Ferns From the Chinle Formation (Upper Triassic) in the Fort Wingate Area, New Mexico

GEOLOGICAL SURVEY PROFESSIONAL PAPER 613-D

Ferns From the Chinle Formation (Upper Triassic) in the Fort Wingate Area, New Mexico

By SIDNEY R. ASH

CONTRIBUTIONS TO PALEONTOLOGY

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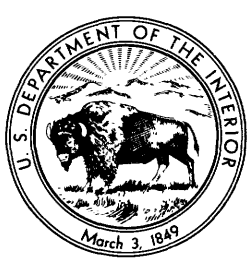
Revision of five Late Triassic ferns and a review of previous paleobotanical investigations in the Triassic formations of the Southwest



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CONTRIBUTIONS TO PALEONTOLOGY

FERNS FROM THE CHINLE FORMATION (UPPER TRIASSIC) IN THE FORT WINGATE AREA, NEW MEXICO

By SIDNEY R. ASH

ABSTRACT

Fossil plant remains apparently were first reported from the Upper Triassic rocks in the Southwest in 1850 by Lt. James H. Simpson, who had discovered petrified wood in them in eastern Arizona on September 5, 1849. Subsequently, similar petrified wood was found in the same stratigraphic unit at many places in the Southwest, particularly in northeastern Arizona. The unit containing the wood was named the Chinle Formation by Gregory in 1917 and was reported to contain Late Triassic vertebrates.

Although fossil wood is abundant in the Chinle, leaf remains are comparatively rare. A small, poorly preserved collection of leaves was described by John S. Newberry in 1876 from the lower part of what is now considered to be the Chinle Formation in Arroyo del Cobre, northern New Mexico. Only a few other leaves had been described before Lyman Daugherty published his report (1941) on some collections obtained mostly from the lower part of the Petrified Forest Member of the Chinle Formation in Petrified Forest National Park. His collections were larger and better preserved than any studied previously, and his comprehensive report is the principal reference on the Chinle flora.

Recently, some new collections were made from the lower part of the Chinle in the lower red member near Fort Wingate, N. Mex. and from some of Daugherty's old localities in the Petrified Forest. Detailed redescriptions, based on some of this new material and on the types described by Daugherty, are given of the fertile and sterile leaves of *Todites fragilis* Daugherty, *Cynepteris lasiophora* Ash, n. gen. and sp., *Wingatea plumosa* (Daugherty) Ash, and *Clathropteris walkeri* Daugherty. The sterile leaf of *Cladophlebis daughertyi* Ash, n. sp., is also redescribed in detail.

Reinvestigation shows that the known Chinle megaflora consists of 40 species referrable to 37 genera. It includes species based on leaves, fructifications, and petrified stem material. One species has been referred to the Fungi, two to the Equisetales, two to the Lycopodiales, 12 to the Filicales, and 18 to the Gymnospermae. Five new species of uncertain classification are also known. It had been thought that the Chinle flora correlated closely with the large flora from the Upper Triassic Newark Group of the Eastern United States and less closely with the rather poorly known Late Triassic megaflora of Sonora, Mexico. These conclusions seem to be erroneous, as they were based mostly on misidentifications, as detailed study of the specimens in question has shown. The only unit that unquestionably contains some of the same species is the Dockum Group in west Texas.

INTRODUCTION

The Chinle Formation of Late Triassic age, which is widely exposed in parts of the Southwestern United States, contains fossil leaves and fertile structures at several localities. Some of these fossils have been described previously, but recent work has shown that much remains to be learned about the flora. Not only have some undescribed species been found, but well-preserved specimens of certain previously described forms have been collected, making it possible through the application of specialized techniques to enlarge our knowledge of them greatly.

During the last few years some large collections of leaf fossils have been made from the Chinle Formation near Fort Wingate in the Zuni Mountains of western New Mexico (figs. 1, 2). Before this, the most significant collection had been made in Petrified Forest National Park in eastern Arizona (fig. 2) during the 1930's. That flora was studied by Lyman Daugherty, and his report (1941) is the most significant publication about the Chinle flora.

This is the second in a series of reports which describe in detail members of the Chinle flora. A new female bennettitalean fructification was described in the first report (Ash, 1968). The present study is divided into two parts. The first part is a historical account of the paleobotanical investigations in the Triassic formations of the Southwest. The second part contains stratigraphic data on the new localities at Fort Wingate, a discussion of the Chinle flora and its correlations, and detailed redescriptions of the leaves of five ferns based primarily on new material collected in the Fort Wingate area. These species previously were known only from Arizona.

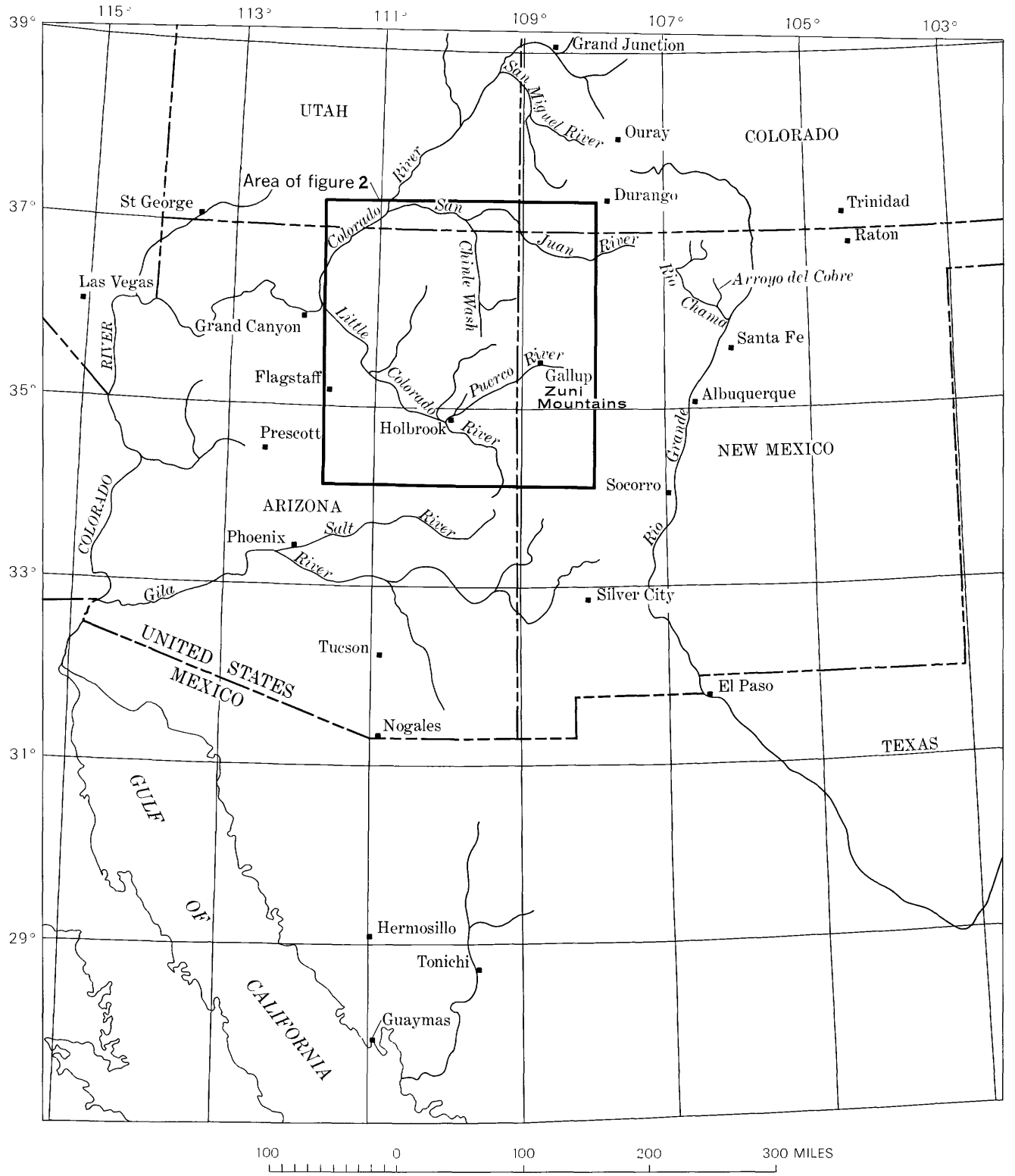

FIGURE 1.—Part of the Southwestern United States and adjacent areas in Mexico.

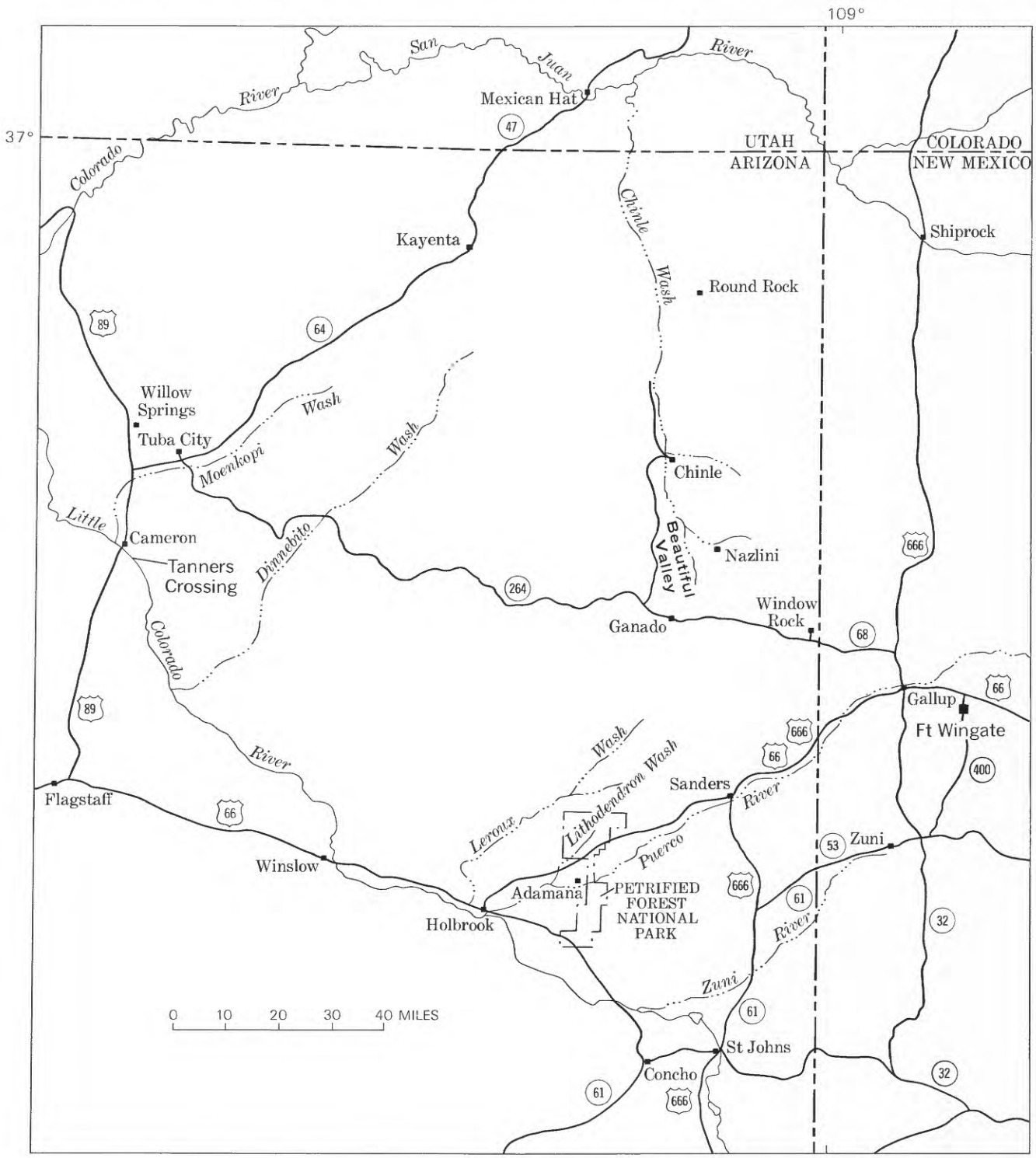

FIGURE 2.—Northeastern Arizona and adjacent areas.

ACKNOWLEDGMENT

My appreciation is extended to Charles B. Read of the U.S. Geological Survey, Albuquerque, N. Mex., who originally pointed out the possibilities of an investigation of the Chinle flora. He also directed me to several areas where well-preserved fossil leaf remains were present and was helpful in various ways during the early stages of the project. His continuing interest and encouragement are acknowledged with pleasure.

I am also grateful to Prof. Thomas M. Harris, FRS, Department of Botany, The University, Reading, England, for his advice and friendly counsel during the preparation of this report. The constructive criticism of K. H. Alvin, Botany Department, Imperial College of Science and Technology, London, Peter D. W. Barnard, Department of Botany, The University, Reading, England, and Donald Eggert, Department of Botany, University of Iowa, are appreciated. I am indebted to the authorities of The University, Reading, England, and of Midland Lutheran College, Fremont, Nebr., for furnishing me with laboratory facilities in which I could work on my material. The specimens described by Lyman Daugherty that were examined in connection with this report were borrowed from the University of California Museum of Paleontology through the courtesy of Dr. Wayne L. Fry. A research grant from the Geological Society of America helped finance some of the fieldwork.

PREVIOUS INVESTIGATIONS

Triassic petrified wood was used by American Indians in what is now the Southwestern United States. The Indians made arrowheads and other implements out of the petrified wood, and some used large blocks as building stones in their houses in the Petrified Forest National Park in northeastern Arizona (fig. 3). The Piutes of Utah, who believed the petrified logs to be the shafts of their thunder god, Shinauav (Powell, 1876, p. 69), may have recognized that the material they were using resembled wood. Apparently, the Navajo did not, for they have a tradition that the petrified logs in the area are the bones of Yietso, the Great Giant or Monster, whom their forefathers killed when they occupied the country (Swaine and Hegewald, 1882, p. 1–2). They call the logs "yietsobitsin" (bones of Yietso), according to Reagan (1925, p. 239).

Although the Spanish lived in parts of the Southwest for several hundred years before it was acquired by the United States, there is no record that they particularly noticed Triassic petrified wood.

FIGURE 3.—Small pueblo made of sections of petrified logs in Petrified Forest National Park, Ariz. The pueblo, now called "Agate House," was built and occupied by American Indians about 600 years ago. Recently, it was partially restored.

U.S. ARMY EXPLORING EXPEDITIONS

The occurrence of Triassic plant remains in the Southwestern United States was announced first by members of some of the U.S. Army expeditions sent out by the American Government to explore that region after it was acquired from Mexico. One or more scientifically trained men often accompanied the expeditions, and collections generally were made of fossils, minerals, rocks, plants, animals, and Indian artifacts discovered en route. Nearly all the early scientific work accomplished in the Southwest was done in conjunction with these expeditions. The resulting reports not only make fascinating reading but also contain significant contributions to the geology, zoology, botany, archeology, and geography of the areas explored. Undoubtedly, they also contributed to the successful occupation and early development of the Southwest. The work of many of these expeditions has been discussed in detail by Goetzmann (1957, 1966).

WASHINGTON EXPEDITION

Fossil plant remains apparently were first reported from the Upper Triassic rocks in the Southwest by Lt. James H. Simpson in 1850. He had discovered a petrified log on September 5, 1849, while accompanying the Army expedition led by Lt. Col. John M. Washington from Santa Fe, N. Mex., into east-central Arizona. The log that Simpson found protruded from a bed of conglomerate exposed in the walls of one of the deep canyons east of the present settlement of Chinle, Ariz. Probably the fossil was in the Shinarump Member of the Chinle, as this unit is the only thick bed of conglomerate known to be exposed in that area and to contain petrified wood.

SITGREAVES EXPEDITION

The second description of the occurrence of fossil plants in the Triassic rocks of the Southwest was given in the report of the U.S. Army expedition that explored parts of New Mexico and Arizona in 1851 under the command of Capt. Lorenzo Sitgreaves. Members of the expedition observed petrified wood a few miles south of the area now called the Petrified Forest National Park of Arizona on September 28, 1851. Sitgreaves (1854, p. 7) described the scene as follows: "The ground was strewed with pebbles of agate, jasper, and chalcedony, and masses of what appeared to have been stumps of trees petrified into jasper, beautifully striped with bright shades of red (the predominating color), blue, white and yellow."

Dr. S. W. Woodhouse, M.D., the physician and naturalist on the Sitgreaves expedition, was the first scientifically trained person to see Triassic plant fossils in the Southwest and to publish a description of the occurrence. He said (Woodhouse, 1854, p. 36) that, "After leaving Camp No. 5 some distance, we passed the remains of a large petrified tree, the wood of which was agatized. It was broken in pieces, as if by a fall, and its root was uphill. It must have been upwards of three feet in diameter."

WHIPPLE EXPEDITION

During 1853 and 1854 the U.S. Army expedition commanded by Lt. Amiel W. Whipple explored a proposed railway route along the 35th parallel of north latitude through the Southwestern United States. On December 2, 1853, members of the expedition discovered large quantities of petrified wood in the same general area in northeastern Arizona where the Sitgreaves expedition had found it. Lieutenant Whipple (1855, p. 74) described the occurrence in the following words:

> Quite a forest of petrified trees was discovered to-day, prostrate and partly buried in deposits of red marl. They are converted into beautiful specimens of variegated jasper. One trunk was measured ten feet in diameter, and more than one hundred feet in length. Some of the stumps appear as if they had been charred by fire before being converted to stone. The main portions of the trees have a dark brown color; the smaller branches are of a reddish hue. Fragments are strewn over the surface for miles.

A dry wash draining that particular area was named, rather appropriately, Lithodendron Creek,[1] by Lt. Whipple. The sketch of a scene in Lithodendron Creek in his report is reproduced here (fig. 4) because it is the first published illustration of Triassic plant fossils from what is now the Southwestern United States.

Jules Marcou, a French-Swiss geologist, was the expedition's geologist and mining engineer. He described the occurrence of petrified wood in Lithodendron Wash in a résumé (Marcou, 1855a, p. 43; 1855b, p. 871; 1858, p. 13). As he was the first professional geologist to observe this unusual sight, it is pertinent to repeat his description here:

> On the western declivity of the Sierra Madre [Zuni Mountains], between Zuni and the Rio Colorado Chiquito, there is really a petrified forest of trees thirty and forty feet long, divided into fragments from six to ten feet in length, with a diameter of three or four feet, some being still upright enclosed in the sandstone. These trees and remains of petrified wood belong nearly all to the family of the conifers, and some to that of the ferns with arborescent stems, and to the *calamodendron*.

[1] Now generally called Lithodendron Wash.

FIGURE 4.—Sketch of a scene near Lithodendron Creek, or Lithodendron Wash, Ariz., in 1853. This is the first illustration of Triassic plant remains from what is now the Southwestern United States to be published. It was probably sketched by the Whipple Expedition's topographer and artist, Balduin Möllhausen. (From Whipple, 1855, p. 74.)

Elsewhere in the résumé Marcou correlated the entire sequence of rocks between the Cretaceous and Carboniferous formations in the Southwestern United States, including the petrified wood-bearing unit, with the Trias of Europe. He said the rocks containing petrified wood in the Lithodendron Wash area were equivalent to the Keuper of Germany. These correlations apparently were based on similar lithology and stratigraphic position, as Marcou had not found any diagnostic fossils in the sequence.

Marcou returned to Europe because of poor health and was unable to prepare a final report for Lieutenant Whipple. His notes and collections were turned over to William P. Blake, the geologist in the office of the U.S. Pacific Railroad Explorations and Surveys, who used them to compile a lengthy report on the geology of the area explored by the Whipple expedition. Marcou's field notes were included in the report in the original French together with a translation by Blake (Marcou, 1856). In his own part of the report, Blake gave a more detailed discussion of the petrified wood than Marcou had done in his résumé. He also studied several specimens of petrified wood in the collection from Lithodendron Wash in polished section and noted (Blake, 1856, p. 34) that "the rings of annual growth, the medullary rays, and the cells, are distinctly and beautifully preserved, and can be clearly seen by the naked eye." Some thin sections were made of the wood and given to Prof. George C. Schaffer, an American paleontologist, to study and describe. Unfortunately, however, Professor Schaffer never published his findings, and nothing is known of the whereabouts of the sections.

Blake believed that the age of the rocks containing petrified wood in Lithodendron Wash had not been established conclusively by Marcou. Furthermore, because of the lack of diagnostic fossils, he questioned Marcou's correlation of all the formations between the Cretaceous and Carboniferous rocks in the Southwest with the Triassic of Europe. He stated (Blake, 1856, p. 78), "They may be in part Cretaceous, as they most probably are—in part Carboniferous, or may possibly contain representatives of all the Secondary group below the Cretaceous."

Balduin Möllhausen, the expedition's topographer and artist, described his experiences in a book (1858a, b). In it he gave a description and a sketch of the scene in Lithodendron Wash. The book also contained a report by H. R. Geoppert, the German paleobotanist, on several specimens of petrified wood obtained by Möllhausen from Lithodendron Wash. In a note at the back of the book, Goeppert (in Möllhausen 1858a, p. 492; 1858b, p. 831) discussed the specimens in the following words:

* * * the six specimens forwarded to me by Mr. Möllhausen all belong to the coniferous species, and indeed to the *Abietinae;* and, like those of the coal formations, show no concentric circles in the wood, or at most only very faint and indistinct traces of them. A specimen which I examined with particular attention seemed to belong to the Araucaria type, and after having been considered with reference to the already described species, was named in honor of its discoverer *Araucarites Möllhausianus.*

Although Goeppert was the first paleontologist to make a microscopic study of Triassic petrified wood from the Southwestern United States and to publish his findings, he neglected to describe the species, so *A. möllhausianus* is a nomen nudum.

IVES EXPEDITION

On May 7, 1858, members of a U.S. Army expedition, under the command of Lt. Joseph C. Ives, while exploring in Arizona, discovered a large deposit of petrified wood about 60 miles northwest of Lithodendron Wash and several miles south of the Hopi Indian villages.[2] The fossil wood was in the unit Marcou had correlated with the Keuper of Europe. Dr. J. S. Newberry, the expedition's physician, reported (1861, p. 79) that it apparently was coniferous.

Newberry (1861, p. 96–97) later observed petrified wood in the same stratigraphic unit elsewhere in Arizona and in western New Mexico. Those specimens examined by him appeared to be waterworn, and he

[2] Fossil leaves were discovered a few days later, on May 10, 1858, in a 12-foot bed of lignite just below the Cretaceous sandstone that caps the mesas near the Hopi villages. Newberry indicated (1861, p. 83) that he thought they were possibly of Jurassic age. Knowlton (1919, p. 699) classified this collection as Triassic? in his "Catalogue of the Mesozoic and Cenozoic plants of North America." However, the plant-bearing bed was included in the Dakota Sandstone of Late Cretaceous age by H. E. Gregory (1917, p. 51). Thus, Newberry's collection is beyond the scope of this report, and it is not further considered here.

concluded that "all had been *transported*, but not far from their place of growth" (Newberry, 1861, p. 80). He also considered Marcou's correlation of the petrified-wood-bearing unit with the Keuper to be questionable. Newberry did not hazard an age determination and simply indicated that the petrified-wood-bearing rocks lay between limestone of Carboniferous age and sandstone of Cretaceous age. He did suggest, however, (Newberry, 1861, p. 75) that the lower part of the rocks in this interval could be of Permian just as well as of Triassic age.

MACOMB EXPEDITION

Fossil leaves of Triassic age were first discovered in the Southwestern United States in 1859. This significant discovery was made by Dr. J. S. Newberry while he was serving as a geologist with the U.S. Army expedition commanded by Capt. J. N. Macomb which was exploring northwestern New Mexico and adjacent areas in the Southwest. Unfortunately the publication of Newberry's report on the geology of the area explored by the Macomb expedition and his description of the fossil leaves was delayed by the American Civil War and was not printed until 1876.

The leaves were found associated with a sandstone copper deposit which had been mined in the small canyon called Arroyo del Cobre, a few miles northwest of Abiquiu, N. Mex. (fig. 1). Newberry described the abandoned copper mine to be high on the south wall of Arroyo del Cobre in the lower part of a bed of coarse-grained yellow sandstone about 150 feet thick. He said that the mine workings were extensive and consisted of galleries, some of which were timbered and others walled off with neatly laid masonry. The ore occurred as isolated concretions and masses in the sandstone and also replaced or was concentrated around twigs, wood, and carbonaceous trash in the unit. Recognizable fossil leaves were found only in the roof shale, and, according to Newberry (1876, p. 69), it contained "thousands of impressions of plants * * * [and] abundant specimens were procured." However, he described only two species, *Otozamites macombii* n. sp. and *Zamites occidentalis* n. sp., and illustrated two others, *Brachyphyllum* sp. and *Pachyphyllum*? sp., from this locality. Newberry concluded that the flora was of Triassic age because *O. macombii* occurred also at a locality near Tónichi, Sonora, Mexico (fig. 1), in association with several other species of plant fossils that were found in rocks of Triassic age in North Carolina, Virgina, and Europe. The only mines in Arroyo del Cobre that fit his description are those called Minas de Pedro on the recent U.S. Geological Survey topographic map of the area. (See fig. 5.)

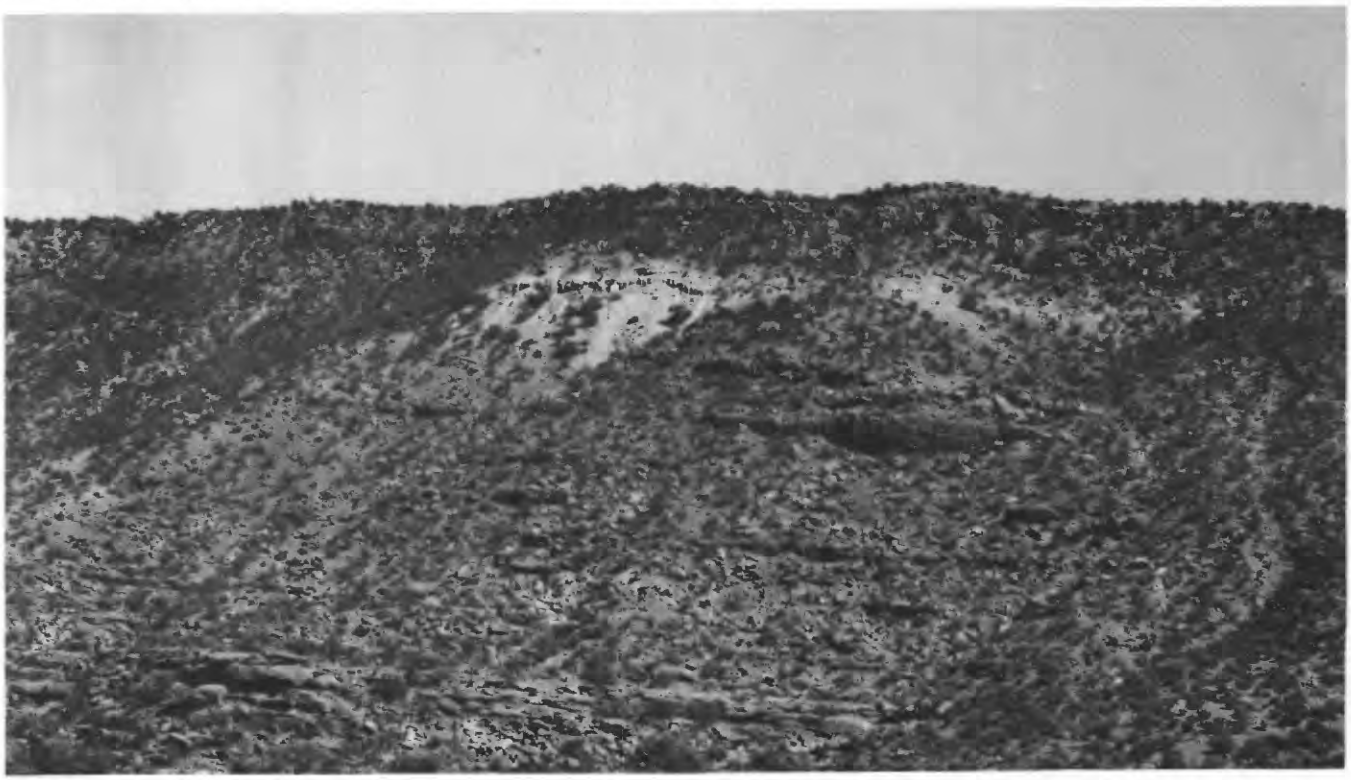

FIGURE 5.—Southeast wall of Arroyo del Cobre, N. Mex. Minas de Pedro copper mines are near the top of the picture in the ledge of light-colored sandstone which is about 400 feet above the floor of the canyon. Numerous fossilized leaves occur in the roof-shales of these mines, and John S. Newberry probably collected fossils from them in 1859.

