Studies of Pre-Selma Cretaceous Core Samples From the Outcrop Area in Western Alabama

GEOLOGICAL SURVEY BULLETIN 1160

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A group of papers by W. H. Monroe, R. E. Bergenback, N. F. Sohl, E. R. Applin, E. B. Leopold, H. M. Pakiser, and L. C. Conant

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

PREFACE

In 1954 four core holes were drilled in the pre-Selma Cretaceous strata of the Alabama Coastal Plain in order to get unweathered samples within a few miles of the outcrops. During the next few years several specialists studied the cores, and their reports are published as consecutive parts of this bulletin.

Watson H. Monroe, who spent many years studying the Coastal Plain strata in Alabama and Mississippi, conceived and supervised the drilling and planned the later studies. His earlier published report (W. H. Monroe, 1955, Cores of pre-Selma Cretaceous rocks in the outcrop area in western Alabama: Gulf Coast Geol. Societies Trans., v. 5, p. 11–37) contains a brief description of the stratigraphy, together with logs and other information regarding the core holes, and he has provided the introductory chapter to this bulletin. Richard E. Bergenback studied the petrology of the cores, which included finding the distribution of grain sizes, determining the mineralogy of the grains and the matrix of the sediments, and having X-Ray identifications made of the clay minerals. Norman F. Sohl studied the mollusks and other large fossils obtained from the cores and compared them with other faunal suites collected in Alabama and Texas. Esther R. Applin studied the sparse microfauna, comparing it with faunas obtained from deep wells downdip in Georgia, Alabama, and Mississippi and with outcrop samples from Texas, and has described a new species of Foraminifera. Estella B. Leopold and Helen M. Pakiser obtained a large pollen and spore assemblage by digesting carbonaceous layers of some of the cores in acid; this flora includes much new material, which is not described here.

The Bergenback, Sohl, and Applin reports discuss the probable environment in which the sediments accumulated. Louis C. Conant, who spent several years studying and mapping these sediments, has written a summary chapter integrating some of the surface and subsurface information.

Quarter-cuts of the cores belonging to the U.S. National Museum have been deposited on indefinite loan with the Alabama Geological Survey at University, Ala., and with the Shell Oil Co. at Jackson, Miss. They are available there for inspection and study.

LOUIS C. CONANT.

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By WATSON H. MONROE

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

GEOLOGICAL SURVEY BULLETIN 1160-A

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STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES, WESTERN ALABAMA

A. GENERAL DESCRIPTION OF CORES OF PRE-SELMA CRETACEOUS STRATA IN WESTERN ALABAMA

By Watson H. Monroe

ABSTRACT

Four core holes were drilled by the U.S. Geological Survey in western Alabama near the outcrop of Upper Cretaceous rocks to obtain unweathered samples and accurate thicknesses of the pre-Selma formations. Data on these cores are compared with published outcrop information and will aid in correlating rocks of similar age penetrated in deep oil-test holes in southern Alabama and Mississippi.

The core holes penetrated the entire thickness of the Eutaw and McShan formations, part of the Gordo formation, all the Coker formation including the Eoline member, and the Vick formation. Plant and animal fossils, most of which are described in other chapters of this bulletin, were obtained from the Vick formation, from the Eoline member of the Coker formation, and from the Eutaw formation. Bright-colored sediments characteristic of the upper member of the Coker formation and of the Vick formation on the outcrop are similarly colored in the cores, at depths too great to be the result of Recent weathering. A core of the Vick formation contains veinlets of silty calcite; this calcite closely resembles the "pink lime" found in the pre-Upper Cretaceous Comanche rocks downdip.

INTRODUCTION

A study of the stratigraphy of the outcropping pre-Selma Upper Cretaceous rocks in Alabama and Mississippi was started in May 1944 as a part of the U.S. Geological Survey's war-time program of oil and gas investigations. The project resulted in publication of reports by L. C. Conant, D. H. Eargle, W. H. Monroe, J. H. Morris, and C. W. Drennen, which are listed with the references cited in this report. The geologic interpretations these authors made were based almost entirely on examination of weathered roadside outcrop samples and of cuttings from wells drilled by rotary methods. Thicknesses of units were determined by piecing together short sequences and by projection of dips for many miles. As the work progressed the authors recognized more and more the need for a few carefully drilled core holes near the outcrop in order to obtain unweathered, undisturbed samples and to determine accurately the thicknesses of the units.

Four core holes were drilled by a contractor for the U.S. Geological Survey in the fall of 1954. The combined depth of the four holes was 1,686 feet, and 844 feet of core was recovered. All the holes were started a short distance above the top of an identifiable stratigraphic unit and were drilled through a lower horizon identifiable stratigraphically, though two of the holes were drilled into rocks of questionable Paleozoic age.

Much descriptive material on the cores was published by W. H. Monroe (1955), and the reader is referred to that paper for detailed megascopic descriptions of the four cores. Electric logs of these holes are also illustrated in Monroe's report (1955, figs. 2, 3). Lithologic logs of the holes are shown graphically on plate 1, which accompanies Bergenback's chapter in this bulletin. Minor discrepancies between the writer's and Bergenback's descriptions may be attributed to the fact that Bergenback's definitions are based on more careful laboratory studies.

The locations of the four test holes with relation to the outcrop of pre-Selma formations are shown on a generalized geologic map of western Alabama (fig. 1).

Many people contributed to the drilling project, especially L. C. Conant, who selected the drill sites and obtained permission of land owners to drill the holes; P. E. LaMoreaux, who provided electric logging equipment; C. W. Drennen, who supervised some of the drilling; and W. M. Edens of the Walters Drilling Co., who superintended the coring.

STRATIGRAPHIC RELATIONS

The outcropping pre-Selma Cretaceous rocks in western Alabama were mapped by Monroe, Conant, and Eargle (1946), who recognized six formations: Cottondale, Eoline, Coker, Gordo, McShan, and Eutaw. The Cottondale, Eoline, Coker, and Gordo formations were assigned to the Tuscaloosa group. The name McShan formation was applied to sand and clay formerly included in the lower part of the Eutaw formation in Alabama but included in the Tuscaloosa formation in Mississippi. In the same year Conant (1946) applied the name Vick formation to semiconsolidated pre-Tuscaloosa, post-Paleozoic sediments near Vick, Ala.

Subsequent studies (Drennen, 1953a, 1953b) farther north and farther east in Alabama showed that the Cottondale formation is a very local facies of the Eoline formation, and the name Cottondale was abandoned. Drennen also determined that the Eoline inter-

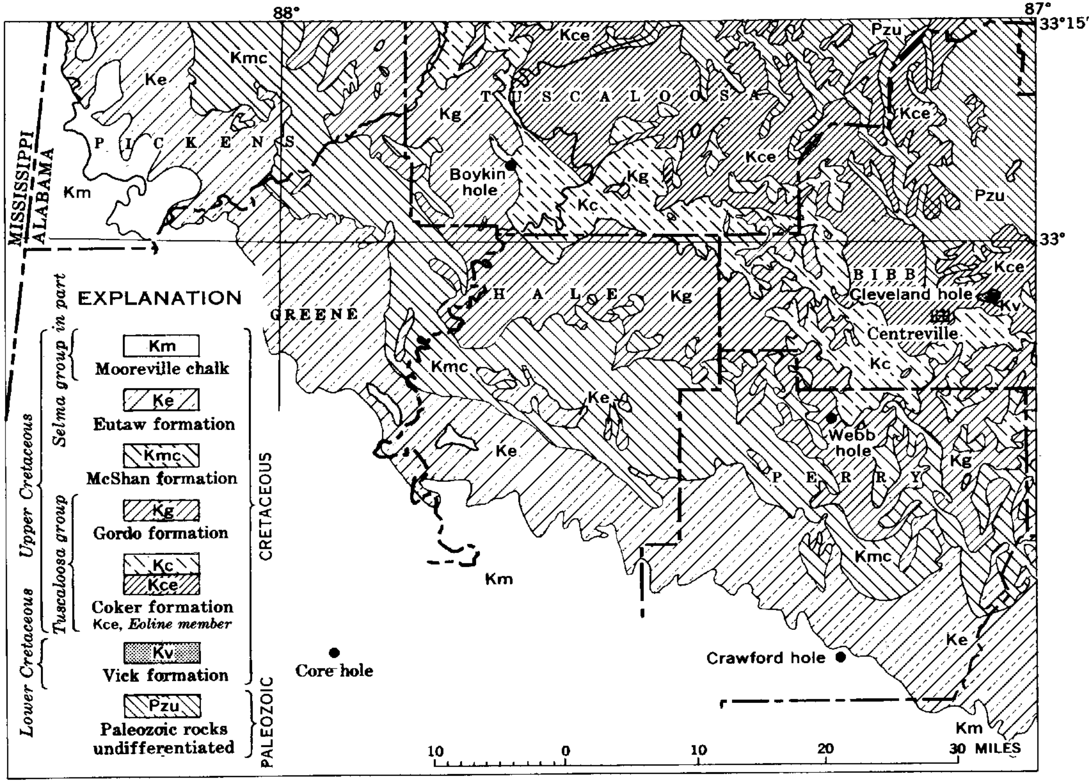

FIGURE 1.—Generalized geologic map of pre-Selma Cretaceous formations in western Alabama, showing location of drill holes.

tongues with the overlying Coker formation, and he therefore redefined the Coker to include the Eoline as a lower member.

The present classification of outcropping pre-Selma Cretaceous rocks includes five formations—in ascending order, the Vick formation; the Coker and Gordo formations, which constitute the Tuscaloosa group; the McShan formation; and the Eutaw formation. These formations, consisting mainly of sand, gravel, silt, and clay, and the lower part of the Mooreville chalk of the Selma group were cored in the four holes.

PRE-SELMA ROCKS

VICK FORMATION

The Vick formation crops out in road cuts and sink holes near Vick, about 4 miles east of Centreville in Bibb County, Ala., and consists of gray and reddish clay; brick-red, lavender, and gray sandy clay; and semiconsolidated clayey sandstone (Conant, 1946). These sediments are overlain unconformably by the basal beds of the Eoline member of the Coker formation and are more consolidated and have brighter colors than the overlying sediments. Conant considered the possibility of a Paleozoic age for the Vick, as the sediments somewhat resemble highly weathered Pennsylvanian rocks; however, because the nearest Paleozoic rocks along the strike of the Appalachian system are highly folded and faulted limestone and dolomite of Cambrian and Ordovician age, this possibility was discarded. The lithologic resemblance of the strata of the Vick formation to rocks of Comanche and Cotton Valley age in wells downdip in southern Alabama and Mississippi led Conant to suggest that the formation is of Early Cretaceous or Jurassic age. After publishing his paper, Conant found some poorly preserved leaves in one of the clay beds, which were identified as dicotyledons by Roland Brown. As dicotyledons were much more abundant in the Cretaceous than in the Jurassic, the Vick is now believed to be of Comanche age, probably a nearshore equivalent of some part of the Trinity group. The Vick was penetrated in the Cleveland and the Webb holes (pl. 1).

The Cleveland core hole which was drilled at the type locality of the Vick formation, crossed the contact between the Vick and the overlying Eoline member of the Coker formation at about 9.5 feet. The hole was drilled through 70.4 feet of Vick and penetrated 0.7 foot of dolomite of probable Cambrian or Ordovician age. The Vick formation in this hole consists principally of coarse-grained sandstone. The lower 10 feet of the Vick is very pebbly, and large cobbles are present in the basal 2 feet. A clayey silt 19.5 to 25.5 feet from the top contained impressions of leaves, identifiable only as dicotyledons (R. W. Brown, written communication, 1955).

The Webb hole, which entered the Vick formation at a depth of 554 feet, passed through 104 feet of Vick and into 2 feet of hard salmon-colored shale that the author believes to be of Paleozoic age. In this hole the Vick consists of alternating beds of highly micaceous, fine to coarse, red and greenish-gray sand, and red, brown, and gray clay; the lower 20 feet contained much coarse gravel and cobbles. Between 40 and 50 feet from the top of the formation is a 3-foot-thick unit of moderate-brown clayey, micaceous silt, cut by vermiculate veinlets of silty calcite, which is pink when washed. This calcite resembles the diagnostic "pink-lime" flakes commonly used to identify Comanche rocks in deep wells in southern Alabama and Mississippi. In general the rocks assigned to the Vick formation in the Webb hole contain much more mica and have colors brighter and stronger than any of the rocks in the overlying Tuscaloosa. The lower part of the Tuscaloosa contains abundant gravel and large cobbles, suggesting a sharp stratigraphic break. There seems little reason to doubt that the Vick in the Webb hole is of Comanche age, probably a nearshore equivalent of some formation in the Trinity group.

COKER FORMATION

The Coker formation consists of the Eoline member and an unnamed upper member. The Eoline member of the Coker formation, in the Tuscaloosa group, consists of a basal sand and gravel of locally varying coarseness and thickness, overlain by interbedded glauconitic sand and gray laminated clay. The presence of glauconite and locally of fossil marine shells indicates that this part of the Coker formation is a marine deposit. The upper member consists of highly crossbedded, generally nonglauconitic micaceous sand and varicolored clay. The clay characteristically contains spherules of siderite and of limonite or hematite. The Coker formation was penetrated in the drilling of both the Boykin and Webb holes (pl. 1).

EOLINE MEMBER

The Eoline member of the Coker formation differs considerably in the Boykin and Webb holes. In the Boykin hole it is 291 feet thick consisting of about 15 feet of sand and gravel at the base and grading upward into 30 feet of medium to coarse sand, which is overlain by about 246 feet of alternating beds of laminated gray clay and glauconitic sand. Lignite and lignitic clay beds are common, particularly in the upper half of the member, and the laminated clay and silt beds contain a large amount of fossil plant material. At the top of the Eoline member the Boykin hole penetrated 10 feet of waxy clay that is probably bentonitic. Very small Foraminifera of the family Saccamminidae were found by Mrs. Esther R. Applin in sand

and clay (core depth 404.3–437.6 feet, from which only 3.3 feet of core was recovered); Mrs. Applin's conclusions on the fauna and on the environment it suggests are published in her part of this bulletin.

In the Webb hole, the Eoline member is 334 feet thick and consists of fine-grained glauconitic sand and gray laminated clay, with a basal gravelly sand 85 feet thick. This thick basal sand more than accounts for the greater thickness of the member in the Webb as compared to the Boykin hole. As in the Boykin hole, the drill penetrated probable bentonite in the uppermost part of the Eoline member. The clay in the Webb hole contains a small amount of plant material and several zones of mollusks. Most of the mollusks are in clayey silt in the upper half of the member and are abundant in two layers of calcareous sandstone 93 to 103 feet below the top of the member. The mollusks have been studied by Norman F. Sohl, whose report is a separate part of this bulletin.

The upper contact of the Eoline member was not distinct in either the Boykin or the Webb hole but was determined by (1) a change in color from yellowish gray and olive in the Eoline to variegated red and orange above, (2) the glauconite in sand a short distance below the top of the Eoline, and (3) the top of the uppermost bentonitic clay in each hole, which accorded well with the other two criteria. The contact was thus placed in a sequence of clay and silt and apparently is conformable.

UPPER MEMBER

The unnamed upper member of the Coker is 185 feet thick in both the Webb and Boykin holes and consists of varicolored clay and sand. The colors are, in general, light red and reddish yellow, mottled with darker shades, such as dusky red and yellowish and reddish brown. Siderite spherules are abundant in several units and the clays characteristically contain abundant spherules of limonite or hematite.

GORDO FORMATION

The Gordo formation rests unconformably on the Coker formation. As mapped by Monroe, Conant, and Eargle (1946, p. 200–204), it is about 300 feet thick and consists of alternating thick beds of gravelly sand and of varicolored clay which locally contains abundant spherules of siderite.

In none of the core holes in pre-Selma rocks was the entire thickness of the Gordo penetrated, but the Boykin and Webb holes (pl. 1) were drilled through the basal part, and the upper 22 feet was penetrated in the Crawford hole (pl. 1). The basal part of the Gordo in the Webb hole contained much coarser gravel than in the Boykin hole; some of the cobbles from the Webb hole are as much as 70 mm long.

The upper part of the Gordo formation in the Crawford hole consists predominantly of light-gray clay, mottled with red.

McSHAN FORMATION

The McShan formation rests disconformably on the Gordo formation and generally consists of gray laminated clay interbedded with sand having variable amounts of glauconite. The glauconite in the McShan is predominantly pale green, in contrast with the predominantly dark-green glauconite in the overlying Eutaw formation.

In the Crawford hole (pl. 1) the full thickness of the McShan was penetrated, 215.5 feet, which compares reasonably well with the thickness of 240 feet as estimated by Monroe, Conant, and Eargle (1946, p. 205) for the McShan in the Warrior River valley, some 35 miles to the northwest. Though core recovery was poor, most of the McShan in the Crawford hole appears to be sand. The lower 75 feet of the formation consists mostly of medium to coarse sand, containing abundant pebbles in the bottom 30 feet. A few fossils from the McShan in the Crawford hole are listed in Mr. Sohl's report.

EUTAW FORMATION

The Eutaw formation rests on the McShan, but whether the contact is unconformable is uncertain. The two formations are much alike lithologically, but the Eutaw contains much coarser and darker glauconite and has abundant mollusks, especially in the upper part.

A complete section of 157 feet of the Eutaw formation was penetrated in the Crawford hole (pl. 1). Crustacean remains and shark teeth were found at many places throughout the formation, but molluscan fossils were found only in the upper 60 feet.

SELMA GROUP

MOOREVILLE CHALK

Drilling in the Crawford hole (pl. 1) penetrated the lower 26 feet of the Mooreville chalk of the Selma group. This lower part of the Mooreville is mainly a chalky marl that contains abundant coarse grains of glauconite and many fossil shells. The basal 3 feet of the formation is glauconitic, phosphatic, very fossiliferous sand and hard calcareous sandstone.

CONCLUSIONS

Information obtained by drilling of the test holes has made it possible to determine accurately the thicknesses of several of the pre-Selma formations; has indicated the correlation of the Vick formation of the outcrop area with the Comanche rocks of southern Alabama and Mississippi; has shown a definite change in facies in the Eoline member of the Coker formation, from sandy mollusk-bearing

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beds in the Cahaba River valley to carbonaceous, more clayey beds in the Warrior River valley; and has also proved that the strong, bright colors seen in many of the formations on the outcrop are present in the rocks at depths too great to be the result of Recent weathering.

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Petrology of Pre-Selma Strata From Core Holes in Western Alabama

By RICHARD E. BERGENBACK

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

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[Plate 1 is in pocket]

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STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

B. PETROLOGY OF PRE-SELMA STRATA FROM CORE HOLES IN WESTERN ALABAMA

By Richard E. Bergenback

ABSTRACT

Petrologic studies are reported on four sets of core samples of Coastal Plain sediments from western Alabama. These samples are from the Vick formation of Early(?) Cretaceous age, and from the Coker, Gordo, McShan, and Eutaw, formations of Late Cretaceous age but older than the Selma group.

Grain-size analyses of many small channel samples cut from discrete lithologic units within each formation show that the sediments are dominantly sandy and that the several stratigraphic units may be differentiated in a general way by grain-size distribution and sorting. Thus the Eutaw formation is better sorted than the McShan, although both formations consist of glauconitic sand and silty clay. Random samples, taken from the four formations cannot, however, be relied upon to show these differences.

Thin sections from four rock types in the Vick, Coker, McShan, and Eutaw formations were studied. These types were carbonate-cemented sandstone, chert-cemented sandstone, sand, and silt. The four types consist largely of quartzose mineral and rock fragments that were arbitrarily divided into seven varieties, which were used to deduce the metamorphic and sedimentary source rocks. Point counts show that the proportion of those quartz varieties that are interpreted as being largely of metamorphic origin may be used to differentiate the Vick formation from the others. Relatively large amounts of glauconite distinguish the sediments of the Eutaw and McShan formations from the less glauconitic sediments of the Eoline member of the Coker formation, and from the nonglauconitic sediments of the Vick formation, the upper member of the Coker formation, and the Gordo formation.

INTRODUCTION

In late 1954 the U.S. Geological Survey contracted to have four holes drilled to obtain cores that would provide as complete stratigraphic information as possible about the sequence of Cretaceous sediments underlying the Selma group, which is Late Cretaceous in age. The four holes—the Boykin, Webb, Crawford, and Cleveland holes—are in western Alabama (fig. 1); they penetrated the Vick formation of Early(?) Cretaceous age (Monroe, 1955, and this bulletin) and the Coker, Gordo, McShan, and Eutaw formations of Late

Cretaceous age. Columnar sections that show the positions from which all samples were taken are shown on plate 1.

A petrologic study of the unweathered samples obtained from the cores was made to determine if either grain-size distribution or mineral composition, or both, could be used to differentiate the subsurface Vick, Coker, McShan, and Eutaw formations. The Gordo formation was not studied because it was only partly cored.

All the cores were 2⅞ to 3 inches in diameter, but the percentage of core recovery ranged from 0 to 100 percent. The parts of the holes from which no core was obtained are shown as NC on plate 1. At some places no core was obtained because the attempts were unsuccessful, but at other places no attempt was made to obtain cores, as in loose sand, in the realization that none would have been obtained. Color terms in this report are the visual estimates of the author.

Acknowledgements are due Watson H. Monroe for suggesting this investigation, for supplying the cores, and for making valuable suggestions during the course of the investigation; Arthur J. Gude, 3d, who identified the clay minerals; and C. S. Ross and Charles Milton, who provided descriptions of thin sections of montmorillonitic clays from the Eoline member of the Coker formation.

STRATIGRAPHY

Monroe, Conant, and Eargle (1946), Conant (1946), and Drennen (1953a, 1953b) have described and named the surface formations of pre-Selma sediments of Cretaceous age in western Alabama. Monroe (1955, and this bulletin) has described the lithology and stratigraphy of the four cores analyzed in this investigation, applying the stratigraphic nomenclature of Drennen (1953a). Table 1 shows the stratigraphic relations of the Vick, Coker, Gordo, McShan, and Eutaw formations.

The sediments of the Vick formation are present in the Webb and Cleveland cores, and those of the Coker formation are present in the Boykin and Webb cores. Of the 300-foot total thickness of the Gordo formation, the top 22 feet was penetrated by the Crawford hole, and the bottom 41 and 35 feet by the Boykin and Webb holes, respectively. The Eutaw and McShan formations are present only in the Crawford core. The thicknesses of these units and the drilling record have been reported by Monroe (1955, and this bulletin).

PETROLOGY

SAMPLING

Channel samples for grain-size analyses were taken from discrete lithologic units within each formation (pl. 1). Samples for thin-section study of the composition and distribution of mineral and rock fragments were randomly selected from sandstone, sand, and silt sequences in the Vick, Coker, and Eutaw formations. Lithologic units of clay, silty clay, clayey silt, and sand were spot sampled for identification of clay minerals by X-ray analysis.

GRAIN-SIZE ANALYSES

Grain-size analyses of these relatively unlithified sediments of Cretaceous age were made both by sieving and by the use of a hydrometer (Krumbein and Pettijohn, 1938). No attempt was made to determine particle-size distribution of the clays. The results of the grain-size analyses were plotted in the form of cumulative curves from which sorting coefficient values were obtained. The first and third quartiles (25 percent and 75 percent) were used to determine the sorting coefficients, and the limits set by Trask (1932, p. 70–72) were used to determine the degree of sorting: well sorted is less than 2.5, moderately sorted is from 2.5 to 4.0, and poorly sorted is more than 4.0.

As indicated by Pettijohn (1957, p. 21) little or no agreement has been reached with regard to the names applied to aggregates of sedimentary particles. In this report such an aggregate of particles of differing sizes is designated as sand, silt, or clay if 50 percent or more material by weight falls within the limits prescribed for those size grades. If the particle distribution is such that no size grade contains 50 percent or more material by weight, then the aggregate is named for the size grade containing the largest amount (modal class) of the size distribution. Once the aggregate is named, then such modifying size terms as sandy, silty, or clayey are applied if 10 percent or more of material in these size grades is present.

VICK FORMATION: CLEVELAND CORE HOLE

The Cleveland hole penetrated 70.4 feet of the Vick formation, of which 41.9 feet of core was obtained. The cores consist chiefly of interbedded coarse pebble- and granule-bearing sandstone and unconsolidated sand and silt (pl. 1). Five sandstone beds, which are partly chert cemented and porous, show graded bedding ranging from very coarse sandstone at the base to fine sandstone at the top. The base of each graded sandstone bed contains granules or pebbles of chert and metaquartzite (table 2). Between the sandstone beds are beds of unconsolidated gray and yellow sand and silt.

At the base of the formation is an unconsolidated pebble- and cobble-bearing sand unit which is 6.5 feet thick. Almost no core of this lower unit was recovered, so the unit could not be studied.

Mechanical analyses of the lithified and unconsolidated sediments of these core samples show that very fine to very coarse sand composes 50 percent or more of the material, by weight, in 21 of 22 samples (fig. 2). In addition, the samples contain as much as 16 percent

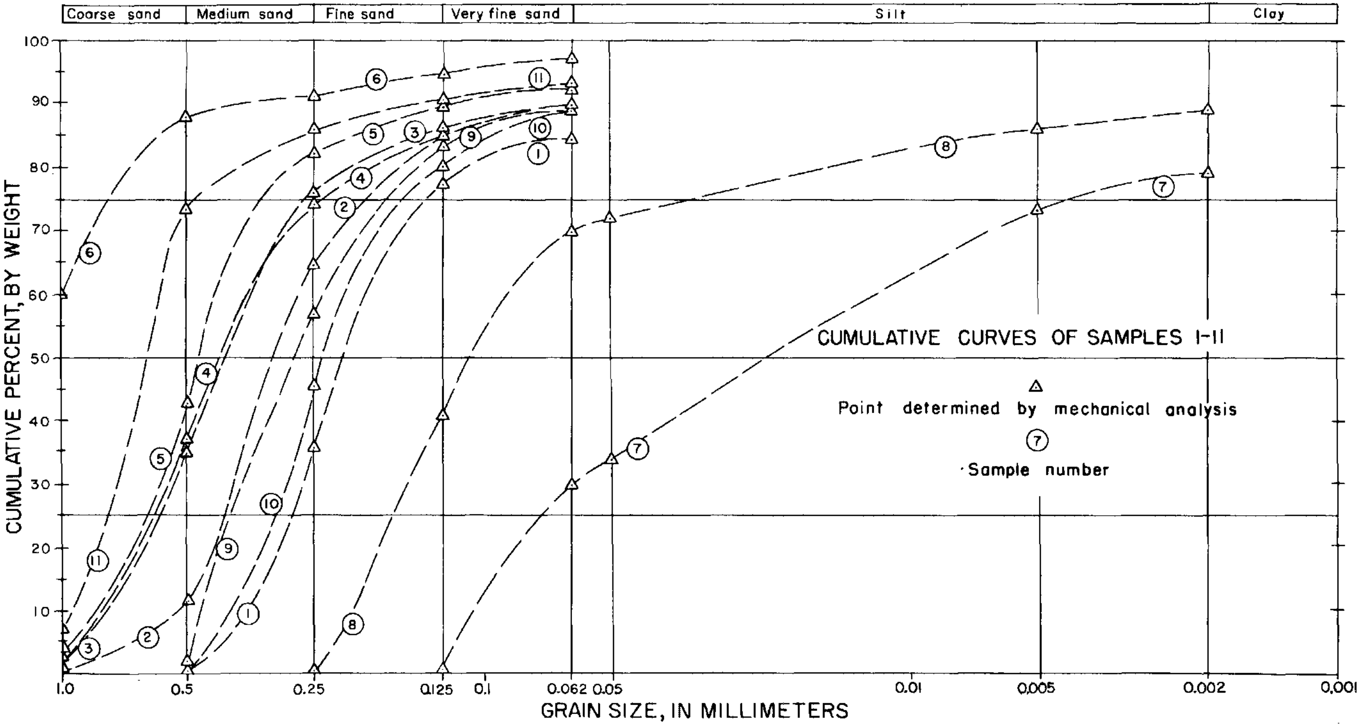
TABLE 1.—*Correlation of stratigraphic units in the*

Drennen (1953b)						Monroe (1955, and this bulletin)					
Series	Group	Formation	Member or bed	Thickness (feet)	Outcrop	Series	Group	Formation	Member or bed	Thickness (feet)	Web core hole
Upper Cretaceous	Selma	Mooreville	Basal sandy [1]	10–25	Sandy chalk or hard chalky sandstone with grains of glauconite, phosphate, and fossil fragments. Contact with Eutaw formation is sharp.	Upper Cretaceous	Selma	Mooreville	Basal sandy		
		McShan and Eutaw undifferentiated		[1] 430±	Clay, sand, and gravelly sand; clay is silty, massive to subfissile, and gray to black, or massive waxy and grayish green; generally rests conformably on Gordo formation. Basal sands are fine to medium, massive to crossbedded.			Eutaw			
								McShan			
	Tuscaloosa	Gordo		300	Clay, sand, and gravel. Consists locally of 3 units, each of which is composed of heterogeneously bedded clay, sand, and gravelly sand having persistent clay at top and persistent sandy gravel at base. Lies unconformably on Coker formation.		Tuscaloosa	Gordo		35	Basal sand containing pebbles and cobbles. Contact with Coker formation is sharp.
		Coker	Upper	50–400	Lenticular variegated massive ferruginous clay that is locally sandy and locally contains spherules of siderite. Contact with Eoline member is transitional.			Coker	Upper	185	Varicolored clay and sand having abundant spherules of siderite, limonite, and hematite in clay. Contact with Coker formation is transitional.
			Eoline		Lenses of thinly laminated gray clay having partings of rippled glauconitic fine sand, underlain by basal sandy gravel as much as 30 ft thick. Rests conformably on Vick formation and unconformably on rocks of Paleozoic age.				Eoline	334	Lignitic clay and lignite bed in upper part, underlain by interbedded glauconitic sand and gray laminated clay, cobbly basal sand. Rests conformably on Vick formation.
Lower (?) Cretaceous		Vick		100	Red and lavender clay underlain by medium to coarse micaceous sand.	Lower (?) Cretaceous		Vick		104	Alternating beds of highly micaceous, fine to coarse red and greenish-gray sand, and red, brown, and gray clay. Basal 20 ft is pebbly and cobbly sand. Rests with sharp contact on shale of probable Paleozoic age.

[1] Information from Monroe, Conant, and Eargle (1946).

core holes with the outcropping units in western Alabama

Monroe (1955, and this bulletin)—Continued					
Thickness (feet)	Boykin core hole	Thickness (feet)	Crawford core hole	Thickness (feet)	Cleveland core hole
		26	Chalky marl containing abundant coarse grains of glauconite and shell fragments, underlain by basal glauconitic, phosphatic, fossiliferous sand and calcareous sandstone.		
		157	Gray laminated clay interbedded with sand containing dark-green coarse glauconite; underlain by basal pebble-bearing sand. Rests with sharp contact on McShan formation.		
		215.5	Gray laminated clay interbedded with sand containing pale-green fine glauconite; underlain by basal medium to coarse sand containing pebbles. Overlies the Gordo fromation disconformably.		
Lower 41	Basal sand containing pebbles and cobbles.	Upper 22	Light-gray clay mottled with red, interbedded with thin-bedded gray sand.		
185	Varicolored clay and sand; abundant spherules of siderite, limonite, and hematite in clay. Contact with Coker formation is transitional.				
291	Thick sequence of alternating beds of laminated gray clay and glauconitic sand having lignitic clay and thin lignite beds in upper part; grades downward into medium to coarse sand that in turn grades downward into medium to coarse basal sand and gravel. Rests with sharp contact on rocks of Paleozoic age.				
				70.4	Sandstone of various degrees of coarseness interbedded with sand, silt, and clay; bottom 10 ft pebbly and cobbly sand. Rests with sharp contact on rocks of Paleozoic age.


Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
GRAIN SIZE, IN MILLIMETERS
1.0
0.5
0.25
0.125
0.1
0.062
0.05
0.01
0.005
0.002
0.001
CUMULATIVE CURVES OF SAMPLES 1-11
Point determined by mechanical analysis
Sample number

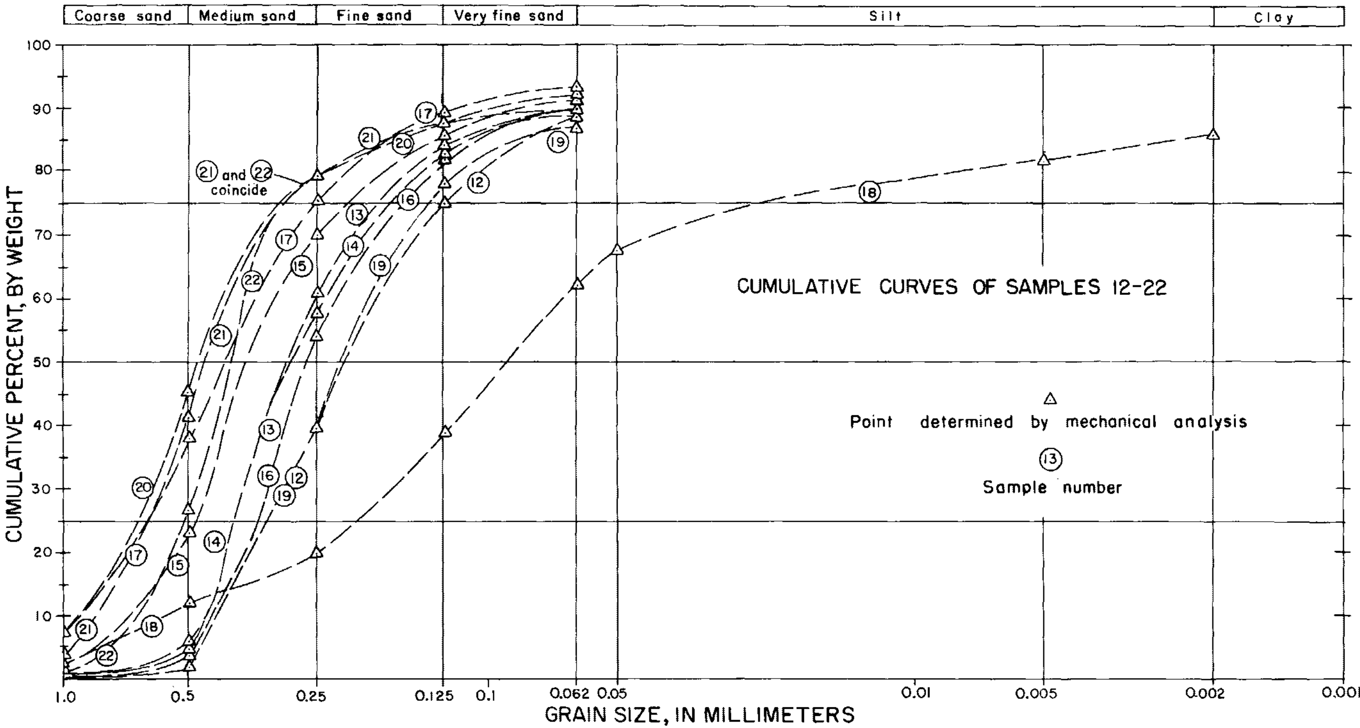


FIGURE 2.—Grain-size analyses of samples of the Vick formation, Cleveland core hole.

