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

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Cretaceous and Early Tertiary Floras of the Intermountain Area—A Summary

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ABSTRACT.—Vegetational history of the modern floras of the Intermountain region had their beginnings during the Cretaceous period. The Lower Cretaceous formations, Cedar Mountain and Dakota Sandstone, contain a variety of plant types, including ferns, cycadeoids, angiosperms and conifers. These are often associated with coal deposits. Warm temperate to tropical climatic conditions are reflected in the Upper Cretaceous and Lower Tertiary floras of this region.

The vegetational history of the modern floras of the intermountain region had its beginning in the Cretaceous. Conifers, the dominant gymnosperms, underwent a long period of evolution during the Mesozoic, but by Upper Cretaceous their numbers and importance were diminishing because of competition from the rapidly rising flowering plants (Tidwell, et al., 1971a).

"Most of the plants of these ancient (Cretaceous) forests had large thick textured leaves similar to those of plants found today at lower latitudes where ample rain and mild temperature throughout the year made conditions suitable for warm-temperate to subtropical forests. They contrast sharply with the small-leaved sclerophyllous plants in the regions of these fossil localities today, where desert, sub-desert, woodland, steppe and chaparral communities are present" (Axelrod, 1950, p. 222).

In Utah, eastern Colorado and northern New Mexico, the Lower Cretaceous (Aptian or Albian) is represented by the Cedar Mountain Formation. The presence of the conifer *Frenelopsis varians* and the fern *Tempskya* suggests that the formation is Lower Cretaceous in age (Brown, 1950, Read & Ash, 1962), as does its stratigraphic position. Stokes (1944) defined the Cedar Mountain Formation as those sediments lying between the Brushy Basin member of the Jurassic Morrison Formation and the Cretaceous Dakota Sandstone Formation. These sediments were formerly considered as part of either the Morrison or the Dakota. Stokes (1952) further defined two members of the formation, the basal Buckhorn Conglomerate and the upper Cedar Mountain Shale. In Utah, the Cedar Mountain Shale consists of brown, gray and green shales and at least one horizon of nearly coalified material. Also present are occasional white sandstone lenses and channel fills of yellowish conglomeratic sandstones which bear petrified wood. East of the Colorado River, a formation of green to purple or somewhat varicolored shale, sandstone, limestone and dark shales (Brown, 1950) overlying a basal conglomerate, occupies the same relative position that the Cedar Mountain Formation does on the west side of the river. This formation was called the "Post-McElmo" (Coffin, 1921), but was later renamed the Burro Canyon Formation (Stokes and Phoenix, 1948). Young (1960) proposed that the Burro Canyon and Cedar Mountain formations are a physically continuous unit and should both be referred to as the Cedar Mountain Formation.

During Lower Cretaceous times, the cycadeoids were distinctive plants on upland slopes. They are preserved in the Burro Canyon Formation near

Naturita, Colorado (Brown, 1950) and the Cedar Mountain Formation near Cedar Mountain and Moab, Utah (Furniss and Tidwell, 1972; Furniss, 1975). The most pronounced feature of the Burro Canyon Formation or eastern Cedar Mountain Formation is the lack of any angiospermous species (Fisher, Erdmann, and Reeside, 1960). However, angiospermous wood has been described from the Cedar Mountain Formation (Thayn, Tidwell, and Stokes, 1973; Thayn, 1973). The fossil fern, *Tempskya,* is also well represented in the Cedar Mountain sediments. Specimens of this genus were reported by Katich (1952) who collected several near Castle Dale, Utah, Stokes (1952) who discovered them near Cedar Mountain east of Huntington, Utah, and McKnight and Rigby (1962) who collected specimens near Moab, Utah. Specimens found near Castle Dale (Tidwell and Hebbert, 1972) were in growth position in pyritic-carbonaceous shales which suggests that they were growing in swamps. The top of one specimen was surrounded by a splay sand indicating that it grew near a major distributary system.

A Lower Cretaceous (Cenomanian) flora from the Dakota Sandstone near Westwater, Utah, consists of nineteen species and one variety representing fourteen genera. Plants of this flora were collected from a light-tan, ash layer five to ten inches in thickness which occurs between two coal seams. The leaves occur in dense mats which can be traced laterally and appear to follow possible stream channels. The flora is dominated by the ferns: *Astralopteris* (Tidwell, et al., 1967; Rushforth and Tidwell, 1968), *Matonidium,* (Rushforth, 1970), *Gleichenia, Asplenium,* and others which are more representative of older floristic types (Rushforth, 1971). If angiosperms were not present in this flora, it would probably be considered much older than Cenomanian.

Mahabale (1954) considered the matoniaceous ferns to be among a select group of ferns that are accurate climatic indicators. *Matonidium* is closely related to the modern genus *Matonia* which is restricted in habitat to the humid tropical upland region of Malayan Peninsula. Of the living species of *Gleichenia,* most are tropical in distribution.

Rushforth (1971) postulated that the area of eastern Utah during Dakota times was a broad, swampy mudflat near the edge of the sea. Dense vegetation composed largely of ferns and *Equisetum* grew in pockets in this area. Under favorable conditions, these plants could have accumulated in sufficient volume to have contributed to the present coal deposits in the Dakota sediments. Various types of angiosperms and possibly gymnosperms grew on nearby upland areas or along streams. Their leaves and trunks, in various stages of decomposition, were carried to lowland areas where they probably formed a large portion of the coals.

Chaney (1954) analyzed 200 species of leaves from the Dakota flora in order to determine the paleoclimate of Dakota times. He found that 73% have entire margins, 44% are over 10 cm long and 74% are thick in their texture, and concluded that plants of the Dakota flora lived under more subtropical than temperate conditions. He further pointed out that 72% of the leaves from the Dakota have camptodromic venation which, according to him, suggests again a tropical or subtropical climate for this flora.

The Dakota Sandstone Formation from Coal Canyon, Arizona, as discussed by Agasie (1967), exhibits floristic characteristics similar to those of the Westwater flora. Palynological analysis indicates that the Dakota vegetation was composed of a fern-angiosperm alliance with a minor gymnospermous component. It also indicates subtropical to tropical climatic conditions for this region during Dakota times. Fern spores are the dominant microfloral component, particularly those related to the Schizaeceae. This family is often represented in preangiospermous floras (Harris, 1961), and preliminary collection of megafossils from the area also indicates the presence of many ferns related to an old Jurassic-Wealden vegetational type (Rushforth, 1971).

Pierce (1961) and Hall (1963) studied plant microfossils from the Dakota Sandstone in Minnesota and Iowa. Pierce reported 24 species of palynomorphs representative of angiospermous plants, 36 species of gymnospermous palynomorphs, and approximately 20 species of fern spores. Based on this, he postulated that angiospermous species are not as important in this formation as is indicated by the megafossil record.

Thus, a more accurate concept of the flora of the Dakota Sandstone Formation as a unit may be formed (Rushforth, 1971). In western America, the Dakota flora is a fern-angiosperm alliance with a relatively small gymnospermous component. To the east, this flora changes character, becoming an angiosperm-dominated flora with ferns and gymnosperms present.

Parker (1968) in his report on the Upper Cretaceous Blackhawk flora in central Utah, surmised on the basis of leaf morphology, distribution of modern correlatives, and the absence of exclusively cool-temperate genera, that the general environment of the Blackhawk flora was a lowland in a humid, warm-temperate to subtropical climate.

Thiessen and Sprunk (1937) also dealt with the Blackhawk Formation, specifically the Lower Sunnyside Coal. They found that this coal, which ranges from 7 to 14 feet thick in the vicinity of the Columbia mine, is composed mostly of the remains of coniferous plants.