In the Macomb report, Newberry (1876) also included descriptions and illustrations of several leaves obtained from Triassic rocks near Tónichi, Sonora, Mexico. Two species from the Chinle have been compared with specimens described by Newberry from the Mexican locality. The comparisons are in error, but when both floras are better known, common species may be recognized. This large and potentially important flora has not been adequately or completely studied. Recently Silva Pineda (1961) described a few species from the Tónichi area, and a complete bibliography of the flora is included in her report.

INVESTIGATIONS BETWEEN 1876 AND 1917

HEGEWALD EXPEDITION

In 1878, the General of the Army, Gen. William T. Sherman, instructed Lt. Col. P. T. Swaine, the Commanding Officer of Fort Wingate, N. Mex., to procure two moderate-sized petrified logs from that region for display in the Smithsonian Institution in Washington, D.C. Accordingly, 2d Lt. J. F. C. Hegewald,[3] who was stationed at Fort Wingate, was detailed to carry out General Sherman's request, and during May 1879 a small detachment of men under his command journeyed to Lithodendron Wash. There, two long segments of the same large dark-colored log were collected and then transported to Fort Wingate. A light-colored log, obtained about 2 miles north of the fort (fig. 6), was substituted for one of the dark-colored specimens, according to Swaine and Hegewald (1882, p. 3), and only this log and one of the two long segments obtained in Lithodendron Wash were shipped to Washington in September 1879 (Ward, 1889, p. 917). Nevertheless, Knowlton (1889, p. 2) reported that there was one long light-colored log and two shorter dark-colored logs in the collections of the Smithsonian. According to Dr. Francis M. Hueber, Curator of Paleobotany, Smithsonian Institution (written commun., 1966), one long specimen of light-colored wood from Fort Wingate is in storage at the museum, and two shorter dark-colored

[3] The first published report (Swaine and Hegewald, 1882) concerning this incident indicated that Lieutenant Hegewald's initials were J. T. C., and all subsequent publications have continued the practice. Hegewald's initials actually were J. F. C. (U.S. Military Academy, 1920).

FIGURE 6.—Northward view at Fort Wingate, western New Mexico. Old Fort Wingate is in right foreground. One of the large petrified logs now in the Smithsonian Institution was collected in 1879 from the low mesa shown near the right of the picture. Petrified wood is still abundant on the mesa top. The mesa is underlain by the Sonsela Sandstone Bed, which divides the Petrified Forest Member of the Chinle Formation into two parts in this area.

logs from "Lithodendron Valley" are on exhibit in the National Museum's Hall of Fossil Plants and Animals. Apparently the single segment from Lithodendron Wash was broken after it was shipped from Fort Wingate.

GEORGE F. KUNZ

George F. Kunz apparently was the first person to report the occurrence of large deposits of highly colored petrified wood about 20 miles south of Lithodendron Wash in northeastern Arizona. The area containing these deposits has often been called Chalcedony Park and was first described in a paper that Kunz presented to the New York Academy of Sciences on October 5, 1885. Kunz illustrated his presentation with specimens and thin sections of wood from the new locality. The paper was subsequently published (Kunz, 1885, 1886).

Kunz noted that none of the silicified wood found elsewhere in the world is as beautifully colored as that in Chalcedony Park. He described (Kunz, 1885, p. 11) the wood as follows:

> Here we have every imaginable shade of red, yellow, brown, and green. Sometimes the colors appear in distinct spots, forming a mottled appearance, then again all blend so imperceptibly as to make a much more pleasing and harmonious effect than the decided banding of the agate, where the lines of demarcation between the colors are so distinct as to become obstrusive. The colors above mentioned are often relieved by white, black and gray and by transparent spaces of brilliant quartz crystals, or—as sometimes occurs—of amethyst.
>
> Broken sections of the hollow trunks are often lined with amethyst, quartz, and calcite, which add to their brilliancy to the endless variety of color.

Kunz stated that the red color in the wood was caused by hematite, the yellows and brown by limonite, and the black by manganese. He also stated that a contributing factor to the unusual appearance of the wood was fungi which had attacked the trees before they were fossilized.

Kunz reported that Chalcedony Park covered 1,000 acres and contained about 1 million tons of silicified wood. According to him, all the trees were prostrate and indiscriminately scattered throughout the area. Some projected from the hillsides, whereas others were completely exposed as a result of erosion of the overlying rocks. The trees were broken in fragments and sections of various sizes. He mentioned that one tree was more than 200 feet long and 8 feet in diameter. Another was described as being more than 100 feet long and 3–4 feet in diameter; both ends of the log were still imbedded in rock, so its entire length was unknown. This particular log was especially unusual, for it bridged a canyon about 55 feet wide. He referred to the log as "Agate" or "Natural Bridge," and illustrated it with a woodcut in his 1886 article. Agate Bridge is still in place, although it has been reinforced to prevent it from falling apart.

According to Kunz, volcanic action overthrew the trees in what is now eastern Arizona, and they were covered with volcanic ashes and tufa. Then hot water associated with the volcanic action and, charged with silica and other minerals, percolated through the deposit. The water infiltrated the trees, and the minerals in solution in the water slowly replaced the organic material in the wood. Apparently, some of the wood was partially decayed before it was mineralized, for Kunz reported finding traces of fungal mycelium in some specimens and that other specimens had the general features of wood that had rotted before fossilization. He thought that frost action was responsible for the fracturing of the petrified wood.

Kunz noted that Dr. P. H. Dudley of New York City had examined specimens of the wood with a microscope and reported that some belonged to the genus *Araucaria*. Others resembled the extant conifer *Juniperus virginianus*.

The commercial aspects of the deposit of petrified wood were also discussed by Kunz. He thought that there would be great demand for the petrified wood for use in inlay work, interior paneling, floor tiles, table tops, mosaics, jewelry, and other types of decoration because of its unusual color and hardness. He estimated, however, that only about 1,000 tons of the petrified wood in Chalcedony Park was suitable for this type of work. Foreigners were quite interested in the wood, and Kunz told of a Russian who paid $500 for a section of a log 28 inches in diameter and 30 inches long. The section apparently was to be cut into table tops. He also reported that a large quantity of wood had been shipped abroad for cutting.

Kunz (1890, p. 135–142) later described some of the occurrences of petrified wood in Arizona and elsewhere in the West. He discussed the deposit of petrified wood in Chalcedony Park in some detail and included several pictures of the area. Obviously, he had rejected his earlier theory on the petrification of the wood in Chalcedony Park, for he stated (Kunz, 1890, p. 137) that "there is every evidence to show that the trees grew beside some inland sea. After falling they became waterlogged, and during decomposition the cell structure of the wood was entirely replaced by silica from sandstone in the walls surrounding this great inland sea." He concluded the article with a discussion of the commercial uses of the petrified wood in Chalcedony Park.

FRANK KNOWLTON AND WILLIAM FONTAINE

Frank Knowlton of the U.S. National Museum studied the specimens of petrified wood obtained in the Southwest at the request of General Sherman. Knowlton (1889, p. 1–2) described them as *Araucarioxylon arizonicum* n. sp. He acknowledged (p. 3), however, that the name might be a synonym of *Araucarites möllhausianus* Goeppert, the name proposed for one of the specimens Möllhausen had collected from Lithodendron Wash in 1854. Knowlton could not verify his suspicion because *A. möllhausianus* is a nomen nudum so he proposed the new name.[4]

Knowlton described *Araucarioxylon arizonicum* as having obscure growth rings that are typically narrow. The bordered pits on the radial cell walls are generally uniseriate. Bordered pits also occur on the tangential cell walls, which is unusual in the genus *Araucarioxylon* (Knowlton, 1889, p. 4). The medullary rays are uniseriate and are high.

In the fall of 1887, Maj. John W. Powell, Director of the U.S. Geological Survey, collected fossil plant remains from a copper mine in Arroyo del Cobre, N. Mex. In 1889 Professor Knowlton visited the same area and obtained additional specimens. Most of those he collected came from the so-called old copper mines on the east side of Arroyo del Cobre. Knowlton (Fontaine and Knowlton, 1891) considered the mines to be those from which Newberry collected fossil material in 1859, but he admitted that they were possibly not the same. Knowlton's description of the old copper mines suggests to me that they are different and are those called Las Minas Jimmie on the U.S. Geological Survey topographic map of the area. (See fig. 7.)

Some fossils collected by Knowlton came from mines which he called the new copper mines, opened earlier in that year (1889) in the northwestern part of Arroyo del Cobre. According to Knowlton (Fontaine and Knowlton, 1891, p. 282), these mines were several hundred feet lower stratigraphically than the old copper mines. Paleontological studies (Vaughn, 1963) indicated that rocks of Early Permian age underlie the strata containing the old copper mines. This would suggest that the new copper mines are in rocks of Early Permian age. No copper mine is known to me in the northwestern part of the basin, so it was not possible

[4] In Knowlton's revision (1890, p. 617) of the genus *Araucarioxylon* Kraus, *Araucarites möllhausianus* was changed to *Araucarioxylon möllhausianum*.

FIGURE 7.—East wall of Arroyo del Cobre, N. Mex. The adits of the Las Minas Jimmie copper mines are in the ledge of light-colored sandstone near the center of the picture. They are about 100 feet above the floor of the canyon and are probably the old copper mines described by Prof. Frank Knowlton, from which he collected fossil leaves in 1889. He also collected fossilized wood from a bed of shale overlying the bed of sandstone.

for me to find Knowlton's locality in that area and determine for myself its stratigraphic location. The fossils collected by Knowlton from the new copper mines are not diagnostic, and I believe that the so-called new copper mines are in rocks of Early Permian, not Late Triassic, age. Additional work in Arroyo del Cobre may solve this problem.

The collections made in Arroyo del Cobre by Powell and Knowlton were the subject of a report by Fontaine and Knowlton (1891) in which Fontaine described and illustrated the specimens obtained from the new copper mines. The specimens proved to be the pith casts of the two species, *Equisetum abiquiense* and *E. knowltoni*. Fontaine also discussed briefly the leaf remains collected from the old copper mines and reported that they represented seven species, including *Zamites powelli* n. sp. This species was described in three short sentences and illustrated. Fontaine concluded (Fontaine and Knowlton, 1891, p. 283) that the fossils from these copper mines "indicate that the beds are not older than the Rhetic [sic]." Several fragments of wood collected from a shale bed a few feet above the bed bearing the fossil leaves at the old copper mines were studied by Knowlton and were referred to *Araucarioxylon arizonicum*. The specimens of wood obtained from the strata containing leaves were to poorly preserved to be identified, although Knowlton thought they were coniferous.

A short popular account of the Petrified Forest of Arizona by Knowlton (1913) included a generalized diagnosis of the megascopic characteristic of *Araucarioxylon arizonicum* and *Woodworthia arizonica*.

LESTER F. WARD

The petrified forests which had been reported by Sitgreaves, Woodhouse, Marcou, Kunz, and others in northern Arizona remained relatively unknown until the northern part of the territory was settled in the late 1870's. From that time on they were threatened increasingly by jewelers, casual souvenir hunters, professional and amateur gem collectors, and various commercial interests. On occasion entire logs were blasted apart for the amethyst crystals they sometimes contained. During the early 1890's, a mill was installed in the town of Adamana to crush petrified logs from Chalcedony Park into abrasives. Alarmed at the prospect of the total destruction of that petrified forest, the legislature of the Territory of Arizona petitioned the United States Congress in 1895 to have the area set aside as a national park. As a result of the petition, paleobotanist Lester F. Ward of the U.S. Geological Survey was instructed to make an examination of the area (Ward, 1900b, p. 3; 1901a, p. 292) and to report on "the advisability of setting that locality apart as a national park." During the fall of 1899, Ward spent several weeks in northeastern Arizona working on his assignment and studying the geology of the Little Colorado River area. He submitted the requested report to the Director of the U.S. Geological Survey in 1900 and recommended that the area containing Chalcedony Park be withdrawn immediately from entry and established as a national park. Shortly thereafter, the area was withdrawn, and on December 8, 1906, President Theodore Roosevelt established Petrified Forest National Monument.[5] Thus, this unusual natural wonder was preserved for the enjoyment and study of succeeding generations of casual visitors and scientists.

The report containing Ward's (1901a) recommendation about Chalcedony Park also included a summary of the geology, paleontology, and history of the area. A more technical report on the geology and paleontology of the Petrified Forest–Little Colorado River region (Ward, 1900a) was also based upon his work in Arizona in 1899. During the spring of 1901, Ward returned to Arizona and continued his geological investigations in the same general area. His findings were published first in the American Journal of Science (Ward, 1901b); later he included a revision of the article in his monograph (Ward, 1905) on the Mesozoic flora of the United States.

Ward (1905) divided the rocks between the Carboniferous and Cretaceous strata into three formations—the Moencopie Formation (at the base), the Shinarump Formation (in the middle), and the Painted Desert Formation (at the top), as shown in figure 8. The Moencopie Formation, named for Moencopie Wash, was said to be 600–700 feet thick and to rest unconformably on the Carboniferous rocks. Ward suggested (1905, p. 19) that the lower part of the Moencopie probably was of Permian age, although he considered the upper to be of Triassic age. The Shinarump, as defined by Ward (1905, p. 44), was about 1,600 feet thick and included a persistent bed of conglomerate at the base containing large quantities of petrified wood. This unit alone had been called the Shinarump Conglomerate by Powell (1876), but Ward extended the name to include all the fossil-wood-bearing Triassic rocks in the region and also raised it in rank. He indicated that the Shinarump Formation was of Triassic age and divided it into two members. The lowest was named the Lithodendron Member after Lithodendron Wash, where it was prom-

[5] Subsequently, the monument was enlarged to include the petrified forests in Lithodendron Wash, and Petrified Forest National Monument was designated a national park on December 8, 1962.

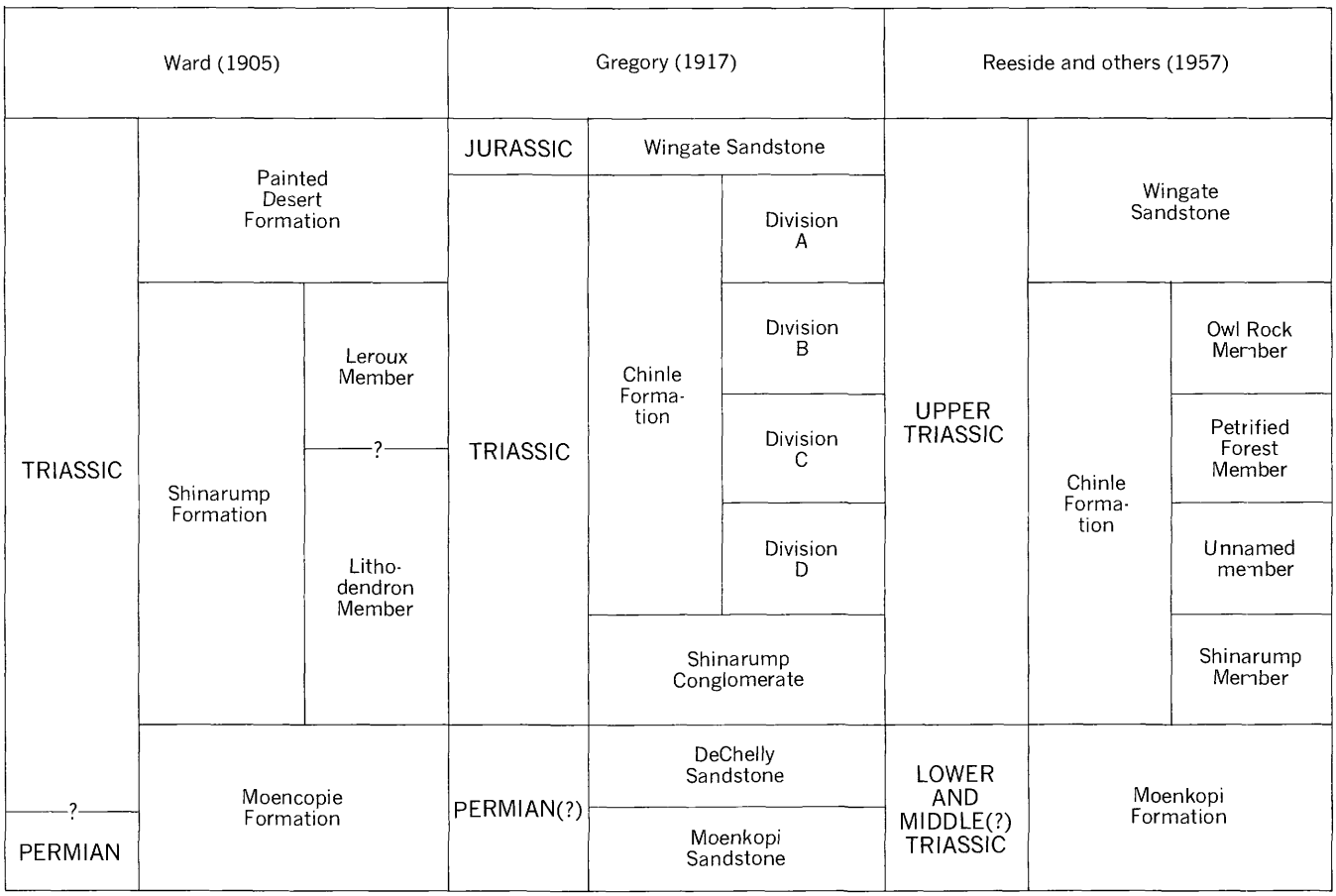

FIGURE 8.—Nomenclature and age assignments of the Chinle Formation and overlying and underlying rocks in parts of northeastern Arizona. The exact position of the boundary between members of Ward's Shinarump Formation is not known.

inently exposed. The member contained abundant petrified wood, especially in the Petrified Forest, and the so-called lower and upper forests of the Petrified Forest occur in this unit. Ward reported that the Lithodendron Member was 300–800 feet thick. The upper member of the Shinarump Formation was named after Leroux Wash which enters the Little Colorado about 25 miles west of Chalcedony Park. According to Ward, the Leroux Member, which was as much as 800 feet thick, contained abundant petrified wood and included the so-called middle forest of the Petrified Forest. He reported (Ward, 1905, p. 37) that the overlying Painted Desert Formation was as much as 1,200 feet thick and that it contained a small amount of petrified wood locally. The formation was also considered to be of Triassic age.

Ward searched for leaf remains while he was in Arizona, but the only specimens found were some poorly preserved imprints in the Shinarump Formation near Tanners Crossing. He thought that they represented coniferous twigs and branches and he illustrated (Ward, 1905, pls. 1, 2) some as *Araucarites shinarumpensis* n. sp. A petrified cone was collected by Ward from the Shinarump Formation in the Valley of the Little Colorado River northwest of the Petrified Forest. The cone was described (Ward, 1900a) very briefly as *Araucarites chiquito* n. sp. but was not illustrated. In 1901 Ward discovered some specimens of wood which seemed to be typical *Araucarioxylon arizonicum*, except that they contained rows of elliptical blisterlike objects. Thinking that they were resin pockets, he (1905, p. 35) named the specimens of wood *Araucarites monilifer*.[6] Until going on this trip, Ward had thought (1900a, p. 331–332) that all the petrified wood in the Triassic formations was transported prior to burial. However, he discovered more than 20 stumps in the Leroux Member which he was convinced stood precisely where they had grown (1905, p. 33–34).

[6] Daugherty demonstrated (1941, p. 44) that these bodies were pecky heart rot caused by a wood-destroying fungus and that they are imbedded in typical *A. arizonicum* wood. They were described as *Polyporites wardii* by Daugherty.

PAUL PLATEN AND E. C. JEFFREY

A specimen of fossil wood from the southern part of what is now the Petrified Forest National Park was described by Paul Platen (1908, p. 108) as *Araucarioxylon* sp. The material was not illustrated, however, and Platen's contribution to the study of Triassic paleobotany of the Southwest is small.

Dr. Edward C. Jeffrey, a botanist at Harvard University described (1910) a new genus and species of fossil plants based on petrified wood from the Petrified Forest as *Woodworthia arizonica*. He demonstrated that this form had the same type of internal structure as members of the living Araucarineae, except that it lacked the persistent leaf traces found in the secondary wood. Another point of difference is the presence of persistent short-shoots in *Woodworthia*, which show as characteristic pits on the surface of the specimens.

INVESTIGATIONS SINCE 1917

H. E. GREGORY AND OTHERS

Herbert E. Gregory's geologic report (1917) became the basis of modern stratigraphic work in the Triassic rocks of much of the Southwestern United States. Although his report concerned primarily northeastern Arizona and western New Mexico, many of the Triassic units he recognized were soon demonstrated to extend into northwestern Arizona, southern Nevada and Utah, and parts of northern New Mexico. Rocks that Ward had referred to the Shinarump Formation, Gregory named the Chinle Formation, and the term Shinarump was restricted to the basal conglomerate directly below the Chinle Formation; this was a return to the original definition of the Shinarump. (See fig. 8.) The name Chinle was taken from the Chinle Valley, where the formation is exposed. Gregory recognized four mappable units in the Chinle, designating them, from youngest to oldest, divisions A, B, C, and D. Division A is equivalent to the basal part of Ward's Painted Desert Formation; division B and the upper part of division C are equivalent to Ward's Leroux Member; and the lower part of division C and division D are equivalent to Ward's Lithodendron Member of the Shinarump Formation. Gregory reported the occurrence of invertebrate and vertebrate fossils of Triassic and Late Triassic age in the Chinle. He considered both the Shinarump and the Chinle Formations to be of Late Triassic age.

H. E. Gregory accepted the name Moenkopi (which had been proposed by Ward) for the unit directly underlying the Shinarump, although the spelling of the name had been changed by the U.S. Geographic Board from the older form, Moencopie. The Moenkopi Formation, which Ward had held to be of Triassic and possibly of Permian age, was considered by Gregory (1917, p. 30–31) to be entirely of Permian(?) age, although he admitted that the paleontologic evidence on the age was conflicting. David White had identified some poorly preserved plant fossils from the Moenkopi as *Walchia piniformis* and *W. gracilis*. These species, according to White, are characteristic of rocks of Permian age. However, some of the invertebrates suggest a Permian age, although others were held to indicate an early Triassic age by Girty. McKee (1954) summarized the evidence on the age of the Moenkopi Formation. He showed that all the invertebrates and vertebrates now known from the formation indicate that the lower part of the Moenkopi is of Early Triassic age and that the upper part may be Middle Triassic age (McKee, 1954, p. 10–11). The problem of the "Permian" plant fossils in the Moenkopi has not been resolved, but it is generally accepted that the formation is not of Permian age.

The petrified wood in the Chinle Formation and in the Shinarump Conglomerate was discussed at length by H. E. Gregory (1917, p. 49–50). He pointed out that petrified wood is characteristic of both units; it is not limited to particular horizons in either unit but is usually present wherever they are exposed. The especially large concentrations of petrified wood in certain areas were termed "fossil forests" by Gregory. These included—in addition to the fossil forest in Lithodendron Wash—one in Beautiful Valley (south of Chinle), another at Round Rock (north of Chinle), one near Willow Springs, and another south of Ganado. The fossil forests in Chalcedony Park, south of Lithodendron Wash, which are in the Petrified Forest National Park were outside Gregory's report area and, thus, were not included in his list.

Gregory was of the opinion that all the petrified wood in the Chinle and Shinarump had been carried some distance as driftwood by flooding streams before it was buried and fossilized. His evidence included the fact that most of the logs have worn surfaces on both ends and rarely have roots or limbs attached. In addition, many of the logs appear to be battered and are usually without bark. According to Gregory, the stumps reported to be in place by Ward (1905, p. 33–34) actually did not have roots extending downward and obviously did not grow where they are now found. He also noted that the sandstone beds containing petrified wood are crossbedded and lenticular, which suggests that they were deposited in a fluviatile environment.

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Since 1917, most of the divisions recognized by Gregory in the Chinle Formation have been given formal names and in some cases, subdivided. In much of east-central Arizona and west-central New Mexico, division A is now included in the Wingate Sandstone, and division B is called the Owl Rock Member of the Chinle (fig. 8). Gregory himself named (1950) division C, which contains most of the fossilized wood in the Petrified Forest of Arizona, the Petrified Forest Member of the Chinle Formation. Division D remains unnamed or is called informally the lower red member of the Chinle in this area. The Shinarump is now considered to be the basal member of the Chinle Formation. As discussed elsewhere in the present report, the Chinle is generally thought to be of Late Triassic (Keuper) age, the age determination being based mostly upon vertebrate fossils.

The sandstone from which Newberry, Powell, and Knowlton collected fossil plants in Arroyo del Cobre, N. Mex., is the Agua Zarca Sandstone Member of the Chinle, according to C. B. Read (written commun., 1967) and is considered to be the basal member of the Chinle in that area. In Arroyo del Cobre, Permian vertebrates have been collected from localities several hundred feet below the base of the Chinle (Vaughn, 1963), and Late Triassic vertebrates have been collected from localities several hundred feet above it (Colbert, 1960) in a shale unit correlated with the Petrified Forest Member of the Chinle. The bed containing fossil-plant remains is generally considered to be of Late Triassic (Keuper) age (Reeside and others, 1957).

