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A PRELIMINARY REPORT OF THE GEOHYDROLOGY OF THE MISSISSIPPI SALT-DOME BASIN

by C. A. Spiers and L. A. Gandl

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply inch-pounds unit	By	To obtain SI units
inch (in)	25.4	millimeters (mm)
acre	2.471	hectometer (hm^2)
foot (ft)	0.305	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
foot per mile (ft/mi)	18.9	centimeter per kilometer (cm/km)
	0.189	meter per kilometer (m/km)
cubic foot per day per square foot $(ft^3/d)/ft^2$	.305	cubic meter per day per square meter $(m^3/d)/m^2$
cubic foot per day per foot $(ft^3/d)/ft$	0.093	cubic meter per day per meter $(m^3/d)/m$

The conversion from temperature in degrees Fahrenheit (°F) to temperature in degrees Celsius (°C) is expressed by: °C = 5/9 (°F-32).

A PRELIMINARY REPORT OF THE GEOHYDROLOGY OF THE MISSISSIPPI SALT-DOME BASIN

by C. A. Spiers and L. A. Gandl

ABSTRACT

The U.S. Department of Energy is investigating the suitability of salt domes in the salt-dome basin in Mississippi as repositories for storing radioactive wastes. The Department of Energy has requested that the U.S. Geological Survey describe the ground-water hydrology of the Mississippi salt-dome basin, giving special attention to direction and rate of movement of water.

This report presents results of the first part of a continuing investigation and summarizes data obtained from one year of extensive literature search and data compilation. Data compilation and literature review were done in order to define the regional ground-water hydrology in the salt-dome basin with respect to (a) ground-water flow, (b) facies changes, (c) geological structure, (d) recharge and discharge, (e) freshwater-saltwater relations, and (f) identification of localities where additional data are needed.

Fresh ground water in the salt-dome basin in Mississippi extends to depths of more than 3,000 feet (914 meters). The depth to the base of freshwater generally increases along the south or southwest direction of dip of the strata. The principal aquifers in the basin consist of the Wilcox Group, the Sparta Sand, the Cook Mountain Formation, the Cockfield Formation, and the Miocene aquifers.

The Louann Salt, Jurassic in age, is generally believed to be the bedded salt from which domes in the salt-dome basin are derived. Although most salt domes in Mississippi are roughly circular in plan view and range in diameter from about 0.5 to 3.5 miles (0.8 to 5.6 kilometers), great diversity exists in dome geometries, dome-to-caprock relations, and dome-to-flankrock orientations. Heights above the Louann Salt are known to range from 10,000 to 20,000 feet (3,000 to 6,000 meters).

From the 50 piercement-type salt domes in the Mississippi salt-dome basin, three (Richton, Cypress Creek, and Lampton) domes were selected for more intensive study. To further evaluate the geohydrology of Richton, Lampton, and Cypress Creek domes as possible sites for storage of radioactive waste, an intensive geohydrologic study based on a comprehensive test drilling program near the domes is needed.

INTRODUCTION

Purpose and Scope

An investigation of the suitability of salt domes in the salt-dome basin in Mississippi as repositories for storing radioactive waste is being conducted by the U.S. Department of Energy. The Department of Energy has requested that the U.S. Geological Survey describe the geohydrology of the entire basin as well as locally near selected domes, giving special attention to direction and rate of movement of ground water. The direction and rate of ground-water flow as well as other hydrologic characteristics are significant because transport by ground water is considered to be the principal mechanism by which radioactive wastes might enter the biosphere.

This report describes the regional ground-water hydrology in the salt-dome basin with respect to (1) ground-water flow, (2) facies changes, (3) geological structure, (4) recharge and discharge, and (5) freshwater-saltwater relations, and identifies localities where additional data are needed. This report is a product of the first part of a continuing investigation and summarizes the results of one year of extensive literature search and data compilation. Data obtained for this investigation came from U.S. Geological Survey files, other state and federal agencies, and private consultants. Information used in this investigation include: (1) water-well logs, (2) geophysical logs, (3) water-quality data from aquifers, (4) hydraulic characteristics as determined from aquifer test data, (5) water levels from wells, and (6) topographic, surficial and structural geologic, and water-quality maps.