Plant remains were reported from the Mesaverde Group by Richardson (1909), and by Fisher, Erdmann, and Reeside (1960) from both Colorado and Utah; by Lee (1912) in Colorado; and by Brown (1956) in Arizona. Richardson (1909) lists *Sequoia reichenbachii* (Gein.) Heer, *Eriocaulon parosum* Lesq., *Ficus latifolia* (Lesq.) Knowlton, *Myrica torreyi* Lesq. and a species of *Magnolia* from the Book Cliffs north of Grand Junction. Lee (1912) found many of the same species from the Paonia Shale Member and the overlying portion of the Mesaverde Group. He added the fern *Pteris russellii* Newb., *Equisetum,* and angiosperm leaves which probably represent species of *Sabalites, Salix, Populus, Platanus, Ficus* and other genera.

From north of Thompson, Utah, Richardson (1909) reported the fern *Anemia elongata* (Newb.) Knowlton, the conifer *Sequoia reichenbachii* (Gein.) Heer, and the angiosperms, *Myrica torreyi* Lesq., *Sabalities grayanus* Lesq. and a species of *Malapaenna.* From his description, it appears that most of his collections came from the upper Farrer Facies of the Price River Formation, just below the conglomerate of the Tuscher Formation of the Mesaverde Group.

Other Cretaceous floras are found in the Frontier Formation (Knowlton, 1917; Andrews and Pearsall, 1941) and the Aspen Shale (Brown, 1933) in southwestern Wyoming. They collectively indicate a climate closer to subtropical rather than warm-temperate. Axelrod (1950) considers the environmental differences in these floras a function of age rather than geographic position.

Of the 25 described species of plant megafossils composing the flora of the Frontier Formation, there are seven species of ferns, one species of *Equi-*

setum and 17 species of angiosperms including those assigned to *Quercus, Ficus, Salix, Aralia* and *Cinnamomum* (Andrews and Pearsall, 1941).

Lohrengel (1969) studied the palynomorphs from the Upper Cretaceous Kaiparowits Formation near Escalante, Utah. He described 41 genera and 80 species of fern, cycad, conifer, and angiosperm spores and pollen. He considered the lower portion of this formation as probably deltaic sediments deposited in a rapidly subsiding basin. He noted that diagnostic deltaic sedimentary features such as point bars, natural levees, channel sandstones, and back-swamp deposits are common in the lower part of the formation.

Based upon palynomorphs of *Azolla, Sphagnum,* and members of the Taxodiaceae present in the Kaiparowits flora, Lohrengel (1969) proposed a low, marshy to swampy topography for this area during Kaiparowits time. Possible uplands are indicated by the presence of tree ferns (Cyathaceae and Dicksoniaceae), *Araucaria, Picea* and members of the Podocarpaceae. Lohrengel (1969) also suggests that part of the drainage basin during the deposition of the Kaiparowits Formation was semiarid to arid for at least some seasons of the year, as is suggested by the occurrence of the families Proteaceae, Cycadaceae and possibly Palmae.

Plant megafossils are not uncommon in the Kaiparowits Formation. These have been studied only as a reconnaissance by Knowlton (in Richardson, 1927). The plant megafossils indicate an upland gymnospermous and dicotyledonous flora. Those tentatively identified by Knowlton are a species of *Araucaria* (*Dammarites*), two species of *Podozamites* and *Platanus,* one species each of *Betula, Menispermites, Cinnamomum* and *Viburnum.* Of these, only *Araucaria* has a representative in the pollen flora. Lohrengel (1969) postulated that the Kaiparowits flora grew in a subtropical to warm-temperate climate. Precipitation for that time was probably similar to the present precipitation of the Gulf Coast Region.

The climatic history of the Rocky Mountains during the Tertiary and extending into the Quaternary was dominated by: (1) a general, often interrupted, cooling from Oligocene onwards; and (2) a progressive drying from the early Miocene into the Pleistocene because of the increasing elevation of the Sierra Nevada and the Cascades (Antevs, 1952).

The transition from Upper Cretaceous to Lower Tertiary appears to be rather gradual. Dorf's (1942) studies on the Lance, Medicine Bow and Laramie floras show a progressive change from subtropical to warm-temperate as one proceeds from south to north, while the Fort Union and Denver floras, which are found essentially in the same region during the Paleocene, reflect similar climatic modifications (Chaney, 1947).

Paleocene formations were deposited in basins between the mountain ranges created by the Laramide Orogeny. These are well represented in Montana, North Dakota, South Dakota and Wyoming by the Fort Union Formation, in New Mexico by the Ojo Alamo Formation, and in central Utah by the North Horn Formation.

A Paleocene flora has been studied from the Fort Union Formation near Baggs, Wyoming (Roth and Tidwell, 1975; Roth 1975). The beds in which the plants are preserved are composed of sideritic siltstones and sandstones. A major system of channel fills consisting of coarse- to fine-grained sandstones and clay ball concretions, some of which contain leaves folded and broken by stream action, is associated with the sideritic beds. A lake deposit, composed of fine-grained, gray green to black shales, is also associated with the fossiliferous beds. The sideritic beds are interpreted as backwater paludal deposits associated with the delta of the river system. The channel fills have also yielded a mammalian fauna. The mammals have been dated as Middle Upper Torrejonion (J. Keith Rigby, Jr., pers. comm.). This is one of the few localities where a close mammal association allows for accurate dating of a flora.

Paleocene paleobotany, like the Cretaceous, is being subjected to extensive revision. It has been estimated that 60-70 percent of the previous taxonomic assignments of early Tertiary paleobotanists are incorrect (Dilcher 1974). For the present, the specimens of the Baggs Fort Union flora are assigned to taxa described in older reports. As more precise systematic studies are done in the future, these names will be changed to reflect more exact taxonomic relationships. Based on the descriptions of Brown (1962), Koch (1964), Wolfe (1966), Bell (1949), Shoemaker (1966), Ward (1886), and Newberry (1898), 39 different species have been recognized in the flora of which 23 are assigned to previously described species, 1 to a new species and the remaining 15 are presently of unknown affinity. In descending order, the most abundant species of this flora are: *Carya antiguorum, Platanus nobilis, Platanus raynoldsii* and *Cercidiphyllum arcticum.* Together they represent 74% of the specimens collected. Other genera represented are *Populus, Magnolia, Vitis, Trochodendroides, Hamamelites, Persea, Lindera, Cinnamomum, Viburnum, Ampelopsis, Cissus, Pterocarya, Juglans, Phyllites,* and *Ficus.*

An analysis of leaf physiognomy suggests that this flora lived in a warm-temperate to subtropical, seasonably dry to moist climate. A correlation of the species to the favored climates of their nearest living relatives supports this conclusion.

From the Fort Union Formation, Brown (1962) described algae, fungi bryophytes, as well as several ferns and fern allies, conifers, cycads and ginkgoes. The angiosperms of this formation are diverse and include palms, willows, magnolias, witchhazel, sweetgum, birch, maples, hydrangea, cherry, grape, ash, breadfruit, and *Zelkova,* among others. Brown concluded that there is no floral break between the Cretaceous and Paleocene. It is apparent now that many early Paleocene plants cannot be distinguished clearly from their late Cretaceous predecessors, and species thought to be restricted to Paleocene must be cited with some reservations.

