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DEPARTMENT OF CONSERVATION

DIVISION OF GEOLOGY

REPORT OF INVESTIGATIONS No. 6

CRETACEOUS, PALEOCENE, AND LOWER EOCENE GEOLOGIC HISTORY OF THE NORTHERN MISSISSIPPI EMBAYMENT

By

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By Richard G. Stearns

Abstract

Subsurface data show that in the northern Mississippi Embayment Cretaceous, Paleocene, and lower Eocene deposition occurred in a single sedimentary cycle.

The cycle began with Cretaceous deposition of nonmarine Tuscaloosa gravel, restricted in area. Marine advance and depositional limits reached a maximum in the Paleocene with the deposition of Porters Creek Clay, which once generally extended beyond the embayment limits. Deposition ended in the early Eocene with nonmarine Wilcox beds, now restricted to the subsurface near the embayment axis. Uplift and erosion resulting in marked truncation followed to complete the cycle.

Overlying middle Eocene Claiborne Group beds overlap all the lower Eocene Wilcox Group and part of the Paleocene Midway Group, all around the northern end of the embayment north of the Tennessee-Mississippi border.

Within the cycle five advances and regressions of the sea, which are illustrated by stratigraphic cross sections and a series of paleogeographic maps, are recorded.

The pattern of contemporary subsidence of the embayment is shown on four isopach maps, which indicate that the present trough shape of the embayment appeared during latest Cretaceous and persisted through the Paleocene and early Eocene.

Subsidence of the embayment trough strongly influenced geography from late Paleocene through early Eocene. During this time the sea occupied bays that followed the embayment axis. A delta was prominent in western Kentucky and northwestern Tennessee during Late Cretaceous and late Paleocene.

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INTRODUCTION

General Statement

The Mississippi Embayment is an extension of the Coastal Plain and reaches into the interior as far north as Cairo, Illinois. Almost complete preservation of the original extent of many stratigraphic units from Cretaceous through Eocene makes this region of considerable interest in both stratigraphy and historical geology.

Lateral variations from marine to nonmarine beds here furnish a rare opportunity to investigate the shifting patterns of paleogeography. Lateral variations in thickness also furnish the opportunity to investigate the shifting tectonic patterns of the embayment as it assumed the form reflected in its present area.

Present Investigation

This investigation is a part of Tennessee's ground-water program carried out in cooperation with the United States Geological Survey. Western Tennessee, which is part of the Mississippi Embayment, is the area where the largest potential supplies of ground water exist. Inasmuch as drill holes are scarce in western Tennessee, it was believed desirable to gather data from other States of that province in order to understand better the distribution of aquifers in Tennessee.

Many stratigraphic units here are for the most part restricted to the subsurface, and some are buried. Information used in constructing the maps contained in this report is almost exclusively from bore holes (Fig. 3). Unfortunately, poor drilling records and lack of sampling render many bore holes useless. The only consistent record throughout the area is electric logs of wells, many of which have no other stratigraphic information. Such logs are used for the correlation and lithologic interpretation of this report.

Previous Investigations

Although many workers have investigated sediments of this area, few have worked primarily with the subsurface, and still fewer with electric logs.

Brown (1947) correlated many wells in Mississippi by both samples and electric logs. The present work in Mississippi is based on his publication. His correlations in Bolivar County, Mississippi, are the standard for Eocene correlations used herein.

Renfroe (1949) correlated many wells in eastern Arkansas, and his correlations are in agreement with those of Brown. The electric and lithologic log of the Cockburn-Robinson No. 1 well (Table 1) serves as a reference section for correlation in eastern Arkansas.

The stratigraphic cross section of West Tennessee by Schneider and Blankenship (1950) was the first published electric-log correlation for that part of the State. The U. S. Geological Survey–Tennessee Division of Geology test wells in that section are heavily relied upon for the relationship between lithology and electric-log patterns.

Caplan (1954) described the subsurface geology of northwest Arkansas with particular reference to oil and gas possibilities. Stratigraphic units, particularly in the Cretaceous,

TABLE 1.—ELECTRIC-LOG CORRELATIONS
(Depths in feet)

ARKANSAS

No.	Well name and number	Location	Total depth	Elev. (msl)	Base "500-ft. sand"	Base "1,400-ft. sand"	Top Cretaceous	"X Point"	Top Paleozoic
1	Stone-Hopkins 1	28-16N-2E	744	258					669
2	Crenshaw-Goldman 1-A	6-15N-2E	726	255			422		
4	Ramsey-Singer 1	35- 9N-4E	3512	210	1020	1400	2170		2880
5	Cross-Rhodes 1	20- 8N-2E	2500	220	750	1060	1820		
6	Davis-DeMange 1	22- 8N-7E	5022	224	1005	1583	2400		3190
7	Stanley-Danner 1	18- 8N-9E	3352	225		1620	2525		3305
8	Cross-Newman 1	28- 7N-1E	2070	215	875	1060	1870		
9	Cross-Surrat 1	33- 7N-2E	2548	220	960	1275	2060		
10	Irene-Nevils 1	14- 6N-6W	1323	200	85		562		660
11	Irene-Self 1	28- 6N-5W	2170	210	95		832		988
12	Taubman-Peel 1	26- 6N-3W	1600	200	485	590	1395		1575
13	Manning-Park 1	4- 6N-5E	4452	205			2450		3275
14	Ramsey-Sanderson 1	15- 6N-7E	3503	212	1150	1720	2585	3345	3500
15	Tatum-Miller 2	7- 5N-2W	1744	215	745	875	1681		
16	Tatum-Nathan 1	18- 5N-2W	1785	197	688	880	1618		
17	Manning-Gregg 1	20- 5N-5E	3988	205	1240	1620	2525	3303	3390
19	Barnwell-Thombaugh 1	8- 4N-1W	2672	214	1070	1319	2122	2625	2670
20	Petroleum-Caples 1	17- 4N-1W	2725	214	1100	1380	2194		2725
21	Hargraves-Peters 1	21- 4N-1W	2505	205	1105	1380	2230		
22	Wier-Lynn 1	7- 4N-1E	2792	205	1155	1360	2262		
23	Martin-Stewart 1	3- 3N-5W	3240	210	640	740	1590		1876
24	Sohio-Gann 1	22- 3N-3W	3164	170	1030	1240	2120	2645	2645
25	Silver-Chambers 1	17- 2N-7W	1980	227	600		1340		1465
26	Cockburn-Robinson 1	14- 2N-1E	3643	203	1432	1840	2750	3415	3545
27	Victory-Clayton 1	10- 1N-5W	3383	220	1185	1465	2230		
28	Curtis-West-Day 1	1- 1N-5W	2876	222	1170	1449	2230		2703
29	Ryan-McCollum 1	24- 2S-5W	3731	215	1660	2065	2905		3530
30	Rambo-Nivens 1	16- 3S-8W	3102	206	1620	1860	2670		3075
31	Flesh-Rosencrantz 1	2- 3S-6W	3633	219	1740	2090	2940		3463
32	McAlester Co. -Howe 1	27- 3S-2E	4574	171	1605	2350	3455	4280	4459
33	Youngblood-West 1	24- 4S-2W	4183	185	1865	2390	3446	4160	4183
34	McAlester Co. -Welch 1	24- 4S-2E	4953	174	1705	2425	3503	4338	4522
35	Fohs-Miller 1	33- 5S-4W	4558	190	2115	2760	3690	4402	4518
36	Blackwell-Fox 1	23- 5S-3W	4372	195	2050	2585	3565	4275	4335
37	Columbia-Victoria 1	34- 8S-3W	4915	174	2150	2950	3895	4700	4875
38	Allaum-Moore 1	34- 9S-10W	3821	268	1925	2350	3250		
39	Lion-Holderfield 1	21-10S-9W	4606	223	1945	2340	3280		3920
40	Lion-Clinton 1	10-10S-8W	4204	262	2095	2590	3558		4200
41	Lion-Reef 1	25-11S-9W	4248	185	1970	2410	3292		4000
42	Magnolia-Sturgis 1	30- 9N-3W	5994	217					495
43	States-LaFerney 1	25- 6N-8W	4821	230					330
44	Layton-Layton 1	17- 2N-7W	1411	295	590		1335		
45	Continental-Dewitt 1	32- 5S- 2W	4520	195	2040	2710	3675	4395	4510
46	Wadley-Brown 1	33- 5S -3W	4543	197	2115	2770	3695	4400	4540
47	Continental-Cunningham 1	3- 6S -2W	4607	196	2020	2635	3690	4422	4607
48	Martin-Parnell 1	25- 6S-15W	2125	234	1270		1640		2010
49	Seaboard-Anderson-Tully 1	30-10S-1E	4819	153	2115	2800	3745	4510	4795
50	Delta-Grief 1	32-10S-1W	5295		2155	2855	3715	4490	4855
51	Seaboard-Core Hole B	14-10N-2E	2114	239	545	800	1540		2090
52	Seaboard-Core Hole A	19-10N-2E	1983	235	455	700	1430		1980
53	Seaboard-Core Hole C	8- 9N-2E	2125	232	600	850	1570		2120
54	Seaboard-Core Hole F	11- 2N-2W	3153	182	1245	1530	2450		3090
55	Seaboard-Core Hole J	28- 1S -7W	2590	200	1260	1520	2290		2530
56	Seaboard-Core Hole K	11- 3S -4W	3916	200	1770	2240	3200		3915

KENTUCKY

No.	Well name and number	Location	Total depth	Elev. (msl)	Base "500-ft. sand"	Base "1,400-ft. sand"	Top Cretaceous	"X Point"	Top Paleozoic
3a	Roof 1	McCracken Co.		475	176				
3b	Reidland Water Dist.	"		400			100		
3c	West Paducah School	"		355			150		340

