BRIGHAM
YOUNG
UNIVERSITY

GEOLOGY STUDIES

Volume 22, Part 3—July 1976

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Brigham Young University Geology Studies

Volume 22, Part 3—July 1976

Aspects of Coal Geology, Northwest Colorado Plateau
Some Geologic Aspects of Coal Accumulation, Alteration, and Mining
In Western North America: A Symposium

Papers prepared for presentation at a symposium at the annual meeting of the Coal Geology Division of the Geological Society of America, Salt Lake City, Utah, October 20, 1975, and adjunct papers pertinent to the annual field trip, October 17-19, 1975, in the Western Book Cliffs, Castle Valley, and parts of the Wasatch Plateau, Utah. *The Field Guide and Road Log* appears as Volume 22, Part 2—October 1975, *Brigham Young University Geology Studies.*

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A publication of the
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Brigham Young University
Provo, Utah 84602

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Brigham Young University Geology Studies is published semiannually by the department. *Geology Studies* consists of graduate-student and staff research in the department and occasional papers from other contributors. *Studies for Students* supplements the regular issues and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

ISSN 0068-1016

Distributed July 30, 1976

Price $5.00

(Subject to change without notice)

7-76 600 15639

The Paleoecology of the Fluvial Coal-forming Swamps and Associated Floodplain Environments in the Blackhawk Formation (Upper Cretaceous) of Central Utah

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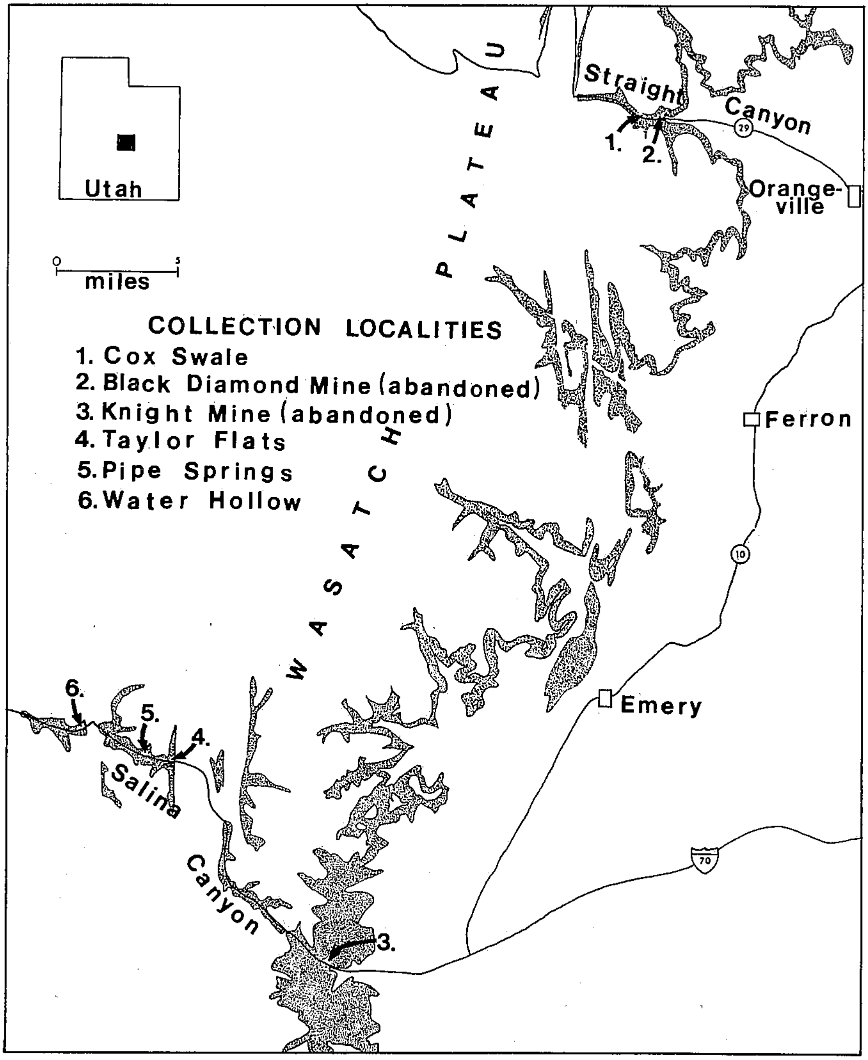
ABSTRACT.—More than 7,400 fossil plant specimens, representing 116 species, were recently collected from the Upper Cretaceous Blackhawk Formation in the Wasatch Plateau. The western portion of the Formation consists chiefly of fluvial, lenticular sandstones, siltstones, shales and coal deposited on a broad floodplain west of the Cretaceous Interior Seaway. Three major types of sedimentary environments existed here: peat-forming swamps, bottomlands, and river point bars. The swamp environment supported a plant community dominated by two trees: *Sequoia cuneata,* an evergreen conifer; and *Rhamnites eminens,* a deciduous angiosperm. Subordinate trees consisted of several other conifers and angiosperms. *Geonomites imperialis,* a small palm, was abundant near swamp margins and the herbaceous understory was composed entirely of ferns. Two aquatic plants, a water lily, *Nymphaeites dawsoni,* and a water chestnut, *Trapa paulula,* were present. The bottomland community was dominated by *Platanus raynoldsii,* an angiosperm. Several other angiosperms were present as subordinate trees, including palms, but conifers were rare and unimportant. Ferns seem to have been the only herbaceous plants. The river point bars do not appear to have supported a plant community. Instead, all the fossils collected in these sediments seem to have been transported some distance before burial. One plant, *Araucaria* sp., a conifer, was not found in other communities and may have been transported downriver from areas nearer the highlands. The Blackhawk floodplain communities were different in several ways from those existing today, but do have certain features which are similar to living floodplain communities along the Mississippi River.

INTRODUCTION

Fossil leaves and other plant remains are extremely abundant in the Blackhawk Formation (Upper Cretaceous) of the Wasatch Plateau and Book Cliffs in central Utah. Large numbers of specimens have been collected from outcrops and within coal mines throughout the Formation. A number of representative specimens are on display at the Price Historical Museum, the Utah Museum of Natural History and at Dinosaur National Monument. In addition, several regional universities have small study collections, including Brigham Young University, the University of Utah, and the College of Eastern Utah. A larger study collection is housed at the U.S. National Museum in Washington.