E. W. BERRY

In 1921, a small collection of fossil leaves was made from the Shinarump Conglomerate in southern Utah by R. C. Moore (Gregory and Moore, 1931, p. 53). Dr. Edward W. Berry (1927) of Johns Hopkins University examined the fossils and reported that one species in the collection was the same as *Zamites powelli* which had been described from the Poleo Sandstone in northern New Mexico by Fontaine. Berry concluded, however, that the specimens of this form actually should be referred to the genus *Otozamites*, rather than *Zamites*. Because of this change and because the species had not been adequately described, Berry (1927, p. 305–307) gave a detailed diagnosis of the form, calling it *Otozamites powelli* (Fontaine) Berry. Some cycad fronds from the Shinarump Conglomerate in southeastern Utah were determined to be a new species by Berry (1930). He named them *Pterophyllum bakeri* n. sp.

LYMAN H. DAUGHERTY

The one person who has done the most to increase our knowledge of the flora of the Chinle Formation is Lyman H. Daugherty of San Jose State College, San Jose, Calif., who began his work in 1932. In that year he was given a specimen of fossil wood from the Petrified Forest which proved to represent a new genus and was subsequently described as *Schilderia adamanica* by Daugherty (1934). This species is smaller than *Araucarioxylon arizonicum* and has a swollen fluted base. The most striking microscopic characteristic of the species is the large multiseriate rays of the herringbone type found in the recent genus *Ephedra* and in a few recent genera of dicotyledons. Two or three narrow uniseriate rays occur between the multiseriate rays in this curious species. It has been tentatively placed in the Gnetales by Daugherty (1941, p. 95).

Daugherty made several collecting trips to the Southwest during 1933–37. Specimens were collected from the Chinle at several localities in Arizona and Utah, from the Poleo Sandstone in northern New Mexico near the Arroyo del Cobre localities of Newberry, Powell, and Knowlton, from the Dockum Group of eastern New Mexico and west Texas, and from the Shinarump Conglomerate in southern Nevada. At the same time that Daugherty was working in the Southwest, the park naturalist of the Petrified Forest, M. V. Walker, was collecting leaf fossils from some localities in the Petrified Forest. Walker's collections were turned over to Daugherty, who studied them as well as his own collections, and published a report in 1941. This report was the most comprehensive discussion of the Triassic floras of the Southwest that had been published up to that time. Furthermore, it has remained the only significant report on the subject, although a few brief studies on the Chinle plants have been published since 1941.

Daugherty discussed 41 species of fossil plants in his report. Although most of the work was new, Daugherty also repeated descriptions of most of the species previously described from the Chinle. Most of the species were based upon leaf remains but two were based on seeds, two on cones, five on fossilized wood or pithcasts, and four on spores or pollen grains. The flora was found to be dominated by the ferns, which were represented by 10 species, of which the largest family present was the Osmundaceae with six members. Both the cycads and the conifers were represented by six species each. Seventeen of the forms were new species; seven were new genera and new species; and only 11 forms were referred to previously described species. The remaining six

forms were too fragmentary or poorly known for specific identification.

All the spores and nearly all the leaves studied were obtained from the lower part of the Chinle Formation (division C) in the Petrified Forest. A few of the leaves were found also at three localities in the Chinle elsewhere in Arizona. Only one species, based on a leaf fossil, *Otozamites powelli*, was found in both the Chinle Formation in Arizona and the Dockum Group (considered to be approximately equivalent to the Chinle Formation) in west Texas. One leaf fossil (*Yuccites poleoensis*) was found only in the Poleo Sandstone in northern New Mexico near Arroyo del Cobre. Specimens of *Araucarioxylon arizonicum* and *Woodworthia arizonica* were obtained from several localities in the Chinle Formation in the Petrified Forest and from the Dockum Group at one locality in Texas. *A. arizonicum* was also reported from the Chinle Formation in southern Utah and at several localities in Arizona outside the Petrified Forest, from the Poleo Sandstone in northern New Mexico, and from the Shinarump Conglomerate in southern Nevada.

Daugherty reported that six species occurred in the floras of both the Chinle Formation and the Newark Group of the Eastern United States. In addition, he said that both floras contained six closely related species. He noted that two species were found in both the Chinle Formation and the Keuper of Germany and that both formations contained 11 other closely related species. Seven species from the Chinle were found to resemble forms from the Rhaetian of Greenland. A comparison of the Chinle flora with the Rhaetian floras of Japan showed that the two floras had four species that were closely related. Daugherty concluded, therefore, that the Chinle flora in the lower part of the Chinle is of Keuper age, as it "closely resembled" the Newark and the Keuper floras.

Daugherty has continued to do some work on the Chinle flora. In 1960, he described *Itopsidema vancleavei*, a new genus tentatively referred to the Osmundaceae. It was based on several fragments of an arborescent stem collected in the Petrified Forest National Monument. In 1963, he published a description of some tertiary and secondary fossil roots, which were found filling the hollow center of a log of *Araucarioxylon arizonicum* in the Petrified Forest. The name *Araucariorhiza joae* was proposed for the roots, which Daugherty (1963, p. 805) thought to be "those of a member of the Araucarineae and possibly represent roots of *Araucarioxylon arizonicum*."

M. V. WALKER

M. V. Walker, the park naturalist at the Petrified Forest who discovered some of the fossil leaf remains that Daugherty studied, investigated (Walker, 1938) the ridgelike, channellike, and tunnellike structures in many specimens of *Araucarioxylon arizonicum*. He attributed the structures to the action of several different species of insect larvae and suggested that the larvae probably girdled and killed many of the trees that were eventually petrified. Thus, the larvae may have been responsible for the concentration of logs at a certain level in the park, as at least 50 percent of these logs contain the structures he described.

R. W. BROWN

The late Roland W. Brown described two plant fossils from the Upper Triassic Dolores Formation in southwestern Colorado in 1956. One fossil he referred to *Brachyphyllum munsteri* Schenk. The other is a palmlike leaf, which he named *Sanmiguelia lewisi*. It has large elliptical, strongly pleated leaves attached by sheathing petioles to a rather stout stem. Unfortunately, all the specimens of this interesting and highly controversial fossil are impressions in a bed of very fine grained standstone. As no organic remains of *S. lewisi* have been found, it is difficult to establish its relationships to other plants. Brown pointed out, however, that it does not resemble any other known plant, living or extinct, except the palms and a few species of the monocotyledons. If these specimens were found in rocks of Tertiary age, they would undoubtedly be accepted without hesitation as representing a palm, according to Brown. Therefore, he tentatively regarded *S. lewisi* as a primitive palm, although he stated (Brown, 1956, p. 209) that "This species, if not a primitive palm, is a palmlike monocotyledon * * *." If Brown's ideas are correct, then the specimens of *S. lewisi* are the oldest known megascopic remains of the angiosperms.

No new data bearing on the status of *Sanmiguelia* has been published since Brown's original study, and the fossil has not been accepted unequivocally as an angiosperm by all authorities. In a review of the evidence of pre-Cretaceous angiosperms, Scott, Barghoorn, and Leopold (1960) admit that *Sanmiguelia* is the best known example of a pre-Cretaceous angiosperm. They argued, however, that as its status is unsettled, *Sanmiguelia* could be a cycadophyte because the Mesozoic members of that group have a wide range of struc-

ture. Hughes (1961) suggests in his analysis of pre-Cretaceous angiosperm evidence that *Sanmiguelia* could be an undescribed cycadophyte or ginkgophyte just as well as an angiosperm, especially as it does not show any conclusive angiosperm characters.

Bock (1962) reassigned *Sanmiguelia* to *Paloreodoxites* Knowlton, 1930, but other authors apparently have not agreed with this change, although the genera are at least superficially similar. In the same paper, Bock also stated that the petiole of the form was elliptical in cross section like a cycadophyte and had actually been collected from rocks of Jurassic, not Triassic, age. According to Arnold (1964, p. 5), however, the stem bearing an attached leaf of *Sanmiguelia* was misinterpreted by Bock for the petiole. He also demonstrated that Bock erred when he stated that *S. lewisi* was collected from rocks of Jurassic, not Triassic, age. Arnold regarded *Sanmiguelia* as an angiosperm because no one "has shown any real cycadophytic or ginkgophytic characters in it."

During 1958, Roland Brown published a short paper on the fossil quillworts. In it the plant fossils that Daugherty (1941, p. 82) had described from the Chinle as *Lepacyclotes circularis* Emmons and thought to be "the basal portion of the flower of a *Williamsonia*" were referred to *Isoetites circularis* (Emmons) Brown, n. comb.

C. A. ARNOLD

Dr. Chester A. Arnold of the University of Michigan transferred (1947, p. 196–197) the species that Daugherty had described as *Laccopteris smithii* to the genus *Phlebopteris*. A few years later Arnold (1956) reviewed the fossil ferns from North America referable to the Matoniaceae. In his report, a new species, *Phlebopteris utensis*, was described from the Chinle Formation in southern Utah and compared with *P. smithii* (Daugherty).

In 1964 Arnold described the occurrence of *Cordaites*-type leaf fossils with *Sanmiguelia lewisi* in the Dolores Formation of Colorado. He compared them with the leaf Daugherty had described from the Poleo Sandstone in northern New Mexico as *Yuccites poleoensis*. Arnold showed that *Yuccites* is preoccupied and that *Pelourdea* Seward is the appropriate name for these fossils. He therefore proposed the name *Pelourdea* poleoensis (Daugherty) n. comb. for these straplike leaves from southwestern Colorado and northern New Mexico and gave an amended diagnosis for the species.

R. A. SCOTT AND OTHERS

Richard A. Scott, of the U.S. Geological Survey, demonstrated (1960a) that the spore identified by Daugherty as *Equisetosporites chinleana* should be referred to the genus *Ephedra*. This form, now called *Ephedra chinleana* (Daugherty) R. A. Scott, has also been recognized at several localities in the Chinle Formation in southern Utah (Scott, 1960a, p. 276). Scott (1960b) has studied some of the petrified wood that is often associated with uranium deposits in rocks of Triassic age on the Colorado Plateau. All the specimens that he examined belonged to *Araucarioxylon arizonicum* Knowlton.

Personnel and students of the University of Arizona have begun detailed microenvironmental studies in the Petrified Forest National Park. These studies consider the stratigraphy, paleozoology, and palynology of the Chinle Formation. In addition, electron-microscope studies were made of the petrified wood. Two preliminary reports describing their results have been issued (Roadifer and others, 1964; Bryant and Roadifer, 1965), and the final report is awaited with interest. More recently, some of the pollen and paleoecological work was briefly described in an abstract by Gottesfeld and Kremp (1968).

Charles N. Miller, Jr., of the University of Montana reinvestigated (1968) *Chinlea campii* Daugherty and *Osmundites walkeri* Daugherty which were described from the Chinle Formation in eastern Arizona. The two species were based on petrified stems and originally were referred to the fern family Osmundaceae by Daugherty (1941). Miller concluded that the two species are conspecific and interpreted the stems to be the ephemeral aerial shoots of a lepidophyte. The binomial *Chinlea campii* Daugherty emended Miller, is now the valid name for these stems. Some undetermined stems described by Daugherty and similar stems from the Chinle are called *Chinlea* sp., as diagnostic details are not preserved.

PRESENT INVESTIGATION

The present investigation began in 1959 as part of my work with the U.S. Geological Survey in Albuquerque, N. Mex. That year I collected leaf remains in the Fort Wingate area, New Mexico, at the suggestion of Charles B. Read, who had collected there in 1941. Although Read's collections had not been described, they were the basis for the reclassification of some of the rocks below what is now called the Sonsela Sandstone Bed as Upper Triassic, rather than Permian (Read and Wanek, 1961, p. 3). After 1959, as time permitted, I collected additional Triassic plant remains near Fort Wingate and in other areas, including Petrified Forest National Park in Arizona, Arroyo del Cobre in northern New Mexico, and west Texas. Some of the better preserved leaf and fertile structures were studied in Eng-

land under the direction of Prof. T. M. Harris in 1964–66, and preliminary summaries of my findings were published (Ash, 1967a, b). A detailed description of *Williamsonia nizhonia* n. sp., a new bennettitalean cone, was also published (Ash, 1968).

SUMMARY OF THE PRE-CENOZOIC STRATIGRAPHY IN THE FORT WINGATE AREA, NEW MEXICO

Fort Wingate is about 12 miles southeast of Gallup in west-central New Mexico and about 75 miles east of Petrified Forest National Park, Ariz. (figs. 1, 2). Fort Wingate was an important U.S. Army post during the late 19th century. The buildings have since been used as an Indian boarding school.

During the present investigation, the geology of the area was studied in some detail, with particular regard to the distribution and location of fossil plant material. Several stratigraphic sections were measured, and a composite section of the pre-Cenozoic rocks exposed near Fort Wingate is shown in figure 9. Several sections were also measured in the southern part of Petrified Forest National Park, Ariz., and a composite section for that area is given in figure 9, as well as suggested correlations of some of the units between the two places.

The geology in the vicinity of Fort Wingate was described briefly by Callahan and Cushman (1955) in their report on the ground-water resources of the area. Read and Wanek (1961) and Baars (1961) described the Permian formations in connection with their studies of the regional distribution of the Permian rocks in the Colorado Plateau. Cooley (1957, 1959) reported on the Triassic stratigraphy of parts of eastern Arizona and western New Mexico. The principal formations exposed in the area are shown on the map of a part of northwestern New Mexico published by O'Sullivan and Beaumont (1957) and on the more recent geologic map of New Mexico (Dane and Bachman, 1965). These reports and maps largely supersede earlier investigations in the area.

PERMIAN SYSTEM

GLORIETA SANDSTONE

The Glorieta Sandstone is the oldest formation exposed in the vicinity of Fort Wingate. There, it has a total thickness of about 200 feet, as estimated from an isopach map (Baars, 1961, fig. 17). The Glorieta is exposed only in the walls and on the floor of Milk Ranch Canyon, where the upper 43.5 feet of the formation crops out. In the canyon the Glorieta can be divided into two units. The lower unit is 30 feet thick and consists of whitish to slightly yellowish well-cemented massive coarse-grained sandstone. It contains tangential cross-laminations which dip southwestward. The unit weathers rounded to blocky and generally forms a cliff. Its base is not exposed. The upper unit is about 13.5 feet thick and consists mostly of sandstone and a few thin beds of shale. The sandstone is pinkish, well cemented, thin bedded, and fine to medium grained. Typically, it forms a steep ledgy slope.

According to Baars (1961, p. 198), primary sedimentary structures in the Glorieta imply that it was deposited in an environment of "littoral to upper neritic marine aspects, with local eolian conditions." Although no diagnostic fossils have been reported from the Glorieta Sandstone, it is considered to be of Early Permian (late Leonard) age because it is between two formations of that age (Baars, 1961, p. 199).

SAN ANDRES LIMESTONE

The San Andres Limestone is exposed only on the walls and adjacent slopes of Milk Ranch Canyon and in the walls and on the floors of the three deep narrow north-trending canyons that debouch into the valley containing Fort Wingate. Its lower surface is exposed only in Milk Ranch Canyon, whereas the upper surface, which is very irregular, is exposed in all four canyons. In the Fort Wingate area the thickness of the San Andres ranges from 0 to 80 feet because of pre-Moenkopi(?) erosion.

This formation is composed mostly of grayish deeply weathered medium- to thick-bedded dolomitic limestone which generally weathers brownish. Locally, the San Andres contains bluish chert and a few thin beds of red siltstone and one bed of hard white sandstone. The upper few feet of the formation is brownish red and contains irregular masses of grayish limestone and greenish- and yellowish-stained patches and stringers. Many small vugs (as much as one-half inch in diameter, larger) and thin undulating stringers (as much as one-quarter inch across) filled with clear quartz occur throughout the formation. Several irregular cracks in the San Andres Limestone in Milk Ranch Canyon contain mudstone and sandstone similar to that found in the overlying Triassic rocks.

Poorly preserved remains of brachiopods, crinoids, and cephalopods, as well as quantities of fossil hash, were noted in the San Andres by the author. Baars (1961, p. 203) reported the occurrence of eight species of marine invertebrates in the formation at a nearby locality, and conodonts have been reported (Clark and Ethington, 1962) from the unit in the same general area. The fossils indicate that the San Andres Limestone is a marine deposit of Early Permian (Leonard) age.

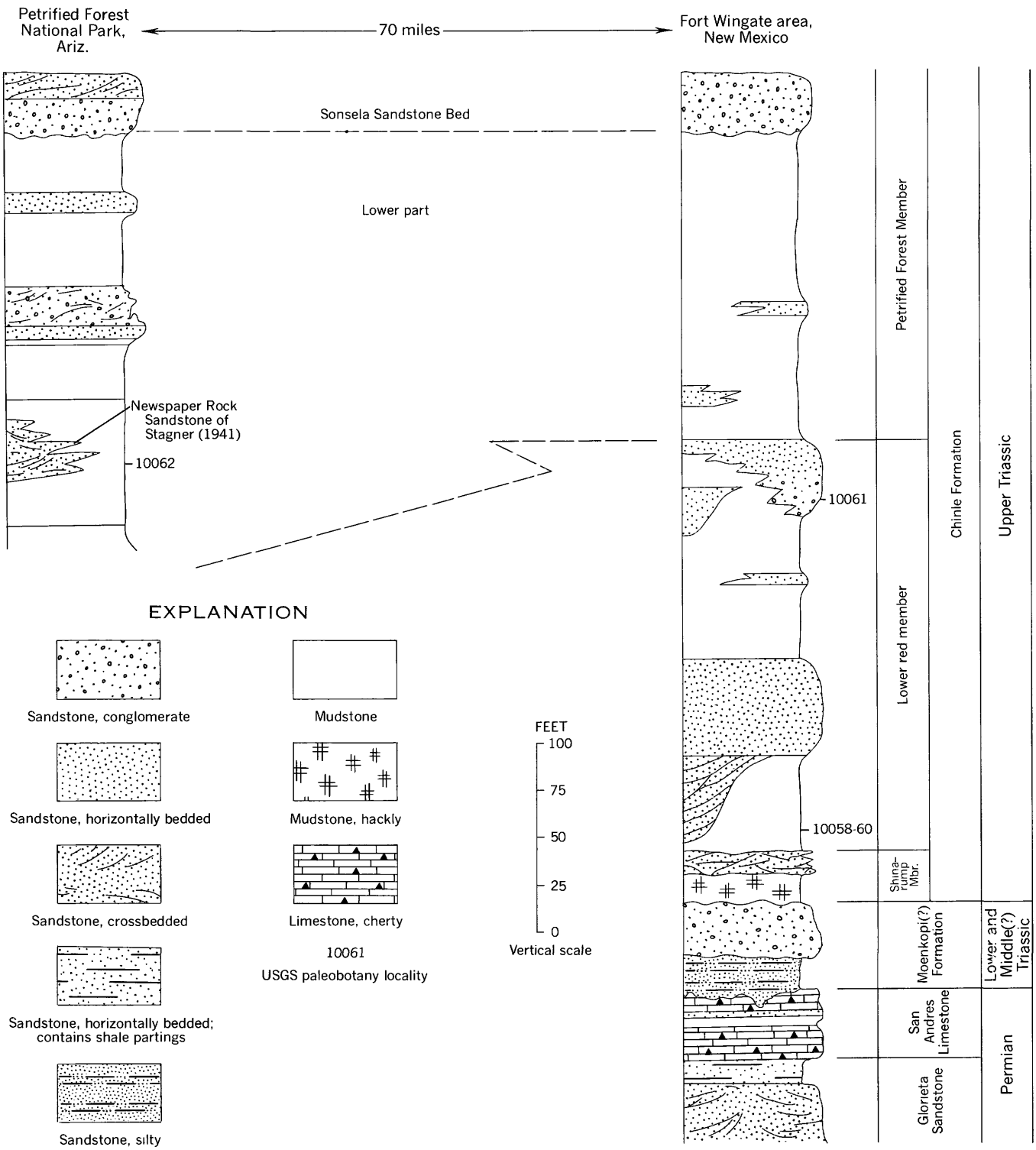

FIGURE 9.—Composite stratigraphic sections of the lower part of the Chinle Formation in the southern part of Petrified Forest National Park, Ariz., and in the Fort Wingate area, New Mexico.

UNCONFORMITY BETWEEN THE PERMIAN AND TRIASSIC ROCKS

The Permian rocks are separated from the overlying Triassic rocks by an erosional unconformity which extends throughout the Colorado Plateau. Present knowledge concerning the unconformity in the region has been summarized by several authors, including McKee (1954, p. 33–35), McKee and others (1959, p. 2), Baars (1961, p. 209–210), and Repenning, Cooley and Akers (1969). The unconformity was briefly described by Cooley (1957, p. 26–27, 1959, p. 66) and Baars (1961, p. 209) in the Fort Wingate area.

Generally, the unconformity has only slight relief, but near the Fort Wingate area it has nearly 100 feet of relief. In some places, such as in the vicinity of Milk Ranch Canyon, steep-walled depressions have been cut into the Permian rocks, and relief may be 30 or more feet within a small area. Locally, the San Andres Limestone is missing because of erosion and rocks of the Triassic age lie on the Glorieta Sandstone.

At some places a limestone breccia in the San Andres is directly below the unconformity; elsewhere, deeply weathered limestone may underlie the unconformity. In the Fort Wingate area the surface is overlain by reddish thin-bedded flat-lying siltstone of the Moenkopi(?) Formation. The characteristics of the unconformity and of the sediments above and below indicate that the surface formed in the same type of environment in which modern karst topography forms.

The length of time represented by the unconformity differs slightly in the Colorado Plateau. The underlying sediments are of Early Permian age throughout the region, whereas the overlying sediments of the Moenkopi Formation are of Early Triassic age in northwestern Arizona, become progressively younger toward the southeast, and may be of Middle Triassic age in eastern Arizona and western New Mexico (Akers, 1964, p. 23–24). Thus, in the Fort Wingate area the unconformity may represent all of Late Permian time and most, if not all, of Early Triassic time. However, until diagnostic fossils are found in the Moenkopi(?) in the Fort Wingate area, this is only conjecture—especially as there is some question about the correlation of the "true" Moenkopi with the Moenkopi(?) Formation that overlies the erosional unconformity in the Fort Wingate area.

TRIASSIC SYSTEM

MOENKOPI(?) FORMATION

In the present report, the rocks overlying the karst erosional surface that is cut into the Permian rocks, and underlying the Shinarump Member of the Chinle, are referred to as the Moenkopi(?) Formation. As their name implies, the rocks probably correlate with the Moenkopi Formation, of Early and Middle(?) Triassic age, which is widely distributed in parts of the Southwest. This correlation is thought to be reasonable, for the Moenkopi is thickest in northwestern Arizona and adjacent areas and thins southeastward to a featheredge in western Colorado and eastern Arizona, according to McKee (1954). Thus, a thin veneer of Moenkopi sediments in western New Mexico would be consistent with the regional distribution of the formation.

The Moenkopi in eastern Arizona has been correlated with the upper part of the formation in southeastern Utah; therefore, the Moenkopi(?) Formation of the Fort Wingate area probably correlates with only the upper part of the formation. Several authors have recognized this possibility, as indicated by the names they applied to this unit in western New Mexico. For example, Cooley (1959, p. 68–69) called it Upper Moenkopi(?) sediments, whereas Repenning, Cooley, and Akers (1969, p. B12) later used the term Moenkopi(?) Formation, which points out the possible correlation but is not as awkward as the term previously used by Cooley.

The Moenkopi(?) Formation in the Fort Wingate area is composed of two units of contrasting lithology and topographic expression. The lower unit consists of reddish thin-bedded sandy siltstone and silty fine-grained sandstone. In some places the sandstone contains well-rounded grains of quartz and is crossbedded. The unit is as much as 80 feet thick and forms a slope. An unconformity with 1–5 feet of relief separates the two units. The upper unit is composed of grayish coarse-grained conglomeratic sandstone containing quartz, jasper, and quartzite pebbles, some of which are as much as 4 inches across. Although pebbles occur throughout the unit, they are generally concentrated in lenses that are particularly abundant in the lower part. The unit contains generally low angle crossbedding and ranges from 3 to 25 feet in thickness because of the unconformities that separate it from the underlying unit and the overlying Shinarump Member of the Chinle Formation.

The age of the Moenkopi(?) Formation is problematical, as no diagnostic fossils have been reported from it. Theoretically, the Moenkopi(?) could be of Late Permian to early Late Triassic age, for it is between rocks of Early Permian and middle Late Triassic age. However, because regional study suggests that the Moenkopi(?) Formation is correlative with the upper part of the Moenkopi, it is considered to be of the same age as that part of the formation, or possibly slightly

younger (Cooley, 1959, p. 69). Cooley's evidence is the karst topography formed on the Permian rocks in the Fort Wingate area and the unconformity of rather low relief formed on the Permian rocks in adjacent areas in eastern Arizona. This indicated to him that while the basal sediments of the Moenkopi were being deposited in eastern Arizona, the Permian rocks in western New Mexico were still undergoing erosion; they were not buried until some time later.

PRE-CHINLE UNCONFORMITY

The unconformity between the Chinle Formation and the Moenkopi(?) Formation is exposed at many localities in the vicinity of Fort Wingate. It is only slightly irregular, and the local relief is usually less than 1–2 feet, although its total relief may be 10–20 feet in the area. Elsewhere, the pre-Chinle unconformity is one of the most conspicuous unconformities on the Colorado Plateau. Its characteristics indicate that it was formed by subaerial erosion, and McKee (1954, p. 38) believed that the unconformity formed over a long period of time. In many places the unconformity is extremely irregular; it contains numerous channels, which, according to Evensen (1958, p. 95), resemble the channels of modern streams. The pre-Chinle unconformity apparently formed during late Middle and early Late Triassic time.

CHINLE FORMATION

The Chinle is widely exposed in the Fort Wingate area. There, the exposures are typical of the formation, as the mudstone units form steep soft slopes which are relatively free of vegetation and are often quite colorful. The beds of sandstone and conglomerate hold up ridges and form cliffs and are usually more subdued in color. The formation at Fort Wingate can be divided into five lithologic units that represent about half the vertical thickness of the entire Chinle in the region. The uppermost part of the formation is exposed outside the immediate vicinity of Fort Wingate. The units recognized at Fort Wingate are, from bottom to top, the Shinarump Member, the lower red member, the Petrified Forest Member (lower part), the Sonsela Sandstone Bed, and the Petrified Forest Member (upper part). Fossil leaves have been collected from only the lower red member, but petrified wood is common in all members and is especially abundant in the Sonsela Sandstone Bed.

The Chinle Formation is thought to have been deposited by streams flowing on "a relatively flat low-lying surface" (McKee and others, 1959, p. 14). The fluvial origin is suggested by the lithology and the sedimentary structures in the formation, which are similar to those of modern stream deposits (Poole, 1961, p. C139). Poole (1961, C139) studied the cross-strata in the Chinle and demonstrated that "drainage trends are closely related to the positions of major Triassic highlands * * *." He also determined that during the time the Chinle sediments were deposited, streams flowed in a northerly direction in what is now the Fort Wingate area (Poole, 1961, fig. 199.1). Apparently, the highland in southern New Mexico and Arizona was the main source of these sediments because the material in "the lower part of the Chinle becomes coarser southward toward the Mogollon highland region * * *." (Poole, 1961, p. C141.)