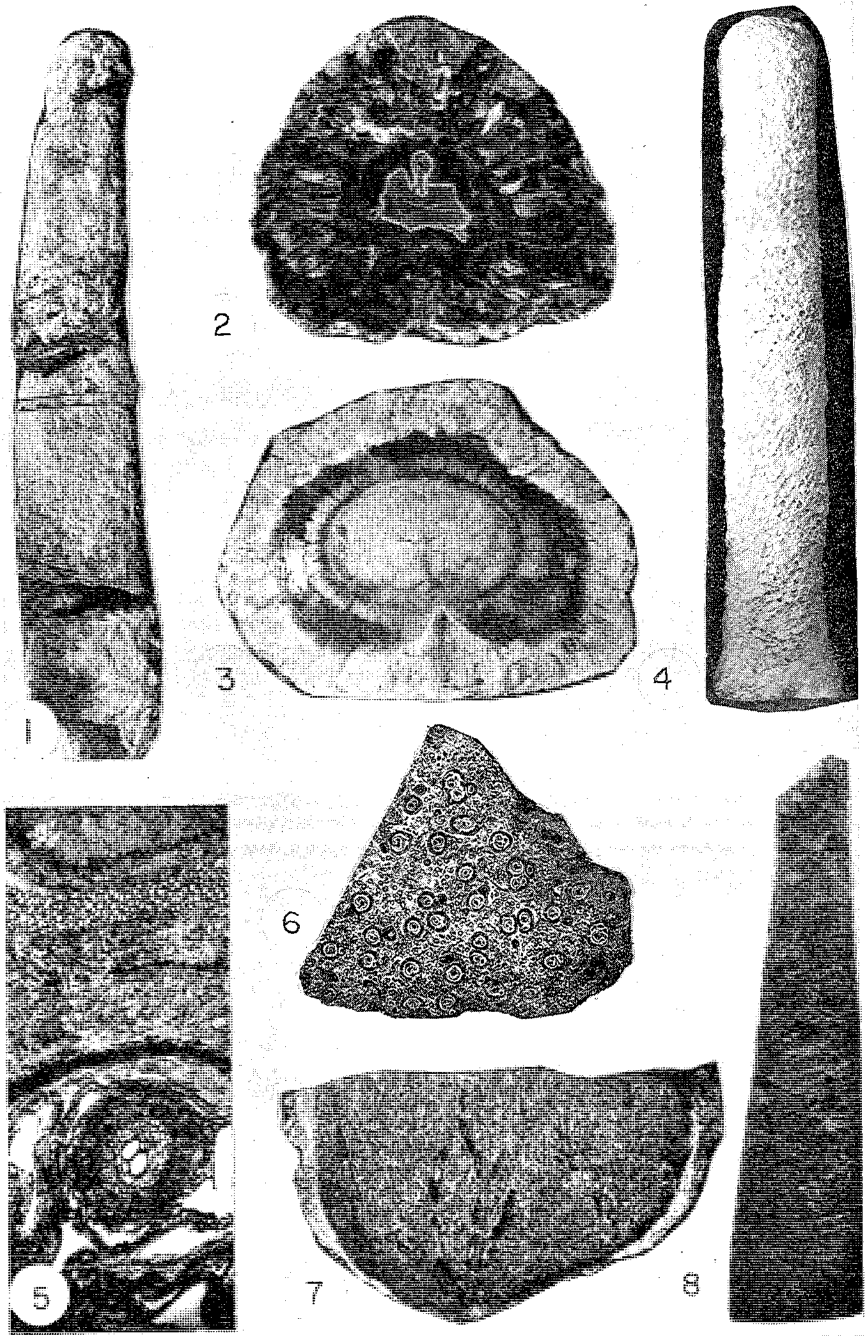
According to Axelrod (1958), evidence from fossil floras of the central Rocky Mountain region indicate that the Madro-Tertiary geoflora was already in existence during the latter part of the early Tertiary. An unusual feature of the Eocene landscape in the western United States was a system of large, interior lakes that occurred in portions of Utah, Colorado and Wyoming, covering an area of approximately 40,000 square miles called the Green River Lake System (Stokes, 1966). Sediments deposited in the lake which formed the Green River Formation consist of algal reefs, fine-grained sandstones, siltstones, marls and organically enriched shales known as Kerogen or oil shales. Kerogen shales are light brown to black in color and contain hydrocarbons in the form of waxy spores and pollen grains (Clark and Stearn, 1960). Bradley (1931) considered the lakes of this system comparatively shallow, averaging 50 to 60 feet and not more than a few hundred feet deep in the central portion of their basins. As the waters fluctuated, lacustrine and fluvial deposits accumulated alternately around the lake margins (Sears and Bradley, 1924). The lake waters were mostly alkaline (complex carbonates and bicarbonates) and a pH somewhat higher than seven has been postulated for most of the history of these lakes (MacGinitie, 1969). Lundell and Surdam (1975) in discussing the stromatolites of the Green River Formation mention a possible high salinity for the lake waters. They based this on comparisons with modern stromatolites of Shark Bay, Australia where salinity eliminates the organisms that feed on algae. "The absence of gastropods and pelecypods associated with the stromatolite units in the Green River Formation probably implies that high salinity was a necessary condition for stromatolite development in Eocene lakes Gosiute and Uinta also" (Lundell and Surdam, 1975, p. 623).

The lake basins were surrounded by mountainous regions except towards the south. These ranges may have had elevation of 5000 feet or more (MacGinitie, 1969). The megaflora as described by MacGinitie consisted of 77 species. Of these there are 67 angiosperms, 7 ferns, and 3 gymnosperms. He organized these plants into four groups based upon the habitat of related living species.

(1) Vegetation of lake margins and flood plains. This was a low forest of sycamores, poplars, willows, sumac, various legumes and laurels, associated with cattails, ferns and horsetails.
(2) Vegetation of low elevations around lake margins. Plants were trees or shrubs adapted to subhumid conditions and typified by Mormon tea (*Ephedra*), hackberry, evergreen oaks, pines and shrubs or trees of legume, sumac, and soapberry families. This was a varied group of hard-leafed and drought-resistant plants.
(3) Vegetation of moderate elevation and north-facing slopes. These were broad-leafed deciduous trees that grew in cooler and dryer conditions than group 2.
(4) Vegetation of conifer-hardwood and montane conifer zones. Plants of this group were represented by pollen from plants which grew above 3000 or 4000 feet.

EXPLANATION OF PLATE 1

FIG. 1.—*Cycadeoidea medullara.* The figured specimen is 1.2 m long. Note the columnar shape of the trunk.
FIG. 2.—*Cycadeoidea medullara.* Cross section (.25X).
FIG. 3.—*Monanthesia* sp. Cross section demonstrating the large pith, narrow xylem region and thick armor (1.6X).
FIG. 4.—*Monanthesia* sp. The figured specimen is 2.16 m high. Note the distinct pattern of leaf bases and cones on the surface of the trunk.
FIG. 5.—*Tempskya superba.* Cross section illustrating a root in the lower portion of the photograph with two small, protoxylem elements and two large, metaxylem elements. Immediately above the root the dark layer represents the epidermis of a stem.
FIG. 6.—*Tempskya jonesi.* Cross section showing scattered stems and small roots which fill the space between them to form a false trunk (.5X).
FIG. 7.—*Tempskya jonesi.* Longitudinal section of a false trunk with a stem branching as it progresses upward (.5X).
FIG. 8.—*Tempskya minor.* False trunk approximately 65 cm long. Note how it tapers toward the apex.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Axelrod (1958) considered some of the plants described by Brown (1934) as representative of some of the earliest possible Madro-Tertiary species. According to MacGinitie (1969) the closest resemblances in environment and composition of the Green River flora to a modern type is to be found in the savanna-woodland floras along the equatorial border of the dry tropics. This may be represented by areas east of Mazatlan, Mexico, around Santiago, Argentina, or Monterrey, Mexico.

Four species of *Palmoxylon* (fossil palm axes Pl. 2, figs. 1, 3) have been described from the Green River Formation in Eden Valley, Wyoming (Tidwell, et al., 1971c; 1973). Axes of palms are fairly abundant in this formation and are associated with dicotyledonous and coniferous woods. Eleven species of dicots were identified and reported by Kruse (1952). Others are currently under study by the authors. MacGinitie (1969) considered them to be earliest Middle Eocene and therefore slightly older than his megaflora. Viewed as a group, the flora depicted by the woods are from a possible lowland habitat, having definite tropical aspects.

