

ABSTRACT

PALYNOLOGY OF THE SUBSURFACE FRIO FORMATION IN LIBERTY AND CHAMBERS COUNTIES, TEXAS

By

Khosrow Ebtehadj

The study area located in southeast Texas is part of the Gulf Coast Geosyncline, a large sedimentary basin covering an area from Alabama to the northeastern part of Mexico. The subsurface Frio Formation in the three wells studied represents a marine regressive stratigraphic unit with minor transgressive and regressive phases. The age of the subsurface Frio in Liberty and Chambers Counties is believed to be Oligo-Miocene, thus representing a time transgressional rock unit.

The two major objectives have been to determine the nature and composition of the microfossil assemblage, and its usefulness for establishing stratigraphic-palynological horizons. Thus ten palynologic horizons are recognized based on relative abundance and last occurrence of a number of palynomorphs.

The relative abundance of different groups of palynomorphs aid in deciphering the paleoecologic conditions which existed at the time of sedimentation.

One hundred sixty-eight microfossils are identified and described. Of this total number there are four new genera and 32 new species belonging to 19 genera. The majority of the Frio plant microfossil assemblage, based on their modern counterparts, have a subtropical to tropical distribution possibly indicating a similar distribution of the parent flora. A small part of the microfossil floral assemblage is represented by palynomorphs which today have a warm temperate to temperate distribution.

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FORMATION IN LIBERTY AND CHAMBERS
COUNTIES, TEXAS

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Geology

1969

ACKNOWLEDGMENTS

The author wishes to express his deepest and most sincere gratitude to Dr. Aureal T. Cross of the Department of Geology and the Department of Botany and Plant Pathology, Michigan State University, under whose guidance this study was made, for his assistance and constructive criticism and his innumerable suggestions. The author is deeply indebted to Dr. C. E. Prouty, Dr. J. H. Fisher, Dr. J. E. Smith of the Department of Geology, Michigan State University, and to Dr. J. H. Beaman, Department of Botany and Plant Pathology, Michigan State University for their suggestions and critical reading of the manuscript.

The author also expresses his gratitude to Esso Production Research Company, Houston, in providing sample material for this study and for preparing photographic plates.

Appreciation is also gratefully given to Dr. W. C. Elsik of Humble Oil and Refining Company, Houston, Texas, and to Dr. G. L. Williams of the Pan American Petroleum Corporation, Research Center, Tulsa, Oklahoma, for their examination of slides and photomicrographs used in this study and suggestions concerning the taxonomic identity of a number of palynomorphs.

The author wishes to acknowledge the patience and constant encouragement of his wife Farideh throughout the time devoted to this study.

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INTRODUCTION

Purpose and Scope

The subsurface Frio Formation of southeast Texas has been correlated readily using Foraminifera, but this control is limited to the downdip marine part of the formation. The updip sections lack marine microfossils. This study has two principal objectives: (a) To establish a microfossil assemblage based on the presence of different types of palynomorphs, and to record their geologic range and modern affinity. (b) To set up biostratigraphic horizons using quantitative and qualitative methods of correlation.

The relative abundance of microplanktonic organisms to land-derived palynomorphs sheds some light on the environmental conditions under which a stratigraphic unit may have been deposited. Thus relative abundance of such organic entities is indicative of distances from paleoshoreline or possible depths of water.

Variation in spore and pollen abundance with respect to the total number of palynomorphs present at a given horizon may aid in determining distances from parent flora and also indicate changes in environment.

Three wells were analyzed. There is a noticeable gradation from updip brackish or lagoonal environment,

with a higher proportion of sand, to more marine with predominantly shaly and silty sediments. The three wells are in a north-south line, and the distance separating the first from the last well is 24 miles.

Previous Work

There is no published report on Frio palynology. R. Malloy formerly with Humble Oil and Refining Company, Houston, now with Gulf Oil, Houston, has worked on the palynology of the Frio Formation in southwest Texas, and Dr. G. Morales of Esso Production Research Company, Houston, has also successfully zoned the formation by using charophytes, but both reports are confidential company projects.

The marine subsurface Frio has been zoned using Foraminifera and Ostracoda. Garret (1938) listed and described the Hackberry foraminiferal assemblage; Stuckey (1946) described Textularia seligi of the Lower Frio; Ellis (1939) described Cibicides hazzardi, Nodosaria blanpiedi and Nonion struma. Garrett and Ellis (1937) described Marginulina texana from the subsurface of Jefferson County, Texas, and Ellisor (1933) was presumably the first author to publish a small list of the invertebrate fauna.

There are relatively few reports on the palynology of the Gulf Coast Tertiary sediments, some of the more notable authors are: Elsik (1968), Stover, et al. (1966), Engelhardt (1964), Drugg and Loeblich (1967),

Gray (1960), and Jones (1962). But on the whole the amount of literature on Tertiary palynology in the United States is meager in comparison to the number of published reports by European workers.

I. GEOLOGY

The Gulf Coast Geosyncline

The term Gulf Coast Geosyncline was coined by Barton, Ritz and Hickey in 1933 and refers to a large sedimentary basin which covers an area of 250,000 square miles extending from Alabama to the northeastern part of Mexico. This basin contains about 60,000 feet of Mesozoic and Cenozoic sediments.

The shape of the geosyncline has been about the same since the Cretaceous period, but subsurface information obtained from the upper Gulf Coast indicates, according to Bornhauser (1958), that geosynclinal conditions prevailed during Jurassic and early Cretaceous times. This area of the ancestral geosyncline covered southern Mississippi, Louisiana, southern Arkansas and eastern and southern Texas.

The Gulf Coast Geosyncline is an asymmetrical sedimentary basin with its axial plane dipping approximately four degrees shoreward. To explain the asymmetry the concept of "flexures" was proposed by Colle et al., (1952). They define flexure as the zone downdip from which the rate of dip and thickening of beds is augmented. Hardin (1962) attributes the origin of flexures to

deposition across the shelf break, with the steep continental slope being responsible for the increased thickening of stratigraphic units. Thus each succeeding younger flexure is located seaward or downdip from the previous older one. Hence the area of maximum sedimentation for each succeeding younger stratigraphic unit is found downdip from the thickest sequence of beds of the preceding older units. The plane connecting the loci of maximum thicknesses for each stratigraphic unit dips toward the shore, this explains the tilting of the geosynclinal axis shoreward (Figure 1).

Sedimentation in the Gulf Coast Geosyncline

There are five major structural features characterizing the northwestern limb of the geosyncline which have influenced sedimentation throughout the Cenozoic era, these are: Rio Grande Embayment, San Marcos Arch, East Texas Embayment and its downdip counterpart the Houston Embayment, Sabine Uplift, and finally the Mississippi Embayment (Figure 2).

The area of maximum sedimentation or depocenters shifted eastward during Cenozoic time, hence one finds that maximum sedimentation in Eocene and Oligocene times was in the Rio Grande Embayment and presumably sediments were supplied by rivers ancestral to the Rio Grande which were draining the Sierra Madre Oriental of Mexico

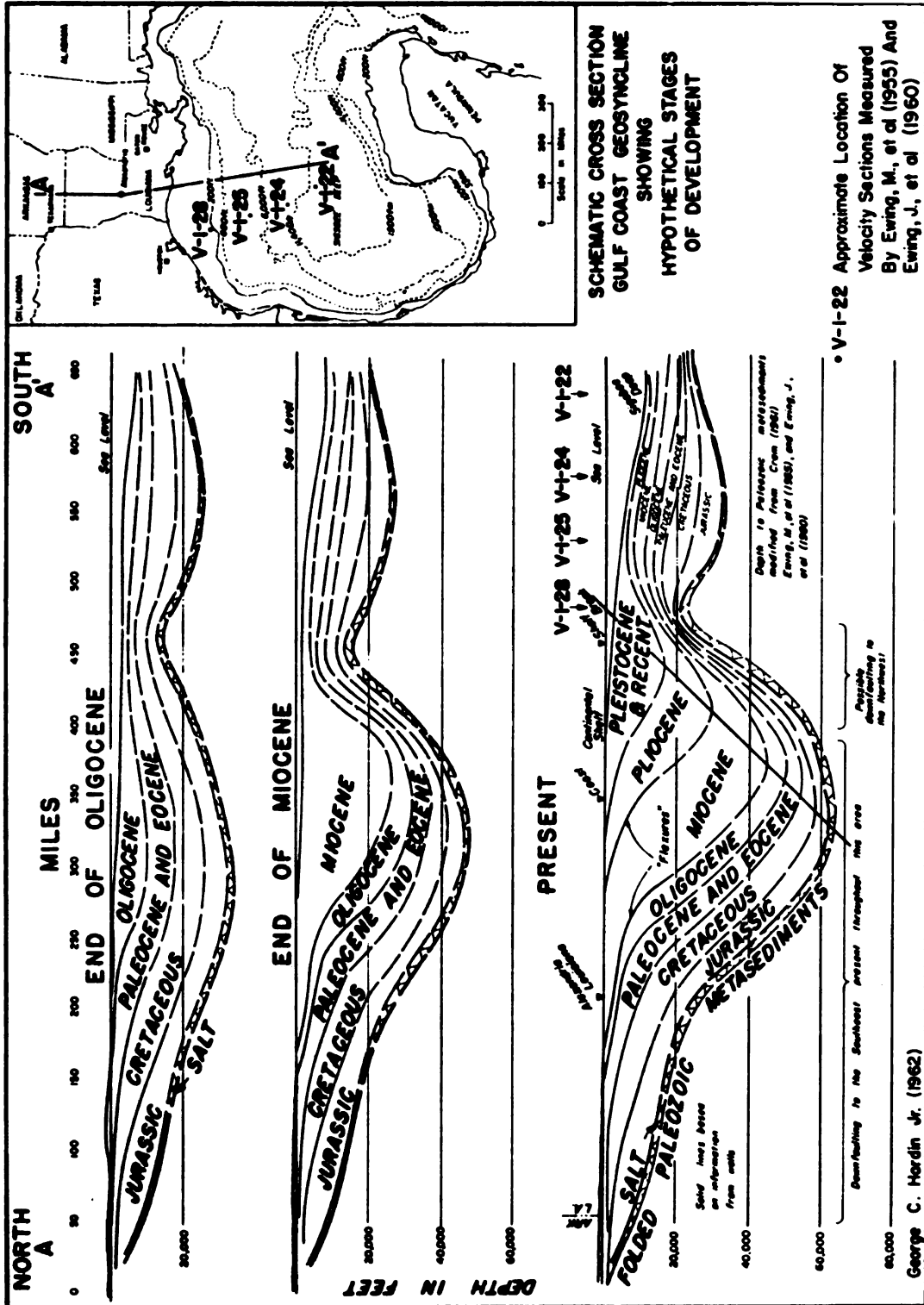


Figure 1. Hypothetical stages in the development of the Gulf Coast Geosyncline from George C. Hardin, Jr., 1962 (in *Geology of the Gulf Coast and Central Texas and Guidebook of Excursions*).

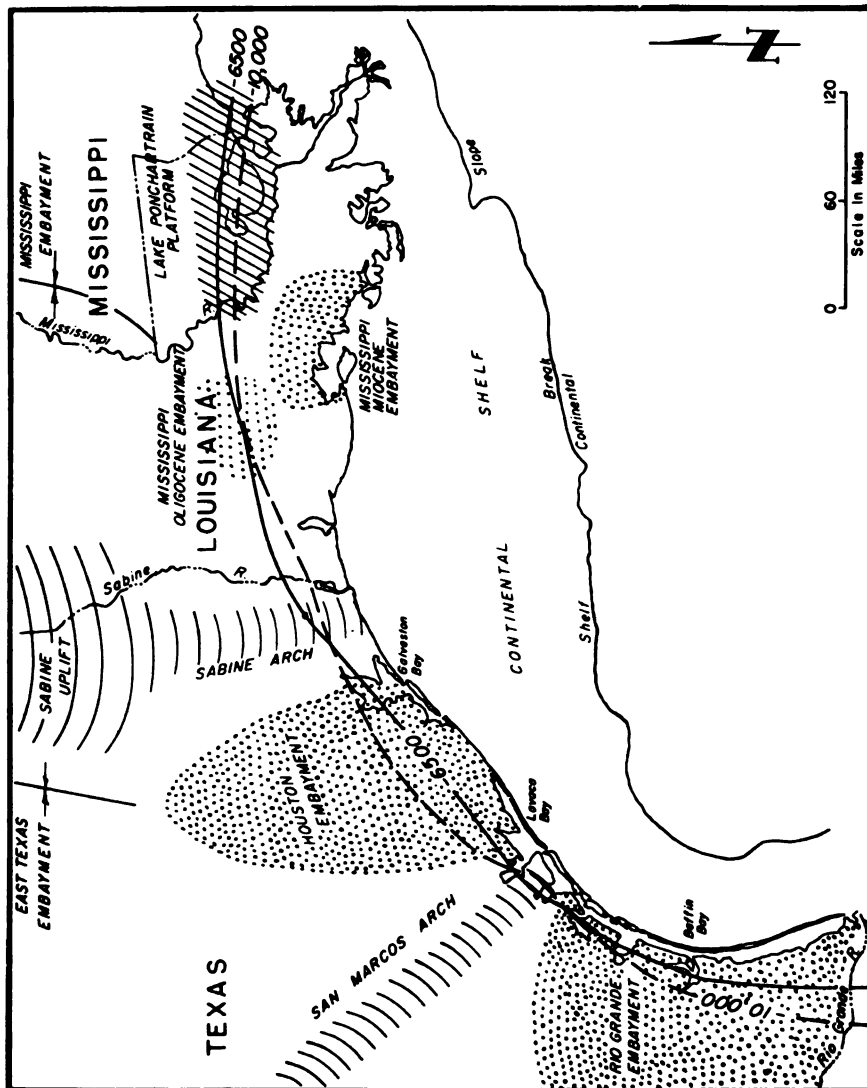


Figure 2. Major structural elements of the Gulf Coast Geosyncline. The solid contour line (-6500 ft.) is drawn on top of the Heterostegina zone of the Anahuac Formation and the dashed contour line (-10,000 ft.) is drawn on the top of the Vicksburg Formation (Oligocene). From George C. Hardin, Jr., 1962 (in Geology of the Gulf Coast and Central Texas and Guidebook of Excursions).

and mountainous regions of western Texas, New Mexico, and Colorado. Eocene and Oligocene sediments thin over the San Marcos Arch and thicken in the Houston Embayment. Accordingly one finds that the Vicksburg and Frio sediments substantially thicken in the embayment and thin out farther east over the downdip equivalent of the Sabine Uplift which is called the Sabine Arch (Figure 3).

The combined thicknesses of the Frio and Anahuac formations (believed by some geologists to be Upper Oligocene to Middle Miocene in age) is over 10,000 feet thick in south Texas and this thickness is maintained in southwestern Louisiana, but post-Anahuac sediments i.e. Miocene and younger, reach a thickness of approximately 30,000 feet in the Mississippi Embayment. At the present time the Mississippi river has deposited about 8,000 feet of Pleistocene and Recent sediments in south-eastern Louisiana and thus represents the principal source of supply of material to the Gulf of Mexico (Figure 4).

Frio Formation

Introduction

The Frio Formation of south Texas is undoubtedly one of the most complex Cenozoic formations of the Gulf Coast area. The purpose of this section is to describe the nature and complexities of some of the problems involved in interpreting the stratigraphy of the Frio.

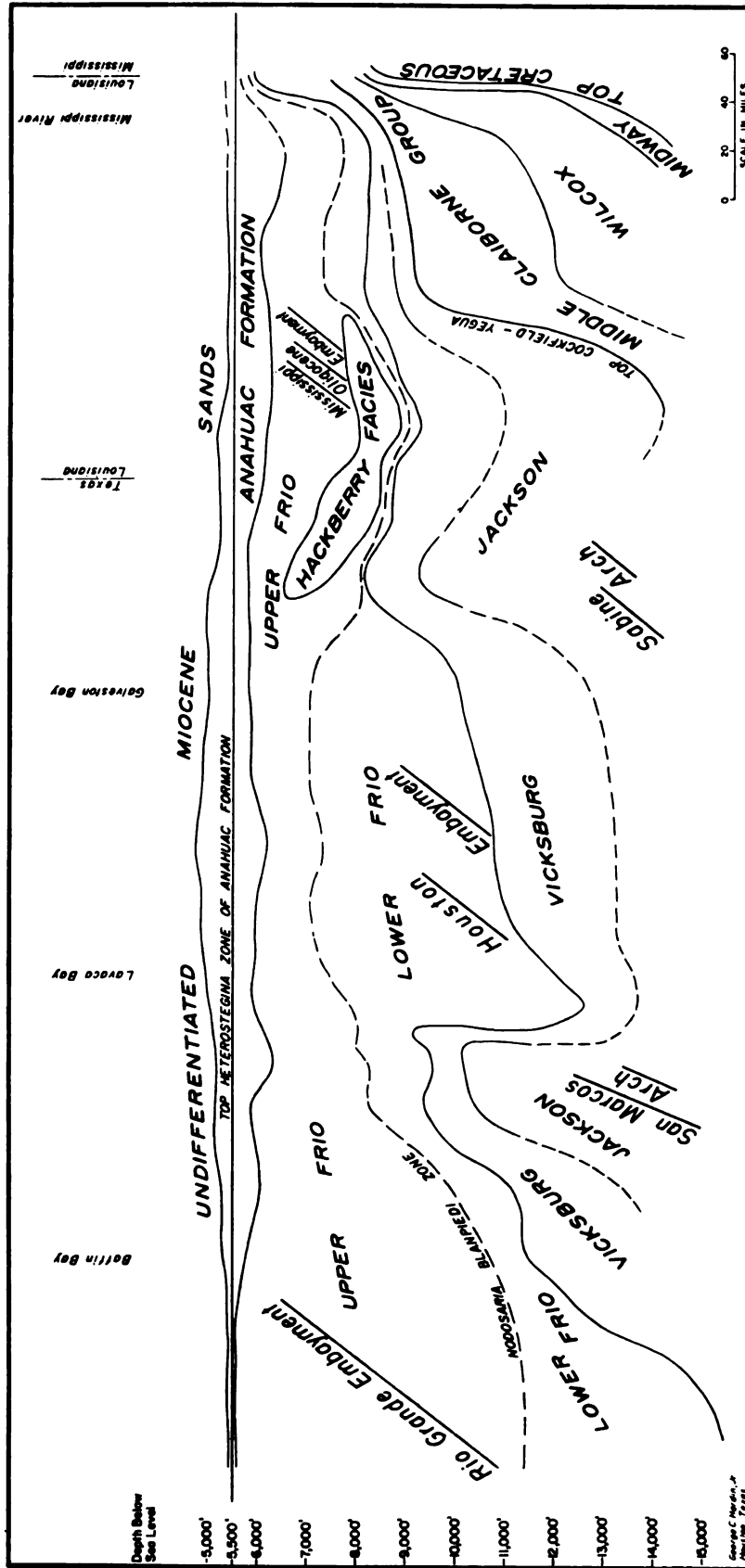


Figure 3. Strike cross section through southeastern Texas and southern Louisiana. Section is drawn taking the -6500 feet contour line on the top of the Heterostegina zone of the Anahuac Formation. From George C. Hardin, Jr., 1962 (in Geology of the Gulf Coast and Central Texas and Guidebook of Excursions).

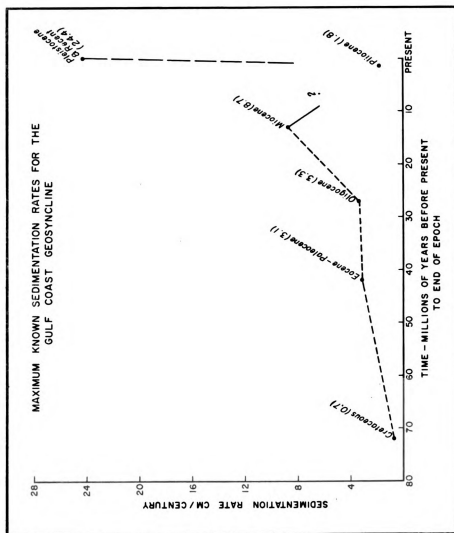


Figure 4.

Graph showing maximum rate of sedimentation from the Cretaceous period to the Recent in the Gulf Coast. From George C. Hardin, Jr., 1962 (in Geology of the Gulf Coast and Central Texas and Guidebook of Excursions).

History

E. T. Dumble in 1894 defined the surface Frio in an area between Weedy Creek and Oakville along the Atascosa River. His description apparently included lithologic units which belong to the Jackson as well as the Catahoula age. Later on Dumble (1924) recognized the volcanic nature of some of the beds and described the Frio in the Fayette section as follows:

The Frio marks a change from a formation that is characteristically sandy to one that is mostly clay. The lowest beds which can with certainty be referred to the Frio in the Atascosa section were found on the river southwest of Fant City, a short distance above the mouth of Weedy Creek. A yellow, massive, calcareous sand with bands of hardened light green sand was here overlain by green, waxy clays with thin streaks of gypsum, rusty streaks and cherty concretions. These clays weather white and are for the most part non-calcareous. Highly characteristic exposures of these beds occur up Weedy Creek for several miles. Similar beds continue down the river, some of the clays being bright green or blue-green when fresh, but all weather white and resemble caliche when exposed. Nearing the middle of the section the green, waxy clays and greenish sands carry bands of calcareous concretions. The upper beds are light green clays and sandy clays with calcareous concretions distributed through them irregularly for the most part but sometimes in lines. Some beds of brown sand occur. The final exposure of the Frio is found just south of the sharp bend in the Nueces where it changes from its northeast to its southerly course.

Plummer in 1932 was apparently first to use the Frio as a subsurface unit. He indicated that the Frio lay beneath the Middle Oligocene Anahuac Formation and above the Vicksburg Formation. Ellisor in 1932 defined the subsurface Frio in the same stratigraphic framework

and described a small invertebrate fauna. It became evident in later years from the work of Israelsky that part of the surface Frio might actually represent the subsurface Vicksburg. Warren (1957) suggested that the surface Frio should be called Vicksburg and proposed a type locality in Jefferson Davis Parish, Louisiana to define the subsurface Frio. The stratigraphic relationships of the Frio subsurface and its surface equivalent has not been solved yet. This is possibly due to the fact that the "surface" Frio is composed of non-marine sand and clay and no reliable index fossils are present (Figure 5).

Frio Stratigraphy

There is no general agreement in subdividing the Frio. Holcomb (1964) maintains that since there is not enough variation in lithology vertically or laterally two units should be recognized, Upper and Lower Frio. This subdivision refers to the lithologies included between the top of the Vicksburg Formation marked by the last occurrence of Textularia warreni and the last occurrence of Anomalina bilateralis or its updip "equivalent" Nodosaria blanpiedi. The Upper Frio is defined as that lithologic interval overlying the lower marine Frio and underlying the marine Anahuac wedge (Figure 6).

Reedy (1949) has three subdivisions of the Frio in Orange and Jefferson counties of southeast Texas. According to Reedy, the Upper Frio is composed of

Figure 5. From C. W. Holcomb, 1964 (in Transactions of the Gulf Coast Association of Geological Societies).

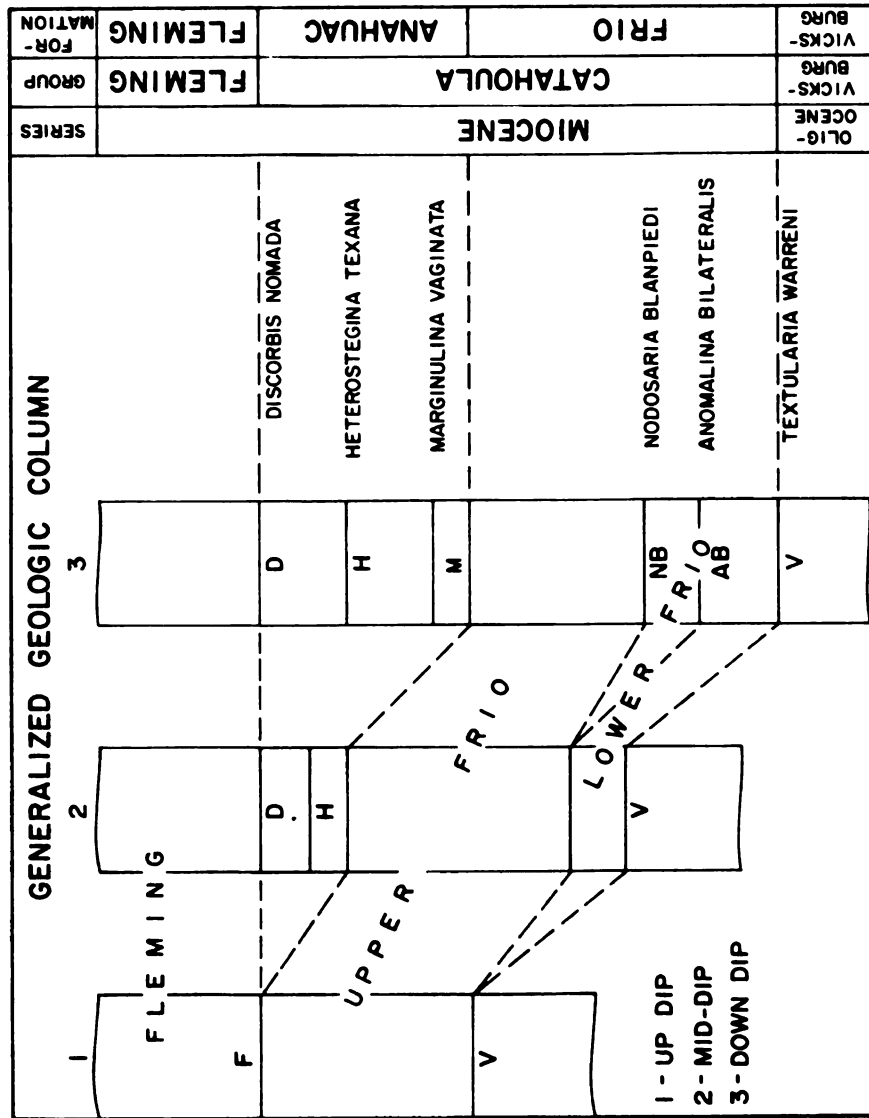


Figure 6. Diagram of the subsurface divisions from the Vicksburg Formation up through the Anahuac Formation. From C. W. Holcomb, 1964 (in transactions of the Gulf Coast Association of Geological Societies).

massive-bedded sands of neritic to marine facies deposited during a marine progressive onlap and it is characterized by Cibicides hazzardi. Downdip these massive sands grade into shaly sands. The Middle Frio is characterized by a marine shale wedge representing the shale phase of deposition of transgressive-regressive shore line and it contains a very rich foraminiferal fossil assemblage known as the Hackberry Assemblage. The Lower Frio is composed of four sand members with alternating shales, but downdip the individual sands grade into shales (Figures 7 and 8).

Sediments of the Frio illustrate a succession of numerous minor transgressions and regressions of the sea, but as a whole unit it was laid down as a regressive sequence. At the end of the Vicksburg time the sea started to withdraw and, according to Boyd and Dyer (1964), a barrier bar was deposited along the paleoshoreline. Depending on the geographical location, the sea receded either relatively fast allowing a horizontal or lateral buildup, which is the case in the Rio Grande delta system, or a vertical buildup with a slowly retreating sea. The Frio barrier bar complex was terminated with the transgression of the Anahuac sea.

Boyd and Dyer have divided the Frio barrier bar system into three recognizable environmental units: the Frio barrier bar, a lagoonal environment and a continental shelf environment. The barrier bar consists of coarse to

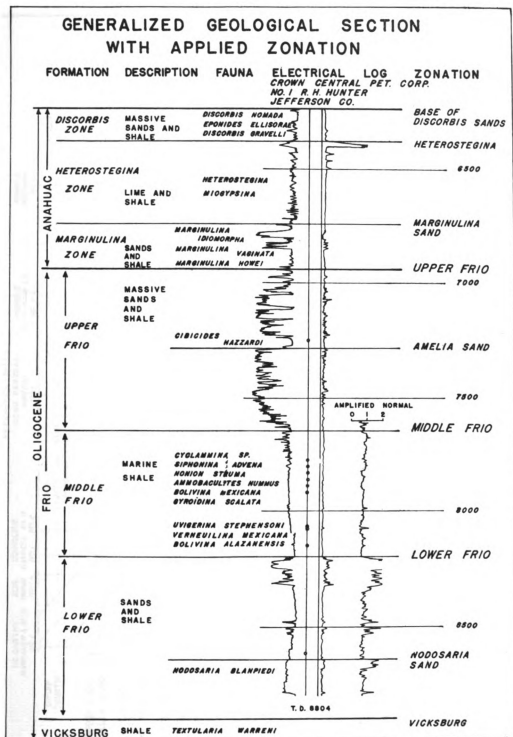


Figure 7. From Frank Reedy, Jr., 1949 (in Bulletin of the American Association of Petroleum Geologists).

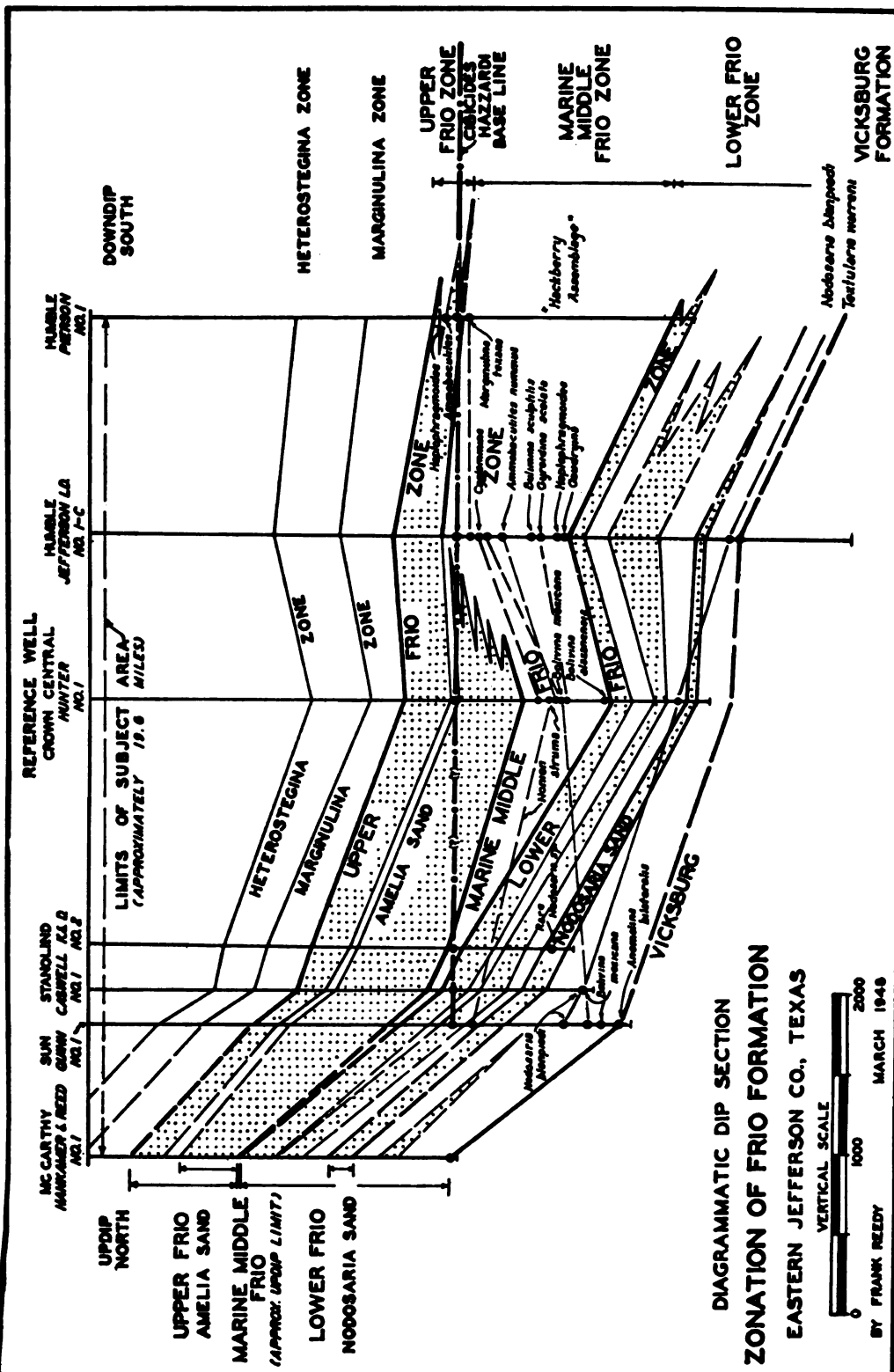


Figure 8. Dip section showing transgression of the zones of the Frío Formation. From Frank Reedy, Jr., 1949 (in Bulletin of the American Association of Petroleum Geologists).

fine grained quartzose sand. These sands were transported westward by longshore currents, storms and winds together with the tidal effect resulted in washover fan deposits in the lagoonal area behind the bar. Oil reservoirs are mainly encountered in the top portion of the barrier bar. The lagoonal environment comprises shales, siltstones, and washover sands deposited behind the barrier bar. Brackish water faunal assemblages are present in the lagoonal environment. The continental shelf environment is mainly composed of marine shales with occasional shelf sand deposited presumably by turbidity currents.

Tectonic Features Associated With the Frio

Frio sedimentation in the Gulf Coast was influenced by five major structural features encountered along the north-western limb of the geosyncline (Figure 3), as well as by a series of northeast-southwest depositional faults. These faults were active during deposition of clastic sediments, thereby thickening sediments into the downthrown side. But the thickening of Frio sediments is usually limited to the Lower Frio since many of the depositional faults die out in the Upper Frio. One of the most well-known faults affecting the Frio is the Sam Fordyce-Vanderbilt or Vicksburg fault system (Figure 9).

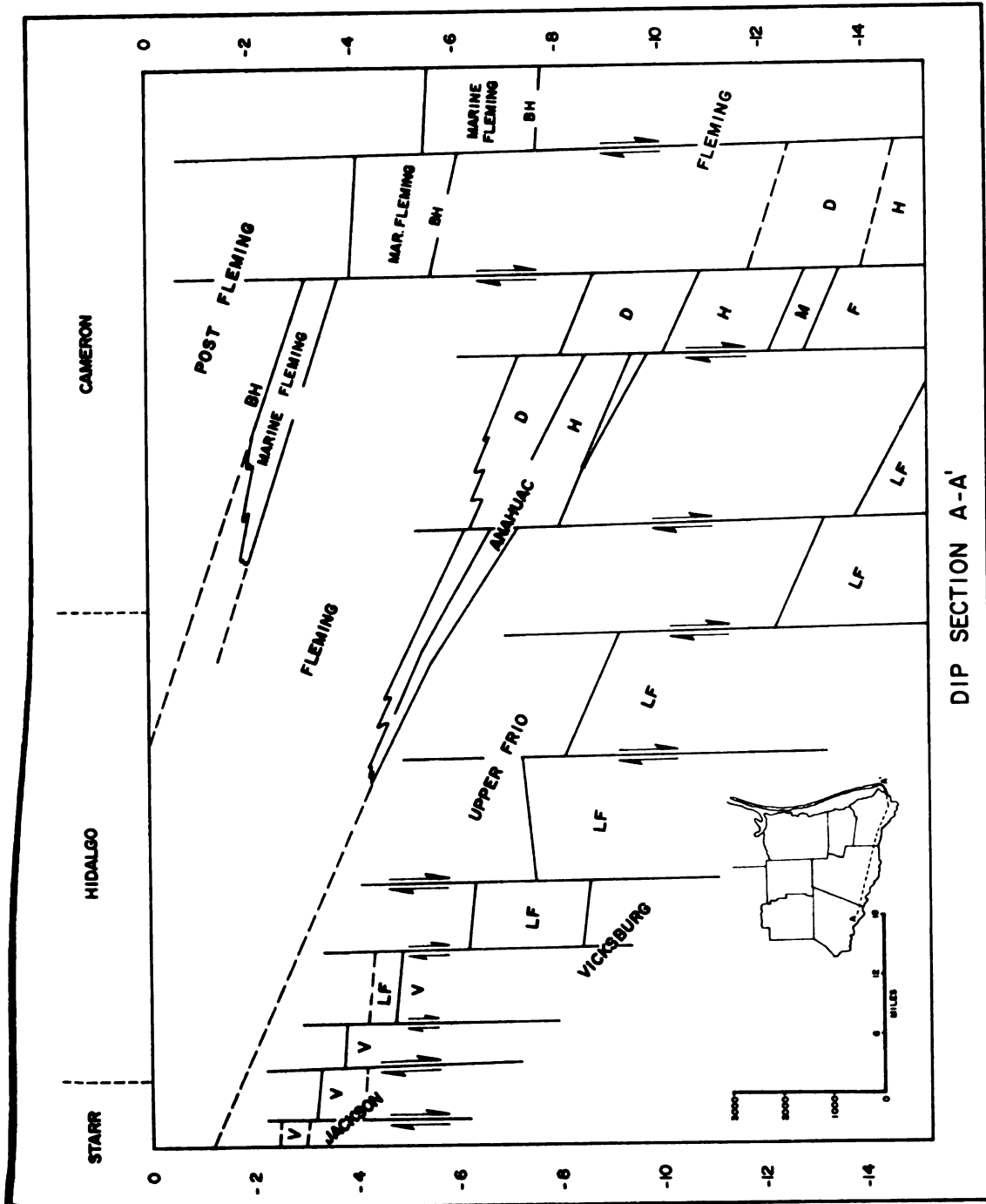


Figure 9. Cross section showing faulting affecting progressively younger beds. From C. W. Holcomb, 1964 (in Transactions of the Gulf Coast Association of Geological Societies).

Age of the Frio

There is no general agreement with regards to the age of the subsurface Frio. It seems that the majority of geologists tend to consider it as Oligocene. However, according to Johnson and Mathy (1957) some stratigraphers have indicated that the Frio is possibly equivalent to the Lower Catahoula of south Louisiana which is Miocene. Holcomb favors a Miocene age for the Frio without giving any reasons, and it appears that most oil companies consider the Frio as Miocene. According to Butler (1960) the age problem originated when the Middle Anahuac Heterostegina species were erroneously identified as Heterostegina antillea occurring in the Middle Oligocene on the island of Antigua British West Indies and hence the Frio being older than the Anahuac was thought to be Oligocene.