SHINARUMP MEMBER

The Shinarump Member of the Chinle Formation is divisible into two units of contrasting lithology. The lower unit is about 15–35 feet thick and is composed of massive sandy mudstone. It is typically bluish with a purplish cast and may have yellow streaks. The unit is well indurated, weathers hackly, and forms steep slopes or nearly vertical cliffs. This lower unit is separated from the underlying Moenkopi(?) Formation by a slight erosional unconformity as described above. The upper surface is also irregular and has 1–2 feet of relief locally, although it may have as much as 10 feet of relief within the entire area.

The upper unit is about 15–25 feet thick and is composed of gray, hard crossbedded sandstone that locally contains small pebbles. Individual beds are thin, and the unit weathers slabby. It often forms a bench with rather steep sides and may overhang the lower unit. (See fig. 10.) The upper surface is poorly exposed in the area but seems to be slightly irregular.

Plant remains are the only fossils reported from the Shinarump. In many places in Arizona and Utah, the member contains lenses and pockets of trashy carbonaceous material and petrified wood (Stewart and others, 1959, p. 505). Petrified wood is common in the Shinarump in the Fort Wingate area, also, but none has been studied.

LOWER RED MEMBER

The lower red member in the Fort Wingate area can be divided into a thick slope-forming lower unit and a relatively thin ledge-forming upper unit. As the name implies, the member is typically red or reddish, although in some places, such as along State Highway 400 south of the school, it is rather greenish especially in the lower part.

The lower unit consists of numerous lenticular beds of claystone, mudstone, and silty sandstone. They inter-

FIGURE 10.—Upper part of the Shinarump Member of the Chinle Formation, 2 miles south of Fort Wingate, N. Mex. The contact between the lower and upper parts of the Shinarump is at the base of the ledge-forming crossbedded unit. The contact between the lower red member and the Shinarump Member is obscured by the trees.

tongue and grade into each other so that an individual bed cannot be traced for any great distance. In places the unit contains discrete channel deposits. One such channel is exposed in a roadcut south of Fort Wingate (fig. 11). It is composed of several beds of hard sandstone and is surrounded by soft sandy mudstone. Another channel deposit is exposed near the top of the unit (fig. 12). It consists of a lenticular bed of gray mudstone within a large mass of reddish mudstone.

The upper unit is about 20–30 feet thick and is composed of fine- to medium-grained sandstone. It also contains a few thin beds of claystone and lenses of conglomerate. The unit is predominantly white to yellow. Both the upper unit and the sandstone beds in the lower unit contain crossbedding and ripple marks.

Schultz (1963, p. C31–C35) determined that most clay in the member is montmorillonitic, although rather large quantities of illite, chlorite, and kaolinite are also found near the base and top of the member. He concluded that the clay is of volcanic origin and that the montmorillonitic clay had been transported by water, probably as fragments of tuff from a distant source area, which may have been to the south. The kaolinitic clay probably formed locally and was transported only a short distance, whereas the chlorite apparently was transported for some distance from the east.

All the fossil leaves known to occur in the Fort Wingate area are in the lower, slope-forming part of the lower red member; 10 leaf-bearing localities have been found in it thus far. These localities contain many of the same species that Daugherty (1941) described from the Petrified Forest Member in Petrified Forest National Park. Several undescribed forms have also been obtained from these localities. Most of the pteridophytes in the area have been studied in detail and can be compared with species described elsewhere. Most of the higher plants, on the other hand, have not been

FIGURE 11.—Large channel-type deposit near the base of the lower red member of the Chinle Formation, exposed in a roadcut 2 miles south of Fort Wingate on State Highway 400. USGS paleobotany locality 10060 is near the base and beneath the channel.

FIGURE 12.—Badland topography that has formed on the lower red member of the Chinle Formation 1 mile south of Fort Wingate. The light-colored rock near the center of the picture apparently is a channel-type deposit. USGS paleobotany locality 10061 is in this distinctive unit.

described, and it is premature to discuss that part of the flora, except to note that it seems to compare rather closely with the flora from Petrified Forest National Park.

Ferns occur at USGS paleobotany localities 10058, 10059, and 10060 (near the base of the member), and at locality 10061 (near the top), the upper locality being about 125 feet stratigraphically above the lower, as shown in figure 9. Comparison of the two floras shows that the lower contains six species of ferns and the upper contains three of the same species (table 1). Differences probably are not significant, as the species that occur in the lower flora are also in the overlying Petrified Forest Member in Petrified Forest National Park (table 1). None of the species has been reported from localities in any other formation. Further discussion of the flora from the Fort Wingate area is included in the section "Chinle Flora" of the present report.

TABLE 1.—*Comparison of the fern leaves in the lower red member of the Chinle Formation in the Fort Wingate area, New Mexico, with those in the lower part of the Petrified Forest Member of the Chinle Formation in Petrified Forest National Park, Ariz.*

	Lower red member in the Fort Wingate area		Petrified Forest Member (lower part) in Petrified Forest National Park, Ariz.
	Lower flora	Upper flora	
Todites fragilis	×	×	×
Clathropteris walkeri	×	------	×
Apachea arizonica [1]	------	------	?
Cynepteris lasiophora	×	×	×
Phlebopteris smithii	×	------	×
Wingatea plumosa	×	------	×
Cladophlebis daughertyi	×	×	×
Cladophlebis "reticulata"	(2)	------	×
Cladophlebis cf. denticulata	------	------	×
Sphenopteris arizonica	------	------	×

[1] See discussion on the validity of this species in the systematic description of *Clathropteris walkeri*.
[2] This species has not been found in the Fort Wingate area. It was collected from the base of the lower red member at a locality about 30 miles east of the Fort Wingate area.

Bones, teeth, and other vertebrate remains are common in the lower red member in the Fort Wingate area, but most of the material is fragmentary and unidentifiable. The remains of a thecodont, *Acompsosaurus wingatensis* n. sp., were described from the badland exposures of the member a short distance northeast of Fort Wingate, and fragments thought to be referrable to the phytosaur *Paleorhinus* were also reported from the same locality (Mehl and others, 1916). Recently, Dr. E. H. Colbert (written commun., 1967) identified the remains of the amphibian *Eupelor frasii* and the phytosaur *Rutiodon*? from a horizon near the one containing USGS paleobotany locality 10061.

PETRIFIED FOREST MEMBER

Lower part

The lower part of the Petrified Forest Member of the Chinle is about 130 feet thick in the Fort Wingate area. It consists of mostly claystone and soft sandstone. The claystone is composed mainly of montmorillonite (Schultz, 1963, p. C36–C39). Near the base it contains small amounts of kaolinite, chlorite, and illite; toward the top of the unit, the chlorite increases, and the montmorillonite decreases. Usually, individual beds intertongue and intergrade. The unit is predominantly purple and the claystone weathers to form frothy-surfaced slopes.

Schultz concluded (p. 1963, C37–C38) that the clays were of volcanic origin and that they had been transported by water from a source area in southern New Mexico and Arizona. Some of the material was apparently deposited as discrete particles of tuff, which was then altered. Some of the clays may have formed in the source areas before transportation and final disposition.

No fossils except petrified wood have been found in this part of the Chinle in the Fort Wingate area, but, as noted previously, the leaves in the Petrifed Forest National Park occur in this part of the Petrified Forest Member.

Sonsela Sandstone Bed

The Sonsela Sandstone Bed, which divides the Petrified Forest Member of the Chinle into two units, caps many of the cuestas and cliffs in the area. For example, the cuestas north, of Fort Wingate Indian School are capped with the Sonsela Sandstone Bed. (See fig. 6.) In this area the Sonsela is about 32 feet thick and consists of several intertonguing beds, some of which are composed of fine- to medium-grained yellow to gray crossbedded sandstone. Others are composed of hard brown conglomerate containing pebbles as much as 1 inch in diameter. Beds of sandy conglomerate and conglomeratic sandstone are also present in the unit. None of the beds can be traced over a very long distance, as they lens out or grade into an adjacent unit. The lower contact of the Sonsela is irregular and has several feet of relief; the upper contact is just slightly irregular.

Petrified wood is the only common fossil in the Sonsela. One of the type specimens of *Araucarioxylon arizonicum* mentioned previously was collected from this unit in the Fort Wingate area.

Upper part

The upper part of the Petrified Forest Member generally is about 800 feet thick in west-central New Mexico, but in the Fort Wingate area most of the unit has been removed by erosion. There, the thickest section is

on the hill south of the school, where about 200 feet is preserved. Elsewhere in the area, only scattered thin remnants remain on the Sonsela Sandstone Bed.

The unit is composed mostly of grayish-red-purple mudstone and sandstone which usually looks reddish brown from a distance. According to Schultz (1963), the clay is mostly montmorillonite with small amounts of illite and chlorite. Individual beds intertongue laterally and intergrade, and as a result none of the beds is persistent over a very large area.

Fragments of petrified wood are the only fossils known in the unit at Fort Wingate.

CHINLE FLORA

STRATIGRAPHIC DISTRIBUTION

Nearly all the plant fossils described from the Chinle Formation were collected in east-central Arizona and west-central New Mexico. In most of this region the Chinle Formation is usually divided into the six mappable units listed below (from top to base). The thickness of each was taken from Cooley (1959).

Units of the Chinle Formation	*Thickness (feet)*
Owl Rock Member	50–300
Petrified Forest Member:	
Upper part	800
Sonsela Sandstone Bed	35–200
Lower part	125–300
Lower red member	0–270
Shinarump Member	0– 75

Most plant fossils described from the Chinle occur below the Sonsela Sandstone Bed in the lower part of the formation. In the Fort Wingate area, fossil leaves were collected from the lower red member; in Petrified Forest National Park, leaves were obtained mainly from the lower part of the Petrified Forest Member. Elsewhere in the region, a few leaves have been identified from the Chinle Formation, but the horizon from which they came cannot be evaluated in terms of the members given above. One poorly preserved species has been reported from the Shinarump Member. Petrified wood occurs in all but the Owl Rock Member, but the only wood that has been described was collected from the lower part of the Petrified Forest Member and the Sonsela Sandstone Bed.

The floras in both the lower red member and the overlying Petrified Forest Member are similar. Seven of the 10 species of fern leaves known in the Petrified Forest Member are in the lower red member (table 1). One of the three species not represented in the lower red member flora may be incorrectly identified and may be referable to one of the other seven species. Thus, only two species based on fern foliage from the Petrified Forest Member definitely have not been collected from the lower red member. Although all the leaves of higher plants in the lower red member have not been examined in detail, preliminary studies showed that many of the species in the Petrified Forest Member also have been collected from the lower red member. The principal difference in the two floras is the absence in the lower red member of nearly all the species based on petrified wood that have been described from the Petrified Forest Member. Some of these exceptions may be due to accidents of preservation or collecting. Probably none are of stratigraphic significance.

In the vicinity of Arroyo del Cobre, the Chinle is divided into four members, as listed below from top to base (Colbert, 1960). The thickness of each is also given.

Units of the Chinle Formation Arroyo del Cobre area	*Thickness (feet)*
Petrified Forest Member	400–500
Poleo Sandstone Lentil	60
Salitral Shale Tongue	0–100
Agua Zarca Sandstone Member	100

Nearly all the fossil plants reported from Arroyo del Cobre were collected from the sandstone bed at the base of the Chinle Formation, which, as noted above, is the Agua Zarca Sandstone Member according to C. B. Read (written commun., 1967). Two pith casts were obtained from a horizon thought to be of Triassic age by Knowlton (Fontaine and Knowlton, 1890, p. 282), but the locality description suggests that the casts were actually derived from the underlying Permian rocks. Daugherty collected several fossils on Poleo Mesa, and I suspect that they were obtained from the Agua Zarca or its equivalent.

The correlation of the Triassic rocks in the Arroyo del Cobre area with those in east-central Arizona is difficult because of large intervening areas where Triassic rocks either are not exposed or have been removed by erosion. Thus, correlations between the two areas have to be based mainly on lithologic characteristics and vertebrate fossils, and there is room for conflicting opinions. Cooley (1959, p. 71–72) suggested that the Agua Zarca correlates with the upper part of the lower red member; the Salitral, with the lower part of the Petrified Forest Member; the Poleo, with the Sonsela Sandstone Bed; and the Petrified Forest Member, in this area, with the upper part of the Petrified Forest Member in west-central New Mexico and east-central Arizona. A somewhat different correlation was proposed by Colbert (1960) and by Colbert and Gregory (in Reeside and others, 1957, p. 1462–1464). They correlated the Agua Zarca and Salitral with the Shinarump Member, and

the Poleo with the lower red member. However, they also correlated the Petrified Forest Member in the Arroyo del Cobre area with the upper part of the Petrified Forest Member of the Chinle in Arizona.

The Chinle flora in the Arroyo del Cobre area is not well enough known to confirm or contradict any of these correlations. The vertebrate fossils, on the other hand, seem to be of some correlative value, according to J. T. Gregory (1957, p. 13). He indicated that the vertebrates from the Petrified Forest Member in this area seem to be more advanced than those from the lower part of the Petrified Forest Member in northeastern Arizona. In addition, they are similar to those in the upper part of the Petrified Forest Member in Arizona, according to Colbert and Gregory (in Reeside and others, 1957, p. 1464). Thus, the faunal evidence seems to indicate that the Chinle flora in Arroyo del Cobre occurs in the lower part of the Chinle Formation, just as it does in western New Mexico and eastern Arizona.

USGS PALEOBOTANY LOCALITIES

10058. In the lower part of the lower red member of the Chinle Formation (about 90 ft above the San Andres Limestone) in a roadcut on the east side of New Mexico State Highway 400 approximately 1¼ miles south of the Fort Wingate Post Office.

10059. In the lower part of the lower red member of the Chinle Formation (about 85 ft above the San Andres Limestone) in a roadcut on the east side of New Mexico State Highway 400 approximately 1½ miles south of the Fort Wingate Post Office.

10060. In the lower part of the lower red member of the Chinle Formation (about 80 ft above the San Andres Limestone) in the same roadcut as the previous locality and approximately 100 feet south of it.

10061. In the upper part of the lower red member of the Chinle Formation (about 225 ft above the San Andres Limestone) in the badlands about 1½ miles southeast of the Fort Wingate Post Office. This may be the same as USGS paleobotany locality 8958, which was discovered by C. B. Read and W. E. Salter in 1941.

10062. In the Petrified Forest Member of the Chinle Formation just below a thin tongue of the Newspaper Rock Sandstone of Stagner (1941) in the low hills on the west side of the principal road through Petrified Forest National Park, Ariz. SE¼ sec. 22, T. 18 N., R. 24 E. This is probably the same as Daugherty's (1941) locality p9301–1.

COMPOSITION

The composition and status of the megaflora in the Chinle Formation were discussed by Daugherty (1941, p. 24–27) and have been summarized more recently by Ash (1964, 1967a). The flora includes species based on leaves, fructifications, and stem material. Some specimens are preserved as compressions, others as petrifications or impressions. At present, the flora consists of 40 reasonably well defined species referable to 37 genera. A few additional species have been reported or briefly described, but in all cases the specimens are so poorly preserved or of such a nature that they cannot be critically evaluated. As collecting proceeds, the numbers, given above, will undoubtedly increase, but they give an indication of the size of the flora as it is now known.

Representatives of most major plant groups have been described from the Chinle Formation. One species has been referred to the Fungi, and two have been assigned to the Equisetales and to the Lycopodiales. The best understood and second largest group in the flora is the Filicales. It comprises 12 well-characterized species that are referrable to 10 genera. Five of the fern species based on foliar material are redescribed in detail under "Systematic Descriptions" of this report, and a cross-referenced list of all the ferns and fernlike fossils is included. The largest group in the flora is the Gymnospermae, which includes 16 described and two undescribed new species. Although the classification of several of the forms has not been determined, it is clear that members of the Cordaitales, Bennettitales, Ginkgoales, and Coniferales are present. One species has been referred tentatively to the Gnetales. Five new species of uncertain classification are also known.

CORRELATION AND AGE

In his compresensive study of the Chinle flora, Daugherty (1941) concluded that it was closely related to the flora in the Upper Triassic Newark Group of the Eastern United States. This conclusion was based on six species that he thought were common to both floras and six other species in the Chinle that he considered to be similar to forms in the Newark. Daugherty (1941, p. 37) stated that any differences "must be due in part to different climatic conditions during the time of deposition."

My own research on the Chinle flora suggests that this flora is not closely related to the so-called "Newark flora" of the Eastern United States. The floras do contain some of the same genera, but only one or two species may be common to both. Otherwise, they seem to be quite distinct.

The six species from the Chinle flora that Daugherty held to be identical with the species in the Newark flora are listed below, together with my own findings:

Cladophlebis microphylla. The specimens identified as *C. microphylla* are here referred to *C. daughertyi* n. sp. They do not appear to resemble any described species in the Newark flora of the Eastern United States.

Cladophlebis reticulata. A single small fragmentary leaf was referred to this species. However, close examination of the specimen suggests that it is distinct from *C. reticulata* and does not closely resemble any described species in the Newark flora. The leaf compares with specimens obtained recently from the lower red member of the Chinle at a locality about 30 miles east of Fort Wingate. Possibly, all these specimens should be described as a new species of *Cladophlebis.*

Lepacyclotes circularis. The several specimens Daugherty assigned to this species were transferred tentatively to *Isoetites circularis* (Emmons) Brown. They do look somewhat like those curious plant fossils from the Newark flora, although they differ in detail. The Chinle specimens may be correctly assigned generically, but I think they should be referred to a species other than *circularis.*

Lonchopteris virginiensis. Specimens that have been referred to this species are here assigned to *Cynepteris lasiophora* n. gen., n. sp. They do not resemble any described form in the Newark flora.

Macrotaeniopteris magnifolia. The two specimens referred to this species were misidentified. They have about 42 lateral veins per centimeter, whereas *M. magnifolia* has only about 20 per centimeter. These specimens do not resemble closely any in the Newark flora. Cuticles of several specimens from the Chinle that agree in gross morphology with those considered by Daugherty have been examined. Two specimens came from Daugherty's locality in Dinnebito Wash, Ariz., and the others were collected from the upper part of the lower red member of the Chinle Formation near Fort Wingate, N. Mex. All the specimens have syndetocheilic stomata. Leaves with the gross morphology and cuticle shown by these specimens are usually referred to the genus *Nilssoniopteris* Nathorst. Although it is assumed that Daugherty's two specimens also have syndetocheilic stomata, the possibility exists that they do not. Until cuticle preparations can be made of Daugherty's specimens, this question will remain open. However, his material probably does not vary greatly from the specimens I have examined.

Neocalamites virginiensis. The material that was referred to this rather imperfectly characterized genus and species may be correctly identified. The Chinle and Newark specimens need to be studied in detail, however, and the whole question of the status of *Neocalamites* must be critically evaluated before any significant conclusions can be drawn about their value as index fossils.

The six species that were held by Daugherty (1941, p. 36–38) to be closely related to forms in the Newark Group are *Araucarioxylon arizonicum, Clathropteris walkeri, Otozamites powelli, Pagiophyllum newberryi, Phlebopteris* (*Laccopteris*) *smithii,* and *Podozamites arizonicus.* Three additional, but poorly known, species (*Lycostrobus chinleana, Zamites occidentalis,* and *Equisetites* sp.) in the Chinle were tentatively considered also to be closely related to forms in the Newark. In most cases, however, Daugherty did not specify which of the species in the Newark Group were closely related to the nine forms in the Chinle which makes it difficult to verify his conclusions.

Three of the species listed by Daugherty (*C. walkeri, O. powelli,* and *P. smithii*) definitely do not closely resemble any species described from the Newark Group. One species (*A. arizonicum*) may fairly closely resemble *A. woodworthi* from the Newark, but both species have not been reconsidered since they were originally described in the late 1800's. The other five species are too poorly known because of poor preservation and limited material to be compared with any forms in the Newark Group with any assurance at all.

In summary, of the six species in the Chinle flora identified with members of the Newark flora, four (*C. microphylla, C. reticulata, L. virginiensis,* and *M. magnifolia*) were apparently misidentified and seemingly do not resemble any form in the Newark flora. Furthermore, one species (*L. circularis*) is probably wrongly identified and is not represented in the Newark flora. The sixth (*N. virginiensis*) may be correctly identified, but its value as an index fossil is questionable. Eight of the nine other species in the Chinle held to be closely related to forms in the Newark Group are now

considered to be distinct or are too poorly known to be of comparative value. The ninth species, *A. arizonicum*, may be closely related to a form in the Newark. Thus, the Chinle and Newark floras do not seem to be as closely related as was formerly thought.

Daugherty (1941, p. 39) thought that the Chinle flora correlated also with the large flora in the Upper Triassic rocks of Sonora, Mexico. The principal studies of the Mexican flora are by Newberry (1876) and Silva Pineda (1961). Only a small part of the flora has been described, so any factual conclusions about the composition and correlation of the Mexican flora are difficult to make. The collections described by Newberry and Silva Pineda contain several species superficially resembling specimens in the Chinle flora, but detailed examination showed that they are distinct, and it appears at this time that the two floras are not closely related.

Daugherty (1941, p. 17) reported that the Dockum Group in west Texas, which is considered to be the lateral equivalent of the Chinle, contained several of the Chinle species. Species of *Araucarioxylon arizonicum*, *Otozamites powelli*, and *Woodworthia arizonica* were definitely identified in the Dockum, and *Pelourdea* (*Yuccites*) *poleoensis* was tentatively identified. No one else has worked on the Dockum flora, and Daugherty (1941) only mentioned it briefly in his report on the Chinle flora. Recently, I collected specimens of *O. powelli* and two undescribed species from several localities in the Tecovas Formation in the lower part of the Dockum in west Texas. They compare exactly with species known from the Chinle, and it is apparent that the Chinle flora is more closely related to the Dockum flora than it is to any other now known.

The Chinle Formation is generally considered to be of Late Triassic age (Reeside and others, 1957, p. 1456). The age determination is based primarily upon vertebrate fossils, which suggest that the Chinle correlates with the Lettenkohle and Gypskeuper of the Keuper, the type Upper Triassic of Germany. According to J. T. Gregory (1957, p. 17), the Chinle vertebrates also indicate that the formation correlates with all but the upper part of the Newark Group in the Eastern United States. He considered the lower part of the Chinle to be slightly older than the principal fossil-leaf-bearing part (Cumnock Formation and equivalent units) of the Newark Group in the Eastern United States. This theory has been strengthened by Baird and Patterson (1967), who reported that in North Carolina the Pekin Formation (which underlies the Cumnock Formation) contains a reptilian fauna association similar to the fauna in the lower fossil-leaf-bearing part of the Chinle Formation—that is, in the lower part of the Petrified Forest Member and the lower red member. The apparent differences in the age of the fossil-leaf-bearing units in the Newark and Chinle may help explain why the two floras are so distinct.

SYSTEMATIC DESCRIPTIONS

Phylum PTERIDOPHYTA
Order FILICALES

Family OSMUNDACEAE

Genus TODITES Seward, 1900, em. Harris, 1961

Emended diagnosis.—Leaf bipinnate; pinnules with a midrib and diverging lateral veins. Fertile pinnules bearing sporangia either along the veins or scattered over the lower side of the lamina. Sporangia large, ovoid, almost sessile; cells of apical region thickened, opening by a longitudinal slit. Spores with a triradiate scar.

Todites fragilis Daugherty, 1941

Figures 13, 14; plate 1

1941. *Todites fragilis* Daugherty, p. 52–53, pl. 6, figs. 3, 5.

Emended diagnosis.—Leaf bipinnate, petiolate, lanceolate, as much as 6 cm wide, 12.5 cm long. Petiole and rachis as much as 1.2 mm wide, surface smooth, showing fine cellular striate about 20μ wide, surface bearing stiff backward- and outward-pointing multicellular hairs 700μ–800μ long, 16μ–23μ thick, arising from a slightly enlarged base, shaft with parallel sides, widening slightly at transverse cell walls, tapering to a sharp point in upper quarter of hair, usually composed of four or five cells.

Pinnae arising at about 45° and bending outward to about 80°, sometimes recurved; rachis slender; lamina linear-lanceolate as a whole; apex obtuse; lamina asymmetrical; acroscopic part of lamina about twice as wide as basiscopic part. Lower part of lamina divided into pinnules; acroscopic pinnules being more strongly developed than basiscopic; lowest one to four pinnules having lamina divided to pinnae rachis, but later ones divided progressively less deeply, having shallow indentations along margin in upper part of pinae, indicating divisions between individual pinnules. First pinnule arising on acroscopic side close to and usually overlapping rachis. First few acroscopic pinnules roughly parallel to main rachis, others inserted at an angle of 60°–70°; typically 4–9 mm long, 1.5–2.5 mm wide. No pinnules near rachis on basiscopic side of pinna rachis; basiscopic pinnules about 2–3 mm long, 1 mm wide, inserted at an angle of about 20°–35°. Pinnule margins entire to obtusely dentate; substance of

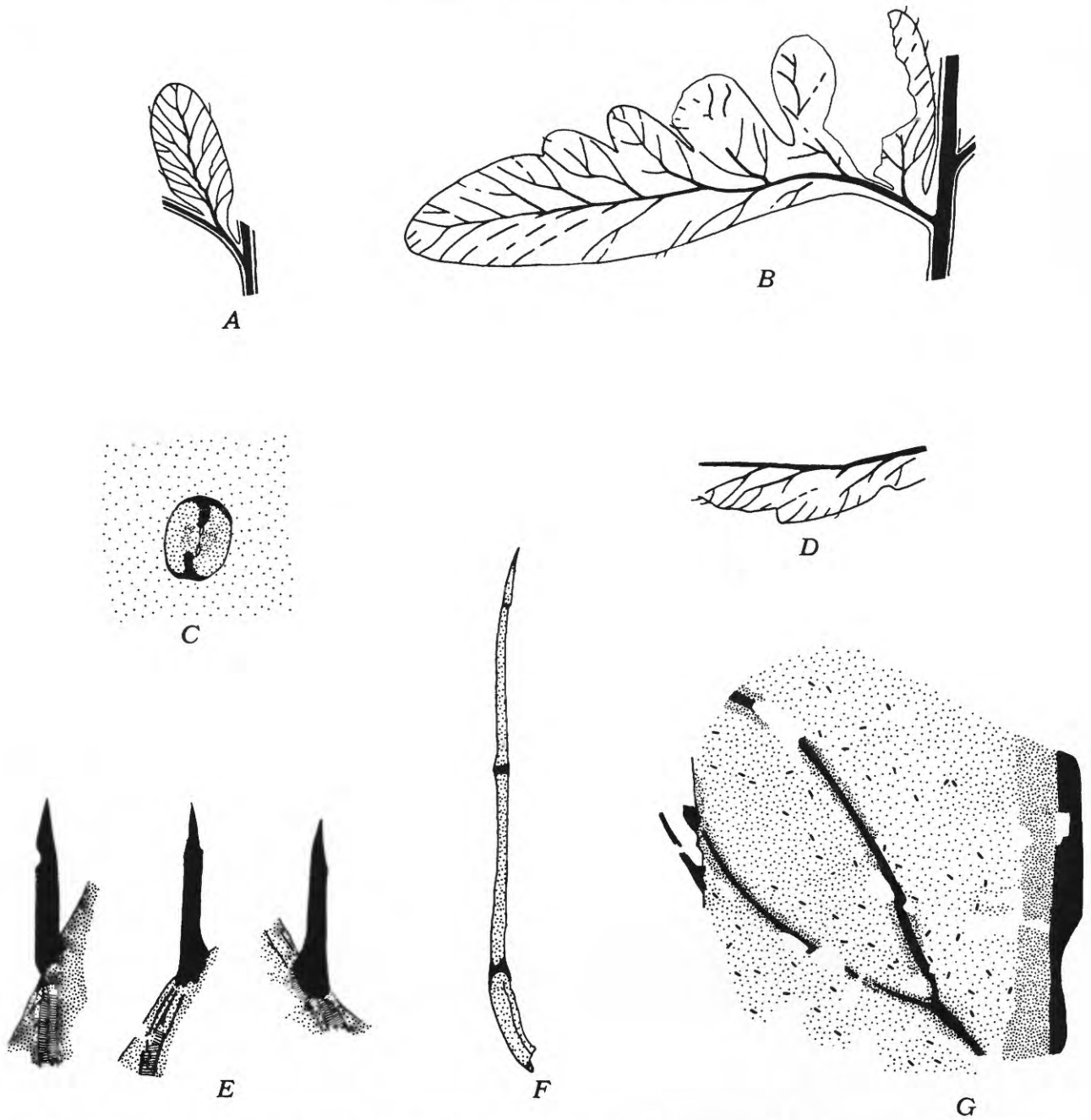

FIGURE 13.—*Todites fragilis* Daugherty from USGS paleobotany locality 10061, lower red member of Chinle Formation, Fort Wingate, N. Mex. *A*, First pinnule of a sterile pinna, showing lamina divided to the pinna rachis. Transfer preparation, USNM 42935, × 5. *B*, Small sterile pinna, showing deeply divided pinnules near main rachis on acroscopic side of pinna rachis and less deeply divided pinnules elsewhere on pinna. Transfer preparation, USNM 42935, × 5. *C*, Stoma on lower epidermis, showing thick region near aperture. Transfer preparation, USNM 42935, × 400. *D*, Three fused sterile pinnules from basiscopic side of pinna, showing shallow indentations along outer margin denoting location of divisions between individual pinnules. Transfer preparation, USNM 42935, × 5. *E*, Three spinelike hairs from margins of pinnule; edge of pinnule shown by stippling; tracheids indicated by ladderlike figures in veins. Transfer preparation, USNM 42937, × 100. *F*, Hair from pinna rachis of pinnule. Transfer preparation, USNM 42936, × 100. *G*, Part of sterile basiscopic pinnule (lower epidermis); pinna rachis shown at right of drawing; lower margin of pinna at left; stomatal apertures shown by short black lines (a few may be missing); one nearly complete marginal hair and base of another are shown. Transfer preparation, USNM 42936, × 50.

