EARLY PERMIAN VESICULATE POLLEN FROM TEXAS, U.S.A.*

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ABSTRACT

Twenty-five vesiculate pollen types and related taxa of Early Permian age are reported, and the new taxa are described.

The genera identified are: *Alisporites, Complexisporites, Endosporites, Florinites, Hamiapollenites, Nuskoisporites, Pityosporites, Platysaccus, Potonieisporites, Schizaeoisporites, Striatites, Strotersporites, Sulcatisporites, Vesicaspora, Vestigisporites, Vittatina* and *Wilsonites.*

Vesiculate pollen taxa increased rapidly in Early Permian time. With this increase it is not surprising to observe considerable morphologic diversity. For example, *Vittatina* (LUBER) Wilson, 1962, lacks vesicles. Specimens corresponding to *Vittatina* morphologically but possessing definite rudimentary sacci are herein described. These specimens are the basis for a new genus named *Costapollenites.*

The pollen of *Vittatina, Hamiapollenites,* and *Costapollenites* all possess a costate or ribbed proximal surface, which in proximal view may resemble the pollen of *Ephedra* and *Welwitschia.* However, *Vittatina, Hamiapollenites,* and *Costapollenites* differ from *Ephedra* and *Welwitschia* in that their costae are restricted to their proximal surfaces although they may possess distal bands at right angles to the proximal costae.

INTRODUCTION

AN applied palynological study of Pennsylvanian and Lower Permian rocks from Texas was undertaken some years ago. A great diversity of monosaccate, bisaccate, and striate spores and pollen was a prominent feature of the Early Permian (Wolfcamp) spore and pollen assemblages, effectively distinguishing them from those of the Late Pennsylvanian (Virgil). Some of the taxa may have originated in Late Pennsylvanian time. However, vesiculate taxa were of minor significance in the Late Pennsylvanian, with the possible exception of a species of *Pityoporites* which is discussed in this paper.

Morphology and size are greatly varied in a number of the vesiculate taxa. These differences suggest that plant evolution was occurring at a rapid rate during Early Permian time. That such variation can present many obstacles to an orderly classification is evidenced by the numerous emendations and new combinations that appear in almost every new publication concerning Permian pollen and spores.

Permian assemblages from the continental United States have been reported only by Wilson (1959, 1962) and Jizba (1962). We amplify this record and discuss some taxonomic problems presented by this Early Permian assemblage.

We wish to thank the Shell Oil Company for permission to publish on the pollen from the part of the Permian discussed herein.

STRATIGRAPHY

The material examined was obtained from carefully selected well cuttings. Although we examined Permian material from several wells, the material discussed is from rocks in about a 100-foot interval in Shell's R. P. Yost well in Callahan County, Texas. This interval was above the first occurrence of late Wolfcamp fusulinids. Furthermore, the Permian spore and pollen flora found is correlative with Wolfcamp spore and pollen floras obtained from nearby wells. Below the interval represented by the samples studied, a prominent floral " break " marking the top of the Pennsylvanian was found. We believe that the flora reported is of Wolfcamp age, but admit that it possibly may be of early Leonard age. The assemblage is older than that reported by Wilson (1962) from Oklahoma. He obtained 68 percent *Lueckisporites*, whereas we obtained no specimens difinitely assignable to *Lueckisporites* (Potonié & Klaus) Klaus, 1963.

DESCRIPTIVE PALYNOLOGY

The specimens discussed and figured in this report represent the vesiculate and allied taxa that were found in sufficient number and well enough preserved to be described. Palynologists working further in this floral province will undoubtedly discover additional Early Permian vesiculate taxa.

*Publication authorized by the Director, U.S. Geological Survey.

Figured specimens have been assigned USNM numbers and are in the United States National Museum, Washington, D. C. All specimens discussed or listed have been circled on the slides with black ink. Microscope coordinates are given for all specimens mentioned. Coordinates for the center of a 1×3 microscope slide are $108{\cdot}0 \times 12{\cdot}3$.

Photographs, 35 mm. kodachromes, of specimens of new species mentioned in this paper are available from us on a limited loan basis.

Vittatina (Luber) Wilson, 1962 emend

Type species — *Vittatina subsaccata* Samoilovich, 1953 (SAMOILOVICH, 1953, p. 44, Pl. IX, Fig. 4a), designation by Wilson (1962).

Generic diagnosis — Pollen bilateral, almost circular to elliptical in proximo-distal orientation; proximal surface with 7 to 20 costae or ribs alternating with grooves; grooves sometimes bifurcating, thereby increasing the number of costae; a short, straight, or curved monolete aperture often present on the proximal surface; distal surface without or with 1 to 3 or more thickened bands oriented at right angles to the proximal costae; equator rimlike, similar to proximal costae; proximal ornamentation ranging from smooth to granulate, verrucose or pitted, distal surface smooth to granulate.

Discussion — Samoilovich (1953) credited Luber (1940) with the original description of *Vittatina*. Zauer (1960) indicated that the original description was given by Luber in Luber & Waltz (1941). Considerable confusion pertaining to the original description and name has resulted as noted by Jansonius (1962). Actually, to our knowledge, the name *Vittatina* does not occur in Luber & Waltz (1941), inasmuch as the species subsequently assigned to the genus appeared as *Zonalates vittifer* and *Azonaletes striatus*. *Vittatina* was not validated by Samoilovich (1953) even though he designated holotypes for the the species and subspecies of *Vittatina* he described. *Vittatina* was validated by Wilson (1962) when he designated *Vittatina subsaccata* Samoilovich, 1953, as the type species.

Zauer (1960) did not describe species of *Vittatina*, but reported some important observations and ideas concerning the morphology of the genus. A definite aperture occurs on what he considered to be the proximal surface of the grain. This aperture is short, is "one-rayed," and is a simple cleft in the exine. The proximal surface is ribbed; the distal surface may be smooth, granular, or ribbed. Zauer thought the presence of a thickened distal belt, rib, or costa in the approximate position of the sulcus could be an adaptation allowing hygroscopic swelling and contraction of the thin areas of the distal surface of the exine. He believed that the nexine and sexine were differentiated, and that baculae causing a reticulate pattern on the ribs were visible. He did not believe that *Vittatina* is related to *Welwitschia* because *Welwitschia* lacks baculae. For this and other reasons, Zauer was convinced that *Vittatina* was related to the seed ferns. He diagrammatically illustrated four types of *Vittatina*: (1) those with many transverse distal costae, (2) those with a smooth distal side, (3) those with a smooth distal side having a thin area, and (4) those with a median transverse distal costa.

Samoilovich (1953) designated holotypes for new species and varieties of *Vittatina* that he described. Wilson (1962) emended *Vittatina* to exclude species possessing bladders because, "Samoilovich (1953, p. 44) used a term that may be translated 'incipient air sacks?' for the structures of the linear ends of the grains of *Vittatina subsaccata*. The illustration of the holotype (SAMOILOVICH, 1953, Pl. IX, Fig. 4a) does not show structures that can be unequivocally termed sacci."