TABLE 2.—*Sorting coefficients of samples from the Vick formation*

Vick formation									
Cleveland core samples					Webb core samples				
Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient	Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient
1	0.216	0.292	0.140	1.4	47	0.205	0.300	0.148	1.4
2	.330	.415	.190	1.5	48	.360	.590	.205	1.7
3	.410	.590	.263	1.5	49	.340	.465	.205	1.5
4	.430	.580	.245	1.5	50	.043	.078	.007	3.4
5	.470	.630	.370	1.3	51	.092	.140	.064	1.5
6	1.130	1.450	.770	1.4	52	.088	.110	.038	1.7
7	.026	.084	.004	4.6					
8	.108	.170	.033	2.3					
9	.283	.390	.170	1.5					
10	.243	.310	.157	1.4					
11	.700	.880	.470	1.4					
12	.215	.320	.126	1.6					
13	.300	.380	.177	1.5					
14	.300	.410	.165	1.6					
15	.350	.490	.210	1.5					
16	.260	.345	.163	1.5					
17	.405	.630	.255	1.7					
18	.088	.195	.020	3.1					
19	.215	.335	.135	1.6					
20	.470	.680	.300	1.5					
21	.460	.640	.295	1.5					
22	.410	.520	.310	1.3					

silty and clayey particles, 9 percent granules, and 1 percent pebbles by weight.

VICK FORMATION: WEBB CORE HOLE

The Webb hole, about 17 miles southwest and about 12 miles, downdip from the Cleveland hole, penetrated 104 feet of the Vick formation, from which 27 feet of core was recovered. In contrast with the Cleveland hole, the cores from this hole show no distinct beds of sandstone. Instead, they consist chiefly of unconsolidated well-sorted yellowish- and greenish-gray sand and silty sand, and reddish-brown and grayish-yellow sandy and clayey silt. The sand is very fine to medium grained. Figure 3 and table 2 present the grain size and sorting of these sediments.

Textural analyses of the available core specimens of this formation show that very fine to coarse sand composes 50 percent or more of the material, by weight, in 5 of the 6 samples. The sand locally contains about 1 percent granules.

The basal 32 feet of the Vick formation in this core hole consists largely of pebble- and cobble-bearing sand. No cores were obtained of this basal unit.

COKER FORMATION

The Coker formation consists of the Eoline member in the lower part and of an unnamed upper member. All or nearly all the formation was penetrated by both the Webb and Boykin core holes. The Webb hole penetrated 519 feet of sediments of the formation, of

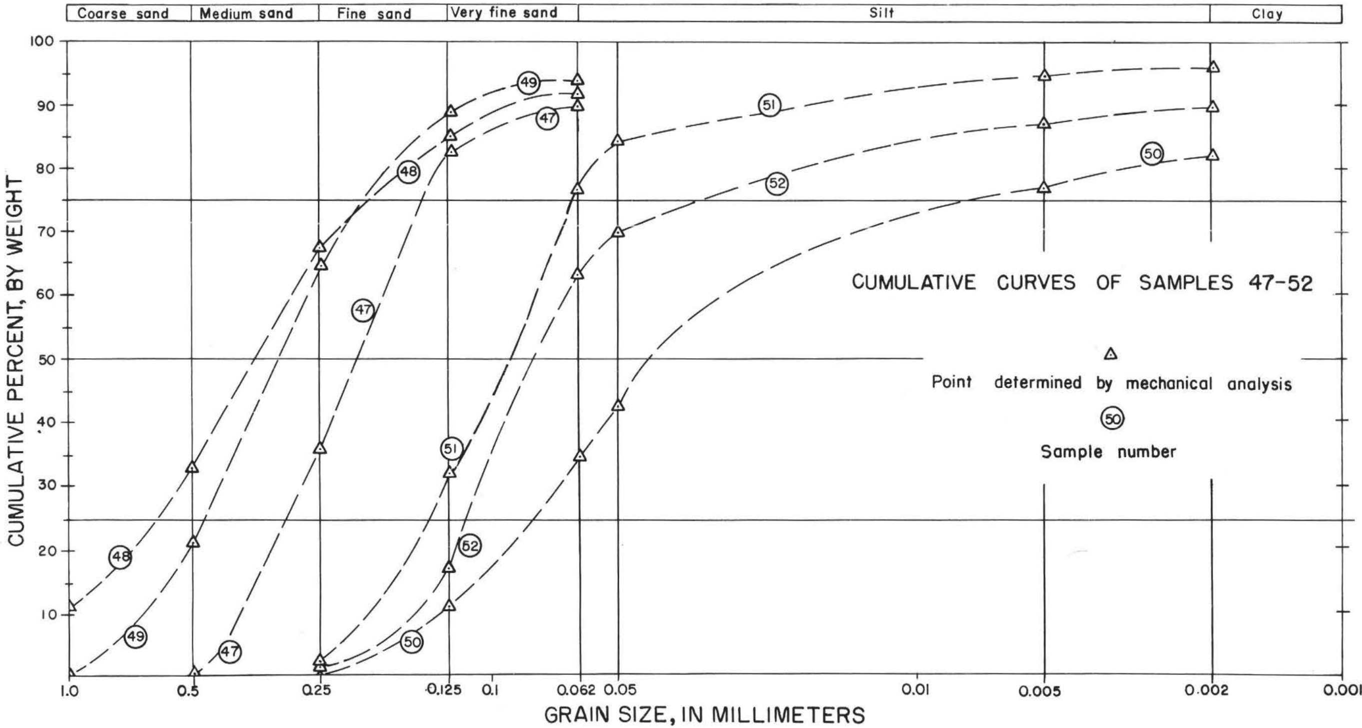


FIGURE 3.—Grain-size analyses of samples of the Vick formation, Webb core hole.

which 334 feet is assigned to the Eoline member and 185 feet to the upper unnamed member. In the Boykin hole the formation is 476 feet thick, of which 291 feet is assigned to the Eoline member and 185 feet to the upper member. Core recovery of the Coker formation from the Webb and Boykin holes was about 45 and 55 percent, respectively. These holes are about 30 miles apart, approximately along the strike of the formation. The Webb hole is in the valley of the Cahaba River, and the Boykin hole is in the valley of the Warrior River.

EOLINE MEMBER

In both the Webb and Boykin test holes the basal part of the Eoline member is a gravelly sand; this sand is 85 feet thick in the Webb hole and 15 feet thick in the Boykin hole (pl. 1). This coarse basal unit is overlain in both holes by a succession of 245 to 250 feet of interbedded and finely laminated gray sandy and clayey silt and silty clay, and fine to medium crossbedded glauconitic silty and clayey sand.

A lignite bed 2 feet thick is present 45 feet below the top of the member in the Webb core hole. Four lignite beds, ranging from 0.5 to 2.1 feet in thickness, are present in the upper 130 feet of the Boykin cores (pl. 1). Fossil mollusks found in several of the cores from the upper 100 feet of the Eoline member in the Webb hole are discussed by Sohl in another part of this bulletin.

The upper contact of the Eoline member is not distinct in the cores from either of the holes. Monroe (1955, p. 15; and this bulletin) has listed criteria for selecting the contact.

Mechanical analyses (figs. 4, 5; table 3) show that sorting in the beds ranges from good to poor. In general, the samples from the Webb cores contain more and better sorted sand than those from the Boykin cores.

Particle-size analyses of samples from the Eoline member of the Coker formation show that very fine to medium sand composes 50 percent or more of the material, by weight, in 38 of 58 samples. An additional 13 samples, 11 of them from the Boykin cores, are classified as sand because the modal class of the size distribution is between 0.062 and 2.0 mm (figs. 4, 5).

UPPER MEMBER

Of the 185-foot thickness of the upper member of the Coker formation in both the Webb and Boykin core holes, 130 feet of core was recovered from the Webb hole and 115 feet from the Boykin hole. This member consists chiefly of interbedded reddish-brown clay, silty clay, sandy and clayey silt, and silty and clayey sand.

TABLE 3.—*Sorting coefficients of samples from the Eoline member of the Coker formation.*

Coker formation, Eoline member									
Boykin core samples					Webb core samples				
Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient	Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient
22	0.066	0.135	(?)	(?)	20	0.013	0.040	0.0028	3.8
23	.045	.068	0.0127	2.3	21	.170	.197	.135	1.2
24	.044	.080	.009	3.0	22	.042	.087	(?)	(?)
25	.056	.100	(?)	(?)	23	.060	.105	.0185	2.4
26	.032	.073	(?)	(?)	24	.100	.140	.064	1.5
27	.047	.085	(?)	(?)	25	.120	.200	.054	1.9
28	.131	.172	.083	1.4	26	.165	.230	.110	1.4
29	.073	.119	(?)	(?)	27	.075	.104	.0041	5.1
30	.073	.120	(?)	(?)	28	.067	.098	.0062	3.9
31	.064	.100	.0017	7.7	29	.063	.096	.0044	4.7
32	.105	.155	.055	1.7	30	.077	.100	.0585	1.3
33	.165	.190	.130	1.2	31	.203	.265	.165	1.3
34	.041	.083	(?)	(?)	32	.115	.170	.071	1.5
35	.060	.100	.0019	7.3	33	.078	.120	.045	1.6
36	.085	.150	.005	5.5	34	.245	.310	.180	1.3
37	.079	.150	.0255	2.4	35	.063	.112	.0034	5.7
38	.060	.099	.0036	5.2	36	.145	.190	.105	1.4
39	.031	.068	(?)	(?)	37	.155	.243	.084	1.7
40	.042	.079	.0015	7.2	38	.190	.260	.155	1.3
41	.036	.086	(?)	(?)	39	.098	.170	.026	2.6
42	(?)	.0078	(?)	(?)	40	.041	.083	.009	3.0
43	.056	.084	.012	2.6	41	.174	.215	.117	1.4
44	.165	.200	.145	1.2	42	.180	.200	.130	1.2
45	.068	.100	.026	1.9	43	.089	.134	.038	1.9
46	.029	.072	(?)	(?)	44	.105	.165	.062	1.6
47	.051	.095	(?)	(?)	45	.075	.135	.013	3.2
48	.061	.108	.0046	4.8	46	.257	.340	.188	1.3
49	.155	.185	.120	1.2					
50	.068	.100	.024	2.1					
51	.100	.135	.076	1.3					
52	.300	.410	.250	1.3					

The samples of the core recovered from these holes consist largely of interbedded silty and clayey sand, sandy and clayey silt, and a little silty clay—all of which have a wide range in sorting (figs. 6, 7; table 4). Samples from both holes suggest that grain sorting is poorer toward the base of the member. In general, the sediments in the Webb samples are less well sorted than those from the Boykin hole (table 4).

Of the 40 analyses of samples of sediments from the upper member of the Coker formation, 30 contain 50 percent or more material, by weight, in the sand sizes (figs. 6, 7).

GORDO FORMATION

None of the holes penetrated the entire Gordo formation, which is about 300 feet thick. According to Conant and Monroe (1945), the Gordo formation on the outcrop generally consists of interbedded gravel, gravelly sand, sand, and clay with the gravel and gravelly sand decreasing in abundance upward. The Gordo is the upper formation of the Tuscaloosa group.

The Boykin and Webb holes penetrated the lower 41 and 35 feet of the Gordo formation, respectively, and the Crawford hole penetrated

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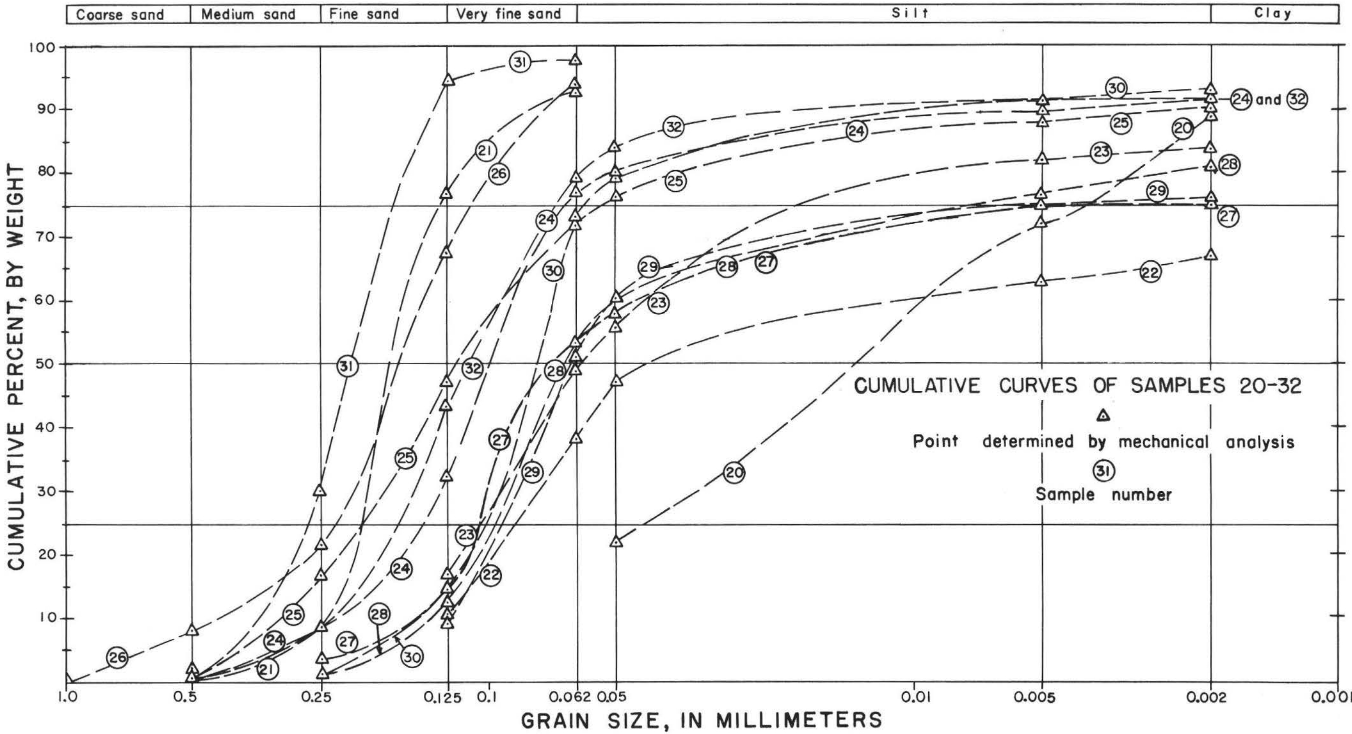

Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
GRAIN SIZE, IN MILLIMETERS
1.0
0.5
0.25
0.125
0.1
0.062
0.05
0.01
0.005
0.002
0.001
24 and 32
CUMULATIVE CURVES OF SAMPLES 20-32
Point determined by mechanical analysis
Sample number

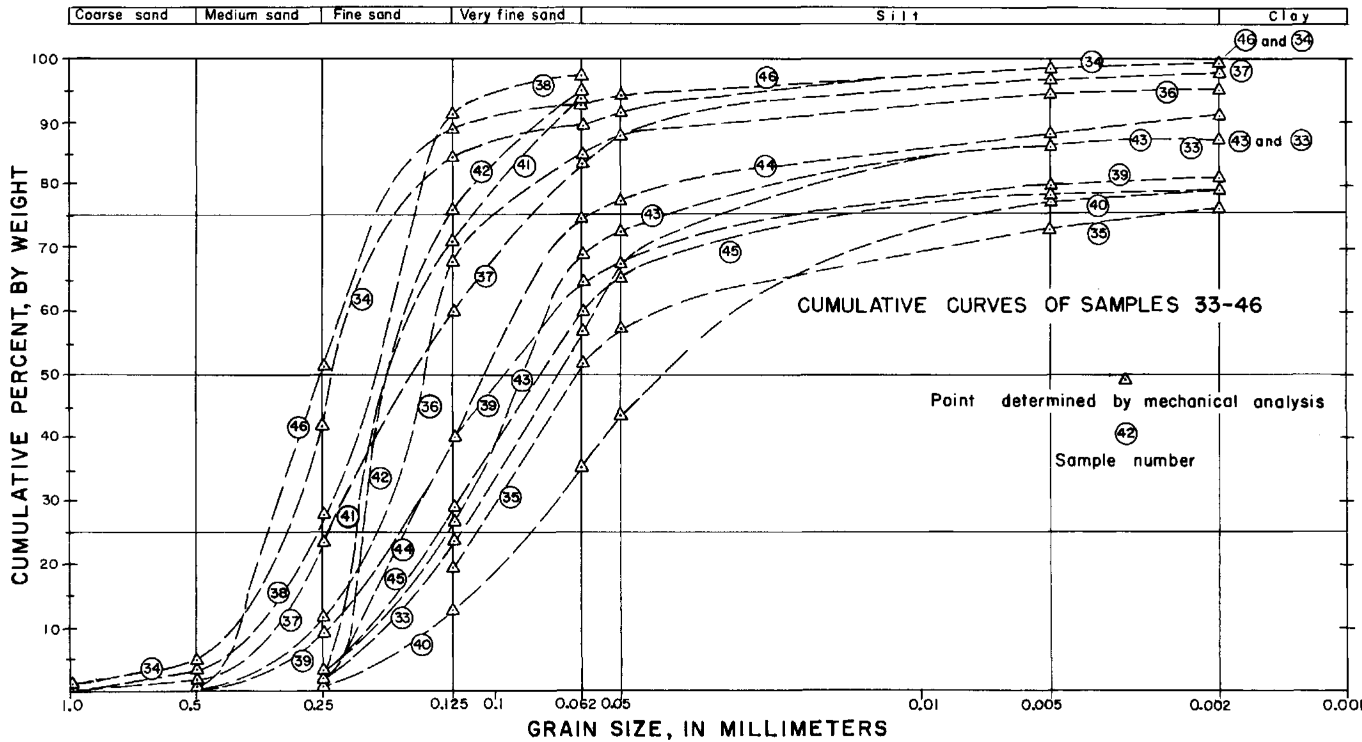
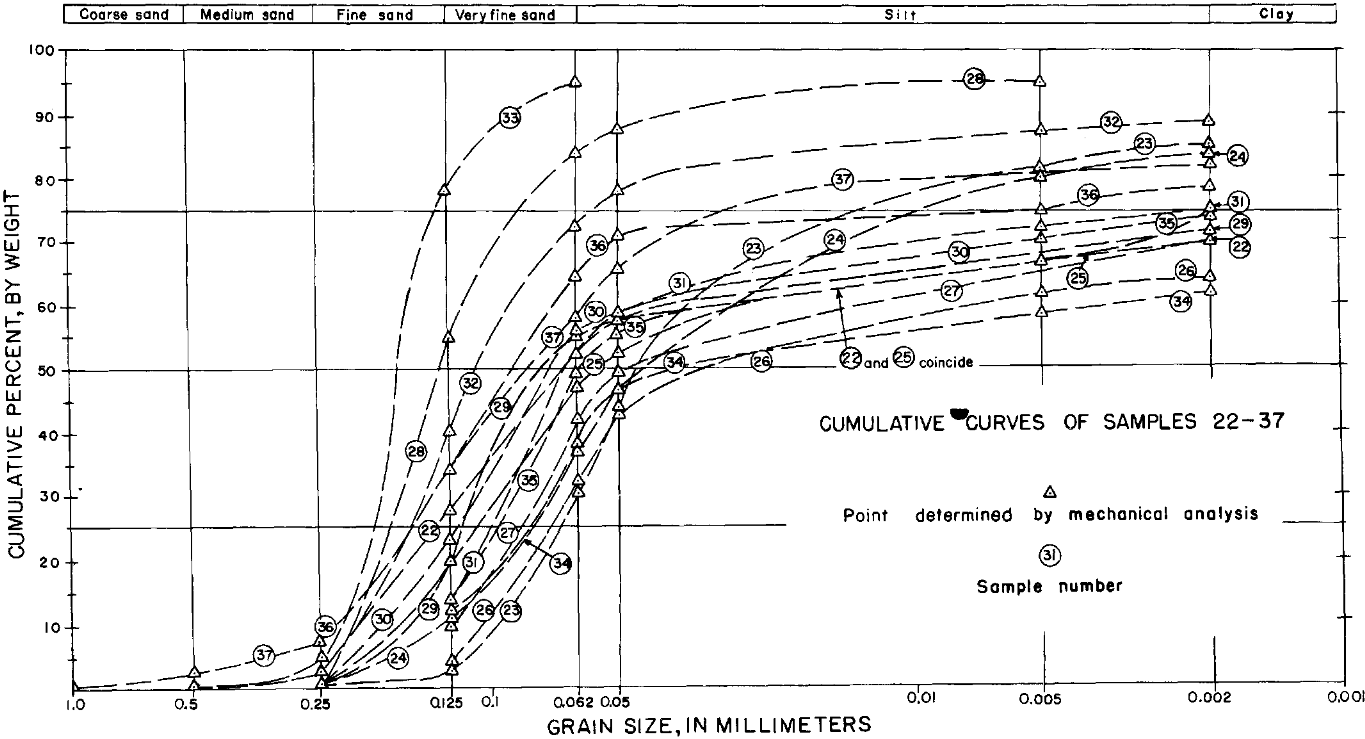


FIGURE 4.—Grain-size analyses of samples of the Eoline member of the Coker formation, Webb core hole.


Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
GRAIN SIZE, IN MILLIMETERS
1.0
0.5
0.25
0.125
0.1
0.062
0.05
0.01
0.005
0.002
0.001
22 and 25 coincide
CUMULATIVE CURVES OF SAMPLES 22-37
Point determined by mechanical analysis
Sample number

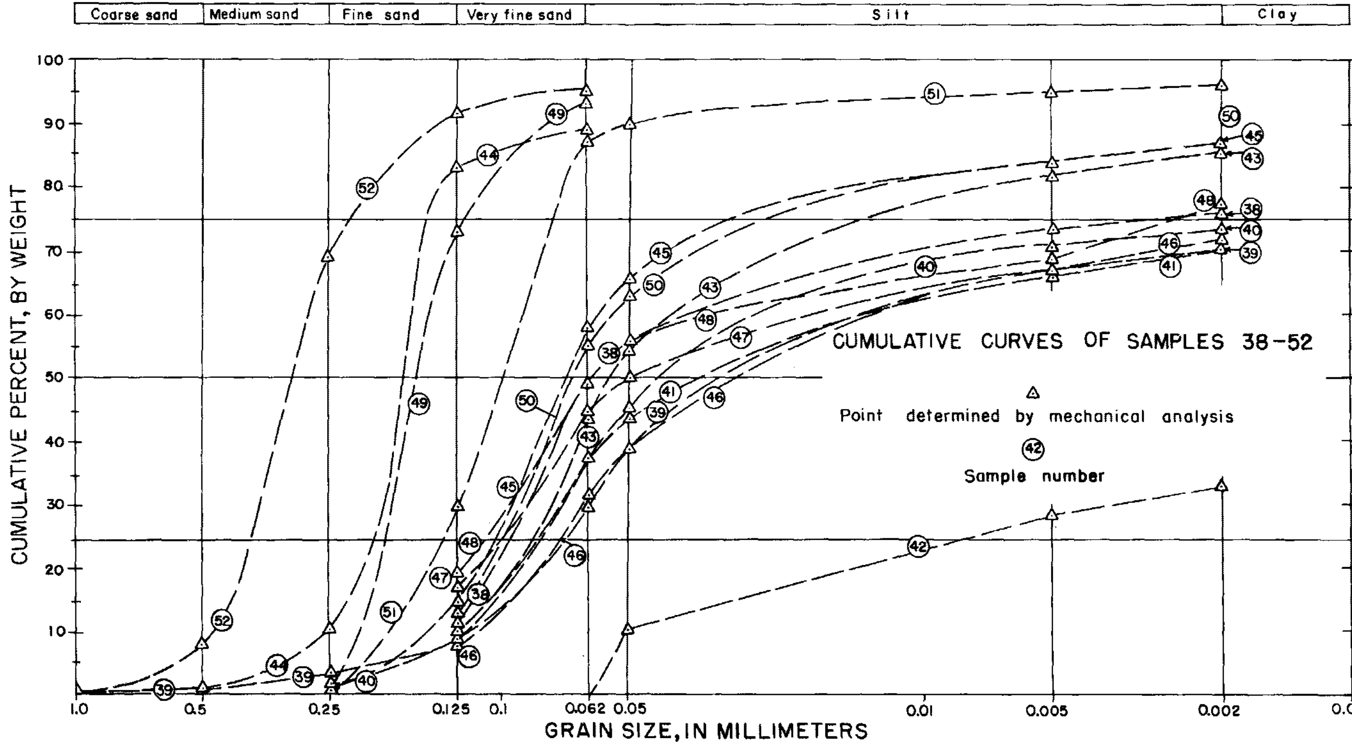
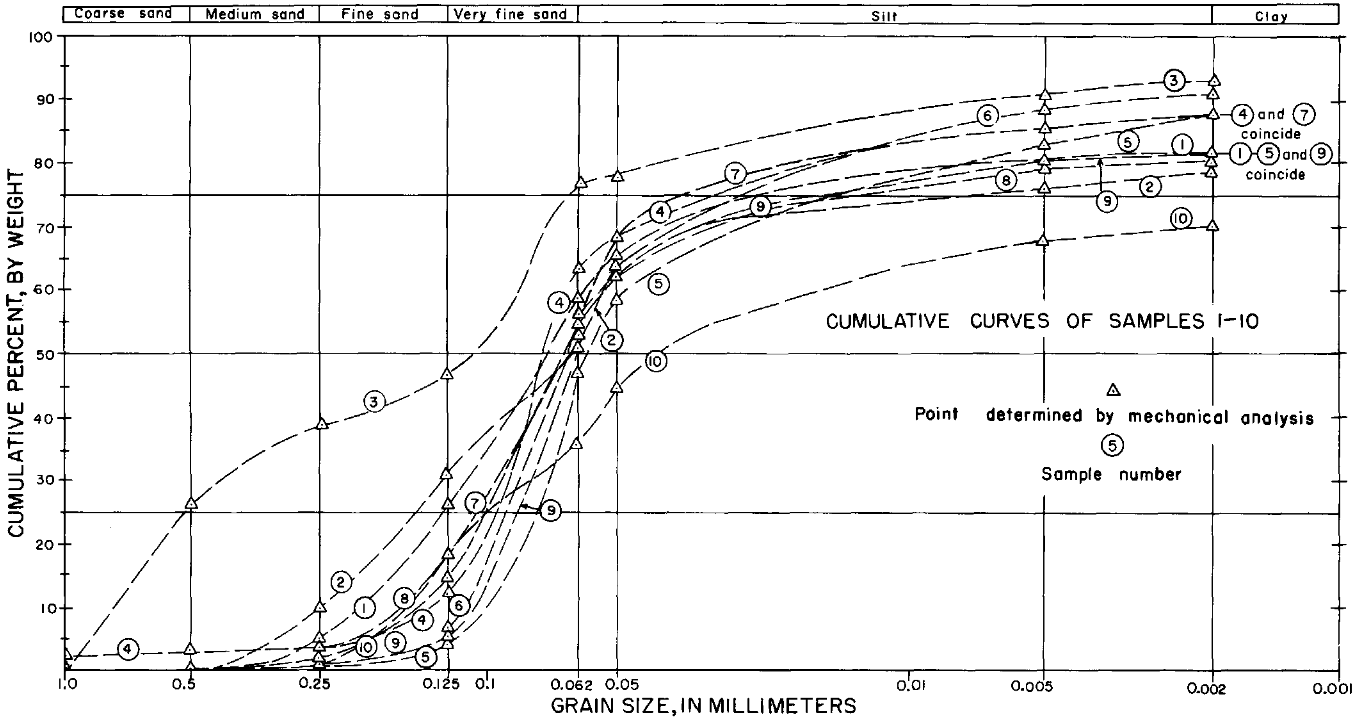


FIGURE 5.—Grain-size analyses of samples of the Eoline member of the Coker formation, Boykin core hole.


Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
100
90
80
70
60
50
40
30
20
10
1.0
0.5
0.25
0.125
0.1
0.062
0.05
0.01
0.005
0.002
0.001
GRAIN SIZE, IN MILLIMETERS
CUMULATIVE CURVES OF SAMPLES 1-10
Point determined by mechanical analysis
Sample number
4 and 7 coincide
1 5 and 9 coincide

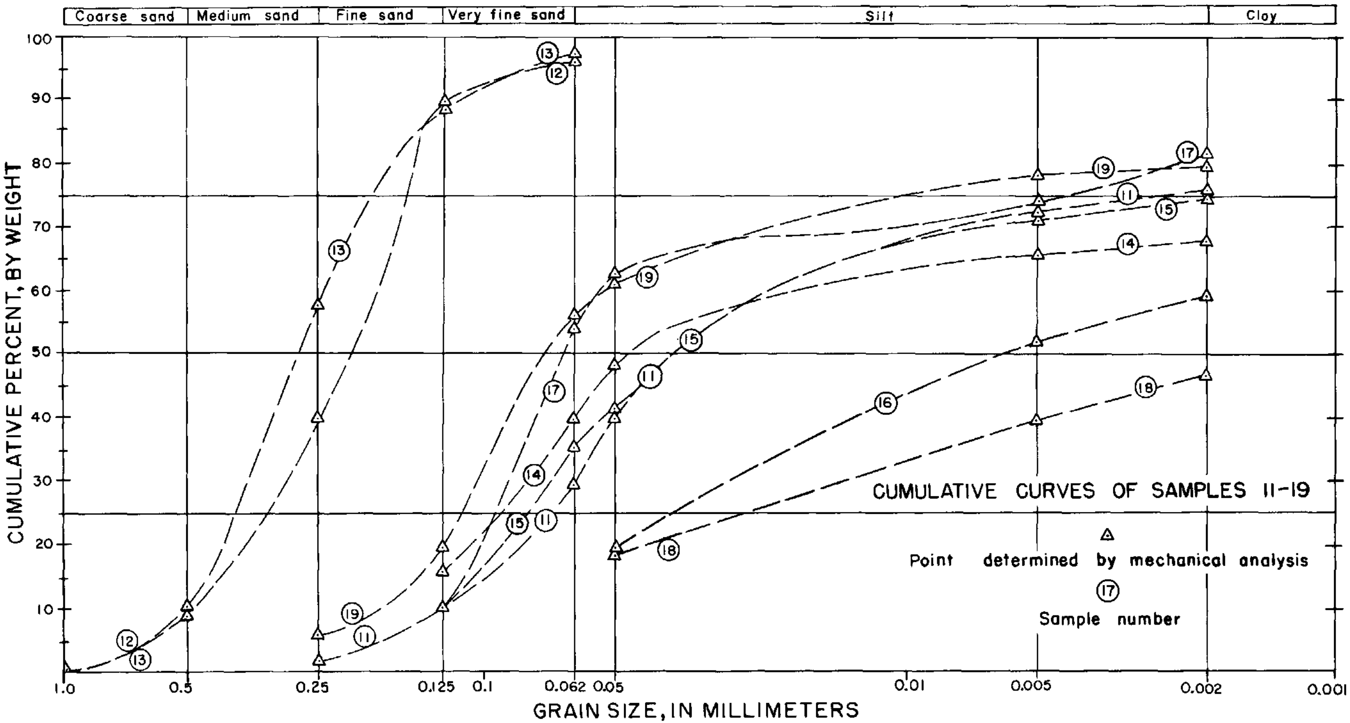
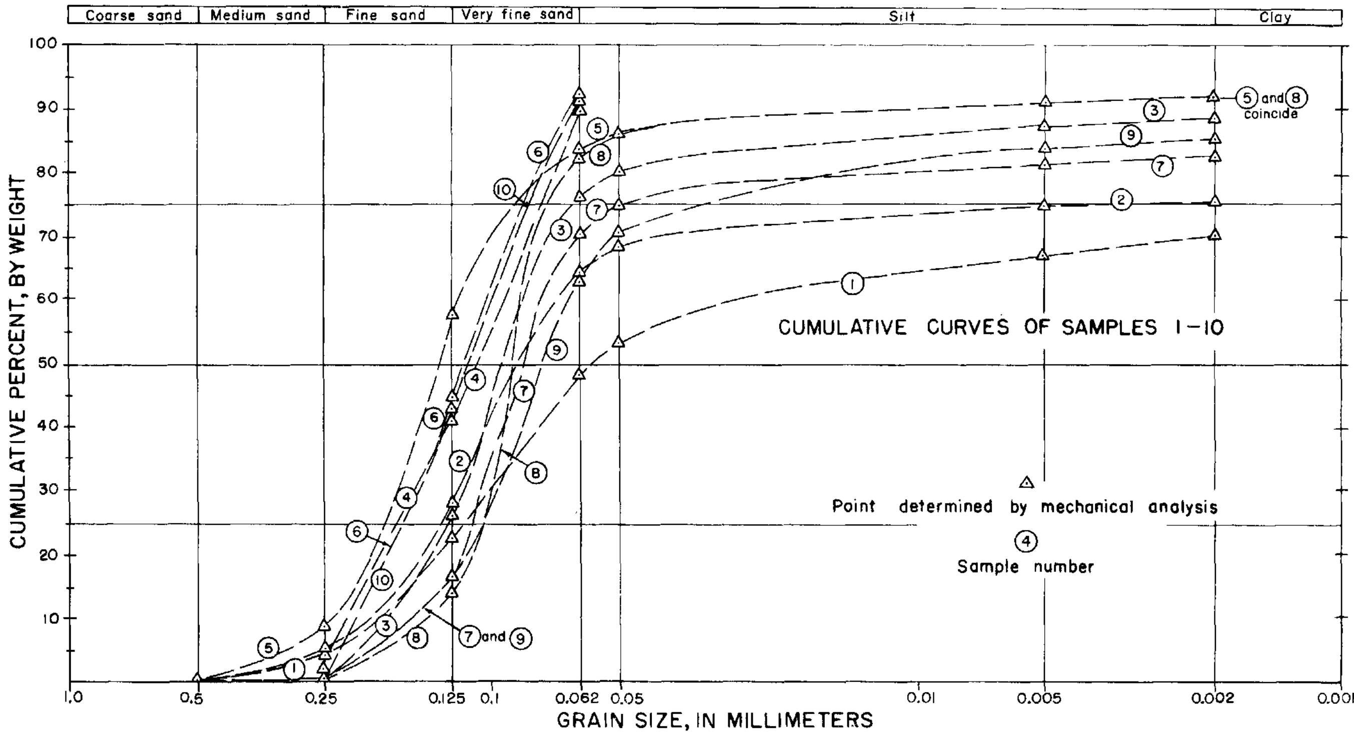


FIGURE 6.—Grain-size analyses of samples of the upper member of the Coker formation, Webb core hole.


Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
GRAIN SIZE, IN MILLIMETERS
1.0
0.5
0.25
0.125
0.1
0.062
0.05
0.01
0.005
0.002
0.001
5 and 8 coincide
7 and 9
CUMULATIVE CURVES OF SAMPLES 1-10
Point determined by mechanical analysis
Sample number

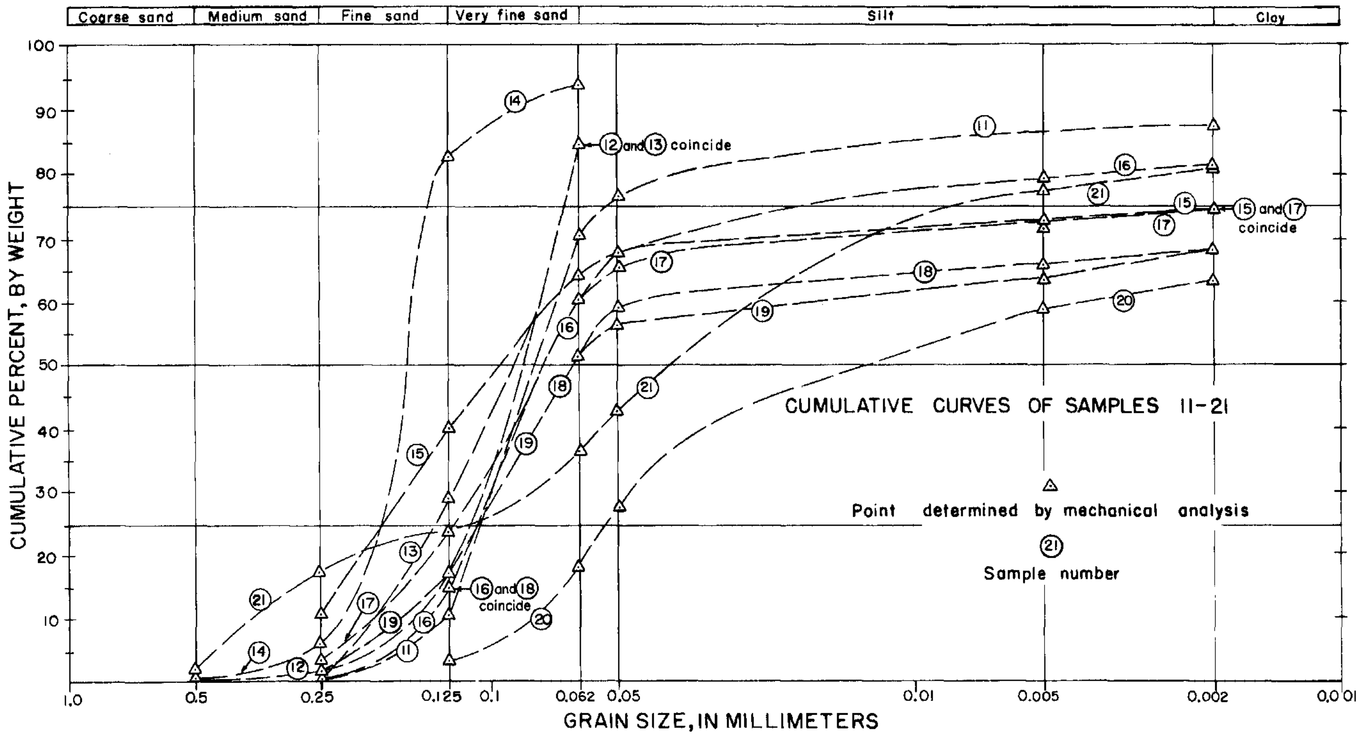


FIGURE 7.—Grain-size analyses of samples of the upper member of the Coker formation, Boykin core hole.

TABLE 4.—*Sorting coefficients of samples from the upper member of the Coker formation*

Coker formation, upper member									
Boykin core samples					Webb core samples				
Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient	Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient
1	0.056	0.116	(?)	(?)	1	0.075	0.130	0.0245	2.4
2	.086	.113	0.002	8.4	2	.062	.150	.0094	4.0
3	.092	.127	.065	1.4	3	.107	.515	.066	2.8
4	.110	.170	.076	1.5	4	.066	.095	.0285	1.8
5	.135	.180	.088	1.4	5	.058	.080	.0165	2.2
6	.115	.170	.084	1.4	6	.076	.095	.030	1.8
7	.083	.110	.049	1.5	7	.067	.113	.00032	5.7
8	.089	.105	.074	1.2	8	.072	.102	.008	3.6
9	.074	.105	.028	1.9	9	.063	.086	.0173	2.2
10	.110	.160	.080	1.4	10	.045	.097	(?)	(?)
11	.082	.105	.053	1.4	11	.0375	.067	.00265	5.0
12	.084	.110	.066	1.3	12	.210	.320	.160	1.4
13	.089	.132	.066	1.4	*13	.280	.390	.185	1.4
14	.160	.180	.142	1.1	14	.047	.092	(?)	(?)
15	.092	.175	(?)	(?)	15	.0365	.080	.0017	6.9
16	.075	.105	.017	2.5	16	.00057	.0255	(?)	(?)
17	.074	.125	(?)	(?)	17	.064	.096	.0046	4.6
18	.064	.102	(?)	(?)	18	.00136	.0235	(?)	(?)
19	.064	.124	(?)	(?)	19	.073	.117	.0107	3.3
20	.014	.053	(?)	(?)					
21	.038	.110	.007	4.0					

*This sample is a check sample against sample 12.

only the upper 22 feet. The core samples from the base of the Gordo consist of gray pebbly to cobbly sand and interbedded gray and orange sandy and clayey silt and silty clay. The samples from the upper part of the formation consist of interbedded red and gray silt and silty clay, and thin beds of gray very fine to fine silty and clayey sand. No grain-size determinations were made on the samples of the Gordo.

McSHAN FORMATION

The entire 216-foot thickness of the McShan formation was penetrated by the Crawford core hole, but only 54 feet of core was recovered. The McShan formation consists of a basal pebbly sand, 30 feet thick, that grades upward into 45 feet of fine to medium glauconitic sand, which in turn is overlain by fine to medium glauconitic, silty sand interbedded with gray sandy and clayey silt.

The McShan formation could not be completely sampled because of the large losses in coring; but, on the basis of the samples taken, the formation is made up of interbedded, well-sorted to poorly sorted granular to pebbly, silty and clayey sand (fig. 8; table 5).

Very fine to medium sand constitutes 50 percent or more material, by weight, in all 15 grain-size analyses (fig. 8). The sand in these 15 samples locally contains as much as 48 percent silt- and clay-sized particles, 8 percent pebbles, and 7 percent granules.

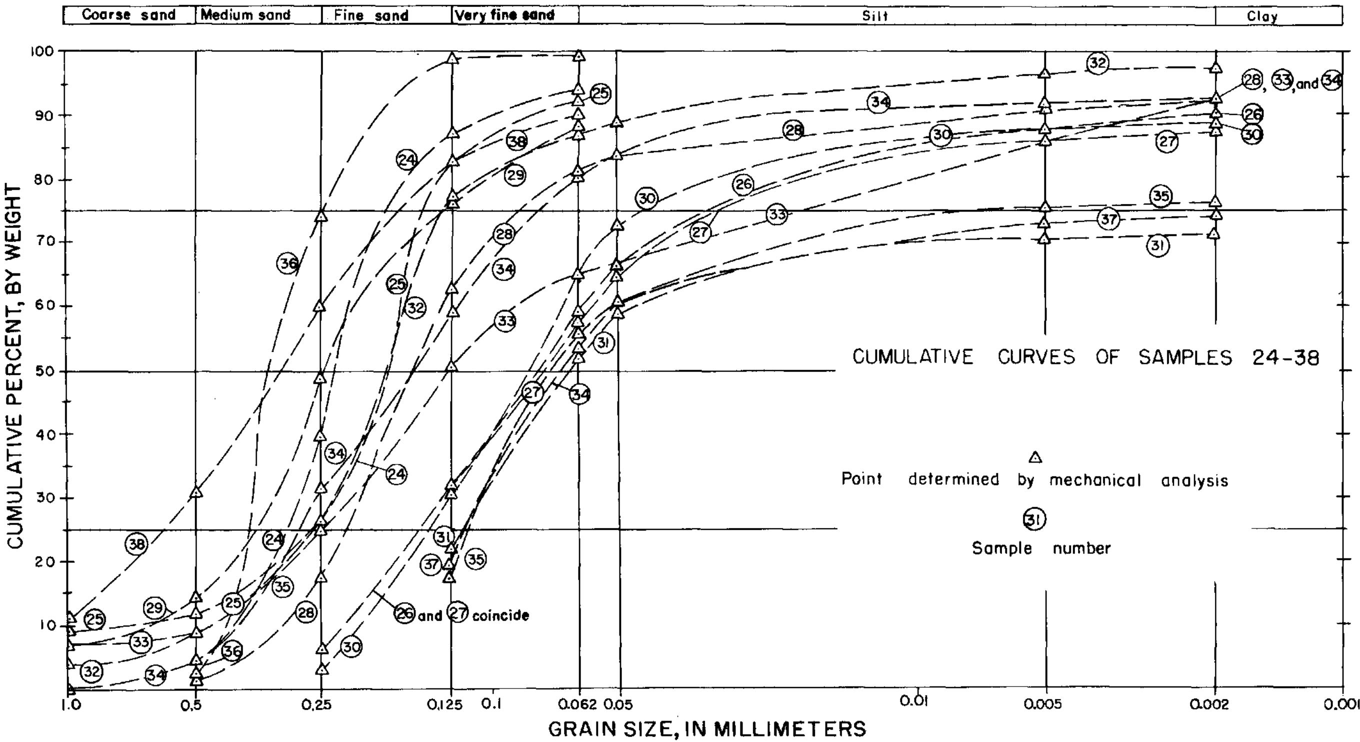


FIGURE 8.—Grain-size analyses of samples of the McShan formation, Crawford core hole.

TABLE 5.—*Sorting coefficients of samples from the Eutaw and McShan formations*

Eutaw formation					McShan formation				
Crawford core samples					Crawford core samples				
Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient	Sample	Median 50 percent	First quartile 25 percent	Third quartile 75 percent	Sorting coefficient
1	0.248	0.385	0.180	1.5	24	0.230	0.300	0.180	1.3
2	.145	.170	.098	1.3	25	.175	.260	.145	1.3
3	.205	.215	.165	1.1	26	.080	.145	.034	2.1
4	.182	.210	.175	1.1	27	.077	.148	.029	2.2
5	.110	.133	.087	1.2	28	.155	.225	.075	1.7
6	.202	.215	.175	1.2	29	.245	.350	.130	1.6
7	.245	.310	.200	1.2	30	.085	.150	.046	1.8
8	.110	.145	.072	1.4	31	.064	.118	(?)	(?)
9	.095	.155	.060	1.6	32	.180	.255	.133	1.4
10	.130	.240	.076	1.8	33	.125	.255	.023	3.3
11	.220	.292	.122	1.5	34	.158	.295	.075	1.9
12	.114	.193	.050	1.9	35	.068	.112	.005	4.7
13	.160	.280	.088	1.8	36	.340	.375	.250	1.2
14	.273	.335	.205	1.3	37	.068	.113	.001	8.9
15	.108	.170	.065	1.6	38	.320	.584	.160	1.9
16	.208	.252	.170	1.2					
17	.078	.114	.060	1.4					
18	.185	.230	.138	1.3					
19	.182	.217	.132	1.3					
20	.203	.215	.165	1.1					
21	.086	.150	.036	2.1					
22	.215	.268	.175	1.2					
23	.305	(?)	.190	(?)					

EUTAW FORMATION

The Eutaw formation was completely penetrated by the Crawford core hole, with a recovery of 90 feet of core from the total thickness of 157 feet. The Eutaw formation is lithologically similar to the underlying McShan formation except that the Eutaw contains more sand, and the glauconite grains are coarser and darker green. Many fossils are present in the upper part of the Eutaw formation.

The samples consist largely of well-sorted sand (fig. 9; table 5) and silty sand. Figure 9 shows that the lower half of the Eutaw formation contains more silt-sized particles than the upper half.

Very fine to medium sand composes 50 percent or more material, by weight, in all 23 textural analyses (fig. 9). Individual samples contain as much as 35 percent silt and clay, 9 percent pebbles, and 4 percent granules. A moderately well sorted, fine to coarse sand at the base of this formation contains as much as 18 percent pebbles and 11 percent granules.

MOOREVILLE CHALK

The Crawford core hole was started in the lower part of the Mooreville chalk of the Selma group and penetrated the lower 26 feet of this formation, from which only 12 feet of core was recovered. The Mooreville chalk consists mainly of argillaceous chalk having abundant coarse dark-green grains of glauconite and abundant fragments of fossils. The basal 3 feet consists of glauconitic, phosphatic, fossiliferous sand and carbonate-cemented sandstone.

SUMMARY OF GRAIN-SIZE ANALYSES

Table 6 is a summary of the grain-size analyses of samples taken from the subsurface Vick, Coker, McShan, and Eutaw formations. On the basis of the available samples it is clear that these sediments are dominantly sandy and that a large part of the sand-sized material is well sorted. In addition, the sediments of the Vick, McShan, and Eutaw formations are better sorted and somewhat coarser than those of the Coker formation. Also, the sediments of the Eutaw formation are better sorted than those of the McShan.

In considering these formational differences in textural sorting and distribution, it must be realized that individual samples taken at random from the four formations cannot be relied upon to show overall differences in grain-size distribution and sorting. The general statements made in this summary are based on a large number of samples taken from only those parts of the four formations that are coherent enough to be recovered when cored.

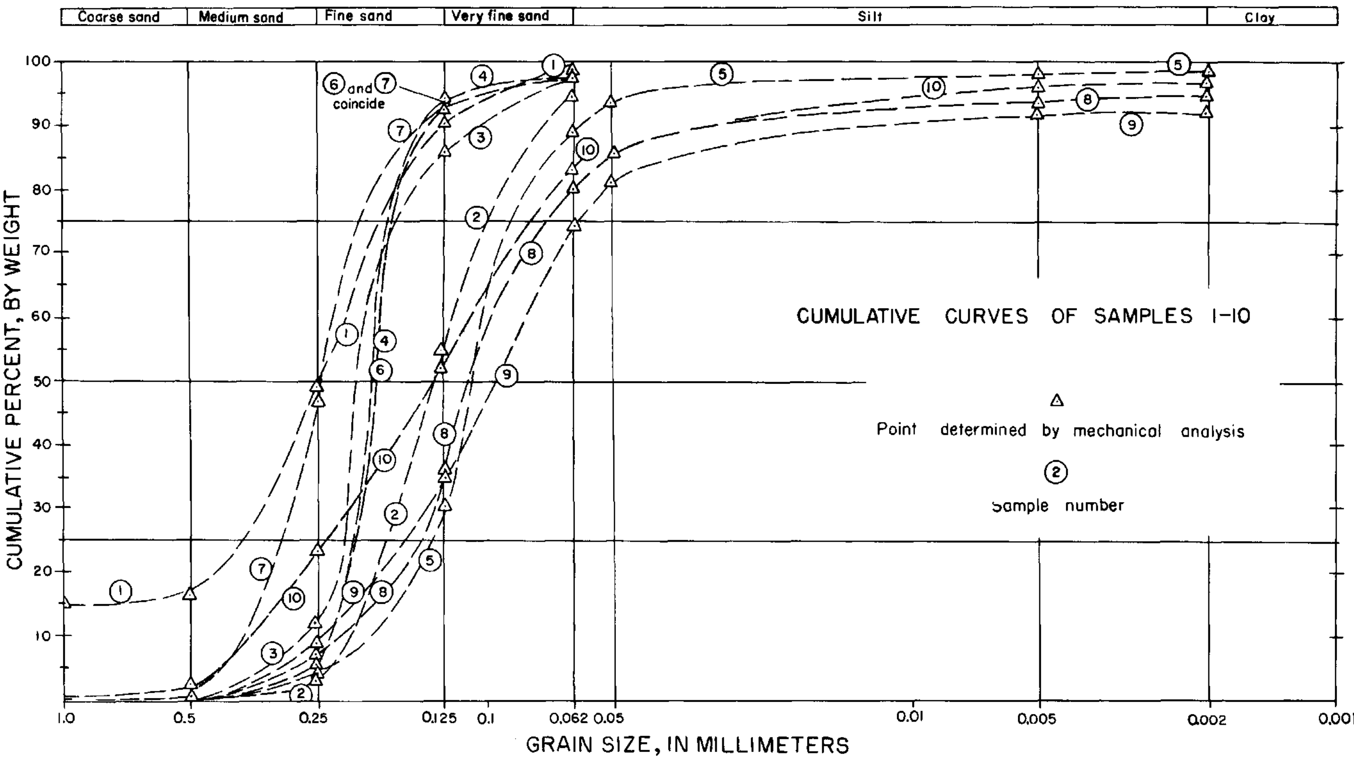
TABLE 6.—*The total number of samples and their sorting coefficients compared with the number of samples containing more than 50 percent sand*

Formation		Core hole	Total number of samples	Sorting coefficients: Well sorted less than 2.5	Sorting coefficients: Moderately sorted 2.5 to 4.0	Sorting coefficients: Poorly sorted greater than 4.0	Number of samples having more than 50 percent sand
Eutaw		Crawford	23	22	1		23
McShan		do	15	11	1	[1]1 2	15
Coker	Upper member	Webb	40	7	4	[1]4 4	30
		Boykin		12	2	[1]5 2	
	Eoline member	Webb	58	18	5	[1]1 3	38
		Boykin		11	2	[1]12 6	
Vick		Cleveland	22	20	1	1	21
		Webb	6	5	1		5

[1] Samples from which either the 25 percent or 75 percent quartile was unobtainable.

ROCK-FORMING MATERIALS

Thin sections of carbonate-cemented sandstone, chert-cemented sandstone, and relatively unlithified sand and silt were examined to determine the composition and distribution of rock and mineral fragments. These thin-section studies were made in an effort to differentiate among the formations and to obtain information on which to base interpretations on the probable origin and source areas of the sediments.



Coarse sand
Medium sand
Fine sand
Very fine sand
Silt
Clay
CUMULATIVE PERCENT, BY WEIGHT
GRAIN SIZE, IN MILLIMETERS
6 and 7 coincide
CUMULATIVE CURVES OF SAMPLES 1-10
Point determined by mechanical analysis
Sample number

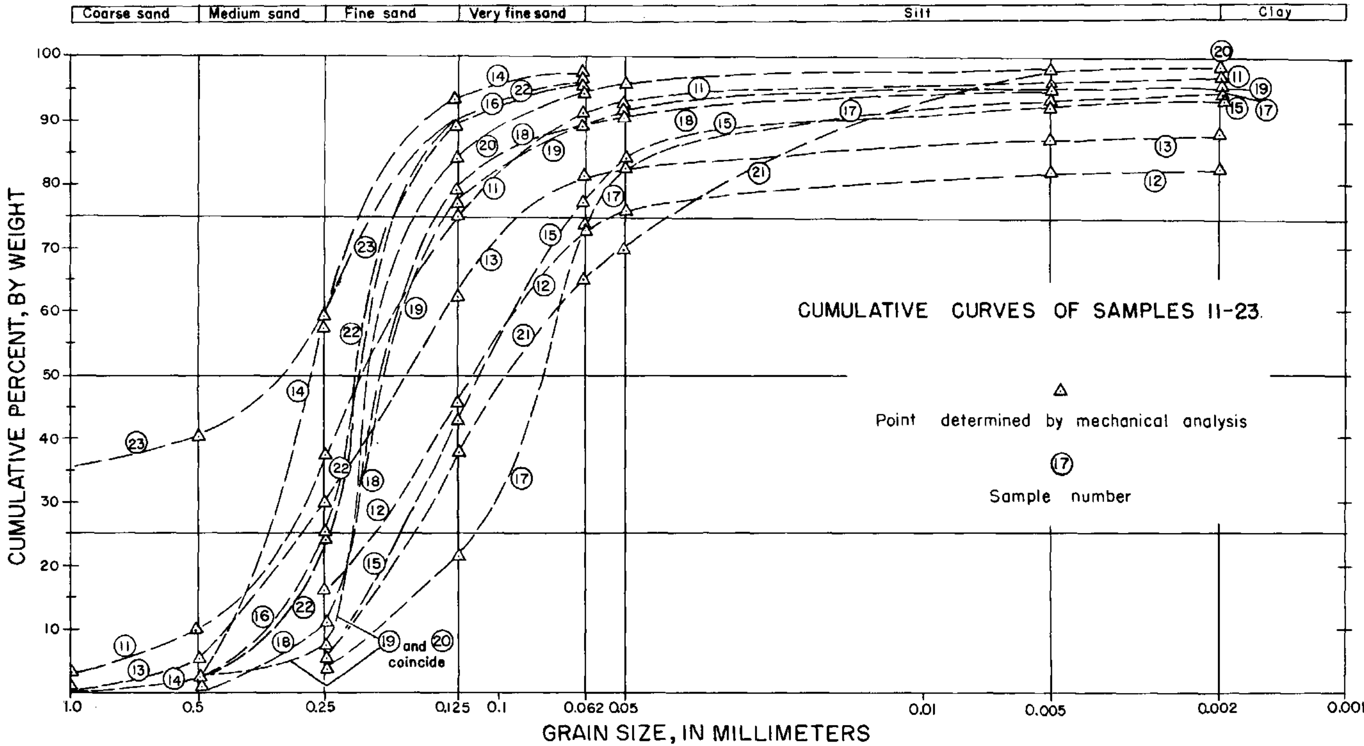


FIGURE 9.—Grain-size analyses of samples of the Eutaw formation, Crawford core hole.

The rock and mineral fragments identified in thin section include: 7 varieties of quartz grains, 3 of which are individual grains and 4 of which are composite grains (rock fragments); orthoclase, microcline, and plagioclase feldspar; muscovite; chlorite; glauconite; tourmaline and traces of a few other minerals; and rock fragments of chert and schist. The matrix or interstitial materials include clay paste and cements of carbonate, chert, and chalcedony.

The 7 varieties of quartz were distinguished by using a procedure modified from that of Folk (1957, p. M–7); 3 varieties of individual quartz grains may be arbitrarily distinguished by the extinction characteristics of the grains under crossed nicols, and 4 varieties of composite quartz grains may be differentiated by the orientation, shape, and interrelations of the particles that make up the grains (fig. 10).

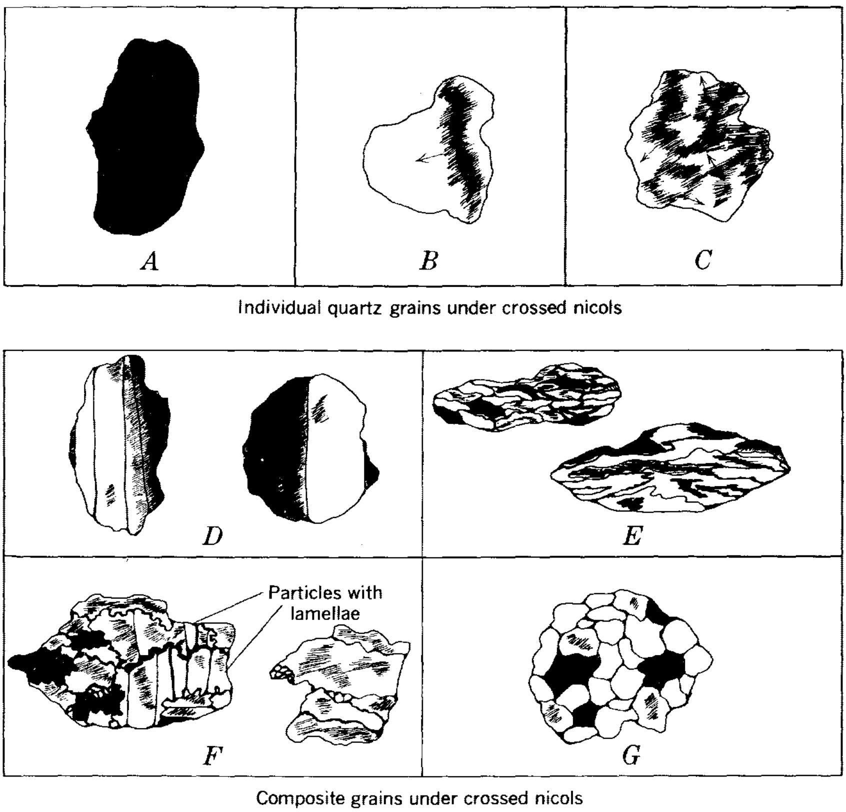


FIGURE 10.—Varieties of quartz in subsurface sediments of the Vick, Coker, McShan, and Eutaw formations. *A*, Unstrained whole grain at extinction at once. *B*, Moderately strained grain has sweeping extinction shadow. *C*, Strongly strained grain has irregular extinction shadows. *D*, Two or more individuals, in subparallel optical orientation, with straight borders. *E*, Particles, in semiparallel optical orientation, with relatively smooth borders. *F*, Two or more individuals, in random optical orientation, with crenulated borders. *G*, Two or more individuals, in random optical orientation, with smooth borders.

The extinction characteristics of the individual quartz grains under crossed nicols are a measure of the degree of straining the grains have undergone. Those that are unstrained to slightly strained are distinguished by an abrupt extinction upon rotation of the microscope stage, generally less than 8°; those that are moderately strained show an extinction shadow that sweeps smoothly across them upon rotation of the microscope stage, generally no more than 20°. The moderately strained quartz grains can be related to the quartz grains that contain well-developed lamellae, which are considered to be a composite quartz variety because in many of them the extinction shadow moves from lamella to lamella, giving a total effect of sweeping smoothly across the grain. Strongly strained quartz grains show extinction shadows that sweep slowly and irregularly across the grain upon rotation of the microscope stage for generally more than 20°.

Composite quartz grains that are aggregates of two or more grains are divisible into four varieties on the basis of optical orientation of constituent particles and the nature of the particle borders. One variety has constituents or lamellae that are in parallel to subparallel optical orientation and have straight borders; these grains are considered to be largely fragments of metaquartz derived from rocks of metamorphic origin such as gneiss, schist, and metaquartzite, but possibly some have come from vein quartz. A second variety has elongate constituents in parallel to semiparallel optical orientation, with smooth to partly crenulated borders; these grains are probably derived from schistose metamorphic rocks. A third variety has mostly unstrained constituents in random optical orientation and with smooth borders; these grains are considered to be derived from orthoquartzitic sedimentary rocks and from recrystallized metamorphic rocks. A fourth variety has particles with crenulated to granulated borders, indications of strong straining within the particles and lamellae, or "bands" within some particles; these grains are probably derived largely from metaquartzites and other relatively coarse-grained metamorphic rocks.

All these rock and mineral fragments are present in the Vick, Coker, McShan, and Eutaw formations, but their abundance in each formation differs somewhat. The abundance of fragments and of the matrix materials was determined by counting one hundred points per thin section. By counting points in increments of 25 and comparing the percent distribution of each increment, these point-count results were found to be accurate within 5 percent.

Thin-section analyses of these sediments showed that the sediments can be grouped for study and comparison as carbonate-cemented sandstone, chert-cemented sandstone, sand, and silt.

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CARBONATE-CEMENTED SANDSTONE

Six carbonate-cemented sandstone beds ranging in thickness from 0.5 to 1.5 feet are represented in samples from the Crawford and Webb core holes. In the Crawford hole, 1 of these sandstone beds is at the base of the Mooreville chalk and 2 are in the Eutaw formation; in the Webb hole 3 sandstone beds are present in a 35-foot zone in the upper half of the Eoline member of the Coker formation (pl. 1).

Composition.—The carbonate-cemented sandstone beds contain the following materials: six varieties of quartz, which is moderately to well sorted and sharply angular to well rounded, with some broken rounded grains; orthoclase, microcline, and plagioclase feldspar; pale-green and pale-tan to opaque, ellipsoidal to almost spherical, well-rounded grains of glauconite; muscovite; chert; and schist. Coarse-grained to granule-sized shell fragments, well-rounded fragments of phosphate (probably collophane) and phosphatized fecal pellets(?) are sparesely present, along with traces of zircon, pink garnet, kyanite, and light-brown tourmaline (table 7).

The mineral and rock fragments are set in a matrix consisting largely of coarsely crystalline calcite whose crystals show the luster mottling (Pettijohn, 1957, p. 653) seen in many carbonate-cemented sandstone beds elsewhere. Many single small crystals of calcite contain as many as 30 fine to medium grains of quartz sand. A thin section of the Mooreville chalk from the Crawford hole (sample 5, table 7) contains 14 percent argillaceous calcilutite admixed with the crystalline calcite material; luster mottling is not well developed in this sample. A thin section of the Eoline member in the Webb core hole (sample 21, table 7) contains small areas having dozens of microscopic pale yellow-brown ovoid bodies and widely scattered quartz grains, all of which are cemented with finely crystalline calcite.

Mode of formation.—The generally well-sorted nature of these sandstone beds and their well-cemented condition suggest that these sediments were winnowed of interstitial silt and clay and the interstices were subsequently filled with carbonate. It is possible that the luster-mottling of the cementing material may have resulted from recrystallization or reorganization of an interstitial lime mud, but the generally well sorted grains and the absence of ghost structures of mineral and rock fragments, other than a few widely scattered unstable plagioclase grains, indicate pore filling by crystalline calcite. Another indication of pore filling is that many grains do not touch any other grain in the thin section. This observed relation could result from a random cut through a well-sorted rock, but many of these grains are far enough from other grains to suggest that the sand grains were forced apart slightly by the crystallization of the carbonate.

Table 7.—*Percentage of rock-forming materials in thin sections of carbonate-cemented sandstone (or arenaceous carbonate) from the Coker, Eutaw, and Mooreville formations*

Formation	Sample	Grain size [1]	Rock and mineral fragments																					Matrix			Other
			Quartz varieties									Rock fragments other than quartz varieties				Mineral grains											
			Individual grains				Composite grains (rock fragments)									Feldspar				Other							
			Unstrained	Moderately strained	Strongly strained	Total	Sub-parallel orientation, straight borders	Semi-parallel orientation, moderately smooth borders	Random orientation, smooth borders	Random orientation, crenulated borders	Total	Chert	Schist, undifferentiated	Phosphatic material	Total	Orthoclase	Microcline	Plagioclase	Total	Muscovite	Chlorite	Glauconite	Total	Argillaceous calcilutite	Crystalline carbonate cement	Total	
Crawford core hole																											
Mooreville chalk	5	f-m	25	1	----	26	9	----	----	----	9	----	----	----	----	----	1	----	1	----	----	----	----	14	44	58	[2]6
Crawford core hole																											
Eutaw	7	f-m	29	2	2	33	10	1	----	4	15	----	1	----	1	----	----	----	----	----	----	6	6	----	45	45	----
	10	f-m	22	6	3	31	4	----	----	5	9	2	1	1	4	----	----	----	----	1	----	4	5	----	51	51	----
Webb core hole																											
Eoline member Coker	20	f-m	32	1	1	34	9	2	----	10	21	4	----	----	4	2	----	----	2	----	----	----	----	----	39	39	----
	21	f-m	19	3	----	22	3	----	----	3	6	----	----	----	----	----	1	1	3	----	----	1	1	----	[3]65	65	[4]3
	23	f-m	29	1	1	31	7	----	----	5	12	----	----	----	----	----	3	1	4	----	----	7	7	----	45	45	[5]1

[1] f = fine grained, m = medium grained.
[2] Shell fragments.
[3] Includes patches with tiny ovoid bodies (20 percent).
[4] Shell fragments: this rock may be classified as an arenaceous carbonate.
[5] Detrital garnet.

Cementation rather than reorganization also is suggested by the fact that some grains of glauconite seem to have been forced open, either with no apparent pattern or along apparent lines of cleavage (fig. 11). The same force that apparently forced the sand grains apart may also have broken open some of the glauconite grains.

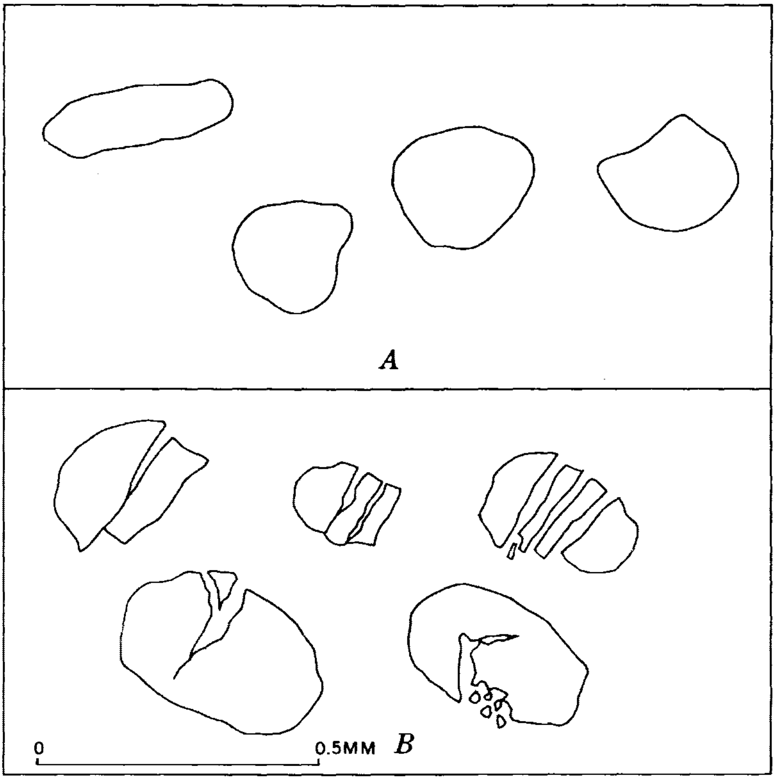

FIGURE 11.—Drawings of glauconite grains in carbonate-cemented sandstone of the Eutaw formation. Sample 10 from the Crawford core hole. Magnification about 75×. *A*, Typical rounded ellipsoidal to nearly spherical and broken rounded grains of glauconite. In carbonate-cemented sandstone. *B*, Typical grains of glauconite that seem to have been split by the force of crystallization during cementation of the carbonate-cemented sandstone.

These observations on glauconite also suggest that the glauconite grains did not form where these well-winnowed sands accumulated, but were probably reworked and transported from a nearby area where they were forming. The fracturing of glauconite in this carbonate-cemented sediment indicates that the grains of glauconite were not nearly as strong as grains of quartz and feldspar; but, because there are well-rounded, unbroken glauconite grains in many of these sediments, it is likely that the sand collected in an area of winnowing currents of only moderate strength, and not in an area of strongly agitated water. The presence of sharply angular shell fragments supports this interpretation.

The tiny pale yellow-brown ovoid bodies cemented by finely crystalline calcite that form patches in the carbonate-cemented sandstone beds of sample 21 in the Eoline member are probably phosphatized fecal pellets of some marine organism.

Provenance.—The presence of several varieties of quartz in each of these carbonate-cemented sandstone beds suggests a multiple source for the sediments. Further, the mixture of sharply angular, well-rounded, and broken rounded mineral grains of approximately the same size also suggests that the material was derived from terranes underlain by both crystalline and sedimentary rocks.

Some of the unstrained and moderately strained quartz grains and most of the feldspars were probably derived from igneous rocks, and possibly also some from recrystallized metamorphic rocks. Most of the strongly strained quartz, quartz grains with lamellae, schistose quartz aggregates, and other composite grains, along with trace amounts of garnet and kyanite, were probably derived from metamorphic rocks. The rounded and broken rounded grains of all the quartz varieties, along with rounded chert grains, trace amounts of rounded tourmaline and zircon. and well-rounded phosphatic fragments indicate a source underlain by sedimentary rocks.

The fragments of fossils may represent animals that lived at the site of deposition, or they may have been brought in from nearby. It is likely that some or much of the glauconite was derived from neighboring areas.

The phosphatic grains probably were derived from phosphatic rocks inasmuch as silt-sized angular grains of quartz are occluded in these fragments, and veinlets of phosphate crosscut phosphatic grains.

CHERT-CEMENTED SANDSTONE

Five partly chert-cemented and somewhat porous sandstone beds of the Vick formation were encountered in the Cleveland core hole and two were encountered in the upper part of the Vick formation in the Webb core hole (pl. 1).

Composition.—The principal constituents of the chert-cemented sandstone beds are: fine-grained to very coarse grained, subrounded to well-rounded quartz of the seven previously described varieties; orthoclase, microcline, and plagioclase feldspar; chert; schist; and muscovite (table 8). These constituents are set in chert and chalcedonic cement.

