblage in central Oregon immediately following the major climatic cooling that took place in the beginning of the Oligocene epoch. The rocks of this flora have been age-dated at 32ma (Manchester, written comm., 1987). Wolfe feels that this climatic change was rapid (one to two million years duration), so the onset of the change is likely to have been 33ma to 34ma. Notably absent after the climatic change are such tropical and subtropical plants as palm, cycad, magnolia, cinnamon, fig, Engelhardia (tropical member of the walnut family), Tapirira (cashew family), Astronium (tropical tree), Meliosma (aguacatilla), and Paleophytocrene (tropical liana). Represented and typical of the temperate floras of the Oligocene in central Oregon are Metasequoia (dawn redwood), Cercidiphyllum (katsura), Platanus (sycamore), Ulmus (elm), Alnus (alder), Quercus consimilis (live oak), Juglans (walnut), Crataegus (hawthorn) and Acer (maple).

Seventeen percent of the dicotelydenous species found in this locality are entire margined, although several other localities in central Oregon thought to be of similar age produced percentages from twenty four to thirty four (Manchester and Meyer, 1987). Such measurements are indicators of a warm temperate paleoclimate at Fossil, Oregon 32ma.

The approximately ten to eleven degree (centigrade) decline in mean annual temperature believed to have taken place during the climatic deterioration is strikingly illustrated by the contrasting fossil plant communities of the

Hancock Field Station flora and the Fossil, Oregon flora.

GRAY BUTTE FOSSIL FLORAS:

Documentation of most of the temperature decline event itself has come to light through the discovery of a number of fossil leaf localities on and near Gray Butte, a 1,554m peak about 29km south of Madras, Oregon (Ashwill, 1983).

Of the more than twenty fossil leaf sites, some extensive, some very small, found in this area, five stratigraphically successive ones host fossil floral communities that begin with mainly tropical plants, change to mixed tropical and temperate plants, and finish with a typical lower John Day Formation (lower Oligocene) assemblage of temperate plants.

1-KINGS GAP FLORA: LOCALITY MSA/F-64.

This, the most recently discovered of the five floras, has not yet been well collected and studied. However, eleven different dicot species plus Ginkgo are known to be present. Of the dicots, about sixty to seventy percent of the species have entire margined leaves. This suggests that the paleotemperature at the site was tropical in nature. Leaf sizes and textures support this observation,. Only two of the genera, Ulmus (elm), and Alnus (alder) are also found in younger floras at Gray Butte.

2-SUMNER SPRING FLORA: LOCALITY MSA/F-1.

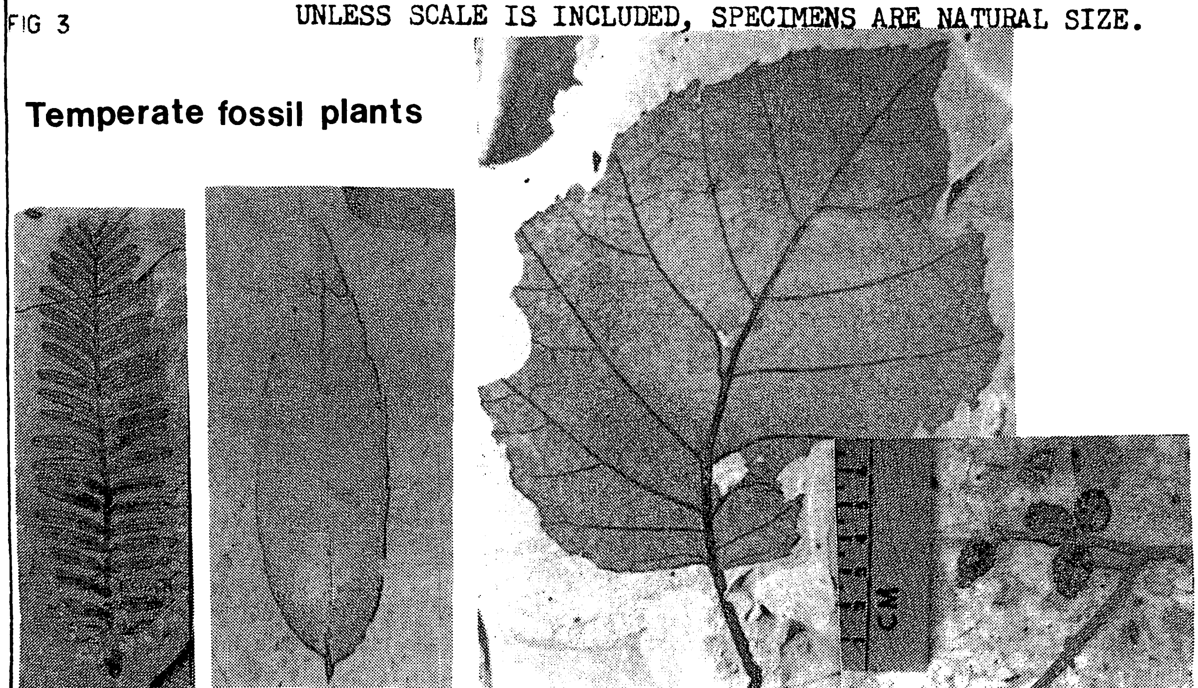
Plants found at this site are mixed tropical and temperate in affinity (Ashwill, 1983). Of twenty two identified taxa, five are today found in tropical or subtropical conditions only. Sixteen grow today in temperate regions, and several of this sixteen taxa also grow in tropical climates.

3-NICHOLS SPRING FLORA: LOCALITY MSA/F-5.

This flora also hosts mixed tropical and temperate plants (Ashwill, 1983). Metasequoia (dawn redwood), Mahonia (Oregon grape), Platanus (sycamore), Quercus simulata (live oak), Betula (birch), Alnus (alder), Crataegus (hawthorn) and Acer (maple) are typical of lower Oligocene plant assemblages in central Oregon. The three different maple species all are common to other fossil floras found in central Oregon and are of similar age (Wolfe, 1987).

FIG 3 UNLESS SCALE IS INCLUDED, SPECIMENS ARE NATURAL SIZE.

Temperate fossil plants



a b c d

a-Dawn redwood (Metasequoia occidentalis) b-Live oak (Quercus consimilis) c-Alder (Alnus sp.) d-Alder cones

Subtropical and tropical elements of this flora include Torreya (California nutmeg), Cinnamomophyllum (cinnamon), Litseaphyllum (laurel family) and Paleophytocrene (tropical liana).

4-CANAL FLORA: LOCALITY MSA/F-8.
In the Canal flora group of plants, tropical and subtropical elements are not present (Ashwill, 1983) All of the taxa found in this flora are common to many other "Bridge Creek" floras ("Bridge Creek" is a generic term often used in reference to the collective fossil floras found in the lower John Day Formation of central and eastern Oregon). The Bridge Creek flora (Chaney, 1924) was the first of these floras to be well studied.
Notable is the large number of twigs of Metasequoia (dawn redwood) found in this flora. Metasequoia today is a streamside tree found in the mountain valleys of central China. Although this genus has been found in older floras, it commonly is abundant in the "Bridge Creek" floras.

5-TRAIL CROSSING FLORA: LOCALITY MSA/F-6.
This fossil flora is located stratigraphically about 60m higher than the Canal flora. Plants found at this site are also typical of the "Brige Creek" floras. The assemblage differs from the Canal flora mainly in the absence of Metasequoia. This may be the result of climatic change, or it may have happened because of local topographic changes.

The five Gray Butte floras, all within a 2.5km radius and in apparent stratigraphic succession have recorded the major climatic deterioration of the early Oligocene epoch.
The age of the Gray Butte area is presently unclear (Bishop and Smith, 1990). A radiometric measurement (Robinson, 1975), stratigraphic and fossil evidence (Smith, 1986; Ashwill, 1983) indicate an Oligocene to early Miocene age. Radiometric ages of a 1987 study suggest a late Miocene age (Obermiller, 1987). When funding becomes available for the making of definitive age determinations of the strata hosting the five Gray Butte floras discussed, we should have a more clear perception of the time involved in this dramatic climatic cooling event.

HEATH RANCH FLORA: LOCALITY MSA/F-16.
The John Day Formation of central and eastern Oregon is known to host numerous fossil plant localities in its lower strata and numerous vertebrate fossil localities in its upper parts. The two types of fossils in general seem to be somewhat mutually exclusive in their occurrence. The Heath Ranch fossil flora near Warm Springs, Oregon is an exception to this generality. It lies near the middle part of the formation and fills a longstanding gap in the paleontological record.
The fossil site is located near the mouth of the Warm Springs River. It is exposed in a small hill at the base of a steep 300m slope in the clay-rich John Day Formation. Landsliding is common nearby, and we cannot at present be certain that the site was not originally higher stratigraphically than it is now If it presently lies in its original stratigraphic position, it is likely to be about 27ma in age. If it has moved downslope, it is younger, but not likely younger than 22ma. More precise age estimates must await age determination of the site, or further geological field study.
The plant community collected at the Heath Ranch site indicates that the paleoclimate was moist, warm and equable. The presence of Taxodium (swamp cypress) suggests that the plants were growing in a lowland area. The oak leaves found here as well as in all other local floras younger than this one were lobed in contrast to the live oak leaves found in older sites (Fig. 4). This alteration of leaf morphology is thought to be the result of environmental stress because of changing climate.

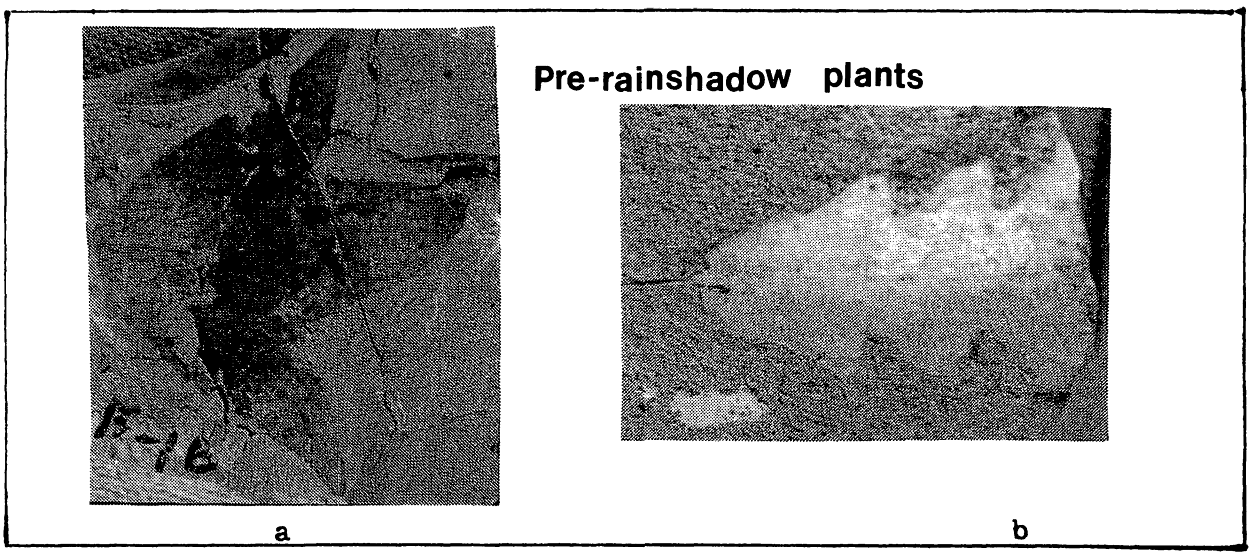
PELTON FLORA: LOCALITY MSA/-15.
Near Pelton dam on the Deschutes River, the Pelton flora occurs between two flows of the Columbia River Basalt Group. The lower of the two flows has been age-dated at about 15.7ma (Smith, 1986).
Among the plants listed in table 1 for this site, the two species of lobed oak, Robinia (locust), rose, and Crataegus (hawthorn) suggest a possible drier weather regime for this site at the time the trees grew here than regimes of older sites.

FOREMAN POINT FLORA: LOCALITY MSA/F-17.

The fossil leaves near Foreman Point just north of the Warm Springs Indian Reservation lie immediately beneath a flow of Columbia River basalt. Although a lower flow is not exposed at this place, lithology of the host rocks as well as chemical and magnetic polarity meaurements of the flow makes it seem likely that the occurrence is between the same two flows as those that encase the Pelton flora (Gary A. Smith, personal comm., 1985). The age of the flora is probably about 15ma.

At about the time these lavas were erupted, the High Cascade Mountains (a later developement than the Western Cascade Mountains) were beginning to be formed. Looking for signs of increased aridity in the fossil floras deposited at this time does not produce unambiguous evidence of any considerable rain shadow from a growing mountain range. The High Cascades apparently were not elevated enough at the time to be reflected in the fossil plant assemblage. The plants at the Pelton site contain some trees that grow in somehat dry conditions, and this was at first sight taken to indicate a drying trend at the time of deposition. However, subsequent discovery of the Foreman Point fossils by Harry Phillips of Warm Springs, Oregon seems to negate this possibility. The plant community growing at Foreman Point 15ma is a diverse one, includes three conifer species (one of them swamp cypress) and the last Ginkgo (maiden hair tree), walnut and avocado so far found locally. Conditions were obviously quite moist when this group grew. It seems probable that the Pelton flora represents plants growing on a drier, perhaps sloping site. The Pelton and Foreman Point floras are roughly age-equivalent to the Mascall flora found about 140km to the east (Chaney, 1959).

FIG. 4



a-Sweet gum (Liquidambar sp.) b-White oak (Quercus sp.)

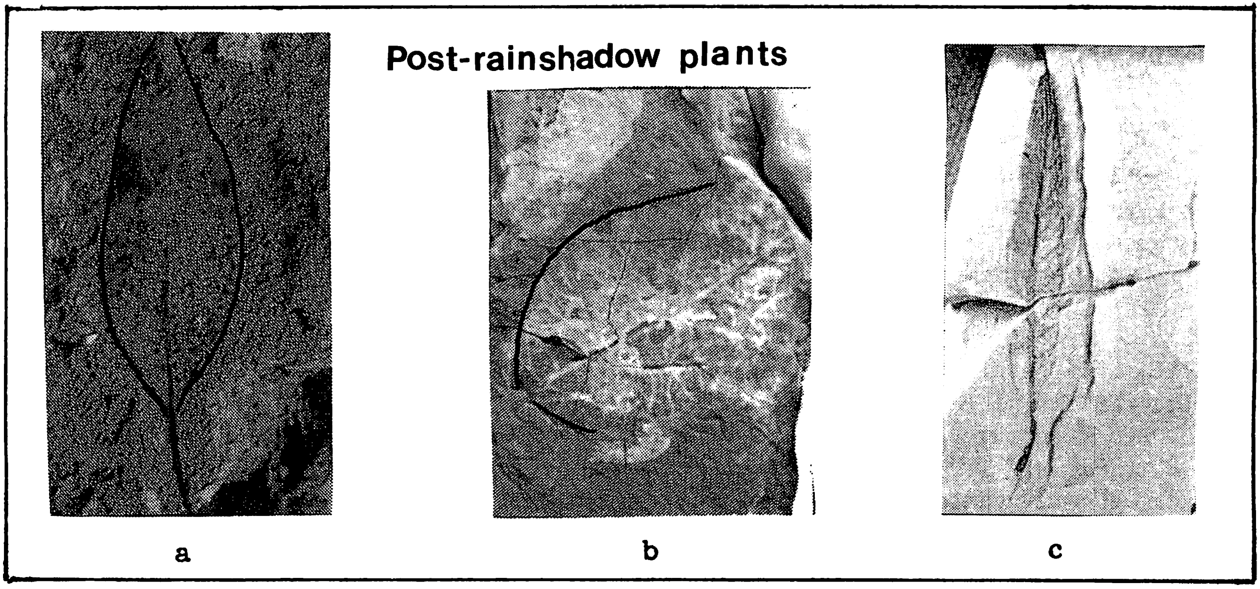
VIBBERT FOSSIL FLORA: LOCALITY MSA/F-12.

A mudflow that traveled down the ancestral Deschutes River about eight million years ago left a good record of the vegetaion that bordered the stream near the town of Gateway, Oregon. Until the discovery of this flora, it was believed by many geologists and paleoclimatologists that by this point in time the High Cascade Mountains probably had become an effective barrier to the Pacific Ocean moisture. The finding of a fairly diverse mixed conifer-hardwood forest in the fossil record of that time shows that not to have been the case. It is true that most of the genera found at the Vibbert locality grow today in the drier areas of America. Certainly, all of the tropical and subtropical elements had disappeared from the scene by then. Castanea (chestnut), and Platanus (sycamore) make their last local appearance in this flora. The spruce (Picea) is surprising, since it today is mostly an upland or very moist lowland tree. Nevertheless, close scrutiny of the plant aggregation shows that with these few excetions, modern equivalents to most can be found growing either in the immediate vicinity, or in the nearby Cascade Mountains. Crustal uplift and mountain building was making itself felt 8ma, but not to the extent seen today.

ROUND BUTTE DAM FOSSIL FLORA: LOCALITY MSA/F-49 and JUNIPER CANYON FOSSIL FLORA: LOCALITY MSA/F-7.

These two small floras, although several miles apart, are both situated approximately the same vertical distance stratigraphically above the Pelton basalt, which has been age-dated at 7.4ma. They are probably about six million years old. With only Populus (cottonwood), Salix (willow), Quercus (white and black oak), Alnus (alder), Crataegus (hawthorn), Prunus (chokecherry) and Acer (maple) present in these fossil floras, we now see a depauperate assemblage that illustrates a marked decrease in annual rainfall in the area. The High Cascade Mountains had by 6ma made a very noteworthy impact on the local climate, abetted by a general crustal uplift of the entire region about seven million years ago (Edward Taylor, Oregon State University, pers. comm. 1987)

FIG 5



a-Hop tree (Ptelea sp.) b-Chokecherry (Prunus sp.) c-Willow (Salix)

KAHNEETA FOSSIL FLORA. LOCALITY MSA/F-68, DESCHUTES FOSSIL FLORA. LOCALITY MSA/F-14 and REHERMANN FOSSIL FLORA: LOCALITY MSA/F-24

These three localities all are located about eighteen meters below the rimrocks of the Agency Plains lava flow, which has been age dated at about 5ma. The Deschutes flora site has been age dated twice, one reading being 4.4ma, and the second 5.4ma. The 4.4ma reading is likely spurious.

When Chaney studied the classic Deschutes flora (Chaney, 1938), he listed only five species. Later, the two impressions identified as Prunus irivingi (chokecherry) were reassigned to other genera. Since then the author has found one impression of Quercus (white oak) in stream sands at the base of the deposit. The number of species for the Deschutes flora thus remains at five.

Adding to this from the Kahneeta flora Mahonia (Oregon grape), another willow (Salix), another cottonwood (Populus), currant (Ribes), rose (Rosa), and from the Rehermann flora Ptelea (hop tree) we still have only eleven species of plants that are known from this final chapter in the story of past plant life in the Madras, Oeregon area. All of the genera except Ptelea are found today growing either at streamside locally or in moister areas within a few miles of the sites.

The dry-climate aspect of these last plant assemblages reinforce the observation that the local climate underwent a marked change in the direction of aridity about seven million years ago, and with undoubted irregular swings, has continued in this trend to the present.

Unfortunately, no fossil floras younger than five million years of age have so far been located locally. Geological reasons for the change from depositional to erosional conditions bringing about this lack are explained by Smith (1986)

CONCLUSIONS:

The paleoclimate indicators of central Oregon fossil plant assemblages point to an early Oligocene major cooling of the formerly tropical climate to that of a more temperate regime. This parallels observations in many parts of the northern hemisphere.

Similarly, the continued cooling and drying conditions of Miocene to recent time in central Oregon mirrors northern hemispheric trends. A combination of regional uplift and High Cascade Mountains construction created a rain shadow about 7ma that resulted in a depauperate fossil flora in later deposits. The semi-arid climate created continues today in the area.

Generally, the highly diverse floras of Eocene time in this region were replaced by less diverse floras. Plants dependant on equable, warm, moist conditions became more and more rare in the record as time progressed. Finally, most of the more primitive plants are missing from the late Mio-Pliocene record in central Oregon. The survivors in this semi-arid paleoenvironment are plants that have evolved characters needed to live under harsh condtiions.

ACKNOWLEDGEMENTS:

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IMPRESSIONS OF FALLEN LEAVES

Fossil leaves reveal a great deal about the evolution of flowering plants, and about ancient enviornments.

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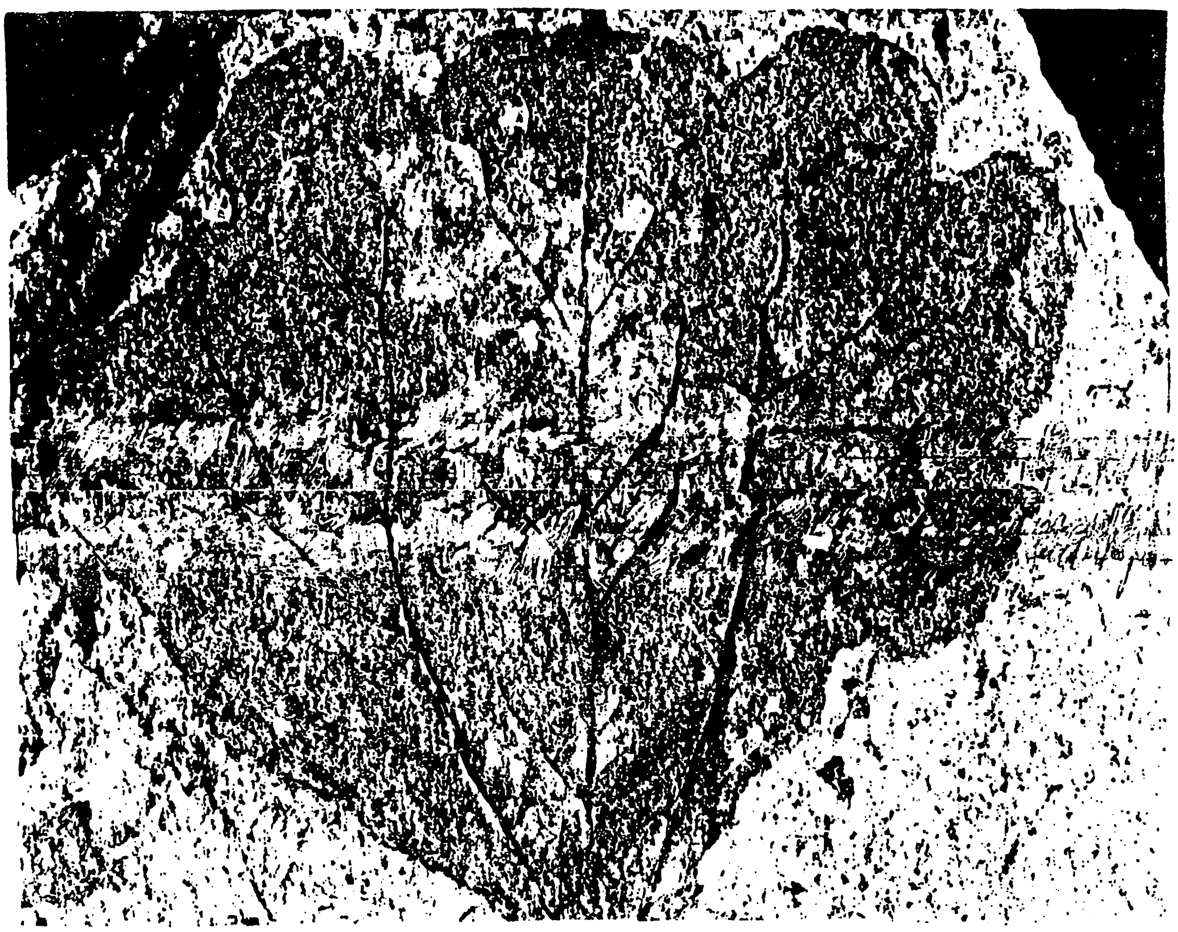
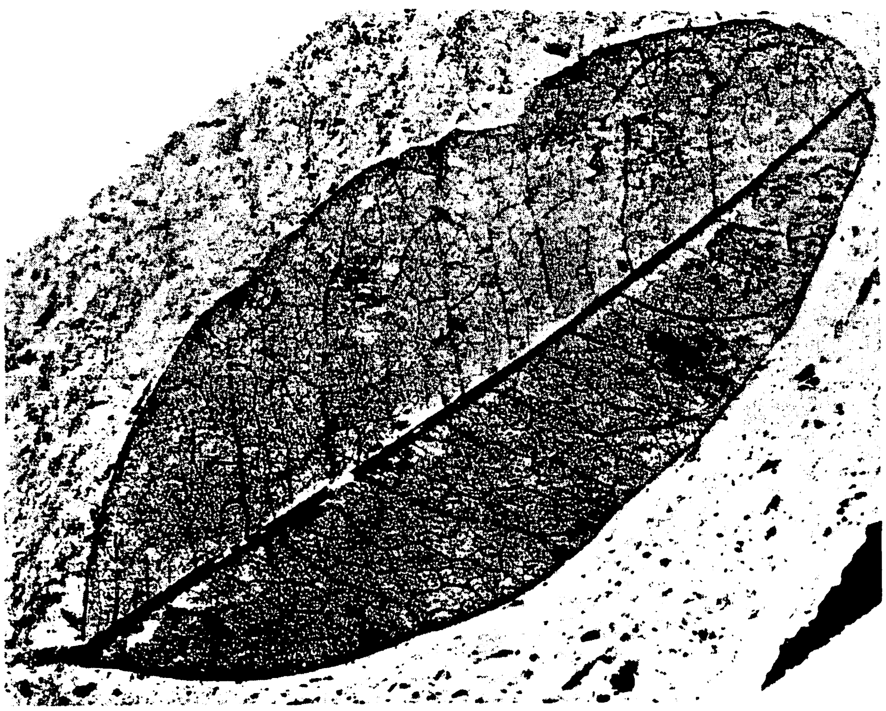
The wonderful thing about a plant to a paleontologist is that nearly any part of it can become fossilized. Fossils of animals are almost entirely of the hard parts: bones, shells, teeth, or scales. It is unlikely that a paleozoologist will ever see the soft parts of an extinct animal-parts that had crucial functions such as digestion, circulation, and reproduction. Paleobotanist do find leaves that were the site of photosynthesis and respiration; wood that carried water and nutrients and gave support; roots that took in fresh nutrients and anchored the plant to the ground; fruits or seeds that were the method of dispersal; and flowers and pollen, a plant's reproductive organs.



However, the catch to the completeness of the fossil record of plants is that parts are seldom found attached to one another. It is often difficult to match a fossil fruit with the corresponding fossil leaf, wood, or pollen. As a result, paleobotanists tend to study dispersed organs independently; that practice has complicated interpretations of biology and relationships of fossil plants species.

Another problem for paleobotanists interested in angiosperms, or flowering plants, is that living angiosperms are classified mainly by characteristics of their flowers. Unfortunately, flowers are rarely preserved in the fossil record because they are so fragile. That means paleobotanist must generally depend on fossil leaves, fruits, and seeds,wood,or pollen. Those parts of fossil plants may be hard to place in existing plant groups because the leaf (or wood or fruit) characteristics of living plants are not well known.
Leaves cannot be transported very far in most river environments without being destroyed. Most leaves are fossilized near the plant that produced them.