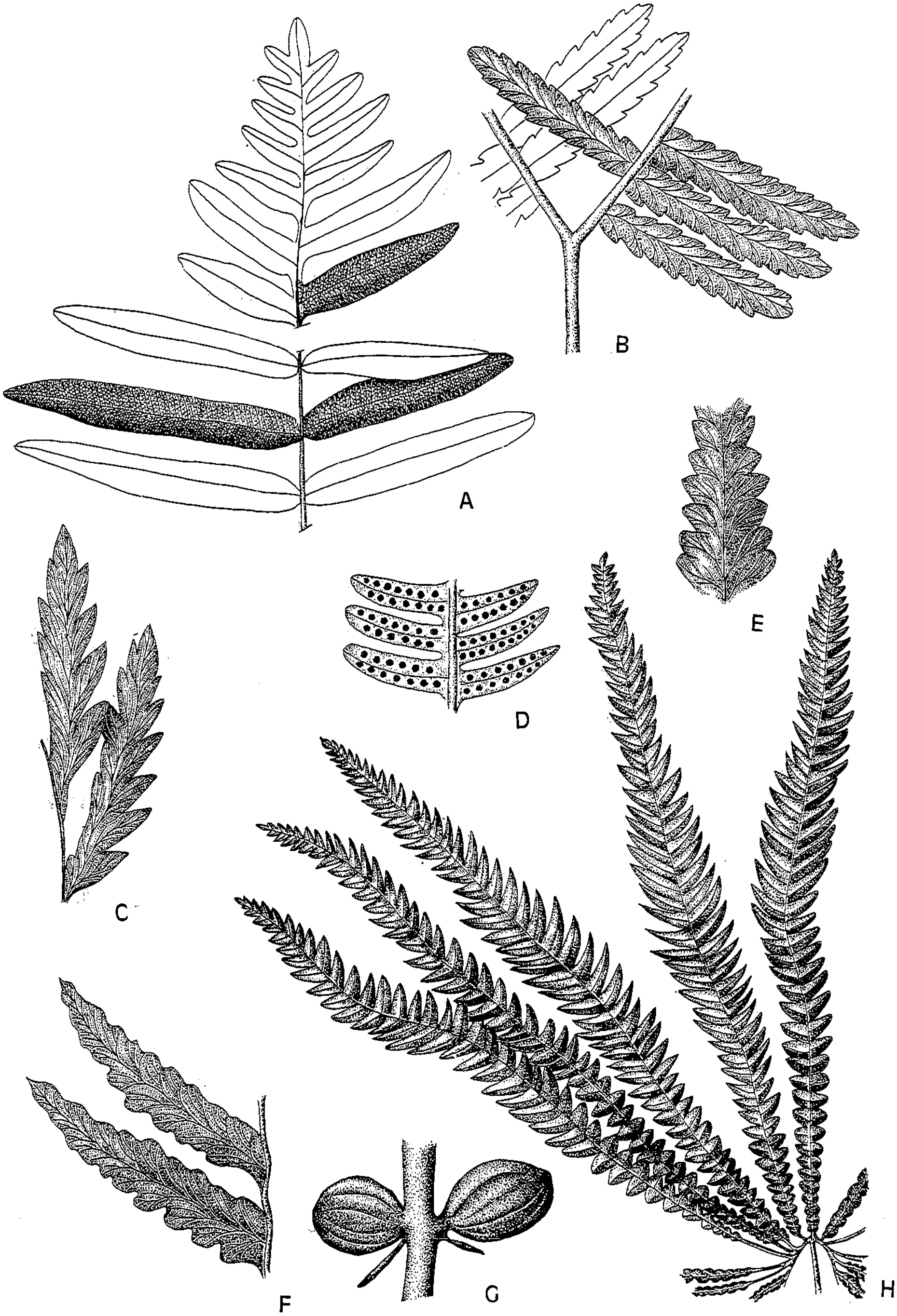
Species of fossil palm material (*Palmoxylon* and *Rhizopalmoxylon,* the genus for petrified palm roots) have been reported from the Dipping Vat Formation of Tertiary age near Redmond, Utah (Tidwell, et al., 1972). The Dipping Vat Formation (McGookey, 1960) is one of a series of formations deposited in association with a large, late Eocene lake in central Utah. The formation consists of coarse-grained, evenly bedded, tuffaceous sandstones that are gray, white or gray blue in color. These sediments are locally hydrothermally altered to red, and are strikingly similar in appearance to some horizons of the Jurassic Arapien Shale which the Dipping Vat unconformably overlies in some areas.

Rhizopalmoxylon specimens (Pl. 2, fig. 2) from the Redmond Hills west of Redmond were originally reported as being from the Arapien Shale (Tidwell, et al., 1970a, 1971b). However, it has been demonstrated that these roots are, without question, in the Dipping Vat Formation (Tidwell, et al., 1972; Scott, et al., 1972).

Axes of *Palmoxylon gustavesonii* were collected from Dipping Vat strata that unconformably overlie the Arapien Shale from which the species *Palmoxylon simperi* and *P. pristina* were previously reported (Tidwell, et al., 1970b). Although it has not been conclusively demonstrated how these *Palmoxylon* axes arrived in the Arapien, the possibility of their derivation from younger strata is sufficient to cast doubt on their being in place in this formation.

Petrified palm axes and dicotyledonous woods are also presently being studied from the Eocene Golden Ranch Formation in Dog Valley west of Nephi, Utah. There appear to be at least two species of *Palmoxylon* and three dicotyledonous species in this flora.

TEXT-FIGURE 1.—Fossil leaves from the Dakota Sandstone Formation. A.—*Astralopteris coloradica* (Brown) Tidwell, Rushforth, and Reveal (.5X). B.—*Gleichenia delicatula* Heer (.5X). C.—*Asplenium dicksonianum* Heer (.5X). D.—*Matonidium brownii* Rushforth (.5X). E.—*Cladophlebis constricta* Fontaine em. Berry (.5X). F.—*Cladophlebis parva* Fontaine em. Berry (.5X). G.—*Equisetum lyelli* Mantel (1X). H.—*Matonidium brownii* Rushforth (.5X).



COMPOSITION OF THE FLORA FROM THE CEDAR MOUNTAIN FORMATION

This flora consists mostly of petrified materials from localities near Moab, Castle Dale and Ferron, Utah. Only recently has a compressional leaf flora been collected in association with false trunks of *Tempskya*. These false trunks were in growth position. Brown (1950) reported fossil plants from the Cedar Mountain (Post-McElmo) and Dakota Sandstone Formation near Naturita, Colorado.

Division: Filicophyta, Family: Tempskyaceae

Tempskya knowltoni.—Brown (1950) reported that Stokes collected *Tempskya knowltoni* Seward from the Cedar Mountain Formation of Utah. Other species collected from this formation include *Tempskya whiteheadi* sp. nov., *T. jonesii* sp. nov., *T. minor*, Read and Brown, *T. superba*, Arnold (Pl. 1, figs. 5-8).

Fern Foliage.—An unidentified type of fern foliage has been found in gray siltstones approximately two inches beneath a *Tempskya*-bearing horizon east of Castle Dale, Utah. It resembles *Anemia fremontii* Knowlton and *Onychiopsis mantelli* (Brongn.) Seward which are also Cretaceous in age.

