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Aspects of the Palynology of the Chinle Formation (Upper Triassic), Colorado Plateau, Arizona, Utah, and New Mexico

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CONTENTS

ABSTRACT

This study deals with 16 palynological samples from Arizona, New Mexico, and Utah, that represent six members of the Chinle Formation of Late Triassic age. The samples, in ascending sequence, show a gradual change in the spore-bisaccate ratio from a preponderance of spores to numerical dominance of bisaccate pollen grains. This change is interpreted to indicate a climatic trend toward increasing aridity. The trend is thought to represent the decreasing energy phase of the oldest of three depositional cycles posited by Lupe (1977, 1979). The late Karnian age indicated for the Chinle Formation by pollen and spores is based on material from the lower part of the formation, leaving open the possibility that the upper part of the Chinle may be younger.

INTRODUCTION

The Chinle Formation of Late Triassic age crops out over a large area of the Colorado Plateau in Arizona, New Mexico, Utah, and Colorado. Both its depositional history and its stratigraphic relationships are important in locating uranium deposits present in the formation. Laterally variable lithologies and complex intertonguing make difficult the interpretation of intraformational relationships from field observations alone.

Both plant microfossils and megafossils occur in the Chinle Formation. Previous studies of palynomorphs from the Chinle have dealt chiefly with material from the Petrified Forest Member, in the lower part of the formation. These palynomorphs have been interpreted as indicating correlation with the Karnian Stage of the Upper Triassic of Germany (Dunay and Fisher, 1974).

Although Ash (1980) has delimited three floral zones based chiefly on leaf remains in American Upper Triassic rocks including the Chinle Formation, no previous attempt has been made to determine possible changes in composition of palynoflorules with time within the formation. The present report is concerned with pollen and spores from 16 localities, widely distributed both geographically and stratigraphically within the Chinle Formation. The study is a search for aspects of floral composition that might bear upon the stratigraphic and paleoenvironmental history of the formation.

PALYNOLOGY

SAMPLE LOCALITIES

Except for one sample, all material examined for this report was collected by Schultz (1963) for his analysis of clay-minerals in Triassic rocks of the Colorado Plateau. His collections consisted chiefly of fine-grained sediments; many were obtained from fresh exposures inside uranium mines. Consequently, the more organic of these samples yield palynomorphs more consistently than do the commonly oxidized surface samples from the Chinle. One sample, U.S. Geological Survey Paleobotany locality D1341, was collected from an outcrop by Scott. Locality data are given in table 1. Geographic distribution of the samples bearing Schultz's locality numbers is shown on figure 1. Detailed locations are given in Schultz (1963). Locality D1341 is in the Circle Cliffs, Utah, in the general vicinity of number 58 on figure 1. The exact location is given in Scott (1960).

Table 1.—Sample localities in the Chinle Formation

Member	USGS Paleobotany Locality No.	Schultz (1963) Locality No.	Schultz (1963) Sample No.	State
Church Rock	D3630	19	GR 5	N. Mex.
	D3649A	79	TH 6	Utah
Petrified Forest	D3627	9	HU 1	Ariz.
	D3629	16	RR 7	Ariz.
	D3631	31	LC 6	Utah
Moss Back	D3633	33	BJ 10	Utah
	D3647	69	Wi 6	Utah
	D4727C	36	MP 5.9	Utah
Monitor Butte	D3638B	53	BN 4	Utah
	D3640B	58	LD 7	Utah
	D3641	59	SD 6	Utah
Shinarump	D3634A	38	PH 7	Utah
	D3650A	None*	DF 3c	Utah
	D3650B	None*	DF 3	Utah
	D1341	Coll. by Scott		Utah
Temple Mountain	D3648	70	RH10	Utah

*No locality number was assigned by Schultz to these Deer Flat samples. See Schultz (1963) for more complete data on his localities.

AFFINITIES OF PALYNOMORPHS

The assemblage of palynomorphs in the sample from locality D1341 is by far the best preserved and most diverse of those dealt with in this study. Some 60 taxa have been identified from this sample, and many more, perhaps 30-40 additional forms, are present in the complex of bisaccates.

Among the difficulties in applying names to Late Triassic palynomorphs is the existence at that time of a morphologically overlapping complex of bisaccate pollen grains. Even in an assemblage such as that from locality D1341, in which bisaccates are not numerically dominant, they are present in a bewildering variety of forms. The consistent application of names to members of this bisaccate complex is an incompletely resolved problem in Mesozoic palynology.

This work on the palynology of the Chinle Formation is exploratory rather than definitive; identifications are neither complete nor final. Because the assemblage from locality D1341 includes virtually all the forms present at the other localities studied, efforts to identify palynomorphs were concentrated

