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PALYNOLOGY OF QUATERNARY TERRACES AND FLOODPLAINS OF THE WASHITA AND RED RIVERS, CENTRAL AND SOUTHEASTERN OKLAHOMA

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THOMAS ALDEN BOND

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PALYNOLOGY OF QUATERNARY TERRACES AND
FLOODPLAINS OF THE WASHITA AND
RED RIVERS, CENTRAL AND
SOUTHEASTERN OKLAHOMA

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INTRODUCTION

This investigation deals with fossil pollen recovered from sediments of oxbow lakes on terraces and floodplains along the Washita River in central Oklahoma and the Red River in southeastern Oklahoma (fig. 1). The objectives of this investigation of oxbow lake sediments were: (1) to study the vertical sequence of pollen floras to determine if any floristic change took place that would indicate ecological and climatic changes during deposition of the sediments, and which should aid in interpreting geologic and geomorphic history of the river systems and (2) to determine the usefulness of spores and pollen in relative dating of sediments in oxbow lakes. When established, these dates can be checked against Carbon-14 dates, ages of archeological sites and vertebrate and invertebrate faunas collected in the area. Many of the vertebrate and invertebrate remains previously studied occur in terrace deposits. Previous to the present investigation, the studies of Kapp (1965) and Wilson (1965) are the only

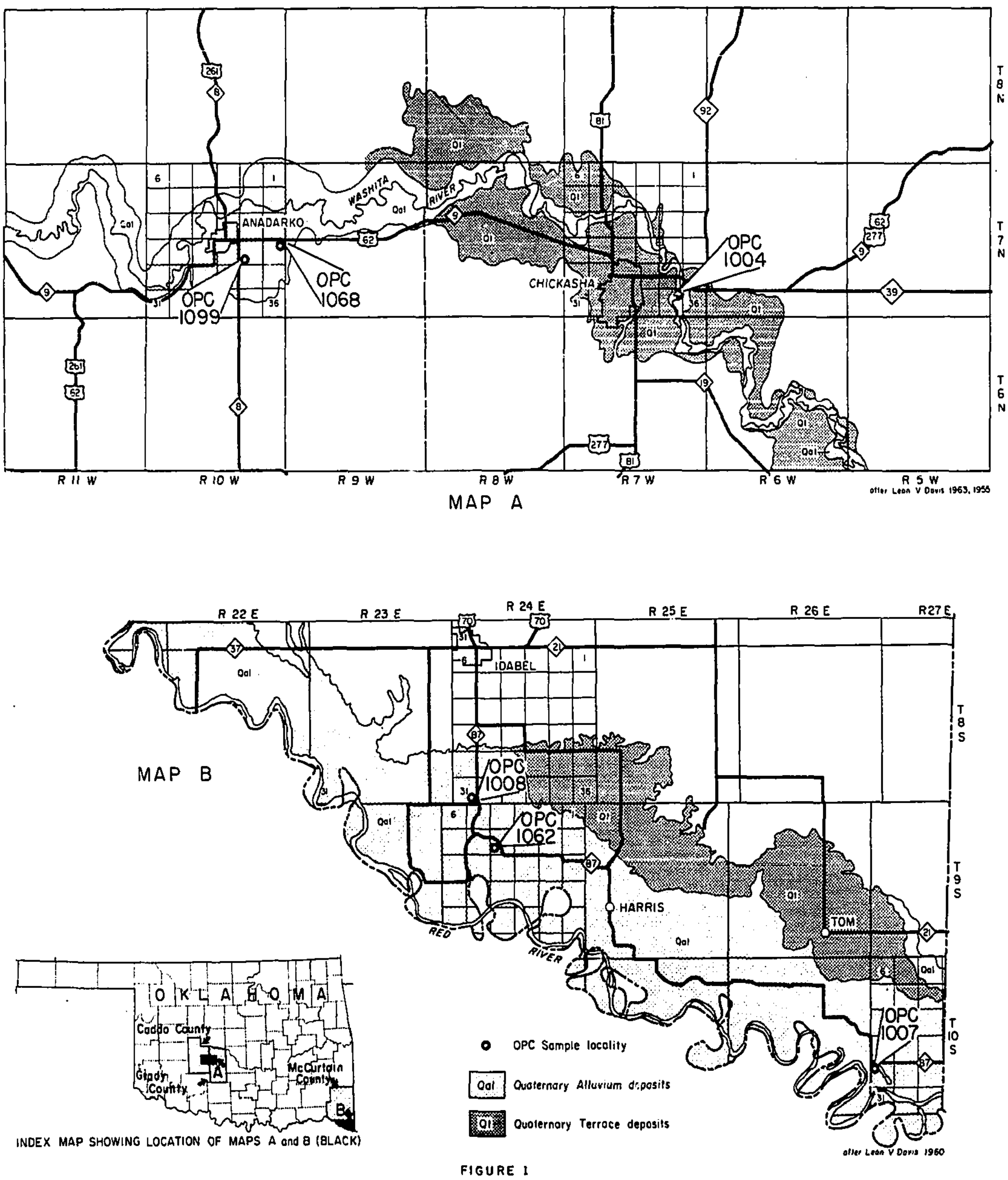


FIGURE 1

QUATERNARY PALYNOLOGICAL SAMPLE LOCATION MAPS
PORTIONS OF CADDO, GRADY AND MC CURTAIN COUNTIES, OKLAHOMA

T. A. Bond — 1966

MILES

Pleistocene palynological studies within the borders of Oklahoma.

Present drainage systems in Oklahoma were established during late Tertiary or early Pleistocene as shown by the reworked Tertiary gravels on the High Plains and in terrace deposits of major rivers (Tanaka and Davis, 1963, p. 24).

Because post-Wisconsin vegetational history is incompletely known in Oklahoma, palynological investigations of oxbow lake and terrace deposits may be the best sources for obtaining this information, and should aid in climatic and geomorphic studies of post-Wisconsin time.

The vegetational history of Late-Glacial and Postglacial time is better known than that of earlier glacial and interglacial times. Kapp (1965) stated that palynological investigations of pre-Wisconsin deposits have not been more actively pursued because: (1) the identity of older glacial and interglacial deposits must await detailed stratigraphic studies by Pleistocene geologists, (2) the older deposits are not normally as abundant and easily sampled as are surface deposits, (3) some sediments are inorganic and do not contain enough well-preserved pollen to allow interpretation of the vegetation, and (4) in glaciated areas, the latest glacier generally obliterated or buried earlier Pleistocene deposits.

Because Oklahoma is approximately 200 miles from the southernmost glacial border, most Pleistocene studies in the High Plains area have been confined to vertebrates and invertebrates. This situation is due to the fact that the invertebrates and vertebrates are most obvious to collectors and their study does not require microscopic techniques. Therefore, relatively little has been done concerning the vegetational history using pollen analysis. This is unfortunate, for although Oklahoma was approximately 200 miles from the southern glacial border during Wisconsin time, climatic changes should have been significant in causing changes in the vegetational composition of the state. Recent palynological investigations show this to be the case.

Studies of pre-Wisconsin vegetation (Illinoian and Sangamon) by Kapp (1965) in southwestern Kansas and the adjacent Oklahoma Panhandle have established that the vegetation of this area was of a Rocky Mountain nature as a result of the climate during this period. Wilson (in press) has found that the vegetation changed from an arborescent type to a non-arborescent type in response to climatic changes in Wisconsin-age material from the Domebo Site in central Oklahoma. More recent studies (Wilson, 1965) of late Wisconsin and Postglacial sediments along Tesesquite Creek in Cimarron County, Oklahoma, although incomplete, indicate that similar vegetational changes occurred.

PHYSIOGRAPHY, GENERAL GEOLOGY AND CLIMATE

Washita River Area

Physiography

Deposits studied in the Washita River watershed were collected in Caddo and Grady Counties, Oklahoma. These two counties are in the Central Lowlands section of the Great Plains Province (Fenneman, 1938, p. 616-617). Locally, in Oklahoma, this area is assigned to the Central Redbed Plains (Curtis and Ham, 1957).

Topographically, the area is of relatively low relief, at few places exceeding 50 feet. The bedrock dips southwestward. The area is well drained and in some local areas, deeply dissected. A northwestward trending drainage divide extends along the northern part of the counties. North of this divide the drainage is into the southeastward flowing Canadian River, and to the south drainage is in to the Washita, which flows southeastward, essentially parallel to the Canadian River.

Many of the main streams in Oklahoma, including the Washita, have relatively straight courses with remarkable parallelism. The present parallelism suggests that the major streams are superimposed and were once consequent streams flowing upon a Tertiary mantle which extended eastward from the Rocky Mountains. Subaerial deposition in the late Tertiary was extensive and probably did much to relocate streams. Straightness and parallelism would thus be favored (Fenneman, 1938, p. 620).

All rivers except the Washita have their channels in wide beds of sand, and at many places are braided. The bedrock beneath the stream bed is of variable lithology in the Washita area, which fact may account for some of the differences in mapping. Davis (1955) in Grady County differentiated terrace deposits from the floodplain alluvium; however, in mapping Caddo County, Tanaka and Davis (1963) did not separate terrace deposits from floodplain alluvium.

General Geology

The bedrock exposed in Caddo and Grady Counties in central Oklahoma is of Permian age (Table 1). In the western edge of the area near Anadarko, Oklahoma, rocks of the Whitehorse Group are, in ascending order, the Marlow and Rush Springs. The Marlow Formation is composed of evenly bedded, sandy or silty shale, ranging in thickness from 90 to 128 feet. The Rush Springs is a fine-grained, cross-bedded sandstone containing silty lenses. The Washita River valley has been cut into the Rush Springs terrace. The Cloud Chief Formation crops out in scattered outliers above the Rush Springs Sandstone (Tanaka and Davis, 1963, p. 5).

TABLE 1. GENERALIZED SECTION OF GEOLOGIC FORMATIONS IN THE CADDO AND GRADY COUNTY AREAS

(Davis 1955 and Tanaka and Davis 1963)

System	Group	Formation	Thickness (feet)	Lithology
QUATERNARY		Alluvium and Terrace deposits	0-105	*Gravel, sand, silt, and clay on the present and old flood plains of the Washita River and its tributaries.*
		High-level gravels	0-25	*Unconsolidated gravel occurring as thin, scattered remnants of formerly extensive deposits on higher ground, slumped along valley slopes.*
PERMIAN		Cloud Chief Formation	0-100	*Gypsum and anhydrite, dolomite at base; clay shale and silt or sandy shale.*
	Whitehorse	Rush Springs Sandstone	0-340	*Fine-grained cross-bedded to even-bedded sandstone; includes irr gular silty lenses and silty shale wedges.*
		Marlow Formation	0-125	*Mostly even-bedded brick-red clay shale, or sandy shale; more sandy toward northwest. Verden Sandstone Member occurs near the upper-middle part*
	El Reno	Dog Creek Shale	0-300	*Mostly even-bedded dark-red gypsiferous clay shale interbedded with gypsiferous siltstone and very-fine-grained sandstone grading into pure gypsum locally.*
		Blaine Formation	0-150	*Mostly interbedded gypsum, red shale, and dolomite.*
		Flowerpot Shale	0-150	*Red to reddish brown, shale, and some gray and gray-green shale.*
		Chickasha Formation	135-260	*Heterogeneous mixture of sandstones, shales, siltstones and intraformational siltstone conglomerates some of which are highly cross-bedded; gradational contact with underlying Duncan.*
		Duncan Sandstone	0-250	*Sandstone with minor amounts of interbedded shale and intraformational siltstone conglomerates.*

Terrace and alluvial deposits occur along major streams and are extensive along the Washita River.

The Washita River area contains deposits termed high-level gravels (Tanaka and Davis, 1963, p. 24) which do not occur or have not been reported from the other area of study in the southeastern part of the state. The coarse gravels which occur as scattered deposits and as slump along the valley slopes are probably remnants of a thick mantle of debris which was spread over the bedrock during Late Tertiary or Early Pleistocene time (Tanaka and Davis, 1963, p. 24). The high-level gravels may be equivalent to the High Plains terrace deposits in north-central Texas, such as the Seymour Gravel. The sediments were probably laid down by streams in a drainage system which may be unrelated to the present drainage. Tertiary gravels are composed of schist, gneisses, quartzites and siliceous wood which are foreign to Oklahoma and which may have had their source area in the Rocky Mountains. Most of the gravel deposits in Oklahomaare thin and of small aerial extent (Tanaka and Davis, 1963, p. 24).

Alluvium and terrace materials were not differentiated by Davis and Tanaka in Caddo County in 1963. They are both stream laid deposits and because of their complexity due to several cycles of erosion and deposition involving considerable reworking, they cannot be differentiated. According to Tanaka and Davis (1963), these deposits were laid down during three cycles of erosion and deposition, two of which can be identified in the smaller stream valleys in the area. During the first cycle broad stream valleys were eroded into the bedrock. These valleys were then alluviated with sand and gravel containing quartz, quartzite, chert, flint, jasper and silicified wood which came either from a source area in the Rocky Mountains or reworked Tertiary gravels from the High Plains to the west. During the second cycle, the streams degraded their channels, removing much of the older terrace deposits. The valleys were then partly refilled with reworked older terrace deposits but primarily with sand and silt derived from the bedrock. In the third, and shortest cycle, valleys were cut into the younger terrace deposits and again filled with sand, silt and clay from the surrounding bedrock, forming the Recent alluvium. The present valley of the Washita River, cut into the Rush Springs Sandstone, has a relatively wide floodplain in the vicinity of Anadarko. This condition prevails from Anadarko eastward to the town of Verden, Oklahoma, where the floodplain narrows appreciably. A study of the geology indicates that the Rush Springs Sandstone thins eastward and changes strike slightly toward the nose of the Anadarko Syncline. This thinning and change of strike occurs near Verden. At this locality, the Washita River has cut through the Rush Springs Sandstone into the older Marlow Formation, which is a slightly more resistant sandy, clay shale. This change of formation may account for the narrowed floodplain from Verden eastward.

Eastward toward Chickasha, Oklahoma, the river has cut through the Marlow Formation into the underlying Dog Creek Shale and Blaine Formation. The Dog Creek is a relatively sandy, clay shale with gypsiferous siltstone and stringers of gypsum. The Blaine Formation is composed of interbedded gypsum, red clay shale and dolomite. At Chickasha, it has cut through the Dog Creek Shale and into the underlying Chickasha Formation, which is a heterogeneous mixture of sandstones, shales, siltstones and mudstone conglomerates. In this vicinity the floodplain averages three-fourths of a mile in width compared to slightly more than one mile at Anadarko. This decrease in width from Anadarko to Chickasha may be controlled by the varying resistance of the rocks through which the river has cut its channel.

The alluvium and terrace deposits in the vicinity of Chickasha resemble those at Anadarko. Three cycles of terrace formation are evident at Chickasha, but there is little or no trace of the High Plains gravels.

Climate

Chickasha, Oklahoma, the eastern limit of the area and Anadarko, Oklahoma, the western limit, are 18 miles apart and have essentially the same climate. According to Thornthwaite (1941, p. 3, pl. 3), the region is classed as moist-subhumid. The winter temperatures are generally moderate with occasional short periods of severe cold and some snow. Summer temperatures are often uncomfortably hot but the nights are generally cool.

Average annual precipitation is 30.81 inches with more than 80 percent of the precipitation occurring during the growing season from March 1 to October 31.

The average temperature is 61.6°F with the lowest reported temperature being -11°F on January 4, 1947 and the highest 116°F on August 11, 1936 (Davis 1955, p. 19-20).

Red River Area

Physiography

The Red River area, southern McCurtain County, Oklahoma, and Little River County, Arkansas, is in the Gulf Coastal Plain Province (Fenneman 1938, p. 115). The north boundary of the Gulf Coastal Plain Province is the north edge of the outcrop of the Trinity Group (Cretaceous). The northern part of southern McCurtain County, Oklahoma, is characterized by rolling topography due to differential erosion of the sands and clays of the Trinity Group, and the overlying terrace gravels (Davis 1960, p. 8). In the southern part of the county, from Little River southward to Red River, the general dip of the rocks is southward, in some cases interrupted by faulting and local gentle folding. The alternation of resistant and weak strata forms a cuesta topography. The limestones and other resistant beds form northward-facing escarpments with gentle southerly dipping slopes. Local relief in most places does not exceed 100 feet and generally is much less (Davis 1960, p. 9).

The Red River, flowing southeastward, is the southern boundary of McCurtain County, Oklahoma, and adjoining Little River County, Arkansas. A high terrace deposit, ranging in width from one-half mile to four miles in some places and approximately 20 miles long, borders the northern edge of the alluvium of Red River.

The area of study lies entirely within the Red River drainage basin. According to Fenneman (1938, p. 115), the Red River possesses certain peculiarities not found in other rivers of the state. It follows the axis of a structural depression analogous to that of the Mississippi River but less well-marked. The Red River has a wide, relatively shallow channel and a low gradient. Because of the nature of its upper basin in the Interior Lowland Province the sediment load is large, resulting in intricate stream meanders and braiding over a wide alluvial plain containing numerous oxbow lakes and marshy areas.

Another peculiarity of Red River, and one which may have played an important part in the physiographic development of the southern part of the two counties, is the "Red River Rafts". These "rafts" were masses of driftwood which, through its long course in northwestern and central Louisiana, filled the channel completely, retarded the current, and formed deposits of sand, mud, and organic debris behind and within the raft, as it grew upstream. The "rafts" are thought to have formed in the fifteenth century and were not completely removed until 1873, by which time they had achieved or attained a length or 160 miles with an upstream growth rate of approximately four-fifths of a mile per year. At the time of removal they reached almost to the Arkansas boundary (Fenneman, 1938). This obstruction had two major effects on the surrounding topography. The immediate effect was deposition of mud and sand and aggradation of the flood-plain creating new courses. Another effect was ponding of tributary valleys. Lakes, 5 to 25 miles in length, formed in these valleys. When the "rafts" were finally removed, the channels were downcut and the lakes began to drain and disappear (Fenneman, 1938, p. 117).

