MEMOIR 6

Cretaceous -Tertiary Palynology, Eastern Side of the San Juan Basin, New Mexico

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Abstract

Early studies of vertebrate and plant fossils in the San Juan Basin confirmed a late Cretaceous age for the Kirtland shale and a Tertiary age for the Nacimiento formation, but resulted in disagreement over the age of the intervening Ojo Alamo sandstone. Dinosaur evidence indicated a late, but not latest, Cretaceous (Montanan) age, but fragmentary plant megafossils suggested a Tertiary age. Pollen and spore florules collected from within, above, and below the formation tend to confirm a Tertiary age and reflect the environmental changes that accompanied local uplift at the Cretaceous-Tertiary transition.

The most significant ecologic change takes place at the base of the Ojo Alamo sandstone with the appearance of many podocarpaceous and ulmaceous pollen. The most significant change in terms of common forms occurs between the basal Ojo Alamo florule and one collected from a shale unit in the middle of the formation. The basal florule has only four forms in common with the overlying or underlying florules and could be either Cretaceous or Paleocene. The middle florule, however, has nine forms in common with the overlying Nacimiento florules, suggesting Tertiary affinity. Middle Montanan dinosaur bones and fragments, which occur in a similar shale unit on the western side of the basin, may have been reworked or erroneously identified.

Proteaceous grains and *Tilia* are the dominant dicotyledonous types in the Kirtland shale florule. Conifers are absent.

The florule from the base of the Ojo Alamo sandstone contains more than 7o percent *Podocarpus* pollen, ulmaceous pollen, and several other probable upland types. The middle Ojo Alamo florule contains a mixture of probable upland and lowland forms, as does a florule from the base of the Nacimiento formation. A florule in the lower part of the Nacimiento formation is similar to the florule at the base. Ulmaceous pollen, *Momipites*, and *Cupanieidites* are the most persistent dicotyledonous types in these three florules. A florule from the uppermost part of the Lewis shale is a northern equivalent of the Kirtland or lower Ojo Alamo florule but is very different because of a more coastal environment on the opposite shore of the Lewis sea.

The classification system used in this study employs a combination of extant, organ, and form genera arranged in a phylogenetic outline. Eight new genera, *Bombacacipites, Brevicolporites, Confertisulcites, Intertriletes, Kurtzipites, N avisulcites, Rectosulcites,* and *Ulmoideipites,* are established, and several others are validated. Of the 88 fossil descriptions, 39 are new species and 4 are descriptions of dinoflagellates and marine microfossils incertae sedis from the Lewis shale.

Introduction

Early collecting by Cope (1875) and other vertebrate paleontologists led to the discovery of extremely rich Paleocene mammalian faunas in the Puerco and Torrejon beds along the southern side of the San Juan Basin. Later, assemblages of late Cretaceous dinosaurs and other reptiles were found in the underlying Ojo Alamo, Fruitland, and Kirtland sediments. The plant megafossils collected from the same formations tended to substantiate the findings of the vertebrate paleontologists. The Puerco and Torrejon beds contained a Paleocene flora (Reeside, 1924), and Knowlton (1916) assigned a late Cretaceous age to the Fruitland-Kirtland flora. The intervening Ojo Alamo sandstone, however, became a source of controversy. The dinosaurs in this formation indicated that the formation was Cretaceous, and not even latest Cretaceous, in age (Gilmore, 1919). The few plant megafossils and field evidence assembled by Reeside (1924) suggested a Paleocene age. One objective of this study is to determine what bearing the pollen and spore evidence has on the controversy.

An interesting sequence of physical and biologic changes took place in the San Juan Basin at the end of the Cretaceous period. Profound changes in vertebrate faunas and associated vegetation accompanied local and regional uplift and a secular climatic change. Some tentative conclusions about ecology have been made as a first step toward understanding the nature and timing of the changes that occurred during the transition from the Cretaceous to the Tertiary.

It seemed advisable that the first pollen and spore study of this interval be a reconnaissance to outline gross changes. More than 7o samples of shale and coal were collected from within, above, and below the Ojo Alamo sandstone. Only six of the samples contained pollen and spores that were well enough preserved and in sufficient quantity for description. Fortunately, the florules are strategically located and should represent the different environments. The florules came from the vicinity of Cuba, New Mexico, and are situated as follows with respect to the Ojo Alamo sandstone:

Nacimiento 2 florule:	115 feet above the Ojo Alamo sandstone (in coal).
Nacimiento 1 florule:	I foot above Ojo Alamo sandstone (in carbonaceous mudstone).
Ojo Alamo 2 florule:	1 foot above base of middle shale unit in Ojo Alamo sandstone (in carbonaceous mudstone).
Ojo Alamo 1 florule:	In shale lens at base of Ojo Alamo sandstone (in carbonaceous siltstone).
Kirtland shale florule:	37 feet below Ojo Alamo sandstone (in carbonaceous mudstone).
Lewis shale florule:	4 inches below the Animas formation, about 3o miles north of the above localities (in gray mudstone).

Complete locality descriptions are given under the discussions of individual florules. In addition, each locality is shown on the geologic map and the diagrammatic cross-section (fig. 1).

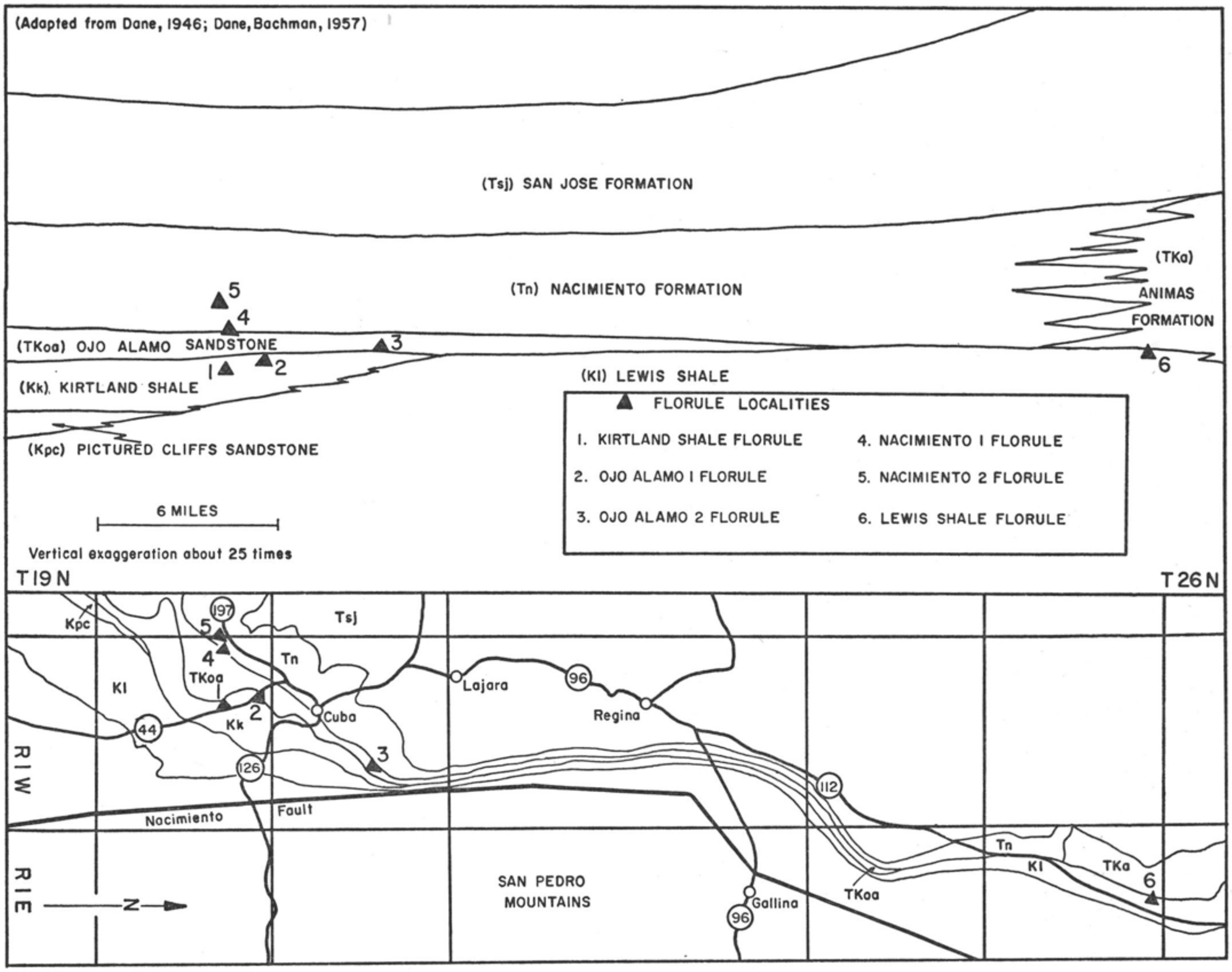

Figure 1

Geologic map and diagrammatic cross-section of eastern side of San Juan Basin, showing florule localities

There have been only a few descriptive papers on North American Cretaceous and Tertiary pollen and spores (Wodehouse, 1933; Miner, 1935; Wilson and Webster, 1946; Schemel, 1950; Traverse, 1955; Rouse, 1957; Groot and Penney, 1960). The present paper adds a number of new genera and species to the few already described. Most of the foreign literature was consulted; however, only a few forms appeared conspecific, and most could not be related to previously described material. The author has used the descriptive part of this paper for an expression of his views on pollen and spore classification, the essential conclusion being that procedures already available are adequate and new rules are unnecessary.

Acknowledgments

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Geologic History, Environment, and Age of Stratigraphic Units

The retreating Cretaceous sea and local uplift were the dominant controls for sedimentation along the eastern side of the San Juan Basin during the late Cretaceous and early Tertiary periods. In the final stage of its eastward withdrawal, the Lewis sea formed a small embayment into the San Juan Basin area with a northern, southern, and western shore. The withdrawal can be divided into an early, slow phase and a later, rapid phase. During the early phase, the northern, southern, and probably western margins of the embayment were replaced by the littoral sands of the Pictured Cliffs sandstone and the backshore swampy muds of the Kirtland shale and the Fruitland formation (fig.). During the later part of this phase, the Pictured Cliffs sands thinned and locally disappeared in the extreme east-central part of the basin. The littoral and brackish conditions, once represented in the sands of the Pictured Cliffs sandstone, persisted in the swamps bordering the much smaller embayment (Fruitland formation and Kirtland shale; fig. r).

The Kirtland shale thickens westward, suggesting the formation of a local Kirtland basin (Silver, 195o) during the latter part of this first phase. Zapp (1949) concluded that the Kirtland sediments in the northern part of the basin had a northern source. These observations suggest local warping and uplift in the north during the latter part of the early, slower phase of withdrawal.

The more rapid phase of withdrawal accompanied accelerated uplift around the northern and, perhaps, other margins of the basin. Uplift in the San Juan Mountain area to the north shed a large wedge of coarse arkosic sand, the Animas formation, southward, further restricting the sea. Actually, uplift in this area began during the early, slower phase of withdrawal at the same time that the Pictured Cliffs and Fruitland formations were being deposited (fig. 1). A new pulse, however, hastened the withdrawal in the central part of the eastern side of the basin, where the arkosic sands of the Animas formation are in contact with the marine Lewis shale. Dinoflagellates and hystrichospherids collected only 4 inches below the base of the Animas formation indicate that marine or brackish conditions persisted until overcome by the Animas sands from the north. (The Lewis shale florule was collected at this locality.)

A similar sequence of events took place along the southern side of the embayment. The conglomeratic and arkosic sands of the Ojo Alamo sandstone spread over the southern part of the basin. Reeside (1924, P. 29) studied the pebbles in the Ojo Alamo sandstone and concluded that the source was unknown but that they were more likely to have come from the east or south than from the north. Dane (1946) noted that the formation thins in its northern exposures. Whatever the source, the sand apparently was introduced at about the same time as the accelerated pulse of Animas sand deposition. Dane concluded that the Ojo Alamo sandstone was equivalent to a sand about r oo feet above the base of the southernmost exposures of the Animas formation. Like the Animas formation, the sands of the Ojo Alamo sandstone rest on the Lewis shale, and the influx of these sands probably helped push the Lewis sea from the San Juan Basin.

The continuous deposition of Ojo Alamo sand was interrupted occasionally by swampy conditions, as evidenced by silty zones within the sandstone that locally develop into mudstone and siltstone lenses more than 20 feet thick. The Ojo Alamo 2 florule was collected from a carbonaceous zone near the base of such a lens in the eastern side of the basin. Dinosaur bones and fragments came from a similar lens in the western side of the basin.

The volume and rate of deposition from the larger San Juan highland to the north soon overshadowed the short-lived pulse of Ojo Alamo deposition as the Ojo Alamo sands were covered over by the sand, silt, and clay of the Nacimiento formation (fig. r). In the Cuba area, the change to Nacimiento deposition marked a return to a lowland swampy environment similar to that represented by the Kirtland shale but with a different source.

The fact that all the lithologic units near the Cretaceous-Tertiary boundary are in facies contact with the Lewis shale, which was undergoing continuous deposition, indicates a conformable sequence along the eastern side of the basin. There is some evidence for unconformity between the Ojo Alamo sandstone and the Nacimiento formation in the western part of the basin, but the time lapse is small (Simpson, 195o). The Ojo Alamo contacts at the localities near Cuba appear transitional, with no evidence of unconformity.

The ages of the stratigraphic units near the Cretaceous-Tertiary transition have been determined by associated plant megafossils, vertebrates, marine invertebrates, and nonmarine invertebrates. Pertinent information about the age, lithology, and environment of the several formations is given in Table 1. There is general agreement, it should be noted, for the age of all units but the Ojo Alamo sandstone.

Another unit of doubtful age is the uppermost part of the Lewis shale where it is overlain by the Ojo Alamo sandstone and the Animas formation. Dinosaur fragments in the lower part of the Animas formation in Colorado suggest a Cretaceous age in that area (Simpson, 195o, p. 76). Dane (1946) stated that Roland Brown was restudying the Animas flora, which was also collected in Colorado, and had made the tentative observation that both a Cretaceous and Paleocene flora were present. The lower part of the Animas formation is probably Cretaceous in Colorado, but the basal part of the formation becomes younger toward the south, and it is not known if the regression passed into the Tertiary. Ammonites have been found about 220 feet below the top of the Lewis shale at the pollen and spore florule locality, but this does not fix the age of the uppermost beds. If the sandstone 1 oo feet above the base of the Animas formation is equivalent to the Ojo Alamo sandstone, as suggested by Dane (1946), the uppermost beds of the Lewis shale would be approximately correlative with the Cretaceous Kirtland shale. The Kirtland shale pollen and spore florule and the Lewis shale florule would be near time-equivalents.

TABLE 1. SUMMARY OF LITHOLOGY, ENVIRONMENT, AND AGE OF FORMATIONS ALONG THE EASTERN SIDE OF THE SAN JUAN BASIN

FORMATION	Kirtland shale	Ojo Alamo sandstone	Nacimiento formation	Animas formation	Lewis shale
LITHOLOGY	Alternating layers of gray and carbonaceous mudstone with some micaceous siltstone and sandstone.	Light-colored, massive, cross-bedded, medium- to coarse-grained, feldspathic, conglomeratic sandstone. Medial silty zone in places changes to lenses of carbonaceous mudstone and siltstone.	Light- and dark-gray clay, gray siltstone, fine- to medium-grained white to buff sandstone, carbonaceous clay, and coal.	Coarse-grained, conglomeratic, andesitic sandstone. Lower part is chiefly feldspathic sandstone and conglomerate; upper part chiefly soft sandstone and greenish clay.	Gray, calcareous, marine shale with some sandy beds and thin beds of concretionary limestone.
ENVIRONMENT	Low swampy area behind the southern shore of the Lewis sea. Supply of sediments small and mainly from the south.	"Orogenic" sandstone, probably derived from an uplift to the east, south, or southwest. Thins to the north along eastern side of basin.	Low swampy area south of the San Juan highland. Sediments coarser toward, and derived from, the north.	Southern flank of San Juan highland. Fluvially transported sands and clays.	Upper part near- and offshore muds adjacent to edge of small embayment into the San Juan Basin. Brackish.
UPPER CONTACT	Conformable with Ojo Alamo sandstone. Local scouring and irregularities.	Conformable in eastern side of basin.	Unconformable around margins of the basin.	Unconformable with San Jose formation.	Conformable with Pictured Cliffs sandstone, Fruitland formation, Kirtland shale, Animas formation, and Ojo Alamo sandstone.
LOWER CONTACT	Conformable with Pictured Cliffs sandstone; elsewhere with Fruitland formation.	Conformable.	Conformable along eastern side of basin.	Conformable with Fruitland formation and Lewis shale.	Conformable with La Ventana sandstone (Mesa Verde group).
AGE: PLANT MEGAFOSSILS	Cretaceous (Montanan). Knowlton (1916).	Tertiary? Knowlton in Reeside (1924).	TORREJON—Tertiary. Knowlton in Reeside (1924). — — — — — — — PUERCO—Tertiary. Knowlton in Sinclair and Granger (1914).	Tertiary (collections mostly from upper part). Knowlton (1924). — — — — — — — *Lower* part Cretaceous, *upper* part Tertiary. R. Brown in Dane (1946).	
AGE: VERTEBRATES	Cretaceous (Montanan, but not latest Montanan). Reeside review (1924), Colbert (1950).	Cretaceous (Montanan, but not latest Montanan). Reeside review (1924), Colbert (1950).	Paleocene (primitive mammalian fauna; no dinosaurs). Reeside (1924), Simpson (1950).	*Lower* part Cretaceous, from dinosaur fragments. Simpson (1950).	
AGE: MARINE INVERTEBRATES					Cretaceous (Montanan); collections not from uppermost part. Reeside (1924).
AGE: NONMARINE INVERTEBRATES	Cretaceous (late Montanan). Stanton (1916).				

Character of Pollen and Spore Florules

Table 2 summarizes the pollen and spore content of the six florules studied, and Table 3 shows the common forms and their range of occurrence. The following discussion of individual florules gives their locality, as well as a few comments on significant characters and paleoecology.

KIRTLAND SHALE FLORULE

The Kirtland shale florule was taken from the upper carbonaceous zone in a medium-gray micaceous mudstone approximately 37 feet below the base of the Ojo Alamo sandstone. The locality is about 200 yards west of New Mexico State Highway 44, 3.6 miles south of its junction with State Highway 126 in Cuba.

Proteacidites thalmanni is the dominant dicotyledon, followed by other proteaceous types, *Cupanieidites* cf. C. *reticularis,* and *Tilia wodehousei.* Polypodiaceous spores and *Lycopodium* spores are very common, but spores are subordinate to pollen in variety and number. Conifers are absent.

The sedimentary environment represents a swampy area behind the retreating Lewis sea. The source of sediment was probably to the south, although the influx of new material was slight and the florule must represent mostly the vegetation in the immediate area. The absence of conifer pollen is significant in this respect.

OJO ALAMO 1 FLORULE

This florule was found in a thin carbonaceous layer within a light brownish-buff siltstone lens at the base of the Ojo Alamo sandstone. The locality is in a roadcut on the east side of New Mexico State Highway 44, 1.9 miles south of its junction with State Highway 126 in Cuba.

Podocarpaceous pollen are extremely abundant and comprise about 7o percent of the total number of grains in the florule. *Podocarpus sellowiformis* is the most abundant, although *Podocarpus northropi* and *Podocarpus zuniensis* grains are also common. Pinaceous conifers were not observed. Spores and monosulcate pollen are a minor element in the florule, but dicotyledonous pollen, especially *Ulmoideipites* and *Paliurus triplicatus,* are quite common. The florule is very different from the underlying one in the Kirtland shale and has only three forms in common with it. Two of these species, *Confertisulcites knowltoni* and *Liliacidites hyalaciniatus,* are monosulcate grains that are common in the Kirtland shale florule but are rare in the basal Ojo Alamo florule. The third species, *Paliurus triplicatus,* is rare and poorly preserved in the Kirtland shale florule but common in the Ojo Alamo florule.

The stratigraphic relations suggest that the florule was deposited in a low moist area that was covered over by the sands of the Ojo Alamo sandstone. The abundance of conifers and ulmaceous pollen suggests that the florule is decidedly more upland or temperate than the one in the Kirtland shale. The very high frequency of *Podocarpus* pollen may be partly due to concentration by streams that had their headwaters in remote highlands; however, most of the grains are well preserved and unbroken, and must have been derived from a nearby forest that may have been established on the advancing sands of the Ojo Alamo sandstone. Kuyl et al. (1955, p. 65) point out that *Podocarpus* trees are at present restricted to mountainous areas above 2,000 meters. Stratigraphic relations indicate that the Ojo Alamo sandstone was deposited very near sea level. The ecologic requirements of *Podocarpus* may certainly have been different from those today, but this example suggests that the *Podocarpus* forests owe their development to a nearby local uplift that also contributed the conglomeratic and feldspathic sands of the Ojo Alamo sandstone.

There is ample evidence of a distinct secular change to lower temperatures at the end of the Cretaceous (Dorf, 1955, p. 587; Van der Hammen, 1957, p. 74). It is difficult, however, to estimate how much of this change was recorded in the Ojo Alamo florules and how much of the more temperate character of the florule was the result of local uplift. Furthermore, the more xeric flora established on well-drained sands would be different from a lowland swamp flora, and this difference might easily be confused with more temperate conditions. In the case of the Ojo Alamo I florule, it must be assumed that all three factors, local uplift, secular change, or locally xeric conditions, contributed to the more temperate aspect of the florule.

OJO ALAMO 2 FLORULE

The florule was found in a carbonaceous zone at the base of a middle shale unit within the Ojo Alamo sandstone. The florule was taken from a medium-gray mudstone a few inches above a thin coal unit that overlies the lower sandstone unit. The locality may be reached by traveling o.6 mile east on New Mexico State Highway 126 from its junction with State Highway 44 in Cuba, then north on a dirt road for 1.0 mile, then east for 1.6 miles to the crest of the first prominent hill. The middle shale unit is exposed in a south-facing cliff about loo yards to the northwest.

