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UPPER CRETACEOUS AND PALEOCENE FLORAS OF THE RATON BASIN, COLORADO AND NEW MEXICO

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INTRODUCTION

Fossil plant remains, particularly leaves, occur at many localities in the Upper Cretaceous Trinidad and Vermejo formations and in the Upper Cretaceous and Paleocene Raton Formation in the Raton basin of Colorado and New Mexico. The fossils are especially abundant in the coal-bearing portions of the Vermejo and Raton formations and are of special interest because they can be used to locate the Mesozoic-Cenozoic boundary in the basin. They also enable scientists to visualize the paleoecological conditions in the Raton basin at the time when these formations were being deposited.

The purpose of this paper is to summarize Upper Cretaceous and Paleocene floras in the Raton basin. Although it is based primarily on the monograph published by Knowlton (1917) on the Vermejo and Raton floras, this paper reflects the changes made in the classification and nomenclature of some of these plant fossils since 1917. These changes were proposed by Dorf (1938, 1942), Brown (1962) and Read and Hickey (1972). It is possible that additional changes will be proposed in the future as the Upper Cretaceous and Paleocene floras of the western interior of the United States are currently being restudied by L. J. Hickey of the U.S. National Museum.

GEOLOGIC SETTING

The Raton basin is a Laramide structural basin that contains as much as 12,000 ft of Upper Cretaceous and lower Tertiary rocks (Baltz, 1965). In most of the basin the fossil-bearing strata are flat-lying, but near the edges they dip into the basin at a relatively low angle. The lowest of the plant-bearing formations in the Raton basin is the Trinidad Sandstone of Late Cretaceous (Montana) age (Fig. 1). It is 0-300 ft thick and consists of buff to gray, slightly arkosic, fine to medium grained sandstone and some interbedded gray shale. The Trinidad intertongues with both the underlying Pierre Shale and the overlying Vermejo Formation.

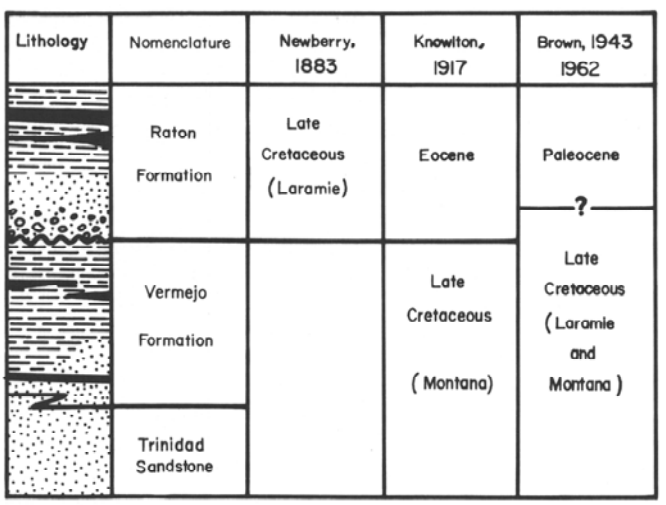


Figure 1. Nomenclature and age assignments of the Upper Cretaceous and Tertiary rocks in the Raton basin.

The Vermejo Formation is 0-550 ft thick in the Raton basin and consists of buff to gray and green siltstone, slightly arkosic sandstone, carbonaceous and coaly shale and coal. The formation contains many plant fossils. An erosional unconformity separates the Vermejo Formation from the overlying Raton Formation (Fig. 1).

The Raton Formation is 0-1700 ft thick and consists of gray, fine- to coarse-grained arkosic sandstone, shale, and many beds of coal. Typically the basal part of the Raton is a gray to purple-gray pebble conglomerate or gray conglomerate sandstone. According to Brown (1962), this basal conglomerate has a sugary aspect that makes it easy to distinguish from all other conglomerate beds in the area. The lower few hundred feet of strata in the Raton (including the basal conglomerate) do not contain any coal but they do contain a few plant fossils. Coal and plant fossils, however, are very abundant in the upper "productive" part of the formation. In much of the Raton basin the Raton Formation is overlain unconformably by the Poison Canyon Formation of Paleocene age but to the west the formations intertongue with each other (Baltz, 1965).

The position of the Mesozoic-Cenozoic boundary in the Raton basin and the age of the formations involved has been a source of disagreement for years. Geologists have had to rely on paleobotanists to locate this boundary because plant remains are the only known fossils in the sequence of beds containing the boundary. As noted below, early paleobotanists disagreed on the ages of several floras in the basin.