General Geology

Bedrock exposed in the area consists of sedimentary rocks of the Comanche and Gulf Series of the Cretaceous System (Table 2). The oldest unit, the Holly Creek Formation, is succeeded by the De Queen Limestone and overlying Antlers Sand. These constitute the Trinity Group in the area of this study. It crops out in the northern part of southern McCurtain County, Oklahoma, and Little River County, Arkansas. Above this sequence, from oldest to youngest are the Fredericksburg and Washita Groups, which crop out as essentially east-west bands across the southern part of the counties. The Trinity, Fredericksburg and Washita Groups constitute the Comanche Series in this area (Davis, 1960, p. 17).

Overlying the Comanche Series is the Gulf Series consisting of the Woodbine Formation at the base succeeded by the Tokio Formation and undifferentiated Ozan and Brownstown Formations (Davis, 1960, p. 17).

TABLE 2. GENERALIZED SECTION OF GEOLOGIC FORMATIONS IN THE SOUTHERN PART OF MC CURTAIN COUNTY, OKLAHOMA

after Davis, 1960

System	Series	Group	Formation	Thickness	Lithology
CRETACEOUS	Pleistocene and Recent		Alluvium	0-80	*Gravel, sand, silt, and clay on the present and old floodplains of the Red River and its tributaries.*
			Terrace deposits	0-40	*Unconsolidated gravel, sand, silt, and clay occurring in large an small deposites, probably remnants of more extensive deposits found mostly on high ground over the southern part of county.*
	Gulf		Ozan and Brownstown Formations	---	*Soft chalky marls and limestones with interbedded calcareous clays.*
			Tokio Formation	0-505	*Gray cross-bedded sand interbedded with gray and dark gray shale.*
			Woodbine Formation	0-355	*Upper member mostly gray to brown cross-bedded quartz sand and sandy gravel. Lower member cross-bedded tuffaceous sand, red clay and gravel lentils*
	Comanche	Washita	Includes Kiamichi Formation of Fredericksburg Group	0-235	*Gray fossiliferous limestones and calcareous dark blue shale which thins eastward*
		Fredericksburg	Goodland Limestone	25-130	*Thin bedded dense limestone at the top; soft, chalky and massive limestone in the lower part; entire formation fossiliferous.*
		Trinity	Paluxy Sand	0-900	*Mostly quartz sand with some interbedded clay and a few shaly limestone lentils.*
			De Queen Formation	0-190	*Clayey limestone, blue-gray and gray; thins westward.*
			Holly Creek Formation	0-1070	*Gravel, mostly interbedded with clay and silt; thins westward.*

Above the Gulf Series are terrace deposits and alluvium of the Quaternary System. Alluvial deposits overlie the bedrock in the valleys, being most extensive in the valley of the Red River. Alluvium and terrace deposits are generally considered together by Davis (1955) because the mode of deposition is the same; however in McCurtain County they have been mapped separately on the basis of position and texture, and therefore are described below as separate units.

Alluvium is stream-deposited material of Recent age consisting of unconsolidated sand, gravel and clay in intergrading and intertonguing beds. Generally it is thickest in the center of the valley and thins outward from the stream. The thickness of the alluvium along the Red River varies from 13 feet to a maximum of 110 feet as recorded in drillers logs (Davis 1960, p. 49).

Terrace deposits occur at higher levels above the alluvium of the floodplain and are scattered or discontinuous in some areas. They consist of unconsolidated stream-laid deposits similar to the floodplain alluvium except that the sand and gravel fraction is coarser and little or no clay is present. They are generally a blanket type deposit rather than intertonguing or intergrading. The terrace deposits where found, vary in thickness, but are generally less than 30 feet.

Climate

McCurtain County, Oklahoma, and adjacent Little River, Arkansas, have a humid climate (Thornthwaite, 1941, p. 3). Winter temperatures are generally mild with only occasional short periods of severe cold. Summer days are uncomfortably hot with many warm nights. The annual precipitation has ranged from 28.72 inches in 1936 to 73.39 inches in 1957 (Davis, 1960, p. 11). Approximately 60 percent of the annual precipitation occurs from December through May.

Temperature at Idabel, county seat of McCurtain County, Oklahoma, has ranged from -11°F on February 2, 1951, to 114°F on August 10, 1936. January has the lowest average temperature and July and August have the highest. The average annual temperature at Idabel is about 64.4°F which is about 3.8°F above the state average. The sample collection locality in Arkansas is about 22 miles southeast of Idabel and the climate probably does not vary much from that area.

OTHER QUATERNARY INVESTIGATIONS IN OKLAHOMA

Pleistocene studies of Oklahoma have been concerned largely with invertebrates, particularly mollusks, vertebrates, and archeological materials. Carbon-14 dates are available for several of these. To facilitate a discussion of Oklahoma Pleistocene, the state has been divided into five divisions: northwest, southwest, central, northeast and southeast.

In the northwestern area of Oklahoma extensive Pleistocene vertebrate and invertebrate work has been done by Hibbard (1940, 1949, and 1953) and by Taylor and Hibbard (1955). Much of that work was done in Beaver, Harper and Woods Counties, Oklahoma, and Meade County in southwestern Kansas. A molluscan fauna known as the Bar M Local Fauna from Harper County, Oklahoma, was related by Taylor and Hibbard (1955) to the Berends Local Fauna (Taylor, 1954) of Beaver County, Oklahoma, thought to be Illinoian in age. Recently Myers (1965) published a Carbon-14 date of 21,360 ± 1,250 years B.P. on the Bar M Local Fauna based on molluscan shells. If this date is correct, then these deposits are of Wisconsinan age rather than Illinoian.

The Jones Local Fauna in adjoining Meade County, Kansas, is the latest cool-climate glacial age assemblage in the area and is considered Wisconsinan in age (Hibbard, 1940, 1949, 1953, p. 389). The Jinglebob Local Fauna, also in Meade County, Kansas, is referred to the Sangamon interglacial age (Hibbard, 1952, 1953, p. 389). A Pleistocene stream channel described by Myers (1962, p. 224-229) was assigned to the Crooked Creek Formation (Kansas-Yarmouth in age).

The major palynological study in this area is that of Kapp (1965) who investigated Hibbard's localities in Harper and Beaver Counties, Oklahoma, and Meade County, Kansas. The palynological environmental interpretations for local and regional climate support, in general, Taylor and Hibbard's (1959) conclusions. These authors have stated that the glacial and interglacial deposits are Illinioan and Sangamon respectively; but at present, no palynological assemblage is known that can be used as an index to any part of the Pleistocene with the possible exception of the palynological record of the Hypsithermal Period. The palynological assemblage in other cases must be associated with other stratigraphic evidence to indicate specific ages. The Berends locality is substantiated as being from a period of maximum glaciation on the basis of pine (*Pinus*), spruce (*Picea*) and Douglas fir (*Pseudotsuga*) pollen recovered from sediments in this locality. Douglas fir has distinct Rocky Mountain affinity and Kapp (1965) suggests that the mean summer temperature was at least 10°F lower during the period than at present. The Jinglebob locality was dated by Hibbard (1952, 1953, p. 389) as late Sangamon in age. Kapp (1965) stated that palynological evidence shows that during this period the predominant vegetation was a pine savannah. The absence of chenopod-amaranths, a sparseness of ragweed (<u>Ambrosia</u>) and sagebrush (<u>Artemisia</u>) pollen suggests that the uplands were moist and that the plant cover was relatively well established. Winters were apparently warmer than at present, and there was probably twice the present rainfall. The climate was much less continental. The Illinoian and Sangamon dates of Kapp (1965) are somewhat in question, especially in regard to the Berends locality. The Bar M locality has been equated by Taylor and Hibbard (1955) with the Berends locality, one of Kapp's collected localities. As stated before (Myers, 1965) a Carbon-14 date of 21,360 ± 1,250 years B. P. for the Bar M locality places some doubt on the Illinoian and Sangamon dates of both Taylor (1954) and Kapp (1965). The latter author (p. 25) has stated that the Illinoian glacial vegetation of northwestern Oklahoma and southwestern Kansas was similar to the vegetation of the Wisconsinan pluvial time in the Llano Estacado of the southern High Plains. The vegetation in the Llano Estacado was dominated by pine and spruce during this time. Therefore the pine-spruce occurrence of Kapp (1965) which he defines as representing cooling during Illinoian and Sangamon time, may actually be a northward continuation of the Wisconsin pluvial spruce-pine vegetation of the Llano Estacado. The investigations mentioned above pertain at least in part to terrace and alluvial deposits of the Cimarron River in that area. The only other palynological work in northwestern Oklahoma is a study conducted by L. R. Wilson in Tesesquite Creek valley in Cimarron County, Oklahoma. From a buried forest bed in the creek bank, wood samples have been collected for Carbon-14 age dating as well as clay samples for palynological investigations. Spore and pollen fossils from this locality were recovered from a blue-black clay which may be an important stratigraphic marker in the alluvial deposits of Oklahoma. Rhizophagites butleri, a fungus, and associated pollen of spruce, pine and many composites have been observed (Wilson, 1965). Stratigraphic evidence suggests the age of the forest bed to be late Wisconsinan.

In the southwestern area, the Domebo Site, located in sec. 29, T. 5 N., R. 10 W., Caddo County, Oklahoma, has contributed vertebrate, invertebrate, archeological and palynological information. Wilson (in press) has reported a Carbon-14 date of 11,045 B. P. from wood samples collected in association with an extinct mammoth skeleton in a blue-black clay deposit at a depth of approximately 36 feet. A log and tree stump, from a depth of 34 feet, yielded a Carbon-14 date of 10,123 B. P.. Both dates are late Wisconsinan. The palynological evidence places the levels of the Hypsithermal Period approximately two to four feet above the Carbon-14 date of 10,123 B. P.. The Caddo County localities described in the present investigation occur within 10 miles of the Domebo Site but appear to be younger. There is no evidence of a basal blue-black clay such as that found at the Domebo Site. Spruce pollen and pine pollen occur in the basal and surface samples in small quantities (1 to 9 percent) at the Domebo Site and these pollen fossils have been interpreted as wind blown from the Rocky Mountains. Some pine was found in the Caddo County localities of this investigation but no spruce. According to Kapp (1965) spruce spread into the High Plains during both the Illinoian and Wisconsinan glacial stages. The presence of spruce has been interpreted as indicating a 10°F drop in the mean July temperature during glacial stages and in both areas pine was prominent in the vegetation. Frye and Leonard (1963) have made molluscan studies of Pleistocene terraces along the Red River and their work shows the lowest terrace to be early Wisconsinan and the terrace above to be late Kansan.

No palynological investigations have been made in the northeastern part of Oklahoma. The Arkansas River and the Verdigris River are the major streams in that area which have extensive floodplain and/or terrace deposits of Quaternary age. These two rivers appear to have terrace and oxbow lake deposits suitable for palynological studies.

The southeast section of the state is the second area of this investigation, the area along the Red River in McCurtain County, Oklahoma, and adjoining Little River County, Arkansas. The floodplains and terrace deposits of the Red, Little and Kiamichi Rivers and a few of the larger tributary creeks of these rivers, are suitable for palynological investigations. The oxbow lakes from which the samples were collected are located on the floodplain of the Red River. The pollen profile of these localities (figs. 6-9) shows them to be late Wisconsinan in age. No other palynological studies have been made in the area which can be used for comparison. Frye and Leonard (1963, p. 21) have used mollusks to show that the high terraces in this area are Kansan and Illinoian in age and the lower is of early Wisconsinan age. They have studied the Red River terraces along the entire course from the New Mexico-Texas state line to the Arkansas-Oklahoma state line. These studies also have resulted in a geomorphic history of the Pleistocene as obtained from molluscan faunas contained in a series of descending alluvial terraces. These indicate that, in the Texas Panandle, the terraces are early Wisconsinan in age, in the vicinity of Tillman County, Oklahoma, they are Nebraskan and in McCurtain County, Oklahoma, they are Illinoian and Kansan in age.

TECHNIQUES OF SAMPLE COLLECTION

Three sampling techniques were used in the Red River area. The first technique employed a 6-foot ships auger. The auger was used in localities where the sediments were moist but compacted.

The second technique employed the use of a Davis Peat Sampler. This instrument was used where the sediment was relatively unconsolidated and had a high water content. The sampler consists of a six-inch metal tube with a plunger and pointed end to which can be attached six-foot lengths of steel rod.

The third technique employed was the trenching method. This was used where the sediment was dry and highly compacted. In this technique a trench, four to five feet in depth, was dug. Six-inch segment samples were collected down the side of the trench.

The sampling technique used in the central Oklahoma area along the Washita River was of a different type. These cores of sediment were supplied by Mr. Paul B. Allen of the Hydrologic Research Station at Chickasha, Oklahoma. The cores were cut with a truck-mounted coring rig. The cores, 24 feet in length, were divided into one foot segments.

SAMPLE PREPARATION AND STUDY

Preparation of samples for microscopic examination follows procedures outlined by Wilson (1959a) with some modifications (Bond, 1964). The preparation technique is outlined below.

1. The outside of each sample was scraped to a depth of one-fourth inch to remove any contaminating material which may have adhered to the sample as it was withdrawn from the hole.
2. The samples were cut longitudinally and approximately 10 grams of sample were taken from the center at one foot intervals.
3. Approximately 10 grams of each sample was placed in a Mason jar and covered with 500 cc of distilled water. The jar was agitated for 8 to 12 hours. After agitation the jar was allowed to stand for 30 minutes and the liquid decanted.
4. The sample was placed in a polyethylene beaker and covered with 20 percent hydrochloric acid (HCl) for 24 hours, washed until neutral and returned to the beaker.
5. Sample was covered with 52 percent hydrofluoric

acid (HF), allowed to stand for 24 hours, washed until neutral and returned to the beaker and covered with distilled water.

6. A pipette full of sample was removed and placed in a watch glass for microscopic examination. If the sample was high in organic matter, it was returned to the beaker and treated with 10 percent potassium hydroxide (KOH) for 8 to 10 minutes. In most samples this step was unnecessary except in the uppermost segment samples near the surface.
7. After the above step, small portions of the sample were placed in 15 ml centrifuge tubes and the clay fraction was floated off by the use of Alcojet solution (Bond, 1964).
8. The final residue was stored in an aqueous solution containing 30 percent alcohol as a preservative, and with a few drops of Safranin O as a stain. Approximately 1,000 permanent slides (10 from each level) were prepared from the residues using Clearcol as a mounting medium.

Study Procedure

Microscope slides were studied with the aid of an American Optical Microstar compound binocular microscope, using 10X wide-field oculars, and 10X, 43X, and 97X (oil immersion) objectives. Each slide was examined by systematic horizontal traverses. Microfossils selected for photographing were ringed with glass-marking ink. Notations marked on the slides include sample number, slide number and ring number, i.e. OPC 1108 A-1-1. Ringed specimens were photographed with a Zeiss Photomicroscope, using 35 mm Adox KB-14 film.

After the specimens had been photographed prints were made on single-weight Kodabromide No. 5 paper.

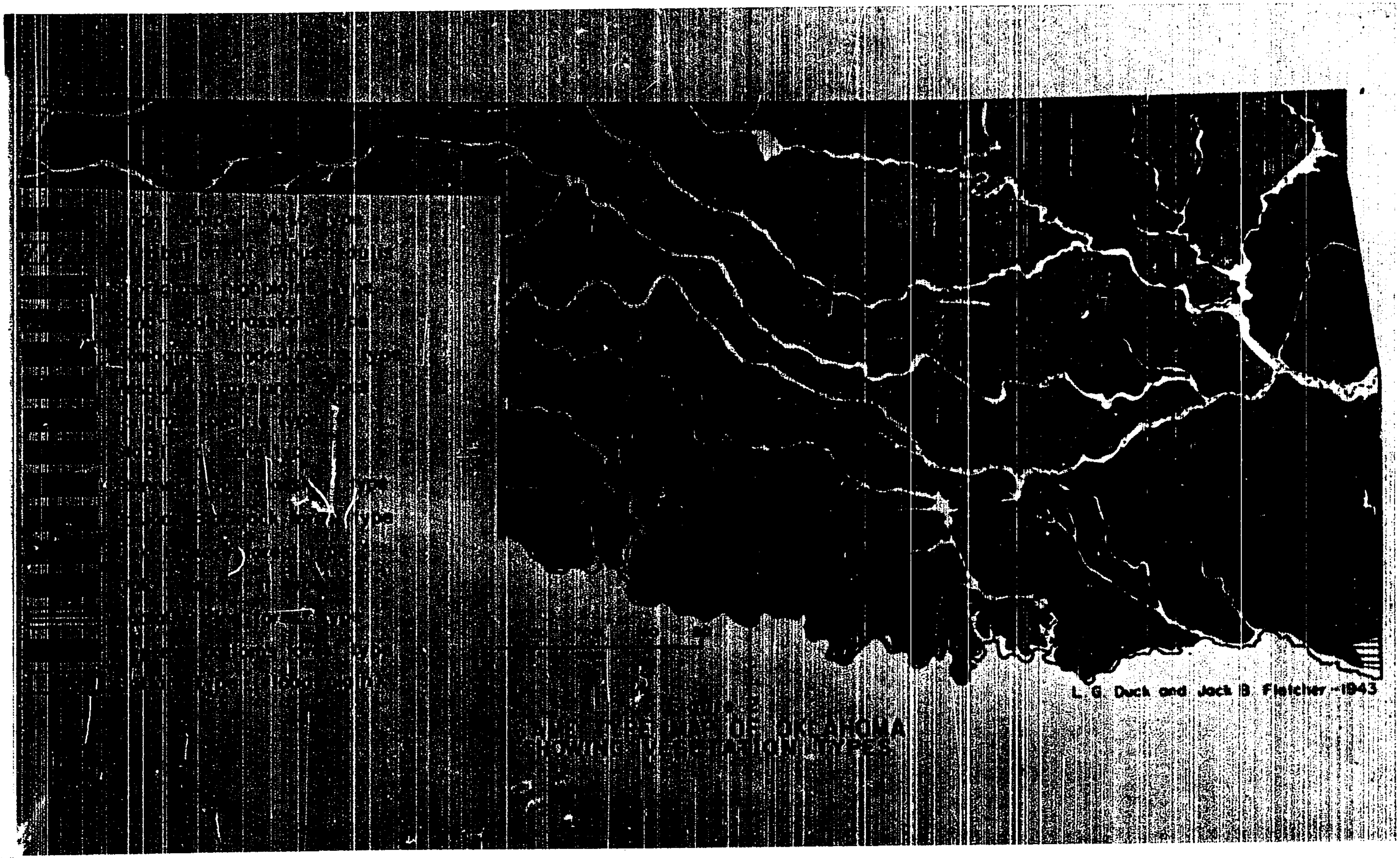
After the specimens on the microscope slides had been identified, assemblage counts were made. A total of 200 fossils was counted from each level using eight slides in order to obtain a representative sample. Relative percentages of genera in each level were calculated and the results plotted as histograms.