Dicotyledonous pollen are dominant in variety, comprising 10 of the 16 species. *Quercus explanata* and the palmlike *Rectosulcites latus* are dominant. *Podocarpus* pollen are common but not nearly so abundant as in the Ojo Alamo 1 florule. Again, pinaceous conifers were not observed. The subdominant flora appears to represent a mixed assemblage of upland and lowland types and contains some Ojo Alamo 1 and Nacimiento species. Salix-like and *Sapindus* leaves were found in the Ojo Alamo sandstone (Reeside, 1924, p. 31-32). *Salix* and *Cupanieidites* (Sapindaceae) are both present in the florule, and the megafossils and microfossils may be related. Silicified palm wood is very common in the sandstone, and *Trichotomosulcites contractus* and the dominant *Rectosulcites latus* both have palmaceous affinity.

Several of the probable upland or more temperate forms in the Ojo Alamo 1 florule are also present in the Ojo Alamo 2 florule *(Podocarpus sellowiformis, Ulmoideipites krempi, Ulmoideipites tricostatus).* In addition, some of the other species, such as *Quercus explanata, Salix* sp., *Momipites inaequalis,* probably represent the more upland, xeric, or riparian environments surrounding the site of deposition.

TABLE 2. SUMMARY OF MICROFOSSILS FOUND IN THE KIRTLAND SHALE, OJO ALAMO SANDSTONE, NACIMIENTO FORMATION, AND LEWIS SHALE

POLLEN AND SPORES IN THE KIRTLAND SHALE FLORULE

Sphagnum sp.
Lycopodium novomexicanum n. sp.
Polypodiidites spp.
Foveotriletes scrobicularis (Ross) R. Potonié, 1956
Liliacidites leei n. sp.
Liliacidites hyalaciniatus n. sp.
Liliacidites sp.
Arecipites microreticulatus n. sp.
Arecipites reticulatus (Van der Hammen, 1954)
Proteacidites thalmanni n. sp.
Proteacidites retusus n. sp.
Proteacidites sp.
Cupanieidites cf. C. *reticularis* Cookson and Pike, 1954
Tilia wodehousei n. sp.
Tricolpites sp. A
Kurtzipites trispissatus n. gen. and sp.
Extratriporopollenites sp.
Paliurus triplicatus n. sp.
Tricolporites traversei n. sp.
Periporopollenites sp.
Monosulcites perspinosus Couper, 1953
Monosulcites sp.
Confertisulcites knowltoni n. gen. and sp.
Navisulcites marginatus n. gen. and sp.
Trilites? sp. A
Perotrilites cubensis n. sp.
Sporites? sp. A
Pollenites? sp.

POLLEN AND SPORES IN THE OJO ALAMO I FLORULE

Podocarpus northropi n. sp.
Podocarpus sellowiformis Zaklinskaja, 1957
Podocarpus zuniensis n. sp.
Liliacidites hyalaciniatus n. sp.
Alnus? sp.
Quercus? sp.
Ulmoideipites tricostatus n. gen. and sp.
Ulmoideipites krempi n. gen. and sp.
Ulmoideipites planeraeformis n. gen. and sp.
Paliurus triplicatus n. sp.
Triporopollenites plektosus n. sp.
Con f ertisulcites knowltoni n. gen. and sp.
Confertisulcites sp.
Sporites neglectus n. sp.

POLLEN AND SPORES IN THE OJO ALAMO 2 FLORULE

Polypodiidites spp.
Intertriletes reticulatus n. gen. and sp.
Podocarpus sellawiformis Zaklinskaja, 1957
Liliacidites leei n. sp.
Trichotomosulcites contractus n. sp.
Salix sp.
Quercus explanata n. sp.
Siltaria cf. S. *scabriextima* Traverse, 1955
Ulmoideipites krempi n. gen. and sp.
Ulmoideipites tricostatus n. gen. and sp.
Cupanieidites aff. C. *major* Cookson and Pike, 1954
Momipites inaequalis n. sp.
Brevicolporites colpella n. gen. and sp.
Tricolpites anguloluminosus n. sp.
Tricolpites sp. B
Rectosulcites latus n. gen. and sp.

POLLEN AND SPORES IN THE NACIMIENTO 1 FLORULE

Rugulatisporites sp.
Podocarpus sellowiformis Zaklinskaja, 1957
"*Pinus haploxylon* type" Rudolph, 1935
"*Pinus sylvestris* type" Rudolph, 1935
Arecipites reticulatus (Van der Hammen, 1954)
Liliacidites leei n. sp.
Ulmoideipites tricostatus n. gen. and sp.
Acer striata (Pflug, 1959)
Tilia danei n. sp.
Nyssa puercoensis n. sp.
Momipites inaequalis n. sp.
Momipites tenuipolus n. sp.
Tricolporites rhomboides n. sp.
Tetradites sp.

POLLEN AND SPORES IN THE NACIMIENTO 2 FLORULE

Lygodiosporites? sp.
Gleicheniidites senonicus Ross, 1949
Polypodiidites spp.
Lycopodium novomexicanum n. sp.
"*Pinus haploxylon* type" Rudolph, 1935
Arecipites reticulatus (Van der Hammen, 1954)
Liliacidites leei n. sp.
Salix sp.
Ulmoideipites tricostatus n. gen. and sp.
Cupanieidites aff. C. *major* Cookson and Pike, 1954
Bombacacipites nacimientoensis n. gen. and sp.
Momipites tenuipolus n. sp.
Triporopollenites plektosus n. sp.
Tricolpites anguloluminosus n. sp.
Tricolporites rhomboides n. sp.

MICROFOSSILS IN THE LEWIS SHALE SAMPLE

Plant Kingdom
Lygodiosporites adriennis R. Potonié and Gelletich, 1933
Polypodiidites spp.
Concavisporites sp.
Laevigatisporites percrassus n. sp.
Cingulatisporites lancei n. sp.
Laevigatosporites sp.
Punctatosporites reginensis n. sp.
Podocarpus sellawiformis Zaklinskaja, 1957
Abietipites spp.
"*Pinus haploxylon* type" Rudolph, 1935
Pinus minima (Couper, 1958)
Ephedra notensis Cookson, 1956
Arecipites reticulatus (Van der Hammen, 1954)
Ulmoideipites krempi n. gen. and sp.
Proteacidites thalmanni n. sp.
Cyrilla minima n. sp.
Cupanieidites aff. C. *major?* Cookson and Pike, 1954
Myrtaceidites? sp.
Momipites sanjuanensis n. sp.
Extratriporopollenites fossulotrudens Pflug, 1953
Tricolpites sp. C
Tricolporites sp.
Eucommiidites couperi n. sp.
Sporites? sp. B
Trilites? sp. B
Peromonolites cf. *P. problematicus* Couper, 1953
Peromonolites sp. A
Peromonolites sp. B
Inaperturopollenites limbatus Balme, 1957
Animal kingdom
Scrinodinium cooksonae n. sp.
Paleoperidinium ventriosum (0. Wetzel) Deflandre, 1935
Incertae sedis
Pterospermopsis sp.
Hystrichosphaera cf. *H. furcata* (Ehrenburg) Wetzel, 1933

TABLE 3. CHART SHOWING POLLEN AND SPORES COMMON TO KIRTLAND, OJO ALAMO, NACIMIENTO, AND LEWIS FLORULES

FOSSIL POLLEN AND SPORES	KIRTLAND SHALE FLORULE	OJO ALAMO 1 FLORULE	OJO ALAMO 2 FLORULE	NACIMIENTO 1 FLORULE	NACIMIENTO 2 FLORULE	LEWIS SHALE FLORULE
Sphagnum sp.	X					
Foveotriletes scrobicularis	X					—
Liliacidites sp.	X					—
Arecipites microreticulatus	X					—
Proteacidites retusus	X					—
Proteacidites sp.	X					—
Cupanieidites cf. C. reticularis	X					—
Tilia wodehousei	X					—
Tricolpites sp. A	X					—
Kurtzipites trispissatus	X					—
Extratriporopollenites sp.	X					—
Tricolporites traversei	X					—
Periporopollenites sp.	X					—
Monosulcites perspinosus	X					—
Monosulcites sp.	X					—
Navisulcites marginatus	X					—
Trilites? sp. A	X					—
Perotrilites cubensis	X					—
Sporites? sp. A	X					—
Pollenites? sp.	X					—
Paliurus triplicatus	X	X				—
Liliacidites hyalaciniatus	X	X				—
Confertisulcites knowltoni	X	X				—
Polypodiidites spp.	X		X		X	X
Arecipites reticulatus	X			X	X	X
Lycopodium novomexicanum	X				X	—
Proteacidites thalmanni	X					X
Liliacidites leei	X		X	X	X	—
Podocarpus northropi		X				—
Podocarpus zuniensis		X				—
Alnus? sp.		X				—
Quercus? sp.		X				—
Ulmoideipites planeraeformis		X				—
Confertisulcites sp.		X				—
Sporites neglectus		X				—
Ulmoideipites krempi		X	X			X
Podocarpus sellowiformis		X	X	X		X
Triporopollenites plektosus		X			X	—
Ulmoideipites tricostatus		X	X	X	X	—
Intertriletes scrobiculatus			X			—
Trichotomosulcites contractus			X			—
Quercus explanata			X			—
Siltaria cf. S. scabriextima			X			—
Brevicolporites colpella			X			—
Rectosulcites latus			X			—
Cupanieidites aff. C. major			X		X	?
Salix sp.			X		X	—
Tricolpites anguloluminosus			X		X	—
Tricolpites sp. B			X			—
Momipites inaequalis			X	X		—
Rugulatisporites sp.				X		—
"Pinus sylvestris type"				X		—
Acer striata				X		—
Tilia danei				X		—
Nyssa puercoensis				X		—
Tetradites sp.				X		—
"Pinus haploxylon type"				X	X	X
Momipites tenuipolus				X	X	—
Tricolporites rhomboides				X	X	—
Lygodiosporites? sp.					X	—
Gleicheniidites senonicus					X	—
Bombacacipites nacimientoensis					X	—
Lygodiosporites adriennis						X
Concavisporites sp.						X
Laevigatisporites percrassus						X
Cingulatisporites lancei						X
Laevigatosporites sp.						X
Punctatosporites reginensis						X
Abietipites spp.						X
Pinus minima						X
Ephedra notensis						X
Cyrilla minima						X
Myrtaceidites? sp.						X
Momipites sanjuanensis						X
Extratriporopollenites fossulotrudens						X
Tricolpites sp. C.						X
Tricolporites sp.						X
Eucommiidites couperi						X
Trilites? sp. B						X
Peromonolites cf. P. problematicus						X
Peromonolites sp. A						X
Peromonolites sp. B						X
Inaperturopollenites limbatus						X
Sporites? sp. B						X

NACIMIENTO 1 FLORULE

The locality can be reached by traveling 4.8 miles south on Torrejon Road from its junction with New Mexico State Highway 44 in Cuba. The florule was taken from a medium-gray, micaceous, carbonaceous mudstone, 1 foot above the Ojo Alamo sandstone, in a small arroyo on the west bank of the Rio Puerco about 0.2 mile east of the road and 3o yards south of a small waterfall in the Rio Puerco.

Dicotyledonous pollen are dominant in number and variety. Pollen frequencies are low, and *Tilia danei* and *Arecipites reticulatus* are the only species that are common. One *Podocarpus* grain was encountered. Pinaceous conifers appear but are uncommon.

Stratigraphic relations show that the Nacimiento formation was derived from the north and is equivalent to the upper part of the Animas formation. The underlying Ojo Alamo sandstone had a different source, and this may account for the appearance of pinaceous conifer pollen. The Nacimiento florule seems to be a mixed upland and lowland assemblage. Upland forms probably include the conifers, *Ulmoideipites tricostatus,* and *Momipites.* Lowland forms would include *Nyssa*, the monosulcate grains, and *T etradites.* The treated residue consisted mainly of broken and abraded tracheary elements and plant fragments, and some of the upland species may have been transported from a distant northern source.

NACIMIENTO 2 FLORULE

This florule was found in an 8-inch coal bed about feet above the Nacimiento 1 florule at the same locality. The coal crops out in a north-facing cliff about 200 yards southwest of the location of the Nacimiento I florule.

Of the 15 species present, 8 belong to dicotyledonous plants, *Cupanieidites* aff. C. *major* and *Momipites tenuipolus* being the most frequent. The dicotyledons are closely related to those in the Nacimiento 1 and Ojo Alamo 2 florules. Some of the spores, and *Liliacidites leei*, however, are also present in the Kirtland shale florule. Only a few poorly preserved and broken pinaceous conifer grains were observed.

The physical environment indicates that the florule was deposited in a low swampy area somewhat similar to the environment of Kirtland deposition before the influx of Ojo Alamo sand. However, the more remote position of the sea, uplift to the north and elsewhere, and perhaps regional uplift and secular climatic change made the climate more varied and temperate than during Kirtland time. The similarity of the two lowland environments is reflected in the common species *Lycopodium novomexicanum*, *Arecipites reticulatus, Liliacidites leei,* and polypodiaceous spores. The probable upland species, however, are related to the more temperate and varied Ojo Alamo florules. Such species might include *Momipites tenuipolus, Salix* sp., *Ulmoideipites tricostatus, Cupanieidites* aff. C. *major,* and *Tricolpites anguloluminosus.*

LEWIS SHALE FLORULE AND FAUNULE

The Lewis shale microfossils were taken from a 4-inchthick medium-gray mudstone immediately underlying the massive sands of the Animas formation. The locality is in a steep east-facing cliff one-half mile N. 34° W. of the junction of New Mexico State Highway 112 and the road to Dead Horse Springs, Deadman's Lookout, and Poison Springs.

The florule is divided about equally between spore-bearing pteridophytes, gymnosperms, dicotyledonous angiosperms, and forms of uncertain systematic position. In terms of frequency, dicotyledonous pollen are dominant. *Proteacidites thalmanni* is abundant, followed by *Momipites sanjuanensis.* Pinaceous conifer grains are common and varied, some attaining a large size. *Ephedra* is of special interest because it is the only grain encountered in the 6 florules. Kuyl et al. (1955, p. 59) suggest that Ephedra-type pollen are replaced by conifers in more temperate regions, and their conclusions are borne out here. Eucommia-type pollen are common in the Jurassic and lower Cretaceous of Europe; their presence here and in the upper Cretaceous of Canada (Rouse, 1957, Tri*fossapollenites)* and eastern North America (Groot and Penny, 196o) suggests that these forms had wide distribution and may have remained common through the upper Cretaceous. The florule does not have affinity with any of the five previously mentioned florules.

The Lewis shale contains ammonites and foraminifers in association with nodular limestone beds about 220 feet stratigraphically below the pollen sample. The foraminifera persist about 6o feet higher in the section but become less varied, and finally only *Robulus* sp. and *Gyroidina* sp. remain. Plant material is very common above this zone, and brackish conditions prevailed to the very top of the shale, as evidenced by the dinoflagellates and hystrichospherids associated with the florule. The abundance of very large grains and the high spore and pollen frequencies indicate that the florule was deposited very near shore. The site of deposition was on the northern shore of the Lewis sea, which was being restricted southward by the influx of coarse clastics from the San Juan highland. The florule probably represents a mixture of coastal species and upland species established on the sands to the north. *Ephedra*, *Momipites sanjuanensis, Ulmoideipites krempi,* and *Cupanieidites* aff. C. *major?* could have been representatives of the upland or inland flora. The Kirtland shale florule or the basal Ojo Alamo florule apparently was being deposited on the opposite side of the Lewis sea or an adjacent swampy region at the same time, and the different geographic situation probably accounts for much of the difference in the florules. *Proteacidites thalmanni*, which is dominant in both the Lewis and Kirtland florules, may have been a coastal species established on both sides of the embayment. Apparently, pinaceous forests clothed the San Juan highland area, whereas podocarpaceous forests were present south of the Lewis sea embayment or the adjacent lowland swamp.

Cretaceous-Tertiary **Boundary**

Previous studies, chiefly of plant megafossils and vertebrates, have determined the ages of the stratigraphic units in the San Juan Basin through correlation with reference sections in the Western Interior. The conclusions of earlier paleontologists as to the age of the units near the Cretaceous-Tertiary boundary are summarized in Table 1. There is general agreement that the Nacimiento formation is Paleocene and the Kirtland shale Cretaceous. The Ojo Alamo sandstone, however, is of Montanan age from vertebrate evidence but Tertiary as determined from a few fragmentary plant fossils. The discrepancy is not merely due to a disagreement in boundary placement, because the whole of "Hell Creek" time or the *"Triceratops* zone" is lost between the two estimates. A review of the paleontological evidence, as it pertains to the Ojo Alamo sandstone, may help clarify the problem.

PALEOBOTANICAL EVIDENCE

Knowlton's collection from the Ojo Alamo sandstone contained only a few fragmentary fossils, and his conclusions as to a Tertiary age for the unit were tentative. It is highly probable, however, that *Sapindus,* which occurred in Knowlton's collection from two separate localities, is a Paleocene index fossil in the Rocky Mountain area. *Sapindus* has not been recorded from beds considered Cretaceous in age, such as the Fruitland formation, Kirtland shale, Vermejo, Laramie, and Lance formations, and the lower part of the Animas formation. *Sapindus* has been found in such Paleocene beds as the Tullock-Ludlow, Fort Union, Raton, Denver, and the upper part of the Animas formation. Its presence in the Ojo Alamo sandstone certainly favors Paleocene age for that unit.

The information from the five small pollen and spore florules cannot be used to fix the position of the boundary. It does, however, suggest that the Ojo Alamo florules are more closely related to the Nacimiento florules than to the one in the Kirtland shale. The Kirtland florule and the Ojo Alamo florule have three forms in common. The Kirtland and Ojo Alamo 2 florules have only the generalized polypodiaceous spores and the long-ranging *Liliacidites leei* in common (table 3). The Ojo Alamo and Nacimiento florules, however, have nine forms in common, including such distinctive species as *Podocarpus sellowiformis, Cupanieidites* aff. C. *major, Ulmoideipites tricostatus, Momipites inaequalis, Salix* sp., and *Tricolpites anguloluminosus.* The most definitive break in the entire sequence is below the Ojo Alamo 2 florule. The Ojo Alamo 1 florule has only *Podocarpus sellowiformis,* Triporo*pollenites plektosus,* and *Ulmoideipites tricostatus* in common with the Nacimiento florules and only one additional species in common with the Ojo Alamo z florule. This paucity of common forms is remarkable because both florules represent the more temperate conditions of post-Kirtland shale deposition. Additional sampling and material would probably increase the number of forms common to the several florules. At present, however, if the boundary were to be placed on the basis of common forms alone, it would appear between the two Ojo Alamo florules.

The most significant ecologic change takes place between the Kirtland and Ojo Alamo 1 florules with the influx of more than 7o percent *Podocarpus* pollen and associated upland species of *Ulmoideipites.* The Ojo Alamo 1 florule has a "Tertiary" ecologic aspect but is not necessarily Tertiary from the standpoint of common forms. The siltstone lens from which the sample was taken could be considered a part of either the Ojo Alamo sandstone or the Kirtland shale, and the florule could also be considered transitional.

The meager information from outside the San Juan Basin does not help directly in fixing the position of the boundary. The Paleocene pollen and spore flora from South Dakota described by Gerhard (1958) contains several forms that appear related to those in the Nacimiento florules, such as *Momipites coryphaeus (= Momipites tenuipolus), Salix implanus (= Salix* sp.), *Nyssa,* and *Cupanieidites.* Three of these general types, *Salix, Momipites,* and *Cupanieidites,* are present in the Ojo Alamo 2 florule. *Momipites-type* pollen and ulmaceous pollen, which become common in the Ojo Alamo sandstone, also appear to become common in the Paleocene (Danian) of Europe and further suggest a Tertiary age for the Ojo Alamo sandstone (see Pflug, 1953, pl. 20, fig. 50-58;
Pl. 24, fig. 72-79).

The age of the Lewis shale florule is difficult to evaluate. Stratigraphic relations indicate that the florule underlies an equivalent of the Ojo Alamo sandstone (fig. I) and should correlate with the upper part of the Kirtland shale. The dominant species in both the Kirtland shale and Lewis shale is *Proteacidites thalmanni.* The other species, however, are very dissimilar. The Lewis shale also contained *Ulmoideipites krempi* and *Cupanieidites* aff. C. *major?,* types which become common in the Ojo Alamo florule. For the present, the uppermost Lewis shale is considered Cretaceous but near enough to the Cretaceous-Tertiary transition to make the age assignment tentative.

VERTEBRATE EVIDENCE

Vertebrate paleontologists agree that the Ojo Alamo fauna is closely related to the underlying Kirtland shale fauna and that both are correlative with the fauna of the Judith River formation (Colbert, 195o, p. 7o). The Ojo Alamo fauna is older than the *Triceratops* fauna found in the Lance formation and is considered late but not latest Montanan in age. The Tertiary aspect of the flora and the Montanan age of the fauna are incompatible.

Reeside (1924, p. 3) reviewed the vertebrate fossil evidence and concluded that poor collecting practices and questionable determinations cast doubt on the validity of correlation. Nevertheless, the many dinosaur bones and fragments found in the Ojo Alamo sandstone have a Montanan aspect and are closely related to the Kirtland-Fruitland faunas (Colbert, 195o, p. 7o). Reeside (1924) pointed out that little vertebrate material has been found away from the type locality. A logical assumption is that the dinosaur bones and fragments may have been reworked from the Kirtland shale. The fossils consist of a horn core, trachodont jaw and skull fragments, isolated teeth, a scapula and dermal plates from an armored dinosaur, part of a frill of a ceratopsian, vertebrae of a large carnivorous dinosaur, and a scapula and ischium of a sauropod. Apparently, articulated parts have not been found. Preservation of the fragments is fair to poor. The Ojo Alamo collections were made in the same local area as those from the Kirtland shale. In view of the wide age discrepancy between the floral and faunal evidence, the possibility that large numbers of bones and fragments have been reworked should be seriously considered.

Faulty identification of the fragmentary material could mean that the dinosaurs are not of Montanan age but do represent an equivalent of the *Triceratops* fauna of the Lance formation and may even be younger. This explanation would agree with the present knowledge of the stratigraphy in the area, because the Kirtland shale, Ojo Alamo sandstone, and Nacimiento formation are conformable, or nearly so, and there is no recognizable hiatus to represent the "*Triceratops* zone."