Description of the Area

The salt-dome basin extends in an east-southeast direction from northeastern Louisiana across Mississippi to southwestern Alabama. It is about 170 mi (273 km) long and 100 mi (161 km) wide (fig. 1).

The salt-dome basin in Mississippi covers parts of four physiographic regions (Fenneman, 1938); (1) Mississippi River alluvial plain in the extreme west and northwest, (2) Loess Hills (or Bluff Hills) in the west, (3) Jackson Prairie in the north, and (4) Southern Pine Hills in the central and southern part of the basin.

The altitude of land surface in the salt basin ranges from 50 to 150 ft (15 to 46 m) in the Mississippi River alluvial plain and from 250 to 600 ft (76 to 183 m) elsewhere in the basin.

Major streams in the basin are from west to east, the Mississippi River, the Big Black River, the Homochitto River, the Pearl River, and the Leaf River.

The climate in the basin area is humid and is characterized by long, hot summers and short, mild winters. The mean annual temperature is about 66°F (19°C). Temperature ranges from a mean monthly low during January of about 50°F (10°C) to a mean monthly high during July of about 82°F (28°C) (Anderson and others, 1973).

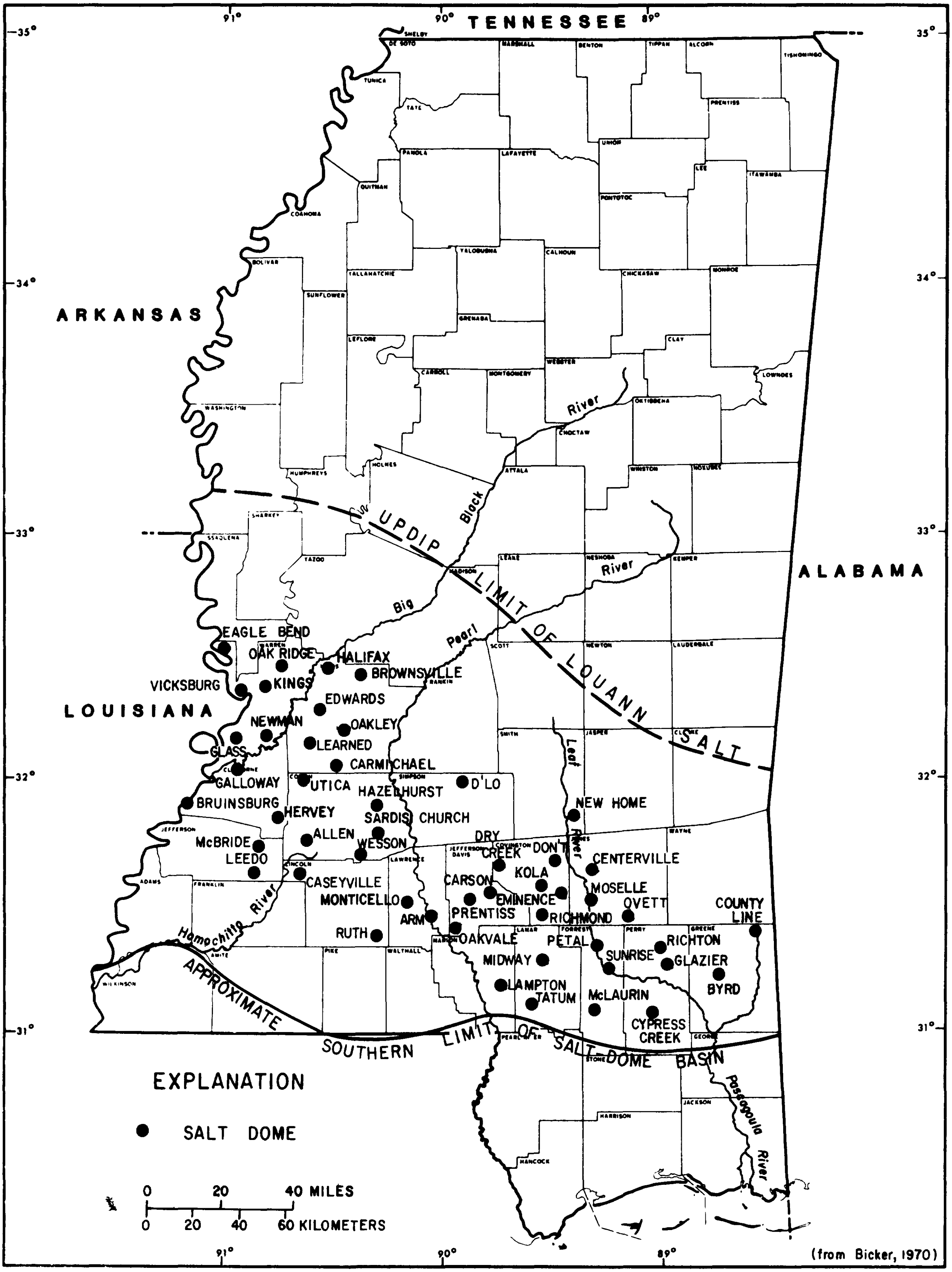


Figure 1.--The location of salt domes in Mississippi.

Rainfall varies from 52 in. (1,320 mm) a year in the northwestern part of the basin to 62 in. (1,570 mm) in the southeastern part (Shows and others, 1966).