In his systematic study of the coal-bearing strata in the Raton basin, Lee (1916) recognized the unconformity between the Vermejo and Raton formations and concluded that it represented the Mesozoic-Cenozoic boundary (Fig. 1). This conclusion was based on the work of Knowlton (1917), who had indicated that the Vermejo flora was of Late Cretaceous (Montana) age and the Raton flora was of Eocene age.

Later, Brown (1943) showed that the barren basal beds of the Raton Formation contain the remains of the curious plant fossil *Palaeoaster* (Fig. 4E) which has never been found in Tertiary strata. The principal flora (here called the upper flora) in the productive part of the Raton is definitely of Paleocene age and occurs several hundred feet above the basal beds of the formation. Brown concluded that the boundary actually is somewhere in the lower part of the Raton below the productive part of the formation (Fig. 1). He was of the opinion that the unconformity between the Vermejo and Raton formations

represented "only an episode in Upper Cretaceous history ..." and demonstrated that most of the Vermejo flora was of Laramide age and that only the lower part was Montanan in age.

The source of the Trinidad Formation was to the west of the Raton basin where the San Luis uplift rose during the first stages of the Laramide orogeny in northern New Mexico (Baltz, 1965). Sediments derived from the positive area were deposited in beach and near-shore environments as the Late Cretaceous sea withdrew northeastward. The intertonguing of the Trinidad with the underlying and overlying units suggests that the regression of the sea was interrupted several times and that the sea may even have transgressed slightly to the southwest a few times. Nevertheless, the overall effect was a retreat of the sea from the Raton basin. Following the deposition of the Trinidad Sandstone, the sea continued to withdraw and the mud, sand and coaly materials of the Vermejo Formation were deposited in deltas, flood plains and swamps. Strong orogenic movements occurred to the west of the basin in late Cretaceous time after the Vermejo Formation was deposited. Consequently, deposition ceased and erosion removed an unknown thickness of the Vermejo at least in the southern part of the Raton basin (Wanek, 1963). Eventually, in latest Cretaceous time, gravels and coarse sands were spread eastward from the uplift over the erosional surface to form the coarse-grained basal beds of the Raton Formation. The bulk of the Raton Formation accumulated below the water table in swamps and flood plains during Paleocene time (Johnson and Wood, 1956). At the same time, the Poison Canyon Formation was being deposited above the water table in a piedmont environment in front of the Sangre de Cristo uplift which was rising just west of the Raton basin. Eventually the Poison Canyon Formation spread eastward over the Raton Formation as the sea continued to retreat to the northeast.

HISTORY OF INVESTIGATIONS

The fossil plants of the Raton basin first became known to science through the efforts of Lt. T. W. Abert of the U.S. Army who had prepared a scientific report on New Mexico for the U.S. Government in 1846-47. Abert, a graduate of the U.S. Military Academy at West Point, had a surprisingly broad scientific background and was well suited for his assignment. He was to have accompanied Steven Watts Kearny on his expedition to liberate New Mexico in the fall of 1846, but he became seriously ill a few weeks after Kearny's Army of the West left Fort Leavenworth, Kansas. Thus, he had to remain behind at Bent's Fort in southern Colorado to recuperate when the expedition continued its march into New Mexico. Eventually Abert recovered sufficiently to continue his journey and on September 16, 1846, he discovered fossil leaves and coal on the north side of Raton Pass. Abert (1848) noted the leaves were dicotyledonous and resembled leaves of modern catalpa and willow. Apparently, he did not collect any of these fossils at that time.

On January 14, 1847, after completing his investigation of New Mexico, Abert returned to the fossil plant locality he had discovered in Raton Pass. This time, he was accompanied by a Mr. Laing who had worked in the Carboniferous coal mines of Missouri. Abert thought the coal-bearing formation in Raton Pass was of Carboniferous age; consequently, he and Laing searched for ferns such as those which occur with the coal in Missouri. According to Abert (1848), Laing "seemed to be positive that he could find me impressions such as he had seen in the Carboniferous formation of Missouri ... but after a long search he was obliged to confess that there were none." Nevertheless, they collected specimens of the leaves that were there and Abert later submitted them to J. W. Bailey, Professor of Chemistry, Mineralogy and Geology at the U.S. Military Academy for identification. Although he did not identify or describe the fossils, Bailey (in Abert, 1848) did report that they were the remains of "plants of comparatively modern origin." Bailey also stated, "it is thus established beyond a doubt, that the great deposit of coal at Raton is not the equivalent of the great coal formation of the United States but is of a much more recent date...." This statement was significant because until that time it was supposed the coal-bearing units along the eastern flanks of the Rockies were merely an extension of the Carboniferous Coal Measures of the mid-western and eastern United States. It took several years for this new data to be generally accepted. In the geologic map of the United States published by Hitchcock in 1853, exposures of Carboniferous Coal Measures are shown at several places along the eastern flanks of the Rocky Mountains including the Raton Mesa area.