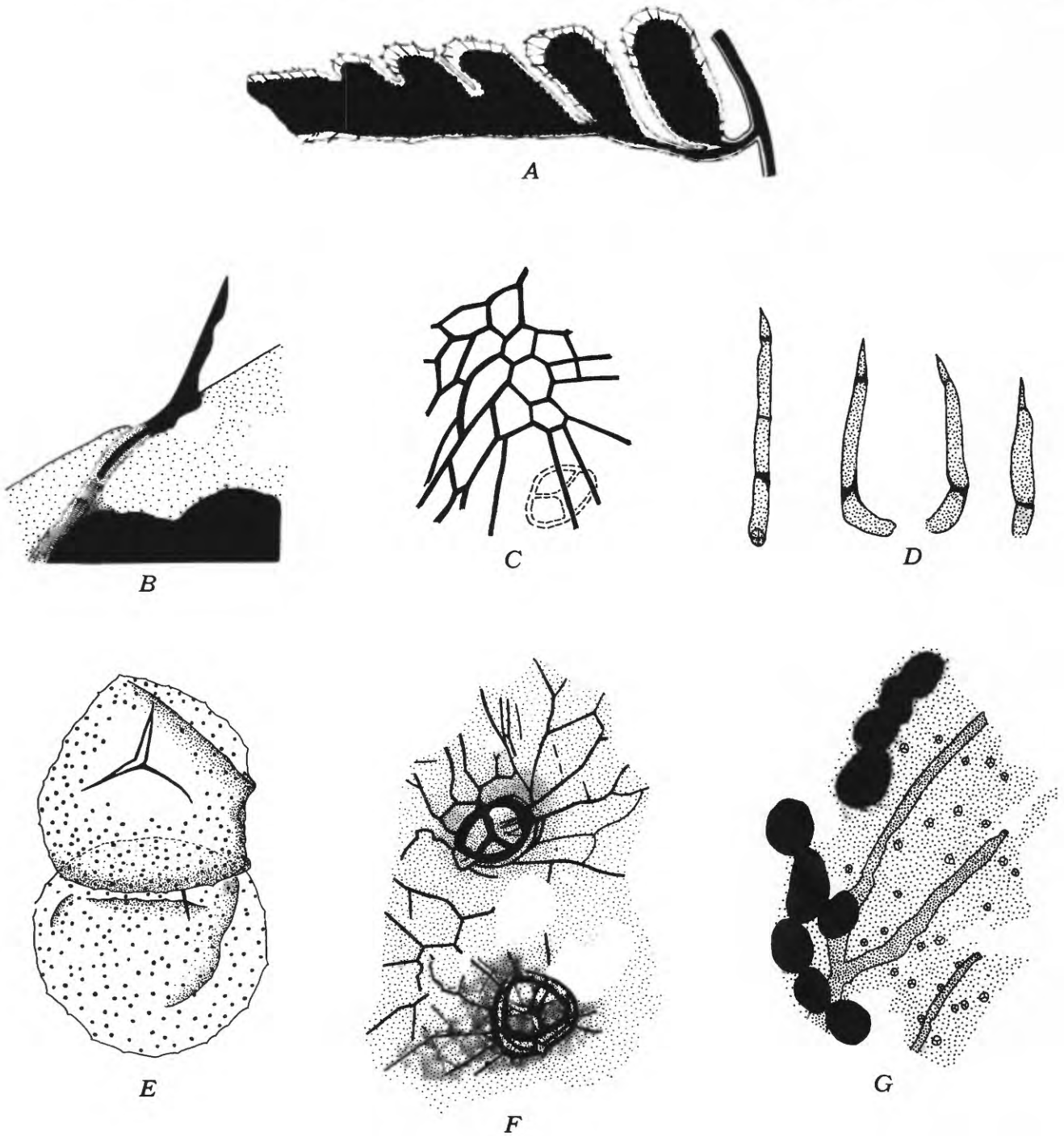

FIGURE 14.—*Todites fragilis* Daugherty, fertile leaf, from USGS paleobotany locality 10061, lower red member of Chinle Formation, Fort Wingate, N. Mex. *A*, Typical fertile pinna, showing obtuse dentation along margin of some pinnules, spines on margins at vein endings, and abundant sporangia (solid black areas on pinnules; sporangia too closely packed to indicate individuals accurately). Apex of pinna missing. Transfer preparations, USNM 42937 and 42938 (part and counterpart), × 5. *B*, Part of fertile pinnule (lower epidermis), showing spine on margin at end of a vein, two sporangia (large black dots) and extent of recognizable tracheids in vein. Transfer preparation, USNM 42937, × 100. *C*, View of thickened cells of apical region of sporangia overlying basal area of attachment of same sporangia. Transfer preparation, USNM 42936, × 300. *D*, Four hairs from lamina, and veins of fertile pinnule. Transfer preparation, USNM 42936, × 100. *E*, Two spores. USNM 42939, × 1,000. *F*, Basal area of attachment of two sporangia and parts of adjacent sporangial cell walls. Transfer preparation, USNM 42940, × 300. *G*, Part of fertile pinnule (lower epidermis), showing numerous sporangial stalks (small circles divided into 3 cells) and several sporangia (large black dots) still attached to lamina. Transfer preparation, USNM 42937, × 50.

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lamina delicate; narrow flange of lamina running decurrently from each pinna along the margins of rachis, joining lamina of next pinna below. Pinnule midrib slender, clearly marked, arising at an angle of 40°–50°, bending forward; lateral veins distinct, prominent, approximately 0.15 mm wide; pinnule midrib and lateral veins bearing hairs like those on main rachis but shorter, 200μ–300μ long, 20μ–25μ thick. Veins in acroscopic pinnules given off pinna rachis at an acute angle, first vein arising from basiscopic side a short distance above pinna rachis, later ones alternating anadromically; veins once forked at a point about midway between midrib and pinnule margin. Lamina on basiscopic side of pinna rachis usually showing once-forked veins only, forking occurring at a point midway between pinna rachis and margin of pinnule. Veins extending to margin of pinnules, tending to curve forward abruptly near margins, frequently running along margin for a short distance; having concentration of about three per millimeter at pinnule margin. Short stiff hairs about 300μ long, 25μ wide, having expanded base, usually present at place where vein reaches margin and occasionally again at end of vein.

Stomata oval, 25μ–30μ long, 10μ–13μ wide; pore typically 10μ–11μ long; scattered, orientation random or parallel to nearest vein; about 65–80 per square millimeter on lower surface of lamina.

Fertile and sterile pinnae on same leaf; fertile pinnae slightly smaller than sterile pinnae; basiscopic lamina even more reduced than in sterile pinnae, but otherwise similar to sterile pinnae. Sporangia numerous, solitary, scattered over lower surface of fertile pinnules, completely covering surface of lamina except in areas near free margins, obscuring midribs and veins. Sporangia round to oval, typically 150μ–230μ in diameter, stalk extremely short, round in section 30μ–35μ wide in diameter, composed of three cells (occasionally four cells), anticlinal walls of stalk cells 4μ thick. Apical region showing straight-walled isodiametric polygonal cells, about 25μ–30μ in greatest dimension, anticlinal walls 3μ thick. Region below sporangial apex showing two or three rows of conspicuous elongated straight-walled cells about 45μ–110μ long, 9μ–18μ wide, anticlinal walls 3μ thick. Ordinary cells of sporangial wall elongated, anticlinal walls about 1μ thick. Spore content probably 128, spore rounded to slightly triangular, width 32μ–42μ, triradiate mark simple, narrow, slightly longer than one-half spore radius, margins unspecialized. Contact facets of spore unornamented; other surfaces covered with small spines slightly less than 1μ high; wall of spore about 1μ thick. Fertile pinnules bearing abundant multicellular hairs between sporangia, similar to those on midrib and veins, except that they are not expanded at transverse cell walls.

Description.—Most of the specimens consist of a short length (usually less than 2 cm long) of the main rachis with a few attached pinnae. The largest specimen known is about 12.5 cm long. All pinnae are incomplete on this specimen; the longest measures 3 cm, indicating that the entire leaf was more than 6 cm wide. The specimen has a petiole about 3.5 cm long. The holotype (Daugherty, 1941, p. 6, fig. 3), which is somewhat smaller, is about 8 cm long and 3.7 cm wide. It shows 20 more or less complete pinnae and apparently came from the middle of a leaf. The thickened cells of the sporangia, as vertically compressed, nearly always lie directly over the stalk. In a few places where the stalk is not covered by the thickened cells, it is covered by a few thin cell walls of the unthickened part of the sporangia. The stalk must be quite short, as it was never seen in side view, and appeared to have been compressed vertically in every specimen. Although the stalk generally is composed of three cells, in one specimen it consisted of four cells.

Several sporangia were macerated, and each yielded 100–125 spores. The spores separated very readily and apparently are mature or nearly so.

Comparisons.—Of all the species of *Todites* known to me, *T. fragilis* most closely resembles *T. princeps* (Presl) Gothan as recently emended by Harris (1961, p. 94–96). Both species have sphenopterid venation, anadromic branching, bear similar hairs on the pinnae rachises and pinnule midribs, have about the same number of spores in a sporangium, and have spores of about the same size and shape. Each of the species has several characteristics that can be used to distinguish it. The most obvious is the distinctly asymmetrical pinnae of *T. fragilis* which have rather short pinnules on the basiscopic side of the pinna rachis and much longer pinnules on the acroscopic side. This contrasts with the nearly symmetrical pinnae of *T. princeps*, which have pinnules on the basiscopic side that are slightly longer than those on the acroscopic side of the pinna rachis. In *T. fragilis* the separation of the pinnules varies from being completely divided to the pinnae rachis near the main rachis to being completely fused in the upper part of the pinnae, whereas in *T. princeps* most of the pinnules are divided nearly all the way to the pinna rachis. The pinnule margins of *T. fragilis* are typically entire, whereas they are notched or lobed in *T. princeps*. In

addition, the sporangia are widely distributed on the lamina of *T. fragilis*, rather than lying along the veins as in *T. princeps*. The spores of *T. fragilis* are finely echinate, not smooth as those of *T. princeps*, and the margins of the pinnules of *T. fragilis* characteristically bear short stiff spinelike hairs at the vein endings which are absent in *T. princeps*. The primary branches (pinnae) of *T. fragilis* are rather like the secondary branches (pinnules) of a large tripinnate leaf of *T. princeps*. Although the two species are similar in some respects they are sufficiently different in other ways to warrant them being considered distinct.

Harris (1931, p. 31; 1961, p. 76) showed that all the known species of *Todites* can be separated into three groups on the basis of venation. *T. fragilis* fits into the *T. princeps* group, which is characterized by sphenopterid venation and formerly contained *T. princeps* alone.

Todites fragilis differs from all the modern members of the Osmundaceae by its larger, more apical patch of thickened cells on the sporangia and by its distinctly asymmetrical pinnules. Among the modern Osmundaceae, *Todites fragilis* most closely resembles *Todea* (*Leptopteris*) *frazeri* by having little modified fertile pinnules in the lower part of the leaf, sporangia covering nearly the entire lower surface of the fertile pinnules, approximately the same number of spores in a sporangia and sphenopterid venation. The sporangia in *Todea* (*Leptopteris*) *frazeri*, however, are several times the size of the sporangia of *Todites fragilis*, and the pinnules are more deeply lobed throughout the pinna than in *Todites fragilis*.

Remarks.—Although only a few fragmentary specimens of *T. fragilis* are known, our knowledge of its characteristics is remarkably complete. There are two important exceptions: the size and shape of the entire leaf is a matter of conjecture, and nothing is known of its epidermal cells.

Material.—Holotype: UCMP (Univ. California Mus. Paleontology) 1539. Paratype: UCMP 1540.

Distribution.—This distinctive fern is rather rare. Only a few small fragments have been found at three localities. The most productive are USGS paleobotany localities 10059 and 10061 in New Mexico, where 12 specimens and four counterparts were collected. The only other locality is in Petrified Forest National Park, where two specimens, including the holotype, were obtained from Daugherty's locality P3901–1 (USGS paleobotany locality 10062 of this report).

Family CYNEPTERIDACEAE Ash, n. fam.

Diagnosis.—Leptosporangiate ferns with compound leaves, all veins originating from pinnule midribs, venation reticulate, no blind-ending vein branches except at margins. Fertile and sterile leaves similar. Sporangia solitary, superficial, open vertically; stalk short; annulus a horizontal ring around apex; complete, small apical plate present.

Genus CYNEPTERIS Ash, n. gen.

Diagnosis.—Leaf twice pinnate, branching katadromic. Adjacent pinnules connected by narrow lamina, margins typically entire, veins anastomose and bifurcate several times, forming a coarse reticulation. Sporangia oval, numerous, attached over and between veins, retained after dehiscence, about 220μ long, 150μ wide; stalk not exactly opposite annulus; annulus apical, complete, uniseriate except near stomium. Spores rounded, triradiate; surfaces nearly smooth.

Type species.—*Cynepteris lasiophora* n. sp.

Remarks.—The name is from κυνη, a cap, and refers to the appearance of the annulus on the apices of the sporangia.

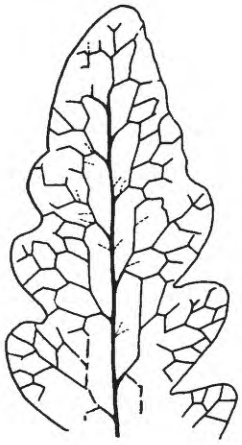
Cynepteris lasiophora Ash, n. sp.

Figures 15, 16; plates 2, 3

1941. *Lonchopteris virginiensis* auct. non Fontaine. Daugherty, p. 49, pl. 5, figs. 1, 2; pl. 6, figs. 1,2.

1941. *Lonchopteris*(?) sp. Daugherty, p. 50, pl. 4, fig. 2. (Specimen from upper part of leaf).

Diagnosis.—Lamina as a whole as much as 24 cm wide, length unknown, possibly 1 m, apex of lamina acute (base and petiole unknown). Main rachis rather slender, not grooved above, smooth, attaining 3 mm in width, showing fine cellular striae 10μ–15μ wide, bearing frequent, slender, but stiff, simple hairs pointing backwards and outwards. Hairs uniseriate, 350μ–600μ long, composed of three or four cells, having bulbous base approximately 35μ–50μ wide, base tapering above (sometimes quite abruptly) to 15μ; sides of hair shaft parallel to a point about 50μ from apex of hair, where it begins to taper to an acute point. Similar hairs occur on pinna rachis and on pinnule midribs, veins, and margins, and occasionally on lamina. Pinna as much as 12 cm long, arising laterally at intervals of 6–15 mm at an angle of 60°–70°, occasionally at a higher angle. Pinna rachis marked with narrow cellular striae about 10μ–15μ wide. Lamina of pinna (taken as a whole) elongated, acute, base constricted; narrow flange of lamina runs decurrently from each pinna along margins of rachis, joining lamina of next pinna below. Branching katadromic throughout.



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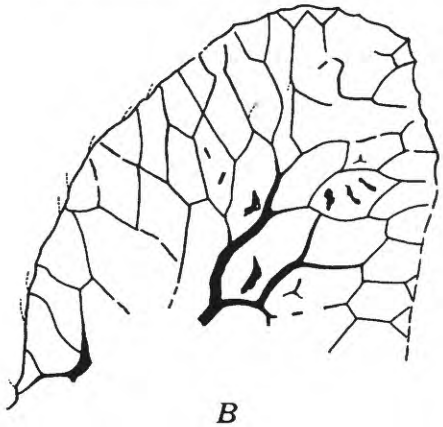

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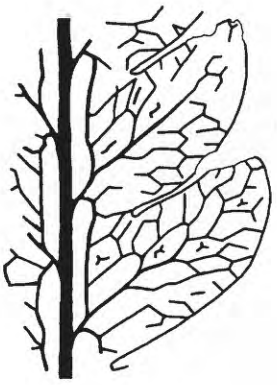

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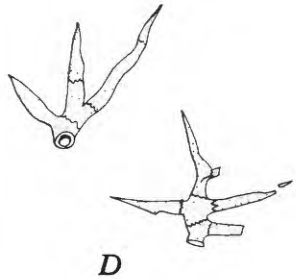

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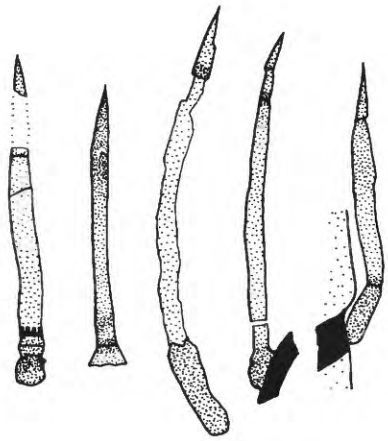

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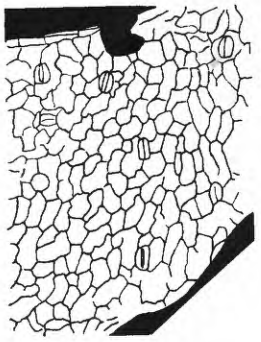

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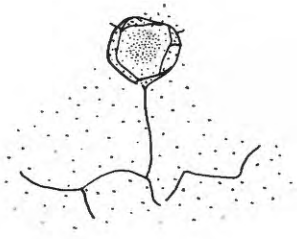

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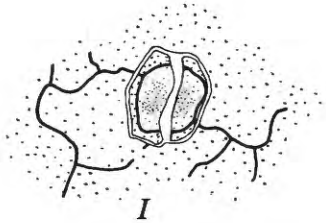

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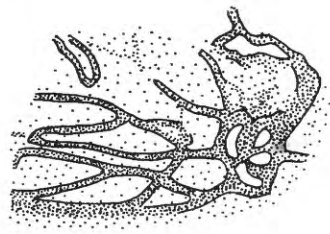
Pinnules decurrent, oblong, typically 2.5–3.5 mm wide and 5.0–7.0 mm long in middle of leaf, becoming smaller (1 mm wide, 2 mm long) in upper part of leaf and larger and often elongated (6 mm wide, 15 mm long) in lower part of leaf; slightly falcate, apex acute to obtuse, margins entire to obtusely dentate, surface flat, substance of lamina delicate, veins projecting on lower side. Adjacent pinnules connected by an undivided lamina about 0.5 mm wide, separated by narrow rounded sinus; some free parts of pinnules overlap. First pinnule arising on basiscopic side of pinna rachis close to main rachis; later ones alternate katadromically, typically arising at 60°–70° to pinna rachis; pinnules in lower part of leaf typically arising at 80°–90° to pinna rachis.

Midrib of pinnule stout at base, becoming slender in middle of pinnule, clearly marked, arising at an angle of 30°–40° but often bending outward near base, sometimes changing direction one or more times, disappearing at or slightly beyond middle of pinnule. Lateral veins distinct, prominent, approximately 0.1 mm wide, alternate, given off midrib at an acute angle and at irregular intervals (about 1–2 mm), forking at once into forward and backward branches which join those of adjacent veins to form primary arches. Primary arches wider than high, angular, giving off two to five outer veins. All outer veins usually anastomosing two or more times with adjacent veins, forming angular, nearly isodiametric to elongated polygonal meshes. Basal web connecting adjacent pinnules containing one strong, forward- and backward-running sinuous vein originating from pinnule midribs; vein parallels pinna rachis, forming a low, long primary arch. Primary arch typically giving off four outer branches which usually anastomose one or more times with adjacent branches. Vein meshes and primary arches never containing blind vein endings; veins always free at margins.

Cells of upper and lower surface irregularly shaped, typically more or less equidimensional, becoming polygonal and elongated near veins and pinna rachis; anticlinal cell walls wavy to slightly sinuous, about 1.5μ thick. Stomata on lower epidermis scattered, sparse, about 60–80 per square millimeter; orientation random or parallel nearest vein, absent in narrow zone along pinnule margins. Guard cell pair usually oval, 27μ–52μ long, 22μ–34μ wide, stomatal aperture 10μ–16μ long; guard cells overlapping epidermal cells to a small extent. Trichome bases on lower epidermis rare to sparse (estimated from 0 to 60 per sq mm), irregularly distributed, usually unicellular, consisting of a ring on surface of small slightly thickened, round or oval epidermal cell about 14μ–23μ across. Free part of two types: (1) a simple hair similar to those on midribs; and (2) stellate hairs consisting of a single basal cell bearing two to five pointed branches. Branches stiff, uniseriate, about 90μ–140μ long, 11μ–22μ thick, composed of two to four cells; individual branches similar to simple hairs.

Fertile pinnules similar in size, shape, and venation to large elongated sterile pinnules in lower part of leaf; fertile and sterile pinnules on same pinna. Sporangia numerous, solitary, scattered over all lower surface of pinnules, or restricted to basal part of pinnules, oval to inversely pear shaped, typically 210μ–245μ long, 140μ–175μ wide, stalk about 24μ in diameter. Ordinary cells of sporangial wall elongate parallel to major axis of sporangium, about 14μ broad, and 35μ–40μ long, anticlinal walls about 1μ–2μ thick, almost straight. Annulus apical, complete, well developed, conspicuous, occupying about one-third of the length of sporangium, sometimes slightly narrower than remainder of sporangium, formed of a single row of 14–16 straight-walled cells

FIGURE 15.—*Cynepteris lasiophora* Ash, n. gen., n. sp. *A–C, D* (left figure), *E–I* from lower red member of Chinle Formation, Fort Wingate, N. Mex. *D* (right figure), *J* from Petrified Forest Member of Chinle, Petrified Forest National Park, Ariz. *A, B, D* (left figure), *E–I* from USGS paleobotany locality 10061; *C* from USGS paleobotany locality 10060; *D* (right figure), *J* from USGS paleobotany locality 10062. *A*, Pinna from upper part of leaf showing indented margin typical in this part of leaf; hairs shown by short dashes. Compare with specimen shown by Daugherty (1941) and illustrated in his report on plate 4, figure 2. USNM 42943, × 5. *B*, Upper part of typical pinnule from central area of leaf showing obtuse dentation, hairs (short dashed lines), and irregularly branching structures of uncertain function between veins. Long dashed lines represent obscure imprints of veins, and margin of pinnule. USNM 42944, × 10. *C*, Part of typical pinna from central region of leaf. Several of the structures of uncertain function shown in vein meshes. USNM 42945, × 5. *D*, Two stellate trichomes. Transfer preparations USNM 42953 and 42951, × 100. *E*, Five simple hairs. Two hairs on right attached to vein (solid black) on pinnule margins. Three hairs on left from transfer preparation, USNM 42954; others are from transfer preparation, USNM 42955. All × 100. *F*, Lower epidermis. Transfer preparation, USNM 42956, × 100. *G*, Bases of two pinnae and adjacent rachis showing constricted bases and narrow flange of lamina running decurrently along rachis between pinnae. Hairs on rachis shown by short white lines, Drawn on a photograph. USNM 42946, × 5. *H*, Trichome base on lower epidermis. Transfer preparation, USNM 42953, × 400. *I*, Stoma on lower epidermis viewed from outside of leaf showing guard cells overlapping ordinary epidermal cells. Thick region near aperture darkly stippled. Transfer preparation USNM 42957, × 400. *J*, Lower epidermis showing stomatal apertures (short lines), trichome bases (large dots), and anastomosing veins. Possibly a few stomata and trichomes are missing. Transfer preparation, USNM 42952, × 25.