Texture and the mode of formation.—The five sandstone units of the Cleveland core hole samples show moderately well developed graded bedding, generally grading upward from a well-sorted coarse to very

TABLE 8.—*Percentage of rock-forming materials in thin sections of chert-cemented sandstones from the Vick formation*

Formation	Sample	Grain size [1]	Rock and mineral fragments																			Matrix			
			Quartz varieties									Rock fragments other than quartz varieties			Mineral grains						Cement			
			Individual grains				Composite grains (rock fragments)								Feldspar				Other					
			Unstrained	Moderately strained	Strongly strained	Total	Subparallel orientation, straight borders	Semiparallel orientation, moderately smooth borders	Random orientation, smooth borders	Random orientation, crenulated borders	Total	Chert	Schist, undifferentiated	Total	Orthoclase	Microcline	Plagioclase	Total	Muscovite	Total	Chert	Chalcedony	Total	Voids
Cleveland core hole																								
Vick	1	f-m	19	10	11	40	15	--	2	10	27	1	1	2	--	1	1	2	8	8	10	--	10	11
	2	m	27	1	6	34	18	3	--	23	44	--	--	--	1	1	2	4	7	7	6	1	7	4
	3	m-c	8	--	11	19	22	6	--	24	52	--	--	--	3	1	1	5	4	4	9	3	12	8
	4	m-c	14	2	3	19	28	--	1	28	57	1	--	1	1	1	--	2	4	4	10	--	10	7
	5	m-c	16	4	3	23	19	1	3	25	48	3	--	3	1	1	--	2	1	1	8	--	8	15
	6	c-vc	8	4	6	18	13	--	1	30	44	7	--	7	--	1	--	1	--	--	23	--	23	7
	7	f-m	22	5	4	31	22	4	2	19	47	--	--	--	2	--	--	2	2	2	9	--	9	9
	8	f-m	14	4	3	21	17	1	--	25	43	1	--	1	1	--	1	2	2	2	10	--	10	21
	9	c	16	8	7	31	18	1	--	24	43	--	--	--	--	--	1	1	2	2	6	--	6	17
	10	f-m	11	9	2	22	21	5	--	22	48	--	--	--	--	--	--	--	2	2	14	--	14	14
	11	f-m	7	1	5	13	18	1	1	23	43	2	--	2	1	--	3	4	14	14	16	--	16	8
	12	f-m	13	6	3	22	22	4	1	12	39	3	--	3	--	--	1	1	11	11	23	--	23	1
	13	f-m	21	4	1	26	19	5	1	18	43	1	--	1	1	--	--	1	9	9	14	--	14	6
	14	m-c	17	4	2	23	29	4	1	18	52	--	1	1	1	--	--	1	4	4	8	--	8	11
	15	f-m	13	10	2	25	12	7	1	21	41	2	--	2	--	--	--	--	2	2	11	--	11	19
	16	m-c	22	1	1	24	17	4	1	18	40	--	--	--	--	1	--	1	5	5	25	--	25	5
	17	m-c	17	5	6	28	18	1	--	22	41	1	--	1	--	--	--	--	2	2	22	--	22	6
	18	m-c	18	6	1	25	20	3	--	18	41	--	1	1	--	--	--	--	4	4	24	--	24	5
	19	c	12	--	1	13	13	6	--	23	42	--	1	1	--	2	1	3	16	16	7	--	7	18
Webb core hole																								
Vick	29	f-m	29	5	3	37	11	11	--	3	25	3	4	7	--	--	1	1	1	1	25	--	25	4
	30	m	24	3	3	30	17	9	--	8	34	--	4	4	--	1	--	1	[2] 8	8	20	--	20	3

[1] f=fine-grained; m, medium-grained; c, coarse-grained.
[2] Includes 3 percent chlorite flakes.

coarse sand to a well-sorted fine to medium sand. In places the coarser sand contains as much as 1 percent pebbles and 9 percent granules. These sandstone beds have been winnowed of all but minor amounts (maximum of 16 percent) of silty and clayey material. With the exception of small amounts of feldspar (5 percent in one sample), these sandstone beds are composed largely of chemically and mechanically stable mineral and rock fragments.

The graded bedding of five units that are stratigraphically near each other suggests deposition by currents of increasing and decreasing velocity, such as characterize streams. This and the stable nature of the clastic material suggest reworking of material that was derived chiefly from a peneplaned area. The sediments of the Vick formation in the Webb core hole are well bedded and sorted and are thought to be marine.

Provenance.—Some of the unstrained and moderately strained quartz, and most of the feldspar, probably came from igneous rocks or recrystallized metamorphic rocks. It is likely that metamorphic rocks contributed large amounts of the strongly strained quartz grains, quartz grains with lamellae, schistose quartz, fragments of schist, and quartz grains interpreted as derived largely from metaquartzite. Sedimentary rocks probably contributed the rounded chert grains and many of the varieties of well-rounded quartz that were derived originally from igneous and metamorphic rocks.

The chert cement was probably brought to these sediments penecontemporaneously from a highly weathered peneplaned area as soluble silica. Supporting this belief is the fact that the sand grains do not seem to be compressed, hence pressure solution between chert and quartz grains within the beds is not indicated as a source of silica.

The associated reddish-brown sandy and clayey silt beds in the Vick formation probably represent reworked iron-stained clayey and silty soils.

SAND

The bulk of the pre-Selma sediments of Late Cretaceous age consist of very fine to medium sand, though some samples contain as much as 59 percent silty and clayey material. The sediments in the upper member of the Coker formation, in both the Webb and the Boykin core samples, are largely red and brown stained, and the higher sand beds contain spherulites of siderite. The sand beds of the Eoline member of the Coker formation and of the McShan and Eutaw formations are glauconitic.

Composition.—The sand grades vertically into silty and clayey sand, sandy and clayey silt, and sandy and silty clay. The chief constituents of the sand beds are: moderately well sorted to well-sorted, very fine to medium, mostly subangular grains of the seven varieties of quartz; three types of feldspar; chert; schist; pale-green and pale-tan to opaque, varishaped but usually ellipsoidal to nearly spherical grains of glauconite; and flakes of muscovite and chlorite. More rarely, grains of sandstone, claystone, spherulitic chalcedony, pink garnet, zircon, and tourmaline are present.

These rock and mineral fragments generally are set in a matrix of clay paste consisting of finely divided flakes and shreds of colorless to pale-green micaceous clay minerals and tiny bits of quartz (table 9). Many minute, opaque, somewhat rounded bodies are present in the interstitial clay paste of the sand, especially in the red- and brown-stained sands; these grains may be incipient, authigenic siderite.

Mode of formation.—The glauconite-bearing sand is presumed to be of marine origin, though the lignite beds adjacent to sand beds in the upper part of the Eoline member of the Coker formation suggest that swampy and lagoonal conditions must have existed at some places. The large amount of interstitial clay paste suggests a lack of winnowing currents, a condition which also suggests swampy backwaters in marginal marine and shallow marine estuaries and lagoons. The thin well-winnowed carbonate-cemented sandstone beds in the Eoline member of the Coker formation and in the Eutaw formation suggest brief incursions of very shallow, more agitated marine waters. The combination of these relations indicates an area of marginal marine and shallow marine accumulation.

The red-bed sequence in the upper member of the Coker formation may indicate rapid sedimentation of red-stained terrestrial materials into lagoonal areas. These red materials may have been soils swept off a landward area that was undergoing uplift. With increased uplift, erosion would have exposed unweathered bedrock in the source area, thus accounting for the abundance of pebbly sand in the overlying Gordo formation.

Provenance.—The large amount of very fine to medium, moderately sorted to well sorted, largely subangular sand in these sediments suggests derivation from preexisting relatively fine grained rocks. The abundance of types of quartz (tables 7–9) interpreted as metamorphic in origin suggests a source area or areas underlain largely by metamorphic rocks. The abundant muscovite and lesser amounts of chlorite flakes, grains of schist, pink garnet, kyanite, and the abundant micaceous materials of the clay paste also indicate a major contribution from fine-grained metamorphic rocks. It is likely that sedimentary rocks also contributed to these sediments, because of the presence of some well-rounded quartz grains, chert grains, and the trace amounts of rounded zircon and tourmaline grains. Some of the clay paste material may also have been derived from clay-rich sedimentary rocks.

SILT

On the basis of mechanical analyses, the silt in the sediments of pre-Selma Cretaceous age was found to be less abundant than the sand (table 10). The silt is randomly distributed in the Vick, Coker, McShan, and Eutaw formations, and is similar in composition to the sand. The large amount of interstitial clay paste suggests that the silt accumulated in quiet water and very likely was derived from virtually the same sources as the sand. Owing to the fineness of the silt, quartz grains were the only readily identifiable constituents.

MARL

Four samples of the marly sediments at the base of the Mooreville chalk in the Crawford core hole (pl. 1) were examined in thin section. These samples were taken from what is probably a transition zone between the detrital quartz-sand sediments of the Eutaw formation and the highly marly rocks of the overlying Mooreville chalk.

Table 11 shows the results of 100 point counts made on each slide. It will be noted that the lower samples, Nos. 3 and 4, contain relatively large amounts of glauconite, detrital quartz fragments, and some finely crystalline carbonate. Samples 1 and 2 consist largely of argillaceous calcilutite and carbonate-filled Foraminifera that are largely pelagic types (E. R. Applin, written communication, Sept. 27, 1957). The marly composition of most of the Mooreville samples, with only the finest of land-derived material and pelagic types of Foraminifera, suggests either a shallow-water deposit with relatively little terrigenous material or a protracted incursion of much deeper, far-from-shore marine waters, as contrasted to the shallow-water and near-shore marine conditions at the time the sediments of the Eutaw formation were deposited.

DISTRIBUTION OF ROCK AND MINERAL FRAGMENTS

Tables 7 to 10 show the percentages of rock and mineral fragments, matrix materials, and voids in the four types of sediment of pre-Selma age that have been discussed. Table 12 shows the average percentages of the rock and mineral fragments in those four types of sediment in the several formations. All of these tables were examined for significant differences in the composition and proportion of rock and mineral varieties in the different formations.

Only minor differences were noted; for example, table 7 shows a somewhat greater amount of feldspar in the Eoline member of the Coker formation than in the other units compared. However, table 10 shows this to be true only among the quantitatively insignificant carbonate-cemented sandstone beds. Table 9 shows that no glauconite was observed in samples from the upper member of the Coker formation, but Drennen (1953a, p. 535) reported that sparse grains

TABLE 9.—*Rock-forming materials, percentage in thin sections, Coker, McShan, and Eutaw formations—44*

Formation	Sample	Grain size [1]	Rock and mineral fragments																				Matrix			Other	Voids
			Quartz varieties									Rock fragments other than quartz varieties			Mineral grains												
			Individual grains				Composite grains (rock fragments)								Feldspar				Other								
			Unstrained	Moderately strained	Strongly strained	Total	Subparallel orientation, straight borders	Semiparallel orientation, moderately smooth borders	Random orientation, smooth borders	Random orientation, crenulated borders	Total	Chert	Schist, undifferentiated	Total	Orthoclase	Microcline	Plagioclase	Total	Muscovite	Chlorite	Glauconite	Total	Clay paste	Crystalline carbonate cement	Total		
Crawford core hole																											
Eutaw	6	f	27	12	3	42	6	1	----	4	11	----	3	3	----	1	1	2	5	----	14	19	12	----	12	[2] 1	10
	8	f-m	19	8	3	30	12	1	----	8	21	1	1	2	----	2	3	5	1	----	20	21	14	----	14	----	7
McShan	11	f-m	24	6	2	32	6	----	1	3	10	----	----	----	----	2	----	2	9	4	12	25	31	----	31	----	----
Boykin core hole																											
Coker, upper member	1	vf	23	13	3	39	11	5	----	2	18	7	----	7	2	1	1	4	9	----	----	9	[3] 19	----	21	[4] 2	2
	3	f	26	8	3	37	12	2	1	7	22	3	5	8	----	1	1	2	5	----	----	5	1	----	1	[5] 4	21
Eoline member	5	vf-f	20	17	9	46	5	1	----	5	11	1	2	3	1	----	1	2	10	----	----	10	25	----	25	[6] 1	2
	6	vf-f	16	18	2	36	2	----	----	4	6	2	2	4	2	----	----	2	2	----	2	4	48	----	48	----	----
	13	m	27	5	5	37	10	----	----	21	31	2	----	2	1	----	3	4	1	----	----	1	9	----	9	[7] 1	15
	14	m	12	9	8	29	14	----	----	19	33	3	----	3	3	1	1	5	----	----	----	----	14	----	14	----	16

Webb core hole [8] [9]

Coker, upper member	2	vf–f	25	6	9	40	3	----	1	1	5	----	----	----	----	----	----	----	5	----	----	5	[3] 50	----	50	----	----
	3	vf–f	20	6	4	30	6	----	----	4	10	----	----	----	----	----	----	----	1	----	----	1	[3] 59	----	59	----	----
	4	vf	19	11	8	38	5	----	----	1	6	----	3	3	----	----	1	1	5	1	----	6	[3] 18	----	46	[4] 28	----
	5	vf	28	18	6	52	----	----	----	----	----	----	----	----	----	2	----	2	8	4	----	12	[3] 35	----	35	[10] 1	----
	6	vf	23	14	8	45	12	1	----	4	17	2	1	3	----	----	----	----	9	----	----	9	[3] 19	----	19	----	7
	7	vf	26	26	2	54	8	----	----	2	10	----	4	4	----	----	----	----	6	----	----	6	[3] 26	----	26	----	----
	8	vf	18	20	10	48	4	----	----	4	8	4	----	4	----	----	----	----	18	----	----	18	[3] 22	----	22	----	----
	9	vf	24	16	4	44	2	----	2	4	8	----	----	----	----	----	----	----	8	10	----	18	[3] 30	----	30	----	----
	11	f–m	28	13	7	48	7	----	----	14	21	----	1	1	----	----	----	----	2	----	----	2	28	----	28	----	----
	12	f–m	26	5	5	36	11	1	2	15	29	----	1	1	----	2	----	2	3	----	----	3	9	----	9	----	20
Eoline member	13	f	26	5	10	41	10	----	----	1	11	----	----	----	1	1	1	3	6	----	----	6	27	12	39	----	----
	14	f	23	14	2	39	4	2	----	1	7	----	1	1	1	1	----	2	15	5	----	20	25	5	30	----	1
	16	f	31	8	5	43	19	----	----	6	25	1	----	1	----	----	2	2	----	----	1	1	28	----	28	----	----
	17	vf–f	24	24	4	52	10	----	----	2	12	----	2	2	----	----	----	----	18	2	2	22	4	----	4	[7] 4	4
	22	vf	10	16	----	26	2	----	----	----	2	----	4	4	----	----	----	----	8	2	----	10	58	----	58	----	----
	24	f–m	22	5	5	32	2	1	1	7	11	----	2	2	1	----	1	2	5	3	6	14	39	----	39	----	----
	25	f	26	7	3	36	8	3	----	1	12	1	----	1	1	1	4	6	3	----	15	18	----	14	14	----	13
	27	f–m	29	9	1	39	7	----	1	12	20	3	----	3	1	1	1	3	----	----	3	3	32	----	32	----	----
	28	m	29	10	4	43	14	1	1	10	26	6	----	6	----	1	----	1	1	----	----	1	10	----	10	[11] 1	12

[1] vf, very fine; f, fine; m, medium.
[2] Detrital garnet.
[3] Brown-stained clay paste.
[4] Spherulites of siderite.
[5] 1 percent sandstone grains, 1 percent fragments of spherulitic chalcedony, 2 percent rims of chalcedony on grains of sand framework.
[6] Thin rims of chalcedony on grains.
[7] Claystone.
[8] Thin section sample 1 from Webb core consists of a pebble of metaquartzite from the Gordo formation.
[9] Thin section sample 15 from Webb core consists of silicified lignite(?) with spherules of chalcedony filling pores of cells.
[10] Detrital pale-green tourmaline.
[11] Chert cement.

TABLE 10—*Percentage of rock-forming materials in thin sections of silt from the Coker and Eutaw formations*

Formation	Sample	Grain size [1]	Rock and mineral fragments																					Matrix			Other
			Quartz varieties									Rock fragments other than quartz varieties			Mineral grains											
			Individual grains				Composite grains (Rock fragments)								Feldspar				Other							
			Unstrained	Moderately strained	Strongly strained	Total	Subparallel orientation, straight borders	Semiparallel orientation, smooth borders	Random orientation, smooth borders	Random orientation, crenulated borders	Total	Chert	Schist, undifferentiated	Total	Orthoclase	Microcline	Plagioclase	Total	Muscovite	Chlorite	Glauconite	Total	Clay paste	Crystalline carbonate cement	Total	
Crawford core hole																										
Eutaw	9	s	14	10	---	24	4	---	---	---	4	---	2	2	---	---	---	---	22	---	4	26	44	---	44	---
Boykin core hole																										
Coker	2	s	18	4	---	22	4	---	---	---	4	---	---	---	---	---	---	---	24	---	---	24	26	---	26	[2] 24
Webb core hole																										
Coker upper member	10	s	12	6	---	18	---	---	---	2	2	1	---	1	---	---	---	---	30	4	---	34	45	---	45	---
Boykin core hole																										
Coker, Eoline member	4	s	7	15	5	27	1	1	---	---	2	---	---	---	---	---	---	---	19	2	1	22	49	---	49	---
	7	s	9	6	---	15	3	---	---	---	3	---	1	1	1	---	1	2	11	---	---	11	68	---	68	---
	8	s	11	5	1	17	4	1	---	2	7	---	---	---	---	---	---	---	21	---	---	21	55	---	55	---
	9	s	20	28	4	52	---	---	---	---	---	---	---	---	---	---	---	---	22	2	---	24	24	---	24	---
	10	s	13	16	7	36	7	---	---	3	10	---	---	---	---	1	---	1	13	---	---	13	40	---	40	---
	11	s	17	11	2	30	6	1	---	3	10	1	---	1	1	---	---	1	6	---	---	6	52	---	52	---
	12	s	19	9	3	31	9	---	---	3	12	---	2	2	1	---	1	2	11	1	---	12	41	---	41	---
Webb core hole																										
Coker, Eoline member	18	s	16	---	2	18	8	---	---	2	10	2	---	2	---	---	---	---	14	---	14	28	42	---	42	---
	19	s	6	6	4	16	---	---	---	---	---	---	---	---	---	---	---	---	30	---	4	34	50	---	50	---
	26	s	9	4	3	16	---	---	---	---	---	---	---	---	---	---	---	---	32	---	2	34	50	---	50	---

[1] s, silt.
[2] Small patches of argillaceous finely crystalline carbonate.

TABLE 11.—*Percentage distribution of constituents of marly sediments at base of Mooreville chalk in samples from Crawford core hole.*

Sample	Depth (feet)	Constituents								
		Argillaceous calcilutite	Crystalline carbonate	Carbonate-filled Foraminifera	Broken shell fragments	Glauconite	Unstrained quartz	Moderately strained quartz	Composite quartz grains	Total
1	6.0	87		12	1					100
2	14.5	85		6		8		1		100
3	21.0	20	19	4		49	6		2	100
4	23.5	47	8	6		28	5	2	4	100

of glauconite are present in outcropping sands of this member. The paucity of glauconite is to be expected, however, as the upper member of the Coker formation is primarily a sequence of red and brown clayey beds.

Table 10, on silt, is not directly comparable with tables 7 to 9 owing to the difference in grain size between sand and silt; the smaller amount of rock fragements in the silt and the larger amount of clay paste and flakes of muscovite and chlorite illustrate this point.

Table 12 shows that the chert-cemented sandstone of the Vick formation, in contrast with the sand and carbonate-cemented sandstone, contains relatively large amounts of the composite quartz grains that are interpreted to be largely of metamorphic origin. Also, the sand and sandstone of the Eoline member of the Coker formation and of the less well sampled Eutaw and McShan formations contain significant amounts of glauconite, and on this basis they can be distinguished from the sand and sandstone of the Vick formation and the upper unit of the Coker. Also, the sand and sandstone of the Eutaw and McShan formations contain significantly larger amounts of glauconite than does the Eoline member.

No quantitative studies were made on the pebbles and granules of the Vick formation, but from available samples it seems that these coarse particles consist largely of chert and of fragments of quartz that are thought to be derived from metaquartzite.

CLAY MINERALS

An attempt was made to differentiate between the clay-bearing sand and silt and the thin clay beds in the pre-Selma formations by means of type and relative abundance of clay minerals. A. J. Gude 3d, of the U.S. Geological Survey, determined the clay minerals by X-ray methods using unfractionated samples. Table 13 shows the results of the clay-mineral analyses, which also include data on quartz and hematite. The samples from the Crawford and Boykin core holes

TABLE 12.—*Average percentages of rock and mineral fragments in thin sections of carbonate-cemented sandstone, chert-cemented sandstone, sand, and silt (matrix and voids excluded)*

Formation	Number of samples	Rock and mineral fragments																					Other
		Quartz varieties									Rock fragments other than quartz varieties				Mineral grains								
		Individual grains				Composite grains (Rock fragments)									Feldspar				Other				
		Unstrained	Moderately strained	Strongly strained	Total	Sub-parallel orientation, straight borders	Semi-parallel orientation, moderately smooth borders	Random orientation, smooth borders	Random orientation, crenulated borders	Total	Chert	Schist, undifferentiated	Phosphatic material	Total	Orthoclase	Microcline	Plagioclase	Total	Muscovite	Chlorite	Glauconite	Total	
Carbonate-cemented sandstone																							
Mooreville chalk	[1] 1	59	3	----	62	21	----	----	----	21	----	----	----	----	----	3	----	3	----	----	----	----	[2] 14
Eutaw	2	49	8	5	62	13	1	----	9	23	2	2	1	5	----	----	----	----	1	----	9	10	----
Coker, Eoline member	3	53	4	1	58	13	1	----	11	25	2	----	----	2	2	3	2	7	----	----	5	5	[3] 3
Chert-cemented sandstone																							
Vick	21	22	6	5	33	24	5	1	26	56	1	1	----	2	----	1	1	2	7	----	----	7	----
Sand																							
Eutaw	2	29	12	5	46	11	2	----	7	20	1	2	----	3	----	3	2	5	4	----	21	25	[4] 1
McShan	1	35	8	3	46	8	----	3	4	15	----	----	----	----	----	3	----	3	13	6	17	36	----
Coker, upper member	12	36	20	9	65	10	1	1	7	19	2	1	----	3	----	1	----	1	9	2	----	11	[5] 1
Eoline member	13	34	17	6	57	11	1	----	10	22	2	2	----	4	2	1	1	4	8	1	4	13	----
Silt																							
Eutaw	1	25	18	----	43	7	----	----	----	7	----	2	----	2	----	----	----	----	22	----	4	26	----
Coker, upper member	2	29	9	----	38	4	----	----	1	5	1	----	----	1	----	----	----	----	53	3	----	56	----
Eoline member	10	24	18	6	48	7	1	----	2	10	1	1	----	2	1	----	----	1	35	1	3	39	----

[1] See table 11 for description of other samples.
[2] Includes shell fragments and detrital garnet.
[3] Shell fragments.
[4] Detrital garnet.
[5] Detrital sandstone and chalcedony.

were glycolated to differentiate between montmorillonite and chlorite. The samples from the Webb hole were not glycolated, and the clay minerals in these samples are reported only in an estimated order of relative abundance whereas those from the Crawford and Boykin holes could be grouped as occurring in major, minor, and trace amounts.

In table 13 samples labelled "a" or "b" are from conglomerates or breccias; samples labelled "a" are from fragments or pebbles of clayey material, those labelled "b" are from the similar clayey matrix surrounding the fragments. These two types of samples were taken to determine whether the clayey fragments were derived from pre-existing sediments or were reworked from nearby areas. As no appreciable differences in the distribution of clay minerals could be found, the fragments are presumed to have been reworked from nearby accumulations of clayey material.

Table 13 shows that kaolinite is most abundant in the upper and lower parts of the Gordo formation (the only parts of that formation available for study); in some layers of the Coker formation, especially in the upper member; and in the Vick formation. Montmorillonite is the dominant clay mineral in the Eutaw and McShan formations and in the Eoline member of the Coker formation, especially in the upper part. Illite or mica and chlorite occur in small amounts, having sporadic distribution in all three cores. Trace amounts of halloysite are present in the Eutaw and McShan formation and in the upper part of the Gordo formation.

CONDITIONS OF ACCUMULATION

Vick formation.—The sediments of the Vick formation were probably deposited by streams over a surface of low relief on rocks of pre-Cretaceous age. The basal pebbly sands may represent reworked lag gravel from this surface of low relief or they may have been derived from areas of higher land. The chert-cemented sandstone beds may represent winnowed stream-deposited material as suggested by their repeated graded bedding and their excellent sorting. Their porosity may also account for the entrance and deposition of the chert cement. It is likely that the chert cement was introduced from without, because almost none of the grains in these beds show signs of compression against adjacent areas, so pressure solution from the nearby grains has probably not been the source of the silica for the chert cement. The source of this silica may have been an area having highly weathered well-drained rocks with a surface of low relief; the dominance of kaolinitic clay in the Vick tends to support this hypothesis. The red beds associated with the Vick formation are probably reworked kaolinitic soils that retained adsorbed iron ions on the clay particles.

TABLE 13.—*Clay mineral varieties, quartz, and hematite, and their relative abundance in the Vick, Coker, Gordo, McShan, and Eutaw formations*

Crawford core hole

[I, major; II, minor; III, trace]

Series	Group	Formation	Member	Sample No.	Depth of Sample (feet)	Quartz	Kaolinite	Illite	Montmorillonite	Chlorite	Halloysite	Hematite	Relative amount of iron
Upper Cretaceous		Eutaw		1	121	II	III	III	I	----	----	----	Low.
				2	130	II	----	III	I	----	----	----	Moderate.
				3	164	II	III	III	I	III	III	----	Do.
		McShan		4	190	I	III	III	I	----	----	----	Do.
				5	283	[1] I	III	II	I	III	III	----	Do.
	Tuscaloosa	Gordo		6	400	I	I	II	II	----	III	II	Moderately high.
				7	407	I	III	II	II	III	III	[2] II	Do.
				8	415	I	II	III	III	----	III	[2] I	High.

Boykin core hole

Series	Group	Formation	Member	Sample No.	Depth of Sample (feet)	Quartz	Kaolinite	Illite	Montmorillonite	Chlorite	Halloysite	Hematite	Relative amount of iron
Upper Cretaceous	Tuscaloosa	Gordo		1	13	I	I	II	----	III	----	----	Low.
		Coker	Upper member	2	41	I	I	II	----	----	----	----	Do.
				3	44	I	I	III	III	----	----	II	High.
				4a	61	I	II	II	III	III	----	I	Do.
				4b	61	I	II	II	III	----	----	I	Very high.
				5a	83	I	II	III	III	III	----	----	Do.
				5b	83	I	II	III	III	III	----	----	Moderate.
				6	170	I	III	III	III	----	----	----	Low.
				7	195	I	III	III	III	III	----	----	Moderate.
				8	202	I	II	III	----	III	----	----	Do.
				9	206	I	II	III	III	III	----	----	Do.
			Eoline	10	227	II	III	III	I	----	----	----	Moderately high.
				11	248	I	III	II	III	I	----	----	Do.
				12	319	II	II	III	I	----	----	----	Do.
				13	349	I	III	III	II	----	----	----	Moderate.
				14	442	I	I	II	III	----	----	----	Do.
				15	467	II	III	III	II	III	----	II	High.

[1] Plus feldspar.
[2] Plus lepidocrocite.

Series	Group	Formation	Member	Sample No.	Depth of sample (feet)	Mineral varieties listed in estimated order of relative abundance
Webb core hole						
Upper Cretaceous	Tuscaloosa	Coker	Upper	1	43	Hematite, quartz, kaolinite, montmorillonite.
				2	45	Quartz, kaolinite, mixed montmorillonite-illite.
				3a	50	Hematite, quartz, kaolinite, montmorillonite.
				3b	50	Quartz, kaolinite, hematite, montmorillonite, halloysite(?).
				4a	65	Quartz, hematite, kaolinite, montmorillonite.
				4b	65	Quartz, kaolinite, mixed montmorillonite-illite.
				5	86	Quartz, hematite, kaolinite, mixed montmorillonite-illite.
				6	90	Kaolinite, quartz, montmorillonite.
				7a	94	Hematite, quartz, kaolinite, montmorillonite.
				7b	94	Siderite, quartz, kaolinite.
				8	107	Quartz, kaolinite, montmorillonite.
				9	113	Quartz, hematite, kaolinite, montmorillonite.
				10	138	Quartz, kaolinite, illite, montmorillonite.
				11	187	Quartz, montmorillonite, kaolinite, illite.
				12	189	Quartz, kaolinite, montmorillonite, illite.
				13	208	Quartz, kaolinite, montmorillonite.
				14	213	Quartz, montmorillonite, kaolinite.
			Eoline	15	221	Montmorillonite, quartz, kaolinite, illite.
				16	226	Montmorillonite, kaolinite, quartz, illite (may be mica).
				17	242	Quartz, montmorillonite, kaolinite, illite (may be mica).
				18	262	Quartz, montmorillonite, mica, kaolinite.
				19a	297	Quartz, montmorillonite, mica, kaolinite, feldspar.
				19b	297	Do.
				20	367	Quartz, montmorillonite, kaolinite, mica, feldspar.
				21	421	Quartz, montmorillonite, kaolinite, mica.
				22	444	Quartz, montmorillonite, kaolinite, mica, feldspar.
Lower Cretaceous		Vick		23	564	Quartz, mica, kaolinite, montmorillonite, feldspar, high Fe.
				24	582	Do.
				25	600	Quartz, mica, kaolinite, montmorillonite, calcite, feldspar, moderate Fe.
				26a	604	Quartz, kaolinite, mica, montmorillonite, feldspar.
				26b	604	Quartz, kaolinite, montmorillonite, mica, feldspar.
				27	616	Quartz, mica, kaolinite, montmorillonite, feldspar, high Fe.

Coker formation, Eoline member.—The glauconite grains, the thin lignite beds, the thin carbonate-cemented sandstone beds, and the foraminiferal and molluscan remains at certain levels in the Eoline member of the Coker formation all point to shallow-marine to marginal-marine conditions of accumulation. Esther Applin (chapter *D* in this bulletin; Monroe 1955, p. 15) interprets the Foraminifera of the family Saccamminidae, found in these sediments, as indicating deposition in very near shore, only slightly brackish water. The thin carbonate-cemented sandstone beds having shell fragments, probably of mollusks, suggest very brief and very shallow incursions of moderately agitated marine waters. In contrast, the relatively large amounts of silt and clay and the considerable range in the degree of sorting of these sediments suggest accumulation in shallow marine embayments in sheltered coastal areas. The montmorillonitic clay in the Eoline member, especially abundant at the top of the unit, may represent volcanic material, but according to C. S. Ross and Charles Milton (written communication, Milton to W. H. Monroe, Sept. 13, 1955) of the U.S. Geological Survey, both of whom examined thin sections of these predonimatly montmorillonitic clays from the top of the Eoline member, there are no shard structures of other clear evidences of volcanic origin. They feel that these montmorillonitic clays may possibly be water transported, possibly from montmorillonitic soils.

Coker formation, upper member.—The dominantly red and brown sediments in the upper member of the Coker formation may represent material derived largely from weathered soils in a source area starting to undergo uplift. These sediments range widely in their degree of sorting, and they are especially poorly sorted in the lower part of the member, suggesting that they represent rapidly deposited, nonreduced material that overwhelmed the shallow marine lagoons and local coal swamps that existed during accumulation of the Eoline member. The abundance of iron-stained kaolinitic clay in the upper member of the Coker formation (table 13) supports the concept ot soil material swept in rapidly from a nearby uplifted surface of relatively low relief. Additional evidence for this interpretation is the gravelly sand that is abundant in the overlying Gordo formation on the outcrop (table 1) and in the subsurface (pl. 1). The coarse clastics in the Gordo may be interpreted as evidence of further uplift of the source area and of the exposure and breakup of bedrock after the soils were largely swept away during the initial uplift.

McShan and Eutaw formations.—Both the McShan and Eutaw formations are of marine orgin, as they contain marine fossils and considerable amounts of glauconite. The sand in the Eutaw formation is better sorted than that in the McShan formation, and this may indicate a tapering off of uplift in the source area after deposition of the Gordo. The moderate amount of randomly distributed silt and clay and the somewhat coarser sand in the McShan and Eutaw formations, as compared with the sand of the Eoline member of the Coker formation, suggest that the sediments in the McShan and Eutaw accumulated in relatively shallow marine water that fluctuated from quiet to well agitated. The thin carbonate-cemented sandstone beds also suggest variability of conditions of accumulation.

Mooreville chalk.—The basal part of the Mooreville chalk is a transitional unit, from the sandy sediments of the Eutaw formation to the argillaceous calcilutite of the Mooreville which has calcite-filled Foraminifera largely of pelagic types. These samples of the Mooreville suggest that the chalk formed in shallow water or was deposited during a landward encroachment of the sea with consequent deepening of the waters in the area from which the core samples were taken.

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Pre-Selma Larger Invertebrate Fossils From Well Core Samples in Western Alabama

By NORMAN F. SOHL

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

GEOLOGICAL SURVEY BULLETIN 1160-C

CONTENTS

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

C. PRE-SELMA LARGER INVERTEBRATE FOSSILS FROM WELL CORE SAMPLES IN WESTERN ALABAMA

By NORMAN F. SOHL

ABSTRACT

This chapter records a dominantly molluscan shallow-water, near-shore marine fauna from the sands in the upper third of the Eutaw formation, in the Crawford hole, southern Perry County, Ala. The zone of *Ostrea cretacea* is interpreted as an oyster bank accumulation. In the lower two-thirds of the Eutaw formation the fauna is dominated by crustaceans and fish.

Cores from the Webb hole, northern Perry County, Ala., yielded a shallow-water marine molluscan assemblage from the Eoline member of the Coker formation. On the basis of the fauna, the Eoline member is correlated with the Woodbine formation of Texas, and affinities with the fauna of the Lewisville member of the Woodbine are noted.

INTRODUCTION

Upper Cretaceous invertebrate megafossils of a pre-Selma age were obtained from cores of two exploratory wells dealt with in this bulletin: the Webb hole and the Crawford hole. The Webb cores yielded a dominantly molluscan assemblage from the Eoline member of the Coker formation; the Crawford cores yielded a smaller but more varied fauna from both the Eutaw and McShan formations, including sponge, bryozoan, molluscan, crustacean, and echinodermal elements.

The cores were examined and cut by L. W. Stephenson and the author in Tuscaloosa, Ala., during a joint field trip in March 1955. The crustaceans obtained from the lower part of the Eutaw formation in the Crawford hole were identified by Henry J. Roberts of the U.S. National Museum. The fish remains from the same interval were identified by D. H. Dunkle, also of the U.S. National Museum.

Illustrations of the several fossil species have not been included, as better preserved material has been illustrated in several publications, especially in those by Stephenson cited in the text; additional references can be found by consulting the bibliographies provided in his papers.

DESCRIPTION OF CORE AND LIST OF FOSSILS FROM CRAWFORD HOLE

In the following descriptions of cores and the accompanying lists of fossils, the cited numbers of fossil collections are those assigned in the U.S. Geological Survey Mesozoic locality register. The depth intervals of the cores are those assigned by Monroe (1955). The colors of the sediments, as noted, are the visual estimates of the author.