During the following years, a number of geologists collected fossil leaves in the Raton basin, including J. L. Le Conte. He obtained fossil plants from several localities in the area while he was making a survey for the Union Pacific Railroad. They were submitted to the famous paleobotanist Leo Lesquereux who reported (1868) that the collection contained five species, including three new to science. Although Le Conte had thought the fossils were of Cretaceous age, Lesquereux determined that they were of Tertiary age. One of the species came from the Vermejo Formation and the others from the Raton Formation.

In the summer of 1869, F. V. Hayden (1873) discovered a layer full of "deciduous leaves, like *Salix*, *Platanus*, *Thuya*, and a broad flaglike plant" at a locality in the Vermejo Formation near Caňon City, Colorado. Hayden also collected a number of leaves from the Raton Formation near Trinidad, Colorado which were studied by Lesquereux. He reported (1872) that the flora contained 21 species including six which he thought were new.

J. S. Newberry (1883) named and briefly described four new species of plants from the Raton Formation which were more fully described and figured by him later (Newberry, 1898). Newberry (1883) thought the Raton Formation was of Late Cretaceous age because he assumed that it was equivalent to the coal-bearing rocks of the Denver Basin which were known to be of Laramide age.

According to Knowlton (1917), George Hadden, "sometime superintendent" of certain coal mines in the Raton basin made a collection of plants from the Upper Cretaceous and Lower Tertiary rocks in the Colorado portion of the basin in 1885. The collection was sold to the collector R. D. Lacoe, of Pittston, Pennsylvania and later donated by him to the U.S. National Museum. This collection was studied by Lesquereux, who prepared a voluminous report on them. This report was never published. At about the same time, Hadden made another and larger collection for Newberry. Although some of the fossils were sent to the U.S. National Museum, the majority were sent to the New York Botanical Garden, Bronx, New York. The ferns in the collection sent to the Botanical

Garden were described by Hollick (1902); however, the bulk of the collection has never been studied.

Early in the present century, Willis T. Lee began a study of the geology of the Raton basin and collected a large number of fossil plants from the Cretaceous and Tertiary rocks in the area. These collections were studied by F. H. Knowlton who did very little collecting in the area himself. Knowlton (1917) also re-examined many of the older collections from this area and published an extensive report on the Cretaceous and Tertiary plant fossils in the Raton basin and adjacent areas. In this report, he described or redescribed 12 species from the Trinidad Sandstone, 96 species from the Vermejo Formation and 148 species from the Raton Formation. Knowlton (1917) determined that the Trinidad and Vermejo formations were of Cretaceous age and that the Raton was Eocene in age.

In 1929, the famous American paleobotanist Roland Brown began a comprehensive study of the Cretaceous and Tertiary floras of the western interior of the United States. Although somewhat on the margin of the principal area of interest the floras of the Raton basin were included in his study. Brown (1943) discussed briefly the Cretaceous-Tertiary boundary problem in the Raton basin and located it in the lower part of the Raton Formation. Later, in his monographic study of the Paleocene floras of the western interior, Brown (1962) confirmed the location of the boundary in the Raton Formation. In this report, he also reduced the number of species in the Paleocene portion of the Raton flora to about 50.

Palynomorphs in five coal beds in the Vermejo Formation in the adjacent Callon City, Colorado coal basin have been studied by R. T. Clark. Regretfully only a small amount of his study have been published (Clarke, 1965, 1966).

FLORISTICS AND PALEOECOLOGY

Trinidad Flora

The Trinidad Sandstone contains just a few poorly preserved plant fossils and many trace fossils which were attributed to the algae by Knowlton (1917). The trace fossils are rough sandstone casts and impressions that have few characters and have been referred to the genera *Caulerpites*, *Chondrites*, and *Ophiomorpha* (formerly called *Halymenites).* All of these fossils are now generally regarded as having been formed by marine organisms of some type (Hantzschel, 1975; Pillmore and Maberry, this Guidebook).

Near Trinidad, Colorado, the Trinidad Sandstone contains tiny oval structures that were described by Lesquereux (1872) as being the remains of a bark inhabiting species of fungi. Knowlton (1917), however, was rather skeptical of the identification because of the poor preservation of the fossils.