If reworking or faulty identification is assumed, there is closer agreement between the vertebrate-floral relations in the San Juan Basin sequence and the type Lance-Fort Union sequence. Dorf (194o) found that the most significant floral differences occurred above the uppermost dinosaur-bearing beds of the Lance formation. This change would correspond to the one at the base of the Ojo Alamo sandstone and would make the Ojo Alamo sandstone a correlative of the Tullock-Ludlow beds.

MARINE INVERTEBRATE EVIDENCE

The closest associated marine fossils are those in the upper part of the Lewis shale. Foraminifera and ammonites occur 220 feet below the top of the formation at the Lewis shale florule locality. Hystrichospherids, dinoflagellates, and marine microfossils incertae sedis are present throughout the uppermost part of the formation, and the ranges of these organisms, when they become known, may help fix the position of the boundary.

Method of Classification

The classification used here is a combination of the "natural" and artificial. This author believes that a system that gives priority to botanical affinity is superior to a completely artificial one; for that reason the phylogenetic systematic outline in the *Catalogue of the Cenozoic plants of North America through 1950* (La Motte, 1952) has been used as a framework of classification.

Fossils identified with extant genera are placed in the systematic outline under the most appropriate taxon. For example, *Salix* appears under the Salicaceae.

Fossil pollen and spores whose affinity is unknown or only poorly known are referred to one of the strictly artificial form genera. No one artificial system is deemed superior to any other, and an attempt has been made to use form genera that have been validly established in the literature whether they are members of an integrated artificial system or not. The inherent difficulty in any completely artificial system is the splitting of a natural taxonomic or ecologic division into several artificial ones. Preference has generally been given to the system of Thompson and Pflug (1953), which is based on the structure of the germinal aperture and tends to minimize this difficulty. A pollen or spore identified with one of the artificial form genera is placed in the systematic outline under the taxon that contains it with certainty. For example, *Triporopollenites* appears under Dicotyledones incertae sedis.

Between the "natural" extant genera and the artificial form genera are a host of pollen types that cannot be placed in an extant genus with certainty and yet clearly show an affinity to a family, subfamily, tribe, or genus. Techniques for naming such organ genera are provided in the International Code (I.C.B.N., 1956, p. 55) and have long been used by paleobotanists. These techniques do not seem to be favored by palynologists, although Wodehouse (1933) long ago used organ genera such as *Momipites* in agreement with the rules and recommendations. More recently, Cookson (1947 and subsequent papers) and Couper (1953 and subsequent papers) have used organ genera that acknowledge taxonomic affinity on the family, subfamily, and tribe level.

Organ genera are more restrictive than those of any completely artificial system, they show natural affinity, and they are broad enough in diagnosis to overcome the difficulties of an artificial system; namely, the splitting of a natural ecologic unit into several genera.

The system made use of in this paper recognizes that the first part of the generic name implies a level of taxonomic certainty. The incorporation of the family ending *aceae* into the generic name may imply a stenopalynous family (a family that contains only one typical pollen type), and the name would appear under that family in the systematic outline. For example, *Myrtaceidites* Cookson and Pike, 1954 would appear under the Myrtaceae.

In some cases the *aceae* ending is incorporated into generic names that represent panpalynous families (new term; families whose common morphologic type is found in one or more other families). *Liliacidites* Couper, 1953 is such a genus, and it would appear under the subclass Monocotyledones in the systematic outline. In this case the affinity is so broad that the genus is actually a form genus.

In the case of a eurypalynous family (a family which contains two or more distinct morphologic types of pollen), the subfamily ending *oideae* may be incorporated into the generic name. An example is *Ulmoideipites* Anderson (this paper), which is placed under the Ulmaceae in the systematic outline. A further division for the tribe is possible, and the generic name uses part of the tribe ending. An example is *Cupanieidites* Cookson and Pike, 1954, which appears under the Sapindaceae in the systematic outline.

The next level of certainty merely adapts the generic name to an expanded diagnosis of the morphological type of a particular genus. An example is *Momipites* Wodehouse, 1933, which includes grains of the *Momisia, Corylus,* and *Engelhardtia* type. *Momipites* appears under the subclass Dicotyledones in the systematic outline because the correct family is not known.

For the organ genera that have been erected here, the Wodehouse (1933) ending *pites* has been used in agreement with the recommendation of the International Code (I.C.B.N., art. PB. 6A). The new monosulcate form genera, *Confertisulcites, Navisulcites,* and *Rectosulcites,* however, have used the *ites* ending in the belief that the word *sulcites* implies a pollen relationship.

New species were described where adequate material was available for description. In some instances, where a species occurs in several different samples, only three or four grains were used in determining the diagnosis. This seemed desirable for a reconnaissance study of this type and for convenience in referring to the same species in different florules.

The frequency of the species in the florule is noted only in a general way under "occurrence." "Rare" means that only 1 or 2 grains were found in the sample; "uncommon," 3 to 10; "common," the species constitutes several percent of the florule; "abundant" and "very abundant," the species is dominant in the florule.

Descriptions of organ and form genera have been omitted except in the case of new genera. Instead, the author and date of the genus are mentioned, and the reference is cited in the bibliography. The date and reference for extant genera, however, are not given.

All holotypes are deposited with the New Mexico Bureau of Mines and Mineral Resources. Paratypes and examples of other described forms are in the writer's collection.

Revision of Monosulcate Genera

The variety of monosulcate pollen in the several florules studied made it desirable to divide the broadly defined form genus *Monosulcites* (Cookson) Couper, 1953 into several other genera. At the present time there are at least five broadly defined and inclusive valid form genera of monosulcate pollen: *Monosulcites* (Cookson) Couper, 1953; *Entylissa* (Naumova) Potonié and Kremp, 1954; *Liliacidites* Couper, 1953; *Palmidites* Couper, 1953; and *Marsupipollenites* Balme and Hennelly, 1956.

Monosulcites and its synonyms *Monocolpopollenites* Pflug and Thompson, 1953 and *Monocolpites* Van der Hammen, 1954 comprise most single-furrowed types of pollen.

Entylissa is now a well-defined genus and is clearly designed to include only a certain type of monosulcate pollen. The principal distinguishing feature of *Entylissa* is the furrow, which is illustrated as expanding toward the ends of the grain. Balme (1957) believed in the validity of *Entylissa* and figured several species conforming to the Potonié and Kremp definition. *Cycadopites* Wodehouse, 1933 is apparently a synonym of *Entylissa.*

Liliacidites comprises reticulate pollen of apparent liliaceous affinity. The chief characteristic of *Liliacidites* is the reticulate sculpture, but monosulcate grains with reticulate sculpture are typical of several other families, so that one cannot be positive of the liliaceous affinity in fossil grains. For this reason, *Liliacidites* is here considered as a panpalynous form genus for reticulate monosulcate pollen unless the family affinity is definitely known.

Arecipites Wodehouse, 1933 is another broadly defined panpalynous monosulcate form and organ genus. Wodehouse did not designate a genotype but apparently considered the minutely pitted *Arecipites punctatus* to be the type species. Although it was not specifically stated, Wodehouse implied that a fine reticulate-pitted sculpture was a generic character. *Arecipites punctatus* Wodehouse, 1933, in which the lumina of the reticulum are apparently less than o.5 micron in diameter, is selected as the type species. Hence, reticulate monosulcate pollen are referable to two genera. Grains whose lumina are about 0.5 micron or less in diameter are placed in *Arecipites,* and grains whose lumina are generally greater than r micron are assigned to *Liliacidites.* The clavate muri which are so common in liliaceous grains should aid in placing borderline species.

Palmidites Couper, 1953 is set aside for large (greater than 5o microns) pollen of known palmaceous affinity. *Palmidites* was also used as a subgenus of *Monosulcites* by Chitaley (1951). Palm pollen is very generalized, and this genus probably will not be of much use unless associated with the anthers of palm megafossils. *Encephalarites* (Bolkhovitina, 1953) and *Bennettites* (Bolkhovitina, 1956) are also in this category.

Marsupipollenites Balme and Hennelly, 1956 was erected for an unusual type of monosulcate pollen whose furrow sides are delimited by two parallel longitudinal folds.

Two new form genera have been separated from *Monosulcites* in this paper. They are *Confertisulcites* and *Navisulcites.*

Confertisulcites is proposed for grains that have a very narrow furrow and whose sides are almost always in contact throughout their length or broadly overlapping. The ends of the furrow are not noticeably expanded, and the furrow reaches the ends of the grain. Similar grains have been referred to *Monocolpopollenites tranquillus* (R. Pot.) Pflug and Thompson (1953, p. 62, fig. 24-37, 39-47).

Navisulcites has a furrow that is narrowly fusiform or boat shaped. The furrow is pointed rather than rounded at the ends, and the greatest breadth occurs at the midpoint, a condition that is more or less opposite to that of *Entylissa.* Similar grains have been referred to as *Ginkgoites* by Zaklinskaja (1957, p. 95, fig. 15-16), to *Monosulcites (Palmidites) spinosa* by Chitaley (1951, pl. 13, fig. 11, text fig. 12), to *Ginkgo tripartita* by Bolkhovitina (1953, pl. ro, fig. 1-2), and to *Monocolpopollenites ingens* by Pflug and Thompson (1953, p. 62, pl. 15).

Rectosulcites is proposed for monosulcate pollen with a straight, broad, parallel-sided furrow. The new genus is most closely related to the more broadly defined *Entylissa,* whose original illustrations show the furrow gradually expanding toward the ends of the grain. In some grains of *Rectosulcites,* the extreme ends of the furrow are slightly expanded and broadly rounded, producing a "keyhole" effect. Grains similar to *Rectosulcites* have not often been described. Wodehouse (1953) illustrates a *Liriodendron* grain with a straight-sided wide furrow, and *Ginkgo typica* (Mal.) Bolkhovitina (1953, p. 62, pl. 4) would appear to fit the new form genus.

Monosulcites (Cookson) Couper, 1953 remains as a genus for monosulcate pollen grains that do not have the characters of the above-cited genera or whose furrows are irregular or poorly defined.

The following is a key to the more broadly defined and inclusive valid form genera:

A. Sculpture coarsely or finely reticulate, pitted, or scrobiculate.

- B. Lumina generally less than 0.5 micron in diameter. Muri low and nonclavate . . . *Arecipites* (Wodehouse, 1933).
- B. Lumina generally greater than 1 micron in diameter. Muri often baculate or clavate . . . *Liliacidites* Couper, 1953.

A. Sculpture otherwise. Smooth, flecked, granular, warty, spinose, etc.

- B. Furrow sides delimited by folds . . . *Marsupipollenites* Balme and Hennelly, 1956.
- B. Furrow sides simple or margined, but not folded.
  - C. Furrow ends broadly rounded.
    - D. Furrow gradually constricted at the midpoint and gradually expanded toward the ends . . . *Entylissa* (Naumova) Potonié and Kremp, [1]954.
    - D. Furrow straight-sided or only slightly expanded at the extreme ends to give a "keyhole" effect . . . *Rectosulcites* n. gen.

C. Furrow ends not broadly rounded.

D. Furrow sides usually in contact and reaching ends of grain, often broadly overlapping . . . Con *fertisulcites* n. gen.

D. Furrow sides not in contact, or furrow does not reach ends of grain.

E. Furrow fusiform or boat shaped, widest at midpoint, pointed at ends . . . *N avisulcites* n. gen.

E. Furrow variable, irregular, poorly defined, or otherwise . . . *Monosulcites* (Cookson) Couper, 1953.

Technique

Shale samples were subjected to an HCl-HF-HCl-HNO_3-HCl treatment. Coal samples were treated with KOH, acetolyzed, and bleached with $NaClO_3$. All samples were stained with safranin, given a final wash in xylene, and mounted in Canada balsam. Single-mounts were made by smearing the residue on a slide in Crown immersion oil, picking up single specimens with a microcapillary tube, transferring to a different slide, and covering the specimen with Canada balsam and a cover slip. The procedure was greatly facilitated by mounting the tube on a micromanipulator. Holotype and paratype specimens and examples of all described forms were mounted in this manner and their position on the slide marked with a diamond scribe. The technique is described more fully elsewhere (Anderson, 1958).

Conclusions

The Ojo Alamo z and Nacimiento florules have several distinctive forms in common, but otherwise there is little similarity among the five florules taken from the Kirtland shale, Ojo Alamo sandstone, and Nacimiento formation. Some of the difference is undoubtedly due to the reconnaissance nature of the study and the fact that only five florules were described from the three formations. However, much of the difference is probably due to the rapid ecologic changes that were taking place as a result of secular and regional climatic variations and local changes in elevation and source area. An altered environment caused by local uplift can be invoked to explain the profound difference between the Kirtland shale florule and the Ojo Alamo 1 florule. In this case the influx of sand from an uplift was accompanied by upland, inland, or xeric conditions that made possible a completely different type of vegetation.

There is little similarity between the Lewis shale florule and the Kirtland shale or Ojo Alamo 1 florule in spite of the fact that one of them must be a near time-equivalent. This example shows that a great deal of caution must be exercised in assigning vertical significance to floral differences until the lateral relationships are known.

Paleobotanical evidence suggests that most of the Ojo Alamo sandstone is Tertiary, but the basal part may be either Cretaceous or Paleocene. The dinosaurs taken from the middle shale unit of the Ojo Alamo sandstone have been considered Montanan in age; the discrepancy may be explained by assuming that the dinosaur bones and fragments have been reworked or misidentified. Alternatively, pre-Lance-type dinosaurs persisted into a "Tertiary" environment.

It is too early to determine which pollen and spore species will be the most useful in zonation. *Momipites tenuipolus* already is recognized as a probable Paleocene index fossil, and *Proteacidites thalmanni* may be restricted to the Cretaceous. Several other common and distinctive species, such as *Ulmoideipites tricostatus, Kurtzpites trispissatus, Paliurus triplicatus, Bombacacipites nacimientoensis, Nyssa puercoensis, Tilia danei,* and *Tilia wodehousei,* are potential Cretaceous, Paleocene, or transitional index fossils, but evaluation must await the publication of work in surrounding areas.

Systematic Descriptions

Kingdom **PLANTAE**

Phylum **BRYOPHYTA**

Class MUSCI

Order **SPHAGNALES**

Family SPHAGNACEAE

Genus **SPHAGNUM** Linné

Sphagnum sp.

Pl. 1, fig.

Description. Very small subtriangular trilete spores with broadly rounded corners and convex sides; wall thick in pro portion to spore size; laesurae almost reaching the periphery, bounded by folds; sculpture smooth to faintly scabrate.

Dimensions. Diameter 15 microns; wall about 1 micror thick.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK

Phylum **PTERIDOPHYTA**

Class **FILICINEAE**

Order **FILICALES**

Family SCHIZAEAECAE

Genus **LYGODIOSPORITES** R. Potonié, 1951

Lygodiosporites adriennis (R. Potonié and Gelletich, 1933) See Cookson (1953)

Pl. *9,* fig. *7*

Description. Small, smooth trilete spores with broadly rounded corners and slightly concave sides; laesurae about three-fourths spore radius.

Dimensions. Diameter 3o microns; wall thickness o.8 micron; rays about 11 microns long.

Occurrence. Uncommon in Lewis shale florule. Uppermost Cretaceous.

Collection numbers. AL 5-I, 2.

Lygodiosporites? sp.

Pl. *7*, fig. 17

Description. Small trilete spores with laesurae relatively short and not reaching periphery; subtriangular outline in polar view; psilate sculpture.

Dimensions. Diameter 24 microns; wall x micron thick.

Occurrence. Rare in Nacimiento 2 florule. Lower Paleocene.

Collection number. AN2 1-1.

Family GLEICHENIACEAE

Genus **GLEICHENIIDITES** (Ross) Delcourt and Sprumont, 1955

Gleicheniidites senonicus Ross, 1949

Pl. 7, fig. 18

Description. Small trilete spores, triangular in polar view with sharply rounded corners and concave sides; laesurae reaching the periphery; psilate sculpture.

Dimensions. Diameter 21 microns; wall 1 micron thick.

Discussion. This form is closest in size to the smaller grout of *Gleicheniidites senonicus* described by Ross (1949, p. 31)

Occurrence. Uncommon in Nacimiento 2 florule. Lowe] Paleocene.

Collection number. AN2 2-1.

Family POLYPODIACEAE Genus

POLYPODIIDITES Ross, 1949

Polypodiidites spp.

Pl. 1, fig. 3, 4, *5, 6, 7;* pl. 5, fig. I, 2; pl. 7, fig. 19, 20; pl. 9, fig. 8

Description. Smooth, moderately thick-walled endospores of polypodiaceous spores; elongate, bilateral, monolete, and usually somewhat bean shaped; some spores have slightly irregular surface, others have a faintly reticulate area surrounding the laesura.

Dimensions. Length ranges from 21 to 45 microns.

Discussion. Several possible types of polypodiaceous spores have been included in the general description.

Occurrence. Abundant in Kirtland shale florule; common in Ojo Alamo 2 florule; abundant in Nacimiento 2 florule; common in Lewis shale florule. Uppermost Cretaceous to lower Paleocene.

Collection numbers. AK 3-I to 6; AO2 I-I, 2; AN2 3-1 to 5; AL 6-1.

Order **LYCOPODIALES**

Family LYCOPODIACEAE

Genus **LYCOPODIUM** Linne

Lycopodium novomexicanum n. sp.

Pl. 1, fig. 2; pl. 8, fig. 1

Description. Trilete spores with very indistinct laesurae reaching the edge of the body; circular to subcircular in polar view; distal surface covered with a reticulum of narrow muri and wide lumina, proximal surface unsculptured or with a trace of disconnected muri; floor of lumina finely granular on distal surface; body bordered equatorially by a thin, nonstaining, irregular flange, with thickened extensions of the faint laesurae often projecting onto the flange.

Dimensions. Entire diameter 42-60 microns, but mostly 55-58 microns; wall 1-1.5 microns thick; muri about 0.5 micron wide; lumina diameter 8- 10 microns; flange as much as 2.5 microns wide.

Discussion. Most similar to *Lycopodium perplicatum* Bolkhovitina, 1956 but distinguished by its very indistinct trilete mark.

Occurrence. Common in Kirtland shale florule; rare in Nacimiento 2 florule. Uppermost Cretaceous to lower Paleocene.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 2-I (holotype), 2, 3, 4; AN2

P T ER IDOPHYTA incertaesedis Genus

CINGULATISPORITES Thompson, 1953

Cingulatisporites lancei n. sp.

Pl. 9, fig. it

Description. Rounded-triangular trilete spores with a delicate cingulum; laesurae raised, extending indistinctly onto the cingulum; cingulum very thin, with an irregular gemmate(?) sculpture; baculate-clavate sculpture on distal surface of spore.

Dimensions. Total diameter 35 microns; cingulum as much as 3 microns wide; wall 2 microns thick at edges; baculae about 2 microns long, 0.5 micron wide, and set about 2-2.5 microns apart.

Discussion. This spore differs from C. *pseudoalveolatus Couper*, 1958 in its smaller size, laesurae which extend indistinctly beyond the inner margin of the cingulum, and longer, thinner sculpturing elements more irregularly spaced. Named for John F. Lance, of the University of Arizona.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection number. AL 9-1 (holotype).

Genus **CONCAVISPORITES** Pflug, 1953

Concavisporites sp.

Pl. 9, fig. 9

Description. Trilete spores with broadly rounded corners and slightly concave sides; laesurae long, extending almost to the periphery, and with heavily thickened lips at the peripheral end only; psilate to finely granular sculpture.

Dimensions. Diameter 44 microns; wall 1.5 microns thick; laesurae margins thickened for outer 7 microns.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 7-1.

Genus **FOVEOTRILETES** (Van der Hammen)
R. Potonié, 1956

Foveotriletes scrobicularis (Ross)
R. Potonié, 1956

Pl. 1, fig. 8

Description. Trilete spores with straight to slightly convex sides and triangular outline in polar view; laesurae well defined, reaching the margin of the spore. Surface finely reticulate (scrobiculate), and the lumina do not open into the laesurae. Wall thicker at corners.

Dimensions. Diameter 3o microns; lumina about o.5 micron in diameter; wall as much as z microns thick at corners.

Occurrence. Uncommon in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 4-1.

Genus **INTERTRILETES** n. gen.

Diagnosis. Trilete spores with a short polar axis and circular to triangular outline in polar view. Sculpturing confined to, or distinctly different in, the triangular areas between laesurae.

Discussion. The most closely related form genera are probably *Laevigatisporites* Ibrahim, 1933 or *Punctatisporites* Ibrahim, 1933, but the localization of the sculpturing is a distinctive character and does not fit the descriptions of these genera. For this reason *Intertriletes* is proposed for trilete spores whose structure or sculpture is different in the pyramic areas.

Occurrence. Paleocene of North America.

Type species (here designated). *Intertriletes scrobiculatus* n. sp.

Intertriletes scrobiculatus n. sp.

P1.5, fig. 3, 4

Description. Trilete spores with broadly rounded corners and straight to slightly concave sides; laesurae about two-thirds the radius, distinct, and with a narrow margo; distal surface psilate, sculpturing on the proximal surface finely reticulate and confined to the triangular area between the laesurae; lumina do not open into the laesurae; lumina adjacent to the margo often arranged in rows but irregularly arranged elsewhere; wall slightly thicker at the corners.

Dimensions. Diameter 31-48 microns; wall about 1 micron thick; lumina and margos about 0.5 micron wide.

Occurrence. Common in Ojo Alamo 2 florule. Lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 2-I (holotype), 2, 3, 4.

Genus **LAEVIGATISPORITES** (Bennie and Kidston)
Ibrahim, 1933

Laevigatisporites percrassus n. sp.

Pl. 9, fig. 10

Description. Smooth trilete spores with rounded thickened corners and straight to convex sides; laesurae slightly gaping and not reaching the periphery; laesurae bordered by a wide granular margo extending to the thickened corner of the spore.

Dimensions. Diameter 4o microns; wall o.5 micron thick on the sides, thickening to 1.5 microns at the corners; laesurae 15-18 microns long; margos 2.5-3 microns wide.

Discussion. Most closely resembles L. *neddeni* subsp. *torus* Pflug, 1953 and L. *neddeni* subsp. *regularis* Pflug, 1953 but has wide, granular, and distinct margos, which extend beyond the laesurae to the thickened corners of spore.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.
Collection number. AL 8-1 (holotype).