TABLE 1—*Continued*

MISSISSIPPI

No.	Well name and number	Location	Total depth	Elev. (msl)	Base "500-ft."sand	Base "1,400-ft." sand	Top Cretaceous	"X Point"	Top Paleozoic
1	Union-Withers 1	18- 2S- 9W	4884	220	1030	1708	2500	3335	3540
2	Johnson-Pritchard 1	28- 4S- 7W	2955	235	775	1245	1950	2719	2800
3	Cullet-Nabors 1	36- 7S- 3E	1416	425				530	1102
4	Richardson-Robbins 1	3- 8S- 1E	3479	400			420	930	1732
7	Blevins-Water 5	16- 9S- 8W	2457		620	1158	2010		
8	Adams-Lewellen 1	9-10S- 1W	4006	569			625±	1200±	1785
9	Guiberson-Lyon 1	3-10S- 3E	2233	500				565	1255
11	Grasty-Lumber Co. 1	7-10S-10E	3538	349					362
13	Onyette-Austin 1	1-11S- 6W	2134	250		622	1385	1960	
14	Ellison-Neely 1	28-11S- 5E	4271	315					945
15	Michael-Temple 1	8-11S- 7E	1762	341					550
20	Honolulu-Davis 1	22-12S- 1E	3325	315			320	815	1700
21	Union-Dinsmore 1	28-12S- 3E	4447	422				535	1420
22	Sinclair-Epperson 1	13-12S - 3E	2962	429				430	1330
24	Davidor-Gladney 1	24-12S- 4E	2656	360				185	1110
26	Hutchings-Stone 1	29-12S- 5E	2507	378				150	1060
27	Carter-Abernathy 1	29-12S- 5E	3491	350				125	1103
28	Carter-Crane 1	31-13S- 1E	9237	392			520	992	2255
29	Carter-Fowler 1	22-13S- 2E	4906	327			139	600	1800
30	Magnolia-Pierce 1	22-13S- 7E	8003	309					1055
31	Magnolia-Snow 1	27-13S- 7E	4769						740
36	Killam-Chennault 1	14-14S- 2E	2787	300				602	1875
37	Carter-Pulliam 1	24-14S- 4E	7029	304				160	1325
38	Carter-Baskin 1	19-14S- 5E	5186	320				135	1310
39	Shell-Gelling 1	34-14S- 6E	5022	328					1122
41	Shell-Holmes A-1	25-14S- 6E	3595	271					1125
44	Union-Henderson 1	22-15S- 4E	10557	437				315	1750
45	Union-Lenoir 1	29-15S- 6E	5826	250					1220
47	Union-Sanders 1	22-15S- 6E	6059	288					1120
50	Union-Rye 1	27-15S- 6E	5529	297					1085
53	Union-Watson 1	31-15S- 7E	6417	278					985
55	Atlantic-Myers 1	31-15S-18W	5751	215					630
57	Carter-McFadden 1	36-16S- 5E	9580	205					1430
59	Henson-Green 1	10-17N- 9E	4517	387			1220		4275
60	Hunt-Phillips 1	33-18N - 3E	4211		990±	1630±	2610		
61	Hunt-Winters 1	28-18N- 3E	5955		1000±	1600±	2580		5950
62	Henson-Stafford	33-18N- 9E	4387	379			1190		4245
63	Gulf-Parker 1	23-19N- 7E	5086	394			1450	1950	4430
64	Allen-Nowell 1	2-19N-13E	4975	268				370	2310
65	Atlantic-Dunning 1	12-19N-16E	9243	184				260	1290
66	Exchange-Wildwood 1	6-20N- 1E	5330		1030	1625	2530	3210	5260
68	Gulf-Cason 1	2-21N- 1W	5900	145	1030	1590	2555	3245	5070
69	Young-Kennedy 1	23-21N- 1E	3278	144	863	1430	2365	3020	
70	Henderson-Greer 1	36-21N- 5E	3479			820	1630	2160	
71	Adams-Avent 1	26-22N- 4E	4030	304	510	980	1825	2418	
72	Lockhart-Lamon 1	22-22N- 6E	2765	294	60	560	1428	1992	
73	Lockhart-Fite 1	25-22N- 6E	3787	324		528	1398	1945	3630
74	Killam-Dattel 1	18-23N- 7W	5118		1975	2645	3650	4433	4972
75	Hunt-Rayner 1	4-23N- 5W	5057	150	1645	2360	3350	4100	5000
76	LaRue-Westbrook 1	18-23N- 2W	4296	136	1255	1902	2890	3608	
77	Williams-Conn. Life 1	28-23N- 5E	3006	201		600	1530	2080	3600
78	Holmans-Thomas 1	18-24N- 7W	4661	159	1850	2595	3558	4322	4588
79	Phillips-Perthshire 1	2-24N- 7W	6009	164	1805	2530	3525	4325	4700
80	Marshall-Ogilvie 1	32-24N- 2E	3976	145	738	1220	2070	2705	
81	Stewart-McRee 1	25-24N- 6E	2960	205		258	1140	1700	
82	Ogg-Bardwell 1	5-25N- 3E	3659	245	500	1108	1930	2535	3355
83	Airmont-Boyle 1	33-25N- 7E	2841	415		337	1160	1690	
84	Honolulu-Davis 2	27-12S - 1E	8390	369			363	870	1760
85	Gulf-Basden 1	20- 7S- 5E	5010	367				125	730
86	Salmon-Wilson Est. 1	29- 9S- 3E	4504	470				600	1250
87	Salmon-Patterson 1	12-11S- 1E	5904	352			340	845	1640
88	Magnolia-Warren 1	26-11S- 3E	7419	513				545	1350
90	Young-Parker 1	18-20N- 3W	4431	133	1605	2440	3430	4150	
91	Young-McClain 1	9-20N- 3W	4467	130	1535	2310	3290	4000	
92	Seaboard -Chicago Mill 1	9-23N- 8W	4785	150	2000	2755	3660	4455	4735

TABLE 1—*Concluded*

MISSOURI

No.	Well name and number	Location	Total depth	Elev. (msl)	Base "500-ft. "sand	Base "1,400-ft." sand	Top Cretaceous	"X Point"	Top Paleozoic
1	Strake-Russell 1	24-19N-11E	2158	271	732	1200	1710		2062
2	City Steel-Water? 1	26-17N-11E	2350		904	1597	2170		

TENNESSEE

No.	Well name and number	Location	Total depth	Elev. (msl)	Base "500-ft. "sand	Base "1,400-ft."sand	Top Cretaceous	"X Point"	Top Paleozoic
1	Henderson-Fields 1	Dyer	3240	260	1040	1530	2200		2780
2	T-1-F (U. S. G. S.)	Fayette	2582	318	615	1050	1632	2255	2530
3	Hay-Morrison 1	Fayette	2722	411				1675±	1993
4	LaZaroz-Beasley 1	Fayette	1767		180	270	775	1475±	1758
5	Watson-Holt 2	Gibson	2355	319	725	970	1460	1950±	2000
6	Maquire-Moore 1	Haywood	2181	445			1275	1865±	2120
8	Corley-Vaughan 1	Lake	2590	289	1140	1590	2100		2430
9	Pure-Gray 1	Lauderdale	3289	303	795?	1242?	1750		2440
10	Gear-Lee 1	Lauderdale	2832	329	1000	1465	1925		2648
11	T-1-M (U. S. G. S.)	Madison	1106	570	140		400	936±	1072
12	T-2-M (U. S. G. S.)	Madison	1289	351	225		520	1100±	1270
13	Lion-Bateman 1	Shelby	2865	250	975	1410	2080		2810
14	Owen-Crumpler 1	Shelby	3010	390	890	1350	2030	2840	3039
15	Pure-McGregor 1	Tipton	2753	270	550?	1050±	1950		2550
16	Nance-Donaldson 1	Hardeman	3780	357			90	750±	1002
17	Benz-Hays 1	Lake	2263	293	1010	1420	1920		2260
18	Memphis	Shelby	1512	247	1055	1480			

are treated in more detail than in the present report. This report includes several correlation sections and an isopach map of the Cretaceous.

Stearns and Armstrong (1955) published a brief general report on the stratigraphy of the northern Mississippi Embayment. They first proposed the relationship between lithology and environment used herein. The report also includes electric-log correlations, isopach and sand-distribution maps, and structure contour maps. The present investigation represents a revision and extension of their work.

Grohskopf (1955) described the subsurface geology of the Mississippi Embayment area of southeast Missouri.

Acknowledgments

The writer is indebted to many people for aid and guidance. Seaboard Oil Company furnished lithologic and electric logs of its core holes in Arkansas. Carter Oil Company also provided electric logs of several of its core holes in Woodruff, Prairie, and White counties, Arkansas. Establishment of electric-log correlations is for the most part due to the generosity of these organizations.

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C. W. Wilson, Jr., of Vanderbilt University, critically read the manuscript and contributed many valuable suggestions.

R. J. Floyd, of the Tennessee Division of Geology, did the final manuscript editing.

GEOLOGY

Surface Geology

Figure 1 is a generalized geologic map of the region. Cretaceous beds and Paleocene Midway Group beds crop out almost all around the embayment edge. Strata of the lower Eocene Wilcox Group crop out only in northern Mississippi. Elsewhere, the Wilcox and upper Midway beds are overlapped by middle Eocene Claiborne Group beds. In part of Arkansas the Claiborne overlaps not only the Wilcox, but also the Midway and Cretaceous.

Correlations

Five major contacts are recognized on electric logs: (1) base of the "500-foot" sand of the Memphis area (Schneider and Cushing, 1948), (2) base of the "1400-foot" sand of the Memphis area, (3) top of the Cretaceous System, (4) a point within the Cretaceous System referred to herein as "X point," and (5) top of Paleozoic rocks. Electric-log correlations of these five contacts are the main basis of this report. The position of these contacts on a generalized electric log is shown in Figure 2. Table 1 gives the drilled depth to each of these contacts for all the wells used.

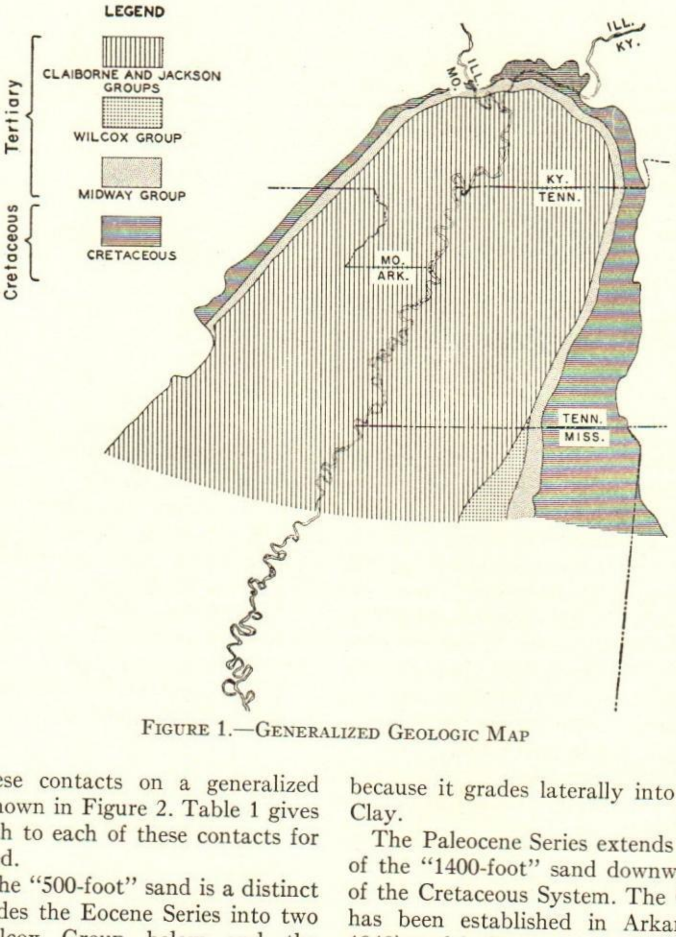

FIGURE 1.—GENERALIZED GEOLOGIC MAP

The base of the "500-foot" sand is a distinct break that divides the Eocene Series into two units, the Wilcox Group below and the Claiborne and Jackson groups above. This contact coincides with the top of the Wilcox of Brown (1947, Pl. 5) in Bolivar County, Mississippi; Renfroe (1949, Pl. 3) in Lee County, Arkansas; and Schneider and Blankenship (1950) in Fayette and Shelby counties, Tennessee.

As used in this report the Wilcox (lower Eocene) extends from the base of the "500-foot" sand to the base of the "1400-foot" sand. The top of the Porters Creek Clay (Paleocene) is customarily used as the boundary between the Wilcox and Midway (Caplan, 1954, p. 95), and in some wells near the Mississippi River the "1400-foot" sand does directly overlie Porters Creek. Elsewhere, however, as much as 200 feet of sandy beds intervene. This interval is included here with the Paleocene Midway rather than the lower Eocene Wilcox, because it grades laterally into Porters Creek Clay.