A locality in the Trinidad about one mile south of Raton, New Mexico, has yielded the remains of five species of dicotyledonus leaves and a locality in the Cation City coal field of Colorado has yielded the remains of a sixth. The fossils include cottonwood *(Populus),* grape (*Vitis),* and *Viburnum*, a relative of the honeysuckle.

Vermejo Flora

The Vermejo Formation contains numerous plant fossils of various types at many localities in Colorado and New Mexico. Although the formation contains petrified wood and palynomorphs, most of the published reports concern only the leaves.

According to Clarke (1965), 50 percent of the palynomorphs in the coal beds were angiosperm pollen grains, 40 percent were fern spores, slightly less than 10 percent were gymnosperm pollen and about one percent were fungal spores or unclassified forms. This breakdown is somewhat different than that derived from the plant megafossils (principally leaves), about 75 percent of which are gymnosperms. In both cases, the percentage of ferns seems unusually high for typical Late Cretaceous floras and may reflect a special environment of deposition.

From the Vermejo Formation in Colorado, nine species of fungal spores were described by Clarke (1966). Clarke noted that fungal spores occur in all the coal beds but were a sparse element in the entire palynomorph assemblage, as they accounted for less than 0.5 percent of the total forms present. He determined that the fungal spores were not useful for zoning the formation.

Fourteen species of ferns have been described from the Vermejo Formation. These are all based on fragments of large fronds. The Polypodiaceae is particularly well represented as nine species in the flora are attributed to that family, including the genera *Polystichum* and *Pteris.* The royal fern family (Osmundaceae) is represented by the remains of the delicate frond of *Osmunda* (Fig. 2C). The gleichenia family (Gleicheniaceae) and the climbing fern family (Schizaeaceae) are represented by two species each. An example of a schizaeaceous fern in the flora is *Anemia* (Fig. 2B).

Nine species of conifers occur in the Vermejo Formation, including two that are based on petrified wood and seven based on leafy shoots. The genus *Sequoia* is represented by one species (Fig. 2D) which may be the ancestor of the living *Sequoia.* Other conifers in the Vermejo, include one or more species of the dawn redwood *Metasequoia,* cypress *(Taxodium),* fir *(Abietites), Widdringtonia*, and *Araucarites* (Fig. 2E), a possible ancestor of the living "monkey-puzzle" tree of the Southern Hemisphere. Two species based on petrified wood were described from the formation and assigned to the genus *Cupressinoxylon.*

The Vermejo flora is dominated, as might be expected, by angiosperms or flowering plants (73 species) with dicotyledons being the most abundant. Nearly all of the fossils may be referred to living dicotyledonous families. According to Knowlton (1917), the willow family (Salicales) is especially well represented as the flora contains five species of willow *(Salix,* Fig. 2A) and a doubtful species of cottonwood *(Populus).* One of the most common leaves in the flora is fig *(Ficus,* Fig. 2G). Knowlton (1917) reports that "there is hardly a collection without one or more species being present and some have as many as half a dozen." Although Knowlton reported that the Vermejo flora contains nearly 20 species of *Ficus* it is probable that some of them represent the same species as many are fairly similar. The breadfruit family (Artocarpaceae) is represented by one species of *Artocarpus* and the beech family (Fagales) is represented by two genera of extinct oak-like leaves, *Dryophyllum* (Fig. 2F) and *Quercophyllum.* Several species of the bittersweet *(Celastrus)* and of *Viburnum* (Fig. 21), a member of the Honeysuckle family were also described from the Vermejo by Knowlton (1917). Other families represented in the flora by one or more species include walnut (Juglandaceae), laurel (Lauraceae), magnolia (Magnoliaceae), sycamore (Platanaceae), grape (Vitaceae), bean (Papilionaceae), and olive (Oleaceae).

There are only a few monocotyledons known in the Vermejo flora. They include a single doubtful species of the