Jansonius (1962) likewise emended *Vittatina* and designated the type species as *V. subsaccata*. Wilson's (1962) paper was published in February and Jansonius' in April; therefore Wilson's account has priority. Although Wilson and Jansonius independently agreed on the selection of the type, they disagreed on the circumscription of the genus as Jansonius did not exclude the presence of "... a more or less inflated bladderlike structure, a solid projection of similar size as bladders ..."

Chaloner & Clarke (1962) described *Vittatina hiltonensis* from the "Upper Permian of Westmorland, England." This species possesses what Chaloner & Clarke referred to as distally offset rudimentary sacci. They clearly pointed out that their use of the term rudimentary sacci does not imply that these structures represent phylo-

genetic precursors of true sacci. The sacci were reported to show an obscure stippled sculpture pattern. The use of the term stippled seems rather appropriate for specimens shown in text-figure 1 and in figures 6 and 7 of plate 80. Internal bladder ornamentation is absent and the stippled ornamentation appears to be external. No aperture or distal thickened bands were reported.

Klaus (1963) recognized Wilson's 1962 validation of *Vittatina*. He observed and described the presence of a " Kurzer Mittelschlitz " in his new species and in *V. costabilis* Wilson. The so-called short slit or aperture on the proximal surface is clearly shown in Wilson's holotype specimen (Pl. 3, Fig. 12), but was not mentioned in his description of this taxon. The proximal slit may indeed be a vestigial aperture and would have to be if this entity is truly a pollen grain. It is characteristically present in our specimens of *V. costabilis*. Although Klaus described his " Kurzer Mittleschlitz " and illustrated it (Figs. 34, 35), he did not emend the genus to include this structure. Furthermore, some of Klaus' excellent photomicrographs show the presence of this aperture (Figs. 95, 97-99).

The presence of proximal and presumably vestigial apertures in *Vittatina* was confirmed by Zauer (1960) and Klaus (1963) in *V. costabilis* Wilson, 1962, and is visible in our material. These apertures are commonly present although not always recognized without careful focusing.

Hart (1964) recognized Wilson's (1962) emendation of *Vittatina* but credited Jansonius (1962) with the designation of the type species. Hart followed Jansonius in that he believed that members of the genus are with or without bladders. Hart recognized 12 species of *Vittatina*, but did not mention the proximal aperture. He did indicate that *V. subsaccata* Samoilovich, *V. saccata* (Hart) Jansonius, *V. saccifer* Jansonius, and *V. wodehousei* (Jansonius) Hart all possess rudimentary sacci or inflated structures. He only mentioned reticulate bladder ornamentation in connection with *V. saccata* and this mention was rather vague, " Terminally the exine forms bladdery swellings, minute rudimentary sacci, or merely meandering reticulate areas." However, Hart (1960) previously said, in the description of this same taxon, " Sacci exine is smooth without infra-structure." His figure 3, a drawing, and figures 1 and 2 of plate 1 show no evidence of internal bladder reticulation. The statement concerning meandering reticulate areas occurred in his 1964 publication and might be considered an addition to his 1960 description. Hart's illustration (1964, Fig. 63) does not indicate reticulate ornamentation, at least not so that it can be ascertained from his drawing.

On the basis of the evidence available we believe that swellings or bulges do occur at the linear ends of some of the species assigned to *Vittatina*. To our knowledge, no clearly defined air sacks or bladders have been illustrated showing the internal bladder reticulation characteristic of modern bisaccate pollen grains. The so-called rudimentary sacci would appear more similar to the linear, sometimes inflated, end structures occurring in pollen of *Welwitschia mirabilis* Hook., 1863. These structures, in the slides of *Welwitschia* pollen which we have, are extremely varied, but in no instance do we consider them to be true bladders (Pl. 1, Figs. 1-5).

Vittatina costabilis (Wilson) emend.

Pl. 1, Figs. 6-8

Holotype — OPC 1-3-4, Wilson (1962, pl. 3, fig. 12).

Species description — This pollen is bilateral, oval to broadly oval in proximo-distal orientation, 40 to 77 microns in length, and 30 to 58 microns in width. The proximal surface is largely covered with 12 to 20 costae with alternating grooves. The costae parallel the long axis of the grain, and usually taper at their extremities. The costae are finely granular to microfoveolate. A linear or cresent-shaped vestigial monolete aperture is present. The linear type of aperture shown in the holotype is most common and is from 8 to 10 microns in length and slightly more than 1 micron wide. The curved or cresent-shaped aperture may be 13 to 16 microns in length and 1 to 2 microns in width. The distal surface is free of costae paralleling the long axis of the grain, but has one median transverse band and may exhibit two terminal transverse bands when specimens are viewed equatorially. These are continuations of the equatorial rimlike structure (Pl. 1, Figs. 7-8).

Occurrence — Wolfcamp, Texas; Guadalupe, Oklahoma.

Age — Early Permian and late Early Permian, respectively.

Discussion — Wilson reported that the distal surface may possess 3 to 7 transverse bands with all but the median transverse band obscure. We would agree that the 2 terminal transverse bands are often obscure as a result of curving or folding of the ends of the proximal costae, but we never have observed more than 3 distal bands (PL. 1, FIGS. 7-8). Klaus (1963) indicated the presence of a prominent medial costa plus 2 distal transverse terminal bands. These latter we believe are accentuated in Klaus' material by distal flexure of the proximal costae as shown in his figure 35b. When this folding is at a minimum, as in the holotype of *V. costabilis*, the costae are obscure and their presence is nearly impossible to ascertain in a proximo-distal view (PL. 1, FIG. 6). Figure 6 (USNM 42429) is from slide M-374 delta and the coordinates are 101·1×15·3; figure 7 (USNM 42430) is from the same slide and the coordinates are 99·9×12·3.

Vittatina sp. A

Pl. 1, Fig. 9

Characteristics — Thin walled, almost transparent, possessing 15 to 18 thin proximal costae and no clear-cut central distal band as do some other species of *Vittatina*, this specimen closely approaches the appearance of *Aumancisporites* (Alpern) Jansonius, 1962. The presence of a very thin distal membrane and the absence of a thickened medial distal band may contribute to the characteristic distally inclined folding of the ends of the grains, in Alpern's and Jansonius' specimens as well as in our own. We are unable to find sufficient characteristics of generic rank to differentiate *Aumancisporites* from *Vittatina*. We believe the two genera should be combined but hesitate to do so on the basis of our material.

Specimen illustrated (USNM 42444) is from slide W-531-17 and the coordinates are 107·8 × 12·1.

Vittatina sp. B

Pl. 1, Fig. 10

Characteristics — It is almost circular in proximo-distal orientation, possesses about 10 foveolate to microfoveolate wide proximal costae and no evident medial distal band, has a short proximal gable-shaped aperture, and is 47 × 39 microns in size.

