AN OPAL PHYTOLITH AND PALYNOMORPH STUDY OF EXTANT AND FOSSIL SOILS IN KANSAS

by

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Diploma, Swiss Federal Institute of Technology, 1980

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

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ACKNOWLEDGEMENTS

I am deeply grateful to Dr. A. Spencer Tomb for his assistance and encouragement throughout this study. I will always remember the severe case of poison ivy he caught in support of my research. I am indebted to Dr. Page C. Twiss for his help with the phytolith study. I would also like to thank Drs. Ted M. Barkley and Clenton E. Owensby for their assistance and helpful suggestions relating to this study. I wish to thank these men for serving on my Advisory Committee.

I am grateful to Dr. William C. Elsik who let me use his unpublished manuscripts, and I would like to thank him and Dr. Charles Kramer for their help with the identification of the fungal spores.

To Dr. Arthur D. Dayton, I wish to express my gratitude for his help with the statistical analysis of my data.

I also wish to thank Regina Martin, Mark J. Curry, and Craig C. Freeman for their assistance in various aspects of assembling this thesis.

The research was supported by funds from the Kansas State Agricultural Experiment Station, and I acknowledge the Kansas State University for the scholarship I received and that made my stay in Manhattan possible.

INTRODUCTION

A study of opal phytoliths, pollen grains and fungal spores in soils was undertaken to correlate phytolith and palynomorph deposition and local vegetation.

The hypothesis that opal phytolith analysis combined with palynomorph analysis could be an important tool in the reconstruction of vegetational history was tested through application of results from extant soils to the study of a paleosol.

The thesis is written in form of two papers that will be submitted to the American Journal of Botany. The first paper furnishes the correlation between phytolith deposition and local vegetation. It illustrates the existing phytoliths and their classification. The second paper furnishes the correlation between palynomorph deposition and local vegetation. It illustrates the existing fungal spore and pollen species. Additional materials are included in the appendices.

OPAL PHYTOLITHS IN EXTANT AND FOSSIL SOILS IN KANSAS

ABSTRACT - Soils under three plant communities (shortgrass prairie, tallgrass prairie and a deciduous forest) were analyzed for opal phytoliths. These data were used to correlate vegetation type with phytolith deposition. The results were applied to the study of a paleosol to determine the vegetation prior to burial. Statistical analysis of the data showed that the phytolith composition differs significantly among the three extant soils, and that the phytolith composition reflects the local vegetation. The paleosol yield more opal phytolith than the extant soils, but showed the same distribution pattern as the extant soil under the woodland.

INTRODUCTION

One of the most diagnostic features of opal phytoliths is their external morphology. Shape and size of silica deposits are controlled by the plant cells in which they are secreted, and therefore they can be characteristic of taxonomic groups. Morphological descriptions and classifications are best developed for the phytoliths of the Gramineae (SMITHSON, 1958; METCALFE, 1960; PEASE, 1967; DORMAAR & LUTWICK, 1969; TWISS et al., 1969; BLACKMAN, 1971; ROVNER, 1971; TWISS, 1978, 1980). Descriptions of dicot phytoliths, especially those from decidous trees, can be found in WILDING & DREES (1968), ROVNER (1971), and WILDING et al., (1977). The opal phytoliths of Pinaceae have been studied by NORGREN (1973) and KLEIN & GEIS (1978).

Soil phytolith studies have been made in Great Britain (SMITHSON, 1958), Australia (BAKER, 1959a; 1959b), Canada (DORMAAR & LUTWICK, 1969), and in the United States (BEAVERS & STEPHEN, 1958; JONES & BEAVERS, 1964a; 1964b; WITTY & KNOX, 1964; SUESS, 1966; PEASE, 1967; WILDING & DREES, 1968; TWISS et al., 1969; NORGREN, 1973; TWISS, 1980). These studies conclude that the occurrence of phytoliths in soils provide information relating to the vegetational history. The dominance of any particular phytolith type in the soil is evidently a reflection of a local dominant group of plants. Assignment of opal phytoliths to a given plant community has been accomplished by SUESS (1966), TWISS et al., (1969), and TWISS (1980).

This study of opal phytoliths correlated phytolith deposition with different vegetation types. The hypothesis that opal phytolith analysis of soils could be an important tool in reconstruction of the vegetational history in grasslands was tested by applying the results from extant soils with well documented vegetation to a paleosol.

MATERIALS AND METHODS

SOIL TYPE AND COLLECTION - The soil samples for the western Kansas shortgrass prairie were taken from the Harney silt loam in Ellis county. The samples for the tallgrass prairie and the woodland site were taken from the Tully silt loam in Riley and Geary counties, Kansas. The paleosol sample was from the bank of Elbo Creek, Pottawatomie county, Kansas. Table 1 contains the locations and collection dates. An approximately 25 cm^3 core of soil through the A-horizon to the top of the B-horizon was taken from each locality. The paleosol sample was taken from the top of the buried soil, 150 cm below the surface.

PHYTOLITH EXTRACTION - The extraction of opal phytoliths from the soils was accomplished using a modification of the method of ROVNER (1971). The method used can be summarized as follows: Seven g soil was soaked for 12 hours in 4 g sodium metaphosphate $[(NaPO_3)_{13}]$ and 100 ml distilled water. The samples were centrifuged (IEC centrifuge, model HNS), the liquid discarded and the residue washed 5 times with distilled water. About 1.5 g wet residue was then placed in a 15 ml centrifuge tube and 10 ml HCl (10%) was added. This mixture was slightly heated in a warm water bath (45°C). The samples were centrifuged for 30 minutes at 1000 rpm. The supernatant was discarded and the sediment was washed 3 times with distilled water. Samples were then placed in a 60°C oven for drying. Samples were mashed through a 200 µm mesh copper screen. Ten ml heavy liquid mixture with a specific gravity of 2.3 (tetrabromoethane and absolute ethanol) was added to each sample and thoroughly mixed. The samples were centrifuged for 30 minutes at 1000 rpm. The supernatant containing the opal phytoliths were decanted and

10 ml heavy liquid was added and the step repeated. The supernatants containing the phytoliths were pooled, the specific gravity was reduced to 1.5 with absolute ethanol, and the mixture was centrifuged. The supernatant was filtered and recycled. Absolute ethanol was added to the residue, mixed well and centrifuged. The supernatant was removed with a pipette. This step was repeated three times and the samples were dried in a 60°C oven. The dried sediment was then put in 1-dram vials for storage.

PHYTOLITH ANALYSIS - For studies with the light microscope, the phytoliths were mounted in Canada Balsam. Two drops of Canada Balsam were placed on a clean slide on a slide warmer, the phytolith residue dusted on it, and mixed with it. The coverslips were placed directly on the drop and the slide left on the slide warmer until the mount was solidified. The slides were removed, sealed with nailpolish and labeled. Three slides of each sample were examined with a bright field microscope using a magnification of 500X. Each slide was crossed three times and each opal phytolith was counted, approximately 200 per slide. The phytoliths were grouped into 5 classes (TWISS, et al., 1969) and the abundance of each class was recorded (Fig. 49).

The counts were statistically treated with an analysis of variance. A sqaure root transformation ($\sqrt{C}$ + $\sqrt{C+1}$) was used to stabilize the variances. The differences within classes and within sites were determined on the transformed means, but were recorded for the means of the counts (Table 2). The differences are significant at the 5% level (SNEDECOR & COCHRAN, 1967).

For examination with the scanning electron microscope, double-sided adhesive tape was mounted on standard specimen stubs, and the phytolith residue was dusted on the tape. The stubs were vapor coated (20-40 nm thick) with gold-palladium while rotating at various angles with respect to the vapor source. The phytoliths were examined at low (1000x, 2000x, 3000x) and

at high magnifications (50,000x) in a ETEC autoscan. The high magnification was used to recognize the distinct, granular surface features of plant opal. Slides are deposited in the Pollen Reference Collection of the Kansas State University Herbarium.

Table 1. Location and collection date (SG: shortgrass prairie; TG: tallgrass prairie; WL: woodland site; PS: paleosol.

SAMPLE	LOCALITY	DATE
SG 1 SG 2 SG 3	Fort Hays Branch Experiment Station, Ellis County, Kansas R 18 W, T 13 S, SW 1/4, Sec. 5	7-10-1980
TG 1	Range Research Unit, pasture 16, Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
TG 2	Range Research Unit, pasture 2 Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
TG 3	Konza Prairie Research Natural Area, Original Konza Prairie, Geary County, Kansas. R 8 E, T 12 S, NW 1/4, Sec. 30	7-25-1980
WL 1	Range Research Unit, pasture 16 Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
WL 2	Konza Prairie Research Natural Area, Kings Creek, South Bank, Riley County, Kansas. R 7 E, T 11 S, SW 1/4, Sec. 12	7-2-1980
WL 3	Konza Prairie Research Natural Area, Kings Creek, North Bank, Riley County, Kansas. R 7 E, T 11 S, SW 1/4, Sec. 12	
PS	Elbo Creek, South Bank, Pottawatomie County, Kansas. R 8 E, T 10 S, NW 1/4, Sec. 10	9-6-1979

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RESULTS

The distribution of phytoliths was examined and classified using the 5-class system of TWISS et al. (1969). The chloridoid class (Fig. 1-6) contains two types of saddle-shaped bodies. These forms are produced by the genera Buchloe, Bouteloua, Eragrostis, and Chloris which are characteristic grasses of the shortgrass prairie. The panicoid class (Fig. 7-13) contains several types that are variations of dumbbells and crosses. These types are produced by the genera Andropogon and Panicum which are typically tallgrass prairie grasses, but also by the cereal grasses Sorghum and Zea. The festucoid class (Fig. 14-18) contains circular, elliptical and rectangular forms. These forms are produced by the genera Elymus, Muhlenbergia, Festuca, and Avena. These are grasses of forest/grassland margins and more mesic sites. The elongate class (Fig. 19-24) contains rod-shaped forms with smooth or sinuous outlines. These types are produced by all grasses and therefore do not have any habitat classification value. The unclassified forms (Fig. 25-30) contain all the phytoliths which could not be put in any of the four classes described above. These forms could be from dicots, monocots other than grasses, and broken and partially decomposed phytoliths.

SEM micrographs (Fig. 31-48) show the morphological variations and the typical granular surface features of plant opal.

The distribution of opal phytoliths within the sites is shown in Fig. 49. All the sites had characteristic distribution pattern, and were characterized by using chloridoid, panicoid and festucoid forms. The shortgrass prairie was characterized by the abundance of chloridoid forms, followed by panicoid and festucoid forms. The tallgrass prairie was described by an abundance of panicoid forms, followed by chloridoid and festucoid forms. The woodland site showed an abundance of festucoid and chloridoid forms, and only a few panicoid ones. The paleosol showed the same pattern as the woodland site.

The comparison of the means of the counts within the different sites and within the different classes of opal phytoliths is shown in Table 2. In the chloridoid class, the shortgrass prairie was significantly different from the tallgrass prairie and woodland site. In the panicoid class and festucoid class, the woodland site differed significantly from the grassland sites. Elongate and unclassified forms did not show significant differences among the sites. The paleosol corresponded with the shortgrass prairie in the chloridoid class, with the woodland site in the elongate and unclassified forms, and differed from all sites in the panicoid class.

Within site, the analysis of variance showed, that the chloridoid, panicoid and festucoid classes were significantly different from each other in the shortgrass prairie. In the tallgrass prairie the panicoid class was significantly different from the festucoid class, but the chloridoid class did not differ significantly from either panicoid or festucoid class. In the woodland site, chloridoid and festucoid class differed significantly from the panicoid class. The same was true for the paleosol.

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Table 2. Distribution of opal phytoliths. Numbers are means of nine counts in SG, TG, and WL, and of 3 counts in PS. Means followed by the same letter are not significantly different at the 0.05 level within a class (rows: a, b) or within a site (columns: x, y). All the others are significantly different.

CLASS \ SITE	SG	TG	WL	PS
Chloridoid	49 a x	28 bxy	28 bx	54a x
Panicoid	28a	35a x	3	16
Festucoid	15a	21a y	31 x	55 x
Elongate	45a x	50a	51ab	71 bx
Unclassified	75a	77a	92ab	113 b

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Fig. 1 - 30: LM micrographs of the different phytolith classes. The micrometer bar is valid for figures 1 - 19, 22, 25 - 30. For figures 20, 21, 23, 24 the 1 µm bar has to be used.

Fig. 1 - 6: Chloridoid class
1, 4: rotated saddles
2, 3, 5: saddles

Fig. 7 - 13: Panicoid class
7: regular, complex dumbbell
8, 9, 10: dumbbell
11: cross
12, 13: side view of dumbbells

Fig. 14 - 18: Festucoid class
14, 15: rectangular
16, 18: elliptical

Fig. 19 - 24: Elongate class
19, 20: sinuous outlines
21, 23: spiny
22, 24: smooth outlines

Fig. 25 - 30: Unclassified forms

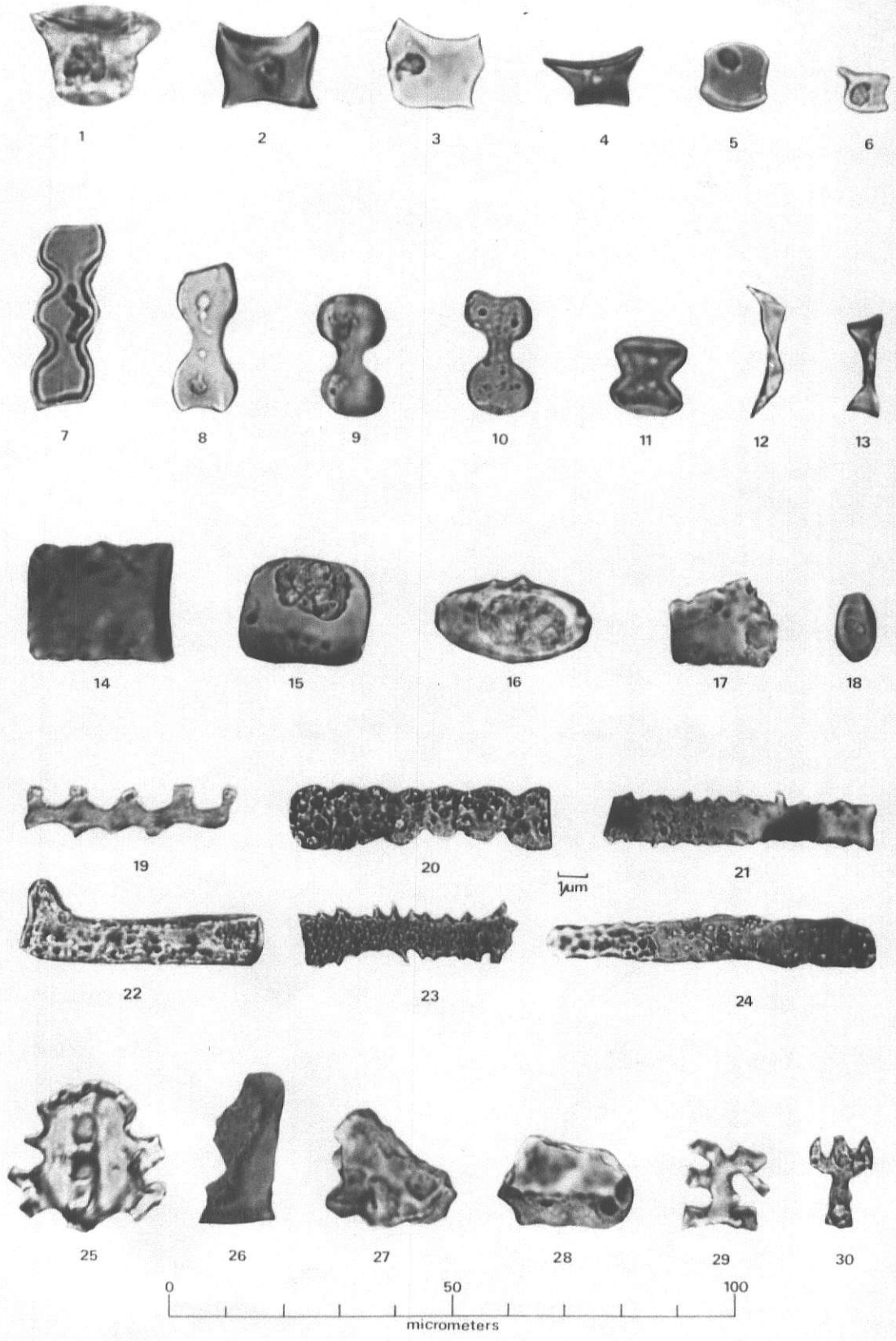
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Fig. 31 - 36: SEM micrographs of opal phytoliths.
Lines in each figure equal 10 μm.