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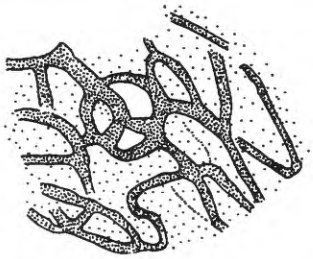

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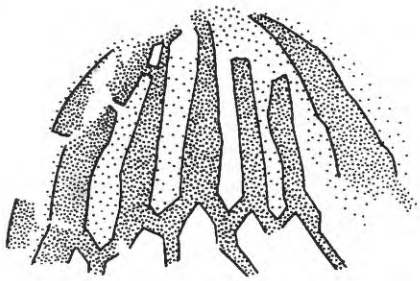

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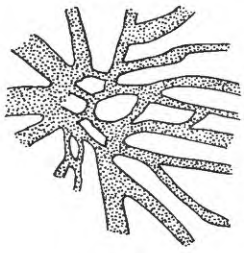

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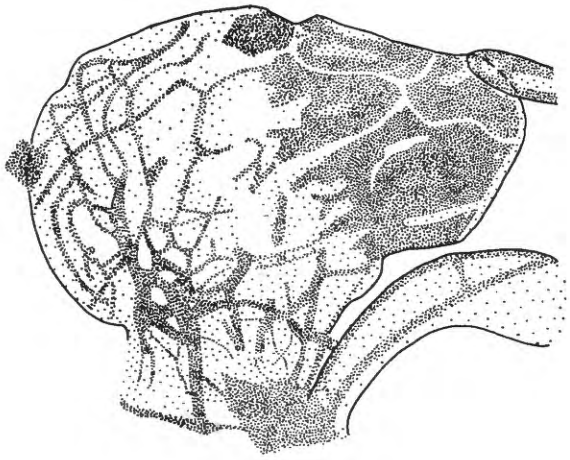

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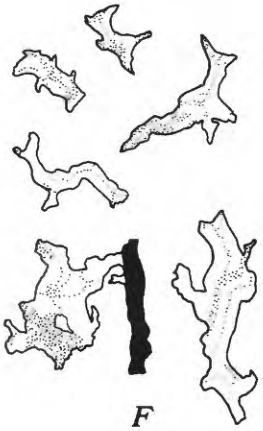

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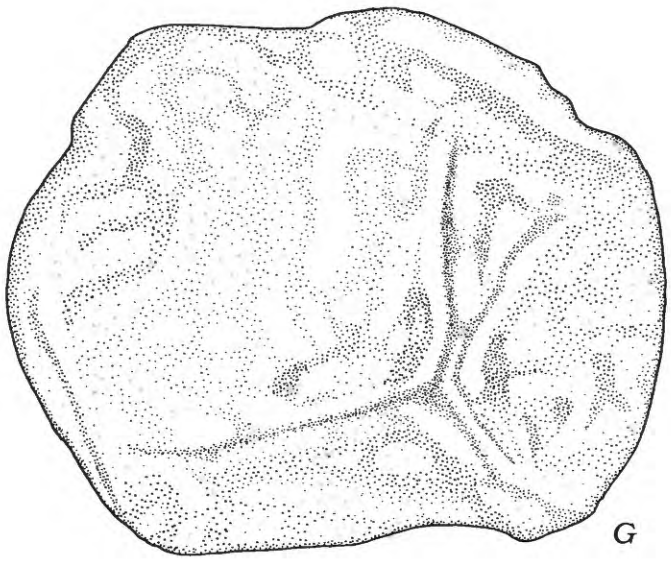

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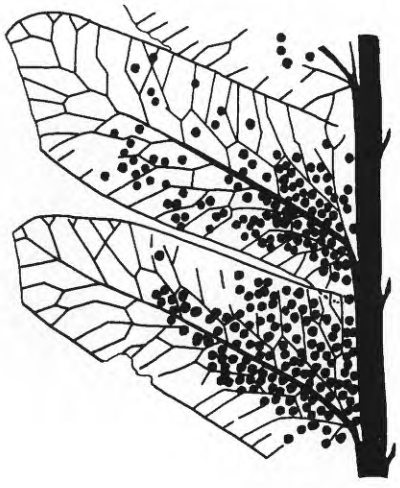


H

except near stomium, here two to four cells deep, cells of annulus about 6μ–9μ broad, 60μ–70μ long, radial walls 6μ–9μ thick, dehiscence longitudinal, stomium along whole length of annulus. Thick-walled cells surround small apical patch of several thin-walled cells. Estimated spore content 64; spores rounded to rounded-triangular, width in polar view 38μ–49μ (mean 42μ, standard deviation 4μ), spore wall 1μ thick. Distal side hemispherical, proximal side slightly flattened, triradiate mark simple, narrow, margins unspecialized, nearly as long as spore radius. Both surfaces of spore covered with irregular broad ridges having low relief and forming low reticulations, wall of spore typically about 1μ thick, irregularly thickened on both inside and outside of wall.

Description.—Most specimens of *Cynepteris lasiophora* studied consist of isolated and fragmentary pinna; a few of the pinnae, however, are attached to a rachis. One of the largest specimens known to me consists of part of the rachis with 13 nearly complete pinnae (pl. 2, fig. 3).

The diagnosis made clear that as we do not know the lower part of the leaf, the statement that the leaf as a whole is lanceolate is not fully certain. The estimate of its length is based on the very slight taper of the rachis in the largest fragments.

The precise attachment of the sporangia is not plain because the specimens showing them do not have the veins clearly preserved. Their stalks have been observed in side view in several places, although mostly they are preserved as vertical compressions. Nearly all the sporangia studied have dehisced, but some of those macerated yielded several dozen spores which were alike and indeed remarkably similar. The spore walls appeared almost smooth, and the sculpture was only recognized when they were studied at high magnification and under phase contrast illumination. One macerated sporangium, which may have been immature, yielded a compact mass of spores 130μ long. The individual spores measure about 40μ wide. From the calculated volume of individual spores and of the whole mass, there would be space for about 64 spores.

The lower surfaces of some sterile pinnules of this species from USGS paleobotany locality 10061 bear numerous irregularly branching structures. They occur on the lamina, mainly between the veins, although a small percentage are attached to an adjacent vein. (See fig. 16F and pl. 3, fig. 1.) Often there is more than one in a vein mesh. They are of various shapes. Some are stellate and have three or more branches. Others consist of a large irregular "trunk" with several branches extending outward. Most of the structures appear to be tubular, and they frequently contain what appear to be cell walls dividing them into two or more cells. The structures vary considerably in size. One of the largest on a pinnae has a "trunk" slightly more than 1 mm long. The "trunk" is about 60μ wide at the broadest and has a rather irregular form. There are at least 10 branches extending outward at various angles from the "trunk." Some are as much as 200μ long, and several bifurcate one or more times.

The function of these curious structures is unknown. They do not seem to be made up of vascular tissue, and they appear to be on the surfaces of the pinnules, so the structures probably are not part of the vascular system of the plant. A second possibility is that they are some type of trichome, but no trichome bases of the size of these structures have been observed on the pinnules. They may be the remains of fungi hyphae. This is more likely, as a few branches were observed which appear to penetrate stomata.

Comparisons.—The material described here cannot be placed in the species *virginiensis* of Fontaine nor in the genus *Lonchopteris* Brongniart as formerly held.

1. Specific differences from *L. virginiensis* Fontaine:

   Daugherty (1941, p. 49) quoted all of Fontaine's (1883, p. 53) description of *L. virginiensis* and used it as a description for the new specimens that he considered from the Chinle of Arizona. However, neither the specimens examined by Daugherty nor the comparable specimens collected by me in

FIGURE 16.—*Cynepteris lasiophora* Ash, n. gen., n. sp. from lower red member of Chinle Formation, Fort Wingate, N. Mex. *A–E, G* from USGS paleobotany locality 10059; *F* from USGS paleobotany locality 10061; *H* from USGS paleobotany locality 10058. *A, B, Basal* area of attachment of two sporangia. Transfer preparation, USNM 42958, × 300. *C*, Side view of annulus showing thick radial walls and relatively narrow cells. Transfer preparation, USNM 42959, × 300. D, Apical part of sporangium. Thin-walled cells of stomium are to right and are continuous with small, thin-walled cells of apical plate. A few of the thick radial walls of annulus are preserved to the left of plate. Transfer preparation, USNM 42960, × 300. *E*, Sporangium in side view. A hair occurs above and to the right, and another occurs below and to the right. Basal cells are below and to the left and some tissue of doubtful nature occurs at base of sporangium. Same specimen as plate 3, figure 6. Transfer preparation, USNM 42959, × 300. *F*, Six selected structures of unknown function from lamina of sterile pinnule. Cell walls within each shown by dotted lines; heavy stippling indicates dark areas in these structures. Structure in lower left is apparently attached to vein. Transfer preparation, USNM 42989, × 50. *G*, Spore, drawn under phase contrast illumination. USNM 42961, × 2,000. *H*, Parts of several typical fertile pinnules. Sporangia shown by large black dots, some may be missing. Drawing from a photograph. USNM 42947, × 5.

New Mexico and Arizona fit Fontaine's description in all respects, nor do they look very much like the type material of *L. virginiensis* collected in Virginia (Fontaine, 1883, p. 53, pl. 28, figs. 1, 2 and pl. 29, figs. 1–4). There are several significant differences. The meshes in the specimens from the Chinle Formation are distinctly polygonal; in those described by Fontaine they are elliptical. Also, the meshes in the Chinle material are broad, whereas they are quite narrow in the species from Virginia. All the veins in the Chinle specimens originate from the midrib, whereas some veins in the Virginia specimens arise from the pinna rachis in the areas between the midribs of adjacent pinnules, as Fontaine noted. Finally, only a few rows of meshes are on either side of the midrib in the specimens from the Chinle, whereas meshes are abundant on either side of the midrib in those from Virginia. Thus, none of the specimens described here from the Chinle can be included in the species *virginiensis* Fontaine.

2. Differences between the present material and *L. bricei*, the type species of the genus *Lonchopteris* Brongniart:

   Lonchopteris Brongniart (type *L. bricei*) is mainly a Carboniferous genus of possible pteridosperm leaves; only a few leaves not of Paleozoic age have been referred to it. *C. lasiophora* differs greatly from *L. bricei*. The pinnules in *C. lasiophora* have few lateral veins leaving the midrib (whereas those of *L. bricei* have abundant veins) and none entering it directly from the pinna rachis (whereas those of *L. bricei* have several), and nearly isodiametric vein meshes instead of much elongated ones. There is also a difference in cuticle. *C. lasiophora*, as is usual in ferns, has no such chemically resistant layer, but *L. bricei* has cuticle chemically resistant to oxidative maceration (Barthel, 1961, p. 831–832, pl. 5, figs. 5–10, and pl. 6, figs. 1–3). A good many Paleozoic species have been included in *Lonchopteris*, but none have the characters of *C. lasiophora*. Of course, the sporangia separate *C. lasiophora* completely from *Lonchopteris*.

The specimen described by Daugherty (1941, p. 50, pl. 4, fig. 2) as *Lonchopteris*(?) sp is identified with *C. lasiophora*. Daugherty had thought is differed from *L. virginiensis* by having pinnules with constricted auriculate bases and coarser reticulations formed by the anastomosing veinlets. However, the parts of that specimen considered by him to be pinnules are actually pinnae in which the pinnules are nearly completely fused, the positions of the sinuses between the pinnules being indicated by slight indentations along the margins of the lamina. A comparison of the figure of Daugherty's specimen (1941, pl. 4, fig. 2) with the figure of *L. virginiensis* (here referred to *C. lasiophora*) given by him on his plate 5, figure 2, demonstrates that the fusing of pinnules in the upper part of the leaf is a characteristic of the species. Constricted auriculate pinnae bases are typical of *C. lasiophora*. (See fig. 16*G*.) The size of the reticulations in Daugherty's specimen is within the size range noted in this species.

Cynepteris lasiophora closely resembles only two previously described species. *Emplectopteris triangularis* Halle (1927) and *Gigantonoclea lagrelii* (Halle) Koidzumi (1936). They have been reported from rocks of Permian age at several localities in China, Korea, and Manchuria (Asama, 1959, p. 56–57). The pinnules of both have the same type of venation and about the same shape as the pinnules of *C. lasiophora*, but they are about twice as large as those described above. In addition, the intercalated pinnules found on the main rachis between the pinnae of *E. triangularis* are not present in *C. lasiophora*. Finally, seeds have been found attached to pinnules of *E. triangularis*, confirming that it is a pteridosperm and, thus, effectively separating it from the spore-bearing *C. lasiophora* (Halle, 1931). The lowest pinnule on the basiscopic side of the pinnae rachis in the upper part of the leaf of *G. lagrelii* is broadly decurrent on both the pinna and main rachis, forming what have been called winglike expansions. These are absent in *C. lasiophora*. The position of *G. lagrelii* has not been determined, but it is usually considered to be a pteridosperm (Halle, 1927, p. 238; Asama, 1959, p. 55). If it is pteridospermous, then it also is distinct from *C. lasiophora*. Should *G. lagrelii* prove to be a fern, it might be rather closely related to *C. lasiophora*.

The general form of a sterile leaf of *C. lasiophora* resembles some of the Dipteridaceae, in particular *Thaumatopteris schenki*. (See Nathorst 1907; Harris, 1931, p. 93–94.) *C. lasiophora* differs from all forms of this alliance, however, in that its vein meshes have no blind endings, and the sporangia are different. The dipterids have their sporangia attached in sori, and their sporangia have a complete oblique annulus. In *C. lasiophora*, the sporangia are solitary, and the annulus is apical.

The spores recovered from the sporangia of *C. lasiophora* resemble a few previously described dispersed spores. They compare rather favorably in size and form with *Todiosporites minor* Couper (1958) reported from the Middle Jurassic of England (Couper,

1958, p. 135, pl. 16, figs. 9, 10) and the Upper Triassic (Keuper) of Austria (Bharadwaj and Singh, 1964, p. 30–31, pl. 1, fig. 28, and pl. 2, fig. 29), but the two species do not have the same type of surface ornamentation. *Verrucosisporites morulae* Klaus (1960) from the Upper Triassic (Keuper) of Austria (Klaus, 1960, p. 130, pl. 29, fig. 11; Bharadwaj and Singh, 1964, p. 34–35, pl. 3, figs. 59–63) is of the same shape and has surface ornamentation somewhat like that in the much smaller spores of *C. lasiophora*. The spore that most closely resembles *C. lasiophora* is *Verrucosisporites* sp. C of Bharadwaj and Singh (1964, p. 35, pl. 3, fig. 66) described from the Upper Triassic (Keuper) of Austria.

Affinity.—Cynepteris lasiophora rather closely resembles some members of the Schizaeaceae in several respects. The sporangia are typically schizaeaceous and of a kind that occurs in no other family of ferns. Among the sporangial characters common to *C. lasiophora* and the Schizaeaceae (especially *Lygodium*) are solitary position, large size and oval-cylindrical shape, very short stalk, apical annulus (not quite opposite the stalk), longitudinal dehiscence, possession of an apical patch of several small thin-walled cells, and, most important of all, the mostly uniseriate, radially aranged cells of the caplike annulus. Another point of agreement is the simple hairs on veins, margins, rachis, and lamina, but this is not an exclusive feature of the Schizaeaceae.

No member of the living Schizaeaceae has sporangia over the surface of broad pinnae. In all, the fertile branches are narrow, and although the sporangia may be placed at a short distance from the end of veins, as in *Lygodium*, Bower, (1926, p. 155) considered them truly marginal. The fossils *Klukia* and *Senftenbergia* also have sporangia a short distance from the margin. In *Cynepteris* they are plainly superficial. This does raise doubt whether *Cynepteris* should be included in the Schizaeaceae. If it is, then this genus could be considered fairly primitive, as it is such an ancient member of the Schizaeaceae, and the modern ferns may be regarded as reduced, having evolved the marginal location of sporangia from ancestors having superficial sporangia. However, this trend is opposite to that which supposedly has characterized leptosporangiate evolution (Bower, 1935, p. 633–634).

The sporangia of some of the fossil members of the Schizaeaceae show a remarkable resemblance in compressions to those of *C. lasiophora*. For example, the sporangium of *Anemia poolensis* illustrated by Chandler (1955, pl. 32, fig. 7) rather closely resembles the sporangium here shown on plate 3, figure 5. Also, the annulus of *A. poolensis* Chandler, 1955 (p. 32, fig. 9, and pl. 33, figs. 14–17), and of *A. cowellensis* Chandler, 1955 (pl. 35, fig. 46), is rather similar to that shown on plate 3, figure 3. The sporangia of *Senftenbergia plumosa* as figured by Radforth (1938, pl. 1) and of *S. sturi* and *S. pennaeformis* also illustrated by Radforth (1939, pl. 1) resemble some of the sporangia of *C. lasiophora* shown in figure 16 and on plate 3 in general appearance.

Most Holocene and fossil Schizaeaceae have spores with strong ornamentation which may be of many kinds—parallel ridges, a reticulation, or papillae. A few, however, have perfectly smooth walls, as does the fossil *Anemia poolensis* Chandler (1955, p. 295, pl. 33, figs. 24–31, and pl. 36, figs. 54–58). We thus have neither a point of agreement nor disagreement in the spores, but, admittedly they do not show one of the more characteristic schizaeaceous forms.

Various Schizaeaceae have pinnate branching. In the fossils *Klukia* and *Senftenbergia* the order is katadromic, as it is in *C. lasiophora*. In *Mohria* and *Anemia* the order is anadromic. The outstanding difference is in the venation, for no living or fossil schizaeaceous genus has conspicuously reticulate venation like that of *C. lasiophora*. It is true that in *Anemia* and *Lygodium* some reticulation may occur in the large leaves, but this is certainly not seen in the fertile parts.

Apparently what is usually considered to be the schizaeaceous type of sporangia was not restricted to this family in the past. Eggert and Taylor (1966) described a new Paleozoic fern, *Tedelea*, which had fertile parts resembling those in some living and fossil Schizaeaceae and Omsundaceae. The anatomy of *Tedelea* is not matched in these two families, however, and is similar to some of the members of the Zygopteridaceae. When *Tedelea* and *Cynepteris* are compared, it is obvious that *Tedela* has more schizaeaceous characters than does *Cynepteris*.

Although *C. lasiophora* more closely resembles some of the Schizaeaceae than members of any other family of ferns, it has several characters which cannot be matched in that family. Some of these unmatched characters are particularly significant. Among them, the superficial, nonmarginal arising sporangia of *C. lasiophora* are especially noteworthy. They contrast with the marginal sporangia that arise along the pinnule margins of the schizaeaceous ferns. The reticulate venation of *C. lasiophora* is an important character which must also be taken into account. Such venation is not as common or ever as well developed in any of the schizeaceous ferns. As *C. lasiophora* differs in so many ways from the Schizaeaceae and other ferns, it is tentatively placed in a new family—the Cynepteridaceae.

Remarks.—The name is from λασιος, hairy, and refers to the hairs that occur so abundantly on the pinnules.

Material.—Holotype: USNM 42948. Paratypes: USNM 42949, UCMP 1536.

Distribution.—*Cynepteris lasiophora* is a minor though persistent element in the Chinle flora of western New Mexico and eastern Arizona. Specimens were collected from nearly every fossil-plant locality in the Fort Wingate Area, New Mexico, and it occurs at two localities in Arizona. In New Mexico it was collected from the lower red member at USGS paleobotany localities 10058–10061; in Arizona it was collected from the Petrified Forest Member at USGS paleobotany locality 10062 in Petrified Forest National Park and from a locality in an unspecified level in the Chinle Formation near Nazlini (Daugherty, 1941, p. 50). The holotype was obtained from USGS paleobotany locality 10062.

Family GLEICHENIACEAE

Genus WINGATEA Ash, n. gen.

Diagnosis.—Leaf large, tripinnate; branching katadromic throughout; fertile and sterile pinnules similar. Pinnules delicate, oblanceolate, acutely pointed; single vein enters each pinnule from secondary branch rachis; midrib may branch several times; veins free at the margins. Fertile pinnules bearing a single, superficial sorus containing a small number of sporangia. Sporangia round in surface view, annulus complete, oblique to horizontal, a single ring of thick-walled cells, conspicuous. Spores rounded-triangular in polar view, triradiate mark simple, margins unspecialized, and surfaces of spore unornamented.

Type species.—*Wingatea plumosa* (Daugherty) Ash.

Remarks.—The name is derived from the settlement of Fort Wingate, N. Mex., which is close to a locality containing specimens of the form.

Wingatea plumosa (Daugherty) Ash, n. comb.

Figure 17; plate 4, figure 1

1941. *Coniopteris plumosa* Daugherty, p. 54–55, pl. 9, figs. 3–5.
?1941. Undetermined fertile frond. Daugherty, p. 99–100, pl. 6, fig. 1. (Called *Dennstaedtia*-like frond in plate description.)

Emended diagnosis.—Lamina lanceolate as a whole, tripinnate, rather large, 12 cm wide in largest fragment, possibly as much as 50 cm long, base and petiole unknown. Main rachis slender, as much as 2 mm wide, not grooved above, smooth, showing fine cellular striae about 10μ wide, bearing frequent slender, simple multicellular hairs about 15μ–30μ wide, as much as 550μ long.

Primary branches linear-lanceolate, apex acute, as much as 6 cm long 2–4 cm wide, opposite to subopposite, arising at intervals of 8–22 cm and at an angle of 60°–70° to main rachis, branches bending outward at a point a few millimeters from rachis to nearly 90°, sometimes recurved. Primary branch rachis about 0.1 mm wide, bearing occasional, slender, simple hairs similar to those on main rachis. Primary and secondary rachises flanked by a continuous flange of lamina about 0.1 mm wide. Secondary branches oblong, apex acute, arising laterally in a katadromic order, at intervals of 2–3 mm, and at an angle of about 35°–45° to primary branch rachis. Secondary branch rachis about 45μ–70μ wide, smooth, bearing sparse simple hairs similar to those on main rachis. Lower basal angle strongly decurrent, upper basal angle strongly contracted.

Lamina of secondary branches typically divided into about seven acutely pointed pinnules. Pinnules about 1–2 mm wide, 2–3 mm long, arising in a katadromic order at intervals of 0.8–2 mm and at an angle of about 30°–40° to secondary branch rachis. Lamina thin, margins showing two or more teeth or deeply cleft, acutely

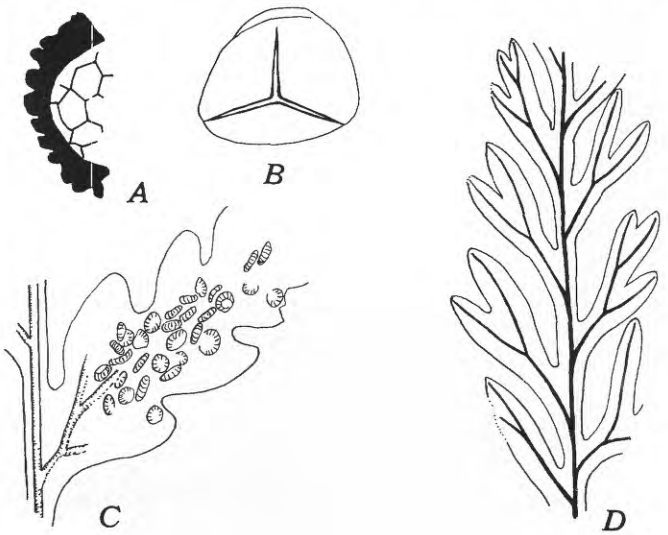


FIGURE 17.—*Wingatea plumosa* (Daugherty) Ash, n. gen., n. comb. *A*, *B*, *D* from USGS paleobotany locality 10059, lower red member of Chinle Formation, Fort Wingate, N. Mex. *C* from USGS paleobotany locality 10062, Petrified Forest Member of Chinle Formation, Petrified Forest National Park, Ariz. *A*, Part of sporangium showing some thick-walled annular cells and some thin-walled cells on distal face. Transfer preparation, USNM 42965, × 100. *B*, Spore. Transfer preparation, USNM 42965, × 500. *C*, Several typical fertile pinnules from large part of leaf illustrated by Daugherty (1941, pl. 9, fig. 3). Impression on rock surface. Cotype, UCMP 1546, × 10. *D*, Sterile pinnules, showing venation and acutely pointed lobes typical of species. USNM 42966, × 10.

pointed lobes. Veins 20μ–40μ wide, ending a short distance from pinnule margins; a single vein enters each pinnule; it may branch one or more times in a katadromic order, each vein usually ending in an acutely pointed lobe. Upper angle of pinnule deeply indented almost to midrib, lower angle decurrent, joining the next pinnule below.

Fertile pinnules similar to sterile, each bearing a sorus about 0.8–1.2 mm in diameter. Sori superficial, typically centered over midrib in lower part of pinnules, occasionally also over secondary branch rachis, containing 8–12 sporangia. Sporangia about 220μ–400μ in diameter in surface view, stalk apparently short. Annulus ringlike, oblique to horizontal, complete, well-developed, conspicuous, formed of a single row of 14–20 straight, thick-walled cells about 70μ long, 6μ–15μ wide, radial walls about 15μ broad. Ordinary cells of distal face of sporangia polygonal about 40μ–50μ in diameter, walls straight, about 3μ thick. Spore rounded-triangular in polar view, 31μ–38μ in diameter, wall about 1μ thick, distal side hemispherical, proximal side flattened, triradiate mark simple, narrow (about 2μ wide), margins unspecialized, nearly as long as spore radius, both surfaces smooth.

Description.—The sori of *Wingatea plumosa* may be protected by an indusium, as Daugherty thought (1941, p. 55), but none were recognized in the dozen transfers made of the fertile branches during the present investigation. Apparently the lamina of this species was rather delicate, judging by the fossil remains. Although parts of the distal face and annulus of the sporangia and hairs were visible, none of the epidermal cells were observed in any of the transfers. All that remained of the lamina was a thin structureless brown film. Epidermal cells of other ferns at the locality were preserved, however.

Comparison.—*Wingatea plumosa* was originally referred to the genus *Coniopteris* Brongniart by Daugherty (1941, p. 55–56) because the fronds resemble *C. hymenophylloides* (Brongniart). This assignment is not tenable. The sterile branches of the two species are remarkably similar, but the fertile are very different. In *W. plumosa* the fertile and sterile branches are similar in outline, and the sori are distinctly superficial, as shown in figure 17*C*. In all species of *Coniopteris*, including *C. hymenophylloides*, the sori are marginal, and the fertile pinnules are usually somewhat modified and do not look exactly like the sterile. The sori of *W. Plumosa* may be protected by an indusium, which would be compatible with *Coniopteris*, but, as noted above, none were observed.

The ultimate branches of *W. plumosa* rather closely resemble in gross morphology the sterile leaves of the extant fern *Botrychium virgianianum*, but the fertile structure of *B. virginianum* is a spike that cannot be matched in *W. plumosa*.

This species superficially resembles several species of *Sphenopteris*, including *S. nystroemi* Halle from rocks of Permian age in China, as pointed out by Daugherty, and *S. damesi* Stur from the upper Carboniferous formations of Germany. The fertile leaves of these species are not known, however, so our comparisons are incomplete.

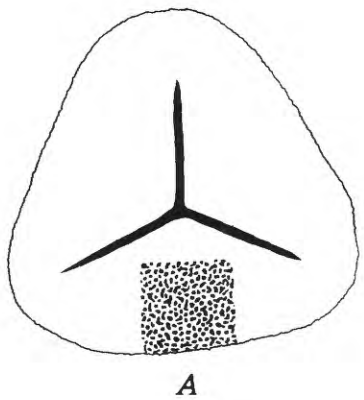
The sporangia of *W. plumosa* resemble those of the modern fern *Gleichenia linearis* in several important characters. They are superficial and about the same general size, and the sporangia apparently are subsessile and develop simultaneously in both *W. plumosa* and *G. linearis*. The annuli are complete and oblique, and the sori lack indusial protection and usually contain 12 or less sporangia. The pinnules are somewhat different in gross morphology, however, and the pseudodichotomous type of branching typical of *Gleichenia* and all living members of the Gleicheniaceae has not been observed in *W. plumosa*.