The Paleocene Series extends from the base of the "1400-foot" sand downward to the top of the Cretaceous System. The Cretaceous top has been established in Arkansas (Renfroe, 1949) and in Tennessee on the basis of fossils. It can be extended to other areas, because this contact corresponds to traceable "kicks" on electric logs. The Cretaceous top does not follow a sand-shale contact but occurs within sands in some areas and within shales in others.

The "X point" (Fig. 2), a slight but characteristic electric-log "kick," divides the Cretaceous System into two units. Both units are of Late Cretaceous age. The "X point" is easily recognized in northeastern Mississippi, and in other areas its approximate position can be traced by the many minor similarities of the electric logs. It occurs in the interval between

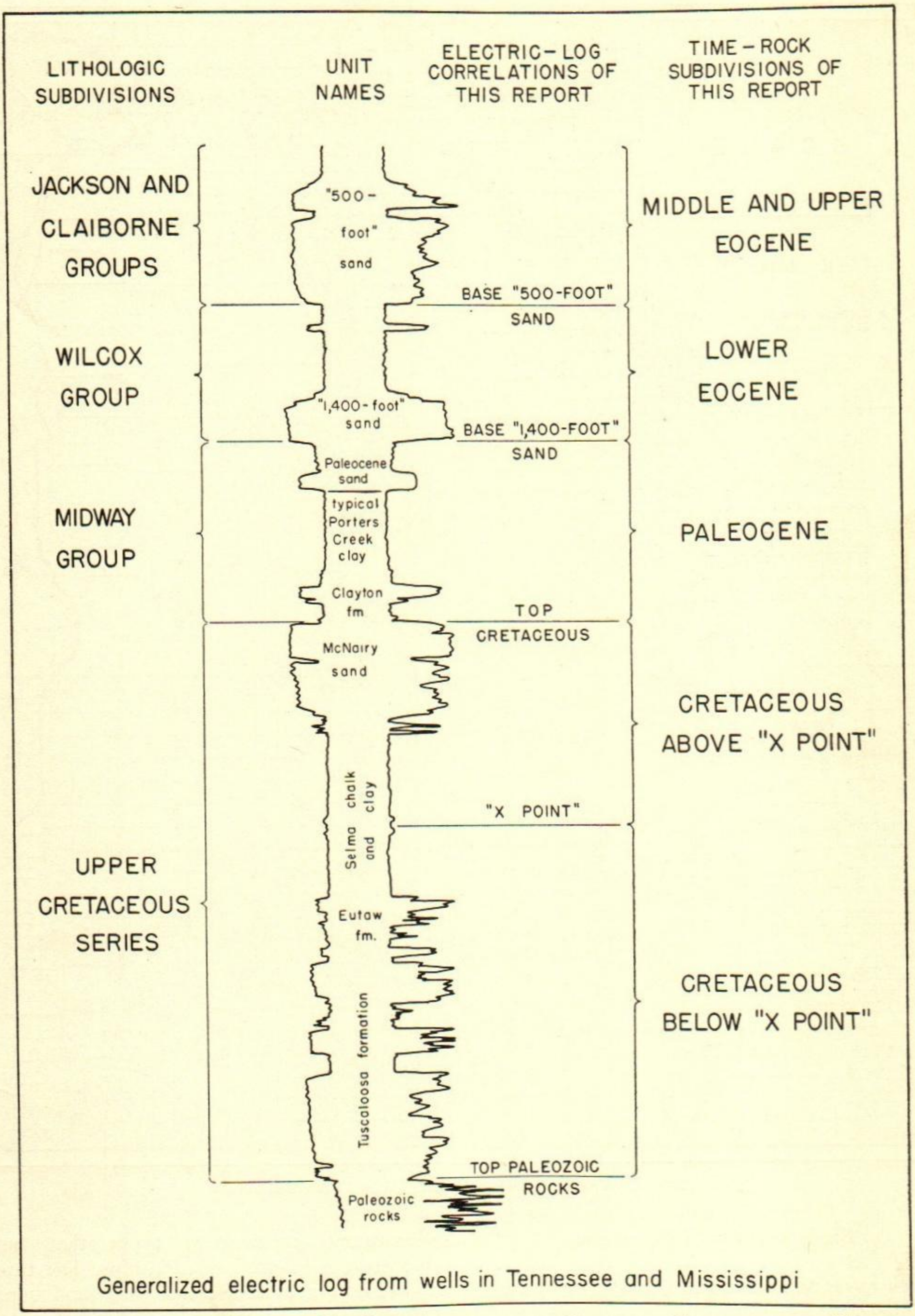

FIGURE 2.—RELATIONS OF ELECTRIC-LOG SUBDIVISIONS OF THIS REPORT TO FORMATIONS AND MAJOR SUBDIVISIONS

the two principal sandy zones in the Cretaceous. The Ripley Formation and its prominent McNairy Sand Member, is above the "X point," and the Tuscaloosa and Eutaw formations are below the "X point" and immediately above rocks of Paleozoic age.

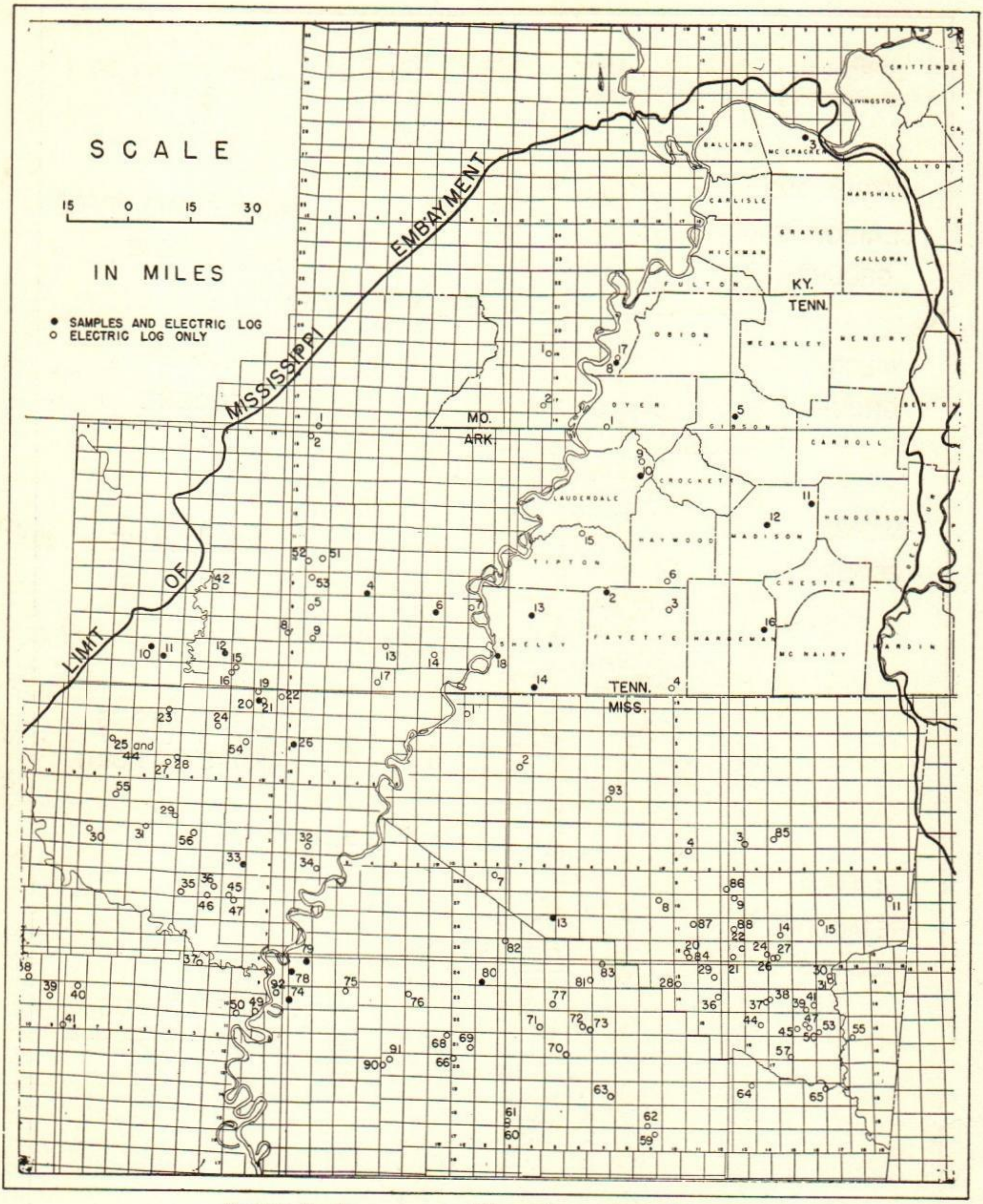

FIGURE 3.—LOCATIONS OF WELLS USED IN THIS REPORT

Environmental Relationships

General statement.—Examination of samples from selected wells (Fig. 3) and changes observable on electric logs suggested general environmental relationships (Stearns and Armstrong, 1955). Although criteria are available for a complex subdivision within some units in certain areas, division was restricted to three sedimentary environment types that best illustrate the inferred relationships. The three subdivisions are back-beach clay and sand, shallow-marine near-shore sandy beds, and deeper-marine clay and shale. Generalized distribution of these types is presented in cross section on Figures 5 and 6. The locations of these cross sections are shown on Figure 4.

Back-beach clay and sand.—Back-beach beds consist of tan, white, pink, and light-gray clay, lignite, and discontinuous sand. The clay beds commonly bear leaf imprints, and glauconite is absent. Such units are difficult to correlate in detail by means of electric logs, even in closely spaced wells, because they are not persistent laterally.

