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THE CHINLE (UPPER TRIASSIC) MEGAFLORA OF THE ZUNI MOUNTAINS, NEW MEXICO

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INTRODUCTION

The Chinle Formation in the Zuni Mountains area of west-central New Mexico contains fossilized leaves at several localities. They are of particular interest because leaf fossils are comparatively rare anywhere in the Chinle even though the formation contains abundant petrified wood nearly every place that it is exposed in the Southwest. A summary of the Zuni Mountains Chinle megaflora is presented in this paper together with a discussion of its correlation and some paleoecological implications.

Less than a dozen species based on leaf remains had been described or reported from the Chinle Formation in the southwestern United States until 1941. In that year Lyman Daugherty of San Jose State College, California, published "The Upper Triassic flora of Arizona", a comprehensive description of a large collection of leaves, fertile structures of several types, and petrified wood from the Chinle and equivalent formations in the Southwest. Most of the specimens were obtained from Petrified Forest National Park, Arizona. Since publication of Daugherty's 1941 paper, only a few additional forms have been described and his report remains the principal reference on the Chinle flora.

During the past few years I have been making as detailed a study as possible of plant megafossil, principally the leaves, in the Chinle in New Mexico and Arizona, and in more-or-less equivalent units in Texas and Sonora, Mexico. Some of the better preserved specimens were studied at the University of Reading, England under the direction of Professor T. M. Harris. The specimens subsequently were described in a thesis presented at Reading University in 1966 for a Doctor of Philosophy Degree. A report describing some of the ferns has been submitted to the U.S. Geological Survey for publication in a professional paper.

LOCALITIES

Leaf fossils were collected from the lower red member of the Chinle at several localities near Fort Wingate and from equivalent strata in the area south of Thoreau near Azul Creek and Cottonwood Canyon. At the Petrified Forest National Park, Arizona, fossil leaves occur below the Sonsela Sandstone Bed of the Petrified Forest Member of the Chinle Formation which overlies the lower red member.

COMPOSITION OF THE MEGAFLORA

The Chinle megaflora is known to consist of 40 well-characterized species that are referrable to 38 genera (Ash, 1967). Only 9 of these are based on petrified wood, a surprising fact when one considers the vast quantities present in the Chinle, and an indication that study of the Chinle petrifications has been neglected. Most of the megaflora described consists of compressed leaves and fertile structures of various types. Nearly all major groups are represented in the flora including the Fungi, lycopods, ferns, conifers, and ginkgos. A number of unclassified forms are also present. Most of the species in the flora were first described from Petrified Forest National Park, Arizona, and many were known only from that one area until my work elsewhere in the Southwest.

The flora in the Zuni Mountains contains many of the species previously described from Petrified Forest National Park and several totally new species. Some of the more interesting species are discussed briefly in this paper although several of them have not yet been studied in detail. Preliminary work suggests that at least three of the species included here are highly characteristic of the lower part of the Chinle and usually are found wherever the formation contains leaf remains.

Pteridophyta

Equisetales

Pith casts of *Neocalamites*, a large member of the horsetails, occur at two localities near Fort Wingate. At one locality about two dozen are exposed on the side of a thick ledge of sandstone. They are distributed over a horizontal distance of about 175 feet. Most of the casts appear to be at approximately the same stratigraphic horizon and they are in the position of growth. (fig. 1). About half of the casts are 1 to 2 meters tall and typically 15-25 cm in diameter; they taper slightly from the base to the top. Rhizome casts attached to the bases of several specimens are nearly a meter in length.

Several casts 30-60 cm long and 20-25 cm in diameter occur in a poorly exposed bed of shale at a second locality. These also are in the position of growth.