W. plumosa has sporangia which closely resemble those of the late Carboniferous genus *Oligocarpia*, the earliest form referred to the Gleicheniaceae. *Oligocarpia* is not pseudodichotomously branched and is also matched by *W. plumosa* in this character, but the pinnules of *W. plumosa* do not resemble those of *Oligocapria*. The sporangia of the Mesozoic genus *Gleichenites* generally resemble the sporangia of this species. Particularly interesting is the close resemblance in form of the sporangia of *W. plumosa* and the sporangium of *G. porsildi* illustrated by Seward (1926, pl. 5, fig. 21) from the Cretaceous of Greenland. However, the sporangia of *W. plumosa* are about half the size of the sporangium from Greenland. The pinnules of *G. porsildi* are altogether different, and its mode of branching is pseudodichotomous.

As the grouping of the sporangia and the annular structure of *W. plumosa* are matched so closely in the Gleicheniaceae, it seems appropriate to assign it to that family.

Material.—Cotypes: UCMP 1546, 1547.

Distribution.—This is a rare form and occurs at only two localities. In New Mexico it was collected from the lower red member of the Chinle Formation at USGS paleobotany locality 10059 in the Fort Wingate area; in Arizona it was collected from the Petrified Forest Member of the Chinle Formation at USGS paleobotany locality 10062 in Petrified Forest National Park.



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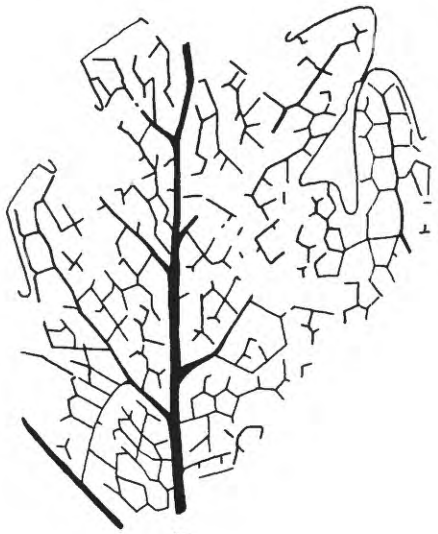

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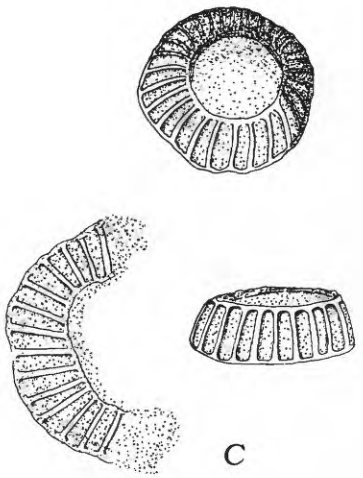

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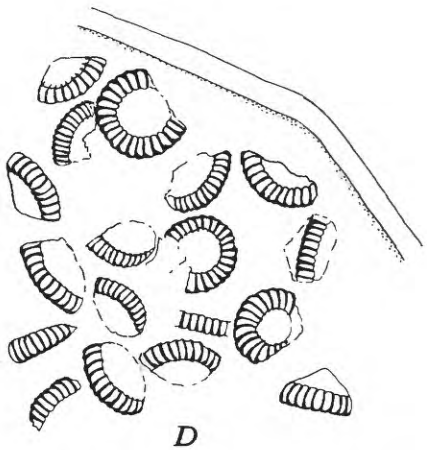

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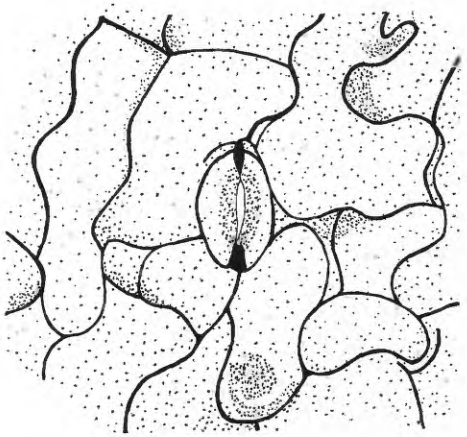

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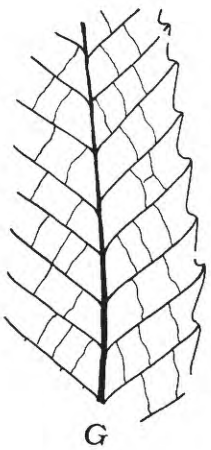

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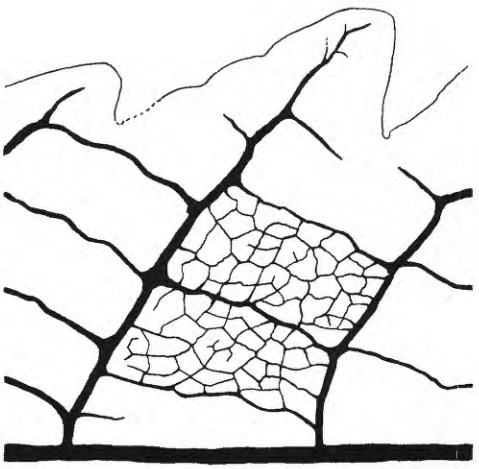

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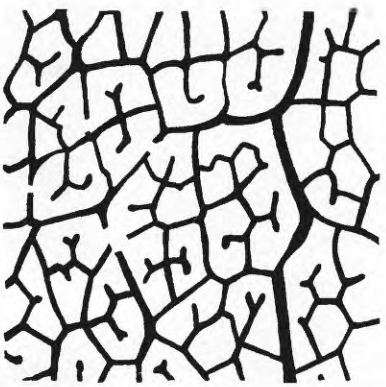


I

Family DIPTERIDACEAE

Genus CLATHROPTERIS Brongniart, 1828

Clathropteris walkeri Daugherty, 1941

Figure 18, plate 4, figures 2–7

1941. *Clathropteris walkeri* Daugherty, p. 56–57, pl. 10, figs. 1–4.

Emended diagnosis.—Leaf of moderate size (16 cm wide in largest, nearly complete specimen), fertile and sterile leaves similar, palmate, orbicular as a whole, petiole dividing into two short basal arms about 1 mm wide, each arm bearing three to five segments (pinnae). Pinnae linear lanceolate, gradually increasing in width to middle, sides then usually subparallel until near apex, where the pinna narrows abruptly, typically 4–10 cm long (at least 15 cm long in largest fragment) and 2–3 cm wide, basal web uniting lamina of adjacent pinnae for 2–4 cm. Pinnae margins strongly toothed, teeth commonly curving forward, apex obtuse to acute, divisions between teeth typically extending less than one-quarter the distance to pinna rachis, rarely more than one-quarter. Substances of leaf rather thick.

Midrib of pinna sunken above, usually smooth, occasionally channeled, slender, as much as 1 mm wide, primary branch veins sunken above, slender, as much as 0.5 mm wide, given off midrib at intervals of 5–8 mm, alternate, typically arising at an angle of about 40°–50° to midrib, rarely at a wider angle, straight, rarely bending forward slightly near apex. Secondary branch veins sunken, slender, about 65μ–100μ wide, occasionally forming irregular rectangular meshes about 4 by 7 mm in a large leaf. Tertiary branch veins delicate, about 24μ–36μ wide, tending to form straight-sided roughly square or polygonal meshes usually 0.1 mm in largest dimension; meshes may enclose blind vein endings. Basal web betwen adjacent pinnae contains irregular polygonal meshes. Surfaces of pinna midrib and primary and secondary branch veins show numerous fine longitudinal cellular striations about 15μ wide. Lower surface of fertile and sterile leaves densely covered by simple, curved, multicellular hairs, 250μ–600μ long, about 15μ–45μ wide. Epidermis thin, cells irregularly shaped, 12μ–30μ wide, 40μ–106 long, long axis oriented parallel to veins in region of vein, elsewhere irregularly oriented; anticlinal cell walls wavy to sinuous, about 1μ thick. Stomata oval, scattered, orientation typcially random, guard cell pair 35μ–45μ long, 20μ–32μ wide usually overlapping epidermal cells to small extent, stomatal pore 12μ–18μ long. Trichome bases consist of a small round cell, typically 15μ–35μ in diameter.

Sori irregularly distributed on lower surface of fertile leaf, round, indistinct, typically containing 7–9 sporangia, placenta obscure, Sporangia probably spherical, 175μ–210μ wide in surface view. Annulus complete, oblique; a single row of 25–30 straight-walled cells about 90μ long and 15μ wide, radial walls about 10μ thick. Spores rounded triangular in polar view, 35μ–42μ in diameter, triradiate mark simple, narrow with unornamented margins extending nearly to the edge of the spore, all surfaces of spore covered with irregularly distributed short, small, warts about 0.5μ high and 0.5μ wide at base.

Description.—The emended diagnosis is based on the holotype and paratypes designated by Daugherty (1941) and on several dozen additional specimens which I collected in New Mexico and Arizona. Several nearly complete small leaves were collected, but most of the specimens consist of small parts of rather large leaves. Some transfer preparations were made of the new specimens, but only those from Petrified Forest National Park showed epidermal features. The other specimens are preserved only as stained impressions.

Comparisons.—The teeth on the pinnae in *Clathropteris walkeri* are about the same size, shape, and proportions as those in *C. meniscoides* that were figured by Harris (1931, p. 90–91) from the Rhaetian of Greenland. The pinnae of *C. walkeri*, however, lack the prominent rectangular to meniscus-shaped (that is, concave on one side, convex on the other) areas formed by the primary branch veins and the secondary veins typical

FIGURE 18.—*Clathropteris walkeri* Daugherty. *B* from USGS paleobotany locality 10059 and *G*, *H* from USGS paleobotany locality 10058, lower red member of Chinle Formation, Fort Wingate, N. Mex. *A*, *C–F*, *I* from USGS paleobotany locality 10062, Petrified Forest Member of Chinle Formation, Petrified Forest National Park, Ariz. *A*, Spore. USNM 42968, × 1,000. *B*, Basal part of small pinna showing irregular polygonal meshes formed by veins. USNM 42973, × 5. *C*, Three selected sporangia (annulus alone visible). Sporangium at lower left has dehisced. Transfer preparation, USNM 42969, × 100. *D*, Part of vein mesh showing orientation and grouping of sporangia; a tertiary vein is visible at top (impression on rock matrix). USNM 42974, × 50. *E*, Three typical hairs from fertile leaf. Transfer preparation, USNM 42969, × 100. *F*, Stoma on lower epidermis, thick region near pore darkly stippled. Irregular width of anticlinal cell walls apparently due to slightly oblique compression of walls. Transfer preparation, USNM 42970, × 400. *G*, Part of typical sterile pinna showing low, forward-pointing marginal teeth, prominent midrib, and less prominent primary and secondary branch veins. USNM 42976, × 1. *H*, Two marginal teeth of sterile pinna. Midrib and primary, secondary, and some tertiary branch veins are shown. Drawn on a photograph. USNM 42978, × 5. *I*, Venation of sterile part. Note numerous blind vein endings. There appears to be a slight swelling at apex of each such ending. Transfer preparation, USNM 42971, × 10.

of specimens of *C. meniscoides* that have been described from the Rhaetian of Greenland by Harris, from the Lower and Middle Jurassic of Portugal (Teixeira, 1948), and from numerous other localities in rocks of Jurassic age in Europe and Asia. The sporangia described by Harris (1931, p. 89) from specimens of *C. meniscoides* collected in Greenland are larger (250μ in diameter) than those borne by *C. walkeri* (150μ–200μ in diameter). Harris has reported that the sori in *C. meniscoides* are composed of 10–15 sporangia, whereas there are 7–9 sporangia in the sori of *C. walkeri*.

Some of the teeth on the pinnae of *C. walkeri* are of about the same shape and have the same proportions as the teeth on the pinnae of the type specimens of *C. elegans* Oishi (1931), but the primary branch veins slant forward at a lower angle in *C. walkeri* (40°–50°) than in *C. elegans* (60°–70°). Furthermore, the fronds of *C. walkeri* are larger than the fronds of *C. elegans*. The teeth on the pinnae of *C. walkeri* are larger than those on the pinnae of *C. reticulata* Kurr which has been described from the Keuper of Germany by Frentzen (1922). In addition, the primary branch veins in *C. walkeri* slant forward at a slightly higher angle than the veins in *C. reticulata*, and the pinnae of *C. reticulata* contain fewer rectangular meshes formed by the primary and secondary veins than are present in the pinnae of *C. walkeri*.

Superficially, *C. walkeri* resembles *C. obovata* Oishi (1932, p. 291, pl. 30, fig. 2, and pl. 32, fig. 1), but they differ in detail. Leaves of *C. walkeri* are slightly smaller than those of *C. obovata*. Pinnae in *C. obovata* are oblanceolate to obovate, whereas they are lienar lanceolate in *C. walkeri*. The teeth on the pinnae of *C. walkeri* generally are shorter than the teeth on *C. obovata*. In specimens of *C. obovata* described from the Middle Jurassic rocks of Yorkshire by Harris (1961, p. 123–126), the sori are regularly distributed and are surrounded by hairs which are apparently absent elsewhere. In *C. walkeri*, the sori are irregularly distributed, and hairs occur over the entire lower surface of the leaf. The primary branch veins in *C. walkeri* are nearly straight throughout their course and bend forward near the margins of the pinnae, whereas in *C. obovata* they bend forward near their base.

Several species of *Clathropteris* have been described from the Upper Triassic rocks in the Eastern United States, but none of them is very similar to *C. walkeri*. The pinnules determined by Newberry (1888, p. 94) as *C. platyphylla* Brongniart and those described as *C. platyphylla* var. *expansa* Saporta by Fontaine (1883, p. 54–58) have primary branch veins that are nearly perpendicular to the midrib, whereas comparable veins are set at an angle of 40°–50° in *C. walkeri*. Also, the fronds of these two forms are considerably larger than those of *C. walkeri*, and the pinnae have rather low broad teeth in comparison with those of *C. walkeri*. *C. rectiusculus* Hitchcock (1855, p. 22–25, fig. 2), which was described from the Triassic rocks in Connecticut, seems to be of about the same size and to have the same type of delicate veins as *C. walkeri*, as pointed out by Daugherty (1941, p. 57). The specimen is small and fragmentary, however, and the only illustration is so poor that it is difficult to judge whether the two species are identical.

Clathropteris walkeri resembles the single fragmentary specimen on which *Apachea arizonica* Daugherty was based. Both leaves are palmate and have spreading pinnae, or lobes, originating from the base of the leaf. The principal differences noted by Daugherty are the marginal characters of the pinnae and the form and venation of the leaf. According to Daugherty, the pinnae margins of *A. arizonica* are entire, whereas they are toothed in *C. walkeri*. Microscopic examination of the holotype of *A. arizonica*, however, shows that there are a few teeth of the same size and shape as those on *C. walkeri*. These teeth also contain venation similar to that occurring in *C. walkeri*. The venation of the lower part of the leaf of *A. arizonica* resembles that in a similar part of a leaf of *C. walkeri* and the venation of the pinnae of *C. walkeri*. The differences in the form of the leaf of *A. arizonica* are believed to be due to the fragmentary nature of the fossil and to its position in the rock relative to the rock surface. The lower surface of the holotype of *A. arizonica* is covered with a dense mat of hairs that are similar in size, shape, and distribution to those on the lower surface of *C. walkeri*. I believe that the specimen called *A. arizonica* is actually the basal part of a leaf of *C. walkeri*. Until a transfer can be made of the holotype of *A. arizonica* or more complete specimens are collected, however, it will be best to tentatively consider *A. arizonica* as valid and distinct from *C. walkeri*.

Material.—Holotype: UCMP 1550. Paratypes: UCMP 1551, 1552, 1553.

Distribution.—This easily recognized form has been collected from USGS paleobotany localities 10058 and 10059 in the Fort Wingate area, New Mexico, and from locality 10062 in Petrified Forest National Park, Ariz. (The type specimen was collected from this locality.)

UNCLASSIFIED FERNS

Form-genus CLADOPHLEBIS Brongniart, 1849

Cladophlebis daughertyi Ash, n. sp.

Figure 19; plate 5

1941. *Cladophlebis microphylla* auct. non Fontaine. Daugherty, p. 46–47, pl. 4, fig. 3, pl. 5, fig. 2 (not fig. 3).

Diagnosis.—Lamina as a whole linear lanceolate, twice pinnate, width typically about 6 cm (largest 29 cm, length possibly 60 cm, apex acute. Petiole unknown, rachis slender as much as 2 mm wide, showing a broad sharply defined channel about 0.5 mm wide; not punctate, without hairs, marked with narrow cellular striae about 15μ wide. Pinnae acute, slightly falcate, largest 11 mm wide, 14.5 cm long, arising laterally, usually alternate, at intervals of about 8–10 mm and at an angle of about 140° in lower part of leaf, changing to 90° in middle and to about 60° near apex of leaf.

Pinnules falcate, oblong (usually at least twice as long as wide), typically 2 mm wide, 5 mm long, apex rather obtuse. First pinnule arising on basiscopic side close to main rachis, later ones alternating katadromically. Pinnules typically arising at 60°–65° to pinnae rachis, basal pinnule on acrosopic side tending to be parallel with main rachis. Basal pinnule on basiscopic side smaller than others but shape normal; basal pinnule on acroscopic side rather enlarged; pinnules of both sides otherwise similar. Adjacent pinnules connected by an undivided laminae about 1 mm broad; pinnules rather crowded, often slightly overlapping; margins of pinnules generally entire, occasionally showing low rounded teeth. Midrib of pinnule stout, usually straight, occasionally slightly undulating, running nearly to apex. Veins making an angle of about 30°–40° to midrib; first veins on basiscopic side originating near pinnae rachis and forking two or three times, later veins forking once or imperfectly twice; venation sparse with a concentration of about two to three vein branches per millimeter at pinnule margins (veins are about 0.4 mm apart), typically 18–22 veins per pinnule; veins ending at a point about 100μ–200μ from pinnule margin.

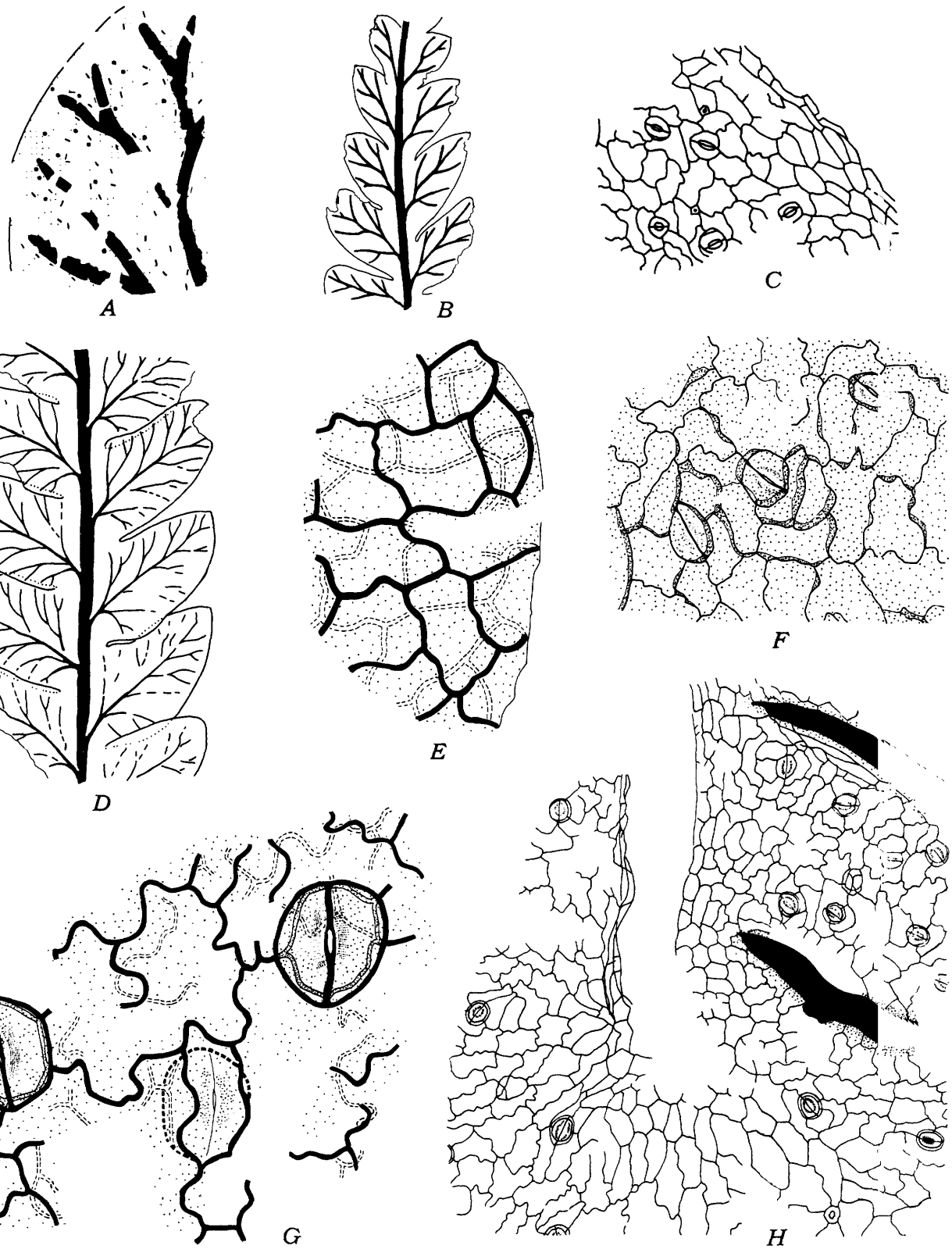
Cells of upper and lower epidermis irregularly shaped, often sinuous walled, usually moderately elongated, distinctly elongated near margins of pinnules and veins, randomly oriented except near margins, where long axes of cells are parallel to margin, and near veins, where they parallel veins. Anticlinal cell walls about 2μ thick, surfaces occasionally bearing marks suggesting contact areas of mesophyll. Stomata evenly distributed except along margin where stomata are typically absent, about 20–30 per square millimeter on lower epidermis, four to five per square millimeter on upper surface, parallel to neighboring veins, others at random, shape round to oval, slightly longer than wide. Guard cell pair 42μ–52μ long, 34μ–45μ wide, usually overlapping epidermal cells to some extent, stomatal pore 15μ–20μ long, surface of guard cells showing radiating striations. Trichome bases common on lower epidermis (about 30–45 per sq mm) less common (about 5 to 10 per sq mm) on upper epidermis, consisting of a rather small polygonal cell, typically 15μ wide, containing a circular thickened scar about 10μ in diameter, free part of trichome unknown.

Description.—The diagnosis is based on the two specimens illustrated by Daugherty as *Cladophlebis microphylla* (UCMP 1530, 1531) and the several dozen specimens that I collected. Most of the specimens consist of isolated and fragmentary pinna; however, in several specimens the pinnae are attached to a rachis. The largest specimen of the species shows a rachis about 2 mm broad, to which are attached 29 pinnae. Complete pinnae on the specimen are 14.5 cm long; pinnules are 2.5 mm wide, 6 mm long.

Acetate film transfers were made of seven specimens and epidermal cells, usually from the lower epidermis, showed in most preparations. (See fig. 19*F*.) In these, the tissue of the veins is still present, lying on top of the lower epidermis, but no trace of the upper epidermis was seen, and nothing of the mesophyll except probable contact marks on the lower epidermis. I know of no explanation of this strange feature of preservation. In a few transfers both the upper and lower epidermis are preserved (fig. 19*E*, *G*), and the tissue of the veins is present between them.

An epidermis with stomata similar to those occurring in this fossil was noted in two Holocene mesophytic ferns, *Alloserus crispa* and *Struthiopteris germsanica.*

Comparisons.—*Cladophlebis daughertyi* differs from *C. microphylla* Fontaine (1883, p. 51–52), with which Daugherty identified it, as follows. The pinnules of *C. daughertyi* are distinctly oblong, not subquadrate; they are inserted at a lower angle (typically 60° instead of 80°), and they are larger (typically 2×5 mm) than the pinnules of *C. microphylla* (3×3 mm). The midrib is rather slender and extends nearly to the apex of the pinnules in *C. daughertyi*, whereas in *C. microphylla* it is quite stout and extends less than halfway up the length of the pinnules. Venation is not as sparse in the pinnules of *C. daughertyi* (about two veins per mm) as in the pinnules of *C. microphylla* (about 1.5 veins per mm). In *C. daughertyi* some of the lateral nerves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fork more than once, especially in the lower part of the pinnules, and the bifurcation usually occurs halfway between the midrib and the pinnule margin. In *C. microphylla* all the lateral nerves fork only once and at a point near the midrib.

Daugherty considered *Pecopteris mexicana* Newberry (described as *P. mexicana* but illustrated as *Alethopteris mexicana* by Newberry, 1876, p. 143–144, pl. 6, figs. 2, 2a) to be the same as his *C. microphylla*. However, a comparison of *C. daughertyi* with the description and illustrations of *P. mexicana* and with a specimen from a locality near the one which yielded the type specimen of *P. mexicana* shows that they are different. Typically, the pinnules of *C. daughertyi* are twice as large as the pinnules of *P. mexicana*, and there are probably more veins per millimeter at the pinnule margin in *C. daughertyi* than in *P. mexicana*.

The only other species of *Cladophlebis* of which we have anatomical knowledge is *C. sahnii* Vishnu-Mittre (1959, p. 51, pl. 1, figs. 5, 6, text figs. 4, 5). Although data concerning this Middle(?) Jurassic form are comparatively meager, enough is known to demonstrate that it differs from *C. daughertyi* in several respects. The pinnules of *C. daughertyi* are considerably larger than the pinnules of *C. sahnii* (1–1.5×1–3 mm), and there are no ridges of elongated cells along the pinnule margins of *C. daughertyi* as there are in *C. sahnii*. Furthermore, the walls of the epidermal cells in the pinnules of *C. daughertyi* are not as sinuous as they are in *C. sahnii*, and the stomata in *C. daughertyi* are round or slightly oval, whereas they are considerably elongated in *C. sahnii*. Finally, trichomes are present on the epidermis of *C. daughertyi;* they have not been reported on the epidermis of *C. sahnii*.

The most similar species known to me are *C. svedbergi* from the basal Liassic of Sweden (Johansson, 1922 p. 19–22) and Greenland (Harris, 1931, p. 54, 57, text-fig. 18); *C. fontainei* Seward (1907, p. 26) from the Jurassic of Turkestan; and *C. grabauana* Pan (1936) from the Rhaetian of Shensi, China *C. svedbergi* is distinguished by having rather large pinnules (as much as 12 mm), a stout rachis, and pinnae that taper abruptly. *C. fontainei* differs in that the pinnules are nearly equidimensional, and venation is rather sparse (14 per pinnule). Because only one specimen of *C. fontainei* is known, however, comparisons are incomplete. *C. grabauana*, though very similar, may be distinguished by the rounded apices of the pinnules. Comparison with this species is also incomplete, as only two small specimens are known. Almost all other species that have been compared have larger pinnules with more numerous veins.

Remarks.—The species is named for Lyman H. Daugherty, who made the first comprehensive study of the fossil leaves, spores, and wood in the Chinle Formation and the Dockum Group of the Southwestern United States.

There has been a mixup in the numbering of one of the specimens of this species, described by Daugherty, which is now in the collections of the University of California Museum of Paleontology. Specimen 1532 in that collection actually is *Cladophlebis microphylla* (here referred to *C. daughertyi* n. sp.), not *C. reticulata;* and specimen 1531 is *C. reticulata*, not *C. microphylla*. These discrepancies apparently are due to the fact that the explanations of figures 2 and 3 on plate 5 have been reversed, as a comparison of the original specimens with Daugherty's descriptions shows.