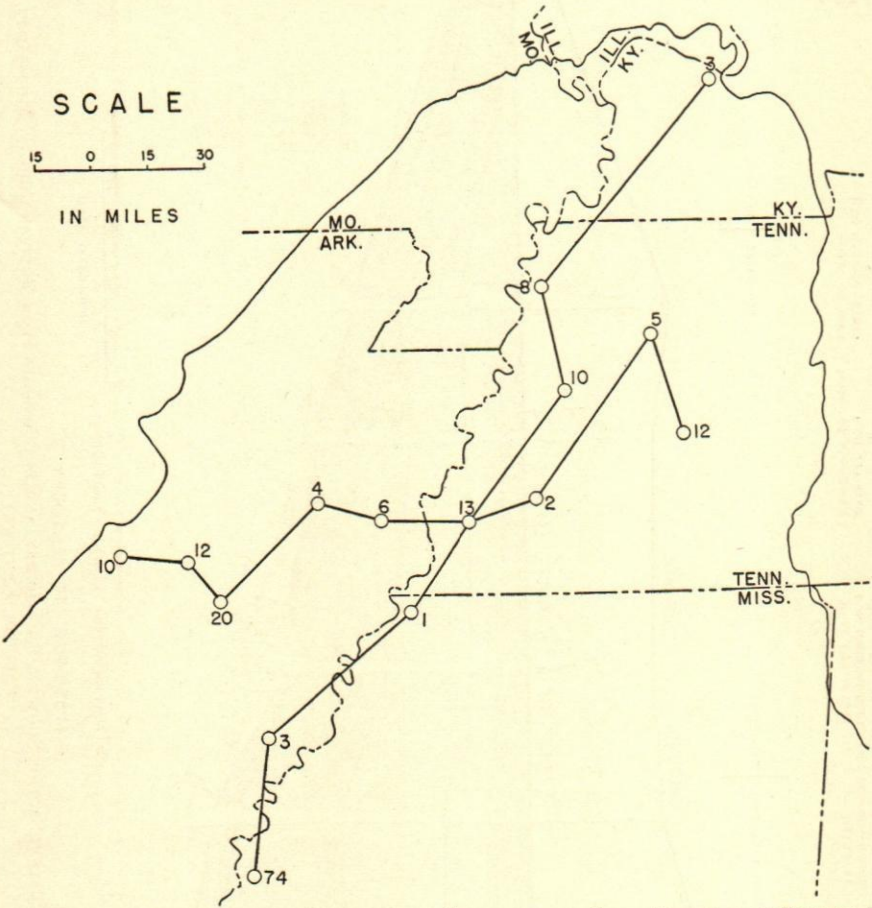

Figure 4.—Index Map Showing the Locations of Stratigraphic Cross Sections on Figures 5 and 6

Shallow-water near-shore sand.—Shallow-water near-shore sand is characterized by good sorting, by the presence of glauconite, and by the presence of marine fossils in some clay interbeds. Such sand tends to have a "blanket" distribution in contrast to back-beach sand bodies which are local and discontinuous. Where shallow-water sand beds grade vertically or laterally into back-beach beds, they commonly contain abundant wood fragments and lignitic material, but where they grade into deeper-water clay beds they may contain glauconite. The "1400-foot" sand is believed to be an example of the shallow-water near-shore deposits.

Deeper-water clay and shale.—The deeper-water clay and shale is characteristically medium gray to dark gray and contains marine fossils, calcareous beds, and glauconite. Drill cuttings are commonly prismatic in shape. Because these clay beds are shown by characteristic patterns on the electric logs, they may be subdivided and widely traced in the subsurface. Slight but characteristic "kicks" in the otherwise monotonous clay-shale pattern were used to trace the "X point" through a predominantly shaly Cretaceous section (Figs. 5, 6).

Isopach and Lithofacies Maps

General statement.—Sand-shale ratios were prepared by using both electric logs and sample

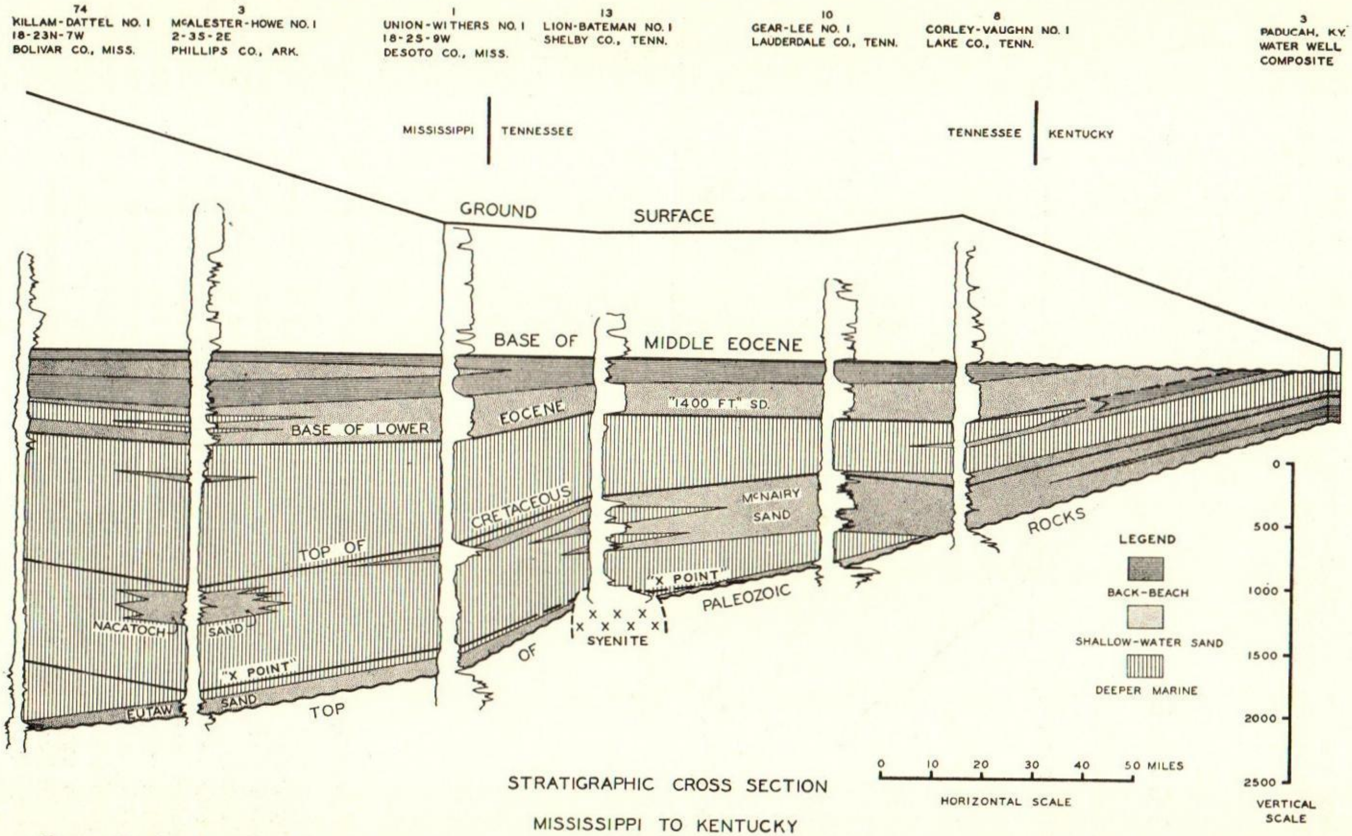

FIGURE 5.—STRATIGRAPHIC CORRELATION SECTION SHOWING ENVIRONMENTAL RELATIONSHIPS FROM BOLIVAR COUNTY, MISSISSIPPI, TO PADUCAH, KENTUCKY

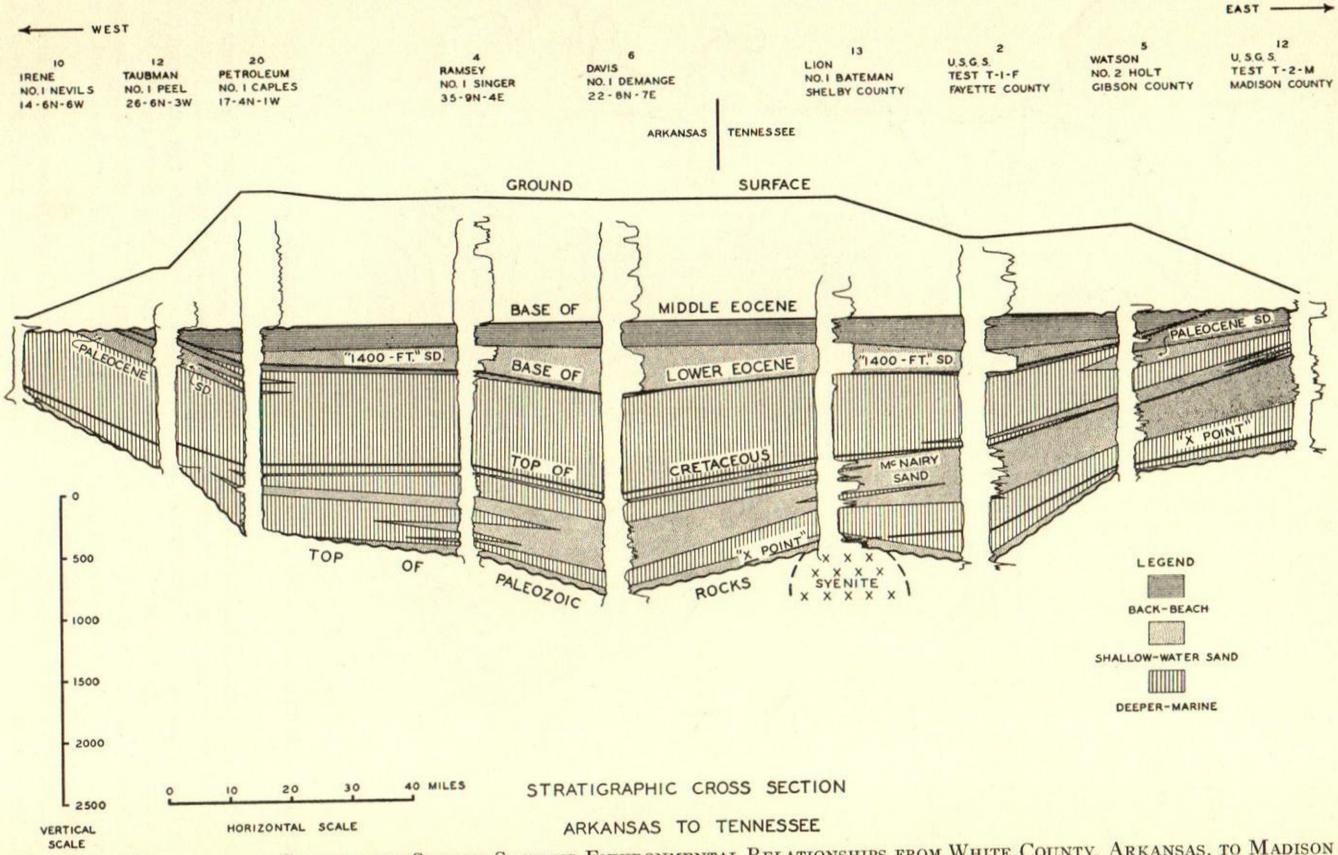

FIGURE 6.—STRATIGRAPHIC CORRELATION SECTION SHOWING ENVIRONMENTAL RELATIONSHIPS FROM WHITE COUNTY, ARKANSAS, TO MADISON COUNTY, TENNESSEE

data. For each unit the number of feet of coarser clastic material (shown in the logs by high resistivity and low self potential) was divided by the number of feet of shale or clay (low resistivity and high self potential). Values of the sand-shale ratios indicate the number of feet of sand per foot of shale. Lignite, ironstone, and chalk were included in the fine clastics.

The maps should be examined with the correlation sections (Figs. 5, 6), because sand-shale ratios give only an average picture of the sand and do not indicate the vertical distribution of sand within the section or the cause for lateral changes in the sand-shale ratics.

Map of Cretaceous rocks below "X point" (*Fig.* 7).—The map of Cretaceous units below the "X point" has a markedly different pattern from all overlying units. At the northwest zero line these older Cretaceous rocks are overlapped. Beyond that line younger Cretaceous units overlie Paleozoic rocks. There is major southward thickening of the Cretaceous where the Tuscaloosa Formation is well developed in Mississippi. The eastward isopach trend here is parallel to the Coastal Plain trend. Evidently the Mississippi Embayment did not assume its present form until after these rocks were deposited.