Specimen illustrated (USNM 42423) is from slide M-374 alpha and the coordinates are 108·5 × 17·9.

Vittatina foveolata sp. nov.

Pl. 1, Figs. 11-13

Holotype — USNM 42425, M-374 beta, coordinates 93·0 × 15·6, Fig. 12.

Paratypes — USNM 42434, M-374 Exp. 1, coordinates 121·4 × 7·0, Fig. 11. USNM 42415, M-373 delta, coordinates 101·5 × 15·0, Fig. 13.

Species description — This pollen is broadly oval to elliptical in proximo-distal orientation. The proximal face is covered with 8 to 12 costae and alternating grooves; the grooves have a tendency to bifurcate and thereby increase the number of costae. A short crescent-shaped aperture may be present on the approximate center of the proximal face. The size is 39 to 62 × 36 to 54 microns. The surface is distinctly and coarsely foveolate. The distal face bears a thickened medial band and possibly two terminal bands at right angles to the long axis.

Discussion — This species is fairly common in our material. The crescent-shaped proximal aperture is difficult to see on most specimens. Some specimens tend to curl or fold at right angles to the proximal costae. This tendency is common in *Vittatina* (PL. 1, FIGS. 12-13).

***Costapollenites* gen. nov.**

Type species — *Costapollenites ellipticus* sp. nov.

Generic diagnosis — Pollen or prepollen, bilateral, elliptical in proximo-distal orientation, consisting of a body, a cap, and a small equatorially united saccus. Proximal cap dark brown with 8 to 11 heavy costae or ribs and alternating grooves parallel to the long axis of the grain; a curved monolete aperture present; distal surface of body with one or more thickened distal bands at right angles to proximal costae. Saccus enclosing body, although appearing bisaccate, a definite equatorial connection present; saccus smooth externally, granular internally, forming pattern suggestive of a definite reticulum.

Costapollenites ellipticus sp. nov.

Pl. 1, Figs. 14-18

Holotype — USNM 42445, slide W-531-17, coordinates 121·6 × 13·1, Figs. 14-16.

Paratypes — USNM 42446, slide W-531-17, coordinates 109·7 × 19·3, Fig. 18. — USNM 42438, slide W-531 alpha, coordinates 102·5 × 9·6, Fig. 17.

Species description — On the basis of seven specimens, overall length is 59 to 73 microns, width variation is 40 to 49 microns, body length variation is 48 to 66 microns, and body-width variation is 36-47 microns. The proximal costae (Pl. 1, Fig. 15) vary in number because some of the grooves split and isolate 2 costae, but 6 to 8 of the costae traverse the entire grain. The proximal aperture (vestigial?) is monolete, curved, and varied in length from 16 to 18 microns. The aperture is sometimes difficult to observe when it is located close to grooves that separate costae. One medial distal band is present; the presence of possible additional bands cannot be proved in the specimens available. The saccus covers all or nearly all of the body on the distal surface. The paratype specimen (Pl. 1, Fig. 17, a distal view) shows the internal granular ornamentation of the saccus covering all or nearly all of the distal surface. The saccus is smooth externally, granular internally, forming a pattern suggestive of a definite reticulum (Pl. 1, Fig. 16).

Discussion — The mode of formation of the saccus or sacci resembles the formation of the terminal bulges in pollen of some specimens of *Welwitschia mirabilis*. However, the terminal bulges in *W. mirabilis* are totally lacking in the reticulate bladder ornamentation. Furthermore, *Costapollenites* has costae paralleling the long axis of the grain only on the proximal surface, whereas *Welwitschia mirabilis* has them completely surrounding the grain (Pl. 1, Fig. 3). One may compare *Costapollenites* with *Vittatina* when considering the presence of the proximal costae, a distal costa at right angles to the long axis of the grain, and the presence of a proximal and presumably vestigial monolete aperture. The presence of a definite saccus or sacci possessing a fine reticulate ornamentation on the inner surface differentiates this taxon from *Vittatina*.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

Additional specimens are USNM 42448, slide W-531 beta, coordinates 117·8 × 14·8; slide W-531 gamma, coordinates 101·9 × 6·1; and slide W-531 alpha, coordinates 102·3 × 6·1.

***Schizaeoisporites* (Potonié) Potonié, 1960**

Schizaeoisporites microrugosus sp. nov.

Pl. 1, Figs. 19-20

Holotype — USNM 42424, slide M-374 alpha, coordinates 101·9 × 16·0, Pl. 1, Fig. 19.

Paratype — USNM 42402, slide M-373 alpha, coordinates 115·0 × 12·6, Pl. 1, Fig. 20.

Species description — The spores are monolete, ellipsoidal to reniform in equatorial (lateral) view, and 60 to 81 microns by 40 to 60 microns in dimension. Dehiscence or monolete suture is not clearly represented. The wall is thin and the surface has narrow anastomosing longitudinal ridges about 2 microns in width; ridges are triangular in cross section and 1 to 2 microns high.

Discussion — This species, although never abundant in our material, is sufficiently common and distinctive to warrant inclusion.

Affinity — Schizaeaceae?

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

***Hamiapollenites* (Wilson) emend.**

Type species — *Hamiapollenites saccatus* Wilson, 1962

Generic diagnosis — Bisaccate pollen grains; body circular to oval in proximo-distal orientation, somewhat elongate in equatorial view; wall 2 to 3 microns thick. Proximal surface of body covered with 8 to 12 or more costae alternating with grooves that parallel the long axis of the grain. Costae of the proximal surface smooth to minutely pitted. Distal surface may possess 1 to 10 bands or ribs at right angles to the proximal costae. Distal body exine between bands or ribs thin, and smooth to granular. Bladders always significantly smaller than body width, usually internally reticulate, and not distally inclined. The overall size ranges from 42 to 90 microns.

Discussion — *Hamiapollenites* was described by Wilson (February, 1962), who designated *H. saccatus* as the type. Jansonius (April, 1962) described *H. bifurcatus* and suggested that *Protodiploxypinus bullaeformis* Samoilovich, 1953, and *Protohap-*

loxypinus tractiferinous Samoilovich, 1953, should be transferred to *Hamiapollenites*. Jansonius formally transferred *Protodiploxypinus bullaeformis* to *Hamiapollenites*, but did not transfer *Protohaploxypinus tractiferinous*. Jizba (September, 1962) proposed *Striatosaccites* for pollen of the *Hamiapollenites* type, designated *Striatosaccites perisporites* as the type, and transferred two of Samoilovich's species to *Striatosaccites*. Hart (1964) recognized *H. saccatus* Wilson, 1962, *H. tractiferinous* (Samoilovich) Hart, 1964, *H. bullaeformis* (Samoilovich) Jansonius, 1962, and *H. karrooensis* (Hart) Hart, 1964. Hart considered *H. bifurcatus* Jansonius, 1962, a synonym of *H. saccatus* Wilson, 1962. Zauer (1960, Pl. 11, Fig. 3) illustrated a specimen classified as *Striatopodocarpites* sp. that might be related to *Hamiapollenites*, and Peppers (1964) questionably assigned a specimen from the Henshaw Formation (Late Pennsylvanian) of Kentucky to *Hamiapollenites*.