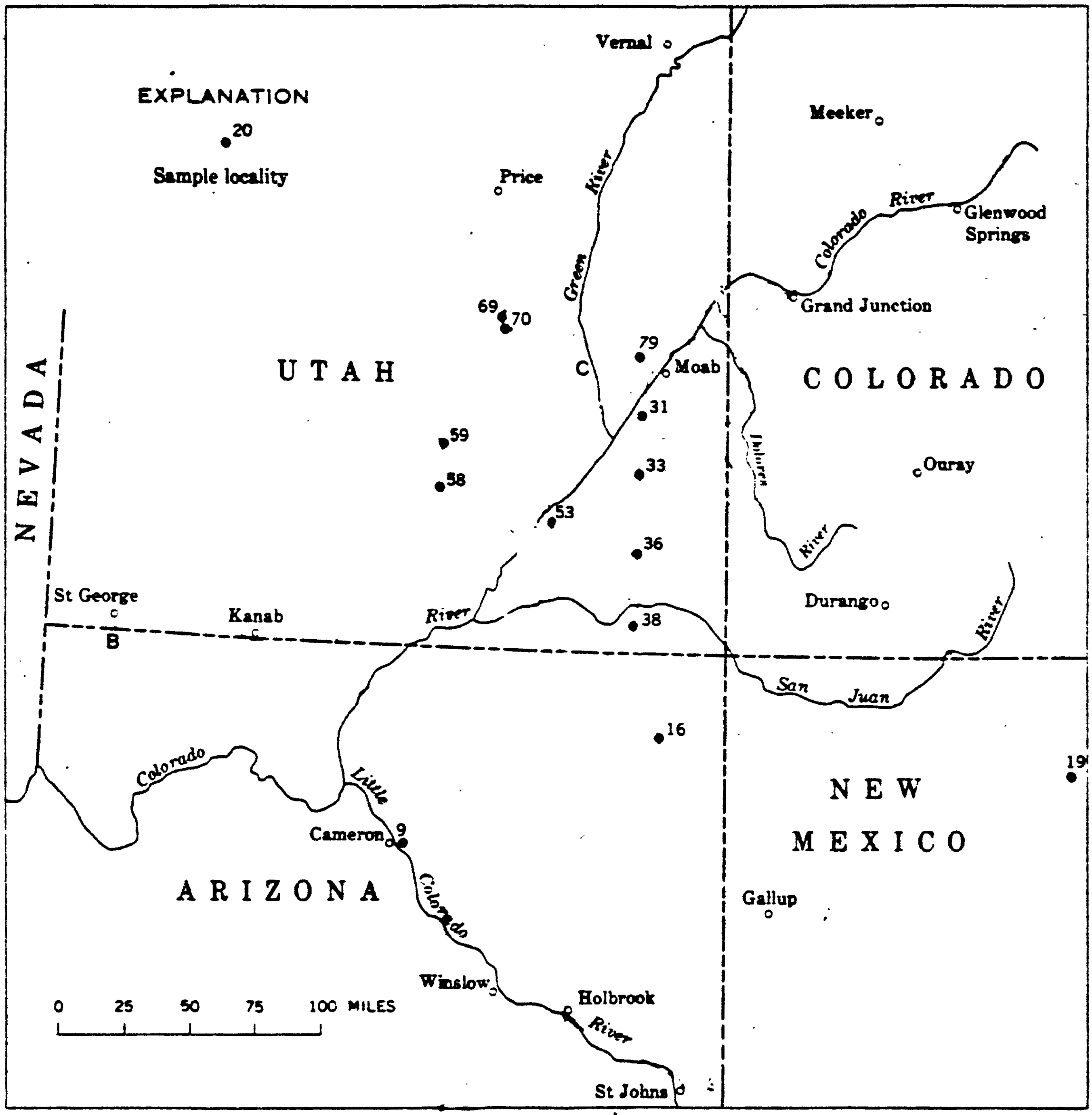

Figure 1-- Distribution of palynological sample localities of table 1 on the Colorado Plateaus. Detailed locality data in Schultz (1963).

upon this sample. Some of the taxa recognized in the assemblages are among new forms named by Fisher and Dunay in their unpublished data on material from the Petrified Forest Member. Names of these taxa have been omitted here. Illustration of the assemblage from locality D1341 is in progress (L. I. Doher, unpub. data).

A tentative list of forms recognized from locality D1341 is given in table 2. This locality is in the Shinarump Member of the Chinle Formation. A similar list of taxa recognized in the sample from locality D3631, from the overlying Petrified Forest Member, is given in table 3. This assemblage contains many fewer taxa than are present in the Petrified Forest Member near its type locality in Arizona (M. J. Fisher and R. E. Dunay, unpub. data, 1981). Because it contains new taxa, the list of palynomorphs identified by Fisher and Dunay from the Petrified Forest Member cannot be used here for direct comparison. However, except for striate bisaccates, virtually all entities recognized in the Shinarump assemblage of locality D1341 are also present in the Petrified Forest Member.

Table 2.—Palynomorph assemblage from U.S. Geological Survey Paleobotany Locality D1341, Shinarump Member, Chinle Formation

Alisporites oppi
Angustisaccus n. sp.
Aratrisporites sp.
Brodispora striata
Calamospora cf. C. mesozoica
Callialasporites n. sp.
Camerosporites secatus
Camerosporites spissus
Chordasporites chinleanus
Cristatisaccus ? sp.
Cycadopites sp.
Cyathidites australis
Daughertyspora chinleana
Deltoidispora sp.
Dictyophyllidites harrissi
Dictyophyllidites harrissi
Dictyophyllidites mortoni
Discisporites ? sp.
cf. Duplicisporites granulatus
Enzonalasporites cf. E. vigens
Enzonalasporites sp.
Equisetosporites chinleana
Equisetosporites steevesi
Falcisporites oviformis
Falcispsporites tecovasensis
Falcisporites sp.
Granamonocolpites luisae
Lycopodiumsporites sp.
Microreticulatisporites cf. M. fuscus
Ovalipollis ovalis
Parcisporites cf. P. cirratus
Parcisporites sp.

