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THE UPPER TRIASSIC CHINLE FLORA OF THE ZUNI MOUNTAINS, NEW MEXICO

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Abstract—The Chinle Formation of Late Triassic age in the Zuni Mountains contains a large flora of about 40 species based on petrified wood, compressed leaves, reproductive structures and palynomorphs. Most of the plant fossils occur in the Monitor Butte Member of the Chinle, but some also occur in the Sonsela Sandstone Bed in the overlying Petrified Forest Member. The flora, which has been known for over a century, contains representatives of most major groups of plants including the horsetails, ferns, seed ferns, conifers, cycads, bennettitales and ginkgoes. It also includes several forms which cannot be classified with certainty at this time and several undescribed taxa. The flora indicates that the climate was warm and moist when the Monitor Butte Member was being deposited in the Zuni Mountains area of New Mexico.

INTRODUCTION

A little over two decades ago I (Ash, 1967) published a report on the Upper Triassic plant megafossils that occur in the Chinle Formation in the Zuni Mountain area in the guidebook prepared for the 18th field conference of the New Mexico Geological Society. At the time I had just begun an investigation of the flora, and the report that was published that year was quite preliminary in nature. Although much more has become known about the flora since then, much is still unknown, so in a sense this is just a progress report. It differs from the earlier report, however, in that herein are comments about the palynomorphs which have been described from the formation in the Fort Wingate area since 1967.

Upper Triassic floras occur at a number of localities in the Chinle Formation in the Zuni Mountains, particularly in the Monitor Butte Member, but almost the only ones which have yet been described occur in the vicinity of Fort Wingate. Because it would be premature to consider the undescribed floras at this time, I will confine most of my remarks to just those which are known from the Fort Wingate area. However, it should be pointed out that the floras at the other localities are generally similar, but they do contain a few different forms that are not known in the Fort Wingate floras.

The Chinle flora in the Fort Wingate area is of considerable significance because so few large, well preserved floras of this age are known. The leaves and reproductive structures at many of the localities near Fort Wingate are preserved as compressions in which the epidermis or cuticle is preserved. Such preservation is unusual and useful as it allows detailed study not otherwise possible. There are also localities in the area where the fossils are preserved merely as iron-stained impressions which only give information on their gross morphology.

LOCALITIES

In the Fort Wingate area, Upper Triassic plant fossils occur in the Monitor Butte Member (called the lower red member in 1967) of the Chinle Formation where they are known principally from horizons very near the base and from others near the top of the unit (Ash, 1970a, b, 1980). The middle part of the unit has never been as thoroughly prospected as the lower and upper parts because it is comparatively poorly exposed. Small amounts of petrified wood also occur in the Sonsela Sandstone Bed in the overlying Petrified Forest Member (Ash, 1967).

PREVIOUS INVESTIGATIONS

As reported elsewhere (Ash, 1972), the first plant fossil to be collected and studied from the Chinle Formation in the Fort Wingate area was a large log which Lt. J. F. C. Hegewald shipped to the Smithsonian Institution in 1879 (Swaine and Hegewald, 1882). The log was subsequently studied by Frank Knowlton (1889) and became the type, together with another log from Petrified Forest National Park in Arizona, of a new species of wood that he called *Araucarioxylon arizonicum*. For many years it was thought that the stratum which contained the log collected by Hegewald in the Fort Wingate area was the Shinarump Conglomerate and that it overlay a thick section of the Moenkopi For-

mation (Darton, 1928). However, in 1941 Charles B. Read of the U.S. Geological Survey collected leaf fossils from the strata underlying the supposed Shinarump Conglomerate and determined that they were identical to the fossils that had been described by Daugherty (1941) from the Chinle Formation in the Petrified Forest of Arizona (Read and Wanek, 1961). Thus, the fossils became the basis for a reassignment of the strata below the bed to the Chinle Formation rather than to the Moenkopi. I began an investigation of the Chinle flora in the Fort Wingate area in 1959 at the suggestion of Read. This investigation, which is still continuing, has resulted in the publication of a number of reports about the flora and the strata in which it occurs.