Fig. 31: Panicoid form from tallgrass prairie site

Fig. 32: Festucoid form from woodland site

Fig. 33: Elongate form from shortgrass prairie site

Fig. 34: Elongate form from woodland site

Fig. 35: Unclassified form from shortgrass prairie site

Fig. 36: Unclassified form from tallgrass prairie site

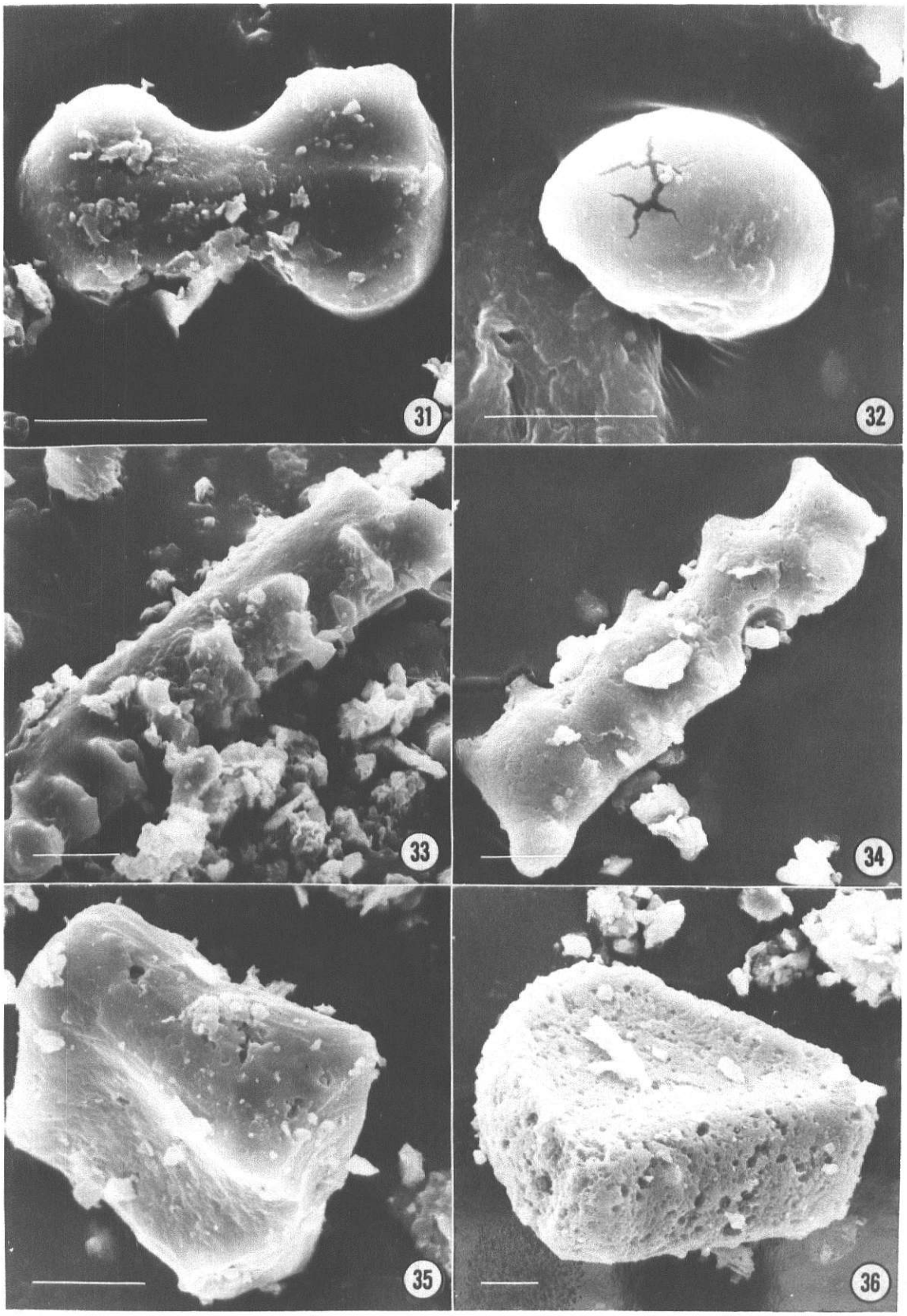
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Fig. 37 - 48: SEM micrographs of opal phytoliths.
Lines in figures 37, 40, 41, 44, 45, 48 equal 1 μm.
Lines in figures 38, 39, 42, 43, 46, 47 equal 0.1 μm.

Fig. 37: Phytolith from leaf if Bouteloua curtipendula (Michx.) Torr.

Fig. 38: High magnification of figure 37, showing the granular surface feature of plant opal

Fig. 39: High magnification of figure 40, showing the granular surface feature of plant opal

Fig. 40: Phytolith from root of Bouteloua curtipendula (Michx.) Torr.

Fig. 41: Unclassified form from woodland site

Fig. 42: High magnification of figure 41, showing the granular surface feature of plant opal

Fig. 43: High magnification of figure 44, showing the granular surface feature of plant opal

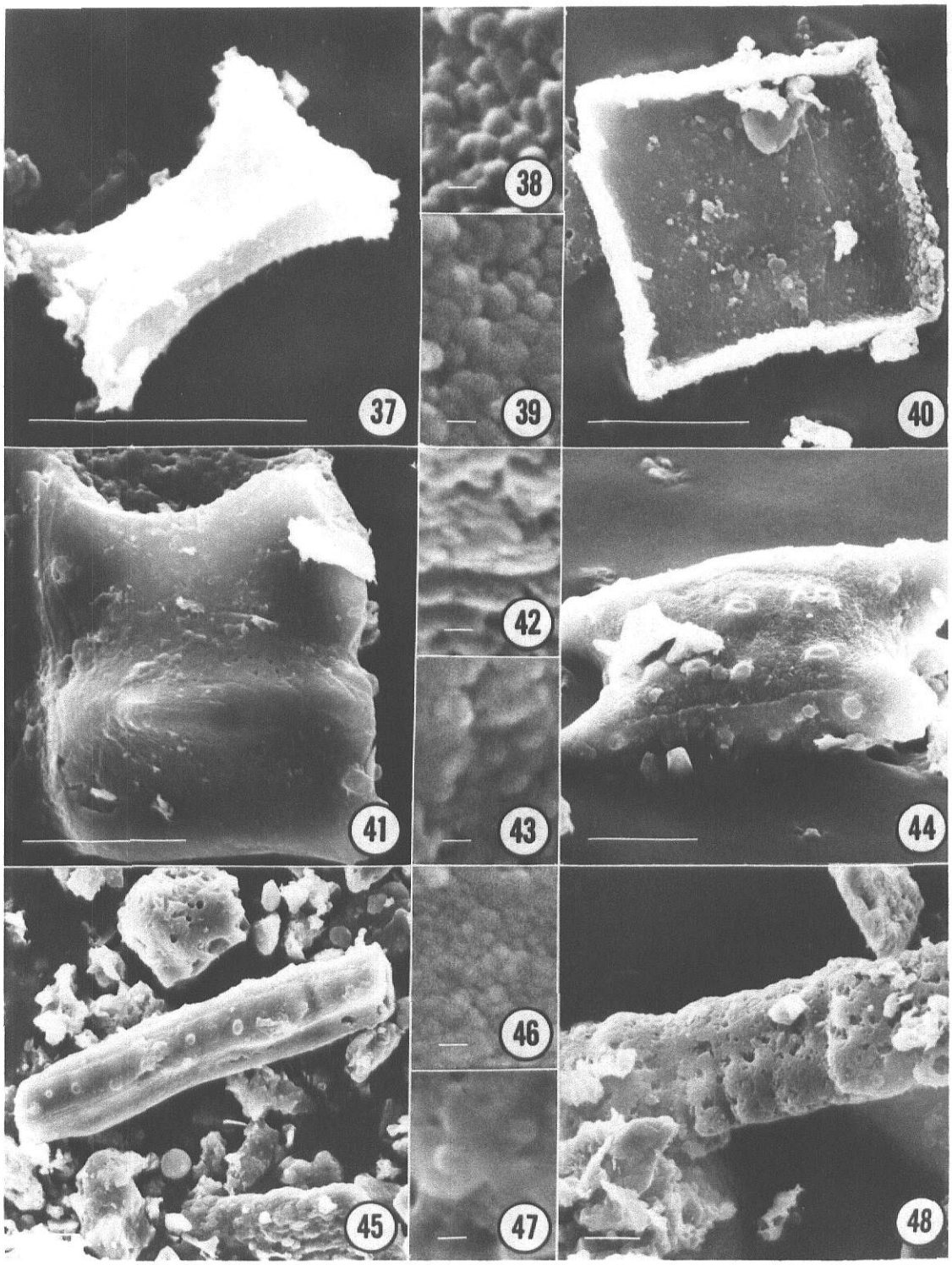
Fig. 44: Unclassified form - Interstomatal opal from woodland site

Fig. 45: Elongate form from woodland site

Fig. 46: High magnification of figure 45, showing the granular surface feature of plant opal

Fig. 47: High magnification of figure 48, showing the granular surface feature of plant opal

Fig. 48: Elongate form from tallgrass prairie site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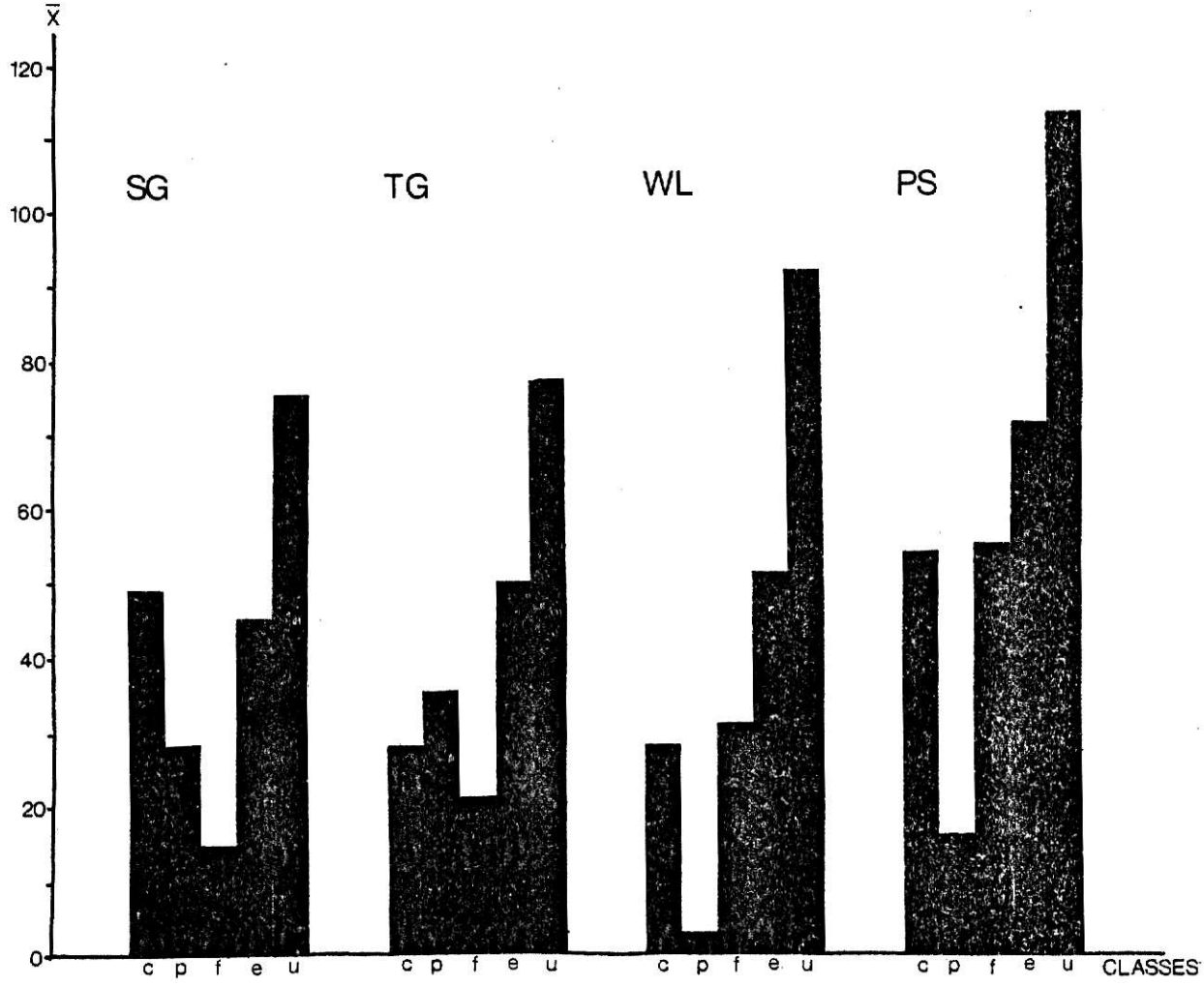

Fig. 49: Distribution patterns of opal phytoliths within sites (SG, TG, WL, PS). The vertical axis indicates means of the counts. (c: chloridoid; p: panicoid; f: festucoid; e: elongate; u: unclassified.

DISCUSSION

The results showed that elongate and unclassified opal phytoliths were not significantly different among the three extant soils (Table 2), and therefore they do not have a value in classifying habitats. The elongate forms are characteristic of the grasses in general (TWISS, 1978), and the unclassified forms probably originate from dicots, or monocots other than grasses, or are broken or partly decomposed opal phytoliths.

Excluding those two types, the opal phytolith assemblage of the extant soils is a reflection of the local vegetation. The abundance of chloridoid types in the shortgrass prairie site mirrors the typical shortgrass prairie grasses (Buchloe, Bouteloua). The non-significant difference in the panicoid class between tallgrass and shortgrass prairie may be partly due to transport from mixed prairie which is adjacent to shortgrass areas. Panicoid opal phytoliths are also produced by the cereal grasses Sorghum and Zea, and these grasses are cultivated near the collection site. Major sources of festucoid phytoliths in the shortgrass prairie area were likely annual bromes and adjacent wheat fields. The soil under the tallgrass prairie showed an abundance of panicoid types which reflects the typical tallgrass prairie grasses (e.g. Andropogon). Those observations agree with SUESS (1966) and TWISS et al. (1969) who showed that soils under native tallgrass prairie yield mostly panicoid and irregular types. The observation also agree with TWISS (1978) who showed that the cereal grasses in this region contribute panicoid (Zea, Sorghum) and festucoid (Triticum) forms to the phytolith assemblage. The chloridoid phytoliths are the smallest forms, and therefore they may be more easily transported than other forms. That may be a reason for the appearance of numerous chloridoid forms in the tallgrass prairie and woodland sites. The abundance of festucoid forms in the woodland site reflects the more mesic

grasses (Elymus, Festuca, Muhlenbergia). The high number of unclassified forms in the woodland site suggests that other taxa, such as deciduous trees may contribute to the phytolith assemblage of the soil.