Table 2.--Palynomorph assemblage from U.S. Geological Survey Paleobotany Locality D1341, Shinarump Member, Chinle Formation--Continued

Patinasporites densus
Pityosporites devolvens
Pityosporites sp.
Platysaccus nitidus
Platysaccus triassicus
Platysaccus sp.
Plicatisaccus n. sp.
Podocarpites sp.
Punctatisporites cf. *P. fissus*
Punctatisporites toralis
Punctatisporites sp.
Retusotriletes sp.
Samaropollenites concinnus
Scopulisporites cf. *C. toralis*
Sulcatisporites sp.
Todisporites major
Todisporites marginalis
Todisporites sp.
Triletes klausii
Tulesporites briscoensis
Granamonocolpites luisae
Lycopodiumsporites sp.
Microreticulatisporites cf. *M. fuscus*
Ovalipollis ovalis
Parcisporites cf. *P. cirratus*
Parcisporites sp.
Patinasporites densus
Pityosporites devolvens
Pityosporites sp.
Platysaccus nitidus
Platysaccus triassicus
Platysaccus sp.
Plicatisaccus n. sp.
Podocarpites sp.
Punctatisporites sp.
Punctatisporites cf. *P. fissus*
Punctatisporites toralis
Punctatisporites sp.
Retusotriletes sp.
Samaropollenites concinnus
Scopulisporites sp.
Todisporites major
Todisporites marginalis
Todisporites sp.
Triletes klausii
Tulesporites briscoensis
Umbrosaccus sp.
Vesicaspora cf. *V. cachoutensis*
Vitreisporites pallidus
Vitriesporites sp.
Wapellites sp.

Table 2.--Palynomorph assemblage from U.S. Geological Survey Paleobotany Locality D1341, Shinarump Member, Chinle Formation--Continued

Zonalasporites cinctus
Zonalasporites sp.

Table 3.--Palynomorph assemblage from U.S. Geological Survey Paleobotany Locality D1341, Petrified Forest Member, Chinle Formation

Alisporites opii
Apiculatisporites sp.
Aratrisporites sp.
Chordisporites chinleanus
Falcisporites oviformis
Klausipollenites gouldii
Monosulcites sp.
Parcisporites sp.
Patinasporites densus
Pityosporites oldhamensis
Platysaccus triassicus
Platysaccus sp.
Protodiploxypinus sp.
Pretricolpipollenites bharadwajii
Punctatisporites sp.
Sulcatisporites sp.
Tulesporites briscoensis
Vallasporites ignacci
Vitreisporites pallidus
Zonalasporites sp.

RELATIONSHIPS OF THE CHINLE PALYNOFLORA

The overlaps in occurrences of taxa and the small size of most assemblages recovered from these Chinle localities hinder the recognition of significant differences among them. In order to evaluate the differences detected, a review of previous paleobotanical work on the Chinle flora and on the floristically similar Dockum Group of Texas and New Mexico is useful.

Discussion of palynofloras as entities tends to create the impression that pollen and spores constitute a category of organisms rather than being only detached plant parts that have limited biological or ecological significance apart from the plants that bore them. To avoid this limiting misconception, information about plant megafossils as well as microfossils is essential to the understanding of floras.

Plant megafossils.--Plant remains in the Chinle have been summarized by Stewart and others (1972). The dominant groups were sphenopsids, caycadophytes, and conifers. The abundance of silicified wood suggests that conifers were the most important of these groups. Ferns, lycopods, cordiataleans, and ginkgoaleans also were present. No angiosperms are known. However, R. W. Brown (1956) described as a palm a putative fossil angiosperm, Sanmiguelia, from the Dolores Formation in Colorado. Stewart and others (1972) regarded the Dolores as equivalent to, and perhaps a part of, the upper Chinle in local areas. No further evidence of the angiospermous affinities of Sanmiguelia has appeared in the past 25 years, and a host of other evidence indicates that the angiosperms originated in mid-Cretaceous rather than in Triassic time.

Daugherty (1941) made the first detailed study of the Chinle flora. He described the foliage of several cycads and ferns, five types of silicified wood, and five palynomorphs. Daugherty interpreted the climatic conditions as tropical to subtropical, with high annual rain fall interrupted by a distinct dry season. One tree, Schilderia, with possible gnetalean affinities, had stems with fluted bases comparable to those of present-day swamp cypress. All of Daugherty's material came from the Petrified Forest Member of the Chinle.

More recently, Chinle megafossils have been studied by Ash. In one summary (Ash, 1969), he lists 37 genera in the flora. Gymnosperms are most numerous, followed by ferns, lycopods and sphenopsids. Ash, who restudied material from Daugherty's localities in the Petrified Forest of Arizona, found that the Chinle plants most closely resembled those of the Dockum Group of Texas. The supposed resemblance of the Chinle flora to the plants of the Upper Triassic Newark Group of the Eastern United States was attributed chiefly to misidentifications.

Plant megafossils are present in the beds representing a Late Triassic lake, Lake Ciniza, within the Monitor Butte Member of the Chinle. From these beds, Ash (1978) identified eight species of bennetitalians, ferns, and unknown gymnosperms. Several aspects of the flora and fauna of this ancient lake were studied by Ash and by others. They concluded that the Chinle climate was warm and moist at the time the lake beds were deposited.

Litwin and others (1981) have published a preliminary report on spores removed from compressed fern megafossils from the Chinle Formation. They have recovered spores from five leaf genera.

Recently, Ash (1980) recognized three floral zones in the Upper Triassic rocks of North America. He termed the oldest of these the Eoginkgoites zone, of middle Karnian age. This zone has been recognized at two localities in the Temple Mountain Member of the Chinle in southeastern Utah (Ash, 1975). The Shinarump Member of the Chinle also contains megafossils typical of this zone at six localities in southern Utah (Ash, 1975). The most completely known Eoginkgoites assemblage occurs in the Pekin Formation in North Carolina.