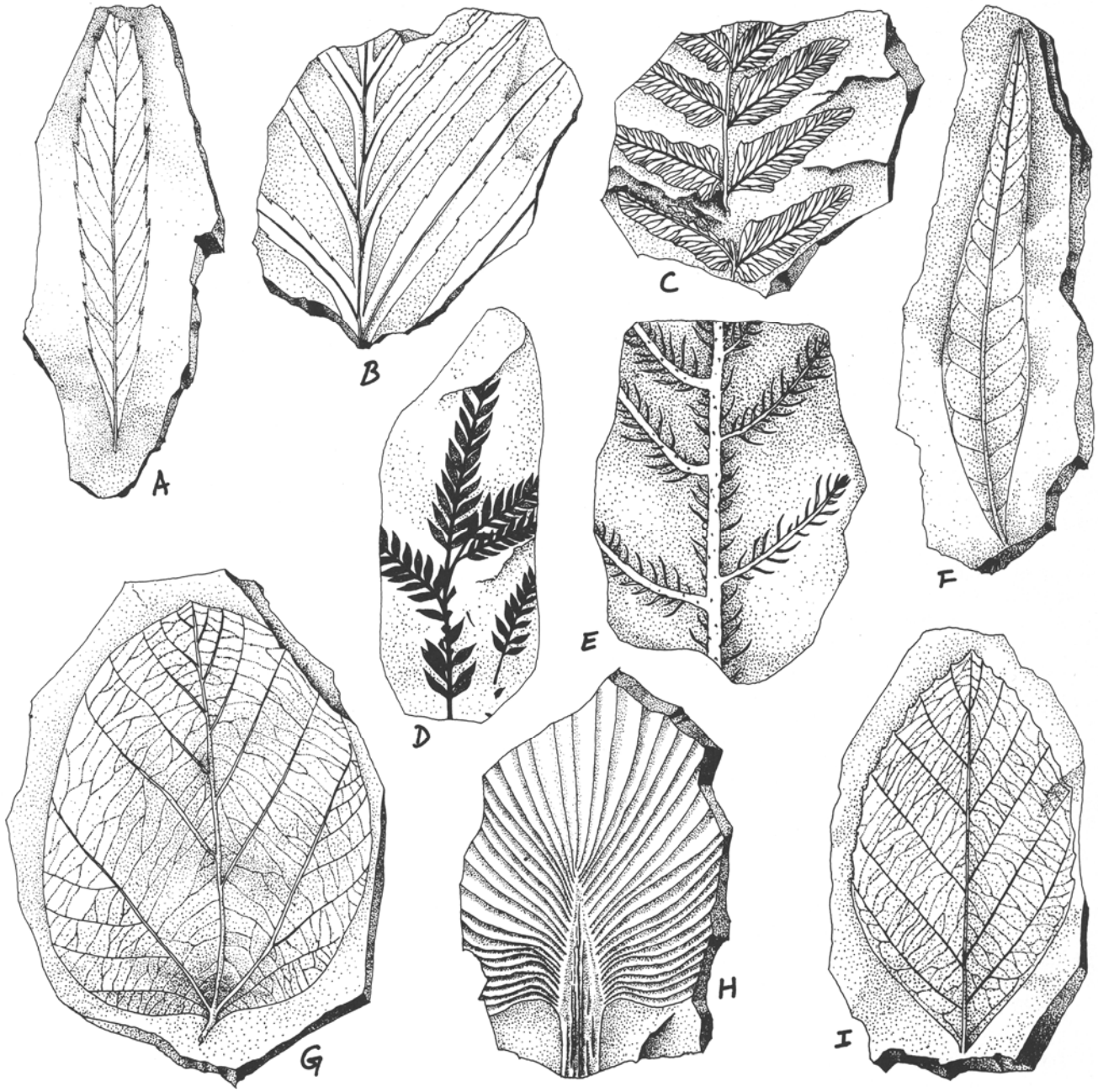


Figure 2. Fossil plants of the Vermejo Formation of Late Cretaceous age in the Raton basin, New Mexico and Colorado. A, Salix. *B,* Anemia. *C,* Osmunda. *D,* Sequoia. *E,* Araucaria. *F,* Dryophyllum, *G,* Ficus. *H,* Sabalites. *I,* Viburnum. *H, X½, all others X I.*

bur-reed *Sparganium,* two species of the palm *Sabalites* (Fig. 2H), and two species that may belong to *Canna,* a distant relative of the banana. Possibly there were additional monocotyledons, but because they generally had soft, delicate leaves, their remains were not preserved.

From the biologic aspects of the Vermejo flora, some tentative ecologic conclusions under which this flora existed may be drawn with a fair degree of probability. Evidence from the ferns is not very impressive and somewhat conflicting. *Osmunda* and *Anemia* are swamp-living forms but *Pteris* usually grows in drier situations. *Polystichum* is not out of place in either swampy or drier habitats.