VEGETATION ANALYSIS

General Plant Distribution in Oklahoma

The general plant distribution in Oklahoma is divided into 12 types following the plan of Duck and Fletcher (1944), with the exception of the Mesquite Grassland Type which, because of its restricted range, is not included by them (Fig. 2). The general plant distribution of the state is described below across the state from the Rocky Mountain elements in the Oklahoma Panhandle to the coastal plain elements in the southeastern part of the state.

Pinon-Juniper Mesa Type: This vegetation type in Oklahoma is limited to the extreme northwest corner of the state encompassing some 87 square miles, predominantely in Cimarron County. This type is in a semi-arid climate with moisture deficiency at all seasons. The average annual precipitation is 17.9 inches and the average annual temperature is 54.8°F. Soil development in this area is at a minimum with the exception of the valley floors. The soil is sandy, being derived from the Omadi (Cretaceous) Sandstone whereas on the hillsides weathered basalt from Black Mesa is the principal source of soil. The principal vegetation types are as follows:


L. G. Duck and Jack B. Fletcher - 1943
MAP OF OKLAHOMA
SHOWING VEGETATION TYPES

Arborescent Species:

<u>Pinus edulis</u>	pinon pine
<u>Pinus ponderosa</u>	western yellow pine
<u>Juniperus monosperma</u>	juniper
<u>Quercus undulata</u>	scrub oak

Non-arborescent Species:

<u>Bouteloua gracilis</u>	blue gramma
<u>B. hirsuta</u>	hairy gramma
<u>Buchloe dactyloides</u>	buffalo grass
<u>Opuntia imbricata</u>	cholla cactus

In addition some species of the tall grass types are found on slopes in more mesic and protected areas.

<u>Shortgrass High-Plains Type</u>: This vegetation type is found mainly in Cimarron, Texas and Beaver Counties, extending partially into western Harper, western Woodward and Ellis Counties. This area in Oklahoma is only a small part of similar grassland reaching between the tall grass prairie and the Rocky Mountains from central Texas north into Canada. The aerial extent in the state is approximately 1,127 square miles and for the most part is restricted to the higher Tertiary materials. The climate of this type is characterized by limited precipitation of irregular seasonal distribution, high rate of evaporation, low relative humidity; high average wind velocity; hot summer days followed by cool nights; and moderate winters with occasional severe cold spells of short duration. The average annual rainfall is from 17 to 24 inches. High summer temperatures of 112°F degrees have been recorded with a mean annual temperature of 55.7°F. The soils are generally fertile and were developed

under grass cover with comparatively low rainfall. Sand from the Tertiary cover is a common constituent. The vegetation of this type is as follows:

Arborescent species:

Quercus havardi	shin oak
Quercus undulata	scrub oak
Celtis reticulata	thick-leaved hackberry

Non-arborescent species:

Andropogon scoparius	little bluestem
Aristida oligantha	wire grass
Bouteloua curtipendula	side-oats gramma
Bouteloua gracilis	blue gramma grass
Buchloe dactyloides	buffalo grass
Commelina sp.	day flower
Polygonum hydropiper	smartweed
Chenopodium album	lambs quarters
Salsola kali var. tenuifolia	Russian thistle
Cassia fasciculata	partridge pea
Psoralea tenuiflora	prairie clove
Euphorbia marginata	snow-on-the-mountain
Opuntia sp.	cactus
Convolvulus sp.	bindweed
Ambrosia sp.	ragweed
Grindelia squarrosa	gumweed
Helianthus annuus	sunflower
Liatris punctata	blazing star
Xanthium sp.	cocklebur

Sand-Sage Grassland Type: This includes all sandy grasslands on which sand-sage (_Artemisia folifolia_) forms a major part of the ground cover. The type occurs throughout the northwestern part of the state, mainly on the north sides of the principal streams and includes about 2,600 square miles. The bulk of this type is found within a climatic province characterized by Duck and Fletcher (1944) as subhumid mesothermal and moisture difficient at all seasons but overlapping to the west into semi-arid climatic conditions. The average annual precipitation is 15 to 17 inches with precipitation increasing eastward to approximately 28 inches. The soils supporting this vegetation type are sands, developed for the most part from Quaternary alluvial material which overlies the Permian redbeds. The vegetation of this type is:

Arborescent and shrubby species:

Celtis reticulata	thick-leaved hackberry
Prunus sp.	sand plum
Rhus trilobata	skunkbrush

Non-arborescent species:

Andropogon gerardi	big bluestem
Andropogon hallii	sandhill bluestem
Andropogon scoparius	little bluestem
Calamovilfa gigantea	big sandgrass
Redfieldia flexuosa	blowout grass
Sorghastrum nutans	Indian grass
Sporobolus cryptandrus	sand dropseed

Mixed-Grass Eroded Plains Type: This type includes approximately 8,500 square miles generally located across the western one-fourth of the state, excluding the Panhandle. A mixture of both tall and short-grass species characterizes the original vegetation with variation in composition on the western and eastern edges where this type merges with the short grass species and the long grass species. At present the vegetational composition is composed, for the most part, of short grass species. This type lies entirely within the climatic province characterized as subhumid, mesothermal and moisture deficient at all times of the year. The type lies between the 22 and 30 inch rainfall belt, and has a wide fluctuation of temperatures throughout the year. Most of the soils are developed from fine grained sandstones, shales and clays of Permian age. The presence of gypsum is characteristic of much of the broken land (Duck and Fletcher, 1944). The vegetation of this type is mostly grasses.

Arborescent species:

Juniperus virginiana	juniper
Quercus havardi	shin oak

Non-arborescent species:

Andropogon scoparius	little bluestem
Bouteloua curtipendula	side-oats gramma
Bouteloua gracilis	blue gramma
Buchloe dactyloides	buffalo grass

Tallgrass Prairie Type: The tall grass prairie vegetation type is characterized by clean cultivation and is found in most of the better agricultural areas of the state with the exception of the Arbuckle and Ozark areas. Climatic peculiarities do not characterize this type insofar as Oklahoma is concerned. This type falls largely within a climate characterized as sub-humid, mesothermal and moisture deficient at all times of the year. The average annual precipitation varies from 42 inches on the east to 26 inches on the west with the majority of the area falling between 28 inches to 38 inches. The soils of this type to the west have their origin from shales and clays of the Permian redbeds and range from light sandy loams to heavier silt loams and clays. In northeastern Oklahoma the type is supported mostly by residual soils formed from the weathering of limestones, fine-grained sand stones and shales (Duck and Fletcher, 1944). The original vegetation of this type consists of the Big Bluestem Subtype and the Little Bluestem Subtype with a portion of the "mixed-grass ecotone type". The natural vegetation of this type consists of the following species:

Arborescent species:

Quercus marilandica	blackjack oak
Quercus stellata	post oak

Non-arborescent species:

Andropogon gerardi	big bluestem
Andropogon saccharoides	silver beard grass
Andropogon scoparius	little bluestem
Bouteloua curtipendula	side-oats gramma
Bouteloua gracilis	blue gramma
Buchloe dactyloides	buffalo grass
Panicum virgatum	switch grass
Sorghastrum nutans	Indian grass

Continued grazing in the western portion of the type is responsible for the decrease in tall grass species and the increase of short grass species. The total area of the Tall Grass Prairie Type is approximately 20,500 square miles. This total also includes an area of tall grass species in northeastern Oklahoma known as the Cherokee Prairie.

Stabilized Dune Type: This type is restricted to the heavily vegetated sand dunes on the north side of the Cimarron and North Canadian Rivers in northwestern Oklahoma, and comprises about 368 square miles. The climate in this type is essentially the same as that for the Sand-Sage Grassland. The soils of this type are of a deep loose sandy nature and subject to blowing where vegetational protection is removed. The type is characterized by its distinct dune-like relief covered with many species of trees, shrubs, grasses and woody annuals. The vegetation of this type is as follows:

Arborescent and shrubby species:

Quercus marilandica	blackjack oak
Quercus stellata	post oak
Celtis sp.	hackberry
Ulmus americana	American elm
Prunus watsoni	sand plum
Rhus aromatica	skunkbrush
Rhus sp.	sumac
Bumelia lanuginosa	chittum wood

Non-arborescent species:

Andropogon gerardi	big bluestem
Andropogon hallii	sandhill bluestem
Andropogon scoparius	little bluestem
Calamovilfa gigantea	big sandgrass
Redfieldia flexuosa	blowout grass
Sorghastrum nutans	Indian grass
Sporobolus cryptandrus	sand dropseed
Vitis sp.	grape

Shinnery Oak-Grassland Type: This type is scattered throughout the western tier of counties of Woodward, Ellis, Roger Mills, Beckham and Harmon and represents the eastern edge of the same type found in portions of the Texas Panhandle and eastern New Mexico. It is characterized by a low, shrubby or dwarf growth of various species of oak (Wiedeman and Penfound 1960, p. 117) forming a possible hybrid variety called shinnery oak or just shin oak. This shin oak (_Quercus havardi_) is intermixed with various species of the tall grasses with little bluestem (_Andropogon scoparius_) predominating, and some short grasses found on more compact soils. The area occupied by this type is characterized by an extremely unstable climate particularly with regard to precipitation. The average rainfall is between 24 and 26 inches per year. Most of the type occupies an area classified as subhumid, mesothermal and insufficient rainfall at all seasons. Most of the soils of this type are hummocky to rolling light textured soils derived mainly from parent material of Quaternary or Tertiary age (Duck and Fletcher, 1944). An approximate total of 1,173 square miles of this type is found in Oklahoma.

<u>Postoak-Blackjack Forest Type</u>: The Postoak-Blackjack forest type represents a transition zone between grassland and forest. It is composed of dominants from both the deciduous forest formation to the east and the grassland formation to the west. The vegetation of this type is as follows:

Arborescent species:

<u>Carya buckleyi</u>	black hickory
<u>Quercus marilandica</u>	blackjack oak
<u>Quercus stellata</u>	post oak

Non-arborescent species:

<u>Andropogon gerardi</u>	big bluestem
<u>Andropogon scoparius</u>	little bluestem

This vegetation type has a climate characterized by subhumid, mesothermal and adequate moisture for all seasons. Average annual rainfall varies from 26 inches in the west to 42 inches in the east with most of the area receiving between

32 and 40 inches. The soil is coarse textured and relatively poor. It is developed from residual sandstones and weathered shales. The soils are leached and acidic. The Postoak-Blackjack forest type consists of approximately 17,600 square miles, generally in the east-central portion of the state, but with extensions as far west as portions of Major, Woodward, Dewey and Comanche Counties.

<u>Oak-Hickory Forest Type</u>: This forest type is located largely in the northeastern part of the state including the Ozarks, and totals approximately 4,000 square miles. The Oak-Hickory forest type is bounded on the west by the Grand River and includes the counties of Adair, Cherokee and parts of Delaware, Sequoyah, Muskogee, Craig, Mayes, Wagoner and Ottawa. The vegetation of this type is:

Arborescent species:

<u>Carya buckleyi</u>	black hickory
<u>Carya glabra</u>	pignut hickory
<u>Carya laciniosa</u>	scaley bark hickory
<u>Quercus alba</u>	white oak
<u>Quercus marilandica</u>	blackjack oak
<u>Quercus palustris</u>	pin oak
<u>Quercus rubra</u>	red oak
<u>Quercus stellata</u>	post oak
<u>Quercus velutina</u>	black oak
<u>Ulmus alata</u>	winged elm

Non-arborescent species:

<u>Andropogon gerardi</u>	big bluestem
<u>Corylus sp.</u>	hazel nut
<u>Podophyllum peltatum</u>	may apple
<u>Benzoin aestivale</u>	spice bush
<u>Sassafras sassafras</u>	sassafras
<u>Sanguinaria canadensis</u>	bloodroot
<u>Vitis sp.</u>	wild grape
<u>Staphylea trifolia</u>	bladdernut
<u>Vaccinium vacillans</u>	huckleberry
<u>Symphoriocarpus orbiculatus</u>	coralberry

This vegetation type is located in the northern part of a climate that is characterized as humid, mesothermal and adequate moisture throughout the year. The average annual precipitation is 38 to 44 inches. The soils of this forest type are fine-textured, light-colored calcareous loams derived from the underlying limestones and where woodland is the natural climax.

Oak-Pine Forest Type: The Oak-Pine forest type is restricted to the Ouachita Mountains area in southeastern Oklahoma. The shortleaf pine (_Pinus echinata_) is found throughout the type with a mixture of various oaks and hickories with pure stands in some areas. Included in this type is about 120 square miles in McCurtain County of the Loblolly Pine-Hardwood Subtype, in which loblolly pine (_Pinus taeda_) is the dominant tree type. The more common vegetation of the combined areas are:

Arborescent species:

Pinus echinata	shortleaf pine
Pinus taeda	loblolly pine
Carya buckleyi	black hickory
Quercus alba	white oak
Quercus marilandica	blackjack oak
Quercus phellos	willow oak
Quercus shumardi	spotted oak
Quercus stellata	post oak
Robinia pseudo-acacia	black locust
Acer saccharum	sugar maple
Tilia americana	basswood

Non-arborescent species:

Andropogon gerardi	big bluestem
Benzoin aestivale	spice bush
Grossularia sp.	gooseberry
Philadelphus pubescens	mock orange

Staphylea trifolia	bladdernut
Rhododendron roseum	pink azalia
Vaccinium vascillans	huckleberry

This forest type lies within a climatic type characterized as humid, mesothermal and adequate precipitation throughout the year. The average annual precipitation varies from 42 to 56 inches. The soils are thin and poorly drained and are derived from sandstones and shales with the valley soils being of a fine texture. The combined forest types occupy an area of about 5,112 square miles.

Cypress Bottoms Forest Type: This forest type can be classified as a subtype of the Bottomland Timber Type and is restricted to the southeastern corner of the state primarily in McCurtain County, along Little River and Mountain Fork River and their tributaries. The vegetation types are as follows:

Arborescent species:

Taxodium distichum	bald cypress
Alnus serrulata	alder
Quercus alba	white oak
Quercus nigra	water oak
Quercus phellos	willow oak
Liquidambar styraciflua	sweet gum
Ilex opaca	American holly
Nyssa sylvatica	sour gum

Non-arborescent species:

Morus sp.	mulberry
Cephalanthus occidentalis	buttonbush

Other non-arborescent species in the understory are variable depending on the environment.

<u>Bottomland Forest Type</u>: This type includes the first bottom of floodplain and stream courses of all the major drainage in the state. The bottomland species vary throughout the state depending upon the amount of moisture. The vegetation of the bottomlands of the Panhandle and western counties are mostly grasses such as buffalo grass. The vegetation of this forest type is as follows:

Arborescent and shrubby species:

Populus sargentii	cottonwood
Salix nigra	willow
Carya aquatica	bitternut
Carya illinoensis	pecan
Juglans sp.	walnut
Quercus marilandica	blackjack oak
Quercus muhlenbergii	chinquapin oak
Quercus stellata	post oak
Quercus velutina	black oak
Celtis sp.	hackberry
Ulmus americana	American elm
Platanus occidentalis	sycamore
Prunus angustifolia	Chickasaw plum
Rhus aromatica	fragrant sumac
Rhus glabra	smooth sumac
Cornus drummondii	rough-leaved dogwood
Bumelia lanuginosa	chittum wood

Non-arborescent species:

Bouteloua gracilis	blue gramma
Buchloe dactyloides	buffalo grass
Sorghum halepense	Johnson grass

Because of the differences in rainfall and other environmental factors, both the number and luxuriance of growth of species increases from west to east along the principal east-west streams. The bottomland soils are extremely fertile and deep being alluvial in origin with saline deposits found in some areas (Duck and Fletcher, 1944). This forest type including the Cypress Bottoms Type, includes approximately 3,400 square miles.