Genus LAEVIGATOSPORITES Ibrahim, 1933

Laevigatosporites sp. Pl. 9, fig. 12

Description. Elongate-oval, bilateral, monolete spores; spore coat mostly smooth but with granular patches; laesurae simple and about three-fourths spore length.

Dimensions. Length 45 microns; width 33 microns; wall r micron thick.

Discussion. May be polypodiaceous.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 10-1.

Genus PUNCTATOSPORITES Ibrahim, 1933

Punctatosporites reginensis n. sp.
P[1].9, fig. 13, 14

Description. Elongate-oval, bilateral, thin-walled, monolete spores with a finely punctate sculpture; laesura indistinct and about two-thirds spore length when present.

Dimensions. Length 35-42 microns; width 22-32 microns; spore coat about 0.5 micron thick.

Discussion. Distinctive in its thin wall, indistinct laesura, and oval outline.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection numbers. AL 11-1 (holotype), 2.

Genus RUGULATISPORITES Pflug, [1]953

Rugulatisporites sp. Pl. 7, fig.

Description. Small trilete spore with subtriangular outline in polar view; lips slightly raised, laesurae not reaching the periphery. Sculpture irregular and rugulate.

Dimensions. Diameter 25 microns; wall about 1 micron thick.

Occurrence. Rare in Nacimiento 1 florule. Lowermost Paleocene.

Collection number. AN 11-1.

Phylum SPERMATOPHYTA
Class GYMNOSPERMAE
Order CONIFERALES
Family PODOCARPACEAE
Genus PODOCARPUS L'Heritier

Podocarpus northropi n. sp.
Pl. 3, fig. II, 12, 13

Description. Small, disaccate pollen with a circular to subcircular body and large, thin, often crumpled bladders; furrow area wide and moderately well defined although narrow and well defined in some grains, apparently owing to folding; bladders much longer than the body and latero-distally attached; body moderately thick walled and with a prominent wavy marginal ridge; body sculpturing granular, bladder sculpturing various, ranging from an incomplete reticulum to a distinct but irregular reticulum, the reticulum gradually becoming much finer and more granular near the body.

Dimensions. Body diameter 23-28 microns; bladder length 31-37 microns; bladder breadth 21-23 microns; total span 45-52 microns; marginal ridge as much as 2.5 microns thick.

Discussion. These grains resemble *Podocarpus nageiaformis* Zaklinskaja, 1957 and *Podocarpidites biformis* Rouse, 1957 but are significantly smaller. Named for Stuart A. Northrop, of the University of New Mexico.

Occurrence. Common in Ojo Alamo 1 florule. Uppermost Cretaceous or lowermost Paleocene.

Type locality. See page 5, Ojo Alamo r florule.

Collection numbers. A011-1 (holotype), 2, 3.

Podocarpus sellowiformis Zaklinskaja, 1957

Pl. 3, fig. 16, 17; pl. 4, fig. I to 4; pl. 5, fig. 5 to 9; pl. 7, fig. 2; pl. 9, fig. 15, 16.

Description. Disaccate pollen with an ellipsoidally longer than broad body and long latero-distally attached bladders; bladders large in proportion to the size of the body and attached throughout their greatest length; bladder attachment a straight or, more often, a slightly outwardly curving line in polar view; bladders not usually constricted at the base; bladders do not encircle the body; furrow area broad and well defined; proximal cap unthickened, but a distinct marginal ridge present; finely rugulate-reticulate sculpturing on the body and in the furrow area; sculpturing on the bladder imperfectly reticulate, becoming finer toward the body.

Dimensions. Diameter of body 28-51 microns; length of bladders 28-46 microns; breadth of bladders 16-27 microns; thickness of cap about 1 micron; marginal ridge as much as 2.5 microns thick; total span from 43 to 7o microns and usually about 6o microns.

Discussion. The systematic position of disaccate pollen of this type has been treated differently by many authors. Zaklinskaja's (1957, P. 105) synonymy shows that similar pollen have been referred to the *Pinus haploxylon* type and to *Podocarpus. Couper* (1953) has referred them to *Podocarpidites,* and Balme (1957) has used Seward's genus *Pityosporites.*

Referring these grains to pollen of *Pinus haploxylon* type would probably be in error because they can be distinguished from pollen of modern *Pinus haploxylon* type by their thinner cap, longer body, and somewhat larger bladders, which are attached throughout their greatest length or only slightly constricted at the base. In addition, the line formed by the bladder attachment on the distal side is straight or outwardly curving, as in podocarp grains, but this same line is usually inwardly curving in grains of *Pinus haploxylon* type. One specimen was observed that contained both types of bladders (pl. 4, fig. 3), but none were observed that had both bladders of the *Pinus haploxylon* type.

These grains differ slightly from Zaklinskaja's (1957) description in their more pronounced marginal ridge. They are consistently smaller than P. *cretacea* (Naumova) Bolkhovitins, 1953.

Occurrence. Very abundant in Ojo Alamo 1 florule; common in Ojo Alamo 2 florule; rare in Nacimiento 1 florule uncommon in Lewis shale florule. Uppermost Cretaceous (?) and lowermost Paleocene.

Collection numbers. AO x 3-I to 12; A02 3-I to 7; AN12-1 AL 12-1, 2.

Podocarpus zuniensis n. sp.

Pl. 3, fig. 14,15

Description. Disaccate pollen of variable size and with a subcircular to elliptical body and large encircling bladders body longer than broad when elliptical; bladders much longer than broad, latero-distally attached; bladders extending beyond the body, coalescing with each other and forming a thin extension of the furrow area, so that the bladders appear tc encircle the grain completely; furrow area well defined and with straight to slightly outwardly curving sides; proximal cap only slightly thickened but with a distinct wavy marginal ridge; sculpturing elements on the body often elongate, giving an irregularly rugulate-reticulate appearance; sculpturing on the bladders an imperfect reticulum, gradually becoming finer toward the body.

Dimensions. Diameter of body 32-44 microns; length of bladders 35-52 microns; breadth of bladders 21-31 microns; thickness of cap about 1-1.5 microns; marginal ridge as much as 3 microns thick; total span from 49 to 77 microns and usually greater than 6o microns.

Discussion. These grains have podocarpaceous affinity and differ from typical *Podocarpus* in their encircling bladders. The species is small for the genus and does not appear closely related morphologically to other described species. It is possible that the encircling bladders are unusual variations in the *Podocarpus sellowiformis* population, but the forms are so distinct that a different species seems warranted.

Occurrence. Ojo Alamo I florule. Uppermost Cretaceous or lowermost Paleocene.

Type locality. See page 5, Ojo Alamo r florule.

Collection numbers. AO, 2-I (holotype), 2.

Family PINACEAE

Genus **ABIETIPITES** Wodehouse, 1933

Abietipites spp.

P1. I0, fig. I, 2, 3

Description. Large, disaccate pollen, generally with long bladders closely attached to the body. Sculpturing patterns unreliable owing to poor state of preservation.

Dimensions. Total span usually 70-77 microns or greater.

Discussion. Grains of both the *Abies* and *Picea* type may be present, but the poor preservation prohibits a closer generic determination.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Collection numbers. AL 13-1, 2, 3.

Genus **PINUS** Linné

"*Pinus haploxylon* type" of Rudolph, 1935

Pl. 7, fig. 3, 4; pl. 8, fig. 2; pl. 10, fig. 4

Description. Disaccate pollen with elongate body and long bladders; bladders slightly constricted at base, not attache(throughout greatest body length, and contact with furrov area forming a slightly inwardly curving line; distinct marginal ridge; sculpture variable owing to corrosion.

Dimensions. Body diameter 35-52 microns; bladder length 38-52 microns; cap as much as 2 microns thick; marginal ridge as much as 3 microns thick; total span 55-68 microns.

Occurrence. Uncommon in Nacimiento fiorule; rare it Nacimiento 2 florule; uncommon in Lewis shale florule. Uppermost Cretaceous to lower Paleocene.

Collection numbers. AN1 3-I, 2; AN2 5-I; AL 14-I.

"*Pinus sylvestris* type" of Rudolph, 1935

Pl. 7, fig. 5

Description. Disaccate pollen with small globular bladder: more or less distally attached to the body, sharply constricted at base, and not attached throughout bladder length or body length; circular body in polar view, with a poorly developed marginal ridge. Variable sculpture owing to corrosion.

Dimensions. Body diameter about 37-43 microns; bladder length as much as 32 microns; cap about 1.5 microns thick.

Occurrence. Rare in Nacimiento florule. Lowermost Paleocene.

Collection number. AN1 4- I .

Pinus minima (Couper, 1958)

P1.10, fig. 5

1958 *Abietineaepollenites minimus* Couper, R. A., Palaeontographica, v. 103, p. 153.

Description. Small, disaccate pollen with a distinct cap and marginal ridge; body broader than long; bladders attached distally, slightly constricted at base, but of the haploxylon type; cap sculpture granular, the mesh on the bladders indistinct.

Dimensions. Body length 29 microns; body breadth 33 microns; bladder length 24 microns; bladder breadth 21 microns; thickness of cap 1.5 microns; total span 48 microns.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 15-1 .

Order **GNETALES**

Family GNETACEAE

Genus **EPHEDRA** Linné

Ephedra notensis Cookson, 1956

P1. I o, fig. 6

Description. Small, thin-walled, ellipsoidal pollen with 10 longitudinal ridges extending to the poles; no furrow; smooth.

Dimensions. Length 26 microns; width 12 microns; wall less than r micron thick.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 16-1.

Class **ANGIOSPERMAE**

Subclass **MONOCOTYLEDONES**

MONOCOTYLEDONES incertae sedis

Genus **ARECIPITES** (Wodehouse, 1933)

1933 *Arecipites* Wodehouse, R. P. [nom. nud.], Torrey Bot. Club Bull., v. 6o, p. 497.

Diagnosis. Elongate-ellipsoidal, bilateral, monosulcate pollen with very finely reticulate or scrobiculate sculpture; lumina generally less than 0.5 micron in diameter; furrow not expanded at ends, usually tightly closed throughout its length or overlapping.

Discussion. Wodehouse (1933, p. 497) did not select a type for the genus but suggested *Phoenix dactylifera* as an example. *Arecipites punctatus* Wodehouse, 1933 agrees most closely with his generic description and is therefore selected as the type species. Wodehouse likewise did not discuss the sculpture of *Arecipites* but implied that it was finely reticulate pitted, as in *Phoenix dactylif era.* This relationship has been clarified in the emended diagnosis, and an arbitrary diameter of 0.5 micron has been set as the upper limit for the lumina of *Arecipites* so as to distinguish the genus from the form genus *Liliacidites* Couper, 1953.

Type species (here designated). *Arecipites punctatus* Wodehouse, 1933.

Arecipites microreticulatus n. sp.

P1.1, fig. 7, 18

Description. Elongate, bilateral, monosulcate pollen with bluntly pointed ends; furrow simple, extending to the ends of the grain and usually overlapping; sculpture very finely reticulate (regularly punctate).

Dimensions. Length 45-5o microns; width 23-25 microns; lumina less than 0.5 micron in diameter; exine about 0.5 micron thick.

Discussion. The large size, very elongate form, and extremely fine but regular reticulation distinguish this species from the most closely related *Arecipites reticulatus* (Van der Hammen, 1954).

Occurrence. Uncommon in upper part of Kirtland shale. Uppermost Cretaceous.

Type *locality.* See page 5, Kirtland shale florule.

Collection numbers. AK 8-1 (holotype), 2.

Arecipites reticulatus (Van der Hammen, 1954)

Pl. 1, fig. 19; pl. 7, fig. 6; pl. 8, fig. 3; pl. 10, fig. 7

1954 *Monocolpites reticulatus* Van der Hammen, Bol. Geol., Colombia, v. **2,** no. r, p. 89.

1954 *Pollenites reticulatus* **B** Van **der Hammen, Bol. Geol.,** Colombia, V. 2, no. 1, p. 96.

Description. Small, elongate-oval, bilateral, monosulcate pollen with rounded ends; furrow simple, extending to the end of grain, often overlapping, never expanded at ends; sculpture finely reticulate.

Dimensions. Length 18-23 microns; width 11-15 microns; exine less than I micron thick; lumina and muri about 0.5 micron wide, sometimes slightly larger in center of grain.

Discussion. These generalized pollen appear to be indistinguishable from the minute reticulate, monosulcate pollen described by Van der Hammen (1954). The size of the lumina is near the upper limit for *Arecipites,* but the simple nonclavate muri favor its placement in that genus.

Occurrence. Uncommon in Kirtland shale florule; common in Nacimiento I florule; uncommon in Nacimiento 2 florule; uncommon in Lewis shale florule. Uppermost Cretaceous to lower Paleocene.

Collection numbers. AK 9-1; AN, 5-1, 2; AN2 6-1; AL 7-I.

Genus **LILIACIDITES** Couper, 1953

Liliacidites hyalaciniatus n. sp.

Pl. 1, fig. 12, 13, 14; pl. 4, fig. 5

Description. Small, ovoid to elongate, bilateral, monosulcate pollen; furrow usually reaching the ends of the grain and expanded toward the ends, bordered by a narrow margo; exine with a nonstaining, reticulate outer layer; the muri junctions appear clavate and can be stained, but the muri themselves are only weakly staining, so that the outer layer appears hyaline in edge view.

Dimensions. Length 22-23 microns; width 13-20 microns; thickness of wall (inner layer) variable, 0.5-1.5 microns; outer layer 1-1.5 microns thick. Clavae (muri junctions) about r micron apart.

Discussion. This species is extremely variable in shape and wall thickness but is readily distinguished by the hyaline, reticulate outer layer.

Occurrence. Common in Kirtland shale florule; rare in Ojo Alamo **x** florule. Uppermost Cretaceous to lowermost Paleocene *(?).*

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 6-1, 2, 3 (holotype); AO1 4-1.

Liliacidites leei n. sp.

Pl. 1, fig. 9, Io, I I; pl. 5, fig. 10; pl. 7, fig. 7; pl. 8, fig. 4, 5.

Description. Small, elongate, bilateral, monosulcate, reticulate pollen with pointed ends (a tendency for one end to be more rounded and less well defined in some grains); furrow extending to the ends of the grain and sometimes overlapping, well defined, and not expanded toward the ends; lumina not opening into the furrow, leaving a slight margo in some grains; lumina irregular and angular in shape, becoming slightly smaller near the ends of the grain; muri wide and low in proportion to the size of the lumina and not constricted at the base.

Dimensions. Length 25-35 microns; width 16-26 microns; lumina 1-1.5 microns in diameter; exine about 1 micron thick.

Discussion. Similar to *Liliacidites variegates* Couper, 1953 but has wider, nonclavate muri. Named for Willis T. Lee, geologist, for his early work in New Mexico and surrounding areas.

Occurrence. Abundant in Kirtland shale florule; uncommon in Ojo Alamo 2 florule; uncommon in Nacimiento 1 florule; common in Nacimiento 2 florule. Uppermost Cretaceous to lower Paleocene.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 5-1, 2 (holotype), 3 to 7; A02 4-I; ANTI 6-1; AN2 7-1, 2.

Liliacidites sp.

Pl. 1, fig. 15, 16

Description. Elongate, bilateral monosulcate grains covered with a broad reticulum; furrow narrow, closed, and well defined, extending to the ends of the grain; wall moderately thick, and muri somewhat clavate.

Dimensions. Length 32 microns; width 20 microns; lumina 2-3 microns in diameter; wall about I micron thick; outer reticulate layer 1.5 microns thick.

Discussion. This form resembles some monolete spores, such as *Woodsia,* but the long furrow and distinct, clavate, firmly attached reticulum suggests liliaceous affinity.

Occurrence. Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 7-1.

Genus TRICHOTOMOSULCITES Couper, 1953

Trichotomosulcites contractus n. sp.

Pl. *5,* fig. 11

Description. Thin-walled trichotomocolpate grain with subtriangular outline and rounded corners in polar view; sides of furrows contracted and often overlapping at the midpoint but expanded and broadly rounded at the periphery; furrows reaching the margin of the grain; no margo; sculpturing finely granular.

Dimensions. Diameter about 3o microns; exine about 0.5 micron thick.

Discussion. Similar grains are found in the Palmae and Liliaceae. Differs from *Trichotomosulcites sub granulatus* Couper, 1953 in its contracted and sometimes overlapping furrows, which are broadly expanded at the ends.

Occurrence. Uncommon in Ojo Alamo 2 florule. Lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection number. A02 5-1 (holotype).

Subclass **DICOTYLEDONES**

Family SALICACEAE

Genus SALIX (Tourn.) Linné

Salix sp.

Pl. 5, fig. 12, 13,14; pl. 8, fig. 6, *7*

Description. Prolate, tricolpate pollen with long furrows reaching nearly to the poles; pores absent, although the middle of the furrow is slightly distorted in some grains; furrows bordered by a narrow margo; sculpturing distinctly reticulate, with angular lumina that decrease in size toward the furrow.

Dimensions. Length (polar axis) 17-21 microns; width 12-14 microns; exine as much as 1 micron thick but usually thinner; lumina as much as 1 micron in diameter but often smaller; muri about 0.5 micron wide.

Discussion. This form is apparently conspecific with *Salix implanus* Gerhard (1958, manuscript name). For this reason it is referred to here as *Salix* sp. pending validation of Gerhard's species.

Occurrence. Common in Ojo Alamo 2 florule; rare in Nacimiento 2 florule. Lowermost to lower Paleocene.

Collection numbers. A02 6-1, 2, 3; AN2 2.

Family BETULACEAE

Genus ALNUS (Tourn.)

Hill *Alnus?* sp.

Pl. 4, fig. 6

Description. Oblate, 4-porate, aspidate pollen with equatorial pores; pores small, elongate, and with a labrum; arci absent; sculpturing reticulate-rugulate.

Dimensions. Diameter 29 microns; exine about 1.5 microns thick; pores about 1.5-2 microns in diameter.

Discussion. This grain resembles *Alnus* more than other members of the Betulaceae or related families, but it does not show arcuate thickenings, and the reticulum is coarser and more rugulate than in modern *Alnus* grains.

Occurrence. Rare in Ojo Alamo I florule. Uppermost Cretaceous or lowermost Paleocene.

Collection number. AO 5-1.

Family FAGACEAE

Genus QUERCUS Linné

Quercus explanata n. sp.

Pl. 5, fig. 15, 16, 7, 18, 9, 20

Description. Prolate tricolpate pollen with long furrows extending far into the polar area; furrows usually of unequal length and often with a margo; a definite pore not present, but the middle of the furrow sometimes slightly gaping; grains tend to be slightly rhomboidal in equatorial view; exine clearly differentiated and thicker at the poles; tectate-columellate exine gives the appearance of scabrate sculpture.

Dimensions. Length (polar axis) 33-48 microns, mostly greater than 4o microns; width 23-37 microns; exine as much as 2 microns thick at poles.

Discussion. Similar to *Quercus longicanalis* Traverse (1955) but more rhomboidal in equatorial view, and the exine is thinner except near the poles.

Occurrence. Very abundant in Ojo Alamo 2 florule. Lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 7-I, 2 (holotype), 3 to 13.

Quercus? sp.

P1.4, fig. 7, 8

Description. Tricolpate, prolate pollen with long furrows; margo indistinct if present; exine differentiated, columellae giving the grain a uniform, coarsely, and regularly scabrate sculpture.

Dimensions. Length 27 microns; width 17 microns; exine about 1.5 microns thick; furrow length 21 microns.

Occurrence. Rare in Ojo Alamo 1 florule. Uppermost Cretaceous or lowermost Paleocene.

Collection number. AO1 6- 1 .

Genus **SILTARIA** Traverse, 1955

Siltaria cf. *S. scabriextima* Traverse, 1955

Pl. 6, fig.

Description. Prolate, tricolporate pollen with long longitudinal furrows extending far into the polar area; closely resembles *Quercus* but has a large ellipsoidal transverse furrow (pore); longitudinal furrows underlain by costae cut by a transverse furrow; exine differentiated and tectate-columellate, giving a scabrate sculpture, thicker in the polar area.

Dimensions. Length (polar axis) 36 microns; width 26 microns; exine as much as 2 microns thick at poles; transverse furrows about **4** microns in diameter.

Discussion. A margo on the transverse furrow was not observed; otherwise the grains conform to the description of Traverse ([1]955).

Occurrence. Uncommon in Ojo Alamo 2 florule. Lowermost Paleocene.

Collection numbers. A02 8-1.

Family ULMACEAE

Genus **ULMOIDEIPITES** n. gen.

Diagnosis. Oblate to only slightly oblate pollen, possessing an ulmoid sculpture; thickened arci often connecting three or more circular to lolongate and sometimes irregular equatorial or subequatorial pores; pores usually with slight, poorly defined annuli continuous with thickened bands (arci) extending from pore to pore in an inwardly curving, outwardly curving, or straight line; sculpture irregularly verrucate (ulmoid), swellings of somewhat irregular size, shape, and distribution.

Discussion. The genus is intended to accommodate certain types of ulmaceous pollen that cannot be related to extant genera with certainty. Species should possess an ulmoid sculpture (often indistinctly) but need not have arci. Forms similar to *Planera, Ulmus, Zelkova,* and *Hemiptelia* would be included, but forms similar to *Celtis, Momisia,* or *Celtoidanthus* Weyland, Pflug, and Jahnichen, 1958 would be excluded.

Occurrence. Cretaceous-Tertiary of North America, Europe, and Asia.

Type species (here designated). *Ulmoideipites krempi,* n. sp.

Ulmoideipites krempi n. sp.

Pl. 4, fig. 12; pl. 6, fig. 2, 3; pl. 10, fig. 8

Description. Slightly oblate pollen with 3 and occasionally 4 pores; outline circular to subcircular in polar view; pores equatorial or slightly subequatorial, circular to irregular in outline, and with a slight annulus; annuli continuous with distinct arci that have poorly defined margins; folding usually equatorial but sometimes at random when the arci are weak; ulmoid sculpture.

Dimensions. Diameter 16-26 microns; pore diameter about 2.5 microns; exine about I micron thick.

Discussion. Most closely related to *Ulmipollenites undulosus* Wolff, 1934 but slightly smaller, generally triporate, and has arci. Named for G. 0. W. Kremp, of the University of Arizona.

Occurrence. Common in Ojo Alamo 1 florule; uncommon in Ojo Alamo 2 florule; rare in Lewis shale florule. Uppermost Cretaceous (?) to lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection numbers. AO1 8-1, 2, 3; A02 9-1 (holotype), 2; AL 18-1.