The conifers, however, afford more definite and valuable criteria. The species of *Sequoia,* as already indicated, may be the predecessor of the living form of this genus. *Sequoia sempervirens,* the California redwood, is confined to the coast range of California and the extreme southwestern corner of Oregon, and ranges from near sea level to approximately 2,500 ft elevation, mainly on the seaward side of the mountains within the fog belt. Here it is subjected to frequent and heavy sea fogs and to typically moist soil and air. The wood *Cupressinoxylon,* also gives some data regarding climatic conditions. One of the species described from the Vermejo flora by Knowlton (1917) is entirely without growth rings, and the other has a slight ring in which only three or four rows of cells are slightly thickened. Generally, it appears that the conifers indicate an absence of marked seasonal changes and the presence of moist, relatively warm, climatic conditions. This



Figure 3. Reconstruction of the Raton basin during the time the Vermejo Formation was being deposited.

interpretation seems to be confirmed by single species of dicotyledonous wood in the formation which was so poorly preserved that it could not be figured or described, but which shows only a slight trace of growth rings.

The monocotyledons indicate marshy or swamp conditions as also suggested by the ferns. Most convincing are the various species of the palm *Sabalites.* At present palms are usually tropical or subtropical in distribution.

The many broad-leaved dicotyledons with numerous drip-points are consistent with a warm, moist climate. Genera that suggest this include *Dryophyllum*, *Ficus*, *Salix* and *Viburnum.*

According to Knowlton (1917), the sea was present in the region, probably as a broad shallow bay or arm when the Trinidad and Vermejo formations were being deposited. The few plant fossils found in the Trinidad Sandstone indicate that the adjacent land areas near the sea were forested, but little is known about the forest, except that it included cottonwood and a few other plants. As time passed, the sea moved eastward, and a series of low-lying swamps and marshes formed (Fig. 3). In the pools and slow moving streams, bur-reeds grew and several types of ferns, figs and palms lived along the swampy shore lines. In or near the dense swamps were several types of conifers such as *Cupressinoxylon*, *Widdringtonia* and many species of fig, with a few breadfruit trees. On the uplands, were sequoias, oaks, walnuts, laurels, ivies and grapes. From the large number of plant types and their characters, it may be presumed that there was an abundance of moisture. The absence of marked growth rings in the wood that has been studied suggests that there was no sharp differentiation of seasons, and based upon appearance of the whole flora the climate was probably warm temperate or perhaps subtropical (Knowlton, 1917). Clarke's (1965) study of the palynomorphs in the Vermejo Formation supports this concept of a warm temperate to subtropical climate. He further suggests, because variation in the relative abundance and occurrence of species is minor, that the ecological conditions were similar during the deposition of each coal bed.

Raton Floras

The Raton Formation contains a lower flora and an upper flora. The lower flora occurs in the basal relatively barren part of the formation and is of Late Cretaceous age. The upper flora occurs in the overlying productive part of the formation mainly in association with coal and is of Paleocene age.

The lower flora is small and includes only *Palmocarpon* (a possible palm fruit), the palm leaf *Sabalites*, and the problematical plant fossil *Palaeoaster* (Fig. 4E). *Palaeoaster* consists of a whorl of 8-12 erect, linear-lanceolate "leaves" and looks something like a flower or an open seed-bearing capsule. The systematic relationships and even the function of *Palaeoaster* are unknown. Nevertheless, *Palaeoaster* appears to be important as it is known only from Cretaceous rocks (Brown, 1943, 1962). *Palmocarpon* and *Sabalites* occur also in Paleocene rocks.

The upper flora (Paleocene) is fairly large as it includes about 50 species (Brown, 1962). No gymnosperms have been reported in the flora which consists principally of angiosperms. It contains five ferns or fern-allies including *Allantodiopsis* (Fig. 4B), *Blechnum* and the wood fern *Dryopteris* (Fig. 4A) and the remains of the quillwort *Isoetites.* Among the 38