Material.—Holotype: USNM 42988. Paratypes: UCMP 1530, 1532.

Distribution.—This species occurs in the lower red member of the Chinle Formation at USGS paleobotany localities 10059 and 10061 in the Fort Wingate area, New Mexico, and in the Petrified Forest Member (lower part) of the Chinle Formation at USGS paleobotany locality 10062 in Petrified Forest National Park, Ariz.

FIGURE 19.—*Cladophlebis daughertyi* Ash, n. sp. *A–D, F, H* from USGS paleobotany locality 10062, Petrified Forest Member of Chinle Formation, Petrified Forest National Park, Ariz. *E, G* from USGS paleobotany locality 10061, lower red member of Chinle Formation, Fort Wingate, N. Mex. *A*, Part of pinnule (lower epidermis); stomatal apertures shown by short black lines, trichome bases shown by large black dots; some of the stomata and trichome bases probably missing. Transfer preparation, USNM 42981, × 25. *B*, Part of apical region of pinna; overlapped edge of pinnule dotted. Transfer preparation, USNM 42982, × 5. *C*, Lower epidermis showing straight-walled cells near margin at upper right of figure. Transfer preparation, USNM 42984, × 100. *D*, Part of typical pinna from central part of leaf; overlapped edge of pinnules dotted. USNM 42986, × 5. *E*, Upper and lower epidermis from marginal area of pinnule, viewed from outside (lower surface), margin is on right; anticlinal cell walls of lower epidermis shown by solid lines, those of upper epidermis shown by broken lines. Transfer preparation, USNM 42987, × 400. *F*, Lower epidermis (somewhat obliquely compressed); anticlinal cell walls darkly stippled. Transfer preparation, USNM 42983, × 200. *G*, Upper and lower epidermis, viewed from outside (lower surface); anticlinal cell walls of lower epidermis shown by solid lines, anticlinal cell walls of upper epidermis shown by broken lines. Transfer preparation, USNM 42987, × 400. *H*, Lower epidermis showing narrow, straight-walled cells near margins of adjacent pinnules and wavy-walled ordinary cells elsewhere. Two veins are on right side of figure. Transfer preparation, USNM 42985, × 100.

INDEX LIST OF FOSSIL FERNS

All the genera and species based on fern and fernlike foliage described or reported from the Chinle Formation are listed below in alphabetical order. The several petrified stems attributed to the ferns are also included. This index list, in general, follows the style of the catalog part of LaMotte's (1944) "Supplement to Catalogue of Mesozoic and Cenozoic Plants of North America." All references cited are included in the bibliography of this report.

Data for each generic citation are arranged in the following order: The generic name, author, date of publication, page reference, and the name and author of the type, or first-described species of the genus.

For each primary specific citation, data are arranged as follows: The generic and specific name, the name of the author, the year of publication, the page number, and the plate or text-figure references. Then follow formation and locality data for the type specimen of the species and other specimens described or reported by the author. Next, in chronological order, are listed citations of the species by later authors together with the year of publication, page, plate and figure references, and formation and locality information. Thus, additional discoveries of the species are connected with the appropriate author and locality data. Brief annotations concerning the fossil are enclosed in parentheses at the end of the primary citation. Beneath each primary citation are listed, in chronological order, synonyms of the species, together with the author, year of publication, page, plate and text-figure references, and formation and locality data.

Apachea Daugherty, 1941, p. 55–56. Type species: *A. arizonica* Daugherty.

A. arizonica Daugherty, 1941, p. 55–56, pl. 9, fig. 2. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. (Sterile foliage, Dipteridaceae. May be a poorly preserved specimen of *Clathropteris walkeri*. See p. D42 in this report.)

Chinlea Daugherty, 1941, p. 45–46, em. Miller, 1968. Type species: *C. campii* Daugherty.

C. campii Daugherty, 1941, p. 45–46, pl. 4, fig. 4 em. Miller, 1968, p. 113, figs. 1–13. Petrified Forest Member of the Chinle Formation, St. Johns area, Arizona. (Poorly preserved petrified stems, Lepidophyta.)

Osmundites walkeri Daugherty, 1941, p. 50–52, pl. 5, fig. 1. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park and St. Johns area, Arizona; Chinle Formation, Dinnebito Wash, Ariz.

Chinlea sp. Miller, 1968, p. 113, fig. 14. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park and St. Johns area, Arizona. (Poorly preserved petrified stems, Lepidophyta.)

Undetermined stem fragments. Daugherty, 1941, p. 100–101, pl. 19, fig. 2; pl. 20, figs. 1, 2. Petrified Forest Member of the Chinle Formation, St. Johns area, Arizona.

Cladophlebis daughertyi Ash, n. sp., p. D43–D45, this report, Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz., and lower red member of the Chinle Formation, Fort Wingate area, New Mexico. (Sterile foliage.)

C. microphylla auct. non Fontaine Daugherty, 1941, p. 46–47, pl. 4, fig. 3; pl. 5, fig. 2. Petrified Forest National Park, Ariz.

C. cf. *denticulata* (Brongniart) Fontaine. Ash, table 1, this paper. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. (Sterile foliage.)

C. microphylla auct. non Fontaine. Daugherty=*C. daughertyi* Ash.

C. reticulata auct. non Fontaine. Daugherty=?*Cladophlebis* n. sp. (See p. D26 of this report.)

Clathropteris walkeri Daugherty, 1941, p. 56–57, pl. 10, figs. 1–4. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. Ash, p. D41–D42, this report; lower red member of the Chinle Formation, Fort Wingate area, New Mexico. (Fertile and sterile foliage, Dipteridaceae.)

Coniopteris plumosa Daugherty=*Wingatea plumosa* (Daugherty) Ash.

Cynepteris Ash, p. D31, this report. Type species: *C. lasiophora* Ash.

C. lasiophora Ash, p. D31–D38, this report. Lower red member of the Chinle Formation, Fort Wingate area, New Mexico; Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. (Fertile and sterile foliage, Cynepteridacea.)

Lonchopteris virginiensis auct. non Fontaine: Daugherty, 1941, p. 49, pl. 5, figs. 1, 2; pl. 6, figs. 1, 2. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz.; Chinle Formation near Nazlini, Ariz.

Lonchopteris (?) sp. Daugherty, 1941, p. 50, pl. 4, fig. 2. Chinle Formation near Nazlini, Ariz.

Itopsidema Daugherty, 1960, p. 775. Type species: *I. vancleavei* Daugherty, 1960.

I. vancleavei Daugherty, 1960, p. 775, text-figs. 1–12. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. (Petrified stem, ?Osmundaceae.)

Laccopteris smithii Daugherty=*Phlebopteris smithii* (Daugherty) Arnold.

Lonchopteris virginiensis auct. non Fontaine. Daugherty=*Cynepteris lasiophora* Ash.

Lonchopteris? sp. Daugherty=*Cynepteris lasiophora* Ash.

Osmundites walkeri Daugherty=*Chinlea campii* Daugherty em. Miller.

Phlebopteris smithii (Daugherty) Arnold, 1947, p. 196–197, text-figs. 91–92. Arnold, 1956, p. 119. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park. Ash, this report, table 1. Lower red member of the Chinle Formation, Fort Wingate area, New Mexico. (Fertile and sterile foliage, Matoniaceae.)

Laccopteris smithii Daugherty, 1941, p. 53–54, pl. 7; pl. 8, figs. 1–3; pl. 9, fig. 1. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz.; Chinle Formation, Dinnebito Wash, Ariz.

P. utensis Arnold, 1956, p. 119–120, pl. 16. Chinle Formation, Garfield County, Utah. (Fertile and sterile foliage, Matoniaceae.)

Sphenopteris arizonica Daugherty, 1941, p. 99, pl. 19, figs. 3, 4. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Arizona. (Sterile fernlike foliage of unknown affinities.)

Todites fragilis Daugherty, 1941, p. 52–53, pl. 6, figs. 3, 5. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz. Ash, this paper p. D27–D31. Lower red member of the Chinle Formation, Fort Wingate area, New Mexico. (Fertile and sterile foliage, Osmundaceae.)

Undetermined fertile frond. Daugherty, 1941, p. 99–100, pl. 6, fig. 4. Chinle Formation, Nazlini, Ariz. (Probably a fragment of *W. plumosa*.)

Wingatea Ash, p. D38, this report. Type species: *W. plumosa* (Daugherty) Ash.

W. plumosa (Daugherty) Ash, p. D38–D40, this report. Lower red member of the Chinle Formation, Fort Wingate area, New Mexico. (Fertile and sterile foliage, ?Gleicheniaceae.)

Coniopteris plumosa Daugherty, 1941, p. 54–55, pl. 9, figs. 3–5. Petrified Forest Member of the Chinle Formation, Petrified Forest National Park, Ariz.

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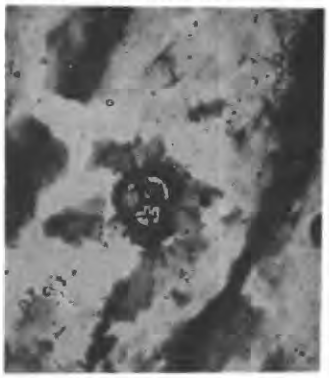
PLATES 1–5

PLATE 1

FIGURES 1–10. *Todites fragilis* Daugherty, USGS paleobotany locality 10061 (p. D27).

1. A multicellular sporangial stalk between two veins in surface view. Transfer preparation, USNM 42936, × 200.
2, 3. Central part of a leaf, × 1 and × 2. The venation is clearly shown in some of the pinnules. USNM 42942.
4. Apex of a leaf showing the asymmetrical pinnae. USNM 42941, × 2.
5. Apical part of a sporangia showing the cells of the annulus and the stomium. Transfer preparation, USNM 42936, × 200.
6, 7. Two spores obtained by macerating a sporangia. Spore on right has been slightly crushed, whereas the other has a more typical outline. USNM 42939, × 100.
8. Two spinelike hairs on the edge of a fertile pinnule. Broken hair in upper part of figure is attached to end of a vein. Several multicellular hairs and two incomplete sporangia are also shown. Transfer preparation, USNM 42936, × 100.
9. Multicellular hairs in marginal area of pinnule. Pinna rachis is near bottom of figure. Transfer preparation, USNM 42936, × 100.
10. Marginal part of fertile pinnule showing densely packed hairs and several incomplete sporangia. Transfer preparation, USNM 42936, × 100.



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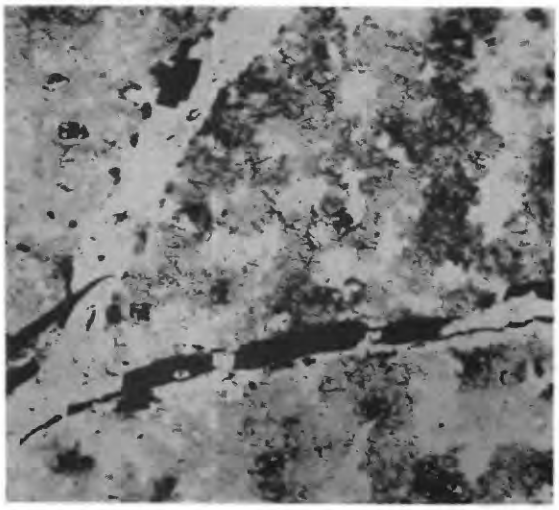
TODITES FRAGILIS Daugherty

PLATE 2

FIGURES 1–5. *Cynepteris lasiophora* Ash, n. gen., n. sp. (p. D31).

1. Lower epidermis. USGS paleobotany locality 10061; transfer preparation, USNM 42963, × 100.
2. Parts of several vein meshes formed by anastomosing veins on lower epidermis. A number of stomata and some epidermal cells are also visible. USGS paleobotany locality 10061; transfer preparation, USNM 42962, × 100.
3. Holotype; part of a large frond. USGS paleobotany locality 10062; USNM 42948, × 1.
4. Two typical pinnae. USGS paleobotany locality 10062; transfer preparation, USNM 42962, × 1.
5. Pinna with rather elongated pinnules. Venation typical of this species visible in some of the lower pinnules. USGS paleobotany locality 10061; USNM 42949, × 1.



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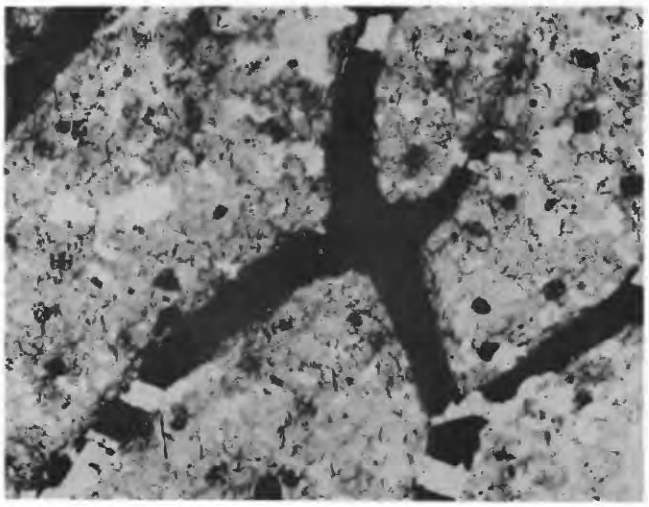

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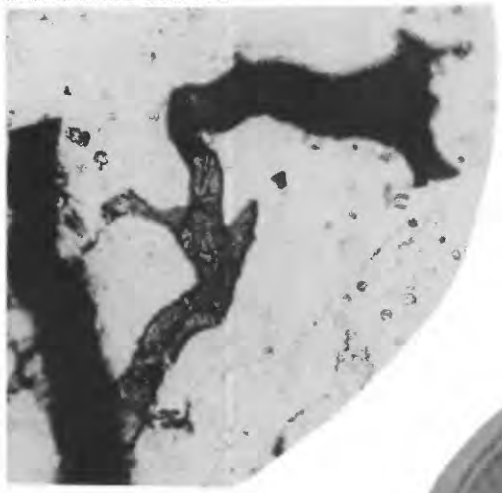
CYNEPTERIS LASIOPHORA Ash, n. gen., n. sp.

PLATE 3

FIGURES 1–7. *Cynepteris lasiophora* Ash, n. gen., n. sp. (p. D31).

1. Two of the irregularly shaped, multicellular structures found on lamina of some sterile pinnules of this species in the Fort Wingate area. Structure on left is attached to a vein. USGS paleobotany locality 10061; transfer preparation, USNM 42957, × 200.
2. Spore obtained from sporangium on specimen USNM 42950. USGS paleobotany locality 10059; USNM 42961, × 1,000.
3. Apical part of two sporangia showing radial walls of annuli and stomium. USGS paleobotany locality 10059; transfer preparation, USNM 42959, × 200.
4. Sporangium containing several spores in side view. USGS paleobotany locality 10060; transfer preparation, USNM 42964, × 200.
5. Side view of empty sporangium, stalk missing. USGS paleobotany locality 10060; transfer preparation, USNM 42963, × 200.
6. Side view of complete sporangium showing basal attachment, apical annulus, and walls of several cells. Same specimen as in figure 16*E* in text. USGS paleobotany locality 10059; transfer preparation, USNM 42959, × 200.
7. Top of sporangium showing apical annulus and stomium. USGS paleobotany locality 10059; transfer preparation, USNM 42960, × 200.



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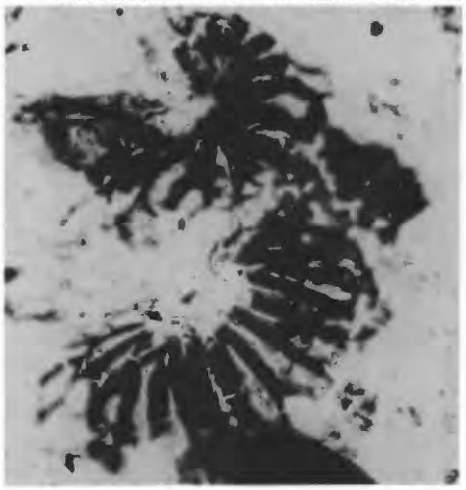

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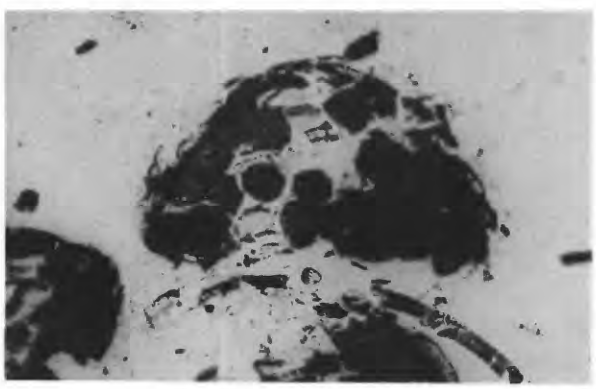

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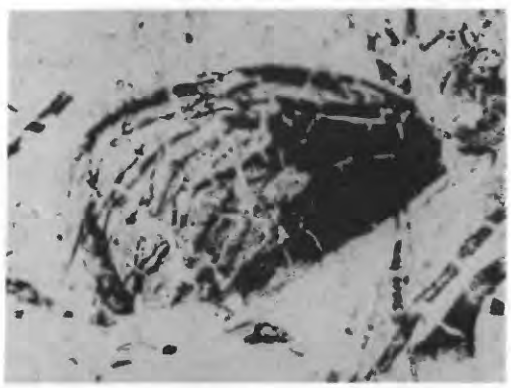

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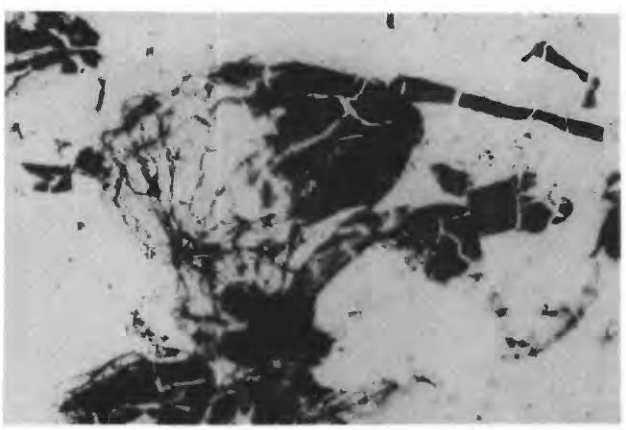

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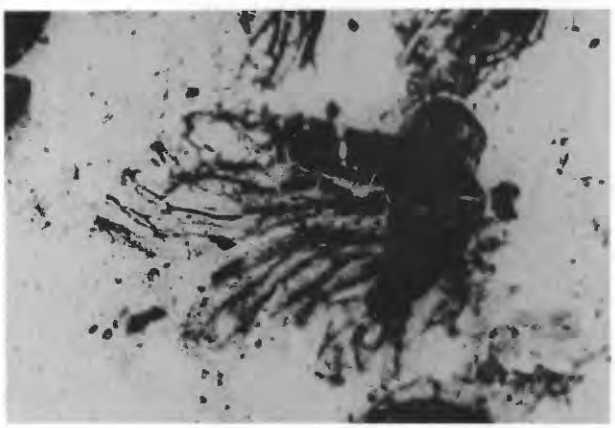

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CYNEPTERIS LASIOPHORA Ash, n. gen., n. sp.

PLATE 4

FIGURE 1. *Wingatea plumosa* (Daugherty) Ash, n. gen. (p. D38). Part of sterile leaf showing delicate pinnules typical of this form. USGS paleobotany locality 10059; USNM 42967, × 2.

2–7. *Clathropteris walkeri* Daugherty (p. D41).

2. Apex of pinna. USGS paleobotany locality 10058, USNM 42979, × 1.
3. Central part of pinna showing marginal teeth. USGS paleobotany locality 10058; USNM 42975, × 1.
4. Parts of two pinnae showing venation typical of this species. USGS paleobotany locality 10058; USNM 42977, × 1.
5. Edge of a mass of spores obtained from sporangium. USGS paleobotany locality 10062; USNM 42972, × 500.
6. View of surface of leaf showing distribution of sporangia within vein mesh. Midrib of pinna is at left. Impression on rock surface. USGS paleobotany locality 10062; USNM 42974, × 5.
7. Basal part of leaf. USGS paleobotany locality 10058; USNM 42980, × 1.

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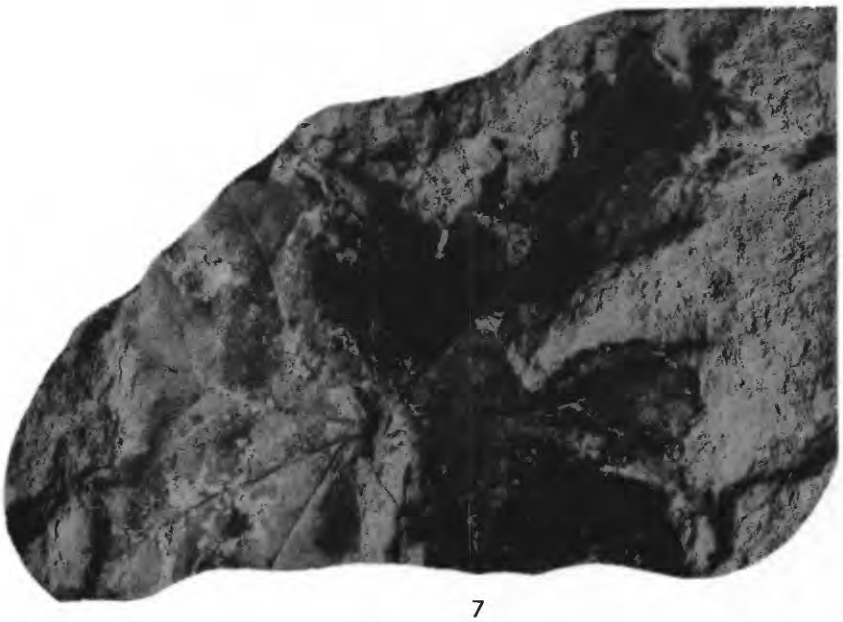

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WINGATEA PLUMOSA (Daugherty) Ash, n. gen., and *CLATHROPTERIS WALKERI* Daugherty

PLATE 5

FIGURES 1–7. *Cladophlebis daughertyi* Ash, n. sp. from USGS paleobotany locality 10062 (p. D43).

1, 2. Parts of two leaves. Venation is particularly clear in figure 2. USNM 42988, 42986b, × 1.

3. Three incomplete pinnae. Outline and venation of pinnules is typical of this species. Counterpart of part of specimen shown in figure 2. USNM 42986a, × 1.

4. An enlargement of a stoma. Note that guard cells overlap adjacent epidermal cells. Transfer preparation, USNM 42984, × 200.

5. Lower epidermis in marginal region of pinnule showing veins ending near edge of pinnule. Transfer preparation, USNM 42981, × 75.

6. Upper and lower epidermis. View looking through upper epidermis at lower epidermis. Note cell walls in upper epidermis clearly cross stomata in lower epidermis. Transfer preparation, USNM 42984, × 200.

7. Stoma between two veins on lower epidermis of pinnule. Radiating striations on surface of guard cells are clearly shown. Anticlinal cell walls on upper epidermis are faintly visible in lower right corner of figure and elsewhere. Transfer preparation, USNM 42984, × 200.

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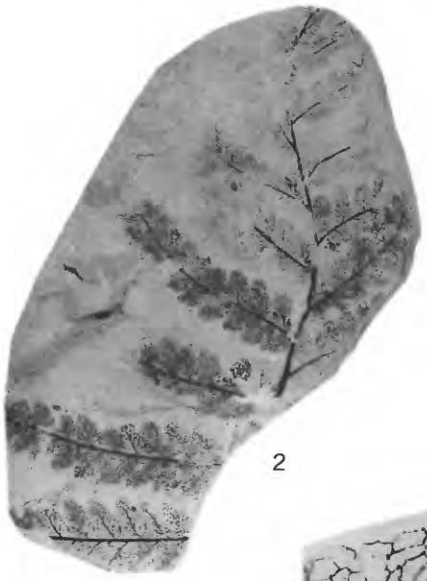

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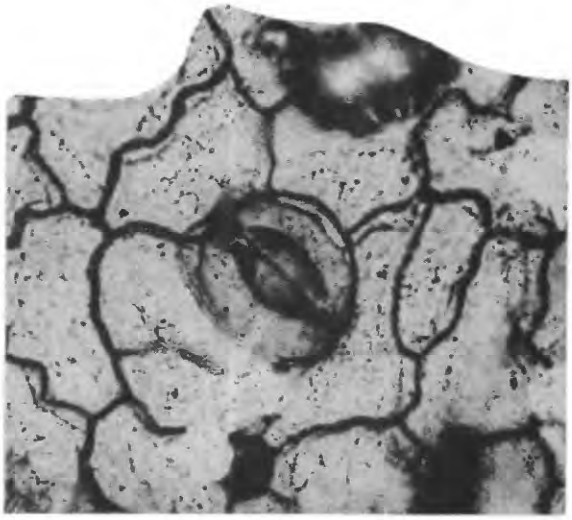

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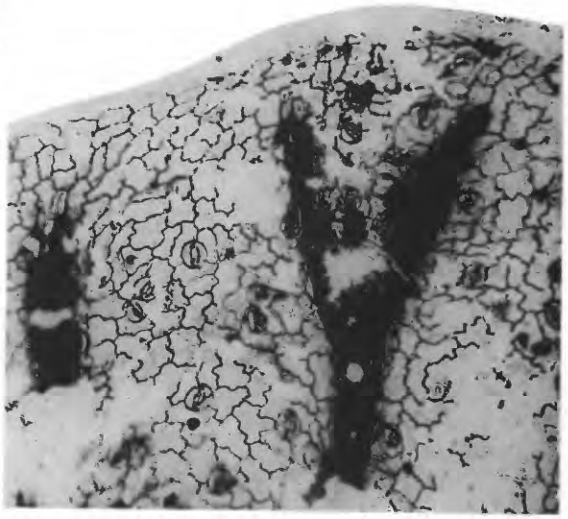

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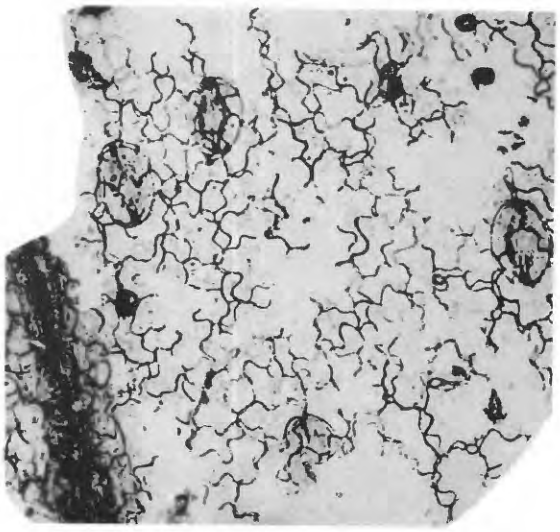

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CLADOPHLEBIS DAUGHERTYI Ash, n. sp.