As a basis for a comprehensive study of the taxonomy and paleoecology of these fossil plants, over 7,400 specimens were recently collected from six major localities in Straight and Salina Canyons in the central and southern portions of the Wasatch Plateau (Text-figure 1). It should be emphasized that all of these collections were made in what have been identified as fluvial sediments on a broad floodplain of the Blackhawk River system (Young, 1966; McGookey, et al., 1972) rather than from sediments laid down in lagoonal, paludal or littoral marine environments which were at or near the western edge of the Upper Cretaceous "Mancos" Seaway, described by Young (1966) and Maberry (1971). These floodplain sediments formed most of



Text-figure 1. Index map of the fossil plant collection localities in the Wasatch Plateau. Several specific collection sites were excavated at each locality. The areal extent of the Blackhawk Formation is indicated by stippling.

the upper and western portions of the Formation in the Wasatch Plateau (Baughman, 1958) and are chiefly in-channel deposits, such as point bars, and over-bank deposits which accumulated in ox-bow lakes, swamps and flat bottomlands. The coals which formed on the floodplain are usually thin (1 cm to 1 m thick), and have generally been of little economic significance.

The fossil plants in this flora which have been identified to date include about 115 species. Of these there is one thalloid liverwort (Bryophyta), one clubmoss-like plant (Lycopsida), 14 ferns (Filicopsida), 2 cycad-like plants (Cycadopsida), and 12 coniferous plants (Coniferopsida), and 86 flowering plants (Angiospermopsida). The angiosperms include 5 monocotyledons and 81 dicotyledons.

As the collections were being made, care was taken to combine as a single unit or "florule" only those fossils which seemed to have been buried together contemporaneously in the sediment at each locality. The thickness represented by these fossiliferous zones is usually about 15 to 25 cm. Such a florule is a mixed thanatocoenose or "death assemblage." And yet, because it has been shown that leaves of living trees are not typically transported more than a few yards after they are shed and deposited in stream-laid sediments (Chaney 1924, 1925), many of these fossil florules are thought to be composed largely of plants which lived immediately adjacent to one another in a specific assemblage or plant community. This method of collecting plant fossils makes it possible to recognize the diversity of local environments which existed on the Blackhawk floodplain during its sedimentary history.

Because several factors of preservation make it relatively unlikely that all species of a community will be preserved, the plants which make up the Blackhawk communities are disproportionately represented in the collections. However, several interesting features of each environment can be deduced from the plants which are represented.

CRITERIA USED TO DETERMINE DEPOSITIONAL ENVIRONMENTS

At the time the fossil collections were being made it became apparent that certain species seemed to be restricted to rocks of a particular lithologic character, while other species might be found in rocks of different character. A quantitative study to support this observation could not be made in the field, but was subsequently made in the laboratory after the specimens were curated, photographed and identified.

The lithologic character of the rocks is in part controlled by local environments of deposition; the leaf fossils found in these rocks are generally from plants that lived in the particular environment represented. Some of the most easily recognized sedimentary environments of modern floodplains are swamps, flat bottomlands adjacent to the swamps, and in-channel river deposits such as point bars (Shelford, 1963). These three environments are comparable to those in which the Blackhawk floodplain sediments are deposited.

Several criteria were used in order to determine the general type of depositional environments of the rocks in which the fossils were collected. These are both sedimentary and biological criteria and are summarized in Table 1. It was found that 19 collection sites were made in rocks of swamp origin, 14 in rocks of bottomland origin and 8 in point bars.

The most abundant species found in the environments are listed in Table 2 where only those represented by 10 or more specimens are included. The total number of specimens of each species in the combined Blackhawk florules is shown with that portion or percentage of total specimens which were collected in each environment. Most of the species indicate a strong preference for a single environment, while a few species seem to overlap.

Not indicated in Table 2 is species frequency. This important ecological calculation reflects the total number of collection sites (within each environ-

TABLE 1
CRITERIA USED FOR IDENTIFICATION OF FLUVIAL ENVIRONMENTS IN THE BLACKHAWK FORMATION

Environment	Sedimentary Features	Biological Features
Swamps	1. Grain size: sandy silt to clay. 2. Sedimentary features: thin-bedded laminae often present; no current structures such as ripple marks or cross-bedding. 3. Organic content: high, dark grey to black in color.	1. Small gastropod shells. 2. Water lily and water chestnut leaves. 3. *In situ* stumps and roots.
Point Bars	1. Grain size: silt, coarse to fine grained sand. 2. Sedimentary features: cross-bedded massive sandstones; gravel lenses; ripple marks. Lensy in nature, laterally intertonguing with siltstones or shales. 3. Organic content: very low.	1. Casts of water-worn wood pebbles and small logs. 2. Leaf preservation poor; seem to be transport damaged. Leaves preserved at angles to horizontal plane.
Bottomlands	1. Grain size: sandy silt to clay. 2. Sedimentary features: thin-bedded, often platy. Raindrop patterns. 3. Organic content: low, light grey to yellow in color.	1. Meandering invertebrate trails. 2. Leaf "mats" are very abundant at every collecting site. 3. *In situ* stumps and roots present.

ment) in which a species occurs. It is thought that because of the bias in various factors of preservation, a fossil species which is represented by even a few specimens in a majority of collection sites is ecologically more significant than a species which might be found in large numbers at a single site.

The plant communities of each of the environments will be discussed below and, where appropriate, compared to modern floodplain communities. In a few cases, plant species which did not have enough specimens for them to be added to Table 2 are discussed since they represent a significant aspect of a particular community.