By taking into consideration only those palynomorphs which have a limited geologic range in the total Frio microfossil assemblage, one is strongly inclined to ascribe an Oligocene to Lower Miocene age to the subsurface Frio. One can definitely exclude a Middle Miocene age as the uppermost age limit for lack of any Compositae pollen, since this family of plants evolved most presumably in Middle Miocene. Thus the author, on the basis of presence of palynomorphs of known limited stratigraphic range and absence of Compositae pollen, considers the

subsurface Frio of southeast Texas as a time transgressional rock unit with an age range of Oligocene to Lower Miocene. The following is a list of Frio palynomorphs which have a limited geologic range:

Homotryblium plectilum Drugg and Loeblich:
Oligocene

Pentadinium laticinctum Gerlach: Middle
Oligocene to Middle Miocene

Acostomcystis potane Drugg and Loeblich:
Oligocene

Leiotriletes adriensis Potonié and Gellertich:
Upper Oligocene

Leiotriletes maxoides Krutzsch: Middle to
Upper Oligocene

Lusatisporis perinatus Krutzsch: Middle
Miocene

Saxosporis duebenensis Krutzsch: Miocene

Polypodiisporites favus Potonié: Miocene

Corsiniipollenites oculusnoctis Nakoman:
Oligocene

Betulaceoipollenites granifer forma mega-
granifer Potonié: Miocene

Liquidambarpollenites stigmosus Raatz:
Miocene

Ilexpollenites iliacus Thiergart: Oligocene
to Miocene

Quercoidites henricii Potonie, Thomson and
Thiergart: Oligocene to Miocene

Sapotaceoidaepollenites lesquereuxiana
Potonié: Oligocene to Miocene

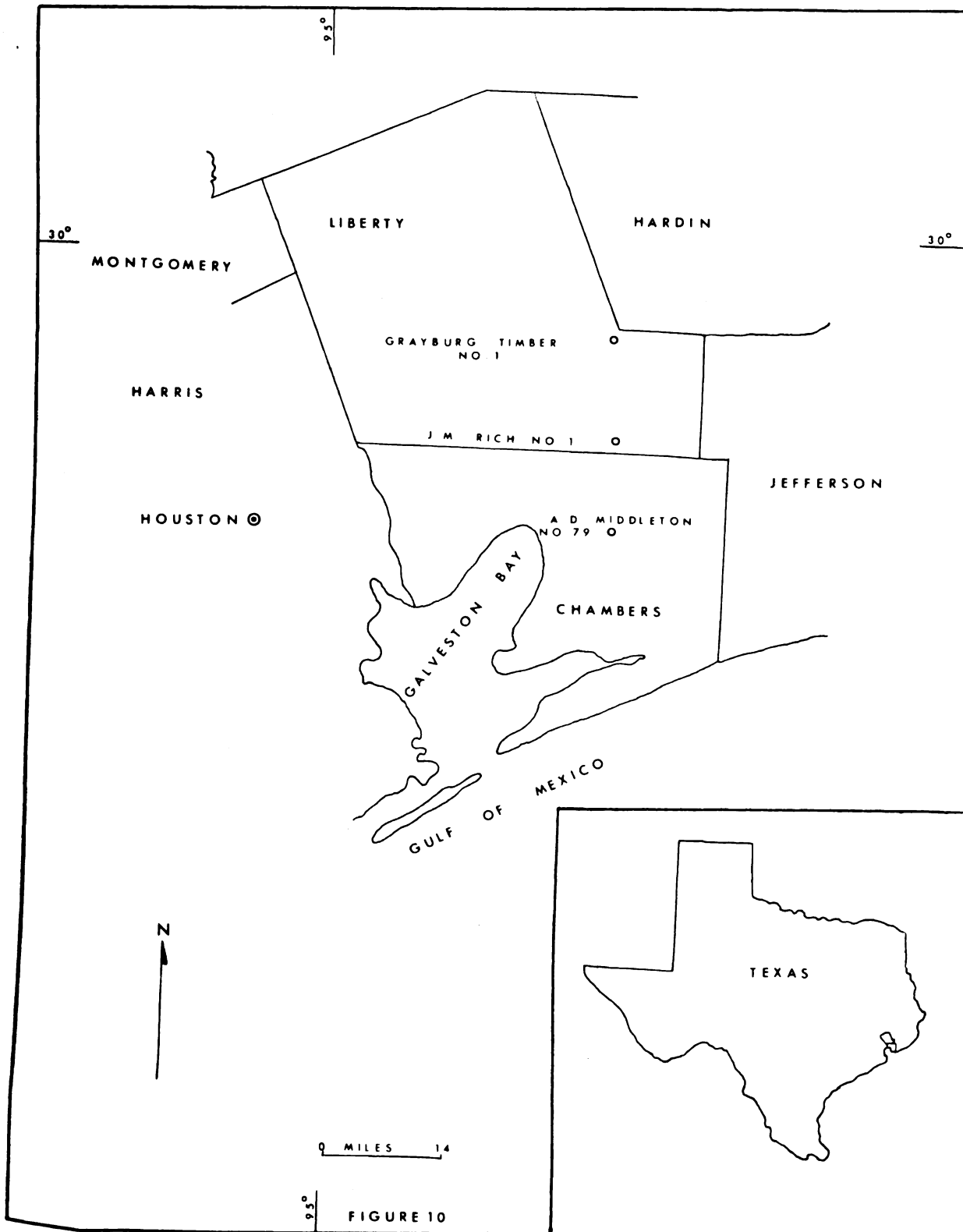
II. SAMPLE LOCATION AND LITHOLOGIC DESCRIPTION

Well Location

Wells Grayburg Timber #1 and J. M. Rich #1 are located in Liberty County, the distance separating them is approximately 12.8 miles. The third well #79 A.D. Middleton is in Chambers County, and it is 11.2 miles south of J. M. Rich #1 well (Figure 10).

Grayburg Timber #1 well is far enough updip that Lower Anahuac Marginulina Zone and Frio markers are not present. The Frio in this well is 1,664 feet thick and is encountered between -4619 feet and -6283 feet contour. J. M. Rich #1 well has a poorly developed fauna and foraminiferal species used for zonation may not be time correlative with the tops picked downdip. In this well the Frio is 1,704 feet thick and it is encountered between -6382 feet and -8086 feet contour. A. D. Middleton #79 is far enough downdip to have a well developed foraminiferal fauna and hence it has been zoned on this basis. Here the Frio is 2,345 feet thick, its top is at the -6861 feet contour and bottom -9206 feet level.

Fig. 10.--Location of wells.



Lithologic Description

The lithologic descriptions of samples listed here are only intended to illustrate variations encountered at different levels within the wells, and are not considered to be accurate petrographic analyses. The location of wells examined, together with sample position and lithologic descriptions, is listed below.

Grayburg Timber Company #1, Hull Field,
Liberty County, Texas

Sample Number	Depth	Lithology
24	4466'-4496'	grayish sandy shale, with occasional Molluscan fossils
1	4589'-4619'	grayish calcareous shale
16	4651'-4681'	grayish sandy shale, with occasional Molluscan fossil remains
2	4743'-4774'	light-gray fissile shale
19	4839'-4865'	grayish sandy shale with fragments of Molluscan(?) remains
21	5017'-5048'	creamy-pink, loosely consolidated sandstone; relatively fine-grained
20	5250'-5280'	loosely consolidated, medium-grained angular-grained sandstone; beige color
5	5352'-5383'	light-gray calcareous sandy clay
25	5496'-5507'	light-gray, fine-grained clayey sandstone with fragments of gray quartzite
6	5590'-5621'	creamy-pink, fine-grained sandstone; grains angular

Sample Number	Depth	Lithology
7	5754'-5786'	light-gray shale mixed with grayish, medium-grained sandstone
13	5879'-5911'	light-gray calcareous shale, mixed with medium, angular-grained sandstone
17	6035'-6066'	same lithology as above
9	6190'-6221'	light-gray clayey sandstone, fine-grained
11	6345'-6376'	same lithology as above

J. M. Rich et. al. #1, Hankamer Field,
Liberty County, Texas

Sample Number	Depth	Lithology
2	6166'-6197'	grayish calcareous shale
3	6382'-6414'	virtually same lithology as above, except for being more sandy
23	6483'-6514'	grayish clayey sandstone, with fragments of Molluscan(?) remains
21	6577'-6594'	grayish silty shale
4	6692'-6723'	practically same lithology as above, except a little more calcareous
5	6847'-6878'	light-gray sandy shale
18	6909'-6940'	virtually same as above, except for presence of pyrite
27	7033'-7067'	light-gray sandy shale, slightly lighter in color than above
6	7098'-7129'	gray-fissile shale
14	7191'-7230'	light-gray silty shale

Sample Number	Depth	Lithology
7	7292'-7323'	same lithology as above
8	7448'-7479'	same lithology as above
20	7572'-7603'	gray-silty fissile shale, occasionally micaceous (biotite), some molluscan fossils present
9	7693'-7724'	gray-silty fissile shale
17	7745'-7776'	light-gray calcareous shale
10	7838'-7869'	light-gray micaceous (muscovite?), loosely consolidated clay
19	7962'-7993'	light-gray mainly calcareous soft clay, with occasional mica flakes
11	8024'-8055'	same lithology as above, but slightly darker gray
16	8117'-8148'	same lithology as above, but dark-gray in color

A. D. Middleton #79, Anahuac Field,
Chambers County, Texas

Sample Number	Depth	Lithology
15	6705'-6861'	light-gray fossiliferous sandy clay, loosely consolidated
19	6861'-6954'	same lithology as above, only slightly more sandy
20	7047'-7138'	light-gray silty shale, slightly calcareous
21	7233'-7327'	same lithology as above
22	7417'-7511'	same lithology as above
23	7638'-7731'	same lithology as above
24	7800'-7926'	same lithology as above

Sample Number	Depth	Lithology
11	8119'-8111'	dark-gray silty shale, slightly calcareous
25	8204'-8237'	same lithology as above
26	8300'-8360'	light-gray well consolidated calcar- eous shale
2	8485'-8579'	same lithology as above
9	8579'-8710'	same lithology as above, only slightly darker in color
7	8710'-8835'	light-gray to light-greenish gray, soft, calcareous, micaceous, shale
1	8936'-9030'	same lithology as above, except less micaceous
8	9112'-9206'	light-gray, soft, calcareous shale
3	9206'-9300'	light-gray, soft, calcareous shale, mixed with light greenish-gray quartzitic sandstone.

III. METHODS

Maceration Techniques

Preparations of the Frio sediments for microscopic examinations were carried out in a procedure similar to standard palynological maceration for the study of acid insoluble micro-organisms. But no attempt was made to wash the well-cuttings, since most of the time these samples of the Frio sediments are under 1 cm in size, and one could not accurately differentiate indigenous sediments from the drilling mud. To release the organic entities from the rock matrix, samples were treated according to the following procedure.

1. Weigh 20 gram aliquot
2. Treat with 10% HCl for 24 hours to remove carbonates
3. Decant the HCl
4. Treat residue with 70% HF for 36 hours for removal of silicates
5. Wash residue once with distilled water and few drops of 10% HCl
6. Wash residue several times with distilled water by centrifugation

7. Treat residue with Schulze solution (1 part KClO_3 to 8 parts concentrated nitric acid) for 5 minutes
8. Leave residue in 5% KOH for 3 minutes, then centrifuge and decant
9. Wash residue twice with distilled water
10. Perform specific gravity separation on residue using ZnCl_2 (sp. gr. 1.95) for 10 minutes
11. Wash residue twice in distilled water with few drops of 10% HCl by centrifugation
12. Wash residue several times with distilled water by centrifugation
13. Wash residue through a sieve (200 micron openings) to remove relatively large organic debris
14. Stain residue with concentrated Safranin O for 30 minutes, last 5 minutes add 2 drops of 10% NH_4OH

Residues are stored in a solution of HEC.*

Sample Analysis

Several slides of each residue were made for Preliminary study to determine and differentiate the palynomorphs. Once the major taxa were established only

*Hydroxy ethyl cellulose.

one slide for each residue was studied to determine relative abundance. Traverses were made at x800 under oil immersion with a Zeiss GFL standard microscope. No regular order of traverses was followed, but careful attention was given so that all areas of the entire slide would be about equally represented in the examination of the sum of 500 specimens counted. A specimen would be included in the total count only if its center was within the field of view. Since there are taxa of many different sizes, such a method of counting would be less biased by the presence of large spores, bisaccate pollen or microplankton.

The sum of 500 specimens counted on each slide was established by analogy to similar species-area curves used in terrestrial plant ecological studies to determine number and size of quadrats. Thus the figure of 500 was determined by plotting a curve of number of taxa identified against number of specimens counted. The departure of such a curve from a normal one may be due to various factors including difference in size of palynomorphs (smaller entities tend to concentrate near the edge of the cover slip).

In Figure 11 two examples are illustrated and it can be observed that the dotted curve reaches a plateau between 425 and 450 specimens counted. But on other similar graphs a plateau was reached on the curve when

Fig. 11.--Two examples are graphically illustrated to indicate the number of entities counted on each slide.

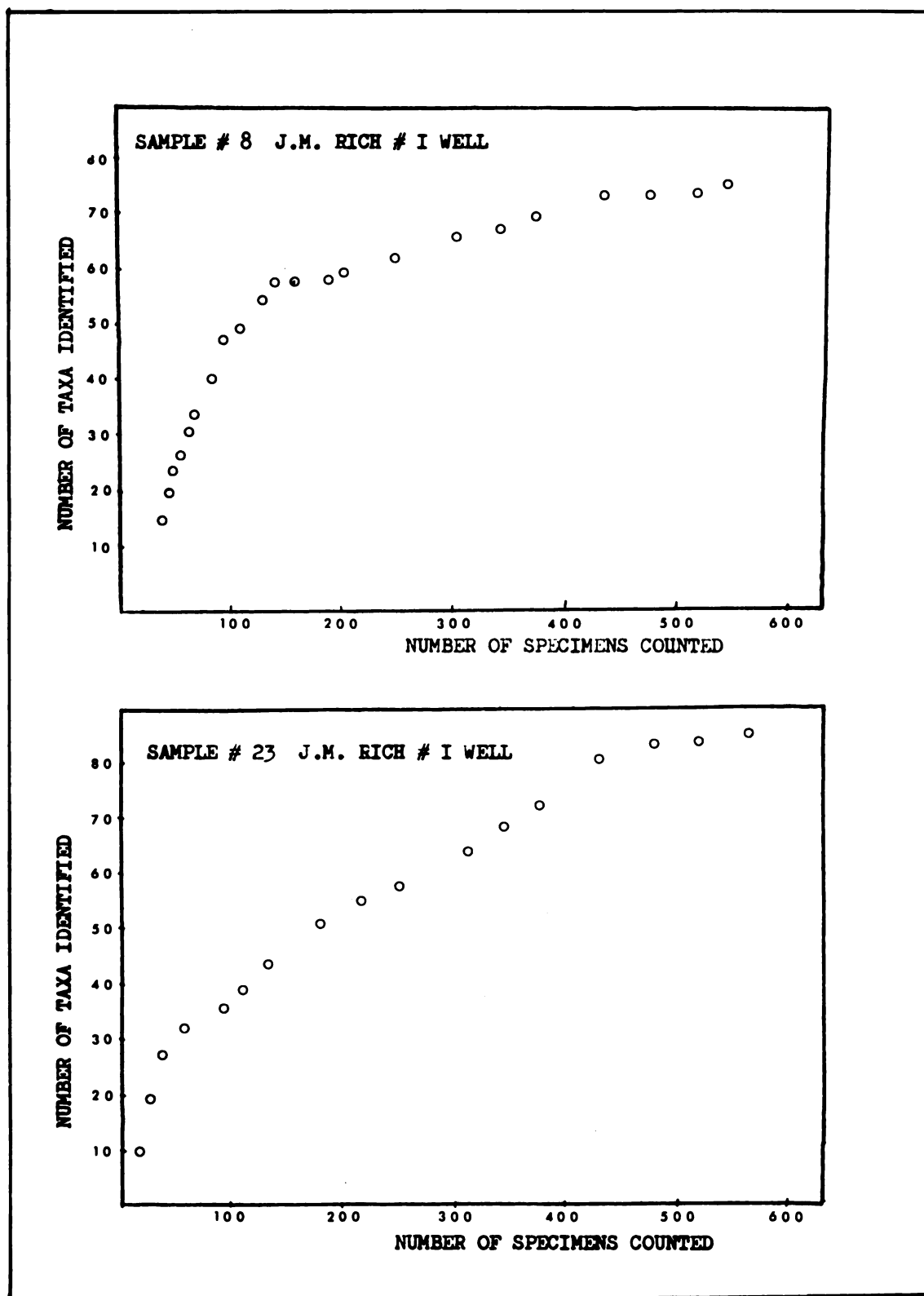


FIGURE 11

500 to 550 grains were studied, thus the sum of 500 was considered as being a relatively reliable figure for quantitative studies.

IV. ZONATION AND CORRELATIONS

Introduction

The purpose of this section is to describe the methods used and results obtained using palynomorphs for biostratigraphic correlation. Principles applied and their disadvantages are discussed in the light of limitations inherent to palynological methods of correlation.

Factors Related to Spore and Pollen Abundance

There are a number of factors which influence the abundance of plant microfossils as they are encountered at different stratigraphic horizons. These factors have been discussed in detail by Cross (1964) and Kuyl et al., (1955) and have been divided into two broad divisions; ecological and sedimentary. There are a number of ecological factors which govern the abundance of plant microfossils. These are: (a) Number of parent plants and their production of pollen and spores, (b) Migration, (c) Evolutionary changes, (d) Climatic variations, and (e) Edaphic control.

a. The absolute abundance of different plant microfossils has a direct relationship with the number of parent plants and their potential in producing spores or

pollen. Since plants vary in their spore output, abundance of a particular spore or pollen does not necessarily imply abundance of parent plant in the flora even from the modern pollen rain. In sedimentation and preservation additional inequities of abundance of the palynomorphs are found which make reconstruction of the original flora very difficult.

b. Certain plants may emigrate while others immigrate due to local environmental conditions. This has only limited value with regard to correlation since migration need not be synchronous at different geographic locations.

c. Evolutionary changes are usually slow but do have great importance for regional correlations. These changes result in appearance of certain forms and disappearance of others either independently or at the expense of each other.

d. Climatic changes can produce alternation of floral elements on a large scale in a relatively short time and thus prove to be useful for regional correlations. But it must not be overlooked that climates may vary only locally as a result of differences in topography.

e. Edaphic changes such as local transgressions into swamp areas or peneplanation will result in changes in local vegetation and thereby prove to be useful only for short range correlations.

Geographic or stratigraphic changes observable in the microfossil flora may also be due to a number of factors which are related mainly to sedimentation. Some of these factors are: (a) Distance from vegetation site, (b) Rate of sedimentation, (c) Variability of wind, and (d) Rainfall and stream flow.

a. The distance from spore or pollen producing areas to the site of their final settling and entombment in sediments bears a direct relation to their absolute and relative abundance. Furthermore, pollen-producing plants in the immediate vicinity of basins of sedimentation will distort the true representation of the regional vegetational pattern. This phenomenon is well illustrated in sedimentary basins which have their own autochthonous vegetation such as *Ericales* in *Sphagnum* bogs or *Rhizophora* in mangrove swamps.

b. Sedimentation rates depend on distances from shore. Thus it is not improbable to encounter more individuals of the same species of a microplanktonic organism per unit volume of sediment farther from shore even though habitat factors such as salinity, temperature and depth of water may limit production of microplankton and result in fewer fossils. Thus microplankton may parallel reduced sedimentation rates. But as a general rule palynomorphs, and larger cuticular fragments and tracheids, which are carried by streams, tend to settle close to the shore line.

c. Seasonal changes in wind direction will alter the plant microfossil assemblage since different plants may shed their spores in different seasons, but the problem becomes less important when there is a long flowering or spore-producing period which is the case in subtropical and tropical forests. In the case of Frio palynomorphs there are indications (see section on paleoecology) that the parent flora was presumably thriving in a subtropical to tropical climate, thus discrepancies due to seasonal wind variations are minimized.

d. Rainfall and stream flow will affect the microfossil flora depending on the nature of streams and their velocities. Thus a rapid stream in a juvenile stage will carry most land-derived palynomorphs to the shore line and very little settling of spores or pollen will take place during its seaward journey. A stream which has reached old age will, by contrast, deposit large amount of palynomorphs during its course before reaching the sea.

Principles of Biostratigraphic Zonation Involved

Several criteria are used to delimit stratigraphic-palynological horizons: (a) Entities which have a limited stratigraphic range are especially useful for correlation purposes. First occurrence of an entity is usually more reliable as a criterion for zonation than last occurrence. Last occurrence is often modified

locally by special habitat conditions. (b) Relative abundance of a fossil entity and its fluctuating representation through time (profile of percentage of relative abundance) can be used for correlation. This method is more subject to variables such as local climatic changes and edaphic factors than (a). (c) A relatively constant association of two or more palynomorphs, and parallel changes in their relative abundance from level to level is a valuable criterion for zonation.

Because extensive use was made of the relative abundance method in correlating wells in the Frio Formation, it would be appropriate to review some of the assumptions and weaknesses of such a method. When horizons are set up on the basis of relative frequency or abundance of a certain number of selected palynomorphs the following conditions must be given consideration:

(a) The assumption that the total number of palynomorphs counted on a slide are truly representative of the microfossil flora present in the sediments at a given stratigraphic level or horizon. (b) The assumption that, if distances are not too great, the distribution of plant microfossils over an area is relatively constant and that any changes in the pattern will be gradual from one area to another. Horizons based on relative abundance of a particular type of palynomorph might prove not to be useful over great distances i.e. several hundred miles.

(c) That changes observed in spore and pollen ratios indicate certain changes in the parent flora. These may characterize and reflect changes on a regional basis, but may also indicate changes within plant communities on a local scale. Thus careful selection of types which are not limited to unusual ecological or environmental factors is paramount.

Method of Zonation

Each sample of the Grayburg Timber #1 and J. M. Rich #1 wells are composite ditch samples representing about 30 feet of section. Samples from the A. D. Middleton #79 well are composite ditch samples, which average about 100 feet of thickness of section. In all, three wells samples were examined, on the average, about every 90 to 100 feet apart, except where abrupt changes in the relative frequency curve for a fossil entity was observed. In such cases at least one additional sample was examined in the intervening zone to supplement the information. In all three wells one sample was examined from the lower part of the Anahuac and one from the upper part of the Vicksburg Formation. A total of 50 samples were studied from the three wells.

Relative abundance curves were drawn for 35 pollen and spores and 15 dinoflagellates and acritarchs. Of this total number, only 11 entities proved to be useful for correlation. One dinoflagellate and one acritarch

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have restricted ranges and the youngest occurrence of each was observed to be within the section studied. The other nine palynomorphs proved to be useful because they are abundant and relatively easy to identify, even though their ranges extend below and above the section studied.

The relative frequency of each species of pollen or spore was determined by dividing the number of specimens counted by the sum of land-derived palynomorphs. Similarly, the relative abundance of a species of microplankton was computed from the total number of microplankton. A relative abundance curve indicates maximum values for a given species, but it must be realized that such a curve is not a continuous log and thus is subject to quantitative variations in the interval which was not sampled. Particular attention was given to the trend of a curve; thus the absolute value for a species is not as important as the pattern it follows. The important factor to take into account is whether an increase or a decrease in relative frequency from one level to another is also reflected in other wells or sampling sites.

Palynological Correlations

Ten horizons can be established from the palynomorph spectra.

Horizon 1: This horizon is the upper limit of the zone characterized by the last occurrence of Homotryblium plectilum. In the Grayburg Timber #1 and the J. M. Rich

#1 wells that time of last occurrence is in the upper part of the Vicksburg Formation while in the A.D. Middleton #79 well the last occurrence of H. plectilum is in the Lower Frio just above the contact with Vicksburg (see Figures 12 and 23). It appears that, due to lack of foraminiferal control, updip, the base of the Frio in the Grayburg Timber #1 and the J. M. Rich #1 wells has been placed too low in previous correlations.

Horizon 2: This horizon is established on the first peak of relative abundance of Quercoidites henrici above the base of the formation. This taxon reaches this peak just above the top of the Vicksburg, then decreases in relative frequency (see Figure 13).

Horizon 3: This horizon is characterized by the first peak of relative abundance of Tricolpopollenites hardiei above the base of the formation. There is another peak about midway up in the formation in the Grayburg Timber #1 and the J. M. Rich #1 wells, but no correlation can be traced to the A. D. Middleton #79 well (see Figure 18).

Horizon 4: This horizon is established at the level where Liquidambarpollenites stigmosus decreases in relative abundance. In the upper part of the Frio L. stigmosus reaches a peak of relative abundance, but this is limited to the Grayburg Timber #1 and the J. M. Rich #1 wells (see Figure 21).

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Horizon 5: This horizon is established on the first significant decrease in relative abundance of Taxodiaceapollenites hiatus above the base of the formation (see Figure 17).

Horizon 6: This horizon is based on the first peak of relative abundance of Engelhardtioipollenites quietus half way up the formation. This palynomorph although present throughout the Frio Formation, tends to decrease in relative abundance upwards near the base of the Anahuac Formation (see Figure 19).

Horizon 7: This horizon is based on the peak of relative abundance of Taxodiaceapollenites hiatus. This peak is present about two-thirds of the way up the formation (see Figure 17).

Horizon 8: This horizon is marked by a sudden decrease in the relative abundance of Taxodiaceapollenites hiatus. This decline in relative abundance is observed two-thirds of the way up the formation (see Figure 17) just above the prominent peak which marks Horizon 7.

Horizon 9: This horizon is marked by a peak of relative abundance of Micrhystridium stephensonii near the top of the Frio. This acritarch although present throughout the Frio occurs in greater relative frequency in the upper two-thirds of the formation (see Figure 22).

Horizon 10: This horizon is characterized by a peak of relative abundance of Quercoidites henricii. This peak is attained above the contact of the Frio and the Anahuac in the Grayburg Timber #1 well, while in the J. M. Rich #1 and the A. D. Middleton #79 wells it is below the contact (see Figure 13).

In all three wells the last occurrence of Acostomocystis potane was observed (see Figure 14), but a time line established on the extinction of this microplankton would cross other horizons based on land-derived palynomorphs, especially in the A. D. Middleton #79 well. Looking at the general trend of these other horizons, it can be assumed that A. potane reached its extinction point later in the more marine downdip part of the Frio Formation, and a tentative time line based on its last occurrence is actually more indicative of changes in its environmental conditions (see Figure 23).

A rather similar line of reasoning is applicable to the species Cordosphaeridium crossii (see Figures 15 and 23). This dinoflagellate decreases in relative abundance in the lower part of the Frio before attaining a peak one third of the way up the formation. Thus tentative time lines would either cross pollen-based horizons, previously indicated, or converge towards them. Hence it is believed that the departure of such time lines from the general trend followed by other palynomorphs could be due to environmental control exerted on C. crossii.

Tentative time lines drawn on the basis of peak of relative abundance and decrease in relative frequency of Cicatricosisporites dorogensis would cross horizons 4 and 5 (see Figures 16 and 23). Such a phenomenon may be due to reworking, this could have been the case of C. dorogensis which is a relatively large sized spore, with a resistant sporoderm capable of withstanding mechanical as well as chemical degradation.

A tentative horizon could be based on the peak of relative abundance of Chenopodipollis sp. 2 (see Figure 20), but there is no corresponding peak in the J. M. Rich #1 well.

Summary of Correlations

In Figure 23 a chart showing the position and lithology of samples together with electric log and palynological horizons are compared graphically. There are a number of observations which should be pointed out: (a) Although a few palynological horizons correspond to samples of same lithology at particular stratigraphic levels within the three wells, it must be realized that many alternations of microfossil flora can be synchronous in areas or at levels which have different lithologies. (b) Not all relative abundance curves show correlative values at the same horizon; this can be explained possibly by lack of closer sampling, also by factors explained in the paragraph dealing with certain

criteria which affect the relative abundance method. (c) As the Grayburg Timber #1 and the J. M. Rich #1 wells were far enough updip there is no reliable foraminiferal control, and the top and bottom of the Frio Formation are tentatively established; hence no comparison could be made with palynological horizons. (d) Horizon 1 which is established on the last occurrence of Homotryblum plectilum does not agree with the foraminiferal zonation. Thus on the basis of the last occurrence of H. plectilum the contact between the Frio and the Vicksburg in the Grayburg Timber #1 and the J. M. Rich #1 wells should be set up at a slightly higher level. Of course it is realized that this is a matter of conjecture and there is no absolute necessity to change the contact between two formations because the position of one species of microplankton does not agree with prior results obtained from foraminiferal zonations. Yet it must be realized that microplankton do not depend to the same extent on bottom conditions as it is the case for benthonic foraminifera. (e) It is not possible to show time equivalency for the top of the Frio in the three wells as no first or last occurrence of a species could be used for correlative purposes.

Comparing electric logs, it can be observed that eight possible correlation points can be set up on relatively similar spontaneous potential and resistivity

profiles. This is the case for the Grayburg Timber #1 and the J. M. Rich #1 wells where changes from sands or shaly sands to shales are noticeable. In the A. D. Middleton #79 well much of the sand phases out and the lithology is mainly shale, thus only three correlation points can be observed, i.e. A, B and C (Figure 23).

Paleoecologic Considerations

Quite an important part of the Frio palynomorphs are dinoflagellate cysts and a smaller number of acritarchs. This is especially the case of the more marine A. D. Middleton #79 well. An assemblage of microplankton, though independent of bottom conditions, is affected by factors such as salinity, temperature, amount of nutrients, and water turbulence. Distribution of microplankton is related to latitude, longitude, and depth of water. According to Upshaw (1964), there is some variation in habitat between chorate cysts (Hystriosphaeids) and the proximate and cavate cysts. Chorate cysts are more abundant on the continental shelf at intermediate depths and decrease in abundance in shallower and deeper waters. The proximate and cavate cysts thrive in large numbers in shallow near shore and brackish waters and they decrease in number away from the shoreline.

A method used by Sarmiento (1957) and Upshaw (1964) is graphically illustrated (Figure 24). Such a curve is

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based on the relative abundance of all microplankton entities computed from the total number of palynomorphs counted, i.e., 500 specimens. The curve in Figure 24 shows that all three wells indicate a decrease in relative abundance of microplankton about the middle of the Frio which would tend to indicate proximity to the shore. This is preceded and followed by peaks of relative frequency indicating a more marine condition. Thus it is possible to infer that the base of Frio is marked by a transgression which is followed by regression and near the top of the formation another transgressive phase was prevailing. This interpretation is further supported by the comparable decrease and increase in relative frequency of occurrence of Foraminifera, represented by inner chitinous linings.

A number of conditions must be fulfilled before environmental interpretation based on relative abundance of microplankton as marine indicators can be effectively applied. (a) It must be considered that the volume of sedimentation usually decreases away from the shoreline; thus larger numbers of microplankton per unit volume of sediment tend to settle out and become buried. It is possible that the sedimentary factor is counterbalanced to some extent by limitations of temperature, salinity and especially nutrients, which thereby restrict or reduce the production of

microplankton away from the shore. (b) "Blooms" of one or more types of dinoflagellate cysts may distort environmental interpretation by over representation of certain entities. (c) As pointed out by Cross, et al. (1966) the abundance of dinoflagellate cysts may depend on changes in direction of prevailing winds and currents. In addition the amount of water run off contributing land derived material may be a limiting factor.

Relative Abundance of Lycopodiaceous Spores

In Figure 25, the relative abundance of Lycopodiaceous spores is determined from the total number of land-derived plant microfossils. It can be observed that there is a noticeable decrease in relative abundance from the Grayburg Timber #1 well to the A. D. Middleton #79 well. This phenomenon may be explained by the following assumptions: (a) As distances increase spores have a smaller chance of preservation because as they are carried by streams they undergo attrition and are destroyed in their journey to final site or deposition. (b) Winnowing action of water may penecontemporaneously recycle spores which have settled down. (c) Durability of spores is an important factor. After spores are carried to great distances by streams usually the more resistant ones are better preserved. (d) Spores of larger size tend to settle out first and, therefore,

decrease in relative abundance to smaller spores or pollen seaward.

The relative abundance of pollen, spores and microplankton may help in deciphering environmental conditions which existed during the deposition of a stratigraphic unit. Figure 26 illustrates such an example. The A. D. Middleton #79 well was selected because it is the most downdip and marine of the three wells and microplankton have higher relative frequency. Therefore, it is easier to contrast the differences in relative abundance of different groups of palynomorphs. The number of microplankton increase from the base upward while the relative frequency of pollen and spores decreases, presumably indicating successively marine conditions upwards from the base. But at a depth of 8300 feet there is a distinctive increase in the number of pollen while spores and microplankton decrease. This could be explained by proximity to a delta. About the middle of the formation spores increase while pollen and microplankton decrease; this might be explained by the presence of swampy conditions in a nearby delta or lagoon. Farther up the well, microplankton again increase in relative abundance indicating a transgressive marine condition. But just below the contact of the Frio with the Anahuac Formation, pollen grains again become abundant and the other two groups of palynomorphs decrease in relative

abundance. This might indicate proximity to the mouth of a stream or at least its delta.

Nature of the Frio Flora

The list of plant microfossil genera, described in the next section (Systematics, p. 72), reveals that the majority of these taxa have a subtropical to tropical distribution if the modern distribution of their extant counterparts can be used to infer comparable climatic requirements of these taxa during the Frio. Yet there are a number of warm temperate to truly temperate elements in the flora. The following is a list of genera with such a climatic distribution:

Taxodiaceapollenites

Nyssapollenites

Liquidambarpollenites

Engelhardtioipollenites

Cicatricosisporites

Leiotriletes

Pinuspollenites

Ilexpollenites

Betulaceoipollenites

Corsiniipollenites

Subtriporopollenites

To explain the presence of the above-mentioned genera in a predominantly subtropical-tropical floral assemblage, three explanations might be considered:

(a) That the temperate element could have been thriving on topographic highs close to the basin of sedimentation and thus have their pollen or spores dispersed and carried by winds and streams to the final burial site;

(b) that it is possible these genera were living at higher latitudes and the presence of their pollen or spores is due to long-distance stream transport; (c) that it is possible that the ecological requirements of these plants may have changed, i.e., Betulaceoipollenites did not have a temperate distribution twenty-five million years ago. But the nature of sediments, and the geological history of the region, tend to indicate that there was no important highland area close to the site of deposition. Furthermore, the possibility of significant changes in the ecological environment seem to be remote. Hence it appears that long distance transport from a higher latitude, or land mass of higher altitude in the hinterland to be the logical explanation.

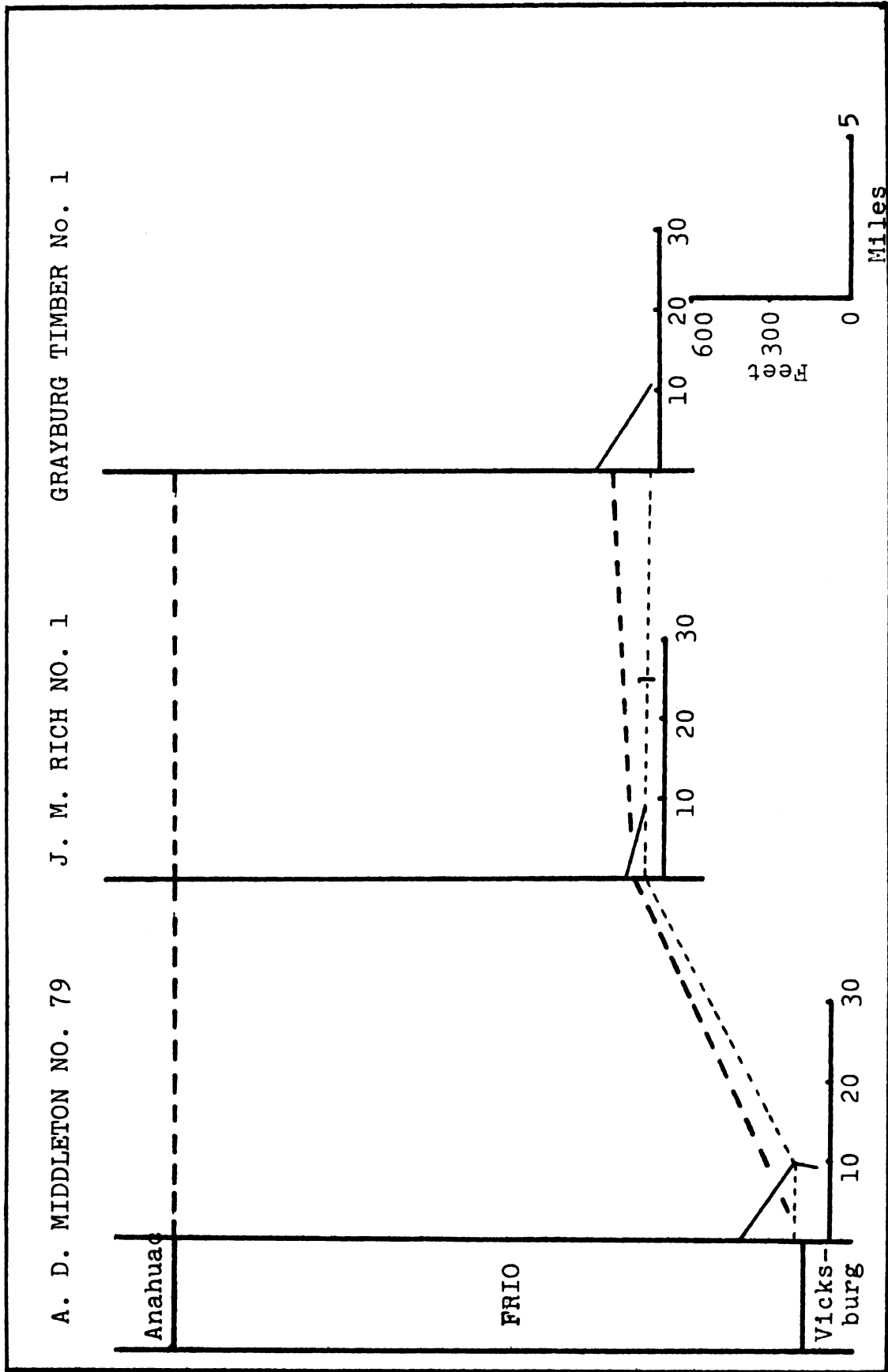


Figure 12. Last occurrence of Homotryblum plectilum. Line indicates correlations.

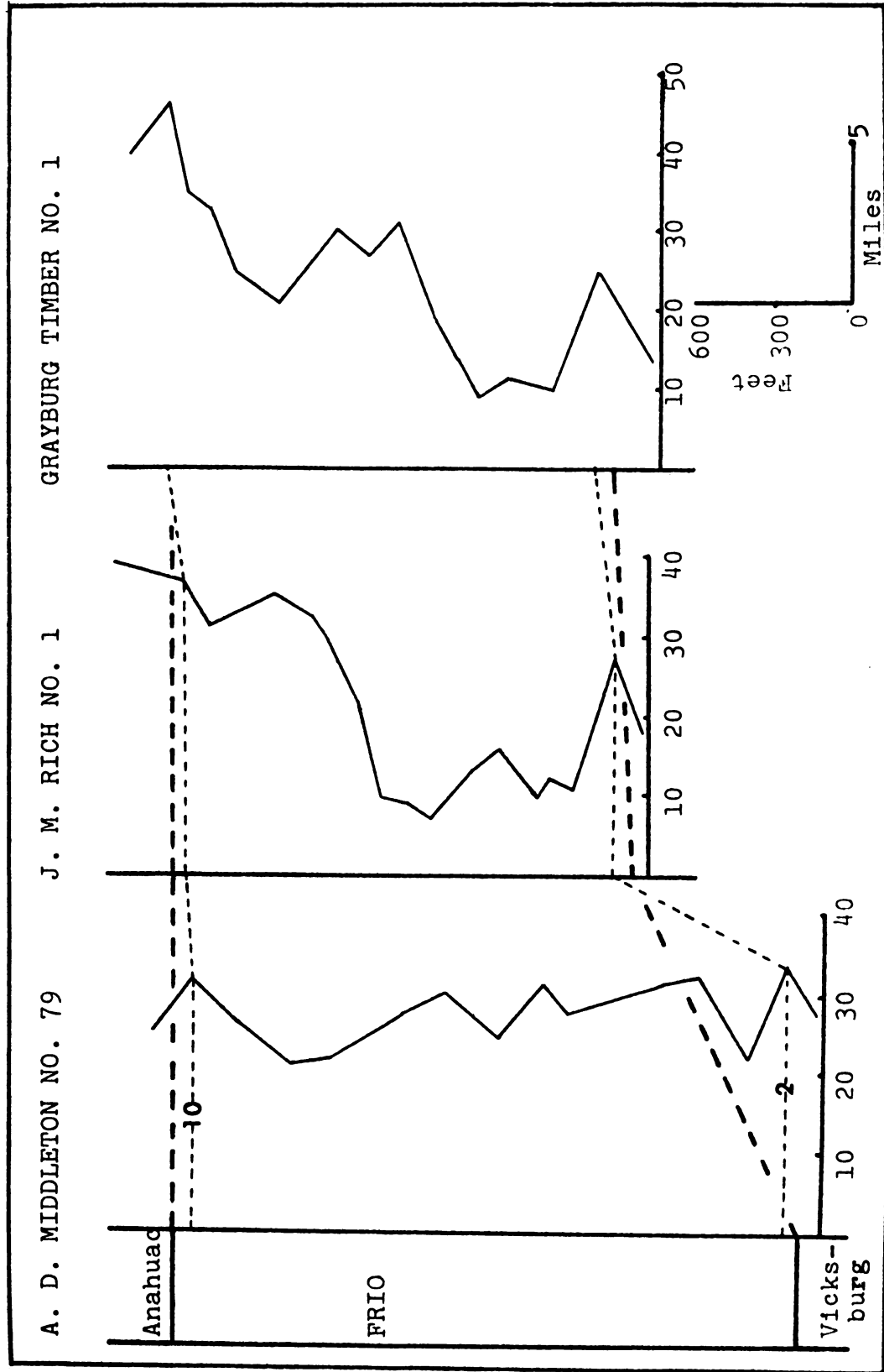


Figure 13. Relative abundance of *Quercoidites henrici* shown as percentage of sum of pollen and spores. Lines indicate correlations.