STRATIGRAPHIC FRAMEWORK

The stratigraphy of the Chinle Formation in the Zuni Mountains has been discussed in some detail elsewhere (Ash, 1970), so only a summary is included here. In the Zuni Mountains the Chinle rests unconformably on the Moenkopi Formation of Early and Middle(?) Triassic age. As is typical of the unit, the Chinle in this area consists principally of a thick sequence of colorful mudrock, several thin beds of subdued-colored sandstone and conglomeratic sandstone and a bed of pinkish limestone. In the Zuni Mountains region the formation is about 1200 ft thick and is divided, from the bottom to the top, into the Shinarump, Monitor Butte, Petrified Forest and Owl Rock members. The Petrified Forest Member is informally subdivided into two parts by a bed of conglomeratic sandstone called the Sonsela Sandstone Bed which has been traced over a large region in western New Mexico and eastern Arizona. A highly fossiliferous unit of limited lateral extent, the Ciniza Lake Beds, occurs in the upper part of the Monitor Butte Member (Ash, 1978).

Several lines of evidence indicate that the Chinle Formation was deposited principally by streams in a large basin that covered much of northwestern New Mexico and adjacent areas in Arizona, Utah and Colorado. The streams flowed to the northwest from the Mogollon highlands across the Fort Wingate area (Stewart et al., 1972).

AGE AND CORRELATION

The flora in the Monitor Butte Member of the Chinle Formation in the Fort Wingate area occurs stratigraphically below the large flora which has been described from the overlying Petrified Forest Member in Petrified Forest National Park in Arizona (Daugherty, 1941; Ash, 1972a). Palynomorphs and vertebrate fossils indicate that the flora in the Petrified Forest Member is Late Carnian and Early Norian in age (Ash et al., 1986). The Monitor Butte flora in the Zuni Mountains area is middle Carnian in age and thus one of the oldest known Upper Triassic floras in North America. The only older Upper Triassic floras are the small, generally undescribed floras that occur in the underlying Shinarump and Temple Mountain members of the Chinle Formation in Arizona and Utah (Ash, 1980).

COMPOSITION OF THE FLORA

A relatively large and varied flora occurs in the Chinle Formation in the Fort Wingate area (see Tables 1, 2). It contains representatives of

TABLE 1. A list of the plant megafossils that have been identified from the Chinle Formation in the Fort Wingate area. The principal references include Ash (1967, 1968, 1970a, 1972c, 1975, 1978, 1986a) and Ash et al. (1982).

Horsetails	<u>Equisetites</u> sp. A <u>Schizoneura harrisii</u> Ash
Ferns and fern-like foliage	<u>Todites fragilis</u> Daugherty emend. Ash <u>Cynepteris lasiophora</u> Ash <u>Wingatea plumosa</u> (Daugherty) Ash <u>Phlebopteris smithii</u> Daugherty emend. Ash, Litwin and Traverse <u>Clathropteris walkerii</u> Daugherty emend. Ash <u>Cladophlebis daughertyi</u> Ash
Bennettitales	<u>Zamites powellii</u> Fontaine emend. Ash <u>Nilssoniopteris cinizia</u> Ash <u>Williamsonia nizhonii</u> Ash
Cycads	<u>Lyssoxylon grigsbyi</u> (Daugherty) emend. Gould
Ginkgoes	<u>Baiera</u> sp.
Conifers	<u>Pagiophyllum readiana</u> Ash <u>P. zuniana</u> Ash <u>P. duttonia</u> Ash <u>P. navajoensis</u> Ash <u>Pelourdea poleoensis</u> (Daugherty) Arnold emend. Ash <u>Araucarioxylon arizonicum</u> Knowlton
Division uncertain	<u>Marcouia neuropteroides</u> (Daugherty) Ash <u>Dinophyton spinosus</u> Ash <u>Dechellyia gormanii</u> Ash

most major plant groups, but the flora is dominated in terms of numbers of specimens by the ferns. Other common fossils include the bennettitalean leaf *Zamites powellii* (Figs. 1N, O) and the leafy shoots and seed-bearing structures (samaras) of the enigmatic gymnosperm *Dinophyton* (Figs. 1j-l). At several localities the stems of the horsetails are fairly common. In the following paragraphs I briefly discuss some of the more interesting plants in the flora; more detailed information on the flora and its members is contained in the references at the end of this paper.