Northwest of the 600-foot isopach line, variations of the sand-shale ratio generally indicate changes in the development of basal sands in the older Cretaceous rocks. Southeast of this line the higher ratios are due to gravel in the Tuscaloosa Formation.

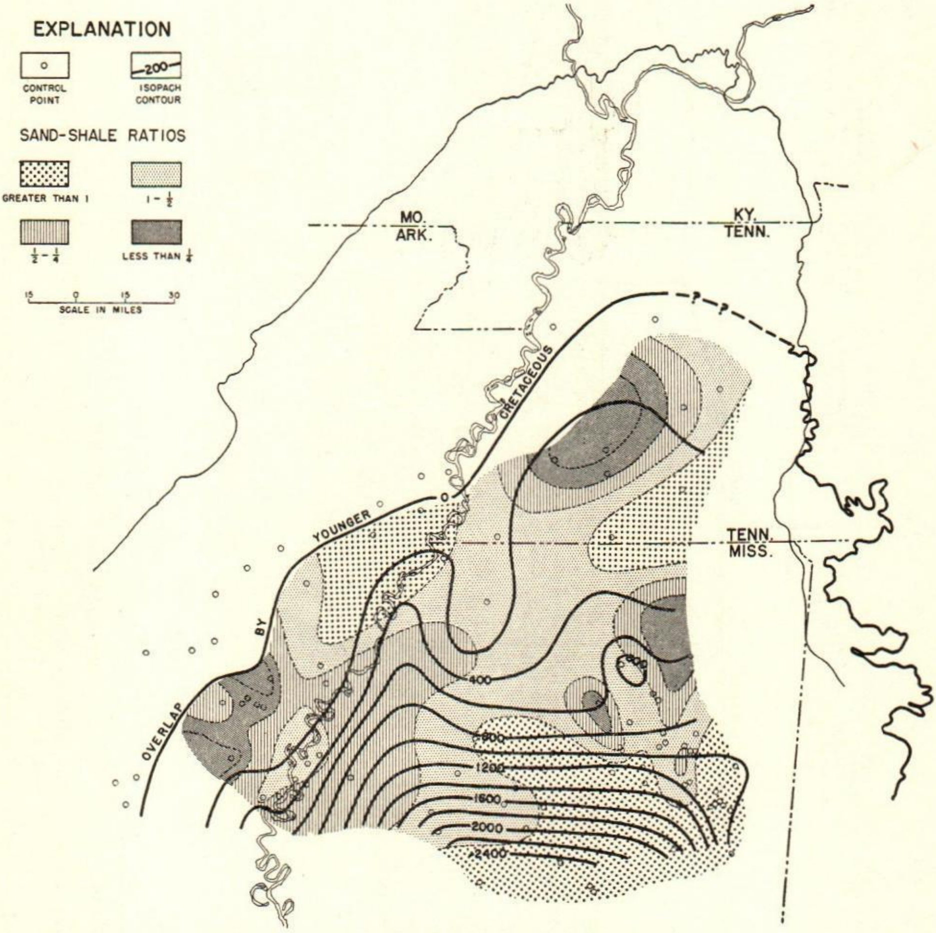

FIGURE 7.—ISOPACH AND SAND-SHALE RATIO MAP OF CRETACEOUS ROCKS BELOW "X POINT"

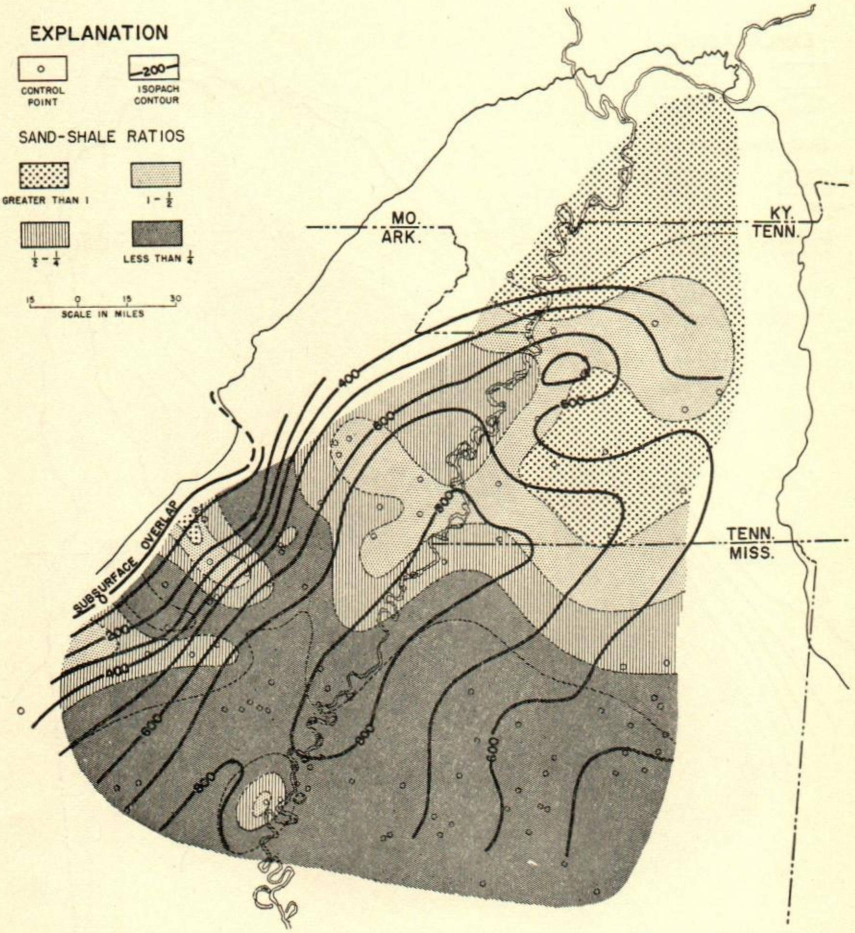

Figure 8.—Isopach and Sand-Shale Ratio Map of Cretaceous Rocks Above "X Point"

Map of Cretaceous rocks above "X point" (*Fig. 8*).—Throughout latest Cretaceous time, progressive westward overlap continued. Beyond the zero line in Arkansas, the top of the Cretaceous is overlapped by Paleocene units that locally rest directly upon Paleozoic rocks. Also, at this time the axis of maximum deposition was along the present Mississippi River, where it persisted in overlying beds. The presence of this axis indicates the beginning of the Mississippi Embayment tectonic trend as opposed to the older Coastal Plain eastward trend (Fig. 7).

The high sand-shale ratios to the north in Tennessee, Kentucky, and northeast Arkansas show the distribution of the McNairy Sand Member of the Ripley Formation. Near the zero edge in Arkansas, high values show that sands other than the McNairy are locally well developed. All these sands are considered to be shallow-water deposits. Sand in the Cretaceous above the "X point" diminishes to the south and disappears in Mississippi.

Map of Paleocene rocks (*Fig. 9*).—This map has an isopach pattern similar to that of Figure 8. Owing to the large proportion of Porters Creek Clay in this interval, sand-shale ratios are low. The increase in the ratios to the north in Tennessee, Missouri, and Kentucky is due to sand at the base of the section. In this area the underlying McNairy Sand Member is also well developed. Higher ratios to the east in Mississippi result from marked increase in sand as marine clay in the upper part of the Porters

Creek grades laterally into shallow-water and back-beach sandy beds.

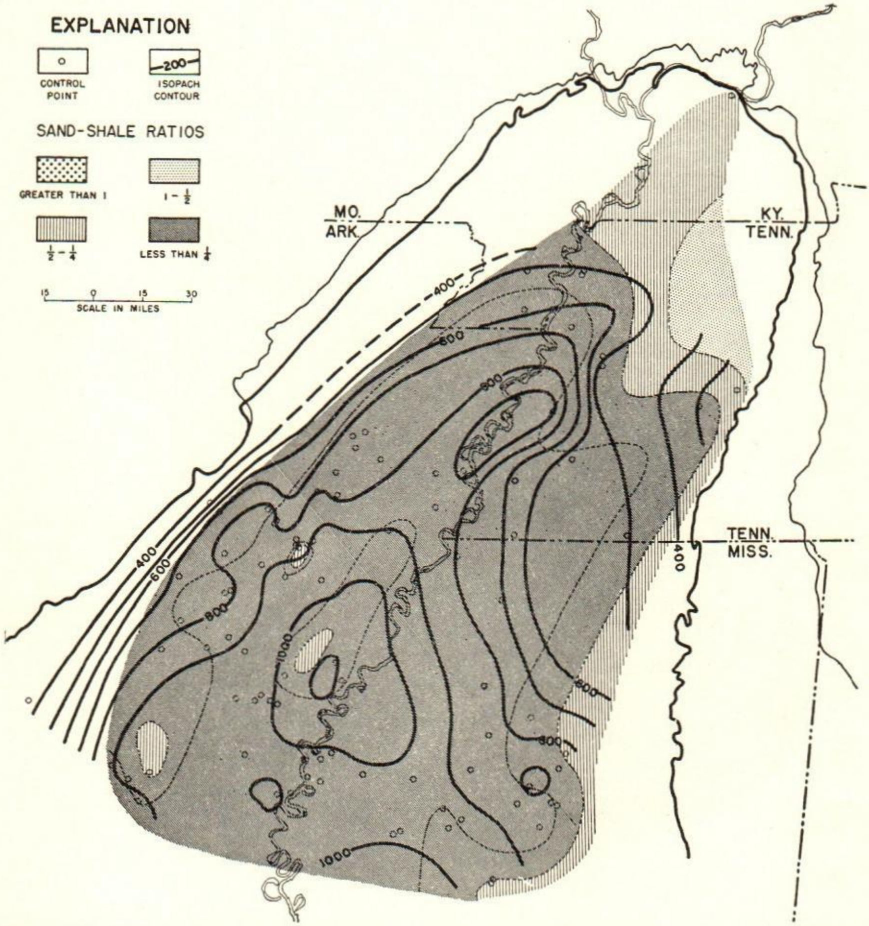

FIGURE 9.—ISOPACH AND SAND-SHALE RATIO MAP OF THE MIDWAY GROUP (PALEOCENE)

Map of lower Eocene rocks (*Fig. 10*).—The map of lower Eocene rocks has approximately the same isopach pattern as shown by Figure 9. The zero line to the west, north, and northeast represents overlap of this unit by the base of the overlying "500-foot" sand. A shallow basin to the south is closed by the 700-foot isopach. Another minor basin is developed in the extreme northeast corner of Arkansas.

Sand-shale ratios show a marked high to the north and along the axis of the Mississippi Embayment. High values in the north, where the total thickness is less than 500 feet, are due to the truncation of the upper shaly part of the section, leaving only the "1400-foot" sand. High ratios southward along the axis are due to greater relative thickness of the "1400-foot" sand.

Lower sand-shale ratios to the east and west are due to gradation of the shallow-water "1400-foot" sand into lignitic clays of the back-beach environment. The lignitic clays also overlie the sand in most of the area. To the south, beds of deeper-water clay occur within the sand, but these are too thin to affect the pattern.

PALEOGEOGRAPHY OF THE CRETACEOUS, PALEOCENE, AND LOWER EOCENE

Gulfward Environmental and Stratigraphic Changes (*Fig. 11*)

Figure 11 shows four representative sections in which environmental types are superimposed on electric logs. These also show the main correlation lines. Three important relationships are demonstrated.