Ulmoideipites planeraeformis n. sp.

Pl. 4, fig. 13

1958 *Polyporopollenites undulosus* (Wolff) [in part], Weyland, Pflug and Jahnichen, Palaeontographica, v. 105, pt. B, pl. 12, fig. 25, form Z.

Description. Oblate, 5-porate pollen with the sides between the pores straight to slightly convex, giving the grains a pentagonal outline in polar view; pores moderately large, thickened, and connected by broad, poorly defined but distinct arci; sculpture irregularly verrucate (ulmoid).

Dimensions. Diameter 3o microns; pore diameter about 3 microns; exine about o.5 micron thick with pore thickenings, arci, and verrucae as much as 1 micron thick.

Discussion. Somewhat similar forms are found in the genus *Planera* and the genus *Hemiptelia.*

Occurrence. Ojo Alamo 1 florule. Uppermost Cretaceous or lowermost Paleocene.

Type locality. See page *5,* Ojo Alamo 1 florule.

Collection number. AO1 9-1 (holotype).

Ulmoideipites tricostatus n. sp.

Pl. 4, fig. 9, 10, II; pl. 6, fig. 4, 5; pl. 7, fig. 8; pl. 8, fig. 8, *9*

1958 Triporopollenites undulatus Pflug [in part], Weyland, Pflug, and Jahnichen, Palaeontographica, v. 105, pt. B, pl. 12, fig. 22.

Description. Oblate, triporate pollen with the pores somewhat depressed and the sides slightly convex, giving the grain a subtriangular outline in polar view; pores equatorial, subcircular to meridionally elongate, and with a slight annulus; distinctive "beaded ribs" parallel the sides of the grains and clearly or diffusely join above the pores; ribs reduced to poorly defined but distinct arci in some grains; sculpture irregularly verrucate (ulmoid) and responsible for the beaded pattern on the arci.

Dimensions. Diameter 7-23 microns; pore diameter about 2 microns; exine about 0.5 micron thick, with annuli and verrucae as much as 1 micron thick; arci as much as 1.5 microns thick.

Discussion. Distinguished from *Ulmoideipites krempi* by the more triangular outline and the distinct "beaded arci."

Occurrence. Common in Ojo Alamo 1 florule; uncommon in Ojo Alamo 2 florule; uncommon in Nacimiento i florule; rare in Nacimiento 2 florule. Uppermost Cretaceous (?) to lower Paleocene.

Type locality. See page *5,* Ojo Alamo florule.

Collection numbers. A01 7-I (holotype), 2,, 3; A02 I0-I; AN, 7-1; AN2 9-I.

Family PROTEACEAE

Genus **PROTEACIDITES** (Cookson) Couper, 1953

Proteacidites retusus n. sp.

Pl. 2, fig. *5,* 6, *7*

Description. Small, oblate, triporate pollen, triangular to asymmetrically triangular in polar view, with rounded corners and straight to slightly concave sides; pores small and circular; exine clearly differentiated, with the endexine thickened to an endannulus; proximal edge of the endannulus appears as a straight or slightly inwardly curving line in polar view; no vestibulum was observed, but it might be obscured by the thick endannulus; very finely and irregularly reticulate sculpture, becoming finer in the polar areas.

Dimensions. Diameter 20 microns; exine about 1.5 microns thick; endannulus about 4 microns wide in polar view; pores less than 2 microns in diameter; lumina about o.5 micron in diameter.

Discussion. These grains might not be considered proteaceous if found alone, but their sculpture and sometimes elongate-triangular outline resemble *Proteacidites thalmanni* n. sp. and suggest proteaceous affinity. This species most closely resembles *Proteacidites rectomarginatus* Cookson, 1950 but is much smaller and appears to have a thicker endannulus.

Occurrence. Common in Kirtland shale florule. Uppermost Cretaceous.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 11-1 (holotype), 2 to 8.

Proteacidites thalmanni n. sp.

Pl. 2, fig. I, 2, 3, 4; pl. 10, fig. 9, 1o, 11, 12, 13

Description. Oblate, triporate pollen grains with an irregularly reticulate sculpture; triangular to elongate-triangular, with straight to slightly convex sides in polar view; pore structure variable, circular to lolongate; elongate pores sometimes pointed at the ends and having a "notchlike" outline in polar view; exine clearly differentiated into two layers, the endexine thickening around the pores to form an endannulus; sculpture coarsely and often irregularly reticulate, becoming finer in the polar areas.

Dimensions. Diameter 7-29 microns; pore diameter 2-4 microns; endannulus variable, as much as 4 microns wide; exine about 1.5 microns thick.

Discussion. The grains in the Kirtland shale florule differ somewhat from the same species in the Lewis shale florule in their finer reticulum and less pronounced "notch." The great variation in pore structure might warrant two separate species. Many grains, however, are transitional between end members of the "notched" and circular pore types, and two species do not seem warranted from the standpoint of natural affinity. The species most closely resembles *Proteacidites granulatus* Cookson, 1953 but is significantly smaller in all dimensions, more definitely reticulate, and often has a notched "pore." Named for Hans E. Thalmann, Stanford University.

Occurrence. Abundant in Kirtland shale florule; very abundant in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 10-1 (holotype), 2 to 7; AL 19-I to *9*.

Proteacidites sp.

Pl. 2, fig. 8

Description. Small, triporate pollen with very large circular pores; grains apparently oblate, with circular outline in polar view; pores with a thick endexinous "apertural collar" or endannulus, and the exine clearly differentiated only around pores; vestibular structure not observed but may be obscured; sculpture finely and irregularly reticulate but uniform over entire grain.

Dimensions. Diameter 21 microns; endannulus as much as 3 microns wide; lumina about 0.5 micron in diameter.

Discussion. This grain resembles *Hakia amplexicaulis,* illustrated by Erdtman (1952, p. 36o), but is much smaller.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 12-I.

Family EUCOMMIACEAE

Genus **EUCOMMIIDITES** (Erdtman) Couper, 1958

Eucommiidites couperi n. sp.

Pl. 11, fig. *7,* 8

Description. Tricolpate pollen with a well-developed median colpus and two narrower, less well-developed colpi on each side; median colpus constricted at the midpoint, gradually expanded at the ends, usually reaching the ends of the grain; lateral colpi not expanded, not reaching the ends of the grain.

Dimensions. Length 20-23 microns; width 14-18 microns; exine less than 1 micron thick.

Discussion. These specimens are smaller and have a thinner exine than E. *troedsonnii* Erdtman, 1948, or E. *minor* Groot and Penny, 1960, or similar grains described by Rouse (1957, 1959). Named for R. A. Couper, of the New Zealand Geological Survey.

Occurrence. Uncommon in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection numbers. AL 27-I (holotype), 2, 3.

Family ACERACEAE

Genus **ACER** Linné

Acer striata (Pflug, 1959)

P1.7, fig. 9

1959 Tricolpopollenites striatus Pflug, Neues Jahrb. Geol. u. Paläont. Abh., v. 107, no. 2, p. 155, pl. 16, fig. 13, 14.

Description. Prolate(?), tricolpate pollen with subcircular outline and gaping furrows in polar view; furrows poorly defined, extending far into polar area; sculpture distinctly striate, with the vallae mostly meridionally oriented.

Dimensions. Diameter 28 microns; exine about 1 micron thick.

Occurrence. Rare in Nacimiento florule. Lowermost Paleocene.

Collection number. AN, 8-1.

Family CYRILLACEAE

Genus **CYRILLA** (Garden) Linné

Cyrilla minima n. sp.

Pl. 10, fig. 14, 15

Description. Small, oblate, tricolporate pollen with wide furrows that narrow sharply and terminate a little more than one-half the distance to the pole; endexine persists and becomes thinner on the furrow margins, appearing as an overhanging process at the periphery; margos indistinct if present, exine sharply differentiated; sculpture psilate.

Dimensions. Diameter x 5-7 microns; exine up to 1.5 microns thick.

Discussion. These grains differ from *Cyrilla barghoorniana* Traverse, 1955 in their smaller size and indistinct margo.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection numbers. AL 20-I (holotype), 2.

Family SAPINDACEAE

Genus **CUPANIEIDITES** (Cookson and Pike) Krutzsch, 1959

Cupanieidites aff. *C. major* Cookson and Pike, 1954

Pl. 6, fig. 6; pl. 8, fig. 10, 11, 12; pl. 10, fig. i 6

Description. Small, oblate, tricolporate pollen with triangular outline in polar view, sides straight or slightly concave or convex, and corners somewhat pointed to rounded; pores small, only slightly thickened, and barely distinguishable from the furrows in polar view; furrows simple and narrow and extending to the poles, where they usually unite and sometimes leave a polar island, which is sharply triangular when present; furrows without a distinct margo but sometimes diffusely thickened; sculpturing scabrate-reticulate (?), with distinct elements regularly spaced.

Dimensions. Diameter17-22 microns; pores 1.5-2.5 microns wide; exine up to 1 micron thick at pores; polar islands up to *5* microns in diameter when present.

Occurrence. Uncommon in Ojo Alamo 2 florule; abundant in Nacimiento 2 florule; rare in Lewis shale florule? Uppermost Cretaceous? to lower Paleocene.

Collection numbers. A02 11-1 ; AN2 10-1 to 5; AL 2 I-I .

Cupanieidites cf. *C. reticularis* Cookson and Pike, 1954

Pl. 2, fig. **9,10**

Description. Very small, oblate, tricolporate grains, the furrows being bordered by well-defined arci; arci unite in the polar area, sometimes leaving a very small polar island; outline triangular in polar view, with rounded corners and straight sides; some specimens show a slight thickening over a wide area around the pores; sculpturing irregularly reticulate.

Dimensions. Diameter 14-7 microns.

Discussion. The specimens differ slightly from *Cupanieidites reticularis* Cookson and Pike ([1]954, p. 214) in their smaller size and more irregular sculpture.

Occurrence. Common in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 13- 2, 3.

Family RHAMNACEAE

Genus **PALIURUS** Miller

Paliurus triplicatus n. sp.

Pl. 2, fig. 19; pl. 4, fig. 15, 16, 7, 18

Description. Small, oblate, triporate pollen with circular to lolongate pores; outline subtriangular to hexagonal in polar view, with the sides of the grain almost always folded back toward the pole to give a slightly concave-triangular outline. (In some grains the sides are not involved in folding, and the outline remains more or less hexagonal. In other grains arcuate folds extend from pore to pore in a more polar position. The folding, however, is usually intense, and some grains even appear trilete or trichotomosulcate.) A slight annular thickening present around some pores; scabrate sculpture.

Dimensions. Diameter 7-27 microns; pore diameter as much as 2.5 microns; exine about 1 micron thick.

Discussion. Similar grains have been reported from the Cretaceous of Canada by Rouse (1957, pl. 2, fig. 35) and of Russia by Bolkhovitina. This species differs from *Paliurus rhamnoides* Bolkhovitina, 1953 in its significantly smaller size.

Occurrence. Rare in Kirtland shale florule; common in Ojo Alamo 1 florule. Uppermost Cretaceous to (?) lowermost Paleocene.

Type *locality.* See page 5, Ojo Alamo 1 florule.

Collection numbers. AK 18-I; AO1 11-1 (holotype), 2 to 6.

Family TILIACEAE

Genus **TILIA** (Tourn.)

Linné *Tilia danei* n. sp.

Pl. *7*, fig. 1 o,

Description. Small triporate pollen with circular to slightly hexagonal outline in polar view; pores lolongate and markedly thickened but not, or only slightly, protruding; an endexinous thickening gives the pores a characteristic curving inner margin in polar view; exine very thin for *Tilia*, and some grains randomly folded; sculpture finely reticulate.

Dimensions. Diameter 18-23 microns; exopores as much as 2 microns wide; exine less than I micron thick except at the pores.

Discussion. The thin exine and small size are the distinguishing characters. *Tiliapollenites pilosus* Gerhard, 1958 appears closely related, but *Tilia danei* has a thinner exine and finer sculpturing pattern. Named after Carle H. Dane, of the U. S. Geological Survey, for his geological work in the San Juan Basin.

Occurrence. Common in Nacimiento 1 florule. Lowermost Paleocene.

Type locality. See page 8, Nacimiento I florule.

Collection numbers. AN x 9-1 (holotype), 2.

Tilia wodehousei n. sp.

Pl. 2, fig. I I, 12, 13

Description. Small, oblate, thick-walled, triporate pollen with subcircular outline in polar view; pores slightly elongate equatorially and not always exactly equatorial, having a pronounced endexinous thickening and sometimes slightly raised margins; exine differentiated, forming a vestibulum; sculpture variable, generally nearly smooth but sometimes very faintly reticulate pitted.

Dimensions. Diameter constant, 20-22 microns; pore width (polar view) as much as 3 microns; exine about 1.5 microns thick.

Discussion. Most closely related to *Tilia vescipites* Wodehouse, 1933, but this species is consistently smaller and usually smooth. The species is distinguished from *Tilia danei* by its thicker wall and finer sculpturing. Named after Roger P. Wodehouse for his early studies of Tertiary palynology.

Occurrence. Abundant in Kirtland shale florule. Uppermost Cretaceous.

Type *locality.* See page 5, Kirtland shale florule.

Collection numbers. AK 14-1 (holotype), 2 to 7.

Family BOMBACACEAE

Genus **BOMBACACIPITES** n. gen.

Diagnosis. Oblate, tricolpate-tricolporate pollen with short, wide furrows and interlobate to intersemiangular outline in polar view; furrows bordered by a margo and usually not reaching more than half-way to the pole; sculpturing usually reticulate, particularly in the polar area, but sometimes granular, warty, spinose, or otherwise.

Discussion. This genus is proposed to receive pollen of the type found in the family Bombacaceae whose generic status cannot be determined more closely.

Occurrence. Early Tertiary of North and South America.

Type species (here designated). *Bombacacipites nacimientoensis* n. sp.

Bombacacipites nacimientoensis n. sp.

Pl. 8, fig. 13

Description. Oblate, tricolpate pollen with short, wide furrows bordered by a wide margo; furrows reaching about one-half the distance to the pole; shape intersemiangular in polar view, the furrows slightly protruding; sculpture reticulate, with narrow, and probably clavate, muri in the polar region; reticulum transitional into clavate sculpturing at the periphery.

Dimensions. Diameter 35-39 microns; margos 2 microns wide; exine as much as 1.5 microns thick; lumina in polar area 2 microns wide.

Discussion. Similar unnamed pollen has been illustrated from the lower Tertiary of Colombia by Kuyl et al. (1955, p. 64, fig. I I).

Occurrence. Uncommon in Nacimiento 2 florule. Lower Paleocene.

Type locality. See page 8, Nacimiento 2 florule.

*Collection number. AN2 1*1-1 (holotype).

Family NYSSACEAE

Genus **NYSSA** Linné

Nyssa puercoensis n. sp.

P1.7, fig. 12

Description. Tricolporate, oblate pollen with long furrows (about three-fourths radius); triangular to subtriangular outline in polar view; longitudinal furrows are narrow near the poles but expand and thicken rapidly near the equator, where a germ pore is present; grains thinner in the area immediately behind the margo than elsewhere; exine differentiated with a tectate-columellate structure and scabrate sculpture.

Dimensions. Diameter 23-26 microns; furrows as much as 3.5 microns wide at the equator; exine and margo as much as 1.5 micron thick.

Discussion. Similar to *Nyssapollenites accessorius* (Potonié) described by Gerhard (1958, p. III) but lacks the striate sculpturing. Consistently smaller than *Pollenites kruschi accessorius* Potonié, 1934.

Occurrence. Uncommon in Nacimiento I florule. Lowermost Paleocene.

Type locality. See page 8, Nacimiento 1 florule.

Collection number. AN1 10-1 (holotype).

Family MYRTACEAE

Genus **MYRTACEIDITES** Cookson and Pike, 1954

Myrtaceidites? sp.

Pl. 10, fig. 7

Description. Small, oblate, tricolporate pollen with slightly protruding and thickened pores; sides sharply convex in polar view; vestibular structure not visible; poorly developed arci extend from the pores to the poles, where they become obscured; sculpture granular.

Dimensions. Diameter 7 microns; pore canal as much as 2 microns long; exine about 0.5 micron thick except neat pores.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 22-I.

Family OLEACEAE

Genus TRICOLPITES *(Co*okson)

Couper, 1953

ouper, 1953

Tricolpites sp. A

Pl. 2, fig. 14

Description. Oblate (spheroidal?), tricolpate pollen with a circular outline in polar view; porelike furrow with ragged, poorly defined margins; finely but distinctly reticulate sculpture; circular lumina.

Dimensions. Diameter 22 microns; exine about I micron thick.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 15-I.

DICOTYLEDONES incertaesedis

Genus **BREVICOLPORITES** n. gen.

Diagnosis. Oblate, equatorially tricolporate pollen with endopore and exopore of nearly the same size but not congruent; exopore lolongate, endopore circular to transversely elongate or merely a thinning of the endexine; exopore not more than three times the diameter of the endopore; outline circular to triangular in polar view.

Discussion. Differs from *Triporopollenites* Pflug and Thompson, 1953 in its incongruent pore structure. Differs from *Trudopollis* Pflug, 1953 in that the interloculum is absent or not discernible, and it is the exopore which is lolongate. Larger than *Minorpollis* Krutzsch, 1959.

Occurrence. Paleocene of North America.

Type species (here designated). *Brevicolporites colpella* n. sp.

Brevicolporites colpella n. sp.

Pl. 6, fig. I I, 12, 13, 14

Description. Small, oblate, tricolporate pollen with short furrows; outline circular in polar view; germinal structures equatorial, and some grains tetraporate; furrows less than one-third the radius, gradually thickened but without a distinct margo; furrows blunt at the end but sometimes irregular and tattered; endopore about one-third the furrow diameter; exine differentiation visible only in the germinal structures; faint, broad arci connect the pores in many grains; scabrate sculpture.

Dimensions. Diameter constant, 7-21 microns; pore diameter about 2-3 microns; exine as much as 1.5 microns thick at furrow edge.

Discussion. The germinal structure of these grains appears symplocaceous, but the circular outline and noncolumellate exine suggest some other relationship. The grains commonly occur in clusters, indicating that the species was growing near the site of deposition.

Occurrence. Common in Ojo Alamo 2 florule. Lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 13-I (holotype), 2 to 5.

Genus **EXTRATRIPOROPOLLENITES** Pflug, 1953

Extratriporopollenites fossulotrudens Pflug, 1953

Pl. 11, fig. 4

Description. Small, oblate, triporate pollen with a triangular outline in polar view and straight to slightly convex sides; pores somewhat protruding, thickened with an annulus, and with a long pore canal; exine differentiated, but no vestibular structure observed; exine with a few fossulae, but the surface generally coarsely granular-verrucate.

Dimensions. Diameter 19 microns; pore canal 4-5 microns long; exine 2 microns thick between pores.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 24-1.

Extratriporopollenites sp.

Pl. 2, fig. 18

Description. Triporate or tricolporate pollen with long protruding pores and furrow extensions (arci) that fuse in the polar area but do not form an island; pores very narrow, and pore canals very long; exine differentiated; body sculpture rugulate-reticulate.

Dimensions. Entire diameter 2o microns; pore to pole distance 12 microns; exine about I micron thick.

Discussion. The extended furrow thickenings and the sculpturing suggest sapindaceous affinity, but the grain is atypical of that family.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 17-1.

Genus **KURTZIPITES** n. gen.

Diagnosis. Oblate, triporate pollen with hexagonal, subcircular, or subtriangular outline in polar view; pores equatorial, lolongate, and with a triangular or crescent-shaped opaque thickening on polar sides pointing toward the poles.

Discussion. The distinctive triangular thickenings of this unusual grain set it apart from other triporate pollen. Named for Edwin B. Kurtz, Jr., of the University of Arizona.

Occurrence. Cretaceous and early Tertiary of North America.

Type species (here designated). *Kurtzipites trispissatus* n. sp.

Kurtzipites trispissatus n. sp.

Pl. 2, fig. 15, 16, 7

Description. Oblate, triporate pollen; sides sharply convex at the midpoint between the pores, forming a hexagonal outline in polar view; pores lolongate and slitlike, with an unusual triangular thickening at their polar ends; the triangularly thickened patch shows no evidence of a furrow and points toward the poles; pores only slightly thickened away from the opaque patch; margins of the thickened triangle sometimes rounded, except at the polar apex, producing a somewhat crescentic outline; thickening and incipient pore structure sometimes present at the midpoint between pores at the equator; sculpturing indistinct, faintly reticulate or infragranulate.

Dimensions. Diameter constant, 20-22 microns; triangular thickenings about 3 microns in diameter; exine less than micron thick.

Discussion. This species is very similar to the unpublished *Triporopollenites falcatus* Gerhard (1958, p. 99- oo) from the Paleocene of South Dakota but differs in its much smaller size, less crescentic thickenings, and more hexagonal outline.

Occurrence. Common in Kirtland shale florule. Uppermost Cretaceous.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 16-1 (holotype), 2, 3.

Genus **MOMIPITES** Wodehouse, 1933

Momipites inaequalis n. sp. Pl. 6,

fig. *7,* 8, 9, I o; pl. 7, fig. 13

Description. Oblate, triporate pollen grains with lolongate equatorial pores; pores not, or only slightly, protruding and only slightly thickened; outline in polar view triangular or, more often, unequally triangular; sides only slightly convex; exine faintly scabrate.

Dimensions. Diameter 16-24 microns; pore diameter about 2 microns; exine as much as I micron thick around pores.

Discussion. These grains are more triangular and elongate than M. *coryloides* Wodehouse (1933) and *Pollenites coryphaeus* Potonié (1931) and most closely resemble *Engelhardtia.* They are most distinctive in their elongate-triangular shape.

Occurrence. Common in Ojo Alamo 2 florule; uncommon in Nacimiento 1 florule. Lowermost Paleocene.

Type *locality.* See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 I2-I, 2 (holotype), 3 to 5; AN1

Momipites sanjuanensis n. sp.

P1. II, fig. 1, 2, 3

Description. Small, thin-walled, oblate, triporate pollen; triangular outline in polar view, with straight, convex, or slightly concave sides; pores of moderate size and thickened with an annulus; poorly defined thickened arci often connect pores or the grains folded in the same region; pores slightly lolongate; sculpture distinctly scabrate (irregular).