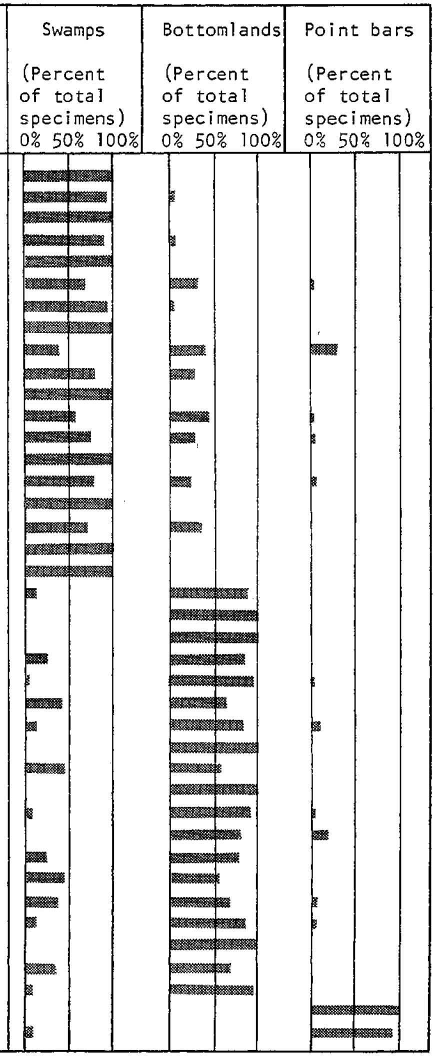
THE PEAT-FORMING SWAMP COMMUNITY

A. The Arborescent Plants

The most important trees in the Blackhawk swamps were the following conifers: *Sequoia cuneata* (Plate 1, figure 4); *Protophyllocladus polymorpha* (Plate 2, figure 5); *Brachyphyllum macrocarpum* (Plate 1, figure 9); and *Moriconia cyclotoxon* (Plate 1, figure 2). The most important angiosperm was *Rhamnites eminens* (Plate 3, figure 2). Other angiosperms will be discussed subsequently.

TABLE 2
THE OCCURRENCE OF THE MOST IMPORTANT FOSSIL PLANTS IN EACH OF THE THREE BLACKHAWK FLOODPLAIN ENVIRONMENTS

Taxa	Total number of specimens collected
Cyathea pinnata	37
Onoclea hebridica	43
Brachyphyllum macrocarpum	155
Moriconia cyclotoxon	35
Nageiopsis sp.	1077
Protophyllocladus polymorpha	123
Sequoia cuneata	504
Widdringtonites reichii	12
Geonomites imperialis	62
Cyperacites sp.	23
Anona robusta	10
Cissus marginata	93
Cornus praeimpressa	42
Ficus planicostata	11
Rhamnites eminens	165
Salix proteaefolia	11
Unknown dicot. 13	13
Unknown dicot. 25	31
Unknown dicot. 32	12
Osmunda hollicki	37
Unknown fern 1	12
Protophyllocladus sp. 2	50
Apocynophyllum giganteum	26
Cercidiphyllum arcticum	354
Cornus denverensis	18
Dryophyllum subfalcatum	202
Dryophyllum sp. 2	26
Ficus laurophylla	11
Laurophyllum coloradensis	55
Manihotites georgiana	71
Menispermum dauricumoides	11
Myrtophyllum torreyi	85
Platanus alata	18
Platanus raynoldsii	243
Viburnum antiguum	30
Unknown dicot. 2	164
Unknown dicot. 3	53
Unknown dicot. 38	14
Araucarites sp.	56
Podozamites sp.	139



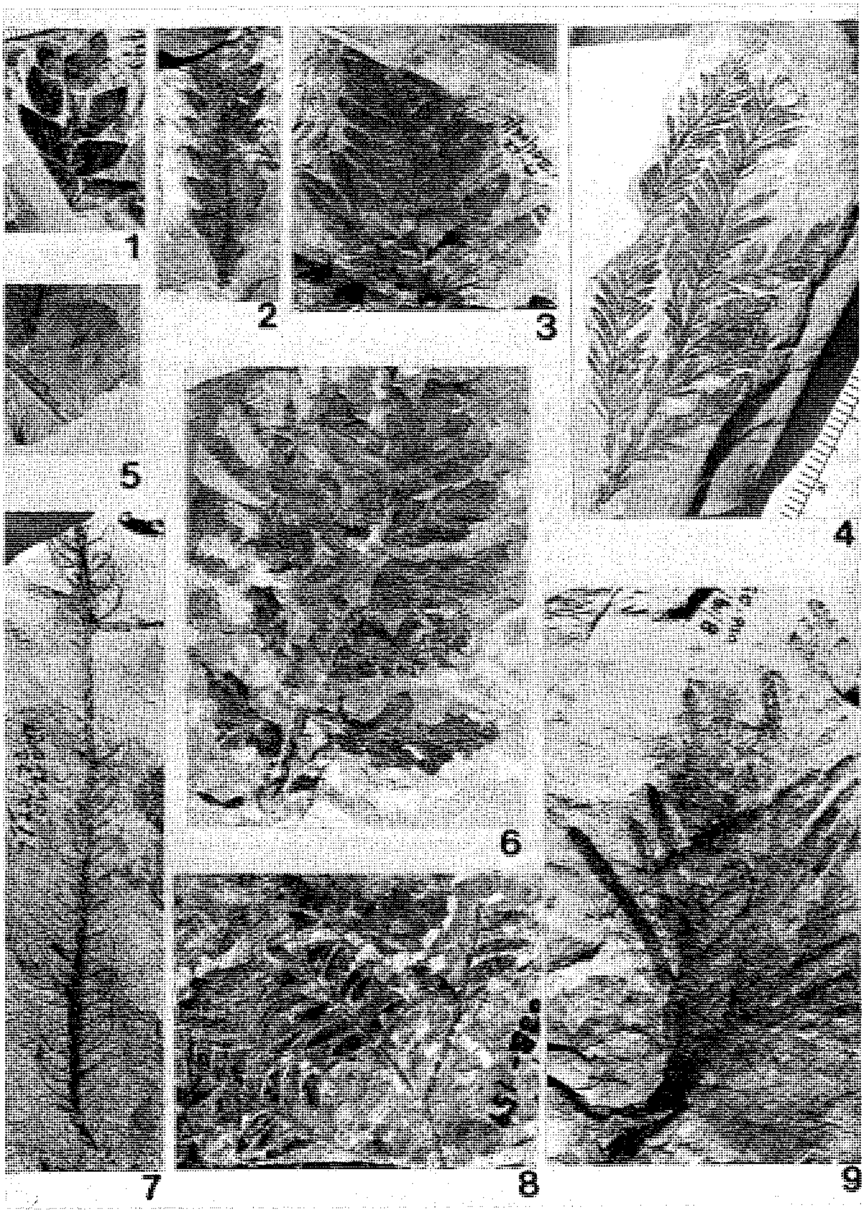
The large number of *Sequoia cuneata, Brachyphyllum macrocarpum,* and *Protophyllocladus polymorpha* specimens is influenced by the ease with which fossil conifers can be identified, even when they are poorly preserved or fragmentary. By comparison it is more difficult to identify accurately the broad leaves of fossil dicotyledons because better preservation and more complete specimens (with leaf margins, tips and bases) are required. A high percentage of the Blackhawk conifer specimens are identified, whereas only about half of the dicotyledonous plants could be identified because of poor preservation. In addition, more poorly preserved dicotyledons are probably discarded in the field than are specimens of conifers. Considering these factors, it seems probable that the total specimens of *Rhamnites eminens* could be nearer that of *Sequoia cuneata.* It seems possible then that *S. cuneata* and *R. eminens* are co-dominant trees, similar to forests in existing swamps of the Mississippi River floodplain where bald cypress (*Taxodium distichum*), a conifer, and water tupelo (*Nyssa aquatica*), a dicotyledon, are co-dominant trees of that plant community (Shelford, 1963). It is interesting to note that the foliage of fossil *S. cuneata* is much like the foliage of living bald cypress to which it is related, while the fossil *R. eminens* leaves are superficially similar in appearance to living water tupelo.