The second of Ash's floral subdivisions is called the Dinophyton zone. Dinophyton is a distinctive plant of uncertain gymnospermous affinities. The Dinophyton assemblage is present in the lower part of the Petrified Forest Member of the Chinle in the Petrified Forest National Park in Arizona. Ash has also identified this zone in the Monitor Butte Member in western New Mexico and northeastern Arizona. The Dinophyton zone is characteristic for the Dockum Group of eastern New Mexico and adjacent Texas. In Eastern United States, the Dinophyton flora occurs in the New Oxford Formation in Pennsylvania. Ash believed that the Dinophyton zone is of late Karnian and possibly Norian age.

The third, uppermost zone is poorly known and provisional due to the meager state of knowledge about plants in the uppermost Triassic beds of the United States.

In summary, the flora of Chinle time was a well-developed and complex one that contained numerous gymnosperms, along with ferns, sphenopsids, cycadophytes, and lycopods. Genera of uncertain affinities and ecology, for example *Dinophyton*, were widespread and are now indicators of stratigraphically significant floral zones. Extensive occurrences of fossil logs signify development of probably coniferous forests. Plant megafossils, studied chiefly from the Petrified Forest Member of the Chinle Formation, have been interpreted as indicating a tropical to subtropical climate.

Plant microfossils.—Daugherty (1941) included five taxa of palynomorphs in his monograph on the Petrified Forest flora. Among these were two bisaccates, a probable lycopod spore, a fungal spore, and a distinctive pollen grain of disputed affinities. He named this grain *Equisetosporites* for its supposed resemblance to spores of modern *Equisetum*, horsetail. *Equisetosporites* was restudied by Scott (1960) from new material and was reassigned to *Ephedra*, an extant gymnosperm. Ash (1972) recovered these pollen grains from a cone that he later (1980) regarded as coniferous.

Daugherty's early palynological work on the Petrified Forest Member of the Chinle was expanded by Gottesfeld and Kremp (1966) and by Gottesfeld (1972). In the Petrified Forest Member, they found that bisaccate pollen composed more than 50 percent and asaccate grains were less than 5 percent of the total, and that a few striate bisaccates were present. Gottesfeld and Kremp (1966) attempted to distinguish two ecological associations, one from a stump horizon containing a paleosol, and another from a lacustrine environment. Bisaccates were more abundant, and the diversity of trilete spores was greater at the lacustrine site.

Gottesfeld (1972) hypothesized three palynofloral associations from his work on the Chinle pollen and spores: an "Upland Gymnospermous Community," the "*Araucarioxylon* Forest Community," and the "Floodplain Swamp Community." His palynological data are not extensive enough to make these concepts unequivocal.

The most extensive published palynological work on the Chinle Formation was done by Stone (1978). He described a palynoflora of 19 entities from the Ciniza Lake Beds (Ash, 1978), an unusual Late Triassic lake found in the Monitor Butte Member near Fort Wingate, New Mexico. Nonstriate bisaccates dominate this assemblage and trilete spores are relatively rare. Nine of the genera and four of the species are common to the Petrified Forest Member assemblages discussed by Gottesfeld (1972) and Gottesfeld and Kremp (1966). The assemblage most closely resembles a palynoflora from the Dockum Group in Texas; twelve genera and eight species are common to both assemblages. Three forms are present that are limited to the Upper Triassic of the American Southwest: *Alisporites opii*, *Pityosporites chinleana*, and *Equisetosporites chinleana*. Stone regarded the assemblage as of early to middle Late Triassic (Karnian-Norian) age.

M. J. Fisher and R. E. Dunay have studied a large palynofloral assemblage from outcrops of the Petrified Forest Member of the Chinle Formation in

Arizona. Their work, as yet upublished, includes 86 species in 65 genera. They recognized all but two of the species recorded by Stone (1978) from the Ciniza Lake Beds in western New Mexico.

Fisher and Dunay compared the Petrified Forest palynoflora with a number of other Late Triassic pollen and spore assemblages, both American and European. These authors have recorded 40 species from the Dockum Group of Texas (Dunay and Fisher, 1979). Of these species, only seven are not also present in the Petrified Forest assemblage. They note that all of the species that are numerically dominant or diagnostic for age in either of these flora also occur in the other. The Petrified Forest assemblage is richer in species, and it also contains more striate bisaccates.

The studies of Stone (1978), Dunay and Fisher (1979), and Fisher and Dunay (unpub. data, 1981) have in common that the palynofloras described are composite ones, derived from several localities whose stratigraphic relationships are not given. Stone's Ciniza Lake Beds assemblage was based on four samples from a vertical sequence from one area and two samples from a second locality. Dunay and Fisher's assemblage from the Upper Triassic Dockum Group was derived from nine localities widely scattered in the Texas Panhandle. The larger assemblage dealt with in Fisher and Dunay's unpublished data came from an unspecified nember of localities, all in a 30-m interval in the lower part of the Petrified Forest Member of the Chinle in the Blue Mesa area of the Petrified Forest, Arizona.

In contrast to these three composite palynofloras, the chief assemblage treated in this study was obtained from a single sample from one locality (D1341) in the Shinarump Member of the Chinle Formation. About 60 taxa have been identified from this sample and many more kinds of bisaccates are present. This sample contains as diverse a palynoflorule as any of the composite assemblages yet reported from Upper Triassic beds of the Southwest.

The large number of taxa in the sample from locality D1341 also is in sharp contrast to the number of forms present in the other samples involved in this study. Each sample represents a separate locality; no vertical sequences from a single locality were available. A maximum of 20-25 entities per sample is typical for all but the sample from locality D1341, the Circle Cliffs locality. This sample includes about 90-100 forms; it is the anomaly rather than the other samples.