REGIONAL GEOHYDROLOGY

General Structure, Stratigraphy, and Geohydrology

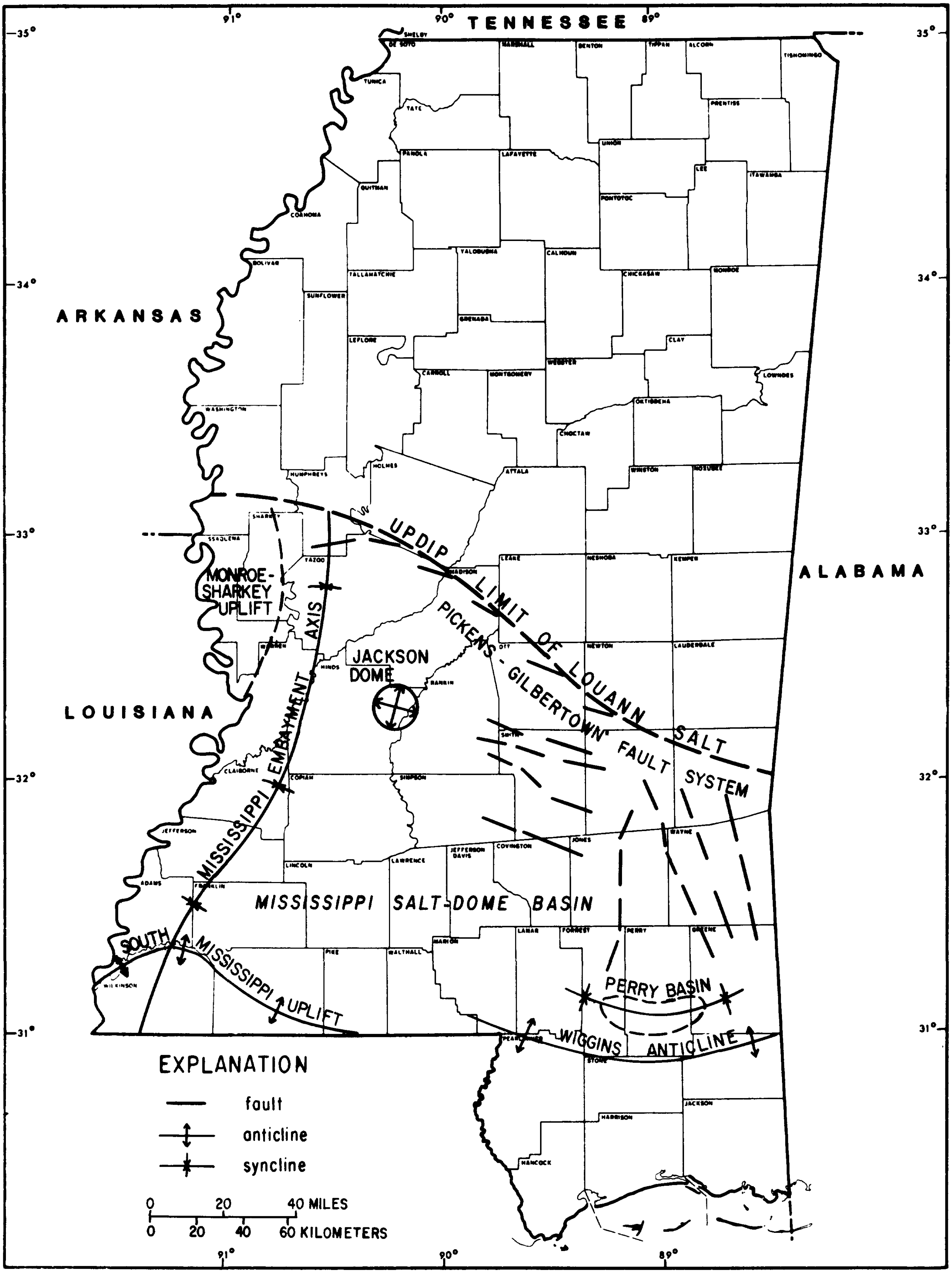
The Mississippi salt-dome basin (fig. 1) contains 50 piercement-type salt domes. The presence of most of these domes has been confirmed by seismic and gravity surveys. Of the 50 salt domes in the Mississippi salt-dome basin, 30 are less than 4,000 ft (1,220 m) from land surface to the top of the dome. The top of caprock of 20 of the domes occurs at a depth of 2,000 ft (610 m) or less; three of these domes (Richton, Cypress Creek, Lampton) have been selected for more intensive geohydrologic studies. Richton Dome is the largest dome in the basin and the top of the dome is also the closest to land surface, about 700 ft (213 m) to the caprock (Bicker, 1970).

The salt-dome basin is roughly limited on the north and east by the Pickens-Gilbertown fault system and on the south by the Wiggins anticline and the South Mississippi uplift (fig. 2). In the northwestern part of the basin the Monroe-Sharkey uplift is the dominant structural feature; the Jackson Dome, caused by igneous intrusion rather than salt piercement, is in the north-central part.

The geologic strata in the basin consist mainly of poorly lithified discontinuous sandstones and interbedded shale with minor amounts of marl, limestone, and sandstone. The southern part of the salt-dome basin is situated near a transition zone where the stratigraphic section changes from predominantly sand in the north to predominantly shale in the south. Also some clay formations in the north, which may act as confining beds, undergo facies changes to water-bearing limestones in the southern part of the basin.

The changing patterns of structure development and sedimentation since the end of the Paleozoic Era has produced stratigraphic complexities in the salt basin. Additional complexity is introduced by numerous ancient river channels in which tongues of channel sands were deposited, generally normal to the present strike of the strata. Although complex, the regional structural and stratigraphic framework is well known, and much of the specific geologic data is available from reports by Eargle (1968) and Anderson and others (1973).

The oldest subsurface formation yet penetrated by test wells is the Louann Salt of Jurassic age, which is believed to be the source bed for the salt domes. The Louann Salt is overlain by younger predominately clastic sediments of Jurassic age that are in turn overlain by marine and deltaic deposits of Cretaceous age. The uppermost deposits are Tertiary deltaic sediments that are overlain locally by thin deposits of Pleistocene sand and gravel.