During the 19th century and first half of the 20th century, paleobotanists tried to identify fossil leaves by comparing their overall shapes to leaves of living plants. That didn't work well because plants of many families have evolved leaves of similar shapes. For instance, leaves of sycamores and maples look alike, but the families are distantly related to each other. The tendency for distantly related plants or animals to evolve similar features is common and is called Convergence. Convergence generally results from natural selection that favors strongly a particular trait. Convergence is frequently detected by studying the trait in greater detail. Because a particular trait developed in two different species through different evolutionary paths, the detailed structure of the trait is generally different.



These leaves are from lower Eocene rocks of Wyoming. Above, one is entire-margined. Left, the other has large rounded teeth. Entire-margined leaves are more typical of warm climates. (From Scott L. Wing)

To avoid problems caused by convergence in overall leaf shape between many groups of angiosperms, paleobotanists have recently begun to study leaves of living plants in great detail. Those studies have shown that patterns of leaf venation and epidermal cells on the leaf's surface are consistent within major plant groups. It is often possible to identify plants solely on the basis of their leaves. Applying such knowledge to the fossil record allows paleobotanists to identify leaf fossils that are not associated with flowers.

The study of fossil leaves has also revealed evolutionary changes in their structer. Leaves of the earliest flowering plants (from Lower Cretaceous rocks-those that are about 140 million years old) had disorganized venation, and patterns formed by the epidermal cells were inconsistent. Through time, angiosperm leaves develpoed greater regularity in the course and thickness of their venation, presumable resulting in strongr leaves less likely to rip. Increasing organization of the veins was accompained by more consistent patterns of epidermal cells arrangement. During the late Early and Late Cretaceous there was also a great increase in the diversity of leaf types. The increased diversity indicates that angiosperms were beginning to occupy a wide range of habitats; they were probably replacing gymnosperms (seeds plants lacking flowers, for example, conifers and the gingko) as the dominant group of land plants. The early evolution of angiosperms and their rise to dominance can be traced by studying fossils of their leaves.

Fossil leaves are also useful in reconstructing environments of ancient river flood plains. Because they are so fragile, most leaf fossils are perserved and fossilized near the plant that produced them. Consequently, distribution of fossil leaves in a layer of mud or sand mirrors the original distribution of plants on the ancient flood plain. In modern river systems different parts of a flood plain support different kinds of vegetation; the same pattern has been recognized in fossil floras collected from sediments deposited on ancient flood plains. Fossil leaves can help determine whether the sediments that contained them were deposited , for instance, on a river levee or a low-lying swapm.

Analysis of ancient climates is another area in which fossil leaves are important tools. Botanists have observed a relationship in living plants between the shape of their leaves and the climate they inhabit. Tropical floras have a higher percent of species with large entire-margined leaves (those lacking any teeth or lobes). Floras that grow in colder climates have more species with small leaves that have teeth or lobes. There is a close relationship between the mean annual temperature in which a flora grows and the percent of species in the flora that have entire-margined leaves. That relationship can be used to 'predict' the mean annual temperature in which fossilized floras grew. Using that technique, paleobotanists have reconstructed cooling and warming episodes that took place over the last 60 to 100 million years.

In North America where many well-known fossil floras occur, the late Mesozoic and the first half of the Cenozoic were generally times of warm climates. The early part of the Eocene epoch probably was the warmest period during the Cenozoic. At that time subtropical floras grew in northern states like Wyoming and North Dakota. Leaf-margin analyses indicate that the mean annual temperature in which the floras grew was about 20 C- it seldom, if ever, froze. During the early Eocene warm-temperate floras grew within the Artic Circle.

The fallen leaves of ages past give valuable information to those interested in ancient environments, past climates, and the evolution of flowering plants. However, interpreting fossil leaves require a broader understanding of living plants and their environment.

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LEAVES & GRASSES

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No two living things could be named, let alone coupled, upon which so much of the present array of faunal life completely depends as leaves and grasses.

The chemistry of carbon, hydrogen, oxygen, nitrogen, and phosphorous, with help from sodium, potassium, calcium, and iron plus trace elements have combined to peak in evolving our brain tissue through the food chain of plant materials. The raw material for double helix replication is fueled mostly by them. DNA and RNA are married to Ls and Gs. What and where would our civilization be without wheat, rice, beans and corn? What would the Ancient Greeks have done without grape leaves? What would Western Civilization have done without grapes? What would Isaac Newton have done without the apple? Albert Einstein without Matzo balls? How could John von Neumann have discovered a new extension of Böolian algebra for high speed computer design without mucilage (to keep him regular)? And Wolfgang Amadeus Mozart without the Sacher Torte (to keep him creative)?

Monumental shrines should be erected to LEAVES & GRASSES because they underpin all present civilization. Consider the madness for MacDonalds--without grasses there would be no cows--without cows where would we get a BIG MAC? The debts are endless.

A good place to look for fossil leaves in the Midwest is the MAZON CREEK AREA: This area contains an abundance of plant fossils. Illinois is one of the richest states in Pennsylvanian plant and animal remains. These fossils precede the developmant of flowering plants and grasses. However, the loose classification of "leaves" can be considered to fit the context. The common Neuropteris pinnules really strike one as "leaves" when an iron carbonate concretion is split open on the banks of Mazon Creek at Benson's or Carr's farms. The sense of belonging to the evolution of life on our planet is pleasingly driven home when one opens a concretion collected in the famous Mazon area to see the very old, sharply veined, black-colored leaf--the firm, heavy, solid-feeling siderite concretion--a real physical thing--a reality with mass. Wonderful to collect, store and display.

The classification, the taxonomy, the analysis, all come later after the emotional excitement subsides. Most collectors of fossils, be they paleontologists, archeologists, biologists, or simply amateurs (undisciplined lovers of a discipline) are driven by the pleasure of anticipation in uncovering the unexpected or the more beautiful specimen of a known or unknown plant or animal.

Fossil hunting is a social contract with man and his past. It is possible to establish a parameter which makes the past representation "come to life." Any good writer can do it. Stephen Gould, Harry Whittington, Conway Morris, for example, bring the Cambrian Sea to life so vividly that one can almost see the forms swimming about. In The Fossil Book by Carrol and Mildred Fenton many past ages are clothed in a prose reality so colorful and interesting that one feels a part of the landscape when touring the fossil horizons they describe.

Get out to the volcanic ash shales of Florissant, Colorado, or to the Green River shales of Kemmerer, Wyoming, or to the Cretaceous mesas of Central Texas, or to the coal fields of Northern Illinois, or to many other places in our vast country (especially Tertiary formations) where leaves and grasses of the past eras abound.

For assistance in identification, consult the following references:

Leaves and Stems from Fossil Forests - Raymond E. Janssen
The Wilmington Coal Flora - George Langford
Correlation and Palynology of Coals, etc - Russel S. Peppers

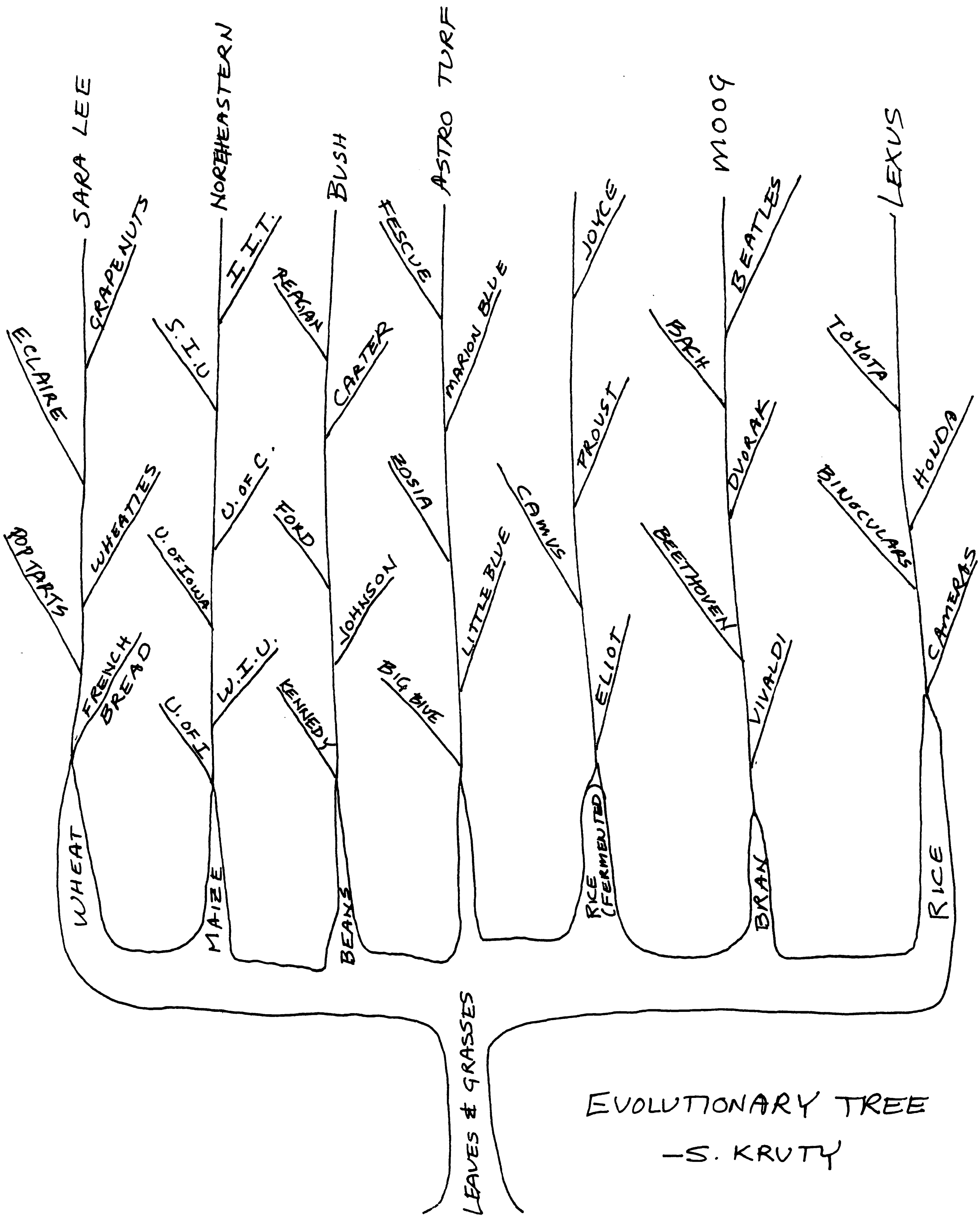
GOOD LUCK! TO ALL YOUNG FOSSIL HUNTERS

Leaves and grasses
feed the masses
of which there are
two kinds --
Those whose mirth
leaves all in worth,
and those who scar
young minds.

So beware lads and lasses,
differentiate your grasses.
Seek the stony lines
not the serrated leaves.
Hunt the fossil kinds
not the coca's cleaves.
Help your budding minds
forget the poppy's seeds.

January 17, 1990
Samuel Kruty
Research Fellow, UNI
Chicago

Samuel Kruty



EVOLUTIONARY TREE

—S. KRUTY

PLANT FOSSILS FROM THE MAZON CREEK AREA

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Plant fossils from the Mazon Creek area have been known for over one hundred years and represent Upland Flora (to a small degree), near shore, swamp, and even marine forms. The original discoveries occurred in the shaft mines near Coal City and on the Mazon River southwest of Chicago. Along the river, several outcrops of the Carbondale Formation can be found and erosion along the banks exposed the nodules which through frost action cracked open and exposed the well preserved animals and plants of the Francis Creek Shale. The plants and animals preserved are molds with occasional carbonization and replacement by other minerals including kaolin, calcite, galena, sphalerite, pyrite and marcasite.

Because the fossils are molds, the two sides are not identical and identification is sometimes complicated by only finding one half. Another complication is due to the necessary use of both form genera. (Genera described by general shape of the plants) as well as true genera based on familial relationships. Since many of the plants are ferns (both seed ferns and true ferns occur), this further complicates the identification because of the tendency of the veination and shape of the leaves to be determined by the stage of development of the plants and whether the pinnules are sterile or fertile. Mature pinnules look different than juvenile pinnules and the pinnules grow and divide into more pinnules by a process known as pinnatification, so many intermediate steps are possible. The last complication arises because of the preservation of many little pieces of a plant instead of large sections being preserved at one time. This led to the description of many portions of the same plant being described as different plants. This last complication was further compounded by the description of many of the same plants in Europe and the U.S. by different authors using different names for the same plants.

There is an impressive list of authors associated with the Mazon Creek Flora. [1&2] Leo Lesquereux published his studies on fossil plants from Illinois in 1866 and 1870 and additional work in his three volume work *Description of The Coal Flora of the Carboniferous Formation in Pennsylvania and Throughout the United States* (1879, 1880 a,b, 1884). R.E. Janssen, E.H. Sellards, A.C. Noe, W.C. Darrah, Jongmans, Arnold, Robert Kosanke, Herman Pfefferkorn, R.A. Peppers, T.L. Phillips and others all made significant contributions both in compression flora and in spore and other studies relating to the Mazon Creek Flora.

Many of the original specimens were collected by amateurs and that tradition still continues to this day. The Langfords, McLuckies, J.C. Carr, Daniels, Thompson and other early collections formed a significant part of early studies. While Helen and Ted Piecko, Stephen LeMay, Frank Greene, Helen Asher, Walter Dabasinkas, Jim and Sylvia Kopeckny, Mildred Scheffel, Wilbert Rath, Richard Rock, Dan Damerow and others found significant specimens and collections more recently. The chain of significant finds still continues with various collectors still finding quantities of new and different animals as well as some plants. The large amounts of significant plant finds is not continuing at the same rate due to the covering of the strip mine hills both by recovery of the land and by the natural growth of plants covering the strip mine hills. Recovery of the land at times allows collection of large amounts of concretions for a short period of time, however the collecting is usually short lived.

The Francis Creek Shale is the member of the Carbondale Formation that contains the fossiliferous concretions. The correlations present in Figure 1 and 2 [1] compare the Carbondale Formation with other mid continent North American and also European, Russiand and Appalachian names. The Mazon Creek Flora is Westphalian D/Stephanian A in age, and forms found in both these time divisions in Europe are also found in Illinois.

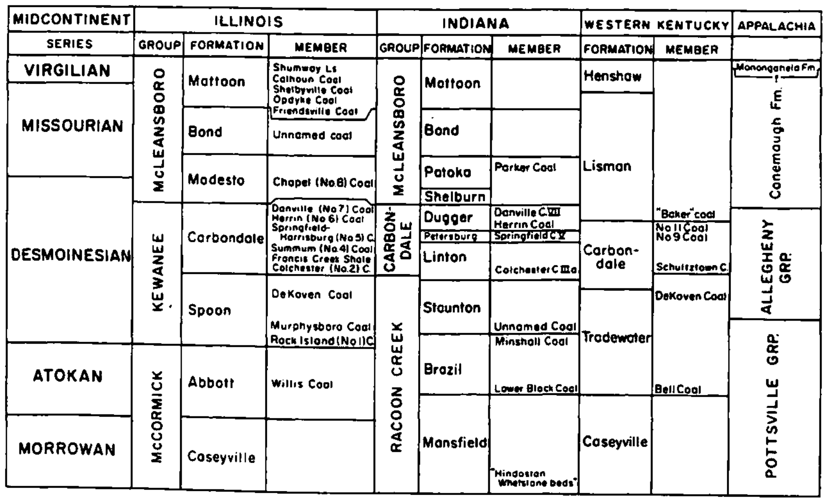

Fig. 1 - Correlation of Pennsylvanian strata in the Illinois Basin and adjacent regions. Names of significant members mentioned in text are shown (after Kosanke et al., 1960; Shaver et al., 1970; Smith and Smith, 1967; and Mullins et al., 1965).

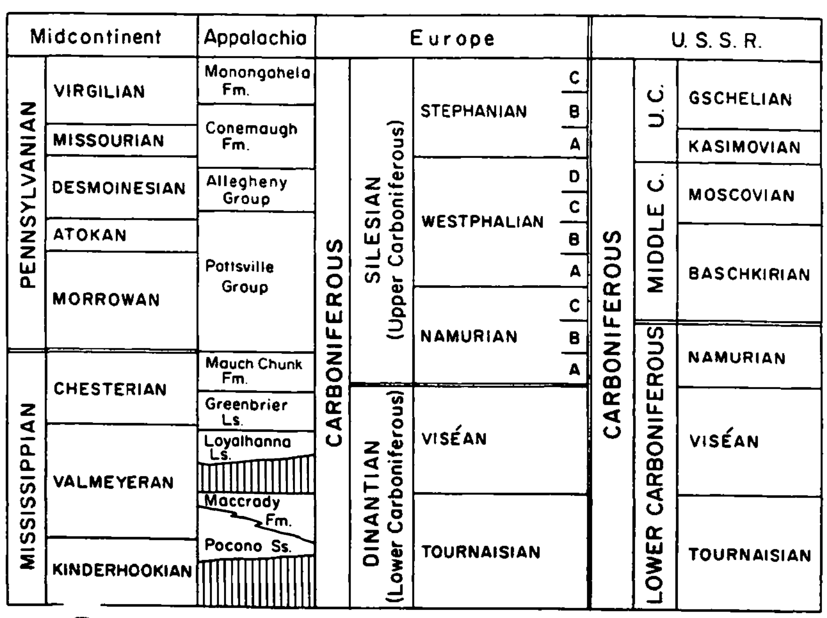

Fig. 2 Correlation of the time-stratigraphy of the Mississippian and Pennsylvanian Systems in the Midcontinent with that of the Carboniferous of Europe and the U.S.S.R. (based on data published by the International Carboniferous Congresses).

The map of the Mazon Creek Area in figure 3 [1] includes most of the concretions containing shaft and strip mines except for the Morris area, Astoria, and some strip mines in the area near LaSalle, Il. Some of these mines are in largely marine areas and have fewer plants that in general are not as well preserved (however excellent plants do occur in the marine areas also). Terre Haute, Ind. also has concretions of approximately the same age, but are somewhat older than the Mazon Creek material, coming from the Brazil Formation, and while some of the species overlap they should not be considered as part of the same Mazon Creek Flora.

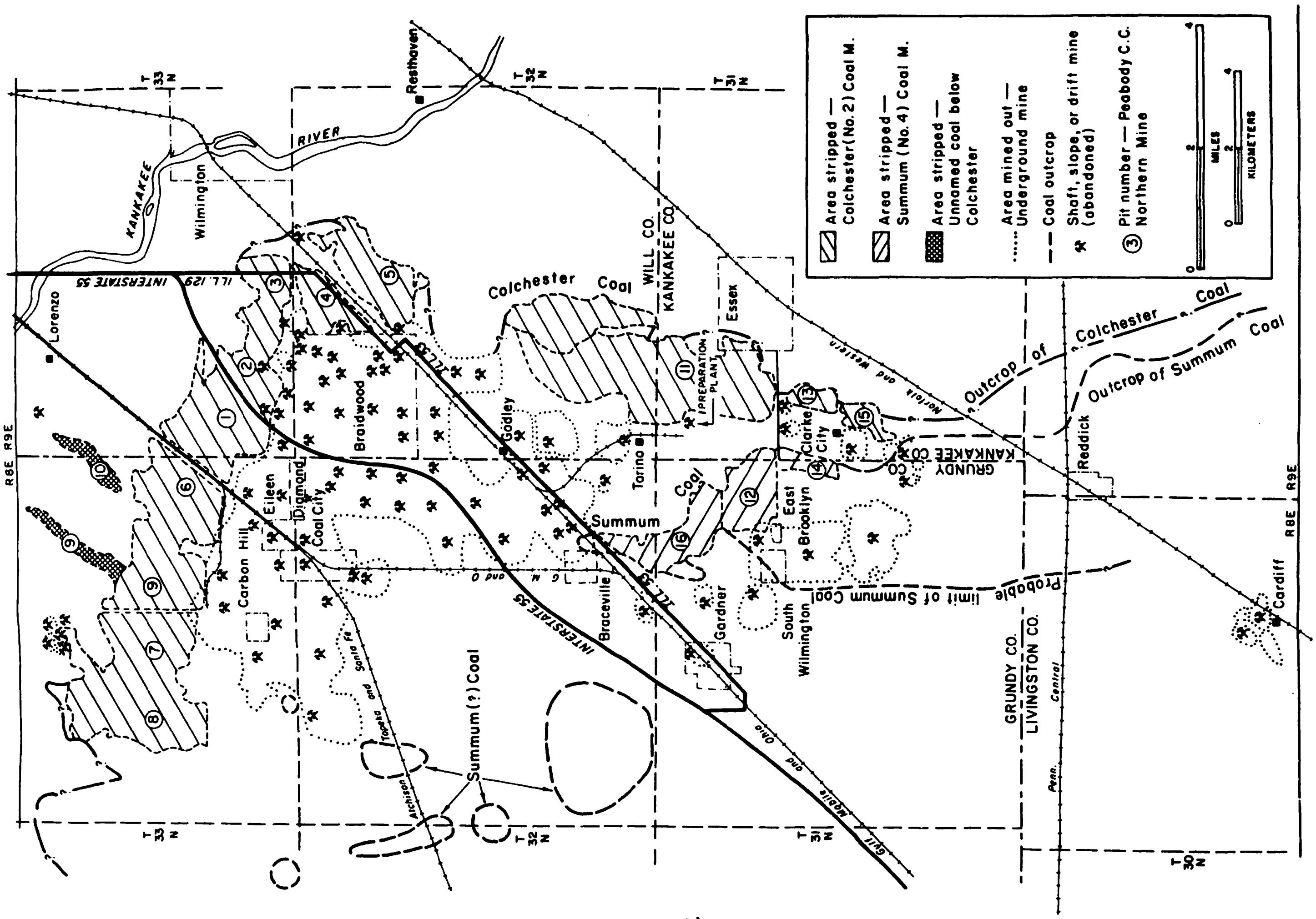

Fig. 3 · Mazon Creek area, famous for its compression-impression plant flora. (Map prepared by W. H. Smith, Illinois State Geological Survey.)

Many of the locations are not currently collectable because of private ownership of the land, levelling of the strip mines, over weathering of the concretions, or because the collecting areas are becoming overgrown. Collecting is diminishing also because the Carbondale Formation produces a relatively high sulfur coal which is not used anymore because of pollution aspects - and mining has now ceased in the area.

The concretions occur in the Francis Creek Shale 2-9 feet above the Colchester (No 2.) Coal [3]. In the shaft mines the Francis Creek Shale was removed and dumped in piles around the shaft because the coal layer for the most part was only 24-36 inches thick and the shale was removed to allow supports for the roof. The strip mining areas sometimes mined bothe the Lowell Coal and the Colchester Coal, but both these coals are bituminous high sulfur coals and mining halted about 1973.

The Pit 11 area (world famous for its diversity of animal life) was the result of a delta[4] which caused deposition of sediment rapidly burying plants and animals from both the land side and from the marine side. This rapid burial preserved even soft bodied forms of life. The plants, however, had been transported longer distances and so for the most part smaller plants are preserved because of breakage and decomposition.

The concretions are mainly siderite or iron carbonate. Siderite forms when iron rich material is introduced into a carbonate rich environment in the presence of some alkalinity. It appears that the concretions formed when the mud run off was introduced into the sea water at the mouth of the delta.

Alkalinity was apparently provided by the partial decomposition of amino acids releasing ammonia.

The other locations have long been thought to have been swamp deposits. Recent ideas point to different local habitats containing different plants. *Cordaites*, *Artisia*, *Cordaicladus*, *Cordaianthus* and *Cordaicarpus* are all portions of *Cordaites*, an Upland Plant. In most areas *Cordaites* fossils are not very prevalent in the Francis Creek Shale though there have been some complete leaves found 30 cm. or more in length. *Cordaites* leaves are long, strap like leaves with longitudinal veination and relatively wide attachment. *Cordaites* is an Archigymnospermae[5] and is related to Ginkgo trees. It makes up less than 2% of the plants[5] and in my collection it is considerably less than 1% of the specimens. The small number of these fossils found is evidenced by the poor representation of photographs in the books on the Mazon Creek Flora. There is a good photograph of a partial leaf in A.C. Noe' *Pennsylvanian Flora of Northern Illinois*, and an additional photograph in George Langford's *The Wilmington Coal Flora* of another partial leaf. Most of the other portions of *Cordaites* including the seeds, cones and wood are much better represented indicating that the leaves were probably fragile and that the place of origin was some distance away from the spot where preserved.

The Lycopods were probably fairly closely associated with *Calamites* because even though they make up only a small percent of the fossils - 6-14% [6]- they make up a large percent of the spores in the #2 coal - again indicating a distance away from the source. The Lycopsids preserved are *Lepidodendron*, *Lepidophloios*, *Sigillaria*, *Asolanus*, *Omphalophloios* (bark of trees), *Lepidophylloides* (*Lepidophyllum*) (leaf), *Lepidostrobophyllum* (Cone bract leaf), *Lepidostrobus* (Cone with microspores), *Lepidocarpon* (Cone with mega spores), *Sigillariostrobus* (Cone), *Sporangiostrobus* (Cone), *Stigmaria* (root), *Selaginites* (leaf) and *Ulodendron* (branch scars). Lycopods are more prevalent (as are the Cordaites specimens) in the area on the north side of the collecting area near Morris, Il.

The Sphenopsids, Filicinae, and Pteriodosperms are more closely associated with one another in the Wilmington-Braidwood areas and even extending into Pit 11. The Sphenopsids or horse tails include the genera *Calamites* (Pith cast of the stem), *Annularia* (leaf whorls), *Asterophyllites* (leaf whorls), *Calamostachys* (Cone), *Palaeostachya* (Cone), *Macrostachya* (Cone), *Sphenophyllum* (leaf whorls), *Sphenophyllostachys* (Cone) and *Bowmannites* (Cone). The horsetails are closely related to modern horsetails or *Equisteum* only in many cases they were much larger.

The Pteridosperms or seed ferns included many form genera for the foliage which are often equivalent to natural groups.[7] *Neuropteris, Linopteris, Cy*clopteris, *Odontopteris, Alethopteris, Desmopteris, Mariopteris, Sphenopteris* (part of this form genus are also true ferns) and Diplothmema are the various form genera for the leaves. Male fructification names are *Codonotheca, Whittleseya, Schopfitheca, Dictyothalmus*, and *Dolerotheca*, while seed names include *Trigonocarpus, Holcospermum, Samaropsis, Codonospermum, Carpolithus, Neuropterocarpus* and *Perispermum*.

The Filicinae or true ferns contain both tree ferns and forms more closely resembling ground ferns. The tree fern leaves if they are sterile should be called *Pecopteris*. The fertile tree fern foliage name are *Asterotheca, Acitheca, Ptychocarpus*, and *Radstockia*. The stem is *Psaronius* in coal balls or *Megaphyton* or *Caulopteris*.