The subordinant (or less abundant) trees in this community consisted, therefore, of the conifers *Brachyphyllum macrocarpum, Protophyllocladus polymorpha, Moriconia cyclotoxon,* and the angiosperms *Cissus marginata* (Plate 2, figure 3) and *Platanus raynoldsii* (Plate 3, figure 7). Rare and less frequently occurring trees included the conifers *Androvettia* sp., *Metasequoia* sp. (neither being listed in Table 2 since only 2 specimens of each were collected) and *Widdringtonites reichii;* plus the angiosperms *Anona robusta, Cornus praeimpressa* (Plate 4, figure 3), *Dryophyllum subfalcatum* (Plate 3, figure 5), *Ficus planicostata, Myrtophyllum torreyi* (Plate 2, figure 4), and unknown dicotyledons number 3 (Plate 4, figure 1), 13, 25 and 32. A few of these plants seem to overlap into the bottomland community, but any species which is represented by at least 10 specimens was considered a member of this assemblage. Some of the rare species were collected in only one site and therefore were very infrequent or unimportant in the living community.

EXPLANATION OF PLATE 1

(All figures, plates 1-4, are ¾ natural size except where noted otherwise.)

FIG. 1.—*Cyathea pinnata* (MacGinitie) La Motte. Frond tip.
FIG. 2.—*Moriconia cyclotoxon* Debey & Ettingshausen. Portion of branching axis, leaf impressions obscured. Dark areas at stem tips are probably male cones.
FIG. 3.—*Osmunda hollicki* Knowlton. Portion of a frond.
FIG. 4.—*Sequoia cuneata* Lesquereux. Branching axis showing broad leaves on young twigs and scale-like leaves on older twigs.
FIG. 5.—Unknown fern #1. Pinnule.
FIG. 6.—*Onoclea hebridica* (Forbes) Bell. Portion of a frond.
FIG. 7.—*Araucarites* sp. Leafy twig.
FIG. 8.—*Nageiopsis* sp. Branching axis with leaves.
FIG. 9.—*Brachyphyllum macrocarpum* Berry. Branching axis with small rhomboidal leaf impressions evident on twigs.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It is interesting to speculate on the size and form of the dominant trees in this forest, since dominant trees in modern plant communities normally are those that are taller, have a greater individual biomass and more leaf surface area than any subordinant tree (McNaughton and Wolfe, 1973). If *Sequoia cuneata* and *Rhamnites eminens* were indeed the dominant trees of the Blackhawk swamps, then they probably were very large, perhaps reaching the height of modern trees, which is commonly about 100 feet (30 m) (Shelford, 1963).

It is interesting that certain living relatives of two Blackhawk conifers prefer nearly the same environment that seems to have been required by the Cretaceous species. These plants are *Taxodium distichum,* previously mentioned as a relative of *Sequoia cuneata;* and *Phyllocladus aspleniifolius,* the celery-top pine of Australia, which is related to *Protophyllocladus polymorpha.* Both living species prefer the shallow, wet-acid, peaty soils of floodplains (Voigt and Mohlenbrock, 1964; Hall, et al., 1970), similar to those which seem to have existed in the Blackhawk swamps. Other Blackhawk swamp conifers either left no living relatives or have living relatives with different ecological requirements. In addition, it is generally not possible to compare habitats of angiosperms since the relationships between Cretaceous and modern angiosperm species is usually unknown.