Mesquite Grasslands Type: This type is not included by Duck and Fletcher (1944) in their text although it does appear on their map accompanying the text (Fig. 2). It is found most commonly in Harmon and Beckham Counties, but is also found scattered northeastward from there in association with the mixed grass-eroded plains type. The vegetation is the same as that of the mixed grass-eroded plains type with the addition of mesquite (Prosopsis juliflora) occurring as scattered stands. The climate and soils are the same as that of the mixed grass-eroded plains type. Because this type is not mapped due to its irregular distribution, no figures as to its aerial extent are available.

Plant Distribution in Washita River Area

The Washita River area includes both Caddo and Grady Counties which have different vegetation types, the Postoak-Blackjack forest type and the Tall-grass Prairie Type. The species of these two vegetation types have been listed under the appropriate headings. These two vegetation types are the regional vegetation for these two counties. The local vegetation of the oxbow lakes, which in this case is considered to be the vegetation from the water line outward to a distance of about 300 yards, is listed in detail for each collected locality.

Anadarko #1 Terrace Oxbow (OPC 1062) and the Anadarko #2 Terrace Oxbow (OPC 1068) are approximately five miles apart and have essentially the same local vegetation. The species are as follows:

Arborescent species:

Populus deltoides	cottonwood
Salix nigra	willow
Quercus marilandica	blackjack oak
Quercus stellata	post oak
Ulmus americana	American elm

Non-arborescent species:

Panicum virgatum	switch grass
Sorghastrum nutans	Indian grass
Sorghum halepense	Johnson grass
Cyperus sp.	sedge
Juncus sp.	rush
Morus sp.	mulberry
Polygonum sp.	smartweed
Chenopodium sp.	pigweed
Cephalanthus occidentalis	buttonbush
Ambrosia psilostachya	western ragweed
Aster sp.	aster
Helianthus annuus	sunflower
Rudbeckia sp.	coneflower
Xanthium sp.	cocklebur
Conyza canadensis	horseweed

The vegetation of the Chickasha Oxbow (OPC 1004) has the same regional vegetation but a different local one. This locality has been quite extensively grazed and has many seeded species. The local vegetation consists of the following species:

Arborescent species:

Populus deltoides	cottonwood
Salix nigra	willow
Celtis reticulata	hackberry

Non-arborescent species:

Cynodon dactylon	bermuda grass
Digitaria sanguinalis	crabgrass
Phytolacca americana	pokeberry
Prunus virginiana	chokecherry
Medicago sativa	alfalfa
Melilotus alba	white sweet clover
Vitis sp.	wild grape
Asclepias sp.	milkweed
Ambrosia psilostachya	western ragweed
Gutierrezia dracunculoides	broomweed
Helianthus annuus	sunflower

Plant Distribution in Red River Area

The regional vegetation of this area falls into several categories, Oak-Pine Forest Type, Oak-Hickory Forest Type, Cypress Bottoms Forest Type, and Loblolly Pine Forest Type. All the species of these types have been listed previously under their appropriate headings.

The local vegetation of the sample localities in this area shows great variation due to many ecologic factors. As in the Washita River area, the local vegetation was recorded from the edge of the water outward to a limit of approximately 300 yards.

The local vegetation at Oxbow Lake "A" (OPC 1008) consists of the following species:

Arborescent species:

Pinus echinata	shortleaf yellow pine
Salix nigra	willow
Carya illinoensis	pecan
Celtis laevigata	southern hackberry
Ulmus alata	winged elm
Ulmus crassifolia	cedar elm
Maclura pomifera	Bois d'Arc
Diospyros virginiana	persimmon
Forestiera accuminata	swamp privet
Fraxinus pennsylvanica	green ash

Non-arborescent species:

Typha latifolia	cattail
Potamogeton hydropiperoides	pondweed
Sagittaria sp.	arrowhead
Bromus catharticus	rescue grass
Leersia sp.	cutgrass
Lolium multiflorum	rye grass
Sorghum halepense	Johnson grass
Carex crus-corvi	crow-spur
Cyperus sp.	umbrella sedge
Juncus sp.	rush
Hymenocallis occidentalis	groundsel
Polygonum sp.	smartweed
Polygonum hydropiperoides	water pepper
Rumex sp.	sorrell
Ceratophyllum demersum	hornwort
Ranunculus sp.	buttercup
Trifolium agrarium	yellow clover
Myriophyllum sp.	water milfoil
Amsonia sp.	dogbane
Verbena sp.	vervain
Veronica sp.	speedwell
Campsis radicans	trumpet vine
Galium sp.	bedstraw
Specularia sp.	Venus looking-glass
Ambrosia psilostachya	western ragweed
Artemisia sp.	wormwood
Pyrrhopappus sp.	false dandelion
Senecio sp.	groundsel

The regional vegetation of Jenkins Reilly Slough (OPC 1062) is the same as that of Oxbow Lake "A". The local vegetation has about the same major constituents as the previous locality, but due to more moisture, additional species are recorded. They are as follows:

Arborescent species:

Pinus echinata	short leaf yellow pine
Pinus taeda	loblolly pine
Populus deltoides	cottonwood
Salix nigra	willow
Carya illinoensis	pecan
Juglans nigra	black walnut
Celtis laevigata	southern hackberry
Planera aquatica	water elm
Ulmus americana	American elm

Maclura pomifera	Bois d'Arc
Liquidambar styraciflua	sweet gum
Platanus occidentalis	sycamore
Crataegus spathulata	hawthorn
Gleditsia triacanthos	honey locust
Diospyros virginiana	persimmon
Forestiera accuminata	swamp privet
Fraxinus pennsylvanica	green ash

Non-arborescent species:

Arundinaria gigantea	giant cane
Leersia sp.	cut grass
Zizaniopsis miliacea	water millet
Carex sp.	sedge
Allium sp.	wild onion
Saururus sp.	lizard-tail
Rosa sp.	wild rose
Rubus sp.	blackberry
Lotus americanus	prairie trefoil
Rhus radicans	poison ivy
Ilex decidua	deciduous holly
Berchimia scandens	supplejack
Ampelopsis arborea	pepper vine
Ampelopsis cordata	vine
Vitis sp.	wild grape
Bignonia sp.	crossvine
Campsis radicans	trumpet vine
Ruellia sp.	ruellia
Cephalanthus occidentalis	buttonbush
Artemisia sp.	wormwood
Pyrrhopappus sp.	false dandelion
Senecio sp.	groundsel

The regional vegetation of the Young Lake locality, consists of the Oak-Hickory Forest Type, the Loblolly Pine Forest subtype and the Cypress Bottoms Forest Type. This locality, because of standing water varying in depth from one to about six feet, is the more mesic of the localities in the Red River area. The local vegetation shows no major changes away from the lake but many aquatic and wet ground species are recorded here which were not found in any of the other localities. The local vegetation consists of the following species:

Arborescent species:

Pinus taeda	loblolly pine
Taxodium distichum	bald cypress
Salix nigra	willow
Betula nigra	river birch
Carya illinoensis	pecan
Quercus lyrata	overcup oak
Quercus nigra	water oak
Quercus phellos	willow oak
Quercus rubra	red oak
Celtis laevigata	southern hackberry
Ulmus americana	American elm
Ulmus crassifolia	cedar elm
Maclura pomifera	Bois d'Arc
Crataegus spathulata	hawthorn
Cercis canadensis	red bud
Gleditsia triacanthos	honey locust
Xanthoxylum clava-herculis	prickly ash
Acer negundo	box elder
Sapindus drummondii	chinaberry
Tilia americana	basswood
Cornus drummondii	rough-leaved dogwood
Diospyros virginiana	persimmon
Forestiera accuminata	swamp privet
Fraxinus pennsylvanica	green ash

Non-arborescent species:

Azolla sp.	water fern
Sagittaria sp.	arrowhead
Leersia sp.	cutgrass
Panicum agrostoides	red top panic grass
Zizaniopsis miliacea	water millet
Carex sp.	sedge
Eleocharis sp.	spike-rush
Scleria sp.	nut-rush
Spirodelia sp.	duck weed
Juncus tenuis	bog-rush
Smilax rotundifolia	greenbriar
Saururus cernuus	lizard-tail
Polygonum sp.	smartweed
Rumex sp.	sorrel
Ranunculus sp.	buttercup
Cocculus carolinus	moonseed
Podophyllum peltatum	may apple
Rosa sp.	wild rose
Rhus radicans	poison ivy
Ilex decidua	deciduous holly
Berchemia scandens	supplejack
Parthenocissus quinquefolia	Virginia creeper
Vitis sp.	wild grape

Myriophyllum sp.	water milfoil
Hottonia inflata	water violet
Penstemon sp.	beard tongue
Utricularia sp.	bladderwort
Cephalanthus occidentalis	buttonbush
Cirsium horridulum	yellow thistle
Vernonia sp.	ironweed
Xanthium sp.	cocklebur

The last locality in the Red River Area, Big Grassy Lake (OPC 1061), has a regional vegetation that is a mixture of the Oak-Pine Forest Type, the Loblolly Pine-Hardwood Forest Type and the Cypress Bottoms Forest Type. Because the sample area is extensively cultivated and burned every two to three years the local vegetation has largely been destroyed except for the larger trees. There are several species of grasses and forbs found here which are probably a result of the intense cultivation and burning. The local vegetation was composed of the following species:

Arborescent species:

Pinus taeda	loblolly pine
Populus deltoides	cottonwood
Carya buckleyi	black hickory
Carya illinoensis	pecan
Carya laciniosa	scaley-bark hickory
Quercus lyrata	overcup oak
Quercus phellos	black oak
Quercus rubra	red oak
Celtis laevigata	southern hackberry
Ulmus americana	American elm
Maclura pomifera	Bois d'Arc
Liquidambar styraciflua	sweet gum
Platanus occidentalis	sycamore
Cercis canadensis	red bud
Diospyros virginiana	persimmon
Fraxinus pennsylvanica	green ash

Non-arborescent species:

Zea mays	cultivated corn
Cyperus sp.	umbrella sedge
Scirpus sp.	bullrush
Cephalanthus occidentalis	buttonbush

SURFACE POLLEN SAMPLES

In order to interpret fossil pollen diagrams, it is necessary to relate them to modern surface pollen samples, and to their ecological significance. Modern surface pollen samples reveal the relationships between vegetation and the local pollen rain. Martin (1963, p. 15) used ooze contained in the bottom of metal-rim stock tanks, the soil surface, and fresh alluvial deposits. In this investigation of oxbow lake sediments, the soil surface technique, with some minor modifications, was used to determine the amount and type of modern pollen deposits. Some of the oxbow lakes, being cut-off from the river channel, have no circulation, so that the ooze on the bottom would most nearly resemble the ooze in the bottom of the stock tanks. However, the pollen collected in the ooze in the lake bottom and from the surface samples as well, are subjected to many modifying factors. Some of these factors are the action of bacteria, soil fungi, chemistry (in particular pH) and in some cases oxidation. Therefore, the lake bottom ooze and the surface samples are not as accurate as yearly collection of the modern pollen rain before it has been subjected to the above weathering processes.

In each sample locality a near-surface or surface soil sample was taken, the depth depending upon the compaction as well as whether the area had been cultivated or not. For the localities in which there was standing water, surface pollen percentages were determined from a sample zero to six inches below the surface. In other localities, especially those which are under cultivation, the surface pollen percentages were determined from a sample zero to one foot below the surface.

The histograms of the Washita River area in Caddo and Grady Counties, (figs. 3-5) show the surface pollen deposits to consist mostly of non-arborescent pollen, hereafter referred to as NAP. The average percentage of pollen preserved for the 13 types listed on the histogram are as follows. The NAP consists of Gramineae (35.2%), and other monocots (2.0%), Compositae (17.0%), Ambrosia and Helianthus (12.7%), Amaranths and Chenopods (6.3%), and ferns (0.17%). The average percentage of arborescent pollen, hereafter referred to as AP, is as follows: Pinus (2.8%), Quercus (8.3%), Carya (3.2%), Juglans (1.2%), Tilia and Ulmus (5.7%), Juniperus (4.0%) and Salix (2.8%). The figures indicate that of the total preserved surface pollen, 73.4%, or almost three-fourths of the total is NAP. This is to be expected because the area is in Tallgrass Prairie Type of Duck and Fletcher (1944) and the NAP producers are the dominants, in both numbers of individuals and species, of both the regional and local vegetation.

The Red River area in southeastern Oklahoma also shows the NAP dominant over the AP but only by about four percent. There are many more arborescent forms in this area, some of which contribute significantly to the surface pollen count, so in some areas more than the 13 pollen types of the Washita River area are used. The average relative percentage of preserved modern pollen contributed by the non-arborescent forms are as follows: Gramineae (20.4%) and all Monocots not grasses (1.1%), Compositae (15.0%), Ambrosia and Helianthus (10.3%), Amaranths and Chenopods (2.8%), and ferns (1.6%). The average relative percentage of preserved AP for this area is: Pinus (22.9%), Quercus (9.8%), Carya (10.0%), Juglans (tr.), Tilia and Ulmus (4.0%), Liquidambar (1.3%), which contributes the major portion of the pollen with Salix (0.8%), and Populus, Fraxinus, Betula, Alnus and Taxodium contributing traces (less than 0.5%). The area is a mixture of the Oak-Pine Forest Type, the Oak-Hickory Forest Type and the Cypress Bottoms Forest Type. Because the majority of the area is forested, the NAP normally should be lower than the AP. However, the slight dominance of the NAP may be explained by the transportation factor, that is, most of the NAP produced by non-arborescent plants falls to the ground in the immediate vicinity of the parent plant and is better preserved because of this. However, much of the pollen produced by arborescent plants is transported, in some cases by specialized structures such as the bladders on pine pollen, from the producing plants. Therefore the AP relative percentage of preserved pollen on the surface should not only be lower than would be expected in a forested area, but also less likely to be preserved.

FOSSIL POLLEN RECORD

Palynological investigation of oxbow lake sediments was undertaken with two main objectives: (1) to study the vertical sequence of the pollen flora to determine if any change took place which would indicate a climatic change during deposition of the sediments and (2) to determine the usefulness of spores and pollen in dating the sediments of oxbow lakes. The statistical approach to these two objectives involved the counting of 200 specimens from each stratigraphic level. These counts were plotted as relative percentages for each stratigraphic level (figs. 3-9). The results of this study indicate that certain species have definite distributional patterns which are interpreted as the result of ecological changes at the site of deposition. Thirteen of the more significant genera, chosen because of abundance as well as ecologic significance, were plotted on the histograms.

The attainment of the two main objectives stated above depends upon the palynological spectrum which appears, at least in part, related to the Hypsithermal Period in the pollen diagrams. This period, referred to by various authors as the Hypsithermal Period, Xerothermic Period, Altithermal Period and Climatic Optimum, occurred approximately 7,000 to 3,000 years B. P. (Deevey and Flint, 1957; Sears, 1961a) and is recognized in nearly all parts of the world. This period is indicated in the pollen diagrams by the high percentage of NAP as compared to AP and in Oklahoma, by the fact that some of the soils appear to be out of phase with the climate. Sears and Couch (1932, p. 67), state that Thornthwaite, in his studies of climate and soil types in Oklahoma, observed that present climatic boundaries do not correspond with the appropriate soil limits but lie west of them. Pollen found by them in the same study indicates that during the deposition of certain pollen types, particularly oak, in two different levels, the climatic conditions were those of central or eastern Oklahoma which are notably drier than the present climate of central Arkansas. These out of phase soils are taken as evidence that warmer temperatures than present occurred in recent past presumably during the Hypsithermal Period. The palynological evidence shows that the vegetation was mostly grassland with scattered relict stands of earlier vegetation growing in favorably protected areas. After the close of the Hypsithermal Period and the return of cooler temperatures and more moisture, the grassland was partially replaced by deciduous and coniferous species (Wilson, 1963, p. 18). The AP percentage increased in the sedimentary deposits as the plants began to migrate southward and westward in Oklahoma.

The palynology of the collected sections is discussed under two major geographic and physiographic areas, the

Washita River Area and the Red River Area.

In the Washita River Area three sections were collected, the Anadarko #1 Terrace Oxbow, the Anadarko #2 Terrace Oxbow, and the Chickasha Oxbow, all of which will be described individually.