Hamiapollenites perisporites (Jizba) comb. nov.

Pl. 1, Figs. 21-26

Holotype — Jizba (1962, Fig. 41, Pl. 123) Leonard, Callahan County, Texas. The type slide is T-153, slide 14, and the coordinates are 33·0 × 127·0. This slide is in the palynological collections of the California Research Corporation, La Habra, California.

Species description — Pollen grain body is circular to subcircular in outline, the proximal surface possesses 8 to 10 costae, and alternating grooves are oriented in the long axis of the grain. Costae are smooth to finely granulose. Distal bands or ribs, 1 to 5 in number, are at right angles to the proximal costae. The distal exine between bands or ribs is thin and smooth to finely granulose. The bladders are usually circular in outline, small in relation to the body, and not distally inclined. The bladders are commonly internally reticulate. On the basis of the 219 specimens measured, the overall size range is 42 to 90 microns.

Occurrence — Wolfcamp, Leonard, Texas.

Age — Early Permian.

Discussion — Descriptions of species of *Hamiapollenites* are based largely on the number of proximal costae and distal bands. *Hamiapollenites* was so abundant in our assemblage that the examination of a large number of specimens was possible. Proximal costae and distal bands vary considerably in number. Furthermore, in some specimens the bladder membrane encircles the body equatorially, and one specimen is covered by small spines. The overall size range observed is 42 to 90 microns, but 91 percent of the specimens range from 46 to 78 microns. Because of the extreme variation in morphology and size, we believe that possibly only one species is represented, and *Hamiapollenites saccatus* Wilson, 1962, has priority. However, we have not observed a single specimen in our collection that possesses more than 5 distal bands. The original description of *H. saccatus* required at least 6 bands, and as many as 10 distal bands are within the circumscription. Owing to this description and to the fact that the description by Jizba (1962) for *Striatosaccites perisporites* closely matched that of our taxon, we decided to transfer Jizba's species to *Hamiapollenites* because this genus has priority over *Striatosaccites*.

The validity of the identifications *Hamiapollenites bullaeformis* (Samoilovich) Jansonius, 1962, *H. tractiferinous* (Samoilovich) Hart, 1964, and *H. karrooensis* (Hart) Hart, 1964, is still questionable. On the basis of the amount of variation displayed in our material we favor the recognition of a single species for specimens having 1 to 5 distal bands.

We consider Jizba's (1962) pollen type A as aberrant specimens of *Hamiapollenites*. We observed a few specimens of this nature in our assemblage.

Figured specimens — USNM 42433, slide M-374 red, coordinates 104·6 × 6·5 (Pl. 1, Fig. 25). USNM 42437, slide M-374 Exp. 37, coordinates 110·1 × 11·8 (Pl. 1, Fig. 21). USNM 42403, slide M-373 alpha, coordinates 101·6 × 20·6 (Pl. 1, Fig. 24). USNM 42426, slide M-374 gamma, coordinates 105·7 × 16·8 (Pl. 1, Fig. 22). USNM 42439, slide W-531 alpha, coordinates 107·8 × 11·0 (Pl. 1, Fig. 23). USNM 42404, slide M-373 alpha, coordinates 106·3 × 4·3 (Pl. 1, Fig. 26).

***Striatites* (Pant) Klaus, 1963**

Striatites splendens (al. *Striatites richteri* Jizba, 1962), sp. nov.

Pl. 1, Fig. 27

Holotype — By designation of Jizba (1962, Fig. 18, Pl. 122), Wolfcamp, Riley County,

Kansas. The type slide is P-14, slide 7, and the coordinates are 42·2 × 134·1. This slide is in the palynological collections of the California Research Corporation, La Habra, California.

Species description — After Jizba (1962, p. 880) under the binomial *Striatites richteri*. "Multistriate, 6 to 16 (mode 11), longitudinal striae, grooves 0·5 mu wide, with 3 to 5 mu maximum spacing; 0 to 4 bifurcating striae in median to submedian positions on cap and separated by nonbifurcating striae. More than one bifurcation of a striation rare. Body subcircular; cap usually appears pitted from corrosion; psilate furrow membrane. Furrow limits indistinct; nexine folds (3-7 mu wide) parallel sacci bases distally. Saccus outline three-fourths of a circle (length:width about 1:2 to 2:3); saccus width 3 to 6 mu longer than body width. In polar view one saccus equals about two-thirds body area. Sacci distally inclined, overlapping one-third to one-half body length. Furrow 12-29 (usually 21-25)mu wide. Sacci may be united by narrow equatorial strip. Sacci in ternally reticulate; irregular reticulum with increased longitudinal muri alignment near distal bases of sacci." Also, see discussion, dimensions, remarks, and occurrence by Jizba (1962, p. 880).

Discussion — Jizba (1962) agreed with Potonié (1958) and considered *Lueckisporites richteri* Klaus, 1955, to belong to *Striatites* Pant, 1955, because her specimens clearly lacked a proximal monolete aperture, a feature that had not been clearly shown for *Lueckisporites richteri*. The presence of the aperture was in doubt until Klaus (1963, Fig. 77) proved that it was on the holotype specimen. He then transferred this species to *Strotersporites* (Wilson) Klaus, 1963. Jizba's specimens and ours clearly lack a monolete proximal aperture. Therefore, in order to name our specimens and the taxon described by Jizba, we have had to designate a holotype specimen and to supply a specific epithet. Our specimens of *Striatites splendens* (Jizba) sp. nov. are in all respects within the circumscription provided by Jizba although the maximum size of our specimens is somewhat smaller.

Occurrence — Wolfcamp, Texas. Jizba (1962) found *Striatites splendens* (Jizba) sp. nov. in Virgil and Wolfcamp rocks in the United States midcontinent area.

Age — Late Pennsylvanian and Early Permian.

Specimen illustrated, USNM 42427, is from slide M-374 gamma and the coordinates are 111·1 × 17·3.

Striatites cf. *S. marginalis* Klaus, 1963

Pl. 1, Fig. 28

Discussion — This species is represented in our assemblage by only one or two specimens. It is an oval bisaccate striate grain with six proximal costae and no evident proximal aperture. The central cell is almost circular in proximal view. The sacci are crescent shaped, are smaller than a half circle, and possess definite internal reticulations. The prominent proximal costae exhibit microreticulate ornamentation. The specimen figured is 60 × 45 microns in overall dimension, somewhat smaller than the holotype (74 × 48 microns), and agrees in all characteristics with the circumscription of the species.

Specimen illustrated, USNM 42447, is from slide W-531-17 and the coordinates are 117·3 × 7·7.