(1) Both oldest and youngest beds occur in the gulfward section. Northward, these disappear as a result of onlap at the base and truncation at the top.

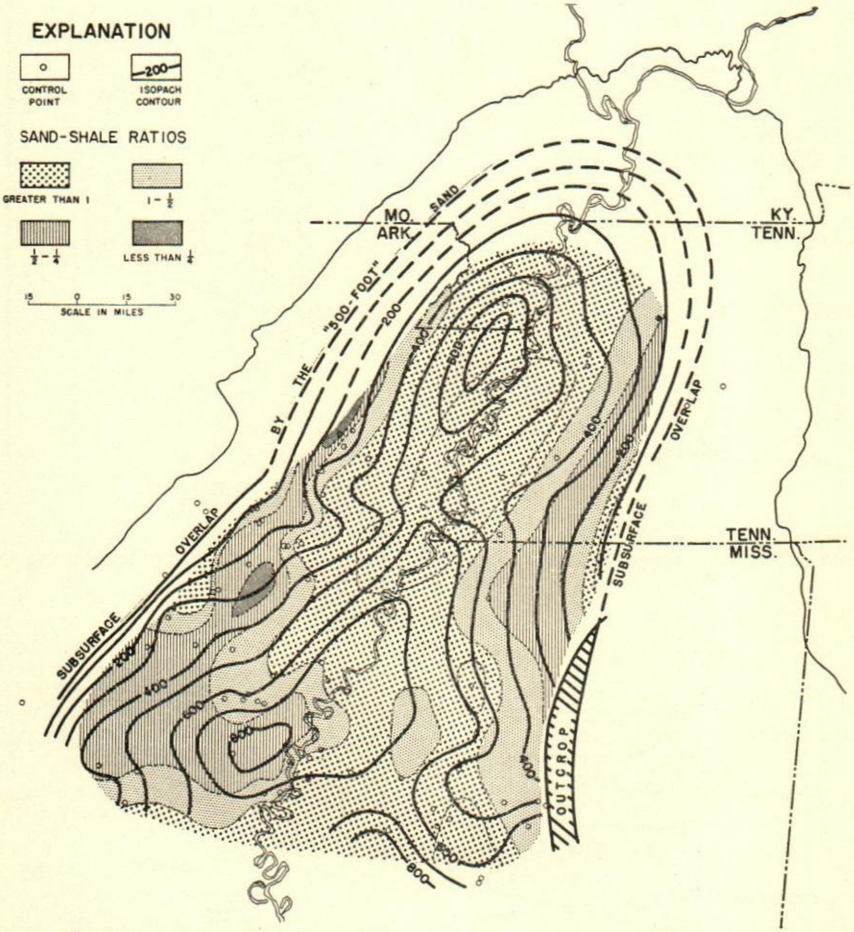

FIGURE 10.—ISOPACH AND SAND-SHALE RATIO MAP OF THE WILCOX GROUP (LOWER EOCENE)

(2) Deeper-water beds dominate the gulfward section, but northward there is a lateral facies change from deeper-marine beds to transitional beds of sand and back-beach material.

(3) Only back-beach sediments and sand occur at the base and top, except where post-depositional truncation has been most severe at the thinnest section in McCracken County, Kentucky.

The same changes that occur northward along the axis of the Mississippi Embayment also occur eastward and westward up the sides of the embayment.

The three types of material within this sequence invariably maintain their proper relative sequence. Deeper-water sediments are always separated from back-beach material by shallow-water near-shore sand in the vertical succession of each well. Lateral variations occur in the same manner between closely spaced wells and also appear to occur between more widely spaced wells.

It is therefore assumed that facies variations occurred throughout the region in this regular manner, and facies correlations and the main electric-log correlations result in the stratigraphic section shown on Figure 12. These same relationships are shown in more detail on Figures 5 and 6.

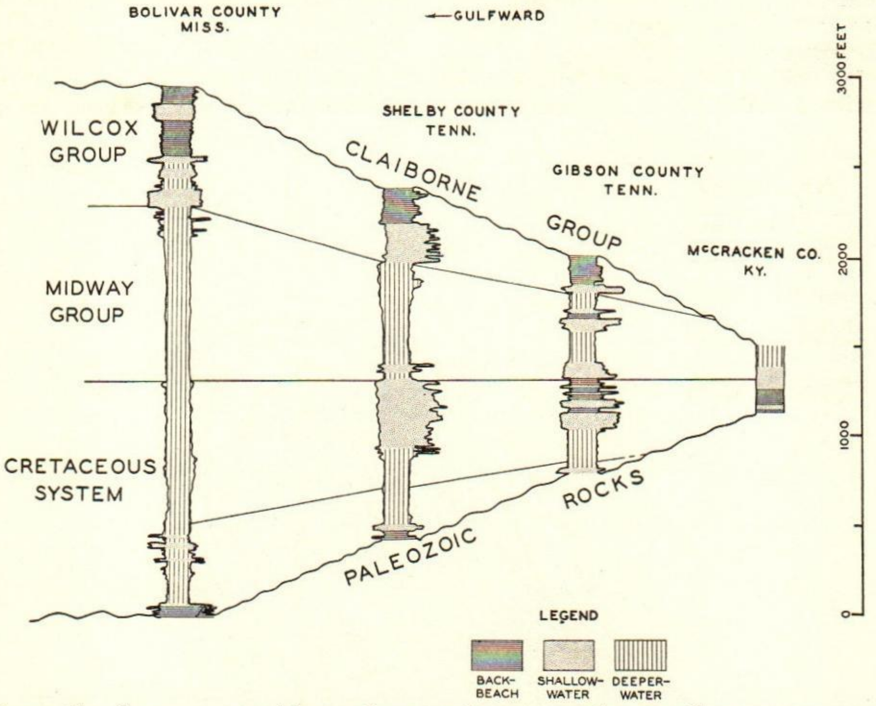

Figure 11.—Correlation of Typical Logs and Lithologies Showing Environmental and Stratigraphic Variations

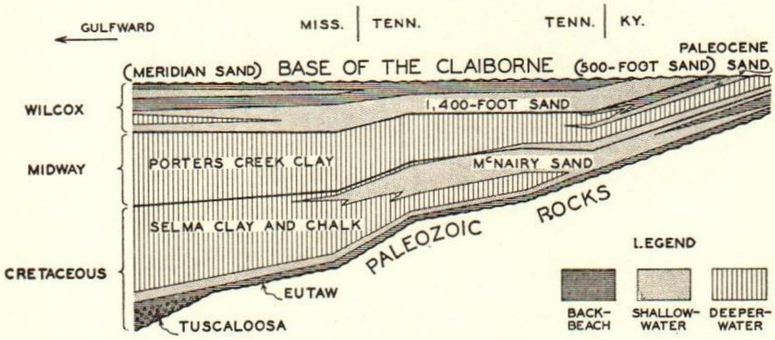

Figure 12.—Transgressive and Regressive Oscillations During Deposition of the Cretaceous, Midway, and Wilcox

Marine Oscillations (Fig. 12)

The Cretaceous, Paleocene (Midway), and lower Eocene (Wilcox) deposits constitute a single sequence bounded above and below by major unconformities. Within this sequence there is no lithologically recognized unconformity, and five major marine oscillations are known.

The first oscillation occurred during deposition of the transgressive Tuscaloosa Formation, Eutaw Formation, and Selma Chalk, and the regressive McNairy Sand Member of the Ripley Formation. The second oscillation began during latest Cretaceous, reached its maximum transgression during the Paleocene with deposition of the Porters Creek Clay, and ended with deposition of the regressive unnamed sand herein referred to as the Paleocene sand. A third oscillation occurred during deposition of uppermost Paleocene, where the Porters Creek Clay is repeated and overlies the Paleocene sand. The fourth oscillation is dominated by transgressive "1400-foot" sand. During the fifth and last transgressive oscillation an unnamed sand was deposited. This sand occurs only as far north as the Mississippi-Tennessee border.

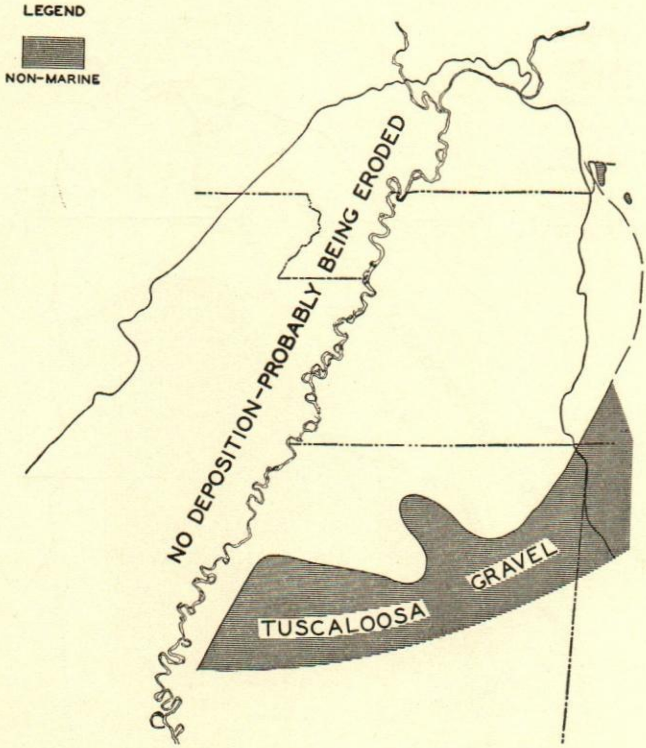

FIGURE 13.—PALEOGEOGRAPHY OF THE LOWERMOST CRETACEOUS

Paleogeographic Maps (*Figs. 13–21*)

General statement.—In construction of the series of paleogeographic maps, it was assumed that maximum transgressions, as well as maximum regressions, are approximately synchronous. The oscillations themselves are in turn founded on a partly observed and partly inferred facies correlation of the three sedimentary environment types.

The maps show the distribution of the three sedimentary environment types at each horizon chosen. These horizons are shown on Figure 2. The shore line, shown by a heavy line, is drawn as an approximation at the boundary between shallow-water sand and back-beach beds.

Two separate phenomena are responsible for the patterns shown on the maps. First, regardless of lithology, the limits of deposition are controlled by tectonic behavior of the area of deposition. Second, the distribution of facies within the area of deposition is controlled not only by subsidence but by rate of sedimentation and perhaps also by sea-level change.

Isopach maps reflect the tectonic pattern of the area. The degree to which environments parallel isopach patterns is of interest because it indicates control, or lack of control, of paleogeography by contemporary structural movements in the embayment area.

Lowermost Cretaceous (*Fig. 13*).—After a long period of erosion, the cycle began with deposition of nonmarine (?) Tuscaloosa gravel on eroded Paleozoic rocks. It is debatable whether the Tuscaloosa is actually nonmarine, but its interbeds of red clay and position below the transitional Eutaw make this the most logical interpretation.