Palynological evidence for the age of the Chinle.--The previous Chinle palynological studies are based on material from the lower part of the formation. All of this material has been determined to be of late Karnian age, based chiefly on comparisons with the European section. A list of age-diagnostic species is given in table 4. The Dockum Group, which contains essentially the same group of age-diagnostic forms, also was considered to be of late Karnian age (Dunay and Fisher, 1979). Locality D1341 also contains many of the same age-diagnostic forms, which indicates that this assemblage from the Shinarump Member of the Chinle is of late Karnian age (table 4).

This picture of a relatively uniform flora throughout the time that the lower portion of the Chinle Formation was deposited is at apparent odds with the floral zonation of Ash (1980) based on megafossils. The Shinarump Member is in his *Eoginkgoites* zone; the stratigraphically higher Petrified Forest

Member is assigned to the Dinophyton zone. Additional Shinarump material would be necessary to evaluate possible consistent palynological differences between the Shinarump and Petrified Forest Members. However, because significant megafossil species may not have distinctive spores or pollen, megafossil and microfossil zonations may not coincide.

Table 4.—Age-significant taxa of palynomorphs known from the Chinle Formation

Taxon	Occurrence Petrified Forest Member	Monitor Butte Member	Shinarump Member
Brodispora striata	X		X
Camerosporites secatus	X		X
Entzonalasporites vigens	X		X
Ovalipollis ovalis	X		X
Patinisporites densus	X	X	X
Vallatisporites densus	X	X	

The age assignment of the Chinle Formation to the Karnian is based upon only a few forms, as table 4 shows. No bisaccates are among the significant species; all but the long-ranging Ovalipollis ovalis and the monosaccate Patinasporites densus are spores. The greater usefulness of spores, versus bisaccates, for age determination in the Triassic limits the age-determining potential of some of the younger samples in this study, which are dominated by bisaccates.

Perhaps the most significant species in table 4 is Brodispora striata. This species, present in both Petrified Forest and Shinarump assemblages, is diagnostic of the upper Karnian Tropites subbullatus zone of Alpine Germany (Dunay and Fisher, 1974). The monotypic genus was first described from the upper Keuper of England (Clarke, 1965).

The association of four species, Camerosporites secatus, Vallasporites ignacii, Patinasporites densus, and Pseudozonalasporites summus is, according to Fisher and Dunay, evidence of a contemporaneous, world-wide palynological event termed the "Camerosporites secatus phase" by Visscher and Krystyn (1978). Three of these four species are present in the Shinarump material of this study (D1341); the fourth, P. summus, is part of an overlapping morphological complex that is difficult to identify with certainty.

The floristic similarities among the assemblages from the Petrified Forest and Shinarump Members and the Dockum Group are striking. These similarities extend beyond the possession of age-diagnostic forms in common with the Karnian section of Europe. One obvious difference between the Petrified Forest and Shinarump palynoflorules exists, however; striate bisaccate genera are a significant component of the Petrified Forest assemblage, and five of these genera have been identified by Fisher and Dunay (manuscript). Striate bisaccates appear to be absent from the Shinarump; only one dubious grain has been seen. No other sample included in this study contains striate bisaccates.

A similar compositional difference was observed by Dunay and Fischer (1979) in their study of Dockum palynofloras from Texas. Assemblages from three of their four areas lacked striate bisaccate genera, but taeniate forms were conspicuous in the palynoflora from the Tule Canyon area. Dunay and Fisher suggested that the difference might be ecological, with the assemblages containing striate bisaccates representing an "upland gymnospermous community." The non-striate assemblages could represent either an "Araucarioxylon forest community" or a "floodplain swamp community." These associations were named by Gottesfeld (1972) rather hypothetically on the basis of some preliminary work on the palynology of the Petrified Forest Member. Dunay and Fisher also noted that forms common in the three other areas are often rare in the Tule Canyon area, where Brodispora striata, Camerosporites secatus, Tulesporites briscoensis and Chordasporites chinleanus are the most common species. If Gottesfeld's work is marred by paucity of palynological data, Dunay and Fisher's analogy is equally flawed by lack of any discussion of stratigraphical relationships or depositional environments of their miles-apart localities.

To summarize, palynological evidence for late Karnian age of the Chinle Formation was derived from the lower part of the formation. The palynoflorule from the Shinarump Member is strikingly similar to that known chiefly from the Petrified Forest Member, including common occurrence of the key species regarded as age-diagnostic in the Late Triassic of Europe. The chief differences between the members are these: 1) the absence of striate bisaccates in the Shinarump, although about five genera occur in the Petrified Forest Member, and 2) the numerical dominance of spores in the Shinarump Member versus the numerical dominance of bisaccate pollen in the Petrified Forest Member. Variation in numbers of striate bisaccates has been considered to have ecological significance in the Dockum Group.

COMPOSITIONAL TRENDS

As noted in the preceding section, differences among even large palynological assemblages from different members of the Chinle Formation are not conspicuous. The characterization of palynoflorules from the several members is complicated by the small number of entities represented in most of them, and by the tendency of spores--the group furnishing many age-diagnostic forms--to decrease in importance relative to coniferous pollen in some assemblages.

This tendency for bisaccate grains to predominate was assesed by counting (200 grains in most cases) the relative numbers of spores and bisaccate pollen grains in the samples of this study. Because the counts were made for survey purposes, small components of other and unrecognizable grains were ignored; thus the total of spores and bisaccates in an assemblage does not actually equal 100 percent of the palynomorphs. The results of this survey are shown in figure 2.