Dimensions. Diameter 13-7 microns; pore diameter microns.

Discussion. Differs from *Momipites coryloides* Wodehouse, 1933 and other species of the *Corylus* and *Engelhardtia* type in its smaller size and the presence of arci.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection numbers. AL 23-1 (holotype), 2, 3.

Momipites tenuipolus n. sp.

Pl. 7, fig. 14; pl. 8, fig. 14,15

Description. Very small, oblate, triporate pollen with small lolongate pores; triangular to subtriangular outline in polar view, with straight or slightly convex sides and broadly rounded corners; pores thickened gradually and not protruding; most grains possess a distinctive thin patch of exine in the polar area, and in some grains the thin area is thickened again at the pole to form a poorly defined "island"; sculpture scabrate to infragranulate.

Dimensions. Diameter 14-20 microns; exine as much as 1.5 microns thick at pore margins; pore diameter as much as 1.5 microns.

Discussion. Gerhard (1958, pl. 4, fig. 29) referred an identical form to *Momipites coryphaeus* (Potonié, 1931). The species, however, is generally smaller than *Pollenites coryphaeus* Potonié, 1931 and differs in the presence of a thin polar area, which is apparently a constant and significant feature.

Occurrence. Uncommon in Nacimiento 1 florule; common in Nacimiento 2 florule. Lowermost to lower Paleocene.

Type *locality.* See page 8, Nacimiento r florule.

Collection numbers. ANI I2-I (holotype), 2; AN2 12-I, 2.

Genus **PERIPOROPOLLENITES** Pflug and Thompson, 1953

Periporopollenites sp.

P1. 2, fig. 21

Description. Large subspherical grain with folding accommodated along the periphery, forming a hexagonal outline; pores small, circular, nonaspidate, and spaced more or less uniformly, perhaps on one side of the grain only; faintly scabrate sculpture.

Dimensions. Diameter about 5o microns; pore diameter 1.5-2 microns; exine 1 micron thick; pores spaced about 18-20 microns apart.

Discussion. Resembles forms in the Juglandaceae but is not aspidate.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 20-I.

Genus **TETRADITES** Van der Hammen, 1954

Tetradites sp.

Pl. 7, fig. 16

Description. Triporate(?) pollen grains loosely united in an open obligate tetrad; grains thin walled and folded; psilate to very finely scabrate sculpture.

Dimensions. Diameter of individual grains 14-7 microns; total diameter about 28 microns; exine less than 1 micron thick.

Occurrence. Rare in Nacimiento florule. Lowermost Paleocene.

Collection number. AN1 14-1.

Genus **TRICOLPITES** (Cookson) Couper,

1953 *Tricolpites anguloluminosus* n. sp. Pl.

6, fig. 15, 16, 7; pl. 8, fig. 7,18

Description. Spherical, tricolpate pollen with gaping furrows in polar view reaching one-half to two-thirds the distance to the pole; furrows closed, with parallel sides when flattened equatorially; sculpturing openly reticulate, with wide lumina and narrow, delicate muri; lumina angular and typically five-sided, and do not open into furrow; furrow bordered by muri, which form a margo; lumina sometimes increasing in size near the furrow.

Dimensions. Diameter 2o-33 microns; exine less than micron thick; lumina about 2 microns in diameter; muri about 0.5 micron wide and more than 1 micron high.

Discussion. Most closely related to *Pollenites willrathae* Potonié, 1934 but significantly smaller.

Occurrence. Common in Ojo Alamo 2 florule; common in Nacimiento 2 florule. Lowermost to lower Paleocene. *Type locality.* See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 14-1 (holotype), 2, 3; AN2 14-1, 2,3.

Tricolpites sp. B

Pl. 6, fig. 18

Description. Thin-walled, tricolpate pollen with simple furrows extending far into the polar area; furrows somewhat gaping when flattened, but the grains have a circular outline in polar view; sculpturing striate in the polar area, with the vallae predominantly meridional; sculpturing becoming reticulate in the equatorial area.

Dimensions. Diameter 25 microns; exine less than 1 micron thick; vallae about 3 microns long and less than 0.5 micron wide in the polar area.

Discussion. Sculpture resembles that of *Acer,* but the grain is too thin walled, too small, and not so prolate as that genus.

Occurrence. Rare in Ojo Alamo 2 florule. Lowermost Paleocene.

Collection number. A02 15-1 .

Tricolpites sp. C

Pl. 11, fig. *5*

Description. Tricolpate, prolate pollen with an ovoid-rhomboidal outline in equatorial view; furrows long and with a trace of colporoid structure; finely scabrate sculpture.

Dimensions. Length 22 microns; width 15 microns; furrow length 16 microns; exine 1.5 microns thick.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 25-I.

Genus **TRICOLPORITES** Erdtman, 1947

Tricolporites rhomboides n. sp.

Pl. 7, fig. I 5; pl. 8, fig. 19

Description. Very small, prolate, tricolporate pollen with a rhomboidal outline in equatorial view; outline triangular, with depressed furrows in polar view; furrows long and having margos; pores not obvious, but the costae under the longitudinal furrows cut by a short transverse furrow (pore); the tricolporate structure also indicated by the bow-shaped furrows and rhomboidal outline; exine columellate; sculpture scabrate.

Dimensions. Length (polar axis) 15 microns; width (equatorial view) 12-14 microns; exine 1.5 microns thick.

Discussion. Most closely related to *Pollenites cingulum* Potonié, 1931 but consistently smaller.

Occurrence. Common in Nacimiento I florule; uncommon in Nacimiento 2 florule. Lowermost to lower Paleocene.

Type locality. See page 8, Nacimiento florule.

Collection numbers. ANI 13-1 (holotype), 2; AN2 15-1.

Tricolporites trdversei n. sp.

Pl. 2, fig. 20

Description. Very small, prolate to slightly rhomboidal pollen with long furrows and moderately thick exine in proportion to the size of the grain; pore not distinctly visible but manifested in a bow-shaped furrow; furrows with a narrow margo; psilate sculpture.

Dimensions. Length 11-12 microns; width (equatorial view) 7-8 microns; furrow length 9 microns; exine about micron thick.

Discussion. These specimens closely resemble an unnamed form figured by Traverse (1955, p. 75) but are slightly smaller. They are significantly smaller than *Pollenites fuses* Potonié, 1931 or *Pollenites quisqualis pusillus* Potonié, 1934. Named for Alfred Traverse, of the Shell Development Co., Houston, Texas.

Occurrence. Common in Kirtland shale florule. Uppermost Cretaceous.

Type locality. See page 5, Kirtland shale florule.

Collection numbers. AK 19- (holotype), 2, 3.

Tricolporites sp.

Pl. I I, fig. 6

Description. Small, prolate, tricolporate pollen with long furrows; pores poorly defined, but furrows bow shaped, suggesting a transverse pore with faint costae; sculpture scabrate.

Dimensions. Length 7 microns; width 11 microns; furrow length 12 microns; exine less than I micron thick.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.
Collection number. AL 26-1.

Genus **TRIPOROPOLLENITES** Pflug and Thompson, 1953 *Triporopollenites plektosus* n. sp. Pl. 4, fig. 14; pl. 8, fig. 16

Description. Thin-walled, spherical or subspherical, randomly folded pollen grains; pores circular, with a slight annulus, and probably equatorially situated, but folding independent of the pore structure; sculpturing finely scabrate.
Dimensions. Diameter 2o-25 microns; pore diameter about 2 microns; exine about o.5 micron thick.
Discussion. No closely related species could be found in the literature, and the species is proposed to comprise randomly folded triporate pollen with an annulus.
Occurrence. Uncommon in Ojo Alamo 1 florule; rare in Nacimiento 2 florule. Uppermost Cretaceous (?) to lower Paleocene.
Type locality. See page 5, Ojo Alamo I florule.
Collection numbers. AO1 10-1 (holotype), 2; AN2 13-1.

SPERMATOPHYTA incertaesedis

Genus **CONFERTISULCITES** n. gen.

Diagnosis. Elongate, bilateral, monosulcate pollen with a closed furrow in contact throughout length or broadly overlapping or easily capable of overlapping; furrow extending to the ends of the grain; sculpture usually psilate to faintly scabrate or flecked.
Discussion. Forms of this type, here removed from the more broadly defined genus *Monosulcites* (Cookson) Couper, 1953, differ from other nonreticulate monosulcate form genera in their closed or overlapping furrow (see page 12).
Occurrence. Mesozoic and Cenozoic, worldwide.
Type *species* (here designated). *Confertisulcites knowltoni* n. sp.

Confertisulcites knowltoni n. sp.

Pl. 3, fig. 3, 4; pl. 4, fig. 19

Description. Thin-walled, elongate, bilateral, monosulcate pollen with rounded ends; furrow simple, or with a narrow margo, and reaching the ends of the grain; furrow usually in contact or overlapping; surface psilate or with irregularly distributed flecks.
Dimensions. Length 4o-53 microns; width 22-27 microns; exine about o.5 micron thick.
Discussion. Differs from *Monocolpopollenites tranquillus* (R. Pot.) Pflug and Thompson, 1953 in its thinner wall. The rounded ends and flecked surface suggest palmaceous affinity. Named after Frank Hall Knowlton, paleobotanist, for his early Cretaceous-Tertiary studies in the area.
Occurrence. Common in Kirtland shale florule; rare in Ojo Alamo 1 florule. Uppermost Cretaceous to (?) lowermost Paleocene.
Type locality. See page 5, Kirtland shale florule.
Collection numbers. AK 23-I (holotype), 2; AO1 12-1, 2.

Confertisulcites sp.

Pl. 4, fig. 20

Description. Very large, thin-walled, elongate, subcylindrical cell with rounded ends; furrow simple, overlapping, and extending to the ends of the grain; sculpturing psilate.
Dimensions. Length 112 microns; width 5o microns.
Occurrence. Rare in Ojo Alamo 1 florule. Uppermost Cretaceous or lowermost Paleocene.
Collection number. AO1 13-1.

Genus **MONOSULCITES** (Cookson) Couper, 1953

Monosulcites perspinosus Couper, 1953

Pl. 3, fig.

Description. Small, elongate, bilateral, monosulcate pollen with large spines; spines low-conical at the base and taper to a sharp, curved tip; germinal structure obscure owing to deep staining.
Dimensions. Length (overall) 31 microns; width (overall) 20 microns; spines as much as 4 microns long.
Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.
Collection number. AK 2 I - I .

Monosulcites sp.

Pl. 3, fig. 2

Description. Small, elongate, bilateral, monosulcate pollen with a thick, wide margo; ends of grain somewhat pointed; furrow not quite reaching the margin and not noticeably expanded at the ends; psilate sculpture.
Dimensions. Length 2o microns; width 11 microns; margo about 2.5 microns wide.
Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.
Collection number. AK 22-I .

Genus **NAVISULCITES** *n.* gen.

Diagnosis. Elongate, bilateral, monosulcate pollen with a boat-shaped or fusiform furrow, widest at the midpoint and gradually tapering to the ends; furrow with or without a margo and may or may not reach the ends of the grain; sculpture variable, usually psilate.
Discussion. Forms of this description, here removed from *Monosulcites* (Cookson) Couper, 1953, differ from other monosulcate form genera in their boat-shaped furrow (see page 2).
Occurrence. Tertiary of Europe, North America, and Asia. *Type species* (here designated). *Navisulcites marginatus* n. sp.

Navisulcites marginatus n. sp.

Pl. 3, fig. *5*

Description. Elongate, bilateral, monosulcate, fusiform grains with somewhat pointed ends; furrow boat shaped or narrowly fusiform, widest at the midpoint and tapering toward the ends; furrow bordered by distinct, wide margos, which also taper to the ends of the grain; exine moderately thick; psilate sculpture.

Dimensions. Length 45 microns; width 3o microns; width of furrow (midpoint) 5 microns; width of margo (midpoint) 2.5 microns; exine about 1.5 microns thick.

Discussion. Most closely related to *Monocolpopollenites ingens* Pflug, 1953, but the margo is wider and tapers more uniformly to the end of the furrow, and the ends of the grain are more pointed.

Occurrence. Uncommon in Kirtland shale florule. Uppermost Cretaceous.

Type locality. See page 5, Kirtland shale florule.

Collection number. AK 24-I (holotype).

Genus **RECTOSULCITES** n. gen.

Diagnosis. Elongate to subspherical, bilateral, monosulcate pollen with a broad, straight, parallel-sided furrow with rounded ends; furrow ends may be broadly rounded and slightly expanded, producing a "keyhole" effect; furrow sides not in contact unless folded or twisted; furrow may reach ends of grain; sculpture various, usually psilate.

Discussion. Forms of this type, here removed from the more broadly defined *Entylissa* (Naumova) Potonié and Kremp, 1954, differ in that the sides of the furrow are straight and parallel, and not medially constricted and gradually expanded at the ends (see page 12).

Occurrence. Tertiary of North America.

Type species (here designated). *Rectosulcites lotus* n. sp.

Rectosulcites latus n. sp.

Pl. 6, fig. 19, 20, 21

Description. Thin-walled, bilateral, monosulcate pollen with broadly rounded ends and broad, parallel-sided furrows; furrows have ends usually not reaching the margins of the grains; extreme end of the furrow often of a greater diameter than the width of the furrow, giving a "keyhole" effect; furrow margins simple and sometimes poorly defined at the ends; grains usually elongate and at least one-third greater in length than in breadth, but some immature grains are nearly circular in outline; size variable; sculpturing psilate to very faintly scabrate.

Dimensions. Length 18-43 microns; breadth 16-26 microns; exine about 0.5 micron thick; furrow as much as 4 microns wide.

Occurrence. Very abundant in Ojo Alamo 2 florule. Lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 2 florule.

Collection numbers. A02 16-1 (holotype), 2 to 6.

PLANTAE incertae sedis

Genus **INAPERTUROPOLLENITES** Pflug and Thompson, 1953

Inaperturopollenites limbatus Balme, 1957 Pl. I I,

fig. 14, 15

Description. Large, subspherical, inaperturate body with thin central area, thickening toward the periphery; exine often ruptured in the thin central region; sculpture granular, with a trace of lineation of elements.

Dimensions. Diameter 50-58 microns; exine ranging from less than 1 micron thick in center to 2 microns thick at periphery.

Discussion. These specimens are slightly smaller than those of Balme (1957) but agree in other particulars.

Occurrence. Common in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 32-1, 2.

Genus **PEROMONOLITES** Couper, 1953

Peromonolites cf. *P. problematicus* Couper, 1953

Pl. II, fig. II

Description. Thick, subspherical body with a thin central area that probably functions as an aperture; periphery greatly thickened and composed of fused setae, which form a coarsely sculptured surface.

Dimensions. Diameter 4o microns; thin central area about 14 microns in diameter; wall about 3 microns thick at the periphery.

Discussion. This form is smaller and exhibits greater fusion of setae than *P. problematicus* Couper.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 3

Peromonolites sp. A

P1. 11, fig. 12

Description. Circular (outline) spore with a setaceous perispore; no apertural thinning or laesurae present; wall thickness indeterminable; setae not fused and somewhat thickened in the middle.

Dimensions. Diameter 47 microns; setae as much as 3 microns long.

Discussion. This unusual grain might possibly be *T suga* but is quite small for that genus.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 31-1.

Peromonolites sp. B

Pl. II, fig. 13

Description. Subspherical spore with a perispore; laesurae not visible; perispore baculate to irregularly reticulate.

Dimensions. Entire diameter 36 microns; endospore 1 micron thick; perispore 3 microns thick; lumen 4-6 microns wide.

Occurrence. Uncommon in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 31-2.

Genus **PEROTRILITES** Couper, 1953

Perotrilites cubensis n. sp. Pl. 3,

fig. 7, 8

Description. Large spores with a thickened periphery, thin polar areas, and wide, gaping laesurae on both sides of the body; laesurae variable, with a margo, but often with an irregular shape; margo may not border the laesura directly but appears to represent the outer thickened edge of a very thin polar membrane that is easily ruptured; equatorial area unevenly thickened by fused setae whose tips project above the surface over the entire body except in the thin polar area; fused setae give rise to an echinate-scabrate sculpture with regularly spaced elements.

Dimensions. Diameter 55-65 microns; wall as much as 5 microns thick at the equator; margo about 1.5 microns wide.

Discussion. This form fits Couper's (1953, p. 31) description of the genus *Perotrilites* if the thick setaceous wall is interpreted as a perispore, as in his genus *Peromonolites.* This species is not closely related to *P. granulates* Couper, 1953 or P. *pseudoreticulatus* Couper, 1953.

Occurrence. Common in Kirtland shale florule. Uppermost Cretaceous.

Type locality. See page *5,* Kirtland shale florule.

Collection numbers. AK 26-I (holotype), 2, 3.

Genus **TRILITES** (Cookson) Couper,

1953 *Trilites?* sp. A Pl.

3, fig. 6

Description. Triangular trilete spore with straight sides and rounded corners in polar view; spore has a thin triangular polar area on the proximal side and perhaps on the distal side; laesurae short, slightly overlapping, and only present in the thin polar area; a pore present at one of the corners, and incipient pore structure present at the other two; sculpture on the border irregularly and finely scabrate; sculpture striate in the thin polar area.

Dimensions. Diameter 36 microns; width of border 10 microns; wall about 1.5 microns thick.

Discussion. This unusual spore, with its porelike structures, is difficult to classify. If the pores were well defined at all three corners, it would take the name of the more advanced triporate type.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 25-I.

Trilites? sp. B

Pl. 11, fig. 10

Description. Subtriangular body with broadly rounded corners and straight to slightly concave sides; body is bordered by a thick beaded rib and possesses an inner body bordered by a similar rib; laesurae not observed, but a slight difference in thickness in one-third of the inner body terminates at the ray position; scabrate-echinate sculpture.

Dimensions. Diameter of inner body 23 microns; entire diameter 34 microns; ribs as much as 2.5 microns thick; wall between the ribs about 0.5 micron thick.

Occurrence. Rare in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 29-I.

Genus **POLLENITES** R. Potonié, 1931

Pollenites? sp.

Pl. 3, fig. 10

Description. Subspherical grain with a very unusual furrow pattern; in polar view the grain has three narrow, slitlike, arcuate, transverse, nonequatorial furrows; furrows bordered on the polar side by thick ribs that join and become attached to the main body of the grain at their junctions, resulting in a large, triangular, polar "island," which remains attached to the body at three points; sculpturing in the polar "island" scabrate; sculpturing on the body striate-costate, with the striae parallel to the slitlike furrows; similar furrows may be present on the other side of the grain.

Dimensions. Diameter 20 microns; diameter of "island" about 15 microns; wall as much as 1.5 microns thick; ribs bordering the furrow about 1 micron wide.

Discussion. The unusual furrow pattern may have been modified from a nonacolpate grain (see Wodehouse, 1935, fig. 29).

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 28-I.

Genus **SPORITES** H. Potonie, 1893

Sporites neglectus n. sp.

Pl. 4, fig. 2 I , 22

Description. Ellipsoidal to spherical, thick-walled, dark, sporelike cells; surface smooth but often marked by small circular porelike holes, large subcircular pits, or granular patches, all irregularly spaced; wall thickness sometimes difficult to determine; margins of the cell sometimes irregular.

Dimensions. Diameter 20-50 microns; wall as much as 4 microns thick.

Discussion. These dark bodies are frequent in many coals and carbonaceous shales, but their systematic position is unknown. The species is proposed for convenience in referring to these generalized structures, which otherwise might not be considered part of the pollen or spore flora.

Occurrence. Common in Ojo Alamo 1 florule. Uppermost Cretaceous or lowermost Paleocene.

Type locality. See page 5, Ojo Alamo 1 florule.

Collection numbers. AO, 14-I, 2 (holotype), 3, 4.

Sporites? sp. A

Pl. 3, fig. 9

Description. Large, fusiform, thin-walled cell with no apertural structure; psilate.

Dimensions. Length 73 microns; width 37 microns.

Occurrence. Rare in Kirtland shale florule. Uppermost Cretaceous.

Collection number. AK 27-1.

Sporites? sp. B

Pl. 11, fig. 9

Description. Subspherical body possessing very large spines of variable size and shape; wall moderately thick; no apertural structure visible.

Dimensions. Overall diameter 28 microns; body diameter 20 microns; spines 3-6 microns long.

Occurrence. Uncommon in Lewis shale florule. Uppermost Cretaceous.

Collection number. AL 28-I .

Kingdom **ANIMALIA**

Class **DINOFLAGELLATA**

Order **DINIFERIDEA**

Family GYMNODINIDAE

Genus **SCRINODINIUM** Klement, 1957

Scrinodinium cooksonae n. sp.

Pl. 9, fig. I, 2, 3

Description. Cell roughly fusiform or kite shaped and constructed of two membranes; inner membrane deeper staining, smooth to somewhat granular, and with a broadly rounded apex and longer antapex; outer membrane almost colorless and tapers to an acute point at each end; the tip of the hypotheca divided in some specimens, and the change from an inner to an outer membrane appears transitional in some specimens; transverse girdle moderately well defined but may be indistinct; when well formed, the girdle consists of two narrow thickenings about 6 microns apart, which project beyond the margins of the cell.

Dimensions. Overall length 75-80 microns; width 43-48 microns; length of inner membrane about 54 microns.

Discussion. Most closely resembles *Gymnodinium pontismariae* Deflandre, 1936 but is significantly and consistently larger, the antapex of the inner membrane is more drawn out, and the inner cell is less set off and less spherical than the illustrations of Deflandre. Named for Isabel C. Cookson, of the University of Melbourne.

Occurrence. Common in Lewis shale florule sample. Uppermost Cretaceous.

Type locality. See page 8, Lewis shale florule.

Collection numbers. AL 1-1 (holotype), 2, 3.

Family P ERIDINIDAE

Genus **PALAEOPERIDINIUM** Deflandre, 1934

Palaeoperidinium ventriosum (0. Wetzel) Deflandre, 1935

Pl. 9, fig. 4

Description. Cell globular, with a sharply truncate and often tattered antapex; the cell forms a small protruding apical horn, which usually has a small opening; transverse girdle distinct.

Dimensions. Length 53-64 microns; width 41-42 microns; transverse girdle about 5 microns wide.