Aphlebia is an irregular basal pinnule of the tree ferns and ground ferns. The other ferns sterile foliage are *Alloiopteris, Sphenopteris* and *Rhodea.* The fertile forms are *Dactylotheca, Senftenbergia, Oligocarpia, Renaultia, Hymenotheca* and *Corynepteris.*

Crossotheca, Myriotheca and *Zeilleria* are fertile foliage genera which may be true ferns or seed ferns.

This last section is modified in form from *A Comparison of the Floras of the Colchester (No. 2) Coal and Francis Creek Shale,* [6] and is used because it does an excellent job of relating the various names associated with the plants of the Mazon Creek area.

If identification of plants of the Mazon Creek area is desired, the following books may be of help.

The American Species of Asterophyllites, Annularia and Sphenophyllum by Maxine Langford Abbott, Paleontological Research Institution, Bulletins of American Paleontology, Vol. XXXVIII, No. 174, 1958

Pennsylvanian Plant Fossils of Illinois, Educational Series 6 by Charles Collinson and Romayne Skartvedt. Illinois State Geological Survey

Upper Pennsylvanian Floras of North America, William C. Darrah, 1969

Leaves and Stems from Fossil Forests by Raymond E. Janssen. Popular Science Series, Vol. 1, Illinois State Museum, reprinted 1979.

Keys to Identify Pennsylvanian Fossil Plants of the Mazon Creek Area, Earth Science Club of Northern Illinois

The Wilmington Coal Flora and *The Wilmington Coal Fauna* and *Additions to the Wilmington Coal Fauna*, by George Langford.

The last publications by George Langford are valuable publications from a picture standpoint, but may be confusing because the nomenclature is not accurate in places and the pictures do not always show distinguishing features.

1. *Development of Paleobotany in the Illinois Basin,* Tom L. Phillips, Herman W. Pfefferkorn and R.A. Peppers, Illinois State Geological Survey, Circular 480

2. *Paleobotanical Studies and Collections,* Tom L. Phillips, University of Illinois and Illinois State Geological Survey

3. *Depositional Environments in Parts of the Carbondale Formation - Western and Northern Illinois,* Pg. 29, Field Guidebook, Illinois State Geological Survey Guidebook, Series No. 8

4. Ibid, *Depositional Environments in the Francis Creek Shale,* Dr. Charles Shabica, Pg. 45

5. *Textbook of Paleobotany,* William C. Darrah, 1939, Pg. 196

6. *Depositional Environments, A Comparison of the Floras of the Cochester (No. 2) Coal and Francis Creek Shale,* R. A. Peppers and H.W. Pfefferkorn, Pg. 69

7. Ibid, Pg. 67

THE GREEN RIVER FLORA

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Few collectors are wholly unfamiliar with the Green River formation of the Western United States. Those who have not actually collected in the formation have nevertheless seen the famous fossil fish at the shows, in catalogs, in magazines, technical papers, and museum collections all over the world. Less well-known than the fish and other rarer vertebrate fossils such as bats, frogs and crocodiles is the extensive and beautifully preserved flora of the Green River shales.

During the Eocene epoch a complex system of lakes existed covering over 25,000 square miles of what is now Wyoming, Utah and Colorado. It was composed of Lake Uinta, Lake Gosiute, and Fossil Lake. This system included many different lacustrine environments and changed in character both geographically and through time. It's maximum development was reached in the Early to Middle Eocene.

Lake Uinta first appeared in the Paleocene, though in this phase some workers refer to it as Lake Flagstaff. The southern part of the lake dried up in the Late Paleocene, but in the Early Eocene it expanded to the east into what is now the Uinta Basin. Lake Uinta as such definately existed from the Earliest Eocene into the late part of the Middle Eocene. If Lake Flagstaff is considered as synonymous with the early phase of Lake Uinta, the lake existed for over 17 million years. Lake Uinta was very shallow and had a fluctuating shoreline. It's 7,000 feet of sediment is one of the thickest lacustrine deposits known on earth. The bulk of plant fossils from Lake Uinta are found in the Middle Eocene, Parachute Creek member.

Lake Gosiute was another large, shallow lake with a varying shoreline. It existed from the Early to the Middle Eocene. Though Lake Gosiute deposits are best-known for fossils fish (Gosiutichthys), "Turritella agate" (Goniobasis sp.), and extensive deposits of fossil algae, leaves also occur in the Laney member. Most commonly preserved are Platanus (sycamore) and Equisetum (horsetail). A lily pad has also been found in this member of the Green River.

Easily the most famous of the Green River lakes is Fossil Lake, a relatively small and deep lake which existed only in the Early Eocene in what is now southwestern Wyoming. Excellent exposures are protected in Fossil Butte National Monument while others are operated as commercial fossil fish quarries. Fish fossils, however, are not the only ones to come out of the Fossil Butte member of the Green River formation. Plant fossils are also abundant. One spectaclar find was of a Sabalites (palm) frond 7 feet long.

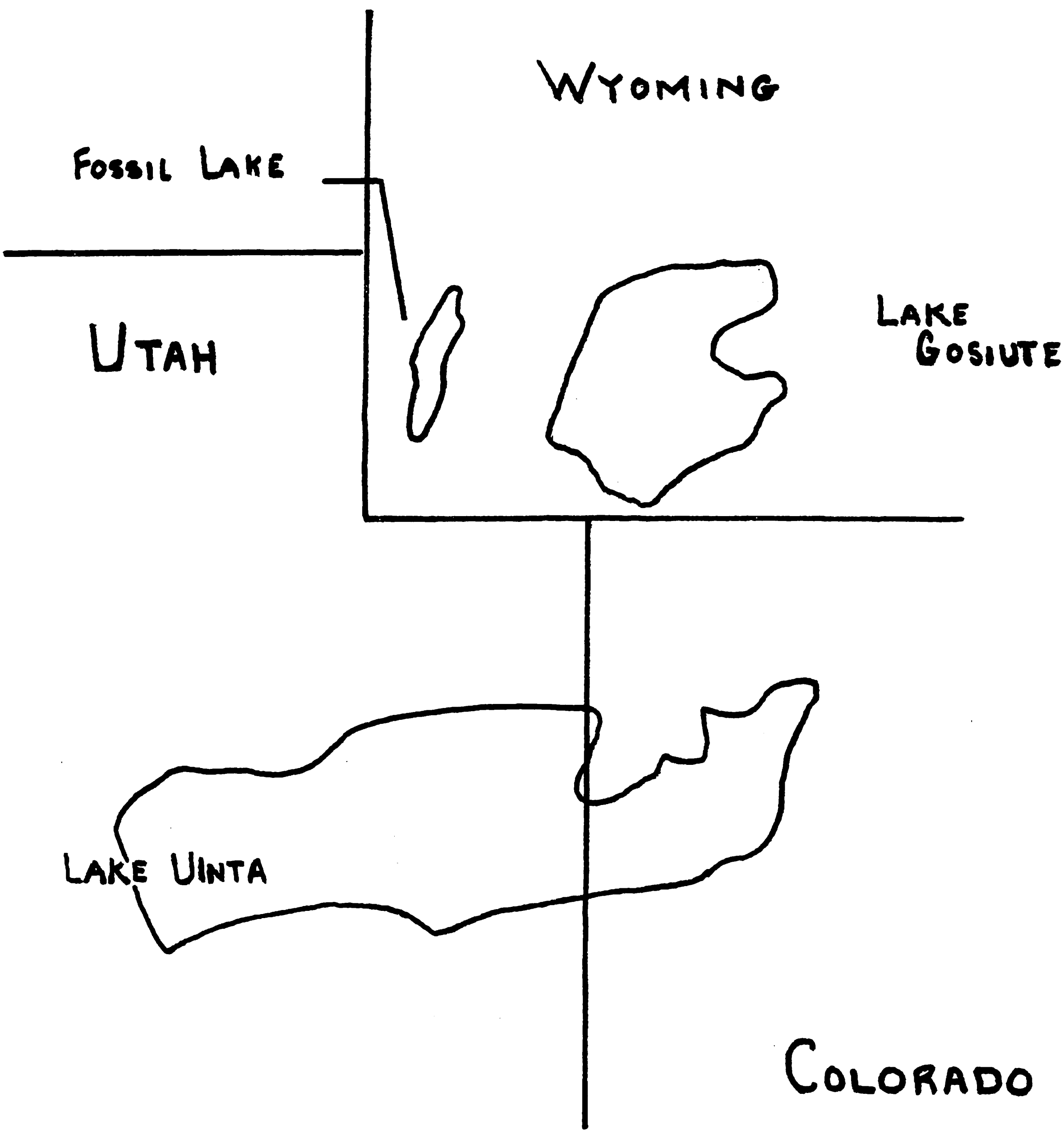
During the millions of years the lakes spread over this area the climate was temperate to subtropical, similar in character to the Gulf coast and Atlantic states today. Late summer and early fall were probably hot and dry, winters relatively dry, with a rainy season occurring in late spring and early summer. Annual rainfall at the shore of Lake Uinta was probably 28 inches and average temperature 67 degrees F. Streams from surrounding highlands brought vast quantities of sediment which was deposited in the shallow waters near the lake shores. Large quantities of volcanic ash are included in these sediments.

The Green River leaves are generally preserved as impressions with heavy carbon deposits in the compressions. The most extensive work with the paleobotany of the Green River formation has been done in the Parachute Creek member. It is likely that the 77 species of magaflora identified so far represent 4 different habitats. The first was the lake shore and flood plains upon which there grew a typical lowland forest of Platanus, Populus (poplar), Salix (willow), and Rhus (sumac). Typha (cattails) and Equisetum grew in swampy areas. The second habitat was the low, well-drained higher ground around the lake borders. Flora here consisted of Ephedra (mormon tea), Celtis (hackberry), Pinus (pine trees), Quercus (evergreen oak), Rhus (sumac), and Sapindus (soapberry). These are all hard-leafed and drought-resistant types. The third grouping consist primarily of broad-leafed deciduous trees of moderate elevations and north-facing slopes. The last group is represented by conifers which are known primarily from their pollen, and which are characteristic of high elevations.

Compositions for the flora varies somewhat by locality. At MacGintie's Wardell Ranch site Mimosites is most common, followed by Zelkova nervosa, Rhus nigricans, platanus wyomingensis, and Cardiospermum coloradensis. Of the genera identified from the Green River deposits, the following still survive in the area: Acer, Celtis, Ephedra, Mahonia, Pinus, Populus, Quercus, Rosa, Salix, and Typha.

The Green River leaves are frequently found in association with excellent insect fossils. The leaves themselves often show signs of insect damagae as distinctive and recognizable as such from the Eocene as it is to gardeners and entomologists today. Ragged leaf margins and neatly cut holes speak of insect habits that have changed little for millions of years. Eventually the great lake system dried up. Leaving behind it one of the most spectacular treasure troves of fossils in the world, a window into the tropical past of North America.

MIDDLE EARLY OR LATE EARLY EOCENE



Map drawn by N. Boyce, after McGrew and Casilliano, 1975.

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A MIOCENE FLORA FROM THE SUCKER CREEK FORMATION, SOUTHEASTERN OREGON/SOUTHWESTERN IDAHO

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Along the border of southeastern Oregon and southwestern Idaho lies an area known by local residences as "Owyhee Country". It is a semi-arid region filled with large valleys and dry basins separated by ancient lava flows whose black, basalt walls often cap the higher slopes. It is an untamed land of deep canyons, dry washes, eroded badlands and, at best, small hills covered with sagebrush and juniper. Its summers are hot and dusty while its winters are snowy and frigid, and the area is populated only by a hand full of small towns and by ranches scattered intermittedly along the few tiny creeks that stubbornly penetrate this harsh, dry land.

One such creek is called Succor Creek, which runs in a south to north direction and for many miles is the main geographical feature that separates southern Idaho from southern Oregon. For local ranchers this small, shallow creek and its surrounding area hold no major importance other than a source for water and grazing for their cattle. But to Paleobotanists, Succor Creek is special for in the shale outcrops exposed along this stream and within the dry gullies and hills on either side exists one of the most prolific Miocene fossil plant beds in North America.

The rocks around Succor Creek are volcanic in origin, consisting of basaltic and rhyolitic flows, rhyolitic ash-flows, pumice and ash air-falls and lacustrine (lake) sediments composed of volcaniclastic sediments, lignite or diatomite. Most of the fossil plants at Succor Creek are preserved in the lacustrine sediments that are found throughout the area.

The first known paleobotanical collection from Succor Creek was made for the U. S. Geological Survey by Waldemar Lindgren, and the material was described by Frank H. Knowlton in 1900. At that time, the Succor Creek flora was assigned to the Payette Formation, which is best known from near Horseshoe Bend, Idaho approximately 70 miles northeast of Succor Creek. Later, during the early part of this century, other Paleobotanists collected at Succor Creek and described the various plant species found there. Workers included Betty Brooks (1935), Chester A. Arnold (1936, 1937), Helen Smith (1938, 1939, 1940), Ralph Chaney and Daniel Axelrod (1959), and Alan Graham (1965). In recent years further collections have been made and described by Ralph E. Taggert and Aureal T. Cross (1980, 1983), Loretta Satchell (1981), Kyle Walden (1986) and Patrick Fields (1983 to present) all from Michigan State University.

Since the 1930's, non-professionals or non-paleobotanical professionals have also aided in the study of the Succor Creek Flora. They include Percy Train, Dr. Patricia Packard and students from the College of Idaho, Caldwell, Idaho, Bake Young, L. R. Hoxie, Gary Eichhorn, Sylvia Reichel, and Howard and Darlene Emry. Over the years these, as well as other, "amateur" paleobotanists have collected and donated to various museums and research centers many plant fossils from Succor Creek.

In 1965 the rocks around Succor Creek were mapped and formally named as the Sucker Creek Formation (and therefore separate from the Payette) by Laurence Kittleman, and the fossil flora from there is now referred to as coming from that lithostratigraphic unit (Kittleman, 1965).

It should be noted that the formation, Sucker Creek, differs in spelling from that of the fossil flora and the stream after which it was named, Succor Creek. When the formation was surveyed and distinguished from the Payette the accepted spelling for the creek was "Sucker". Later, however, the U. S. Board of Geographic Names found that the earliest known residences in the area actually used the spelling "Succor" for the creek. As a result, the creek's spelling (and, in turn, the fossil flora) was changed from "Sucker" to "Succor". However, since the original spelling of geological formations are not to be altered, the formation remained as "Sucker" (Graham, 1965).

The Succor Creek Flora is dated as Middle Miocene, approximately 14-16 million years ago. During the Miocene the Succor Creek area was dotted with many lakes and ponds as well as streams and small rivers that flowed into them. Few mountains existed in the region at that time with the highest elevations probably no higher than 5,000 feet above sea level. Based, in part, on the fossil plants and their closest living relatives, annual rainfall was approximately 50 inches with more rain occurring during the winter months than during the other seasons. Freezing temperatures were virtually absent year round then, while summers were mild and warm with temperatures seldom going above 80°F. This is a sharp contrast to the harsh, dry environment that exists there today. As a result, this mild climate during the Miocene formed ideal conditions for supporting a wide variety of plant and animal life at Succor Creek.

The leaves, seeds, fruits, wood and pollen of at least 135 fossil plant taxa have been or are presently being described from the Succor Creek Flora. Of the wide variety of fossil plants found, however, oaks and their relatives are the most common. At least four "oak" species and possibly more are represented in the flora, and in most collecting localities it is the imprints of "oak" leaves (and occasionally acorns) that are most often preserved.

Based on fossil pollen studies, the Succor Creek Flora represents four major plant communities that existed in that area during the Miocene. They are: (1) Montaine Conifer Complex (spruce, fir, and hemlock), (2) Bottomland/Slope Forest Complex (deciduous trees and shrubs such as oak, birch, beech, elm, willow, oregon grape, maple, sycamore, etc., that compare to extant [existing] deciduous forests in eastern North America and eastern Asia); (3) Swamp Complex (Chinese water-pine, ferns, cattail, horsetail, water lily, etc.); and (4) Xeric or disturbed sites retaining little moisture (dominated by grasses, small shrubs and conifers such as pine).

Times of rapid changes are of most interest to paleobotanists presently studying the area. In examining successive layers, when one finds horizons containing or directly above those with Xeric plant complexes, they are a major source of information. This is because these sites represent sudden catastrophic changes in the Succor Creek Miocene environment, which, in turn, may have greatly effected evolutionary development of the plant communities in that area.

Many of these local environmental changes were brought on by volcanic disturbances such as wide-spread basalt and rhyolite flows (and forest fires as a result of those flows), poisonous gas venting, mudslides, exploding volcanoes and enormous ash falls that periodically blanketed the area during the Miocene. The ash falls, in particular, probably caused severe imbalances in the ecological systems within the Succor Creek region and may have also effected climate by causing periods of cooling. They were probably similar to the one created in Washington during the Mt. St. Helens eruption of May, 1980. Because of these disturbances, hardy plant species that could adapt to them were able to dominate and/or replace those that couldn't.

Later, during the Pliocene Epoch the environment at Succor Creek changed even more drastically when the Cascade Mountains to the west were further uplifted to their present elevation. This mountain chain formed a natural barrier which prevented the warm rains from the Pacific Ocean from entering inland where the lush plant life at Succor Creek flourished. As the rains decreased in the Owyhees and the temperatures grew more extreme, the lakes at Succor Creek dried up and the thick, green forests of the Miocene Epoch were replaced with heartier plants that could withstand the harsh, freezing winters and dry, hot summers of this region. As a result, where oak, sycamore and Chinese water pine once grew, today there are now juniper, sagebrush and grasslands.

Paleobotanical research at Succor Creek is an ongoing process. Although much has already been learned about this region from previous research and fossil discoveries, there are still many questions about the area and its past that have not yet been answered. Perhaps future studies of the area will answer those questions and, in turn, contribute to a better understanding of what existed and occurred in the Northwest during the Miocene Epoch.

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SUCCOR CREEK FLORAL TAXONOMIC DIVERSITY: A CONTINUING WORK IN PROGRESS

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Howard Emry (this volume) has presented an excellent introduction and overview to the history of the Succor Creek flora, its basic composition, and the paleoecologic interpretations made from those remains. In this article, I wish to present a listing of the taxonomic composition and diversity of the flora based upon findings from recent research.

One of the most recent comprehensive reviews of the mega- and micro-fossil flora of the Sucker Creek Formation (= the Succor Creek flora), was by Alan Graham in 1965. In his paper, Graham lists 70 megafossil forms (primarily leaves and seeds) and 46 microfossil forms (pollen and spores). New work on the flora has suggested that more than 125 megafossil and more than 110 microfossil taxa are actually known from the flora. Where did the additional diversity come from? Sources of new names in the list of recognized taxa of the Succor Creek flora are primarily from two areas: the literature and from collections (both existing and newly made).

In the course of a thorough literature review of all the scientific papers that I could discover relating to the Succor Creek flora of the Oregon/Idaho boarder area, I found references to many fossil plant taxa that were apparently not summarized in any single place. Some of the reasons for these ommisions apparently were:

1) old names that had been synonymized to other taxa (when an older validly published name was discovered),
2) misidentifications that some later worker had corrected,
3) new discoveries that were apparently found after the most recent comprehensive overview article (that is, since Graham 1965), and
4) some appear to be validly identified taxa that, for some reason, had not been recognized by subsequent workers.

The first two categories above were correctly omitted from summary lists, but the latter two needed to be incorporated.

While examining the Succor Creek material in several museum collections and in one large private collection, I was able to find a number of taxa that are new to the flora and a few that are new to science. The major holdings of Succor Creek floral material (that I know of, ranked approxiately by size) are located at: Michigan State University (East Lansing); the O.J. Smith Museum of Natural History at the College of Idaho (Caldwell); a Private Collection (Aurora, Colorado); the University of Michigan (Ann Arbor); the U.S. National Museum (Washington, D.C.); and the Carnegie Museum of Natural History (Pittsburgh, Pennsylvania). Comments on the origin and importance of each of these collections are listed below:

The Michigan State (MSU) collections presently comprise the largest Succor Creek collections known to this author. Extensive materials have been collected by Drs. Aureal T. Cross and Ralph E. Taggart and their students over the last 30 years (Taggart 1971, 1973, Taggart & Cross 1980, Cross & Taggart 1983, Satchell 1983). Although all but this author have been primarily interested in microfossils (pollen and spores), the size of the megafloral collection (leaves, stems, seeds, flowers, fruits) has been increased continuously by small, regular field collections. Enhancing this are the large collections I have made for my dissertation research over the last five summer field seasons. This has nearly doubled the megafloral material from Succor Creek that is available at MSU for examination and study (for example see: Fields 1988, 1989).

The Orma J. Smith Museum of Natural History collections are quite large. They house some of the original Helen V. Smith material (Smith 1938, 1939, 1940); a large collection compiled by the late Bake Young of Nampa, Idaho and donated by his family to the College of Idaho in July of 1988; numerous small collections made by the faculty and students of the college over 40 years or so; and extensive donations by Howard and Darlene Emry from their private collecting over the last 10-15 years.

The private collection in Colorado has been and continues to be compiled annually by one family, the Emrys. Although the total number of specimens is moderate to small, the quality is excellent because most have been collected from two or three localities that provide high quality preservation of the leaf impressions. Further, the lessor quality and broken/incomplete specimens are often donated to one of two museums in Idaho. Consequently, these collections and the process by which they are compiled has helped science tremendously. Numerous taxa new to the flora and a few new to science are in this collection, as well as numerous specimens that are better-preserved or more complete than previously known.

The materials housed at the University of Michigan are those collected by Percy Train in 1935 (see Arnold 1965) and by Chester Arnold and Alan Graham in the early 1960's (Graham 1963, 1965). They number between 2,500 and 7,000 according to Graham (1965).

The U.S. National Museum (Washington D.C.) Succor Creek collection, is quite limited in scope, but most important because it represents the original Knowlton/Lindgren material. This was used in the first publication to ever mention fossils from Succor Creek (Knowlton in Lindgren 1900).

The Carnegie Museum's Succor Creek holdings are restricted to the original material used by Betty Watt Brooks for her 1934 dissertation on the flora (Brooks 1934, 1935). There are only 65 specimens total (C. Barnosky, written comm. 2/19/88), but they are of great importance because this represents the first monographic treatment of the Succor Creek flora and the first publication to figure any Succor Creek leaves.

Other small collections are housed at the Burke Museum of the University of Washington (Seattle), the Idaho State Museum (Pocatello), and the University of California Museum of Paleontology (Berkeley).

Collectively, the literature review, examination of museum/private collections, and new additions to the known collections (by this author), have allowed for a substantial addition to the known Succor Creek flora.

A chart summarizing the known taxonomic diversity of the Succor Creek flora through time, is presented below:

RECOGNIZED TAXONOMIC DIVERSITY OF THE SUCCOR CREEK FLORA OVER TIME
(compiled by Patrick F. Fields)

Citation	# of Fossil Taxa Mega-	Micro-
Knowlton in Lindgren 1900	20	/
Knowlton in Russell 1903	9+	/
Knowlton in Lindgren & Drake 1904	18	/
Berry 1932	11	/
Brooks 1935	28	/
Arnold 1936a (*Mahonia* only)	4+	/
Arnold 1936b (*Cedrela* only)	2+	/
Arnold 1937	23+	/
Smith 1938	12	/
Smith 1939	30	/
Smith 1940	60	/
Chaney & Axelrod 1959	55	/
Graham 1963	70	46
Axelrod 1964	48	/
Graham 1965	71	ca.50
Eubanks 1966 (Wood only)	15	/
Taggart 1971 (PhD)	35	90-91
Cross, Taggart, & Parker 1971	6+	22-23
Taggart 1973	5	9
Tanai & Wolfe 1977 (Ulmaceae only)	4	/
Taggart & Cross 1980	60	80
Cross & Taggart 1983	69	71
Satchell 1983 (PhD)	38+	47
Wolfe & Tanai (*Acer* only)	10	/
*Minimum number of taxa	125-135	110-115

(*based upon summary of above and new discoveries either collected by this author or observed by this author in museum or private collections).

Examination of this chart clearly demonstrates the trend toward a greater and greater number of recognized taxa for the Succor Creek flora over time. This trend appears equally true for mega- and mircrofossils alike, once the latter were first recognized (Graham 1963, 1965). However, there are some later papers that list fewer taxa than earlier studies. These appear to be due to either: 1) extensive taxonomic revisions (that recombine the accepted number of taxa into shorter lists), 2) brief or introductory (rather than comprehensive) references to the floral composition, or 3) specialized studies that only consider a single group of taxa (for example a single genus, such as *Acer*).

What follows is a working list of the known taxa that are currently recognized in the Succor Creek assemblages. Some new, as yet not fully identified taxa are omitted from this list; while some of the taxa listed below are based upon unverified reports in the literature that have yet to be examined by this author. With the exception of three pollen taxa named by Alan Graham (as indicated by an asterisk "*" below), all microfossil and wood reports are at the generic level (genus) or higher, while the megafossils are generally reported at the specific level (species). The sequence of angiosperm plant families follows Cronquist's system.

TENTATIVE LIST OF THE GREATER SUCCOR CREEK FLORA SYSTEMATICS
(Compiled by Patrick F. Fields)

Key to Letters and Symbols:
Br= bract, C= cone, F= fern frond, Fr= fruit, L= leaf or leaflet, P= pollen & spores (generic level only), R= rhizome, (R)= reported ambiguously (not yet verified), S= seed, Sh= shoot, W= wood (generic level only), (8)= 8 morphotypes of this taxon honored, (3+)= 3 or more taxa honored, (?)= cited as a questionable number of species or taxonomic assignment.