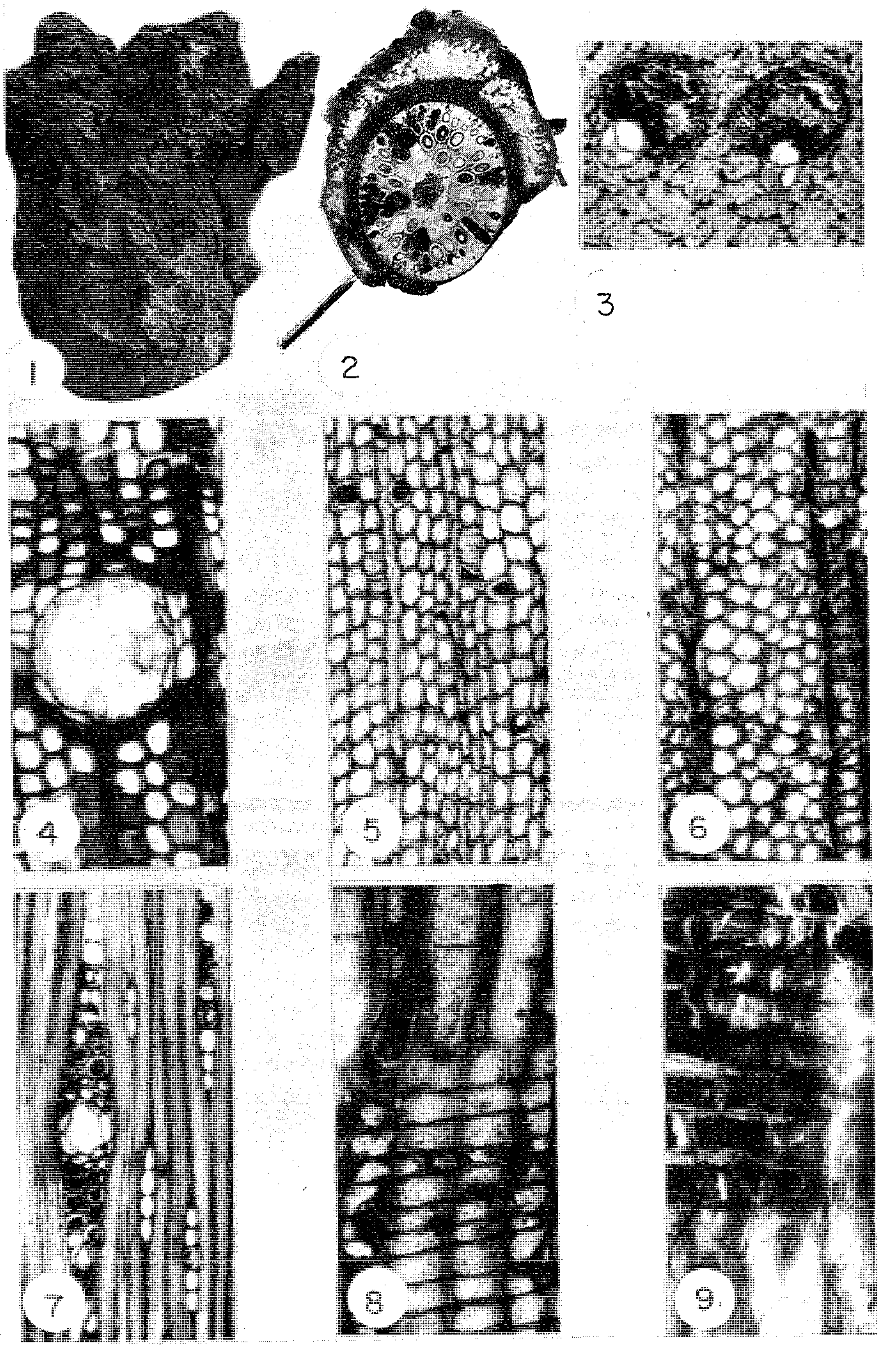
Division: Cycadophyta, Family: Cycadeoidaceae

Cycadeoidea sp.—Brown (1950), figures a fragment of a cycadeoid trunk bearing part of a cone and numerous leaf bases. It is too poorly preserved for specific identification. This specimen was collected from San Miguel County, Colorado.

Cycadeoidea medullara Furniss.—This species was collected north of Moab, Utah. It is a columnar species about forty-eight inches high, ten inches in diameter, and rounded at the apex. A distinctive feature is the presence of a medullary sheath of tightly arranged, axially elongate parenchyma cells at the periphery of the pith (Furniss, 1975).

EXPLANATION OF PLATE 2

FIG. 1.—*Palmoxylon edenense*. The figured specimen is 36 cm long and bears petiole bases at the apex.
FIG. 2.—*Rhizopalmoxylon behuninii*. Note the large metaxylem elements of a palm root (5X).
FIG. 3.—*Palmoxylon macginitiei*. Cross section of a stem showing fibro-vascular bundles, each with 2 large metaxylem elements and reniform bundle caps (33X).
FIG. 4.—*Pityoxylon* sp. Cross section demonstrating a large vertical resin duct with thin-walled epithelial cells (123X).
FIG. 5.—*Mesembryoxylon* sp. Cross section with many dark axial parenchyma cells (123X).
FIG. 6.—*Cedroxylon* sp. Cross section demonstrating the lack of axial parenchyma and resin ducts (123X).
FIG. 7.—*Pityoxylon* sp. Tangential section illustrating a fusiform ray and horizontal resin duct with thin-walled epithelial cells (123X).
FIG. 8.—*Mesembryoxylon* sp. Radial section with a large podocarpoid cross field pit (246X).
FIG. 9.—*Cedroxylon* sp. Radial section showing circular tracheid pitting and pinoid crossfield pitting (123X).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Cycadeoidea cleavelandii Furniss.—This species, described by Furniss (1975), is a columnar, unbranched, central portion of a trunk. In most cycadeoids, leaf traces are U-shaped as they leave the vascular cylinder, but the leaf traces of *C. cleavelandii* consist of two crescent-shaped bundles (Pl. 1, figs. 1-2).

Monanthesia sp.—A seven-foot specimen of *Monanthesia* was collected near Moab, Utah. The trunk is a columnar with a rather constant diameter of twelve inches. It bears spiral, persistent leaf bases with a cone in the axis of each leaf. All of the cones seem to be female, indicating that this was a dioecious species (Pl. 1, figs. 3-4).

Division: Coniferophyta, Coniferales, Coniferous foliage

Brachyphyllum crassicaule Fontaine.—*Brachyphyllum* is the generic designation for coniferous branches bearing spirally arranged overlapping leaves. Brown (1950) reported the presence of *Brachyphyllum* in the Cedar Mountain Formation south of Nucla, Colorado (Text-fig. 2A).

Frenelopsis varians Fontaine.—This genus of mostly coniferous branches is rather distinctive. Brown (1950) regards this genus as an index to the Lower Cretaceous (Text-fig. 2B).

Coniferous Wood

Pityoxylon sp.—Petrified coniferous woods with both horizontal and vertical resin ducts are placed in the genus *Pityoxylon*. Woods of this type have been collected from conglomeratic channel fills in the Cedar Mountain Formation east of Ferron, Utah (Pl. 2, figs. 4, 7).