***Complexisporites* Jizba, 1962**

Complexisporites polymorphus Jizba, 1962

Pl. 1, Fig. 29

Discussion — This bisaccate pollen has a costate central cell. It is oval in outline and its sacci are approximately the same diameter as its body cell; its overall size is 43 to 66 × 34 to 38 microns, and its body is 34 to 38 × 24 to 38 microns. Proximal surface of body cell possesses about four wide costae. Characteristically the suture in the center of the proximal surface is wider and is often divided or roughly trilete in shape. The sacci are crescent shaped, overlap the body on the distal face, and produce characteristic dark areas at the overlap. A circular groove encloses the fissured portion of the body. Distal furrow is usually distinct. The specimens found here agree in all respects with the circumscription of *Complexisporites polymorphus* Jizba, 1962.

The specimen illustrated, USNM 42411, is from slide M-373 beta and the coordinates are 101·5 × 5·4.

***Strotersporites* (Wilson) Klaus, 1963**

Strotersporites

Pl. 2, Fig. 41

Discussion — We have found only one good specimen assignable to this genus. It

is a bisaccate pollen grain having a broadly oval body and bearing coarse costae and D-shaped bladders much wider than the cell. A monolete aperture is possibly indicated adjacent to a groove in the center of the cap. There are 6 to 8 costae, some of which split into 2 costae. Bladders are smooth externally and finely reticulate internally. The size of the specimen observed is 94 × 81 microns in overall dimension, and the cell is 65 × 55 microns.

Figured specimen, USNM 42405, is from slide M-373 alpha and the coordinates are 113·6 × 19·2.

Pityosporites (Seward) Manum, 1960

Pityosporites communis sp. nov.

Pl. 2, Figs. 32-33

Holotype — USNM 42406, slide M-373 alpha, coordinates 111·4 × 7·1, Pl. 2, Fig. 32. The maximum dimension is 63 microns and the body measures 46 × 35 microns.

Paratype — USNM 42435, slide M-374 Exp. 6, coordinates 113·7 × 12·2, Pl. 2, Fig. 33. The overall size is 76 microns and the body measures 46 × 42 microns.

Species description — Pollen grains are bilateral and bisaccate; the body is more or less oval in proximo-distal orientation and is broadly V-shaped in equatorial plane; the cap is thin but distinct. Both cap and body are granulate. The bladders are as wide or wider than the body in proximo-distal orientation, are distally inclined, and are internally reticulate. A thin sulcoid area is present in most specimens. The overall size range is 54 to 84 microns. The known size variation in body length is from 33 to 55 microns.

Discussion — Differentiation of species assigned to the genus *Pityosporites* is difficult because its pollen does not possess some of the distinct morphologic features associated with other Permian bisaccate pollen. A number of taxa have been described, and comparisons have been made. Similarities exist between *P. communis* and *P. westphalensis* Williams, 1955, *P. granulatus* Grebe, 1957, *P. devolens* Leschik, 1956, and *P. similis* Balme, 1957, but the pollen of all these taxa appear to be significantly smaller in overall dimension. *Pityosporites zapfei* Potonié & Klaus, 1954, is the same as *Falcisporites zapfei* Leschik, 1956, and *Alisporites zapfei* Jizba, 1962. Text-figures 9 and 10 of Potonié & Klaus, 1954, show distally inclined bladders, but the size range for pollen of this species is reported to be significantly larger in overall dimension. *P. communis* appears to be most similar to *P. antarcticus* Seward, 1914, in size and morphologic features, but is not identified with it because the cap of *P. communis* is thinner and is not striated in cross section as illustrated by Manum (1960, Fig. 4) for *P. antarcticus*. This difference could have been caused by the manner in which specimens were preserved but we are unable to prove this point.

Occurrence — Virgil and Wolfcamp, Texas.

Age — Late Pennsylvanian and Early Permian.

Platysaccus saarensis (Bharadwaj) Jizba, 1962

Pl. 1, Fig. 30

Discussion — These bisaccate pollen grains are characterized by proportionately large internally reticulate distally inclined bladders and a small oval-shaped body in proximo-distal view. The body lacks a pronounced cap and may or may not display a prominent furrow. Overall size is 40 to 61 microns and averages about 52 microns. The maximum body diameter is approximately one-half the overall length, and the sacci are always much wider than the body in proximo-distal view. This species is smaller than *P. papilionis* (Naum.) ex. Potonié & Klaus, 1954.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

Figured specimen, USNM 42436, is from slide M-374 Exp. 23 and the coordinates are 111·4 × 12·5.

Alisporites (Daugherty) Rouse, 1959

Pl. 1, Fig. 31

Discussion — *Alisporites* sp. is present but rare in our assemblage. Sufficient specimens were not observed for them to warrant serious consideration. The specimen illustrated, USNM 42412 (from M-373 beta, 108·9 × 6·7), is somewhat similar in construction to *A. opii* Daugherty but significantly smaller, being only about 74 microns in greatest dimension.

***Vesicaspora* (Schemel) Wilson & Venkatachala, 1963**

Pl. 2, Fig. 34

Discussion — *Vesicaspora* sp. is not numerically significant in our assemblage. A definite, although thin, union of the bladders is observed when specimen is seen in equatorial view. When seen in proximo-distal view, the equatorial connection of the bladders appears to be wider. The bladders are inclined distally and possess internal reticulate ornamentation. The known size range is 35 to 55 microns.

Figure 34, USNM 42416, is from slide M-373 delta, and the coordinates are 113·4 × 16·9

***Sulcatisporites* Leschik 1956**

Pl. 2, Fig. 35

Discussion — *Sulcatisporites* is present in our assemblage but it is not abundant. Sufficient specimens have not been observed for them to warrant more than a mention in this paper. *Sulcatisporites* cf. *S. splendens* Leschik compares reasonably well with Leschik's illustration (1956, Pl. 22, Fig. 10) of the holotype specimen but is about 10 microns smaller in greatest dimension.

Our specimen, USNM 42413, is from M-373 beta and the coordinates are 114·1 × 6·7.

***Florinites* Schopf, Wilson & Bentall, 1944**

Discussion — One species of *Florinites* is present in the assemblage. It is not abundant, but sufficient specimens have been observed for it to be described.

Florinites elongatus sp. nov.

Pl. 2, Figs. 38-40

Holotype — USNM 42414, slide M-373 beta, coordinates 101·0 × 12·7, Fig. 38, size 186 × 112 microns, body 111 × 73 microns.

Paratypes — USNM 42422, slide M-379 beta, coordinates 107·0 × 16·8, Fig. 39.— USNM 42443, slide W-531 gamma, coordinates 113·3 × 9·5, Fig. 40.