Roots of grasses produce uniform, rectangular phytoliths (PEASE, 1967). Root phytoliths may not always be distinguishable and may inadvertently be included in the festucoid class which could lead to a misrepresentation of festucoid grass frequency.

The results show that phytoliths from soils can be used to reconstruct vegetation types. The opal phytoliths allow a distinction between forest and grassland vegetation on one hand, and between tallgrass and shortgrass prairie on the other (Fig. 49).

Phytoliths from a paleosol can be used to reconstruct the environment of the site prior to burial. The phytoliths of the paleosol from Elbo Creek show the same distribution pattern as the ones from the extant woodland site, but in the paleosol the number of phytoliths is higher (Fig. 49). The significant increase in the unclassified forms may be due to more broken and decomposed phytoliths in the paleosol. The increase in grass phytoliths suggests that more grasses occurred than in the extant woodlands. OWENSBY (pers. comm.) postulated that it could have been a cool-season grassland such as now occur in North Dakota, composed of Agropyron, Stipa, Koeleria, and Bouteloua gracilis (H.B.K) Griffiths. Agropyron and Koeleria produce festucoid forms, Bouteloua gracilis (H.B.K.) Griffiths produces chloridoid forms, and Stipa produces panicoid forms. The analysis of the phytoliths in the paleosol showed an abundance of grass phytoliths which may indicate a grassland, but the distribution pattern of the phytoliths corresponds with the pattern of the extant woodland. These results suggest that the vegetation prior to burial was different from the present day vegetation on the

extant soils. More information on the paleosol must be collected in order to obtain an accurate reconstruction of the vegetation.

The statistical analyses showed that the mean total phytolith number among the three counted slides and among the three localities within the same vegetation type were not significantly different. In future soil phytolith studies, fewer samples can be used without a decrease in accuracy.

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PALYNOMORPHS IN EXTANT AND FOSSIL SOILS IN KANSAS

ABSTRACT - Soils from three plant communities (shorgrass prairie, tallgrass prairie and a deciduous forest) were analyzed for fungal spores and pollen grains. These data were used to correlate vegetation type with palynomorph deposition. The results were applied to the study of a paleosol to determine the vegetation and ecological conditions prior to burial. Pollen analysis distinguished woodland sites from the prairies because of abundance of easily recognized pollen of woody plants. The paleosol yielded a pollen composition different from the three examined extant soils.

INTRODUCTION

Stratigraphic palynological study of lake and bog samples is the most useful tool in the determination of vegetational history. The number of suitable sites for pollen deposition and preservation in the Great Plains is very small and therefore the information about the vegetational history of the region is fragmentary. An overview of what is known of the Pleistocene vegetational history of the Great Plains is given by WRIGHT (1970). Because suitable sediments for pollen analysis in the Great Plains are usually unavailable, careful studies of soil and paleosol palynomorphs could add significantly to the understanding of the past history.

In early pollen analysis, soils received little attention because it was assumed that pollen would be broken down by microbes, or if they survived, they would be mixed by the activities of soil organisms and could not be correctly interpreted. But ERDTMAN (1943), DIMBLEBY (1957), WELTEN (1958), and HAVINGA (1963) demonstrated that soils contain considerable amounts of pollen. The pollen preservation in soils has been investigated extensively by HAVINGA (1967a, 1967b, 1971). Also, problems of pollen movement were examined (BURGES, 1950; WELTEN, 1958; DIMBLEBY, 1957, 1961; RAY, 1959; HAVINGA, 1974). Assignment of pollen deposition to local vegetation has been made by WELTEN (1950), LICHTI-FEREDOVICH & RICHTIE (1965), and SALGADO-LABOURIAU (1979).

This study correlated pollen deposition with different vegetation types. The results were applied to the study of a paleosol.

Conditions favorable for the preservation of pollen are favorable for preservation of fungal spores (WOLF, 1966). Some fungi are parasitic on higher plants, and therefore certain fungal spores can be an indicator for

certain vegetation types. Despite the significance of fungal spores, only a few authors (WOLF, 1966; GEEL, 1972; ELSIK, 1976) made an effort to record and to identify fungal spores. In this study, fungal spores were recorded, and an attempt was made to classify them, using the method by ELSIK (in prep.).

MATERIALS AND METHODS

SOIL TYPE AND COLLECTION - The soil samples for the western Kansas shortgrass prairie were taken from the Harney silt loam in Ellis County. The samples for the tallgrass prairie and the woodland area were taken from the Tully silt loam in Riley and Geary Counties, Kansas. The paleosol sample was from the bank of Elbo Creek, Pottawatomie County, Kansas. Table 1 contains the locations and collection dates. An approximately 25 cm^3 core of soil through the A-horizon to the top of the B-horizon was taken from each locality. The paleosol sample was taken from the top of the buried soil, 150 cm below surface.

POLLEN AND SPORE EXTRACTION - The extraction of pollen and spores was first done after the usual preparation procedures described by DOHER (1965). The technique yielded few pollen grains, and therefore the sample size was increased and treated after the pollen extraction procedures of JOHNSON (1980). About 1.5 kg soil of each sample was placed in a 10 liter plastic bucket. About 1.5 liters HCl (conc.) was added and the mixture was thoroughly stirred, until all carbonates were digested. After 4 hours, 200 ml more HCl was added to make sure that no more carbonates existed. Then water, ca. one half of the volume of the sediment-acid mixture, was added and mixed well. Immediately afterwards the mixture was decanted into a clean bucket. The coarse sediment was discarded. The mixing and decanting was repeated two more times with a 30- and 60-second settling time prior to decanting. Each time the decantant containing the suspended pollen was saved, and the coarse sediment which settled out was discarded. The remaining mixture, containing the pollen and spores, was sieved through a 0.417 mm mesh copper sieve into a clean bucket. The sediment was washed through the sieve with distilled water. This step eliminated any large pieces, especially plant material.

The bucket was then filled with distilled water to about 6 cm below the rim, covered with plastic film, and left undistrubed overnight to settle. The next day, the supernatant liquid was siphoned off without disturbing any of the sediment. The sediment was washed into 250 ml centrifuge tubes, centrifuged (International centrifuge: Size 2, Model S) for 10 minutes at 2000 rpm and the supernatant discarded. Heavy liquid (Zincbromide with a specific gravity of 1.95) was added to the sediment and the mixture stirred well. The remaining aggregates were broken by an ultrasonic cleaner. The mixture was then centrifuged for 5 minutes at 2000 rpm. The supernatant, containing the floated pollen and spores was decanted in 50 ml centrifuge tubes. The specific gravity was reduced by adding diluted HCl. The mixture was centrifuged to precipitate the pollen and other organics. The supernatant was decanted and recycled. The residue pellet was washed four times with distilled water and then stored in 70% ethanol in 1 dram-vials.

Half of the pollen residue was acetolyzed according to the ERDTMAN method (1960) as revised by FAEGRI & IVERSEN (1964).

POLLEN AND SPORE ANALYSIS - For the examination with the light microscope, the pollen grains and spores were mounted in glycerine jelly. Approximately 3 mm^3 of glycerine jelly was placed on a slide on a slide warmer. Air was bubbled in the vials to stir up the residue and two drops of the pollen-ethanol mixture were placed on the jelly, mixed well and coverslipped. The slides were sealed with nailpolish and labeled. The slides were examined with a bright field microscope using a magnification of 450x. For each sample one acetolyzed and two non-acetolyzed slides were examined. Each slide was crossed ten times and each pollen grain and spore was recorded, approximately 400 per slide. The abundance of each type is shown in Figures 104-106.

The counts were statistically treated with an analysis of variance. A square root transformation ($\sqrt{C} + \sqrt{C+1}$) was used to stabilize the variances. The difference within classes and within sites were determined on the transformed means, but were recorded for the means of the counts (Tables 2 and 3). The differences are significant at the 5% level (SNEDECOR & COCHRAN, 1967).

For examination with the scanning electron microscope, round coverslips were glued on standard specimen stubs with silver conducting pain and the residue was placed on the coverslips and air dried. The stubs were vapor coated with gold-palladium (20 - 40 nm thick) while rotating at various angles with respect to the vapor source. The pollen grains and spores were examined at low magnifications (1000x, 2000x, 3000x) and 10,000x in a ETEC autoscan to study sculptural details. Slides are deposited in the Pollen Reference Collection of the Kansas State University Herbarium.

Table 1. Location and collection date (SG: shortgrass prairie; TG: tallgrass prairie; WL: woodland site; PS: paleosol.

SAMPLE	LOCALITY	DATE
SG 1 SG 2 SG 3	Fort Hays Branch Experiment Station, Ellis County, Kansas R 18 W, T 13 S, SW 1/4, Sec. 5	7-10-1980
TG 1	Range Research Unit, pasture 16, Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
TG 2	Range Research Unit, pasture 2 Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
TG 3	Konza Prairie Research Natural Area, Original Konza Prairie, Geary County, Kansas. R 8 E, T 12 S, NW 1/4, Sec. 30	7-25-1980
WL 1	Range Research Unit, pasture 16 Kansas State University, Riley County, Kansas. R 7 E, T 9 S, NW 1/4, Sec. 27	7-1-1980
WL 2	Konza Prairie Research Natural Area, Kings Creek, South Bank, Riley County, Kansas. R 7 E, T 11 S, SW 1/4, Sec. 12	7-2-1980
WL 3	Konza Prairie Research Natural Area, Kings Creek, North Bank, Riley County, Kansas. R 7 E, T 11 S, SW 1/4, Sec. 12	
PS	Elbo Creek, South Bank, Pottawatomie County, Kansas. R 8 E, T 10 S, NW 1/4, Sec. 10	9-6-1979

RESULTS

Sixty pollen species and 26 fungal spore species were recognized from the different sites. Only 26 pollen species and 9 fungal spores species showed a frequency that could be analyzed statistically. Many of the types could not be taxonomically identified, and they are described as "unknown".

LM (Fig. 1 -58, 83 - 94) and SEM (Fig. 59 - 82, 95 - 103) micrographs illustrate the pollen grains and fungal spores used in the description of the sites. Also Carya (Fig. 25), Betula (Fig. 30, 31), Corylus (Fig. 36), and some unknown, but very distinct, pollen grains (Fig. 51, 57) are included.

The comparison of the means within the pollen and fungal spores species is shown in Table 2 for the pollen grains, and in Table 3 for the fungal spores.

POLLEN GRAINS - The shortgrass prairie was characterized by an abundance of pollen species 1 (Gramineae), 6, 15 (Ambrosia), 23 (long spine Compositae), and 24 (Fig. 104). All these pollen species were statistically significant different from the other sites (Table 2). The tallgrass prairie showed an abundance of pollen species 1 (Gramineae), 2, 7, 8, and 12 (Fig. 104), but pollen species 7 and 8 were not significantly different from the shortgrass prairie, and pollen species 1 (Gramineae) not from the woodland site (Table 2). The woodland site was dominated by Quercus pollen (Fig. 104). The paleosol was characterized by pollen species 1 (Gramineae), 21 (Chenopodiaceae/ Amaranthaceae) and 26 (Fig. 105). All these pollen species were significantly different from the other sites (Table 2).

Among the pollen species which occurred in all sites, significant difference between shortgrass and tallgrass prairie was found in 6 pollen species (1, 2, 6, 10, 15, 20), between shortgrass prairie and woodland site

in 6 pollen species (1, 8, 13, 15, 17, 20), and between tallgrass prairie and woodland site in 6 pollen species (2, 6, 7, 8, 10, 13), also. Only 9 out of the 26 pollen species were found in the paleosol. From these, the same 5 pollen species (1, 2, 5, 21, 26) were different from or did not occur in shortgrass and tallgrass prairie, and 4 pollen species (1, 7, 21) differed from the woodland site.

FUNGAL SPORES - The shortgrass prairie was characterized by the abundance of 6 fungal spore types (1, 2, 3, 4, 6, 7), the tallgrass prairie by 4 (3, 4, 5, 6), and the woodland site by 3 fungal spore species (1, 4, 5), (Fig. 106). All the fungal spore species which occurred in the shortgrass and the tallgrass prairie were significantly different from each other, except for fungal spores species 6 (Table 3). Three fungal spore species (2, 3, 6) occurring in the woodland site, were different from the shortgrass prairie, and three fungal spore species (1, 3, 6) were different from the tallgrass prairie. In the paleosol, fungal spore species 9 was very abundant and did not occur in the other sites, except for one count in the woodland site. The other fungal spore species, if they occurred, did not show significant differences (Table 3).

Table 2: Distribution of pollen species. Numbers are means of nine counts in SG, TG, and WL, and of five counts in PS. All means within a pollen species are significantly different at the 0.05 level, except the ones followed by the same letter.

POLLEN SPECIES \ SITE	SG	TG	WL	PS
1: Gramineae (Fig. 47, 58, 59, 60)	55	18a	10a	126
2: Unknown - scabrate, inaperturate (Fig. 1, 2)	16a	48	10ab	4 b
3: Unknown - psilate, inaperturate, with thick exine (Fig. 43)	9a	13a	6a	8a
4: Unknown - psilate, inaperturate, with very thick exine (Fig. 38)	4a	6a	3a	0
5: Unknown - psilate, inaperturate (Fig. 1)	13a	13a	8ab	3 b
6: Unknown - psilate, inaperturate (Fig. 45, 55)	21	8a	4ab	0 b
7: Unknown - psilate, inaperturate, with secondary folds (Fig. 3, 15)	14ab	22 b	7a	18 b
8: Unknown - microechinate, inaperturate (Fig. 8, 14)	16a	23a	1 b	0 b
9: Unknown - echinate, inaperturate (Fig. 7)	7a	4a	0 b	1ab
10: Unknown - psilate or folded, inaperturate (Fig. 50)	4a	12	2a	0a
11: Unknown - scabrate, monocolpate	7a	10a	8a	0
12: Unknown - microverrucate, inaperturate (Fig. 5)	0a	23	0a	0a
13: Quercus (Fig. 27, 28, 29, 69)	5a	7a	39	0a
14: Unknown - psilate, inaperturate, with some content (Fig. 9)	0a	8 b	3 bc	0a c
15: Ambrosia - type (Fig. 17, 18, 21, 22, 63, 64)	20	3a	3a	0a
16: Unknown - verrucate, inaperturate (Fig. 42, 49)	0a	4	0a	0a

Table 2: Distribution of pollen species continued.

POLLEN SPECIES \ SITE	SG	TG	WL	PS
17: Unknown - aspidote, porate (Fig. 10, 12, 40)	10a	4ab	3 bc	0 c
18: Unknown - bacculate, inaperturate (Fig. 46, 80)	8a	7a	2a	2a
19: Unknown - scabrate, inaperturate (Fig. 11)	0a	8	1a	0a
20: Pinus (Fig. 56, 70)	9	2a	2a	0a
21: Chenopodiaceae/Amaranthaceae (Fig. 23, 24, 71)	4a	0a	1a	117
22: Unknown - psilate, inaperturate, cuplike (Fig. 79)	13	0a	0a	0a
23: Long spine Compositae (Fig. 19, 20, 62)	30	0a	0a	0a
24: Unknown - granulate, monoporate (Fig. 16)	41	0a	0a	0a
25: Euphorbiaceae (Fig. 41)	3	0a	0a	0a
26: Unknown - reticulate, tricolpate (Fig. 32, 34, 35, 65, 66, 67)	0a	0a	0a	746

Table 3. Distribution of fungal spores. Means within a fungal spore species which are not significantly different at the 0.05 level are followed by the same letter.