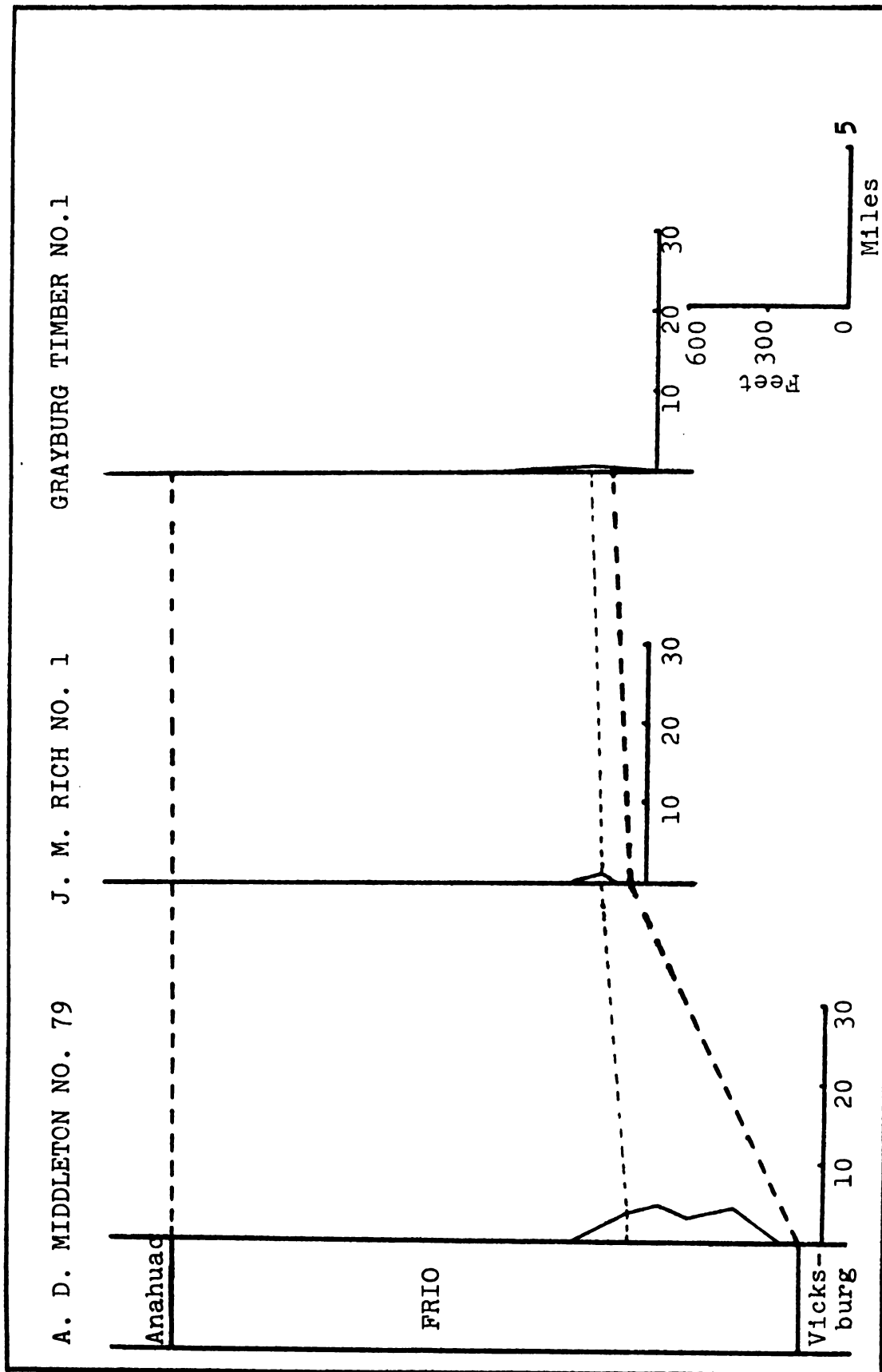


Figure 14. Last occurrence of Acostomocystis potane. Line indicates correlations.

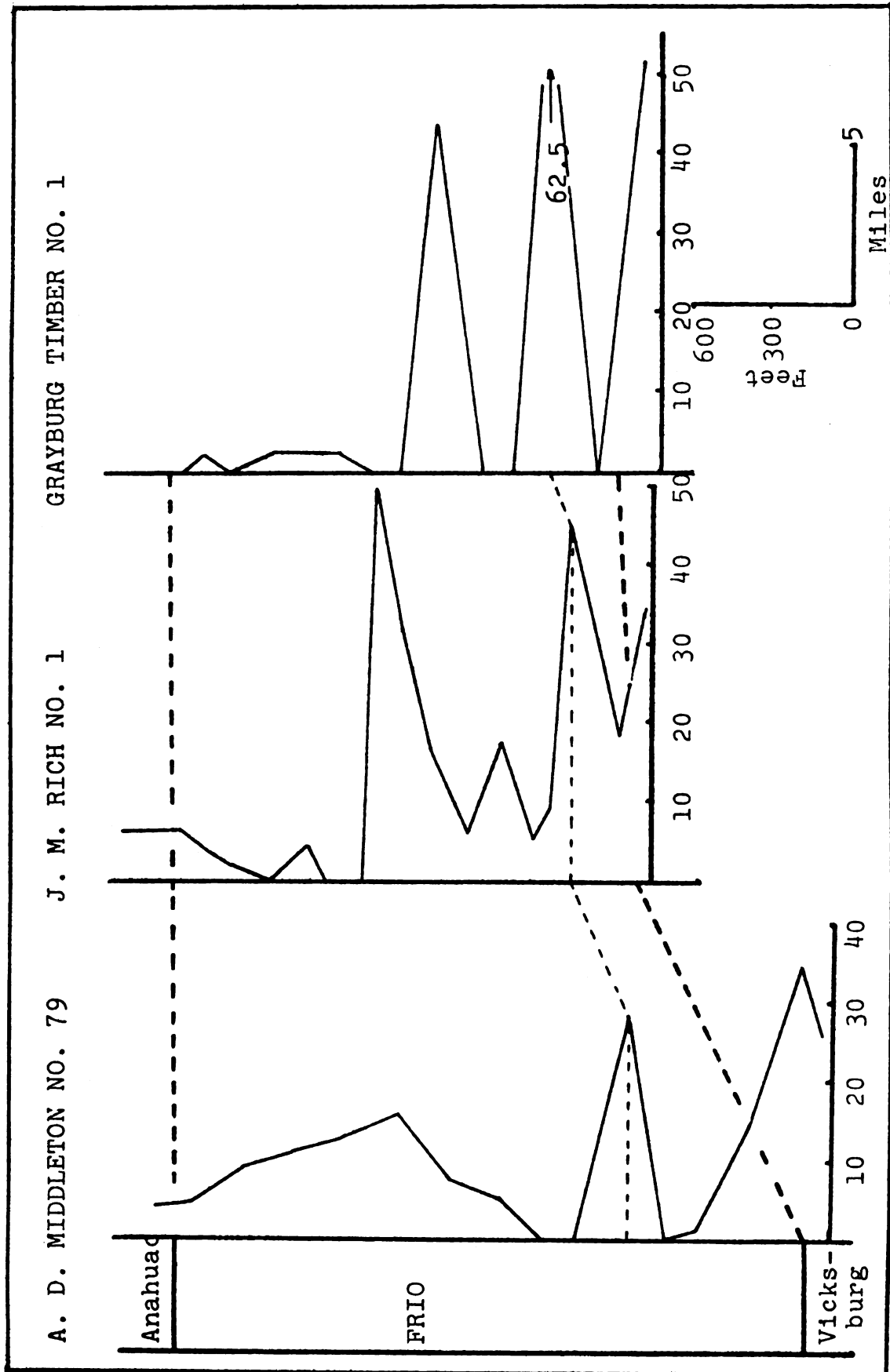


Figure 15. Relative abundance of *Cordosphaeridium crossii* shown as percentage of microplankton sum. Line indicates correlations.

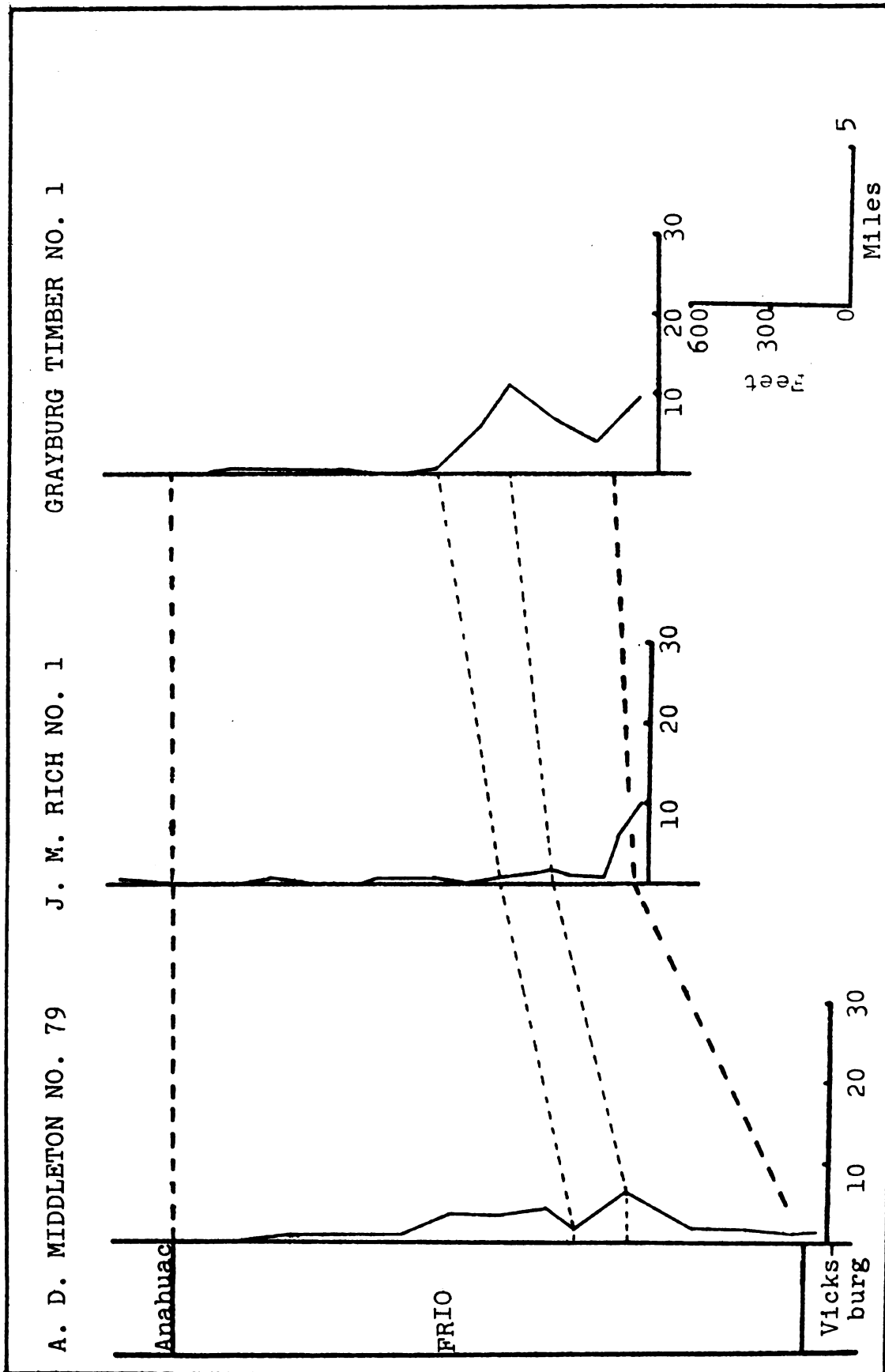


Figure 16. Relative abundance of *Cicatricosisporites dorogensis* shown as percentage of sum of pollen and spores. Line indicates correlations.

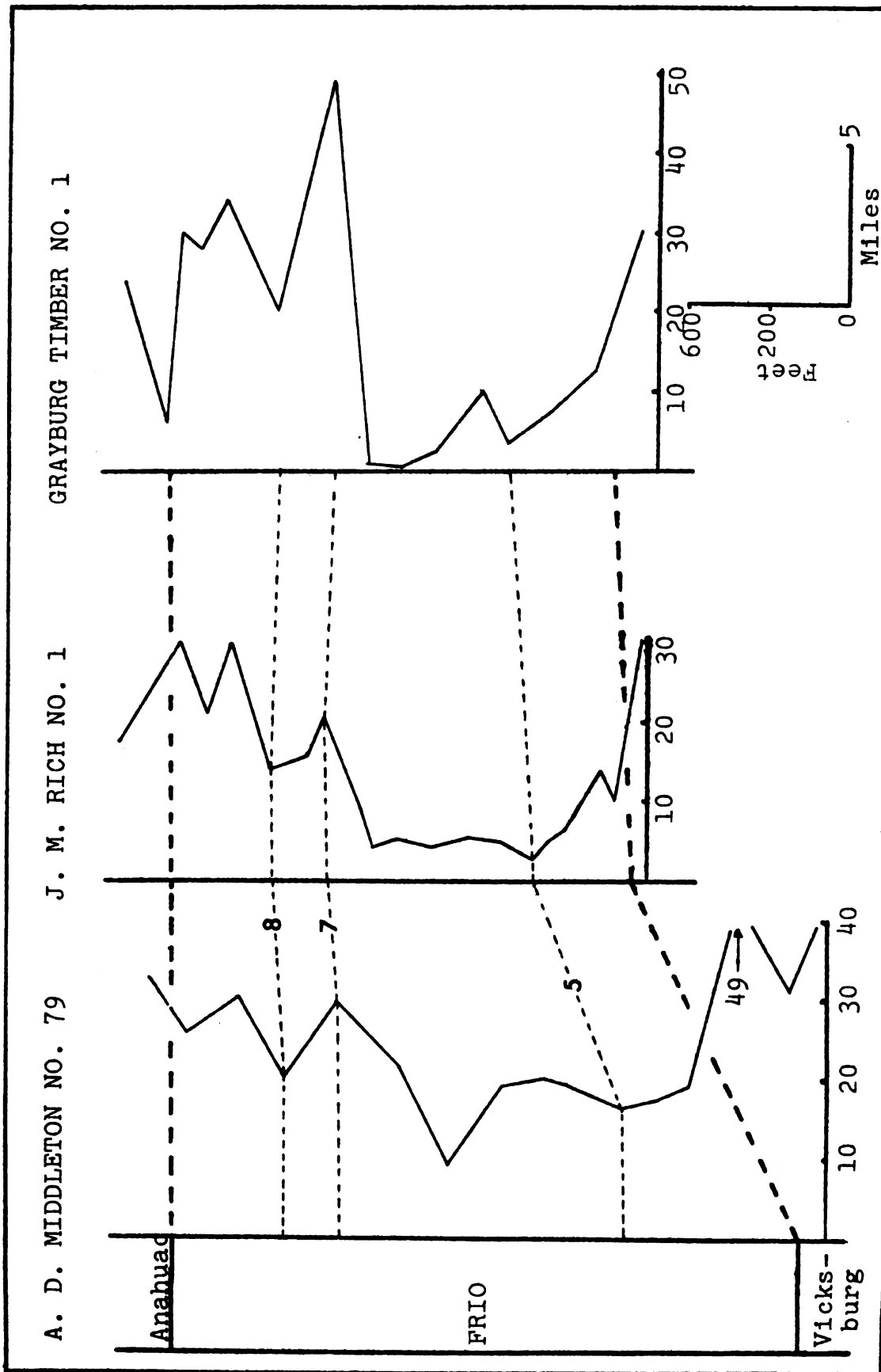


Figure 17. Relative abundance of *Taxodiaceapollenites hiatus* shown as percentage of sum of pollen and spores. Line indicates correlations.

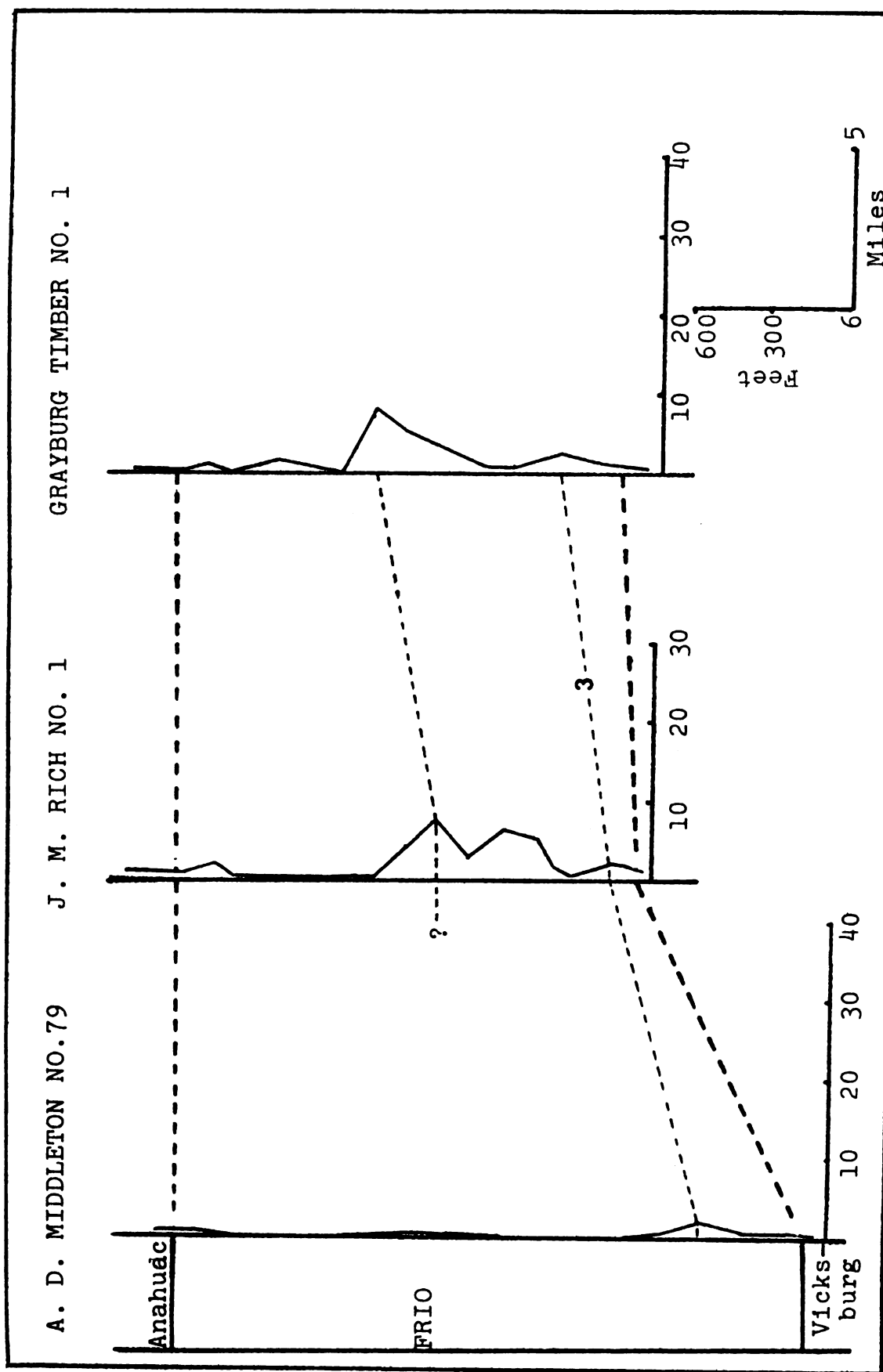


Figure 18. Relative abundance of *Tricolpopollenites hardlei* shown as percentage of sum of pollen and spores. Line indicates correlations.

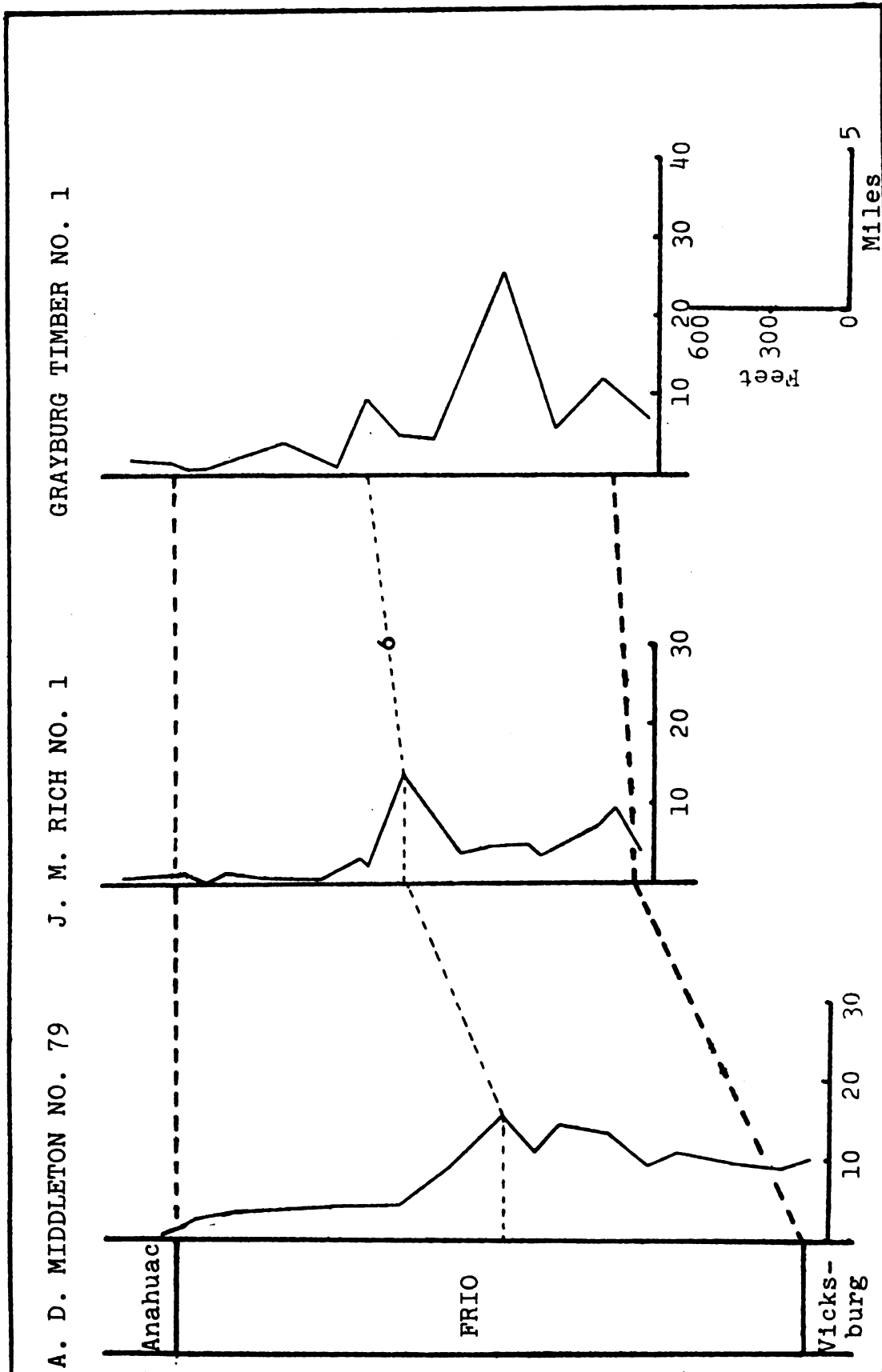


Figure 19. Relative abundance of *Engelhardtioipollenites quietus* shown as percentage of sum of pollen and spores. Line indicates correlations.

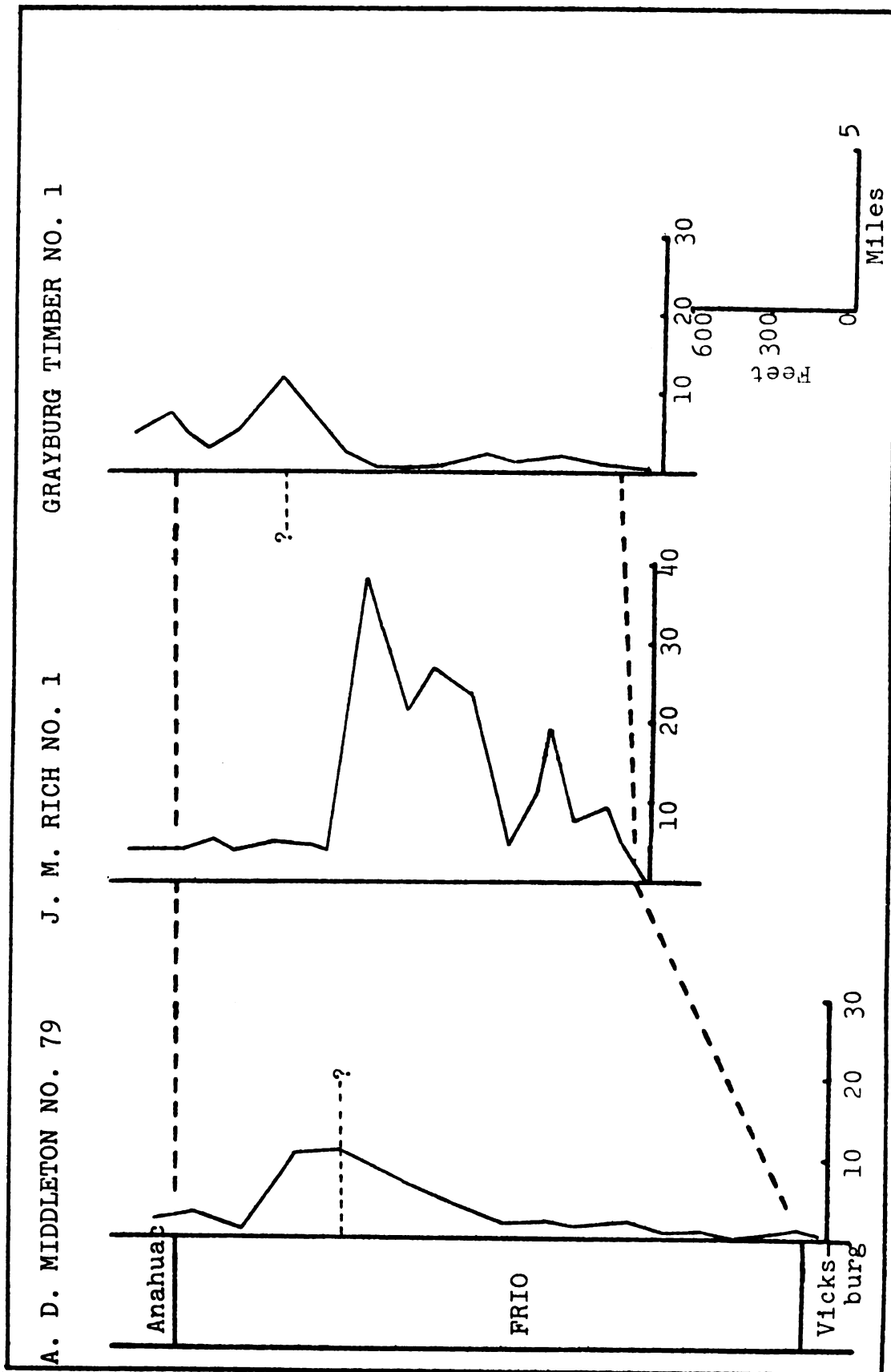


Figure 20. Relative abundance of Chenopodiipollis sp. 2 shown as percentage of sum of Pollen and spores. Line indicates correlations.

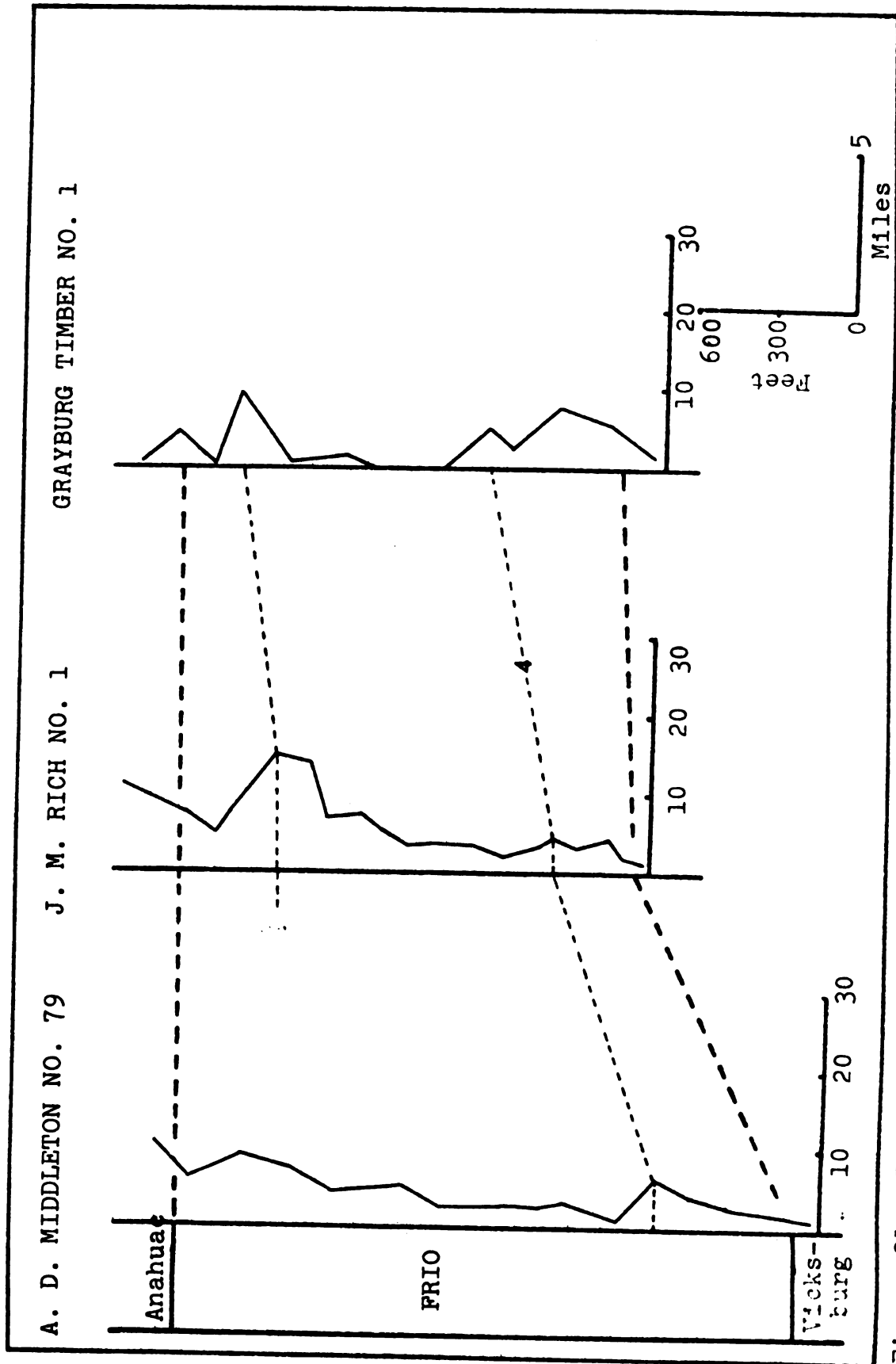


Figure 21. Relative abundance of *Liquidambarpollenites stigmatus* shown as percentage of sum of pollen and spores. Lines indicate correlations.

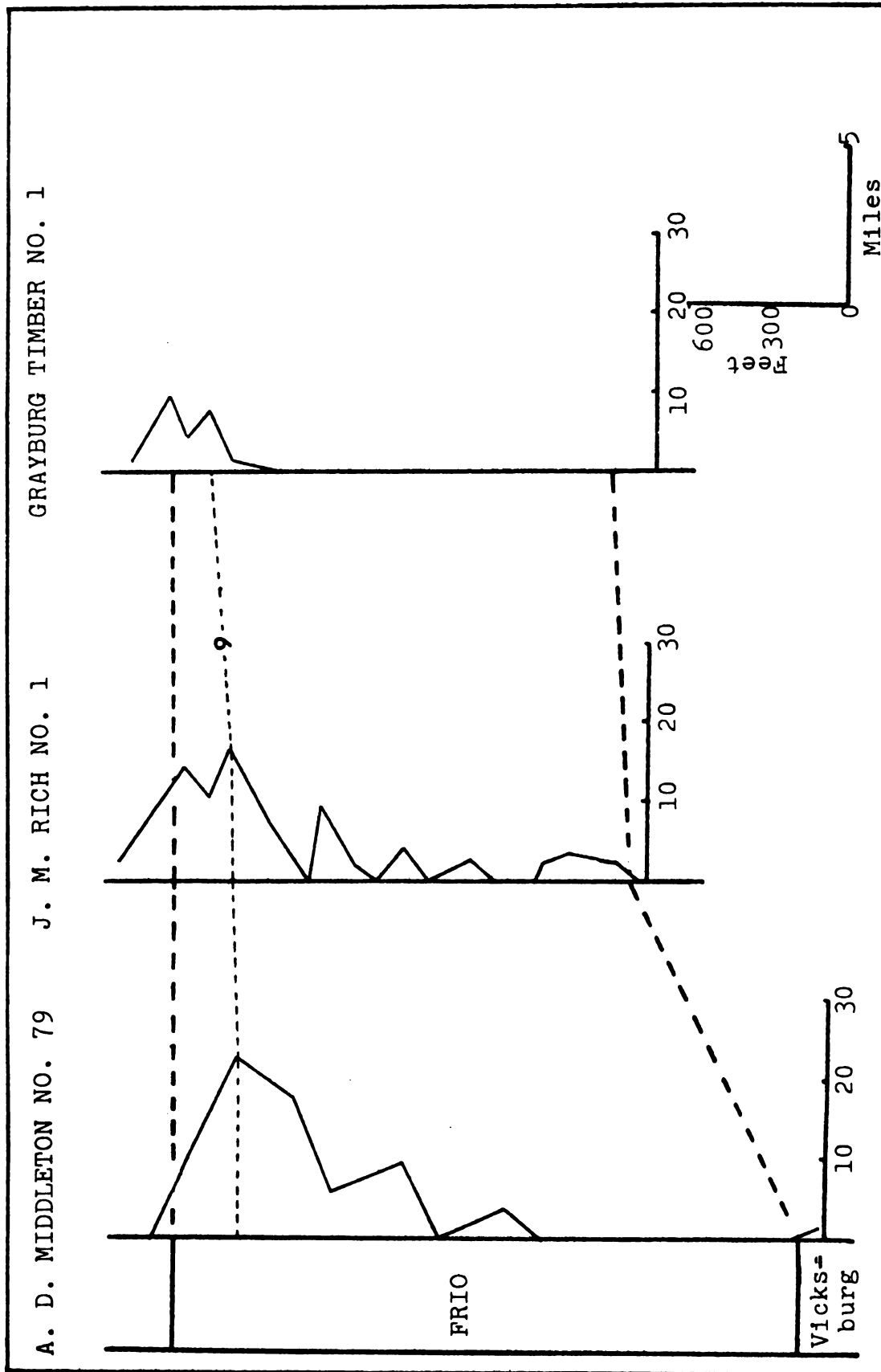


Figure 22. Relative abundance of *Micrhystridium stephensonii* shown as percentage of microplankton sum. Line indicates correlations.

A. D. MIDDLETON NO. 79

J. M. RICH NO. 1

GRAYBURG TIMBER NO. 1

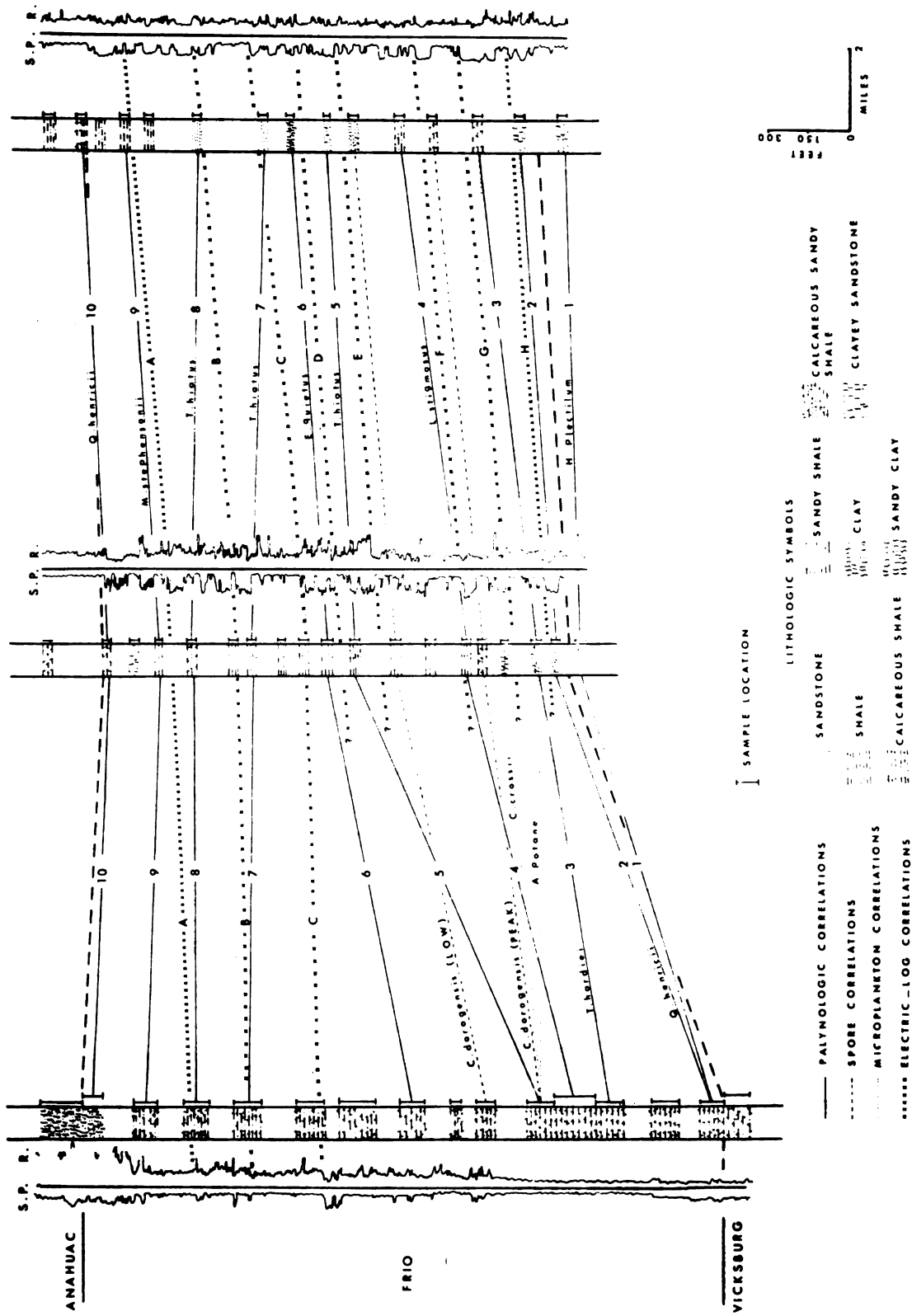


FIGURE 23. PALYNOLOGICAL ZONATION AND CORRELATIONS OF THE SUBSURFACE FRIO FORMATION IN LIBERTY AND CHAMBERS COUNTIES, TEXAS.