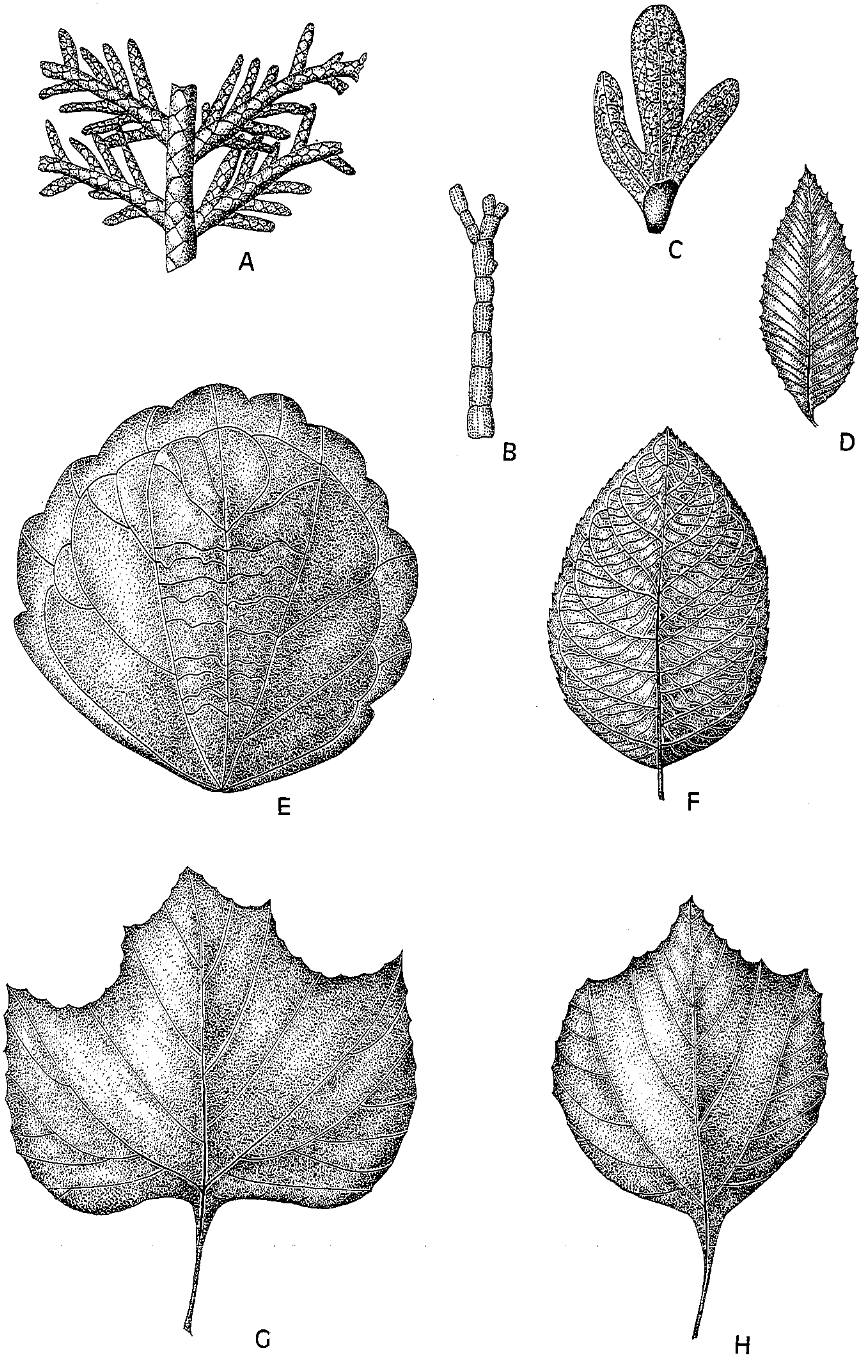
Mesembryoxylon sp.—Woods placed in this genus may be related to *Podocarpus* or *Phyllocladus* of the modern Podocarpace, but do not fit any of the living types. A wood possessing the typical large crossfield pits of the Podocarpaceae has been collected east of Ferron, Utah (Pl. 2, figs. 5, 8).

Cedroxylon sp.—This generic name is applied to fossil woods which lack resin ducts and axial parenchyma, but possess abietinous tracheid pitting. Such a wood occurs east of Ferron, Utah. It could possibly be related to several modern families (Pl. 2, figs. 6, 9).

Division: Anthophyta, Dicotyledonae, Petrified wood

Icacinoxylon pittiense Thayn.—The Icacinaceae is a tropical family with a common wood structure. Families with similar wood structure include the Fagaceae (oaks and beeches), Platanaceae (sycamores), and the Magnoliaceae (tulip tree and magnolia). These woods may have a combination of uniseriate and

TEXT-FIGURE 2.—Fossil leaves from the Cedar Mountain Formation (Lower Cretaceous) (A,B), Fort Union Formation (Paleocene) (E,F,G,H), and Green River Formation (Eocene) (C,D). A.—*Brachyphyllum crassicaule Fontaine* (.5X). B.—*Frenelopsis varians* Fontaine (.5X). C.—*Engelhardtia uintaensis* MacGinitie (.1X). D.—*Zelkova nervosa* (Newberry) Brown (.5X). E.—*Cercidiphyllum arcticum* (Heer) Brown (1X). F.—*Carya antiguorum* Newberry (1X). G.—*Platanus nobilis* Newberry (.25X). H.—*Platanus raynoldsii* Newberry (.25X).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multiseriate rays as well as scalariform perforation plates. In one section of the Icacinaceae, the rays are heterogenous and perforation plates are exclusively scalariform (Pl. 3, figs. 1-3). A wood with these characteristics has been collected near Ferron, Utah (Thayn, Tidwell and Stokes, 1973).

Plataninium sp.—Page (1968) emended the genus *Plataninium* Unger 1842 emd. Vater 1884, to include fossil woods which resemble some members of the Platanaceae, Eupteleaceae, Fagaceae, and Icacinaceae, but whose familial affinities cannot be definitely determined. A wood fitting this category and possessing homogenous rays occurs near Castle Dale, Utah (Pl. 3, figs. 4-6).

Paraphyllanthoxylon utahense Thayn.—The genus *Paraphyllanthoxylon* was first described by Bailey (1924) for a Cretaceous petrified wood from Arizona. The name implies relationship to the genera *Bridelia* and *Phyllanthus* of the Euphorbiaceae, but woods of this genus may also be related to members of the Anacardaceae (cashew family), Bursuraceae (incense tree family), Lauraceae (laurel family), Simarubaceae (quassia family), and Verbenaceae (verbena family). It has been reported from the Cretaceous Wayan Formation of Idaho (Spackman, 1948) and from the Cretaceous of Alabama (Cahoon, 1972) as well as from the Cretaceous and Tertiary of India. Specimens of *Paraphyllanthoxylon* also occur in the Cedar Mountain Formation east of Castle Dale and Ferron, Utah. They are typified by having simple perforation plates and heterogenous uniseriate and multiseriate rays (Pl. 3, Figs. 7-9).

COMPOSITION OF THE FLORA FROM THE DAKOTA SANDSTONE FORMATION

The Dakota Sandstone flora of Utah is known basically from the locality near Westwater, Utah, near the Utah-Colorado boundary. Most of these plant fossils are compressions, although some petrifactions are known. Other petrifactions occur near Ferron. The species are listed with a brief description of each.

Division: Arthrophyta, Family: Equisetaceae

Equisetum lyelli Mantel.—Horizontal rhizomes that are smooth to slightly ribbed. These bear ovoid to globose tubers on short paired branches (Text-fig. 1G).

EXPLANATION OF PLATE 3

FIG. 1.—*Icacinoxylon pittiense.* Cross section showing solitary pores and wide rays. (66X).

FIG. 2.—*Icacinoxylon pittiense.* Tangential section with large heterogenous rays (66X).

FIG. 3.—*Icacinoxylon pittiense.* Radial section demonstrating scalariform (ladder-like) perforation plates (123X).

FIG. 4.—*Plataninium* sp. Cross section with solitary pores and extremely wide rays (66X).