(from Mississippi Geological Society, 1957)

Figure 2.--Structural features in the salt-dome basin.

The piercement salt domes have penetrated the deposits overlying the Louann Salt causing severe structural deformation of the material adjacent and overlying the salt domes. The tops of many piercement salt domes in the basin have penetrated Tertiary deltaic strata ranging from the Wilcox Group of Paleocene and Eocene age upward to the Catahoula Sandstone and Hattiesburg Formation of Miocene age.

Table 1 shows the nomenclature of the surface and subsurface units in the salt-dome basin and describes the lithologic and hydrologic characteristics of each, and figure 3 depicts the areal extent of the outcrop of the geologic units.

Fresh ground water in the salt-dome basin in Mississippi extends to depths of more than 3,000 ft (914 m). Major sources of freshwater in the salt-dome basin include: (1) sands of the Wilcox Group in the northern part of the basin, (2) the Sparta Sand and the Cockfield Formation in the central part and, (3) the Oligocene and Miocene aquifers in the central and southern part. The Mississippi River valley alluvial aquifer in the extreme western part of the salt-dome basin contains freshwater, but it is not considered an important aquifer to this study. Although they are highly exaggerated vertically, the geohydrologic sections presented in figures 4 through 8 illustrate the generalized shallow stratigraphy and the relation of the freshwater to saltwater aquifers. Chemical analyses found in table 2 represent the chemical constituents in each of the major freshwater aquifers in the basin.

The depth to the base of freshwater generally increases in the south or southwest direction of dip of the strata (fig. 9), except for three major abrupt changes where the depth to the base decreases. These abrupt changes mark the limit of the movement of freshwater from the outcrop areas downdip into certain aquifers or groups of aquifers; hence, there is a vertical upward shift in the base of freshwater to the next shallowest fresh aquifer (fig. 9). The most northerly change marks a boundary of freshwater in the lower Wilcox aquifers, and the next abrupt change in the base of freshwater coincides with the downdip limit of freshwater in the Meridian-upper Wilcox aquifer (Boswell, 1976). The third major change is the downdip limit of freshwater in the Sparta Sand (Payne, 1968).

In the area of the salt basin where fresh ground water does not exist beneath the Miocene beds, salt domes tend to be shallower than elsewhere in the basin. The possibility exists that the depth to the tops of the salt domes is in part determined by movement of ground water. The direction and rate of movement of freshwater in the strata into which the upper parts of these domes penetrate is likely to be complicated on a local scale by (1) variable distribution of channel sands, (2) variation of composite thickness of sand interbeds, (3) structured disturbance related to movement of the salt, and (4) pumping. Although little information is available about saline aquifers near these domes, reports by Taylor and others (1968) and Shows and others (1966) give information on the geohydrology of the freshwater aquifers.

Table 2. Chemical analyses from selected wells--Continued.

(DISSOLVED CONSTITUENTS AND HARDNESS GIVEN IN MILLIGRAMS PER LITER)