FUNGAL SPORE SPECIES \ SITE	SG	TG	WL	PS
1: Ascospore - monocellate, psilate, inaperaturate (Fig. 83)	25a	12	23a	0
2: Teliospore of a rust (Uromyces) (Fig. 86, 99)	19a	7 b	7 b	8ab
3: Vegetative sklerotia - multicellate, inaperaturate structure with irregular septation (Fig. 94, 96)	20	39	6a	3a
4: Teliospore - dicellate, psilate, diporate with pore chambers (Fig. 90, 91)	44a	30	37a	0
5: Smutspore - monocellate, echinate, inaperturate (Fig. 87, 88, 98)	5a	22 b	0	9ab
6: Unknown - monocellate, psilate, inaperturate (Fig. 84, 103)	24a	27a	12 b	22ab
7: Teliospore - dicellate, bacculate, inaperturate (Fig. 89)	23	0a	0a	0a
8: Hyphomycete phragmospore - tetracellate, psilate (Fig. 93)	7	0a	0a	0a
9: Unknown - monocellate, psilate, monoporate (Fig. 85)	0a	0a	1a	50

Fig. 1 - 26: LM micrographs of pollen grains

1, 2: Unknown - scabrate, inaperturate

3: Unknown - psilate, inaperturate, with secondary folds

4: Unknown - psilate, inaperturate

5: Unknown - verrucate, inaperturate

6: Unknown

7, 8: Unknown - echinate, inaperturate

10, 12: Unknown - aspidote, monoporate

11: Unknown - perforate, inaperturate

13: Unknown - scabrate, inaperturate

14: Unknown - echinate, inaperturate

15: Unknown - psilate, inaperturated, collapsed walls

16: Unknown - granulate, inaperturate

17, 18, 21, 22: Ambrosia - type

19, 20: Long spine Compositae

23, 24: Chenopodiaceae/Amaranthaceae

25: Carya

26: Unknown - gemmate, inaperturate

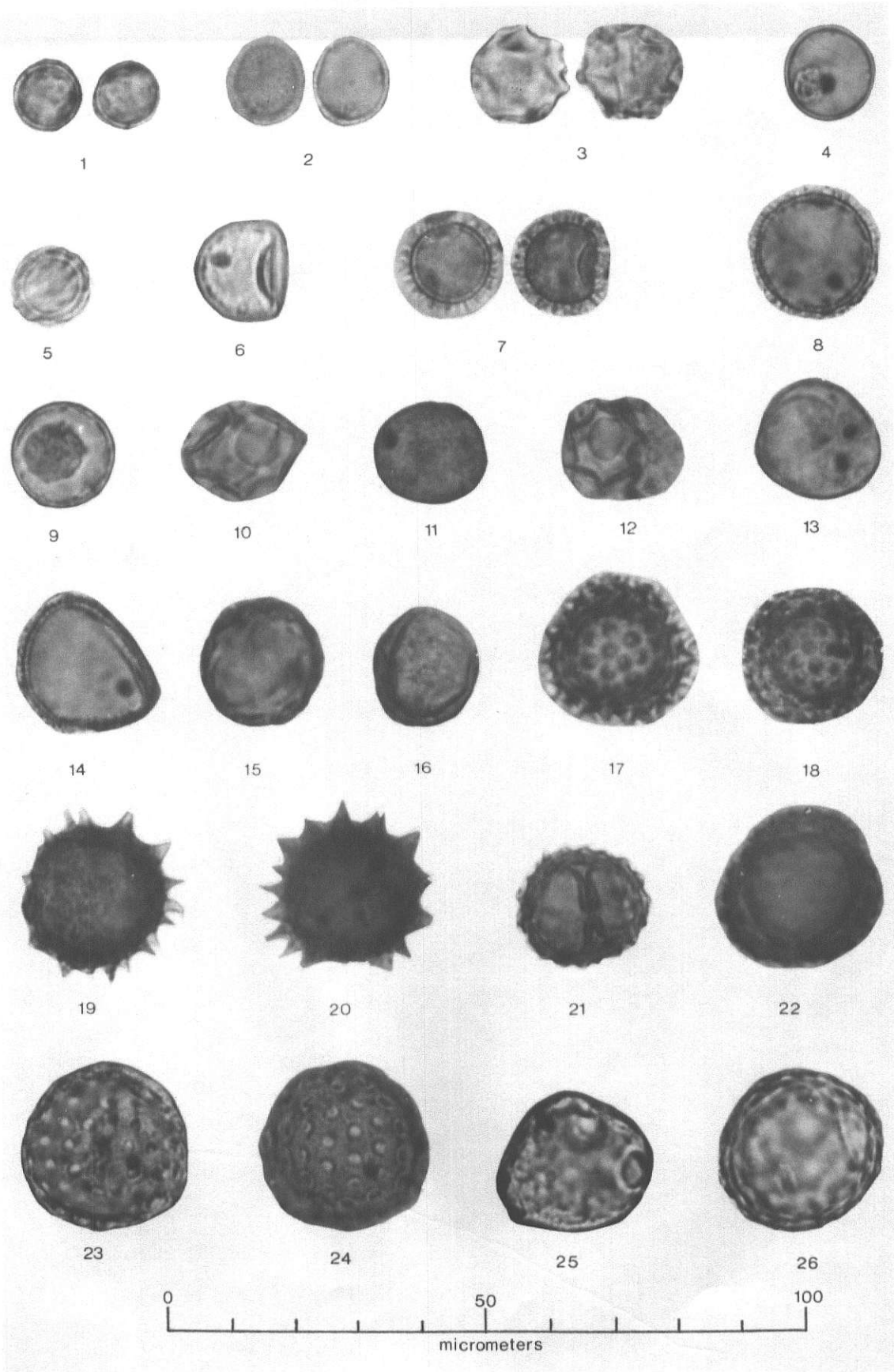
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Fig. 27 - 58: LM micrographs of pollen grains

27, 28, 29: Quercus

30, 31: Betula

32, 34, 35: Unknown - reticulate, tricolpate

33: Unknown - foveolate, tricolpate

36: Cornus

37: Annonaceae

38: Unknown - psilate, inaperturate

39: Unknown - granulate, inaperturate

40: Unknown - aspidote, inaperturate

41: Euphorbiaceae

42: Unknown - verrucate, inaperturate

43: Unknown - psilate, inaperturate

44: Unknown - psilate, monoporate

45: Unknown - psilate, inaperturate

46: Unknown - bacculate, inaperturate

47: Gramineae

48: Unknown - psilate, inaperturate, secondary folds

49: Unknown - verrucate, inaperturate

50: Unknown - folded, inaperturate

51: Unknown - aspidote, porate

52: Unknown - psilate, inaperturate, secondary folds

53: Tsuga ?

54: Unknown - rugulate, inaperturate

55: Unknown - psilate, inaperturate

56: Pinus

57: Unknown - inaperturate

58: Gramineae

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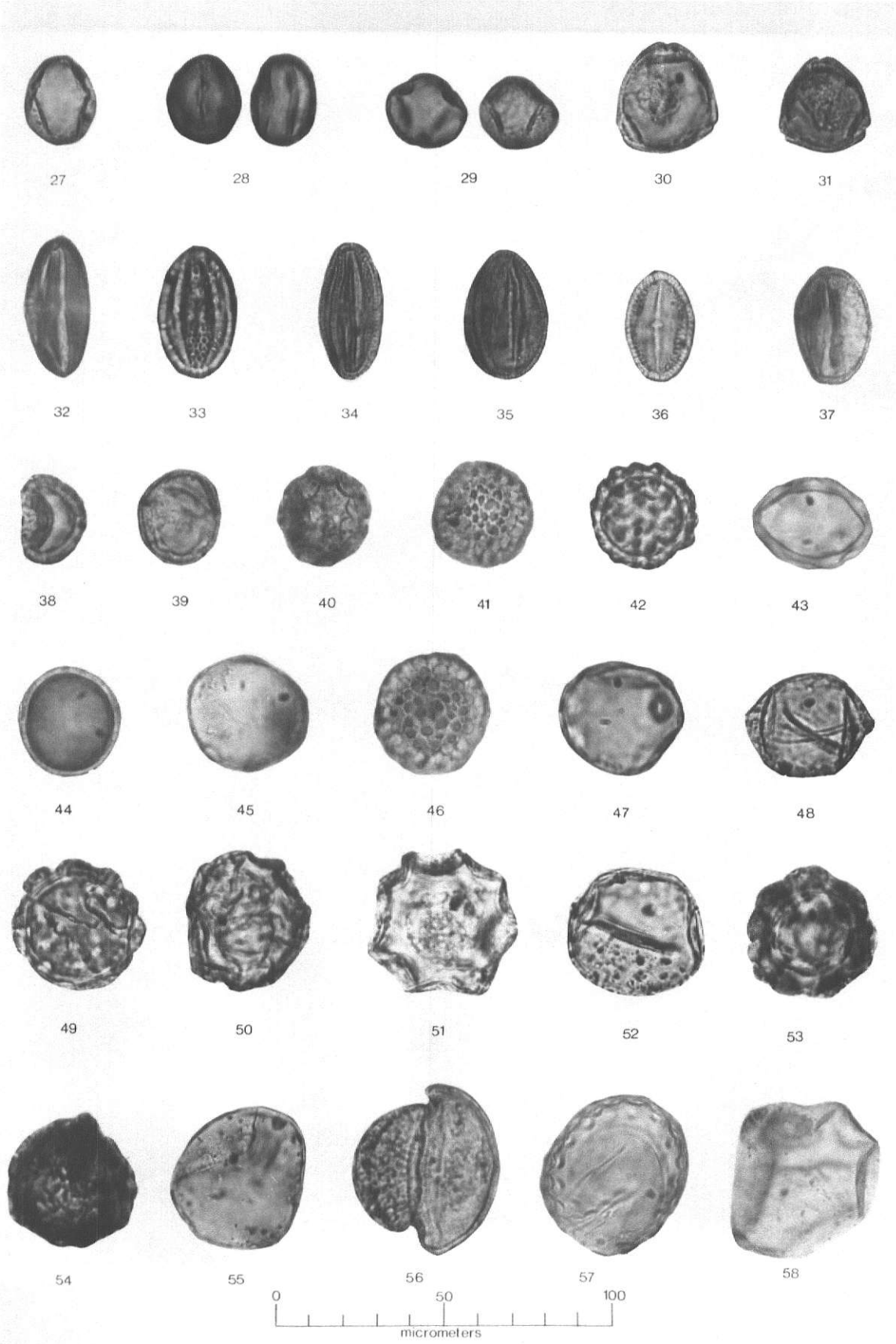
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Fig. 59 - 70: SEM micrographs of pollen grains.
Lines in each figure equal 10 µm.

59, 60: Gramineae

61: Unknown - echinate, triangular

62: Long spine Compositae

63, 64: *Ambrosia* - type

65, 66: Unknown - reticulate, tricolpate

67: Unknown - reticulate, folded

68: Unknown - foveolate

69: *Quercus*

70: *Pinus*

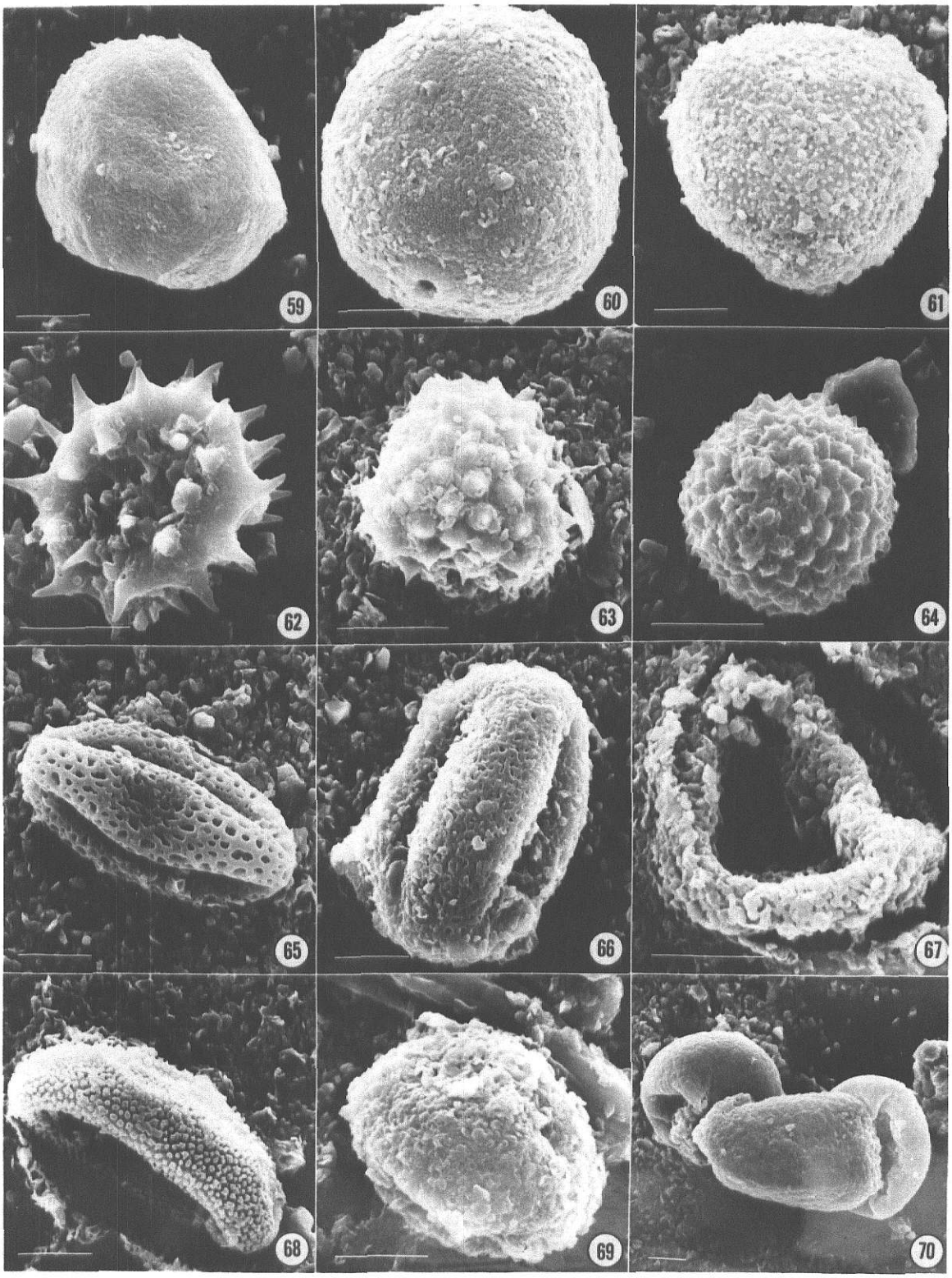
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Fig. 71 - 82: SEM micrographs of pollen grains.
Lines in each figure equal 10 µm.