FIGURE 1

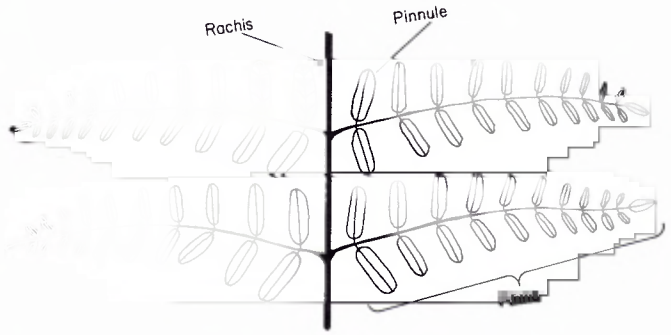
Pith cast of the stem and rhizome of *Neocalamites* sp. exposed on a ledge of sandstone in the lower red member of the Chinle Formation south of Fort Wingate, New Mexico. The stem is about 20 cm in diameter.

Daugherty (1941, p. 58-61) has described similar pith casts from the lower part of the Chinle at Petrified Forest National Park, and at a locality near St. Johns, Arizona. Casts described from a locality on Poleo Mesa, New Mexico may have been in the basal portion of the Chinle Formation but the stratigraphic position was not certain. Daugherty referred all of these specimens to *Neocalamites virginiensis* (Fontaine) Berry. The species was described originally from the Newark Series in the Eastern United States and was one of the species used to correlate that flora with the Chinle. However, the species is poorly known and needs to be thoroughly reevaluated before it can be used as a significant index fossil.

Pterophyta

The ferns are particularly well represented in the Chinle Formation of the Zuni Mountains area. Seven of the ten species based on foliar material in the Chinle megaflora have been collected here. The leaf and sporangia—the most important organs used in the classification of modern ferns—are known in detail for five of the seven species.

Living families recognized in the Zuni Mountains Chinle megaflora are the Osmundaceae, Dipteridaceae and Matoniaceae. One fossil species is assigned to each of these families. In addition, four species of uncertain classification have been collected. Four of the best known species are discussed here. The following sketch shows the terminology used in describing pinnate leaves.



Sketch of a bipinnate (twice pinnate) leaf.

OSMUNDACEAE

Todites fragilis Daugherty is the single species assigned to the Osmundaceae. It is a small delicate fern which is easy to recognize because it has distinctly asymmetrical pinnae as shown in figure 2A. Another distinctive character of this species is the unequal development of pinnules on the upper and lower sides of the pinna rachis. On the lower side the lamina is undivided whereas on the upper side the lamina is divided into sveeral pinnules near the main rachis. The lamina on the upper side however, becomes progressively less deeply divided within a short distance from the main rachis and near the pinna apex it is totally undivided.

The largest known nearly complete specimen of *T. fragilis* is about 6 cm wide and 12.5 cm long.

Only a few specimens of this rare species were collected from two localities near Fort Wingate; it originally was described from Petrified Forest National Park, Arizona (Daugherty, 1941, p. 52-53).

DIPTERIDACEAE

The family is represented by *Clathropteris walkeri*, a fern which has a large palmate leaf with 6 to 10 linear-lanceolate pinnae spreading outward from a basal web so that the entire leaf resembles a hand with the fingers extended (fig. 2C). The margins of the pinnae bear numerous, acutely-pointed, forward-curving teeth. Individual pinnae may be as much as 10 cm long and 3 cm wide and the basal undivided portion of the leaf may be 10 cm wide. This species has net venation with numerous blind vein endings.

The architecture of the leaf of this species compares rather closely with that of the modern members of the Dipteridaceae so that there can be little doubt as to the correct taxonomic assignment of the fossil. It is a common fossil at two localities near Fort Wingate and at the locality in the Petrified Forest National Park, Arizona, from which it was first described by Daugherty (1941, p. 56-57).