Occurrence. Common in Lewis shale florule sample. Uppermost Cretaceous.

Collection numbers. AL 2-I, 2, 3.

MICROFOSSILS incertae sedis Genus

PTEROSPERMOPSIS W. Wetzel, 1952

Pterospermopsis sp.

P[1].9, fig. 5

Description. A deeper staining, subspherical, somewhat granular central body enclosed in a delicate colorless membrane that forms a wide circular border on compression.

Dimensions. Central body about 35 microns in diameter; border about 15 microns wide; overall diameter 65 microns.

Discussion. Very small for the genus.

Occurrence. Rare in Lewis shale florule sample. Uppermost Cretaceous.

Collection number. AL 3-1.

Order **HYSTRICHOSPHAERIDEA**

Family HYSTRICHOSPHAERIDAE

Genus **HYSTRICHOSPHAERA (0.** Wetzel) Deflandre, 1937

Hystrichosphaera cf. *H. furcata* (Ehrenburg) 0. Wetzel, 1933

Pl. 9, fig. 6

Description. Shell small and spherical, and ornamented with radiating simple and bifurcating processes at the junction of the sutures; membrane smooth or very finely granular.

Dimensions. Diameter of shell 38 microns; spines 3-4 microns long; polygons of the suture network about 5 microns in diameter; total diameter 44 microns.

Occurrence. Rare in Lewis shale florule sample. Uppermost Cretaceous.

Collection number. AL 4-I.

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Numbers in boldface indicate main references.

PLATES 1-11

CRETACEOUS-TERTIARY POLLEN, SPORES,
DINOFLAGELLATES, AND
MICROFOSSILS INCERTAE SEDIS

PLATE 1

KIRTLAND SHALE FLORULE

Figure Page

1. *Sphagnum* sp. 14
AK 1-1. Diameter, 15 microns.

2. *Lycopodium novomexicanum* n. sp. 14-15
AK 2-1 (holotype). Diameter, 59 microns.

3-7. *Polypodiidites spp.* 14
3. AK 3-1. Size, 19 X 26 microns.
4. AK 3-2. Size, 16 X 23 microns.
5. AK 3-3. Size, 29 X 45 microns.
6. AK 3-4. Size, 26 X 42 microns.
7. AK 3-5. Size, 20 X 20 microns.

8. *Foveotriletes scrobicularis* (Ross) R. Potonié, 1956 15
AK 4-I. Diameter, 3o microns.

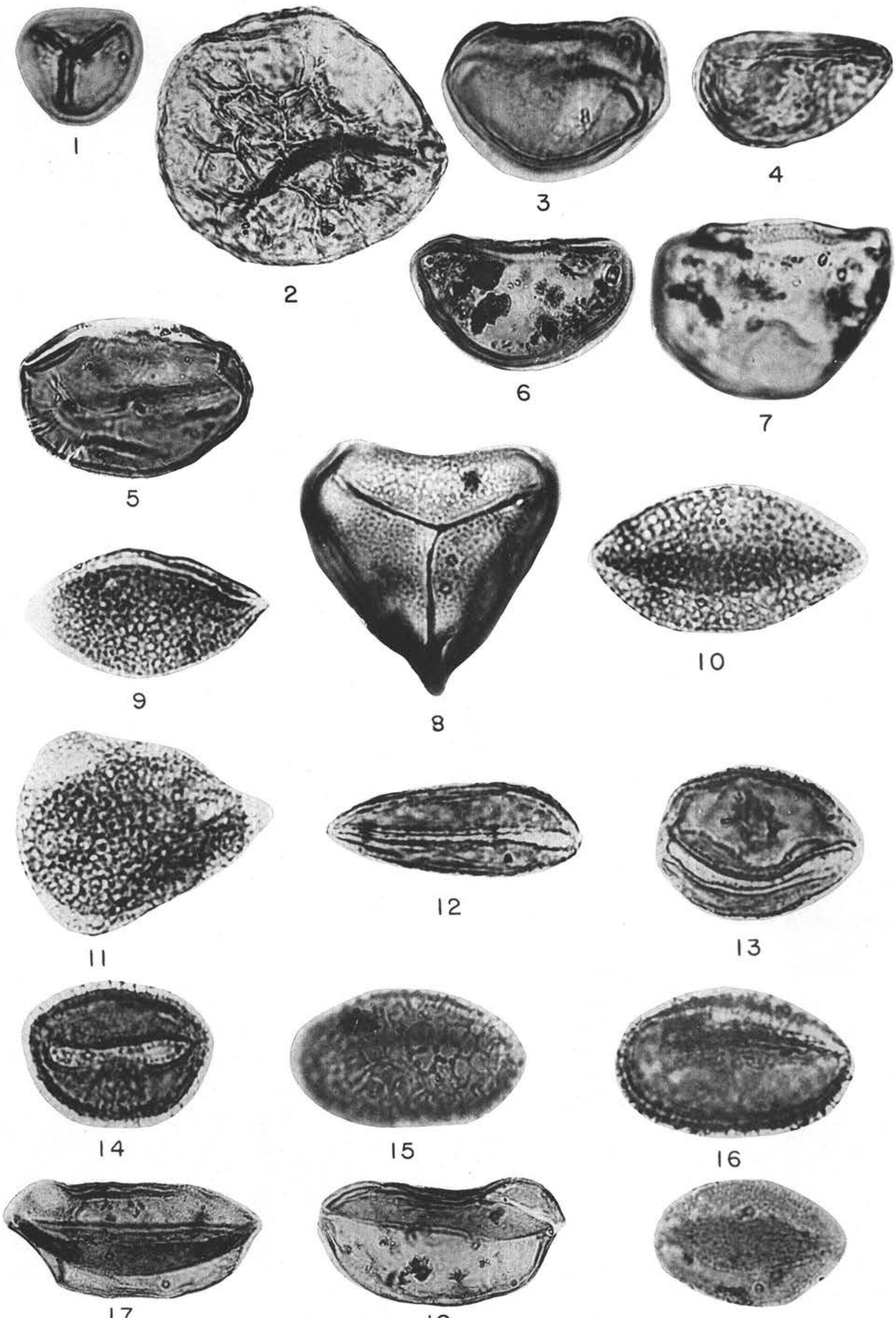
9-11. *Liliacidites leei* n. sp. 18-19
9. AK 5-1. Size, 16 X 29 microns. 1o. AK
5-2 (holotype). Size, 19 X 35 microns. I. AK
5-3. Size, 26 X 32 microns.

12-14. *Liliacidites hyalaciniatus* n. sp. 18
12. AK 6-1. Size, 14 X 33 microns.
13. AK 6-2. Size, 20 X 27 microns.
14. AK 6-3 (holotype). Size, 19 X 25 microns.

15-16. *Liliacidites* sp. 19
AK 7-1. Size, 20 X 32. microns.

17-18. *Arecipites microreticulatus* n. sp. 18
17. AK 8-1 (holotype). Size, 22 X 49 microns.
18. AK 8-2. Size, 25 X 48 microns.

19. *Arecipites reticulates* (Van der Hammen, 1954) 18
AK 9-1. Size, 17 X 23 microns.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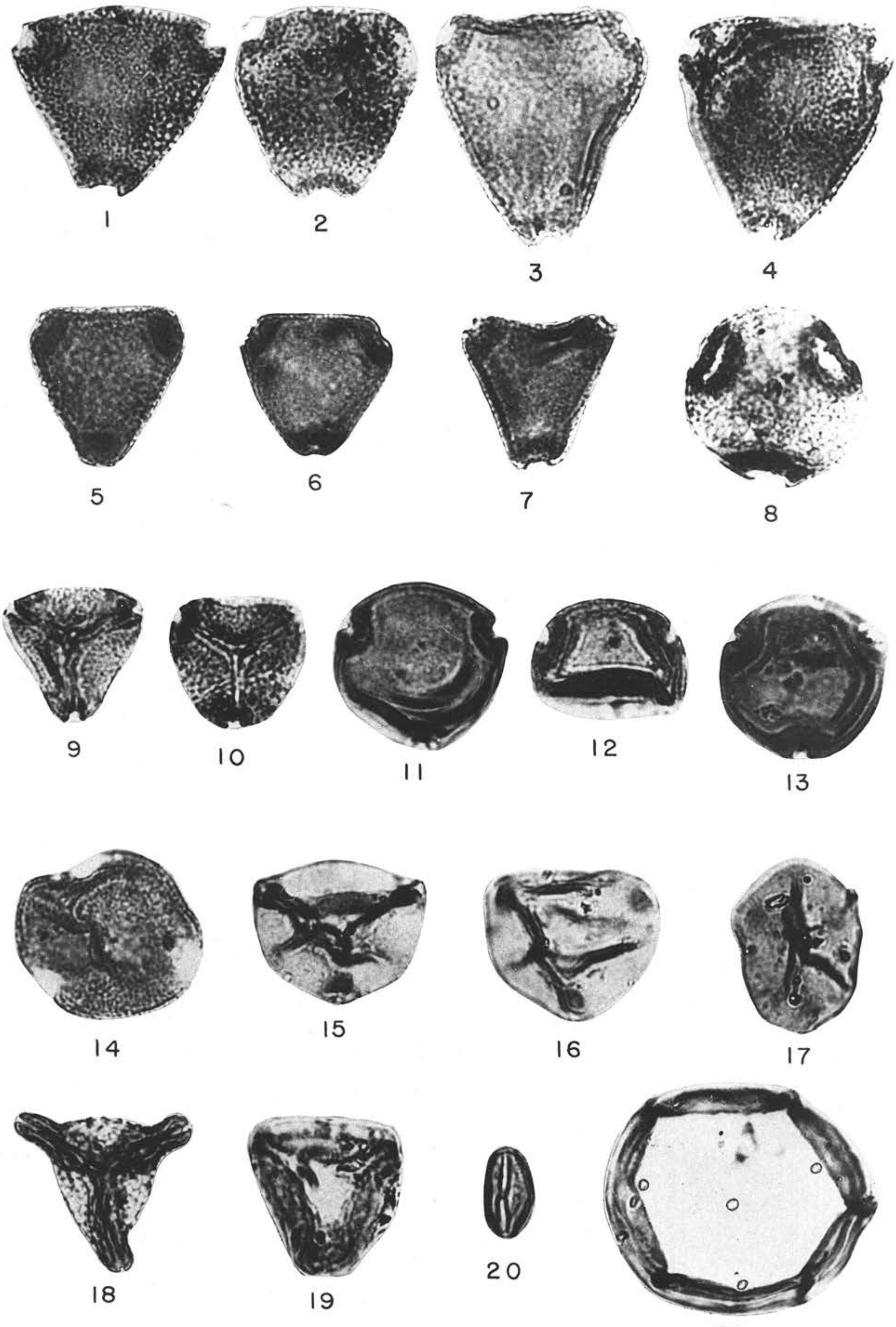
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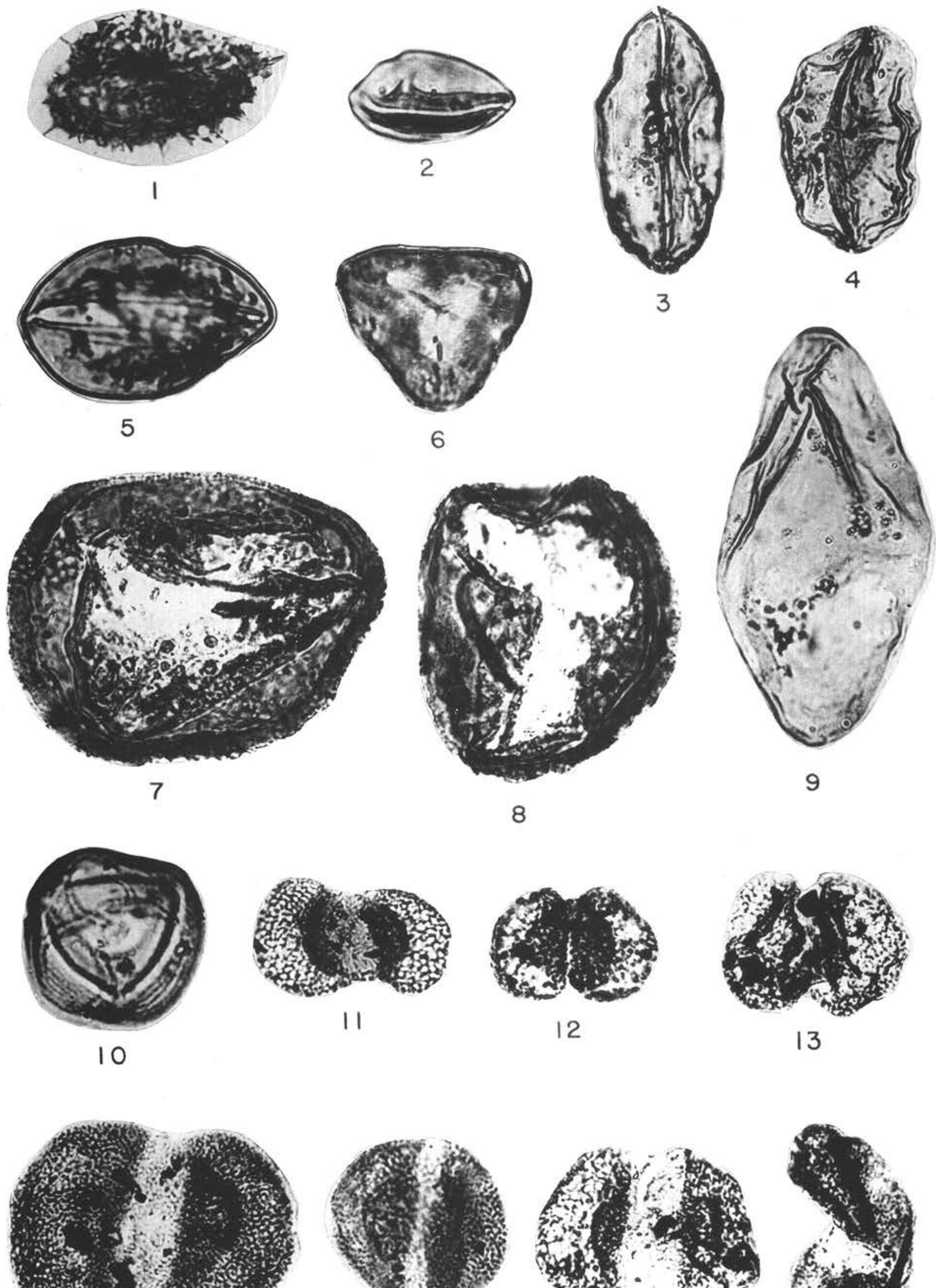
PLATE 2

KIRTLAND *SHALE* FLORULE

PLATE 3

KIRTLAND SHALE FLORULE

0 JO *ALAMO 1* FLORULE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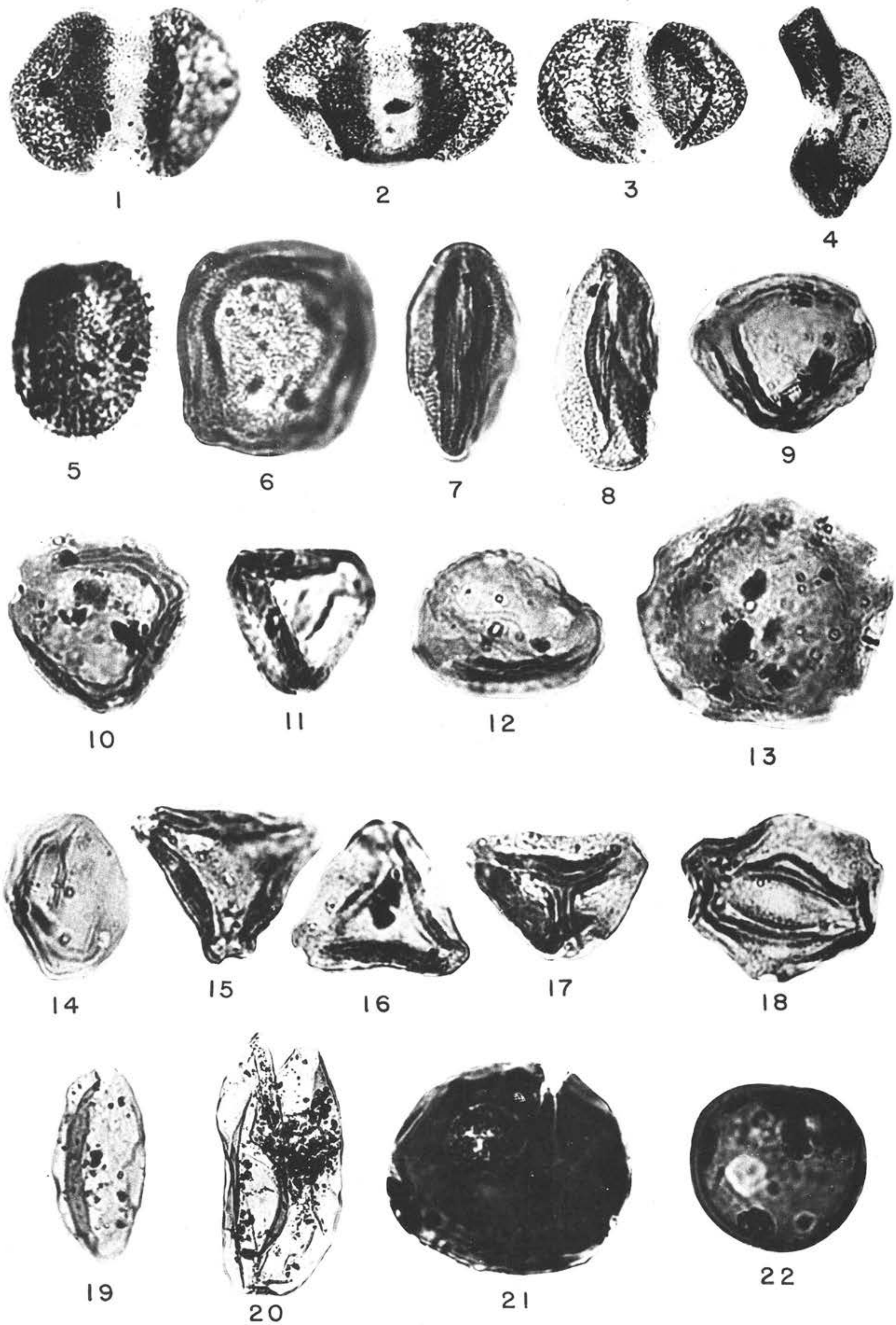
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PLATE 4

OJO *ALAMO 1* FLORULE

Figure Page

1-4. *Podocarpus sellowiformis* Zaklinskaja, 1957 16-17
1. AO1 3-3. Total span, 64 microns.
2. AO1 3-4. Total span, 70 microns.
3. AO1 3-5. Total span, 6o microns.
4. AO1 3-6. Total span, 58 microns.

5. Liliacidites hyalaciniatus n. sp. 18
AO1 4-I. Size, 19 X 22 microns.

6. Alnus? sp. 19
AO1 5-I. Diameter, 29 microns.

7-8. *Quercus?* sp. 20
AO1 6-1. Size, 17 X 27 microns.

9-11. *Ulmoideipites tricostatus* n. gen. and sp............ 20-21
9. AO1 7-1 (holotype). Diameter, 23 microns.
10. AO1 7-2. Diameter, 22 microns.
1 1. AO1 7-3. Diameter, 19 microns.

12. *Ulmoideipites krempi* n. gen. and sp. 20
AOI 8-1. Diameter, 23 microns.

13. Ulmoideipites planeraeformis n. gen. and sp. 20
AO1 9-1 (holotype). Diameter, 3o microns.

14. Triporopollenites plektosus n. sp. 27
AO x 10-1 (holotype). Diameter, 20 microns.

15-18. *Paliurus triplicatus* n. sp. 22
15. AO 1 11-1 (holotype). Diameter, 25 microns.
16. AO1 11-2. Diameter, 22 microns.
17. AO I I 1-3. Diameter, 23 microns.
18. AO1 11-4. Diameter, 26 microns.

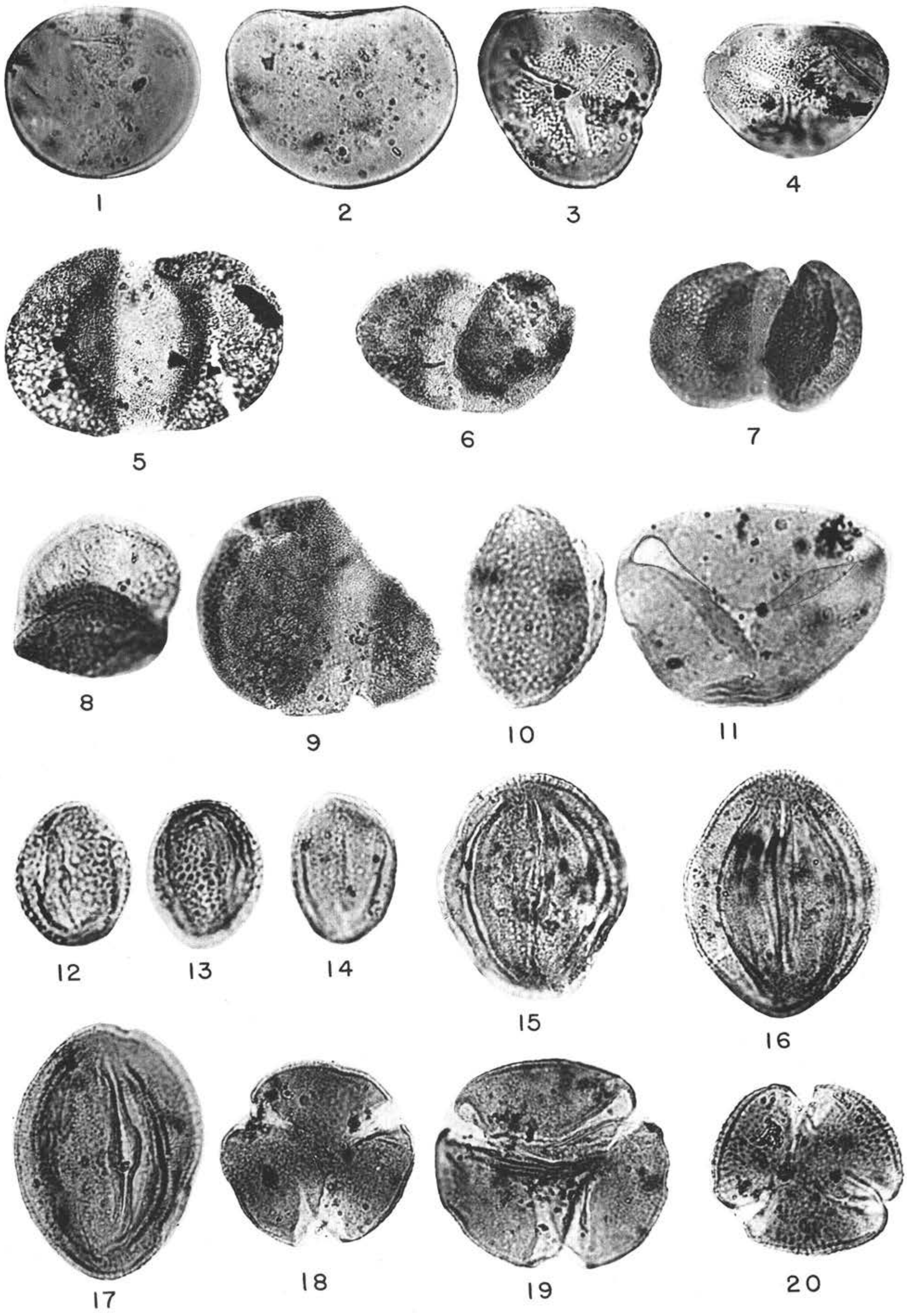
19. Confertisulcites knowltoni n. gen. and sp. 27
AO1 12-I. Size, 27 X 53 microns.