Although the vagaries of such factors as intertonguing make the arangement of sample localities in stratigraphic sequence less than absolute,

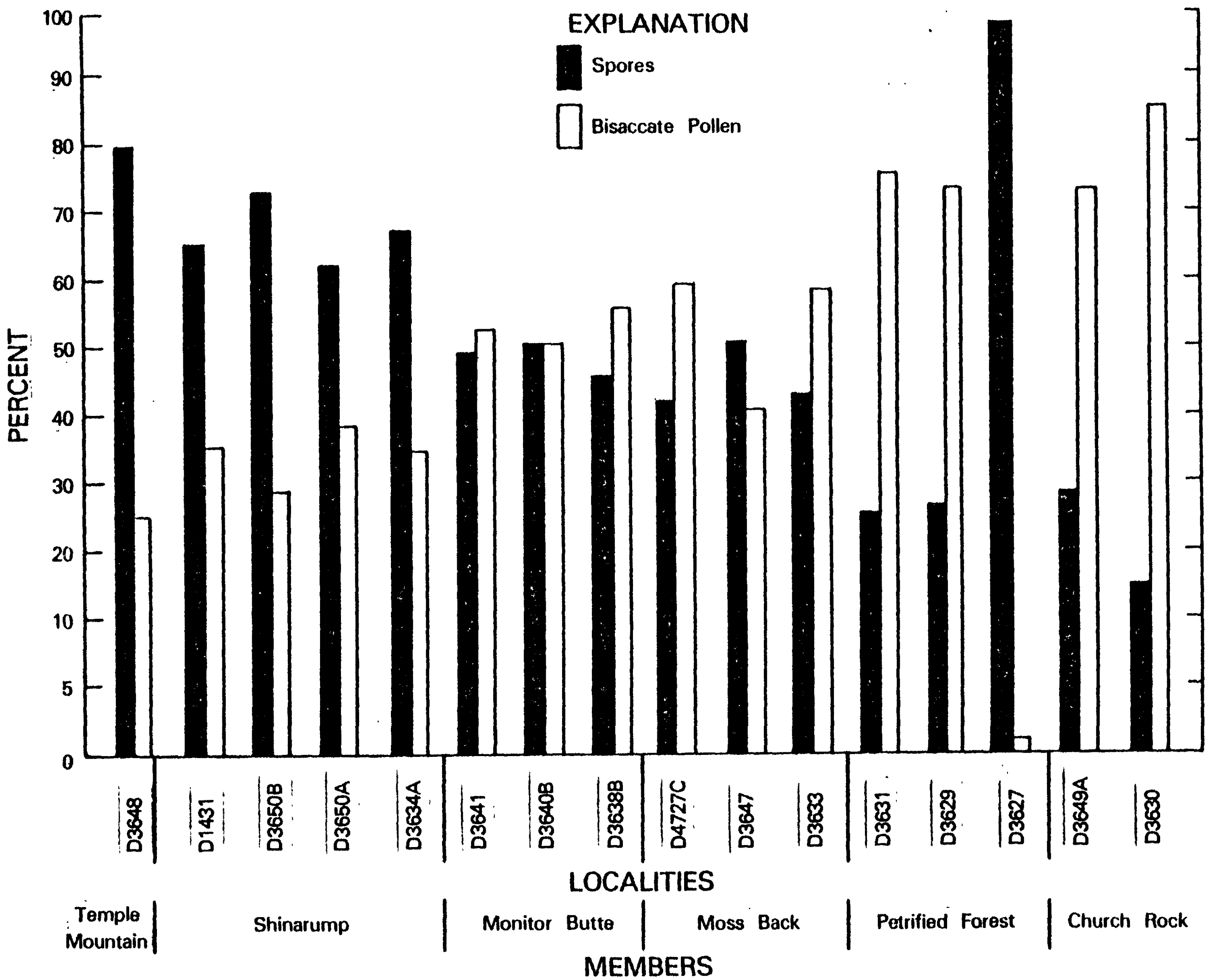

Figure 2-- Approximate percentages of spores and bisaccate pollen in palynoflorules from localities in the Chinle Formation.

Spores　　Bisaccate pollen

a clear-cut general trend emerges from the data in figure 2. Through the interval represented by the samples, the number of spores are reduced gradually relative to the number of bisaccate grains. Or, conversely, the number of bisaccates increases gradually with time relative to the number of spores.

The ratio between numbers of spores and of gynmospermous pollen appears to be controlled chiefly by climate—most cryptograms require greater amounts of moisture than do most gymnosperms (Cornet, 1977). Numerical dominance by bisaccate pollen grains is regarded as indicating upland, more arid conditions. On this basis, the generalized increase in relative numbers of bisaccate pollen grains shown in figure 2 suggests a gradual trend toward increased aridity for the time interval represented by these samples.

A striking exception to the general trend shown in figure 2 is the sample from locality D3627, in the Petrified Forest Member. This assemblage consists almost entirely of Dictyophyllites and about five other simple trilete spores. A clue to its exceptionality is the presence of masses of spores, still aggregated as they formed in sporangia. These masses of undispersed spores most probably represent an in-place situation--a bog or other moist habitat that supported a local concentration of ferns. This sample reasonably can be disregarded as an exception to the general trend toward increased dryness suggested by the data of figure 2.

GEOLOGIC BACKGROUND AND INTERPRETATION

The palynological evidence for a consistent trend toward increased dryness in Chinle time must be interpreted in terms of the known depositional history of the formation. The Chinle Formation, continental in origin, has been studied extensively by Stewart and others (1972). Members of the formation vary markedly in lithology laterally and also intertongue in a complex manner. For southeastern and east-central Utah and the Monument Valley of northeastern Arizona, Stewart and others recognized the following members in ascending order: Temple Mountain, Shinarump, Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock.