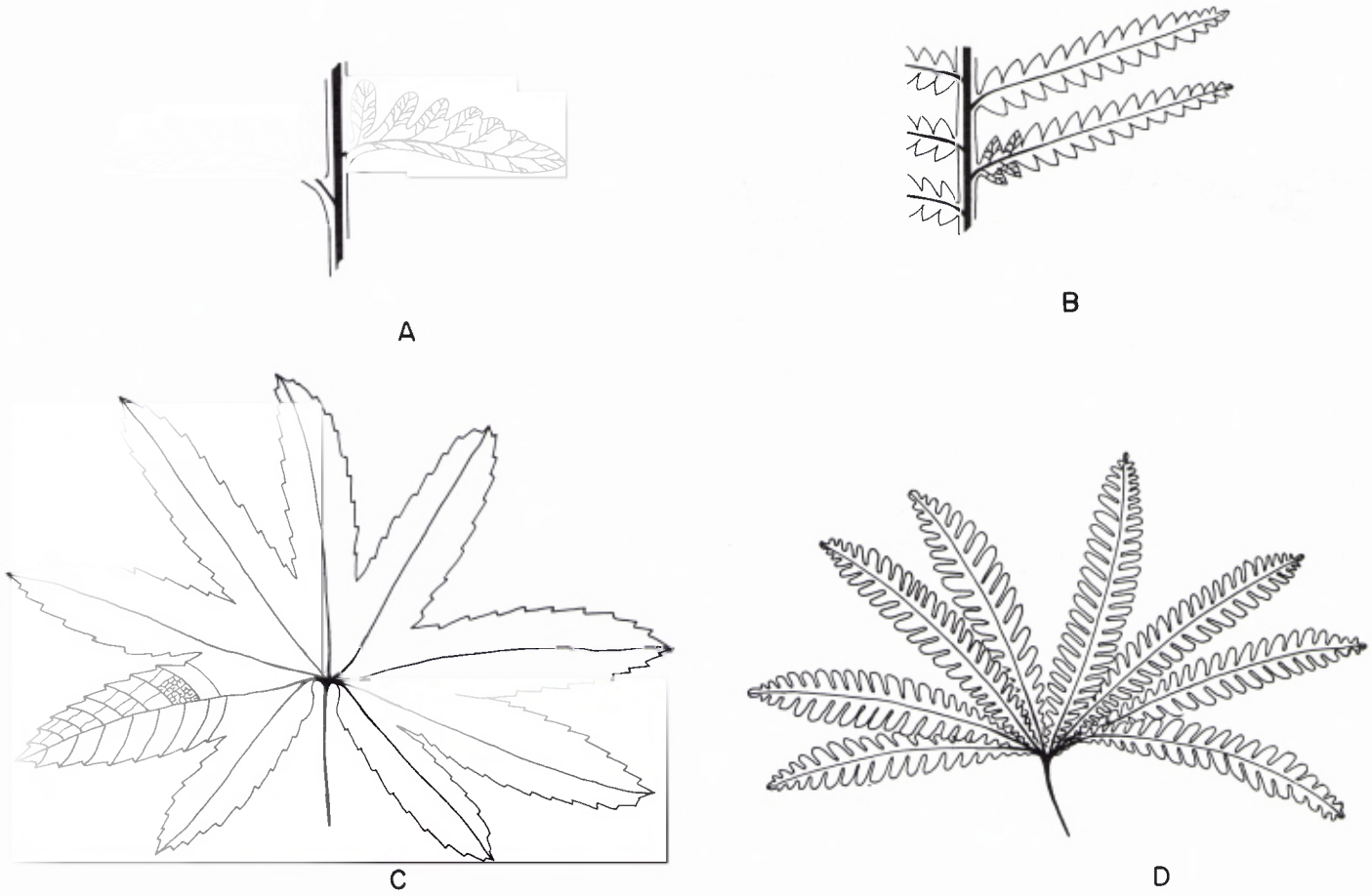


FIGURE 2

Sketches of some of the ferns in the Chinle megaflora. A. *Todites fragilis* Daugherty (×1); B. *Cladophlebis* n. sp. (×1); C. *Clathropteris walkeri* Daugherty (×½); D. *Phlebopteris smithii* Daugherty (×½).

MATONIACEAE

Phlebopteris smithii Daugherty is referred to the Matoniaceae. This fern has a palmately divided leaf which is much more delicate than the palmate leaf of *Clathropteris walkeri*. The basal portion of the leaf is small and the pinnae are deeply divided into pinnules (fig. 2D). There may be as many as 14 pinnae on a leaf. The longest pinnae known measures 16 cm and the largest pinnules on this leaf are about 2.2 cm long and 4 mm wide.