Anadarko #1 Terrace Oxbow

The section collected from the Anadarko #1 Terrace Oxbow shows several definite successional trends in the pollen flora which are interpreted as reflecting changes in ecology, particularly climate. The NAP, represented by the Gramineae, Compositae and other monocots, show two successional trends which are also reflected by the AP composed of pine, hickory and elm. The basal part of the section, 20 to 24 feet in depth, (levels A and B), is composed of coarse to medium sand which appears to represent the old river channel. These two levels are completely barren of spores, pollen and other aquatic life remains with the exception of sponge spicules. Level C (19-20 feet) immediately above the barren samples contains abundant spores and pollen with the NAP (91 percent) dominant over the AP (9 percent). The depth from 18 to 19 feet (level D) is another barren layer of medium-coarse sand with some small gravel. Above this level is a two-foot section, 16 to 18 feet in depth which is abundant in pollen and spores. These two one-foot sections (levels E and F), still show the NAP dominant over the AP. In level E this is 89 percent NAP to 11 percent AP and in level F, 84 percent NAP to 16 percent AP. In level G, at a depth of 15 to 16 feet, occurs another barren layer of medium-coarse sand and small gravels. From a depth of 15 feet upward to 10 feet (levels H through L), the NAP is gradually replaced by AP until in level L the AP is 94 percent of the pollen spectrum. Above level L occurs another two-foot layer of barren medium-grained sand (level M, 8 to 10 feet in depth). From eight feet to the surface (levels N through U) is a continuous pollen record. In these eight feet of sediment the pollen assemblage is dominated by AP in levels N through R. From level S through U, the top three feet of the section, the NAP replaces the AP as the dominant pollen type. Therefore according to the pollen diagram, the Hypsithermal Period is represented in levels C through I based on the complete dominance of the NAP over the AP. In levels J through R, the trend is reversed and the AP is dominant over the NAP. The dominance of the AP is interpreted as representing the native regional and local vegetation. In the top three feet, levels S through U, the NAP is again the dominant component and is interpreted as being, at least in part, the influence of man and cultivation. This influence of man should have decreased the relative percentage of AP due to the cutting and clearing of the timber, thus opening new areas for the invasion of the Gramineae and Compositae along with the cultivation of feed grains and pasture. The top one foot,

FIGURE 3

PALYNOLOGICAL SUCCESSION IN THE ANADARKO NO. 1 TERRACE OXBOW, CADDO COUNTY, OKLAHOMA

OPC 1099

Depth in feet	Pinus	Quercus	Carya	Juglans	Tilia and Ulmus	Juniperus	Salix	Compositae	Amaranths and Chenopods	Gramineae	Ambrosia and Helianthus	Other Monocots (not grasses)	Ferns	
0–1 U	2.5	8.0	1.0	1.5	5.5	3.0	2.0	20.5	7.0	41.0	7.5	1.5		
1–2 T	7.0	5.5	5.0	7.0	10.0	1.5	0.5	22.5	4.0	35.0	2.0			
2–3 S	7.0	12.0	9.0	10.0	7.0	0.5		24.0	2.5	20.0	8.0			
3–4 R	6.0	20.5	15.0	12.0	10.0			17.5		14.0	5.0			
4–5 Q	8.5	23.0	20.0	14.5	11.0			8.0		12.0	3.0			
5–6 P	6.0	22.5	22.0	15.0	10.0			8.5		13.0	3.0			
6–7 O	10.0	30.0	26.0	12.0	12.0		2.0	1.0		2.5	4.0		0.5	
7–8 N	12.0	28.5	22.0	10.0	12.0		3.5	1.5	0.5	3.0	6.0		1.5	
8–10 M	MEDIUM RIVER SAND													
10–11 L	8.0	33.0	28.0	14.0	10.5			3.0		3.0	0.5			
11–12 K	6.5	30.5	30.5	10.0	8.5			5.0		5.5	3.5			
12–13 J	6.0	25.0	28.5	7.0	8.0			8.5	1.0	9.0	7.0			
13–14 I	4.5	18.5	20.0	3.0	5.0			12.0	1.5	22.5	13.0			
14–15 H	18.0	10.5	13.0		7.5		2.0	15.0	2.0	20.0	19.5	0.5	2.0	
15–16 G	MEDIUM TO COARSE RIVER SAND AND SMALL GRAVEL													
16–17 F	3.0	5.5	4.0		4.0			21.5	6.0	31.5	22.0	2.5		
17–18 E	1.5	0.5	0.5		5.0		3.0	20.0	10.0	28.5	27.5	3.0	0.5	
18–19 D	MEDIUM TO COARSE RIVER SAND AND SMALL GRAVEL													
19–20 C	2.0	1.0	0.5		3.0		2.5	19.5	7.0	30.0	31.5	2.0	1.0	
20–22 B	COARSE TO MEDIUM RIVER SAND													
22–24 A	COARSE TO MEDIUM RIVER SAND													

level U, should contain the closest relative percent of the preserved surface pollen rain.

The barren layers of sand interspersed throughout the section apparently represent either the flooding of the oxbow and rapid deposition or the resumption of the oxbow as a relief channel in time of flood. The presence of gravels in these sands would support the idea that the sand was laid down due to relatively rapid flowage in the river.

Anadarko #2 Terrace Oxbow

The section collected from the Anadarko #2 Terrace Oxbow (fig. 4) shows a pollen profile similar to that of the Anadarko #1 Terrace Oxbow except that this profile is more continuous, having only one barren sand deposit in the profile. The bottom three feet, from 17 feet upward to 14 feet (levels A through C) of this profile, shows an almost equal distribution between the NAP and AP, but with the AP slightly dominant by about 10 percent. Above this level, from 14 feet upward to 10 feet (levels D through G), there is a definite NAP dominance with level E having the highest percentage of NAP, (94 percent). This four-foot interval of NAP dominance is interpreted as representing the Hypsithermal Period. Above the 10-foot interval (level G) upward to the six-foot interval (levels H through K) the NAP is gradually replaced by AP. This four-foot interval of AP dominance is interpreted as representing the native vegetation. The next three feet (levels I through N),

FIGURE 4

PALYNOLOGICAL SUCCESSION IN THE ANADARKO NO. 2 OXBOW, CADDO COUNTY, OKLAHOMA

OPC 1068

Depth in inches	Pinus	Quercus	Carya	Juglans	Tilia and Ulmus	Juniperus	Salix	Compositae	Amaranths and Chenopods	Gramineae	Ambrosia and Helianthus	Other Monocots (not grasses)	Ferns
Q 0-1	3.0	10.0	4.0	2.0	8.0	2.0	3.0	15.5	5.0	38.5	10.0	2.0	
P 1-2	8.0	7.0	8.0	5.0	10.0	2.0	5.0	18.5	2.5	20.0	10.0	2.0	2.0
O 2-3	10.0	5.0	10.0	8.5	13.0		10.0	10.0	7.0	7.0	14.5		5.0
N 3-4													
M 4-5	MEDIUM RIVER SAND												
L 5-6													
K 6-7	7.0	11.5	8.0	8.0	9.5		2.0	12.0	10.5	17.0	12.5	1.5	0.5
J 7-8	5.0	19.5	14.0	9.5	15.0		0.5	11.0	4.5	10.0	11.0		
I 8-9	3.0	27.5	24.5	15.0	21.5			3.5		2.0	3.0		
H 9-10	3.5	32.0	30.5	10.0	14.5			3.5		3.0	3.0		
G 10-11	2.0	20.0	18.5	4.0	6.0			15.5	2.0	20.5	10.0	2.0	
F 11-12	2.5	13.0	6.0		4.5			20.0	6.0	27.5	15.0	5.5	
E 12-13		5.0	2.5		4.0			24.5	10.0	33.5	20.5	5.0	
D 13-14	3.0	10.0	5.0		5.0			19.5	8.0	30.5	15.5	3.5	
C 14-15	5.0	15.5	11.5	10.0	9.0			14.0	3.0	22.0	8.0	1.0	
B 15-16	6.0	19.0	18.0	4.5	5.5			15.0	2.0	20.0	10.0		
A 16-17	5.0	17.5	16.5	8.5	10.0			20.0	0.5	17.5	4.5		

consist of a barren medium river sand, which probably is a result of the processes previously mentioned for the Anadarko #1 Terrace Oxbow. In the top three feet of the section the AP dominance declines sharply and is replaced by NAP, possibly the result of man's land clearing and cultivation. The top one foot of sediment should therefore represent essentially the relative percent of the preserved surface pollen rain.

Chickasha Oxbow

The section collected at this locality (fig 5) is the most complete of all the sections in the Washita River Area. It is not broken by any barren sand intervals and appears to have the entire Hypsithermal Period represented; whereas in the other sections, particularly the Anadarko #1 Terrace Oxbow, is disrupted by barren sand lenses. The bottom eight feet of the profile, from 16 feet to 24 feet (levels A through E) shows the AP dominant with pine the dominant component. Pine reaches its highest percentage, 64 percent, in level B. The high percentage of pine along with the other AP contributors is thought to represent the pre-Hypsithermal vegetation. From the top of the 16-foot interval upward to the top of the eight-foot interval (levels F through K) the AP is almost completely replaced by NAP. The NAP reaches a maximum of 97 percent in level H. This dominance of the NAP throughout this interval appears to represent the Hypsithermal Period. In levels L through O (8 feet to 4 feet in depth), the trend is reversed and the

FIGURE 5
PALYNOLOGICAL SUCCESSION IN THE CHICKASHA OXBOW, GRADY COUNTY, OKLAHOMA
OPC 1004

Depth IN Feet	Pinus	Quercus	Carya	Juglans	Tilia and Ulmus	Juniperus	Salix	Compositae	Amaranths and Chenopods	Gramineae	Ambrosia and Helianthus	Other Monocots (not grasses)	Ferns
0-1 S	3.0	7.0	4.5		3.5	7.0	3.5	15.0	7.0	26.0	20.5	2.5	0.5
1-2 R	7.5	6.0	3.0	3.5	5.0	5.0	2.0	20.0	5.0	19.0	21.5	1.0	1.0
2-3 Q	6.5	10.0	9.5	5.5	3.0	5.0	1.0	20.5	3.5	16.0	18.0	1.0	0.5
3-4 P	6.0	18.0	12.0	7.0	3.0	4.0	0.5	14.0	0.5	16.5	15.5	1.5	1.0
4-5 O	7.0	28.0	17.0	10.0	3.0		0.5	9.0		15.0	10.0	0.5	
5-6 N	7.0	30.0	20.5	13.0	4.5			9.0		9.0	7.0		
6-7 M	20.0	27.0	13.5	10.0	4.5			10.0		10.0	7.0		
7-8 L	38.0	19.5	7.5	5.0	7.5			8.0		10.0	4.5		
8-9 K	5.5	4.0	4.0	2.0	8.0			14.0	1.5	34.5	21.5	5.0	
9-10 J	2.0	0.5			0.5			14.0	3.5	41.0	24.5	5.0	
10-12 I	2.0	1.5	1.0		0.5			19.5	5.5	43.0	20.5	8.0	
12-13 H	2.0	0.5			0.5			20.0	8.0	41.5	22.5	5.0	
13-14 G	2.0	2.5	5.0	5.0	1.5			17.0	8.0	37.5	19.0	3.5	
14-16 F	4.0	2.5	11.0	9.5	1.5			13.0	7.0	33.5	15.5	2.5	
16-17 E	20.5	15.0	13.5	12.0	4.0		3.0	9.0	2.0	11.5	14.5	1.5	3.5
17-18 D	25.0	14.5	11.0	10.0	3.0		2.0	7.0		10.5	14.5	1.5	2.0
18-21 C	45.0	10.0	6.0	8.0	1.0			10.0		11.5	7.5		
21-22 B	64.0	4.0	2.5	5.0				8.0	0.5	8.0	3.0		
22-24 A	54.0	7.0	5.5	9.0	1.0			15.5	4.5	14.0	8.0		1.5

NAP dominance is replaced by AP, which suggests cooling and possibly a more moist trend in climate. This four-foot interval is interpreted as being the native vegetation in the area. From four feet upward to the surface, (levels P through S), the NAP is again dominant over the AP possibly due to disturbance by man.

In the Red River Area in southeastern Oklahoma and adjacent Arkansas four sections were collected; Oxbow Lake "A", Jenkins Reilly Slough, Young Lake and Big Grassy Lake.

Oxbow Lake "A"

The section collected at this locality generally contains standing water and relatively unconsolidated sediments. The basal six inches of the section sampled is a barren coarse, sand interpreted to be sediments of an old channel. Above the sand in level A, occurs the beginning of a continuous pollen spectrum. Level A shows the AP to be more abundant than the NAP with pine (42 percent) making up the bulk of the AP. This level contains the pollen record that is predominantly pine which appears to represent part of the pre-Hypsithermal Period. It is unlikely that this six-inch segment contains the entire pre-Hypsithermal pollen record because of the instability of the river channel and what pollen is preserved is probably from the latest stages of that period. Levels B and C (15 to 25 inches) show a dominance of NAP over AP. In these levels the Gramineae and the Compositae are the major NAP contributors with pine

FIGURE 6
PALYNOLOGICAL SUCCESSION IN OXBOW LAKE "A" MC CURTAIN COUNTY, OKLAHOMA
OPC 1008

Depth in inches	Pinus	Quercus	Carya	Tilia and Ulmus	Liquidambar	Ambrosia and Helianthus	Cheno-Amaran	Compositae	Gramineae	All Monocots (not grasses)	Ferns	Salix
0-1 G	16.5	9.5	7.0	6.5	1.0	6.0	4.0	17.0	27.5	1.5	1.5	2.5
1-5 F	24.0	7.0	5.0	3.5		10.0	5.0	22.0	20.5	1.0	1.5	0.5
5-10 E	31.5	7.5	7.5	2.5		8.5	4.5	20.0	17.0	1.0		
10-15 D	39.5	8.0	4.5			12.5	5.0	15.5	15.0			
15-20 C	25.5	5.0	3.5			13.0	0.5	20.5	30.0	2.0		
20-25 B	24.5	10.0	3.0	1.5 (Ulmus)		7.0		17.5	32.0	3.0		
25-30 A	42.0	7.0	6.0	2.5		5.0		11.0	21.5	2.5	0.5	1.0
30-36	RIVER CHANNEL SEDIMENTS-COARSE SAND											

the major AP contributor. In level D (10 to 15 inches) the AP is again dominant over the NAP with pine pollen again the major constituent of the AP. The pollen in this level appears to be representative of the recent native vegetation of the area. Level E (5 to 10 inches), appears to show the influence of man's occupation of the area. Although the AP is still abundant the NAP shows a marked increase, possibly the result of clearing and cultivation. This effect is more evident above in level F (1 to 5 inches) where the NAP is dominant over the AP. Pine remains the major AP contributor throughout the entire sequence of sediments. The pollen in the top one inch of sediment can be taken as a typical sample of the preserved surface pollen rain. The NAP is dominant as one would expect in a cultivated area. Although the forests were cleared for grazing and cultivation, there is still a high percentage of AP in the top sample of sediments. It is higher than that encountered in the Washita River Area, which may be explained by the fact that in the Red River Area the cultivated fields are surrounded, for the most part, by Oak-Pine and Oak-Hickory forests. In the Washita River Area only open prairie are present.

Jenkins Reilly Slough

This deposit (fig. 7) is the deepest collected in the Red River Area. The sediments are not well compacted and although there was no standing water in the oxbow at the time of collecting (January, 1964), the material was

FIGURE 7

PALYNOLOGICAL SUCCESSION IN JENKINS RILLEY SLOUGH, MC CURTAIN COUNTY, OKLAHOMA

OPC 1062

Depth in inches	Pinus	Quercus	Carya	Juglans	Tilia and Ulmus	Liquidambar	Cheno-Amaranths	Ambrosia and Helianthus	Compositae	Gramineae	All Monocots (not grasses)	Ferns	Populus	Salix	Celtis	Fraxinus	Betula	Alnus	Taxodium	Rushes Sedges Typha
0-6 T	23.0	10.0	14.0	T	5.0	3.0	0.5	19.0	3.0	19.5	1.0		0.5	0.5	1.0	T				
6-12 S	28.0	12.0	11.0	1.0	2.0	2.0	3.0	12.0	11.0	13.0		0.5	1.5	0.5	1.0	1.0	1.0			
12-18 R	39.5	17.0	8.0	1.0	1.0	5.0	5.0	2.0	9.0	10.0				0.5	2.0					
18-24 Q	31.5	14.0	10.5	2.5	0.5	8.0	3.0	3.5	6.0	13.5				0.5	3.5					
24-30 P	27.0	15.0	11.0	1.0	2.5	1.5	2.5	6.5	3.5	17.0	5.5	0.5		2.0	4.0					
30-36 O	16.0	25.5	10.0		2.0	6.5	4.0	10.5	8.0	12.0	3.0			2.0	2.0					
36-42 N	20.0	18.5	15.0	1.0	2.0	4.0	2.5	12.0	10.0	14.0	1.0									
42-48 M	25.0	10.0	9.5	1.0	1.5	1.0	2.0	16.0	[illegible]	18.0	1.0									
48-54 L	18.5	7.0	5.5		4.0	2.0	4.0	18.5	18.0	20.5	2.0									
54-60 K	3.5	3.5	2.0	2.0			0.5	31.5	27.0	26.0	3.0	1.0								
60-66 J	COARSE RIVER CHANNEL SAND																			
66-72 I	2.5	5.0	4.0	2.0			4.5	21.0	22.5	34.5	4.0									
72-78 H	2.0	4.5	3.5	2.0	1.5 (Ulmus)		5.5	23.5	23.0	30.5	4.0									
78-84 G	7.5	11.5	8.0	3.0	1.5 (Ulmus)		1.5	21.0	18.5	26.0	0.5									
84-90 F	7.5	14.0	10.0	4.0	2.0 (Ulmus)		2.5	19.5	18.5	22.0					2.5	1.5				
90-96 E	7.0	23.0	15.0	4.0		2.0	3.0	12.5	14.0	17.5		1.0			3.5	1.5	1.0	1.0		
96-102 D	5.0	25.0	14.0	5.0	2.5	3.5	2.5	7.5	13.0	12.5		1.0	2.5	1.0	2.5	1.5	1.0			
102-108 C	7.5	2.0	4.0	3.0	4.0	5.0	8.5	4.0	10.0	10.0		5.0	7.0	3.5		4.0	5.0		3.0	13.5
108-114 B	8.0	22.0	21.5	3.0	1.0	1.0	1.0	9.5	5.0	10.5		1.0	3.0	2.0		1.5	3.0		2.0	5.0
114-120 A	MEDIUM TO COARSE RIVER CHANNEL SAND																			

saturated and resembled quickmud. The basal six-inch sample (level A), taken from a depth of 120 inches, consisted of barren, medium to coarse river sand. In the 24 inches (levels B through E) above the barren sand layer the AP is dominant over the NAP. Oak and hickory pollen are the most abundant of the AP and may be interpreted as being deposited from an Oak-Hickory pre-Hypsithermal forest. Pine also is present but it is not an important fossil element in the assemblage. The next 30 inches above (levels F through K) with the exception of level J, contains more NAP than AP. Level J is a barren coarse sand. Levels F through K with the NAP dominance, appears to represent the pollen record of the Hypsithermal Period. The AP comprises, on the average, only three percent of the pollen in this interval, with oak being the major contributor. In the 36 inches of sediment above the record of the Hypsithermal Period, the dominance of the NAP is replaced by AP. Beginning with level L, pine pollen is a major AP fossil and remains the dominant through level R. This 36 inches of sediment above the record of the Hypsithermal Period horizon is interpreted as containing the preserved pollen of the near recent native vegetation, which according to the pollen record, consisted predominantly of a pine-oak-hickory forest with some grasses and composites as an understory. This is essentially the same native vegetational composition that now exists in the area. The pollen in the top 12 inches (levels S and T) records the change in vegetation which was caused by clearing of the forests and cultivation. In these two levels there is a sharp decrease in the AP percentage with a corresponding rise in the NAP percentage. The top six inches (level T) also contains the preserved surface pollen rain, 57 percent of which is AP. The dominant contributors to this 57 percent AP are pine, oak, and hickory, the present vegetation of the area.