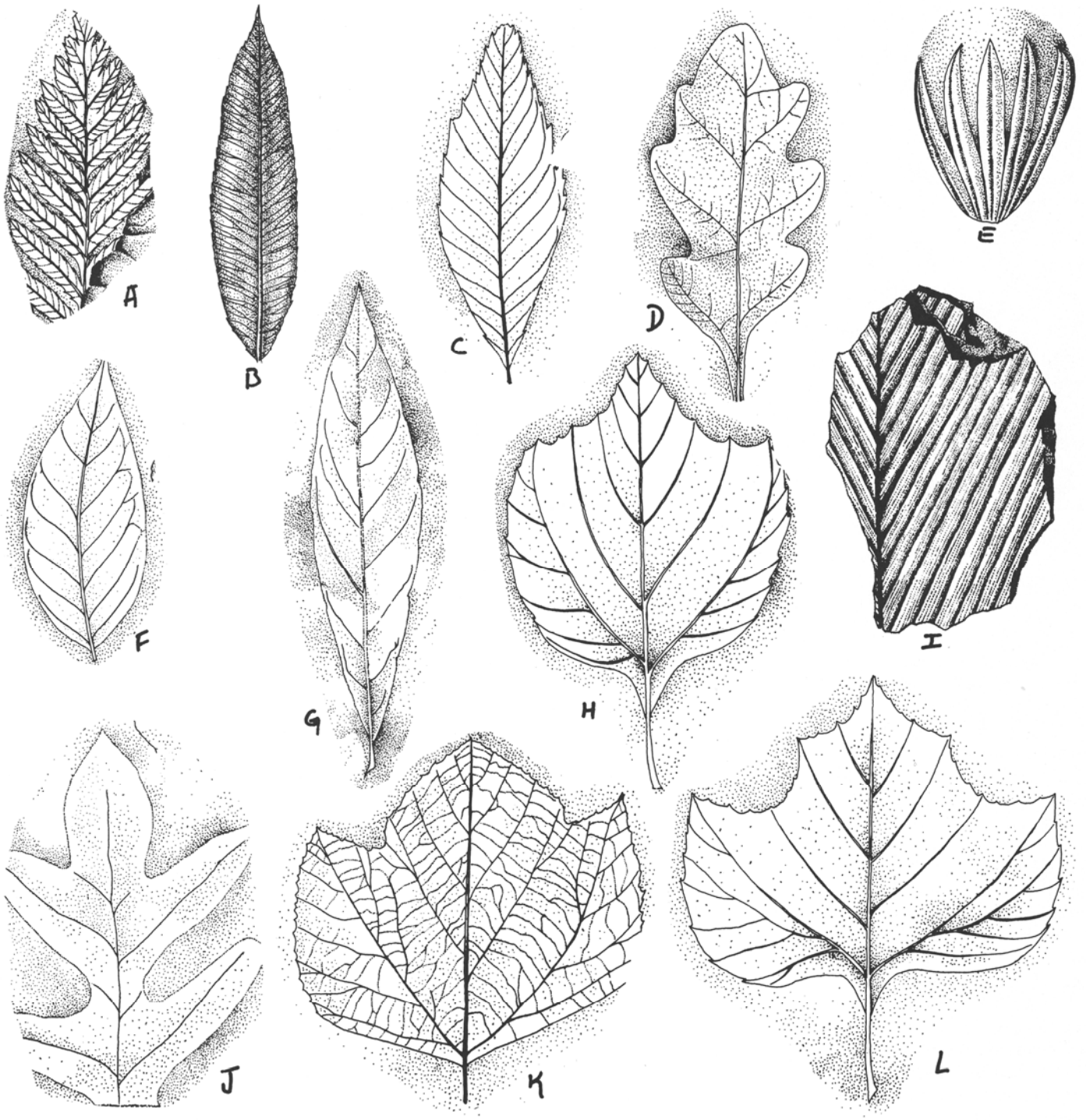


Figure 4. Fossil plants of the Raton Formation of Late Cretaceous and Paleocene age in Raton basin, New Mexico and Colorado. A, Dryopteris. *B,* Allantiopsis. *C,* Carya. *D,* Quercus. *E,* Palaeoaster. *F,* Magnolia. *G,* Laurophyllum. *H, L,* Platanus. *I,* Chamaedora. *J.* Artocarpus. *K,* Cissus. *All X I.*

dicotyledonous species in the flora, there is the waterlily *(Nymphaea)* and the sour gum *(Nyssa).* Also, there are several representatives of the walnut family including *Juglans* and *Carya* (Fig. 4C). The oaks are represented by *Quercus* and *Dryophyllum.* The cottonwood *(Populus)* and sycamore *(Platanus)* are common. Tropical forms in the flora include fig *(Ficus), Magnolia* (Fig. 4F), *Laurophyllum* (Fig. 4G), and breadfruit *(Artocarpus,* Fig. 4J and *Cissus,* Fig. 4K).

Although only six species of monocotyledons have been recognized in the Paleocene portion of the Raton flora their remains are quite common. This is especially true of the palms as palm leaves occur at 40 to 50 localities throughout the basin (Knowlton, 1917). The palms include three species of the palmetto-like *Sabalites* and one species of *Chamaedorea* (Fig. 41). Knowlton (1917) estimated that the palm leaves ranged up to 3 m in diameter. Other monocotyledons in the flora are

some unidentified grass-like plants and the water-plantain *Alismephyllites.*

The Raton floras grew in and around a series of swamps and marshes that existed along the margin of the sea. Waterlilies grew in the shallow open waters and several ferns and the sour gum lived in the marshes along the open water together with the quillwort *Isoetites.* Palms, figs, magnolias, breadfruit and other similar plants grew near the marshes. On the higher ground in nearby areas lived the oaks, walnuts and similar plants.