There is little doubt that this fossil is correctly classified as it exhibits the characteristic architecture of the modern Matoniaceae. The species was first described from Petrified Forest National Park by Daugherty in 1941 (p. 53-54) and collected in 1959 from two localities near Fort Wingate.

UNCLASSIFIED FERNS

Cladophlebis n. sp., one of the more prominent ferns in the Chinle megaflora in the Zuni Mountains, can not be assigned to a family because its fertile leaf has not been collected. It originally was described from Petrified Forest National Park by Daugherty (1941, p. 53-54); however, he had misidentified the form. A detailed description of the form and a revision of its nomenclature has been included in the paper submitted to the U.S. Geological Survey. This species has a rather large twice-pinnate leaf. The largest fragment is almost 30 cm wide and its length was probably 60 cm or more judging by the taper of the main rachis. The pinnules on the other hand are rather small and delicate (fig. 2B). Typically they are about 2 mm wide and 4-5 mm long and are falcate.

SPERMATOPHYTA

Gymnospermae

The gymnosperms, which include the conifirs, ginkgophytes, cycads, and several extinct families, are represented by 16 described and 2 undescribed species and thus constitutes the largest group of plants in the Chinle megaflora. Although the classification of several forms has not been determined, it is clear that members of the Cordaitales, Bennettitales, Ginkgoales, and Coniferales are present. In addition one species based only on petrified wood was referred tenatively to the Gnetales by Daugherty (1941). Many of the species based on leaf remains and previously found only in Arizona occur also in the Zuni Mountains. In addition, several new species have been found at the

Fort Wingate and Azul Creek localities. Three bennettites, a ginkgophyte, and four undescribed gymnosperms from the Zuni Mountains area are considered here.

BENNETTITALES

Certain leaves and fructification found in the Zuni Mountains flora could be assigned on the basis of gross morphology to either the Bennettitales (fossil cycads as they are sometimes called informally) or the Cycadales (true cycads). However, it is possible to separate the bennettitalean fossils from the true cycads if the cuticles are preserved. Thus microscopic examination of the cuticles of the several possible bennettites in the flora shows that only three actually are bennettitalean. They include two leaves, *Otozamites powelli* and *Nilssoniopteris* n. sp., and a flower, Williamsonia n. sp.

Otozamites powelli (Fontaine) Berry is of particular significance because it is the most common fossil leaf found in the Chinle Formation. *O. powelli* is a rather large pinnate leaf which may be as much as 15 cm long and 5 cm wide (fig. 3G). The pinnules are linear with parallel sides and a distinctly truncate apex; typically they are 2-2.5 cm long and 5-9 mm wide. All the veins are parallel and unbranched except in the pinnule base where they diverge and bifurcate within a short distance of the main rachis. Few if any of the veins end in the lateral margins; most continue to the apex of the pinnule.

O. powelli has been collected from nearly every locality containing leaf material in the Zuni Mountains area. It also has been collected from several localities in Arizona and Utah and from two other localities in New Mexico. In every instance the specimens obtained were from the lower part of the Chinle Formation. This species has been recognized also at three localities in the lower part of the Dockum Group of Late Triassic age in West Texas. The type was described by Fontaine (1890) from poorly preserved material collected in northern New Mexico and subsequently was revised by Berry, in 1927, on the basis of new material collected in Utah.

Nilssoniopteris n. sp., is a large strap-like leaf which has parallel sides. It is as much as 10 cm wide and probably 30 cm or more in length; the midrib is about 1 cm wide. Lateral veins are given off the midrib at frequent intervals. These veins are simple (rarely forked), straight, and follow a course which is perpendicular to the midrib. The base and apex of the leaf are not known.

A similar leaf was reported by Daugherty (1941) from a locality at an unspecified level in the Chinle in Dinnebito Wash, Arizona. He identified the leaf with *Macrotaeniopteris magnifolia* which was originally described from the Newark Series. However Daugherty's determination is in error and his specimens should be described as a new species of *Nilssoniopteris*. The single locality in New Mexico containing *Nilssoniopteris* n. sp. is near Fort Wingate.