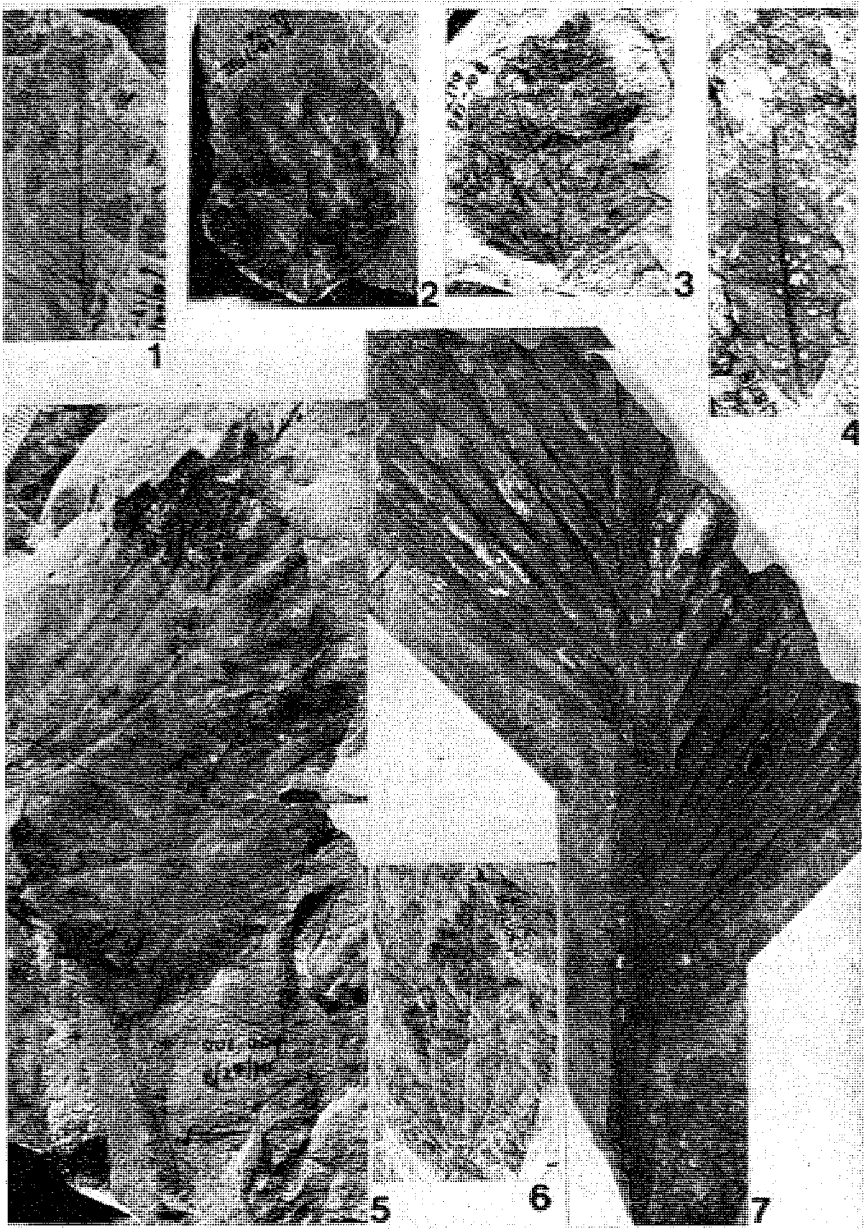
B. The Shrubby Understory

In most of the Blackhawk swamps there probably was no shrubby or herbaceous undergrowth in areas where standing water was present. This is similar to many existing cypress-tupelo swamps (Braun, 1950; Shelford, 1963; Voigt and Mohlenbrock, 1964), though buttonbush (*Cephalanthus occidentalis*) is a common shrub in the shallow margins of standing water in *Taxodium-Nyssa* swamps in southern Illinois (R. E. Taggart, personal written communication, 1975).

The most common shrubby understory tree was the palm, *Geonomites imperialis* (Plate 2, figure 7). Since it is found in nearly equal numbers in both swamp and bottomland communities, it may have grown at the swamp-bottomland margins. These margins are the normal habitat for modern swamp shrubs. *G. imperialis* became locally abundant enough to form thickets of many individuals as close as one meter apart. One of these buried palm thickets can be seen in an overhanging ledge at the Water Hollow Road collection site (Text-figure 1). The leaves of this palm were apparently shed and accumulated around the trunk bases in large numbers, forming "mats"

EXPLANATION OF PLATE 2

FIG. 1.—Unknown dicotyledon 2.
FIG. 2.—*Laurophyllum coloradensis* (Knowlton) Dorf.
FIG. 3.—*Cissus marginata* Brown.
FIG. 4.—*Myrtophyllum torreyi* (Lesquereux) Dorf.
FIG. 5.—*Protophyllocladus polymorpha* (Lesquereux) Berry. A single phyllode.
FIG. 6.—*Cercidiphyllum arcticum* (Heer) Brown.
FIG. 7.—*Geonomites imperialis* (Dawson) Bell. Portion of a single leaf. These leaves often reached 2 meters in length.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which can be seen at several places. One rock slab had 8 layers of fronds in sediment which is now only 4 cm thick. Palm leaves were often found in the lower portions of the sandstones which capped a black or coaly shale, suggesting that the erect palm stems and stiff leaves were inundated by sandy sediment during over-bank deposition.

Nageiopsis sp. (Plate 1, figure 8), a small cycad-like plant, was present at only one site where more than 1000 leaflets were collected. These specimens were close to one another in the rock matrix and could have been shed from a single plant. Specimens of another cycad-like plant, *Podozamites* sp., were collected in a few swamp sites but this plant also seems to have been an infrequent member of the community. Both of these gymnosperms are more typical of Lower Cretaceous floras and seem to be relicts in the Blackhawk.

Of the dicotyledons collected in the swamps none can positively be said to have had a shrubby growth form. However, several species had very small leaves which may have been produced by shrubs, since shrubs often have smaller leaves than trees.