Species description — Prepollen or pollen are elongate, are elliptical to oval in proximo-distal view, do not show evidence of an aperture, and commonly have longitudinal folds and bodies that are oval to circular in outline. Sometimes a circular fold occurs on the distal (?) side, perhaps marking the contact of the body and bladder. The bladder is distinctly internally reticulate. The size range is large, varying from more than 100 to 186 microns although in many specimens it is about 120 to 160 microns.

Discussion — No aperture was evident on any of the specimens assigned to this species. Furthermore, the bladder covers all of the proximal surface and all or nearly all of what is considered the distal surface.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

***Wilsonites* (Kosanke) Kosanke, 1959**

Discussion — *Wilsonites* is identified by its monosaccate and trilete pollen grains in which the bladder covers the entire body. It is distinguished from *Endosporites* basically by the vague appearance of the body, generally coarser bladder reticulation, and absence of a limbus. *Wilsonites* is not numerically important in our assemblage. One new species is described.

Wilsonites ephemerus sp. nov.

Pl. 2, Figs. 36-37

Holotype — USNM 42417, slide M-373 delta, 105·7 × 11·8, Fig. 36, overall size 59 × 52 microns, body 35 × 32 microns.

Paratype — USNM 42428, slide M-374 gamma, 112·9 × 11·3, Fig. 37, overall size 59 × 54 microns, body 35 × 32 microns.

Species description — These prepollen are radial, trilete, and basically circular in overall shape; their bodies are poorly defined. Usually specimens are oriented in good proximo-distal orientation. Their rays are more than three-fourths the radius of the body. Minor folding of the bladder may occur. The bladder is internally reticulate. The known size range is 48 to 62 microns.

Discussion — This species is the smallest yet assigned to the genus; the maximum overall dimensions of many of its specimens approximate the body dimensions of other species. Peppers (1964) illustrated a species of *Wilsonites* in this size range that he referred to *W.* sp. 1.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

Additional specimens are from slide M-374 gamma, coordinates 101·7 × 9·0;

slide M-373 delta, coordinates 105·5 × 5·8; and slide M-373 beta, coordinates 105·3 × 12·6.

***Endosporites* Wilson & Coe, 1940**

Discussion — *Endosporites* is not abundantly represented in our assemblage. Two species are recognized but specific epithets have not been proposed because sufficient specimens for proper circumscription of these taxa are lacking.

Endosporites sp. A

Pl. 2, Fig. 42

Discussion — Spores are roundly triangular or irregularly oval in outline; trilete rays are very short, about one-fourth the radius of the body, and are about equal in length. The body is dark brown, the bladder is coarsely reticulate internally, and the limbus is absent. The known overall length is 100 to 113 microns.

The figured specimen, USNM 42407, is from slide M-373 alpha and the coordinates are 99·2 × 12·6.

Endosporites sp. B

Pl. 2, Fig. 43

Discussion — Spores are virtually circular in outline; trilete rays are long, more than three-fourths the radius of the body, which is dark brown. The bladder is reticulate internally, and a limbus is absent. The known overall size is 90 to 125 microns.

The figured specimen, USNM 42440, is from slide W-531 alpha and the coordinates are 106·0 × 4·5.

***Nuskoisporites* (Potonié & Klaus) Klaus, 1963**

Nuskoisporites cf. *N. dulhuntyi* Potonié & Klaus, 1954

Pl. 2, Fig. 44

Discussion — This specimen possesses the short trilete mark on the dark central cell characteristic of *Nuskoisporites dulhuntyi*. The well-defined coarse reticulum and the peripheral zone so clearly evident on the holotype do not show on our specimen, which is 114 microns in diameter and whose circular central cell is 60 microns in diameter. This specimen fits the original description of the genus by Potonié & Klaus, but not Klaus' 1963 emendation of *Nuskoisporites*.

The figured specimen, USNM 42418, is from slide M-373 delta and the coordinates are 102·2 × 16·4.

Nuskoisporites cf. *N. crenulatus* Wilson, 1962

Pl. 2, Figs. 45-47

Discussion — The characteristics of the forms found in our material are: monosaccate pollen or spores with the saccus covering the distal surface, but often with a portion of the proximal surface free of saccus; circular to elliptical outline; dense body cell that is appreciably thicker and less translucent than the bladder; coarsely verrucate proximal surface. No aperture of any type has been observed. Bladder is smooth externally and is finely to coarsely reticulated internally. Overall size is from 84 to 141 microns, body cell diameter from 53 to 70 microns.

The several grains here assigned to *Nuskoisporites* cf. *N. crenulatus* differ from *Florinites* by possessing a heavy, ornamented body cell. They likewise differ from *Nuskoisporites* in lacking small trilete apertures and definite peripheral zones. The specimens of *Nuskoisporites crenulatus* in Wilson's 1962 paper (Pl. 1, Figs. 1, 2) look very much like our specimens. They likewise do not show peripheral zones or clearly evident apertures. Wilson said in his description of this species "trilete simple, generally obscure. . ." Further work may indicate that a new genus should be erected for these forms.

Figured specimens: USNM 42431, slide M-374 delta, coordinates 101·8 × 17·2, Pl. 2, Fig. 45; USNM 42432, slide M-374 delta, coordinates 110·4 × 18·2, Pl. 2, Fig. 47; and USNM 42408, slide M-373 alpha, coordinates 102·0 × 15·3, Pl. 2, Fig. 46.

***Vestigisporites* Balme & Hennelly, 1956**

Vestigisporites cf. *V. methoris* Hart, 1960

Pl. 2, Figs. 48, 51

Discussion — This species is monosaccate and is elongate oval in overall shape. Its bladder tends to be slightly constricted in transverse plane in some specimens; its body is spherical in transverse plane and has an aperture parallel to the long axis. The overall size is 114 to 139 × 78 to 85 microns; the body is 61 to 71 × 54 to 61

microns. The bladder is distinctly reticulate internally, and the ring thickening possibly represents the contact of the body and bladder. This ring is often prominent but not always present. The aperture is comparatively short and lacks lips. This species is directly comparable to *Vestigisporites methoris* Hart, 1960. It is similar to other species of *Potonieisporites* except for its elongate shape, slight tendency for constricted bladder, lack of lips, and generally shorter sulcus. Probably this species should be assigned to *Potonieisporites*, but we prefer not to transfer it on the basis of the few specimens observed.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

Specimens illustrated are from slide M-373 alpha. The coordinates for figure 48, USNM 42409, are 115·8 × 19·2, and for figure 51, USNM 42410, are 104·7 × 18·0.

Potonieisporites Bhardwaj, 1954

Discussion — The generic diagnosis by Bhardwaj (1954) indicated that *Potonieisporites* is monosaccate, is elliptical to oval in outline, and has a rectilinear monolete aperture parallel to the long axis. The body is oval to circular in outline and folds are characteristically present. In the diagnosis of the type, *P. novicus* Bhardwaj, 1954, the proximal surface with the monolete aperture was reported free of the bladder. Bhardwaj (1955) erroneously gave the type as *P. saarensis*, repeated the generic diagnosis, and described, compared, and discussed *Potonieisporites*. We assume that he intended the free proximal surface to be a generic character because he said, in his comparison on page 134, " The distinguishing features of this miospore are the monolete mark, free proximal side, and the characteristic two series of secondary folds which distinguish it from all the monosaccate genera described by Potonié & Kremp (1954)." A few specimens assignable to *Potonieisporites* occur in our assemblage, but because of their large size appear to be of greater significance than they actually are.