Young Lake

Young Lake (fig. 9) is an area of shallow, standing water. The samples studied were collected near the waters edge approximately 20 feet from the old shoreline. As in the previous localities, the basal samples, levels A and B, 12 inches thick, consist of a barren coarse river sand marking an old channel of the river. Level C, a sample from 18 to 24 inches and directly above the barren sand layers, shows the AP dominant over the NAP by a ratio of almost 3 to 1. Pine is the most abundant AP contributing 55 percent of the total 73 percent AP. This level appears to represent the pre-Hypsithermal vegetation which consisted primarily of a pine-oak forest. Above level C is a 12 inch segment (levels D and E) in which the NAP exceeds the AP as the dominant type. The sequence of samples showing the NAP dominance is believed to represent the pollen record of the Hypsithermal Period. The percentage of pine and oak pollen have decreased sharply but are still present. The

FIGURE 9
PALYNOLOGICAL SUCCESSION IN YOUNG LAKE MC CURTAIN COUNTY, OKLAHOMA
OPC 1007

Depth in inches	*Pinus*	*Quercus*	*Carya*	*Tilia* and *Ulmus*	*Ambrosia* and *Helianthus*	*Cheno-Amaranths*	*Compositae*	*Gramineae*	*Liquidambar*	*All Monocots (not Grasses)*	*Ferns*	
0-1 G	16.5	15.0	11.5	4.0	10.5	3.0	25.0	9.5	1.0	2.0	2.0	
1-6 F	48.0	9.0	22.0	1.0	2.0	2.5	10.0	3.0	0.5	1.0	1.0	
6-12 E	35.0	8.0	13.0		4.5	1.0	15.0	23.5				
12-18 D	21.5	6.5	9.0		5.0	0.5	18.0	29.5				
18-24 C	55.0	10.5	7.0		2.0	2.0	10.0	13.5				
24-30 B	R I V E R S A N D											
30-36 A												

vegetation of the Hypsithermal Period in this locality might be described as a pine-oak savannah. Level F, the top six inches again shows the AP dominance with pine, oak and hickory being the major AP contributors. This level may be interpreted as a pollen record of the native vegetation before forest clearing and cultivation. The native vegetation is predominantly the oak-pine forest type but with a possible extension of the hickory forests from the north. The oak-pine-hickory forest type is essentially the present vegetation of the area. These three pollen types are the major AP contributors (52 percent) in the top one inch of sediment, level G, and appears to be due to the disturbance of the native forest and cultivation by man.

Big Grassy Lake

Big Grassy Lake (fig. 8) has the most tightly compacted sediments of all areas sampled. The area has also been burned and cultivated intermittantly. The basal six-inch segment (level A) contains a barren coarse river sand similar to that in other localities. The 18-inch segment of sample above this barren level (levels A through C) shows the NAP dominant over the AP. Pine (averaging 25 percent) is the dominant AP producer closely followed by oak (averaging 16 percent). This interval of NAP dominance is thought to represent the pollen record of the Hypsithermal Period. Levels D through F, above the deposits of the Hypsithermal Period, are marked by an increase and eventual dominance of

FIGURE 8

PALYNOLOGICAL SUCCESSION IN BIG GRASSY LAKE, LITTLE RIVER COUNTY, ARKANSAS

OPC 1061

Depth in inches	Pinus	Quercus	Carya	Liquidambar	Tilia and Ulmus	Ambrosia and Helianthus	Cheno-Amaranths	Compositae	Gramineae	All Monocots (not Grasses)	Ferns
0-1 H	35.5	4.5	7.5		0.5	5.5	3.5	15.0	25.0		3.0
1-6 G	44.0	6.0	3.5	1.0		3.5	2.0	14.0	27.0	1.5	1.0
6-12 F	55.5	4.5	5.5	2.0		4.5	3.0	14.5	10.5		
12-18 E	55.5	4.5	14.5			3.0	3.0	10.5	15.0		
18-23 D	45.0	3.5	14.5			6.5	1.0	12.0	18.5	1.0	
23-28 C	36.0	7.0	8.0			7.5		15.5	25.5	1.0	
28-36 B	25.0	11.0	8.0			8.0	1.0	16.5	29.0	2.5	
36-42 A	16.0	16.0	7.5			10.0	2.0	17.0	31.5		
42-48 A'	COARSE RIVER SAND										

the AP over the NAP. Pine and hickory are the major AP producers with a small percentage (2 percent) of sweetgum (Liquidambar styraciflua) at the top in level F. This 18-inch segment is interpreted as containing the preserved pollen record of the pre-cultivation native vegetation which is mostly pine-oak forest with some minor stands of hickory. In the top six inches of the sequence (levels G and H) the NAP has increased in percentage but is not dominant over the AP, the ratio between AP and NAP being approximately 1:1. This increase of NAP and decrease of AP is thought to be a result of clearing and cultivation. The top one inch contains a record of the preserved modern pollen rain and pine is the dominant AP type. This is expected since the present regional vegetation is essentially a pine-oak-hickory forest.

RECYCLED FOSSILS

Recycling of fossils in palynological assemblages has been discussed in detail by Wilson (1964). Where recycled palynological material is recognized in an assemblage, it can be of great value in geomorphic and stratigraphic investigations. The recognition and understanding of recycled palynological material is important in interpreting paleogeographic conditions.

Recycling of older fossils into younger Pleistocene sediments has been reported by Cushing (1964) and Bond (1965b, 1965c). Cushing found redeposited Cretaceous pollen and hystrichosphaerids in late-Wisconsin age sediments of east-central Minnesota and Bond found similar fossils of Permian and Cretaceous ages in central and southeastern Oklahoma.

Samples from both the Washita River area and the Red River area contained recycled palynological fossils (Pl. V, figs. 8-15). A single speciman of _Lycospora_ (Pl. V, fig. 8), a spore of Mississippian-Permian age associated with _Lepidostrobus_ and _Lepidocarpon_, a pollen grain (Pl. V, fig. 11), which is assigned to _Ephedra_, a gnetalean genus having a geologic range from Permian to Recent were found. However, Bond (1965c) has shown that these forms are not Recent species. Two other Permian forms were observed. Tririctus sp., a trilete spore (Pl. V., fig. 9, 10) which is tentatively placed with the Selaginellaceae because of the trilete crest and similarity to some modern Selaginella species (Wilson, 1962, p. 12) and Lueckisporites virkkiae (Pl. V., fig. 12) a saccate pollen grain assigned to the Coniferales. Three genera of hystrichosphaerids were also recorded: Hystrichosphaeridium (Pl. V., fig. 13), Cannosphaeropsis (Pl. V., fig. 14), and Baltisphaeridium (Pl. V., fig. 15), common Cretaceous-Tertiary genera (Bond 1965b, p. 126). The order Hystrichosphaeridia, to which the latter three genera belong, comprises a group of microscopic organisms with characteristics suggesting a close phylogenetic affinity to the Protozoa. The group as a whole has a long geologic range from Precambrian to Recent (Wilson and Hoffmeister, 1955).

Unquestionably all of these fossils (Pl. V., figs. 8-15) have been recycled from Late Paleozoic, Permian rocks and presumably from Cretaceous strata in the Texas Panhandle, southwestern Kansas, eastern Colorado and western and central Oklahoma. This recycling of geologically older fossils into younger Pleistocene sediments was a result of extensive erosion during the Wisconsinan Stage of the Pleistocene Epoch.

DISCUSSION

The age determination of the oxbow-lake sediments in this investigation depends largely upon the recognition of Hypsithermal Period fossils preserved in the sediments. This pollen record furnishes a record of climatic fluctuations during the deposition of the oxbow-lake sediments. It is generally agreed by palynologists that a high percentage of non-arborescent pollen (NAP) in the Middle West can be interpreted as meaning a warmer and drier climate than existed during depositional time dominated by arborescent pollen (AP). Pine, oak and hickory pollen are the dominant AP forms which indicate, in Oklahoma, cooler and more moist climatic conditions. Pine pollen has an erratic distribution through all of the pollen spectra in central Oklahoma.

The distribution of living pine, as shown in the vegetational analysis part of this investigation, is restricted to the Mesozoic sandstones of the Oklahoma Panhandle, the alluvial sands of southeastern Oklahoma and the cherts of eastern Oklahoma.

In both the Anadarko #1 Terrace Oxbow and the Anadarko #2 Terrace Oxbow the maximum percentage of pine pollen recorded was 12 percent, and this was, in all cases, directly above a barren sand layer. Faegri and Iversen (1964, p. 102) state that because pine produces great quantities of pollen, 10 percent or less pine pollen is of no significance and indicates that pine scarcely grew in the area. Because figures 3 and 4 show the pine percentage lower than 10 percent throughout the entire sequence, except in the segment directly above a sand layer, pine probably was not an important part of the vegetational composition of the area. The increase of pine pollen above the sand layers may be due to several factors: (1) Pine pollen may have been washed in and deposited in the late stages of deposition in more quiet water after a torrential runoff. The pine pollen washed in may have been due to a "pine period" in the Rocky Mountains or the higher elevations of the Oklahoma Panhandle. The pollen was transported down the rivers as well as blown into the oxbow during the last stages of the sand deposition as well as after the sand deposition. (2) Another possibility could be that the influx of water necessary to deposit the sand layers contributed enough moisture, along with enough sand content in the soil to allow small stands of pine to become established. This theory has some opposition as stated by Oosting (1948) in that the moisture range of pine, as a genus, is quite variable from dry sand plains to the edges of bogs and swamps. (3) Because of the nature of relative numbers, an increase in the percentage of pine pollen is not absolute proof of an increase in pine forest growth, and under unfavorable climatic conditions in which local pollen production is reduced, there could be a relative increase in the amount of pine pollen at the site of deposition (Martin and Mehringer, 1965, p. 443).

The Chickasha Oxbow (fig. 5) has two intervals in the pollen sequence which show extremely high pine pollen frequencies. The basal eight feet is dominated by AP, the bulk of which is pine pollen. This high pine pollen concentration is probably part of the pre-Hypsithermal Period vegetation because the cool, moist climate preceeding the Hypsithermal Period would be favorable for pine forest growth. Another large pine pollen concentration is found in a two-foot layer (levels L and M), directly above the pollen record at the close of the Hypsithermal Period. If normal ecological succession was followed, pine pollen should decrease slowly upward through the section and pine trees might be found growing in the area at the present time. Instead, this high percentage of pine pollen (33 percent) is found in only two feet of sediment. There are no pine trees, except cultivated ones in the area and none are present in the Arbuckle or Wichita Mountains in what should be quite favorable areas. Pine, if it had been present, may have been destroyed by the many prairie fires of the past. This might explain the low pine pollen percent in the upper three feet (levels Q, R, and S).

In the Red River Area three localities in Oklahoma; Oxbow Lake "A" (OPC 1008), Jenkins Reilly Slough (OPC 1062), and Young Lake (OPC 1007) and one locality, Big Grassy Lake (OPC 1061) in Little River County, Arkansas were studied. In these localities the pine as well as the other AP forms seem to follow the normal trend of ecological succession in response to climatic change. Pine is the major dominant of the AP at or near the base of all sections studied in this area. It decreases toward the top and it, as well as the other AP producers, is replaced by NAP. The NAP dominance is interpreted to represent the record of the Hypsithermal Period. At the close of the Hypsithermal Period, the NAP is replaced by AP, with pine the major dominant. Pine and the other AP forms then decrease at the top probably as a result of clearing and cultivation.

SUMMARY

The objectives of this investigation were to determine, by means of pollen analysis, the nature, successional history, environmental significance and relative ages of oxbow lake deposits in central and southeastern Oklahoma.

The surface pollen samples at each locality were collected in order to determine the pollen contribution of the present vegetation to the sediments. The results of this study furnished useful criteria for interpretation of fossil pollen assemblages.

Statistical results of pollen analysis of oxbow lake sediments are presented in histogram form (figs. 3-9) and palynological fence diagrams (figs. 10-11). Dansereau (1951) established the terms *Graminetum*, *Pinetum*, *Quercetum*, *Caryetum* used on the palynological fence diagrams. The terms are listed in order of dominance. For example, *Graminetum* refers to a vegetation type dominated by grasses (Gramineae). *Quercetum*-*Caryetum*-*Pinetum* refers to a forest vegetation dominated by oak-hickory-pine with oak (*Quercus*) the dominant of the three. *Pinetum*-*Quercetum* is essentially a pine-oak forest with pine the dominant.

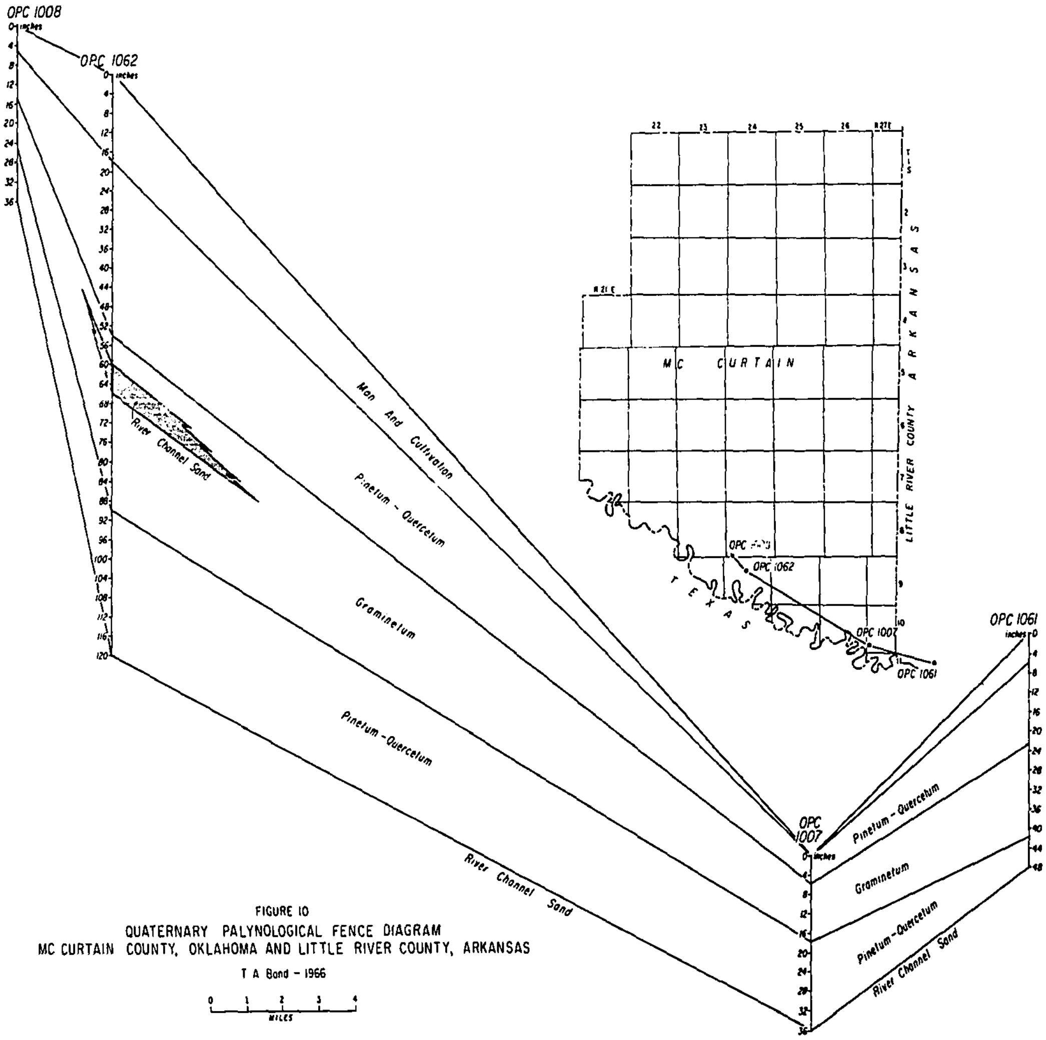
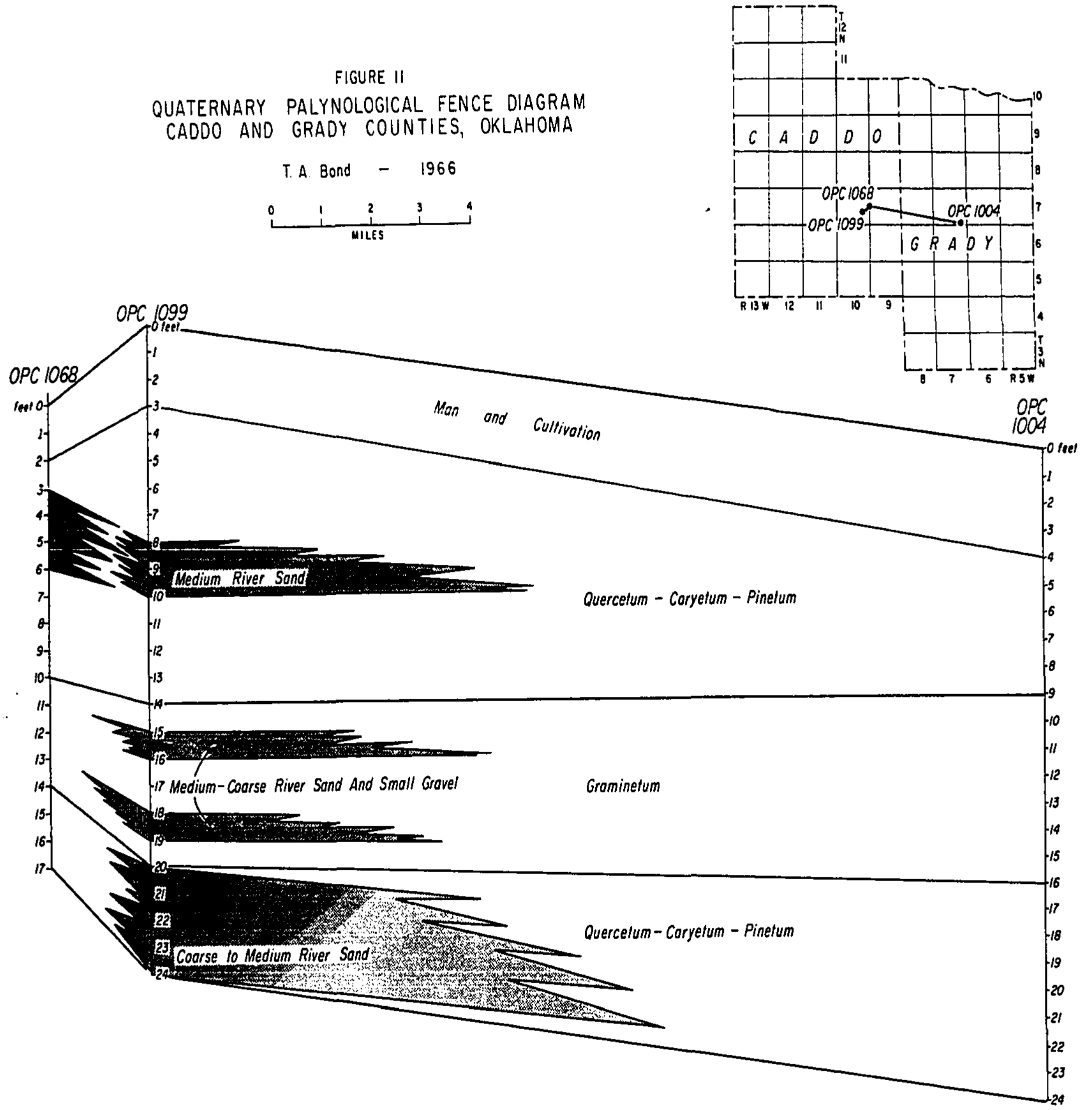