Well no.	Water bearing unit	Well depth (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
								JONES COUNTY										
C035	122 MOCN	483	6/51	29	0.01	3.4	2.1	7.9	5.3	212	8.2	3.8	0.5	243	17	337	7.9	10
D003	124 SPRT	640	4/55	--	--	2.7	1.1	218	5.6	429	49	28	2.0	556	1	880	8.6	70
D045	124 CCKF	710	10/62	15	0.10	1.0	0.0	--	--	--	50	27	0.2	489	10	--	8.4	65
								LAMAR COUNTY										
B001	122 MOCN	400	1/62	20	0.30	4.5	0.7	3.9	1.3	22	1.0	3.1	0.2	60	14	62	5.9	10
J001	122 MOCN	782	5/61	11	0.60	5.2	0.3	58	1.8	154	7.4	4.5	0.0	208	14	261	8.2	30
J003	122 MOCN	1,310	5/61	9.2	0.29	14	1.7	126	3.9	226	99	21	0.9	420	42	675	7.4	10
J005	124 CKMN	2,390	6/61	13	4.40	87	50	7,040	12	510	25	11,000	3.0	--	422	28,900	7.8	40
J011	123 VKBG	1,959	5/61	11	0.43	4.5	0.4	557	11	601	6.6	522	3.0	1,480	13	2,430	8.1	50
								MARION COUNTY										
G006	122 MOCN	1,040	10/66	14	0.27	0.9	0.3	54	2.0	137	6.4	2.4	0.3	148	4	219	7.4	0
Q020	122 MOCN	1,300	8/66	11	0.88	3.0	0.4	8.0	2.6	20	10	2.3	0.1	84	9	64	6.4	50
R002	122 MOCN	850	1/62	47	1.50	2.0	0.5	18	1.7	44	7.6	2.9	0.2	115	7	106	6.5	20
								PERRY COUNTY										
C015	122 MOCN	736	8/78	12	1.10	14	2.3	150	3.0	130	29	180	0.1	447	44	826	6.7	10
C040	122 MOCN	660	8/78	11	0.44	4.9	1.7	31	2.7	88	7.2	7.0	0.0	112	19	185	6.6	2
H010	122 MOCN	810	11/69	12	1.40	17	1.8	730	5.9	478	25	855	1.0	1,920	50	3,430	8.1	--
J015	122 MOCN	576	6/79	20	0.04	4.4	1.4	98	2.1	130	14	85	0.1	312	17	480	7.8	0
M002	122 MOCN	460	5/64	18	0.03	2.6	0.1	154	0.4	148	14	148	0.1	380	7	742	7.9	5
R007	122 MOCN	347	11/69	20	0.01	0.4	0.5	64	0.7	147	7.8	6.7	0.3	172	3	261	7.8	0

Table 2. Chemical analyses from selected wells.