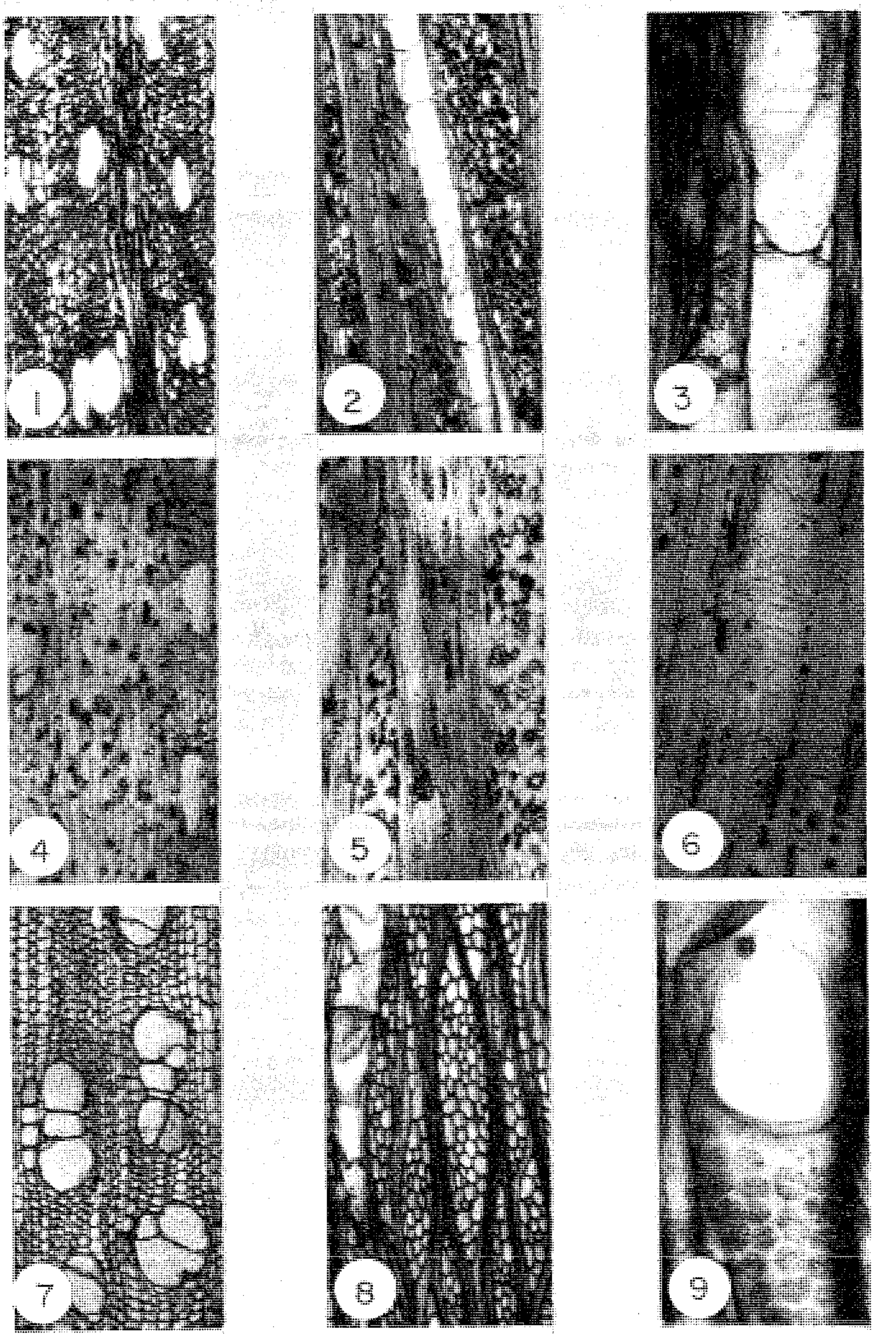
FIG. 5.—*Plataninium* sp. Tangential section illustrating the circular form of the ray cells (66X).

FIG. 6.—*Plataninium* sp. Radial section of a scalariform perforation plate (123X).

FIG. 7.—*Paraphyllanthoxylon utahense.* Cross section. Note the pore multiples and tyloses (membranes) in the pores (66X).

FIG. 8.—*Paraphyllanthoxylon utahense.* Tangential section with heterogenous rays up to six cells wide (66X).

FIG. 9.—*Paraphyllanthoxylon utahense.* Radial section showing alternate vessel pitting and a simple perforation plate (495X).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Division: Filicophyta, Family: Osmundaceae(?)

Cladophlebis constricta Fontaine em. Berry.—Entire leaf unknown from this flora. Pinnules wide with deeply lobed, entire margins, obtuse apices. Midvein strong with open venation. Fertile specimens unknown (Text-fig. 1E).
Cladophlebis parva Fontaine em. Berry.—Pinna appears lanceolate. Pinnules linear-lanceolate, up to 26 mm lg x 6 mm wd, lobed one-half to midrib, margins slightly undulate, apices acute, midvein to apex, open secondary veins. Fertile specimens unknown (Text-fig. 1F).

Family: Gleicheniaceae

Gleichenia comptoniaefolia (Deb. and Ett.) Heer.—Common species in this flora. Leaf at least bipinnate. Pinnules narrow elliptic to deltoid, entire margin, obtuse apices; midvein doesn't extend to apex, numerous secondary veins dividing; three round sori per pinnule.

Gleichenia delicatula Heer.—Common species in this flora. Leaf at least bipinnate. Dichotomously branched specimens are often collected having a large bud in the axis of the dichotomy. Pinnules tend toward ovate but have truncated margin toward pinna apex. Acute to obtuse apices directed toward pinna apex. Primary vein divides immediately into 3 to 5 ultimate veinlets. Fertile specimens unknown (Text-fig. 1B).

Family: Matoniaceae

Matonidium americanum Berry em. Rushforth.—Leaf divides to form collar from which up to 39 pinnae radiate. Pinnules leathery with midvein prominent to near-round apices. Secondary veins divide and remain free of the margins. Round, indusiate sori on each side of midvein.

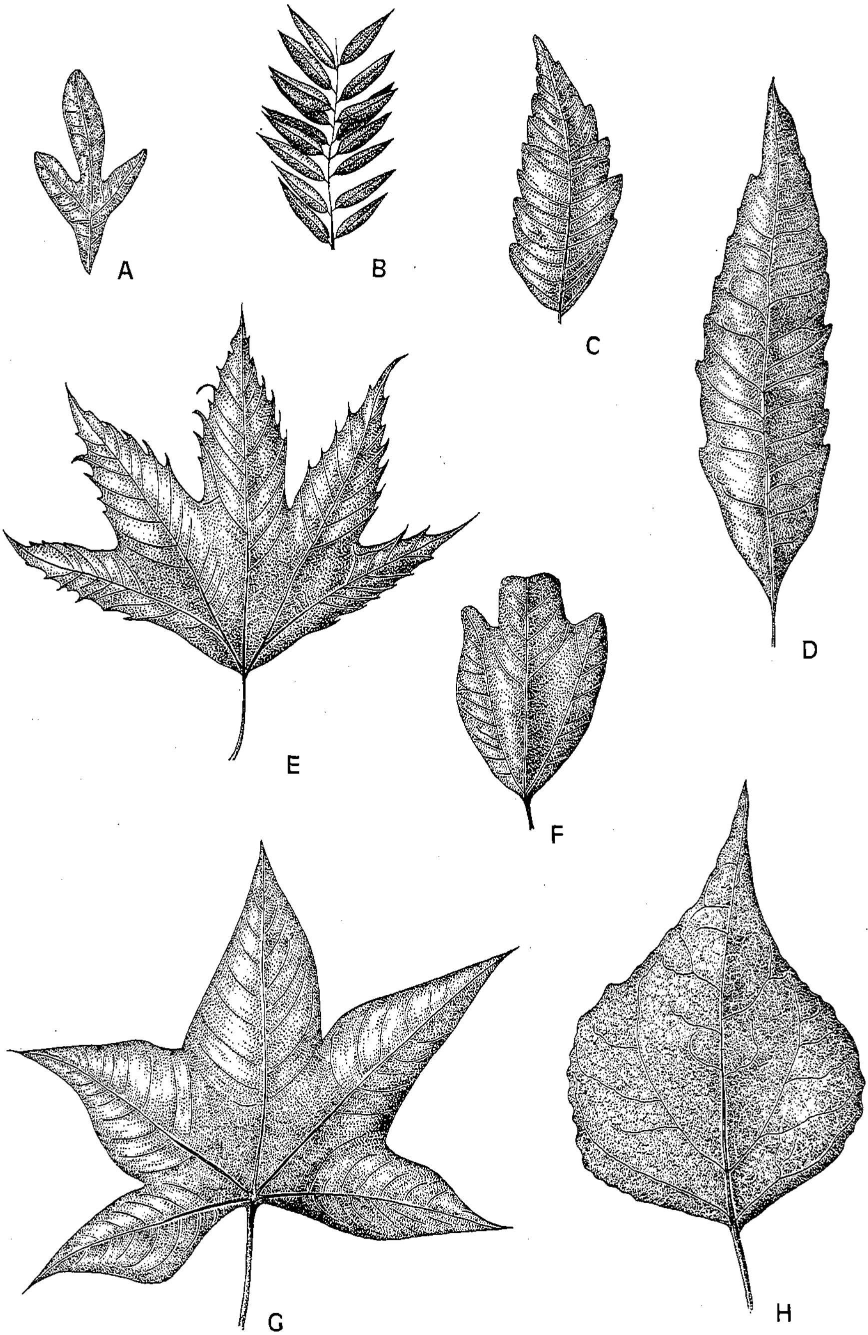
Matonidium brownii Rushforth.—*Matonidium brownii* differs from *M. americanum* in being larger, having less pinnae and in having anastomosing rather than open venation (Text-figs. 1D, 1H).