71: Chenopodiaceae/Amaranthaceae

72, 72: Malvaceae - type

74, 75, 76: Unknown - psilate, inaperturate

77: Unknown - granular, triangular

78, 79: Unknown - psilate, inaperturate

80: Unknown - bacculate, inaperturate

81: Unknown

82: Unknown

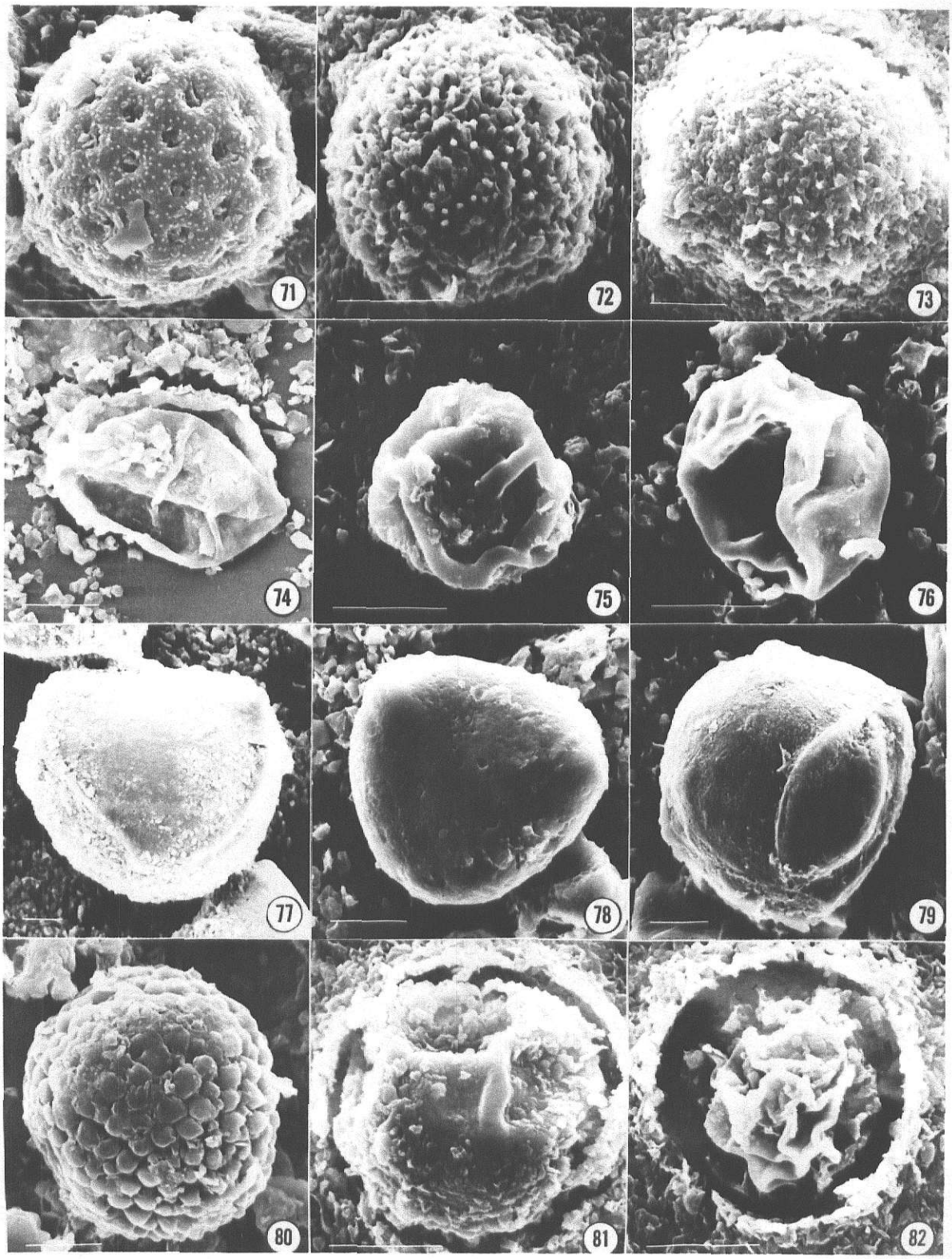
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Fig. 83 - 94: LM micrographs of fungal spores.

83: Ascospore - moncellate, psilate

84: Unknown - monocellate, psilate, inaperturate

85: Unknown - monocellate, psilate, monoporate

86: Teliospore of a rust (Uromyces)

87, 88: Smutspore - monocellate, echinate, inaperturate

89: Teliospore - dicellate, echinate, inaperturate

90, 91: Teliospores - dicellate, psilate, diporate, with pore chambers

92: Teliospore of Puccinia

93: Hyphomycete phragmospore

94: Vegetative sclerotia - multicellate, inaperturate structure with irregular septation

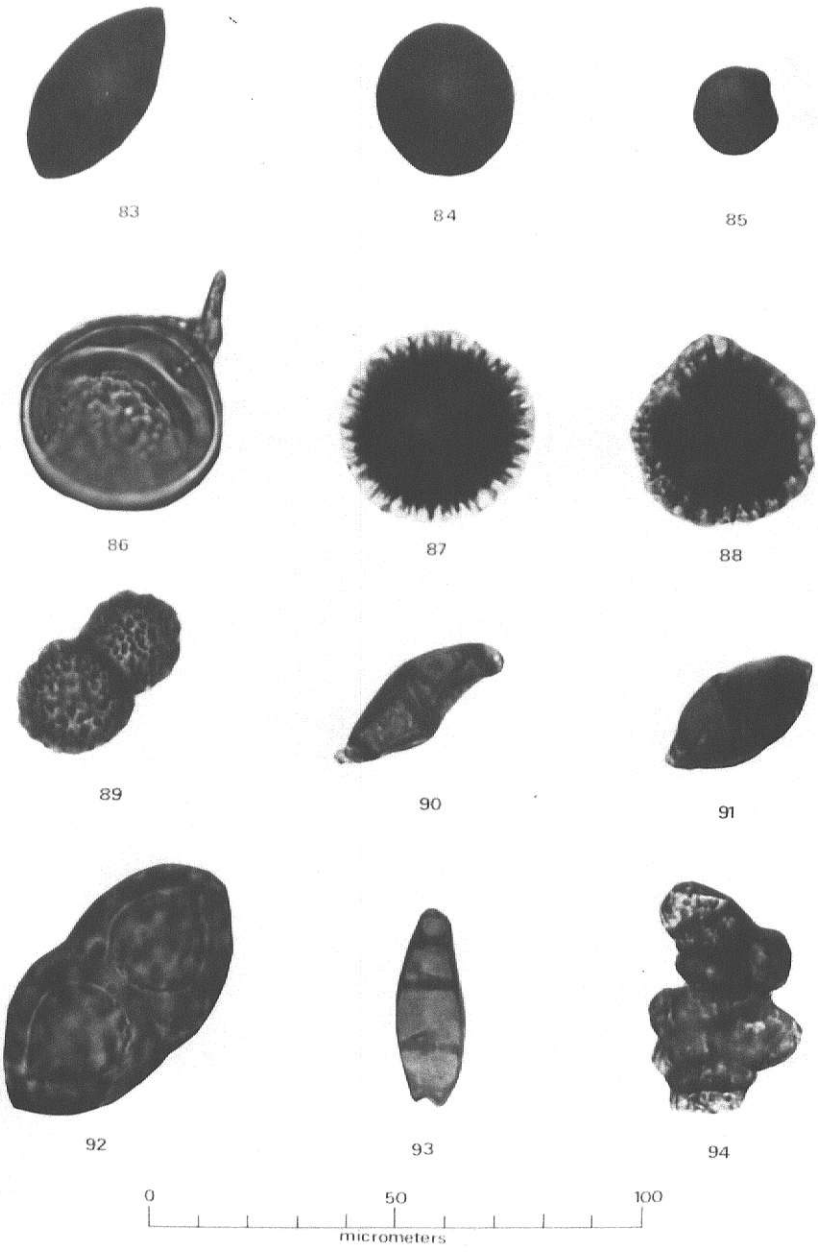
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Fig. 95 - 103: SEM micrographs of fungal spores.
Lines in each figure equal 10 µm.

95: Unknown - monocellate, scabrate, inaperturate

96: Vegetative sclerotia - multicellate, inaperturate structure with irregular septation

97: Unknown - monocellate, scabrate, inaperturate

98: Smutspore - monocellate, echinate

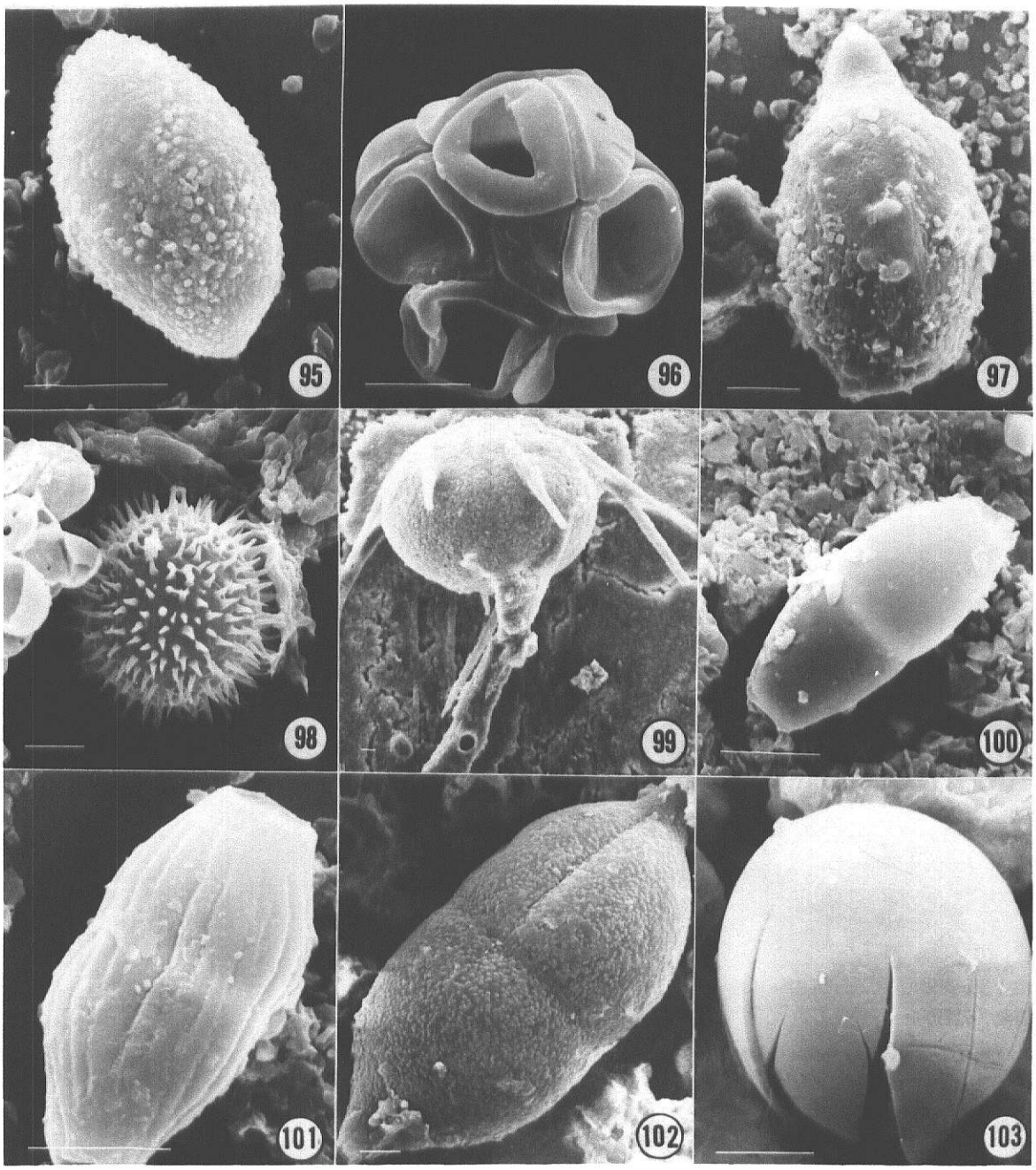
99: Teliospore of a rust (Uromyces)

100: Teliospore - dicellate, psilate

101: Teliospore - dicellate, striate

102: Teliospore - dicellate, foveolate

103: Unknown - monocellate, psilate, inaperturate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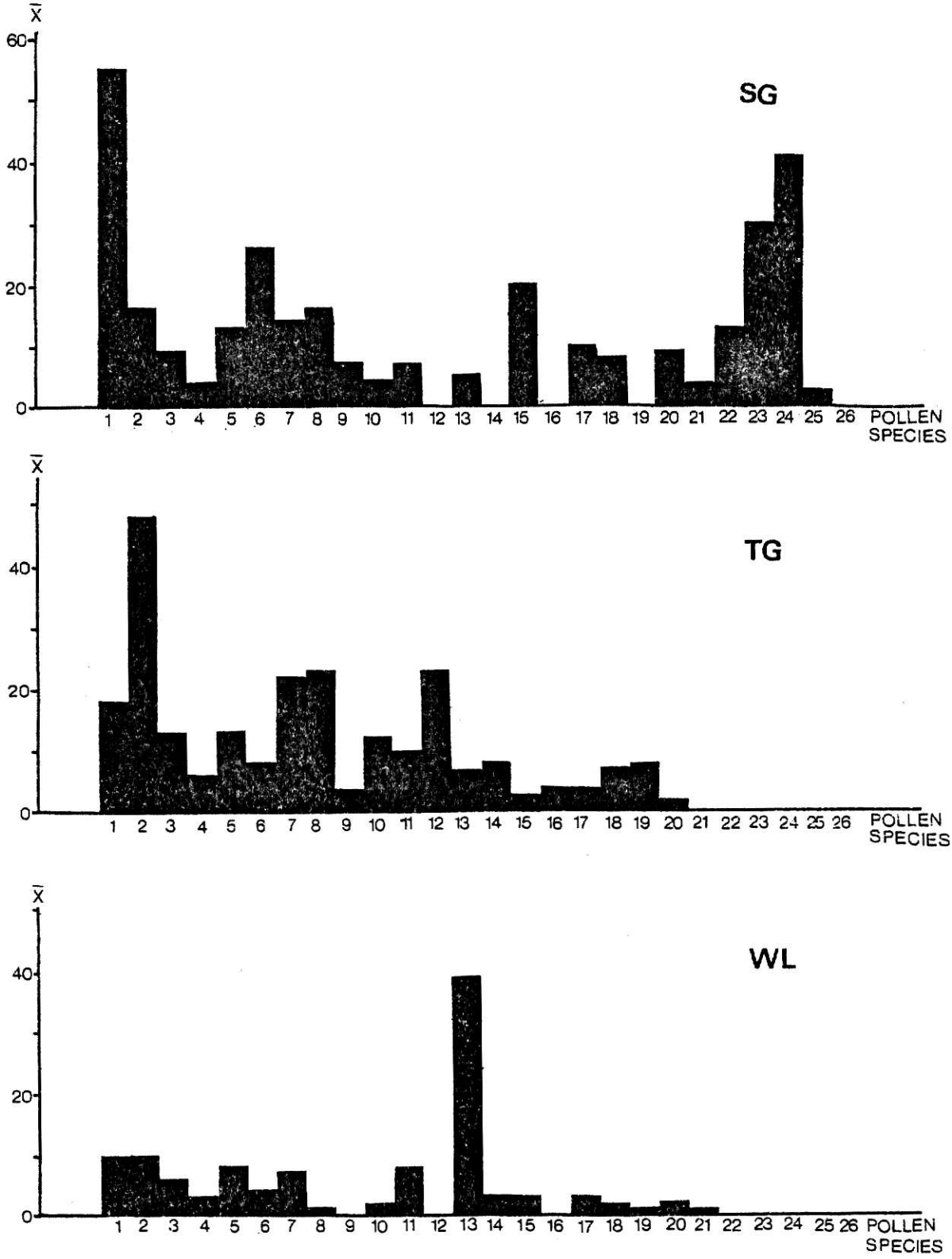

Fig. 104: Distribution histograms of pollen species in extant soils. (1: Gramineae - 13: Quercus - 15: Ambrosia - 20: Pinus - 21: Chenopodiaceae/Amaranthaceae - 23: long spine Compositae - 25: Euphorbiaceae - all other species are unknown.)