Knowlton (1917) concluded that the climate was relatively moist and warm in the Raton basin during Paleocene time. This conclusion was based on the following evidence: (1) presence and abundance of coal beds in the upper part of the Raton Formation; (2) character and luxuriance of the vegetation; (3) relatives of the plants in the Raton flora now live in a warm temperate climate. Warm temperate and humid tropical plants in the Raton flora include fig, breadfruit, magnolia, laurels and the palms. Knowlton suggested that the temperature did not fall below 42°F and that the climate may have been similar to that of South Carolina and Georgia.

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REFERENCES

Abert, J. W., 1848, Report of Lieut. J. W. Abert, of his examination of New Mexico in the years 1846-47: U.S. 30th Cong., 1st sess., Senate Ex. Dox. 23.; p. 3-130; House Ex., Doc. 41; p. 417-546.

Baltz, E. H., 1965, Stratigraphy and history of Raton basin and notes on San Luis basin, Colorado-New Mexico: Amer. Assoc. Petroleum Geologists Bull., v. 49, p. 2041-2075.

Brown, R. W., 1943, Cretaceous-Tertiary boundary in the Denver Basin, Colorado: Geol. Soc. America Bull., v. 54, p. 65-86.

---- 1962, Paleocene flora of the Rocky Mountains and Great Plains: U.S. Geol. Survey Prof. Paper 375, 119 p.

Clarke, R. T., 1965, Fungal spores from Vermejo Formation coal beds, Upper Cretaceous of central Colorado: The Mountain Geologist, v. 2, p. 85-93.

—---- 1966, Palynology of the Vermejo Formation coal of Upper Cretaceous age of central Colorado (abs.): Geol. Soc. America Spec. Paper 87, p. 281.

Dorf, E., 1938, Upper Cretaceous floras of the Rocky Mountain region; I, Stratigraphy and paleontology of the Fox Hills and lower Medicine Bow formations of southern Wyoming and northwestern Colorado: Carnegie Inst. Wash. Publ. 580, p. 1-78.

—---- 1942, Upper Cretaceous floras of the Rocky Mountain region; II, Flora of the Lance Formation at its type locality, Niobrara County, Wyoming: Carnegie Inst. Wash. Publ. 580, p. 79-159.

Hantzschel, W., 1975, Trace fossils and problematica, *in* Treatise on invertebrate paleontology, Part W, supplement 1: Geol. Soc. America, p. W1-W269.

Hitchcock, E., 1853, Outline of the geology of the globe and of the United States in particular: Boston, Phillips, Sampson and Co., 136 P.

Hollick, A., 1902, Fossil ferns from the Laramie Group of Colorado: Torreya, v. 2, p. 145-148.

Johnson, R. B., and Wood, G. F1., Jr., 1956, Upper Cretaceous and Tertiary of Raton basin: Amer. Assoc. Petroleum Geologists Bull., v. 40, p. 707-721.

Knowlton, F. H., 1917, Fossil floras of the Vermejo and Raton formations of Colorado and New Mexico: U.S. Geol. Survey Prof. Paper 101, p. 223-435.

Le Conte, J. L., 1868, Notes on the geology of the survey for the extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas to the Rio Grande: Philadelphia, 76 p.

Lee, W. T., 1917, Geology of the Raton Mesa and other regions in Colorado and New Mexico: U.S. Geol. Survey Prof. Paper 101, p. 9-221.

Lesquereux, L., 1868, Notes on the fossil plants of the lignite beds of the West: Amer. Jour. Sci., v. 45, p. 205-208.

—---- 1873, Lignitic formation and fossil flora: U.S. Geol. Survey Terr. Sixth Ann. Report for 1872, p. 317-427.

—---- 1878, Contributions to the fossil flora of the western Territories. Part 2. The Tertiary flora: U.S. Geol. Survey Terr. Report, v. 7, 366 p.

Newberry, J. 5., 1883, Brief descriptions of fossil plants, chiefly Tertiary, from western North America: U.S. Nat. Mus. Proc., v. 5, p. 502-514.

—---- 1898, The later extinct floras of North America: U.S. Geol. Survey Mon. 35, p. 1-295.

Read, R. W. and Hickey, L. J., 1972, A revised classification of fossil palm and palmlike leaves: Taxon, v. 21, p. 129-137.

Wanek, A. A., 1963, Geology and fuel resources of the southwestern part of the Raton coal field, Colfax County, New Mexico: U.S. Geol. Survey Coal Invest. Map C-45, 2 sheets.