Matonidium brownii var. *magnipinnulum* Rushforth.—Similar to *M. brownii* except larger and narrower pinnules. Round sori with peltate indusium.
Matonidium (?) *lancipinnulum* Rushforth.—Pinnules linear-lanceolate with anastomosing venation. Fertile specimens unknown.

Family: Dipteridaceae

Hausmannia rigida Newberry.—Divided by nearly equal dichotomies to form tongue-shaped leaf segments with rounded apices. Fertile specimens unknown.

TEXT-FIGURE 3.—Fossil leaves from the Green River Formation (Eocene). A.—*Cardiospermum coloradensis* (Knowlton) MacGinitie (.5X). B.—*Mimosites coloradensis* Knowlton (.5X). C.—*Bursera inaequalateralis* (Lesquereux) MacGinitie (.5X). D.—*Allophyllus flexifolia* (Lesquereux) MacGinitie (.5X). E.—*Platanus wyomingensis* (Knowlton and Cockerell) MacGinitie (.25X). F.—*Lindera varifolia* MacGinitie (.5X). G.—*Acer lesquereuxi* Knowlton (.25X). H.—*Populus wilmattae* Cockerell (1X).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Family: Dicksoniaceae

Coniopteris westwaterensis Rushforth.—Leaf with sterile portion below and fertile above. Sterile foliage has lanceolate pinnules with entire to dentate margins. Fertile pinnules reduced with obscure venation. Sporangia not observed.

Family: Polypodiaceae

Astralopteris coloradica (Brown) Tidwell, Rushforth, and Reveal.—Pinna large. Lower pinnules long, linear-lanceolate with stalked to sessile attachment. Upper pinnules basally attached with rounded sinuses. Midvein and secondaries conspicuous. Ultimate veins finer and anastomosing. Round sori, biseriate on each side of midvein (Text-fig. 1A).

Asplenium dicksonianum Heer.—Pinnules lanceolate, entire to deeply cut, basal to single point attachment, somewhat decurrent. Midvein prominent and decurrent, open venation. Fertile specimens unknown (Text-fig. 1C).

Asplenium dakotensis Rushforth.—Similar to *A. dicksonianum,* but pinnules of *A. dakotensis* are smaller, entire and strap-shaped. Fertile specimens unknown.

Division: Anthophyta (Magnoliophyta), Family: Aquifoliaceae

Ilex serrata Rushforth.—Leaves vary from short and wide to long and thin, angular-ovate; acute to acuminate apex, narrow base, petiolate, serrate margins, venation often obscure. Midvein weak secondaries arise acutely and go straight to margins.

Family: Magnoliaceae

Magnolia boulayana Lesq.—Leaf narrowly elliptic in outline, base rounded, entire margins; strong midvein secondaries are parallel, pinnate, and unite with vein above to form loops.

Family: Moraceae

Ficus daphnogenoides (Heer) Berry.—Leaves plus or minus oblanceolate (12 cm lg x 3 cm wd), acuminate apices forming a long drip point, cuneate base, entire margin, midvein strong at base becoming weaker near apex. Secondaries ascend acutely, divide and curve to parallel margins.

Eucalyptus dakotensis Lesq.—Linear leaf, cuneate base, entire obtuse apex, petiolated, midvein prominent, secondaries fine, oblique parallel each other to margins.

Family: Platanaceae

Platanus newberryana Heer.

Family: Salicaceae

Salix newberryana Hollick.

THE BAGGS FORT UNION FLORA

The following four species are the most common species in this flora.

Carya antiguorum Newberry.—This is the most common species in the Baggs flora. The distinguishing characteristics are the ovate rather than spatulate shape, simply serrate margin, conspicuous looping secondary veins and weak interconnecting tertiaries (Text-fig. 2F).

Platanus nobilis Newberry.—Leaves of this species are characterized by a large, 5 lobed shape with 3 primaries that diverge suprabasally and the lack of conspicuous curved secondaries between the margin and lateral primaries (Text-fig. 2G).

Platanus raynoldsii Newberry.—This species has a smaller, 1-3 lobed shape with 3 primaries that diverge suprabasally and conspicuous curved secondaries between the margin and lateral primaries (Text-fig. 2H).

Cercidiphyllum arcticum (Heer) Brown.—Characteristics of this species are the orbicular-deltoid shape, palmate camptodromous venation and unique marginal looping (Text-fig. 2E).

THE GREEN RIVER FLORA

Portions of the Green River flora have been described from several localities in Wyoming, Colorado and Utah. A few relatively common and/or interesting species are mentioned.

Division: Anthophyta, Family: Salicaceae

Populus wilmattae Cockerell.—A broadly ovate leaf with a long acuminate apex and a broadly cuneate base. Margins are somewhat crennate-dentate with small glands attached. Venation is prominent (Text-fig. 3H).

Family: Juglandaceae

Engelhardtia uintaensis MacGinitie.—Fruit composed of nut with four entire wings (Text-fig. 2C).

Family: Ulmaceae

Zelkova nervosa (Newberry) Brown.—This species is very common at some localities in this formation (Text-fig. 2D).

Family: Lauraceae

Lindera varifolia MacGinitie.—A ovate leaf divided into three lobes. This species has a slender midvein with two opposite subprimaries arising from it (Text-fig. 3F).

Family: Platanaceae

Platanus wyomingensis (Knowlton and Cockerell) MacGinitie.—Very common species in this flora. *P. wyomingensis* was originally described as an *Aralia* (Text-fig. 3E).

Family: Leguminosae

Mimosites coloradensis Knowlton.—Fossil leaflets assignable to this species are one of the more common leaf types in the Green River Flora. They are small, tending to be somewhat falcate and appear to be coriaceous (Text-fig. 3B).

Family Burseraceae

Bursera inaequalateralis (Lesquereux) MacGinitie (Text-fig. 3C).

Family: Aceraceae

Acer lesquereuxi Knowlton (Text-fig. 3G).

Family: Sapindaceae

Allophylus flexifolia (Lesquereux) MacGinitie.—Large leaflets with peculiar margins varying from dentate-serrate to undulate, and unusual angular-reticulate tertiary venation and coarse aerolation. Fossil fruits and pollen grains (*Talisiipites* Wodehouse, 1933) assigned to *Allophylus* have also been collected (MacGinitie, 1969) (Text-fig. 3D).

Cardiospermum coloradensis (Knowlton) MacGinitie.—This species is similar to *C. terminalis* (Lesquereux) MacGinitie from the Florissent flora. It differs by more rounded apices on the lobes and less distinct dissection of the leaflets. (Text-fig. 3A).

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