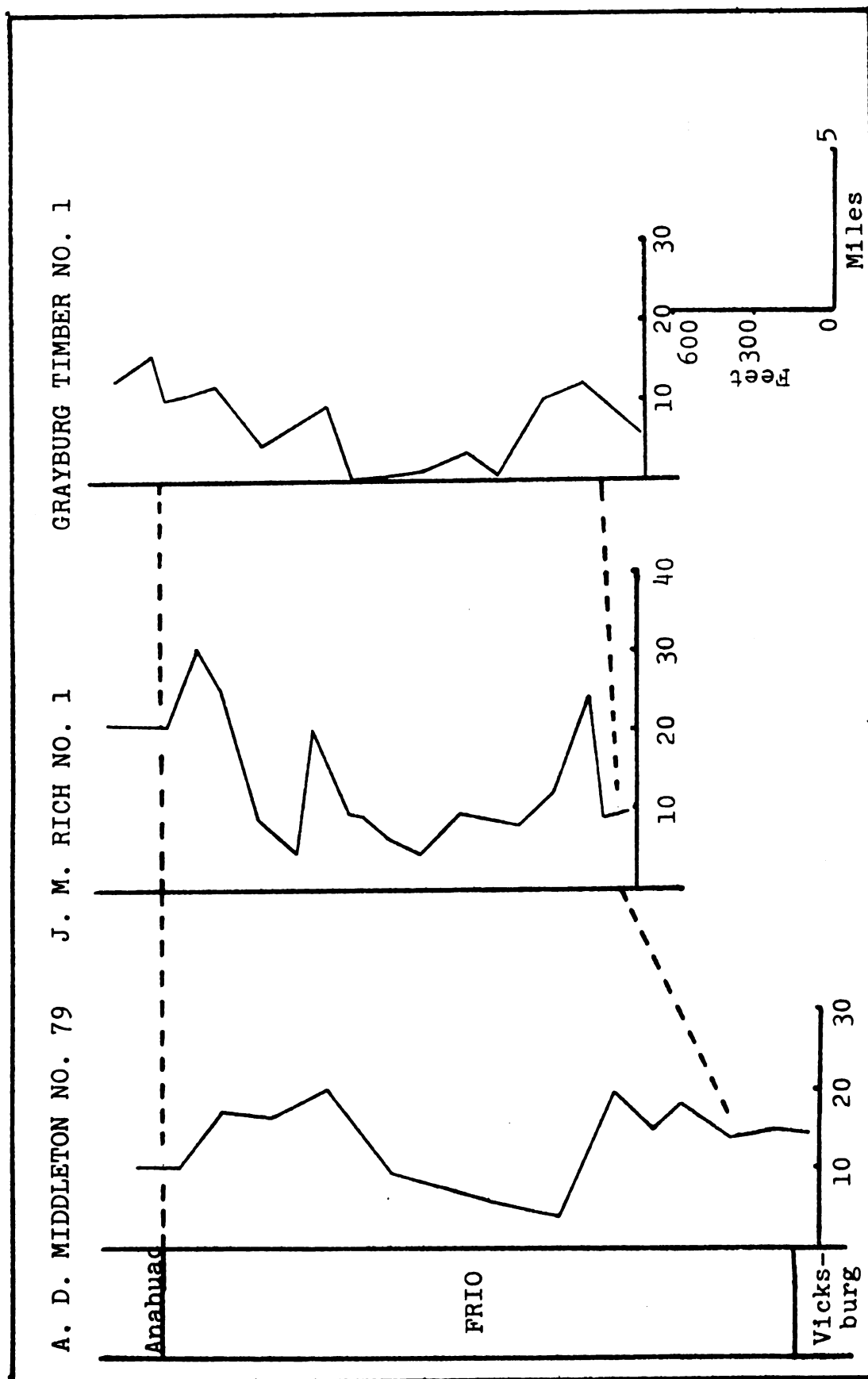


Figure 24. Relative abundance of microplankton shown as percentage of the total palynomorph sum.

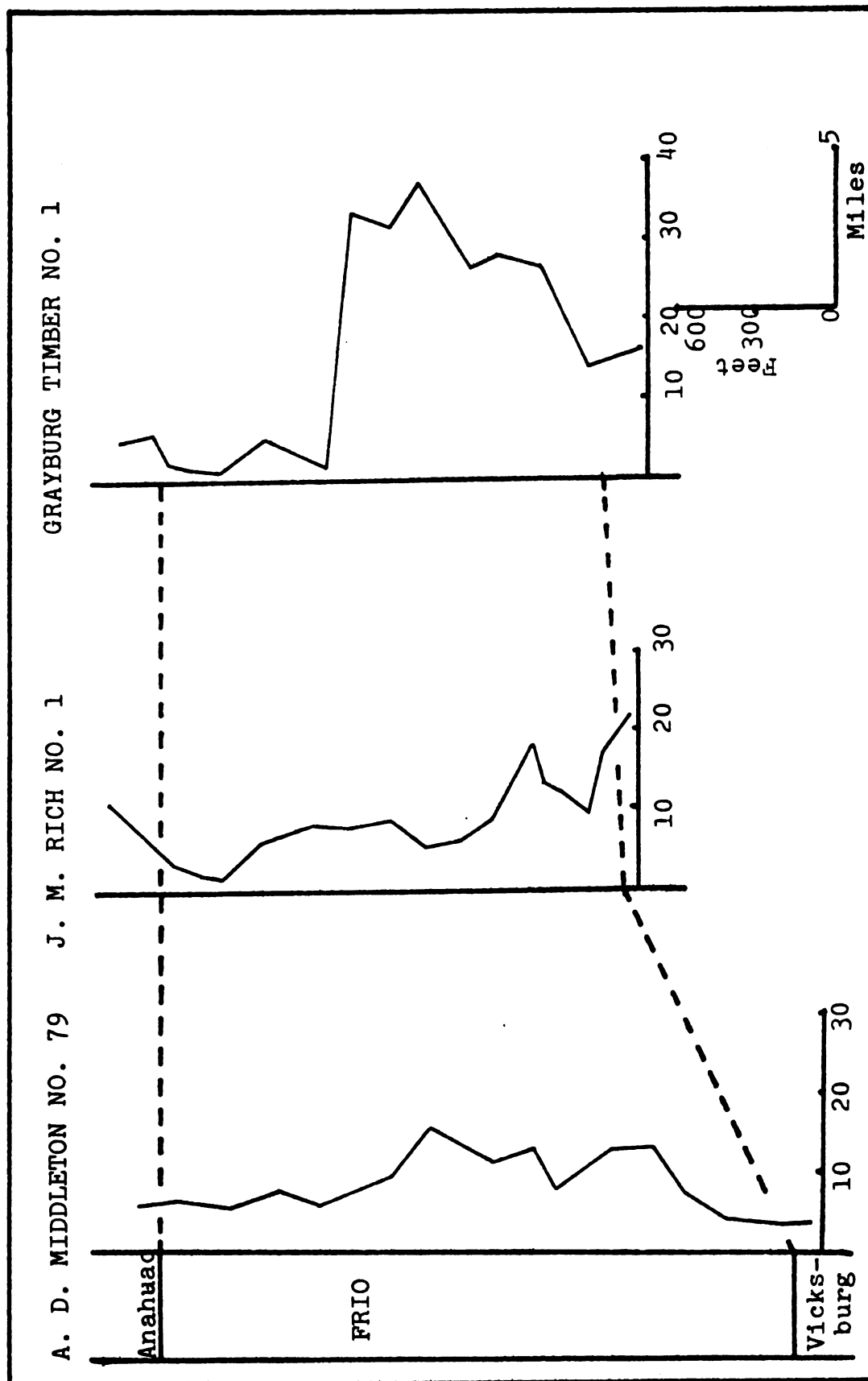


Figure 25. Relative abundance of Lycopodiaceous spores shown as percentage of land derived palynomorph sum.

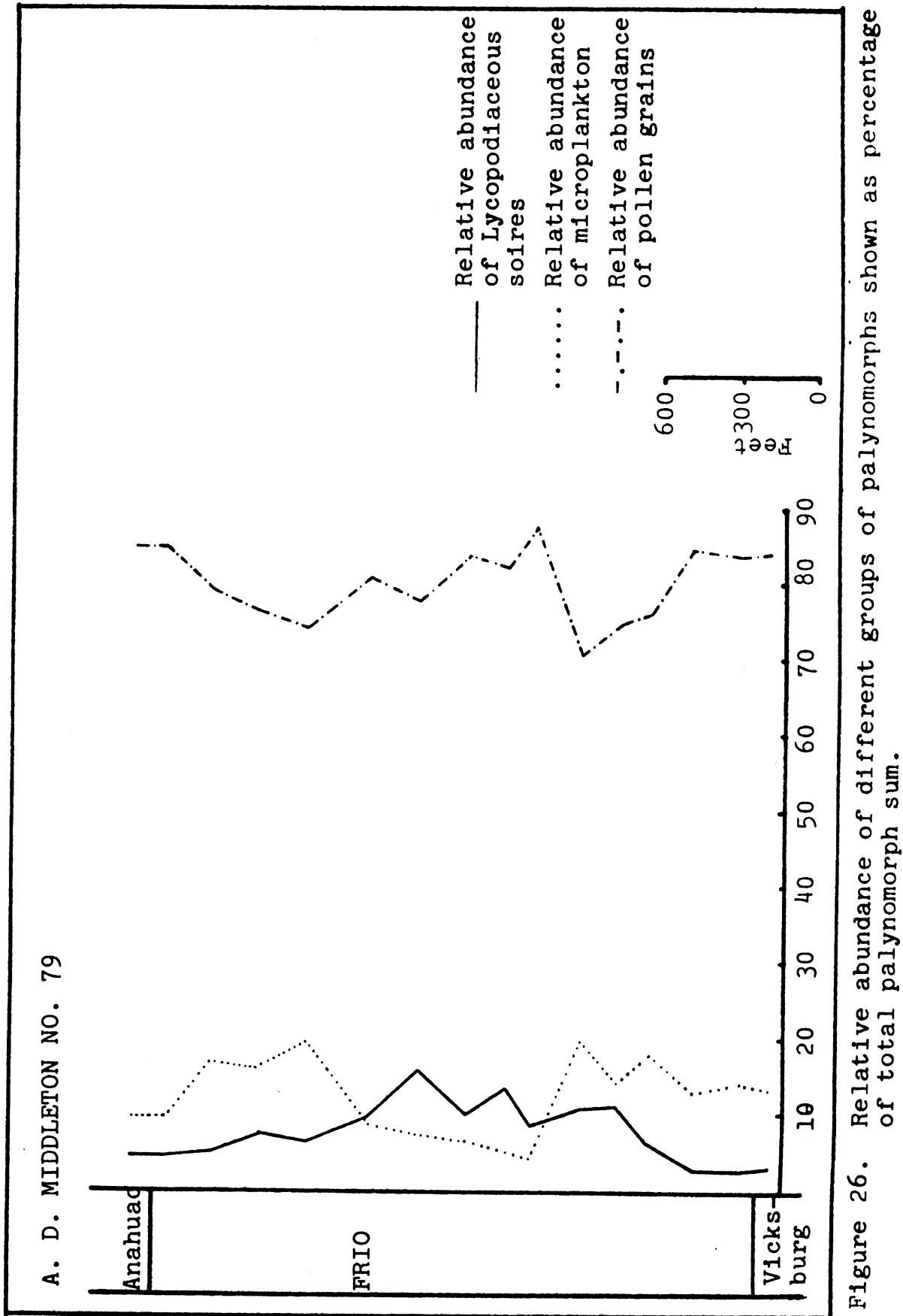


Figure 26. Relative abundance of different groups of palynomorphs shown as percentage of total palynomorph sum.

V. SUMMARY AND CONCLUSIONS

This study was undertaken to establish a microfossil assemblage and demonstrate its usefulness for time-stratigraphic purposes. Palynologic horizons were established based on qualitative and quantitative methods of correlation. The establishment of ten biostratigraphic horizons will, hopefully, supplement information already available in the more marine section of the subsurface Frio Formation which has been zoned using benthonic and planktonic foraminifera. This would enable updip correlations to be made more accurately.

For the purpose of this study, three wells were selected, in Liberty and Chambers Counties, Texas, two of which have a poorly developed foraminiferal fauna and one of which has a good, more nearly normal marine fauna. Fifty composite ditch samples were prepared for microscopic examination. A total of 500 specimens were counted on each slide for quantitative and qualitative studies. It was observed that two microplanktonic organisms had a restricted range and their populations terminated near the upper part of the Vicksburg Formation or in the Lower Frio Formation. The occurrence of relatively large numbers of a particular species is considered to have time-stratigraphic value for correlations.

Based on the presence of taxa of known restricted age and absence of pollen grains of the Compositae the age of the subsurface Frio in the area studied is believed to be Oligocene to Lower Miocene.

One hundred sixty-eight different taxa are described. Included are thirty-two new species of microplankton, pollen, Lycopodiaceous(?) and fungal spores. The 168 taxa represent about 75 per cent of the total Frio palynomorph assemblage. A large number of fungal spores were observed but not described.

The following conclusions are based on results obtained during the course of this study:

1. Presence and relative abundance of a number of palynomorphs proved to be useful in establishing ten horizons.
2. The majority of Frio palynomorphs are present throughout the formation, indicating either slow evolutionary changes or relatively rapid sedimentation or both. Only two microplankton species have a limited range in the sections studied and their last occurrence is recorded.
3. The position of last occurrence of Homotryblium plectilum as recorded in the three wells indicates a lower contact between the Frio and the Vicksburg formations in the Grayburg Timber #1

and the J. M. Rich #1 wells, thus including some of the section of each, now considered to be Vicksburg, in the lower Frio.

4. Most of the biostratigraphic horizons do not link up sediments of similar lithology in the three wells, thus demonstrating their independence of different depositional environments.
5. Relative abundance of microplankton to total palynomorphs indicates environmental or sedimentary basin changes. Some of these differences reflected may be distance from shore or depth of water. Thus the Frio Formation appears to be characterized in Liberty and Chambers Counties by two transgressions and one regression of the sea.
6. Relative abundance of different groups of palynomorphs indicates changes in environment of the nearest source areas, during deposition of Frio sediments in these sections, from deltaic through swampy and back to deltaic conditions.
7. The majority of the terrestrial plant microfossils appear to be from vegetation which is now subtropical to tropical in distribution. A smaller, but significant number of warm temperate and truly temperate elements is

present. It is postulated that their presence could be explained by long distance stream transport.

8. There are eight correlation points between the Grayburg Timber #1 and the J. M. Rich #1 wells established on changes in lithology as reflected by electric logs. Only three correlation points are observed in the A. D. Middleton #79 well. Two of the eight correlation points cross palynological horizons.

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VI. SYSTEMATIC DESCRIPTIONS

The object of this section is to provide taxonomic names and references for the palynomorph assembly of the Frio Formation. Attempt has been made to make a rigorous and as far as possible a thorough taxonomic treatment. Thus careful attention has been applied to the problem of validity and priority of names applied.

The descriptive terms applied with regard to pollen and spore morphology have been borrowed from Faegri and Iversen (1964) and Erdtman (1952). Terms used to describe dinoflagellate cysts and acritarchs have been borrowed from Downie and Sarjeant in Davey et al. (1966). The classificatory scheme used for dinoflagellate cysts is that of Sarjeant and Downie (1966). Pollen and spores are arranged according to an artificial classificatory scheme solely based on their morphology.

Nomenclature

According to the International Code of Botanical Nomenclature there are three different types of genera: natural "Linnean" genera; organ genera, representing parts or stages in the life cycles of a sporophyte; form genera, which refers solely to morphology. The author believes that when studying fossil palynomorphs one should

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preferably use form genera names. Potonié (1958) has pointed out that since a genus is defined by a type species which in turn is based on a sporophyte holotype it would be unjustified to ascribe a taxon to a genus merely on basis of its spore or pollen morphology. Thus to give a fossil palynomorph a modern generic designation would not be completely justifiable without additional information regarding the sporophyte anatomy and morphology. Hence form genera names have been utilized throughout this section with two exceptions. The modern generic name has been applied to "Ephedra" type pollen for lack of a valid morphogenic term. There are two form genera names for Gnetales pollen: Gnetaceaepollenites Thiergart (1938) and Ephedripites Bolchovitina (1953) but neither term is valid notwithstanding the common use of the latter term in recent literature. It would be more appropriate to erect a new morphogenic term which would include the Gnetales pollen. The other exception is the use of the modern genus name Azolla, but since the specimen compared very closely to Azolla bohemica Pacltova (1960) no attempt was made to adopt a form genera name. Whenever possible reference was made to an extant form which has spores or pollen comparable in morphology, together with its present day geographic distribution.

For the purpose of identification published illustrations and descriptions were used and no type specimens

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were examined. The terms used with regard to relative abundance have the following approximate connotations:

Very abundant	25 per 500
Abundant	10-25 per 500
Common	5-10 per 500
Uncommon	3-5 per 500
Rare	2 per 500

Location and Reference Material

Each taxon described is accompanied by a sample location indicating from which of the three wells the slide was made. Reference material which gives the slide number and coordinates are from the stage of a Zeiss GFL standard microscope, and every specimen described has a circle drawn in black ink around it on the cover slip. Vials containing residues together with the slide are on file at Michigan State University.

List of Taxa in the Frio Formation

The following is a list of taxa representing the Frio palynomorph assemblage; each taxon is accompanied by a page number referring to its description, together with a plate and figure number indicating its location.

Class DINOPHYCEAE

Family HYSTRICHOSPHAERACEAE

Hystrichosphaera ramosa var. ramosa

p. 87, pl. 1, Figs. 3, 4 and 4a.

Hystrichosphaera sp. cf. H. ramosa var.

membranaceae p. 87, pl. 1, Fig. 2.

Hystrichosphaera ramosa var. multibrevis

p. 88, pl. 2, Fig. 2.

Hystrichosphaera buccina p. 89, pl. 2, Fig. 3.

Achomosphaera ramulifera p. 90, pl. 1, Figs. 1
and 1a.

Family HYSTRICHOSPHAERIDIACEAE

Hystrichokolpoma rigaudea p. 91, pl. 3, Fig. 2.

Hystrichokolpoma sp. cf. H. rigaudea

p. 91, pl. 3, Figs. 1 and 1a

Friosphaera williamsii Gen. nov. et sp. nov.

p. 92, pl. 3, Fig. 3.

Cleistosphaeridium disjunctum p. 93, pl. 7,

Figs. 2 and 2a

Cleistosphaeridium disjunctum var. brevispinosum

var. nov. p. 93, pl. 9, Fig. 3.

Cleistosphaeridium texasi sp. nov. p. 94, pl. 7,

Figs. 1, 1a, and 1b.

Polysphaeridium pastielsi p. 95, pl. 7, Fig. 3,

also pl. 8, Fig. 1.

Polysphaeridium sp. p. 96, pl. 8, Figs. 2 and

2a.

Cordosphaeridium crossii sp. nov.

p. 96, pl. 9, Figs. 1, 1a and 2.

Family HOMOTRYBLIACEAE

Homotryblium plectilum p. 98, pl. 2, Figs. 1,

1a, and 1b.

Pa

Pa

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Pa

Cyclonephelium proutyi sp. nov.

p. 99, pl. 10, Fig. 1.

Cyclonephelium sp. p. 100, pl. 10, Fig. 4.

Adnatosphaeridium sp. p. 101, pl. 10,

Figs. 2 and 3.

Family GONYAULACYSTACEAE

Gonyaulacysta bilinia sp. nov. p. 102, pl. 12,

Fig. 3.

Gonyaulacysta sp. p. 103, pl. 12, Fig. 2.

Family PALAEOPERIDINIACEAE

Lejeunia sp. p. 104, pl. 12, Fig. 1.

Family DEFLANDRECEAE

Deflandrea minor p. 105, pl. 11, Fig. 1.

Family Incertae Sedis

Thallasiphora sp. p. 105, pl. 13, Figs. 1 and 1a.

Dinogymnium cretaceum p. 107, pl. 11, Fig. 3.

Dinogymnium sp. p. 107, pl. 11, Fig. 2.

Hemicystodinium zoharyi p. 108, pl. 11,

Figs. 4 and 4a.

Hemicystodinium sp. p. 109, pl. 8,

Figs. 3, 3a and 3b.

Family ENDOSCRINIACEAE

Pentadinium laticinctum p. 110, pl. 13,

Figs. 2 and 2a.

Group ACRITARCHA

Subgroup Uncertain

Acostomocystis potane p. 110, pl. 14,
Figs. 1 and 1a.

Subgroup HERKOMORPHITAE

Cymatiosphaera sp. p. 111, pl. 12, Fig. 4.

Subgroup ACANTHOMORPHITAE

Baltisphaeridium sp. 1 p. 112, pl. 4,
Figs. 1, 1a and 2.

Baltisphaeridium sp. 2 p. 113, pl. 4, Fig. 4.

Baltisphaeridium sp. 3 p. 113, pl. 4, Figs. 3
and 3a.

Baltisphaeridium sp. 4 p. 114, pl. 5, Fig. 3.

Baltisphaeridium sp. 5 p. 114, pl. 5, Fig. 4.

Baltisphaeridium sp. 6 p. 115, pl. 5, Fig. 5.

Baltisphaeridium sp. 7 p. 115, pl. 3,
Figs. 4 and 4a.

Baltisphaeridium scalenofurcatum

sp. nov. p. 116, pl. 6, Fig. 1.

Baltisphaeridium cf. B. ehrenbergi var.

brevispinosum p. 117, pl. 5, Figs. 1, 1a,
and 2.

Micrhystridium sp. 1 p. 118, pl. 6, Figs. 6 and
7.

Micrhystridium sp. 2 p. 119, pl. 6,
Figs. 2 and 2a.

Micrhystridium capitatum sp. nov. p. 119,
pl. 6, Figs. 5 and 5a.

Micrhystridium sp. 3 p. 120, pl. 6, Fig. 8.

Micrhystridium stephensonii sp. nov. p. 121,
pl. 6, Figs. 4 and 4a.

Micrhystridium fragile p. 121, pl. 6, Fig. 10.

Micrhystridium sp. cf. Hystrichosphaeridium
patulum p. 122, pl. 6, Fig. 9.

Micrhystridium sp. 4 p. 122, pl. 6, Fig. 11.

Micrhystridium sp. 5 p. 123, pl. 6, Figs. 3 and
3a.

Fern Spores

TRILETE SPORES

Leiotriletes sp. 1 p. 124, pl. 16, Fig. 3.

Leiotriletes sp. 2 p. 125, pl. 14, Figs. 2 and 3.

Leiotriletes sp. 3 p. 126, pl. 15,
Figs. 1 and 1a.

Leiotriletes sp. 4 p. 126, pl. 14,
Figs. 4 and 4a.

Leiotriletes adriensis p. 126, pl. 16,
Figs. 1, 1a and 2.

Leiotriletes maxoides p. 127, pl. 15,
Figs. 2, 4, 4a, and 4b.

Deltoidospora sp. p. 128, pl. 15, Fig. 3.

Cicatricosisporites dorogensis p. 128, pl. 19,
Figs. 1 and 1a.

Lycopodiumsporites sp. 1 p. 129, pl. 19,

Figs. 3 and 3a.

Lycopodiumsporites sp. 2 p. 130, pl. 20,

Figs. 1 and 1a.

Lycopodiumsporites sp. 3 p. 130, pl. 20,

Figs. 2, 2a, 3, and 3a.

Hydrosporis azollaensis subsp. azollaensis

p. 131, pl. 18, Fig. 4.

Azolla bohémica p. 132, pl. 18, Fig. 5.

Camerozonosporites sp. p. 132, pl. 18, Figs. 3

and 3a

(?) Osmundacidites sp. p. 133, pl. 17,

Figs. 4 and 4a.

Family SELAGINELLACEAE

Lusatisporis perinatus p. 134, pl. 16, Fig. 5.

Lusatisporis sp. p. 134, pl. 16, Fig. 4.

Family ANTHOCEROTACEAE

Saxosporis duebenensis p. 135, pl. 17,

Figs. 1, 1a and 2.

Rudolphisporis sp. p. 136, pl. 19,

Figs. 2 and 2a.

Family Incertae Sedis

Forma A Gen. et. sp. nov.

p. 137, pl. 18, Figs. 1 and 1a.

Forma B Gen. et. sp. nov.

p. 137, pl. 18, Figs. 2 and 2a.

Genus Incertae Sedis p. 138, pl. 17, Fig. 3.

MONOLETE SPORES

Laevigatosporites haardti p. 139, pl. 21,

Figs. 1 and 2.

Laevigatosporites sp. 1 p. 139, pl. 21, Fig. 3.

Laevigatosporites sp. 2 p. 140, pl. 21,

Figs. 4 and 5.

Microfoveolatosporis sp. p. 141, pl. 21,

Figs. 6 and 7.

Polypodiisporites favus p. 141, pl. 21, Fig. 12.

Polypodiisporites secundus p. 142, pl. 21,

Fig. 11.

Polypodiisporites sp. 1 p. 142, pl. 21, Fig. 8.

Polypodiisporites sp. 2 p. 143, pl. 21, Fig. 9.

Polypodiisporites sp. 3 p. 144, pl. 21, Fig. 10.

SACCATE POLLEN

Pinuspollenites sp. 1 p. 145, pl. 22, Fig. 5.

Pinuspollenites sp. 2 p. 146, pl. 22, Fig. 1.

Pinuspollenites sp. 3 p. 146, pl. 22, Fig. 2.

Pinuspollenites sp. 4 p. 147, pl. 22, Fig. 3.

Pinuspollenites sp. 5 p. 148, pl. 22, Fig. 4.

Order GNETALESFamily GNETACEAE

Ephedra sp. 1 p. 149, pl. 23, Figs. 5 and 6.

Ephedra voluta p. 149, pl. 23, Fig. 11.

Ephedra sp. 2 p. 150, pl. 23, Figs. 7, 7a, and 8

Ephedra sp. 3 p. 150, pl. 23, Fig. 9.

Ephedra sp. 4 p. 151, pl. 23, Fig. 10.

NON-SACCATE POLLEN

Taxodiaceapollenites hiatus p. 152, pl. 23,
Figs. 1, 2, 3, and 4.

PORATE POLLEN

Corsinipollenites oculusnoctic p. 153, pl. 23,
Fig. 12.

Tiliapollenites sp. 1 p. 154, pl. 23, Fig. 14.

Tiliapollenites sp. 2 p. 154, pl. 23, Fig. 13.

Subtriporopollenites anulatus subsp. anulatus
p. 155, pl. 23, Fig. 15 also pl. 24, Fig. 1.

Subtriporopollenites sp. 1 p. 156, pl. 24,
Fig. 2.

Subtriporopollenites sp. 2 p. 156, pl. 24,
Fig. 3.

Subtriporopollenites sp. 3 p. 157, pl. 24,
Fig. 4.

Triatriopollenites coryphaeus p. 158, pl. 24,
Figs. 5 and 6.

Betulaceoipollenites granifer forma megagranifer
p. 158, pl. 24, Fig. 11.

Betulaceoipollenites sp. p. 159, pl. 24, Fig. 7.

Engelhardtioipollenites quietus n. comb. p. 160,
pl. 24, Figs. 8, 8a, and 9.

Engelhardtioipollenites sp. p. 161, pl. 24,
Fig. 10.

Ulmipollenites undulosus p. 162, pl. 24,
Figs. 12, 13, and 14.

Liquidambarpollenites stigmosus p. 163, pl. 24,

Figs. 15 and 16.

Chenopodipollis sp. 1 p. 164, pl. 24,

Figs. 17 and 18.

Chenopodipollis sp. 2 p. 164, pl. 24, Fig. 19.

Monoporopollenites sp. p. 165, pl. 24,

Figs. 20 and 20a.

Forma A, Gen. et. sp. nov. p. 166, pl. 24,

Fig. 21.

COLPATE AND COLPORATE POLLEN

Ilexpollenites illiacus p. 167, pl. 24,

Figs. 25 and 26.

Quercoidites sp. p. 167, pl. 25, Figs. 11 and 12.

Quercoidites henrici p. 169, pl. 25,

Figs. 1, 1a, and 2.

Tricolpopollenites hians p. 170, pl. 25,

Figs. 8 and 8a.

Tricolpopollenites hardiei sp. nov. p. 170,

pl. 25, Figs. 9 and 10.

Tricolpopollenites sp. 1 p. 171, pl. 24,

Figs. 22 and 22a.

Tricolpopollenites sp. 2 p. 172, pl. 24,

Figs. 23 and 24.

Tricolpopollenites sp. 3 p. 172, pl. 25,

Figs. 3, 3a, and 4.

Tricolpopollenites sp. 4 p. 173, pl. 25, Fig. 5.

Tricolpopollenites sp. 5 p. 174, pl. 25, Fig. 6.

Tricolpopollenites sp. 6 p. 174, pl. 25, Fig. 7.

Nyssapollenites sp. p. 175, pl. 26, Fig. 4.

Pollenites ventosus p. 176, pl. 25, Fig. 23.

Tricolporopollenites sp. 1 p. 177, pl. 25,

Figs. 13 and 13a.

Tricolporopollenites sp. 2 p. 177, pl. 25,

Figs. 14 and 15.

Tricolporopollenites sp. 3 p. 178, pl. 25,

Fig. 16.

Tricolporopollenites sp. 4 p. 179, pl. 25,

Figs. 17 and 17a.

Tricolporopollenites sp. 5 p. 179, pl. 25,

Fig. 18.

Tricolporopollenites sp. 6 p. 180, pl. 25,

Fig. 19.

Tricolporopollenites sp. 7 p. 180, pl. 25,

Fig. 20.

Tricolporopollenites sp. 8 p. 181, pl. 25,

Fig. 21.

Tricolporopollenites sp. 9 p. 182, pl. 25,

Fig. 22.

Tricolporopollenites sp. 10 p. 182, pl. 25,

Fig. 24.

Tricolporopollenites sp. 11, p. 183, pl. 26,

Fig. 1.

Tricolporopollenites sp. 12 p. 183, pl. 26,
Fig. 2.

Tricolporopollenites cf. Tricolporopollenites
sp. 1 Engelhardt p. 184, pl. 26, Fig. 3.
Myrtaceidites mesonesus p. 185, pl. 26,
Figs. 5 and 6.

Sapotaceoidapollenites lesquereuxiana p. 186,
pl. 26, Figs. 10, 11, and 11a.

Sapotaceoidapollenites sp. 1 p. 187, pl. 26,
Fig. 9.

Sapotaceoidapollenites sp. 2 p. 187, pl. 26,
Fig. 12.

Sapotaceoidapollenites sp. 3 p. 188, pl. 26,
Figs. 8 and 8a.

Sapotaceoidapollenites sp. 4 p. 189, pl. 26,
Figs. 7 and 7a.

MONOSULCATE POLLEN

Calamuspollenites pertusus p. 189, pl. 26,
Figs. 13, 13a, and 14.

Calamuspollenites elsikii sp. nov. p. 191,
pl. 26, Fig. 15.

Liliacidites intermedius p. 191, pl. 26,
Figs. 18 and 18a.

Liliacidites sp. p. 192, pl. 26, Figs. 17 and
17a.

Liliacidites cf. Liliacidites variegatus p. 193,
pl. 26, Fig. 16.

Liliacidites variegatus p. 193, pl. 27, Fig. 1.

FUNGI

Dicellaesporites sp. 1 sp. nov. p. 194, pl. 27,
Fig. 2.

Dicellaesporites sp. 2 sp. nov. p. 194, pl. 27,
Fig. 3.

Dicellaesporites sp. 3 sp. nov. p. 195, pl. 27,
Fig. 5.

Dicellaesporites sp. 4 sp. nov. p. 195, pl. 27,
Fig. 19.

Fusiformisporites sp. sp. nov. p. 196, pl. 27,
Fig. 4.

Multicellaesporites sp. 1 sp. nov. p. 197,
pl. 27, Fig. 6.

Multicellaesporites sp. 2 sp. nov. p. 197,
pl. 27, Fig. 7.

Multicellaesporites sp. 3 sp. nov. p. 198,
pl. 27, Fig. 8.

Multicellaesporites sp. 4 sp. nov. p. 198,
pl. 27, Fig. 9.

Multicellaesporites sp. 5 sp. nov. p. 199,
pl. 27, Fig. 18.

Lacrimasporonites smithii sp. nov. p. 199,
pl. 27, Fig. 10.

Lacrimasporonites fisheri sp. nov. p. 200,
pl. 27, Fig. 11.

Dyadosporonites richii sp. nov. p. 200,
pl. 27, Fig. 16.

Diporicellaesporites sp. 1 sp. nov. p. 201,
pl. 27, Fig. 12.

Diporicellaesporites sp. 2 sp. nov. p. 202,
pl. 27, Fig. 13.

Diporicellaesporites sp. 3 sp. nov. p. 202,
pl. 27, Fig. 14.

Diporicellaesporites sp. 4 sp. nov. p. 203,
pl. 28, Fig. 3.

Pluricellaesporites middletonii sp. nov.
p. 203, pl. 27, Fig. 17.

Family MICROTHYRIACEAE

Forma A p. 204, pl. 28, Fig. 1.

Forma B p. 205, pl. 28, Figs. 2 and 2a.

Fungal Hyphae p. 205, pl. 27, Fig. 15.

FORAMINIFERA

Forma A p. 206, pl. 29, Fig. 1.

Forma B p. 206, pl. 29, Fig. 2.

Forma C p. 207, pl. 29, Fig. 3.

Forma D p. 207, pl. 29, Fig. 4.

Class DINOPHYCEAE Pascher

Family Hystrichosphaeraceae Evitt

Genus Hystrichosphaera O. Wetzel, 1932,
emend. Davey and Williams, 1966.

Type species: Hystrichosphaera (Xanthidium) ramosa
(Ehrenberg), 1838. Upper Cretaceous (Senonian); Germany.

Hystrichosphaera ramosa var. ramosa Davey,
Downie, et al., 1966 (p. 33)
Pl. 1, Figs. 1-6; Pl. 3, Fig. 1

Hystrichosphaera ramosa var. ramosa
Pl. 1, Figs. 3, 4 and 4a

Description: Specimen conform in morphology to H. ramosa
var. ramosa in every aspect. Diameter of central body 39
to 43 microns; length of processes 13.7 to 15.5 microns.

Occurrence: uncommon to common depending on horizon
down in the wells.

Location of sample: Well; A. D. Middleton #79
Depth; 6579'-6705'

Reference slide: slide number; 6
coordinates; 41.1 x 99.8
Michigan State University*

Hystrichosphaera sp. cf. Hystrichosphaera
ramosa var. membranaceae (Rossignol),
Davey, Downie, et al., 1966
Pl. 1, Fig. 2

*The initials M.S.U. will be used in further
references.

Description: Chorate cyst, outline of central body spherical. Processes of three type: 1. Solid, closed, bifurcated at about 2/3 of their length, bifurcated again at their tip. 2. Solid, closed, trifurcated at about 2/3 of their length, bifurcated again distally. 3. Two large antapical processes, with broad bases and slightly shorter than previous two types, bifurcated distally, with conspicuous sutural membrane. Periphragm thin and granular. Archaeopyle precingular (not observable in illustrated specimen). Maximum length of central body 34.4 microns; length of gonial and border processes 11.13 microns, length of antapical processes 10 microns.

Discussion: This specimen compares favorably to H. ramosa var. membranaceae, except for the two well developed large dorsal antapical processes.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg Timber #1
Depth; 5250'-5280'.

Reference slide: slide number; 4
coordinates; 35.5 x 110.3
M.S.U.

Hystriosphera ramosa var. multibrevis
Davey, Downie, et al., 1966 (p. 35)
Pl. 1, Fig. 4; Pl. 4, Fig. 6

Hystriosphera ramosa var. multibrevis
Pl. 2, Fig. 2

Description: Specimens conform in morphology to the type specimen in every aspect. Diameter of central body 40 to 46 microns; length of processes 6 to 12 microns.

Occurrence: Common, present throughout the Frio Formation.

Range: H. ramosa var. multibrevis has been recorded from the Lower Cretaceous to the Eocene in England, and from the Upper Cretaceous of France and Germany.

Location of sample: Well; A. D. Middleton #79
Depth; 6861'-6954'.

Reference slide: slide number; 2
coordinates; 40.5 x 101.2
M.S.U.

Hystriosphera buccina Williams, in
Davey et al., 1966
Pl. 2, Fig. 3

Description: Specimens compare favorably in morphology to the species described by Dr. Graham L. Williams. Diameter of central body 55 to 62 microns; length of process minimum 12 to 15 microns, maximum 28 to 31 microns.

Occurrence: Uncommon to rare.

Range: Eocene-Pleistocene.

Location of sample: Well; A. D. Middleton #79
Depth; 8579'-8710'.

Reference slide: coordinates; 29.4 x 116.

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Genus Achomosphaera Evitt, 1963

Type species: A. (al. Hystrichosphaeridium) ramulifera
(Deflandre, 1937a), Upper Cretaceous; France.

Achomosphaera ramulifera (Deflandre), Evitt, 1963
Pl. 1, Figs. 1 and 1a

1937. Achomosphaera (al. Hystrichosphaeridium) ramulifera,
(Deflandre, 1937), p. 74, pl. 14, Figs. 5-6. Upper
Cretaceous; France.

Description: Specimens conform in morphology to the type
species in every aspect. Length of central body 34 to 40
microns, width of central body 30 to 36 microns, length
of processes 13 to 18 microns.

Occurrence: Common, present throughout the Frio Formation.

Range: Upper Cretaceous to Pleistocene (Dr. Graham L.
Williams, personal communication).

Location of sample: Well; J. M. Rich #1
Depth; 7572'-7603'

Reference slide: slide number; 2
coordinates; 36 x 102.5
M.S.U.

Family Hystrichosphaeridiaceae Evitt
(Group 5 of Sarjeant and Downie, 1966)

Genus Hystrichokolpoma Klumpp 1953, emend.
Williams, Downie, in Davey et al., 1966
(p. 176)

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Type species: Hystrichokolpoma cinctum Klumpp 1953.

Eocene; Germany.

Hystrichokolpoma rigaudea Deflandre and Cookson
1955 Pl. 6, Figs. 6-10

Hystrichokolpoma rigaudea
Pl. 3, Fig. 2

Description: Specimens conform in morphology to the type specimen in every aspect. Diameter of central body 36 to 40 microns; length of the antapical process 29 to 32 microns.

Occurrence: Common to uncommon, present throughout the Frio Formation.

Range: Eocene (London Clay) to Pleistocene (recorded by Rossignol, in Israel).

Location of sample: Well; A. D. Middleton #79

Depth; 9425'-9528'

Reference slide: slide number; 4

coordinates; 28.4 x 102.4

M.S.U.

Hystrichokolpoma sp. cf. H. rigaudea
Deflandre and Cookson 1955
Pl. 3, Figs. 1 and 1a

Comparison: Specimens conform favorably to H. rigaudea in most aspects. The only difference is that the long antapical process does not taper distally.

Genus Friosphaera williamsii Gen. nov. et sp. nov.
Pl. 3, Fig. 3

Diagnosis: Chorate cyst, outline of central body spherical. Periphragm thin and granular. Processes variable in shape and size. Tabulation not determinable. Archaeopyle not observed.

Description: Three types of processes observable: 1. Slender, entire, hollow, open distally where it is slightly flared; length 10 to 13 microns. 2. Relatively wide, hollow processes, bifurcated 2/3 of their length, open distally; length 10 to 13 microns. 3. Broad, hollow, striate processes closed distally where a number of small spines are observable; length 12 to 15 microns. Archaeopyle not observed. Diameter of central body 41 to 45 microns (number of specimens examined seven).

Discussion: There are a number of characteristics which this taxon has in common with the genus Hystriochokolpoma, such as presence of broad and long processes as well as smaller ones. Yet since no archaeopyle has been observed and the varied type of processes hinders one to put it in that genus.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg-Timber #1

Depth; 4466'-4496'

Holotype: slide number 1, from 4466'-4496' sample
coordinates; 34.2 x 111

M.S.U.* Pb. No. 9026

* Paleobotanical maceration number.

Genus Cleistosphaeridium Davey et al., 1966 (p. 166)

Type species: Cleistosphaeridium diversispinosum Davey et al., 1966. Eocene; England.

Cleistosphaeridium disjunctum Davey et al.,
1966 (p. 169)
Pl. 11, Fig. 9

Cleistosphaeridium disjunctum
Pl. 7, Figs. 2 and 2a

Description: Specimens conform in morphology to C. disjunctum in every aspect. Diameter of central body 34 to 42 microns; length of processes variable: minimum 7 microns, maximum 13 microns.

Occurrence: Common, present throughout the Frio Formation.

Range: Upper Cretaceous to Pleistocene (Dr. Graham L. Williams, personal communication).

Location of sample: Well; J. M. Rich #1
Depth; 8024'-8055'

Reference slide: slide number; 2
coordinates; 31 x 96.2
M.S.U.

Cleistosphaeridium disjunctum var.
brevispinosum var. nov.
Pl. 9, Fig. 3

Description: Chorate cyst, outline of central body more or less spherical. Periphragm thin and smooth giving rise

to processes. Processes numerous, more or less uniform in size, although some appear slightly thinner than others. Processes wide proximally, acuminate, hollow, closed distally. Archaeopyle apical, with zigzag margin. Diameter of central body 48 to 52 microns; length of processes 8 to 9.5 microns. Number of specimens measured twelve.