Distribution of the Tuscaloosa is totally dissimilar to the embayment pattern but is similar to the isopach map including it (Fig. 7). It is perhaps significant that the zero edge of the Tuscaloosa, except near the Mississippi River, approximately follows the truncated edge of Mississippian rocks. This may mean that the tectonic pattern of the embayment area during Tuscaloosa deposition was a continuation of the earlier uplifts that resulted in exposure of beds as old as Cambrian by erosion before being covered by Cretaceous in northwest Tennessee and southeast Missouri (Grohskopf, 1955, Pl. 3).

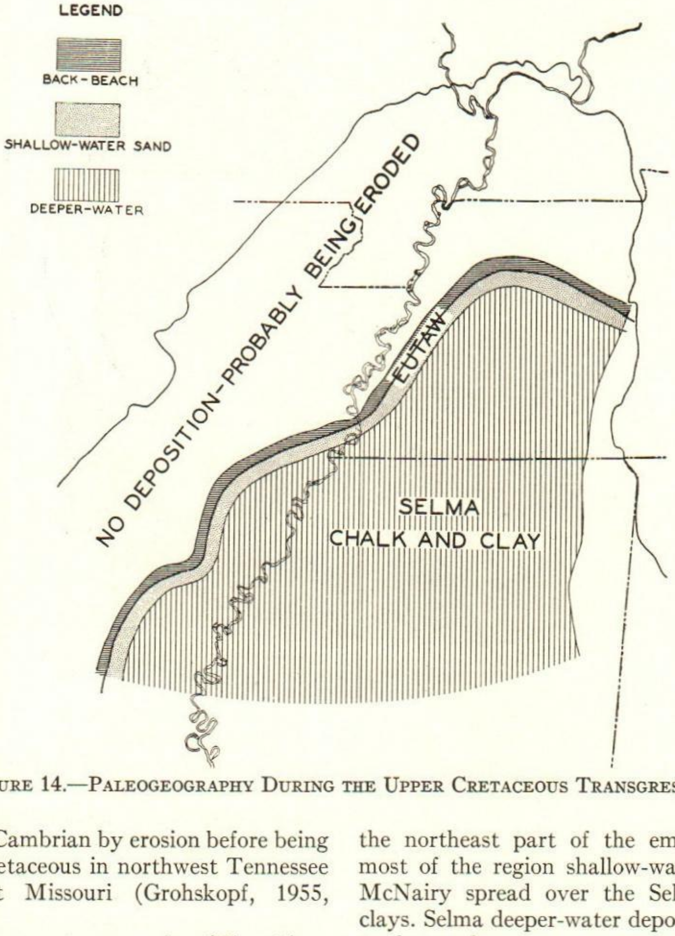

FIGURE 14.—PALEOGEOGRAPHY DURING THE UPPER CRETACEOUS TRANSGRESSION

Upper Cretaceous transgression (*Fig. 14*).—Succeeding the nonmarine Tuscaloosa, the transitional Eutaw and marine Selma were deposited in an advancing sea. This is not the maximum transgression but is at an arbitrary horizon of the "X point" that can be traced on electric logs. A map at an earlier horizon would show the shore line farther southeast, and a map at a higher horizon would show the shore line farther northwest.

Deeper-water clay and chalk dominate this map. There is only a narrow rim of shallow-water sand and back-beach sediments, so that marine transgression and spread of limits of sedimentation practically coincide. This picture is identical in trend with the edge of the isopach map (Fig. 7), because this is the horizon chosen as the top of that isopach interval.

Upper Cretaceous regression (*Fig. 15*).—During the Upper Cretaceous the sea regressed in the northeast part of the embayment. Over most of the region shallow-water sand of the McNairy spread over the Selma chalks and clays. Selma deeper-water deposition continued to the south.

Environment patterns on this horizon are largely dissimilar to the isopach lines of the interval including it. There is a suggestion of the Mississippi Embayment shape in the distribution of Selma deeper-water sediments, and the shore line parallels isopach lines near the zero edge adjacent to the nondeposition area in Arkansas. The northeast termination of that nondeposition area is a present offset of the embayment edge (Fall Line) in Arkansas. This feature controlled the shore line as well as the pattern of onlap. It also influenced deposition later in the Paleocene.

Discordance with the isopach lines of Figure

8 occurs to the northeast where the shore line trends northwestward across the isopach trough. This situation in that northeast area indicates more rapid sedimentation, which drove the sea back by filling the basin as rapidly as it subsided. That this area was a delta, or deltas, is strongly suggested by the lithofacies pattern on Figure 8, which suggests that sand was debouched into the trough in southwest Tennessee and in western Kentucky.

Northwest basal Cretaceous onlap, which started in earlier times, had by this time covered almost all the Mississippi Embayment with Cretaceous sediments. Onlap was slower in that part of Arkansas labeled "no deposition." There, onlap continued after the time represented by this map and into the Paleocene.

Paleocene maximum transgression (*Fig. 16*).—During the Paleocene the sea reached its maximum transgression. Shore-line and back-beach facies are not found within the present embayment limits for these rocks; only the deeper-water beds extend to the outcrop completely around the Mississippi Embayment. How far the sea advanced beyond this present erosional limit is conjectural.

Onlap, which started during the Cretaceous, finally covered the entire basin. In the small area of Cretaceous nondeposition in Arkansas, Paleocene Porters Creek Clay overlaps the Cretaceous and rests directly on Paleozoic rocks.

Upper Paleocene regression (*Fig. 17*).—During the late Paleocene the sea regressed and for the first time formed a wide bay. A "rim" of shallow-water sand was deposited along its shore, but in the bay deeper-water deposition of Porters Creek Clay continued.

Environment patterns are strongly reminiscent of the Upper Cretaceous regression (Fig. 15) except that sand is much less widespread, and an east shore line is visible for the first time in Mississippi. The shore line to the west and north is nearly identical in position with that earlier shore line. The offset of the Fall Line in Arkansas again influenced deposition. Here, the Paleocene sand and the shore line swing northwestward. The earlier Cretaceous deltaic con-

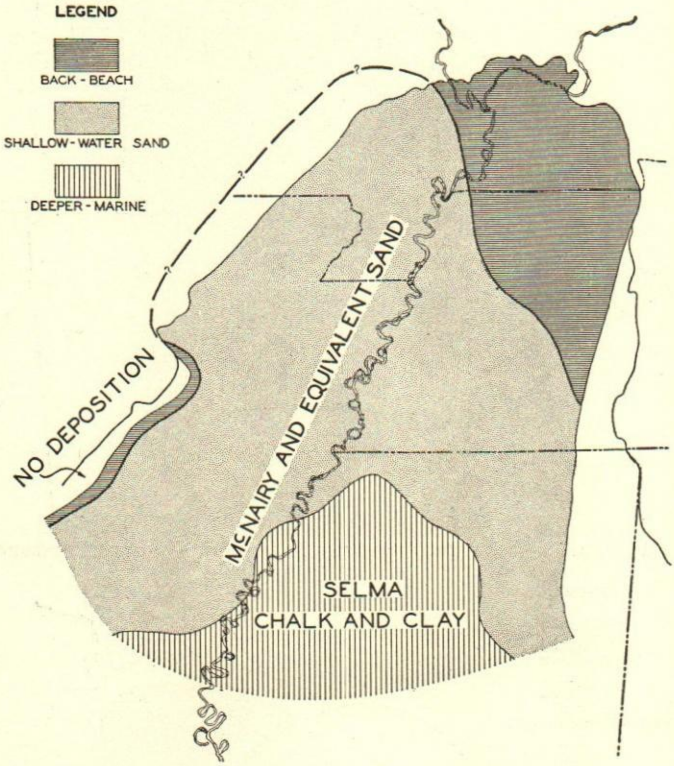

FIGURE 15.—PALEOGEOGRAPHY DURING THE UPPER CRETACEOUS REGRESSION

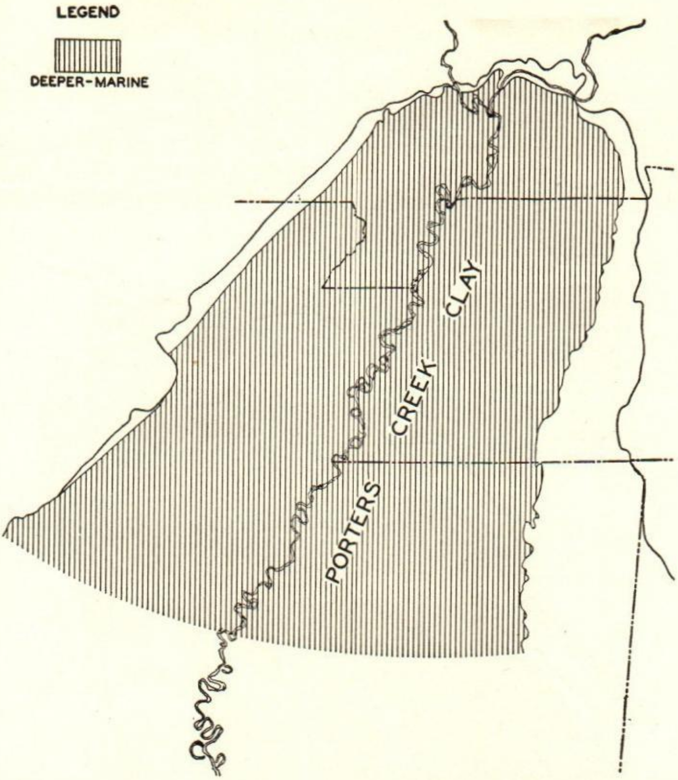

FIGURE 16.—PALEOGEOGRAPHY DURING THE PALEOCENE MAXIMUM TRANSGRESSION

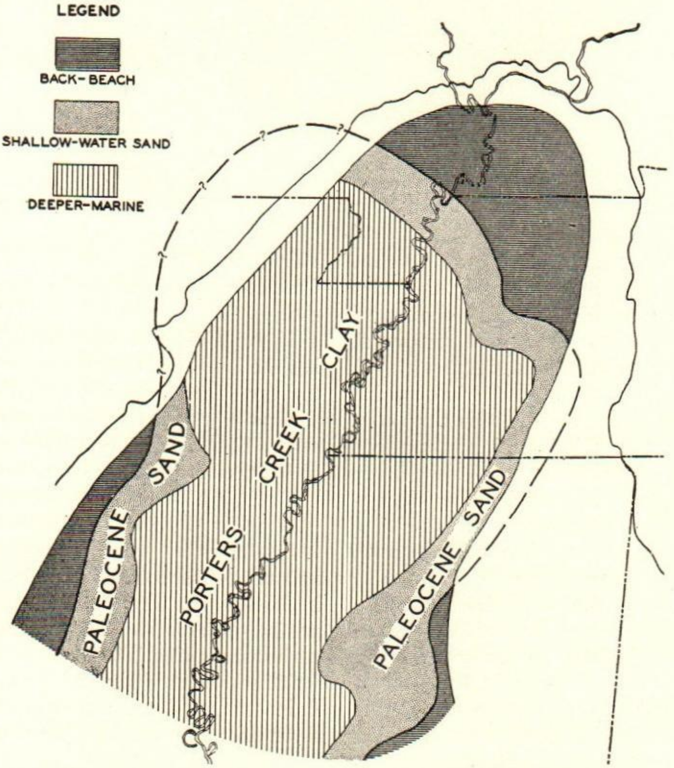

FIGURE 17.—PALEOGEOGRAPHY DURING THE UPPER PALEOCENE REGRESSION

dition to the northeast also was revived at this time.