Major Plant Group	Taxon	Organ (# of Taxa)
--FUNGI	Alternaria	P
	Eumycophyta	P(8)
	Chytridaceae	P
	Fungi Imperfecti	P
	Fungal Remains, Uncertain Affinities	P(13)
--ACRITARCHS	Micrhystridium	P
	Psophosphaera	P
	Sigmapollis	P
	Undifferentiated	P
--ALGAE		
Botryococcaceae	Botryococcus	P
Hydrodictyaceae		P(2+)
	Pediastrum	P
Zygnemataceae	Ovoidites	P
Algal Remains of Uncertain Affinities		P(4)
--VASCULAR PLANTS OF UNCERTAIN AFFINITY		
	Monolete Spores	P(2)
	Trilete Spores	P(2)
--LYCOPSIDA		
Lycopodiaceae	Lycopodium	P(2)
--SPHENOPSIDA		
Equisetaceae	Equisetum octangulatum Smith	P,R
	E. sp.	(2?)R,Sh
--PTERIDOPSIDA		
Blechnaceae	Woodwardia deflexipinna Smith	F,P
Davalliaceae	Davallia solidites Graham*	F,P
Osmundaceae		P
	Osmunda claytonities Graham*	F,P
Polypodiaceae		P(2)
	Polypodium sp.	F,P
Unknown Fern Spore		P

--GYMNOSPERMS

Ephedraceae	Ephedra	P
Cupressaceae		P
	Libocedrus masoni Chaney et Axelrod	Sh
	Cupressus or Juniperus	Sh
	Thuja dimorpha (Oliver) Chaney et Axelrod	Sh
Ginkgoaceae	Ginkgo adiantoides (Unger) Heer	L
Pinaceae	Abies sp.	L,P(2),S(1+)
	Cedrus	P
	Keteleeria sp.	L,P
	Picea lahontense MacGinitie	P(2),S
	P. magna MacGinitie	S
	Pinus harneyana Chaney et Axelrod	L,P(5),S,W
	P. spp.	L(3+)
	P. spp. (male & female cones)	C(2-3)
	Pseudotsuga longifolia Axelrod	L
	Pseudotsuga or Larix	P
	Tsuga sonomensis Axelrod	P,Sh
Podocarpaceae	Podocarpus	P
Taxaceae		P
	Cephalotaxus californica Potbury	L
Taxodiaceae		P,W
	Glyptostrobus oregonensis Brown	C,Sh
	Metasequoia occidentalis (Newberry) Chaney	C,Sh
	Sequoia	Sh(?),W
	Taxodium	Sh
Taxodiaceae, Cupressaceae, Taxaceae		P

--ANGIOSPERMS - DICOTS

Magnoliaceae	Magnolia ovulata Graham	Fr,L(?)
Lauraceae	Persea pseudocarolinensis Lesquereaux	L
	Sassafras columbiana Chaney et Axelrod	L
	Umbellularia	W
Nymphaeaceae		P
	Nymphaea	L,P,Rh
Berberidaceae	Mahonia macginitiei Axelrod	L,P
	M. malheurensis Arnold	L
	M. reticulata (MacGinitie) Brown	L
	M. simplex (Newberry) Arnold	L
	M. sp. (= M. "sinuata" of Axelrod)	L
	M. trainii Arnold	L
Platanacaeae	Platanus bendirei (Lesquereux) Wolfe et Tanai	Fr,L,P,W
	P. youngii Graham	L
Hamamelidaceae	Liquidambar sp.	L,P
Ulmaceae	Celtis sp.	L,P,W
	Ulmus knowltoni Tanai et Wolfe	L,P,W
	U. newberryi Knowlton	L
	U. owyhensis Smith	L
	U. paucidentata Smith	L
	U. speciosa Newberry	L
	Zelkova browni Tanai et Wolfe	L,P(?)
Juglandaceae	Carya sp.	L,P
	Juglans sp.	L,P
	Pterocarya mixta (Knowlton) Brown	L,P

Fagaceae	Castanea spokanensis (Knowlton) Chaney et Axelrod	L,P
	Castanopsis sp.	L,W
	Fagus washoensis LaMotte	L,P
	Lithocarpus klamathensis (MacGinitie) Axelrod	L,P
	Quercus dayana Knowlton	L,P(2)
	Q. eoprinus Smith	L
	Q. hannibali Dorf	Fr,L
	Q. prelobata Condit	(R)
	Q. pseudolyrata Lesquereux	(R)
	Q. simulata Knowlton	Fr,L
	Q. subspp. erythrobalanus	L
	Q. sp.	Fr(?2)
Betulaceae	Alnus hollandiana Jennings	L,P,W
	A. relatus (Knowlton) Brown	L
	A. sp.	Fr(1+)
	Betula sp. (=B. fairii Knowlton of Graham)	L,P,W
	B. thor Knowlton	L
	B. sp.	S
	Carpinus sp.	L,P
	Carpinus-Ostrya	P
	Corylus	P
	Ostrya oregoniana Chaney	L,P
Chenopodiaceae	Sarcobatus	P
Chenopodiaceae-Amaranthaceae		P(3-4)
Tiliaceae	Tilia aspera (Newberry) LaMotte	Br,L,P
Malvaceae		P(2)
	Anoda suckerensis Graham	L
	Sphaeralcea	P
Salicaceae		Fr(2)
	Populus eotremuloides Knowlton	L,P,W
	P. lindgreni Knowlton	L(?)
	P. payettensis (Knowlton) Axelrod	L
	P. pliotremuloides Axelrod	L
	P. voyana Chaney et Axelrod	L
	P. washoensis Brown	L
	Salix hesperia (Knowlton) Condit	L,P
	S. succorensis Chaney et Axelrod	L
	S. spp.	L(1-2)
Ericaceae		P
	Arbutus idahoensis (Knowlton) Brown	L,W
	A. trainii MacGinitie	L
	Vaccinium sonomensis Axelrod (=V. sophoroides of Taggart)	L
Ebenaceae	Diospyros oregoniana (Lesquereux) Chaney et Axelrod	Br,L
Hydrangeaceae	Hydrangea bendirei (Ward) Knowlton	L
	Hydrangea-like calyx	Calyx
Grossulariaceae	Ribes sp.	L
Rosaceae		P
	Amelanchier couleeana (Berry) Brown	L
	Crataegus gracilens MacGinitie	L
	C. sp. (thorny branch)	Sh
	Photinia sp.	L

Rosaceae (con't)	Prunus	W
	Pyrus mckenziei Arnold	L
Fabaceae (Leguminosae)		P(polyad)
	Gymnocladus dayana (Knowlton) Chaney et Axelrod	Fr,L
	Legume Gen. et Sp. undetermined	Fr(2),L
	Legume (thorny branches)	Sh(2-3?)
Eleagnaceae		P
	Shepherdia argenteaites Graham*	P
Onagraceae		P(2)
	Epilobium (?)	P
Nyssaceae	Nyssa copeana (Lesquereux) Chaney et Axelrod	L,P
	N. hesperia Berry	Fr
Cornaceae	Cornus ovalis Lesquereux	L,P
Aquifoliaceae	Ilex fulva MacGinitie	L,P(2)
Buxaceae	Pachysandra	P
Malpighiaceae	Hiraea knowltoni (Berry) Graham	L,S
Aceraceae	Acer latahense Wolfe et Tanai	L,P,W
	A. chaneyi Knowlton	L,S
	A. negundoides MacGinitie	L,S
	A. medianum Knowlton	L,S
	A. busamarum fingerrockense Wolfe et Tanai	S
	A. busamarum busamarum Wolfe et Tanai	S
	A. schorni Wolfe et Tanai	S
	A. septilobatum Oliver	L
	A. scottiae MacGinitie	L,S
	A. tyrellense Smiley	L,S
Anacardiaceae	Rhus sp	L
Simarubiaceae	Ailanthus indiana (MacGinitie) Brown	L,S
Meliaceae	Cedrela pteraformis (Berry) Brown	Fr,L,S
Rutaceae	Evodia (=Melicope + Tetradium)	W
	Ptelea miocenica Berry	L,S
Araliaceae	Oreopanax precoccinea (Brooks) Arnold	L
Apiaceae (Umbelliferae)		P
Oleaceae	Fraxinus coulteri Dorf	L(?),P,S,W
Caprifoliaceae		P
	Symphoricarpos salmonensis Brown	L
Asteraceae (Compositae)		P(9)
	(lowspine)	P
	(highspine)	P(3)
	Ambrosia (lowspine)	P
	Artemesia (lowspine)	P(2)
--ANGIOSPERMS - MONOCOTS		
Potamogetonaceae	Potamogeton	P
Cyperaceae	Carex new sp	L
Poaceae (Gramineae)		P(3)
	Cyperacites sp.	L
Typhaceae	Typha lesquereuxi Cockerell	L,P
Smilacaceae	Smilax sp	L

* In the case of these three taxa only, the specific epithet listed here applies to the microfossils (which were named by Alan Graham) and not the megafossils (which are unknown or have not been specifically determined).

For one familiar with other middle Miocene floras of the Pacific Northwest, a number of points/observations come to mind upon examination of this four-page taxonomic list. The first 1) is the sheer taxonomic diversity of this list! Most other floras have about 60 or fewer recognized taxa in them, while Succor Creek easily exceeds 100 taxa for both the mega- and microfossil floras. The few exceptions (other highly diverse floras, such as those at: Collawash, Or. and Clarkia, Id.) have never been monographed. So, our understanding of their diversity comes from a few preliminary lists and personal communication with those more familiar with these two assemblages (J.A. Wolfe and C.J. Smiley, respectively). A second point of note 2) is the tremendous amount of micropalontological work (palynology) that has been done on Succor Creek samples. I do not know of any other flora in the region that is as well studied. A third point 3) is the suprisingly close correspondence between the mega- and microfossils lists. About half of all pollen taxa presently recognized have a corresponding representative megafossil (either of the same genus or family when the pollen of the whole family is not distinct enough to distinguish as genera). Further, in genera such as pine, about 5 taxa are represented by megafossils and 5 distinct morphotypes of pollen are recognized (Taggart 1971). Fourth 4), about 15 taxa of woods are recognized, and all but three are genera known independantly from pollen, leaves, seeds, or some combination of these three. Fifth 5), Succor Creek has traditionally been considered to represent a low elevation floral assemblage, with distant uplands. This was due to the ample "summer rain indicators" (to use the terminology of Axelrod) and the lack of conifers. However, the latter part of that statement can no longer be considered true. The pollen record has demonstrated conifer proximity, but recent megafloral findings show at least 18 different megafloral coniferous taxa were present (a number nearly identical to the presently known microfloral conifer diversity of at least 17 taxa)! Because of this, the setting for the Succor Creek flora must now be interpreted as somewhat upland (particularly to the south), equible, but cool in paleotemperature. Frosts were rare to absent and rainfall would have been more or less evenly distributed throughtout the year. This would allow for the persistance of the "lowland" or "summer rain" types (such as Cedrela, Oreopanax, and perhaps Magnolia and Diospyros), in the presence of near-by mixed coniferous/broad-leaved forests. A sixth point 6), related to the high diversity of species within some genera, such as Pinus, Acer, Mahonia, Populus, Quercus, and Ulmus. Geologic and palynologic evidence demonstrate the dynamic nature of the volcanic landscape and the local vegetation's corresponding response to these changes (for example see: Cross and Taggart 1983, Satchell 1983). Having numerous species of a given genus living in and responding to different degrees of disturbance or successional vegetative development would be perfectly consistant with that picture. In fact, preliminary observations are beginning to highlite certain taxa as early successional types, others as later post-disturbance followers, and still others as mature forest components. Future analyses will allow for a more definitive determination along these lines. As the over-all data are refined, numerous other observations will become apparent.

My sincere thanks and gratitude are extended to the curators of all the institutions mentioned above, for free access to their Succor Creek fossil collections. Special thanks are due to the Emrys and Drs. Cross, Taggart, and Wolfe for regular and professional help on many aspects of the project.

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A STATEMENT REGARDING SOME OF THE MAJOR APPROACHES TO TERTIARY PALEOBOTANICAL MEGAFLORAL ANALYSIS USED DURING THE LAST CENTURY:

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For those not readily familiar with the mechanics or details of paleobotanical methods and techniques, especially as they apply to floral analysis, I present the following discussion. This was written as a partial response to the often-expressed notions that paleobotany is: 1) just stamp collecting, where all those dusty old leaves are gathered up and then lost (uh, stored) in museum collections never to see the light of day again, 2) paleobotany is a dead science that hasn't made any progress in decades (pardon the intentional pun), and/or 3) nothing new can be contributed to our understanding of all those well-studied fossil floras in the western part of the U.S. They have been worked "to death", so let's look to other types of fossils to make new discoveries, fossil vertebrates have more to offer anyway. What follows is admittedly biased towards fossil leaf, seed, and stem (megafossil) remains from western North America, because that is where my experience and research interests fall. However, I'm sure that the "take-home" message can apply to many disciplines and situations. The story begins with some historical background on how we have analyzed floras in the past and how that has changed over the last 5Ø to 7Ø years. Then a few of the more interesting "nagging" problems that the paleobotanist of today must deal with are discussed.

Throughout much of the historical development of paleobotany as a discipline, megafossil assemblages have been assignable to specific intervals of time. As our understanding and data base have increased, our abilities to assign assemblages to more specific time intervals with greater precision has increased. At first this was accomplished, in essence, through not much more than "picture matching" of fossil specimens to previously described and figured taxa. Also, there was a strong tendency to "force" fossil taxa into modern lineages, leading to an artificially modern aspect to many fossil floras. For example, a quick examination of any monograph on megafossils of late Cretaceous or younger age that was described prior to about 192Ø, will show a surprising number of modern genera (such as <u>Ficus</u>) or "form" genera (such as <u>Platanophyllum</u>) that suggest affinities to modern genera. In nearly every case, when these floras were revised in the 196Ø's or later, the number of modern genera or taxa with stated affinities to modern genera are greatly reduced (for an example using Eocene fossils, compare Berry 1929 to Wolfe and Wehr 1987, for the Republic flora of northcentral Washington).

From the 192Ø's through the 195Ø's the tendency in Cenozoic megafossil paleobotany of the Pacific Northwest has been to compare floral assemblages, as integral units, to those areas that today contain taxa similar to the fossils. Paleoecologic and paleoclimatic parameters were then inferred for the fossils from the best-fit comparisons with the modern assemblages' ecologic and climatic requirements. One aspect of this was the well-known "Geofloral" concept advocated so strongly by Chaney and Axelrod (1959). It suggested that floral assemblages migrated as integral units through time and space, in response to climatic changes, without significant additions or losses of taxa. Further, it did not allow for evolution of lineages within the plant communities (Chaney 1944, 1947, and Chaney and Axelrod ibid.).

During the 1960's through the 1980's more refined taxonomic efforts have led to a more complex approach to the study of megafossil assemblages. This includes "floristics" to compare changes in taxonomic lineages through time, and hence stage-of-evolution (i.e. Axelrod 1964, 1966, 1980, MacGinitie 1969, and Smiley 1963), and "physiognomics" to compare vegetation types that are adapted to specific climatic conditions (i.e. Richards 1952, Webb 1959, Wolfe and Barghoorn 1960, Wolfe and Hopkins 1967, and Wolfe 1979). Both of these two approaches are further discussed in Hickey (1977) and Fields (1983). Another aspect of these newer methodologies is the fact that taxa and lineages were identified independantly on the basis of their morphologies, and not on the modern taxa they were presumed to be allied with. This resulted in lineages being recognized in-and-of themselves from the older forms to the younger taxa (and hence, fossils were no longer "forced" into the modern lineages they were presumed to be related to). This eliminated the artifically modern aspect to floras composed of taxa that in actuality did not have much in common with modern lineages.

These approaches have demonstrated that the "Geofloral" concept, as literally defined by Chaney (1944, 1947) and Chaney and Axelrod (1959), is no longer considered valid because change and/or evolution within independant lineages of taxa has been shown to occur independantly within a unit of vegetation (for example, see: MacGinitie 1962; Wolfe 1966; and Wolfe, Hopkins, and Leopold 1966). And correspondingly, independant plant lineages respond separately to climatic or successional factors.

Over the last 20 years or so, there has been an increasing amount of evidence that the age of megafloral assemblages cannot be accurately interpreted without a great deal of local geographic, temporal, and taxonomic compariative material (Axelrod 1987). For example, floras such as that from Copper Basin, Nv. may appear in aspect to be Miocene aged, when compared to the commonly known lower elevation Miocene floras of the Pacific Northwest. But, isotopic dating has shown that this high elevation floral assemblage is in actuality about 40 my old, that is Eocene (Axelrod 1966). It apparently "looks Miocene" because of the paleosetting of much greater elevation in the Eocene vs. the lower elevation but cooler paleoclimate of the Miocene (Axelrod ibid.). The exact same point was demonstrated for the late Eocene-early Oligocene Florissant flora and recently for the Oligocene Creede flora both of Co. (MacGinitie 1953 and Axelrod 1987, respectively). Prior to these revisions, the floras were considered to be of Miocene age (ibid.). This approach must now be applied (that of better paleogeographic, paleoclimatic, and comparative data) whenever attempting to use floral zones, such as those of Wolfe (1966). Axelrod (1987, p.62-65) has suggested that Wolfe's floral zones may be fine for Alaskan Miocene assemblages, but do not appear to work well for regions very far removed from there. He has pointed out an apparent provinciality to most of the western U.S. floras of the Cenozoic that must be taken into account when applying any generalization about floral assemblages. The provinciality of middle Miocene floras can be seen by comparing the assemblages in central Nv. (Axelrod 1956, Wolfe 1964) to the western Snake River Plain, Id.-Or. (Chaney and Axelrod 1959, Graham 1965, Cross and Taggart 1983, Fields 1983) to those of northern Idaho (Knowlton 1926, Smiley 1985).

A fairly recent approach, utilizing microfossil assemblages in controlled stratigraphic sections, has demonstrated that numerous aspects of ecological vegetation dynamics can now be considered (for example see: Cross and Taggart 1983 and Satchell 1983). These workers have shown that the paleo-vegetation of the Succor Creek region of eastern Oregon has repeatedly responded to such stimuli as fire, vulcanism, and succession (ibid.)

One of the more intriguing problems currently facing a paleobotanist working on Cenozoic megafossil floras (particularly in the Miocene deposits of western North America) is that of taxonomic variability. Modern plant ecologists can, for example, observe a great deal of morphologic variation in the foliage of: young vs. old plants, aquatic vs. aerial shoots, typical foliage vs. that immediately subtending reproductive structures, sun vs. shade leaves, and between extreme endpoints in the geographic range of a taxon (i.e. ecotypes). A paleobotanist must be aware of these and many other types of variation when considering the isolated organs (primarily leaves and leaflets) in a fossil assemblage. Further, he/she must constantly assess how much morphologic difference is present in an observed suite of closely related specimens and at what point more information would be retained by assigning a subset of this variation to a new morphospecies. For a discussion of this author's concept of a species or biological species vs. a morphospecies, please see Fields 1983, app. 5.

Analogous to the biologic problem, within the same geologic formation a paleobotanist must constantly assess taxonomic variation within and between local florules (= closely spaced floral assemblages). The goal of this is to decide when it would be useful to differientiate a new fossil flora rather than leave a given assemblage under the status of another locality (florule) in a known flora. Variable taxonomic input can be due to variable source vegetation (ecologic, successional, or geographic), or something else (Axelrod 1976, Fields 1980). A complicating factor affecting this compositional problem, is any biases caused by depositional processes. This can be either from the hydrodynamics of isolated plant organs or the flow regime and source sediments affecting the fossil-encasing lithology (for example see: Fields 1983 and Spicer 1981).

Given the sporadic and often rare nature of occurrence of megafossil floras (in contrast to microfossil floras), finding enough well preserved leaf-bearing assemblages in close enough geologic, geographic, and temporal proximity has made assessment of morphologic and taxonomic variation nearly impossible. The methods applied by this writer in his own research attempt to utilize as many separate floral horizons in stratigraphic superposition as possible in order to address these "problems" discussed above.

In summary, one can see that paleobotanical techniques have changed and improved frequently over the last century, but that many challanges to floral analysis still exist. We don't have all the answers and interpretations made by even the most careful paleobotanists are subject to reevaluation as new data and methods of analysis become available. New discoveries are being made all the time that lend an air of intellectual stimulation to the whole discipline. Because of this, there is always more work that can be done on even the most well-known floras, let alone on those unstudied for decades or new to science. An example of this can be seen in the enclosed paper entitled: "Succor Creek Floral Taxonomic Diversity: A Continuing Work in Progress".

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THE PETRIFIED FOREST OF ARIZONA

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The beautiful rainbow colored petrified wood of northern Arizona has long been prized by collectors of all sorts - fossil, souvenier, curio, etc.. In fact, it was the threat of raids on the numerous fields of petrified wood by commercial jewelers, souvenier hunters, gem collectors and abrasive manufacturers at the beginning of this century that led the citizens of Arizona (at that time it was still a territory) to petition congress for the establishment of some kind of protection for the "forest" area. In 1906 (6 years before Arizona became a state) President Theodore Roosevelt issued a proclamation establishing the Petrified Forest National Monument. The earliest discoveries of plant fossils of this area were undoubtedly made by prehistoric Indians. Various implements, made of this material, such as projectile points, knives, scrapers, etc. have been found here. Also, over 300 ruin sites have been located in the area. One of these known as "Agate House" was constructed entirely of large petrified wood pieces. The various pot sherds found have been dated between 500 A.D. to 1400 A.A..

For several hundred years the Spaniards traveled, explored and lived in the American southwest. It is difficult to understand that they would not have discovered this petrified wood however, it has not been found in any of their records. Perhaps they found it but did not deem it significant to record.

The honor of the earliest recorded reports of plant fossils in the southwest goes to members of the United States Army. After this region was acquired from Mexico the United States sent numerous army expeditions to explore this region. Even though the officers who led these expeditions were primarily military men trained at West Point they had a broad education and intelligent enough to appreciate scientific research. These men made many valuable contributions in geology, geography, biology, etc.. Lt. James H. Simpson of the U.S. Army Corp. of Topographic Engineers has the honor of writing the first published report of plant fossils in the southwest in 1850. Lt. Simpson was with an expedition commanded by Col. John M. Washington. The expedition was camped near Canyon DeChelly on Sept. 5, 1849 and the lieutenant climbed down the wall of a canyon and "--- found protruding horizontally from the wall, its end sticking out, a petrified tree of about a foot in diameter ---". A specimen of petrified wood along with other specimens was forwarded to Washington, D.C. along with his report.

Other notable military expeditions to the area were led by Capt. Lorenzo Sitgreaves, Lt. Amiel W. Whipple, Lt. Joseph C. Ives, Capt. J.N. Macomb & Lt. Col. P.T. Swaine. Lt. Whipple was so impressed by the large amount of exposed petrified wood that he named a dry wash in the area "Lithodendron Creek" (now Lithodendron Wash). The first published picture (1855) of the petrified wood in the southwest was a sketch of a scene in Lithodendron Creek (Wash) contained in a report by Lt. Whipple. In 1858 the Ives expedition's physician was Dr. John S. Newberry whose keen observation of the stratigraphy and water worn specimens prompted him to conclude "--- all had been transported but not far from their place of growth". In 1859 Dr. Newberry accompanied the Macomb expedition. It was on this expedition that he made the first collection of leaf fossils in the southwest. However a report on them was not published until 1876.

The plant fossils of this area are of late Triassic Age and occur in the Chinle Formation. There are 8 members in the Chinle Fm. all of which have been found to contain petrified wood; the Petrified Forest Member being the most productive. Leaves have been found in only 3 of the lowermost members. The Chinle Fm. is widely exposed in the four corners area, namely Arizona, Utah, New Mexico, Colorado. This is the only place in the U.S. that four states meet. In places the formation is 400 ft. thick. It is possibly the most extensively exposed upper Triassic Fm. in the world.

Although petrified wood is the most extensive fossil found in the Chinle Fm. it is by no means the only one. Seventeen vertebrates, nineteen species of invertebrates along with over 50 species plant megafossils have been collected.

The vertebrates include fish, amphibians and reptiles. Although all of the fish are fresh water species they do present a varied assemblage. There are 9 genera all belonging to the class Osteichthyes. None of them is common. One Paleonescoid fish, Tanaocrossus, is known but from a single specimen. Also included in the fish is one coelacanth genus, Chinlea, and one lungfish genus, Ceratodus. The latter is closely related to the modern Australian lungfish.

The amphibians are represented by but one genus, Metoposaurus. This large amphibian, formerly known as Buettneria undoubtedly had a diet composed entirely of fishes. It has been suggested that they almost never left the water. They were very wide spread in late Triassic time.

The reptiles are represented by 8 genera. The phytosaurs are the most common reptiles found in the Chinle Fm.. They are represented by 2 genera, Phytosaurus & Rutiodon. Perhaps the best known reptile from the Chinle is the dinosaur Coelophysis. That it was widely spread across North America is documented by it's footprints having been found in Utah and bones in Connecticut. Edwin H. Colbert formerly of the American Museum of Natural History, N.Y. and presently with the Museum of Northern Arizona, Flagstaff, has studied and published extensively on the Coelophysis. Due to his work the Coelophysis is probably the best documented dinosaur genus. On June 6, 1985 a momentous event occurred - "Gertie" was lifted from her 225 million year old tomb. Who is Gertie? Gertie is "the earliest datable dinosaur" and was recovered from the Painted Desert portion of the Petrified Forest National Park. Gertie is about the size of a large dog (Great Dane) and although may represent a new genus is very much like the small-headed plateosaur. At present she resides at the University of California Berkeley where she is undergoing extensive research.

The few invertebrates are without question overshadowed by the more abundant vertebrates and plants. The pelecypods are represented by a single genus Unio. Although 8 species have been reported most of them are poorly preserved and difficult to identify therefore many of the species are suspect. Four genera of gastropods have been reported. The arthropods are represented by a single limulid trail and 5 insect burrows.

The plant fossils found in the Chinle flora represent almost all of the major plant groups; conifers, ferns, ginkgos, cycads, sphenopsids, cycadeoides, lycopods and fungi. Of the 50 species of megafossils that have been identified 13 are based on petrifactions. Earlier it was stated that petrified wood has been found in all of the members of the Chinle Formation. An interesting note to this is that from all accounts the first reported piece found by Lt. Simpson was found in a conglomerate member. To this author's knowledge conglomerate is not the most conducive for preservation. Although the first plant fossils in the Chinle were found in 1849 the study of the Chinle flora has been very slow and somewhat erratic. Most of the petrified wood is assigned to the conifer Araucarioxylon arizonicum Knowlton. It is related to the modern Araucarias that are native to South America, New Zealand and Australia. It has been imported to the U.S. and is commonly known as 'Norfolk Island Pine' or 'Monkey Puzzle Tree'. This is the most beautifully colored of the Chinle petrified wood. Although reds are the most predominant, yellow, white, black, purple and brown occur in a variety of shades and combinations. Another cone-bearing tree similar to the Araucaria is Woodworthia arizonica Jeffrey. These specimens are almost always black or dark grey with faint growth rings. Another tree is Schilderia adamanica Daugherty. This wood shows peculiar rays radiating from the center. The fungi are represented by Polyporites wardii Daugherty. This species is based on small bodies that occur in the wood of Araucarioxylon arizonicum. These bodies are usually spheroidal or fusiform and are from 1/4 in. to 4 in. long. They are arranged in vertical rows in the wood and when visible on the surface look like a string of beads.

Small disc like structures 4 to 8 cm. in diameter have been referred to Isoetites circularis (Emmons). These have been identified as ancestors of the modern quillworts. Small radially symetrical stems, 8 to 26 mm. in diameter and up to 6 cm. long, have been identified as club mosses and have been named Chinlea campii (Daugherty). Two other club mosses have been identified; one from an incomplete strobile and the other from small linear leaves.

Two genera of horsetails have been found. These are composed of large pith casts and small compressed leaves and stems and have been referred to the genera Neocalamites & Equisetites. The Equisetites is rare however the Neocalamites has been found in several localities in Arizona and New Mexico. They are generally found in the growth position and it is not unusual to find them with rhizome casts attached to the bases. The largest known is slightly over 2 m. tall and 25 cm. in diameter - the longest rhizome cast was 1 m. in length. Also collected were some compressed stems which resemble the living genus Equisetum.

The ferns are quite probably the best known Chinle plants. At least 12 species have been recognized; two of these are based on petrified stems and the others are based on leaf compressions. Both sterile and fertile specimens have been found. Thus the shape of the various sporangia has been preserved.