Discussion: This taxon compares closely to C. disjunctum, yet it has smaller and more numerous processes, hence the reason to describe a new variety.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg Timber #1
Depth; 4466'-4496'

Holotype: slide number 1, from 4466'-4496' sample
coordinates; 37.5 x 110.8
M.S.U. Pb. No. 9026

Cleistosphaeridium texas sp. nov.
Pl. 7, Figs. 1, 1a and 1b

Description: Chorate cyst, outline of central body spherical. Periphragm thin and granular, giving rise to processes. Processes about sixty in number, variable in shape: 1. Processes solid, closed distally where they are "half" capitate; length 11 to 12.5 microns. 2. Processes bifurcated half-way their length and bifurcated again at their tip; length 12 to 13.5 microns. 3. Processes solid, entire, bifurcated at their tip, where one branch may be longer than the other. Archaeopyle

apical (not observable on specimen illustrated). Diameter of central body 40 to 47 microns.

Discussion: Taxon differs from C. diversispinosum Davey et al., 1966, mainly by virtue of possessing more spines.

Range: Oligocene (Frio Formation) to Pleistocene (Dr. Graham L. Williams, personal communication).

Occurrence: Common to uncommon, present throughout the Frio Formation.

Location of sample: Well; A. D. Middleton #79
Depth; 8485'-8579'

Holotype: slide number 1, from 8485'-8579' sample
Coordinates; 41.4 x 95.6
M.S.U. Pb. No. 9070

Genus Polysphaeridium Davey and Williams,
in Davey et al., 1966 (p. 91)

Type species: Polysphaeridium subtilum Davey and Williams,
in Davey et al., 1966. Eocene (Ypresian); England.

Polysphaeridium pastielsi Williams in
Davey et al., 1966
Pl. 7, Fig. 3 also Pl. 8, Fig. 1

Description: Specimens compare favorably to P. pastielsi as described by Williams. Diameter of central body 32 to 40 microns; length of processes 9.7 to 12 microns.

Range: Eocene.

Occurrence: Common, present throughout the Frio Formation.

Location of sample: Well; J. M. Rich #1
Depth; 7033'-7067'

Reference slide: slide number; 1
 coordinates; 33.1 x 98.2
 M.S.U.

Polysphaeridium sp.
 Pl. 8, Figs. 2 and 2a

Description: Chorate cyst, outline of central body spherical. Periphragm thin and finely granulose, giving rise to processes. Processes numerous, uniform in width but not in length; minimum length 10.6 microns, maximum 18 microns. Processes hollow, broad proximally, open distally with aculeate to denticulate tip. Archaeopyle apical. Diameter of central body 44 to 52 microns.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1
 Depth; 7962'-7993'

Reference slide: slide number; 1
 coordinates; 39.9 x 100.2
 M.S.U.

Genus Cordosphaeridium Eisenack, 1963 emend.
 Davey and Williams in Davey
 et al., 1966 (p. 83)

Type species: Cordosphaeridium (Hystrichosphaeridium)
inodes (Klumpp) 1953. Eocene; German.

Cordosphaeridium crossii sp. nov.
 Pl. 9, Figs. 1, 1a and 2

Emended Diagnosis: Sub-spherical chorate cysts, with central bodies composed of two distinct layers, periphragm variably developed, forming well developed processes, tubiform to buccinate, solid or hollow, intratabular and reflecting a tabulation of 1', 6", 6c, 6"' (lp), 1"" and a variable number of sulcal processes. Archaeopyle precingular resulting from the loss of field (plate) 3".

Discussion: The author had the privilege of consulting Dr. Graham L. Williams who believes that his emended diagnosis of the genus Cordosphaeridium should be modified since the position of the archaeopyle is not apical but precingular.

Description: Chorate cyst, outline of central body sub-circular. Periphragm and endophragm distinct. Periphragm thin and granular. Processes variable in shape and mainly of three types: 1. Processes hollow, entire, open distally; length 18 to 21 microns. 2. Processes hollow, bifurcated near their tip, open distally, width (average) 2.6 microns; length 17.5 to 19.6 microns. 3. Processes hollow, trifurcated near their tip, with distinct ridges or ribs running along their length, open distally, average width 4.2 microns; length 26 to 29 microns. Archaeopyle precingular. Diameter of central body 50 to 61 microns, number of specimens measured thirty.

Occurrence: Uncommon to very abundant especially in Lower Frio (see chapter on correlation).

Location of sample: Figs. 1 and 1a

Well; A. D. Middleton #79

Depth; 9030'-9120'

Holotype: slide number 1, from 9030'-9120' sample
coordinates; 41.5 x 102.8

M.S.U. Pb. No. 9076

Location of sample: Fig. 2

Well; A. D. Middleton #79

Depth; 9206'-9300'

Reference slide: coordinates; 40.5 x 116.1

M.S.U.

Family Homotrybliaceae Sarjeant
and Downie, 1966

Genus Homotryblum (cyst-family Aeroligeraceae
Evitt, 1963a), Davey and Williams,
in Davey et al., 1966.

Type species: Homotryblum tenuispinum Davey and Williams
1966. Eocene; England.

Homotryblum plectilum Drugg
and Loeblich 1967
Pl. 2, Figs. 1, 1a and 1b

Description: Specimens compare favorably in every aspect
to H. plectilum of Drugg and Loeblich (1967). Diameter
of central body 51 to 60 microns; length of processes 13
to 17 microns.

Occurrence: Uncommon to rare.

Range: Oligocene of the Gulf Coast, U.S.A.

Location of sample: Well; A. D. Middleton #79

Depth; 9425'-9528'

Reference slide: slide number; 4

coordinates; 33.3 x 101.9

M.S.U.

Genus Cyclonephelium Deflandre and Cookson,
1955 emend. Williams and Downie in
Davey et al., 1966 (p. 223)

Type species: Cyclonephelium compactum Deflandre and
Cookson, 1955. Lower to Upper Cretaceous; Australia.

Cyclonephelium proutyi sp. nov.
Pl. 10, Fig. 1

Description: Chorate cyst, outline of central body
spheroidal. Periphragm thin and granulose, giving rise
to processes. Processes variable in shape, mainly of
two types: 1. Processes hollow, closed distally either
bifurcated or trifurcated at about 2/3 of their length.
2. Processes hollow, closed distally, either bifurcated
or trifurcated near their tip. Both types of processes
are joined distally by a thin and narrow system of
trabecula. Archaeopyle apical (not observable on specimen
illustrated). Diameter of central body 46 to 52 microns;
length of processes 15 to 18.5 microns. Number of
specimens studied eight.

Occurrence: Uncommon to common especially at the top of the Frio Formation and bottom of the Anahuac.

Location of sample: Well; Grayburg Timber #1
Depth; 4466'-4496'

Holotype: slide number 1, from 4466'-4496' sample
coordinates; 30.8 x 104.8
M.S.U. Pb. No. 9026

Cyclonephelium sp.
Pl. 10, Fig. 4

Description: Chorate cyst, outline of central body spheroidal. Periphragm thin and granular, giving rise to processes. Processes numerous and variable in shape and mode of division; processes can be bifurcated, trifurcated, and some are distally four-branched. System of trabeculation is complex; some processes are joined at 2/3 of their length by wide trabeculae, while others are joined by a thin network of trabeculae only distally. Archaeopyle apical. Diameter of central body 45 to 51 microns; length of processes 15 to 17.5 microns. Number of specimens examined five.

Comparison: Cyclonephelium sp. although quite similar to Cyclonephelium proutyi, differs from it with respect to the position and width of trabeculae which is much broader.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg Timber #1
Depth; 5250'-5280'

Reference slide: slide number; 2
coordinates; 38.7 x 100.5
M.S.U.

Family Adnatospheridiaceae Sarjeant
and Downie, 1966

Genus Adnatosphaeridium Williams
and Downie, in Davey et al.,
1966 (p. 215)

Type species: Adnatosphaeridium vittatum Williams and
Downie, 1966. Eocene; England.

Adnatosphaeridium sp.
Pl. 10, Figs. 2 and 3

Description: Chorate, trabeculate cyst, outline of
central body spheroidal to sub-polygonal. Periphragm
thin and granulose. Processes relatively numerous.
Processes broad proximally, becoming narrow about half
way their length but widen distally where they join one
another by trabeculae. Processes solid, closed, weakly
striate; striations run along their length. Archaeopyle
apical. Diameter of central body 32 to 35 microns;
length of processes 15 to 17 microns. Number of specimens
studied four.

Occurrence: Uncommon to rare.

Location of sample: Fig. 2
Well; Grayburg Timber #1
Depth; 6035'-6066'

Reference slide: slide number; 2
 coordinates; 39.9 x 100.2
 M.S.U.

Location of sample: Fig. 3
 Well; Grayburg Timber #1
 Depth; 6035'-6066'

Reference slide: slide number; 2
 coordinates; 33.3 x 94.2
 M.S.U.

Family Gonyaulacystaceae Sarjeant
 and Downie, 1966

Genus Gonyaulacysta Deflandre 1964 emend.
 Sarjeant, in Davey et al.,
 1966 (p. 111)

Type species: Gonyaulax jurassica Deflandre 1938.
 Upper Jurassic; France.

Gonyaulacysta bilinia sp. nov.
 Pl. 12, Fig. 3

Description: Proximate cyst, outline ovoidal. Tabulation not very distinct in specimens studied, but could establish a tentative one as follows: 3-4'(?), 6", 6"', with 2"' almost triangular in outline. In hypotract one can discern secondary sutures developed along normal field boundary. Cingulum quite well pronounced with pointed edge. Epitract 26 to 28 microns in length, hypotract 39 to 41 microns in length. Overall length 82 to 84 microns;

width 74 to 76 microns. Archaeopyle precingular (not observable on specimen illustrated).

Discussion: G. bilinia was described by Dr. Graham L. Williams in his doctoral dissertation on the London Clay, but he did not subsequently effectively describe it. Hence the specific epithet coined by Dr. Williams is retained here.

Occurrence: Uncommon to rare.

Location of Sample: Well; A. D. Middleton #79

Depth; 7731'-7820'

Holotype: slide number 1, from 7731'-7820' sample
coordinates; 29.5 x 103.3
M.S.U. Pb. No. 9077

Gonyaulacysta sp.
Pl. 12, Fig. 2

Description: Proximate cyst, outline ovoidal, one apical horn present. Tabulation is not determinable, and in general it is rarely that one can see the outline of the fields. Cingulum quite prominent with thick edges. Length of epitract 43 to 46 microns; length of hypotract 25 to 28 microns. Overall dimensions: length 75 to 78 microns, width 56 to 59 microns. Archaeopyle not observed.

Occurrence: Uncommon to rare.

Location of sample: Well; J. M. Rich #1

Depth; 7962'-7993'

Reference slide: slide number; 1
 coordinates; 35.9 x 102.7
 M.S.U.

Family Palaeoperidiniaceae Vozzhennikova,
 1961, emend. Sarjeant 1967

Genus Lejeunia Gerlach, in N. Jb.
 Geol. Palaont., 1961 (p. 112)

Type species: Lejeunia hyalina Gerlach, 1961. Upper
 Oligocene; Germany.

Lejeunia sp.
 Pl. 12, Fig. 1

Description: Proximate cyst, outline pentagonal with
 bilateral symmetry. One apical and two antapical horns
 present. Cingulum 6.4 micron in width and spiral. Cyst
 wall smooth and thin (under 0.5 microns). Tabulation
 absent. No trace of sulcus observable. Overall length
 63.6 microns, width 82.7 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79
 Depth; 9425'-9528'

Reference slide: slide number; 4
 coordinates; 32.3 x 101.9
 M.S.U.

Family Deflandreceae Eisenack

Genus Deflandrea Eisenack 1938, emend.
Williams and Downie in Davey
et al., 1966 (p. 231)

Type species: Deflandrea phosphoritica Eisenack, 1938.

Oligocene; East Prussia.

Deflandrea minor Alberti 1959
Pl. 11, Fig. 1

Description: Specimen compares favorably in all aspects to
that described by Alberti. Overall length 49.2 microns
width 37.1 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 32.1 x 106.5

M.S.U.

Family Incertae Sedis

Genus Thallassiphora Eisenack and Gocht
1960, emend. Davey, in Davey
et al., 1966.

Type species: Bion pelagicum Eisenack 1938. Oligocene;
East Prussia.

Thallassiphora sp.
Pl. 13, Figs. 1 and 1a

Description: Cavate cyst, outline of endocoel ellipsoidal. Periphragm thin and smooth; endophragm is slightly thicker. Characteristic keel present on periphragm. Archaeopyle precingular and triangular convex. Pericoel 26.5 microns wide with thin projections crossing it. Length of endocoel 83.7 microns, width of endocoel 66.8 microns. Overall length 144.5 microns; width 129.2 microns.

Discussion: This specimen resembles T. pelagica (Eisenack) Gerlach 1963, but it differs from the latter by possessing a smooth periphragm instead of a reticulate one which is the case of T. pelagica. Furthermore, it is much smaller in size i.e. 144.5 microns compared to 170 to 220 microns for T. pelagica.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: slide number; 6

coordinates; 30.1 x 101.2

M.S.U.

Family Incertae Sedis

Genus Dinogymnium (Gymnodinium Stein, 1878)
Evitt, Clarke, and Verdier 1967

Type species: Dinogymnium acuminatum Evitt, Clarke, and Verdier 1967, Cretaceous (Maastrichtian); California, U. S. A.

Dinogymnium cretaceum (Deflandre, 1934)
 emend. Evitt, Clarke and Verdier 1967
 Pl. 11, Fig. 3

Description: Specimen compares favorably in all aspects to species of Evitt et al., 1967. Overall length 29.15 microns; width 19 microns.

Discussion: Presumably this taxon is the result of reworking, since the genus Dinogymnium appears to be limited to Upper Cretaceous marine strata. Stanley (1965) has reported D. nelsonense from the Palaeocene Cannonball Formation, but Evitt (1967) believes that this occurrence is plausibly the result of reworking. The author after counting over thirty five thousand grains found no more than fifteen Dinogymnium spp., hence favors Evitt's statement.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 4466'-4496'

Reference slide: coordinates; 29.9 x 98.5

M.S.U.

Dinogymnium sp.
 Pl. 11, Fig. 2.

Description: Proximate cyst, outline biconical with hypotract more round than epittract. Fields with fairly thick sutures. Cingulum relatively broad and well pronounced. Sulcus not visible. Small archaeopyle visible

just below the apical protuberance. Epittract 21.2 microns long; hypottract 19 microns. Overall length 28.6 microns.

Occurrence: Rare.

Location of sample: Well; J. M. Rich #1

Depth; 6847'-6878'

Reference slide: slide number; 2

coordinates; 41.4 x 102.1

M.S.U.

Family Incertae Sedis

Genus Hemicystodinium Wall, 1967

Type species: Hemicystodinium (Hystrichosphaeridium)
zoharyi (Rossignol, 1962), Wall 1967. Pleistocene;
Caribbean Sea.

Hemicystodinium zoharyi
Pl. 11, Figs. 4 and 4a

Description: Specimen compares favorably in all aspects to the species described by Wall. Diameter of central body 48 to 55 microns, length of processes 11 to 15 microns.

Occurrence: Uncommon to abundant in Upper Frio.

Discussion: W. A. S. Sarjeant has included the genus Hemicystodinium in the Cyst-Family Eodiniaceae, but since his paper has not yet been effectively published the author has retained Wall's classification.

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Range: Eocene to Recent.

Location of sample: Well; Grayburg Timber #1

Depth; 4466'-4496'

Reference slide: coordinates; 36.9 x 98.8

M.S.U.

Hemicystodinium sp.
Pl. 8, Figs. 3, 3a and 3b

Description: Chorate cyst, outline of central body spherical. Periphragm thin and finely reticulate, giving rise to the processes. Processes over fifty in number, hollow, entire, broadened proximally and open distally. Processes unequal in length; size range from 9 to 15 microns. Archaeopyle not observable. Diameter of central body 44 to 51 microns.

Occurrence: Uncommon to common.

Location of sample: Well; A. D. Middleton #79

Depth; 8579'-8710'

Reference slide: coordinates; 27.7 x 98

M.S.U.

Family Endoscriniaceae Vozzhennikova, 1965
emend. Sarjeant and Downie, 1966

Genus Pentadinium Gerlach, 1961

Type species: Pentadinium laticinctum, Gerlach 1961.

Middle Oligocene; Germany.

Pentadinium laticinctum
Pl. 13, Figs. 2 and 2a

Description: Specimens compare favorably to the type species in every aspect. Overall size 79.5 to 85 microns.

Occurrence: Uncommon to rare.

Range: Middle Oligocene to Middle Miocene.

Location of sample: Well; J. M. Rich #1

Depth; 6692'-6723'

Reference slide: slide number; 2

coordinates; 37 x 98.2

M.S.U.

Group ACRITARCHA Evitt, 1963
Subgroup Uncertain

Genus Acostomocystis Drugg
and Loeblich, 1967

Type species: Acostomocystis hydria, Drugg and Loeblich
1967. Eocene; Alabama, U.S.A.

Acostomocystis potane Drugg and Loeblich 1967
Pl. 14, Figs. 1 and 1a

Description: Specimens compare favorably in all aspects to A. potane Drugg and Loeblich 1967. Overall dimensions: length 80 to 90 microns, width 72 to 80 microns.

Occurrence: Rare to common in Lower Frío.

Range: Oligocene

Location of sample: Well; A. D. Middleton #79

Depth; 8452'-8455'

Reference slide: coordinates; 39 x 95.5

M.S.U.

Subgroup Herkomorphitae

Genus Cymatiosphaera Wetzel 1933,
emend. Deflandre 1954

Type species: Cymatiosphaera radiata Wetzel 1933.

Cretaceous; Germany.

Cymatiosphaera sp.
Pl. 12, Fig. 4

Description: Acritarch, outline ellipsoidal, composed of two distinct layers. Outer layer thin, folded and granulose divided into a polygonal pattern of reticulation; reticulum of variable size, maximum length 20.1 microns. Inner layer thick and granulose, also with pattern of reticulation; maximum length of reticulum 14.8 microns. Overall dimensions: length 69.9 microns, width 64.1 microns.

Occurrence: Uncommon to rare.

Location of sample: Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 1

coordinates; 37.9 x 98.1

M.S.U.

Subgroup Acanthomorphitae Downie,
Evitt and Sarjeant, 1963

Genus Baltisphaeridium Eisenack 1958,
emend. Downie and Sarjeant 1963

Type species: Baltisphaeridium (al. Ovum hispidum)
longispinosum (Eisenack, 1931) Silurian; Baltic

Baltisphaeridium sp. 1
Pl. 4, Figs. 1, 1a, and 2

Description: Outline of central body circular. Outer membrane thin and granulose giving rise to processes. Processes numerous, two types observable: 1. Processes hollow, slightly broader proximally than distally where they are closed and capitate; length 5.30 to 12.7 microns. 2. Processes short, solid, spiny and closed distally. Diameter of central body 36 to 42 microns.

Occurrence: Common to abundant, especially at the top of the Frio Formation (see chapter on correlation).

Location of sample: Figs. 1 and 1a

Well; A. D. Middleton #79

Depth; 8452'-8455'

Reference slide: coordinates; 28.8 x 92.5

M.S.U.

Location of sample: Fig. 2

Well; A. D. Middleton #79

Depth; 8579'-8710'

Reference slide: coordinates; 36.9 x 107.9

M.S.U.

Baltisphaeridium sp. 2
Pl. 4, Fig. 4

Description: Outline of central body circular. Outer membrane thin and finely granulose. Processes numerous, uniform in size but different in shape. 1. Three processes are hollow and open distally. 2. Processes hollow, broader proximally than distally where they are closed. Diameter of central body 38 to 41 microns; length of processes 6 to 7.5 microns.

Occurrence: Common to uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7745'-7776'

Reference slide: slide number; 2

coordinates; 32 x 93.7

M.S.U.

Baltisphaeridium sp. 3
Pl. 4, Figs. 3 and 3a

Description: Outline of central body circular. Outer membrane thin and smooth giving rise to processes. Process numerous hollow (?), distally bifid, unequal in length, minimum 7.4 microns, maximum 10.6 microns. A small number of processes are trifurcated distally. Pylome not observed. Diameter of central body 42 to 45 microns.

Occurrence: Uncommon to rare

Location of sample: Well; J. M. Rich #1

Depth; 6909'-6940'

Reference slide: slide number; 2

coordinates; 33.9 x 97.9

M.S.U.

Baltisphaeridium sp. 4

Pl. 5, Fig. 3

Description: Outline of central body circular. Outer membrane thin and smooth, giving rise to the processes. Processes in excess of 50 in number, hollow, broader proximally than distally where they are closed and weakly capitate to bulbous. Size of processes variable, minimum 5.8 microns, maximum 12.2 microns. Pylome absent. Diameter of central body 37 to 41 microns.

Occurrence: Uncommon to rare.

Location of sample: Well; J. M. Rich #1

Depth; 6909'-6940'

Reference slide: slide number; 2

coordinates; 33.9 x 97.9

M.S.U.

Baltisphaeridium sp. 5

Pl. 5, Fig. 4

Description: Outline of central body circular. Outer membrane thin and finely granulose giving rise to processes. Processes very numerous, hollow (?), entire. Length of processes variable, minimum 7.4 microns, maximum 11.7 microns. Due to poor preservation of the specimen, presence or absence of a pylome cannot be ascertained. Diameter of central body 44 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1
Depth; 5250'-5280'

Reference slide: slide number; 4
coordinates; 36.2 x 101.8
M.S.U.

Baltisphaeridium sp. 6
Pl. 5, Fig. 5

Description: Outline of central body spheroidal. Outer membrane thin and granular, giving rise to processes. Processes very numerous, similar in shape and width but unequal in length; minimum 5.8 microns, maximum 9 microns. Processes hollow, entire, closed distally with faintly serrate tips. Pylome absent (?). Diameter of central body 49 to 58 microns.

Occurrence: Common, present throughout the Frio Formation.

Location of sample: Well; Grayburg Timber #1
Depth; 4466'-4496'

Reference slide: coordinates; 33 x 107.5
M.S.U.

Baltisphaeridium sp. 7
Pl. 3, Figs. 4 and 4a

Description: Outline of central body circular. Outer membrane thin and granulose giving rise to processes. Processes over 50 in number, solid, proximally with a bulbous base, distally closed and weakly capitate. Processes uniform in width and height, length of processes 6.9 microns, diameter of central body 30 to 37 microns. Pylome present (not visible on specimen illustrated).

Occurrence: Common to uncommon, present throughout the Frio Formation.

Location of sample: Well; A. D. Middleton #79
Depth; 6861'-6954'

Reference slide: slide number; 1
coordinates; 35.5 x 103
M.S.U.

Baltisphaeridium scalenofurcatum sp. nov.
Pl. 6, Fig. 1

Description: Outline of central body ellipsoidal. Outer membrane thin and granular giving rise to processes. Processes over 50 in number, solid, closed distally and bifurcated, one branch of bifurcation is longer than the other one. Processes more or less uniform in length and width. Diameter of central body 29 to 33.5 microns; length of processes 6 to 7.8 microns. Number of specimens examined five. Pylome absent (?).

Discussion: This taxon was described by Dr. Graham L. Willame in his doctoral dissertation on the London Clay, but subsequently did not validly erect it. Thus the specific epithet coined by Dr. Williams is retained here.

Occurrence: Rare.

Range: Eocene to Oligocene.

Location of sample: Well; J. M. Rich #1
Depth; 7962'-7993'

Holotype: slide number 1, from 7962'-7993' sample
coordinates; 33.9 x 102.7
M.S.U. Pb. No. 9057

Baltisphaeridium cf. B. ehrenbergi var.
brevispinosum Sarjeant, 1961
Pl. 5, Figs. 1, 1a and 2

Description: Outline of central body ellipsoidal. Outer membrane thin and distinctly granulose, giving rise to processes. Processes over fifty in number, hollow, closed distally and acuminate. Processes uniform in width and height, length of processes 7 to 8.5 microns. Length of central body 43 to 46 microns, width 35 to 38 microns. No pylome observed.

Comparison: Specimens fit in most respects the specific description given by Sarjeant (1961) especially with regard to the shape of the processes and the ratio of their length to that of the central body. The main differences are that the variety set up by Sarjeant has a smooth body with a diameter of 25 microns.

Occurrence: Uncommon.

Location of sample: Figs. 1 and 1a

Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates; 35.2 x 113.5

M.S.U.

Location of sample: Fig. 2

Well; Grayburg Timber #1

Depth; 5250'-5280'

Reference slide: slide number; 3
coordinates; 34.3 x 111.6
M.S.U.

Genus Micrhystridium Deflandre, 1937,
emend. Downie and Sarjeant, 1963

Type species: Micrhystridium (al. Hystrichosphaera)
inconspicuum (Deflandre, 1935) Cretaceous; France.

Micrhystridium sp. 1
Pl. 6, Figs. 6 and 7

Description: Outline of central body circular. Outer wall thin and smooth giving rise to processes; these do not communicate with test interior. Processes twenty eight in number, broad and bulbous at their base, solid, acuminate, and closed distally. Diameter of central body 7.5 to 9.9 microns; length of processes 2.5 to 2.9 microns.

Occurrence: Uncommon to rare.

Location of sample: Fig. 6

Well; J. M. Rich #1

Depth; 6166'-6197'

Reference slide: coordinates; 38.4 x 92
M.S.U.

Location of sample: Fig. 7

Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates; 40.9 x 105

M.S.U.

Micrhystridium sp. 2
Pl. 6, Figs. 2 and 2a

Description: Outline of test circular. Outer wall thin and smooth giving rise to processes. Processes very numerous, uniform in length and width. Processes proximally slightly widen, thinning greatly towards the tip where they become hair-like. Diameter of central body 10.3 microns; length of processes 7.3 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: coordinates; 34 x 96.2

M.S.U.

Micrhystridium capitatum sp. nov.
Pl. 6, Figs. 5 and 5a

Description: Outline of central body spheroidal to weakly pentagonal. Outer wall thin and smooth giving rise to processes. The processes do not communicate with test interior. Processes about thirty in number, proximally relatively broad and with a bulbous base, solid, closed with capitate tips. Processes unequal in length; minimum 3.6 microns, maximum 6.0 microns. Diameter of test 8 to 9.5 microns.

Comment: The genus Michrystridium with its numerous species exhibits quite a variation with respect to shape of processes, yet as far as the author knows none have capitate processes.

Occurrence: Uncommon to abundant especially in upper two-thirds of the Frio Formation.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Holotype: slide number 1, from 7233'-7327' sample
coordinates; 35.2 x 115.7
M.S.U. Pb. No. 9063

Michrystridium sp. 3
Pl. 6, Fig. 8

Description: Outline of central body circular. Outer wall thin and smooth. Processes about fifteen in number, equal in width but not in length: minimum 3.8 microns, maximum 5.0 microns. Processes slightly broader proximally, solid, with capitate tips. Diameter of central body 9.5 microns.

Occurrence: Common to uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 6909'-6940'

Reference slide: slide number; 2
coordinates; 37 x 88
M.S.U.

Micrhystridium stephensonii sp. nov.
Pl. 6, Figs. 4 and 4a

Description: Outline of test circular. Outer wall thin and smooth giving rise to processes. Processes about twenty-five in number, uniform in width, but not in height; minimum 4.2 microns, maximum 5.8 microns. Processes solid, proximally relatively wide and bulbous, distally closed and capitate. Diameter of central body 9 to 13.5 microns. Number of specimens studied twenty.

Occurrence: Present throughout the Frio Formation, but especially abundant towards the top (see chapter on correlation).

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Holotype: slide number 1, from 7417'-7511' sample

coordinates; 32.9 x 107

M.S.U. Pb. No. 9064.

Micrhystridium fragile Deflandre, 1947
Pl. 6, Fig. 10

Description: Specimens compares favorably to the species set up by Deflandre (1947). Diameter of central body 12 to 16.5 microns; length of processes 8 to 11.5 microns.

Range: This species has been reported from the Middle Jurassic of France (Deflandre 1947d; Valensi, 1947, 1954), and the Upper Jurassic of Britain (Sarjeant, 1959, 1960, 1961a). Williams (1963) has recorded the same

species from the London Clay, Eocene, of England. Thus this species has little stratigraphic value by virtue of its long geologic range.

Occurrence: Rare.

Location of sample: Well; J. M. Rich #1

Depth; 7745'-7776'

Reference slide: slide number; 2

coordinates; 39 x 94.2

M.S.U.

Micrhystridium sp. cf. Hystrichosphaeridium
patulum Williams, 1966
 Pl. 6, Fig. 9

Discussion: This specimen has many features in common with H. patulum Williams, in Davey et al., 1966, especially with respect to the form and variation within the processes. But the absence of an archaeopyle or a pylome of any form hinders one in naming it H. patulum. Diameter of central body 17.6 microns; length of processes 3.8 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Reference slide: coordinates; 33.6 x 100.5

M.S.U.

Micrhystridium sp. 4
 Pl. 6, Fig. 11

Description: Outline of central body circular. Outer wall thin and granular giving rise to processes. Processes twenty-six in number and mainly of two types:
 1. Processes hollow, broad proximally, thinning distally, open with flared tip, length 3 microns, width 0.8 micron. 2. Processes hollow, open distally where they are weakly flared, length 2.1 microns, width 1.3 micron. Diameter of central body 16.8 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 5754'-5786'

Reference slide: coordinates; 37.1 x 105.1

M.S.U.

Micrhystridium sp. 5
 Pl. 6, Figs. 3 and 3a

Description: Outline of test spheroidal. Outer wall thin and finely granular. Processes over thirty in number and of three types: 1. Processes hollow and entire. 2. Processes greatly bifurcated at their tip. 3. Processes hollow with markedly capitate tip. Length of processes uniform 4.2 microns, width variable, from 0.5 micron to much thinner. Diameter of central body 12 to 17 microns. Number of specimens studied six.

Occurrence: Uncommon to rare.

Location of sample: Well; A. D. Middleton #79

Depth; 9206'-9300'

Reference slide: coordinates; 40 x 114.1

M.S.U.

FERN SPORES

TRILETE SPORES

Genus Leiotriletes Naumova, 1937?, 1939,
emend. Potonié and Kremp, 1954

Type species: Leiotriletes (Sporonites Loose, 1932)
sphaerotriangulus Potonié and Kremp, 1954. Westphalian;
Ruhr.

Leiotriletes sp. 1
Pl. 16, Fig. 3

Description: Trilete spore, radially symmetrical, outline subtriangular concave. Laesurae reaches half-way to the periphery. Margo moderate, sporoderm psilate, uniform in thickness. Thickness of sporoderm 1.0 to 1.3 micron. Overall size 50 to 61 microns.

Occurrence: Common.

Affinity: Lygodium (Schizaceae); mostly tropical, rare in temperate regions.

Location of sample: Well; Grayburg Timber #1

Depth; 5590'-5621'

Reference slide: slide number; 2
coordinates; 38.5 x 103.1
M.S.U.

Leiotriletes sp. 2
Pl. 14, Figs. 2 and 3

Description: Trilete spore, radially symmetrical, outline subtriangular convex. Laesurae with weak margo, reaches two-thirds of the way to the periphery. Sporoderm psilate, except between arms of laesurae where it is punctate. Punctuation uniform in size. Exine uniform in width, thickness 0.8 micron. Overall dimension: 53 to 62 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 32.9 x 101.3

M.S.U.

Leiotriletes sp. 3
Pl. 15, Figs. 1 and 1a

Description: Trilete spore, outline subtriangular with straight to moderately convex sides. Laesurae with weak margo spreads half the way to the periphery. Exine very thin, uniform in thickness, psilate throughout. Overall size: 58 to 62 microns.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates 40.9 x 101.6

M.S.U.

Leiotriletes sp. 4
Pl. 14, Figs. 4 and 4a

Description: Trilete spore, outline subtriangular convex. Laesurae with moderate margo spreads two-thirds of the way to the periphery. Exine psilate, average thickness 1.0 micron. Overall size: 40 to 45 microns.

Comparison: Leiotriletes sp. 4 has a thicker exine and is also smaller in overall size than Leiotriletes sp. 3.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: slide number; 6

coordinates; 37.2 x 98

M.S.U.

Leiotriletes adriensis Potonié and Gelletich, 1933 emend.
Krutzsch, 1959a, in Beiheft Geologie 21/22
Pl. 16, Figs. 1, 1a and 2

Description: Specimens compare favorably in all aspects to the species of Krutzsch. Overall size: 55 microns.

Comparison: L. adriensis differs from Leiotriletes sp. 2 because of the punctation which is smaller, and its overall shape which is more subspherical than subtriangular convex. Furthermore the endexine, in L. adriensis is thicker than Leiotriletes sp. 2.

Occurrence: Common, present throughout the formation.

Range: Upper Oligocene.

Location of sample: Well; Grayburg Timber #1

Depth; 5352'-5385'

Reference slide: slide number; 1

coordinates; 37.9 x 102.9

M.S.U.

Leiotriletes maxoides Krutzsch, 1962
Pl. 15, Figs. 2, 4, 4a and 4b

Description: Specimens compare favorably to the species of Krutzsch. Overall size: 64 to 72 microns.

Range: Middle to Upper Oligocene.

Occurrence: Common, present throughout the formation.

Location of sample: Figs. 4, 4a and 4b

Well; A. D. Middleton #79

Depth; 6579'-6705'

Reference slide: slide number; 4

coordinates; 30.8 x 105

M.S.U.

Genus Deltoidospora Miner, 1935

Type species: Deltoidospora hallii (Miner, 1935)

Potonié 1956. Jurassic-Cretaceous boundary; Montana,

U.S.A.

Deltoidospora sp.
Pl. 15, Fig. 3

Description: Trilete spore, outline subtriangular concave. Laesurae with weak margo extends two-thirds of the way to the periphery. Texture psilate, exine thin.

Overall size: 26.5 microns.

Affinity: Lycopodiaceous

Occurrence: Uncommon to rare.

Location of sample: Well; J. M. Rich #1

Depth; 6909'-6940'

Reference slide: slide number; 2

coordinates; 37 x 87.5

M.S.U.

Genus Cicatricosisporites Potonié and
Gelletich 1933

Type species: Cicatricosisporites dorogensis Potonié
and Gelletich, 1933. Eocene; Hungary.

Cicatricosisporites dorogensis
Pl. 19, Figs. 1 and 1a

Description: Specimens compare favorably to the type species of Potonié and Gelletich (1933). Overall size 65 to 76 microns.

Affinity: Anemia possibly (Schizaeaceae), mostly tropical, rare in temperate regions.

Occurrence: Abundant especially in lower two-thirds of the Frio Formation, becoming uncommon to rare in upper part of the formation (see chapter on correlation).

Location of sample: Well; Grayburg Timber #1

Depth; 5879'-5911'

Reference slide: slide number; 2

coordinates; 32.3 x 102.9

M.S.U.

Genus Lycopodiumsporites (Thiergart, 1938)
Delcourt and Sprumont, 1955

Type species: Lycopodiumsporites agathoecus (Potonié)

Delcourt and Sprumont, 1955. Eocene; Germany.

Lycopodiumsporites sp. 1
Pl. 19, Figs. 3 and 3a

Description: Trilete spore, outline triangular convex. Laesurae with moderate margo extends completely to the periphery. Distal surface reticulate; lumina 6.4 microns in width, muri 1.0 micron wide. Proximal surface reticulate; lumina 2.6 microns wide. Exine 1 micron thick. Overall size: 43 microns.

Affinity: Lycopodium; wide in geographic distribution, but particularly abundant in subtropical and tropical forests.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: slide number; 6

coordinates; 35.8 x 101.2

M.S.U.

Lycopodiumsporites sp. 2

Pl. 20, Figs. 1 and 1a

Description: Trilete spore, outline spheroidal.

Laesurae with moderate margo extends to the periphery.

Texture reticulate, width of lumina 5.3 microns, more or less uniform in size, muri under 0.8 micron in thickness.

Exine 6.0 microns thick. Overall size: 58 to 64 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: slide number; 6

coordinates; 34.3 x 101

M.S.U.

Lycopodiumsporites sp. 3

Pl. 20, Figs. 2, 2a, 3 and 3a

Description: Trilete spore, outline spherical.

Laesurae with weak margo reaches periphery. Texture reticulate, reticulum smaller on proximal surface than distal side. Width of lumina 8.0 microns (on distal surface), muri 1.7 micron in width. Exine 4.2 microns wide. Overall size: 54 to 62 microns.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 8452'-8455'

Reference slide: coordinates; 41.5 x 104.3

M.S.U.

Genus Hydrosporis Krutzsch, 1962

Type species: Hydrosporis azollaënsis Krutzsch, 1962

Oligocene - Pliocene; Germany.

Hydrosporis azollaënsis subsp. azollaënsis
Krutzsch, 1962
Pl. 18, Fig. 4

Description: Specimens compare favorably to the species erected by Krutzsch (1962). Overall size 15 to 17.5 microns.

Affinity: Presumably microspore of Azolla; latter is abundant in all continents, but of greatest abundance in the tropics.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 41.9 x 92.9

M.S.U.

Genus Azolla L.

Type species: (based on extant type species).

Azolla bohemica Pacltová, 1960
Pl. 18, Fig. 5

Description: Fragment of Azolla megaspore compares favorably to illustrations of A. bohemica by Krutzsch (1962) and to the species erected by Pacltová (1960).

Occurrence: Common in wells Grayburg Timber #1 and J. M. Rich #1, rare in well A. D. Middleton #79.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2

coordinates; 32.5 x 98

M.S.U.

Genus Camarozonosporites Pant, 1954
emend. Potonié, 1956

Type species: Camarozonosporites (Rotaspora Weyland and Krieger 1953) cretaceus, Potonié, 1956. Cretaceous; Germany.

Camarozonosporites sp.
Pl. 18, Figs. 3 and 3a

Description: Trilete spore, outline subtriangular convex. Laesurae thin with no visible margo, extends presumably all the way to the periphery. Exine thickens in the interradianal parts and thins over radial regions. Thickness of exine in interradianal regions 2.1 microns.

Texture rugulate, rugulae 1.06 micron in width. Overall size: 24 to 28 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Reference slide: coordinates; 39.4 x 100.9

M.S.U.

Genus Osmundacidites Couper, 1953

Type species: Osmundacidites wellmanii Couper, 1953.

Jurassic to Lower Cretaceous; New Zealand.

(?) Osmundacidites sp.
Pl. 17, Figs. 4 and 4a.

Description: Trilete spore, outline subtriangular convex. Laesurae with weak margo extends two-thirds of the way to the periphery. Exine scabrate, 1.06 micron in thickness, slightly thicker over the apices. Overall size: 54 microns.

Discussion: Specimen differs from the generic description of Osmundacidites by virtue of its shape and texture which is not reduced on proximal face.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: coordinates; 33.5 x 110

M.S.U.

Family Selaginellaceae

Genus Lusatisporis Krutzsch, 1963

Type species: Lusatisporis punctatus Krutzsch, 1963.

Middle Miocene; Germany.

Lusatisporis perinatus Krutzsch, 1963
Pl. 16, Fig. 5

Description: Specimens conform favorably in all aspects to the species described by Krutzsch (1963). Overall size: 43 to 51 microns.

Affinity: Selaginellaceae; according to Lawrence (1951) the family with its single genus Selaginella is widely distributed, but it is mostly found in tropical regions.

Occurrence: Uncommon.

Range: Middle Miocene.

Location of sample: Well; J. M. Rich #1

Depth; 7098'-7129'

Reference slide: coordinates; 34.8 x 109.3

M.S.U.

Lusatisporis sp.
Pl. 16, Fig. 4

Description: Trilete spore, outline subtriangular convex. Laesurae strongly developed reaching the

equator. Outer sporoderm wall lifted from inner wall producing a perine-like feature. Exine 9.01 microns in thickness. Texture scabrate. Overall size: 43 to 50 microns.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7745'-7776'

Reference slide: slide number; 2

coordinates; 33.6 x 102

M.S.U.

Family Anthocerotaceae

Genus Saxosporis Krutzsch, 1963

Type species: Saxosporis duebenensis Krutzsch, 1963.

Miocene; Germany.

Saxosporis duebenensis Krutzsch, 1963
Pl. 17, Figs. 1, 1a, and 2

Description: Specimens compare favorably to the type species erected by Krutzsch (1963). Overall size: 46 to 50 microns.

Affinity: Anthocerotaceae.

Range: Miocene.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 2
coordinates; 28.5 x 97.7
M.S.U.

Genus Rudolphisporis Krutzsch, 1963

Type species: Rudolphisporis rudolphii Krutzsch, 1963.

Lower Miocene; Northern Bohemia.