WATER BEARING UNIT--124 MUWX, MERIDIAN-UPPER WILCOX AQUIFER; 124 SPRT, SPARTA SAND; 124 CKMN, COOK MOUNTAIN FORMATION; 124 CCKF, COCKFIELD FORMATION; 123 FRHL, FOREST HILL SAND; 123 VKBG, VICKSBURG GROUP; 122 MOCN, MIOCENE SERIES; 122 MRVA, MISSISSIPPI RIVER VALLEY ALLUVIAL AQUIFER; 110 ALVM, ALLUVIUM.

(DISSOLVED CONSTITUENTS AND HARDNESS GIVEN IN MILLIGRAMS PER LITER)

Well no.	Water bearing unit	Well depth (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
ADAMS COUNTY																		
C002	122 MOCN	612	3/61	42	1.10	64	20	29	3.5	356	12	5.0	0.3	352	240	557	6.7	10
C012	122 MOCN	600	4/61	41	0.23	4.2	0.9	136	4.7	366	12	3.9	0.2	402	14	585	6.9	100
F016	112 MRVA	180	9/61	16	0.69	73	35	11	1.9	400	8.2	12	0.2	389	326	618	7.7	5
K001	122 MOCN	523	6/61	48	0.35	8.0	1.0	94	5.1	255	12	5.0	0.2	307	24	429	7.4	5
FORREST COUNTY																		
A023	122 MOCN	752	3/65	11	0.49	10.0	2.9	23	3.8	96	9.8	2.0	0.1	106	37	187	7.0	10
D004	122 MOCN	485	2/64	26	0.91	5.3	2.6	9.2	3.4	43	8.8	2.5	0.4	80	24	97	6.2	20
D029	110 ALVM	134	5/64	20	0.07	1.4	0.6	2.1	1.1	10	0.2	2.3	0.0	19	6	29	5.3	0
E026	122 MOCN	900	2/74	12	0.10	3.5	2.0	60	3.5	147	7.6	3.2	0.4	177	17	226	8.0	3
HINDS COUNTY																		
D002	124 CCKF	1,177	6/74	15	0.10	0.8	0.1	180	1.5	382	23	22	1.0	443	2	689	8.3	100
G062	124 CCKF	724	6/74	20	0.04	18.0	7.9	140	5.3	289	83	34	0.3	233	77	700	7.6	3
G084	124 SPRT	996	6/75	17	0.01	6.9	0.5	120	0.8	278	7.7	2.1	0.2	273	19	420	8.3	45
H092	124 MUWX	1,444	10/56	9.2	0.85	2.1	0.4	485	5.5	1,170	1.2	14	6.0	116	6	1,790	8.5	90
L030	124 CCKF	1,168	6/74	17	0.02	1.1	0.1	150	1.4	298	40	26	0.6	275	3	625	8.2	80
N015	124 MUWX	1,446	12/45	18	0.04	3.8	1.3	838	12	1,790	0.4	204	4.4	2,080	15	3,210	7.8	60
0015	122 MOCN	169	9/59	21	1.50	48	26	55	10	376	13	24	0.4	383	227	63	7.1	3
0031	123 FRHL	366	6/72	14	0.08	1.1	0.1	280	2.5	675	4.2	21	1.5	704	3	1,080	7.9	160
V077	124 SPRT	2,076	7/78	23	0.03	0.4	0.1	100	0.6	260	3.2	3.8	0.2	259	1	410	8.8	85