Horsetails

The horsetails are represented by pith casts and impressions of large stems that are referred to *Equisetites* (Fig. 1A) and *Neocalamites*. They

TABLE 2. A list of the palynomorphs that have been identified from the Chinle Formation in the Fort Wingate area.

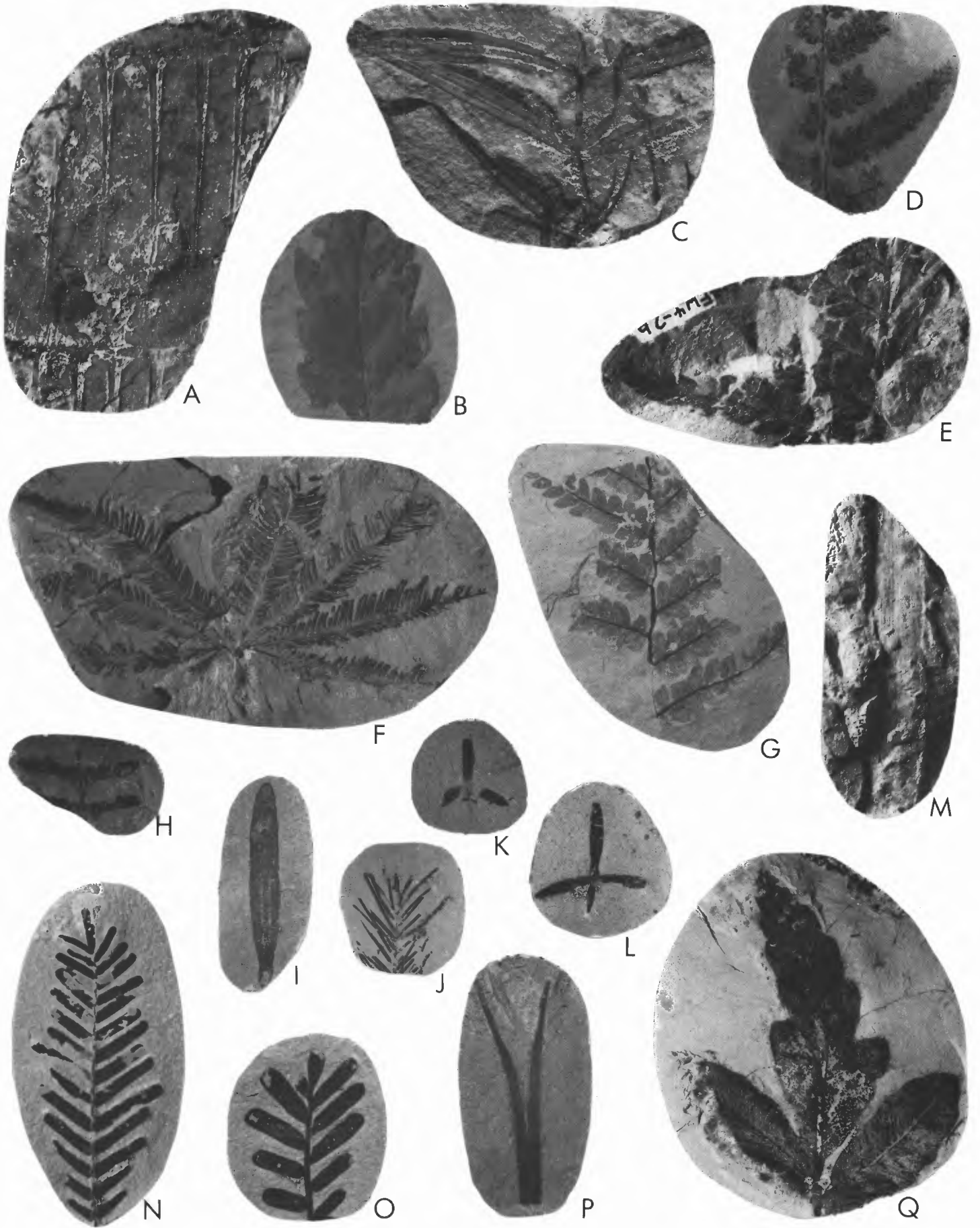
Division Uncertain	<u>Enzonalasporites vigens</u> Leschik <u>Brodipora striata</u> Clarke
Ferns	<u>Dictyophyllidites harrisii</u> Couper <u>Verrucosisporites tumulosus</u> Leschik <u>Verrucosisporites</u> sp. <u>Reticulatisporites jenensis</u> (Rein- hardt and Schmitz) Stone
Seed ferns	<u>Vitreisporites pallidus</u> (Reissinger) Nilsson <u>Alisporites opii</u> Daugherty <u>Alisporites gottesfeldi</u> Stone
Cycads or Ginkgoes	<u>Cycadopites fragilis</u> Singh <u>C. weillandii</u> (Jain) Stone <u>Granomonocolpites lusisae</u> Herbst
Conifers	<u>Platysaccus</u> sp. <u>Patinasporites densus</u> (Leschik) Stone <u>Pityosporites chinleana</u> Daugherty <u>Minutosaccus schizeatus</u> Madler <u>Klausipollenites</u> sp. <u>Granosaccus sulcatus</u> Madler <u>Equisetosporites chinleana</u> Daugherty