SE¼NW¼ sec. 15, T. 18 N., R. 8 E.,
Perry County, Ala., altitude 184 feet

	Depth (feet)
Mooreville chalk, lower part:	
Upper part of core 2 (USGS 25522)	24. 3– 25. 8
A. Sandstone, light-gray, medium- to fine-grained, calcareous.	
Ostrea cretacea Morton	
Anomia preolmstedi Stephenson?	
Exogyra sp.	
Fish vertebrae	
B. Sand, greenish-gray, medium.	
Ostrea cretacea Morton	
Exogyra cf. *E. upatoiensis* Stephenson	
Pecten sp.	
Cardium sp.	
Fish vertebrae	
Upper part of core 3	25. 8– 26. 3
Sand, greenish-gray, medium to fine, some glauconite and phosphatic pellets. (Fossils present but not described specifically from this 0. 5-ft unit.)	
Eutaw formation:	
Core 3 (USGS 25523)	26. 3– 36. 1
Sand, greenish-gray, medium to fine, sparingly glauconitic, some zones a coquina of *Ostrea cretacea.*	
Clione sp. (boring sponge)	
Cyclostomatous Bryozoa	
Cheilostomatous Bryozoa	
Ostrea cretacea Morton	
Exogyra upatoiensis Stephenson	
Gryphaea wratheri Stephenson	
Plicatula sp.	
Anomia preolmstedi Stephenson	
Shark tooth	
Upper part of core 4 (USGS 25525 A)	36. 1– 51. 8
Sand, olive-gray, fine, sparingly glauconitic, micaceous, and fossiliferous; fossils preserved as thin films of altered shell material covering internal molds.	
Cardium (*Trachycardium*) *ochilleanum* Stephenson?	
sp.	
Cymbophora? sp.	

SE¼NW¼ sec. 15, T. 18 N., R. 8 E., Perry County, Ala., altitude 184 feet—Continued

	Depth (feet)
Eutaw formation—Continued	
Bottom part of core 4 (USGS 25525 B)	36. 1– 51. 8
Sand, grayish-green, medium-grained, glauconitic, sparingly micaceous.	
Ostrea sp. (immature)	
Cardium (*Trachycardium*) *ochilleanum* Stephenson?	
Upper part of core 5 (USGS 25526 A)	51. 8– 71. 9
Sand, same as preceding.	
Cardium (*Trachycardium*) *ochilleanum* Stephenson?	
Bottom part of core 5 (USGS 25526 B)	51. 8– 71. 9
Sand, same as preceding.	
Clione sp. (boring sponge)	
Ostrea battensis Stephenson	
sp.	
Cardium (*Trachycardium*) *ochilleanum* Stephenson?	
Shark tooth	
Upper part of core 6 (USGS 25527)	71. 9– 87. 2
Sand, olive-gray, fine, slightly argillaceous, sparingly glauconitic, micaceous.	
Nuculana? sp.	
Nemodon cf. *N. brevifrons* Conrad	
Ostrea battensis Stephenson?	
sp. (immature)	
Lucina sp.	
Linearia cf. *L. metastriata* Conrad	
Cymbophora sp.	
Shark teeth	
Middle of core 6 (USGS 25528)	71. 9– 87. 2
Sandstone, greenish-gray, medium-grained, glauconitic, sparingly micaceous.	
Clione sp. (boring sponge)	
Hardouinea cf. *H. bassleri* (Twitchell)	
Trigonarca sp.?	
Ostrea battensis Stephenson	
Cardium (*Trachycardium*) sp.	
Cyclorisma? sp.	
Cyprimeria? sp.	
Bottom part of core 6 (USGS 25529)	71. 9– 87. 2
Sand, olive-gray, medium, glauconitic, sparingly micaceous.	
Ostrea battensis Stephenson	
Exogyra upatoiensis Stephenson	
Upper part of core 8 (USGS 25530)	97. 5–108. 1
Sand, greenish-gray, fine to medium, argillaceous, glauconitic, micaceous.	
Macruran (indet.-fragments of carapace)	
Shark tooth, vertebra	

SE¼NW¼ sec. 15, T. 18 N., R. 8 E., Perry County, Ala., 184 feet—Continued

	Depth (feet)
Eutaw formation—Continued	
Bottom of core 9 (USGS 25531)	108.1–118.4
Clay, gray, silty, finely micaceous.	
? *Galathea* sp. (carapace and abdominal segments)	
Macruran (one abdominal segment)	
Middle part of core 10 (USGS 25532)	118.4–129.1
Sand, greenish-gray, coarse to medium, slightly micaceous, glauconitic, with scattered phosphatic pebbles.	
Shark tooth	
Upper part of core 11 (USGS 25533)	129.1–139.6
Sand, gray, fine, silty, and some silty clay.	
Hoploparia aff. *H. davisi* (Stenzel)	
?*Enoploclytia* sp. (anterior portion of carapace)	
Ctenoid fish scale	
McShan formation:	
Upper part of core 16 (USGS 25534)	183.0–192.6
Sand, greenish-gray, glauconitic.	
Cylcostomatous Bryozoan	
?*Meyeria* sp. (anterior portion of carapace, abdominal segments and limb fragments)	
Teleostean vertebra	
Scapanorhyncus subulatis (Agassiz)—Goblin shark	
Shark vertebra	
Core 17 (USGS 25535)	192.6–228.5
Sand, light-gray, medium to fine, highly silty, micaceous.	
Macruran abdominal segments	
Bottom part of core 18 (USGS 25536)	228.5–239.3
Sand, gray, medium, containing gray clay and tan silt pebbles.	
Fish vertebra	
Bottom part of core 19 (USGS 25537)	239.3–282.7
Clay, light-gray, silty, with thin interbedded layers of somewhat micaceous silt.	
Crustacean fragments	
Upper part of core 20 (USGS 25538)	282.7–303.3
Silt, gray, clayey, carbonaceous.	
cf. *Arca* sp.	
Lima? sp.	
Shark tooth	
Middle of core 21 (USGS 25539)	303.3–316.6
Sand, light olive-gray, medium-grained, glauconitic, with coarse clay and silty pebbles.	
Cyclostomatous Bryozoa	
Upper part of core 23 (USGS 25540)	368.7–398.5
Sand, greenish, coarse, sparingly micaceous, containing small sideritic pebbles.	
Fish vertebra and other bone fragments	

AGE AND CORRELATION OF EUTAW AND McSHAN FAUNA

Fossils recovered from the Crawford well at a depth of 13.5 to 26.3 feet include numerous indeterminable phosphatic internal molds and some fossil species of Eutaw age; these fossils seem to have been reworked from the underlying Eutaw to become part of the basal unit of the Mooreville chalk. From 26.3 feet downward, stratigraphically distinctive species such as *Ostrea cretacea* Morton, *Exogyra upatoiensis* Stephenson, and *Ostrea battensis* Stephenson are present in cores 3 to 6 at depths of 26.3 to 87.2 feet; these species are diagnostic of the fauna in the Tombigbee sand member, which comprises the upper part of the Eutaw formation in other parts of Alabama and Mississippi (Stephenson, 1936, 1956). Of the fossils listed under the core descriptions, *Ostrea cretacea* Morton is abundant in the 9.6 feet of core 3, a thickness very similar to the thickness of the *O. cretacea* zone where it crops out in western Alabama. Another significant species, represented by a specimen from the middle of core 6, is assigned to the echinoid genus *Hardouinea*. This specimen is too incomplete for positive specific identification; but the plate and pore arrangement is almost identical with that of *H. bassleri* (Twitchell), which is abundant in the Tombigbee sand member of central Alabama.

Other stratigraphically useful fossils in the cores include *Gryphaea wratheri* Stephenson and *Ostrea battensis* Stephenson, which are widespread in the Eutaw formation of Alabama. *Gryphaea wratheri* Stephenson is found also in the Tombigbee sand member of the Eutaw in Mississippi, and in the upper part of the Austin chalk of Texas (Stephenson, 1936, p. 3).

Below core 6 from 87.2–398.5 feet, which includes the lower part of the Eutaw formation and the entire McShan formation, the cores yielded few identifiable megainvertebrates. The fossils that are present are nondiagnostic and for the most part consist of crustaceans. Of these crustaceans, H. R. Roberts (written communication, Dec. 1959) states:

> Although several carapaces are present in the material examined, *Hoploparia* sp. aff. *H. davisi* (Stenzel) is the only form which is well enough preserved to be identified to species. In the case of the other carapaces . . ., unquestionable generic assignments cannot be made because the rostrom or other diagnostic structures are missing.
>
> None of the specimens—decapods or fishes—is of value in determining the precise age of the sediments enclosing them.

The few molluscan species represented in the cores from this part of the hole are likewise undiagnostic.

NOTES ON ECOLOGY

The fauna in the upper 87.2 feet of the Eutaw formation (cores 3–6), as represented in the Crawford hole, is composed of shallow-water forms. The coquina of *Ostrea cretacea* Morton in segments of core 3 (USGS 25523) closely resembles coquina zones in the outcrop area. For example, the *Ostrea cretacea* zone is continuous from the Tombigbee River of western Alabama to the Chattahoochee River at Broken Arrow Bend, 6 miles south of Columbus, Ga. At most places in this area the closely packed shells of *Ostrea cretacea* are almost the only fossils in sections of the Tombigbee sand member which are as much as 100 feet thick, such as in the vicinity of Uchee in the northwestern part of Russell County, Ala. This paucispecific zone of *Ostrea cretacea* probably represents a widespread oyster-bank accumulation, and substantiates Stenzel's (1954, p. 44) observations that most brackish-water oyster banks are paucispecific. These masses of oysters must truly represent optimum conditions of growth. Such conditions exist in waters which have a salinity about midway between fresh and salty (Ladd, 1957).

In the Crawford hole below the oyster coquina zones of core 3, and especially in cores 4, 5, and 6, the sands are coarser and the fauna is less dominated by the ostreid elements. Although other forms dominate at several levels, the fauna in the coarser sands likewise indicates shallow-water, near-shore environments but probably represents waters of higher, more normal salinity than the oyster zones.

Below 97.5 feet in the hole (71.2 feet from the top of the Eutaw), the faunal content changes markedly. Not only are fossils much rarer but the composition changes as crustacean and fish remains become the dominant elements. Clays and other fine sediments are more common than above 97.5 feet, but even the sandy parts that are lithologically similar to the sands of the upper cores are generally barren of fossils.

The decapod crustaceans, which unfortunately are the most common element, yield little information as to habitat or environment, as H. R. Roberts (written communication, Dec. 1959) states:

> All the decapods examined are vagrant bottom-dwelling marine forms. They are macrurans . . . no brachyurans are present. No ecological inferences can be drawn from the specimens at hand.

This section of the core appears analogous to the crossbedded to massive unfossiliferous sands in the Eutaw formation that Stephenson and Monroe (1940, p. 252) postulated as having formed in shallow water near shore. The fauna in the cores from this part of the Eutaw, however, provides no additional information on the environment of deposition of these sands.

DESCRIPTION OF CORE AND LIST OF FOSSILS FROM WEBB HOLE

NE¼NE¼ sec. 16, T. 21 N., R. 8 E., Perry County, Ala., altitude 210 feet

	Depth (feet)
Tuscaloosa group, Coker formation (Eoline member):	
Upper part of core 20 (USGS 25542B)	249. 8–261. 0
Clay, gray, silty, interlaminated with light-gray micaceous carbonaceous silt.	
Lingula cf. *L. subspatulata* Hall and Meek	
Tellina? sp.	
Anomia sp.	
Impressions of indeterminate pelecypods	
Upper middle part of core 20 (USGS 25542A)	249. 8–261. 0
Clay interlaminated with silt as above.	
Lingula cf. *L. subspatulata* Hall and Meek	
Lower third of core 25 (USGS 25543)	289. 2–299. 8
Sand, gray, fine, clayey, micaceous, carbonaceous, with gray clay pebbles.	
Ostrea sp. (small)	
Basal part of core 26 (USGS 25544)	299. 8–328. 8
Sandstone, light olive-gray, poorly sorted, sparingly glauconitic and micaceous, with silt and clay pebbles of various shades of gray and green.	
Nemodon sp.	
Brachidontes sp.	
Ostrea cf. *O. soleniscus* Meek	
Plicatula sp.	
Botula cf. *B. plumosa* Stephenson	
Several impressions of indeterminate pelecypods	

AGE AND CORRELATION OF THE EOLINE FAUNA

The invertebrate fossils recovered from the cores of the Eoline member of the Coker formation of Webb hole are not exceedingly diversified nor are they well preserved. Rather, their importance is chiefly their mere presence, as marine invertebrates are rare in sediments of the Tuscaloosa group. Stephenson (1952, p. 18) has noted four places in Alabama where a meager fauna has been found in the Tuscaloosa. Only one locality, discovered in 1945 by L. C. Conant, near Centreville in Bibb County, Ala. (fig. 1), has yielded actual shell material; at the other localities, only external impressions of fossils in clay can be seen.

The sandstone unit near the base of core 26 (depth 299.8–328.8 feet) can be correlated directly with the outcrop in Bibb County, Ala., both on the basis of the lithologic constituents and the contained fauna. The sandstone in core 26 is almost identical with the calcareous, clay- and silt-pebble-bearing sandstone of the Eoline member exposed in a 25-foot bluff on the east bank of the Cahaba River about 4 miles south of the courthouse in Centreville, Bibb County, Ala. (NW¼ sec. 14, T. 22 N., R. 9 E.). This locality (USGS 19577) has yielded:

Breviarca sp.
Ostrea cf. *O. soleniscus* Meek
Anomia ponticulana Stephenson
Brachidontes fulpensis Stephenson

The invertebrate fauna of the Eoline member of Alabama seems to have its closest affinities with the fauna described by Stephenson (1952) from the Woodbine formation of Texas. It is, however, less clear which of the four members of the Woodbine is the closest correlative of the Eoline member.

Of the species listed above from the Eoline member in the well cores and from the Centreville, Ala., outcrop, *Lingula subspatulata* Hall and Meek is a generalized form and rather poorly known, but, as reported in North America, it ranges throughout the Upper Cretaceous. Although it seems to have little stratigraphic value, it does occur in both the Lewisville and Templeton members of the Woodbine formation. Likewise, *Ostrea soleniscus* Meek, although restricted on the Gulf Coast to the Cenomanian (Stephenson, 1952, p. 74), ranges as high as the Coniacian in the Western Interior. The specimens from Alabama compared with *Ostrea soleniscus* Meek are all small for the species, but they do possess its characteristic beak curvature and probably represent a varietal form. *Botula plumosa* Stephenson, as far as known, is restricted to the Lewisville member of the Woodbine formation, but both the identification of the species in Alabama and its range in Texas are open to some doubt. The specimens of *Brachidontes* from the well cores are too incompletely preserved for specific identification. The more completely preserved specimens from the outcrop (USGS 19577), on the other hand, are assignable to *Brachidontes fulpensis* Stephenson, which occurs in the Dexter, Euless, and Lewisville members of the Woodbine formation of Texas. *Anomia ponticulana* Stephenson from the Eoline near Centreville, Ala., and possibly the *Anomia* sp. from core 20 in the Webb well range through the Woodbine formation in Texas. No species of *Nemodon* from the Woodbine are available for comparison with the specimens from core 26, but all other generically identified specimens listed from the Eoline have representative species in the Woodbine formation of Texas.

On the basis of the above range comparisons, a correlation of the Eoline member of the Coker formation with the Woodbine formation is rather definite, but there is no decisive evidence for correlation with a given member of the Woodbine formation. All the species common to Texas and Alabama are present in the Lewisville member but some may range either up into the Templeton member or may range downward as far as the Dexter member. The slim evidence thus afforded favors a correlation of the Eoline member with the Lewisville member of the Woodbine formation of Texas, but other lines of evidence are needed to substantiate such a correlation (see Applin, this bulletin).

NOTES ON ECOLOGY

The Eoline fauna, as represented in cores 20 and 26 from the Webb hole, suggests a shallow-water near-shore environment. Such an interpretation is decidedly applicable to core 20, which bears the brachiopod *Lingula.* Cooper (1957, p. 265) states that *Lingula* at present is "restricted to shallow water, usually shore zones subject to tidal action" and "has not been taken deeper than 23 fathoms." In the fossil record the common occurrence of *Lingula* in black shale and in sparse faunas has led many authors to assume that it was capable of withstanding stagnant or brackish water conditions. That such conditions are represented by core 20 cannot be ascertained, as the only accompanying forms are the pelecypods *Tellina* and *Anomia.* These forms generally inhabit water of normal salinity but are known from a variety of environments.

The remainder of the fauna of the Eoline member, as represented in core 26 and at the outcrop near Centreville, is not greatly diversified. From a negative standpoint this very lack of diversity in itself points to ecologic conditions that were other than optimum. The dominance of the ostreid and *Brachidontes* elements appears to reflect brackish water conditions such as those in many of the East Coast embayments today. *Anomia* could probably survive under these conditions, although it generally is more typical of normal marine environments. The boring sponge *Clione* today infests oyster shells in bay or estuarine brackish-water oyster banks. Only the shells identified with *Breviarca* and *Nemodon* appear at all out of place in such an environment but even these arcids are known from this type of an environment (Ladd and others, 1957).

The assemblage as a whole suggests shallow-water conditions, and all of the genera have numerous representatives in the near-shore shallow-water faunas of the present seas.

With the possible exception of the arcids, the fauna is composed almost entirely of epifaunal elements that lived on, rather than in, the sea bottom sediment. The arcids have a nesting habit but some forms do burrow. Such organisms as *Ostrea*, *Plicatula*, and *Anomia* attach themselves by cementing their valves to other shells or to any solid object on the bottom. *Brachidontes* attaches itself to plants or to solid objects on the bottom by means of its thread-like byssus. The available evidence does not furnish a definite solution concerning the lack of infaunal or burrowing forms. As the dominant lithologic constituent is a sand, however, a dearth of burrowing forms due to a fine mud bottom, as noted by MacGinitie and MacGinitie (1949), does not seem likely. Barrenness of many beach sands has been accounted for by Hedgpeth (1957, p. 603) and others as due to reworking by burrowing organisms, but this explanation does not account for the presence of the epifaunal elements in the Eoline member of the Coker formation.

Parts of core 26 are conglomeratic layers that contain silt and claystone pebbles associated with a moderate amount of broken shell material and comminuted plant material. These layers indicate current or wave activity sufficient for the transportation and rounding of coarse pebbles and the movement of shell fragments. Other layers in core 26, however, are relatively fine sand, and their included fossils may well have been buried in place.

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A Microfauna From the Coker Formation, Alabama

By ESTHER R. APPLIN

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

GEOLOGICAL SURVEY BULLETIN 1160-D

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By Esther R. Applin

ABSTRACT

Microfossil content and lithologic character of samples from the Eoline member of the Coker formation from the U.S. Geological Survey Boykin 2 hole, Tuscaloosa County, Ala., indicate a very shallow, brackish- to fresh-water depositional environment. A new foraminiferal species *Saccammina eolinensis* is described and figured.

MICROFOSSIL CONTENT AND LITHOLOGY

The marine character of the outcropping Eoline member of the Coker formation in western Alabama was discussed by Monroe, Conant, and Eargle (1946, p. 195–197) and by Eargle (1946), who stated that "the sand beds * * * contain a large number of fossils chiefly mollusks, thick shelled and characteristically with borings of contemporaneous predators." Eargle (1946) traced the formational divisions of the pre-Selma Upper Cretaceous strata from the outcrop into the subsurface in Greene County, Ala., thence south and west into Neshoba County, Miss. The plotted logs of the wells on Eargle's cross section show the occurrences of megafossils in these strata but do not record microfossils. Conant (1946, p. 713) reported a sparse microfauna in shale overlying a basal conglomerate of the Eoline on the O. E. Reeves farm near Centreville, Bibb County, Ala., fig. 1; this is the only published record of a microfauna noted in outcrop samples of the Eoline member of the Coker formation.

Monroe, Conant, and Eargle (1946, p. 211) correlated the outcropping Eoline formation (now classified as the Eoline member of the Coker formation) with the "marine Tuscaloosa" of the subsurface in Mississippi; and Applin and Applin (1946) made an approximate correlation of the middle member of the downdip, subsurface Atkinson formation with the Eoline formation and with the subsurface "marine shale zone" of the Tuscaloosa in Mississippi. In the same article, the Applins stated that this middle member of the Atkinson "was evidently deposited in a rather shallow-water marine environment and contains a sparse, but diagnostic microfauna of arenaceous Foraminifera that is related to the microfauna of the outcropping Woodbine formation of Texas." This characteristic microfauna has been identified from southern Alabama in samples from many oil test wells as far north as southern Marengo County, and from Georgia in well samples as far north as Calhoun and Liberty Counties. The typical microfauna contains several species of *Ammobaculites* that are associated with species of *Ammotium*, *Trochammina*, *Ammobaculoides*, and *Haplophragmoides*. Littoral faunas of this type are generally indicative of inner-neritic, very shallow-marine conditions of deposition. Sandy lenses containing abundant fragments of *Ostrea* are common, particularly near the northern border of the known geographic distribution of the microfauna. The fauna occurs in lenses of shale, which is generally dark gray and dark brownish gray and contains pyrite and fine carbonaceous matter. Both the fauna and the lithology suggest a possible deltaic or lagoonal facies deposited near the inner border of a broad continental shelf.

Monroe, Conant, and Eargle (1946, p. 195) stated, "Fossil leaf fragments are common in clay, especially near the top of the Eoline formation, and locally there is much lignitized wood ranging in size from tiny chips to logs a foot in diameter." These sediments are approximately 50 miles north and updip from the very shallow, probably brackish-water subsurface deposits discussed in the preceding paragraph. The lithologic character, abundance of carbonaceous material, paucity and poor preservation of the megafossils, and geographic location some distance north of sediments and microfaunas, characteristic of very shallow brackish-water environments—all indicate a possible further reduction in depth and salinity of the water in which the Eoline sediments were deposited in the present outcrop area. The ecology of the plant life represented, and the inferred habitat of the macrofossil genera should aid in resolving this problem.

More than a hundred samples of the outcropping Woodbine formation collected in Grayson, Fannin, Denton, Tarrant, and Lamar Counties, Tex., yielded microfaunas. The faunal assemblages were reasonably uniform in composition, but faunas in a few scattered samples collected from the upper part of the Lewisville member of the Woodbine formation in Fannin, Tarrant and Lamar Counties suggest depositional conditions that approximate those postulated for the region of the Eoline outcrop. Although specimens of the usual species of *Ammobaculites*, *Haplophragmoides*, and *Trochammina* are present in the Eoline fauna, the tests are white and very fragile as compared to the more sturdy, generally tan, brown, and gray tests common in the dominant type of Woodbine foraminiferal assemblage. Some specimens of *Saccammina, Lagunculina,* and *Millettella* are also present in the Eoline.

The microfauna in the outcrop sample of the Eoline in Bibb County, Ala., and the fauna obtained from core samples of Eoline sediments in the Boykin 2 hole (fig. 1) near Tuscaloosa, Ala., are alike in character and composition. Many specimens, but only one species of the foraminifer *Saccammina,* are represented, although the minute and highly flexible tests have been crushed and distorted into forms that strongly simulate several other genera of the foraminiferal family Saccamminidae.

Bolli and Saunders (1954) call attention to the inclusion of Recent, fresh-water Thecamoebina species in descriptions of fossil and Recent foraminiferal assemblages. Species of the foraminiferal genera *Proteonina* (now *Saccammina*), *Lagunculina,* and *Millettella* are well represented in the synonomy (op. cit., p. 47) given for specimens of Thecamoebina erroneously described as Foraminifera. Bolli and Saunders (p. 47) give Deflandre's simplified classification of Rhizopoda with tests as—"Group 1—Thecamoebina s. 1.—practically all fresh water forms," and "Group 2—Foraminifera,—practically all marine and brackish water forms."

Using this classification, it would be essential to establish definitely the fresh-water origin of any specimens assigned to genera of the Thecamoebina. Bolli and Saunders further stated (p. 45) "Fossil Thecamoebina have been recorded from rocks as old as Middle Eocene though it is almost certain that the group is of far more ancient origin. The writers consider that the presence of fossil Thecamoebina in either recent or fossil foraminiferal assemblages is so unlikely that it may be ignored." However, these authors referred species of *Proteonina, Leptodermella,* and *Millettella,* described by Cushman (1945, p. 1–3) from the Twiggs clay (Eocene) of Georgia, and specimens of *Proteonina, Urnulina, Millettella,* and *Leptodermella,* described by Cushman and Cahill (1933, p. 5 and 6) from the Miocene of the Coastal Plain of Eastern United States, to the Thecamoebina genera, *Difflugia, Centropyxis* (*Cyclopyxis*), *Centropyxis* (*Centropyxis*), and *Pontigulasia.* Bolli and Saunders justify this change in assignment by suggesting that the forms were Recent specimens of Thecamoebina associated with the true foraminiferal faunal assemblages through the agency of streams located near the outcrops that contain the Eocene and the Miocene faunas. For some of the assemblages discussed, this explanation is not completely satisfactory.

Because the microfaunas from the Eoline outcrop and from the well samples are entirely arenaceous and include one of the foraminiferal genera discussed by Bolli and Saunders, it seems appropriate to preface a description of the species with a statement regarding probable depositional conditions, and the possibilities of postdepositional contamination of the samples. The outcrop sample was cut from an exposure near an abandoned part of an old road just beyond the edge of the valley bottom of a small creek (Conant, 1946, p. 712–713). This locality could, therefore, be the subject of conjectural reasoning similar to that applied by Bolli and Saunders to the Eocene and Miocene localities mentioned above. In this connection, I wish to explain that the method of sampling was that generally employed by collectors of microfossiliferous materials. The outcrop was chipped back to a depth of a foot or more beneath the surface before the sample was cut. The fauna in the well section was found in a core at the depth of 404–437.6 feet in the Boykin 2 hole near Tuscaloosa, Ala. Monroe (1955) recorded the top of the Eoline member of the Coker formation in this hole at 225.4 feet, and gave the following account (written communication) of core 37, in which the microfauna was discovered: "Thirty-three feet cut, recovery 3.3 feet. Most of the recovered core is laminated shale with streaks of clayey sand. Probably all from the bottom of the run." Several samples of the shale were cut from this core for microscopic study. Samples taken at 18 inches and at 20 inches from the bottom of the core contained the microfauna discussed. The material was a compact, thinly laminated greenish-gray shale which contained a few very thin, irregular, very finely micaceous and silty streaks. The shale was baked and then washed leaving a very small concentrate composed of small fragments of the shale, a minor amount of very fine sand, mica, and the microfauna. A few grains of yellowish-green glauconite were also present in the concentrate secured from the sample cut 18 inches from the bottom of the core.

In my opinion, the microfossiliferous outcrop sample of the Eoline was not contaminated in any way, and the fauna in the core samples was clearly indigenous. It follows, therefore, that the fauna is Woodbine, or earliest Gulf in age. However, the question of which group of Rhizopoda the fauna belongs to cannot be definitely answered at this time. No mollusks were found in the cores of the Eoline from the Boykin 2 hole, but leaves and some seed pods were present at several levels. The fissile clay at the outcrop locality also contained only leaf impressions. If the microfossils in the fauna are Thecamoebina, they would be fossil Thecamoebina of early Late Cretaceous age. Considering the hypothetical character of such an assignment, it seems preferable to describe the fauna as Foraminifera with a preferred habitat of shallow, quiet, muddy bottoms in waters of very low salinity.

SYSTEMATIC DESCRIPTION

Order FORAMINIFERA

Family SACCAMMINIDAE

Genus SACCAMMINA M. Sars, 1869

Saccammina eolinensis Applin, n. sp.

Plate 2, figures 1–4

Description.—Test small, unattached, globular, somewhat compressed laterally, and constricted at one end into a short broad neck which terminates abruptly in a narrow slitlike aperture. The form consists of a single, undivided chamber having inner chitinous walls completely covered with an outer layer of well-cemented, very fine silt particles.

Specimens were fairly numerous, but owing, in large part, to compaction of the shale in which they were buried, many of the tests were badly distorted. However, many moderately well preserved forms were also available and provided the basis for the type description given above. A moderate degree of lateral compression is probably a normal feature of the test, and in undamaged specimens the aperture would probably be narrowly elliptical. It is probable also, that a narrow lip may be found on more perfectly preserved tests as traces of this feature were observed on a few specimens.

Measurements.—Height of average specimen, 0.25 mm, breadth of average specimen, 0.19 mm, ratio of length of neck to overall length of average specimen, about one fourth.

Repository.—Figured holotype (USNM 626972). Figured paratypes (USNM 626973–5).

Remarks.—The species described above does show some resemblance to forms that have been ascribed to the order Thecamoebina. This is particularly true of the very finely arenaceous quality of the tests; but, as mentioned in the text, there was no corroborative evidence of a fresh-water origin.

While I was engaged in research on these fossils, Ruth Todd called my attention to a paper in which Vašiček and Růžička (1957) described and illustrated some Carboniferous Thecamoebinas that were apparently similar to the microfossils in the Boykin core. Dr. Vašiček very kindly consented to compare specimens from the Boykin 2 hole with the Carboniferous Thecamoebinas he had described. With his permission I quote from his statement (written communication, 1958) regarding the results obtained.

> Your Cretaceous microfossils are, unlike the representatives of the genus *Prantlitina* known so far, smaller, have both absolutely and relatively thinner and more deformed walls and the building material of finer grains. I don't doubt that they belong to a different species.

As to the generic assignment, one cannot utter such a definite statement. The material of the tests of Carbonian and Cretaceous specimens seems to be (except for the coarseness of the grains) identical as to the quality and arrangement. The flexibility of the walls is observable both in the Carbonian and Cretaceous specimens. The general shape of the tests (as far as it is possible to judge by imperfectly preserved specimens) seems to be similar. Unfortunately, none of the Cretaceous specimens is so perfectly preserved as to make the study of its apertural end possible. That is why I cannot go so far as to assert that the Cretaceous species belongs indisputably to the genus *Prantlitina* though their tests are very similar.

ACKNOWLEDGMENTS

I desire to express my sincere appreciation for the assistance given by Ruth Todd, U.S. Geological Survey, during the study of the fauna, and for her help in completing the descriptive part of the manuscript. I am most grateful to Elinor Stromberg, who made the drawings accompanying the description of the minute new species, and thanks are also tendered to Dr. M. Vasicek for his courtesy and kindness in comparing the species of Thecamoebina described by him with specimens of the Cretaceous rizopods described in this report.

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A Preliminary Report on the Pollen and Spores of the Pre-Selma Upper Cretaceous Strata of Western Alabama

By ESTELLA B. LEOPOLD *and* HELEN M. PAKISER

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

GEOLOGICAL SURVEY BULLETIN 1160-E

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STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

E. A PRELIMINARY REPORT ON THE POLLEN AND SPORES OF THE PRE-SELMA UPPER CRETACEOUS STRATA OF WESTERN ALABAMA

By Estella B. Leopold and Helen M. Pakiser

ABSTRACT

In a preliminary study of the pre-Selma Upper Cretaceous strata the authors report a diverse assemblage of fossil pollen and spores representing a primarily dicotyledonous flora. Two of the vascular plant families represented are now restricted to subtropical areas and one of them is now limited to the southern hemisphere.

Remains of planktonic algae and abundant microforaminifers in the Eutaw and McShan formations suggest that these sediments accumulated in marine waters, probably somewhat below the turbulent wave zone.

The depositional environment of the Coker formation, as inferred from pollen in several lignite seams, was probably shallow water and lagoonal. Pollen and spores that are most abundant in this lignite and in the associated siltstone may be assumed to have been derived locally, and probably represent shore or lagoon-margin vegetation. The modern families to which these pollen are related—for example, the holly, myrtle, tea, and cyrilla families—have representatives that occupy swampy-bay or lagoon-margin habitats in subtropical areas. The land plant assemblage of the Coker formation is only slightly different from that of the overlying lower part of the Gordo formation. The middle part of the Gordo was not sampled and the upper part of the formation was unpolleniferous, so nothing can be inferred from pollen about the depositional environment of the uppermost part of the Tuscaloosa group.

Where affinities with modern vascular plant families can be recognized, pollen and spore identifications to a certain extent corroborate taxa of plant megafossils identified by earlier workers from these strata; but this corroboration is mainly on the family, not the generic level.

Comparison with Cretaceous pollen and spore floras of central and northern Europe supports a Late Cretaceous age for the Alabama pollen flora; a close similarity with Cenomanian and Turonian pollen floras of Germany indicates an early Late Cretaceous age.

INTRODUCTION

The present study is a listing of pollen, spores, and certain other microfossils found in well-core sediments of the Tuscaloosa group and the Eutaw and McShan formations (Monroe, 1955; also see chapter A by Monroe in this bulletin). This report should be considered a

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preliminary contribution, for it is clear from the megafossil remains (Berry, 1919) and from the present evidence that the flora of these strata is an enormously rich and diversified one. The fact that there exist at least 105 species among the 2,000 specimens examined for the present report clearly demonstrates this floristic diversity.

The presently available taxonomic literature concerning microspores and pollen of upper Mesozoic strata is almost entirely based on European material. In the identification of the Alabama material, we compared our specimens with the type figure and descriptions for the species or genera determined. All references utilized in the identifications are included in the bibliography. Though we have encountered many new species and one genus that do not seem to have been named to date, we shall undertake formal description of these at a later date, and for the present report shall refer to the new forms as "confer" (cf. or compare) with their most nearly related species.

SOURCE OF MATERIAL AND METHODS USED

Twenty-nine samples of sediments from the Tuscaloosa group and the McShan and Eutaw formations were taken from three cores (table 14), and were studied for contained pollen, spores, and other microfossils. The locations of these three core holes are shown on the index map of plate 1; the lithologic composition of the core sediments was diagrammed by Bergenback on plate 1 and the positions of the samples analyzed for pollen and spores are shown to the extreme right of the lithologic section of each core. The segments of core utilized in the pollen and spore study are listed according to depth and lithotype in table 14.

The polleniferous material of the Tuscaloosa group includes three groups of samples, one from each of the two cores of the Eoline member of the Coker formation, and one from the Gordo formation. The unnamed upper member of the Coker formation was sampled (Webb hole, 212.2–214.9 feet depth and Boykin hole, 204.2–206.3 feet depth—depth intervals from Monroe, 1955) near its base but these sediments contained no plant fossils; the general mottled pink and yellow color of the unit suggests an oxidation state that makes it an unlikely source for fossil pollen and spores. The only sample obtained from the Gordo formation containing plant fossils is from a gray clay unit in the lower part of the formation, near the top of the Boykin hole. Samples from the main part of the Gordo formation were not available because the bulk of the unit was not cored, but two samples (lower part of Crawford hole, 399.1–420.8 feet depth) of sandy clay from near the top of the formation were prepared and found to be unfossiliferous.