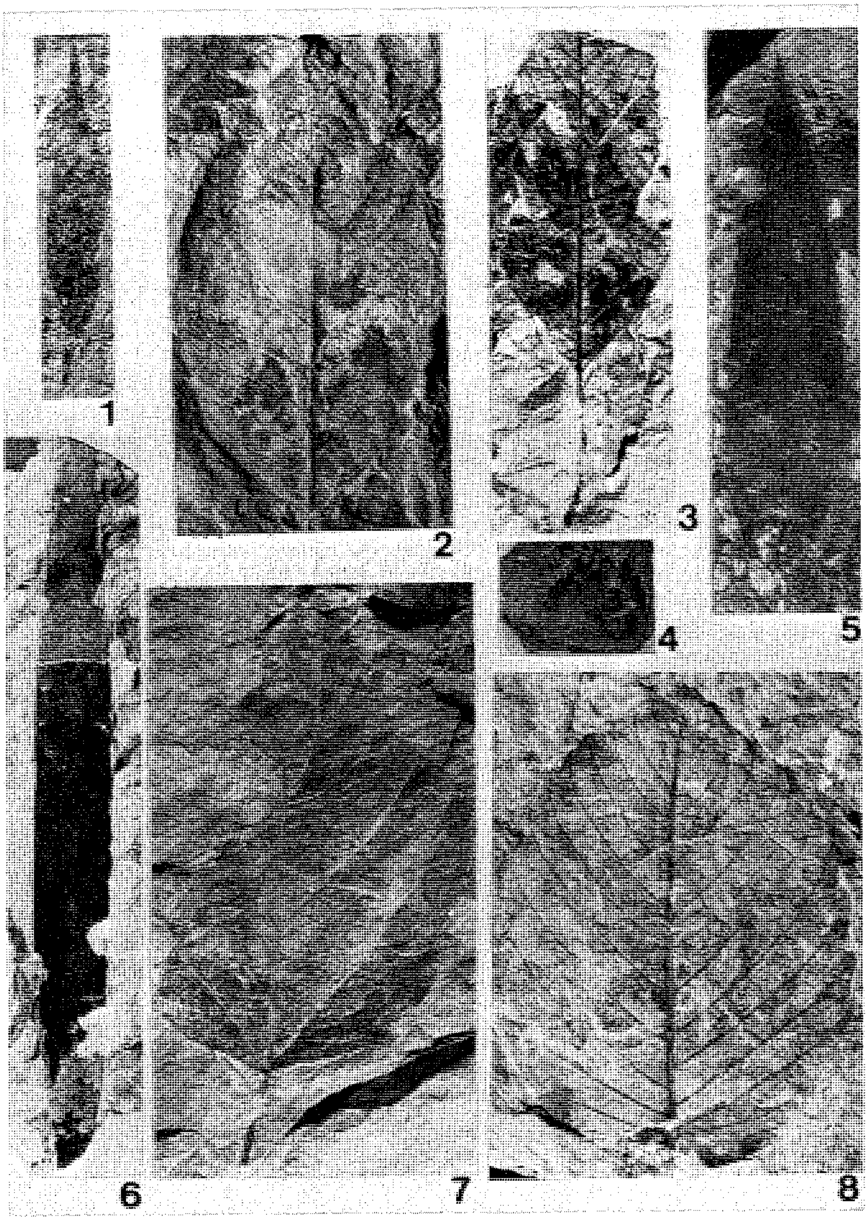
C. The Herbaceous Understory

The known herbaceous understory was made up chiefly of two ferns, *Cyathea pinnata* (Plate 1, figure 1) and *Onoclea hebridica* (Plate 1, figure 6). Both ferns were collected in about half the sites and from the number of specimens collected they appear to have been locally abundant. Interestingly, extant species in the genus *Cyathea* are known as "tree ferns" because of their tall, slender palm-like growth habit; however, there is no evidence that the fossil *Cyathea pinnata* was of large size. A living species of this genus, *Cyathea glabra,* is of a small size or "stemless," and grows directly on the organic substrate of peat-forming swamps in Malaysia (Anderson, 1961). Living species of the genus *Onoclea* are restricted to swamps and areas of acid soil where one species, *Onoclea sensibilis,* is an abundant and important member of the herbaceous layer in the cypress-tupelo swamps in Louisiana (Penfound, 1952). Both of these living ferns require an environment similar to that presumed for their Cretaceous relatives.

These plants could not live in areas where the soil surface was covered by water and probably were restricted to swamp margins, or existed as epiphytes on tree buttresses, hummocks, floating logs, and decaying stumps. All of these swamp substrates currently allow the growth of a variety of herbaceous plants (Braun, 1950; Shelford, 1963; Voigt and Mohlenbrock, 1964).

EXPLANATION OF PLATE 3

FIG. 1.—*Ficus laurophylla* Lesquereux.
FIG. 2.—*Rhamnites eminens* (Dawson) Bell.
FIG. 3.—*Dryophyllum* sp. 2.
FIG. 4.—*Nymphaeites dawsoni* (Hollick) Dorf. Fragment of circular leaf.
FIG. 5.—*Dryophyllum subfalcatum* Lesquereux.
FIG. 6.—*Cyperacites* sp. Linear leaf or stem.
FIG. 7.—*Platanus raynoldsii* Newberry.
FIG. 8.—*Viburnum antiguum* (Newberry) Hollick.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Of the angiosperms collected, none seems to have been herbaceous except two aquatic species which will be discussed subsequently. The typical angiosperm leaves have the appearance of being thick, and perhaps coriaceous, and are therefore believed to have been produced by woody plants.

D. The Aquatic Plants

It is significant that the only aquatic plants found in the collection were obtained in rocks of swamp origin. These include a water lily, *Nymphaeites dawsoni* (Plate 3, figure 4), and a water chestnut, *Trapa paulula* (Plate 4, figure 2). Neither of these species are included in Table 2 since fewer than 10 specimens were collected. In addition, several cattail-like leaves of *Cyperacites* sp. (Plate 3, figure 6) were collected, although it is not certain that this plant was aquatic. These species were rare, but add weight to the evidence accumulated in favor of a complex swamp community. Water depth where these plants were growing probably was shallow since they must have been rooted in soil under the water. Living analogues cannot live in water deeper than 1 m (Shelford, 1963).

The infrequency of aquatic vegetation in these swamps supports a study by Ostrom (1964) who examined the reports of several Upper Cretaceous floras in order to determine the amount of aquatic vegetation which was present as potential food for hadrosaurian (duck bill) dinosaurs. He concluded that there was little evidence for an abundance of soft aquatic and herbaceous vegetation which had long been thought to be the diet of these animals. He suggested instead that these herbivores ate the coarser vegetation of the abundant woody conifers and angiosperms.

Several gastropod shells were also collected in rocks of swamp origin.

E. The Swamp Conifers

One interesting aspect of the Blackhawk swamp community is the relatively large number of gymnosperm species. This differs from existing swamps where, at most, only three species ever grow associated with one another. The presence of these species smees to reflect the intermediate position of the Blackhawk flora between the earlier Mesozoic floras dominated by conifers and the later Cenozoic floras dominated by angiosperms. Of these conifers, six genera became extinct before the end of the Cretaceous Period (*Androvettia, Brachyphyllum, Moriconia, Nageiopsis, Podozamites, Widdringtonites*), and another genus was eliminated from the Northern Hemisphere late in the Paleocene or early Eocene (*Protophyllocladus*). Only *Metasequoia* and *Sequoia* continued on into the Tertiary in North America, where late in the Tertiary *Metasequoia* was lost from the Western Hemisphere. Though the genus *Sequoia* is present