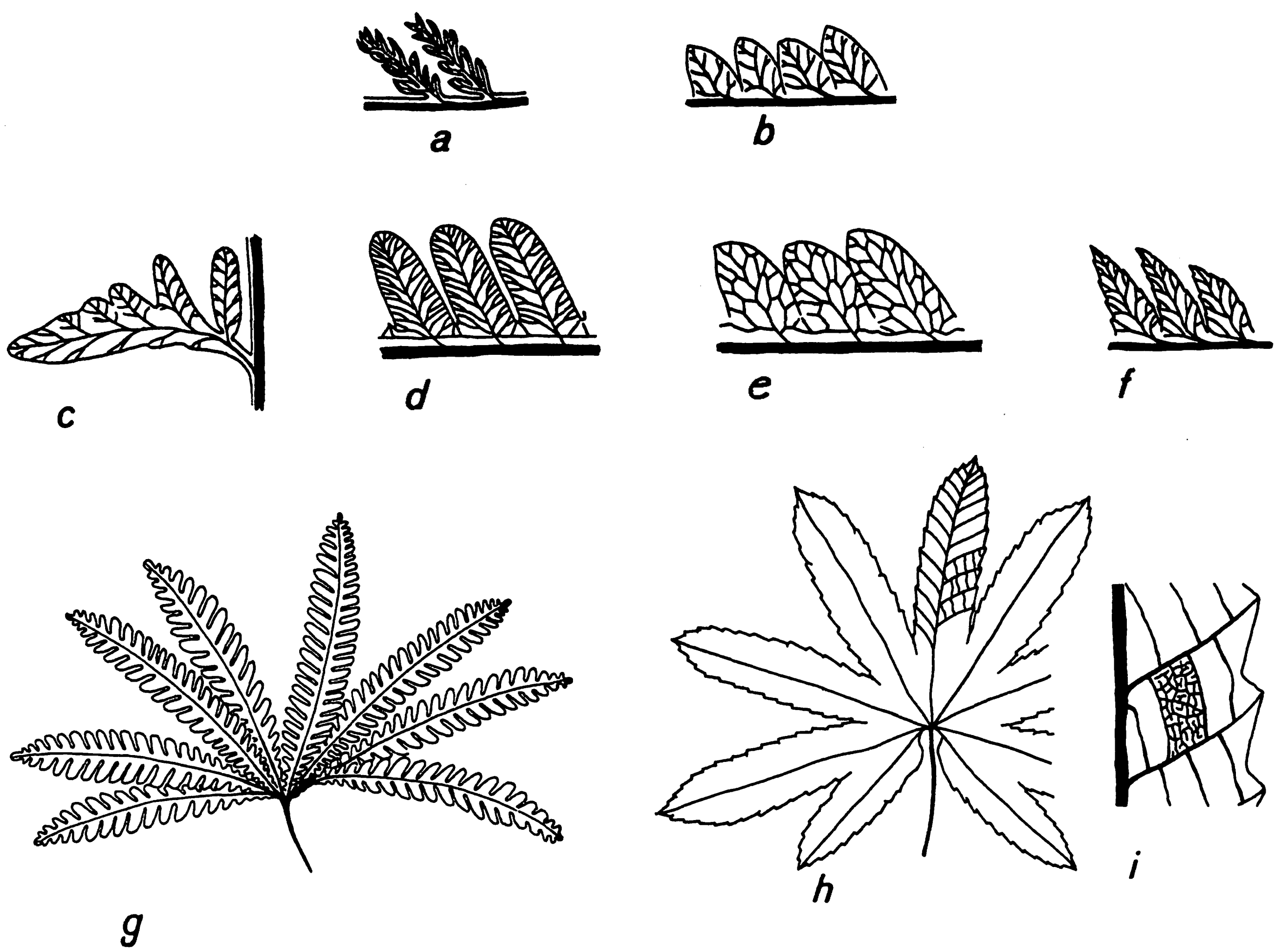

FIGURE 1. Sketches of some of the Chinle ferns. All X2 except *g*, *h*.

a. *Wingatea plumosa* (Daugherty) Ash.
b. *Cladophlebis daughertyi* Ash.
c. *Todites fragilis* Daugherty.
d., *g*. *Phlebopteris smithii* (Daugherty) Arnold;
d. detail showing the venation in three pinnules,
g. the entire leaf, X½.
e. *Cynepteris lasiophora* Ash.
f. *Cladophlebis* sp. B.
h., *i*. *Clathropteris walkeri* Daugherty;
h. the entire leaf, X½,
i. detail showing the reticulate venation.

This is an important element in classifying ferns. Fig 1 shows some of the ferns found.

Coniferous foliage and reproductive structures have been found in some locations. Since none of these have been found attached to branches or trunks it is impossible to assign them to the same genus and species as petrified wood. Six species have thus far been identified. See Fig. 2. The family relationships remain uncertain. Impressions of large linear leaves and small oval seeds have been assigned to the Cordaites. Two species of leaves have been assigned and the seeds have been assigned to the common genus Samaropsis. Two leaf forms have been determined to be ginkgoalean. This is debatable. They have been assigned the names Baiera arizonica Daugherty and Sphenobaiera spectabilis (Daugherty).

The class Cycadopsida is fairly well represented in the Chinle megaflora. Identification has been based on both petrified stems and leaf compressions. One petrified stem has been assigned to Lyssoxylon grigsbyi Daugherty and has been placed in the order Cycadales - a true cycad. The order Bennettitales is represented with 7 species. One is based on petrified stem material, one is based on reproductive structure and 5 on leaf compressions. This order has been erroneously called "fossil cycads" - they are actually cycadeoids. Superficially the two orders Cycadales & Bennettitales cannot be distinguished from one another. Only by observation of the cuticles of the leaf through a microscope can

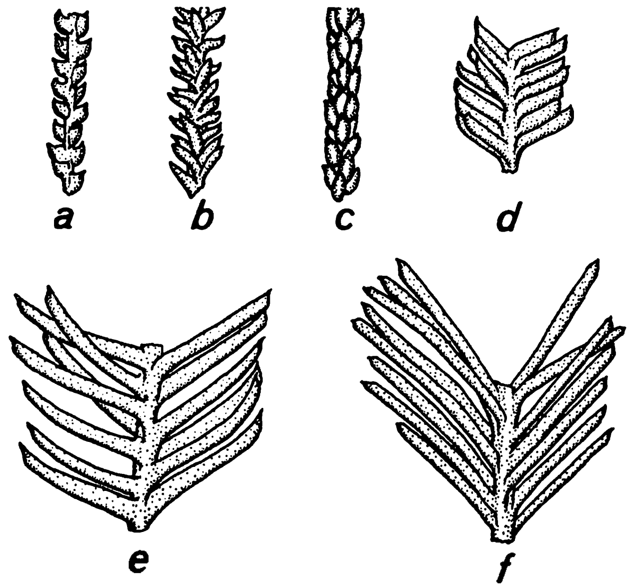

FIGURE 2. Sketches of some of the Chinle gymnosperms. All X2.

a. Brachyphyllum sp. A.
b. Pagiophyllum simpsonii.
c. Pagiophyllum sp. B.
d. Pagiophyllum sp. C.
e. Pagiophyllum sp. D.
f. Dinophyton spinosus.

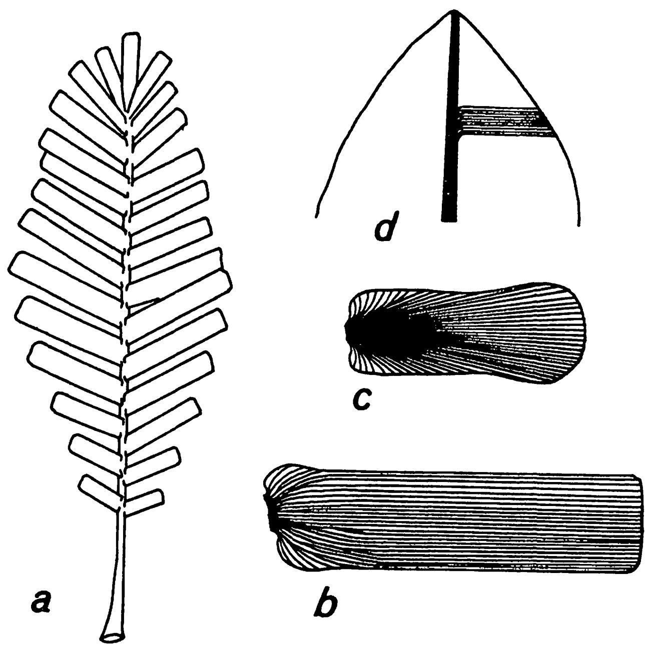

FIGURE 3. Sketches of certain Chinle bennettitites.

a., b. Otozamites powelli (Fontaine) Berry;
a. entire leaf, X½,
b. a pinna showing the venation, X2.
c. Otozamites macombii Newberry, a single pinna showing the venation, X2.
d. Nilssoniopteris sp. A., apex of a typical leaf, X1.

the two be differentiated. The genus Otozamites is represented by two species, O. powelli (Fontaine) & O. macombii Newberry. See Fig. 3. These two species are very distinctive and well characterized. Of the two, O. powelli is the more common and almost all locations that have yielded leaf impressions contain this species. The species assigned from a reproductive structure is based on a single specimen.

FIGURE 4. A reconstruction of the floodplain swamp community.

The varied, though in many instances rare, plant and animal life along with stratigraphic studies has made the reconstruction of the paleoecology in the Petrified Forest area relatively easy. Paleomagnetic studies show that the Petrified Forest was at a latitude of about 18° north during Triassic time. The abundance of red beds, the abundance of thick-walled pollen and spores and the presence of fresh water limestone gives indication of an arid environment. We can therefore assume the local climate was warm and arid to semi-arid. There was however sufficient rainfall to maintain permanent streams in the lowland areas. Stream laden sediments contain large amounts of volcanic ash thereby indicating some vulcanism at their source. There is evidence that shows that there were 3 distinct communities in the Petrified Forest. The first community was the flood plain swamp. See Fig. 4. This community was dominated by ferns and bennettitaleans which formed a thick ground cover. Horsetails (Equisetales) grew along the streams edge. Fig. 4 shows two trees growing at the water's edge in the right background. These are Schilderia adamanica. These trees had swollen fluted bases like the present day Bald Cypress that is seen growing in swamps in the southern United States. Studies show that the two have a similar microscopic wood structure, therefore the inference of a similar mode of growth.

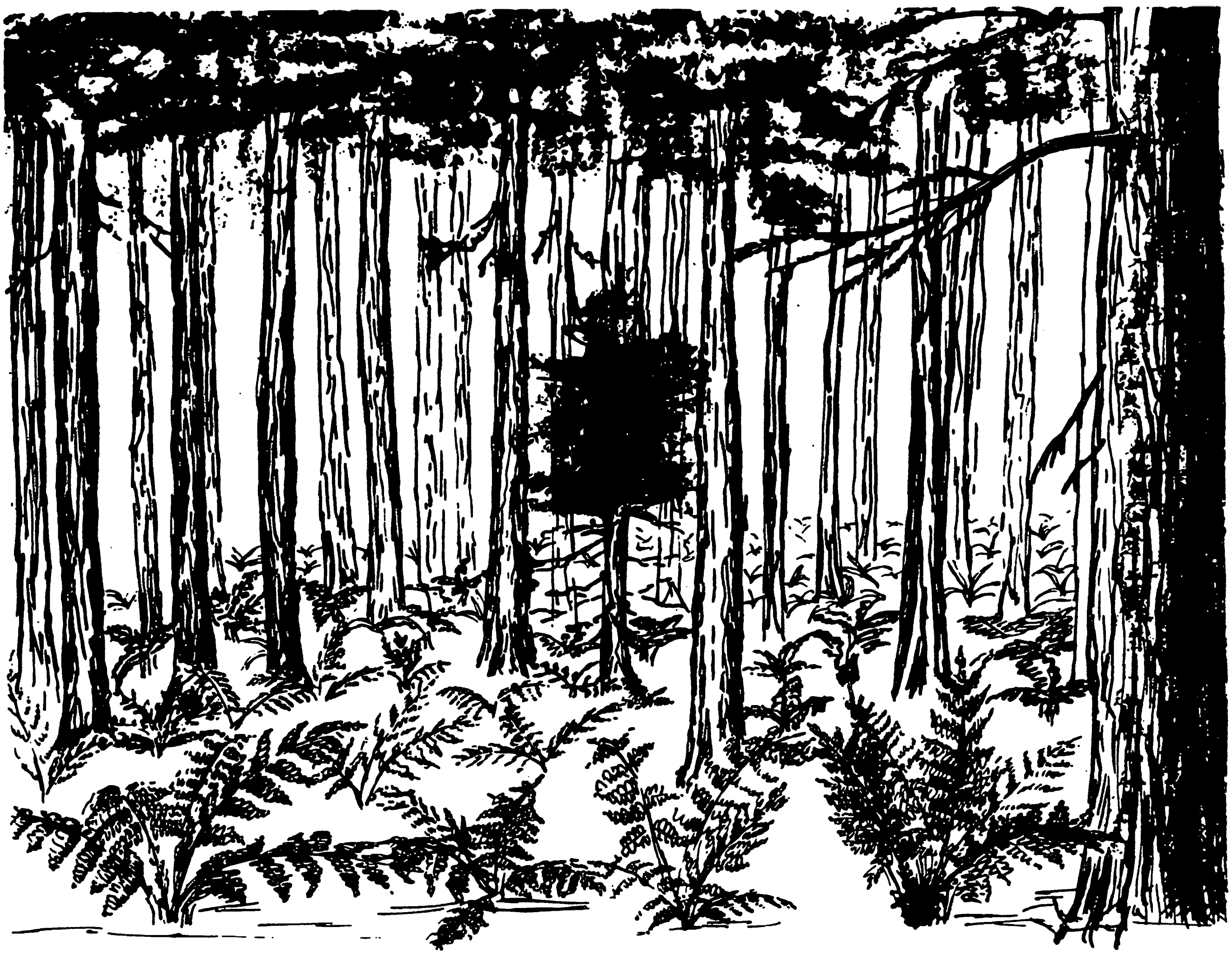

FIGURE 5. A reconstruction of the *Araucarioxylon* forest.

The large fish eating Phytosaurs dominated the stream and the large weak legged amphibians were also present. The large dicyndont reptile Placerias gigas, being a herbivore was undoubtedly present.

The next community was an Araucarioxylon forest. This forest was akin to the Coast Redwood Forests of our Pacific coast. See Fig. 5. The Araucarioxylon had an average diameter of 4 to 5 ft. and they grew approximately 10 to 15 ft. apart. They grew to heights of 150 to 200 ft. and their branches were restricted to the tops of the trees. One location has been found to contain stumps in their growth position. This would indicate a dense canopy with the forest floor in almost complete shade. It appears that this forest community was almost a pure stand of Araucarioxylon.

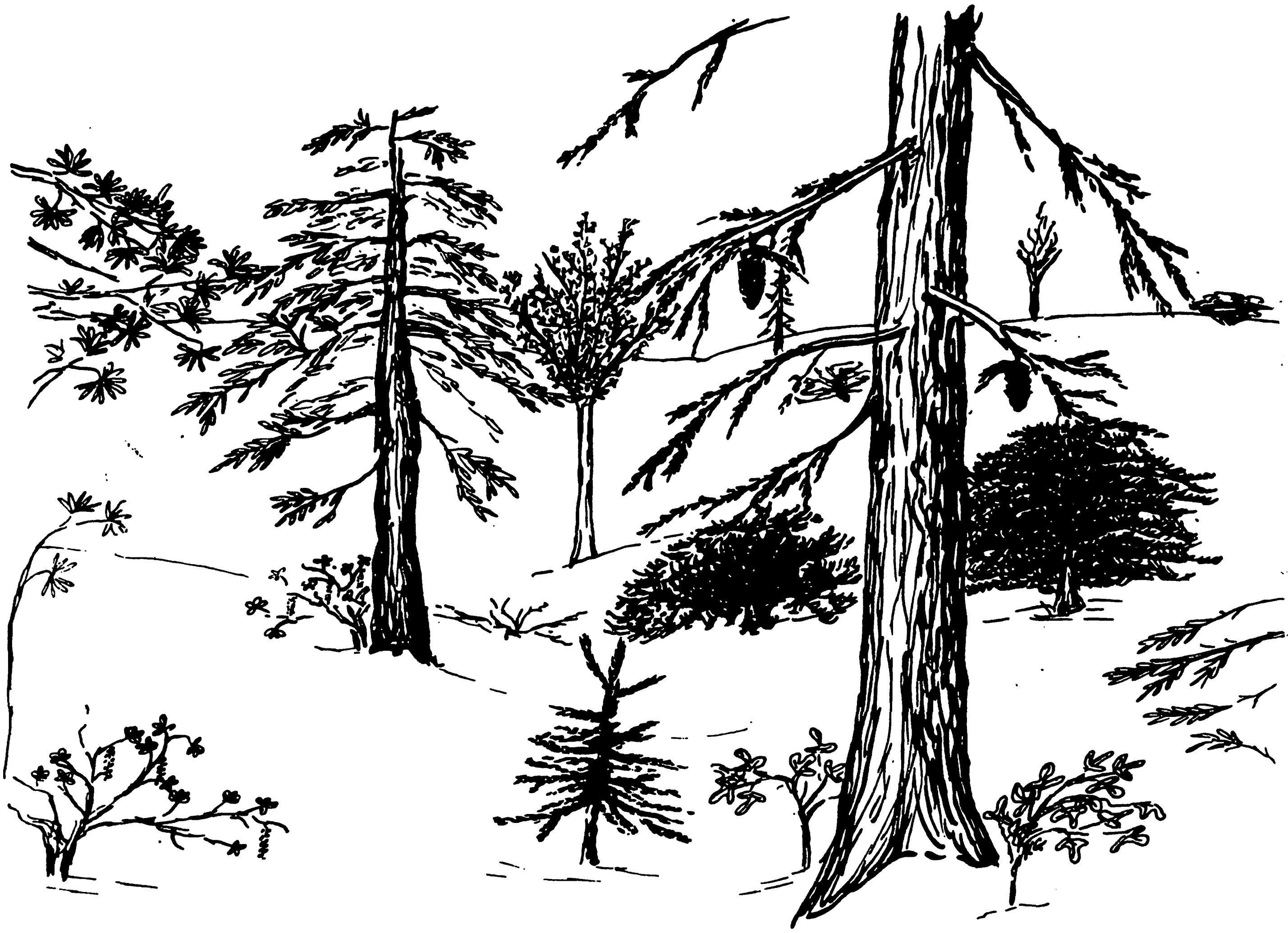

FIGURE 6. A reconstruction of the upland gymnospermous community.

The third community is called the upland Gymnospermous Community. See Fig. 6. Much of the inference about the make up of this community is based on pollen and spore analysis. This community is shown to have been composed of ginkgophytes, shown to the left in Fig. 6 and also in the center, a cordaites and some conifers. It is interesting to note that the pollen of Sagenopteris has been commonly found in the Chinle but no macrofossils have been found. However, macrofossils of Sagenopteris have been found in the Triassic of the eastern United States and Mexico. No doubt this community was inhabited by a variety of reptiles of small and medium size. One candidate for this habitation is Hesperosuchus. Colbert (1952) states "--- the adaptations of this pseudosuchian indicate that it was primarily an upland animal, living on firm, dry ground". It is a good possibility that Coelophysis, the primitive dinosaur, was also an inhabitant of this community although his remains have not yet been discovered here.

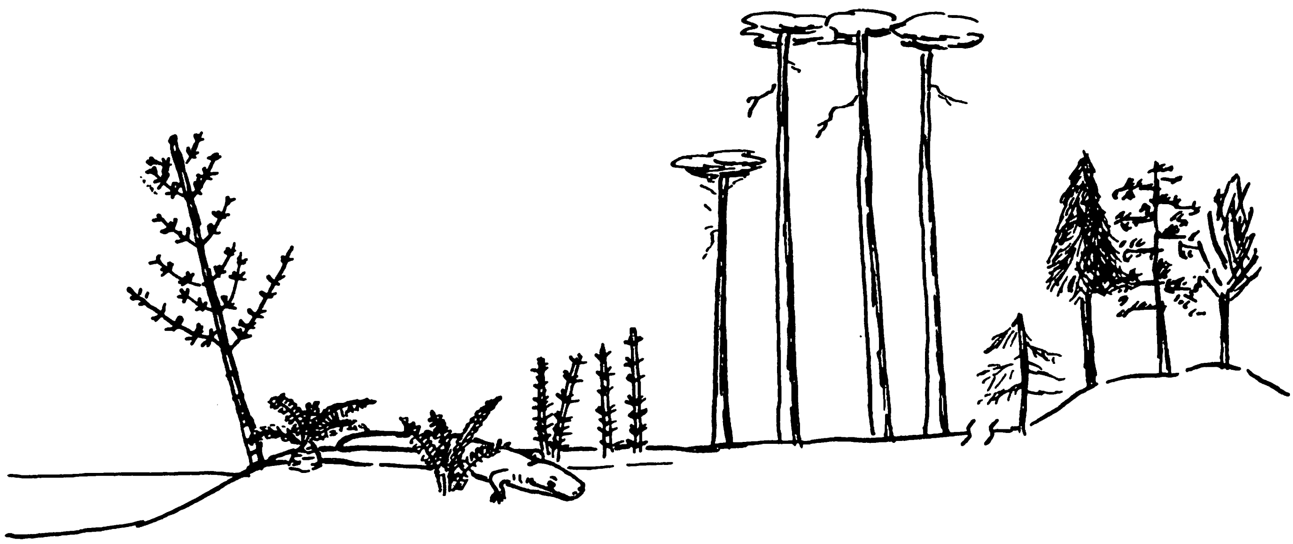

FIGURE 7. A diagram of the relationships of the three Chinle communities.

Fig. 7 shows the relationships of the 3 Chinle communities just discussed. The flood plain swamp community, along the stream, is shown on the left. To the right of the flood plain swamp is the Araucarioxylon forest. Though the site of occupation is moist it is better drained and more stable. The upland community is to the far right. Note that the relief of this 'high ground' is not very high. It is possible that these upland sites were merely low hills. So long as the upland plants were out of reach of the water table they did not need to be very high above base level. It has been found that a relief of 20 - 30 ft. is ample.

There is a cliche that goes I have good news and bad news which do you want first? I have given you the good news first. The bad news is that there is very little area open to public collecting. There is, of course, no collecting in the Petrified Forest National Park. Much of the surrounding land is Indian Reservation - also no collecting. There are 2 private ranches that adjoin the park - one, The Milky Ranch is definately off limits. The second, The Dobell Ranch, allows collecting for a fee however, only petrified wood has been found on this property.

NOTE:

All illustrations are from reference #1.

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*** Petrified Forest Update ***

Three weeks after I finished writing the article on the Petrified Forest I came across some new material on the subject. I feel that it is significant enough for me to convey this information to you.

In 1981 the University of California at Berkeley (U.C.B.) conducted some field work in the Petrified Forest National Park (it gained National Park status in 1962) under the direction of paleontologist Rob Long. The most noteworthy find that field season was the first dinosaur ever found in the park. At the time it was believed to possibly be the oldest dinosaur to be found.

Other discoveries made that year were significant enough to warrant a return the following year - and the next, and the next, and ---. The field sessions are still going on. Although this venture is by no means secretive, it is certainly unpublicized. The ongoing study is by far the most extensive yet undertaken there. The multidisciplinary research has had as many as ten projects going on during a single summer season. Thus far about 200 collecting sites have been investigated.

What has all of this research produced? The discoveries have been nothing short of phenominal. The number of vertebrate species has risen to 34. Included in this are six dinosaurs - three carnivores and three herbivores. The total number of plant species has risen as well - at last count about 200. Although the exact count is not presently available, the number of invertebrates has also increased.

Naturally, all of these discoveries have furnished more ammunition for the paleoecologists to work with. However, there is still disagreement concerning the climatic conditions. Hopefully, further research will settle the issue.

Evolutionary traits have also undergone much extensive research and considerable new insight has been gained. Noteable examples of evolutionary shifts are the placement of the legs of <u>Postosuchus</u>. The sprawling legs were slowly shifted under the body, thus giving the animal greater mobility on land. The heavily armoured alligator like body shape of Desmatosuchus was transformed to a radically flattened, elliptical body which has been likened to an elliptoid frisbee with a head and tail.

Sadly all of this new found material has contributed to a situation that is all too prevelant in many of our educational institutions. The U.C.B. has a warehouse full of fossils on which no preparation has been done.

Some Pennsylvanian Leaves from the Chieftain Number 20 Mine Near Terre Haute, Indiana

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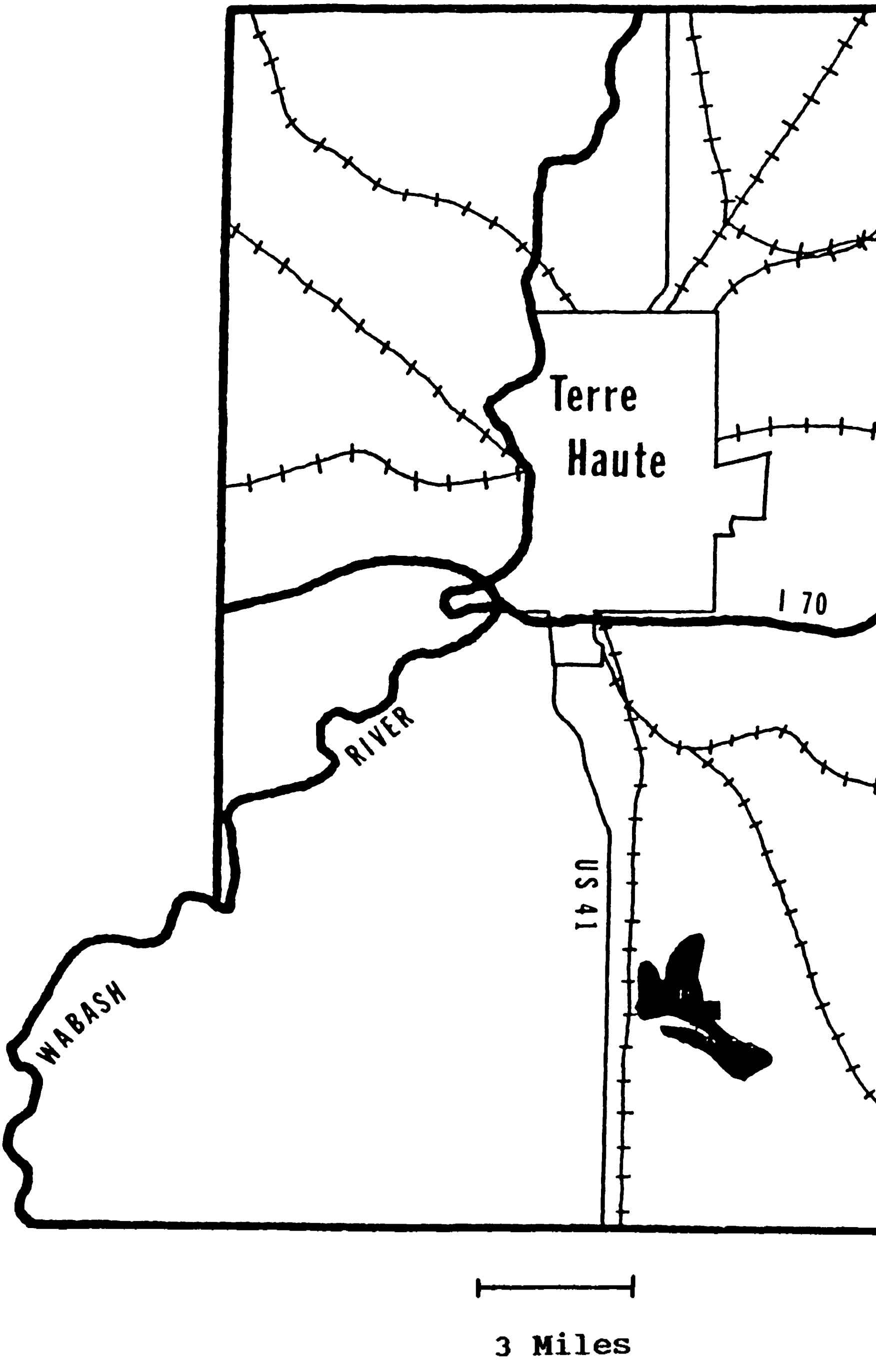
Crawfordsville, Indiana, 47933

The coal measures of Vigo County, Indiana have been productive in the collection of Pennsylvanian leaves for decades and will be productive for many years into the future. The Chieftain Number 20 Mine of the Peabody Coal Company is located ten miles south of Terre Haute, Indiana (Figure 1). The mine is east of U.S. Highway 41 and can be reached by several secondary roads. For a complete map, order the 7.5 minute Lewis Quadrangle from the Indiana Geologic Survey, 611 North Walnut Grove, Bloomington, Indiana, 47405.