Although deeper-water Porters Creek Clay crops out around the Mississippi Embayment edge, this upper horizon is truncated and overlapped by the Claiborne everywhere except Mississippi and a small adjacent area in Tennessee. Succeeding horizons of uppermost Paleocene and the lower Eocene are progressively more restricted to the trough of the embayment. Edges of the facies patterns on Figure 17 and succeeding maps are the inferred lines of truncation of each horizon beneath the overlapping Claiborne.

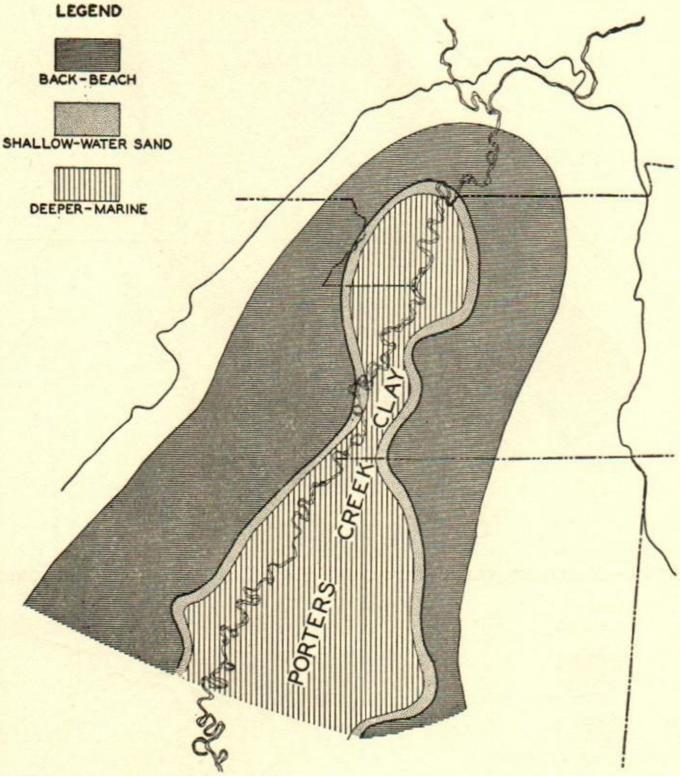

FIGURE 18.—PALEOGEOGRAPHY AT THE END OF THE PALEOCENE

End of the Paleocene (*Fig. 18*).—Before the end of the Paleocene there was a slight transgression (not shown on a map), but by the end of the Paleocene the sea had assumed the shape of a long narrow bay extending along the axis of the Mississippi Embayment. In this bay, deposition of Porters Creek Clay continued. Lignitic back-beach sediments are predominant elsewhere, and shallow-water sand is of little significance.

The marine bay closely follows the isopach trough of Figure 9. This horizon is more restricted in area than that of the preceding map (Fig. 17). It is overlapped by Claiborne everywhere except in southernmost Tennessee and in Mississippi. (Fig. 1.)

First lower Eocene transgression (Fig. 19).—At the beginning of the lower Eocene the sea again advanced to occupy an open bay similar to that of Figure 17, and a widespread blanket of shallow-water sand was deposited. Back-beach sediments occur to the east and west, but sediments deposited at the northern shore line have been eroded, and Claiborne there rests unconformably on the "1400-foot" sand. Deeper-water clays occur only in the embayment trough far to the south.

Following deposition of the "1400-foot" sand the sea withdrew (not shown on a map), and lignites overlie this sand even in the center of the trough. This is the most widespread lower Eocene horizon but it crops out only in Mississippi. Elsewhere, it is overlapped by Claiborne,

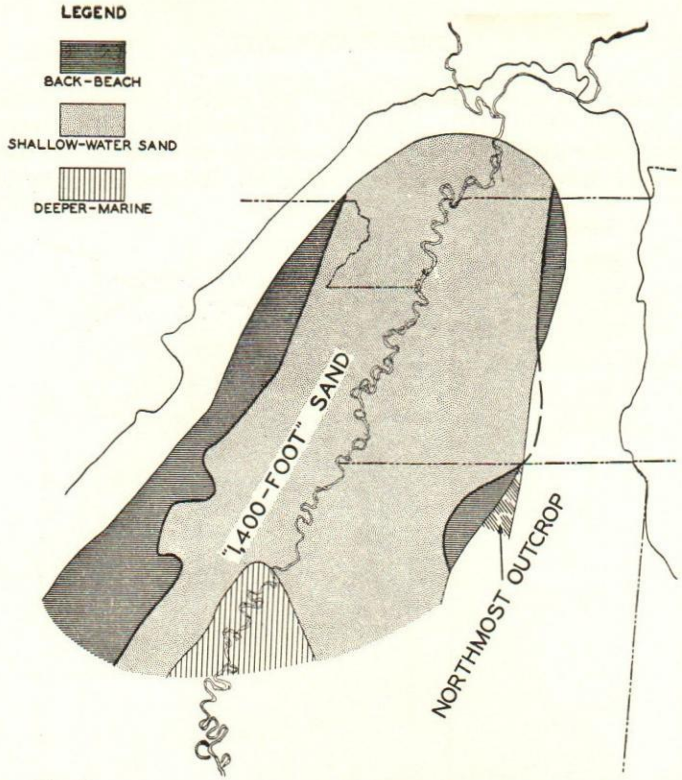

FIGURE 19.—PALEOGEOGRAPHY DURING THE FIRST LOWER EOCENE TRANSGRESSION

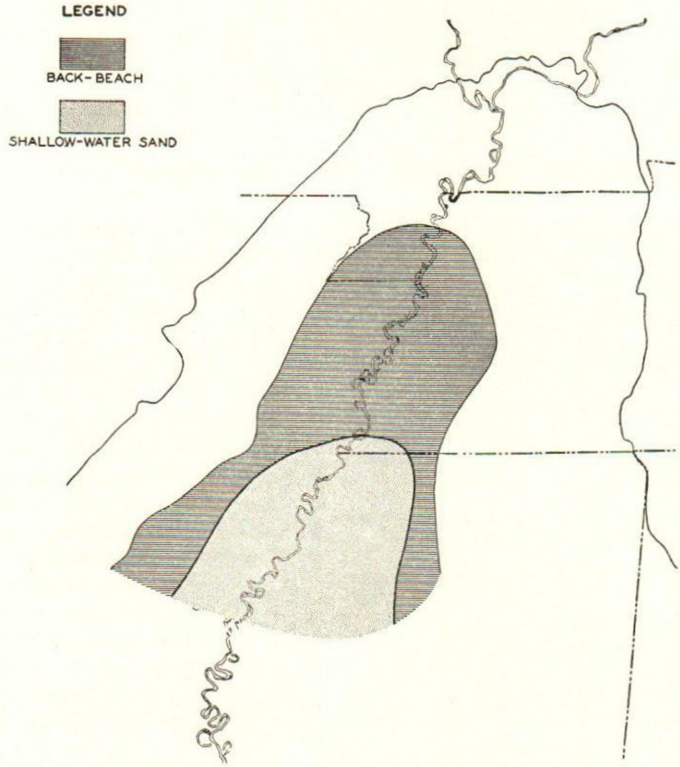

FIGURE 20.—PALEOGEOGRAPHY DURING THE SECOND LOWER EOCENE TRANSGRESSION

and still higher horizons of the lower Eocene are progressively restricted to the trough.

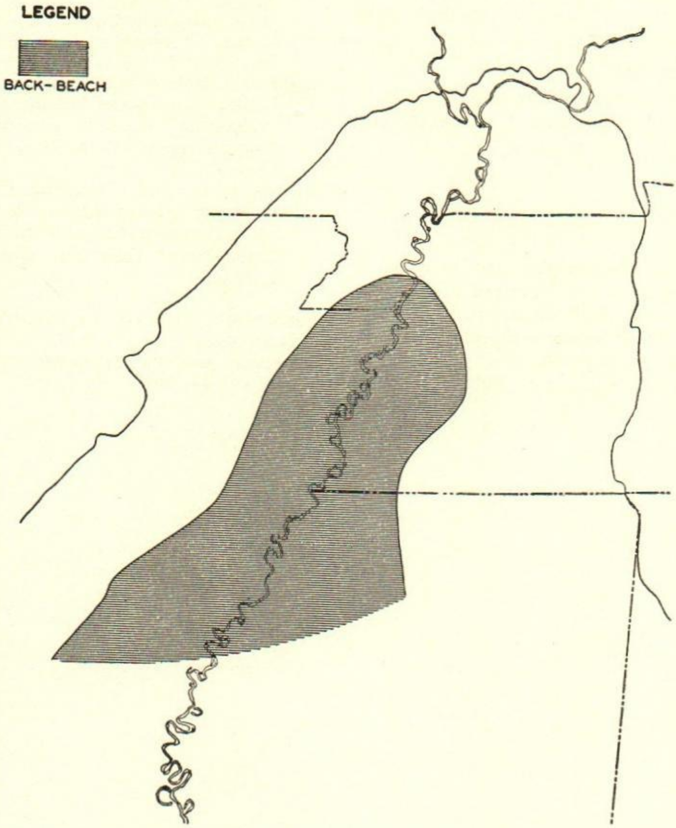

FIGURE 21.—PALEOGEOGRAPHY DURING DEPOSITION OF THE LATEST PRESERVED LOWER EOCENE

Second lower Eocene transgression (*Fig. 20*).—The sea invaded again for the last time during the lower Eocene. It advanced only as far north as the southwest corner of Tennessee and left as a record an unnamed glauconitic sand; no deeper-water beds occur here. Beds of this age do not crop out anywhere in the area studied.

Second lower Eocene regression (*Fig. 21*).—Following this advance, the sea withdrew, as shown by uppermost lower Eocene beds which contain lignite throughout the region.

CONCLUSIONS

In the northern Mississippi Embayment, Cretaceous, Paleocene, and lower Eocene sediments were deposited in a single sedimentary cycle bounded above and below by truncating unconformities. The cycle is broken within only by the disconformity at the Cretaceous-Paleocene boundary.

Nonmarine or shore-facies material is lacking at the Cretaceous-Paleocene boundary, except where it was deposited both above and below the contact, as in northwest Tennessee. This suggests to the writer that in the northern embayment this boundary represents not a withdrawal of the sea, but a "stillstand" in which constant geographic conditions persisted while deposition was lacking or very slow. Slight deposition is suggested by widespread glauconite and phosphatic material at and near this boundary.

At the lower boundary of the cycle, Cretaceous and Paleocene beds rest upon Paleozoic rocks ranging in age from Cambrian to Pennsylvanian. At the upper boundary the lower Eocene Wilcox Group is overlapped by beds of the middle Eocene Claiborne Group around the end of the Embayment north of the Tennessee-Mississippi border.

Within the cycle, five advances and regressions of the sea are recorded. The geographic patterns of these advances and regressions were strongly influenced by contemporary structural movements in the region. The earliest (late Cretaceous) advance was from the southeast. The second (Paleocene) advance extended beyond the embayment limits; its pattern is unknown because the shore facies is not present. During the last three advances (late Paleocene through lower Eocene) the sea occupied bays that followed the Embayment axis.

The structural trough shape of the Embayment appeared during latest Cretaceous and persisted through early Eocene.

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