Recently, Lupe (1977) has studied depositional environments of the Chinle Formation in southeastern Utah. Both in the San Rafael Swell and in the Canyonlands area, Lupe found that the formation consists of a series of three cyclic fluvial-lacustrine sequences, each becoming more fine grained upward. A cycle typically begins with proximal braided stream sandstones and conglomerates, grades upwards into distal braided stream sandstones, ranges through floodplain or overbank fine-grained sandstones, siltstones and mudstones, and concludes with lacustrine siltstones and mudstones, often capped with paleosols.

Lupe's tripartite, genetic interpretation of the upper portion of the Chinle Formation is compared to the lithostratigraphic nomenclature of Stewart and others in figure 3.

In a further consideration of Chinle depositional environments, Lupe and Silberling (unpub. data, 1982) point out that, in contrast to upper portions of the formation, lower members--the Temple Mountain and Shinarump Members--

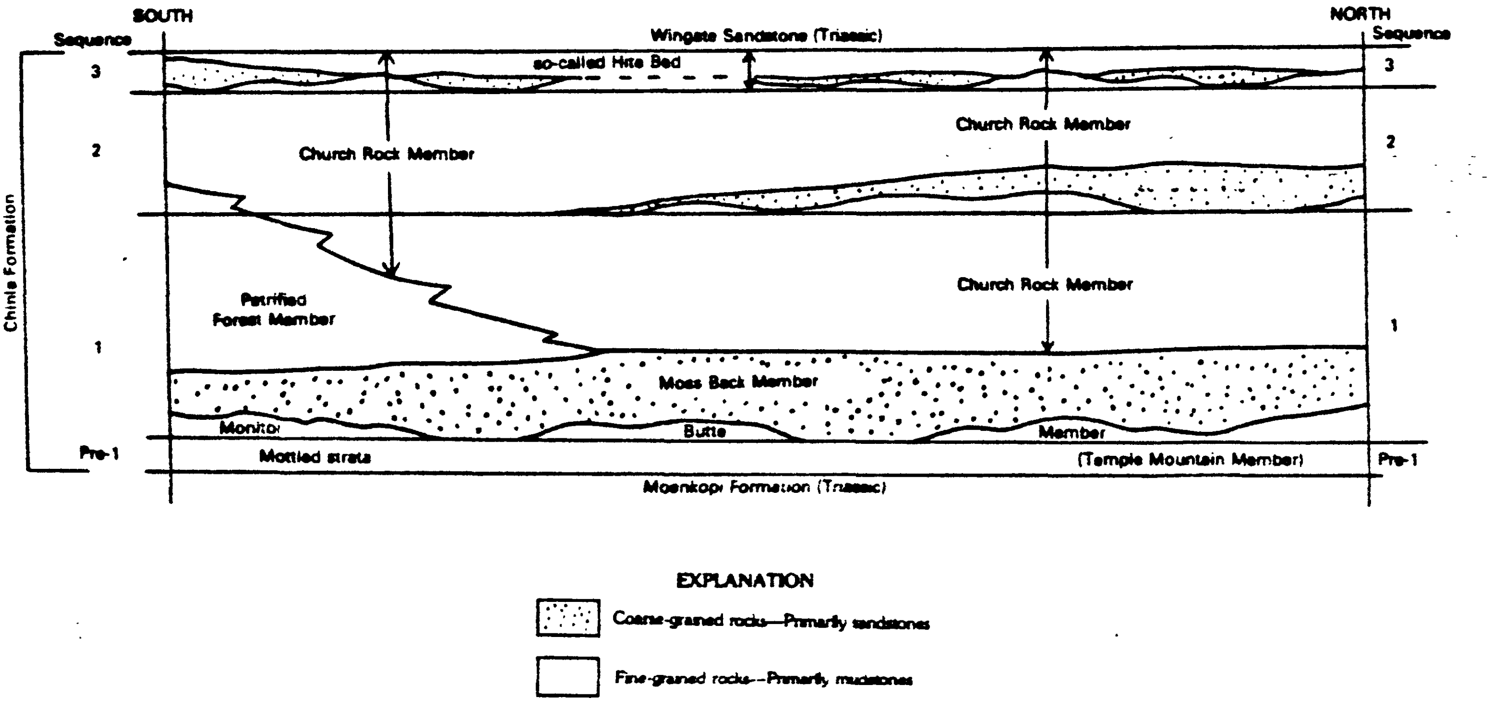

Figure 3-- South-north schematic section in central Utah showing the lithostratigraphic nomenclature of Stewart and others (1972) and the stratigraphic framework of the depositional sequences of Lupe (1979).

suggest deposition under conditions of stagnation rather than during cyclical alluviation. They interpret the top of the Shinarump Member as representing an unconformity. After this break in deposition, the cyclical deposition that created the upper members began.

Lupe (1979) pointed out that the approach used by Stewart and others (1972) resulted in the use of several stratigraphic units to contain the lithologically different but time-equivalent rocks at the bases of the depositional units. However, the lithologically similar but non-synchronous units at the tops of the sequences tended to be placed in too few units.

Not all western Upper Triassic rocks are nonmarine. In Nevada, 500 km to the west, the Auld Lang Syne Group represents a marine sequence containing three depositional cycles (Lupe and Silberling, 1979). The three consecutive influxes of terrigenous sediments came from a source to the east; the energy level of each influx decreases toward the end of each cycle. The three marine depositional cycles in Nevada are separated by two intercalated calcareous units containing marine mollusks that tie in with the standard European stages and zones. The first episode of calcareous deposition was early middle Norian in age; the other is early late Norian.