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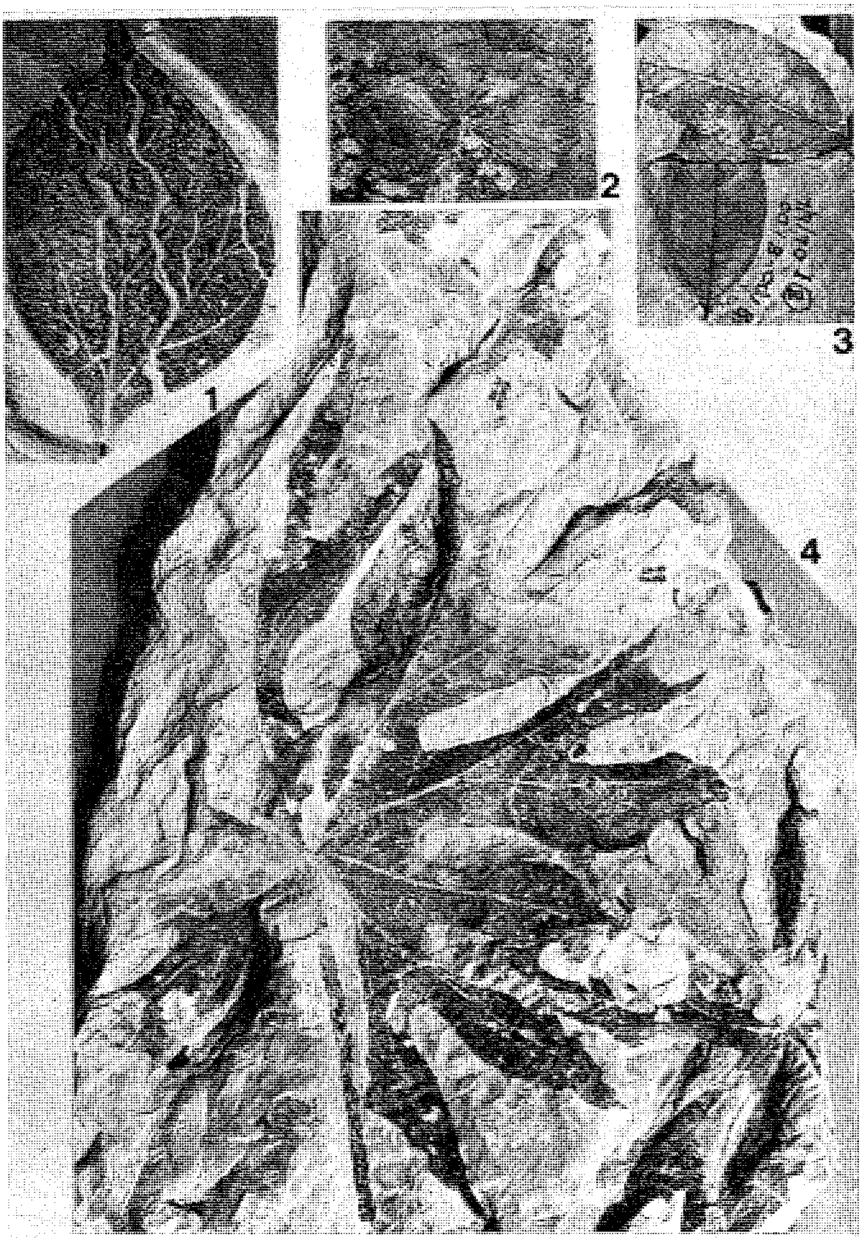
EXPLANATION OF PLATE 4

FIG. 1.—Unknown dicotyledon 3.
FIG. 2.—*Trapa paulula* Fragments of three leaves.
FIG. 3.—*Cornus praeimpressa* Knowlton. Two leaves.
FIG. 4.—*Manihotites georgiana* Berry. Two multilobed leaves. Note the long thin petiole of the leaf on the left. x½



in North America today, the species *S. cuneata* disappeared from the record by the end of the Paleocene. Eight of these extinctions correlate with the disappearance of the extensive fluvial and coastal swamp habitats associated with the Mancos Seaway. This correlation suggests that they were mostly restricted and highly adapted to swamp or wet-acid environments and became extinct when these environments were reduced in size and isolated as the sea receded. Most of these species seem to have been restricted to the shores of the great interior seaway, of which the Mancos is a part, throughout the Cretaceous Period.

The large number of coniferous plants contributed much of the biomass to accumulating peat and support some of the results of the study made by Thiessen and Sprunk (1937) who determined that much of the organic mass of the Sunnyside coals was formed from coniferous remains. More recently Maberry (1971) indicated that this coal was composed mostly of plant debris including abundant spores and waxes, some of which may also have been of conifer origin. Though some parts of the Sunnyside coal apparently did not accumulate in fresh water swamps, the fluvial swamp community described above probably could survive mildly brackish water as can modern cypress-tupelo forests (Penfound, 1952) and therefore may have been the source of the Sunnyside and other thick coals in the lower Blackhawk Formation.

THE BOTTOMLAND COMMUNITY

A. The Arborescent Plants

Four bottomland angiosperms are represented in our collections by more than 100 leaf compressions. These are *Cercidiphyllum arcticum* (Plate 2, figure 6), *Dryophyllum subfalcatum* (Plate 3, figure 5), *Platanus raynoldsii* (Plate 3, figure 7), and unknown dicotyledon 2 (Plate 2, figure 1). *D. subfalcatum* and *P. raynoldsii* were the most important and frequently occurring species, being collected in large numbers at more than half of the sites. *C. arcticum* and unknown dicotyledon 2 were not collected in as many sites, but large numbers of specimens were recovered. Subordinate and rare angiosperms were *Apocynophyllum giganteum, Cornus denverensis, Dryophyllum* sp. 2 (Plate 3, figure 3), *Ficus lauraphylla* (Plate 3, figure 1), *Laurophyllum coloradensis* (Plate 2, figure 2), *Manihotites georgiana* (Plate 4, figure 4), *Myrtophyllum torreyi* (Plate 2, figure 4), *Platanus alata, Viburnum antiguum* (Plate 3, figure 8), and unknown dicotyledons 3 (Plate 4, figure 1) and 38.

In addition, three conifers were present but rare, *Sequoia cuneata, Protophyllocladus polymorpha* and *Protophyllocladus* sp. 2.

This community appears to have been co-dominated by at least two and perhaps more dicotyledon species, much like existing bottomland forests where slight changes in elevation, nearness to the river channel and other factors allow one species or another to become extremely abundant locally (Voigt & Mohlenbrock, 1964). The fossil trees probably formed a forest which had the appearance of the modern "hardwood bottoms" adjacent to cypress-tupelo swamps on the Mississippi floodplain where the canopy is nearly 100 feet (30 m) high and shades a normally sparse, shrubby and herbaceous understory, (Shelford, 1963; Voigt and Mohlenbrock, 1964).

Certain features of modern bottomland dominants would have been advantageous to the Cretaceous trees and include an ability to thrive in poorly aerated, often saturated bottomland soils; seedlings which can tolerate submergence for several weeks; adventitious root production when basal areas are buried by silt; and very rapid growth (Voigt and Mohlenbrock, 1964).