occur at several horizons in the Monitor Butte Member in the Fort Wingate area and elsewhere in the Zuni Mountains. In the Fort Wingate area they are especially abundant in a bed of sandstone near the top of the unit where about two dozen still occupy positions of growth (Ash, 1967, 1978a). Recently the remains of the horsetail *Schizoneura* (Fig. 1B) were described (Ash, 1986) from the Fort Wingate area. Its occurrence here is noteworthy as it most typically occurs in the Triassic of the southern continents and has never before been described from North America.

Ferns and fern-like foliage

Delicate fern foliage and fern-like foliage are quite common in the Monitor Butte Member at several localities in the Zuni Mountains but are particularly common in the Fort Wingate area. The fossils are generally large and so remarkably well preserved that we not only know the outline of the foliage itself but we have very detailed knowledge of their epidermis, sporangia and spores. Consequently, the entire plants can now be reconstructed with considerable assurance (Ash et al., 1982). The fossils have been assigned to six species, all of which have been described in considerable detail (Ash, 1970; Ash et al., 1982; Litwin, 1984). All of the species are extinct, but *P. smithii* (Fig. 1F) and *C. walkerii* (Fig. 1B) are members of living families that now inhabit moist, tropical areas and in fact are very close to certain living

FIGURE 1. Selected plant megafossils from the Monitor Butte Member of the Chinle Formation in the Fort Wingate area, New Mexico. Figure M, $\times 1/2$, all others are $\times 1$. Adapted from Ash (1967, 1970a, 1972b, 1978a). A, *Equisetites* sp. A. B, *Clathropteris walkerii* Daugherty emend. Ash. C, *Schizoneura harrisii* Ash. D, G, *Cladophlebis daughertyi* Ash. E, *Cynepteris lasiophora* Ash. F, *Phlebopteris smithii* Daugherty emend. Ash and others. H, *Todites fragilis* Daugherty emend. Ash. I, Samara of *Dechellyia gormanii* Ash. J, Leafy shoot of *Dinophyton spinosus* Ash. K, L, Samaras of *Dinophyton spinosus* Ash. M, *Pelourdea poleoensis* (Daugherty) Arnold emend. Ash. N, O, *Zamites powellii* Fontaine emend. Ash. P, *Baiera* sp. Q, *Marcouia neuropteroides* (Daugherty) Ash.



taxa (Ash, 1970a; Ash et al., 1982). On the other hand, the species *Cynepteris lasiophora* (Fig. 1E) is a representative of an extinct family that is known only from the Upper Triassic of North America (Ash, 1970a). As shown in Table 2, fern spores are fairly abundant, and some represent ferns that are not otherwise represented by fossils. Some of the fern spores found in the area include *Dictyophyllidites harrisii* (Fig. 2A) and *Verrucosiporites tumulosus* (Fig. 2B).