Lupe and Silberling (1979, p. 470) believed that "the fluvial systems that deposited Chinle sediments also transported the terrigenous clastics into marine environments in Nevada. This suggested genetic relationship between these widely separated sedimentary sequences is supported by similarities in their compositions. Extrapolation of the relatively well dated marine rocks in Nevada to the Chinle Formation in east-central Utah indicates that the older age limit there may be Norian rather than Karnian."

If Lupe and Silberling are correct, the episodes of calcareous deposition in the Auld Lang Syne Formation coincide with the development of soils in the upper Chinle Formation during periods of low energy. This correspondence implies that the upper Chinle is of Norian age.

Interpretation of the palynological data of figure 2 as part of a single, long-range, climatic cycle results in a time problem. The several members of the Chinle Formation represented by the samples used in this study imply that much of the formation was deposited in an interval during which there was a consistent trend toward increased aridity. Although no determination of the duration of Chinle time exists, several factors, including Lupe's (1979) demonstration of three depositional cycles in its upper part, suggest that this duration was in the order of millions of years. Known Triassic climatic cycles are much shorter (Van Houten, 1964).

Cyclical sedimentation and its possible relationships to climate were studied in the Upper Triassic Lockatong Formation of Northeastern United States by Van Houten (1964). He identified short, intermediate, and long cycles. He suggested that short cycles were about 22,000 years in duration and probably were controlled by the 21,000 year precessional cycle; intermediate cycles were about 100,000 years long, based on varve counts. Long cycles lasted about one-half million years. All three cycles resulted from fluctuation of precipitation at differing orders of magnitude. Elliot (1961) has observed a comparable sequence of sedimentary cycles of three differing lengths in rocks of Keuper age in England, although the time relationships between the British and American cycles are not clear.

Climatic control of floral composition in the Late Triassic of the Eastern United States has been examined by Cornet (1977). He found that diversity of palynoflorules as expressed by the spore-gymnosperm ratio, falls into a pattern that fits Van Houten's theory of cyclic climatic control. He was able to demonstrate correspondence with all three levels of cycles.

Thus, the data of the present study appear to raise a contradiction between the known length of Late Triassic climatic cycles and the inference of a single trend toward aridity throughout a much longer time period, during which the deposition of several members of the Chinle Formation took place. This apparent contradiction led to a reexamination of the stratigraphic positions of Schultz's samples used in this study. Despite the several members of the Chinle represented, none of these samples originated at a stratigraphic position higher than within the first of the three episodes of cyclical deposition in the upper part of the formation (Robert Lupe, oral commun., 1981). The lateral relationships of Schultz's sample localities reflect the interfingering nature of some members of the Chinle Formation.

This situation makes possible a more reasonable interpretation of the drying trend shown by figure 2 as concomitant with the decreasing energy-decreasing flow stage of the first of the depositional cycles present in central Utah and elsewhere in the Chinle. Although no absolute time frame is available for the Chinle cycles, Van Houten's estimate of 500,000 years for a long climatic cycle is a more approximate context for the observed Chinle floral shift than if it occurred over a substantial part of the time of deposition of much of the formation. Thus, the apparent discrepancy can be resolved. The palynological evidence is consistent with, and lends support to, the concepts of Lupe (1979) and Lupe and N. J. Silberling (unpub. data, 1982) regarding cyclical deposition in the accumulation of the Chinle Formation.

The three depositional cycles suggested by Lupe (1979) and the three floral zones of Ash (1980) overlap only in part. The *Eoginkgoites* zone in the Chinle Formation extends well below the base of the lowest depositional cycle, which also includes Ash's *Dinophyton* zone. Although Ash does not delimit clearly the top of the *Dinophyton* zone, probably all or most of this zone is contained within the lowest depositional cycle (fig. 3). Thus, the possibility is open that the upper beds of the Chinle could be younger than Karnian--the age commonly attributed to the entire formation but which is actually based on plant fossils from only the lower part of the formation.

The stagnation-cyclical deposition account of Chinle sedimentation provides a framework against which floral change in Chinle time can be viewed, albeit necessarily in speculative terms. During Chinle time, a large, complex, and cosmopolitan flora was established in the American Southwest. This flora had numerous taxa in common with Europe, Northeastern United States, and Texas. The climate was tropical to subtropical, and many of the plants grew in moist, low-lying environments as indicated by the preponderance of spores in Shinarump time. The presumption of limited relief is born out by the lack of striate bisaccate pollen in the Shinarump flora (as now known), and by the suggested origin of the coarse-grained sediments of the member as pediment alluvium deposited under relatively stagnant, rather than high-energy, conditions.

In late middle or early Late Triassic time, an abrupt uplift took place to the east of the present-day Colorado Plateau, creating a source area which provided sediments that were transported to the west. Uplift may have resulted in more suitable habitats for the kinds of upland plants that produced both striate and nonstriate bisaccate pollen. The initial increases in rainfall produced by the orogenic effect were diminished gradually by erosion of the highlands. This decrease in moisture, probably in concert with a broader climatic factor, limited the grain size of the transported sediments, and at least locally depauperized the dominantly moisture-loving flora of Shinarump time.

By Petrified Forest time gymnosperms had gained dominance. This ascendancy continued to increase through the end of the first depositional cycle. The available record of plant microfossils in the Chinle does not extend beyond the end of the first of Lupe's depositional cycles. Although the bulk of paleobotanical evidence points to a late Karnian age for most of the lower Chinle, the possibility appears to be open that the upper portions included in the latter two depositional cycles may be younger.

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