A female bennettitalean flower has been collected from a locality near Fort Wingate. The flower which has not yet been described will be referred to as *Williamsonia* n. sp. in this paper. It has been compressed vertically so that the lanceolate shaped perianth bracts radiate outward more or less symmetrically from the central gynaecial portion of the flower (fig. 3H). The bracts are about 1.5 cm long and 4 mm wide and the gynaecium is about 6 mm in diameter.

Although the specimen has been compressed, the gynaecium shows some relief which indicates that it was originally globular or ovoid. Comparison of the cuticle of *Williamsonia* n. sp. with that of the two bennettite leaves known in the flora, *O. powelli* and *Nilssoniopteris* n. sp., indicates that the flower can not be attributed to either with any degree of confidence.

GINKGOALES

Several fragmentary leaves from a locality near Fort Wingate are referred tentatively to the Ginkgoales. The leaves are linear and deeply divided into two equal segments (figs. 3C, D). In the largest specimen the undivided portion is about 4 mm wide and 2.5 cm long. It contains eight narrow, parallel veins. The segments are about 2 mm wide and more than 5 cm long. Each contains four parallel veins which terminate at the rounded apex of the segment.

The base of the leaf is unknown and the cuticle is not preserved on any of the specimens which have been collected. Thus it is difficult to classify the leaf with any assurance. However, the specimens do resemble in gross morphology the upper parts of *Baiera*, a ginkgoalean genus known from rocks of Early Triassic through Middle Cretaceous age.

It is noteworthy that several species of *Baiera* have been reported from the Newark Series in the eastern United States (Fontaine, 1883, p. 85-88). A species of *Baiera* has been described also from Petrified Forest National Park by Daugherty. In all cases, however, none of these specimens compares closely with those from Fort Wingate. They compare rather closely with the upper part of the supposed ginkgophyte *Czekanowskia* which is frequently found in the rocks of Upper Triassic (Rhaetic) age in the northern hemisphere and in the Jurassic (Harris, 1931, p. 151).

Although it is not safe to assign the fossils from the Chinle to a particular genus because of our lack of knowledge of certain of their features it is felt that they can be considered ginkgoalean since they do exhibit some of the characters typical of some members of the family.

UNCLASSIFIED GYMNOSPERMS

The Chinle Formation in the Zuni Mountains area contains several undescribed gymnosperous leaves and fertile structures. None of them has been assigned to a family as the specimens are either too poorly preserved or have not yet been studied sufficiently to make meaningful assignments.

One of the more common species of the Chinle flora in the Zuni Mountains and elsewhere in the Southwest is a fossil which at least superficially resembles the shoots of some modern conifers. (figs. 3E, F). The axis of the