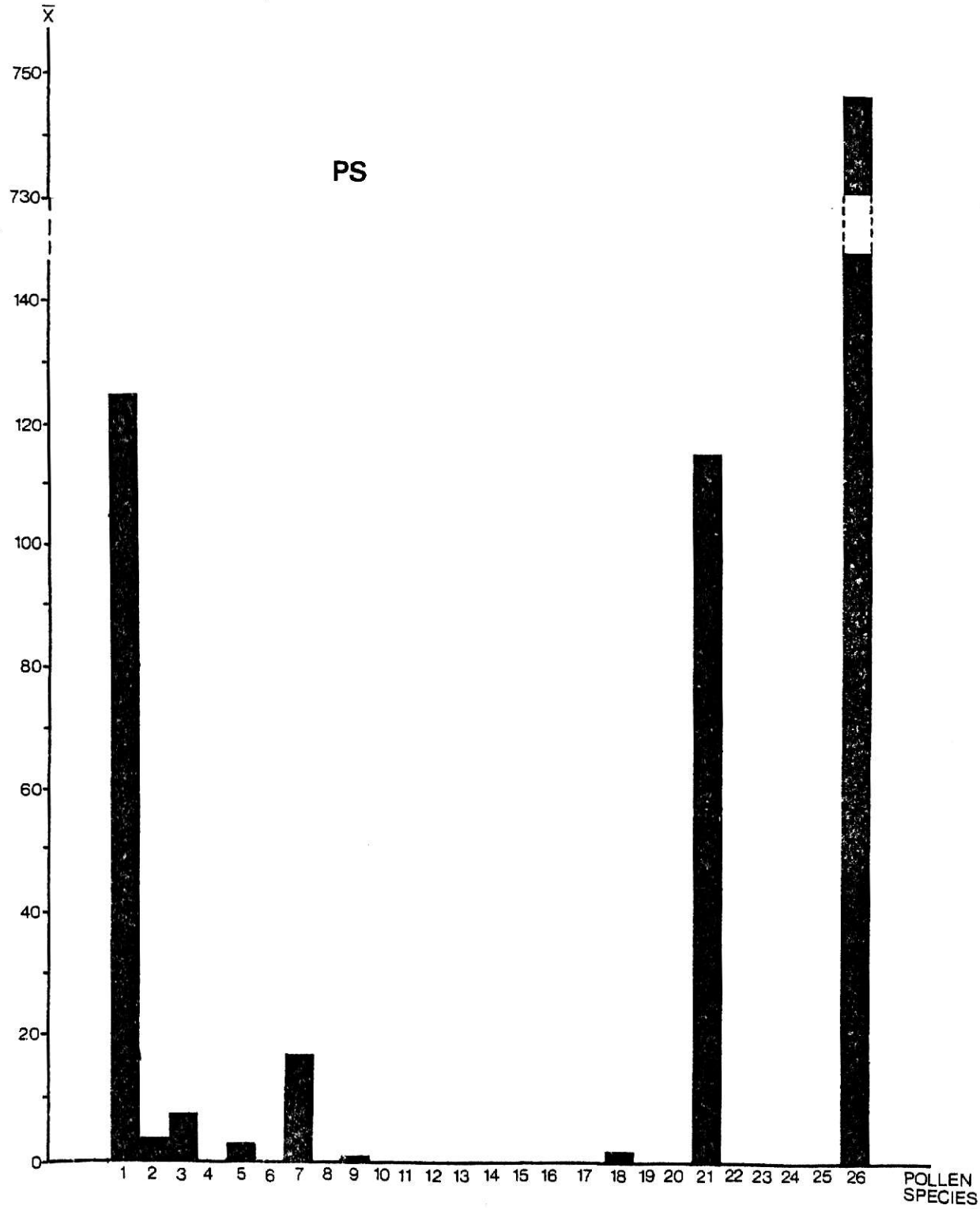

Fig. 105: Distribution histogram of pollen species in the paleosol (1: Gramineae - 21: Chenopodiaceae/Amaranthaceae - 26: Unknown - tricolpate reticulate.)

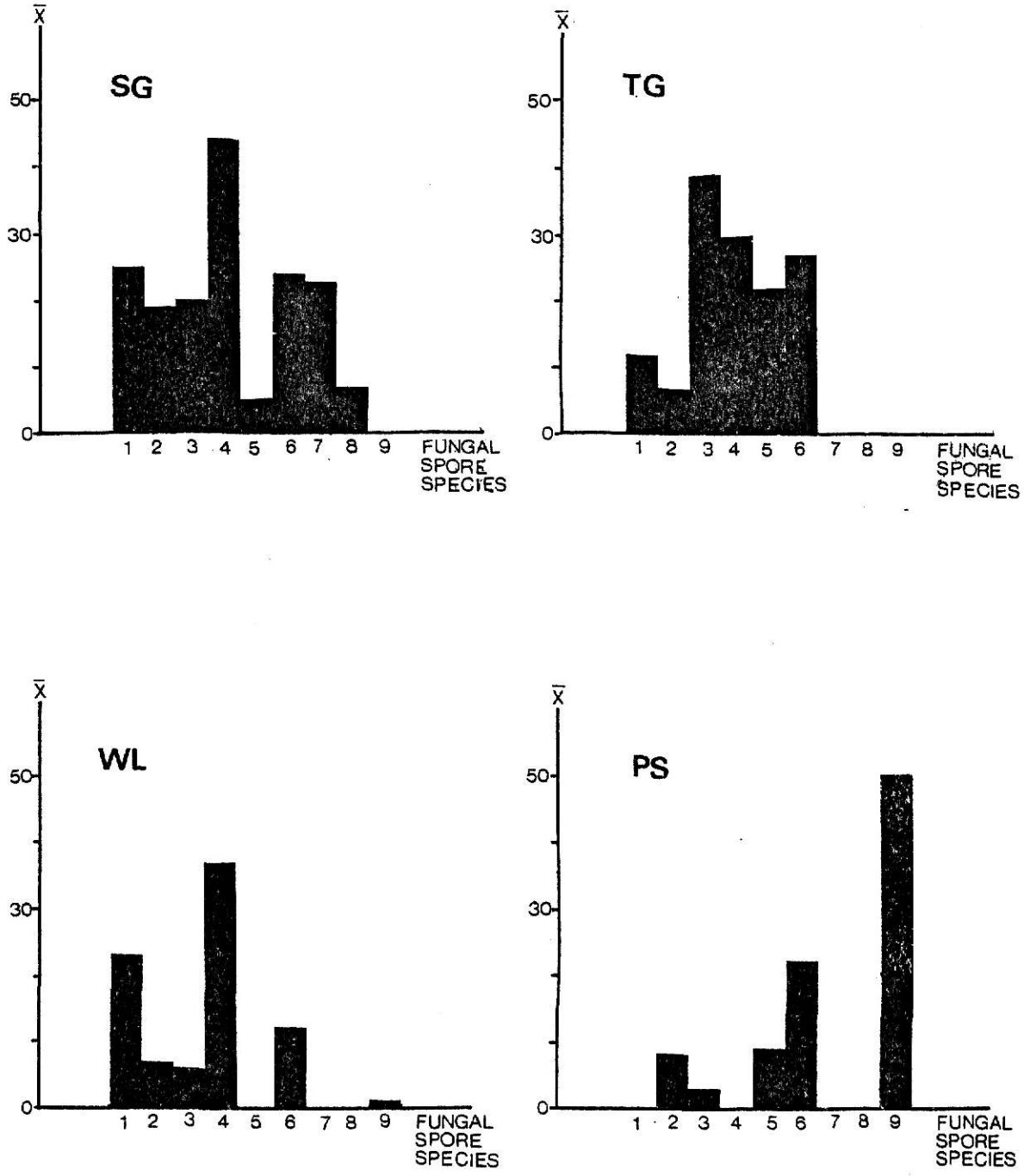

Fig. 106: Distribution histograms of fungal spore species (3: vegetative sclerotia - 4: Teliospore - 5: Smutspore - 9: Unknown)

DISCUSSION

The pollen analyses of the different sites showed that a certain vegetation type can only be distinguished by groups of pollen species. Conclusions based on individual pollen species, especially the absence or frequent occurence of single pollen species, can be misleading (Fig. 104).

The shortgrass prairie is characterized by Gramineae (1) and Compositae pollen (15, 23), and the unknown pollen species 6 and 24. The nearly complete absence of tree pollen indicates grassland vegetation. The relatively high number of pine pollen may have come from the pine plantation near the collection site, and not from long-distance transport. The large amount of long spine Compositae pollen in the shortgrass prairie site may have come from the sunflower breeding field, which was upwind of the collection site. The high frequency of Ambrosia-type pollen can be explained by the abundance of western ragweed, Ambrosia psilostachya DC., which can produce up to several thousand pounds of biomass per acre (LAUNCHBAUGH & OWENSBY, 1978). The tallgrass prairie is characterized by the unknown pollen species 2, 7, 8, 12 and Gramineae (1) pollen. Only a few Compositae pollen were recorded in the tallgrass prairie. The amount of grass pollen was much smaller in the tallgrass prairie. The grasses of the tallgrass prairie have much lower sexual reproduction than the grasses of the shortgrass prairie (OWENSBY, pers. commun.), and therefore they do not produce as much pollen. The woodland site is characterized by Quercus pollen which reflects the most abundant tree species (Quercus macrocarpa Michx. and Quercus muhlenbergia Engelm.). The grass pollen is produced by the grass in the understory. The woodlands are in the lowlands along the streams surrounded by upland prairie. Therefore, pollen produced in the tallgrass prairie could be transported in by wind or water.

That the different sites can be characterized by only a few pollen species is due to differential pollen production. Entomophilous species produce considerably less pollen than anemophilous species. Even among different anemophilous species there are considerable variations in pollen production (ANDERSEN, 1967; ERTDMAN, 1969).

The paleosol was dominated by the pollen species 26. That tricolpate, reticulate grain could not be identified. BRYANT (pers. comm.) suggested that it might be Salix, but it is almost twice the size of any known Salix pollen. HALL (pers. comm.) recalled something resembling it in samples from central Texas, but also could not identify it. After pollen species 26, Gramineae and Chenopodiaceae/Amaranthaceae pollen are also common. The abundance of Chenopodiaceae/Amaranthaceae pollen could indicate a disturbed weedy area or it could be from a Chenopodiaceae shrub (e.g. Atriplex). The site may have been in the floodplain of the Kansas River, and therefore could have been disturbed. The great amount of grass pollen may suggest a grassland. Cool-season grasses, Agropyron, Bromus, Festuca and Poa, common in the current northern desert shrub regions of the Western U.S., could supply the grass pollen; Atriplex and Sacrobatus could supply the Chenopodiaceae/Amaranthaceae pollen (OWENSBY, pers. comm.). The identification of the tricolpate, reticulate pollen grain and C-14 dating of this paleosol may help to determine the vegetation prior to burial.

The occurence of only nine pollen species in the paleosol suggests that some pollen species are not well preserved. HAVINGA (1971) investigated the preservation of different pollen and spore species and found that the relative frequency of the species can shift considerably in the course of time in different environments. Many pollen species are easily destroyed soon after deposition and do not occur in the fossil record.

Correlation between pollen deposition in extant and fossil soils must account for the differential resistance of the pollen species to degradation. The absence of a pollen species in the paleosol does not mean that a taxon did not occur in the plant community prior to burial, but rather it may not have been preserved.

The fungal spore data show that different sites may be identified by groups of fungal spore species (Fig. 105). The two grassland sites have more fungal spore species than the woodland site. Using fungal spores, the shortgrass prairie can be distinguished from the tallgrass prairie. Five out of the six fungal spore species which occur in both sites are significantly different in abundance.

The paleosol yields a smaller fungal spore complement than the extant soils. That may well be because fungal spores are not preserved. Fungal spore species 9 and 6 characterize the buried soil. Species 9 is dominant in the paleosol, but it is absent from the extant soil.

The extant grassland sites had more fungal spore types than the woodland site, and tallgrass prairie soils can be distinguished from shortgrass prairie soils by the significant difference between the fungal spore species. Fungal spores, like pollen grains, are apparently preserved selectively as indicated by the few kinds in the paleosol. The fungal spore data show that they should not be disregarded in the analysis of soil palynomorphs. They aslo have "index value."

The study of pollen grains and fungal spores with the SEM did not reduce the problem of the unknown species. It only allowed a better description of the sculpturing of pollen grains and spores.

The statistical analyses of the soil palynomorphs showed that the means among the three different counted slides and among the three localities within the same vegetation typre have no significant difference. In the future, soil palynomorph studies of fewer samples can be used without a decrease in accuracy.

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APPENDICES

LITERATURE REVIEW

OPAL PHYTOLITHS

Soluble silicon is taken up by plants in the form of $Si(OH)_4$ through the transpiration stream. JONES & HANDRECK (1967) described this uptake as a nonselective passive process, but there is evidence for "metabolic exclusion or preferential concentration" of silica in some plants (WILDING et al., 1977). In plant cells, silicon usually occurs in a form of its oxide (LANNING, 1958) and is deposited in cell walls of both shoots and roots. The silica that is secreted in the lumen of the cells is referred to as opal phytoliths.

Monocots contain 10 to 20 times more silica than dicots. On a dry weight basis, grasses contain 3 to 5% silica (WILDING & DRESS, 1968). Silica content of plants also increases with age and relative maturity. One of the most diagnostic features of biogenic opal bodies is their external morphology. Shape and size of thesilica deposits are controlled by the plant cells in which they are secreted, and therefore they can be characteristic of taxonomic groups. Morphological descriptions and classifications of opal phytoliths are best developed for monocots, parituclarly for the Gramineae (SMITHSON, 1958; METCALFE, 1960; SENDULSKY & LABOURIAU, 1966; SUESS, 1966; PEASE, 1967; CAMPOS & LABOURIAU, 1969; DORMAR & LUTWICK, 1969; TWISS et al., 1969; SÖNDAHL & LABOURIAU, 1970; TEIXEIRA DA SILVIA & LABOURIAU, 1970; BLACKMAN, 1971; BERTOLDI DE POMAR, 1971; TWISS, 1978; TWISS, 1980). Descriptions of opal phytoliths of dicots, especially those from decidious trees, can be found in WILDING & DRESS (1968), ROVNER (1971), and WILDING et al., (1977). The opal phytoliths of coniferous plants, especially those from the Pinaceae have been studied by NORGREN (1973) and KLEIN & GEIN (1978).

METCALFE (1960) recognized the types of silica bodies for descriptive purposes by their micromorphology. He described cubical, round, oblong, saddle-shaped, elongated, cross-shaped, dumbbell-shaped, and intermediate forms. SUESS (1966) divided the silica bodies in irregular and regular types. With the regular bodies he could classify grassland regions. The shortgrass prairie showed chloridoid types and the true prairie showed panicoid ones. Four classes of grass phytoliths have been recognized by TWISS et al., 1969. The festucoid class which includes the grass tribes Festuceae, Hordeae, Aveneae and Agrostideae; the panicoid class which includes the tribes Andropogoneae, Paniceae and Maydeae, the chloridoid class which includes the Chlorideae, and the elongate class which occurs in all grasses. ROVNER (1971) makes a distinction between panicoid and poacoid phytoliths based on discrete morphological features. His poacoid class covers the same forms as TWISS's festucoid class. TWISS's chloridoid types are in ROVNER's panicoid class. ROVNER also stated that rod-shaped types are present in all the classes. BLACKMAN (1971) studied types and distribution of silica bodies of grasses of range grasslands in southern Alberta, Canada. She divided the opal phytoliths in a festucoid class containing usually hat-shaped forms, and in a panicoid class containing saddles and dumbbells. BERTOLDI DE POMAR's (1971) classification of opal phytoliths is based on sizes and shapes. Phytoliths larger than 40 µm were put in the group of macrosiliconphytoliths, and the smaller ones in the microsiliconphytoliths. Both groups include forms grouped in morphotribes. Unfortunately, he put shapes that result of orientation of silica bodies in different morphotribes.