Rudolphisporis sp.
Pl. 19, Figs. 2 and 2a

Description: Trilete spore, outline subspherical.
Laesurae with moderate margo extends all the way till near the endexine. Exine 2.1 microns thick, echinate and reticulate on the proximal surface; lumina variable in size being large at the center of the specimen, 7.4 microns wide. Muri 2.1 microns wide. Foveolate on the distal surface, foveae 3.7 microns wide. Spines 2.1 microns high, 3.4 microns wide, and 6.4 microns apart. Overall size 51 microns.

Affinity: Anthocerotaceae.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Reference slide: slide number; 3
coordinates; 31.3 x 109.3
M.S.U.

Forma A Gen. et sp. nov.
Pl. 18, Figs. 1 and 1a

Diagnosis: Trilete spore, radially symmetrical, outline triangular concave, kyrtome present. Texture verrucate.

Description: Trilete spore. Laesurae with strong kyrtome extends over two-thirds of the way to periphery.

Texture verrucate, verrucae slightly larger in the radial regions, diminishing in size in the interradiial zone. Verrucae 2.6 microns apart. Exine 0.86 micron thick. Overall size 46 to 50 microns; five specimens studied.

Discussion: This taxon exhibits some resemblance to Concavisporites (Pflug, 1953) especially with respect to overall shape and presence of a kyrtome, but it differs in texture, since Concavisporites includes mainly psilate forms.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Holotype: slide number 3, from 7417'-7511' sample
coordinates; 38.2 x 104.4

M.S.U. Pb. No. 9064

Forma B Gen. et sp. nov.
Pl. 18, Figs. 2 and 2a

Diagnosis: Trilete spore, radially symmetrical, outline subtriangular concave. Kyrtocone present. Psilate on distal surface, verrucate on proximal side.

Description: Trilete spore. Laesurae relatively short extends about half the way to the periphery. Well defined kyrtocone observable. Texture psilate on distal side, but verrucate on proximal surface. Verrucae irregularly spaced, 0.86 micron high. Overall size 38 to 47 microns. Number of specimens studied eight.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7745'-7776'

Holotype: slide number 2, from 7745'-7776' sample
coordinates; 33.9 x 108.9
M.S.U. Pb. No. 9055

Genus Incertae Sedis
Pl. 17, Fig. 3

Description: Trilete spore, outline subtriangular. Laesurae extends all the way to the periphery. Kyrtocone present (?). Exine psilate except in the vicinity of laesurae where round projections can be seen. Exine thickens in the interradial regions. Thickness of exine 3.7 microns. Overall size: 33.4 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 5139'-5159'

Reference slide: slide number; 1
 coordinates; 35 x 101.9
 M.S.U.

MONOLETE SPORES

Genus Laevigatosporites Ibrahim, 1933

Type species: Laevigatosporites vulgaris Ibrahim, 1933.
 Paleocene; Ruhr.

Laevigatosporites haardti Potonié and Venitz, 1934
 Pl. 21, Figs. 1 and 2

Description: Specimens compare favorably to the species described by Potonie and Venitz (1934). Length 30 to 38 microns, width 24 to 27 microns.

Occurrence: Abundant, present throughout the formation.

Synonyms: Phaseolites (Wilson), Punctatosporites (Ibrahim) and Reticulatosporites (Loose).

Location of sample: Well; Grayburg Timber #1
 Depth; 6035'-6066'

Reference slide: slide number; 2
 coordinates; 36.3 x 96
 M.S.U.

Laevigatosporites sp. 1
 Pl. 21, Fig. 3

Description: Monolete spore, bilaterally symmetrical, outline in meridional view reniform. Laesura extends on

two-thirds of the surface. Exine psilate except near laesura where it becomes punctate. Exine about 0.5 micron thick. Length 28 to 32 microns, width 18 to 22 microns.

Occurrence: Abundant, present throughout the formation.

Location of sample: Well; J. M. Rich #1

Depth; 7191'-7230'

Reference slide: slide number; 2

coordinates; 31.8 x 100

M.S.U.

Laevigatosporites sp. 2
Pl. 21, Figs. 4 and 5

Description: Monolete spore, bilaterally symmetrical, reniform in meridional view. Laesura extends two-thirds of the length to the periphery. Exine psilate uniform in width, thickness 0.86 micron. Length 49 to 51 microns, width 39 to 41 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Reference slide: coordinates; 30.8 x 110.8

M.S.U.

Genus Microfoveolatosporis Krutzsch,
1959

Type species: Microfoveolatosporis pseudodentatus

Krutzsch, 1959. Middle Eocene; Germany.

Microfoveolatosporis sp.

Pl. 21, Figs. 6 and 7

Description: Monolete spore, bilaterally symmetrical, outline in meridional view reniform. Laesura extends two-thirds of the way to the periphery. Margo weak. Texture foveolate, foveae about 0.5 micron across, getting smaller near laesura. Exine 1.6 micron thick. Length 45 to 61.5 microns, width 25 to 34 microns.

Affinity: Schizaea; according to Lawrence (1951) the genus although occasionally found in temperate regions is mostly tropical.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 6190'-6221'

Reference slide: slide number; 3

coordinates; 38.6 x 100.2

M.S.U.

Genus Polypodiisporites Potonié, 1934

Type species: Polypodiisporites favus Potonié, 1934.

Miocene; Germany.

Polypodiisporites favus Potonié, 1934

Pl. 21, Fig. 12

Description: Specimens conform favorably in all aspects to the type species erected by Potonié (1934). Length: 50 to 56 microns, width 37 to 43 microns.

Affinity: Polypodiaceae.

Range: Miocene.

Occurrence: Uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1

coordinates; 34.5 x 101

M.S.U.

Polypodiisporites secundus Potonié, 1934
Pl. 21, Fig. 11

Description: Specimen conforms favorably to all aspects of the species described by Potonié (1934). Length: 42.4 microns, width 29.7 microns.

Range: Eocene.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 5754'-5786'

Reference slide: coordinates; 36.5 x 101.3

M.S.U.

Polypodiisporites sp. 1
Pl. 21, Fig. 8

Description: Monolete spore, ovate in equatorial view, bilaterally symmetrical. Laesura extends two-thirds of the way over the surface of the grain. Margo well developed. Texture weakly verrucate to rugulate. Exine 0.5 micron thick. Length 42.4 microns, width 29.1 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Reference slide: coordinates; 38 x 101.4
M.S.U.

Polypodiisporites sp. 2
Pl. 21, Fig. 9

Description: Monolete spore, outline reniform in meridional view, bilaterally symmetrical. Laesura extends over two-thirds of the length of the grain. Margo weak to moderate. Texture weakly verrucate, getting psilate near laesura. Verrucae under 0.86 micron in height and width. Exine 1.0 micron thick. Length 30.2 microns, width 22.7 microns.

Comparison: Polypodiisporites sp. 2 differs from Poly-
podisporites sp. 1 by virtue of its size and texture.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth: 4651'-4681'

Reference slide: slide number; 2
 coordinates; 40 x 111.1
 M.S.U.

Polypodiisporites sp. 3
 Pl. 21, Fig. 10

Description: Monolete spore, outline in meridional view reniform, bilaterally symmetrical. Laesura extends over two-thirds of the surface. Margo moderate. Texture verrucate, verrucae different in size; maximum height 1.7 microns, width 5.6 microns. Smaller verrucae present near laesura. Exine 1.0 micron thick. Length 42 to 49 microns, width 26 to 30 microns.

Synonym: Verrucatosporites, Pflug and Thomson (1953).

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79
 Depth; 6861'-6954'

Reference slide: slide number; 1
 coordinates; 42 x 98
 M.S.U.

GYMNOSPERMOUS POLLEN

SACCATE POLLEN

Genus Pinuspollenites Raatz, 1937
 emend. Potonié, 1958

Type species: Pinuspollenites (Pollenites Potonie, 1931)
labdacus Raatz 1937, emend. Potonié, 1958. Oligocene-
 Miocene; Germany.

Pinuspollenites sp. 1
 Pl. 22, Fig. 5

Description: Bisaccate pollen grain. Corpus more or less elliptical in polar view, marginal ridge well developed. Sacci circular, smaller than corpus, exine 1.6 micron thick in cap region, texture punctate. Exine of sacci 1.06 micron thick, coarsely reticulate, lumina 2.65 microns across, muri about 0.5 micron in thickness. Reticulum becomes smaller towards the periphery of sacci. Dimensions: overall height 42.4 microns, length 74.2 microns. Corpus: height 35.5 microns, length 44.5 microns. Sacci: height 31.8 microns, length not observable.

Affinity: Pinus; according to Lawrence (1951) the genus is of wide geographic distribution, although occurring mostly at lower latitudes and elevations.

Occurrence: uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 5754'-5786'

Reference slide: coordinates; 32.4 x 110

M.S.U.

Pinuspollenites sp. 2
Pl. 22, Fig. 1

Description: Bisaccate pollen grain. Corpus elliptical in polar view, marginal ridge not observable, exine punctate. Sacci elliptical, about the same size as the corpus, reticulate, reticulum more or less of the same size, lumina 1.7 micron across, muri under 0.5 micron. Overall height 63 microns, length 70 microns. Corpus: height 63 microns, length not observable. Sacci: height 56 microns, length not observable.

Occurrence: Common, present throughout the formation.

Location of sample: Well; J. M. Rich #1

Depth; 7572'-7603'

Reference slide: slide number; 2

coordinates; 36.9 x 90.9

M.S.U.

Pinuspollenites sp. 3
Pl. 22, Fig. 2

Description: Bisaccate pollen grain. Corpus more or less subtriangular in polar view with well developed marginal ridge, exine 1.25 micron thick finely reticulate, tectate, baculate-clavate. Sacci circular in outline and smaller than the corpus, exine 1.0 micron thick and reticulate, lumina 3.2 microns, muri 0.86 micron, reticulum decreases in size near periphery. Overall height 50.3 microns, length 79.50 microns. Corpus:

height 40.8 microns, length 55.1 microns. Sacci:

height 32.3 microns, length 32.3 microns.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 2

coordinates; 34.5 x 102.1

M.S.U.

Pinuspollenites sp. 4
Pl. 22, Fig. 3

Description: Bisaccate pollen grain. Corpus circular in polar view, marginal ridge weakly developed, exine 2.1 microns thick, reticulate, reticulum uniform in size (?), lumina 3.2 microns across, muri 0.5 micron in thickness. Sacci reniform, exine 2.6 microns thick, reticulate, reticulum larger in center of bladder becoming small near the periphery. Maximum width of lumina 4.8 microns, width of muri 1.1 micron. Overall height 54.6 microns, length 79 microns. Corpus: height 54.6 microns, length 47.7 microns. Sacci, height 45 microns, length 35 microns.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Reference slide: slide number; 3
 coordinates; 40.6 x 103.9
 M.S.U.

Pinuspollenites sp. 5
 Pl. 22, Fig. 4

Description: Bisaccate pollen grain, corpus more or less circular in polar view with well developed marginal ridge, exine 1.3 micron thick, tectate, baculate-clavate, producing a reticulate pattern, lumina 0.86 micron across, muri under 0.5 micron in thickness. Sacci reniform in shape, exine 2.1 microns thick, reticulate, lumina 1.1 micron across, muri under 0.5 micron in thickness. Overall height 42.4 microns, length 56.2 microns. Corpus: height 42.4 microns, length 35.5 microns. Sacci: height 38.2 microns, length 20.7 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates; 39.3 x 100.4
 M.S.U.

ORDER GNETALES

Family GNETACEAE

Genus Ephedra Linnaeus

Type species: (based on extant type species).

Ephedra sp. 1
Pl. 23, Figs. 5 and 6

Description: Perprolate pollen grain, bilaterally symmetrical, polyplicate, folds are parallel to the long axis. Plication smooth of the distachyate type i.e., with zigzag pattern between plications. Exine psilate, thin generally except near poles where it thickens slightly. Polar axis 47 to 56 microns, equatorial diameter 15.9 to 20 microns.

Discussion: Since the form genera Ephedripites (Bolchovitina) and Gnetaceaepollenites (Thiergart) are not valid terms and Equisetosporites (Singh) includes non-dystachyate forms, the author rather reluctantly adopts the extant generic name.

Occurrence: Common, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 37 x 105.8

M.S.U.

Ephedra voluta Stanley, 1965
Pl. 23, Fig. 11

Description: Specimen conform favorably in all aspects to the species erected by Stanley (1965). Polar axis 35.5 microns, equatorial diameter 21.2 microns.

Occurrence: Rare.

Location of sample: Well; J. M. Rich #1

Depth; 7098'-7129'

Reference slide: slide number; 1

coordinates; 34.2 x 108.1

M.S.U.

Ephedra sp. 2
Pl. 23, Figs. 7, 7a, and 8

Description: Perprolate pollen grain, bilaterally symmetrical, polyplicate. Plicae 1.0 micron wide, straight to slightly wavy, no conspicuous distachya present. Plicae generally psilate and parallel to polar axis. Exine very thin and psilate, slight pinching in polar region. Polar axis 46 to 54 microns, equatorial diameter 14 to 18 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2

coordinates; 39.8 x 94.2

M.S.U.

Ephedra sp. 3
Pl. 23, Fig. 9

Description: Perprolate pollen grain, polyplicate, bilaterally symmetrical. Plicae thin of the distachya type. Exine psilate and very thin. Polar axis 26 to 28 microns, equatorial diameter 8 to 9.5 microns.

Comparison: Ephedra sp. 3 differs from Ephedra sp. 1 essentially by virtue of its smaller size.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Reference slide: coordinates; 39.8 x 102.9

M.S.U.

Ephedra sp. 4
Pl. 23, Fig. 10

Description: Perprolate pollen grain, polyplicate, bilaterally symmetrical, plicae parallel to the long axis. Plication of the distachya type, producing knotty or gnarled positive features between folds. Polar area slightly angular. Exine psilate under 0.86 micron in thickness. Polar axis 46.6 microns, equatorial diameter 19.08 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Reference slide: coordinates; 31.9 x 101.

M.S.U.

NON-SACCATE POLLEN

Genus Taxodiaceapollenites Kremp, 1949

Type species: Taxodiaceapollenites (Pollenites Potonié, 1931) hiatus Kremp, 1949. Middle Tertiary; Germany.

Taxodiaceapollenites hiatus Kremp, 1949
Pl. 23, Figs. 1, 2, 3 and 4

Description: Specimens compare favorably in all aspects to the type species of Kremp (1949). Overall size: 25 to 37 microns.

Affinity: Presumably Taxodium, although other genera such as Sequoia, Metasequoia and Cryptomeria have similar pollen. According to Lawrence (1951) Taxodium occurs in North America from southern Delaware to Florida and Mexico, extending west into Illinois, Missouri and Texas.

Occurrence: Very abundant, peak of abundance half way through the Frio Formation.

Range: Middle Tertiary

Location of sample: Fig. 1

Well; Grayburg Timber #1

Depth; 5250'-5280'

Reference slide: slide number; 2

coordinates; 37 x 110.5

M.S.U.

Location of sample: Fig. 3

Well; J. M. Rich #1

Depth; 7033'-7067'

Reference slide: slide number; 1
 coordinates; 37.5 x 97.1
 M.S.U.

PORATE POLLEN

Genus Corsinipollenites Nakoman, 1965

Type species: Corsinipollenites (Pollenites Thiergart,
 1940) oculusnoctis Nakoman, 1965. Oligocene; Germany.

Corsinipollenites oculusnoctis Nakoman, 1965
 Pl. 23, Fig. 12

Description: Specimen compares favorably to the type species
 described by Nakoman (1965). Overall size: 51 microns.

Occurrence: Rare.

Affinity: Presumably related to the Oenotheraceae; cf.
Epilobium, Fuchsia, Oenothera, especially abundant in
 temperate regions.

Location of sample: Well; A. D. Middleton #79
 Depth; 6861'-6954'

Reference slide: slide number; 2
 coordinates; 37 x 103.1
 M.S.U.

Genus Tiliapollenites (Potonié, 1931)
 Potonié and Venitz, 1934

Type species: Tiliapollenites instructus (Potonié, 1931)
 Potonié and Venitz, 1934. Eocene; Germany.

Re: L. C. 15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-31-32-33-34-35-36-37-38-39-40-41-42-43-44-45-46-47-48-49-50-51-52-53-54-55-56-57-58-59-60-61-62-63-64-65-66-67-68-69-70-71-72-73-74-75-76-77-78-79-80-81-82-83-84-85-86-87-88-89-90-91-92-93-94-95-96-97-98-99-100-101-102-103-104-105-106-107-108-109-110-111-112-113-114-115-116-117-118-119-120-121-122-123-124-125-126-127-128-129-130-131-132-133-134-135-136-137-138-139-140-141-142-143-144-145-146-147-148-149-150-151-152-153-154-155-156-157-158-159-160-161-162-163-164-165-166-167-168-169-170-171-172-173-174-175-176-177-178-179-180-181-182-183-184-185-186-187-188-189-190-191-192-193-194-195-196-197-198-199-200-201-202-203-204-205-206-207-208-209-210-211-212-213-214-215-216-217-218-219-220-221-222-223-224-225-226-227-228-229-230-231-232-233-234-235-236-237-238-239-240-241-242-243-244-245-246-247-248-249-250-251-252-253-254-255-256-257-258-259-260-261-262-263-264-265-266-267-268-269-270-271-272-273-274-275-276-277-278-279-280-281-282-283-284-285-286-287-288-289-290-291-292-293-294-295-296-297-298-299-300-301-302-303-304-305-306-307-308-309-310-311-312-313-314-315-316-317-318-319-320-321-322-323-324-325-326-327-328-329-330-331-332-333-334-335-336-337-338-339-340-341-342-343-344-345-346-347-348-349-350-351-352-353-354-355-356-357-358-359-360-361-362-363-364-365-366-367-368-369-370-371-372-373-374-375-376-377-378-379-380-381-382-383-384-385-386-387-388-389-390-391-392-393-394-395-396-397-398-399-400-401-402-403-404-405-406-407-408-409-410-411-412-413-414-415-416-417-418-419-420-421-422-423-424-425-426-427-428-429-430-431-432-433-434-435-436-437-438-439-440-441-442-443-444-445-446-447-448-449-450-451-452-453-454-455-456-457-458-459-460-461-462-463-464-465-466-467-468-469-470-471-472-473-474-475-476-477-478-479-480-481-482-483-484-485-486-487-488-489-490-491-492-493-494-495-496-497-498-499-500-501-502-503-504-505-506-507-508-509-510-511-512-513-514-515-516-517-518-519-520-521-522-523-524-525-526-527-528-529-530-531-532-533-534-535-536-537-538-539-540-541-542-543-544-545-546-547-548-549-550-551-552-553-554-555-556-557-558-559-560-561-562-563-564-565-566-567-568-569-570-571-572-573-574-575-576-577-578-579-580-581-582-583-584-585-586-587-588-589-590-591-592-593-594-595-596-597-598-599-600-601-602-603-604-605-606-607-608-609-610-611-612-613-614-615-616-617-618-619-620-621-622-623-624-625-626-627-628-629-630-631-632-633-634-635-636-637-638-639-640-641-642-643-644-645-646-647-648-649-650-651-652-653-654-655-656-657-658-659-660-661-662-663-664-665-666-667-668-669-670-671-672-673-674-675-676-677-678-679-680-681-682-683-684-685-686-687-688-689-690-691-692-693-694-695-696-697-698-699-700-701-702-703-704-705-706-707-708-709-710-711-712-713-714-715-716-717-718-719-720-721-722-723-724-725-726-727-728-729-730-731-732-733-734-735-736-737-738-739-740-741-742-743-744-745-746-747-748-749-750-751-752-753-754-755-756-757-758-759-760-761-762-763-764-765-766-767-768-769-770-771-772-773-774-775-776-777-778-779-780-781-782-783-784-785-786-787-788-789-790-791-792-793-794-795-796-797-798-799-800-801-802-803-804-805-806-807-808-809-810-811-812-813-814-815-816-817-818-819-820-821-822-823-824-825-826-827-828-829-830-831-832-833-834-835-836-837-838-839-840-841-842-843-844-845-846-847-848-849-850-851-852-853-854-855-856-857-858-859-860-861-862-863-864-865-866-867-868-869-870-871-872-873-874-875-876-877-878-879-880-881-882-883-884-885-886-887-888-889-890-891-892-893-894-895-896-897-898-899-900-901-902-903-904-905-906-907-908-909-910-911-912-913-914-915-916-917-918-919-920-921-922-923-924-925-926-927-928-929-930-931-932-933-934-935-936-937-938-939-940-941-942-943-944-945-946-947-948-949-950-951-952-953-954-955-956-957-958-959-960-961-962-963-964-965-966-967-968-969-970-971-972-973-974-975-976-977-978-979-980-981-982-983-984-985-986-987-988-989-990-991-992-993-994-995-996-997-998-999-1000-1001-1002-1003-1004-1005-1006-1007-1008-1009-1010-1011-1012-1013-1014-1015-1016-1017-1018-1019-1020-1021-1022-1023-1024-1025-1026-1027-1028-1029-1030-1031-1032-1033-1034-1035-1036-1037-1038-1039-1040-1041-1042-1043-1044-1045-10

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Tiliapollenites sp. 1
Pl. 23, Fig. 14

Description: Triporate pollen grain, outline spherical, pores equatorial. Pores equatorially distributed on one hemisphere, diameter 2.1 microns, annulus 2.65 microns thick, characteristic post-vestibulum present. Exine 1.6 micron thick, tectate, columellate, reticulate, on one surface reticulum larger at the center becoming smaller near periphery. On the other side of grain reticulum uniform in size. Maximum width of lumina 1.7 micron, overall size 37 to 39.5 microns.

Affinity: Tilia, mostly tropical in distribution with a few extensions into temperate regions.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 39.8 x 99.4

M.S.U.

Tiliapollenites sp. 2
Pl. 23, Fig. 13

Description: This species is practically identical to Tiliapollenites sp. 1, the only difference is that the reticulum is uniform on both hemispheres. Overall size 42.4 microns.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7098'-7129'

Reference slide: slide number; 2

coordinates; 36.8 x 106.8

M.S.U.

Genus Subtriporopollenites Pflug
and Thomson, 1953

Type species: Subtriporopollenites anulatus subsp.

anulatus Pflug and Thomson, 1953. Danian to Lower Eocene;
Germany.

Subtriporopollenites anulatus subsp. anulatus
Pflug and Thomson 1953, Pl. 23,
Fig. 15 also Pl. 24, Fig. 1

Description: Specimens compare favorably to the taxon
described by Pflug and Thomson (1953). Diameter 35 to
50 microns.

Affinity: Carya (Juglandaceae), distributed widely in
eastern and western hemispheres.

Junior synonym: Caryapollenites (Raatz, 1937) Potonié,
1960.

Occurrence: Abundant, present throughout the formation.

Location of sample: Pl. 23, Fig. 15

Well; Grayburg Timber #1

Depth; 4651'-4681'

Reference slide: slide number; 2
coordinates; 34 x 98.5
M.S.U.

Location of sample: Pl. 24, Fig. 1
Well; Grayburg Timber #1
Depth; 5139'-5159'

Reference slide: slide number; 1
coordinates; 31.9 x 101.5
M.S.U.

Subtriporopollenites sp. 1
Pl. 24, Fig. 2

Description: Triporate pollen grain, pores subequatorial present on one hemisphere only, outline spherical, anisopolar. Pores 4.2 microns in diameter, annulus 1.06 micron wide. Exine 1.6 micron thick, psilate to more or less scabrate. Diameter 32.3 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79
Depth; 8579'-8710'

Reference slide: coordinates; 29.4 x 110.7
M.S.U.

Subtriporopollenites sp. 2
Pl. 24, Fig. 3

Description: Triporate pollen grain, pores subequatorial present in one hemisphere only, outline of grain

spherical. Pores 1.06 micron in diameter, annulus 1.6 micron wide. Exine 2.12 microns thick, ectexine clearly differentiable from endexine. Texture psilate to scabrate. Overall size 25 to 28 microns.

Occurrence: Uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 5496'-5507'

Reference slide: slide number; 1

coordinates; 36.9 x 100.5

M.S.U.

Subtriporopollenites sp. 3
Pl. 24, Fig. 4

Description: Triporate pollen grain, pores subequatorial in distribution, outline spherical. Pores 2.65 microns in diameter, annulus 1.06 microns in diameter, annulus 1.06 micron wide. Exine 1.06 micron thick, scabrate. Overall size 26 microns.

Occurrence: Rare.

Location of sample: Well; J. M. Rich #1

Depth; 7292'-7323'

Reference slide: slide number; 2

coordinates; 32.2 x 98.9

M.S.U.

Genus Triatriopollenites Pflug, 1953

Type species: Triatriopollenites rurensis Pflug and Thomson, 1953. Danian to Eocene; Germany.

Triatriopollenites coryphaeus Thomson
and Pflug, 1953
Pl. 24, Figs. 5 and 6

Description: Specimens compare favorably in all aspects to the species set up by Pflug and Thomson (1953). Overall size 21 to 25 microns.

Affinity: Myricaceae (?).

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79
Depth; 6861'-6954'

Reference slide: slide number; 1
coordinates; 41 x 99.1
M.S.U.

Genus Betulaceoipollenites Potonié, 1951

Type species: Betulaceoipollenites (Pollenites, Potonié 1931) granifer Potonié, 1951. Miocene; Germany

Betulaceoipollenites granifer forma
megagranifer Potonié, 1951
Pl. 24, Fig. 11

Description: Specimens compare favorably in all aspects to the species erected by Potonié (1951). Overall size 25 to 32 microns.

Affinity: Betula (Betulaceae), found mostly in the northern hemisphere.

Range: Miocene.

Occurrence: Common, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2

coordinates; 36.9 x 93.8

M.S.U.

Betulaceoipollenites sp.
Pl. 24, Fig. 7

Description: Triporate pollen grain, pores equatorial in distribution, outline subtriangular convex. Pores 1.29 micron in diameter, circular in shape, annulus 1.29 micron thick. Exine 0.86 micron thick, slightly thicker near pores up to 1.29 micron, no vestibulum or post-vestibulum present, a weak labrum observable. Texture punctate, punctation uniform in size and distribution. Overall size 23 to 26 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 1

coordinates; 37 x 95.4

M.S.U.

Genus Engelhardtioipollenites (Potonié
1951) ex. Potonié, 1960

Type species: Engelhardtioipollenites punctatus (Potonié
1931) Potonié, 1960. Miocene; Germany.

Engelhardtioipollenites (Pollenites quietus Potonié
1934, Triatriopollenites quietus Thomson and
Pflug, 1953) quietus n. comb.
Pl. 24, Figs. 8, 8a, and 9

Description: Triporate pollen grain, pores located at the corners, outline subtriangular convex. Exine thickens near pores and thins in the interporal regions. Characteristic thickening and folding of exine in the polar area observable. Atrium present, endopore 5.8 microns wide, exopore 1.25 micron across. Exine in interporal zones 0.86 micron thick, punctate, punctation uniform in size and distribution. Overall size 20.6 to 24 microns.

Discussion: This taxon compares favorably to Triatriopollenites quietus of Pflug and Thomson (1953) and like their species it has the typical polar thickening found in the genus Engelhardtioipollenites Potonié (1960) hence the author has used this ground to set up a new combination.

Affinity: Engelhardtia (Juglandaceae), occurs according to Lawrence (1951) in both eastern and western hemispheres.

Range: Middle Eocene.

Occurrence: Abundant, present throughout the formation, peak of abundance half way down the Frio Formation (see chapter on correlation).

Location of sample: Well; Grayburg Timber #1

Depth; 5352'-5383'

Holotype: slide number 1, from 5352'-5383' sample
coordinates; 36.4 x 106.9
M.S.U. Pb. No. 9033

Engelhardtioipollenites sp.
Pl. 24, Fig. 10

Description: Triporate pollen grain, pores equatorial at the corners, outline triangular convex. Pores elliptical under 0.86 micron across, typical atrium present. Exine 1.29 micron thick except near pore where endexine is detached from ectexine to form the atrium, endospore 3.87 microns wide. Texture psilate to weakly scabrate. Overall size 13 to 15 microns.

Occurrence: Uncommon to rare.

Location of sample: Well; A. D. Middleton #79

Depth; 9206'-9300'

Reference slide: coordinates; 36 x 112.2
M.S.U.

Genus Ulmipollenites Wolff, 1934

Type species: Ulmipollenites undulosus Wolff, 1934.

Pliocene; Germany.

Ulmipollenites undulosus Wolff, 1934
Pl. 24, Figs. 12, 13, and 14

Description: Specimens conform favorably to the type species of Wolff (1934). Overall size 25 to 33 microns.

Affinity: Ulmus (Ulmaceae), mostly distributed throughout the northern hemisphere, and more particularly in the tropics and subtropics.

Synonym: Ulmoideipites Anderson (1960). Elsik in a paper due to appear in Pollen et Spores will emend the genus Ulmoideipites to include only verrucate ulmoid pollen (personal communication).

Range: Pliocene (very rare).

Occurrence: Common, present throughout the formation.

Location of sample: Fig. 14

Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 37.9 x 106.1

M.S.U.

Location of sample: Fig. 13

Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 1
 coordinates; 46.2 x 95.1
 M.S.U.

Genus Liquidambarpollenites Raatz, 1937

Type species: Liquidambarpollenites (Pollenites Potonié, 1931) stigmosus Raatz, 1937. Miocene; Germany.

Liquidambarpollenites stigmosus Raatz, 1937
 Pl. 24, Figs. 15 and 16

Description: Specimens compare favorably to the type species of Raatz (1937). Overall size 25 to 30 microns.

Affinity: Liquidambar (Hamamelidaceae), indigenous to eastern North America and to eastern Asia.

Range: Miocene.

Occurrence: Abundant, present throughout the formation.

Peak of abundance in Upper Frio.

Location of sample: Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 2
 coordinates; 39.8 x 99.7
 M.S.U.

Genus Chenopodipollis Krutzsch, 1966

Type species: Chenopodipollis multiplex (Weyland and Pflug 1957), Krutzsch, 1966. Tertiary; Germany.

Chenopodipollis sp. 1
Pl. 24, Figs. 17 and 18

Description: Polyporate pollen grain, anisopolar, outline spheroidal. Pores 1.3 micron in diameter evenly distributed over the surface, annulus 1.3 micron in width. Exine 1.3 micron thick, intectate, psilate to weakly scabrate. Overall size: 15 to 21 microns.

Affinity: Chenopodiaceae, most abundant in xerophytic and halophytic areas.

Occurrence: Abundant to common, present throughout the formation.

Location of sample: Fig. 17

Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 29.2 x 96.5

M.S.U.

Location of sample: Fig. 18

Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates; 36.3 x 116.5

M.S.U.

Chenopodipollis sp. 2
Pl. 24, Fig. 19

Description: Polyporate pollen grain, pores evenly distributed on the surface, anisopolar, outline

spheroidal. Pores 1.72 micron in diameter, uniform in size and distribution, annulus 1.3 micron wide. Exine 0.86 micron thick, punctate, punctae uniform in size and distribution. Overall size: 16 to 21 microns.

Occurrence: Very abundant, present throughout the formation, peak of abundance in Upper Frío.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 35.9 x 104.6

M.S.U.

Genus Monoporopollenites Meyer 1956,
emend. Potonié, 1960

Type species: Monoporopollenites graminoides (Meyer, 1956) Potonié, 1960. Upper Tertiary; Bavaria.

Monoporopollenites sp.
Pl. 24, Figs. 20 and 20a

Description: Monoporate pollen grain; outline circular. Pore 1.72 micron in diameter, annulus 1.72 micron wide. Exine under 0.86 micron in thickness. Texture scabrate. Overall size 22 to 26 microns.

Occurrence: Uncommon to rare.

Affinity: Gramineae (?).

Location of sample: Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 34.7 x 96.7

M.S.U.

Forma A, Gen. et sp. nov.

Pl. 24, Fig. 21

Diagnosis: Diporate pollen grain, pores located in one hemisphere and equatorial indistribution, outline circular.

Description: Pores circular in outline diameter 1.6 to 1.8 microns, annulus 1.7 to 1.9 microns in width. Exine thin and uniform in thickness except for slight thickening near pores. No atrium, vestibulum or postvestibulum observable. Texture psilate to weakly scabrate. Overall size 15 to 18 microns, number of specimens studied four.

Affinity: Unknown.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Holotype: slide number 1, from 7233'-7327' sample

coordinates; 36 x 100.8 Pb. No. 9063

M.S.U.

COLPATE AND COLPORATE POLLEN

Genus Ilexpollenites Thiergart, 1937

Type species: Ilexpollenites (Pollenites Potonié, 1931)
iliacus Thiergart, 1937. Oligocene to Miocene; Germany.

Ilexpollenites iliacus Thiergart, 1937
 Pl. 24, Figs. 25 and 26

Description: Specimens compare favorably to the type species of Thiergart (1937). Polar axis 24 to 27 microns, equatorial diameter 18 to 21 microns.

Affinity: Ilex (Aquifoliaceae); according to Lawrence (1951) the genus is common to eastern United States and Asia, with its chief center of world distribution in Central and South America.

Range: Oligocene to Miocene.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Reference slide: coordinates; 40.3 x 105

M.S.U.

Genus Quercoidites Potonié, Thomson
 and Thiergart, 1950

Type species: Quercoidites (Pollenites Potonié, 1931)
henricii Potonié, Thomson and Thiergart, 1950. Oligocene to Miocene; Germany.

Quercoidites sp.
 Pl. 25, Figs. 11 and 12

Description: Tricolporate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Colpi spread on two-thirds of the polar axis, narrow near the poles becoming wide and forming a distinct geniculus near the pores. Pores equatorially distributed 2.65 microns in diameter, annulus moderate. Exine 1.3 micron thick becoming thicker near poles, ectexine clearly differentiable from endexine. Texture scabrate to weakly verrucate. Polar axis 21 to 28 microns, equatorial diameter 19 to 23 microns.

Discussion: As the genus Quercoidites stands now it incorporates all tricolpate pollen grains which have a distinct geniculus and with a texture close to the extant genus Quercus. But since one can find in modern Quercus pollen a transition from tricolpate to tricolporate grains, and furthermore the presence of a geniculus is an indication of a pore hence the author deems it appropriate to emend the genus Quercoidites to include tricolporate Quercus-like pollen.

Emended diagnosis: Tricolpate or tricolporate pollen grains, prolate, size variable, colpi long, open or closed with distinct geniculus which may grade into a pore-annulus system. Exine sculpture variable.

Affinity: Quercus (Fagaceae), dominant in temperate and subtropical regions of the northern hemisphere.

Occurrence: Very abundant in lower part of the Frio Formation, becoming uncommon from the upper two-thirds of the formation.

Location of sample: Well; J. M. Rich, #1

Depth; 8117'-8148'

Holotype: slide number 1, from 8117'-8148' sample
coordinates; 36.7 x 104.6. Pb. No. 9059
M.S.U.

Quercoidites henricii Potonié, Thomson
and Thiergart, 1950
Pl. 25, Figs. 1, 1a, and 2

Description: Specimens conform favorably to the type species described by Potonié, Thomson, and Thiergart (1950). Polar axis 22 to 28 microns, equatorial diameter 17 to 21 microns.

Range: Oligocene to Miocene.

Occurrence: Very abundant especially in bottom of Lower Frio and top of the Upper Frio.

Location of sample: Well; Grayburg Timber #1

Depth; 5250'-5280'

Reference slide: slide number; 2
coordinates; 32.6 x 114.6
M.S.U.

Genus Tricolpopollenites Pflug and
Thomson, 1953

Type species: Tricolpopollenites (Pollenites Potonié, 1934) parmularius Pflug and Thomson, 1953. Eocene; Germany.

Tricolpopollenites hians Stanley 1965
Pl. 25, Figs. 8 and 8a

Description: Specimens compare favorably in all aspects to the species described by Stanley (1965). Polar axis 20 to 24 microns, equatorial diameter 12 to 15 microns.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Reference slide: coordinates; 35 x 107.2

M.S.U.

Tricolpopollenites hardiei sp. nov.
Pl. 25, Figs. 9 and 10

Description: Tricolpate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Colpi wide, spread over two-thirds of the surface, in polar view a fine membrane present between colpi. Exine 1.3 microns thick, ectexine clearly differentiable from endexine, ectexine baculate forming a fine reticulation, baculae under 0.5 micron in height and width. Polar axis 29 to 38 microns, equatorial diameter 20 to 29 microns. Number of specimens studied seventeen.

Affinity: Unknown.

Occurrence: Abundant to common, present throughout the formation, peak of abundance halfway down the formation in wells Grayburg Timber #1 and J. M. Rich #1.

Location of sample: Fig. 9

Well; Grayburg Timber #1

Depth; 6345'-6376'

Holotype: slide number 2, from 6345'-6376' sample
coordinates; 30.9 x 100.5. Pb. No. 9040
M.S.U.

Location of sample: Fig. 10

Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 1
coordinates; 41.1 x 95
M.S.U.

Tricolpopollenites sp. 1
Pl. 24, Figs. 22 and 22a

Description: Tricolpate pollen grain, isopolar, outline prolate. Colpi long and narrow except for middle one which is slightly wider than other two. Exine 1.72 microns thick, tectate, clavate, clavae about 0.5 micron in height producing a reticulate pattern, lumina under 0.5 micron in diameter. Polar axis 21 to 24 microns, equatorial diameter 18 to 19.5 microns.

Occurrence: Common to uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7745'-7776'

Reference slide: slide number; 2

coordinates; 36.4 x 99.5

M.S.U.

Tricolpopollenites sp. 2

Pl. 24, Figs. 23 and 24

Description: Tricolpate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Colpi relatively long and wide. Exine 0.5 micron thick, psilate to more or less scabrate. Polar axis 23 to 26 microns, equatorial diameter 17 to 20 microns.

Occurrence: Common to uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 4466'-4496'

Reference slide: coordinates; 35.9 x 101.7

M.S.U.

Tricolpopollenites sp. 3

Pl. 25, Figs. 3, 3a, and 4

Description: Tricolpate pollen grain, isopolar, outline prolate. Middle colpus slightly shorter than other two. Exine 1.72 microns thick, ectexine clearly differentiable from endexine, exine semitectate, baculate, baculae 1.3 microns high forming a distinct reticulum, lumina about 0.5 micron in diameter, muri under 0.5 micron in width.

Polar axis 27 to 31 microns, equatorial diameter 20 to 21.5 microns.

Occurrence: Uncommon to rare.

Location of sample: Figs. 3 and 3a

Well; Grayburg Timber #1

Depth; 5754'-5786'

Reference slide: coordinates; 31.9 x 110.8

M.S.U.

Location of sample: Fig. 4

Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 37.8 x 109.8

M.S.U.

Tricolpopollenites sp. 4
Pl. 25, Fig. 5

Description: Tricolpate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Middle colpus slightly shorter than other two, colpi narrow spread over two third of the polar axis. Exine 1.72 microns thick, tectate, gemmate, gemmae 1.0 micron high and less than 0.5 micron wide, ectexine differentiable from endexine. Gemmae form a reticulate pattern with small lumina and relatively thick muri. Polar axis 26 microns, equatorial diameter 15.4 microns.

Comparison: This taxon differs from Tricolpopollenites sp. 3 with regards to its length of colpi and structure of exine.

Occurrence: Uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 37.2 x 107.1

M.S.U.

Tricolpopollenites sp. 5
Pl. 25, Fig. 6

Description: Tricolpate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Colpi relatively narrow, extends over two-thirds of the polar axis, fine granular material present between colpi. Exine 1.72 microns thick, tectate, punctate, punctae uniform in size and distribution. Polar axis 26 to 29 microns, equatorial diameter 18 to 21 microns.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 7638'-7731'

Reference slide: coordinates; 35.4 x 107.8

M.S.U.

Tricolpopollenites sp. 6
Pl. 25, Fig. 7

Description: Tricolpate pollen grain, isopolar, bilaterally symmetrical, outline prolate. Colpi long and narrow.

Exine under 0.5 micron in thickness, intectate, baculate, possibly duplibaculate producing a reticulate pattern, both lumina and muri under 0.5 micron. Polar axis 18 microns, equatorial diameter 12 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 5590'-5621'

Reference slide: slide number; 2

coordinates; 32.7 x 96.8

M.S.U.

Genus Nyssapollenites Thiergart, 1937

Type species: Nyssapollenites (Pollenites Potonié 1931)

pseudocruciatus Thiergart, 1937. Miocene; Germany.

Nyssapollenites sp.
Pl. 26, Fig. 4

Description: Tricolporate pollen grain, isopolar, bilaterally symmetrical, outline suboblate, equatorially subtriangular convex. Pores 2.0 microns in diameter, annulus 2.4 microns wide. Exine 2.0 microns thick, ectexine clearly differentiable from endexine, texture scabrate to weakly verrucate. Polar axis 21 to 26 microns, equatorial diameter 15 to 19.5 microns.