Potonieisporites grandis sp. nov.

Pl. 2, Figs. 50, 52-53

Holotype — USNM 42421, slide M-373 gamma, coordinates 110·7 × 8·8, Pl. 2, Fig. 50, size 102 × 73 microns.

Paratypes — USNM 42419, slide M-373 delta, coordinates 106·4 × 12·7, Pl. 2, Fig. 52. USNM 42441, slide W-531 alpha, coordinates 105·3 × 20·4, Pl. 2, Fig. 53.

Species description — These monosaccate prepollen are oval to elliptical in proximodistal view. The body is brown to dark brown and has a distinct monolete aperture oriented in the long axis and extending the entire length of the body. Lips are characteristically present and longitudinal folds of the body occur adjacent to the lips. Some overlap of the bladder on the proximal surface may occur at the equator. The bladder is internally reticulate. The known size range is 105 to 132 microns in overall length and the variation in width is 72 to 110 microns. The known variation in body length is 81 to 94 microns and in width is 42 to 67 microns.

Discussion — This species is characterized by a dark body and longitudinal folds parallel to the lips.

Occurrence — Wolfcamp, Texas.

Age — Early Permian.

Potonieisporites? sp.

Pl. 2, Fig. 49

Discussion — A few specimens were found that resemble prepollen of *Potonieisporites*. They are large, are monosaccate, and have monolete apertures. This species differs from *Potonieisporites* in that the bladder is definitely present on the surface bearing the monolete aperture. The internal bladder reticulation is sharply defined and can be traced over the body even though the body is dark brown in color. This feature differs from the presently accepted circumscription of *Potonieisporites* as described by Bhardwaj (1954, 1955). The aperture and parallel folds adjacent to the aperture do not extend the entire length of the body. Some minor folds of the bladder are present.

Figure 49 illustrates a specimen of *Potonieisporites*? sp. that has an overall size of 194 × 165 microns and a body measurement of 130 × 113 microns. The illustration of this specimen, USNM 42442, is from slide W-531 alpha, and the coordinates are 101·4 × 19·3.

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EXPLANATION OF PLATES

PLATE 1

(*Figs.* 1-15 *and* 17-31 *are shown at about* × 500. *Fig.* 16 *is an oil immersion photomicrograph and greatly enlarged*)

1-5. Pollen of *Welwitschia mirabilis* from a slide in the collection of the Illinois Geological Survey. The negative numbers from Illinois Geological Survey Coal Section are 4971, 4972, 4899, 4895, and 4894.

6-8. *Vittatina costabilis* (Wilson) emend. Fig. 6 is a proximo-distal view clearly illustrating costae and alternating grooves, distal median band at right angles to the proximal costae, and the proximal linear aperture. Fig. 7 is an equatorial view of another specimen showing the terminal bands, median distal band, equatorial ridge, and the distal and proximal surfaces. Fig. 8 is a drawing of the specimen shown in Fig. 7 to diagrammatically illustrate the relation of the three distal bands to the proximal costae.

9. *Vittatina* sp. A showing the numerous costae and typical folding of the ends of the grain.

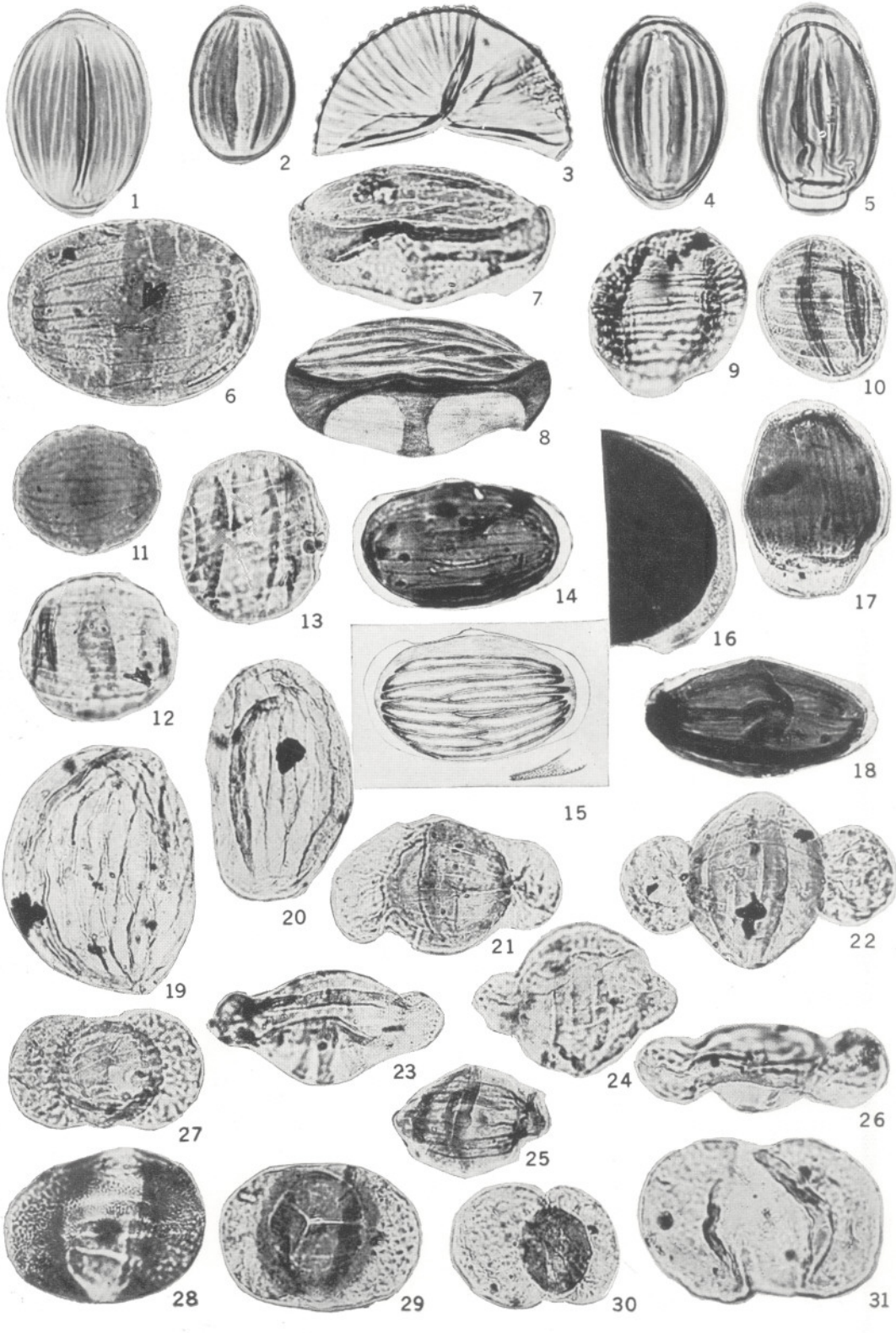
10. *Vittatina* sp. B showing the wide proximal costae which are finely foveolate, and the short proximal gable-shaped aperture.