--Continued--

Principal Water-Bearing Units and Confining Beds

Wilcox Group

The heterogeneous Wilcox Group includes thick beds of brown, gray, and green clay and shale, clayey sand, and, at irregular intervals, thin, hard limestone beds. Lignite is common throughout the Wilcox and is particularly abundant in the upper and middle parts. Wilcox strata dip toward the southwest part of the basin at a rate of about 45 ft/mi (850 cm/km) (fig. 10). Downdip, facies changes result in more shales and limestone occurring in the Wilcox beds. These low-permeability beds restrict the flushing of the formations by freshwater and allow saline water to remain. Figures 6 through 10 are geohydrologic sections that show stratigraphic relations, structural trends, and the base of freshwater.

Generally, freshwater in the Wilcox moves downdip toward the south or southwest (Boswell, 1975), but where water in the Wilcox becomes saline, little is known about the rate and direction of ground-water flow. Most water wells that would provide water-level information and data needed to determine hydraulic characteristics for the aquifers are located updip in the freshwater part of the Wilcox Group.

Where the Wilcox contains freshwater, the water is predominately a sodium-bicarbonate type (table 2). Generally, water in the Wilcox changes from a calcium-bicarbonate type near the outcrop areas to a sodium-bicarbonate type as it moves southwestwardly downdip. Oil-test data indicate that the water in the Wilcox in the central part of the salt-dome basin is predominantly a sodium-chloride type (rather than sodium bicarbonate) having total dissolved solids ranging from 1,400 mg/L in Madison County to 89,000 mg/L in Forrest County.

Further estimation of water quality using electric logs for Wilcox aquifers in the salt-dome basin will require collection of water samples to determine formation factors. Newcome (1975a) determined average formation factors for the Wilcox beds, but his data came only from the freshwater and slightly saline-water zones.

Sparta Sand

The Sparta Sand increases in thickness from about 75 ft (23 m) in the outcrop area to more than 400 ft (122 m) in the southwest part of the basin. The Sparta Sand comprises thick beds of gray and brownish sandy shale, brown clayey sand, with lignite occurring at some horizons. The underlying Zilpha Clay and Winona and Tallahatta Formations, which are mostly shale, hydraulically separate the Sparta from the Wilcox Group (figs. 4-8).

The Sparta beds dip about 30 ft/mi (570 cm/km) toward the southwest part of the basin (fig. 11). The beds dip more steeply in the southwest part of the basin near the Gulf Coast geosyncline.