TABLE 14.—*Source and type of samples studied for contained pollen, spores, and other microfossils*

USGS paleobotany loc.	Formation	Sample	Lithotype	Depth intervals sampled (feet)[1]
Core from Crawford hole, sec. 15, T. 18 N., R. 8 E., Perry County				
D1110	Eutaw	1	Siltstone	111.2–118.4
	do	2	Claystone	129.1–131.3
	do	3	do	136.0–139.6
D1456	McShan	4	do	186.5–192.5
	do	5	do	296.5–302.3
	do	6	do	314.5–316.6
	Gordo	7	do[2]	399.1–402.1
	do	8	do[2]	410.1–420.8
Core from Boykin hole, sec. 5, T. 24 N., R. 4 E., Tuscaloosa County				
D1457	Gordo	1	Sandy siltstone	10.5– 20.6
D1111	Coker, upper member	2	Lignite[2]	204.2–206.3
	do	3	do	247.7–249.2
	Coker, Eoline member	4	Claystone	near 270.5
		5	do	270.5–271.4
		6	do	314.2–324.4
		7	do	324.4–335.0
		8	Lignite	346.4–348.5
		9	do	352.0–353.8
		10	Silty claystone	378.1–385.1
		11	Sandstone[2]	476.0–477.6
Core from Webb hole, sec. 16, T. 21 N., R. 8 E., Perry County				
D1109	Coker, upper member	1	Claystone[2]	212.2–214.9
	Coker, Eoline member	2	Claystone	226.8–229.8
		3	do	229.8–232.6
		4	do	238.8–248.0
		5	Sandy claystone	248.0–261.0
		6	Claystone	298.0–299.6
		7	Siltstone	360.0–364.0
		8	Claystone	374.3–375.8
		9	do	427.0–430.0
		10	do	457.3–460.0

[1] Depth intervals from Monroe, 1955.
[2] Sediment sampled contained no fossil pollen or spores.

From the Crawford core six polleniferous samples were obtained—three from the middle and upper parts of the McShan formation, and three from the middle part of the Eutaw formation (table 14).

The Boykin hole samples of the Tuscaloosa group and the Crawford hole samples of the McShan and Eutaw formations can be considered a coarsely sampled composite pollen section of the pre-Selma strata, the largest sampling gaps being the probably unfossiliferous upper member of the Coker and the chiefly unsampled Gordo formation. The Webb hole pollen samples, which are spaced from less than 1 to 50 feet apart within the Eoline member of the Coker formation, serve as a laterally equivalent pollen sequence for comparison with the Eoline member in the Boykin hole.

The methods by which the sediments were treated in order to isolate the pollen and spore fraction include the hydrofluoric acid technique described by Faegri and Iversen (1950, p. 62), and the heavy liquid flotation method described by Funkhouser and Evitt (1959). The fossil material was stained with Safranin "O" and mounted in glycerine jelly; after the slides were cured with low heat (50°C) for a few days, the coverslips were sealed with lacquer.

The pollen and spore species are noted in table 15 according to relative abundance in the organic residues, as follows:

	Percent
Rare (R)	<1
Frequent (F)	1–10
Common (C)	10–33
Abundant (A)	33–50
Dominant (D)	>50

COMPOSITION OF THE MICROFOSSIL ASSEMBLAGE AND AFFINITIES WITH MODERN PLANTS

The pre-Selma Upper Cretaceous pollen and spore flora as listed in table 15 embraces a total of 105 identified species and 92 genera. Fifteen forms represent hystrichomorphs and unicellular algae, 30 species are sporae dispersae representing members of pteridophyte groups, 18 species are Gymnospermae, and 40 species are Angiospermae.

FAMILY HYSTRICHOSPHAERIDEAE

The unicellular forms placed in the Hystrichosphaerideae bear organ generic names and are of uncertain affinities. Some evidence indicates that certain hystrichomorphs are members of the Dinoflagellata (Cookson, 1956; Braarud, 1945). Hystrichomorphs may be abundant in modern marine sediments (McKee, Chronic, and Leopold, 1959), though they are occasionally found as fossils in continental deposits.

Most of the species of Hystrichosphaerideae in the present material are known from Upper Cretaceous strata of Europe. *Micrhystridium inconspicuum* Deflandre (1937) was described from Cenomanian sediments from the Paris Basin, but its total stratigraphic range is not known. *Pterospermopsis ginginensis* Deflandre and Cookson, which is now known only from marine Upper Cretaceous Senonian strata of Western Australia, is found in McShan and Eutaw sediments here (plate 9, fig. 6). The forms *Micrhystridium piliferum* Deflandre, *Hystrichosphaeridium multifurcatum* Deflandre, and *Hystrichosphaera cornigera* Wetzel are all common in the Silex deposits of the Paris Basin (Deflandre, 1937). *Hystrichosphaeridium pulcherrimum* Deflandre & Cookson (pl. 9, fig. 13) is a Cretaceous form known primarily from Australia. The other Hystrichosphaerideae species

TABLE 15.—*Microfossils identified in core samples of pre-Selma Upper Cretaceous sediments in western Alabama*

[Relative abundance in samples indicated by R, rare; F, frequent; C, common; A, abundant; and D, dominant]

Species identified	Webb core									Boykin core									Crawford core					
USGS paleobotany locality	D1109									D1111								D1457	D1456			D1110		
Formation	Coker, Eoline member									Coker, Eoline member								Gordo	McShan			Eutaw		
Sample No.	10	9	8	7	6	5	4	3	2	10	9	8	7	6	5	4	3	1	6	5	4	3	2	1
Forminifera																				D	F	D	A	D
Hystrichosphaerideae:																								
Hystrichosphaera cornigera Wetzel																				R				
Membranilarnax pterospermoides Wetzel																					R			
Schizosporis reticulatus Cookson & Dettman																				R				
Pterospermopsis ginginensis Deflandre & Cookson																					R	R		
Hystrichosphaeridium multifurcatum Deflandre			R			R	R												R	C	R	F	R	F
H. pulcherrimum Deflandre & Cookson					R														R					R
H. truncigerum Deflandre																							R	
Hystrichosphaeridium Deflandre															R				R		R	F	C	F
Micrhystridium sp. Deflandre																					R			
M. bacilliferum Deflandre																								R
M. parvispinum Deflandre																			R	R	R			
M. inconspicuum Deflandre														R							R			
M. pavimentum Deflandre																					R			
M. piliferum Deflandre						R																	R	
Sporites echinosporus R. Potonié																			R					
Tetraporina Naumova																					R			
Dinoflagellata:																								
Undetermined													R						R				R	
Deflandrea bakeri f. *pellucida* Deflandre & Cookson																								R
Gonyaulax transparens Sarjeant																							R	
Paleohystrichosphora Deflandre																						R		
cf. *Wetzeliella glabra* Cookson											R									F	R	R	F	
Chroococcales:																								
cf. *Aphanothece*																				R				
Sporae Dispersae:																								
Baculatisporites primarius (Wolff) Thomson and Pflug																				R				
Cicatricosisporites brevilaesuratus Couper																		R						
C. dorogensis R. Potonié and Gelletich	F	R		C	F			F			C	R	F	F	F	C	F	C		C	C		R	R
C. dunrobensis Couper											R				R									

TABLE 15.—*Microfossils identified in core samples of pre-Selma Upper Cretaceous sediments in western Alabama*—Cont.

[Relative abundance in samples indicated by R, rare; F, frequent; C, common; A, abundant; and D, dominant]

Species identified / Name of core	Webb core									Boykin core									Crawford core					
USGS paleobotany locality	D1109									D1111								D1457	D1456			D1110		
Formation	Coker, Eoline member									Coker, Eoline member								Gordo	McShan			Eutaw		
Sample No.	10	9	8	7	6	5	4	3	2	10	9	8	7	6	5	4	3	1	6	5	4	3	2	1
Sporae Dispersae—Continued																								
Cingulatisporites dubius Couper																		R			R			
C. problematicus Couper																		R						
cf. *C. scrabatus* Couper											R										R			
Concavisporites cf. *C. punctatus* Delcourt and Sprumont		F					F	R		F	C		F	F	R	C	C					R	F	R
C. rugulatus Pflug	R																							
Corrugatisporites arcuatus Weyland & Greifeld																					R			
Cyatheacidites annulata Cookson														R										
Cyathidites mesozoicus (Thiergart) R. Potonié	R										R													
Deltoidospora hallii Miner	R								C	F							C				R			R
Densoisporites perinatus Couper											R							R				R		
Gleichenia circinidites Cookson	R																							
Gleicheniidites senonicus Ross									R	F	R													
Hymenozonotriletes reticulatus Bolkhovitina																					R			
Leiotriletes cf. *L. subtilis* Bolkhovitina		R					R										R							
Lycopodium cerniidites Ross																F								
Monolites major Cookson	F	R	R	C	C		C	F	F	C	F	F		F	F	F	C	C		C	R	C	R	A
Osmundacidites wellmanii Couper																				R				
Plicatella trichacantha Malawkina	R	R		R						R	R							R			R			
Polypodiaceaesporites haardti (R. Potonié and Venitz) Thomson & Pflug	R	R		R					F		R							R		R		R		R
Poroplanites porosinuosus Pflug									F		F													
Rugulatisporites quintus Thomson and Pflug			R	C																				
Schizaeoisporites eocaenicus (Selling) R. Potonié										R				R										R
Schizoplanites reductus Pflug								R																
Sporites arcifer Thiergart	R																						R	
Taurocusporites reduncus (Bolkhovitina) Stover																		R						
Torisporis intrastructurius Krutzsch																		R						
Trilites verrucatus Couper	R																	R						R
Trilites undetermined	R	F		F	F	R		F			F				R	F			F	F	F	C		R
Triplanosporites sinuosus Thomson & Pflug				R			R		C		F	F			C	F	C						R	
Verrucatosporites alienus (R. Potonié) Thomson & Pflug										R					R									

Gymnospermae:																								
Abietineaepollenites microreticulatus Groot & Penny																	R							R
Araucariacites australis Cookson	F	F									F			F				F		F	C	R		R
Caytonipollenites pallidus (Reissinger) Couper																								R
Classopollis classoides Pflug			R		R	R -														R				R
C. torosus (Reissinger) Couper	R												R											
Cycadopites cf. *C. follicularis* Wilson and Webster											R									R				F
Dacrycarpites australiensis Cookson & Pike																				R	R			
"*Dacrydiumites florinii*" Cookson & Pike	R	R																						
Ephedra Tournefort ex L.				F									R		F	R	F		R				R	
Eucommiidites troedssonii Erdtman				R																				
Gynkaletes cf. *G. retroflexus* (Luber) Luber	R	R																						
Inaperturopollenites dubius (R. Potonié & Venitz) Thomson & Pflug.	R	F	R	C		C		F	F	C	F		R	R	R		C	F	R	C	C			A
Labiisporites granulatus Leschik				R			R																R	
Laricoidites magnus (Potonié) R. Potonié & Venitz		C	R	F		C	C	F		C	R	F	D	C	D	A	A	C	C		C	F	C	F
Monosulcites minimus Cookson	F			R																	R	R	F	R
Parvisaccites enigmatus Couper																		R			R			
Perinopollenites cf. *P. elatoides* Couper		C		F		F	F	F			F			R	C	A	R		R					
Pinuspollenites labdacus (R. Potonié) Raatz				R																				
Pityosporites microalatus R. Potonié	F	F	R	R		R	R			C			F	R	R			C	R	R		F	F	
Podocarpidites cf. *P. major* Couper	R																				R	R		
cf. *P. biformis* Rouse	R	R		R						F			F							F	R			F
cf. *Podocarpus* (L'Heritier) Persoon	R									R	R					R		D	C			R		
Sequoiapollenites polyformosus Thiergart				F							R						R -			F				
Taxodiaepollenites hiatus (R. Potonié) Thiergart		C		F		C		F		C			R		F	F	C	F	F	A	D	C	F	A
Tsugaepollenites mesozoicus Couper						R				R						R	R							
Monocotyledonae:																								
Liliacidites intermedius Couper																							R	
Sabalpollenites areolatus (R. Potonié) R. Potonié	F	R				R		F		R											R			
Dicotyledonae:																								
Triporate pollen:																								
Basopollis atumescens (Pflug & Thomson) Pflug																		R						
B. orthobasalis (Pflug) Pflug							R																	
Complexipollis praetumescens Krutzsch																		R			R			
Conclaripollis anulopyramis Pflug																				R				
Extratriporopollenites audax Pflug				R	R									R				R						
Latipollis normis Krutzsch				R																				
L. subtilis Krutzsch				R										R							F	R		
L. latis Krutzsch				R														R			R	R		
cf. *Minorpollis minimus* Krutzsch																					R			
Monstruosipollis monstruosis Krutzsch			R	R	R									R										
Nudopollis ornatus (Pflug) Pflug																		R						
cf. *Oculopollis* Pflug																								R
cf. *Paliurus rhamnoides* Bolkhovitina				R																			R	
Sporopollis laqueaeformis Weyland & Greifeld							R															R		R
S. pseudosporites Pflug	R		R	R										R								F	R	
Sporopollis Thomson & Pflug							R														R			
Triatriopollenites arboratus Pflug			R	R															R					

TABLE 15.—*Microfossils identified in core samples of pre-Selma Upper Cretaceous sediments in western Alabama*—*Con.*

[Relative abundance in samples indicated by R, rare; F, frequent; C, common; A, abundant; and D, dominant]

Species identified																								
Name of core	Webb core									Boykin core									Crawford core					
USGS paleobotany locality	D1109									D1111								D1457	D1456			D1110		
Formation	Coker, Eoline member									Coker, Eoline member								Gordo	McShan			Eutaw		
Sample No.	10	9	8	7	6	5	4	3	2	10	9	8	7	6	5	4	3	1	6	5	4	3	2	1
Dicotyledonae—Continued																								
Triporate pollen—Continued																								
T. rurensis Pflug & Thomson																			R		R	R	F	R
T. coryphaeus subsp. *microcoryphaeus* R. Potonié																								R
cf. *T. concavus* Thomson & Pflug																						R		
Triorites cf. *T. edwardsii* Cookson	R		C	C	R	F	F	F	R	R			F	F	R		F				R	R	R	R
"*Triporopollenites*" Pflug & Thomson				R		R		R					F	R								R	R	R
Trivestibulopollenites betuloides Thomson & Pflug																				F	F	R	R	F
Turonipollis turonis Krutzsch							R											R						
Tricolpate pollen:																								
Cupanieidites major Cookson		R																						
Fraxinoipollenites pudicus (R. Potonié) R. Potonié				R				F					F			F								
Myrtaceidites parvus forma *anesus* Cookson								R			R													
Platanoidites gertrudae (R. Potonié) R. Potonié, Thomson & Thiergart.	R	R		F		R	R			R	R			R	F	R	C				R	R		F
Platanoidites R. Potonié, Thomson & Thiergart								F			R						C							
Pollenites grossularius R. Potonié	R																							
P. megagertrudae R. Potonié				R	R		C			F	R		R		F		C							
P. ornatus R. Potonié								F	R						F									
P. quisqualis R. Potonié	R										R													
Quercoidites henrici (R. Potonié) R. Potonié, Thomson & Thiergart.	R	F	R	R				R		C	A	F	F	A	F	F		F		F	F		R	R
Q. microhenrici (R. Potonié) R. Potonié, Thomson & Thiergart								R	R										R		R			
Salix discoloripites Wodehouse		R									R													
Tenerina tenera Krutzsch			R																			R		R
Tricolpites Cookson ex Couper	R	F	C	F	R	C	A	D	C	A	D	F	F	F	C	F	F	F	A	F	F	F	F	F
"*Tricolpopollenites retiformis*" Pflug & Thomson	R	R	R			R	R	R			F		F		R		R	R	R	R	R	R	R	R
Tricolporate pollen:																								
Araliaceoipollenites edmundi R. Potonié								F								R								
Cyrillaceaepollenites megaexactus (R. Potonié) R. Potonié																						F		F
C. megaexactus subsp. "*brühlensis*" Thomson										F		R	R	R	C	F			R		R			
Dicotetradites cf. *D. clavatus* Couper										R	F	C	F	F										
Ilexpollenites margaritatus forma *minor* Pflug & Thomson										C										F				

I. margaritatus forma *medius* Pflug & Thomson	----	----	----	----	----	----	----	----	----	----	R	----	F	R	F	F	----	--------	----	----	----	----	----	----
Pollenites cingulum subsp. *oviformis* R. Potonié	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--------	----	F	----	----	----	----
P. genuinus R. Potonié	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	F	----	--------	----	----	----	----	----	----
P. kruschi R. Potonié	----	----	----	----	----	----	----	----	----	----	----	----	----	----	R	----	----	--------	----	----	----	----	----	----
P. kruschi subsp. *analepticus* R. Potonié	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	R	--------	----	----	----	----	----	----
P. kruschi "asp. *pseudolaesus*" (R. Potonié) Thomson & Pflug	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	F	F	--------	----	----	R	----	R	----
Porocolpopollenites Thomson & Pflug	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--------	R	F	F	F	R	F
P. orbiformis Thomson & Pflug	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--------	----	----	----	----	R	----
"*Tricolporopollenites microreticulatus*" Pflug & Thomson	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--------	----	----	----	F	R	R
"*T. distinctus*" Groot & Penny	----	----	----	----	----	----	----	----	----	----	R	----	----	----	----	----	----	--------	----	----	----	----	----	----
Symplocoipollenites vestibulum (R. Potonié) R. Potonié	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--------	----	----	F	----	----	R
Tricolporate pollen, undetermined	----	----	----	----	----	----	----	----	----	----	A	----	----	----	----	----	R	--------	----	----	R	R	----	R

identified here are known to be wide ranging in the Mesozoic and Paleozoic of Europe.

CLASS DINOFLAGELLATA

Two algal forms in the Eutaw formation are clearly members of the planktonic group Dinoflagellata: *Gonyaulax* Diesing is a living genus which is entirely an open water plankter, and most of its presently known living species have marine habitats. *Paleohystrichosphora infusorioides* Deflandre (pl. 9, fig. 14) is a form species typical of marine Upper Cretaceous sediments of Europe. Species of *Deflandrea* Eisenack similar to the present material (pl. 9, figs. 15, 16) are known from marine Upper Cretaceous through Eocene sediments in Australia.

ORDER CHROOCOCCALES

A colonial alga composed of 15 cells embedded in a filmy, if not gelatinous, envelope, and having smooth ovoid cells 7 by 4 microns in size, appears to be a member of the Chroococcales. The form resembles the modern genus *Aphanocapsa.*

ORDER LYCOPODIACEAE

A member of the Lycopodiaceae, *Lycopodium cerniidites* Ross resembling the modern subtropical species *Lycopodium cernuum* L. occurs in the Coker and McShan formations. Leaves and strobili of *Lycopodium* and leaves of *Lycopodites* were found in the Tuscaloosa flora by Berry (1919), who stated elsewhere (Berry, 1910) that *Lycopodium* megafossils are rare in the American Cretaceous.

CLASS FILICINEAE

Of the 30 species of pteridophyte spores identified from the pre-Selma samples, only 7 can be assigned to modern families with certainty, and only 1 represents a living genus.

The terrestrial fern family Schizaeaceae, which has four living component genera, is well represented in the Tuscaloosa group (pl. 3, figs. 1–13; pl. 6, figs. 1–5). The organ genus *Plicatella* Malawkina has affinities with a part of the modern genus *Anemia* Swartz, especially with the living species *A. adiantifolia* (L.) Swartz. *Cicatricosisporites* R. Potonié and Gelletich has affinities both with *Anemia* and *Mohria* Swartz, and *Schizaeoisporites* Potonié closely resembles its living counterpart *Schizaea* Smith, especially *S. digitata* (L.) Swartz. All living species of Schizaeaceae are restricted to subtropical and tropical regions, except two species of *Schizaea* which have boreal distributions. Fossil spores are the only evidence of this family in these pre-Selma strata.

Spores assignable to the modern austral and tropical fern genus *Gleichenia* Smith are present in the Eoline member of the Coker formation. Our specimens are of the *G. circinata* type and compare in all respects with Cookson's late Mesozoic species *G. circinidites* Cookson. Spores of probable affinities with the Gleicheniaceae are represented by the species *Gleicheniidites senonicus* Ross. Megafossils of *Gleichenia* were found by Berry (1919) within the Tuscaloosa group at Shirleys Mill, Ala. That leaf locality is considered by Monroe (written communication, 1960) to be part of the Coker formation.

CLASS GYMNOSPERMAE

Of 22 genera of gymnosperm pollen, 18 of which are identified on the species level, 1 is a living genus, and about half of the species can be assigned to modern families. By far the most interesting aspect of the gymnospermous forms reported here are those which assuredly represent the now exotic family Podocarpaceae. Except for a single report of *Podocarpus* (L'Heritier) Persoon in northeastern Mexico (Sharp, 1949), evidence indicates that living members of this family are restricted to the Southern Hemisphere. The fossil forms are as follows:

Fossil form	Affinity
Dacrycarpites australiensis Cookson & Pike (pl. 7, figs. 1–2)	*Podocarpus* (L'Heritier) Persoon, section *Dacrycarpus*
"*Dacrydiumites* (Phyllocladites) *florinii*" Cookson & Pike	*Dacrydium* Soland (group b of Cookson, 1953)
Parvisaccites radiatus Couper (pl. 7, fig. 3)	*Dacrydium cupressinum* Soland ex Forster f.
cf. *Podocarpus* (an unnamed pollen genus) (pl. 7, fig. 7)	*Podocarpus* and *Phyllocladus* Rich
Podocarpidites cf. *P. biformis* Rouse (pl. 7, figs. 12–13)	*Podocarpus*
Podocarpidites cf. *P. major* Couper (pl.4, figs. 11–13 and, pl. 7, figs. 4–6).	*Podocarpus*

Reports of fossil remains of undoubted Podocarpaceae in the United States are rare in the paleobotanical literature. A podocarpaceous plant from the Tuscaloosa group, known to have been widespread in Cretaceous vegetation of west-central and eastern United States (Dakota, Magothy, and Raritan formations), is *Protophyllocladus subintegrifolius* (Lesquereaux) Berry, but its actual relation to the modern genus *Phyllocladus* is still in doubt, according to Berry (1919, p. 58). Two species of American Eocene woods, *Podocarpoxylon washingtonense* Torrey and *P. texense* Torrey, may be assigned to the Podocarpaceae according to an evaluation by Kräusel (1948). A study of Lower Cretaceous or Upper Jurassic pollen from British

Columbia by Rouse (1959) provided the first published evidence that pollen assignable to the Podocarpaceae is represented in North American Mesozoic strata.

Pollen of the *Podocarpidites biformis* type is, according to our observations, common in Lower Cretaceous sediments of Wyoming and very rare in younger strata of that area.

Another interesting pollen is *Caytonipollenites pallidus* (Reissinger) Couper in the Eutaw formation (pl. 6, figs. 33 and 34), a species which Couper (1958) has shown represents pteridosperm pollen and assigned provisionally to the family Caytoniaceae. Pollen forms of this sort are known in Triassic and Jurassic rocks of Utah (R. A. Scott, oral communication, 1960), and are common in Upper Jurassic and less common in Lower Cretaceous sediments (Lower Greensand or Aptian) of England (Couper, 1958). Megafossil remains of the pteridosperms, or seed ferns, are known to range from Mississippian through Jurassic (Arnold, 1947); published records of the unique order Caytoniales demonstrate only Jurassic and Lower Cretaceous occurrences. As far as we know, the *Caytonipollenites* in the Eutaw formation represents the first Upper Cretaceous record of Pteridospermae.

The broad-leaved conifer family Araucariaceae, now distributed mainly in temperate climates and now limited to the southern hemisphere, is represented by pollen in all four formations of this study by the pollen genus *Araucariacites* Cookson (pl. 6, fig. 29), which closely resembles modern pollen of *Araucaria* Jussieu and *Agathis* Salisbury species. The family is represented in the Eutaw and McShan floras by leaves assigned to the species *Araucaria bladensis* Berry and *A. jeffreyi* Berry (Berry, 1919).

Couper (1958, p. 130) has suggested that the pollen genus *Classopollis* (Pflug) Couper, of which two species were found in the pre-Selma sediments, might have its affinities with the family Araucariaceae on the basis of the similarity of the genus to the pollen of *Pagiophyllum* Heer, a provisional fossil member of the family. Pollen of *C. classoides* Pflug is figured on plate 6 (figs. 30–32).

Classopollis and *Araucariacites* are common in our Upper Cretaceous collections from Colorado and Wyoming and occur occasionally in lower Paleocene sediments of Wyoming.

Three species of the pollen assemblage as identified here are clearly members of the Taxodiaceae, resembling pollen of *Taxodium* Rich and *Sequoia* Endlicher; these are *Taxodiaepollenites hiatus* (Potonié) Thiergart, *Inaperturopollenites dubius* (Potonié & Venitz) Thomson & Pflug (pl. 6, figs. 25–28), and *Sequoiapollenites polyformosus* Thiergart (pl. 4, fig. 1). Individual pollen grains of Taxodiaceae are rarely sufficient to identify even genera in modern material; but tallies of 100 grains from acetolysed pollen taken from male cones of all living genera of

Taxodiaceae indicate that *Taxodium* pollen differs from that of the other members of the family in at least two features. *Taxodium* pollen is characterized by a relatively thin cell wall which contributes to characteristically high frequency (20 to 75 percent) of split pollen, while among pollen of other Taxodiaceae, splitting is generally less than 5 percent. *Taxodium* pollen is also characterized by the small number (less than 15 percent) of grains bearing papillae; but at least among the nearest relatives of *Taxodium*, papillae occur on from 66 to 99 percent of the pollen grains. (Lacking papillae, *Cunninghamia* R. Brown and *Athrotaxis* D. Don pollen differ from that of *Taxodium* by having especially thick walls; Cupressaceae pollen are not considered here because they differ from the fossils in question in having larger gemmae scattered on the exteriors of the pollen walls.)

In the present material, we have discovered that the split pollen grains of the *Taxodium* type, assigned to *Taxodiaepollenites hiatus* (pl. 6, figs. 27 and 28), are somewhat more numerous in each sample than unbroken spherical pollen of the same type, assigned to *Inaperturopollenites dubius* (pl. 6, figs. 25 and 26). As can be seen in table 15, *T. hiatus* and *I. dubius* occur together in almost every sediment sample examined, and are especially abundant in sediments of the Coker formation.

Though leaves and twigs from the Tuscaloosa group have been assigned to three species of the genus *Sequoia* Endlicher by Berry (1919), papillate pollen that might represent *Sequoia* (pl. 4, fig. 1) were found to be exceedingly rare in the present material.

Pollen representing two forms of the modern genus *Ephedra* Tournefort ex L. are the only fossils of the Gnetaceae yet uncovered in the Tuscaloosa group, but the genus is known to range from Triassic to Recent (Scott, 1960). One form that is like the pollen of the living species *E. torreyana* is figured on plate 6 (figs. 23 and 24).

Pollen assigned to the species *Pityosporites microalatus* R. Potonié and *Pinuspollenites labdacus* (R. Potonié) Raatz represent Pinaceae cf. *Pinus* (Tournefort) L. (pl. 4, figs. 4–10). Megafossil remains of *Pinus* have been described from middle and lower beds of the Tuscaloosa group and are known from other Upper Cretaceous deposits in the United States. *Tsugaepollenites mesozoicus* Couper may be considered a member of the pine family, having affinities with *Tsuga* Carrière.

The members of the gymnosperm list in table 15 not mentioned in this discussion are gymnospermous pollen of uncertain position.

CLASS ANGIOSPERMAE

The angiosperm flora as represented by pollen, like the megafossil forms of the pre-Selma strata, is primarily dicotyledonous. Only two pollen types, *Sabalpollenites areolatus* (R. Potonié) R. Potonié and *Liliacidites intermedius* Couper (pl. 7, figs. 16–18) can be considered monocots, but these are not assignable to living families because their morphology is suggestive of several: Palmae, Bromeliaceae, Calycanthaceae, or Liliaceae.

The Dicotyledonae of the flora represented by pollen include 55 forms or 40 identified species, a relatively unimpressive number when compared with 123 dicot species that have been described from leaves from the Tuscaloosa group (Berry, 1919). But where pollen can be assigned to still existing dicot families, an interesting corroboration of taxa exists between pollen and megafossil evidence. Pollen species assigned to dicotyledonous families are listed below in table 3 along with their distribution in the pre-Selma Cretaceous formations:

TABLE 16.—*Dicotyledonous families represented by pollen in pre-Selma strata*

Family	Pollen species	Formation	Family identified by leaves in Tuscaloosa group (Berry, 1919)
Salicaceae	*Salix discoloripites*	Coker	X
Fagaceae	*Quercoidites henrici*	Coker, McShan, Eutaw	
	Q. microhenrici	Coker, McShan	
Aquifoliaceae	*Ilexpollenites margaritatus*	Coker, McShan	X
Myrtaceae	*Myrtaceidites parvus*	Coker	X
Cyrillaceae	*Cryillaceaepollenites megaexactus*	Coker, McShan, Eutaw	
Theaceae	*Pollenites ornatus*	Coker	X
Araliaceae	*Araliaceoipollenites edmundi*	Coker, McShan	X
Symplocaceae	*Symplocoipollenites vestibulum*	McShan	

The family Salicaceae is represented in the flora by leaves assigned to *Salix* (Tournefort) L. and *Populus* L. by Berry (1919), and by *Salix* pollen as listed above in table 16. The few specimens we have assigned to *Salix* are entirely like modern *Salix* pollen of the *S. discolor* Muhl. type.

Some of the specimens referred to *Quercoidites henrici* (R. Potonié) R. Potonié, Thomson & Thiergart (pl. 5, figs. 10–11) seem to be quite like the pollen of modern *Quercus* (Tournefort) L. but the others seem tricolporoid, perhaps like *Fagus* (Tournefort) L. We consider these tricoplate forms, which occur in three pre-Selma formations, sufficiently diagnostic to assign them to the family Fagaceae. No members of the family were found in the Tuscaloosa group by Berry (1919).

Large and small pollen of the family Aquifoliaceae, common in the Coker formation, are assigned to forms of the organ species *Ilexpollenites margaritus* (R. Potonié) Thiergart. As in certain European Tertiary material of this species, our specimens resemble the pollen of the genus *Ilex* (Tournefort) L. and *Nemopanthus* Raf., but the size of the clavae and, for the most part, the size of the pollen cell are much smaller than in pollen of living *Ilex* or *Nemopanthus* species. The pollen morphology of the family is so unique among living dicots that there can be little mistake about the affinity cited. Hollylike leaves assigned to *Ilex*, which are similar to leaves of modern *Ilex* species in margins and veination, are mentioned by Berry (1919) as being frequent in sediments of the Tuscaloosa group.

The dicotyledonous pollen listed in table 15 as *Platanoidites* sp. is a unique form resembling pollen of the plane tree, *Plantanus occidentalis*, in having a pronounced membrane across the colpae, and very obvious gemmae of uniform size on the colpae membranes: these unusual features are known to us in the pollen of the Platanaceae and Hammamelidaceae. Though several species of leaves from the Tuscaloosa were assigned to the Platanaceae (Berry, 1919), their morphology was more conclusive than that of the pollen we have identified as *Platanoidites* (pl. 5, figs. 14–15).

Pollen of the Cyrillaceae is represented in the flora of the Gordo and McShan formations by the species *Cyrillaceaepollenites megaexactus* (R. Potonié) R. Potonié. Though Potonié (1960, p. 102) has synonymized the *C. megaexactus* forma *"brühlensis"* Thomson with the species *C. megaexactus* we refer to the form here because its type provides more convincing evidence for assignment in this family than the type for *C. megaexactus*. As in the Rheinish lignite specimens on which this species was founded (Potonié, 1931), the range in morphology within *C. megaexactus* includes the pollen characters of both *Cliftonia* Banks et Gaertner and *Cyrilla* Gardner. Also the fossil material exhibits a somewhat greater range of variation in wall structure or texture than modern reference material of the family we have seen. Remains of Cyrillaceae are reported in the Brandon lignite (Oligocene) of Vermont (Traverse, 1955), but we know of no other fossils of the group yet recorded in the American literature. European fossils of the family are mainly of middle and late Tertiary age.

Pollenites ornatus R. Potonié, found in the Coker formation, was first described from Eocene lignites of Germany by Potonié (1934), who suggested that the species is similar to pollen of *Jasaminum* (Tourefort) L. of the Oleaceae. Specimens assignable to *P. ornatus* from the Tuscaloosa group, and some specimens in U.S. Geological Survey collections from the Laramie formation of Late Cretaceous age in Colorado, are closely similar to the pollen morphology of *Gordonia* Ellis or *Schima* Reinwardt ex Blume of the Theaceae; in our material this similarity suggests an affinity with that family. No megafossil remains from the Tuscaloosa group have thus far been assigned to the Theaceae.

Two species sporadically distributed in the Coker and Gordo formations are *Myrtaceidites parvus* forma *anesus* Cookson of the Myrtaceae, and *Cupanieidites major* Cookson of affinities with either Myrtaceae or Sapindaceae. These forms occur in Upper Cretaceous and lower Paleocene strata in Colorado and Wyoming. Megafossil forms having affinities with *Eucalyptus* L'Heritier and *Eugenia* Michaux ex L. of the Myrtaceae are cited by Berry (1919) in the Tuscaloosa flora, but he recorded no sapindaceous megafossils.

PALYNOMORPH ZONES OF THE PRE-SELMA STRATA

Although many components of the pre-Selma pollen and spore flora have a somewhat random distribution within the four formations, a number of species seem to be restricted to certain parts of this section, or show definite changes in abundance within the section. Rather clear differences also exist between the laterally equivalent parts of the Eoline member of the Coker formation in the Boykin and Webb cores. These differences, which apparently represent facies changes, suggest that definition of pollen zones here should be undertaken with some caution. Berry (1919), in his study of the plant remains, noted only minor differences between the flora of the Tuscaloosa group and that of the McShan and Eutaw formations, and comparatively small floristic changes from bottom to top within the Tuscaloosa group (Berry, 1919, p. 22).

With respect to the palynomorphs identified here, including the algae and hystrichomorphs, significant changes exist at only one level within the pre-Selma section, and these occur at or near the top of the Tuscaloosa group. These changes involve a partial replacement of land plants by aquatic forms as well as a significant change in species of land plants.

FACIES CHANGES

The replacement of land plants by aquatic forms appears rather abruptly near the base of the McShan formation. Clay above the basal sandy gravel of the McShan formation in the Crawford core contains a mixed gymnospermous and dicotyledonous land plant assemblage and very occasional hystrichomorphs (algae?), but the clay only 12 feet higher in the core contains predominantly microforaminifer remains; hystrix forms are both varied and more abundant, and land plant forms are numerically unimportant. Near the top of the McShan formation and in the middle part of the Eutaw formation, remains of microforaminifers are frequent to dominant—hystrix and dinoflagellate algae occurring regularly. That this change is related to increased depth of water is suggested by the overall lithologic evidence and by modern environments in which microforaminifers accumulate.

A study of the sedimentary environment of some marine microorganism remains within Kapingamarangi lagoon by McKee, Chronic, and Leopold (1959) indicates that microforaminifers occur in small numbers in several sediment types on the lagoon floor, but their numbers per gram of bottom sediment are especially great in the environment where clay-sized particles are the chief constituent of the sediment. At Kapingamarangi, this environment is where water depths are from 225 to 240 feet, the deepest and quietest part of the lagoon floor. Though little is yet known about their taxonomy, these microforaminifera (<150 microns) from Kapingamarangi are taxonomically distinct from both the "larger" (>1 mm) and "smaller" (150 microns to 1 mm) Foraminifera (in the usage of Wilson and Hoffmeister, 1952, p. 26).

The Kapingamarangi study (McKee, Chronic, and Leopold, 1959) also demonstrated that planktonic dinoflagellate algae and their hystrixlike resting cysts accumulate primarily in the deeper parts of the lagoon along with the clay-sized sediments; that these microorganisms are deposited allochthonously in water below wave base at Kapingamarangi lagoon is of interest here.