Affinity: Nyssaceae, according to Lawrence (1951)
members of this family are found in eastern North America
and Asia.

Occurrence: Uncommon.

Location of sample: Well; A. D. Middleton #79

Depth; 9112'-9206'

Reference slide: coordinates; 35.1 x 112.3

M.S.U.

Genus Pollenites H. Pot., 1893

Pollenites ventosus Potonié, 1931
Pl. 25, Fig. 23

Description: Specimens compare favorably to the species
described by Potonié (1931). Overall size 14 to 17 microns.

Affinity: Unknown.

Occurrence: Uncommon.

Range: Eocene.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Reference slide: coordinates; 30.1 x 99.4

M.S.U.

Genus Tricolporopollenites Pflug
and Thomson, 1953

Type species: Tricolporopollenites (Pollenites Potonié,
1931) dolium Thomson and Pflug 1953. Middle Tertiary;
Germany.

Tricolporopollenites sp. 1
Pl. 25, Figs. 13 and 13a

Description: Tricolporate pollen, isopolar, bilaterally symmetrical, outline prolate to perprolate. Colpi narrow cover two-thirds of the equatorial axis. Pores aligned along the equator, 1.72 microns in diameter, annulus very thin. Exine just over 0.5 micron in thickness differentiable into ectexine and endexine, texture scabrate. Polar axis 16 to 19 microns, equatorial diameter 11 to 13 microns.

Occurrence: Uncommon to common especially in lower two-thirds of the Frio Formation.

Location of sample: Well; J. M. Rich #1

Depth; 8117'-8148'

Reference slide: slide number; 1

coordinates; 29.1 x 109.1

M.S.U.

Tricolporopollenites sp. 2
Pl. 25, Figs. 14 and 15

Description: Tricolporate pollen grain, isopolar, outline prolate. Colpi extend over two-thirds of the polar axis. Pores more or less aligned along the equator, circular in shape, 1.72 microns in diameter, annulus under 0.5 micron in thickness. Exine 1.0 micron thick, tectate, clavate to baculate clavae 0.5 micron high producing a reticulum, both lumina and muri under 0.5

microns. Polar axis 16.4 microns, equatorial diameter 13.8 microns.

Occurrence: Uncommon to rare.

Location of sample: Fig. 14

Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1

coordinates; 37.9 x 99

M.S.U.

Location of sample: Fig. 15

Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1

coordinates; 38.9 x 107.8

M.S.U.

Tricolporopollenites sp. 3
Pl. 25, Fig. 16

Description: Tricolporate pollen, isopolar, outline prolate to perprolate. Colpi thin and long. Pores aligned along the equator, outline of pore circular 1.72 microns in diameter, annulus very thin. Exine just under 1.0 micron in thickness, scabrate. Polar axis 21.2 microns, equatorial diameter 13.2 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Reference slide: coordinates; 42.3 x 105

M.S.U.

Tricolporopollenites sp. 4

Pl. 25, Figs. 17 and 17a

Description: Tricolporate pollen grain, isopolar, outline prolate to suboblate. Colpi extend over two-thirds of the polar axis. Pores aligned along the equator, circular 0.5 micron in diameter, annulus 1.3 microns in thickness. Exine 0.86 micron thick, tectate, clavate-baculate forming a fine reticulation, lumina and muri under 0.5 micron. Polar axis 13.2 microns, equatorial diameter 12.2 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 5496'-5507'

Reference slide: slide number; 1

coordinates, 36.2 x 96.5

M.S.U.

Tricolporopollenites sp. 5

Pl. 25, Fig. 18

Description: Tricolporate pollen grain, isopolar, outline prolate. Colpi length over two-thirds of the polar axis. Pores aligned along the equator, circular 3.01 microns in diameter, annulus very thin under 0.5 micron. Exine 1.8 microns thick, tectate clavate, clavae 1.3 microns

high, giving rise to a reticulum, lumina under 0.86 micron in diameter, muri very thin. Polar axis 23.3 microns, equatorial diameter 16.4 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Reference slide: coordinates; 38 x 109.6

M.S.U.

Tricolporopollenites sp. 6
Pl. 25, Fig. 19

Description: Tricolporate pollen, isopolar, outline prolate. Colpi spread over two-thirds of the polar axis. Pores aligned along the equator, circular 3.01 microns in diameter, annulus under 0.5 micron in width. Exine 1.72 microns thick duplibaculate, semitectate, reticulate, lumina just over 0.5 micron in width. Polar axis 21.2 microns, equatorial diameter 15.4 microns.

Occurrence: Uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Reference slide: coordinates; 39.1 x 110.1

M.S.U.

Tricolporopollenites sp. 7
Pl. 25, Fig. 20

Description: Tricolporate pollen grain, isopolar, outline in equatorial view prolate and circular in polar view. Colpi long and narrow. Pores aligned along the equator, circular 2.15 microns in diameter, annulus very thin. Exine 0.5 micron thick, psilate to weakly scabrate. Polar axis 21.7 microns, equatorial diameter 19.6 microns.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1

Depth; 7448'-7479'

Reference slide: slide number; 2

coordinates; 41.9 x 111.2

M.S.U.

Tricolporopollenites sp. 8
Pl. 25, Fig. 21

Description: Tricolporate pollen grain, isopolar, outline prolate. Colpi long and relatively thin. Pores aligned along the equator, outline circular 2.1 microns in diameter, annulus under 0.5 micron in width. Exine 1.8 microns thick clearly differentiable into ectexine and endexine, tectate, baculate-clavate producing a fine reticulum. Polar axis 23 to 29 microns, equatorial diameter 18 to 21.5 microns.

Occurrence: Common.

Location of sample: Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1
coordinates; 36.7 x 95.5
M.S.U.

Tricolporopollenites sp. 9
Pl. 25, Fig. 22

Description: Tricolporate pollen, isopolar, outline prolate. Colpi spread on two-thirds of the length of the polar axis. Pores elliptical, maximum length 2.2 microns, annulus under 0.5 micron in width. Exine 1.72 microns thick, foveolate, foveae under 0.5 micron in size. Polar axis 23 to 29 microns, equatorial diameter 15 to 18 microns.

Occurrence: Uncommon.

Location of sample: Well; J. M. Rich #1
Depth; 7098'-7129'

Reference slide: slide number; 1
coordinates; 35.5 x 110
M.S.U.

Tricolporopollenites sp. 10
Pl. 25, Fig. 24

Description: Tricolporate pollen, isopolar, prolate. Colpi spread on two-thirds of the polar axis. Pores aligned along the equator, circular, diameter 0.5 micron, weak annulus present. Exine about 0.7 micron thick, scabrate, thickening in polar regions. Polar axis 11.5 to 14 microns, equatorial diameter 6.5 to 8.5 microns.

Occurrence: Common to uncommon, present throughout the formation.

Affinity: Castanea (Fagaceae), mostly of temperate and subtropical regions.

Location of sample: Well; A. D. Middleton #79

Depth; 9206'-9300'

Reference slide: coordinates; 33.6 x 111.7

M.S.U.

Tricolporopollenites sp. 11
Pl. 26, Fig. 1

Description: Tricolporate pollen, isopolar, prolate. Colpi relatively short and wide. Pores aligned along the equator, circular, diameter 5.5 microns, annulus very thin. Exine 0.86 micron, psilate to weakly scabrate. Polar axis 20 to 25 microns, equatorial diameter 15 to 18.5 microns.

Occurrence: Common to uncommon.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2

coordinates; 39.3 x 95.3

M.S.U.

Tricolporopollenites sp. 12
Pl. 26, Fig. 2

Description: Tricolporate pollen grain, isopolar, outline prolate. Colpi spread over two-thirds of the length of the polar axis and relatively wide. Pores circular, diameter 0.7 micron, aligned along the equator. Exine 1.7 microns thick, tectate, baculate-clavate, baculae about 1.0 micron high producing a reticulum, lumina under 0.5 micron. Polar axis 16 to 20 microns, equatorial diameter 12 to 15 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Reference slide: coordinates; 38 x 96.5

M.S.U.

Tricolporopollenites cf. Tricolporopollenites
 Sp. 1 Engelhardt, 1964
 Pl. 26, Fig. 3

Description: Specimens compare favorably to the species described by Engelhardt (1964). Polar axis 22 to 26 microns, equatorial diameter 13 to 16.3 microns.

Occurrence: Rare.

Location of sample: Well; J. M. Rich #1

Depth; 7098'-7129'

Reference slide: slide number; 1

coordinates; 40.1 x 103.8

M.S.U.

Genus Myrtaceidites Cookson and Pike, 1954.
emend. Potonié, 1960 in Synopsis III

Type species: Myrtaceidites mesonesus Cookson and Pike,
1954, emend. Potonié 1960. Australia; Eocene to Pliocene.

Myrtaceidites mesonesus Cookson
and Pike, 1954
Pl. 26, Figs. 5 and 6

Description: Specimens compare favorably to the type
species described by Cookson and Pike (1954). Overall
size 14 to 17 microns.

Affinity: Uncertain, according to Cookson and Pike (1954):
"Some of the larger examples of M. mesonesus are morpho-
logically close to certain species of Eucalyptus, such
as E. tessellaris F. Muell, in which the exine is
unthickened around the apertures."

Range: Eocene to Pliocene.

Occurrence: Common to uncommon.

Location of sample: Fig. 5

Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1

coordinates; 35.5 x 95.7

M.S.U.

Location of sample: Fig. 6

Well; A. D. Middleton #79

Depth; 8710'-8835'

Reference slide: coordinates; 36.9 x 109.5

M.S.U.

Genus Sapotaceoidapollenites Potonié,
Thomson and Thiergart 1950

Type species: Sapotaceoidapollenites (Pollenites
Potonié, 1931) manifestus Potonié, Thomson and Thiergart,
1950. Miocene; Germany.

Synonyms: Sapotaceoipollenites Potonié, 1951, Tetra-
colporopollenites Thomson and Pflug, 1953.

Sapotaceoidapollenites (Manilkara Traverse,
1955) lesquereuxiana Potonié, 1960
Pl. 26, Figs. 10, 11 and 11a

Description: Specimens compare favorably to the species
described by Traverse (1955). Polar axis 32 to 40 microns,
equatorial diameter 30 to 34 microns.

Affinity: Sapotaceae, primarily tropical found both in
eastern and western hemispheres.

Occurrence: Common in lower two-thirds of the Frio
Formation, uncommon to rare in upper part of the formation.

Range: Oligo-Miocene.

Location of sample: Figs. 11 and 11a
Well; J. M. Rich #1
Depth; 7385'-7416'

Reference slide: coordinates; 30.5 x 106.8

M.S.U.

Location of sample: Fig. 10

Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 42.8 x 105.5

M.S.U.

Sapotaceoidapollenites sp. 1
Pl. 26, Fig. 9

Description: Tetracolporate pollen grain, isopolar, bilaterally symmetrical, outline suboblate with slight protuberance at equator. Colpi long and narrow. Pores aligned on the equator, circular, diameter 1.85 microns, annulus indistinct. Exine 1.0 micron thick, psilate to more or less scabrate. Polar axis 21 to 25 microns, equatorial diameter 13 to 15 microns.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1

Depth; 4589'-4619'

Reference slide: slide number; 2

coordinates; 33.2 x 103.6

M.S.U.

Sapotaceoidapollenites sp. 2
Pl. 26, Fig. 12

Description: Tricolporate pollen grain, isopolar, bilaterally symmetrical, outline suboblate. Colpi thin

and relatively short i.e. less than two-thirds of the length of the polar axis. Pores aligned along the equator, circular, diameter 3.4 microns, annulus under 0.5 micron in width. Exine 1.3 microns thick, endexine clearly distinguishable from ectexine, texture psilate. Polar axis 22 to 28 microns, equatorial diameter 17 to 24 microns.

Occurrence: Common, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 5352'-5383'

Reference slide: slide number; 1

coordinates; 36.5 x 104

M.S.U.

Sapotaceoidapollenites sp. 3
Pl. 26, Figs. 8 and 8a

Description: Tetracolporate pollen, isopolar, bilaterally symmetrical, outline suboblate. Middle coplus slightly shorter than other two. Pores aligned along the equator, elliptical, long axis 1.3 microns, annulus very thin. Exine 1.0 micron thick differentiates into a light stained ectexine and a dark stained endexine, texture psilate to faintly scabrate. Polar axis 18.02 microns, equatorial diameter 13.25 microns.

Occurrence: Uncommon to rare.

Location of sample: Well; Grayburg Timber #1

Depth; 5754'-5786'

Reference slide: coordinates; 34.1 x 98.5

M.S.U.

Sapotaceoidapollenites sp. 4
Pl. 26, Figs. 7 and 7a

Description: Tetracolporate pollen, isopolar, bilaterally symmetrical, outline oblate. Colpi long and thin. Pores aligned along the equator, elliptical, long axis 1.4 microns, annulus indistinct. Exine under 0.5 micron in thickness, finely scabrate. Polar axis 13 to 15.5 microns, equatorial diameter 10 to 12.9 microns.

Occurrence: Abundant to common.

Location of sample: Well; J. M. Rich #1

Depth; 6483'-6514'

Reference slide: coordinates; 39.5 x 96.8

M.S.U.

MONOSULCATE POLLEN

Genus Calamuspollenites Elsik, 1966

Type species: Calamuspollenites pertusus Elsik, 1966.

Lower Eocene; Gulf Coast, U.S.A.

Calamuspollenites pertusus Elsik, 1966
Pl. 26, Figs. 13, 13a and 14

Description: Specimens compare favorably to the type species described by Elsik (1966). Length 35 to 47.5 microns, width 21 to 30.4 microns.

Affinity: According to Elsik (1966): "The exine pattern of C. pertusus is basically the same as that found in Calamus guruba and Calamus microcarpus (Palmae) and Liriodendron tulipifera (Magnoliaceae). C. microcarpus and L. tulipifera are generally monosulcate but the ectosexine between the rows of punctae is swollen into verrucae or low rugulae. C. guruba has a sculpture pattern and wall thickness identical to C. pertusus, but C. guruba is normally bisulcate. Pollen similar to C. pertusus are found in the extant families Palmae and Magnoliaceae, and possibly in other families as well. It is evident that Calamuspollenites should be treated strictly as a form genus."

Occurrence: Common to uncommon.

Location of sample: Figs. 13 to 13a

Well; A. D. Middleton #79

Depth; 6861'-6954'

Reference slide: slide number; 1

coordinates; 34.9 x 89.2

M.S.U.

Location of sample: Fig. 14

Well; Grayburg Timber #1

Depth; 5352'-5382'

Reference slide: slide number; 1
 coordinates; 36.5 x 108.9
 M.S.U.

Calamuspollenites elsikii sp. nov.
 Pl. 26, Fig. 15

Description: Monosulcate pollen grain, anisopolar, bilaterally symmetrical. Sulcus spreads over two-thirds of the pollen's length till nearly the nexine, width 0.86 micron. Exine 1.0 micron thick clearly differentiated into an ectexine and an endexine, infrapunctate, punctae uniform in size and distribution separated by small verrucae. Polar axis 23 to 26 microns, equatorial diameter 17 to 18.6 microns, number of specimens studied seven.

Occurrence: Rare.

Location of sample: Well; Grayburg Timber #1
 Depth; 6035'-6066'

Holotype: slide number 2, from 6035'-6066' sample
 coordinates; 36.1 x 112.8. Pb. No. 9038
 M.S.U.

Genus Liliacidites Couper, 1953

Type species: Liliacidites kaitangataensis Couper, 1953.
 Cretaceous; New Zealand.

Liliacidites intermedius Couper 1953
 Pl. 26, Figs. 18 and 18a

Description: Specimens compare favorably to the species described by Couper (1953). Length 39 to 46 microns, width 28 to 33 microns.

Affinity: Liliaceae, widely distributed, especially abundant in warm temperate and tropical regions.

Occurrence: Common to uncommon, present throughout the formation.

Range: Upper Cretaceous to Miocene.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2

coordinates; 32.5 x 100.7

M.S.U.

Liliacidites sp.
Pl. 26, Figs. 17 and 17a

Description: Monosulcate pollen, anisopolar, bilaterally symmetrical. Sulcus 24.5 microns long and 1.3 microns wide. Exine tectate, duplibaculate, reticulate, in center of grain lumina 1.7 micron wide, near the edge 0.5 micron, muri 0.86 micron thick. Length 32.3 microns, width 24.4 microns.

Occurrence: Common to uncommon, present throughout the formation.

Location of sample: Well; Grayburg Timber #1

Depth; 6035'-6066'

Reference slide: slide number; 2
 coordinates; 33.5 x 102.6
 M.S.U.

Liliacidites cf. Liliacidites variegatus
 Couper, 1953
 Pl. 26, Fig. 16

Discussion: Taxon resembles L. variegatus Couper (1953) quite closely especially with regards to texture and size, the only basis for not including it in L. variegatus is the size of lumina in the center of the grain which is 0.5 micron while for L. variegatus it is 1.0 micron. Length 23 to 26 microns, width 16 to 17.5 microns.

Occurrence: Rare.

Location of sample: Well; A. D. Middleton #79
 Depth; 8579'-8710'

Reference slide: coordinates; 38.4 x 107.8
 M.S.U.

Liliacidites variegatus Couper, 1953
 Pl. 27, Fig. 1

Description: Specimens compare favorably to the species described by Couper (1953). Length 26 to 30.5 microns, width 17.5 to 21 microns.

Occurrence: Common.

Range: Upper Cretaceous to Lower Oligocene.

Location of sample: Well; J. M. Rich #1
 Depth; 7745'-7776'

Reference slide: slide number; 2
coordinates; 37.4 x 100
M.S.U.

FUNGI

Genus Dicellaesporites Elsik, 1968

Type species: Dicellaesporites popovii Elsik, 1968.
Paleocene; Texas, U.S.A.

Dicellaesporites sp. 1 sp. nov.
Pl. 27, Fig. 2

Description: Bicellular spore, elliptical, septate, inaperturate. Septa with two large triangular thickening, perforate (?). Sporoderm one-layered under 0.5 micron in thickness, slightly thicker at apices, psilate. Length 27 microns, width 16.4 microns.

Location of sample: Well; J. M. Rich #1
Depth; 7572'-7603'

Holotype: slide number 2, from 7572'-7603' sample
coordinates; 33.1 x 101.8. Pb. No. 9053
M.S.U.

Dicellaesporites sp. 2 sp. nov.
Pl. 27, Fig. 3

Description: Bicellular spore, septate, elliptical, inaperturate. Septa with two more or less triangular thickening and with a slit which runs parallel to the

sporoderm wall. Spore wall thin except at apices, one-layered, finely scabrate. Length 31 to 33.4 microns, width (maximum) 8 to 9.01 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 7233'-7327'

Holotype: Slide number 1, from 7233'-7327' sample coordinates; 42.9 x 113.1. Pb. No. 9063.
M.S.U.

Dicellaesporites sp. 3 sp. nov.
Pl. 27, Fig. 5

Description: Bicellular spore, septate, inaperturate, elliptical. Septation simple i.e. without thickening or slit, width 2.2 microns. Wall one-layered 0.5 micron thick, punctate, punctae uniform in size and distribution. Length 27.03 microns, maximum width 17.5 microns.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Holotype: slide number 2, from 7693'-7724' sample coordinates; 33.9 x 100.9. Pb. No. 9054
M.S.U.

Dicellaesporites sp. 4 sp. nov.
Pl. 27, Fig. 19

Description: Bicellular spore, septate, inaperturate, ellipsoidal. Septum simple 6.9 microns thick. Wall one-

layered 1.8 micron thick, psilate. Length 72 microns, width at septum 44.5 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Holotype: slide number 1, from 8204'-8237' sample coordinates; 30.8 x 110.9. Pb. No. 9068 M.S.U.

Genus Fusiformisporites Rouse 1962,
emend. Elsik, 1968

Type species: Fusiformisporites marii Elsik, 1968.

Paleocene to Upper Tertiary; Gulf Coast, U.S.A.

Fusiformisporites sp. sp. nov.
Pl. 27, Fig. 4

Description: Bicellular, septate, inaperturate, ellipsoidal fungal spore. Septation simple, septum 1.8 microns thick. Two-layered wall, sporderm thin except at apices, striate striation numerous parallel to cell wall. Length 17.2 microns, maximum width 9.5 microns.

Affinity: Cookeina.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Holotype: slide number 1, from 7417'-7511' sample coordinates; 34.9 x 111.7. Pb. No. 9064. M.S.U.

Genus Multicellaesporites Elsik, 1968

Type species: Multicellaesporites nortonii Elsik, 1968.

Paleocene; Gulf Coast, U.S.A.

Multicellaesporites sp. 1 sp. nov.
Pl. 27, Fig. 6

Description: Linear, tetracellular, inaperturate, septate fungal spore. Septa perforated at mid-point, perforations aligned, septum 1.0 micron thick. Sporoderm one-layered 0.5 micron thick, slightly thicker at the apices, scabrate. Length 31.8 microns, maximum width 10.6 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Holotype: slide number 1, from 7417'-7511' sample coordinates; 35 x 102.4. Pb. No. 9064.
M.S.U.

Multicellaesporites sp. 2 sp. nov.
Pl. 27, Fig. 7

Description: Fungal spore, tetracellular, inaperturate septate, linear. Septa simple 0.5 micron thick. Wall one-layered thin and granular. Length 28.09 microns, maximum width 13.78 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Holotype: slide number 1, from 6705'-6861' sample
coordinates; 42 x 107.6. Pb. No. 9060.
M.S.U.

Multicellaesporites sp. 3 sp. nov.
Pl. 27, Fig. 8

Description: Six-celled, linear, septate, inaperturate
fungal spore. Septation simple 1.3 microns thick. Two-
layered wall 0.5 micron thick, psilate to weakly scabrate.
Length 25.4 microns, maximum width 6.5 microns.

Location of sample: Well; Grayburg Timber #1
Depth; 6345'-6376'

Holotype: slide number 1, from 6345'-6376' sample
coordinates; 30.9 x 113.5. Pb. No. 9040
M.S.U.

Multicellaesporites sp. 4 sp. nov.
Pl. 27, Fig. 9

Description: Fungal spore, tetracellular, linear,
inaperturate, septate. The two apical cells on the
extremities are hemispherical. Septa with triangular
thickening, each septum has two thickenings. Wall two-
layered, layers equal in thickness, psilate to weakly
scabrate. Length 25 microns, maximum width 12.7 microns.

Location of sample: Well; Grayburg Timber #1
Depth; 5250'-5280'

Holotype: slide number 4, from 5250'-5280' sample
coordinates; 35.8 x 107.1. Pb. No. 9032
M.S.U.

Multicellaesporites sp. 5 sp. nov.
Pl. 27, Fig. 18

Description: Fungal spore, tricellular, linear,
inaperturate, septate. Septa thick and without secondary
thickening. Two-layered wall, maximum thickness 3.2
microns, psilate to weakly scabrate. Length 71.5 microns,
maximum width 44 microns.

Location of sample: Well; Grayburg Timber #1
Depth; 5590'-5621'

Holotype: slide number 2, from 5590'-5621' sample
coordinates; 35.9 x 104.9. Pb. No. 9035
M.S.U.

Genus Lacrimasporonites Clarke, 1965
emend. Elsik, 1968

Type species: Lacrimasporonites basidii (Rouse, 1962)
Elsik, 1968. Paleocene; Gulf Coast, U.S.A.

Lacrimasporonites smithii sp. nov.
Pl. 27, Fig. 10

Description: Fungal spore, monoporate, elliptical, non-
septate. Pore apical 0.86 micron in diameter, annulus
0.5 micron in width. One-layered wall under 0.5 micron

in thickness, psilate. Length 25.4 microns, maximum width 18.5 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 7638'-7731'

Holotype: slide number 1, from 7638'-7731' sample
coordinates; 36.1 x 101. Pb. No. 9065
M.S.U.

Lacrimasporonites fisheri sp. nov.
Pl. 27, Fig. 11

Description: Elliptical fungal spore, monoporate, nonseptate. Pore apical slightly protruding, diameter 1.0 micron. Two-layered wall of equal thickness, slightly thicker near pore, psilate. Length 30.7 microns, maximum width 18.02 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 6705'-6861'

Holotype: slide number 1, from 6705'-6861' sample
coordinates; 38.9 x 98.9. Pb. No. 9060
M.S.U.

Genus Dyadosporonites Elsik, 1968

Type species: Dyadosporonites schwabii Elsik, 1968.

Paleocene; Gulf Coast, U.S.A.

Dyadosporonites richii sp. nov.
Pl. 27, Fig. 16

Description: Fungal spore, diporate, bicellular, septate, ellipsoidal. Pores elliptical located at each end of spore, long axis 5.8 microns, short axis 2.8 microns, annulus thin under 0.5 micron in width. Septum simple 1.06 microns wide. Wall one-layered, very thin and scabrate. Length 38.9 microns, maximum width 21.73 microns.

Location of sample: Well; J. M. Rich #1

Depth; 8117'-8148'

Holotype: slide number 1, from 8117'-8148' sample coordinates; 31.1 x 101. Pb. No. 9059 M.S.U.

Genus Diporicellaesporites Elsik, 1968

Type species: Diporicellaesporites stacyi Elsik, 1968.

Paleocene; Gulf Coast, U.S.A.

Diporicellaesporites sp. 1 sp. nov.
Pl. 27, Fig. 12

Description: Fungal spore, six cellular, diporate, septate. Septa with two triangular thickening each, perforated. Pores located at each end of the spore, circular in outline, diameter 2.1 microns. One-layered wall under 0.5 micron in thickness, scabrate. Length 22.3 microns, maximum width 9.5 microns.

Location of sample: Well; A. D. Middleton #79

Depth, 8485'-8579'

Holotype: slide number 1, from 8485'-8579' sample
coordinates; 42 x 98. Pb. No. 9070
M.S.U.

Diporicellaesporites sp. 2 sp. nov.
Pl. 27, Fig. 13

Description: Fungal spore, tetracellular, diporate,
septate, ellipsoidal with conical end cells. Septa with
two triangular thickening each and splitted. Pores more
or less circular, diameter under 0.5 micron. One-
layered wall, thin, psilate to scabrate. Length 21.7
microns, maximum width 11.1 microns.

Location of sample: Well; J. M. Rich #1
Depth; 7033'-7067'

Holotype: slide number 1, from 7033'-7067' sample
coordinates; 31.6 x 101.6. Pb. No. 9048
M.S.U.

Diporicellaesporites sp. 3 sp. nov.
Pl. 27, Fig. 14

Description: Fungal spore, diporate, six-cellular,
septate, more or less lentil-shaped. Septa with two
triangular thickening each. Two-layered wall more or
less equal in width, thickness 1.3 microns, becoming
thicker near the end cells, texture psilate. Length
39.7 microns, maximum width 16.9 microns.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Holotype: slide number 1, from 6345'-6376' sample
coordinates; 39.1 x 99.8. Pb. No. 9040
M.S.U.

Diporicellaesporites sp. ⁴ sp. nov.
Pl. 28, Fig. 3

Description: Fungal spore, diporate, seven-celled,
septate, linear. Septa thick with two triangular
thickening on each. Pores more or less circular, diameter
5.3 microns. Two-layered wall 2.1 microns thick,
psilate. Length 88 microns, maximum width 33.4 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8204'-8237'

Holotype: slide number 1, from 8204'-8237' sample
coordinates; 39.1 x 98.9. Pb. No. 9068
M.S.U.

Genus Pluricellaesporites Hammer, 1954
emend. Elsik, 1968

Type species: Pluricellaesporites melanii Elsik, 1968.

Paleocene; Gulf Coast, U.S.A.

Pluricellaesporites middletonii sp. nov.
Pl. 27, Fig. 17

Description: Fungal spore, symmetrical around one long axis, monoporate, tetracellular, septate. Septa with two triangular thickening. Pore circular, located at end of one cell, diameter 1.3 micron. Two-layered wall 0.86 micron thick, slightly thicker near pore, psilate. Length 21.7 microns, maximum width 9.5 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Holotype: slide number 1, from 8485'-8579' sample coordinates; 33 x 108. Pb. No. 9070
M.S.U.

Family MICROTHYRIACEAE

Forma A
Pl. 28, Fig. 1

Description: Fungal spore, septate, inaperturate, outline circular. Numerous thick radial septa and slightly thinner interr radial connections present producing a concentric pattern. Wall 2.3 microns thick, diameter 70 microns.

Location of sample: Well; A.D. Middleton #79

Depth; 7327'-7417'

Reference slide: slide number 1
coordinates; 35 x 101.9
M.S.U.

Forma B
Pl. 28, Figs. 2 and 2a

Description: Fungal spore, inaperturate, septate, outline circular. Radial septa as thick as interrarial connections. Wall thin and granulose. Diameter 58.3 microns.

Comparison: This taxon has fewer interrarial connections than Forma A, thus the concentric pattern is not as well developed.

Location of sample: Well; J. M. Rich #1

Depth; 7693'-7724'

Reference slide: slide number; 2

coordinates; 39 x 96.4

M.S.U.

Fungal Hyphae
Pl. 27, Fig. 15

Description: Linear fungal hyphae, eight-celled, septate. Septa with two small triangular thickening, splitted, openings aligned and parallel to edge of cell. Wall single-layered, psilate. Cells 10.07 microns high and 7.4 microns wide. Overall length 94.34 microns.

Location of sample: Well; Grayburg Timber #1

Depth; 6345'-6376'

Reference slide: coordinate; 39.1 x 112.1

M.S.U.

FORAMINIFERA

Forma A
Pl. 29, Fig. 1

Description: Inner chitinous lining, of Foraminifera.
Chambers uniserial, planispiral evolute. Proloculum
spherical 10.07 microns in diameter. Overall size 86.4
microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: slide number; 6
coordinates; 32.2 x 101
M.S.U.

Forma B
Pl. 29, Fig. 2

Description: Inner chitinous lining of Foraminifera.
Chambers uniserial eight in number, planispiral, evolute.
Proloculum 13.4 microns in diameter. Overall size 53
microns.

Discussion: It is difficult to identify the inner
chitinous remains of Foraminifera, since one could be
dealing with a juvenile form which exhibits recapitulation
in its ontogeny. Thus one is faced with the uncertainty
as to once the specimen has reached maturity what would
be its taxonomic identity.

Location of sample: Well; A. D. Middleton #79

Depth; 7417'-7511'

Reference slide: slide number; 3

coordinates; 34 x 102.2

M.S.U.

Forma C
Pl. 29, Fig. 3

Description: Inner chitinous lining of a foraminiferal proloculum. Diameter 47 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: coordinates; 32.5 x 116.4

Forma D
Pl. 29, Fig. 4

Description: Inner chitinous lining of a foraminiferal proloculum. Diameter 19.6 microns.

Location of sample: Well; A. D. Middleton #79

Depth; 8485'-8579'

Reference slide: coordinates; 33.98.3

M.S.U.

REFERENCES

REFERENCES

- Alberti, G. 1959b. Zur Kenntis der Gattung Deflandrea Eisenack (Dinoflag.) in der Kreide und im Alttertiar Nord und Mitteldeutschlands. Mitt. Geol. Staatsinst., Hamburg, vol. 28, pp. 93-105, pls. 9-11.
- Barton, D. C., Ritz, C. H., and Hickey, M. 1933. Gulf Coast geosyncline. Am. Assoc. Petrol. Geologists, Bull., vol. 17, pp. 1446-1458.
- Bolchovitina, N. A. 1953. Spore and pollen characteristics of Cretaceous deposits of Central regions of USSR. Acad. Sci. USSR, Inst. Geol. Soc., no. 145 (Geol. Series No. 61), pp. 1-183, pls. 1-16.
- *Bornhauser, M. 1958. Gulf Coast Tectonics. Bull. of American Assoc. Petrol. Geol., vol. 42, no. 2, pp. 339-370.
- *Boyd, D. R., and Dyer, B. F. 1964. Frio barrier bar system of south Texas. Trans. Gulf Coast Assoc. Geol. Socs., vol. 14, pp. 309-322.
- *Butler, A. E. 1960. Miocene-Oligocene boundary problems in Gulf Coast. American Assoc. Petrol. Geol., Bull. 44, part 2, p. 1600.
- *Colle, J., et al. 1952. Sedimentary volumes in Gulf coastal plain of United States and Mexico, Pt. 4, volume of Mesozoic and Cenozoic sediments in western Gulf coastal plain of United States. Geol. Soc. American Bull., v. 63, pp. 1193-1200.
- Cookson, I. C., and Pike, K. M. 1954. Some dicotyledonous pollen types from Cainozoic deposits in the Australian region. Australian Jour. Bot., vol. 2, no. 2, pp. 197-219.
- Couper, R. A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. New Zealand Geol. Surv. Palaeont. Bull., Bull. 22, 77 pp.

*Reference used for geology of the Gulf Coast.

- Cross, A. T. 1964. Plant microfossils and geology: an introduction. *Palynology in Oil Exploration*, A Symposium. Soc. Econ. Paleon. and Mineral. Spec. Pubs, no. 11, pp. 3-13.
- Cross, A. T., et al. 1966. Source and distribution of palynomorphs in bottom sediments, southern part of Gulf of California. *Marine Geology.*, 4, pp. 467-524.
- Davey, R. J., et al. 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bulletin of the British Museum (Natural History) Geology*, supplement 3, 248 pp., pls. 1-26.
- Davey, R. J., and Williams, G. L., in Davey, R. J., et al. 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. British Mus. (Nat. Hist.) Geol.*, suppl. 3, pp. 28-105.
- Deflandre, G. 1947. Sur quelques micro-organisms planctoniques des silex jurassique. *Bull. Inst. Oceanogr. Monaco.*, 921, pp. 1-10, Figs. 1-5.
- Deflandre, G., and Cookson, I. C. 1955. Fossil microplankton from Australian Late Mesozoic and Tertiary sediments. *Australian Journ. Mar. Freshwater Res.*, vol. 6, pp. 242-313.
- Downie, C., and Sarjeant, W. A. S., in Davey, R. J. et al. 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. British Mus. (Nat. Hist.) Geol.*, suppl. pp. 10-18.
- Drugg, W. S., and Loeblich, A. R. Jr. 1967. Some Eocene and Oligocene phytoplankton from the Gulf Coast, U.S.A., *Tulane Studies in Geology*, vol. 5, no. 4, pp. 181-194.
- *Dumble, E. T. 1924. A revision of the Texas Tertiary section with special reference to the oil-well geology of the Coast region. *Bull. American Assoc. Petrol. Geol.*, vol. 8, no. 4, pp. 424-444.
- *Dumble, E. T., 1894. The Cenozoic Deposits of Texas. *Journal of Geology*. Vol. 2, pp. 549-567.
- *Ellis, A. D. Jr. 1939. Significant Foraminifera from the Chickasawhay Beds of Wayne County, Mississippi. *Journ. Paleon.*, vol. 43, no. 4, pp. 423-424.

- *Ellisor, A. C. 1933. Jackson Group of formations in Texas with notes on Friso and Vicksburg. Bull. American Assoc. Petrol. Geol., vol. 17, no. 11, pp. 1293-1350.
- Elsik, W. C., 1968. Palynology of a Paleocene Rockdale Lignite, Milam County, Texas. Part I, Morphology and Taxonomy. Pollen et Spores, vol. 10, no. 2, pp. 261-314, pls. 1-15.
- Elsik, W. C., in Stover, L. E., et al. 1966. New genera and species of early Tertiary palynomorphs from Gulf Coast. The Univ. of Kansas Paleont. Contributions, paper 5, pp. 1-11.
- Engelhardt, D. W. 1964. Plant microfossils from the Eocene Cockfield Formation, Hinds County, Mississippi. Mississippi Geol. Research Papers, Bull. 194, pp. 65-96, pls. 1-5.
- Erdtman, G. 1952. Pollen morphology and plant taxonomy, Angiosperms. Almqvist and Wiksells Boktryckeriak-tiebolag, Uppsala, pp. 11-24.
- Evitt, W. R. 1963. A discussion and proposals concerning fossil dinoflagellates, hystrichosphaeres and acritarchs. Proc. Nat. Acad. Sci., vol. 49, nos. 2 and 3, pp. 158-164, 298-302.
- Evitt, W. R., et al. 1967. Dinoflagellate studies III. Dinogymnium acuminatum n. gen., n. sp. (Maastrichtian) and other fossils formerly referable to Gymnodinium. Stein. Stanford Univ. Publications, Geol. Sciences, vol. 10, no. 4, pp. 3-27, pls. 1-3.
- Fægri, K., and Iversen, J. 1964. Textbook of modern pollen analysis, Ejna Munksgaard, Copenhagen, 237 pp.
- *Garrett, J. B. 1938. The Hackberry Assemblage--an interesting foraminiferal fauna of post-Vicksburg age from deep wells in the Gulf Coast. Journ. Paleon., vol. 12, no. 4, pp. 309-317.
- *Garrett, J. B., and Ellis, A. D., Jr. 1937. Distinctive foraminifera of the genus Marginulina from Middle Tertiary beds of the Gulf Coast. Journ. Paleon., vol. 11, no. 8, pp. 629-633.

- Gerlach, E. 1961. Mikrofossilien aus dem Oligozan und Miozan Nordwestdeutschland unter besonderer Berücksichtigung der. Hystrichosphaerideen und Dinoflagellaten. N. Jb. Geol. Palaont. Abh., Stuttgart, 112, pp. 143-228, pls. 25-29.
- Gerlach, E. 1963. Hystrichosphaerideen und andere Kleinelebewesen aus Oligozan Ablagerungen Nord und Mitteldeutschlands. Geologie, Berlin, 1, pp. 301-320, pls. 1 und 2.
- Gray, J., 1960. Temperate pollen genera in the Eocene (Clairborne) flora, Alabama. Science, vol. 132, pp. 808-810.
- *Hardin, G. C., Jr. 1962. Notes on Cenozoic sedimentation in the Gulf Coast Geosyncline, U.S.A. In Geology of the Gulf Coast and Central Texas: Houston Geol. Soc. for 1962 Meetings of the Geol. Soc. America and Associated Societies. pp. 1-15.
- *Holcomb, C. W. 1964. Frio Formation of southern Texas. Trans. Gulf Coast Assoc. Geol. Soc., vol. 14, pp. 23-33.
- *Israelsky, M. C., 1940. Notes on the Frio: Report of Houston Geological Society Study Group. Bull. American Assoc. Petrol. Geol., vol. 24, no. 2, pp. 376-382.
- *Johnson, R. B., and Mathy, H. E. 1957. The south Texas Frio trend. Trans. Gulf Coast Assoc. of Geol. Soc., vol. 7, pp. 207-218.
- Jones, E. L. 1962. Palynology of the Midway-Wilcox boundary in south-central Arkansas. Gulf Coast Assoc. Geol. Soc. Trans., vol. 12, pp. 285-294, pls. 1-3.
- Kremp, G. O. W. 1949. Pollen analytische untersuchung des Miozanen Braunkohlenlagers von Konin an der Warthe. Palaeontographica B, vol. 90, pp. 53-93.
- Krutzsch, W. 1959. Mikropalaontologische (sporen-palaontologische) Untersuchungen in der Braunkohle des Geiseltales. Geologie Jg. 8, Beih, 21/22, 145 pp.
- Krutzsch, W. 1962. Atlas der Mittel-und Jungterieren Dispersen Sporen und Pollen sowie der Mikroplanktonformen des nördlichen Mitteleuropas. Vol. I. Deutscher Verlag der Wissenschaft, Berlin. 232 pp.