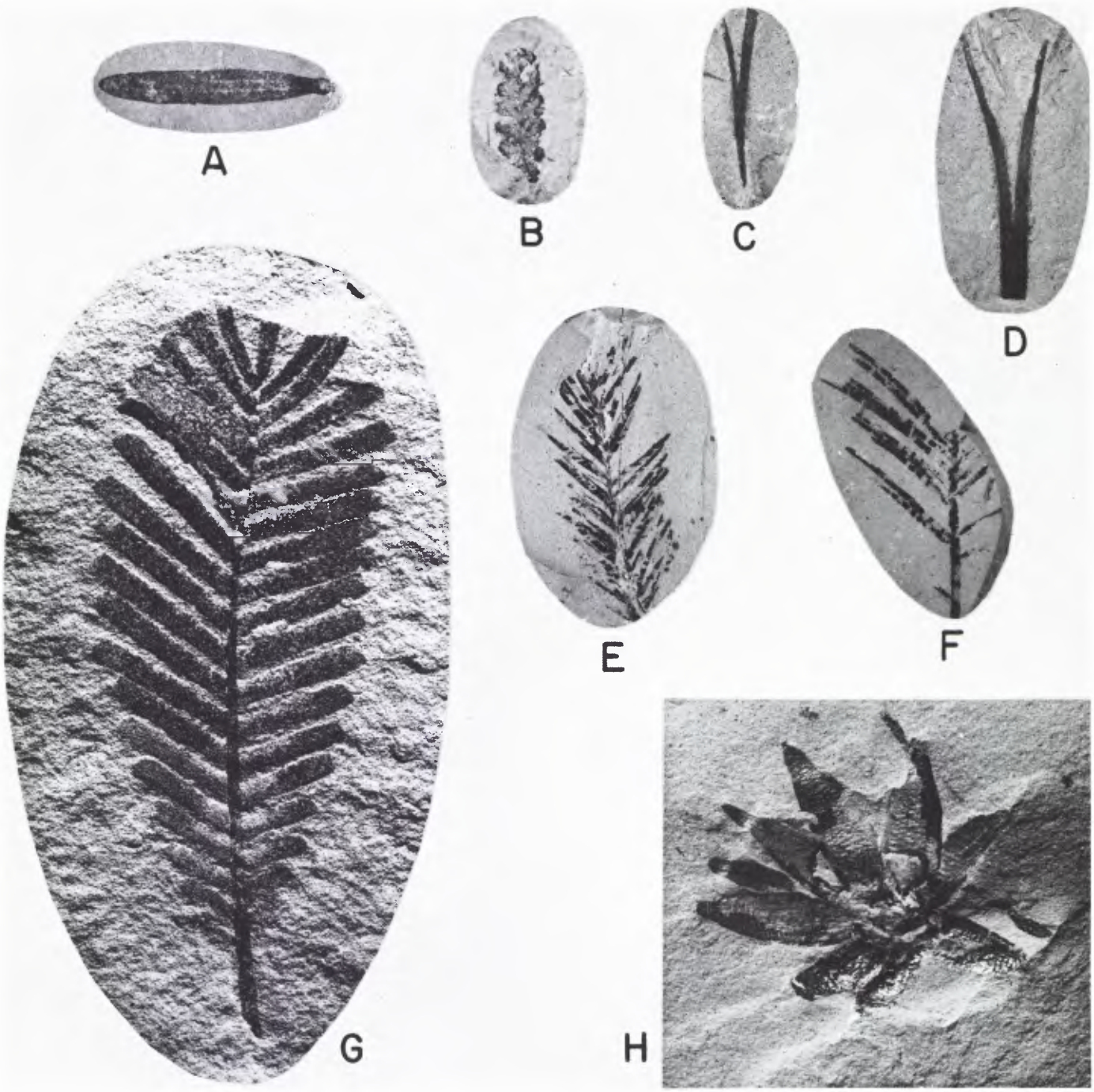


FIGURE 3

Representative seed plants from the lower red member of the Chinle Formation in the Zuni Mountains, New Mexico. All figures original size unless otherwise indicated. A. Samara (winged seed) of unknown affinities; B. Pistillate cone of unknown affinities; C, D. Ginkgophytic leaf; two specimens showing the bifurcated apex; E, F. Gymnospermous shoots of unknown affinities; the species is common in the Chinle Formation; G. *Otozamites powelli* (Fontaine) Berry; a good example of the species which is highly characteristic of the Chinle Formation; H. *Williamsonia* n. sp., (×2); a female benettitalean flower.

shoot is slender (1 mm or less in diameter) and is usually unbranched. Typically it is 5 to 10 cm long and bears frequent, spirally attached, narrow linear-lanceolate leaves that are 10-25 mm long and about 0.4-0.6 mm wide. This species which is now under study has been collected from localities in the Fort Wingate area and the area south of Thoreau.

A fertile structure of some interest is a single-winged samara (fig. 3A) which occurs rather frequently in the Chinle. The wing is linear with a rounded apex and is about 3.5 cm long, and about 6 mm wide. The single seed is oval and about 3 mm by 2 mm.

Another interesting fertile structure collected from the Chinle is a small pistillate cone collected in the Fort Wingate area (fig. 3B). The speciman is too poorly preserved to study in detail but the fragment recovered is 2.2 cm long and about 9 mm in diameter.

Another form which is rather common in the coarse grained sediments is a long, more-or-less straplike, leaf with parallel sides and venation. Paleozoic leaves of this type generally are referred to *Cordaites*, but study of the cuticle of these leaves has shown that they are not cordaitean. Similar types of leaves from the Chinle in northern New Mexico and from the Dolores Formation in southwestern Colorado have been referred to *Pelurodea poleonensis* (Daugherty) by Arnold (1964, p. 6-7). However the cuticle of *P. poleonensis* has not been described so identification with this form is uncertain.