The apparent absence of microforaminifers and scarcity of dinoflagellate algae in the Tuscaloosa group and their presence in large numbers in the McShan and Eutaw formations may be attributed to environmental factors. Several lines of evidence suggest that sediments of the Tuscaloosa group were deposited in shallow water and were oxidized intermittently during deposition. The presence in the Eoline member of the Coker formation of lignite beds and crossbedded glauconitic sands with oysters and brackish-water larger Foraminifera (Applin, chap. D of this bulletin) point to a shallow water lagoonal or shoreline environment of deposition for that member. The variegated color and the general absence of glauconite in sediments of the upper member of the Coker formation suggest a very shallow water environment in which possibly the sediments were intermittently exposed to the air during deposition, as perhaps in a tidal flat environment.

In contrast, the comparatively great amounts of glauconitic sand and absence of lignite beds or oxidized zones in the McShan and Eutaw formations suggest a depositional environment of somewhat deeper water than that of the Tuscaloosa group. The great numbers of microforaminifers, along with the other remains of marine life such as sharks' teeth (Monroe, 1955) and oysters and other mollusks (Sohl, chap. C of this bulletin) in the McShan and Eutaw formations, strongly support this interpretation.

FLORISTIC ZONES

Of the 105 species in the total palynomorph flora, 34 are in the Tuscaloosa group, but not in the McShan and Eutaw formations. Conversely, 22 species in the McShan and Eutaw formations seem to be lacking in the Tuscaloosa flora (table 17). Disregarding the assortment of algae and microforaminifer remains, 13 species of the

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TABLE 17.—*List of palynormorphs of restricted distribution within the pre-Selma section*

Forms in Tuscaloosa group, not found in McShan and Eutaw formations	Forms in McShan and Eutaw formations, not found in Tuscaloosa group
Hystrichosphaerideae:	Hystrichosphaerideae, microforaminifers, and dinoflagellate algae:
Micrhystridium inconspicuum	*Hystrichosphaera cornigera*
	Membranilaranx pterospermoides
	Schizosporis reticulatus
	Pterospermopsis ginginensis
	Micrhystridium bacilliferum
	M. parvispinum
	M. pavimentum
	Microforaminifers
	Paleohystrichosphora infusorioides
Sporae Dispersae:	Sporae Dispersae:
Taurocusporites reduncus	*Baculatisporites primarius*
Cicatricosisporites brevilaesuratus	*Corrugatisporites arcuatus*
C. dunrobensis	*Hymenozonotriletes reticulatus*
Cingulatisporites problematicus	*Osmundacidites wellmanii*
Concavisporites rugulatus	
Cyatheacidites annulata	
Cyathidites mesozoicus	
Gleichenia circinidites	
Gleicheniidites senonicus	
Leiotriletes cf. *L. subtilis*	
Lycopodium cerniidites	
Poroplanites porosinuosus	
Rugulatisporites quintus	
Schizoplanites reductus	
Torisporis intrastructurius	
Gymnospermae:	Gymnospermae:
Classopollis torosus	*Caytonipollenites pallidus*
"*Dacrydiumites florinii*"	*Dacrycarpites australiensis*
Eucommiidites troedsonii	
Pinuspollenites labdacus	
Tsugaepollenites mesozoicus	
Monocotyledonae:	Monocotyledonae:
None	*Liliacidites intermedius*
Dicotyledonae:	Dicotyledonae:
Triporate pollen:	Triporate pollen:
Basopollis atumescens	*Triatriopollenites rurensis*
B. orthobasalis	*T. coryphaeus*
Extratriporopollenites audax	*Trivestibulopollenites betuloides*
Latipollis normis	
Monstruosipollis monstruosis	
Turonipollis turonis	
Tricolpate pollen:	Tricolpate pollen:
Cupanieidites major	None
Fraxinoipollenites pudicus	
Myrtaceidites parvus	
Pollenites megagertrudae	
P. ornatus	
Salix discoloripites	
Tricolporate pollen:	Tricolporate pollen:
Araliaceoipollenites edmundi	*Pollenites cingulum*
Pollenites genuinus	*Porocolpopollenites*
	"*Tricolporopollenites microreticulatus*"
	Symplocoipollenites vestibulum

McShan-Eutaw flora do not occur in the Tuscaloosa group. Our data indicate that of the 90 nonaquatic species, the combined differences between the floras of the Tuscaloosa group and of the McShan and Eutaw formations amount to about 55 percent of the land-plant flora. Because of the limited scope of the sampling for the present report, we feel that some of the floristic differences now apparent between these two segments of pre-Selma strata may disappear with exhaustive sampling and larger tallies. In part, this might be expected because about two-thirds of the forms in table 17 are known to have a wide distribution within the Cretaceous.

Part of the differences in floras of the Tuscaloosa group and of the McShan and Eutaw formations may be explained by evolutionary changes. The dicotyledonous flora of the Eoline member of the Coker formation contains a group of very distinctive triporate *Normapolles* Pflug types which are very similar to some of the earliest dicot pollen types from the European Cretaceous section, and these distinctive forms are so different from pollen of modern groups that no affinities with modern families can be cited. These forms include several species that Krutzsch (1959) has described and figured from Turonian sediments of Germany, which are well dated by the presence of *Inoceramus labiatus* (Schlotheim) and *Scaphites geinitzi* (d'Orbigny) fossils.

The distinctive *Normapolles* forms are listed below with their known stratigraphic ranges according to Krutzsch (1957, 1959):

Complexipollis praeatumescens Krutzsch	Lower and middle Turonian
Latipollis subtilis Krutzsch	Lowest Turonian
L. normis Krutzsch	Middle Turonian
L. latis Krutzsch	Middle Turonian
Monstruosipollis monstruosis Krutzsch	Turonian and Santonian
Tenerina tenera Krutzsch	Turonian and Coniacian
Turonipollis turonis Krutzsch	Lower Turonian

Five of these species seem to be restricted to the Turonian in Germany and the other two range from Turonian through Coniacian and Santonian strata respectively. All these forms are present in the Eoline member of the Coker formation, and half of them also occur in the McShan-Eutaw collections. No other records on these species except those by Krutzsch (1957, 1959) are available to us at the time of this writing.

These dicot pollen types are less numerous in the McShan-Eutaw flora, and accompanying them are a group of simple triporates that are not seen in the Tuscaloosa group: *Trivestibulopollenites betuloides* Thomson and Pflug, *Triatriopollenites coryphaeus* (R. Potonié) Thomson and Pflug, *T. rurensis* Pflug and Thomson, which closely resemble pollen of modern Betulaceae genera, and cf. *T. concavus* Thomson and Pflug which is similar to some living Myrtaceae forms.

Appearing in every pollen sample of the McShan-Eutaw strata are many diverse species (mainly unnamed) of the genus *Porocolpopollenites* Thomson & Pflug, which are indeed absent in Tuscaloosa group sediments. (According to Potonié (1960), the genus *Porocolpopollenites* is synonomous with *Symplocoipollenites* Potonié 1951, but we do not agree. Both are valid genera.)

The Tuscaloosa group also has a very much richer fern flora than the overlying strata and contains several forms not found in the McShan and Eutaw—for example, *Leiotriletes*, *Cingulatisporites*, *Hymenozonotriletes*, and others listed in table 4.

Further zonation of these pre-Selma strata may well be possible by additional sampling and statistical tallies of forms. We expect that in a later report on the flora of these strata we shall be able to present histograms demonstrating more precisely relative abundance of forms.

STRATIGRAPHIC INTERPRETATION AND AGE OF THE FLORAS

The forms that probably are of greatest use in correlating the flora from the pre-Selma strata with other floras are the dicotyledons. Available records of Cretaceous floras clearly indicate that the percent of dicot forms in the total assemblage, and the stage of evolution these dicots represent, are far more valuable criteria for generalized dating within Cretaceous rocks than the use of individual lower plant forms or groups. With this in mind, a comparison of the dicotyledons of this flora with those of other dated floras from the region is pertinent.

In a recent summary of the pollen floras in the Potomac group of Cretaceous age in the eastern United States, Groot and Penny (1960) stated that dicot pollen represent less than 28 percent of pollen and spore tallies within those strata. In table 18, the range of percentages for the Raritan formation and older Cretaceous strata are listed, along with a tally from USGS collections from the type section of the Magothy formation; ages of the formations are listed according to Dorf (1952) and the Stephenson committee (Stephenson and others, 1942).

By comparison, the average of 39 and 38 percent of dicots in the Tuscaloosa and McShan-Eutaw floras, respectively, is higher than percent of dicots for the Potomac group as observed by Groot and Penny (1960) and significantly lower than their percentage in the available USGS material from the Magothy formation.

In a recent evaluation of evidence concerning the evolutionary rise of the angiosperms, Scott, Barghoorn, and Leopold (1960) concluded that many of the pre-Cretaceous fossil "angiosperms" are of questionable affinities, that the preponderant clear evidence of early angiosperms indicates that they first appear in the fossil record in

TABLE 18.—*Comparative percentages of dicot pollen and spore tallies of the Potomac group of Maryland and Delaware (Groot and Penny, 1960) and pre-Selma Cretaceous strata of Alabama*

Age	European Stages	Age of the pre-Matawan strata of the Atlantic Coastal Plain		Dicot pollen as percent of pollen and spore tallies (Groot and Penny, 1960; USGS data)	Age of pre-Selma Cretaceous strata of the Gulf Coastal Plain (Stephenson and others, 1942)	Dicot pollen as percent of pollen and spore tallies (this report)
		Stephenson and others, 1942	Dorf, 1952			
Late Cretaceous	Santonian					
	Coniacian	Magothy formation	Magothy formation	40 to 60 percent	Eutaw (=Mc Shan and Eutaw formations)	29 to 51 percent, 38 percent average
	Turonian					
	Cenomanian	Raritan formation	Raritan formation	28 percent, average	Tuscaloosa formation (=Coker and Gordo formations)	19 to 75 percent, 39 percent average
Early Cretaceous	Albian	Patapsco formation	Patapsco formation	2 to 26 percent		
	Aptian		Arundel formation			
	Neocomian	Arundel and Patuxent formations	Patuxent formation	0 to 21 percent		

late Early Cretaceous (Albian) time, and that their remains are infrequent until early Late Cretaceous (Cenomanian stage). In a sample of the Patuxent formation (table 18), Groot and Penny (1960) recorded as much as 21 percent angiosperm pollen, but, because they recognized that some of their data were at variance with those from other Neocomian material, they concluded that the angiosperm-rich material very probably is younger than Neocomian (Groot and Penny, 1960, p. 228). Pollen and spore tallies are not available from European Cenomanian through Coniacian and Senonian strata but floral lists indicate that the first striking increase in dicot species occurs in the Turonian (Krutzsch, 1957).

Comparison of the actual species of the Tuscaloosa and Eutaw-McShan floras with our collections from the Magothy formation (USGS Paleobotany loc. D1322) indicates a marked similarity of the floras; many of the dicot as well as gymnosperm species are in common. In addition, an array of highly distinctive dicot pollen types (for example *Oculopollis* Pflug, *Trudopollis* Pflug, and others) that are known from the Senonian of Europe (Weyland and Greifeld, 1953) occur in the Magothy in profusion, but are essentially rare or lacking in the pre-Selma material. (We report one tentatively identified *Oculopollis* specimen in our youngest sample.)

About half of the 20 forms that Groot and Penny (1960) described from the Potomac group also are represented in the pre-Selma floras. Most of the dicots described by Groot and Penny are of simple, primitive morphology, being mainly of tricolpate and tricolporoid structure.

The most rewarding comparison of the pre-Selma floras is with the material of Krutzsch (1957, 1959) from five Turonian localities in Germany. From a third to a fourth of the dicots in the present material, which have not been previously described from American material, occur in Krutzsch's assemblages of Turonian age. These forms are structurally complex, with gross morphology so different from that of known living dicots that their relations to extant plant families are not at all understood. They include the form genera *Complexipollis, Latipollis, Turonipollis, Sporopollis, Monstruosipollis, Tenerina,* and others.

One dicot species in the flora at hand, cf. *Paliurus rhamnoides* Bolkhovitina, is named from Cenomanian and Turonian strata of central Russia (Bolkhovitina, 1953). Several fern spores named from Lower Cretaceous strata of Russia (for example, *Hymenozonotriletes, Leiotriletes,* and "*Chomotriletes*" (now *Taurocusporites*) *reduncus* of Bolkhovitina, 1953) are present also, but these are known to be wide-ranging Cretaceous forms.

Pollen data from the Raritan and Magothy formations reported by Margaret W. Steeves [1] indicate that a gradual increase in species and numbers of dicot pollen occurs within the Raritan formation. Because of their unique morphologies, many of these dicot forms cannot be assigned to modern families. We have not compared our material directly with Dr. Steeves' flora, but her observation that the upper parts of the Raritan formation are rich in dicotyledonous forms suggests that a careful comparison of the Raritan flora with the present material might be profitable indeed.

The Tuscaloosa and McShan-Eutaw floras, lacking the structurally advanced forms of *Oculopollis* and *Trudopollis*, are pre-Senonian in age, and probably they are older than the Magothy formation in its type area in Maryland. That these floras are younger than the parts of the Potomac group as reported by Groot and Penny (1960) is shown by the relatively higher compositional percentages of dicots, and by the more advanced morphology of the dicot forms represented in the pre-Selma floras. The unpublished data of Steeves concerning the Raritan pollen flora is permissive evidence for the correlation of the upper part of the Raritan formation with the Coker formation, as suggested by Stephenson and others (1942). The similarity of the dicot forms of the pre-Selma Late Cretaceous floras with those of uppermost Cenomanian, Turonian, and Coniacian deposits of Germany (Krutzsch, 1957), supports an early Late Cretaceous age for the floras in the Tuscaloosa group and the McShan and Eutaw formations.

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General Remarks on the Pre-Selma Cretaceous Strata of Western Alabama

By LOUIS C. CONANT

STUDIES OF PRE-SELMA CRETACEOUS CORE SAMPLES FROM THE OUTCROP AREA IN WESTERN ALABAMA

GEOLOGICAL SURVEY BULLETIN 1160-F

CONTENTS

ILLUSTRATION

F. GENERAL REMARKS ON THE PRE-SELMA CRETACEOUS STRATA OF WESTERN ALABAMA

By Louis C. Conant

ABSTRACT

The Vick formation, previously known in only one small outcrop area, has now been identified in the shallow subsurface. Evidence in this series of papers points to a nonmarine environment for the Vick and mainly a shallow and commonly brackish-water marine environment for the overlying Tuscaloosa group and the McShan and Eutaw formations. The distribution of gravel in several formations suggests that the Tennessee and Sequatchie Rivers flowed into the Cahaba and Warrior Rivers during Cretaceous time.

EXTENT AND THICKNESS OF THE VICK FORMATION

The preceding papers have supplied many facts regarding the thickness, petrology, paleontology, and conditions of accumulation of the pre-Selma Cretaceous strata of western Alabama; they have confirmed some theories that evolved during the surface mapping from 1944 to 1948; and they have supplied new information. Here an attempt is made to synthesize some of the newly acquired subsurface information with knowledge previously obtained, some of it not heretofore published.

The Vick formation has been entirely unknown beyond its 1-square-mile outcrop area (fig. 1; Conant, 1946), and its suggested Early Cretaceous age has never been satisfactorily established. The presence in the Webb hole of at least 104 feet of beds that seem to be of the same unit indicates that the Vick is present at least 15 miles downdip, or southwest, from the outcrop area. This supports the original concept that the few outcrops of the Vick formation represent a subsurface unit that is almost completely overlapped by the beds of the Tuscaloosa group. The exact age of the Vick, however, is still not established, though Monroe reports fossil leaves of probable Cretaceous age, and also points out the similarity between some of the core samples and the Lower Cretaceous beds of the deeper subsurface. It is only fair to note, however, that some geologists who have studied the subsurface units in Mississippi and Alabama believe the Vick should be correlated with the "Lower Tuscaloosa" of the subsurface, which is of Late Cretaceous age. A satisfactory resolution of the Vick problem will probably require additional samples from the updip area, where few drill holes have encountered it. Until this is accomplished, the Vick formation is considered to be of Early(?) Cretaceous age.

If the 104 feet of sediments in the Webb hole is the total thickness of the Vick, then the formation has about the same thickness as at the outcrop, where it was estimated to be about 100 feet thick (Conant 1946). This is in marked contrast to thicknesses of 2,500 to 3,000 feet of beds of Jurassic and Early Cretaceous age that are commonly encountered in oil-test wells in Wilcox County, Ala., about 50 miles farther south. If the beds identified as Vick on the outcrop and in the Webb hole are correlative with some of the Lower Cretaceous beds of the deeper subsurface, it is surprising that they are not thicker in the Webb hole, perhaps as much as 500 feet thicker. Monroe believed that the hole bottomed in shale of Paleozoic age, but he also considered the possibility that the lowest rocks encountered in the hole may belong to the Vick formation. It might well be, however, that these lowest rocks are the top of another succession of Jurassic or Lower Cretaceous strata that are a few hundred feet thick.

Geologists who have studied the deeper subsurface sediments in the Coastal Plain of central-western Alabama and central-eastern Mississippi (Applin and Applin, 1947; Eargle, 1948) have shown that the top of Lower Cretaceous rocks is marked by the highest occurrence of red shale containing "pink-lime" nodules and veinlets, and that it represents a major uncomformity. Evidence of this uncomformity should be carefully searched for in cores from updip holes and in water wells as they are being drilled. Carefully prepared structural maps, showing the configuration of both the bottom and top of Lower Cretaceous sediments, and isopach maps of this unit should indicate the areal limits of rocks of Early Cretaceous age in the absence of fossil evidence. Also, the lower part of the Cretaceous rocks in eastern Alabama and western Georgia should be studied and correlated with the Cretaceous rocks in western Alabama to determine age and facies relations.

RELATIONS BETWEEN CRETACEOUS AND PRESENT DRAINAGE SYSTEMS

The 30 feet of coarse gravel at the presumed base of the Vick formation in the Webb hole is especially interesting. During the surface mapping, Monroe, Conant, and Eargle (1946) frequently noted that the sediments in nearly every formational unit were somewhat coarser near the present Warrior River. This prompted them to wonder if the Warrior follows the approximate course of a Cretaceous stream. The presence of so much gravel in the Vick formation in the Webb hole, near the Cahaba River, brings to mind a water well this writer saw drilled at Brent, Ala. (fig. 12), on Jan. 1, 1946. That well, drilled for a municipal water supply in the heart of the town, started on the flood plain of the Cahaba River about 25 feet above an exposed contact across the river between Paleozoic rocks and the overlying Coastal Plain sediments. For 64 feet the drill penetrated clay, sand, and gravel. At that time it was not certain whether the sediments are of Cretaceous age, occupying an ancient stream channel, or are much younger, perhaps filling a Pleistocene valley of the Cahaba River. During Cretaceous time a major stream may have had a course similar to that of the present Cahaba in the Brent area, and was entrenched at least 40 feet in the Paleozoic rocks. If this interpretation is valid, the material encountered in the water well is the basal part of the Coker formation. About 12 miles downstream, in the area of the Webb well, the supposed ancient river deposited similar coarse gravel during Vick time, so at least part of gravel at Brent may belong to the Vick formation instead of the Coker formation.

Any assumption that the Warrior and Cahaba Rivers are descendants of Cretaceous streams has several interesting implications. For one thing, it means that at least part of the major stream pattern has not been greatly changed by tilting, Coastal Plain deposition, or other cause. An understanding of these Cretaceous drainage relations may well explain some aspects of the abnormal course of the Tennessee River. As shown on figure 14, the Cahaba River is directly in line, geographically and structurally, with the Tennessee River above Chattanooga, Tenn. At Chattanooga the Tennessee River turns sharply westward out of a mature valley and follows a deep gorge through a high ridge. In another few miles it joins the Sequatchie River and turns southwestward again, then for 60 miles follows a mature valley on the breached Sequatchie anticline directly toward the headwaters of the Warrior River. At Guntersville, Ala., the Tennessee River again, for no apparent reason, turns abruptly westward, leaving its well-developed valley. Only a low divide separates the headwaters of the present Warrior from the reach of the Tennessee near Guntersville. These relations, which have been observed and discussed by many others (for example, Hayes and Campbell, 1894; Johnson, 1905; Adams, 1928), suggest strongly that at one time the Tennessee River continued southwestward from Chattanooga to the course of the present Cahaba River, and that the Sequatchie River at one time flowed into the Warrior River. This drainage pattern

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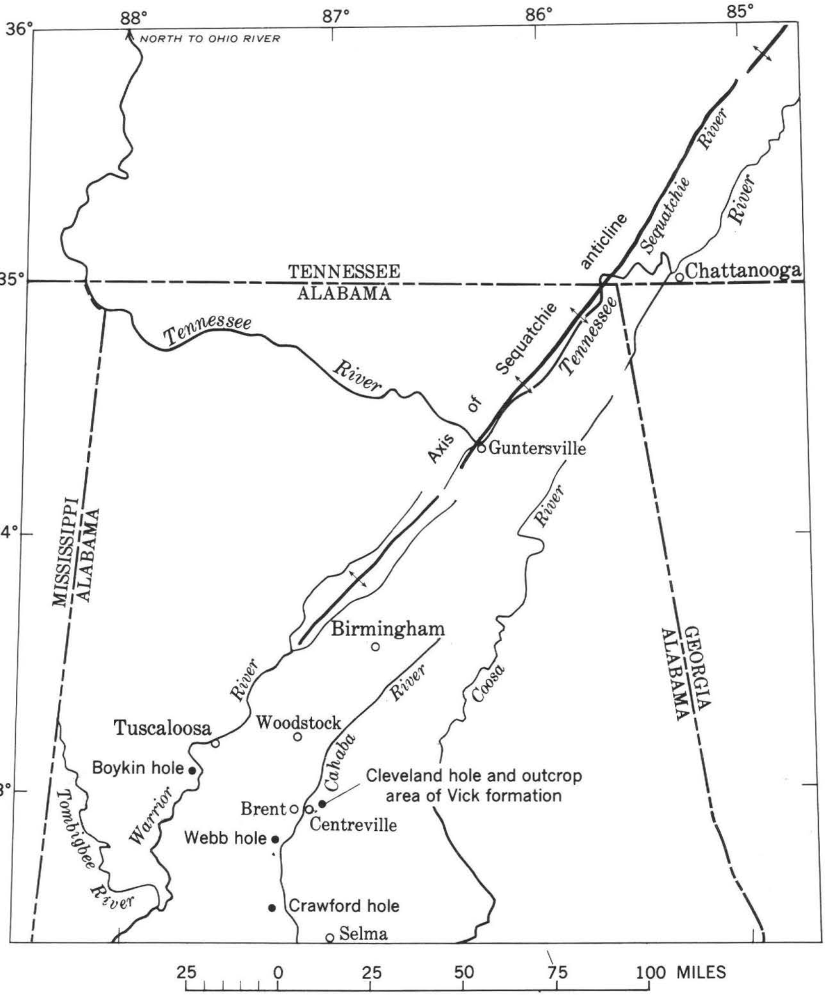

FIGURE 12.—Major drainage lines in north Alabama and part of Tennessee.

during Cretaceous time would explain the greater abundance of gravel in the Cretaceous sediments near the present rivers.

The gravel in the Gordo formation is much coarser in the Webb well than in the Boykin. If the samples from these two wells are typical of their areas—the Warrior and Cahaba Valleys, respectively—then it appears that coarser gravel was being transported and deposited in the Cahaba River Valley than in the Warrior Valley. Likewise, the abundant gravel in the lower 30 feet of the McShan formation in the Crawford hole may have similar significance. In the surface mapping of the beds in the area of the Warrior Valley a little gravel was observed at the base of the McShan, but at many places the gravel may have been overlooked. If the Crawford samples give a true representation of the basal McShan in that area, then it appears that a larger or more active stream was entering the Gulf at that time along the course of the Cahaba River than along the course of the Warrior.

Thus, the suggestions are strong that from some time during the Early Cretaceous until McShan time in the Late Cretaceous an ancestral Cahaba River was transporting more gravel than was the supposed ancestral Warrior River. This, in turn, suggests, but by no means demonstrates, that the Tennessee River may have flowed into the Cahaba, and that the Sequatchie River may have flowed into the Warrior.

Unpublished observations, by this writer, of the Coastal Plain beds where they lap onto the folded Appalachians, particularly near Woodstock, Ala. (fig. 12), indicate that a subdued valley-and-ridge topography existed at the beginning of deposition of Upper Cretaceous sediments. The relief on this surface was on the order of 100 to 200 feet. Rather than indicating a well-developed peneplain with sluggish streams inundated by the sea, this observation suggests that the Cretaceous sea advanced onto an area of moderate relief and moderately active drainage. The coastline probably was strongly indented, and many embayments had brackish water. If this deduction is correct, further detailed work on the Cretaceous sediments in western Alabama should reveal evidence of considerably different environments of deposition within short distances.

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[Italic page numbers indicate major references]

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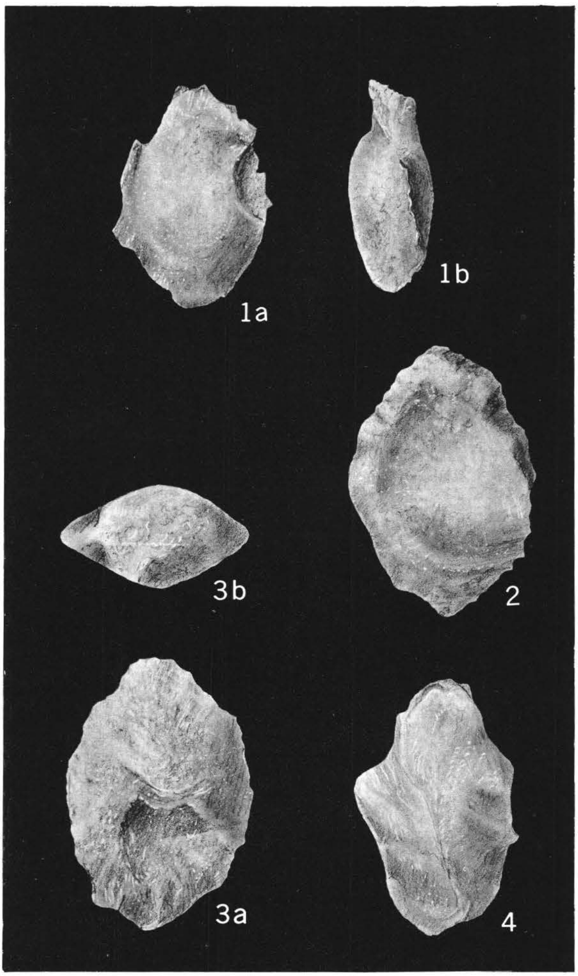
PLATES 2–9

PLATE 2

FIGURES 1–4. *Saccammina eolinensis* Applin, n. sp., × 112 (p. 69). Eoline member of Coker formation. USGS Boykin hole, core 404–436.7 feet, Tuscaloosa County, Ala.

1. Paratype, USNM 626973. *a*, Front view; *b*, side view.
2. Paratype, USNM 626974.
3. Holotype, USNM 626972. *a*, Front view; *b*, top view.
4. Paratype, USNM 626975.



SACCAMMINA EOLINENSIS APPLIN, N. SP.

PLATE 3

[All figures magnified 500 ×]

FIGURES 1, 2. *Cicatricosisporites brevilaesuratus* Couper 1953. Slide D1457–1(2) at 100 × 7.4.

3–7. *Cicatricosisporites dorogensis* R. Potoni° & Gelletich, 1933.
3, 4. Slide D1111–9(5) at 128.8 × 6.9.
5, 6. Slide D1111–9(5) at 104.1 × 8.3.
7. Slide D1111–9(5) at 116.5 × 8.

8, 9. *Cicatricosisporites* sp.? Slide D1457–1(3) at 128.8 × 10.5.

10–13. *Cingulatisporites problematicus* Couper 1958.
10, 11. Slide D1457–1(5) at 113.9 × 11.
12, 13. Slide D1457–1(2) at 105 × 9.9.

14, 15. *Taurocusporites reduncus* (Bolkhovitina) Stover 1962. Slide D1457–1(3) at 129.3 × 20.8.

16, 18–19, 27. 16. Slide D1109–10(5) at 127.8 × 23.1.
18, 19. Slide D1109–10(4) at 105.8 × 5.1.
27. Slide D1109–10(5) at 122 × 23.
Trilites sp.

17. *Trilites veriucatus* Couper 1953. Slide D1457–1(3) at 109.9 × 17.1

20–25. *Triplanosporites sinuosis* Pflug & Thomson 1953.
20. Slide D1109–7(2) at 115.2 × 19.2.
21. Slide D1111–9(5) at 123.5 × 14.5.
22, 23. Slide D1111–9(5) at 121.7 × 12.8.
24, 25. Slide D1109–4(2) at 123 × 9.8.

26. *Concavisporites rugulatus* Pflug 1953. Slide D1109–10(4) at 132 × 4.3.

28–30. *Leiotriletes* cf. *L. subtilis* Bolkhovitina 1953. Slide D1109–4(2) at 122.7 × 12.

31. *Sporites arcifer* Thiergart 1948. Slide D1109–10(1) at 119.3 × 11.9

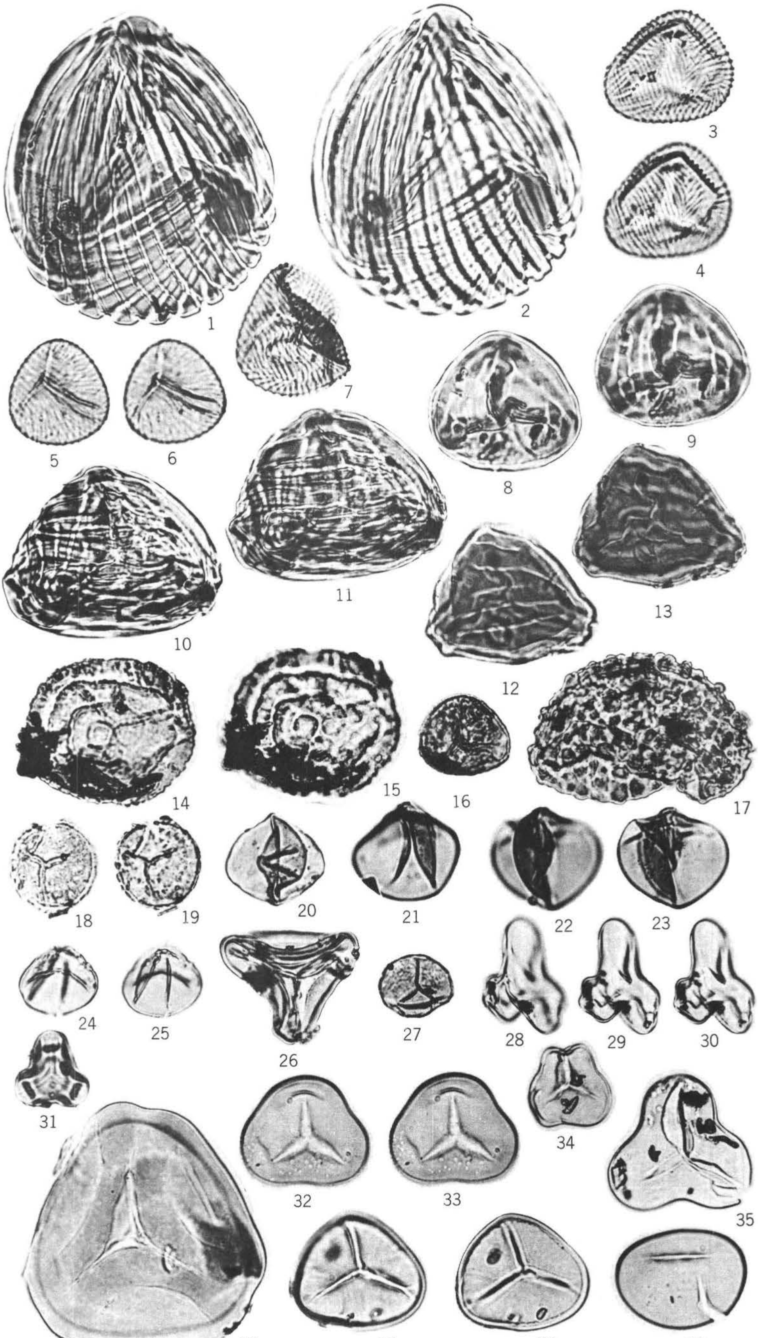
32–34. *Cyathidites mesozoicus* (Thiergart) R. Potoni° 1956.
32, 33. Slide D1111–9(5) at 133.5 × 13.5.
34. Slide D1109–10(5) at 109.9 × 23.

35. *Concavisporites* cf. *C. punctatus* Delcourt & Sprumont 1955. Slide D1109–4(5) at 121.4 × 16.

36. *Torisporis intrastructurius* Krutzsch 1959. Slide D1457–1(2) at 114.9 × 18.1.

37, 38. *Deltoidospora* cf. *D. hallii* Miner 1935. Slide D1109–10(4) at 136.1 × 12.3.

39. *Monolites major* Cookson 1947. Slide D1111–9(5) at 112.4 × 4.9.



FERN AND LOWER PLANT SPORES OF THE TUSCALOOSA GROUP

PLATE 4

[All figures magnified 500 ×]

FIGURES 1. *Sequoiapollenites polyformosus* Thiergart 1938. Slide D1111–9 (5) at 133.5 × 8.2.

2. *Inaperturopollenites* Pflug 1953. Slide D 1109–4(4) at 130.2 × 9.1.

3. *Cingulatisporites* cf. *C. scabratus* Couper 1958. Slide D1111–9 (5) at 120.7 × 4.7.

4–7. *Pityosporites microalatus* (R. Potonié) Thomson & Pflug 1953.
4. Slide D1109–10(4) at 122.5 × 12.2.
5, 6, 7. Slide D1109–10(4) at 132.1 × 16.5.

8–10. *Pinuspollenites labdacus* (R. Potonié) Raatz 1937. Slide D1109–7(4) at 109.2 × 10.1.

11–13. *Podocarpidites* cf. *P. major* Couper 1953. Slide D1109–10(4) at 120.8 × 4.