- Krutzsch, W. 1963. Atlas der Mittel-und Jungtertiären Dispersen Sporen und Pollen Sowie der Mikroplanktonformen des nordlichen Mitteleuropas. Vol. III. Deutscher Verlag der Wissenschaft, Berlin.
- Kuyl, O. S., Muller, J., and Waterbolk, H. T. 1955. The application of palynology to oil geology with reference to western Venezuela. Geol. en Mijnb. Neue Series 17, Nr. 3, pp. 47-86.
- Lawrence, G. H. M. 1951. Taxonomy of vascular plants. Macmillan Co., 823 pp.
- Nakoman, A. 1965. Annales de la Societe Geologique Nord., vol. 85, no. 2, p. 155.
- Pacltova, Bl. 1960. Plant microfossils (mainly sporomorphae) from the lignite deposits near Mydlovary in Ceske Budejovice basin. Part 1. Sborink UUG, 25, Reihe Palaont., 68.
- *Plummer, F. B. 1932. Cenozoic Systems in Texas. The Geology of Texas, vol. I, Pt. 3, Bur. Econ. Geol. Bull., 3232, pp. 519-818.
- Potonié, R. 1931. Pollenformen aus Tertiären Braunkohlen (3 Mitt). Jb. Preuss. Geol. L. A. f. 52:1-7.
- . 1934. Zur Mikrobotanik der Kohlen und Iher Verwandten I. Zur Morphologie der Fossilen Pollen und Sporen. Arb. Inst. F. Palaeob. U. Petrogr. Brennst, 4, 5.
- . 1934. Zur Mikrobotanik des Eozänen Humodils des Geiseltals. Arb. Inst. Palaeobot. U. Petrogr. Brennst., Preuss. Geol. L. A. Berlin 4, pp. 25-125.
- . 1951. Revision Stratigraphisch Wichtiger Sporomorphen Mitteleuropäischen Tertiärs. Palaeontographica Ab. B., Bd. 91, pp. 131-151.
- . 1958. The taxonomy of fossil plants (includes spore dispersae) in the International Code of Botanical Nomenclature. The Paleobotanist, vol. 7, pp. 32-42.
- . 1960. Synopsis der Gattungen der sporae Dispersae. III Teil: Nachtrage Sporites Fortsetzung Pollenites Mit General Beih. Geol. Jb. 39, 189 pp.

- _____, and Gelletich, J. 1933. Uber Pteridophyten-sporen Einer Eozanen Braunkohle aus Dorog in Ungarn. Sber. Ges. Nat. Freunde, vol. 33, pp. 517-528.
- _____, and Venitz, A. 1934. Zur Mikrobotanik des Miozanen Humodils der Niedeueheinischen Bucht. Preuss. Geol. Landes, Inst. Palaeobot. U. Petrogr. Brennsteine, Arb., vol. 5, pp. 1-54.
- _____, Thomson, P. W., and Thiergart, F. 1950. Zur Nomenklatur und Klassifikation du neogenen Sporomorphae (Pollen und Sporen). Geol. Jahrb. Band 65 , pp. 35-70.
- Raatz, G. V. 1937. Mikrobotanisch-stratigraphische Untersuchung der Braunkohle des Muskauer Bogens. Preuss. Geol. Landes., Abh., neue Folge, vol. 183, pp. 1-48.
- *Reedy, R., Jr. 1949. Stratigraphy of Frio Formation Orange and Jefferson Counties, Texas. Bull. American Assoc. Petrol. Geol., vol. 33, no. 11, pp. 1830-1858.
- Sarjeant, W. A. S. 1961. Microplankton from the Kellaways Rock and Oxford Clay of Yorkshire. Palaeont., vol. 4, pt. 1, pp. 90-118, pls. 13-15.
- _____, and Downie, C. 1966. The classification of dinoflagellate cysts above generic level. Grana Palynologica, vol. 6, no. 3, pp. 503-527.
- Sarmiento, R. 1957. Microfossil Zonation of Mancos Group. Bull. American Assoc. Petrol. Geol., vol. 41, no. 8, pp. 1683-1693.
- Singh, C. 1964. Microflora of the Lower Cretaceous Mannville Group, east-central Alberta. Research Council Alberta. Bull. 15, 239 pp., 29 pls.
- Stanley, E. A. 1965. Upper Cretaceous and Paleocene dinoflagellate and Hystrichosphaerids from north western south Dakota. Bull. American Paleont., vol. 49, no. 222, pp. 179-383, pls. 19-49.
- Stover, L. E., et al. 1966. New Genera and species of Early Tertiary Palynomorphs from Gulf Coast. Univ. of Kansas Paleont. Contributions, Paper 5, pp. 1-11, pls. 1-5.

- *Stuckley, C. W., Jr. 1946. Some Textulariidae from the Gulf Coast Tertiary. *Journ. Paleont.*, vol. 20, no. 2, pp. 163-165.
- Thiergart, F. 1938. Die pollen-flora der Niederlansitzer Braunkohle, besonders in Profil der Grube Marga bei Senftenberg. *Jahrb. Preuss. Geol. Landes.*, vol. 58, pp. 282-351 (Separatum, 1937).
- Thomson, P. W., and Pflug, H. 1953. Pollen und sporen des mitteleuropaischen Tertiars. *Palaeontographica*, Abt. B, Band 94, pp. 1-138, pls. 1-15.
- Traverse, A. 1955. Pollen analysis of the Brandon Lignite of Vermont, U.S.A. *Bur. Mines Rept. Inv.*, no. 5151, 107 pp.
- Upshaw, C. F. 1964. Palynological zonation of the Upper Cretaceous Frontier Formation near Dubois, Wyoming. In *Palynology in Oil Exploration*, a Symposium. *Soc. Econ. Paleon. and Mineral. Spec. Pubs.* no. 11, pp. 153-168, pl. 1
- Wall, D. 1967. Fossil microplankton in deepsea cores from the Caribbean Sea. *Palaeontology*, vol. 10, part 1, pp. 95-123.
- *Warren, A. D. 1957. The Anahuac and Frio sediments in Louisiana. *Trans. Gulf Coast Assoc. Geol. Socs.* vol. 7, pp. 221-235.
- Williams, G. L. 1963. Organic-walled microplankton of the London Clay. Unpublished doctorate thesis. Univ. of Sheffield, England.
- , in Davey et al. 1966. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bull. British Mus. (Nat. History) Geol.*, suppl. 3, p. 248, pp. pls. 1-26.
- Wolff, H. 1934. Mikrofossilien des pliozanen Humodils. *Preuss. Geol. Landes., Inst. Palaobot. U. Petrog. Brennsteine, Arb.*, vol. 5, pp. 55-86.

PLATES

PLATE 1

- 1 - 1a Achomosphaera ramulifera
- 2 Hystrichosphaera sp. cf. H. ramosa var.
membranaceae
- 3 - 4a Hystrichosphaera ramosa var. ramosa

All illustrations x1000 unless otherwise indicated.

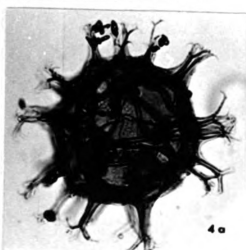
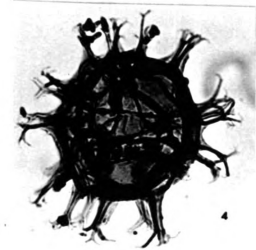
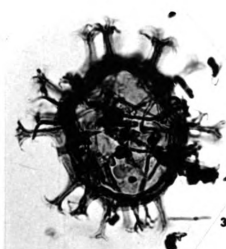
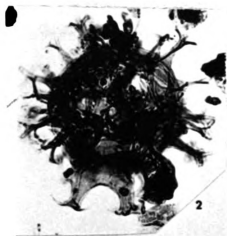
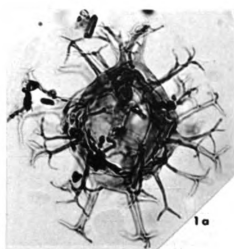
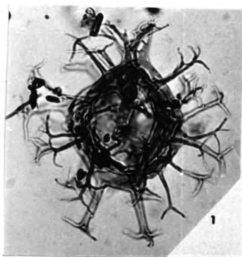


PLATE 2

- 1 - 1b Homotryblium plectilum, 1a photographed by
phase contrast.
- 2 Hystrichosphaera ramosa var. multibrevis.
- 3 Hystrichosphaera buccina

All illustrations X1000 unless otherwise indicated.

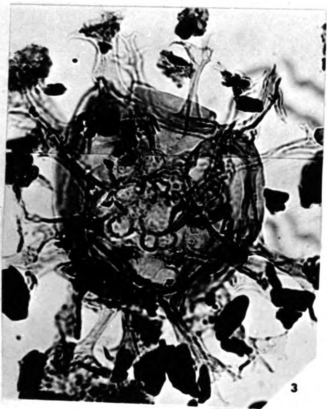
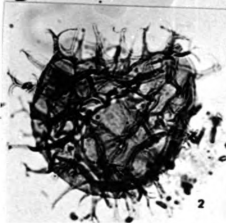
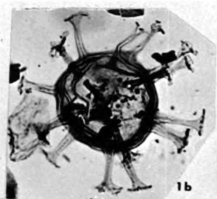
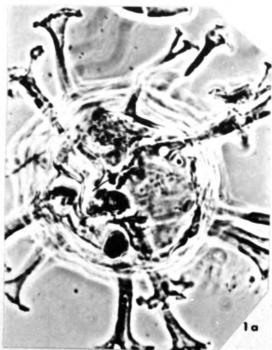
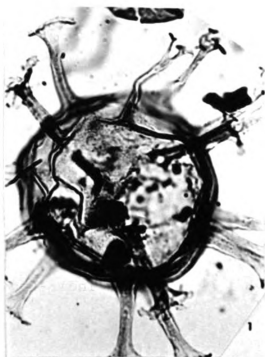


PLATE 3

- 1 - 1a Hystrichokolpoma sp. cf. H. rigaudeau
- 2 Hystrichokolpoma rigaudea
- 3 Friosphaera williamsii Gen. nov. et sp. nov.
- 4 - 4a Baltisphaeridium sp. 7, 4 photographed by
phase contrast

All illustrations x1000 unless otherwise indicated.

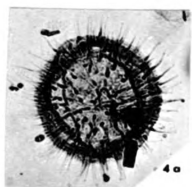
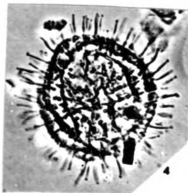
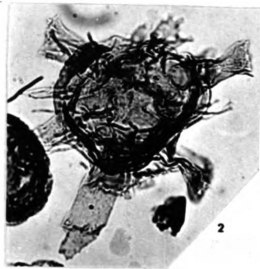
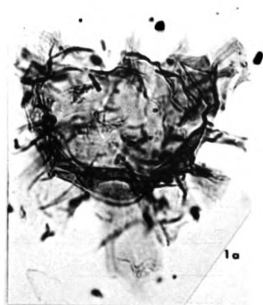
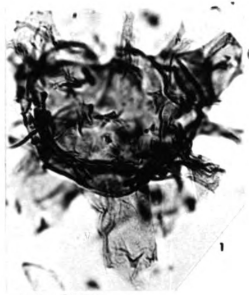


PLATE 3

PLATE 4

- 1 - 2 Baltisphaeridium sp. 1, 1a photographed by phase
contrast.
- 3 - 3a Baltisphaeridium sp. 3, 3a photographed by phase
contrast.
- 4 Baltisphaeridium sp. 2

All illustrations x1000 unless otherwise indicated.

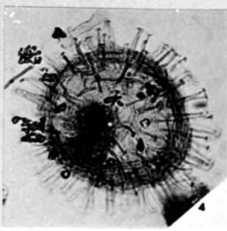
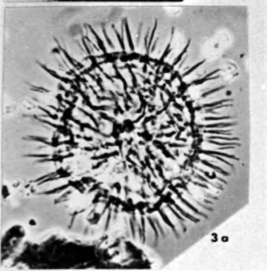
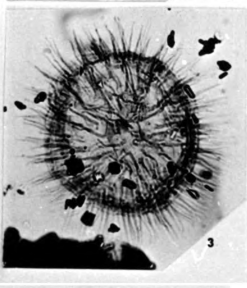
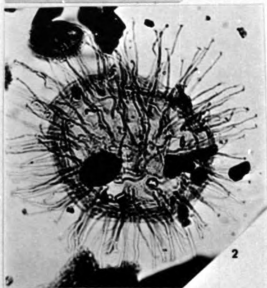
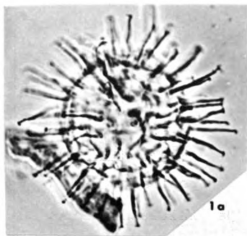
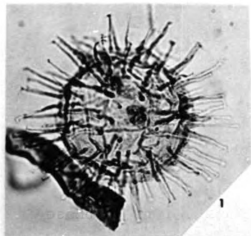


PLATE 4

PLATE 5

- 1 - 2 Baltisphaeridium sp. cf. B. ehrenbergi var.
brevispinosum, 1a photographed by phase contrast.
- 3 Baltisphaeridium sp. 4
- 4 Baltisphaeridium sp. 5
- 5 Baltisphaeridium sp. 6

All illustrations x1000 unless otherwise indicated.

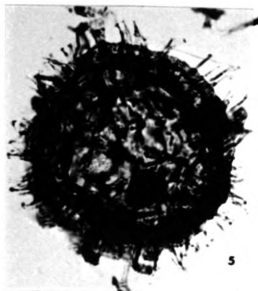
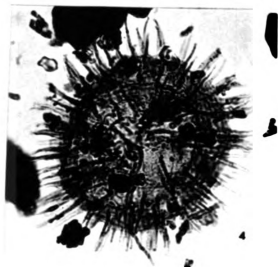
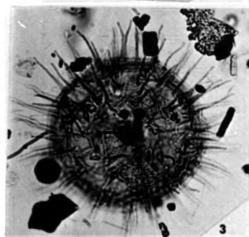
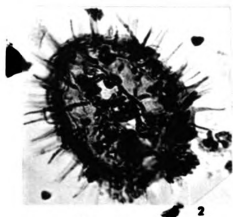
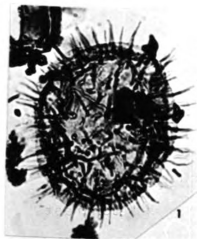


PLATE 5

PLATE 6

- 1 Baltisphaeridium scalenofurcatum sp. nov.
- 2 - 2a Micrhystridium sp. 2, 2a photographed by phase
 contrast.
- 3 - 3a Micrhystridium sp. 5, 3a photographed by phase
 contrast
- 4 - 4a Micrhystridium stephensonii sp. nov., 4a
 photographed by phase contrast.
- 5 - 5a Micrhystridium capitatum sp. nov., 5a photographed
 by phase contrast.
- 6 - 7 Micrhystridium sp. 1
- 8 Micrhystridium sp. 3
- 9 Micrhystridium sp. cf. Hystrichosphaeridium patulum
- 10 Micrhystridium fragile
- 11 Micrhystridium sp. 4

All illustrations x1000 unless otherwise indicated.

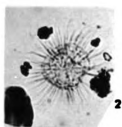


PLATE 7

- 1 - 1b Cleistosphaeridium texasi sp. nov., 1a and 1b
photographed by phase contrast.
- 2 - 2a Cleistosphaeridium disjunctum, 2a photographed
by phase contrast.
- 3 Polysphaeridium pastielsi

All illustrations xl000 unless otherwise indicated.

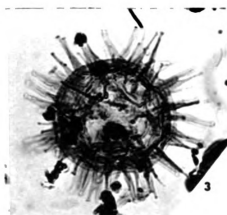
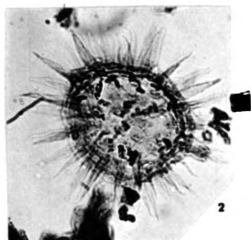
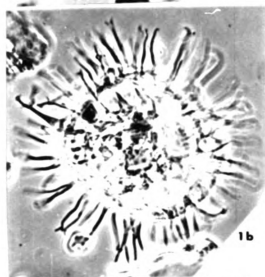
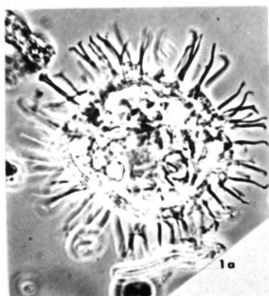


PLATE 8

- 1 Polysphaeridium pastielsi
- 2 - 2a Polysphaeridium sp., 2a photographed by phase
 contrast.
- 3 - 3b Hemicystodinium sp., 3a and 3b photographed by
 phase contrast.

All illustrations x1000 unless otherwise indicated.

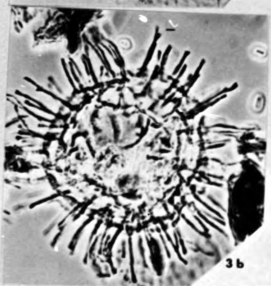
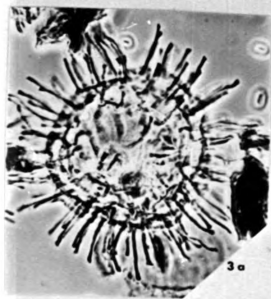
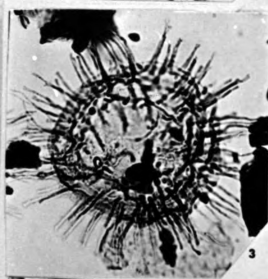
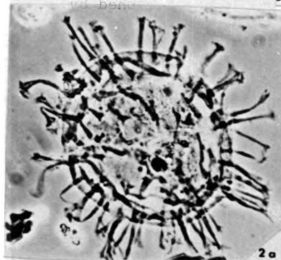
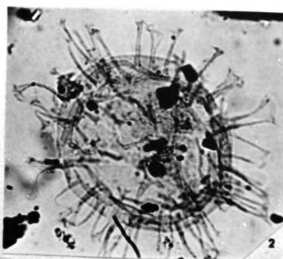
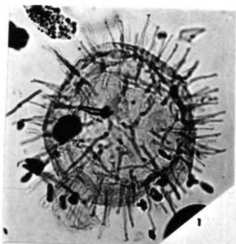


PLATE 8

PLATE 9

- 1 - 2 Cordosphaeridium crossii sp. nov., 1 and 2
 composite photographs
- 3 Cleistosphaeridium disjunctum var.
 brevispinosum var. nov.

All illustrations x1000 unless otherwise indicated.

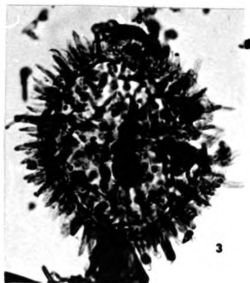
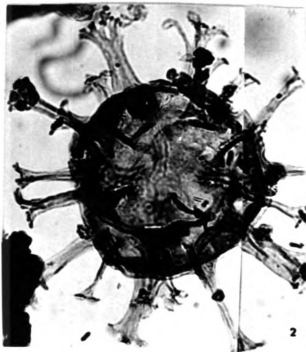
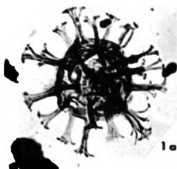
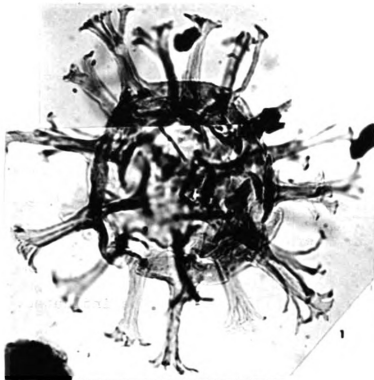


PLATE 9

PLATE 10

- 1 Cyclonephelium proutyi sp. nov.
- 2 - 3 Adnatosphaeridium sp.
- 4 Cyclonephelium sp.

All illustrations x1000 unless otherwise indicated

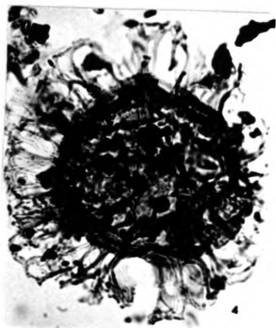
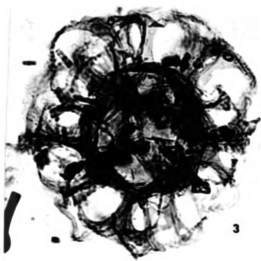
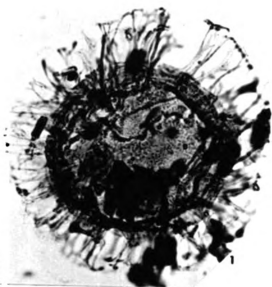


PLATE 11

- 1 Deflandrea minor
- 2 Dinogymnium sp.
- 3 Dinogymnium cretaceum
- 4 - 4a Hemicystodinium zoharyi, 4a focuss to show shape
 and position of archaeopyle

All illustrations x1000 unless otherwise indicated.

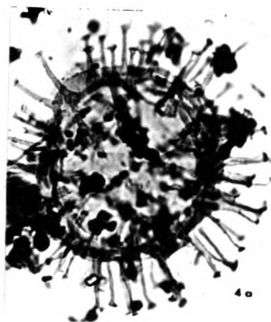
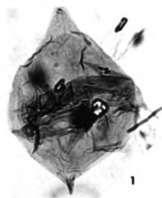


PLATE 11

PLATE 12

- 1 Lejeunia sp., composite photograph
- 2 Gonyaulacysta sp.
- 3 Gonyaulacysta bilinia sp. nov.
- 4 Cymatiosphaera sp.

All illustrations xl000 unless otherwise indicated.



PLATE 13

- 1 - 1a Thallasiphora sp., 1a photographed by phase
contrase.
- 2 - 2a Pentadinium laticinctum

All illustrations x1000 unless otherwise indicated.

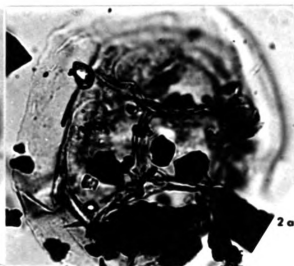
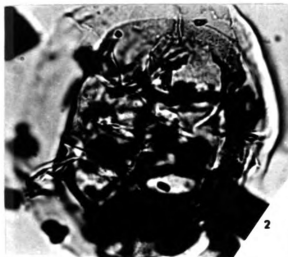
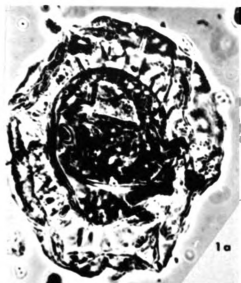


PLATE 14

- 1 - 1a Acostomocystis potane, 1a photographed by phase contrast.
- 2 - 3 Leiotriletes sp. 2
- 4 - 4a Leiotriletes sp. 4, 4a focuss on proximal surface to show extent of laesurae.

All illustrations x1000 unless otherwise indicated.

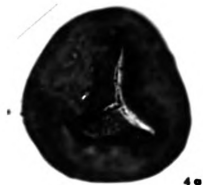
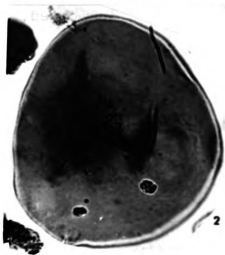


PLATE 15

- 1 - 1a Leiotriletes sp. 3, 1 focuss on sporoderm,
1a focuss on proximal laesurae.
- 2 Leiotriletes maxoides
- 3 Deltoidospora sp.
- 4 - 4b Leiotriletes maxoides, 4b focuss on proximal
laesurae to shown punctation.

All illustrations xl000 unless otherwise indicated.

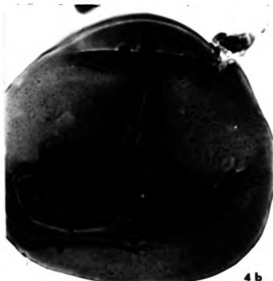
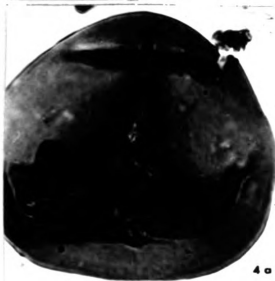
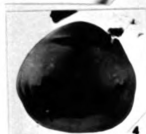
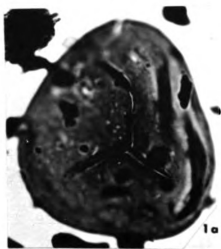


PLATE 16

- 1 - 2 Leiotriletes adriensis
- 3 Leiotriletes sp. 1
- 4 Lusatisporis sp.
- 5 Lusatisporis perinatus

All illustrations x1000 unless otherwise indicated.



PLATE 17

- 1 - 2 Saxosporis duebenensis, 1 focuss on proximal
 laesurae, 1a focuss on spines.
- 3 Incertae Sedis
- 4 - 4a (?) Osmundacidites sp., 4 focuss on sporoderm

All illustrations x1000 unless otherwise indicated.

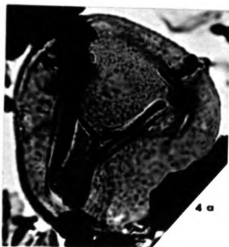
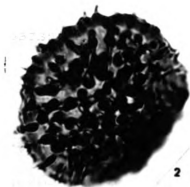
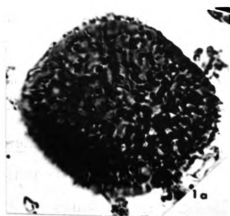
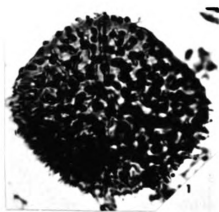
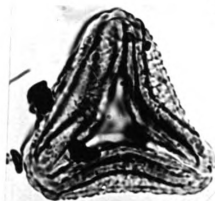


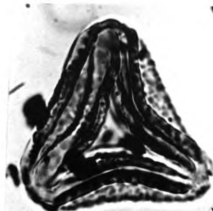
PLATE 18

- 1 - 1a Forma A Gen. nov. et. sp. nov., 1a focuss on
 proximal laesurae and kyrtome, 1 focuss on
 sporoderm.
- 2 - 2a Forma B Gen. nov. et. sp. nov., 2 focuss on
 distal surface to show verrucate texture, 2a
 focuss on proximal laesurae to show psilate
 texture.
- 3 - 3a Camarozonosporites sp., 3 focuss on rugulae.
- 4 Hydrosporitis azollaensis subsp. azollaensis
- 5 Azolla bohemica

All illustrations x1000 unless otherwise
indicated.



1



1a



2



2a



3



3a



4



5

PLATE 19

- 1 - 1a Cicatricosisporites dorogensis, 1 focuss on proximal laesurae, 1a focuss on distal surface.
- 2 - 2a Rudolphisporis sp., 2 focuss on proximal laesurae, 2a focuss on spines.
- 3 - 3a Lycopodiumsporites sp. 1, 3 focuss on distal surface, 3a focuss on proximal laesurae.

All illustrations x1000 unless otherwise indicated.

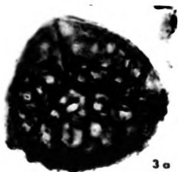
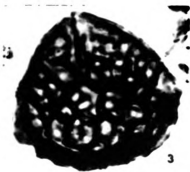
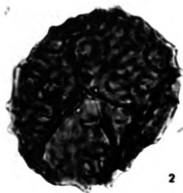


PLATE 20

- 1 - 1a Lycopodiumsporites sp. 2, 1 focuss on proximal
laesurae, 1a focuss on sporoderm.
- 2 - 3a Lycopodiumsporites sp. 3, 2 focuss on proximal
laesurae, 2a focuss on distal surface.

All illustrations x1000 unless otherwise
indicated.

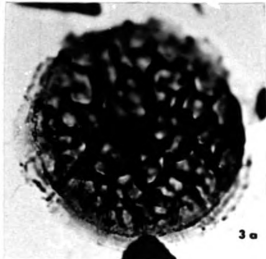
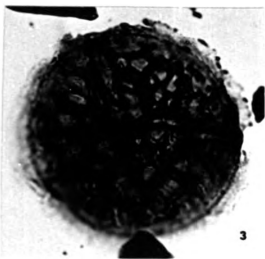
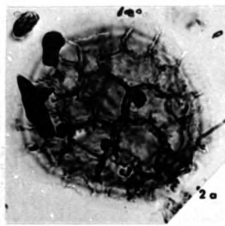
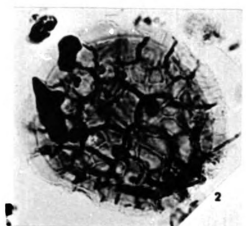
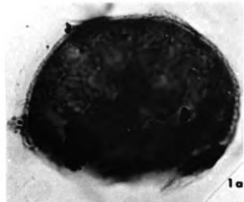
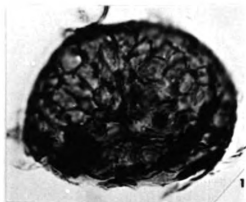


PLATE 21

- 1 - 2 Laevigatosporites haardti
- 3 Laevigatosporites sp. 1
- 4 - 5 Laevigatosporites sp. 2
- 6 - 7 Microfoveolatosporis sp.
- 8 Polypodiisporites sp. 1
- 9 Polypodiisporites sp. 2
- 10 Polypodiisporites sp. 3
- 11 Polypodiisporites secundus
- 12 Polypodiisporites favus

All illustrations x1000 unless otherwise indicated.

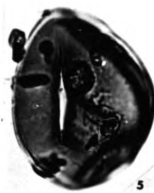
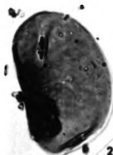


PLATE 22

- 1 Pinuspollenites sp. 2
- 2 Pinuspollenites sp. 3
- 3 Pinuspollenites sp. 4
- 4 Pinuspollenites sp. 5
- 5 Pinuspollenites sp. 1

All illustrations x1000 unless otherwise
indicated.

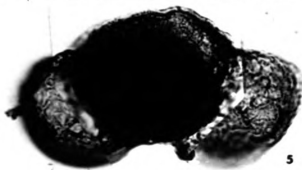
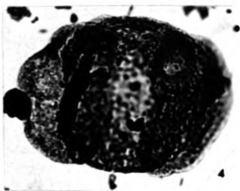
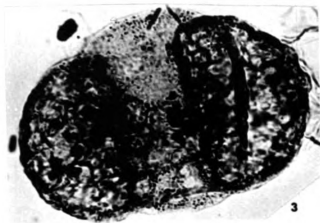
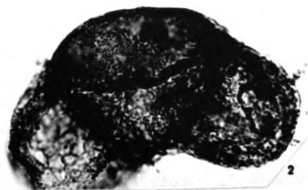


PLATE 23

- 1 - 4 Taxodiaceaepollenites hiatus
- 5 - 6 Ephedra sp. 1
- 7 - 8 Ephedra sp. 2
- 9 Ephedra sp. 3
- 10 Ephedra sp. 4
- 11 Ephedra voluta
- 12 Corsinipollenites oculusnoctis
- 13 Tiliapollenites sp. 2
- 14 Tiliapollenites sp. 1
- 15 Subtriporopollenites anulatus

All illustrations x1000 unless otherwise indicated.



PLATE 23

PLATE 24

- 1 Subtriporopollenites anulatus
- 2 Subtriporopollenites sp. 1
- 3 Subtriporopollenites sp. 2
- 4 Subtriporopollenites sp. 3
- 5 - 6 Triatriopollenites coryphaeus
- 7 Betulaceoipollenites sp.
- 8 - 9 Engelhardtioipollenites quietus n. comb.,
8 focuss on atria, 8a focuss on punctae.
- 10 Engelhardtioipollenites sp.
- 11 Betulaceoipollenites granifer forma mega-
granifer
- 12 - 14 Ulmipollenites undulosus
- 15 - 16 Liquidambarpollenites stigmosus
- 17 - 18 Chenopodipollis sp. 1
- 19 Chenopodipollis sp. 2
- 20 - 20a Monoporopollenites sp. , 20 focuss on pore and
annulus, 20a focuss on exine.
- 21 Forma A gen. et. sp. nov.
- 22 - 22a Tricolpopollenites sp. 1, 22 focuss on exine
structure, 22a focuss on colpi.
- 23 - 24 Tricolpopollenites sp. 2, 23 Equatorial view,
24 polar view.
- 25 - 26 Ilexpollenites iliacus, 25 Equatorial view,
26 polar view.

All illustrations x1000 unless otherwise
indicated.

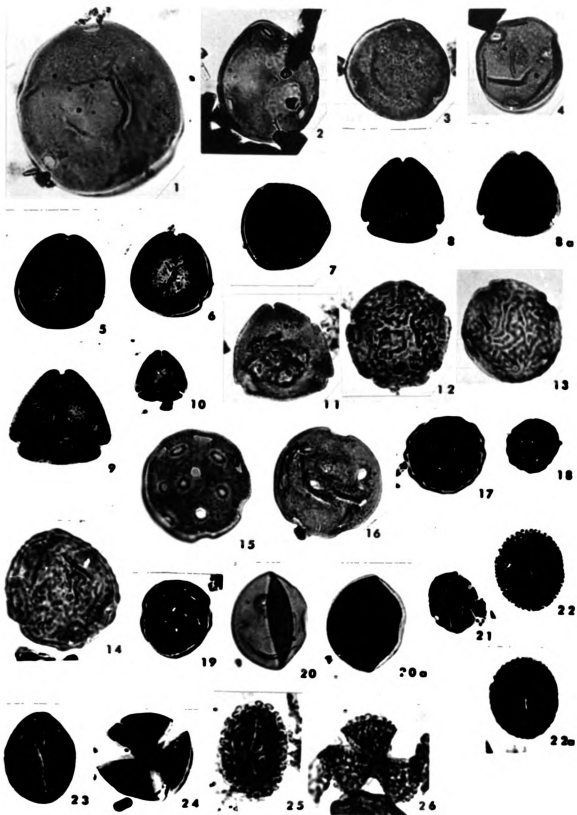


PLATE 24

PLATE 25

- 1 - 2 Quercoidites henricii, 2 two grains in polar
 and equatorial views
- 3 - 4 Tricolpopollenites sp. 3, 3 focuss on exine
 structure, 3a focuss on colpi, 4 polar view
- 5 Tricolpopollenites sp. 4
- 6 Tricolpopollenites sp. 5
- 7 Tricolpopollenites sp. 6
- 8 - 8a Tricolpopollenites hians, 8 focuss on reticulum
- 9 - 10 Tricolpopollenites hardiei sp. nov., 9
 Equatorial view, 10 polar view
- 11 - 12 Quercoidites sp.
- 13 - 13a Tricolporopollenites sp. 1, 13 focuss on
 apertures, 13a focuss on exine structure
- 14 - 15 Tricolporopollenites sp. 2
- 16 Tricolporopollenites sp. 3
- 17 - 17a Tricolporopollenites sp. 4, 17 focuss on exine
 structure, 17a focuss on pore-annulus system
- 18 Tricolporopollenites sp. 5
- 19 Tricolporopollenites sp. 6
- 20 Tricolporopollenites sp. 7, two grains in
 equatorial view and one in polar view
- 21 Tricolporopollenites sp. 8
- 22 Tricolporopollenites sp. 9
- 23 Pollenites ventosus
- 24 Tricolporopollenites sp. 10

All illustrations x1000 unless otherwise indicated.

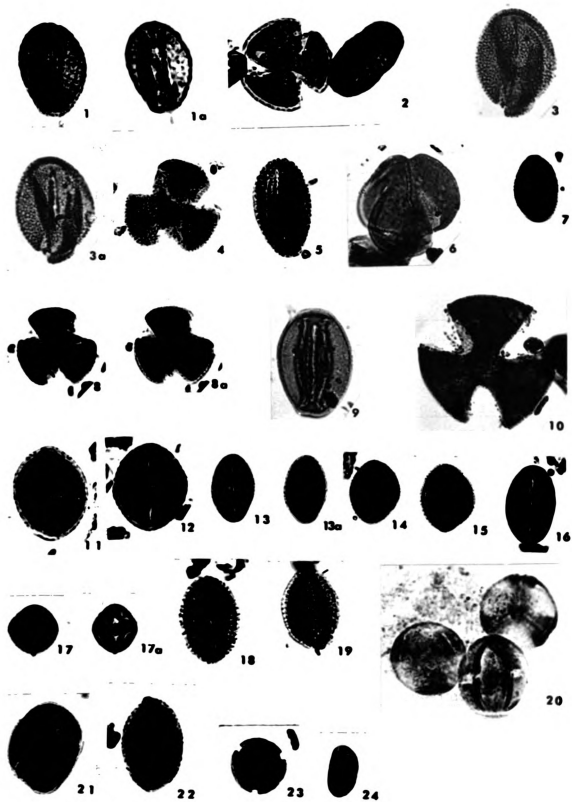


PLATE 25

PLATE 26

- 1 Tricolporopollenites sp. 11, Polar view
- 2 Tricolporopollenites sp. 12, Polar view
- 3 Tricolporopollenites sp. cf. Tricolporopollenites
 sp. 1, Engelhardt
- 4 Nyssapollenites sp.
- 5 - 6 Myrtacidites mesonesus
- 7 - 7a Sapotaceoidapollenites sp. 4, 7 focuss on
 apertures, 7a focuss on exine structure
- 8 - 8a Sapotaceoidapollenites sp. 3, 8 focuss on
 exine structure
- 9 Sapotaceoidapollenites sp. 1
- 10 - 11a Sapotaceoidapollenites lesquereuxiana, 11
 focuss on exine structure, 11a focuss on pores
- 12 Sapotaceoidapollenites sp. 2
- 13 - 14 Calamuspollenites pertusus
- 15 Calamuspollenites elsikii sp. nov.
- 16 Liliacidites sp. cf. Liliacidites variegatus
- 17 - 17a Liliacidites sp. , 17 focuss on sulcus, 17a
 focuss on muri
- 18 - 18a Liliacidites intermedius, 18 focuss on reticulum,
 18a focuss on clavae

All illustrations x1000 unless otherwise indicated.

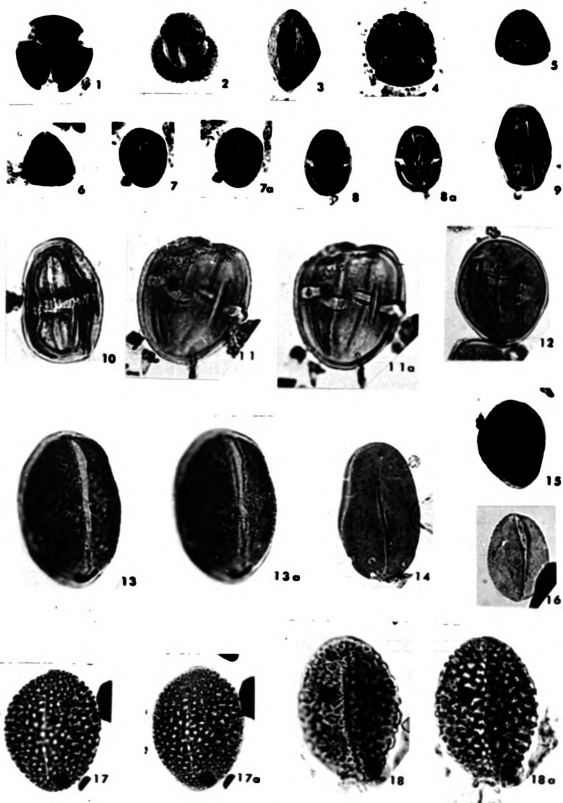


PLATE 27

- 1 Liliacidites variegatus
- 2 Dicellaesporites sp. 1, sp. nov.
- 3 Dicellaesporites sp. 2, sp. nov.
- 4 Fusiformisporites sp., sp. nov.
- 5 Dicellaesporites sp. 3, sp. nov.
- 6 Multicellaesporites sp. 1, sp. nov.
- 7 Multicellaesporites sp. 2, sp. nov.
- 8 Multicellaesporites sp. 3, sp. nov.
- 9 Multicellaesporites sp. 4, sp. nov.
- 10 Lacrimasporonites smithii sp. nov.
- 11 Lacrimasporonites fisheri sp. nov.
- 12 Diporicellaesporites sp. 1, sp. nov.
- 13 Diporicellaesporites sp. 2, sp. nov.
- 14 Diporicellaesporites sp. 3, sp. nov.
- 15 Fungal Hyphae
- 16 Dyadosporonites richii sp. nov.
- 17 Pluricellaesporites middletonii sp. nov.
- 18 Multicellaesporites sp. 5, sp. nov.
- 19 Dicellaesporites sp. 4, sp. nov.

All illustrations x1000 unless otherwise indicated.



PLATE 27

PLATE 28

- 1 Forma A (Microthyriaceae)
- 2 - 2a Forma B (Microthyriaceae)
- 3 Diporicellaesporites sp. ⁴, sp. nov.

All illustrations x1000 unless otherwise
indicated.

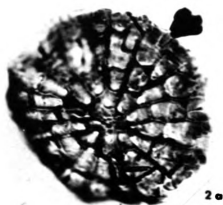
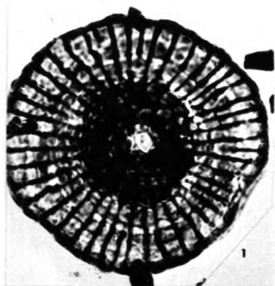


PLATE 29

- 1 Forma A (Foraminifera)
- 2 Forma B (Foraminifera)
- 3 Forma C (Foraminiferal proloculum)
- 4 Forma D (Foraminiferal proloculum)

All illustrations x1000 unless otherwise
indicated.