FIGURE 10
QUATERNARY PALYNOLOGICAL FENCE DIAGRAM
MC CURTAIN COUNTY, OKLAHOMA AND LITTLE RIVER COUNTY, ARKANSAS
T A Bond - 1966

FIGURE 11

QUATERNARY PALYNOLOGICAL FENCE DIAGRAM
CADDO AND GRADY COUNTIES, OKLAHOMA

T. A. Bond — 1966



Oxbow lake deposits of both areas are believed to be Late Wisconsinan or early Postglacial in age, even though the oxbow lakes themselves may not be found on Wisconsin age terraces. The basis for this late Wisconsinan or early Postglacial age dating is the pollen record of the Hypsithermal Period present in the oxbow lake sediments. As shown in figures 10 and 11 the Hypsithermal Period (Graminetum) occurs at a different level in each deposit and appears to be due to sedimentation rate as well as source areas of sediment. Therefore spores and pollen are useful for dating sediments of oxbow lakes, particularly in conjunction with Carbon-14 dates. The Washita River oxbow lakes assemblages were compared with those of the Domebo Site and the Carbon-14 dates available at that locality. On comparison of pollen profiles it appears that the Washita River oxbows are, on an average, older than 7,000 years B. P. and younger than 10,123 years B. P. which would be late Wisconsinan. Also there is no record of the blue-black clay deposits in the Washita River oxbows. The sterile sand and gravel layers in the two sections collected at Anadarko are the result of extensive cutting and filling and reworking of terrace deposits. Evidence of this fact is supported by their present position on the edge of the floodplain. The Chickasha Oxbow has no sand layers present. It is thought that the Chickasha Oxbow is slightly older than the two Anadarko localities because of the record of the pre-Hypsithermal vegetation which is not present in the two

Anadarko localities. There is evidence that the Chickasha Oxbow may have been located on a terrace, in which case it would not receive the extensive reworking that the two Anadarko localities on the floodplain underwent. Later as the channel shifted to the east, the oxbow was re-excavated and lowered onto the floodplain, its present position. The location of this oxbow, directly against the sloping sides of the terrace support this theory.

The oxbows of the Red River area are also late Wisconsinan in age. The recognition of the Hypsithermal Period in all the localities supports this age date. This date cannot be as closely interpreted as the Washita River area because there are presently no Carbon-14 dates available. However, stratigraphic evidence supports a late Wisconsinan date. The Red River basin stands in a unique position as it is the major western tributary to the Mississippi River that, at least in its headwater region, has not been directly influenced by either mountain or continental glaciation. Therefore, the evidence of cutting and filling of its valley has been well preserved, and the stratigraphy thoroughly investigated (Frey and Leonard, 1957; 1963). These periods of valley cutting in the Red River basin were: (1) Tertiary, (2) early Nebraskan, (3) early Kansan, (4) early Illinoian, (5) early Wisconsinan (probably early Altonian), (6) Two-creekan and early Valderean, (7) minor trenching during the Recent. Episodes of valley alluviation were during: (1)

Neogene, (2) late Nebraskan and earliest Aftonian, (3) late Kansan and earliest Yarmouthian, (4) late Illinoian and earliest Sangamon (which agrees with Kapp, 1965), (5) the Woodfordian substage of the Wisconsinan, (6) the late part of the Valderean substage of the Wisconsinan and (7) minor alluviation during the Recent, (Frye and Leonard, 1963, p. 31-32). Therefore the Red River basin of Texas and Oklahoma records the history of the Pleistocene in a series of descending alluvial terraces deposited, for the most part, during the retreatal phase of their appropriate glacial cycles (Frye, 1961, p. 603). In the Red River and Bowie Counties of Texas, directly across the river from the area of this investigation, there is present the Hardeman (Kansan) terrace, below which is a terrace of Illinoian age which in turn is below the Ambrose (early Wisconsinan) terrace (Frye and Leonard, 1963, p. 21). Below this sequence is the present floodplain of the Red River. If the above terrace sequence is followed, the floodplain, stratigraphically would be late Wisconsinan with some Recent alluviation. This evidence supports a late Wisconsinan age for the oxbow lakes on the present floodplain because the floodplain itself lies below the level of the older as well as the early Wisconsinan terraces. The sediment above the Hypsithermal Period in the pollen profiles of these lakes could be attributed to Recent alluviation.

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APPENDIX

Plate I

Figure

1. <u>Rhizophagites</u> sp. A
38.3 x 35.7 microns; OPC 1004A-1-2

2, 8. <u>Rhizophagites</u> sp. B.
(2) 22.9 microns; OPC 1004N-4-1
(8) 20.4 microns; OPC 1004D-3-1

3, 4. Fungus sp. A
(3) 63.6 microns; OPC 1004A-6-4
(4) 51.0 microns; OPC 1004A-4-2

5. Fungus sp. B
30.6 x 20.4 microns; OPC 1004M-1-2

6. Fungus sp. C
47.5 x 17.5 microns; OPC 1004N-2-1

7. Fungus sp. D
28.0 x 17.8 microns; OPC 1004A-5-1

9. Fungus sp. E
76.5 x 22.9 microns; OPC 1004R-2-1

10-13. <u>Oedogonium</u> sp.
(10) 76.5 x 33.1 microns; OPC 1008B-2-4
(11) 229.5 x 102.0 microns; OPC 1061A-1-2
(12) 216.7 x 89.2 microns; OPC 1062T-1-4
(13) 436.0 x 89.2 microns; OPC 1008G-2-2

14,15. <u>Dryopteris</u> sp.
(14) 79.0 x 53.5 microns; OPC 1004J-5-2
(15) 89.2 x 63.7 microns; OPC 1004E-3-1

16. <u>Polystichum</u> sp.
30.6 x 25.5 microns; OPC 1004H-3-2

PLATE I

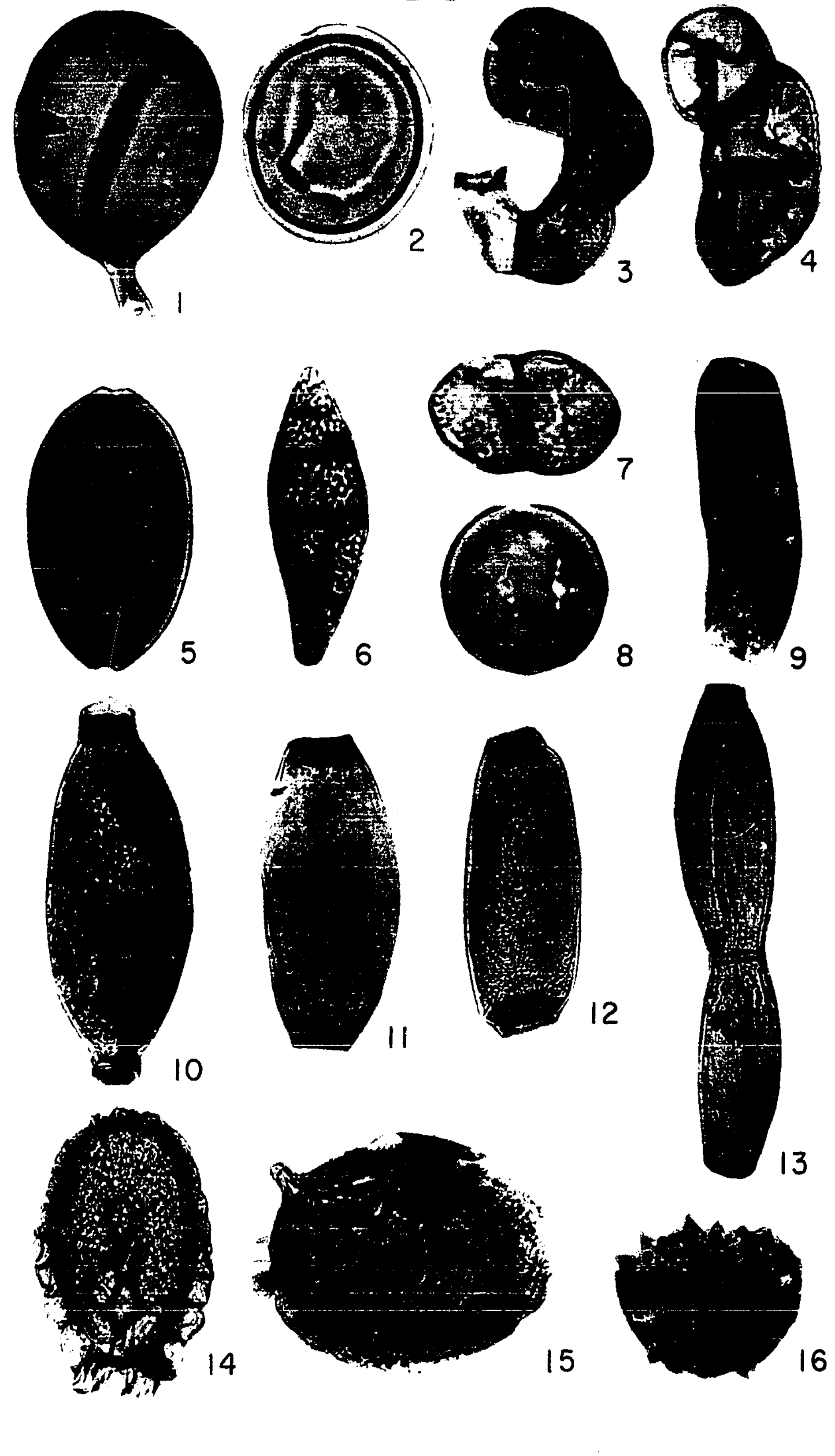

Plate II

Figure

1-3. Fern spores
(1) 20.4 microns; OPC 1004P-1-2
(2) 20.4 microns; OPC 1008B-1-1
(3) 17.8 x 20.4 microns; OPC 1004A-1-4

4. *Helianthus* sp.
22.9 microns; OPC 1004A-2-3

5. *Polygonum* sp. A
37.5 microns; OPC 1061F-2-1

6, 7. *Polygonum* sp. B.
(6) 33.0 microns, low focal plane; OPC 1007F-1-10
(7) 33.0 microns, high focal plane; OPC 1007F-1-10

8. Liliaceae pollen type A
28.0 x 20.0 microns; OPC 1004Q-4-1

9. *Chenopodium* sp. A
22.5 microns; OPC 1004D-1-1

10. *Chenopodium* sp. B.
25.0 microns; OPC 1004F-3-1

11. *Ambrosia* sp.
20.0 microns; OPC 1004E-1-4

12. *Aster* sp.
25.0 microns; OPC 1004Q-4-2

13. Onagraceae pollen type A
51.0 microns; OPC 1061H-3-3

14, 15. Compositae pollen type A
(14) 51.0 microns, high focal plane; OPC 1004J-4-1
(15) 51.0 microns, low focal plane; OPC 1004J-4-1

16. Compositae pollen type B
43.3 x 38.2 microns; OPC 1062D-5-1

17. *Taraxacum* sp.
30.6 microns; OPC 1004A-4-1

18. Compositae pollen type C
20.4 microns; OPC 1004E-1-2

19, 21. *Myriophyllum* sp.
(19) 22.9 microns; OPC 1007C-8-1
(21) 25.5 microns; OPC 1007C-10-2

Plate II-Continued

Figure

20. Compositae pollen type D
25.5 microns; OPC 1062D-3-3

PLATE II

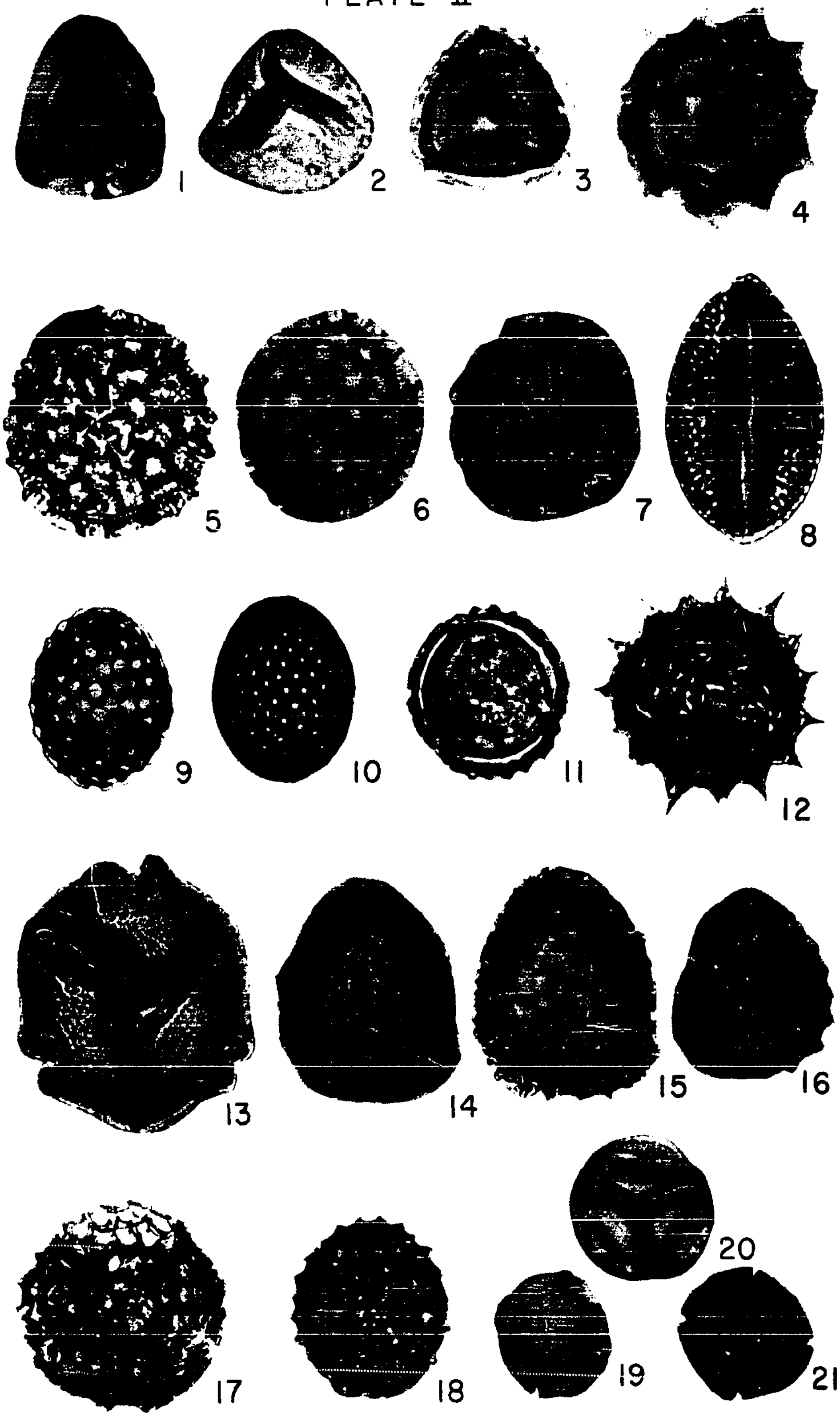

Plate III

Figure

1. *Scirpus* sp.
   71.4 x 61.2 microns; OPC 1004C-3-1

2. *Setaria* sp.
   45.0 x 37.5 microns; OPC 1004H-5-1

3-11. Gramineae pollen types
   (3) 53.5 x 28.0 microns; OPC 1004A-1-1
   (4) 33.1 x 17.8 microns; OPC 1004N-3-3
   (5) 22.9 x 17.8 microns; OPC 1004N-3-2
   (6) 102.0 x 51.0 microns; OPC 1061D-5-1
   (7) 45.9 x 30.6 microns; OPC 1004I-2-1
   (8) 63.7 x 25.5 microns; OPC 1061D-6-2
   (9) 96.0 x 25.0 microns; OPC 1061D-4-2
   (10) 20.4 x 56.1 microns; OPC 1004A-6-2
   (11) 30.5 x 16.5 microns; OPC 1061H-2-3