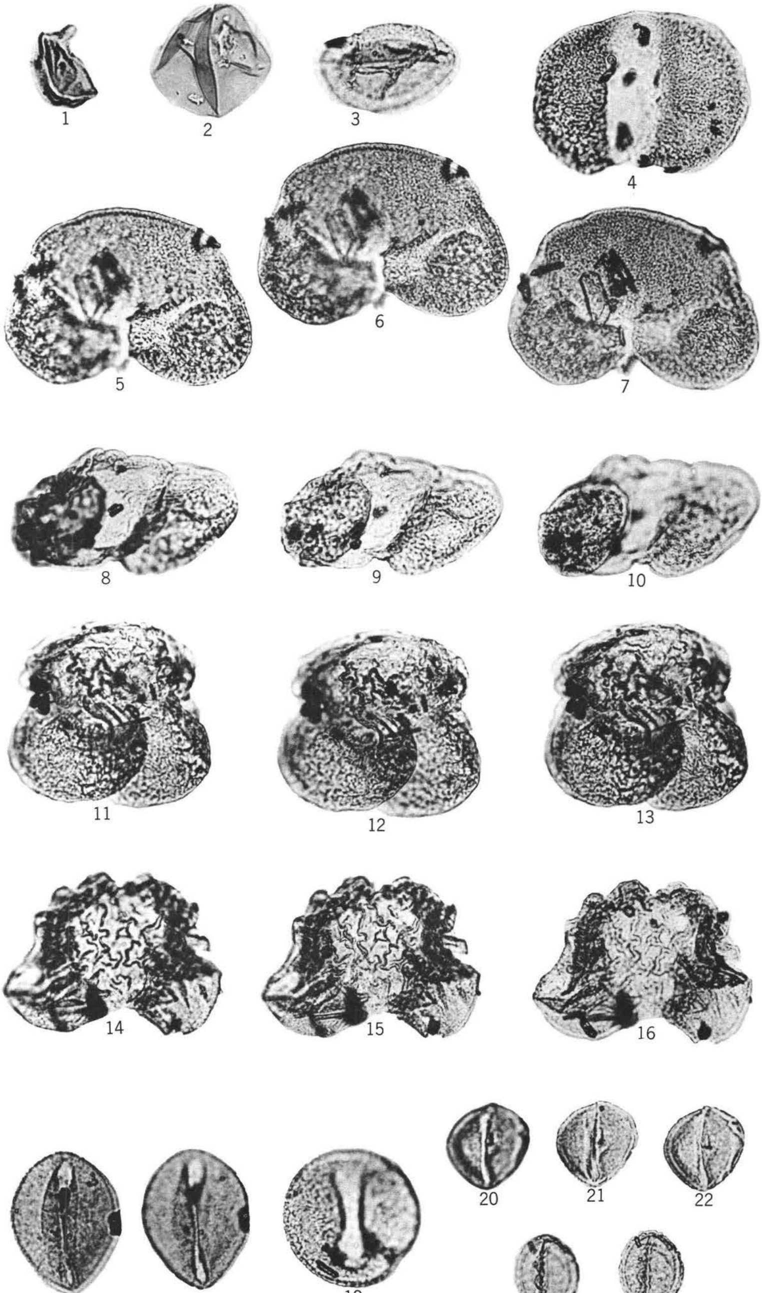
14–16. *Podocarpidites* cf. *P. biformis* Rouse. Slide D1109–10(4) at 105.8 × 5.1.

17–18. *Cycadopites* cf. *C. follicularis* Wilson & Webster 1946. Slide D1111–9(5) at 124.4 × 6.7.

19. *Gynkaletes* cf. *G. retrfloexus* (Luber) Luber 1956. Slide D1109–10(4) at 130.5 ×19.3.

20–22. ?*Gynkaletes* Luber 1955. Slide D1109–10(5) at 129.7 1× 3.

23, 24. *Perinopollenites* cf. *P. elatoides* Couper 1958. Slide D109–4(2) at 122.2 × 18.



GYMNOSPERM POLLEN OF THE TUSCALOOSA GROUP

679-264 O—64——10

PLATE 5

[All figures magnified 500 ×]

FIGURES 1–5. "*Tricolpopollenites*" Thomson & Pflug 1953 (unnamed species).
1, 2. Slide 1109–4(3) at 114.8 × 20.
3. Slide D1111–9(5) at 111.4 × 9.2.
4, 5. Slide D1109–10(5) at 125.8 × 2.9.

6, 7. *Pollenites quisqualis* R. Potonié 1934.
6. Slide D1109–10(5) at 108.9 × 23.
7. Slide D1111–9(5) at 126.2 × 9.3.

8, 9, 18, 19. *Pollenites megagertrudae* R. Potonié 1931.
8, 9. Slide D1109–7(3) at 117.9 × 4.8.
18, 19. Slide D1109–4(3) at 125.9 × 20.

10, 11. *Quercoidites henrici* (R. Potonié 1931) R. Potonié, Thomson & Thiergart 1950. Slide D1109–7(4) at 116.8 × 10.2.

12, 13. *Pollenites grossularius* R. Potonié 1934. Slide D1109–10(5) at 104.2 × 11.7.

14, 15. *Platanoidites* Potonié, Thomson & Thiergart, 1950. Slide D1111–9(5) at 130.5 × 4.9.

16. "*Tricolpopollenites* cf. *T. retiformis*" Thomson & Pflug 1953. Slide D1111–9(5) at 127 × 14.5.

17. "*Tricolpopollenites retiformis*" Thomson & Pflug 1953. Slide D1111–9(5) at 108.8 × 9.1.

20, 21. *Salix discoloripites* Wodehouse 1933. Slide D1111–9(5) at 111.5 × 9.4.

22. cf. *Paliurus rhamnoides* Bolkhovitina 1953. Slide D1109–7 (4) at 129 × 12.4.

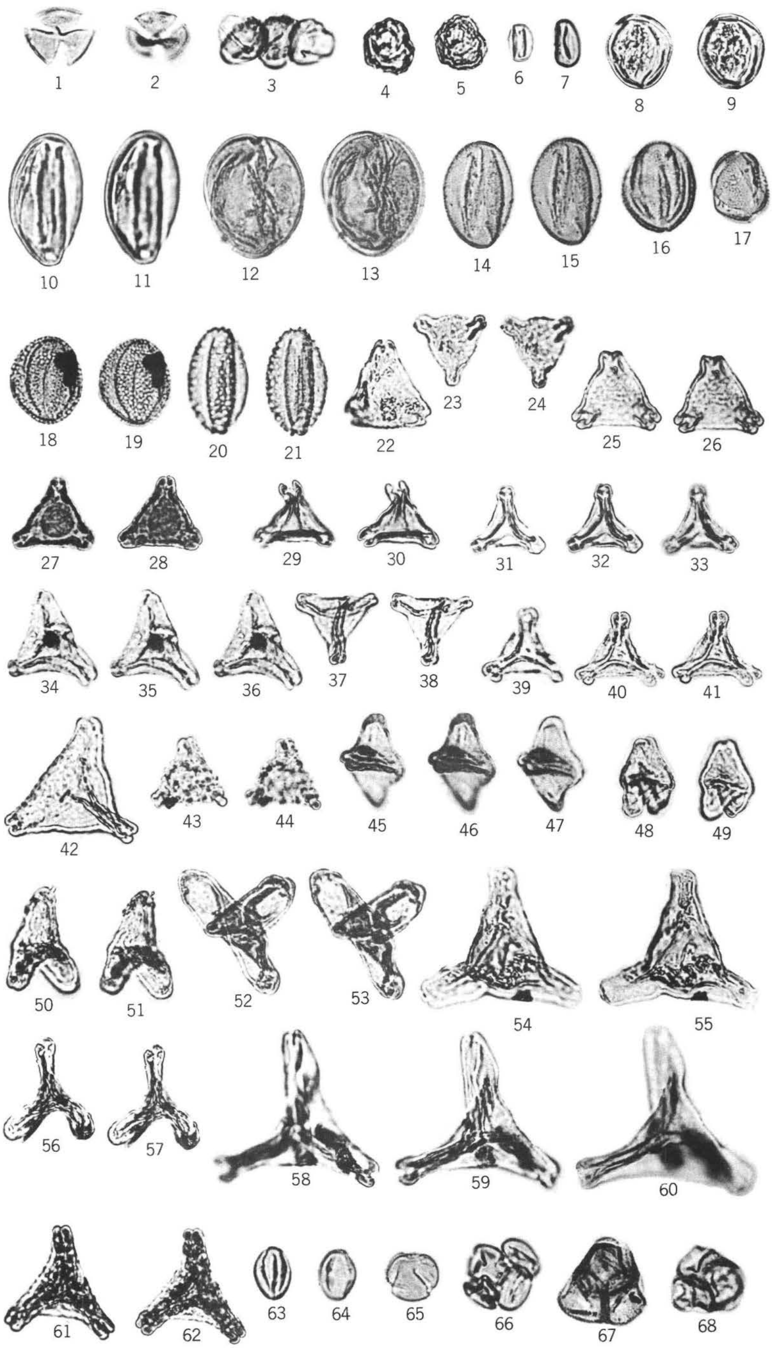
23, 24. *Triorites* cf. *T. edwardsii* Cookson & Pike 1954. Slide D1109–7(4) at 124 × 6.2.

25, 26. *T. edwardsii* Cookson & Pike 1954. Slide D1109–4(3) at 122.4 × 20.

27, 28. *Basopollis orthobasalis* (Pflug) Pflug 1953. Slide D1109–4(2) at 102.2 × 11.8.

29–33. *Sporopollis* Pflug 1953.
29, 30. Slide D1109–4(3) at 103.3 × 17.8.
31, 32, 33. Slide D1109–4(3) at 138.9 × 18.

34–38. *Sporopollis pseudosporites* Pflug 1953.
34, 35, 36. Slide D1109–7(4) at 131.5 × 7.5.
37, 38. Slide D1109–10(5) at 109.9 × 20.



DICOTYLEDONOUS POLLEN OF THE TUSCALOOSA GROUP

PLATE 5—Continued

[All figures magnified 500 ×]

FIGURES 39, 40, 41. *Sporopollis* cf. *S. pseudosporites* Pflug 1953. Slide D1109–7(3) at 111.2 × 17.1.

42. *Complexipollis praeatumescens* Krutzsch 1959. Slide D1457–1(4) at 117.2 × 16.9.

43, 44. *Triorites* cf. *T. edwardsii* Cookson & Pike 1954. Slide D1109–7(2) at 110 × 13.4.

45–47. *Latipollis latis* Krutzsch 1959. Slide D1109–7(4) at 114.4 × 3.8.

48, 49. *Latipollis normis* Krutzsch 1959. Slide D1109–7(3) at 115.1 × 8.

50–53. *Latipollis* cf. *L. latis* Krutzsch 1959.
- 50, 51. Slide D1457–1(5) at 113 × 13.
- 52, 53. Slide D1457–1(2) at 106.4 × 5.

54–60. ?*Latipollis* Krutzsch 1959. Polar view.
- 54, 55. Slide D1109–7(4) at 128.8 × 22.
- 56, 57. Slide D1457–1(3) at 115.2 × 19.
- 58–60. Slide D1109–7(4) at 136 × 18.3.

61, 62. *Nudopollis ornatus* (Pflug) Pflug 1953. Slide D1457–1(2) at 110.5 × 5.3.

63, 64. "*Tricolporopollenites distinctus*" Groot & Penny 1960.
- 63. Slide D1111–9(5) at 105.1 × 13.
- 64. Slide D1111–9(5) at 123.9 × 4.9.

65. "*Tricolpopollenites parvulus*" Groot & Penny 1960. Slide D1111–9(5) at 119.4 × 4.7.

66. Tricolpate pollen undetermined. Slide D1111–9(5) at 103 × 8.5.

67, 68. *Dicotetradites* cf. *D. clavatus* Couper 1953.
- 67. Slide D1111–9(5) at 104.9 × 9.6.
- 68. Slide D1111–9(5) at 103.9 × 9.6.

PLATE 6

[All figures magnified 500 ×]

FIGURES 1, 2. *Plicatella trichacantha* Malawkina 1949. Slide D1456–4(3) at 138.2 × 20.

3, 4. *Cicatricosisporites* sp. R. Potonié & Gelletich 1933. Slide D1456–4(3) at 102.4 × 12.

5. cf. *Schizaeoisporites* sp. R. Potonié 1951. Slide D1110–1(3) at 129.5 × 7.8.

6, 7. *Sporites arcifer* Thiergart 1948. Slide D1110–2(5) at 126.4 × 22.9.

8. *Cingulatisporites* cf. *C. scabratus* Couper 1958. Slide D1456–4(3) at 122.1 × 8.4.

9, 10. cf. *Rugulatisporites* Thomson & Pflug 1953. Slide D1110–2(5) at 127.1 × 22.8.

11, 12. *Densoisporites perinatus* Couper 1948. Slide D1110–3(3) at 117.2 × 5.1.

13–15. *Deltoidospora hallii* Miner 1935.
- 13. Slide D1456–4(1) at 129.5 × 8.9.
- 14, 15. Slide D1110–1(5) at 113.9 × 10.8.

16, 17. *Hymenozonotriletes reticulatus* Bolkhovitina 1953. Slide D1456–4(5) at 101.5 × 19.

18. *Corrugatisporites arcuatus* Weyland & Greifeld 1953. Slide D1456–4(5) at 106.5 × 22.8.

19. *Cingulatisporites dubius* Couper 1958. Slide D1456–4(3) at 119 × 17.9.

20. Araucariaceae? Slide D1456–4(1) at 126.9 × 18.

21, 22. Spores undetermined.
- 21. Slide D1456–5(1) at 127.2 × 10.3.
- 22. Slide D1456–4(5) at 114.8 × 23.

23, 24. *Ephedra* sp. Tournefort ex Linnaeus 1737. Slide D1110–2(5) at 122.1 × 14.7.

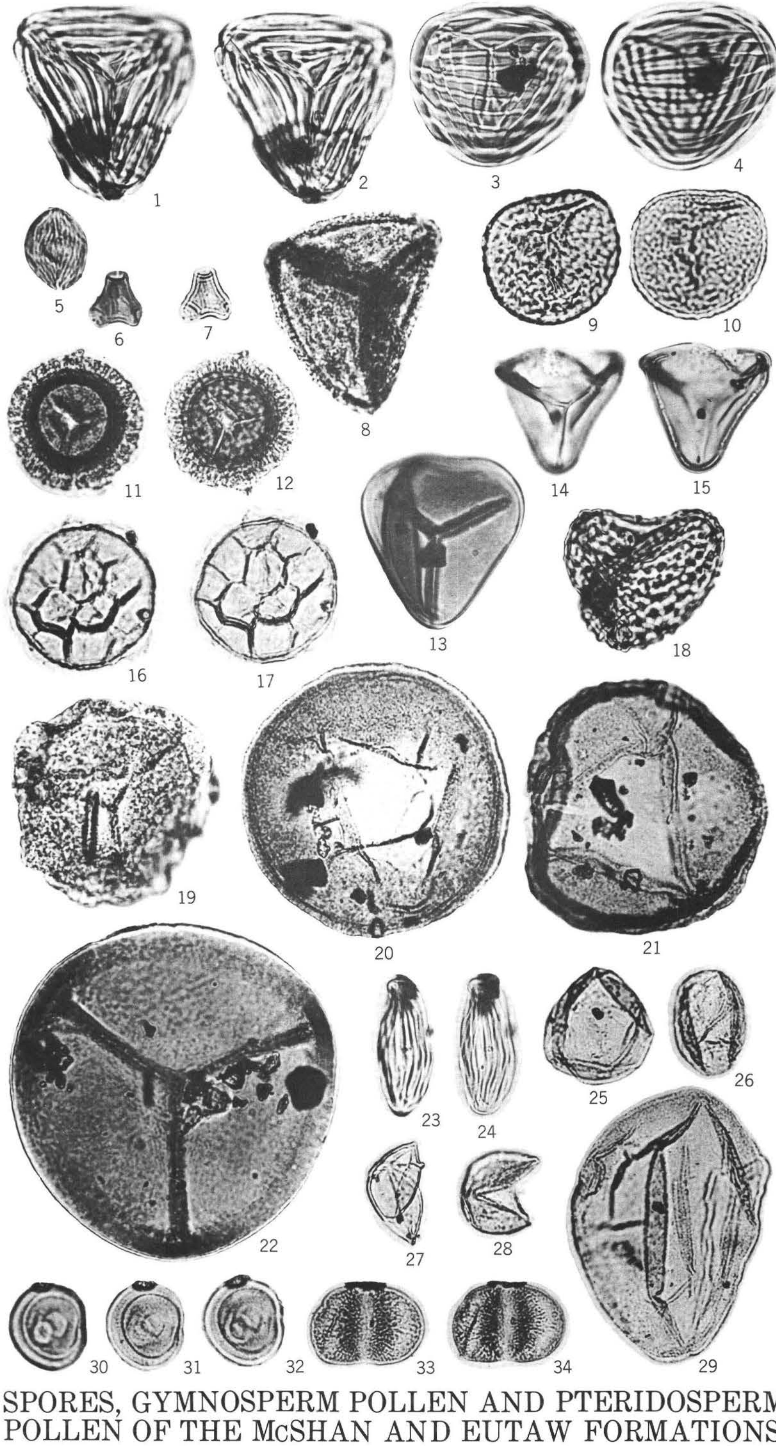
25, 26. *Inaperturopollenites dubius* (R. Potonié & Venitz) Thomson & Pflug 1953.
- 25. Slide D1456–4(3) at 134.3 × 17.2.
- 26. Slide D1456–4(3) at 131.2 × 11.

27, 28. *Taxodiaepollenites hiatus* (R. Potonié) Thiergart 1940.
- 27. Slide D1110–3(5) at 123.9 × 22.1.
- 28. Slide D1456–4(3) at 130.5 × 8.9.

29. *Araucariacites australis* Cookson 1947. Slide D1456–4(3) at 123 × 19.

30–32. *Classopollis classoides* Pflug 1953. Slide D1456–5(1) at 123.5 × 14.

33–34. *Caytonipollenites pallidus* (Reissinger) Couper 1958. Slide D1110–1(3) at 131.7 × 5.2.



SPORES, GYMNOSPERM POLLEN AND PTERIDOSPERM POLLEN OF THE McSHAN AND EUTAW FORMATIONS

PLATE 7

[All figures magnified at 500 × except figure 7]

FIGURES 1, 2. *Dacrycarpites australiensis* Cookson & Pike 1953. Slide D1456–4(3) at 141.1 × 3.3.

3. *Parvisaccites radiatus* Couper 1958. Slide D1456–4(3) at 119.2 × 13.4.

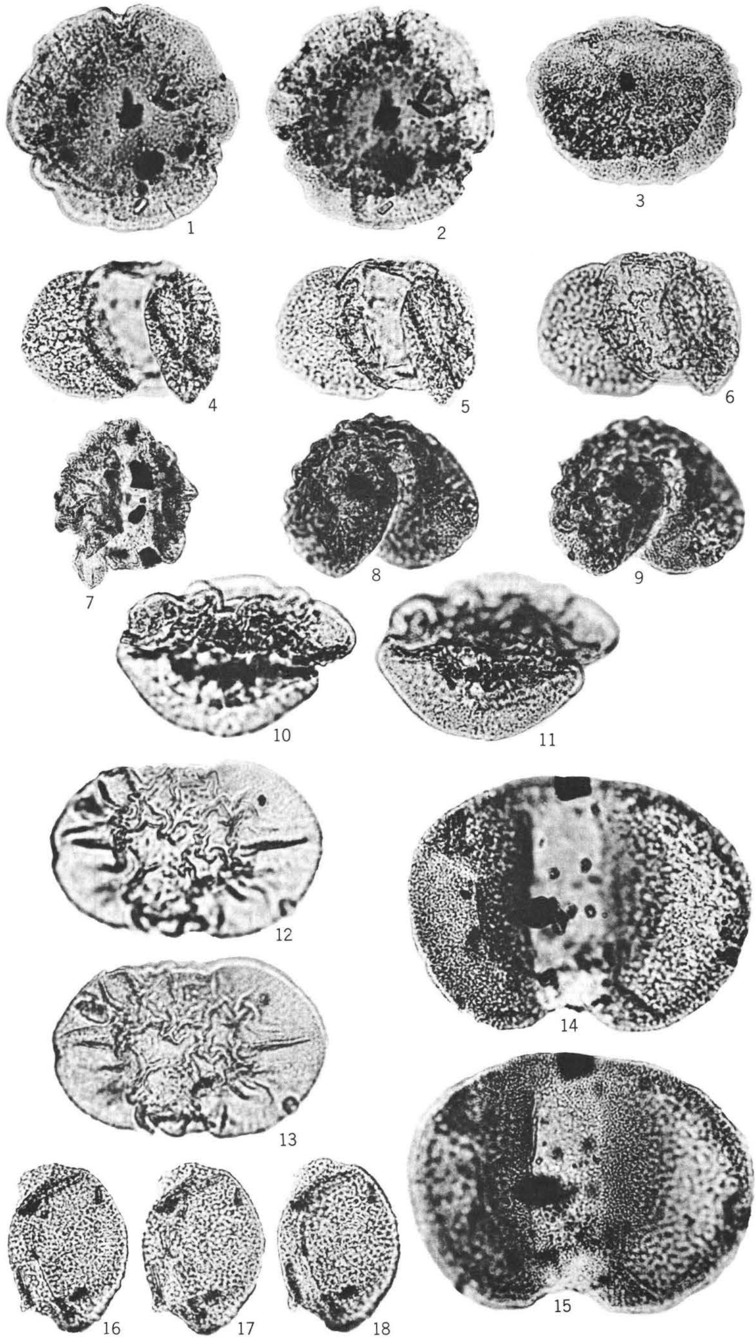
4–6. *Podocarpidites* cf. *P. major* Couper 1953. Slide D1110–3(5) ta 113.6 × 11.8.

7. cf. *Podocarpus* (L'Heritier) Persoon 1807. (× 375). Slide D1456–6(1) at 123.3 × 11.9.

8–13. *Podocarpidites* cf. *P. biformis* Rouse 1957.
- 8, 9. Slide D1110–1(3) at 124.2 × 9.9.
- 10, 11. Slide D1456–4(3) at 141.2 × 10.2.
- 12, 13. Slide D1110–1(6) at 105.3 × 1.8.

14–15. *Abietineaepollenites microreticulatus* Groot & Penny 1960. Slide D1110–1(3) at 134.9 × 9.2.

16–18. *Liliacidites intermedius* Couper 1953. Slide D1110–2(6) at 110.1 × 4.4.



GYMNOSPERM AND MONOCOTYLEDONOUS POLLEN OF THE McSHAN AND EUTAW FORMATIONS

PLATE 8

[All figures magnified 500 ×]

FIGURE 1. *"Tricolpopollenites* cf. *T. retiformis"* Thomson & Pflug 1953. Slide D1110–1(6) at 132.1 × 9.8.

2, 3. *Platanoidites gertrudae* (R. Potonié 1931) R. Potonié, Thomson & Thiergart, 1950. Slide D1110–1(6) at 117.7 × 12.

4, 5. *Quercoidites microhenrici* (R. Potonié 1931) R. Potonié, Thomson & Thiergart 1950. Slide D1456–6(2) at 139.2 × 9.

6, 7. *Quercoidites microhenrici* subsp. *intragranulatus* Thomson & Pflug 1953. Slide D1456–4(1) at 123 × 9.8.

8. *"Tricolpopollenites retiformis"* Thomson & Pflug 1953. Slide D1110–1(3) at 130.8 × 4.1.

9–13. *Triatriopollenites rurensis* Pflug & Thomson 1953.
- 9. Slide D1456–4(7) at 128.3 × 14.1.
- 10. Slide D1110–1(6) at 128.5 × 20.2.
- 11. Slide D1456–4(3) at 136.3 × 12.4.
- 12, 13. Slide D1110–1(4) at 130 × 10.

14, 15. *Triatriopollenites* cf. *T. concavus* Thomson & Pflug 1953.
- 14. Slide D1110–3(4) at 106.4 × 6.4.
- 15. Slide D1110–3(4) at 131.6 × 16.1.

16, 17. cf. *Minorpollis minimus* Krutzsch 1959. Slide D1456–4(1) at 123.5 × 10.7.

18–20. *Trivestibulopollenites betuloides* Thomson & Pflug 1953. Slide D1110–3(5) at 131 × 2.8.

21–23. *Sporopollis* Pflug 1953.
- 21, 22. Slide D1456–4(3) at 131.3 × 8.
- 23. Slide D1456–4(5) at 137 × 5.

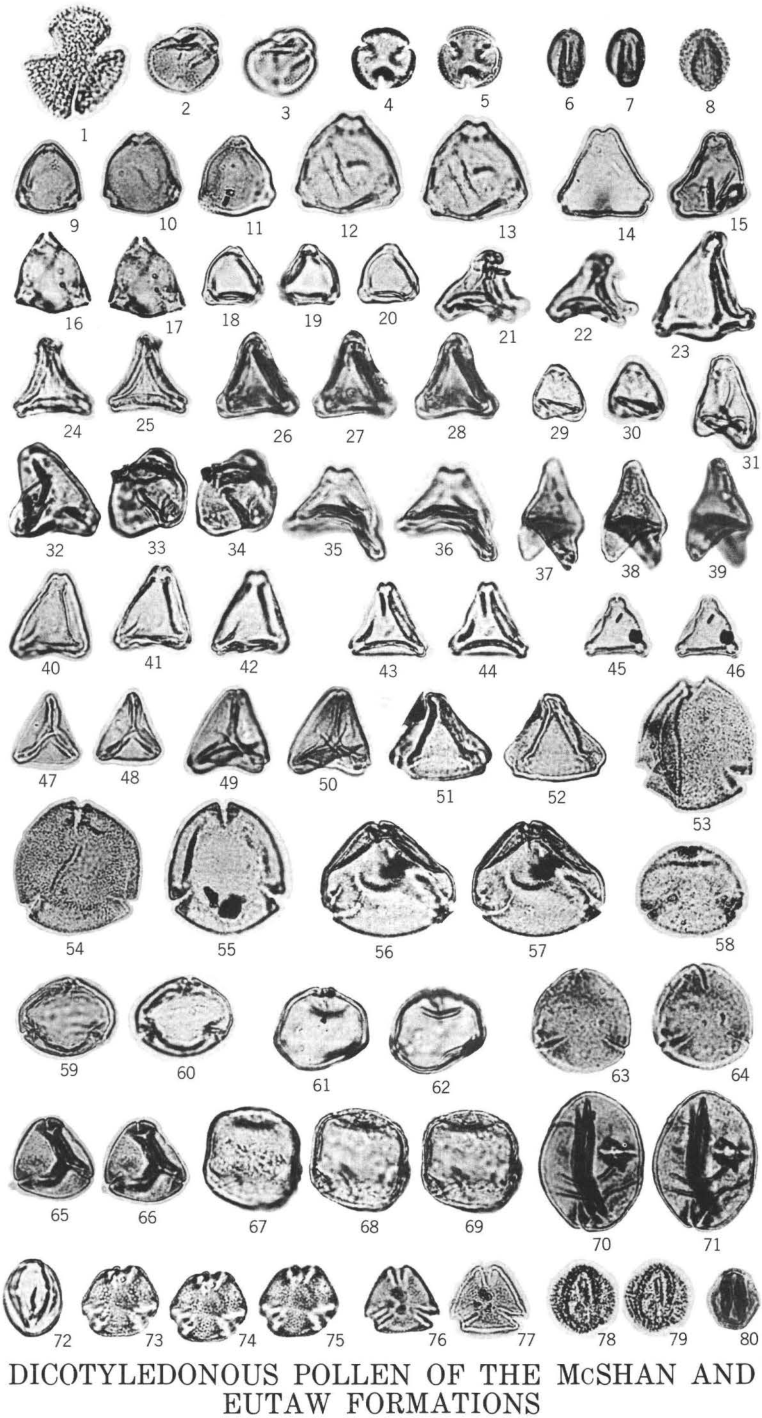
24, 25. cf. *Paliurus rhamnoides* Bolkhovitina 1953. Slide D1110–2(5) at 103.4 × 16.2.

26–28. *Conclavipollis anulopyramis* Pflug 1953. Slide D1456–5(1) at 110.8 × 17.

29, 30. *Latipollis subtils* Krutzsch 1959. Slide D1110–3(3) at 138.7 × 9.1.

31–34. *Latipollis* Krutzsch 1959.
- 31. Slide D1110–3(4) at 114.5 × 6.4.
- 32. Slide D1456–4(3) at 136.2 × 11.1.
- 33, 34. Slide D1456–4(3) at 120 × 10.

35, 36. *Triatriopollenites* Pflug 1953. Slide D1456–6(2) at 128 × 3.6.



DICOTYLEDONOUS POLLEN OF THE McSHAN AND EUTAW FORMATIONS

PLATE 8—Continued

FIGURE 37, 38, 39. *Latipollis latis* Krutzsch 1959. Slide D1456–4(1) at 126 × 9.4.

40–46. *Sporopollis pseudosporites* Pflug 1953.
- 40, 41, 42. Slide D1110–3(4) at 103×4.1.
- 43, 44. Slide D1110–3(5) at 107.8 × 9.5.
- 45, 46. Slide D1110–3(5) at 134.5 × 22.

47, 48. *Sporopollis laqueaeformis* Weyland & Greifeld 1953. Slide D1110–3(4) at 127.4 × 4.0.

49, 50. *Sporopollis* Pflug 1953. Slide D1456–4(1) at 110.8 × 6.2.

51, 52. *Tenerina tenera* Krutzsch 1957. Slide D1110–1(4) at 117.2 × 9.4.

53–58. *Porocolpopollenites* Thomson & Pflug 1953 (some unnamed species).
- 53. Slide D1456–4(3) at 124.3 × 12.2.
- 54. Slide D1110–1(6) at 127 × 17.9.
- 55. Slide D1456–4(8) at 101.4 × 16.8.
- 56, 57. Slide D1456–4(5) at 98.2 × 20.2.
- 58. Slide D1456–4(8) at 116.3 × 11.9.

59, 60. *Porocolpopollenites orbiformis* Thomson & Pflug 1953. Slide D1110–2(5) at 111.3 × 13.

61–64, 67–71. *Porocolpopollenites* Thomson & Pflug 1953 (some unnamed species).
- 61, 62. Slide D1456–5(1) at 126.5 × 16.
- 63, 64. Slide D1110–1(3) at 117.4 × 19.9.
- 67, 68, 69. Slide D1110–3(4) at 104 × 15.7.
- 70, 71. Slide D1456–4(1) at 129.8 × 6.3.

65, 66. *Symplocoipollenites vestibulum* (R. Potonié 1931) R. Potonié 1951. Slide D1456–4(7) at 121.5 × 14.3.

72. "*Tricolporopollenites* cf. *T. eschweilerensis*" Thomson & Pflug 1953. Slide D1110–2(3) at 128.6 × 13.7.

73–77. *Pollenites kruschi* (R. Potonié) "asp. *pseudolaesus*" (R. Potonié) Thomson & Pflug 1953.
- 73, 74, 75. Slide D1456–4(5) at 133.9 × 18.8.
- 76, 77. Slide D1110–2(5) at 137.8 × 20.1.

78, 79. "*Tricolporpollenites*"Thomson & Pflug 1953 (unnamed species with bacculae). Slide D1110–1(5) at 111.3 × 3.3.

80. "*Tricolporopollenites*" Thomson & Pflug 1953 (unnamed species). Slide D1110–1(3) at 134.4 × 9.9.

PLATE 9

[All figures magnified 500× except figure 4]

FIGURE 1. Fungal teleutospore of the Basidiomycetae. Slide D1456–4(5) at 128.5 × 7.

2, 3. cf. *Tetraporina* Naumova 1950. Slide D1456–4(3) at 131.1 × 12.2.

4. Microforaminifer (× 250). Slide D1110–1(3) at 131.8 × 6.0.

5. *Schizosporis reticulatus* Cookson & Dettmann 1959. Slide D1456–5 (1) at 122.2 × 19.9.

6. *Pterospermopsis ginginensis* Deflandre & Cookson 1955. Slide D1456–4(3) at 132.5 × 5.2.

7. *Hystrichosphaeridium* cf. *H. multifurcatum* Deflandre 1937. Slide D1110–1(3) at 125.3 × 5.4.

8. *Micrhystridium pavimentum* Deflandre 1945. Slide D1456–4(3) at 129 × 22.9.

9. *Sporites echinosporus* R. Potonié 1934. Slide D1456–6(4) at 129 × 21.

10. *Micrhystridium piliferum* Deflandre 1936. Slide D1110–2(5) at 108 × 7.3.

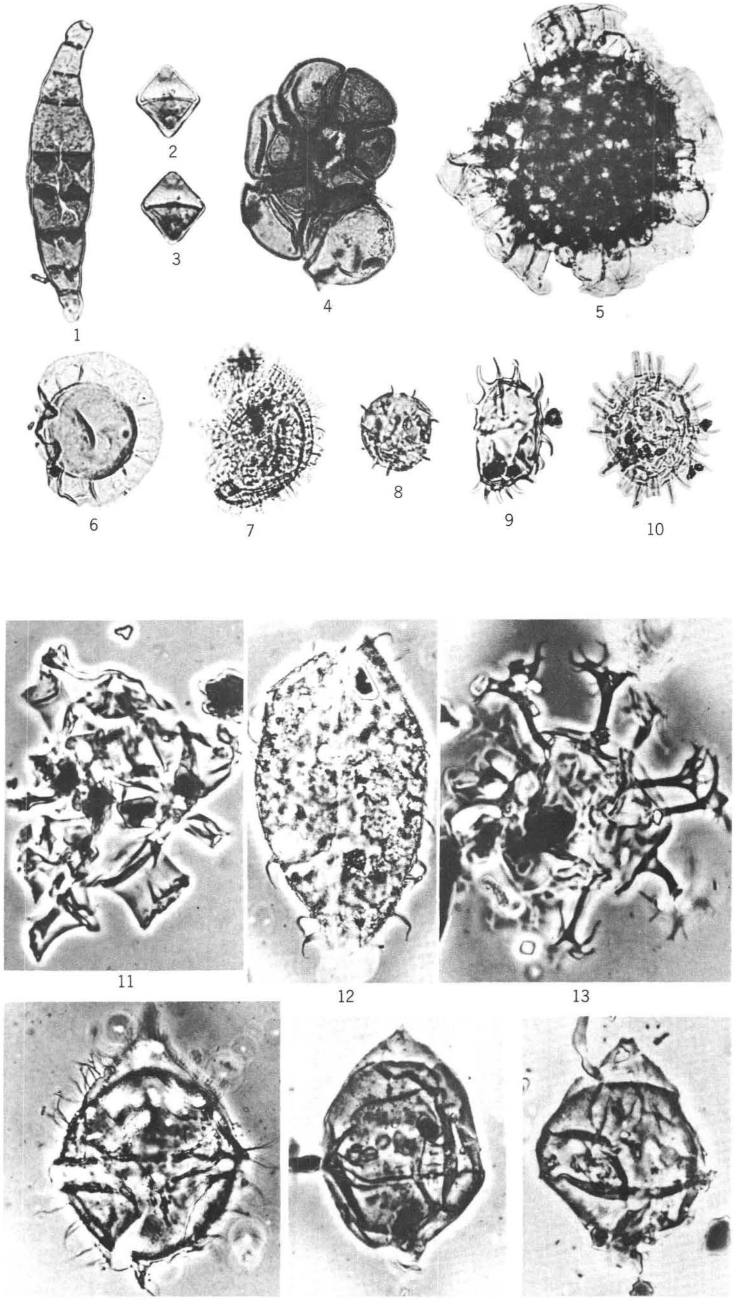
11. *Hystrichosphaeridium truncigerum* Deflandre 1937. Slide D1110–2 (5) at 106.2 × 14.

12. *Hystrichosphaeridium xanthiopyxides* var. *parvispinum* Deflandre 1937. Slide D1110–1(6) at 125.1 × 20.2.

13. *Hystrichosphaeridium pulcherrimum* Deflandre & Cookson 1955. Slide D1110–1(6) at 107 × 11.6.

14. *Paleohystrichosphora infusorioides* Deflandre 1955. Slide D1110–3 (1) at 129.9 × 18.9.

15, 16. *Deflandrea bakeri* forma *pellucida* Deflandre & Cookson 1955.
- 15. Slide D1110–1(3) at 132.2 × 16.4.
- 16. Slide D1110–1(3) at 134 × 9.



MICROFORAMINIFERS, DINOFLAGELLATE ALGAE AND HYSTRICHOSPHAERIDEAE OF THE McSHAN AND EUTAW FORMATIONS