Opal phytoliths can be released into the soil by natural decay of the plant material containing the biogenic silica, by grass or forest fire, or through the dung of herbivores. SUESS (1966) observed that there are more morphological varieties of opal in plants than in recent soils. He suggests

that some phytoliths are composed of partly soluble silica-organic substances. Only the "true" opals show a fairly high stability to weathering processes (BEAVERS & STEPHEN, 1958) and phytoliths persist under oxidizing environments. WILDING (1967) provided evidence that opal phytoliths are stable in soil for at least 13,000 years.

The occurence of opal phytoliths in a soil at a given site should allow identification of the vegetation that previously occupied the site. Efforts have been made to use opal phytoliths as an "index mineral" (BEAVERS & STEPHEN, 1958) by comparing amounts, shapes and sizes of opal extracted from soils with those from plants.

SMITHSON (1958) presents evidence that phytoliths of British soils can be assigned to grass tribes or groups of tribes. The plant opal in Illinois soils, as reported by BEAVERS & STEPHEN (1958), are identical with those obtained from some principal native grasses. They also showed that opal grains are particularly common in the A-horizon. BAKER (1959) analyzed phytoliths in soils for shape distribution and found that the assemblages are dominated by rod-shaped forms and nondescript types, followed by dumbbell- and boat-shaped forms. Unusual branched particles were observed by BRYDON (1963) in the sand fraction of the upper soil horizons, and have been identified as opal bodies from Pseudotsuga needles. In a grassland-forest transition zone in Oregon WITTY & KNOX (1964) showed that the soil opal content can be an effective indicator of the vegetation history. SUESS (1966) showed that soils under native tallgrass prairie yield mostly panicoid and irregular types. The buried soil, he examined showed more chloridoid types than recent soils. The study by WILDING & DREES (1968) presents opal phytolith distribution for selected prairie and forest soils in Chio. Soils developed under prairie impact yield many more phytoliths than soils under forest. LUTWICK (1969) characterized the forest-grassland

transition zone by the occurence of fescue phytoliths. He found more opal phytoliths in relative moist, well drained soils and where vegetation had been continuously grass. Examination of amount and shape of opal phytoliths which have been accumulated in soil profiles is also described by NORGREN (1973) as a useful method of studying vegetation history. DORMAAR & LUTWICK (1969) showed that infrared spectra of humic acids from grassland soils differ from the ones from forest soils. They found a positive relationship between the presence of phytoliths within the A-horizons and the grassland character of the infrared spectra of humic acids.

The potential of opal phytolith studies has also been recognized by archaeologists. Soil samples from an archaeological site in Ecuador showed silica bodies which could be identified as Zea mays L. (PEARSALL, 1978). Opal phytoliths were also used in the paleo-environmental reconstruction at the Hudson-Meng site, Nebraska (LEWIS, 1978). Phytoliths of an archaeological site in Israel could be recognized as coming mostly from wheat (LIEBOWITZ & FOLK, 1980).

The dominance of any particular phytolith shape in the soil is evidently a reflection of a local dominant group of plants, supplying the phytoliths to the soil. The occurence of certain classes of opal phytoliths in the sediments can be an indicator of certain types of vegetation. Opal phytoliths are therefore useful both in establishing that a buried stratum is a paleosol, and in determining the vegetation present when the paleosol was formed.

Opal phytolith analysis provides information about the vegetation history comparable to palynological data. That is especially interesting where pollen is absent, or where paleobotanical information is not available through pollen studies. The morphological variation of opal phytoliths in the monocots, especially the Gramineae shows an opposite trend to the pollen

morphology - monoporate pollen is characteristic for the Gramineae. That can be very advantageous in analysis of grassland communities, because phytolith data enable a distinction between tribes of grasses or groups of tribes, and therefore a distinction between different types of grasslands.

POLLEN AND SPORES

Stratigraphic palynological study of lake and bog samples is the single most useful tool in determination of vegetational history. The number of suitable sites for pollen deposition with preservation in the Great Plains is very small and therefore the information about the vegetational history of the region is fragmentary. WRIGHT (1970) gives an overview of what is known of the vegetational history of the Great Plains.

The Pleistocene series in Kansas is divided into eight stages in the time-stratigraphic classification by the State geological survey (ZELLER, 1968). The four periods of continental glaciations are the Nebraskan, Kansan, Illinoisan, and Wisconsinan stage. The four interglacial stages, the Aftonian, Yarmouthian, Sangamonian, and Recent are characterized by warmer climates and stable land surfaces. Figure 1 shows the climatic changes during the Pleistocene stages in the Central United States.

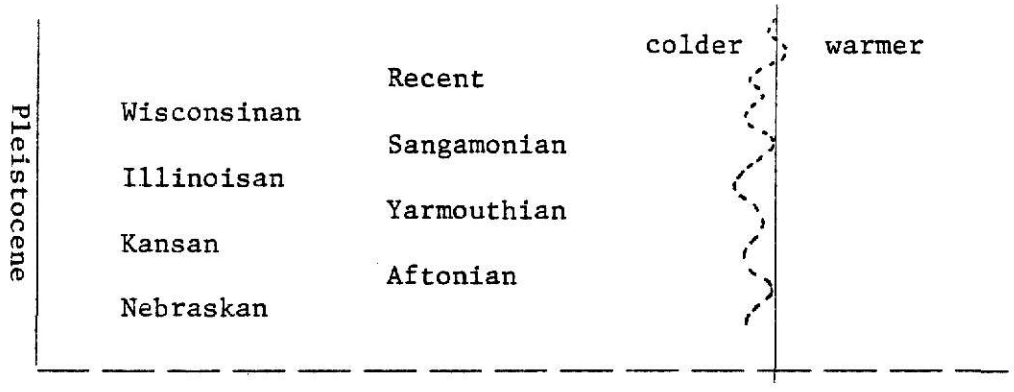

Fig. 1: Climatic changes during the Pleistocene in the central United States (LEOPLOD, 1969) - Vertical line indicates modern norms

KAPP (1970) furnished evidence that during the Illinoisan glacial age, a confierous forest existed in the Great Plains. Pollen analytical evidence from Sangamon sediments in southwestern Kansas and adjacent Oklahoma (KAPP, 1970) suggests an expansion of prairie vegetation (grass and compositae pollen) with localized stands of Pinus.

The existence of woodlands in the Great Plains during the Wisconsinan galcial age is well documented. WATTS & WRIGHT (1966) divided the pollen diagram from the Nebraska sandhills into a lower zone in which Picea makes up 50% or more of the pollen sum, and an upper zone, in which Compositae and Chenopodiaceae/Amaranthaceae pollen are much more abundant. In South Dakota, according to WATTS & BRIGHT (1968), a boreal forest (Picea, Larix, Fraxinus) with shrubby areas dominated the vegetation up to about 10,000 years BP. GRUEGER (1973) showed that northeastern Kansas was dominated by Picea (not Abies, as identified by HORR, 1955) about 11,000 BP. Most of east, central, north and west Texas was covered by areas of grasslands, woodlands and parklands during most of the full-glacial period (BRYANT & SHAFER, 1977).

Post glacial climatic changes were very slow and progressed from the west to east and from south to north. The expansion of grassland occurred 1000 to 2000 years earlier in Kansas than in more northernly parts of the Great Plains. McGREGOR (1968) dated with C-14 the start of the transition from boreal forest to prairie in northeastern Kansas at about 8000 BP. The beginning of the forest/prairie ecotone occurred about 4000-5000 years ago. The present day vegetation of northeastern Kansas is a mosaic of deciduous forest and prairie (GRUEGER, 1973).

More data are needed to work out the time relations and to detect shifts in vegetational composition. Because the most often utilized sediments are

usually unavailable in the Great Plains, careful study of soil and paleosol palynomorphs could add significantly to the understanding of the history of the Great Plains.

In early pollen analysis, it was generally assumed that pollen would be broken down by microbial activity in aerated soils or that the activity of soil organisms would serve to mix it so that any stratification would be lost. Therefore, it was decided that soils did not warrant palynological examinations and that pollen analysis of mineral soils was best avoided.

ERDTMAN (1943) demonstrated that certain soils contain considerable quantities of pollen. DIMBLEBY (1957) believes that thigher levels of preservation occur only in soils of pH less than 6. But WELTEN (1958) recorded preservation of pollen in soils of much higher pH values. HAVINGA (1967a, 1967b, 1971) investigated the pollen preservation in soils. He stated that differences in chemical composition of the sporopollenin might cause differences in the oxidation rate under natural conditions. The lower the sporopollenin content, the higher the susceptibility to corrosion and oxidation. The pollen composition of a soil would therefore be changed by selective corrosion. Psilate exines are said to be less resistent to corrosion than non-psilate ones, and pollen of Juniperus, Popolus, and Cactaceae are all fragments.

Knowing that pollen grains can survive in soils, one is still faced with the problems of pollen movement. BURGES (1950) showed in an experiment that fungal spores with a mucilaginous coat wash downwards readily in a sandy soil, while spores that have a waxy nonwetting coat remain on the surface. RAY (1959) examined the effect of earthworms in soil pollen analysis. His experiments showed that larger earthworms quickly carry pollen through any part of the soil in which they are working. DIMBLEBY (1957, 1961) hypothesized that the whole pllen content, regardless of grain size,

is washed down in the soil slowly and steadily with time. WELTEN (1958) concluded, that the activity of soil organisms cause a local, vertical turnover and that this is more important than downwash. HAVINGA (1974) also concluded that downwash of pollen grains as free particles is not considered to be an important process. His microscopic examinations of the soil revealed that pollen grains are enclosed in aggregates. MUNAUT (1967, cit. in HAVINGA, 1974) and GUILLET (1972, cit. in HAVINGA, 1974) stated that the aggregates would gradually decompose as a result of microbial activity. The released pollen grains would sink, but be recaptured by other aggregates. This process could be repeated several times, and it could be fairly rapid in biologically active soils.

Despite of the problems of movement, the analysis of the vertical distribution of the pollen in the soil has frequently revealed a distinct stratification (BILLARD et al., 1971; DIMBLEBY, 1957, 1961; WELTEN, 1958, 1962; HAVINGA, 1963). The interpretation of thos pollen profiles can be highly valuable if used in connection with the historic dynamic processes of the soil profile.

Occasionally, soils become fossilized as a result of burial (Paleosols). Pollen preserved in the old soil surface provide a useful source of information about the type of vegetation and the ecological conditions prior to burial. In buried soils, the overall pollen composition of the soil is more interesting than stratification. Under such circumstances, problems of pollen movement are less important and buried soils may be an "ideal" object in investigating recent vegetational history. Effective reconstructions and correlations require accurate fossil pollen identification.

Information on pollen and spore morphology is available, but there is relatively little that could be used for identification of fossil materials

from the prairies. SEARS (1930) and McANDREWS et al., (1973) described fossil pollen and spores in the Great Lakes region and their keys are also useful in prairie regions. The norwest European pollen floras and keys (FAEGRI & IVERSEN, 1964; MOORE & WEBB, 1978; NILSSON et al., 1977; PUNT, 1976) are not wholly applicable, but they are commonly used. The information available in North America includes RICHARD's (1970a, b) pollen atlas of trees and shrubs around Quebec, MARTIN & DREW's (1969, 1970) SEM micrographs of southwestern pollen grains, and LIEUX's (1980a, b) atlas of tree pollen of the southeastern United States. KAPP's (1969) key and WODEHOUSE's (1935) "pollen grains" are also helpful sources for identification. The pollen of many anemophilous taxa are described in "hayfever literature" (WODEHOUSE, 1971; OGDEN et al., 1974).

As early as 1934, it was recognized that the most important criteria for a correct interpretation of pollen analytical data is the comparison of the pollen rain with the vegetation (FIRBAS, 1934). WELTEN (1950) studied modern pollen deposition in alpine vegetation in order to find a correlation between pollen deposition and local vegetation. The pollen residue was consistent with the flora of the locality. Shrubs and forbs may be underrepresented due to vegetative reproduction or entomophily, and forb pollen is more labile. LICHTI-FEDEROVICH & RITCHIE (1965) showed that distinct vegetational regions can be characterized in terms of pollen composition. Grasslands are characterized by 60-70% herb pollen and about 20% tree types. Continuously forested landscape is characterized with less than 40% herb pollen and more than 50% tree pollen. Pollen and spore assemblages of surface samples from the Venezuelan Andes (SALGADO-LABOURIAU, 1979) also refelected the regional vegetation. All these studies indicate that there is a positive correlation between pollen deposition with preservation in soils and local vegetation, and that can be used in reconstruction of vegetational history.

Conditions favorable for the preservation of pollen grains are also favorable for preservation of fungal spores (WOLF, 1966). Some fungi are parasitic on higher plants and therefore certain fungal spores can be an indicator of certain vegetation types; e.g., Tetraploa is a grassland indicator and Hypox is found around woody regions (ELSIK, pers. comm.).

Despite the significance of fungal spores, palynologists made little effort to record the presence of fungal spores, and even less effort to identify them. Fungal spores lack the complex apertures often found in pollen and spores of higher plants. They are diverse in origin and morphology; they may be of almost any shape and any number of cells.

Although fungi differ in biochemical and genetic composition, no techniques of practical value in using such characters have been developed yet. That leaves only morphological characters for identification. ELSIK (in prep.) uses primarily spore wall, presence or absence of septa, and characture of apertures for identification. As secondary features he uses ornament and overall shape.

Analysis of fungal spores, along with pollen analysis may also have value in the reconstruction of vegetational history.

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SOIL DESCRIPTIONS

HARNEY SILT LOAM - In the SOIL SURVEY of Ellis County, Kansas (USDA, 1975)[1] a representative profile through the Harney silt loam is described as follows: The upper layer is about 25 cm thick. The upper 15 cm are dark grayish-brown silt loam, and the lower 10 cm are dark grayish-brown light silty clay loam. The subsoil is about 75 cm thick, and it can be divided in three parts: 22 cm grayish-brown, firm heavy silty clay loam; 28 cm grayish-brown, firmly silty clay, and 25 cm light brownish-gray calcerous, friable heavy silty clay loam. The permeability of these soils is moderately slow, and the available water capacity is high.

TULLY SILT LOAM - In the SOIL SURVEY of Riley County and part of Geary County, Kansas (USDA, 1975)[2] a representative profile is described as follows: The surface layer is very dark gray silty clay loam, about 25 cm thick. The subsoil is about 104 cm thick and can be divided in four different layers: The first layer of this subsoil is very dark grayish-brown heavy silty clay loam. The next layer is dark grayish-brown silty clay. Next is a layer of grayish-brown silty clay. The lower layer is brown silty clay. The subsoil is very hard when dry and firm when moist. Tully soils are well drained. Their subsoil is slowly permeable.

PALEOSOL - It is a band of about 90 cm silty clay loam of appr. 10% sand, 30% clay, and 60% silt; 150 cm below the present day surface. It is very dark brown (10 YR 2/2) moist, and contains secondary carbonates. Overlying alluvium is calcerous silt loam of appr. 15% sand, 20% clay, and 65% silt. It is dark grayish-brown (10 YR 4/2) moist (BIDWELL, pers. comm.).

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[1] UNITED STATES DEPARTMENT OF AGRICULTURE, 1975: Soil Survey of Ellis County, Kansas. U.S. Dept. Agr.: 86 pp.

[2] UNITED STATES DEPARTMENT OF AGRICULTURE, 1975: Soil Survey of Riley County and part of Geary County, Kansas. U.S. Dept. Agr.: 71 pp.

VEGETATION DESCRIPTIONS

Tables 1 - 3 list the major vegetation elements at the different collection sites. The vegetation maps (Figure 2 - 5) show the surroundings of the collection sites.