The Chieftain Number 20 Mine removed Coal VII (The Danville Coal). Coal VII forms the top stratigraphic unit of the Dugger Formation, Carbondale Group. The siderite concretions that contain the leaf impressions are found in the lower Shelburn Formation, McCleansboro Group (Figure 2). For a complete stratigraphic description see Patrick (1989). The lower Shelburn Formation is a sandy shale and the siderite concretions are concentrated just above Coal VII. Because of their position just above the coal, they were removed last and consequently are mixed in the surface layer over the spoil banks in the coal mine. The spoil banks have some vegetative cover but are gullied and the siderite concretions can be found within these gullies.

The leaves collected from the Chieftain Number 20 mine are varied and abundant. Stratigraphically they are younger than those collected from the Mazon Creek. The following descriptions represent only a partial listing of the leaves that can be collected from the spoil piles. They represent a mix of Lepidodendrales, Calamitales, Cordaites, Sphenophyllales, and Pteridaspermales.

The concretions are a reddish color when weathered with dark inner surfaces. Some of the concretions from the spoil banks will have dark exterior surfaces. The leaf impressions are usually well preserved and an occasional animal impression will be found.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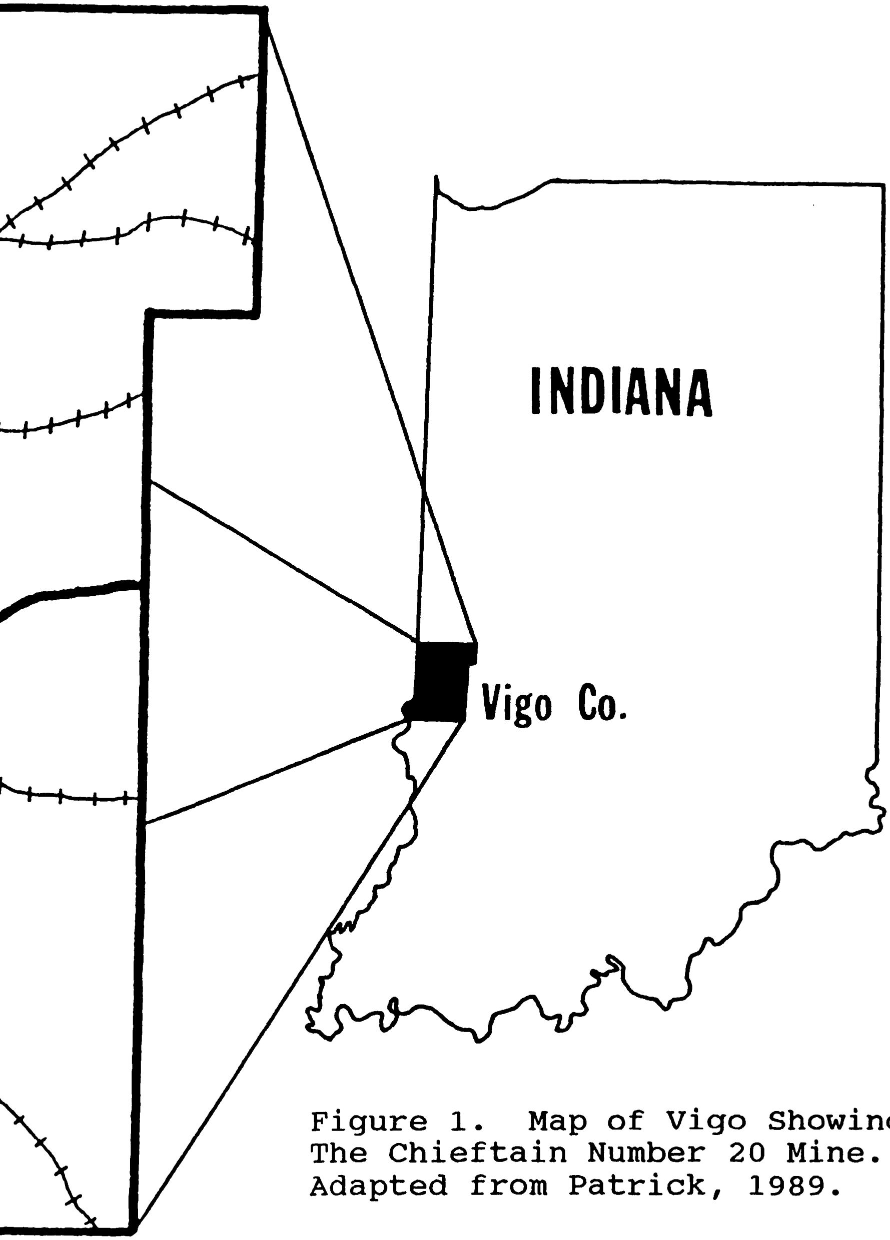


Figure 1. Map of Vigo Showing The Chieftain Number 20 Mine. Adapted from Patrick, 1989.

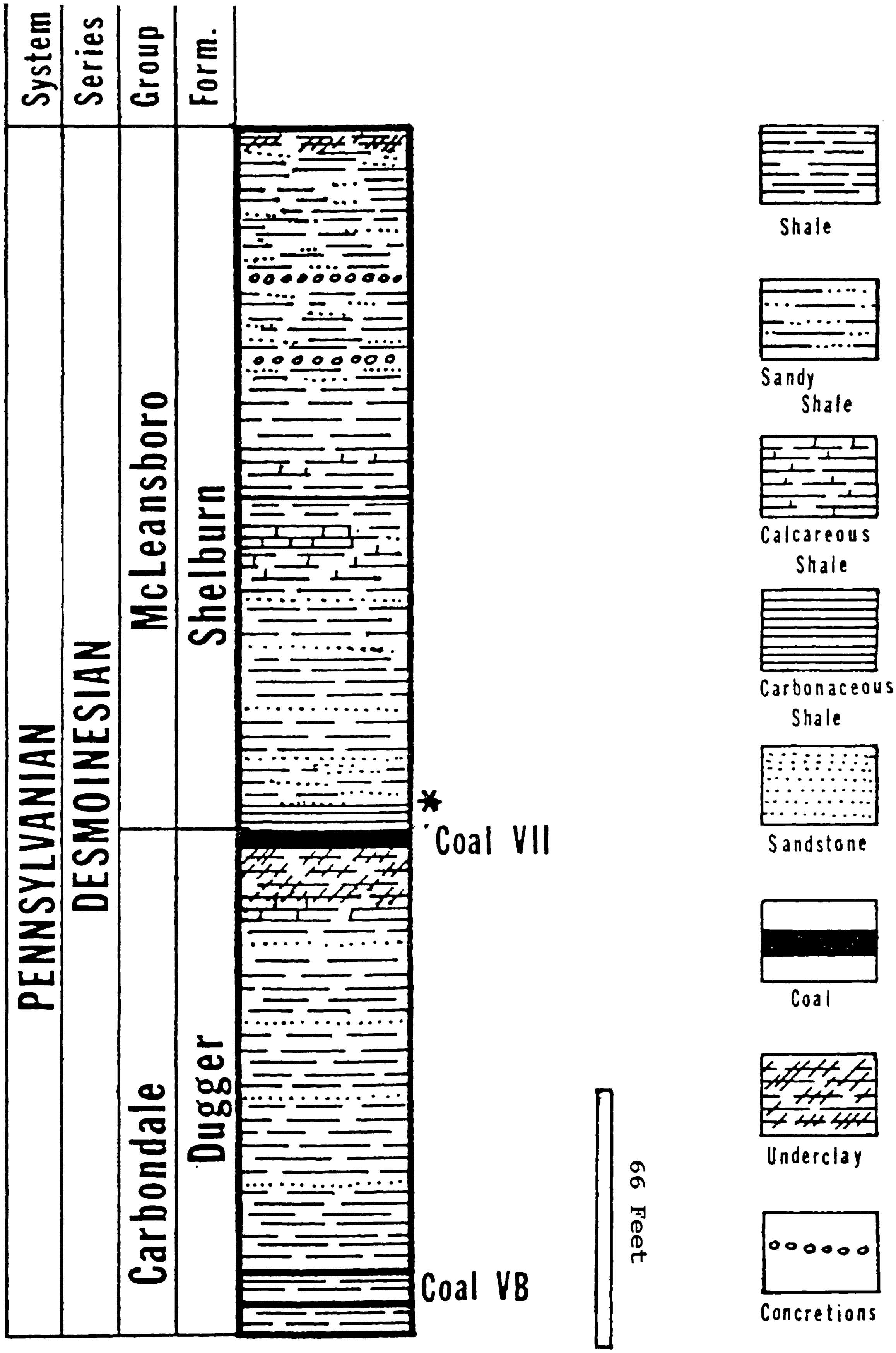
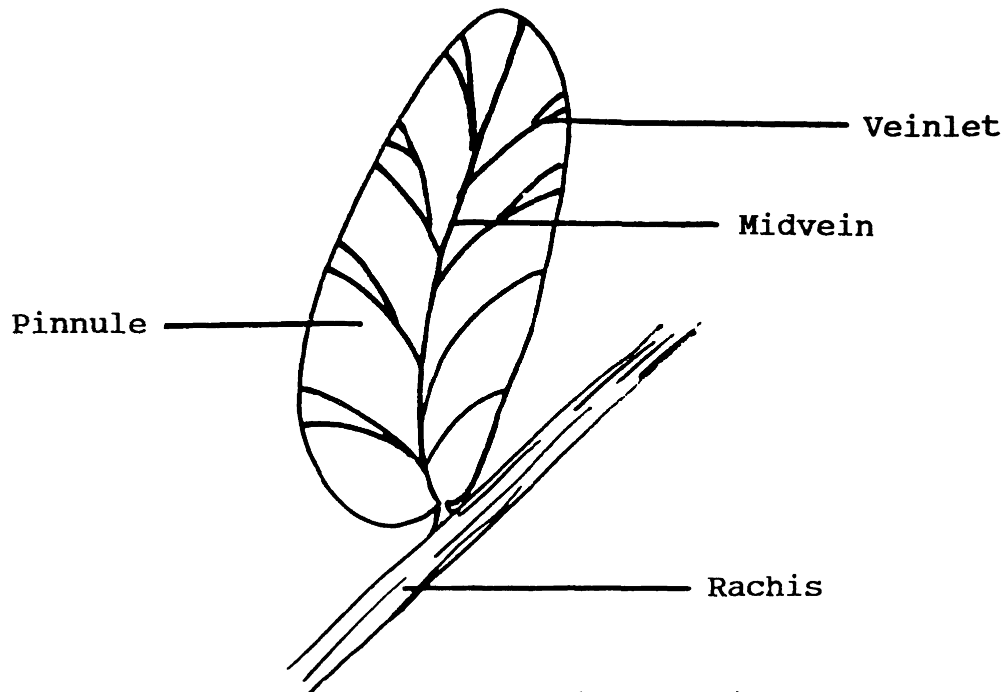


Figure 2. Stratigraphic Section of Vigo County, Indiana. After Weir 1952.

Leaf Descriptions

The following descriptions represent only twelve of the many types of Pennsylvanian leaves that can be collected from the mined area. Figure 3 illustrates some basic characteristics used in the identification of these leaves. Each diagrammed specimen has a magnification number under it. Most of the drawings are enlarged for ease of identification.



Definitions Figure 3

Pinnule - The leaflet portion of the frond. The pinnule may be broadly attached to the rachis or it may be narrowly attached through a bundle of veins.

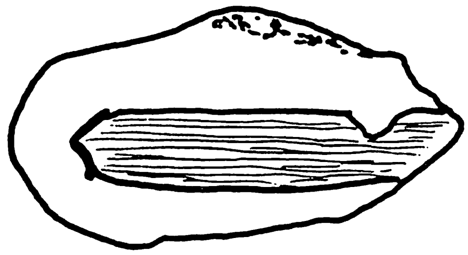
Midvein - The primary vein of the pinnule. The midvein can be distinct, indistinct, or missing entirely.

Veinlet - Any small vein off of the midvein. Veinlets can fork or continue to the pinnule margin with no change. They can be distinct or indistinct. Some leaf species are identified by the number of forks on the veinlet or the count of veinlets on the margin.

Rachis - Branch off of a stem to which the pinnule is attached. The rachis can be smooth or veined, wide or narrow.

Frond - The rachis and all pinnules. The fronds can be complex but are not usually preserved within a concretion except in the smaller species.

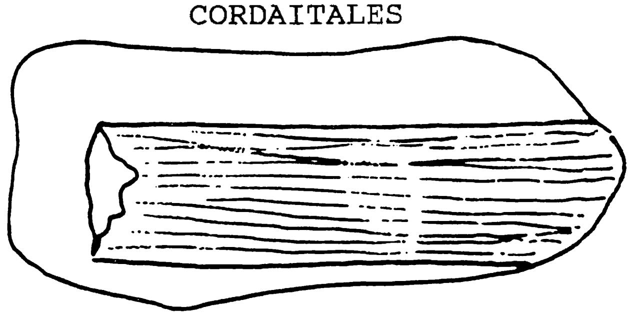
LEPIDODENDRALES



Lepidophyllum longifolium Brongniart
Figure 4 (X3)

L. longifolium is a slender needle-like leaf that can measure up to 8 inches in length and 1/4 inch in width. These leaves are common but seldom if ever whole. The leaf has parallel veins that are distinct. These veins run the entire length of the leaf. While **L. longifolium** is common it may not represent a common tree because of the numbers of individual leaves produced by each tree.

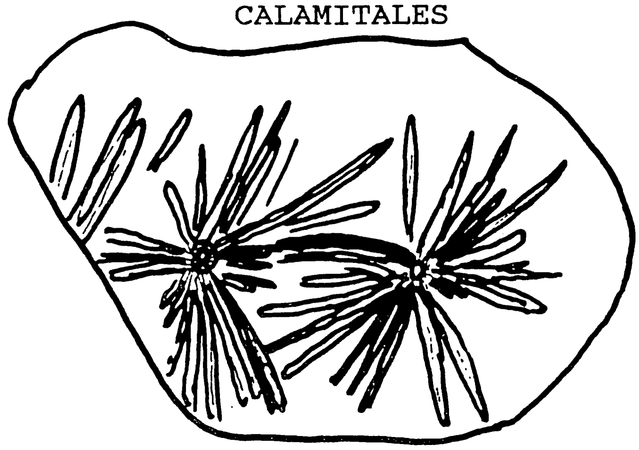
CORDAITALES



Cordaites borassifolius (Sternberg) Unger
Figure 5 (X1)

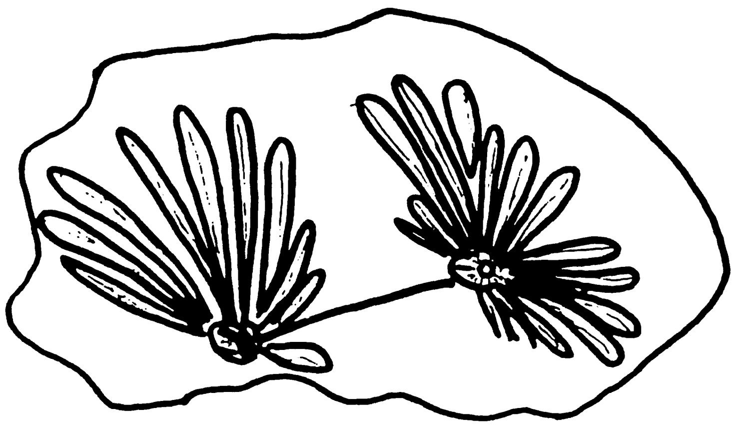
C. Borassifolius is a common strap-like leaf that can be more than 1/2 inch wide. Only incomplete specimens are found. The venation is distinct and runs the entire length of the concretion. These leaves can be confused with **Calamites** but they do not have the stem nodes of **Calamites**. The vein pattern in a well preserved specimen will alternate between a thick vein and a narrow vein.

CALAMITALES



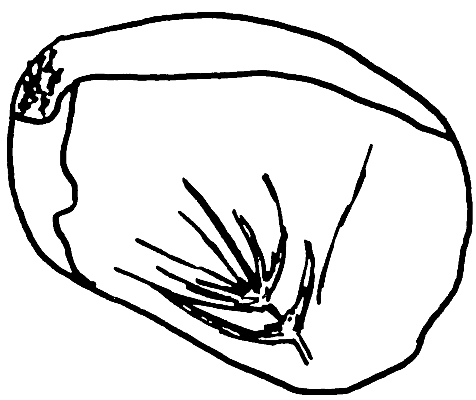
Annularia radiata (Brongniart) Sternberg
Figure 6 (X1.5)

A. radiata is a common leaf that is easily identified by its whorl of pinnules. The leaf whorl and stem are preserved in the same plain. The widest point on the leaf is at the mid-point from the stem. All leaves are about the same length with a midvein visible on some specimens.



Annularia stellata (Schletheim) Wood
Figure 7 (X1.5)

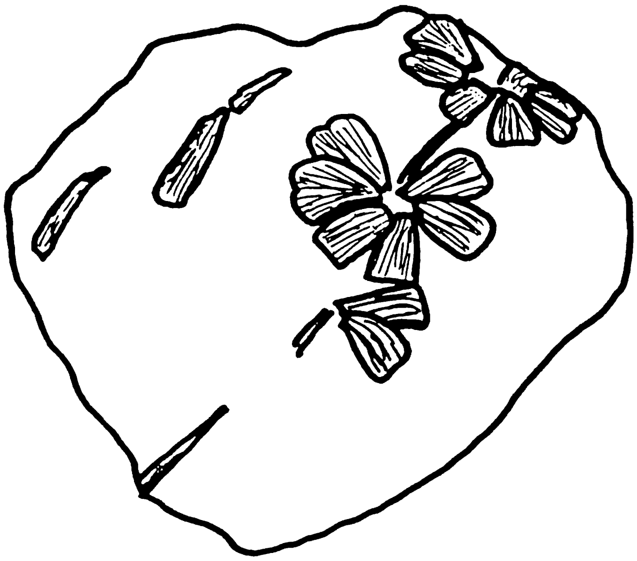
A. stellata is common and similar to **A. radiata** but the leaves are of different length within the whorl. The individual leaves are widest past the midpoint. There will be a midvein present in the better preserved specimens.



Asterophyllites equisetiformis (Schlotheim) Brogniart
Figure 8 (X1.5)

A. equisetiformis has a needle-like leaf whose whorl is around the stem and not laid out flat like **Annularia radiata** or **Annularia stellata**. The leaves are longer than the distance between the nodes. They are curved and can number 15 to 30 per whorl. **A. equisetiformis** leaves are narrower than either **Annularia radiata** or **Annularia stellata**.

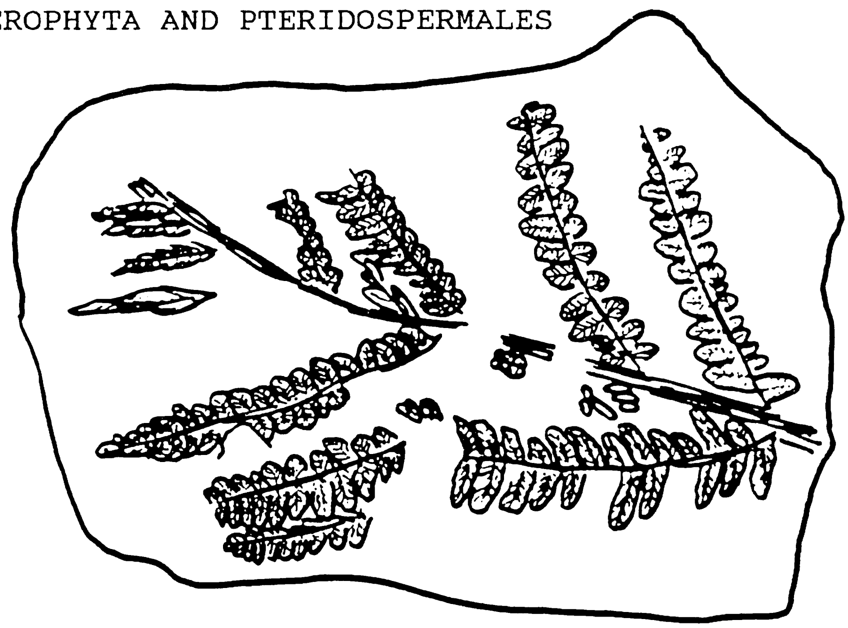
SHENOPHYLLALES



Sphenophyllum emarginatum Brongniart
Figure 9 (X1.5)

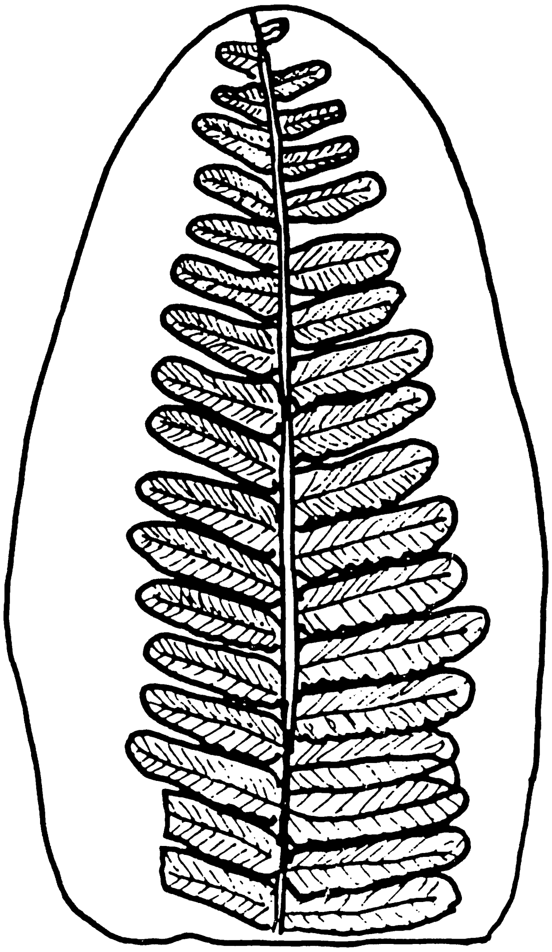
S. emarginatum is from a small plant that covered the forest floor. The leaves are small and slightly triangular. Each leaf margin has rounded teeth with one vein per tooth. Whorls of 6 to 9 leaves are common on stems that are less than 1/4 inch in diameter.

PTEROPHYTA AND PTERIDOSPERMALES



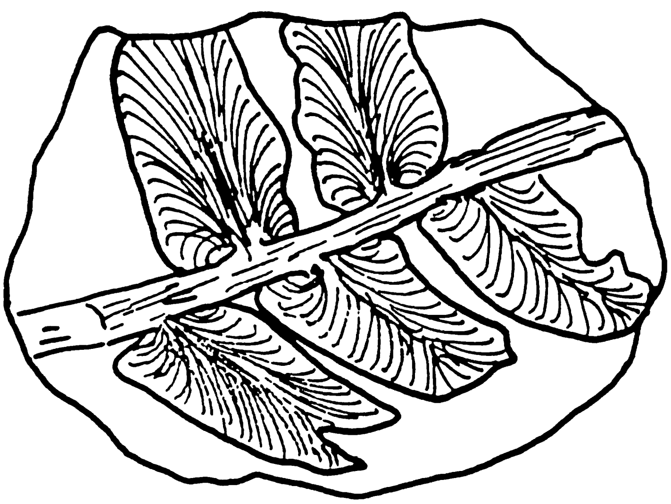
Pecopteris oreopteridia
Figure 10 (X2)

P. oreopteridia is a common leaf that was formerly called **Asterotheca oreopteridia**. The pinnules alternate on the rachis and appear to attach to it at an angle. The pinnule base is wide at the point of attachment to the rachis. The midvein is straight. The veinlets fork once near the midvein and again near the margin. The frond is very large and is seldom complete.



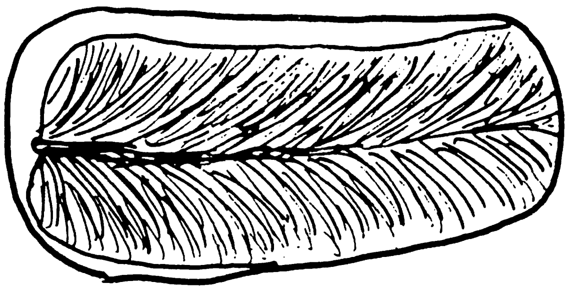
Pecopteris miltoni
Figure 11 (X1.5)

P. miltoni is a very common leaf form from the Chieftain Number 20 Mine. The pinnules alternate on the rachis and are broadly attached at their base. The margins can be ruffled or smooth in appearance. The veinlets fork at least once after separation from the midvein and may fork again near the margin.