Bennettitales

The Bennettitales, or fossil cycads as they are sometimes called, are represented in the flora by two species based on leaves and one based on a reproductive structure. One of the leaves, *Zamites powellii* (Fig. 1N, O), is one of the most common plant megafossils in the Chinle flora at most localities in the Zuni Mountains, especially in the Fort Wingate area. The flower-like reproductive structure called *Williamsonia nizhonii* occurs only rarely in the Chinle Formation (Ash, 1968). The Chinle bennettitaleans, especially *W. nizhonii*, are remarkably similar to some of those rather commonly found in the Middle Jurassic of England (Harris, 1969). The bennettitaleans in the Chinle Formation

are some of the oldest known fossils that can be assigned to this interesting group of gymnosperms and show that the group was well established by Late Triassic time.

Cycads

The cycads are represented in the Chinle flora by only two small trunks called *Lyssoxylon* and possibly by the pollen grains *Cycadopites fragilis* (Fig. 2D). The trunks are from the Monitor Butte Member at a locality east of Fort Wingate near Coolidge, and the pollen grains are from the same member in the Fort Wingate area.

Ginkgoes

The ginkgoes are represented by a few fragments of a narrow, linear leaf that is deeply divided into two equal segments (Fig. 1P). Although the base of the leaf and its cuticle are unknown, it is probable that the fossil represents a species of *Baiera*, a genus that ranges from the Early Triassic into the Cretaceous. The occurrence of these fossils in the Monitor Butte Member is particularly interesting because so few specimens of early Mesozoic ginkgoes are known in North America.