Table 1: Major elements of the shortgrass prairie on the collection site (LAUNCHBAUGH, 1967).[1]

	Species
Dominants:	Buchloe dactyloides (Nutt.) Engelm. Bouteloua gracilis (H.B.K.) Griffiths Ambrosia psilostachya D.C.
Subdominants:	Agropyron smithii Rydb. Bromus tectorum L. Bromus japonicus Thunb. Aristida longiseta Steud. Aristida purpurea Steud. Sporobolus asper (Michx.) Knuth var. asper Psoralea tenuiflora Pursh. var. tenuiflora

Table 2: Major elements of the tallgrass prairie on the collection site (OWENSBY, pers. comm.).

	Species
Dominants:	Andropogon gerardi Vitam. Andropogon scoparius Michx. Sorghastrum nutans (1.) Nash.
Subdominants:	Panicum virgatum L. Panicum oligosanthes Schult. var. scribnerianum (Nash.) Fern. Koeleria pyramidata (Lam.) Beau. Sporobolus asper (Michx.) Knuth var. asper Carex brevior (Dewey) Mack. Carex gravida Bailey var. lunellia (Mack.) Herm. Artemisia ludoviciana Nutt. var. ludoviciana

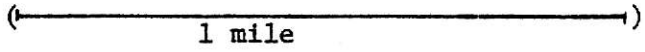
[1] LAUNCHBAUGH, J.L., 1967: Vegetation relationships associated with intensity of summer grazing on a clay upland range site in the Kansas 20- to 24 inch precipitation zone. Agr. Exp. Stat. Bull. 154: 24 pp.

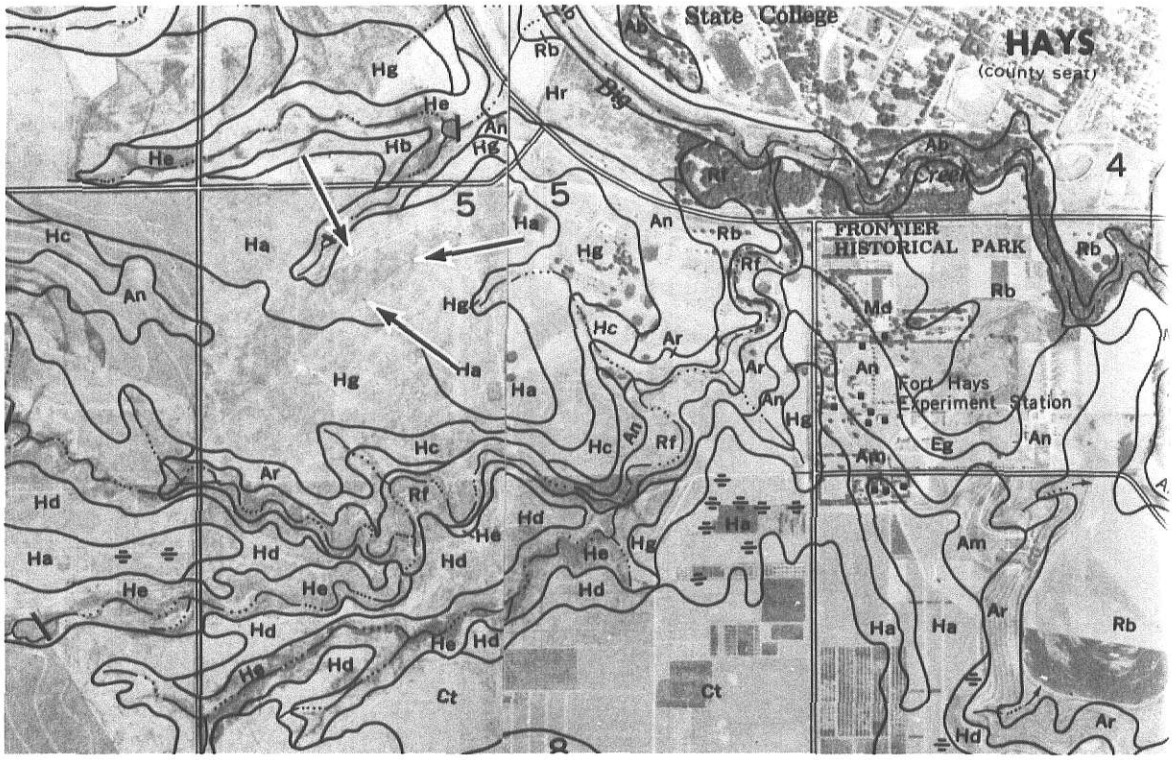
Table 3: Major elements of the woodland area on the collection site (FREEMAN, 1980).[2]

	Species
Overstory:	Quercus macrocarpa Michx. Quercus muehlenbergia Engelm.
Understory:	Amorpha fruticosa L. Toxicodendron radicans (L.) O. Ktze. ssp. negundo (Greene) Gillis Muhlenbergia frondosa (Poir.) Fern. Spartina pectinata Link. Hysterix patula Moench. Elymus canadensis L. Bromus japonicus Thunb. Carex hystericina Muhl.

[2] FREEMAN, C.C., 1980: Annotated list of the vascular flora of Konza Prairie Research Natural Area. Kansas State Univ.: 27 pp.

Fig. 2: Shortgrass prairie soil collection site (SG 1, SG 2, SG 3): Pine plantation and sunflower breeding field were east to the collection sites.




State College
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(county seat)
FRONTIER
HISTORICAL PARK
Fort Hays
Experiment Station
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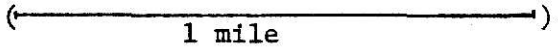
Fig. 3: Tallgrass prairie soil collection site (TG 3): no cultivated fields in the surrounding areas



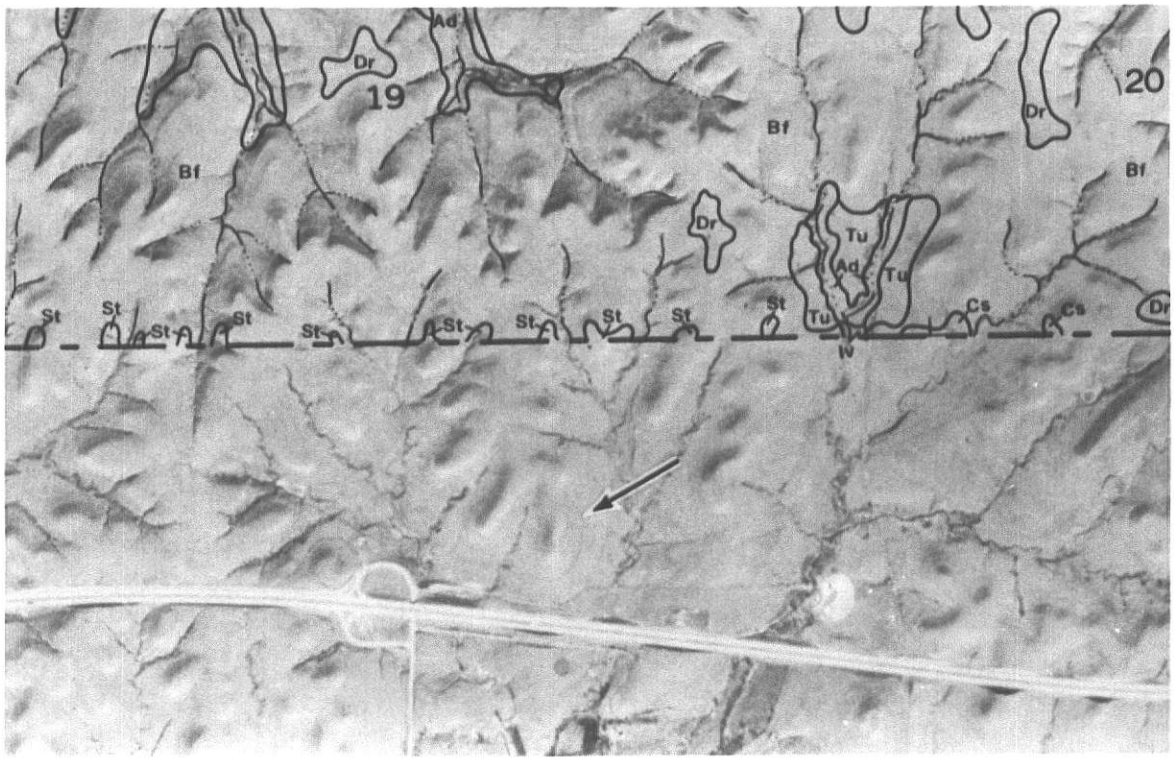

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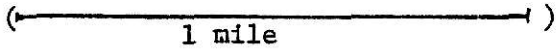
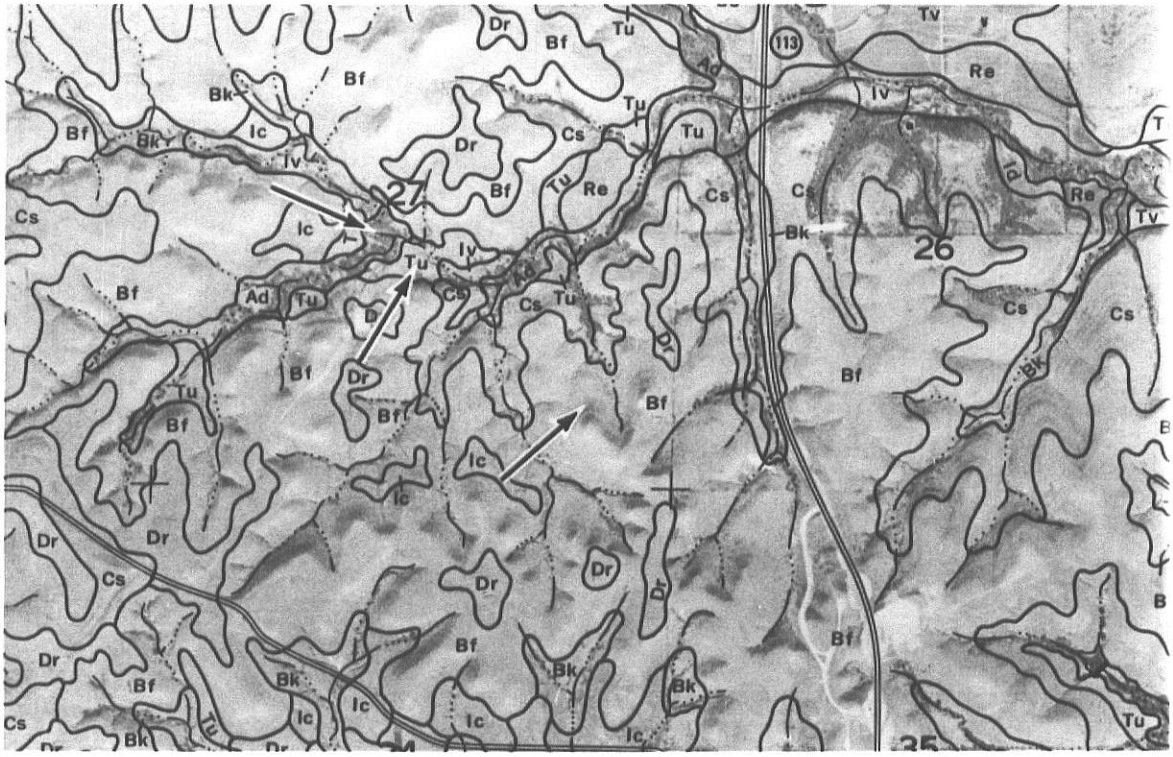
Fig. 4: Tallgrass prairie and woodland soil collection sites (TG 1, TG 2, WL 1): no cultivated fields in the surrounding areas.

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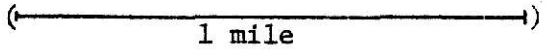
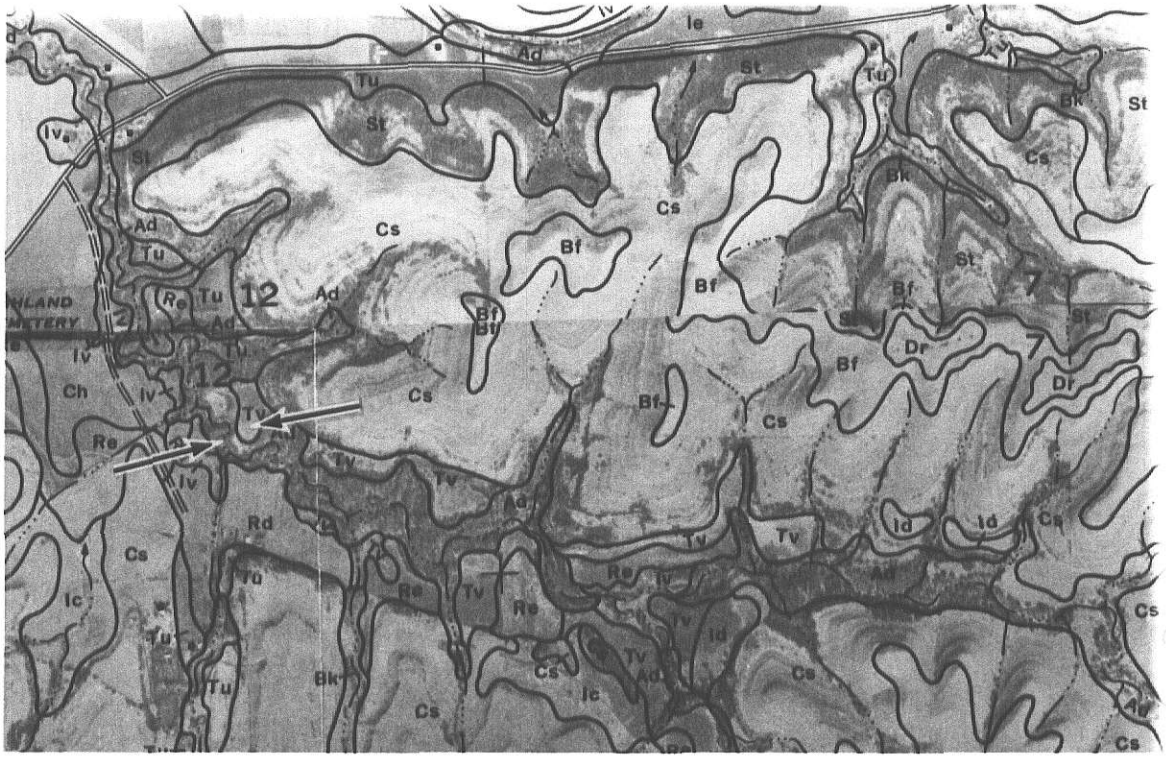
35

Fig. 5: Woodland soil collection sites (WL 2, WL 3):

A wheatfield was south to the collection sites.

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7

AN OPAL PHYTOLITH AND PALYNOMORPH STUDY OF EXTANT AND FOSSIL SOILS IN KANSAS

by

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Diploma, Swiss Federal Institute of Technology, 1980

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

AN OPAL PHYTOLITH AND PALYNOMORPH STUDY OF EXTANT AND FOSSIL SOILS IN KANSAS

ABSTRACT

Soils from three plant communities (shortgrass prairie, tallgrass prairie and a deciduous forest) were analyzed for opal phytoliths, pollen grains and fungal spores. These data were used to correlate vegetation type with phytolith and palynomorph deposition. The results were applied to the study of a paleosol to determine the vegetation and ecological conditions prior to burial. Light microscopy and scanning electron microscopy were used to elucidate the different forms of phytoliths, pollen grains and fungal spores. Statistical analyses of the data showed that the phytolith composition differs significantly among the three extant soils. Pollen analysis failed to differentiate between tallgrass and shortgrass prairie, because the pollen could not be attributed accurately to the different grass taxa that are characteristic of these vegetation types. However, pollen analysis distinguished woodland sites from the prairies because of the abundance of easily recognized pollen of woody plants. The comparison of the extant soils to the paleosol showed that the plant community prior to burial may have been a cool season grassland. The results demonstrate the importance of combined phytolith and pollen analysis, because phytoliths provide additional, refined botanical data not available in pollen studies, especially in grasslands.