PALEOECOLOGICAL CONSIDERATIONS

It is not possible in this brief article to review all the lines of evidence bearing on the paleoecology of the Chinle Formation nor to discuss the various theories of those who have considered the subject. My remarks instead will be confined mainly to what the plant fossils (especially the leaves) indicate about the climate when the lower part of the Chinle was being deposited in the Zuni Mountains and adjacent areas in New Mexico and Arizona. This discussion is preliminary in nature and does not apply to the upper part of the Chinle since its flora is not now known.

Fossil plants generally reflect the climate in which they lived just as modern plants reflect the climate in which they live and the leaves appear to be the most useful of all plant structures in this regard. Therefore specimens of nearly all of the species based on leaves now known in the Chinle have been examined. They exhibit the following characters which are thought to be indicative of the climate at the time the plants were alive.

1. The cuticle on the leaves of the seed plants is relatively thin (1-3μ).
2. Stomata are not sunken and the guard cells either overlap adjacent epidermal cells or are on the same level as the epidemal cells.
3. Stomata in most species are unprotected by hairs or other structures and they do not occur in deep grooves or furrows.
4. Leaves of all but one species are broad and are not reduced and many appear to have been thin and rather delicate in life.

All of these characters support the theory that the climate was rather humid. In fact, the stomatal characters of several ferns in the lower Chinle flora can be matched in certain mesophytic ferns now growing in the humid tropics. (Ash, 1967).

The theory that the climate during lower Chinle time was humid tropical is substantiated also by the fact that living relatives of many of the ferns in the Chinle megaflora now live in the humid tropics. For example, the living genera referred to the Matoniaceae and the Dipteridaceae occur in the Indo-Malayan region. Also the largest specimens of the modern relatives of *Neocalamites* live in the humid tropical regions of the world although some of the smaller species are found in temperate and cooler regions. At present gymnosperms are found in practically all climatic regions; however, the cuticle of the Chinle fossils attributed to the Gymnospermae exhibit structures consistent only with growth in a humid climate.

A second and independent line of evidence bearing on the subject is given by the vertebrate remains found in the Chinle. Colbert (1948, p. 235, 1960, p. 61) interprets them as indicating that the climate was warm, tropical or sub-tropical, which is compatible with the evidence given by the plants.

Most of the leaf remains occur in or adjacent to what apparently are stream and lacustrine deposits and one may suppose that the vegetation originally was concentrated along stream courses and around lakes. However, the fossil concentrations may be due to accidents of preservation and thus not indicative of the general climatic conditions during Chinle time. Because a number of the leaves in the megaflora are delicate and could not have been transported far, they at least must have lived adjacent to their site of deposition.

CORRELATION

The Chinle flora at one time was thought to correlate with the flora in the Upper Triassic Newark Series in the eastern United States (Daugherty, 1941, p. 37). This conclusion was based on six species reported to be common in both floras, and nine other species in the Chinle which were held to be closely related to forms in the Newark. My own work however, suggests that the two floras do note correlate closely (Ash, 1967).

Some of the forms in the Chinle used for earlier correlation were misidentified, others are too poorly known to be of correlative value, and several do not resemble specimens in the Newark flora. Both floras do contain a few of the same genera but the Chinle contains a large number of genera not known in the Newark Series. It is possible that the two floras contain one or two of the same species; otherwise they are distinct.

It was thought also that the Chinle flora was closely related to the large flora in the Upper Triassic rocks of Sonora, Mexico. Only a small part of that flora has been fully described and it therefore is difficult to draw firm

conclusions; these two floras appear to be distinct at this time.

The only sequence which unquestionably contains some of the same species found in the Chinle is the Dockum Group in West Texas. Daugherty, (1941, p. 17), reported that the Dockum contained four of the Chinle species and I have collected two other species from the Tecovas Shale Member of the Dockum near Lubbock and Amarillo. It appears that the Chinle flora is more closely related to the Dockum flora than it is to any other flora now known.

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