20. Confertisulcites sp. 27
AO1 13-I. Size 5o X 112 microns.

21-22. *Sporites neglectus* n. sp. 29
2 I . AO1 14-I. Diameter, 29 microns.
22. AO1 14-2 (holotype). Diameter, 21 microns.

PLATE 5

OJO ALAMO 2 FLORULE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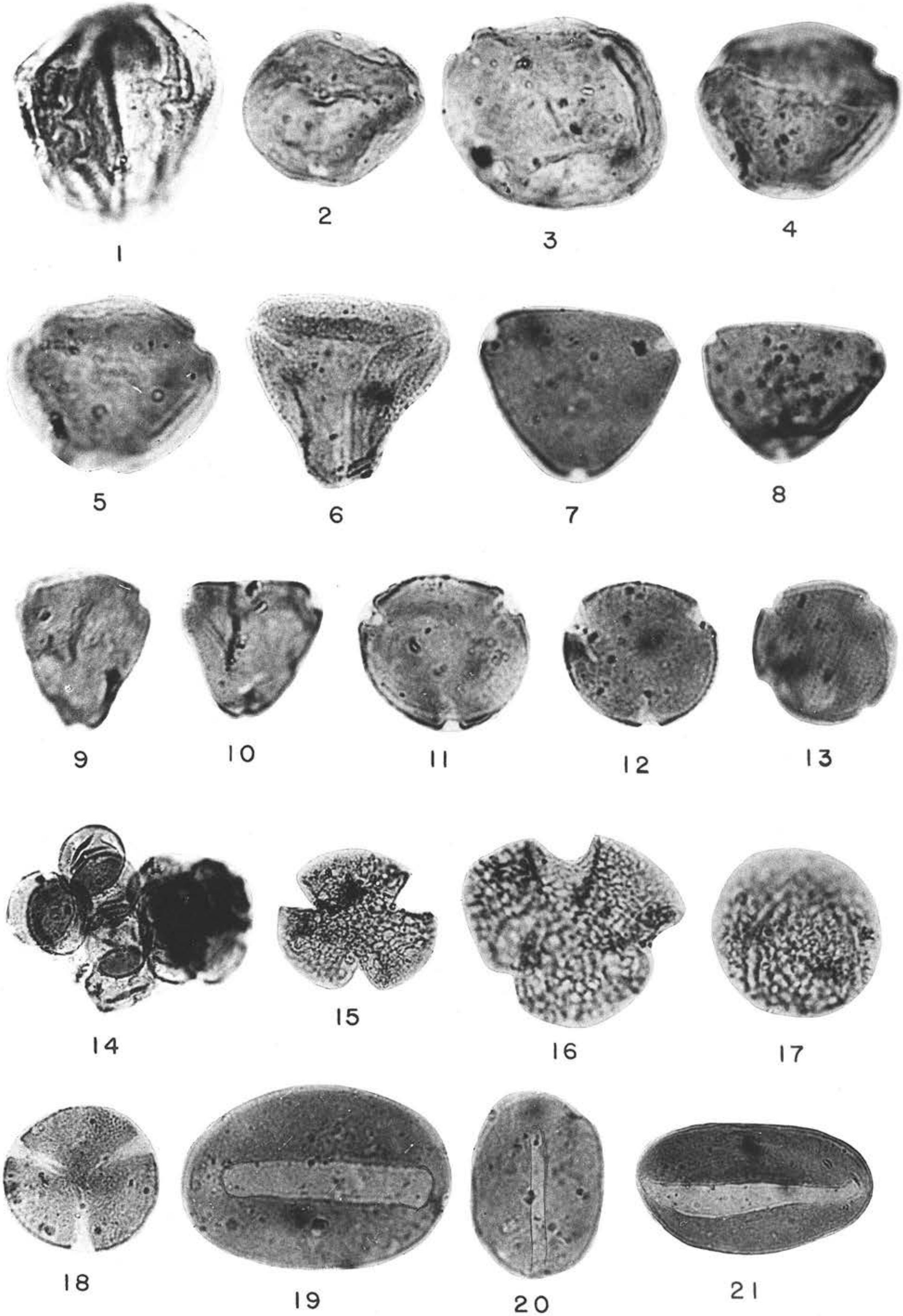
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PLATE 6

OJO ALAMO 2 FLORULE

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2–3.	*Ulmoideipites krempi* n. gen. and sp.	20
	2. AO2 9–1 (holotype). Diameter, 22 microns.	
	3. AO2 9–2. Diameter, 25 microns.	
4–5.	*Ulmoideipites tricostatus* n. gen. and sp.	20–21
	4. AO2 10–1. Diameter, 23 microns	
	5. AO2 10–1. Diameter, 23 microns.	
6.	*Cupanieidites* aff. *C. major* Cookson and Pike, 1954	22
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7–10.	*Momipites inaequalis* n. sp.	25
	7. AO2 12–1. Diameter, 24 microns.	
	8. AO2 12–2 (holotype). Diameter, 22 microns.	
	9. AO2 12–3. Diameter, 19 microns.	
	10. AO2 12–4. Diameter, 16 microns.	
11–14.	*Brevicolporites colpella* n. gen. and sp.	24
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	20. AO2 16–2. Size, 15 × 22 microns.	
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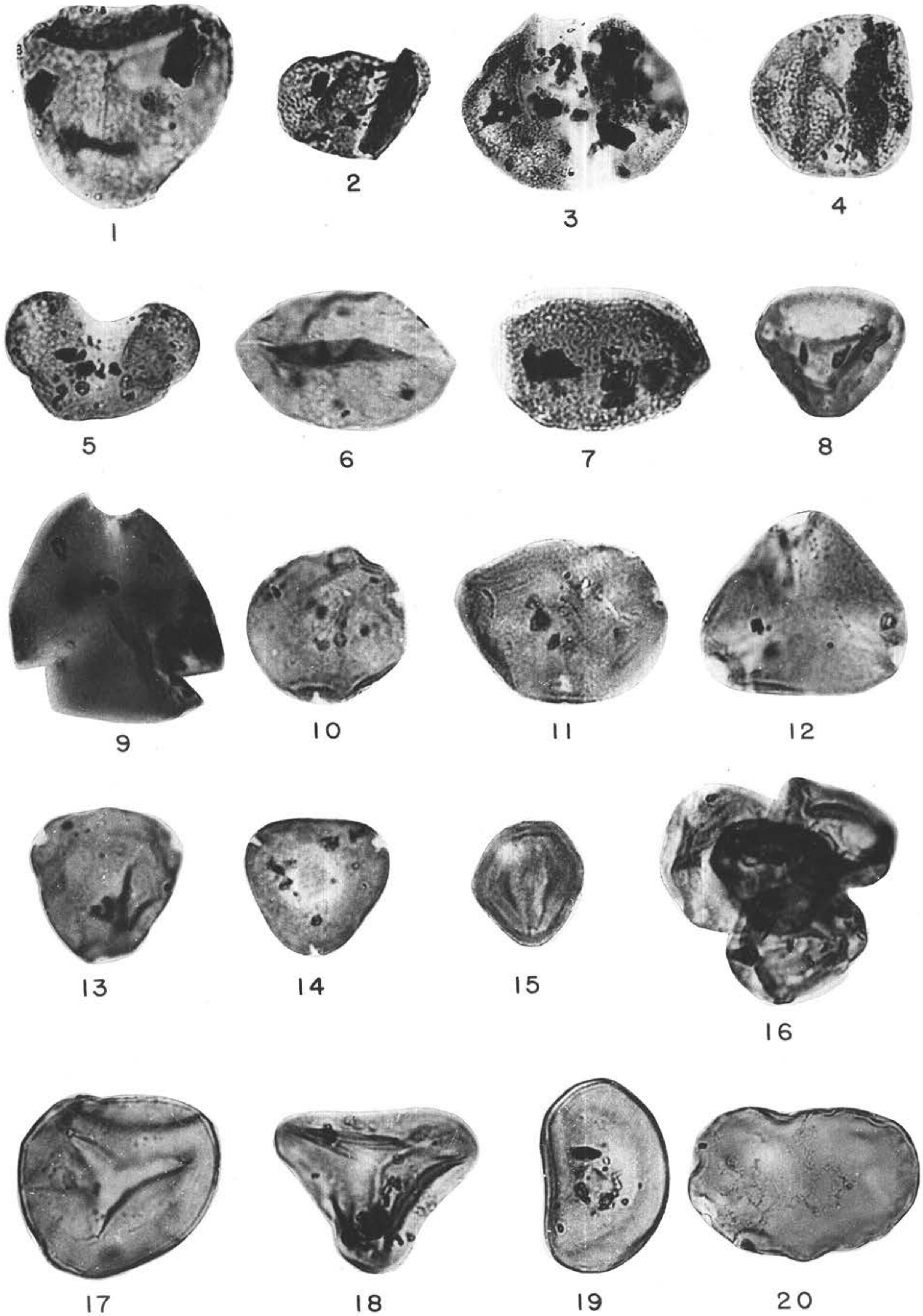
PLATE 7

NACIMIENTO 1 FLORULE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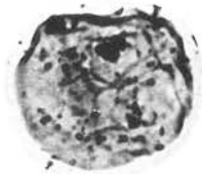
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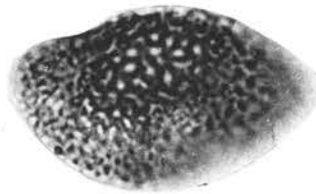
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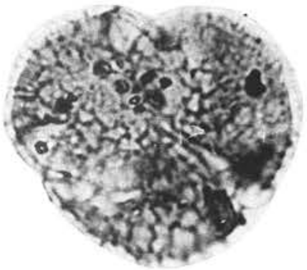
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PLATE 8

NACIMIENTO 2 FLORULE

Figure		Page
1.	*Lycopodium novomexicanum* n. sp. .... AN2 4–1. Diameter, 42 microns.	14–15
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6–7.	*Salix* sp. .... 6. AN2 8–1. Size, 15 × 21 microns. 7. AN2 8–2. Size, 14 × 19 microns.	19
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PLATE 9

LEWIS SHALE FLORULE AND FAUNULE

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	3. AL 1–3. Size, 43 × 79 microns.	
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6.	*Hystrichosphaera* cf. *H. furcata* (Ehrenburg) O. Wetzel, 1933	30
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7.	*Lygodiosporites adriennis* R. Potonié and Gelletich, 1933	14
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8.	*Polypodiidites* sp.	14
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9.	*Concavisporites* sp.	15
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11.	*Cingulatisporites lancei* n. sp.	15
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12.	*Laevigatosporites* sp.	16
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	13. AL 11–1 (holotype).	
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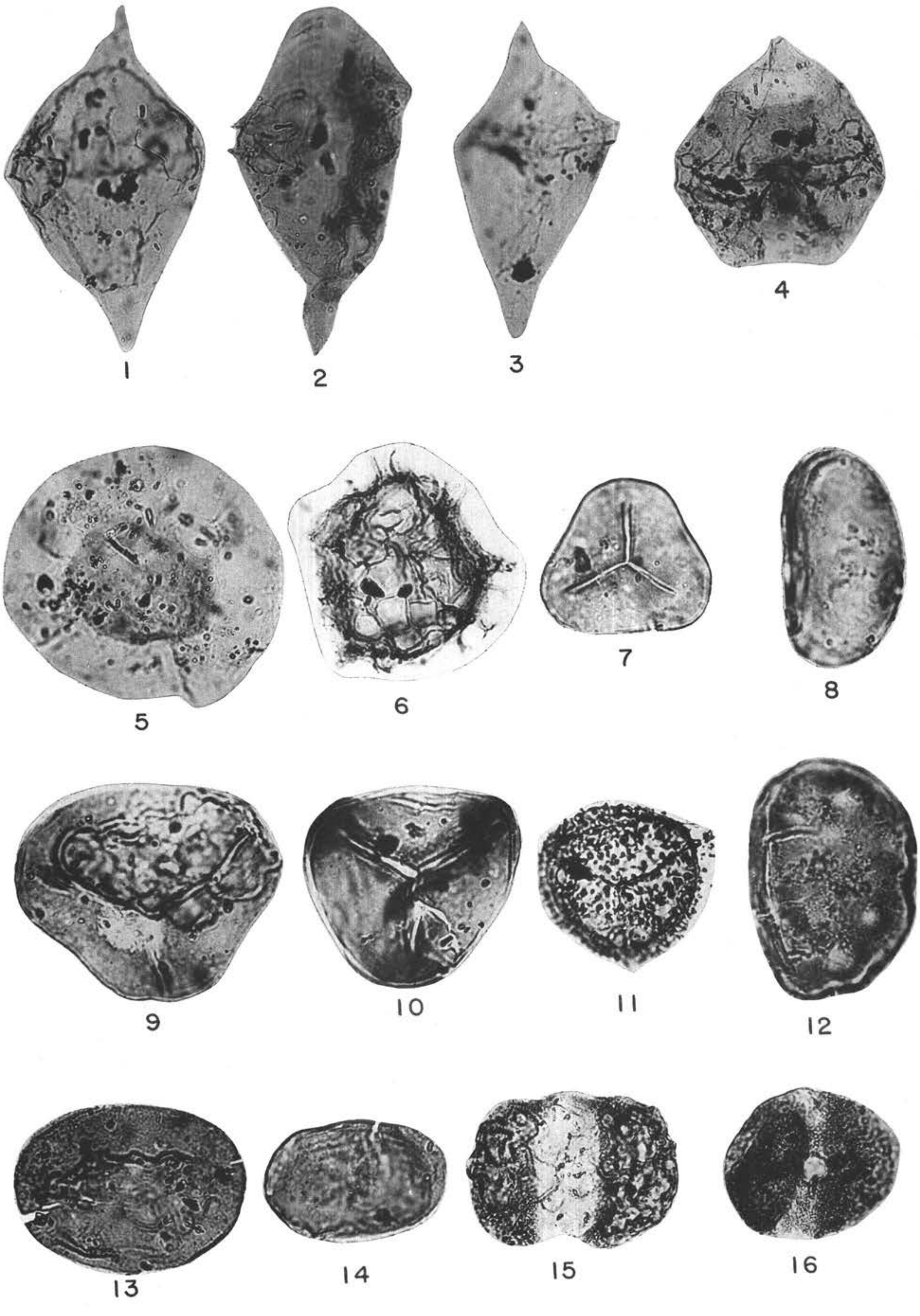
	15. AL 12–1. Total span, 51 microns.	
	16. AL 12–2. Total span, 45 microns.	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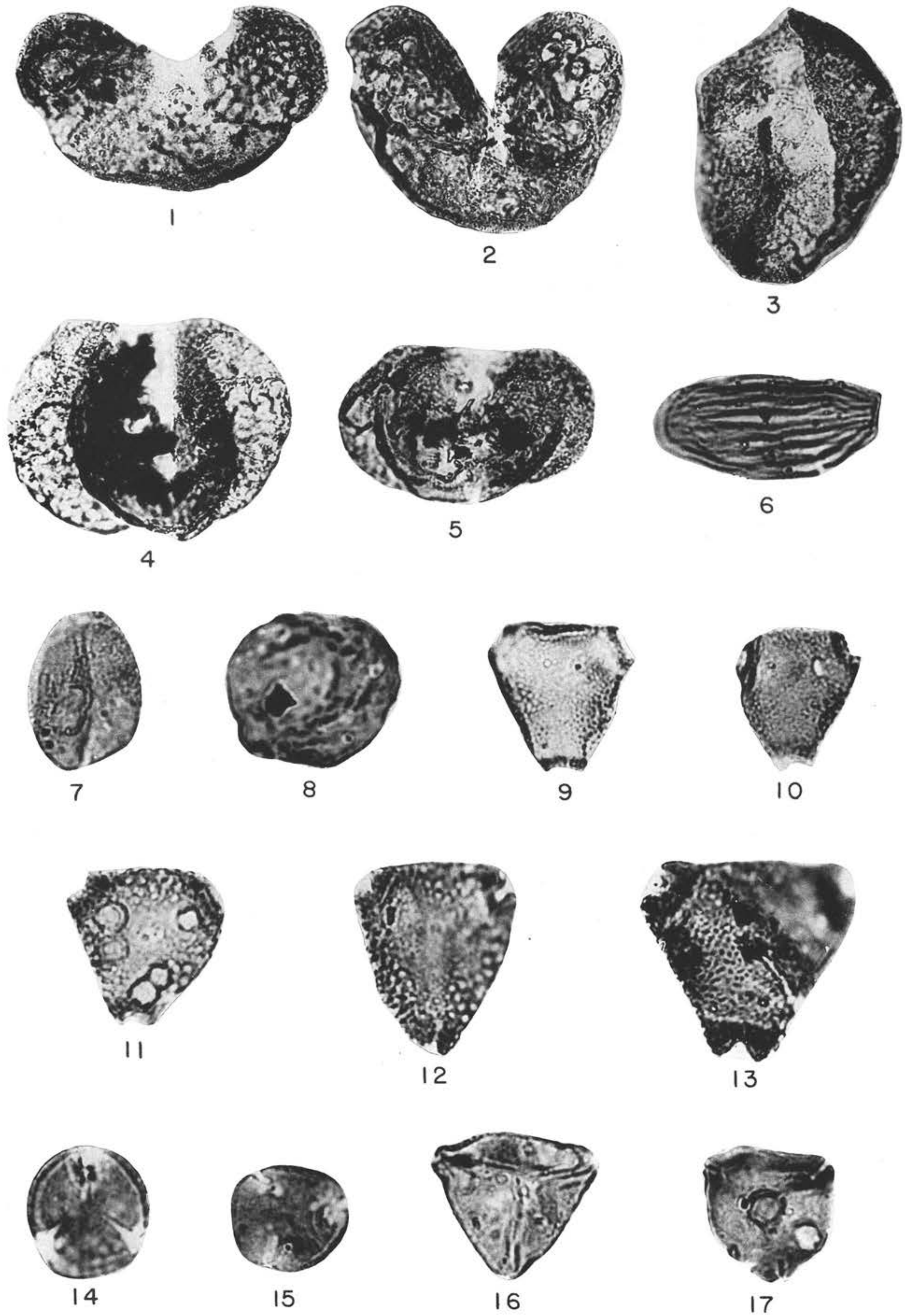
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PLATE 10

LEWIS SHALE FLORULE

PLATE 11

LEWIS SHALE FLORULE

Figure | Page

1-3. *Momipites sanjuanensis* n. sp. 25
I. AL 23—I (holotype). Diameter, 15 microns.
2. AL 23-2. Diameter, 15 microns.
3. AL 23-3. Diameter, 16 microns.

4. *Extratriporopollenites fossulotrudens* Pflug, 1953 24
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5. *Tricolpites* sp. C 26
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6. *Tricolporites* sp. 26-27
AL 26—I. Size II X 17 microns.

7-8. *Eucommiidites couperi* n. sp. 2I
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8. AL 27-2. Size, 14 X 22 microns.

9. *Sporites?* sp. B 3o

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o. *Trilites?* sp. B 29
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I. *Peromonolites* cf. *P. problematicus* Couper, 1953 28
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12. *Peromonolites* sp. A 28
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13. *Peromonolites* sp. B 28-29
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14-15. *Inaperturopollenites limbatus* Balme, 1957 28
14. AL 32—I. Diameter, 54 microns.
15. AL 32-2. Diameter, 58 microns.


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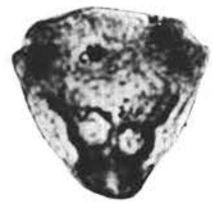
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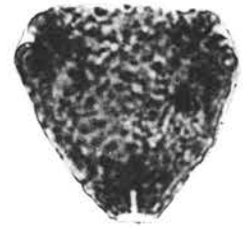
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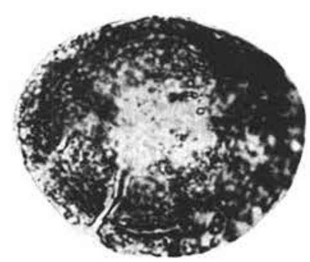
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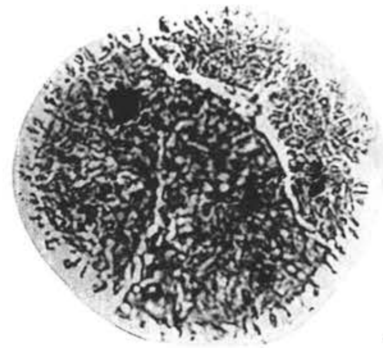
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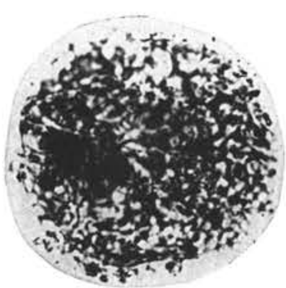
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