The most abundant trees, *Platanus raynoldsii* and *Dryophyllum subfalcatum,* are interesting since leaves of *P. raynoldsii* closely resemble those of several living species of *Populus* (cottonwood), particularly *P. deltoides* which is often a dominant member of the bottomland forest on portions of the upper Mississippi river floodplain (Voigt and Mohlenbrock, 1964). *D. subfalcatum,* a supposed live oak-like plant is one of the most widespread of the Cretaceous angiosperms. Brown (1937) and Dorf (1942) both used it as an index fossil of the late Cretaceous.

One of the most interesting plants is *Manihotites georgiana* (Plate 4, figure 4). A few fragmentary specimens were collected in swamp deposits, but the species seems to have preferred bottomland habitats. The broad leaf blades are the largest of any in the collection, up to 30 cm long and attached to a stiff, narrow petiole at least 18 cm long. At the collection site near the Black Diamond Mine (abandoned) in Straight Canyon, more than 20 nearly complete leaves and fragments of about 50 others could be seen. Recently, A. T. Cross (personal written communication, 1975) collected additional specimens with fruits at this locality (Cross, et al., 1975, p. 67, fig. 20 B) and a detailed description of this plant is being prepared which will include epidermal cell patterns and fine venation.

The importance of the conifers *Sequoia cuneata* and *Protophyllocladus polymorpha* in this community was minimal, since nearly all of these specimens could be identified, whereas only half of the dicotyledon specimens were well preserved enough to be identified. These conifers are thought to be among those plants which overlapped the normal swamp-bottomland borders. *Protophyllocladus* sp. 2 was unique to bottomlands and very infrequent. No other conifers were collected in bottomland sites in spite of their abundance in the swamps. In fact, several sites yielded no conifer fossils at all, presumably—or at least in part—because the sites were located some distance from swamps at the time of deposition.

B. The Shrubs and Vines

The only bottomland plant which is known to be of shrub size was the palm *Geonomites imperialis.* It was collected in about one-third of the sites. However, no thick palm leaf mats were observed here as they were in swamps. Corner (1966) reports that all species of the modern genus *Geonoma* are members of the understory in Brazilian bottomland forests.

About six bottomland dicotyledons had very small leaves which may have been shed from shrubby plants. These species are rare and unimportant members of the community.

Menispermum dauricumoides, another dicotyledon, was probably a bottomland vine. Leaves of this plant are remarkably similar to those of the living moonseed vine, *Menispermum canadensis,* a common vine of bottomland forests of North America today (Voigt and Mohlenbrock, 1964).

C. The Herbaceous Understory

The herbaceous understory consisted of several ferns, *Osmunda hollicki* (Plate 1, figure 3) and unknown fern 1 (Plate 1, figure 5) being the most frequent. Specimens of this fern were collected in about one-third of the sites. Several extant species of the genus *Osmunda* prefer wet woodland or bottomland soils and often form an extensive understory apparently similar to *Osmunda hollicki* (Voigt and Mohlenbrock, 1964).

There is no evidence in the bottomland community for the existence of herbaceous dicotyledons.

THE PLANTS OF THE POINT BARS

Most of the leaves and twigs collected in point bars were also recovered in both swamp and bottomland sediments. Generally, they all were damaged and preserved at angles to the normal horizontal bedding. These factors suggest that they had been picked up by the river from adjacent swamps or bottomlands, transported downstream, and accumulated as drift on point bars where they were later buried. Shelford (1963) observed this process happening on the Mississippi River and reported that a great amount of leaves and twigs is buried annually in point bars in this manner.

Leafy twigs of *Araucaria* sp., a conifer (Plate 1, figure 7, however, were not collected in swamps or bottomlands, but were recovered only in point bars. Parts of this plant probably were among those transported downstream but instead of being carried from adjacent floodplain areas, may have come from the upper parts of the Blackhawk River system where this type of plant was rooted in the well-drained, sandy soils that its living relatives require (Hall, et al., 1970).

Several *in situ* small, woody root systems were observed and collected in point bars, but could not be identified. They indicate that a few shrubby plants lived on the point bars, but their identity and abundance is unknown.

THE CLIMATE

Morphological features of extant plant leaves of a given area indicate the type of climatic conditions under which the plants live. These features include leaf size, leaf margins and dripping points. It has been shown that tropical floras have a high proportion of large, entire-margined leaves with dripping points and that this proportion gradually decreases northward in forests of subtropical, warm temperate and cold temperate zones. Paleoclimatic conditions in which Upper Cretaceous and Tertiary floras lived are determined by comparing the proportion of fossil leaves which exhibit these features with modern floras (MacGinitie, 1969).

Since more than half of the Blackhawk angiosperm leaves are medium sized with entire margins and dripping points, the climate was warm temperate to subtropical but clearly not tropical.

Growth rings in a lignified conifer log and occasional "mats" or accumulations of fossil leaves which seem to have been shed at the end of the growing season both suggest that this warm climate was also seasonal.

SUMMARY

Several similarities exist between the structure of the Blackhawk floodplain communities and living communities of the Mississippi River floodplain. Both the Blackhawk and modern swamp forests are co-dominated by a conifer and an angiosperm, palms are abundant shrubs of the understory, herbaceous plants

are common at swamp margins, and floating aquatic plants are present. Blackhawk and modern bottomland forests support several dominant angiosperm species, often have an understory of shrubby palms and vines, and have an herbaceous layer which is sometimes sparse. The occurrence of fossil plants in Blackhawk point bars is also similar to existing point bars where large amounts of leaves and twigs are buried after being transported by the river. Living relatives of a few Blackhawk species prefer nearly the same habitats that their Cretaceous ancestors required.

In spite of these similarities, there are significant differences which emphasize the antiquity of the Cretaceous communities. Among these are the unusually large proportion of coniferous trees which existed in the swamps and the apparent lack of any terrestrial herbaceous angiosperms in both swamp and bottomland forests.

The Blackhawk flora lived in a warm temperate to subtropical climate which had well defined seasons.

ACKNOWLEDGMENTS

Grateful acknowledgment is extended to Aureal T. Cross, Michigan State University, and William D. Tidwell, Brigham Young University, for their generous assistance and suggestions both in the field and laboratory. My thanks is also extended to Erling Dorf, Princeton University, who provided me the opportunity to use his extremely valuable "Catalogue of Mesozoic and Early Cenozoic Plants of North America" for assistance in the identification of the fossil specimens. Part of this research was supported by NSF Grant GA-429 to Aureal T. Cross, Michigan State University.

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