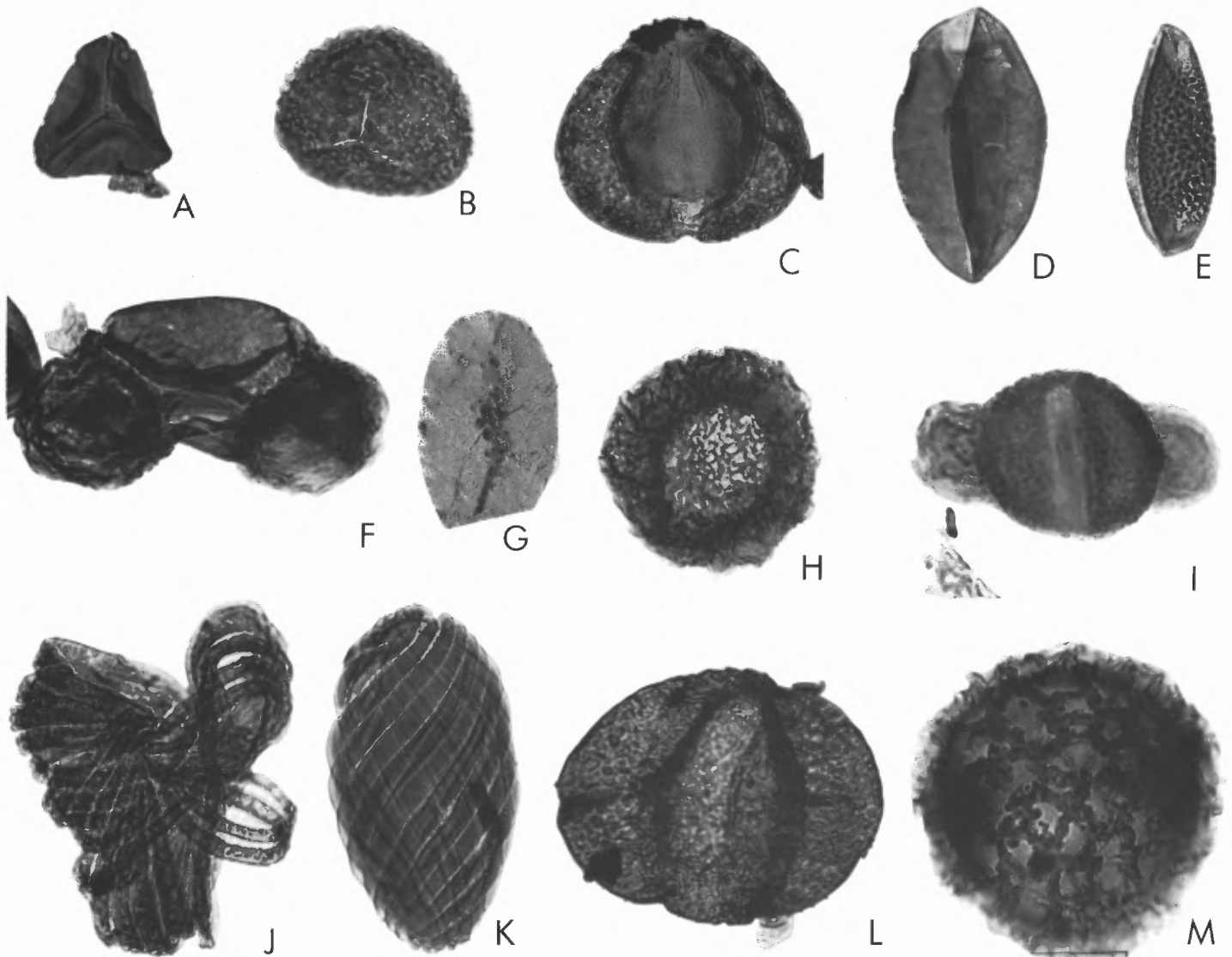


FIGURE 2. Representative palynomorphs and a pollen-bearing organ (microsporangia) from the Monitor Butte Member of the Chinle Formation in the Zuni Mountains, New Mexico. The measurement following the name of each form is the widest dimension of the fossil. A, *Dictyophyllidites harrisii* Couper, 36 μm . B, *Verrucosiporites tumulosus* Leschik, 50 μm . C, L, *Alisporites opii* Daugherty, 127 μm , 100 μm . D, *Cycadopites fragilis* Singh, 46 μm . E, *Granamonocolpites luisae* Herbst, 56 μm . F, *Pityosporites chinleana* Daugherty, 84 μm . G, microsporophyll containing the grains *Pityosporites chinleana*, $\times 1$. H, *Patinasporites densus* Leschik, 63 μm . I, *Minutosaccus schizeatus* Madler, 40 μm . J, K, *Equisetosporites chinleana* Daugherty, 57 μm , 79 μm . M, *Reticulatisporites jenensis*, 56 μm .

Conifers

In the Fort Wingate area, the conifers are represented by rare isolated leaves, leafy shoots, pollen grains and a moderate amount of petrified wood. The petrified wood occurs mainly in the Sonsela Sandstone Bed, although small amounts also occur in other sandstone beds in the Monitor Butte Member. Only one example of petrified wood, one of the type specimens of *Araucarioxylon arizonicum* has been described from the Fort Wingate area. Nevertheless, it is assumed that the bulk of the Upper Triassic wood in the area belongs to that species because it is so similar in gross morphology. The coniferous foliage found in the Fort Wingate area includes the leafy shoots of four species of *Pagiophyllum* and the remains of the large strap-like leaf *Pelourdea* (Fig. 1M). *Pelourdea* has been found throughout the Monitor Butte Member in the Zuni Mountains, whereas all the species of *Pagiophyllum* are known only from the Ciniza Lake Beds in the upper part of the Monitor Butte Member in the Fort Wingate area (Ash, 1978a). Coniferous pollen grains of several types are also known here, but they are not very common (Stone, 1978; Litwin, 1986). Some, if not all, of the species of *Pagiophyllum* probably came from large trees, whereas new discoveries in Utah show that the *Pelourdea* plant was short and shrubby and inhabited stream margins (Ash, 1987). Coniferous pollen includes *Patinasporites densus* (Fig. 2H), *Minutosaccus schizeatus* (Fig. 2I) and *Equisetosporites chinleana* (Fig. 2J, K).