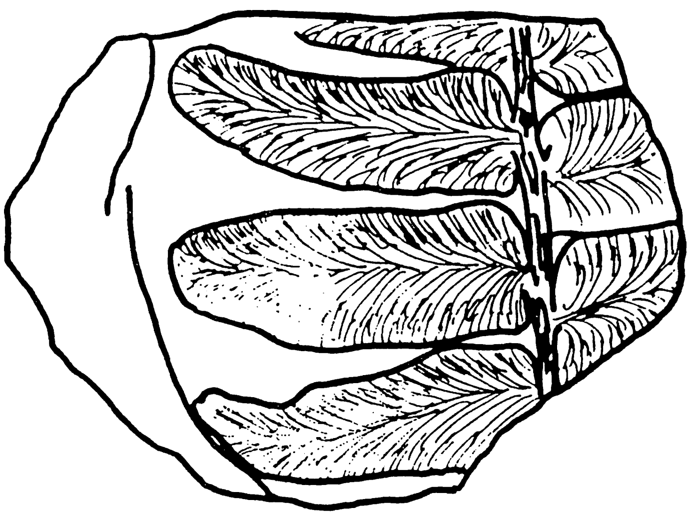
Mixoneura jennyi D. White
Figure 12 (X1.5)

M. jennyi is rare but is so distinctive that identification is easy. It has a pinnule that is narrowly attached to a large rachis. Several veins pass from the rachis to the pinnule. While a midvein is present it is composed of several separate strands. The veinlets divide 1 to 5 times as they near the margin.



Neuropteris scheuchzeri Hoffman
Figure 13 (X1)

N. scheuchzeri is the most common **Neuropteris** species found at the Chieftain Number 20 Mine. The siderite concretions hold one pinnule or a portion of one pinnule. The pinnule may be tongue shaped. As with all **Neuropterids** the pinnule is narrowly attached to the rachis with a short stalk. The veins and veinlets form a fan-like pattern that is finely spaced. The midvein is not present. The apex of the pinnule is rounded and there may be hairs scattered over the surface. The **Neuropteris** frond is very large and the large number of concretions holding **N. scheuchzeri** may not represent many individual trees.



Neuropteris flexuosa Sternberg
Figure 14 (X1.5)

N. flexuosas' pinnule has a slightly wider stalk at the point of attachment to the rachis. The veins and veinlets are fine and very closely spaced. The midvein, if not entirely absent, is not distinct. **N. flexuosa** is rare at the Chieftain Mine.

The following listing gives the Pennsylvanian leaves that are not figured in this article but occasionally can be collected from the spoil banks.

Pecopteris hemitelioides Brongniart
P. Squamosa Lesquereux
P. cisti Brongniart
Ptychocarpus unitus (Brongniart) Weiss
Palmatopteris furcata (Brongniart) Potonie
?Dicksonites pluckencti Schlotheim
Senftenbergia pennaeformis Brongniart
?Crossotheca sagittata (Lesquereux) Zeiller
Aphlebia sp.
Neuropteris fimbriata Lesquereux
N. rarinervis Bunbury
N. violetta Langford
Mariopteris nervosa (Brongniart) Zeiller
M. muricata (Schlotheim) Zeiller

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PENNSYLVANIAN PLANT FOSSILS OF EASTERN KENTUCKY:

With particular attention given to the flora of the Breathitt formation near Hazard, Perry County, Kentucky

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FORWARD:

I have enjoyed the unique opportunity for the last ten years to be employed by the Kenyucky Department of Surface Mining. For the first five years, I served as a field geologist for the Department. In the course of duties associated with that position, I visited several hundred strip mines in the vicinity of the Hazard Coal District of Eastern Kentucky. As a field geologist I was able to examine numerous rock exposures and spoil banks, and was able to collect rock samples and fossils.

This was a very unique opportunity due to the current insurance and mining regulations and policies. Unless a collector or paleontologist has a personal friend in the hierarchy of a coal company, the chances of obtaining permission to collect within active coal mine are very slim. Also to be considered is the very nature of modern coal mining methods which cover and uncover material so rapidly that no area remains the same for more than a day or so. The revegetation regulations are also very strict and only coal mining personal, state and federal mine inspectors are allowed within reclaimed areas.

INTRODUCTION:

The purpose of this report is to privide a brief geological setting of the Pennsylvanian outcrop in Eastern Kentucky; to provide an annotated list of the currently accepted fossil plants to be found in the Breathitt Formation and to provide a list of helpful publications.

THE BREATHITT FORMATION:

The Breathitt Formation contains the best of the flora and fauna and most of the mineable coal beds. The Breathitt Formation attains a maxium thickness of 950 meters to the southeast and contains 30 major coal beds. The Breathitt Formation has been correlated to the Tradewater Formation of the Western Kentucky coal field, the Pottsville series of Ohio. The Kanawha Formation of West Virginia and the Atokan Series of the mid-contient region.

PLANT FOSSILS:

The fossil plants that occur in the Breathitt Formation are preserved primarily as casts of rooting organs, stump and log, or as compressions along bedding planes. Normally the rooting organs are associated with the fireclays immediately beneath the coal beds. Occasionally upright stumps are present with associated logs, rarely upright stumps with attached trunks are observed.

In the area surrounding Hazard, Kentucky; where most of my research has been directed, the fossil plants are primarly preserved as compressions found in the roof shales overlying the coal seams. The fauna and flora that I have accumulated over the last ten years seems to indicate a correlation to the European Westphalian B Interval.

Paleobotanical research has been carried on in the United States since the middle of the nineteenth century. However specific knowledge concerning the Pennsylvanian floras of North America and their correlation to the European Pennsylvanian Standard has been hotly debated. Thus the Appalachian Region of North America are difficult, particularly Eastern Kentucky, about which so little has been published. Although it is generally accepted that the Pennsylvanian rocks of Eastern Kentucky are part of an ancient delta complex, little is known about the transportation and deposition of the fossil plant material.

GEOLOGY

The Pennsylvanian rocks of Eastern Kentucky are comprised of alternating beds and lenses of sandstone and shale with minor beds of marine limestone, fireclay (volcanic ash), conglomerate and coal. These Pennsylvanian rocks form a wedge that becomes thicker to the southeast. These clastic sediments were probably derived from the weathering of the Appalacian Mountains to the east and southeast.

The lower portion of the Pennsylvanian outcrop in Eastern Kentucky is the Lee Formation and is comprised mostly of orthoquartzite. The upper portion of the Breathitt Formation is comprised of shale, subgraywacke (dirty sandstone), and siltstone.

About fifty- percent of my collection remains to be identified. This is due in part to the preservation of the fossils and in part to the lack of published data. Fossils found in the roof shales tend to include some calicum and iron sulfate, that will decompose unless coated with plastic spray. Plastics sprays tend to destroy some of the finer detail needed to identify fossil plants to species level. Fossils found in the sandstone and siltstone usually do not need to be tampered with, however the fine detail has been lost due to the sandy texture of the enclosing rock.

ANNOTATED:

The following list is in alphabetical order. I have included a few representative plant spores that are documented in the literature. The general collecting area is included and where I have personally collected a specimen, the word "collected" appears. The word "reported" denotes that another worker has indicated that a specimen has been collected and identified.

ALETHOPTERIS arberia - Hazard area - reported

A. decurrens - Grannies Branch - reported

A. lonchitica - Grannies Branch - reported

A. serli - Hazard area - collected

ALLOIOPTERIS tenuissima - Hazard area - collected

ANNULARIA galioides - Grannies Branch - reported

A. radiata - Hazard area - collected

ARTISIA sp.- Hazard area - collected

ASOLANUS sp.- Grannies Branch - reported

ASTEROPHYLLITES charaeformis - Hazard area - collected

A. equisetiformis - Hazard area - collected

A. longifolius - Grannies Branch - reported

BOTHRODENDRON minutifolium - Hazard area - collected

BOWMANITES sp.- Grannies Branch - reported

CALAMOSPORA sp.- (plant spore) - Whitesburg Coal Seam

CALAMITES cisti - Hazard area - collected

C. undulatus - Hazard area - reported

CALAMOSTRACHYS gemancia - Hazard area - reported

CORDAIANTHUS lindleyi - Hazard area - reported

C. major - Hazard area - reported

CORDAICARPUS sp.- Hazard area - reported

CORDAICLADUS sp.- Hazard area - collected

CORDAITES principalis - Hazard area - collected

CYCLOGRANISPORITES sp. - (plant spore) - Princess #3 Coal Seam

CYCLOPTERIS sp. Hazard area - collected

DICTYOTRILETES sp.- (plant spore) - Princess #3 Coal Seam

ENDOSPORITES sp.- (plant spore) Princess #3 Coal Seam

GNETOPSIS anglica - Hazard area - reported

LAEVIGATOSPORITES sp.- (plant spore) - Princess #3 Coal Seam

LEPIDODENDRON aculeatum - (cone) - Hazard area - collected

LEPIDOPHYLLOIDES longifolium - Grannies Branch - reported

LEPIDOSTROBOPHYLLUM ornatus - (cone) - Hazard area - collected

L. sp. - Hazard area - collected

LINOPTERIS (RETICULOPTERIS) muensteri - Hazard area - collected

L. sp. - Hazard area - collected

LYCOSPORA SP.- (plant spore) - Princess #3 Coal Seam

MARIOPTERIS hirta - Hazard area - collected

M. nervosa - Grannies Branch - reported

MICRORETICULATISPORITES sp.- (plant spore)-Princess #3 Coal Seam

MOOREISPORITES sp. - (plant spore) - Princess #3 Coal Seam

NEUROPTERIS gigantea - Grannies Branch - reported

N. heterophylla - Grannies Branch - reported

N. rarinervis - Hazard area - collected

N. tennuifolia - Hazard area - collected

PALEOSTACHYA elongata - (cone) - Hazard area - reported

PARAACALMOSTACHYS sp. - Hazard area - collected

PECOPTERIS pennaeformis - Hazard area - collected

P. plumosa - Grannies Branch - reported

RHACOPHYTON sp.- Hazard area - collected

SAVITRISPORITES sp.- (plant spore) - Fireclay Coal Seam

SIGILLARIA ovata - Hazard area - collected

S. rugosa - Hazard area - collected

SPRENOPHYLLUM cuneifolium - Hazard area - collected

S. magus - Hazard area - collected

SPHENOPTERIS amoena - Grannies Branch - reported

S. footneri - Hazard area - collected

S. (PALMATOPTERIS) furcata - Hazard area - collected

S. obtusiloba - Grannies Branch - reported

S. souichi - Hazard area - collected

S. striata - Hazard area - collected

S. ("RHODEA") subpetiolata - Hazard area - collected

STIGMARIA ficoides - Hazard area - collected

TRIGONOCARPUS sp.- Hazard area - collected

ULODENDRON magus - Grannies Branch - reported

WILSONITES sp. - (plant spore) - Princess #3 Coal Seam

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PENNSYLVANIA, THE PENNSYLVANIAN PERIOD
PALEOBOTANY AND PLANTS

A. GERALD ZVIRBLIS
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MOUNTAINTOP, PENNA. 18707

Let's face it - you just can't publish a MAPS Digest for Expo XII on plants and leaf fossils without including an article on the fossil plants of Pennsylvania. Why? Because the entire block of the Earth's history listed in the geologic table as the Pennsylvanian Period,which ranged from 320 to 280 million years ago, is named after the Commonwealth of Pennsylvania. The reason for this honor is because of the great profusion of fossil plants which were first discovered in the coal-bearing strata which is so well represented in the State and the subsequent studies which were conducted by geologists and paleobotanists from the mid-1800's up to the present.

When coal was first mined in Pennsylvania, it was noted by the miners that the overlying shale layer contained a great amount of beautifully preserved plant impressions. Large slabs of shale were literally covered with fern fronds, leaves, seeds, cones, roots, whole trunks of fossil lycopods and, in some cases, impressions of insects such as cockroaches and dragonflies. According to a report from the Second Geological Survey of Pennsylvania, in a deep mine located near Mundy Street and Route 309 in Wilkes-Barre, Luzerne County, miners discovered that the base of the coal vein contained an entire forest of upright fossil tree trunks in situ. The stone casts of the trunks stood right where they had been growing. The shale layer overlying the coal vein(the roof of the mine) contained a long section of amphibian tracks which was removed in three sections and brought to the surface. The three slabs were then sent to museums. I don't have a copy of the article but I think that the total length of the slabs measured thirty feet.

During the mid-1800's Geology was still a young science. Scientists from Europe were becoming attracted to the United States because of the many discoveries of mineral resources and mines being opened all over the country. The Carboniferous floras of Europe had already been studied by various botanists and geologists and now their interest was turning to the unexplored fertile ground of the United States.

An early work by Brongniart of France entitled "Histoire des Vegetetaux Fossiles"(1838) described some Carboniferous plant specimens from Pennsylvania but the history of the Carboniferous flora in the United States really begins a few years later...

In 1847, Leo Lesquereux, a Swiss botaniat emigrated to the United States and set up a watchmaking shop in Ohio. He also worked as a Paleobotanist traveling, identifying and describing fossil plant collections while working on commission from private collectors and various State geological surveys. One of his more well known backers was the famous Swiss geologist Louis Agassiz of Harvard.

In 1852 Leo began studying collections of plants for the Commonwealth of Pennsylvania's First Geological Survey and published a list of 111 new or unusual species in 1854. These were later published in a report by H.D. Rogers in 1858.

Based upon this earlier work, Leo was commissioned by the Commonwealth of Pennsylvania's Second Geological Survey to do a paleobotanical survey of the State's Carboniferous flora. This work resulted in the publishing of the now famous "Coal Flora Atlas" of 1879 and 1880, Volume 1 and 2, and Volume 3 of 1883. This work is universally considered to be the foundation of Carboniferous Paleobotany in the United States.

During the above period Lesquereux received much financial assistance and backing by a private citizen, Mr. R.D. Lacoe of Pittston, Pa. Many of these early specimens are presently stored in the Harvard University Herbarium, the U.S. National Museum, the Pennsylvania State Museum and the Illinois State Natural History Museum.

Lesquereux did a prodigious amount of work in his long career having looked at a great numbers of fossil specimens including the Mazon Creek-Wilmington flora of Illinois which was made famous by George Langford in his two volumes of that flora.

As a result of the previous work done by Lesquereux, he was called upon by other states to examine their collections and subsequently did work for Illinois, Arkansas, Indiana, Tennessee etc. Others continued this work after Lesquereux, however, the work consisted of comparing and correlating the U.S. flora with that of Europe. It should be noted that two important recent works are: "A Critical Review of the Upper Pennsylvanian Floras of Eastern United States with Notes on the Mazon Creek Flora of Illinois" by Wm. C. Darrah, 1969 and "Fossil Plants from the Anthracite Coal Fields of Eastern Pennsylvania" by John Oleksyshyn, 1982.

The original plant fossils collected by Lesquereux and others came from the three separate mining areas in the State of Pennsylvania: the northern anthracite coal basin and the southern anthracite coal basin both located in the East and the bituminous coal fields located in the western part of the State. Most of the original sites where these "type" fossils have been collected either no longer exist or else the rock has weathered so much over the years that fossils are no longer recognizable or collectable. I remember, as a child, living in the northern anthracite basin in Scranton, Lackawanna county and seeing fossil plant specimens lying all over spoil heaps in great profusion. In the late 1960's, 1970's and 1980's I collected every available waste pile in the Scranton-Wilkes-Barre basin as well as the southern basin. Many beautiful deep-mined specimens, although slightly weathered, could still be found. Collecting at active strip mines in Wanamie, Carbondale and Hazleton yielded many beautiful specimens.

There are three basic subphyla of Pennsylvanian Period plants which consist of a number of Families and Genera.

Subphylum: Lycopodiophyta
Family: Lepidodendraceae
Family: Sigillariaceae

Subphylum: Equisetophyta
Family: Calamitaceae
Family: Sphenophyllaceae

Subphylum: Pterophyta and "Pteridophylla"
Family: Sphenopteridaceae
Family: Eusphenopteridaceae
Family: Dicksoniaceae
Family: Mariopteridaceae
Family: Pecopteridaceae
Family: Alethopteridaceae
Family: Neuropteridaceae
Family: Cordaitaceae

Some of these fossil specimens are really "different looking". A good example is the "scaly-barked" Family of trees called the Lepidodendraceae. These were large trees which had long thin leaves which grew out of the trunk in a spiral pattern and left diamond-shaped leaf scars when they fell off. The result is a fossil impression resembling a "tire track" or a "snake-skin" as the local residents refer to them. Trees of the Family Sigillariaceae had a somewhat similiar appearance except for parallel lines running the length of the trunk.

The Calamitaceae were large shrubs or trees which had branches with whorled leaves. Fossil impressions of their trunks are characterized by parallel lines with perpendicular nodes every few inches. The Subphylum Pterophta contained all the "seed-ferns", true ferns and Cordaites. Large slabs containing whole fronds of these plants are sometimes found. You can imagine the surprize and pleasure a collector experiences finding something like this. I've had similiar experiences and I guess part of the joy of collecting fossils is the thought about what lies around the next corner or under the next rock.

Pennsylvania"s mines have produced a wealth of fossil specimens which can be found today in private collections and in major museums throughout the world. The older collections made in the last century which are housed in dusty backrooms of museums are still being studied today. Because of the State's unique and extensive Carboniferous strata and because of the labors of the early scientists who came here the Commonwealth of Pennsylvania occupies one of the unique positions in the history of the Earth.

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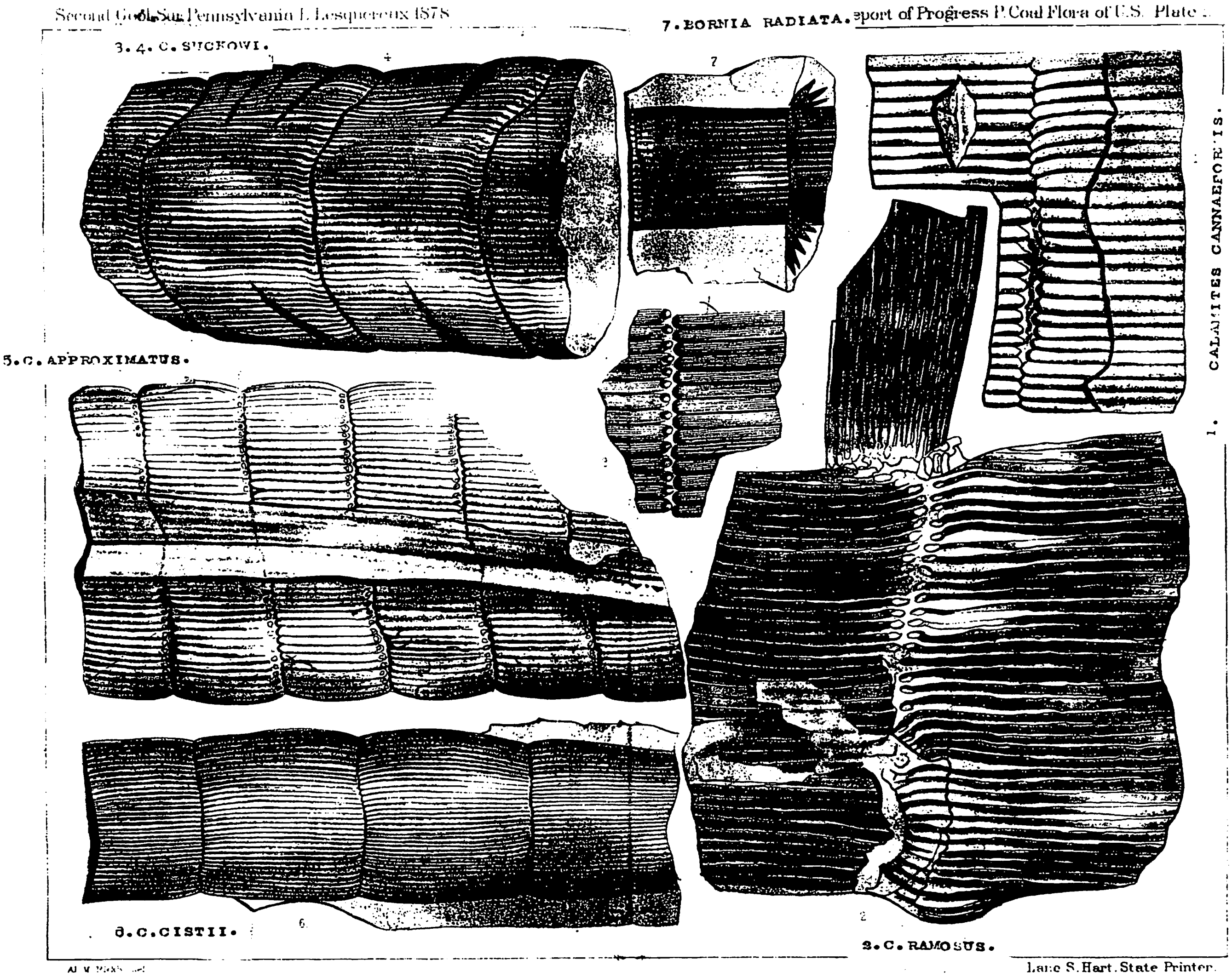


Figure 1. Plate 1 of Report of Progress P of Atlas to the Coal Flora of Pennsylvania.

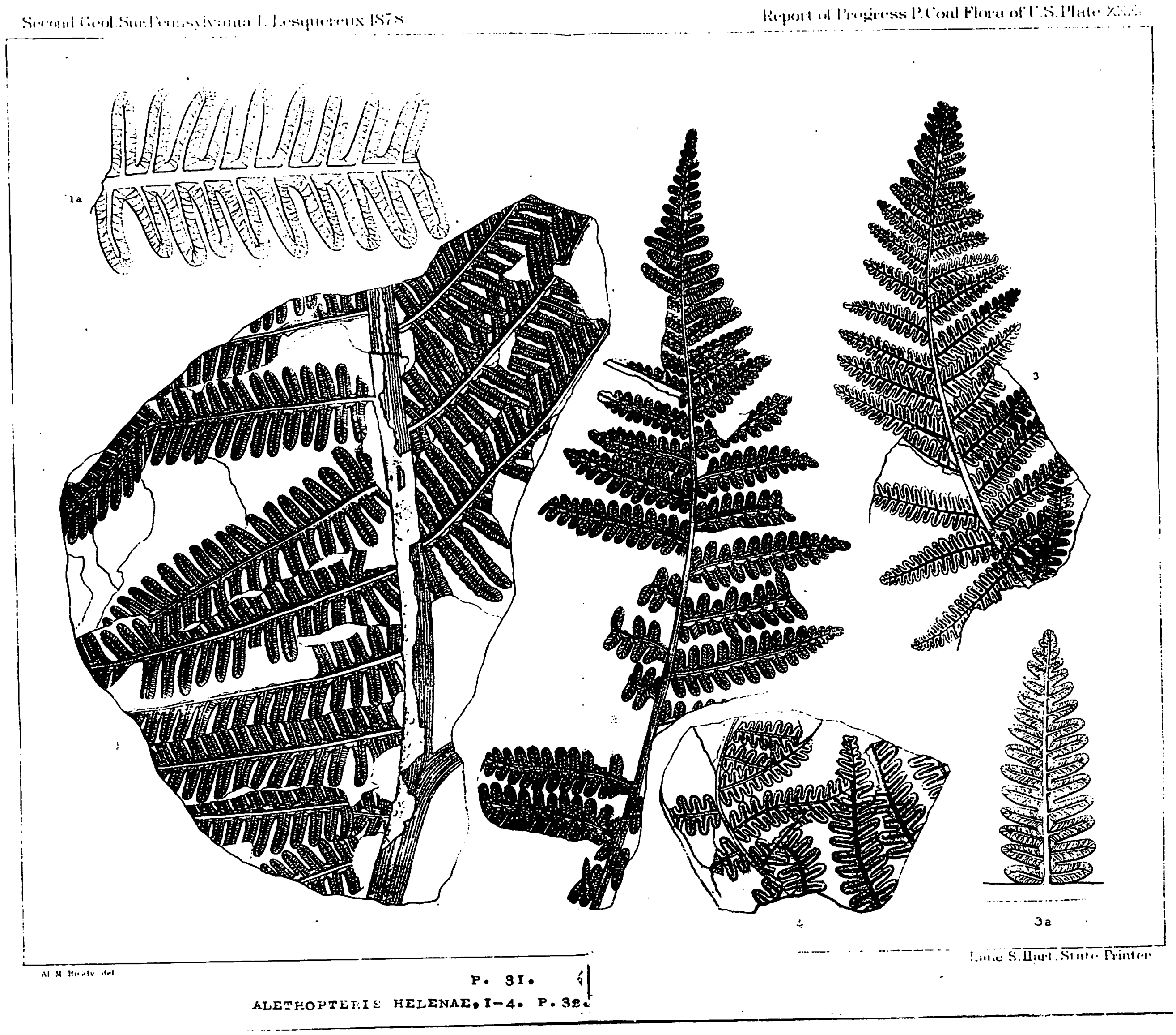


Figure 2. Plate 31 of Report of Progress P of Atlas to the Coal Flora of Pennsylvania.