12,13. *Polypodium* sp.
   (12) 58.3 x 28.0 microns; OPC 1062P-1-3
   (13) 53.5 x 28.0 microns; OPC 1062E-3-4

14. Liliaceae pollen type B
   102.0 x 32.2 microns; OPC 1061B-5-1

15. *Ilex* sp.
   51.0 x 25.5 microns; OPC 1062D-2-1

16,19. *Salix* sp.
   (16) 25.5 x 17.8 microns; OPC 1004A-6-5
   (19) 25.5 x 15.0 microns; OPC 1004D-5-1

17. *Fraxinus* sp.
   22.5 x 17.5 microns; OPC 1004M-4-1

18. *Cephalanthus* sp.
   21.0 x 15.0 microns; OPC 1004H-1-4

PLATE III

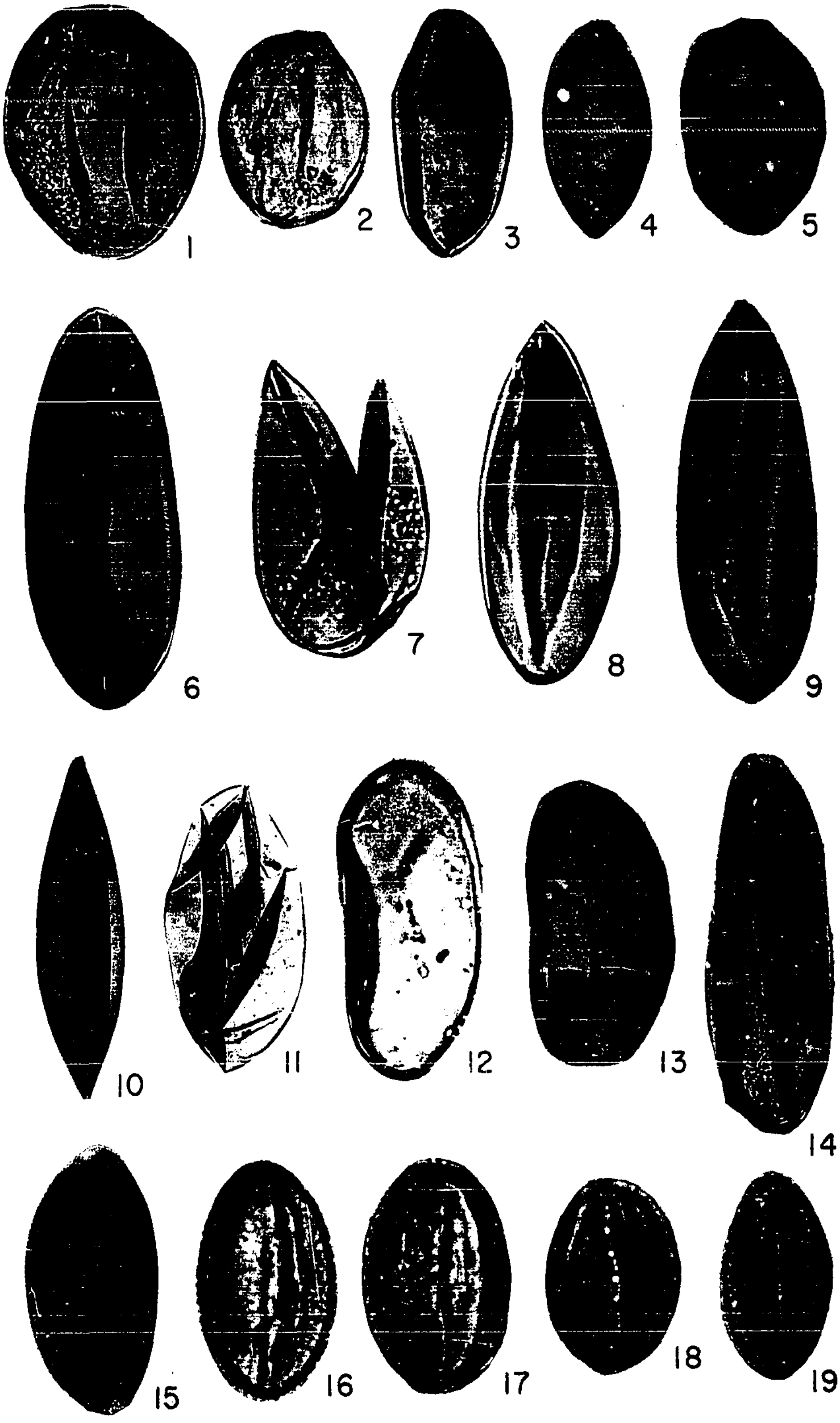

Plate IV

Figure

1, 2. Liliaceae pollen type C
(1) 76.5 x 37.5 microns; low focal plane; OPC 1007E-8-8
(2) 76.5 x 37.5 microns; high focal plane; OPC 1007E-8-8

3. Monosulcate pollen type A
51.0 x 25.5 microns; OPC 1007C-10-5

4. Liliaceae pollen type D
50.5 x 23.7 microns; OPC 1004C-4-4

5. Nymphaceae pollen type
63.7 x 30.6 microns; OPC 1004F-5-2

6. *Rhus* sp.
38.2 x 25.0 microns; OPC 1004Q-1-3

7. Tricolpate pollen type
38.5 x 22.9 microns; OPC 1062I-1-1

8. *Typha* sp.
38.0 microns; OPC 1008F-2-2

9. Onagraceae pollen type B
50.0 x 52.5 microns; OPC 1004C-1-1

10. *Fraxinus* sp.
25.5 microns; OPC 1007F-3-3

11,13. *Quercus* sp.
(11) 33.1 x 35.7 microns; OPC 1004B-1-3
(12) 28.0 x 20.4 microns; OPC 1007E-4-2
(13) 20.4 x 12.7 microns; OPC 1004E-3-5

14. *Alnus* sp.
28.0 microns; OPC 1004N-2-3

15,17. *Ulmus* sp.
(15) 33.1 microns; OPC 1062T-2-2
(17) 25.5 microns; OPC 1062T-3-2

16. *Betula* sp.
25.5 microns; OPC 1007F-2-5

18. *Liquidambar* sp.
30.6 microns; OPC 1062Q-4-1

19. *Juglans* sp.
40.8 microns; OPC 1004Q-2-5

Plate IV-Continued

Figure

20. *Tilia* sp.
    25.5 microns; OPC 1004E-1-5

21. *Carya* sp.
    45.9 x 51.0 microns; OPC 1004Q-1-1

PLATE IV

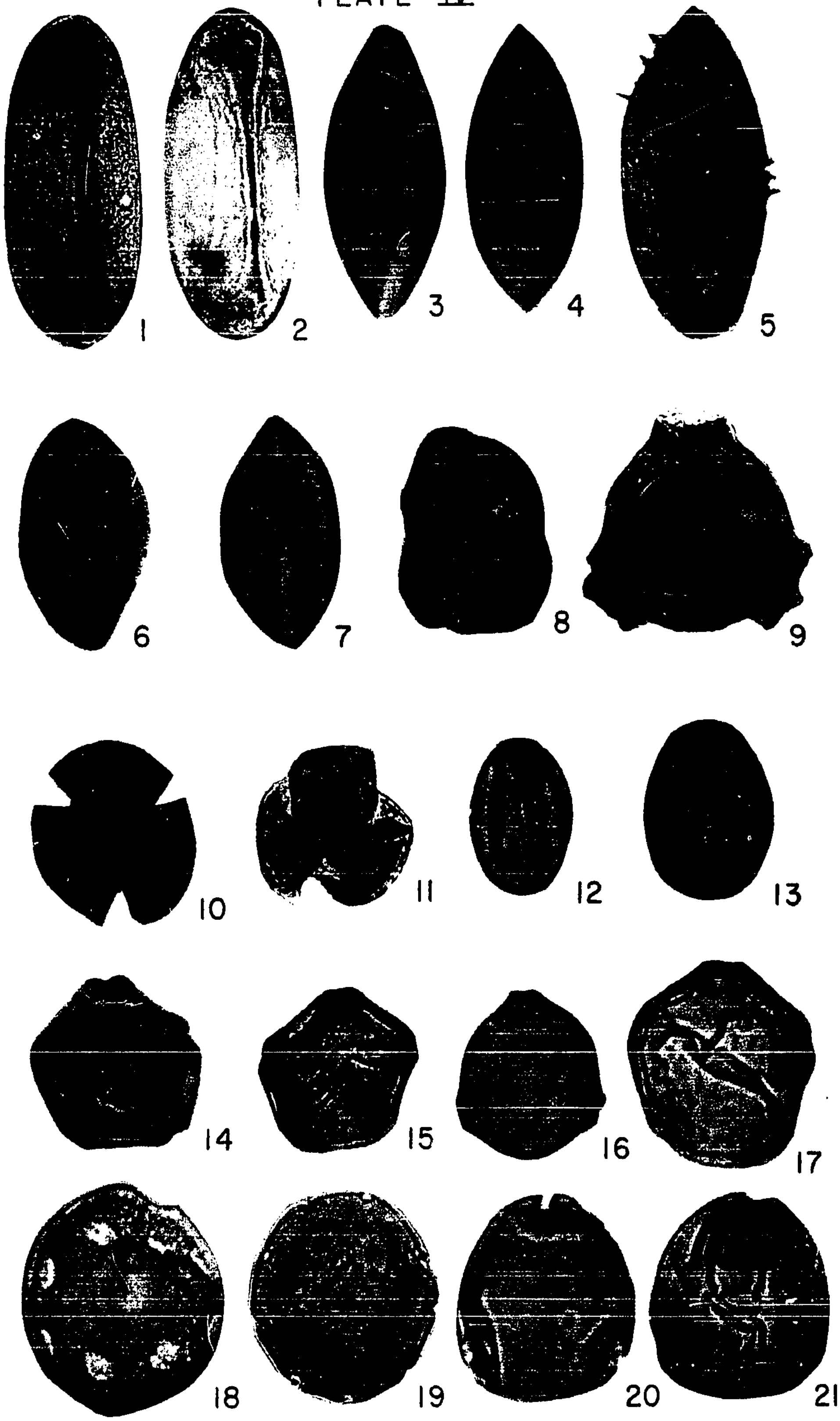

Plate V

Figure

1. <u>Juniperus</u> sp.
   25.5 x 20.0 microns; OPC 1004R-3-1

2-7. <u>Pinus</u> sp.
   (2) 68.8 x 45.9 microns; OPC 1008G-2-1
   (3) 81.6 x 45.9 microns; OPC 1007F-2-4
   (4) 65.0 x 45.0 microns; OPC 1004E-3-2
   (5) 71.4 x 51.0 microns; OPC 1099I-4-1
   (6) 79.0 x 40.8 microns; OPC 1007E-4-7
   (7) 63.5 x 50.0 microns; OPC 1004Q-2-3

8. <u>Lycospora</u> sp.
   25.5 microns; OPC 1062E-1-6

9,10. <u>Tririctus</u> sp.
   (9) 35.7 microns, low focal plane; OPC 1004H-2-1
   (10) 25.7 microns, high focal plane; OPC 1004H-2-1

11. <u>Ephedripites</u> sp.
   68.8 x 43.3 microns; OPC 1004H-3-3

12. <u>Lueckisporites virkkiae</u>
   35.7 x 25.5 microns; OPC 1062F-1-2

13. <u>Hystrichosphaeridium</u> sp.
   50.0 x 35.0 microns; OPC 1004L-3-4

14. <u>Cannosphaeropsis</u> sp.
   32.0 x 25.0 microns; OPC 1004F-2-1

15. <u>Baltisphaeridium</u> sp.
   61.0 microns; OPC 1004A-2-5

PLATE V

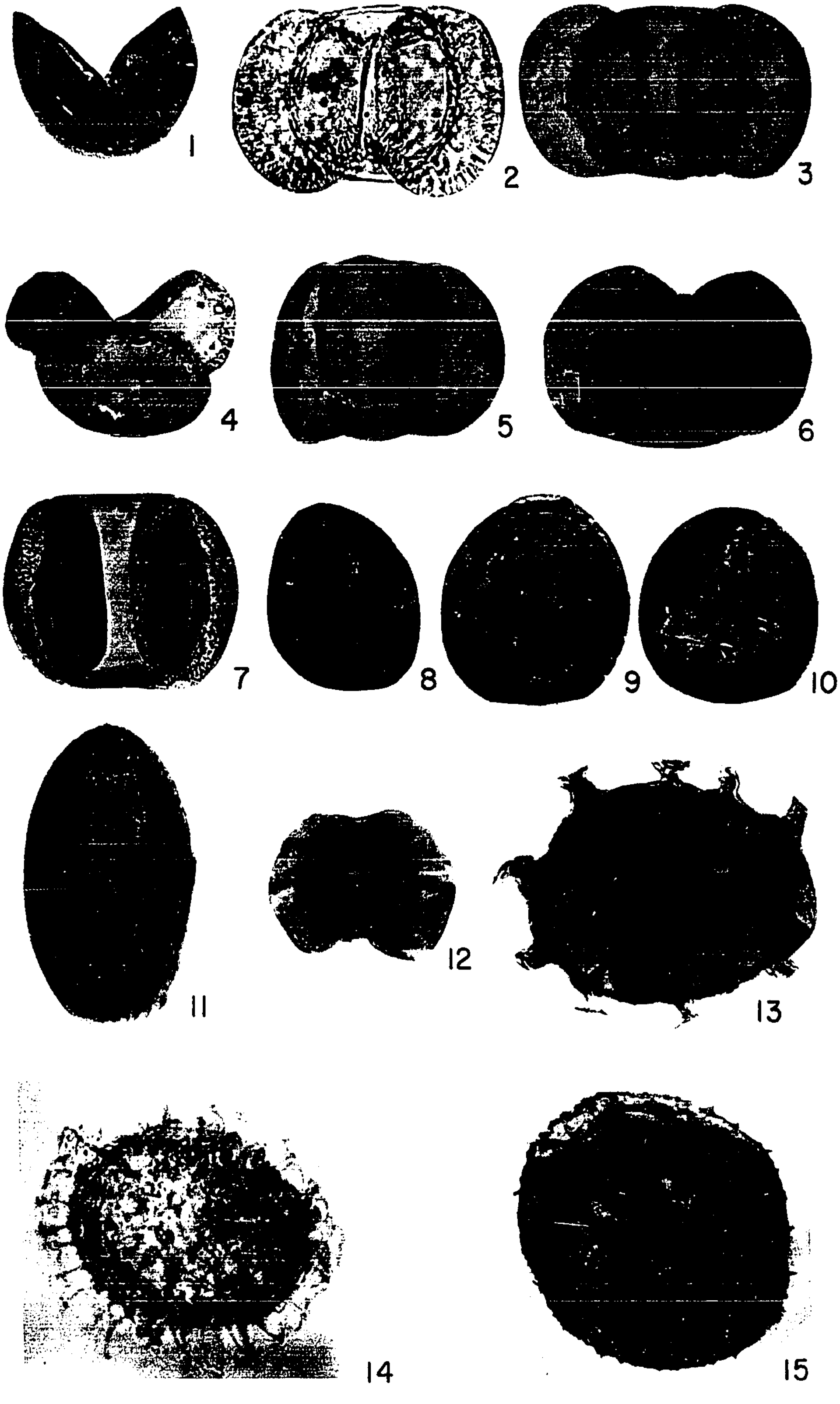

Plate VI

Figure

1. Protozoan cyst Type A
   119.8 x 79.0 microns; OPC 1004H-1-1

2. Protozoan cyst Type B
   51.0 x 38.2 microns, spine average 25.0 microns; OPC 1008G-2-3

3. Protozoan cyst Type C
   51.0 x 38.0 microns; OPC 1061H-3-4

4. Bryozoan statoblast
   348.8 x 218.0 microns; OPC 10620-2-1

5. Protozoan cyst Type D
   63.7 microns; OPC 1004A-6-3

6, 7. Protozoan cyst Type E
   (6) 48.0 microns, spines average 12.7 microns; OPC 1062T-1-2
   (7) same specimen, detail of wall and spines

8. Protozoan cyst Type F
   102.0 microns; OPC 1004A-3-1

9,10. _Typha_ plant tissue
   (9) mat of _Typha_ plant tissue
   (10) same specimen, details of connecting joints

PLATE VI