The low frequency of all types of coniferous fossils found in the Fort Wingate area suggests that these plants were not very common here during the Upper Triassic. This, together with their fragmentary nature, suggests that they were washed into the area from higher regions to the south. The petrified wood is somewhat water worn, which suggests that the trunks were transported a considerable distance prior to burial.

Unclassified Gymnosperms

Several gymnospermous leaves and seeds of uncertain classification are known from the Monitor Butte Member in the Fort Wingate area. Some of them may represent seed ferns, but this is unclear at this time. Three of the fossils are particularly noteworthy. The first is *Dinophyton*. It is represented in the flora by leafy shoots bearing long narrow acutely pointed leaves (Fig. 1J) and by seed-bearing structures which have been compared to pinwheels or 4-bladed propellers (Fig. 1K, L). The cuticles of these fossils are very tough and bear many sharp hairs (Ash, 1970b). Recently it has been suggested (Krassilov and Ash, 1988) that *Dinophyton* is closely related to the gnetales, an advanced gymnosperm.

A second unclassified member of the flora is *Dechellyia*. This curious fossil, which was first described (Ash, 1970b) from Canyon DeChelly National Monument in eastern Arizona, is represented in the Fort Wingate area by linear winged seeds (Fig. 1I) that resemble the winged seeds of some species of maple and ash. Interestingly, the distinctive leaves of this plant have not yet been recognized in the Fort Wingate area.

The third of these enigmatic forms is the delicate and rather fern-like leaf *Marcouia* (Fig. 1Q). This leaf was named in honor of Jules Marcou who examined the geology of the Zuni Mountains in November 1853 (Marcou, 1856). The classification of this fossil is uncertain. Although the leaves look very fern-like, sporangia have never been found on any of them, but a specimen from Arizona bears a small oval seed-like body (Ash, 1972b). Thus, it is very possible that *Marcouia* is some sort of a gymnosperm, possibly a seed fern. However, more complete and better preserved specimens of this leaf must be found before its classification can be determined with assurance.

Possible seed-fern pollen found in the Monitor Butte Member includes *Alisporites opii* (Figs. 2C, L) and *Pityosporites chinleana* (Fig. 2F). Microsporangia containing the form *P. chinleana* have been collected from the Monitor Butte Member a few km south of Thoreau. These structures (Fig. 2G) closely resemble the microsporangia of certain seed ferns.

DISCUSSION

The weight of evidence supports the conclusion, voiced in my earlier article (Ash, 1967), that the climate in the Fort Wingate area was warm

and moist when the Monitor Butte Member of the Chinle was being deposited. As noted in that paper, several lines of evidence support this conclusion. For example, the most abundant plant fossils in the area are the remains of plants, such as the horsetails and ferns, that required abundant moisture and warm to hot temperatures. Furthermore, the size of the horsetail fossils indicates a wet climate because their giant Carboniferous ancestors inhabited coal-forming swamps. The largest living representatives of this group of plants live where there is abundant moisture and warm to hot climates. The variety, abundance and anatomy of the fern fossils in the flora also indicate that the climate must have been warm and quite humid at that time. In fact, the living descendants of certain ferns (*P. smithii* and *C. walkerii*) in the flora now live under such climates in southeast Asia. The abundance of bennettitaleans in the Chinle flora suggests that the climate was warm, as their nearest living relatives (cycads) live in warm to hot regions in the Southern Hemisphere. The paucity and fragmentary nature of the coniferous fossils in the flora seems to indicate that these xerophytic plants did not live in large numbers in the Fort Wingate area, which suggests that the climate was too humid for them to survive there.

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