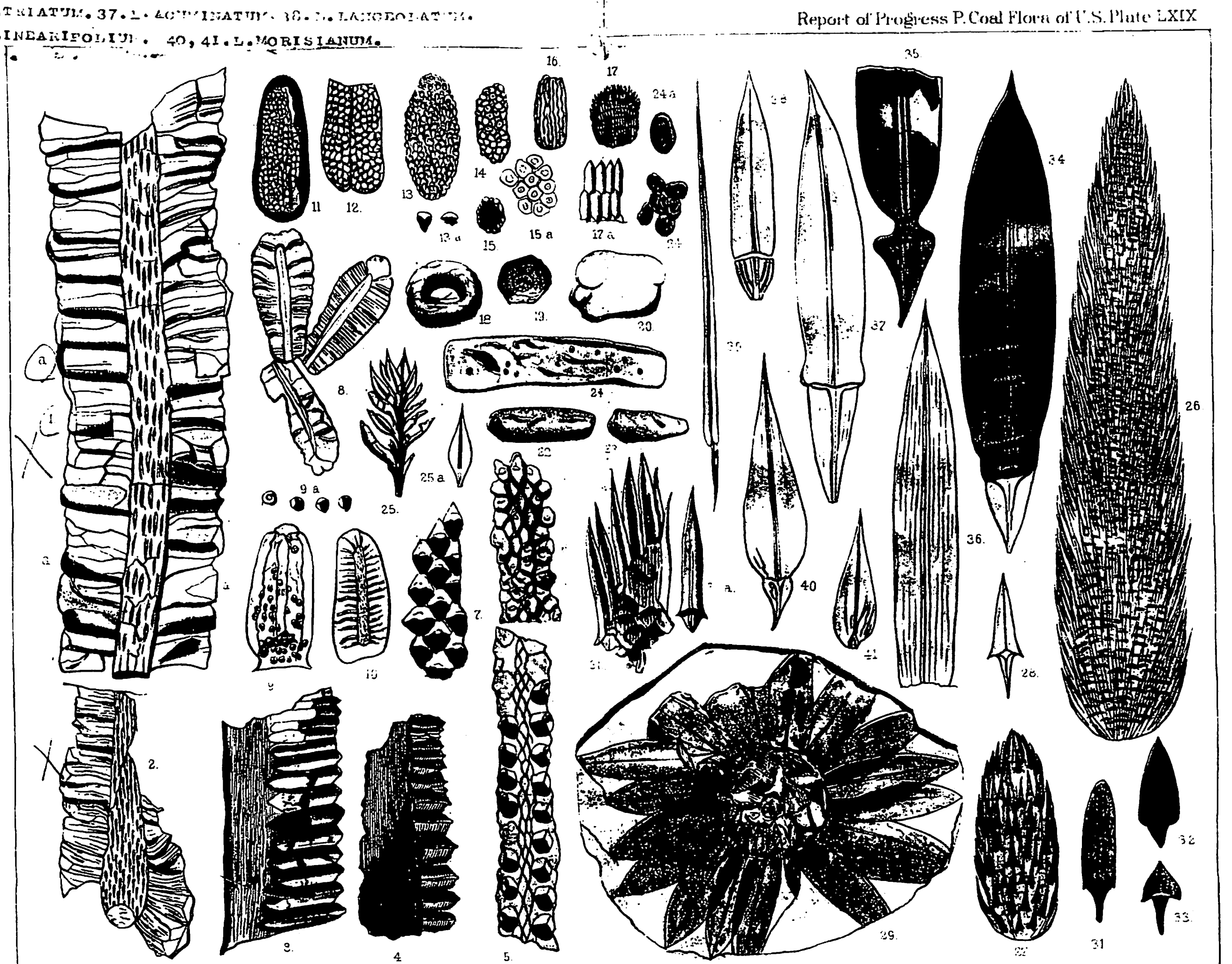
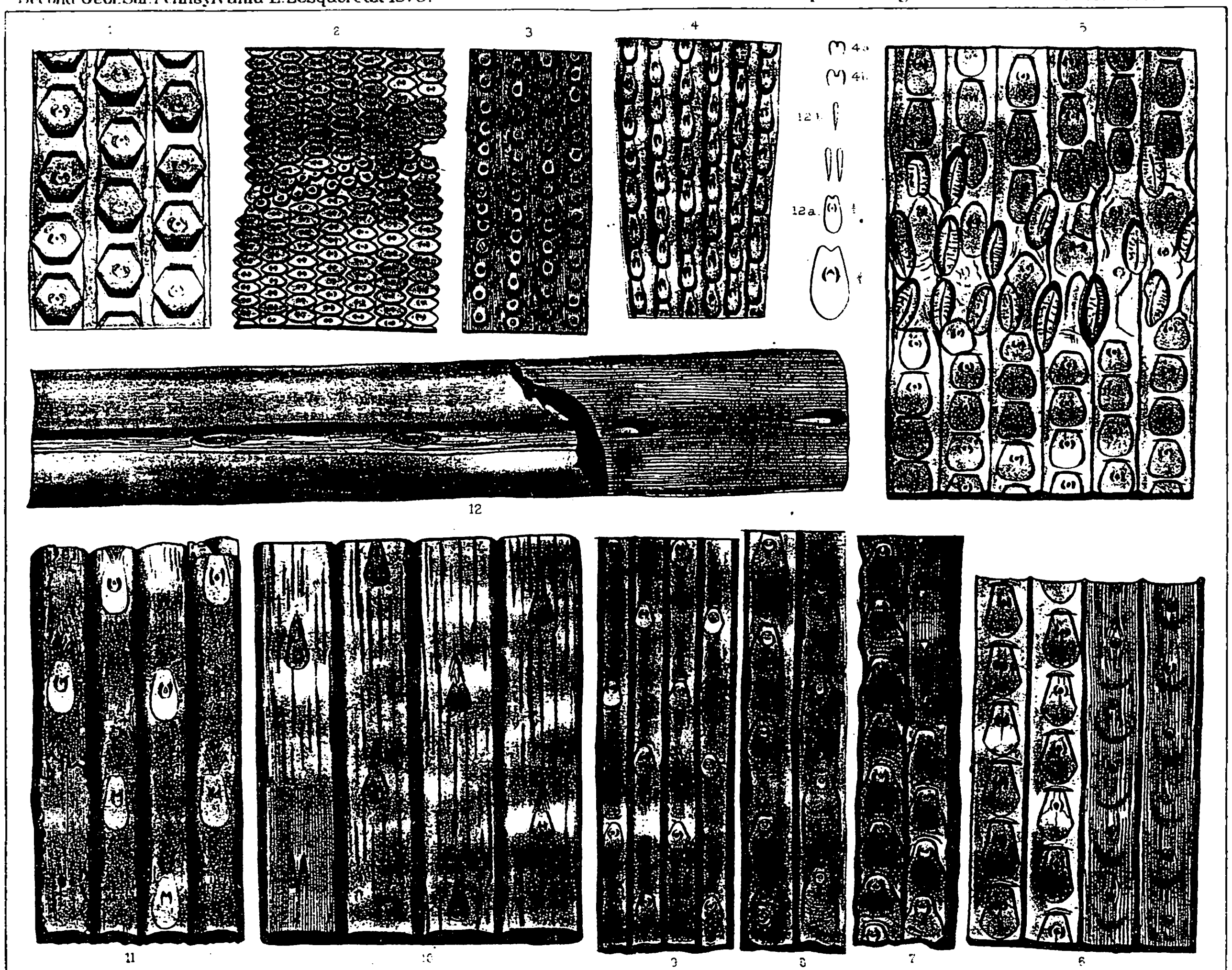


Figure 3. Plate 69 of Report of Progress P of Atlas to the Coal Flora of Pennsylvania.

Second Geol. Sur. Pennsylvania L. Lesquereux 1878. Report of Progress P. Coal Flora of U.S. Plate LXXII.



Ai Y Richly, del. Lane S. Hart, State Printer.

1. SIGILLARIA HEXAGONA. 2-4B. S. TESSELLATA. 5, 6. S. MAMILLARIS. 7, 8. S. ATTENUATA. 9. S. LESCURII. 10. S. LEPTODERMA. 11. S. WOLZII. 12-12b. S. LACOEI.

Figure 4. Plate 72 of Report of Progress P of Atlas to the Coal Flora of Pennsylvania.

8 FOSSIL PLANTS FROM ANTHRACITE FIELDS

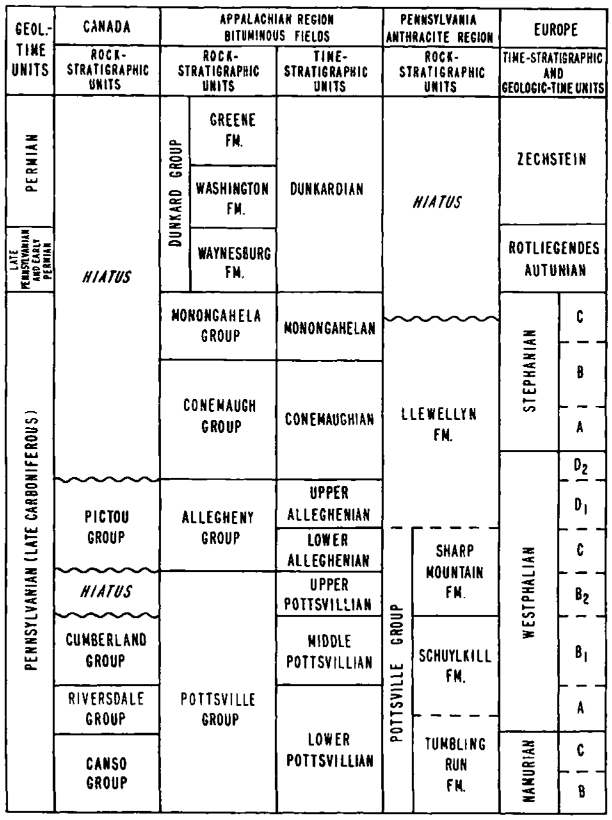


Figure 4. Correlation chart of Pennsylvanian and Permian strata in the Anthracite region of Pennsylvania, the bituminous fields of the Appalachian region, the Maritime Provinces of Canada, and western Europe.

The collecting locality above the Baltimore coal bed is located about 1.5 km (0.9 mi) west of Wanamie, Luzerne County, in the Nanticoke quadrangle, on the south side of the road from Wanamie to Glen Lyon (Figure 6).

Figure 5. A correlation chart from John Oleksyshyn's book," Fossil Plants From The Anthracite Coal Fields of Eastern Pennsylvania." General Geology Report 72, Pa. Geological Survey, Fourth Series.

FOSSIL FLOWER DATES BACK TO DINOSAUR DAYS

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Scientists say they have identified a tiny, fossilized plant from the age of the dinosaurs as the earliest flower ever discovered, and it may represent an ancestor to all 300,000 species of flowering plants alive today.

The 1-inch-high flattened fossil collected in southeastern Australia is believed to be 120 million years old, at least 5 million years older than the oldest previously reported flower, said the Yale University researchers.

The "Koonwarra plant," as it is being called until a formal name is bestowed, seems to have been a small, unimpressive herb resembling the modern black pepper plant.

Its importance may be great, however, said researchers David W. Taylor, a biologist, and Leo J. Hockey, a professor of geology, geophysics and biology.

Taylor said that " it had the leaves of a gymnosperm but it also has the characteristics of both monocots and dicots." Gymnosperms are large, non-flowering trees such as pines that came earlier in evolution, while monocots and dicots are the two major categories of modern flowering plants, known scientifically as angiosperms.

Flowering plants dominate most of the world's ecosystems, said Taylor in a telephone interview, and include most of the major crop plants of the world.

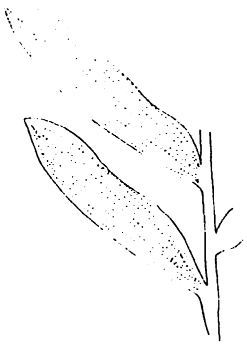
The scientists, who published the oldest angiosperm yet found and may represent an ancestor to all angiosperms. Since angiosperm pollen 10 million years older has been discovered previously, the Koonwarra probably is not a "missing link" between gymnosperms and angiosperms.

Taylor identified the primitive angiosperm after reading a scientific paper in which the plant had been misidentified as a fern.

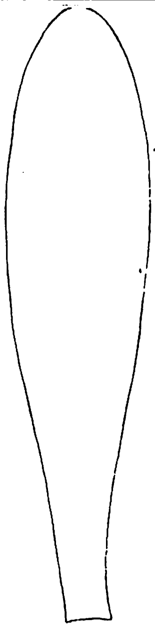
By Boston Globe

Outline Key

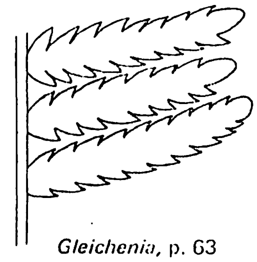
Ferns and Fernlike Foliage



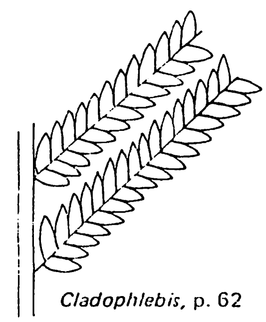
Podozamites, p. 94



Cordaites, p. 83



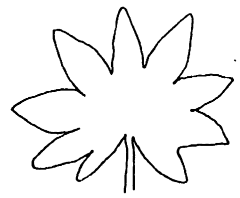
Gleichenia, p. 63



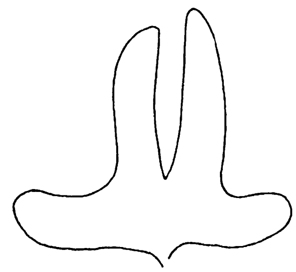
Cladophlebis, p. 62

Picea (spruce) cone scale, p. 92

Sphenopteridium, p. 70
Sphenopteris, p. 69

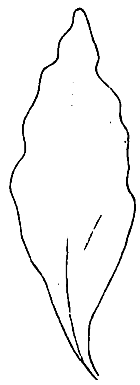


Clathropteris, p. 65
Lygodium (climbing fern), p. 63

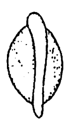


Lygodium (climbing fern), p. 63

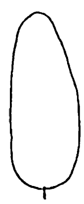
Abies (fir) needle, p. 90



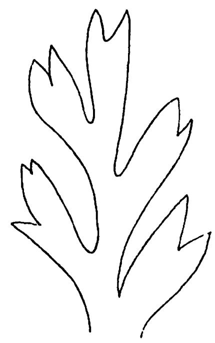
Protophyllocladus, p. 93



Sequoia (redwood) seed, p. 88

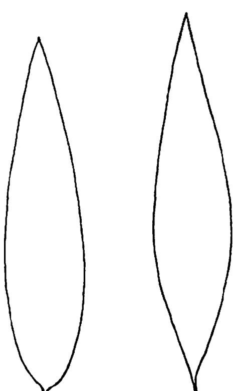


Crossopteris pinnule, p. 68
Neuropteris pinnule, p. 68

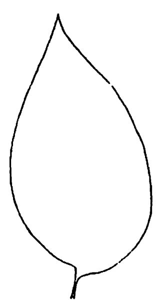


Wingatea, p. 64

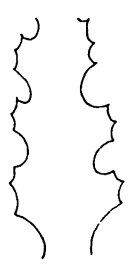
Crossopteris, p. 68
Neuropteris, p. 68
Pecopteris, p. 70



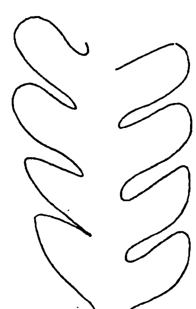
Pterocarya (wingnut), p. 114
Rhus (sumac) leaflets, p. 101
Salix (willow), p. 110



Ulmus (elm), p. 104

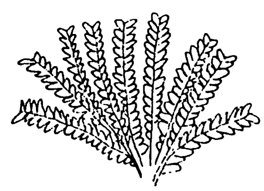


Alloiopteris, p. 62
Corynepteris, p. 62

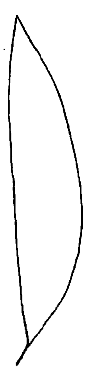


Cynepteris, p. 63
Gleichenia, p. 63

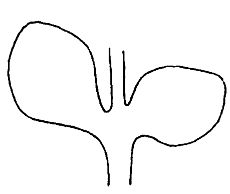
Coniopteris fertile pinnae, p. 64



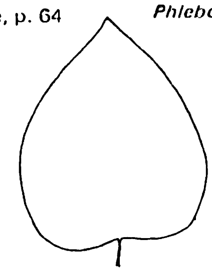
Malatonidium, p. 65
Phlebopteris, p. 65



Cedrela leaflet, p. 100
Sapindus (soapberry) leaflet, p. 101



Equisetum (horsetail) bulbils, p. 58



Alnus (alder), p. 110
Cercidiphyllum (katsura tree), p. 97
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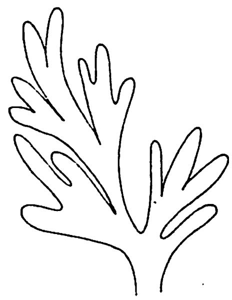
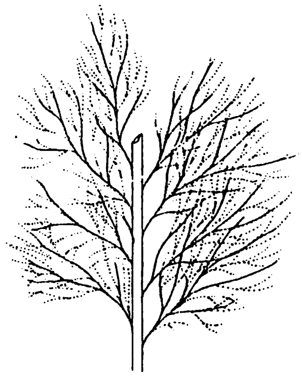
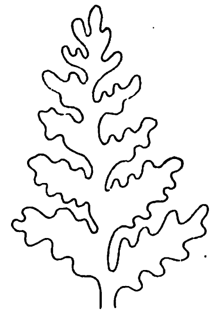


Rhodea, p. 69
Sphenopteris, p. 69
Zeilleria, p. 70

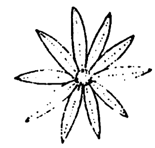


Rhodea, p. 69
Zeilleria, p. 70



Sphenopteris, p. 69

Calamitean Foliage



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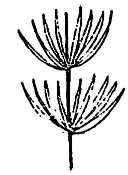
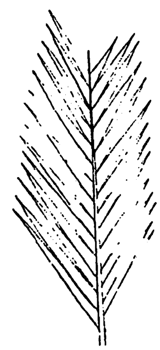
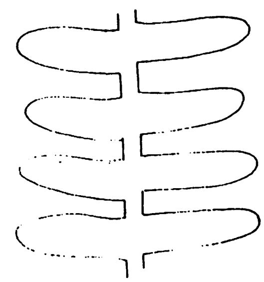


Asterophyllites, p. 55

Cycadophyta Foliage



Pseudocycas, p. 78



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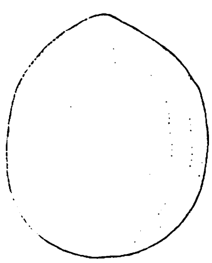
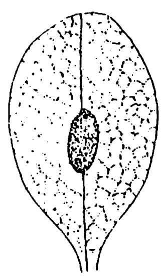
Otozamites, p. 79

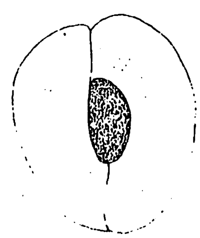
Seeds, Fruits, and Microsporangiate and Seedlike Structures



Juglans (walnut), p. 113



Koelreuteria (goldenrain tree), p. 102



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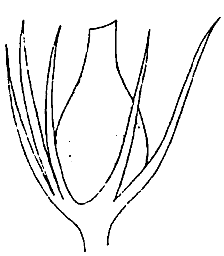
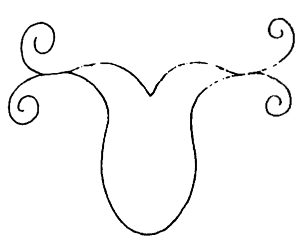
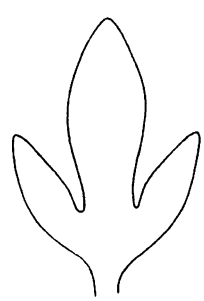


Rigbyocarpus, p. 72

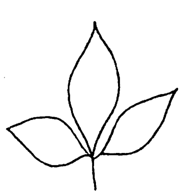


Cornucarpus, p. 72



Engelhardtia, p. 114

Lobed and Compound Leaves



Acer (maple, p. 103
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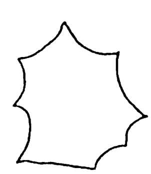
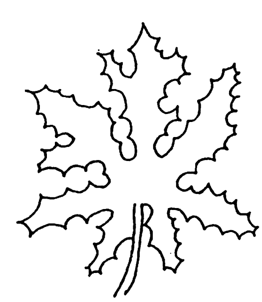


Mahonia (Oregon grape) leaflet, p. 98



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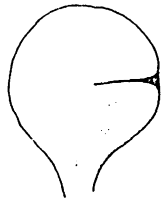
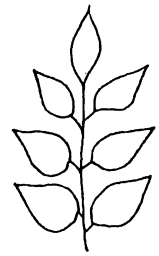

Jensensispermum, p. 74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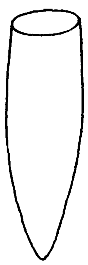
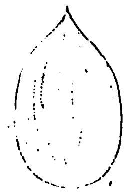
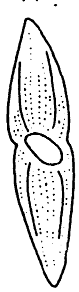
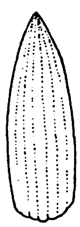

Carpolithus, p. 73


Juglans (walnut), p. 113


Ailanthus (tree of heaven), p. 99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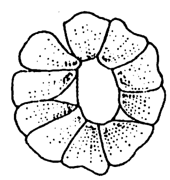
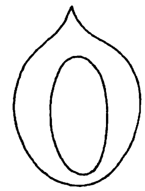
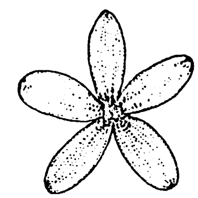
Fruits, Flowers, and Seeds


Fagopsis, p. 111


Carya (hickory), p. 114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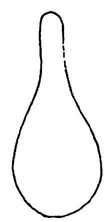
Ficus, p. 73


Acer (maple) samara, p. 103


Fagopsis immature fruit, p


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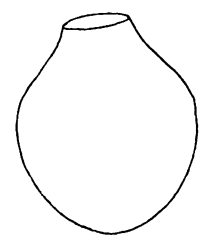
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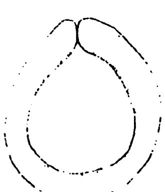
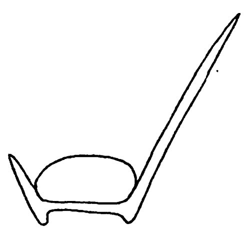

Cardiocarpus, p. 71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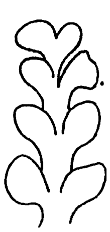
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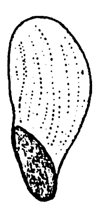
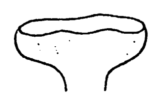
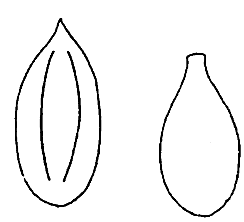

Lomatia, p. 108


Carpolithus, p. 73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Araucaria (Norfolk Island pine), p. 85
Sequoia (redwood), p. 88
Walchia, p. 84

Pinus (pine), p. 90

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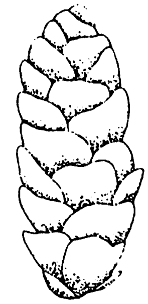
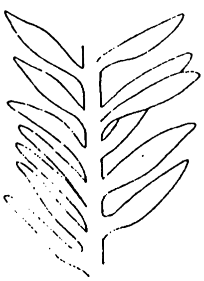
Picea (spruce), p. 92



Tsuga (hemlock), p. 91



Metasequoia (dawn redwood), p. 89
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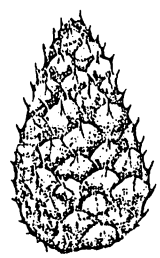
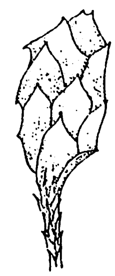
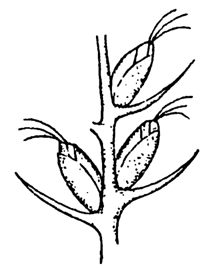


Araucaria (Norfolk Island pine), p. 85



Glyptostrobus (water pine), p. 88



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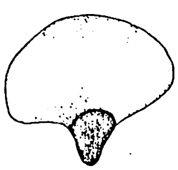
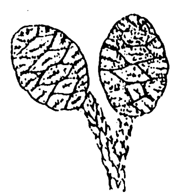
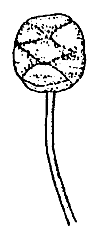


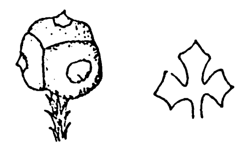
Abies (fir) cone scale, p. 91



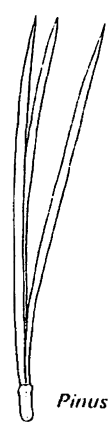
Sequoia (redwood), p. 88



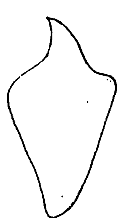
Metasequoia (dawn redwood), p. 89



Chamaecyparis (white cedar), p. 86



Pinus (pine), p. 90

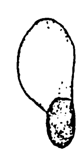


Araucaria (Norfolk Island pine) cone scale, p. 85

Pinus (pine) seed, p. 90

Picea (spruce) seed, p. 92

Tsuga (hemlock) seed, p. 92



Abies (fir) seed, p. 91

Brachyophyllum, p. 87
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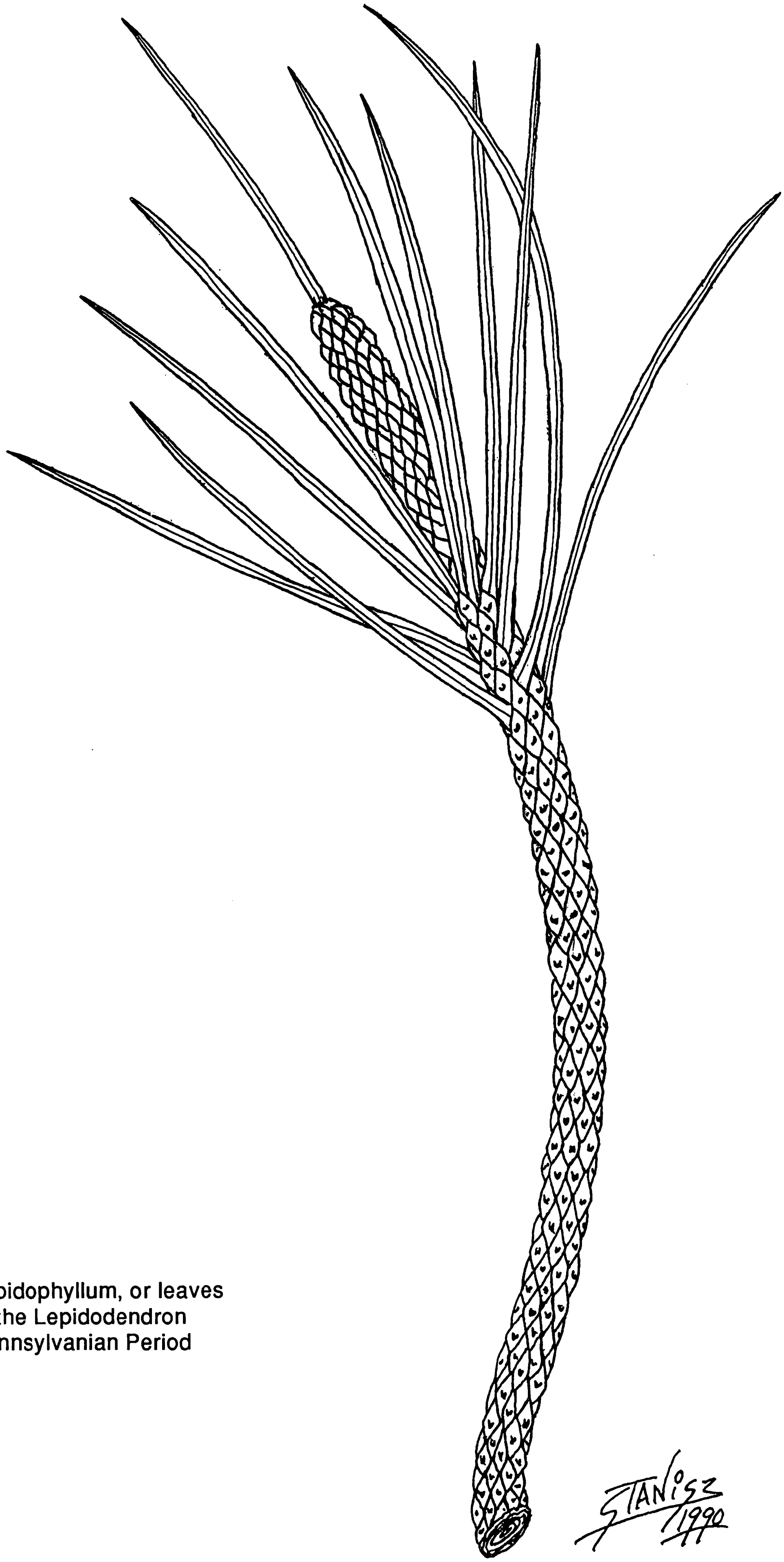
NOTE:
Illustrations, Tidwell, W.D., 1975, Common Fossil Plants of Western North America, Provo, Utah: Brigham Young University.



Lepidophyllum, or leaves
of the Lepidodendron
Pennsylvanian Period