11-13. *Vittatina foveolata* sp. nov. Fig. 12 is the holotype and Fig. 11 and 13 are paratype specimens. This taxon is broadly oval to somewhat elliptical in proximo-distal view possessing 8 to 12 costae which are coarsely foveolate. A short crescent-shaped proximal aperture is present in the center of Fig. 12. The distal median band shows in Fig. 11.

14-18. *Costapollenites ellipticus* gen. and sp. nov. Fig. 14 is the holotype in proximal view. The body is very dark brown with proximal costae and alternating grooves, proximal monolete aperture, and bladders which are widest at the ends of the grain and encircle the body at the equator of the grain. Fig. 15 is a drawing of the holotype specimen. The internal bladder ornamentation is depicted in the insert, and the oil immersion photomicrograph, Fig. 16, shows a portion of the bladder of the holotype specimen greatly enlarged. Figs. 17 and 18 are paratype specimens. Fig. 17 is a distal view which shows the median distal band, a crescent-shaped aperture from the proximal side of the grain, and the bladder ornamentation covering the distal surface of the grain.

19-20. *Schizaeoisporites microrugosus* sp. nov. Fig. 19 is the holotype specimen and Fig. 20 a paratype specimen; both show the characteristic ridges.

21-26. *Hamiapollenites perisporites* (Jizba) comb. nov. These specimens illustrate the degree of variation in size, shape, and number of transverse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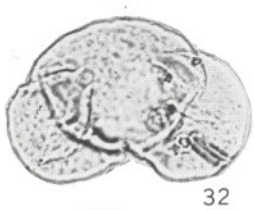
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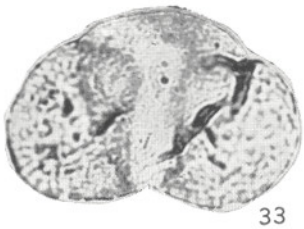
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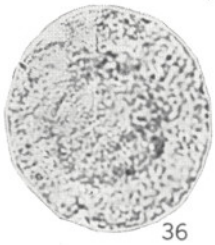
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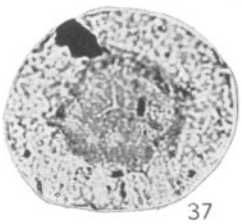
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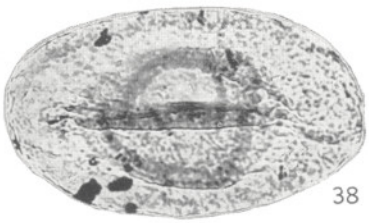
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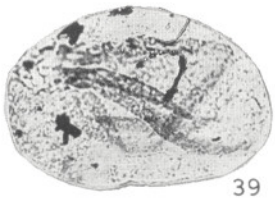
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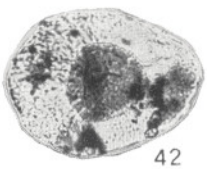
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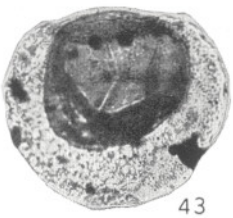
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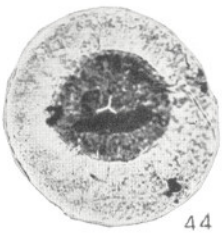
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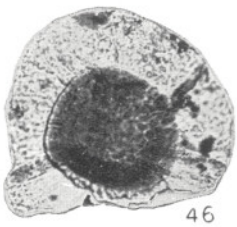
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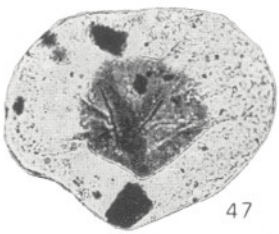
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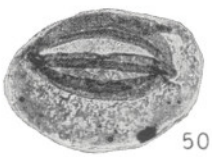
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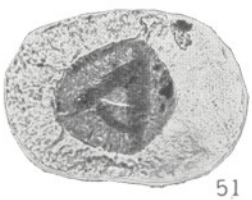
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bands. Figs. 23 and 26 are equatorial views and show that the bladders are not distally inclined. Three transverse bands are present in Fig. 23, and One in Fig. 26.

27. *Striatites splendens* (al. *S. richteri* Jizba, 1962) sp. nov.

28. *Striatites* cf. *S. marginalis* Klaus, 1963.

29. *Complexisporites polymorphus* Jizba, 1962.

30. *Platysaccus saarensis* (Bharadwaj) Jizba, 1962.

31. *Alisporites* sp.

PLATE 2

(*Figs.* 32-37 *shown at about* × 500, *Figs.* 38-53 *at about* × 250)

32-33. *Pityosporites communis* sp. nov. The holotype specimen, Fig. 32, in equatorial view shows the characteristic thin proximal cap and distinctly bisaccate distally inclined bladders. Fig. 33, a paratype, is a slightly oblique equatorial view.

34. *Vesicaspora* sp. showing the thin equatorial connection of the bladders.

35. *Sulcatisporites* cf. *S. splendens* Leschik, 1956.

36-37. *Wilsonites ephemerus* sp. nov. Both specimens show the relatively small size for the genus, vague appearance of the body, trilete aperture, and coarse internal bladder reticulation. Fig. 36 is the holotype, Fig. 37 the paratype specimen.

38-40. *Florinites elongatus* sp. nov. Fig. 38 is the holotype specimen in proximo-distal view. Folding of the bladder is not uncommon and a prominent fold is shown in the long axis of the specimen. Figs. 39 and 40 are of paratype specimens in equatorial view and illustrate that a portion of the body is free of the bladder on the distal side of each of these specimens.

41. *Strotersporites* sp. is rare in our assemblage and this is the only good specimen observed.

42. *Endosporites* sp. A has short trilete rays.

43. *Endosporites* sp. B has long trilete rays.

44. *Nuskoisporites* cf. *N. dulhuntyi* Potonié and Klaus, 1954.

45-47. *Nuskoisporites* cf. *N. crenulatus* Wilson, 1962.

48 & 51. *Vestigisporites* cf. *V. methoris* Hart, 1960.

49. *Potonieisporites* ? sp.

50. *Potonieisporites grandis* sp. nov. holotype specimen showing the monolete aperture extending the length of the body and prominent lips.

52-53. *Potonieisporites grandis* sp. nov. paratype specimens.