Freshwater in the Sparta moves downdip to the south and west in south Mississippi as far south as Copiah and Simpson Counties. Payne

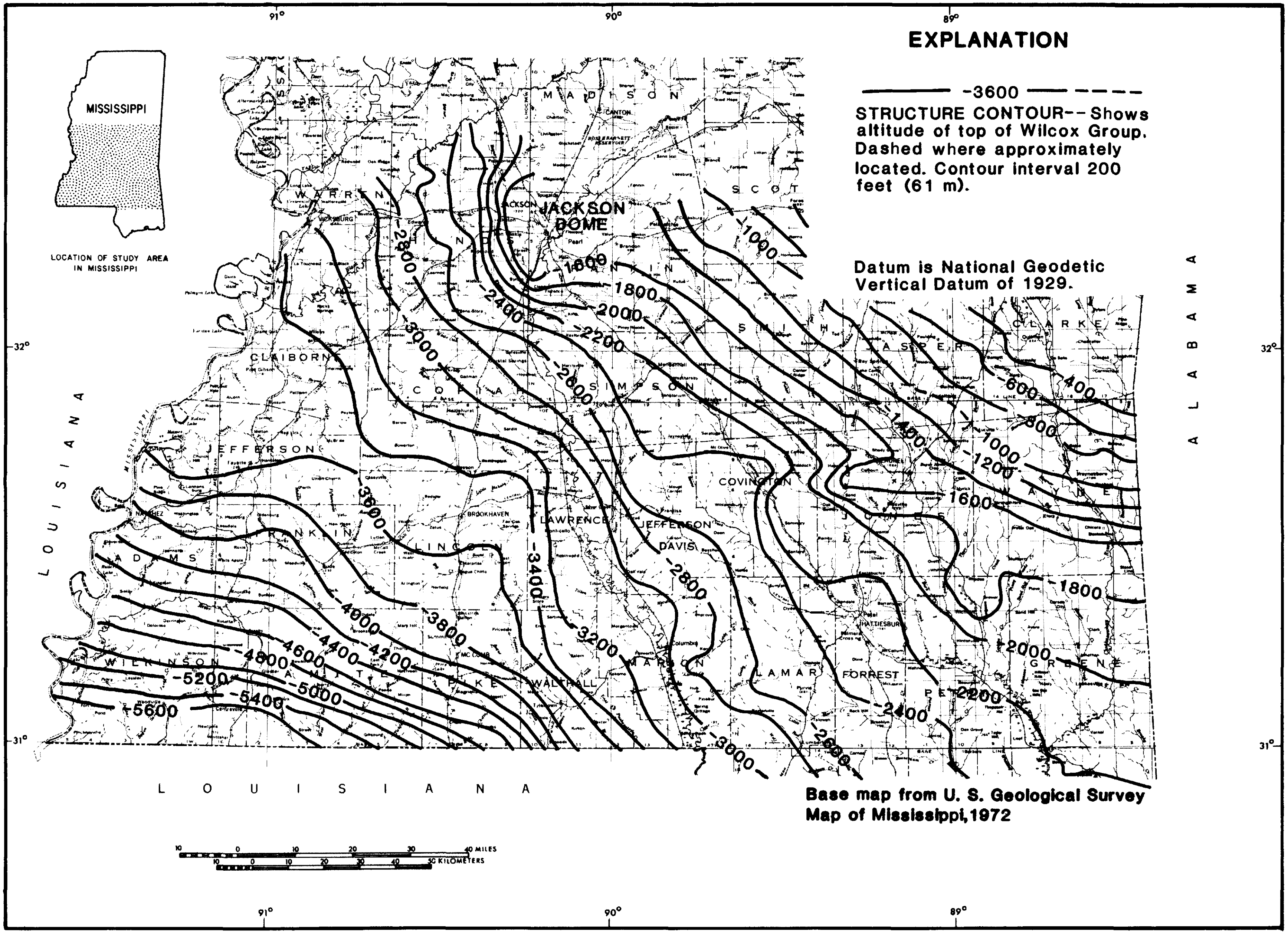


Figure 10.-- The configuration of the top of the Wilcox Group.

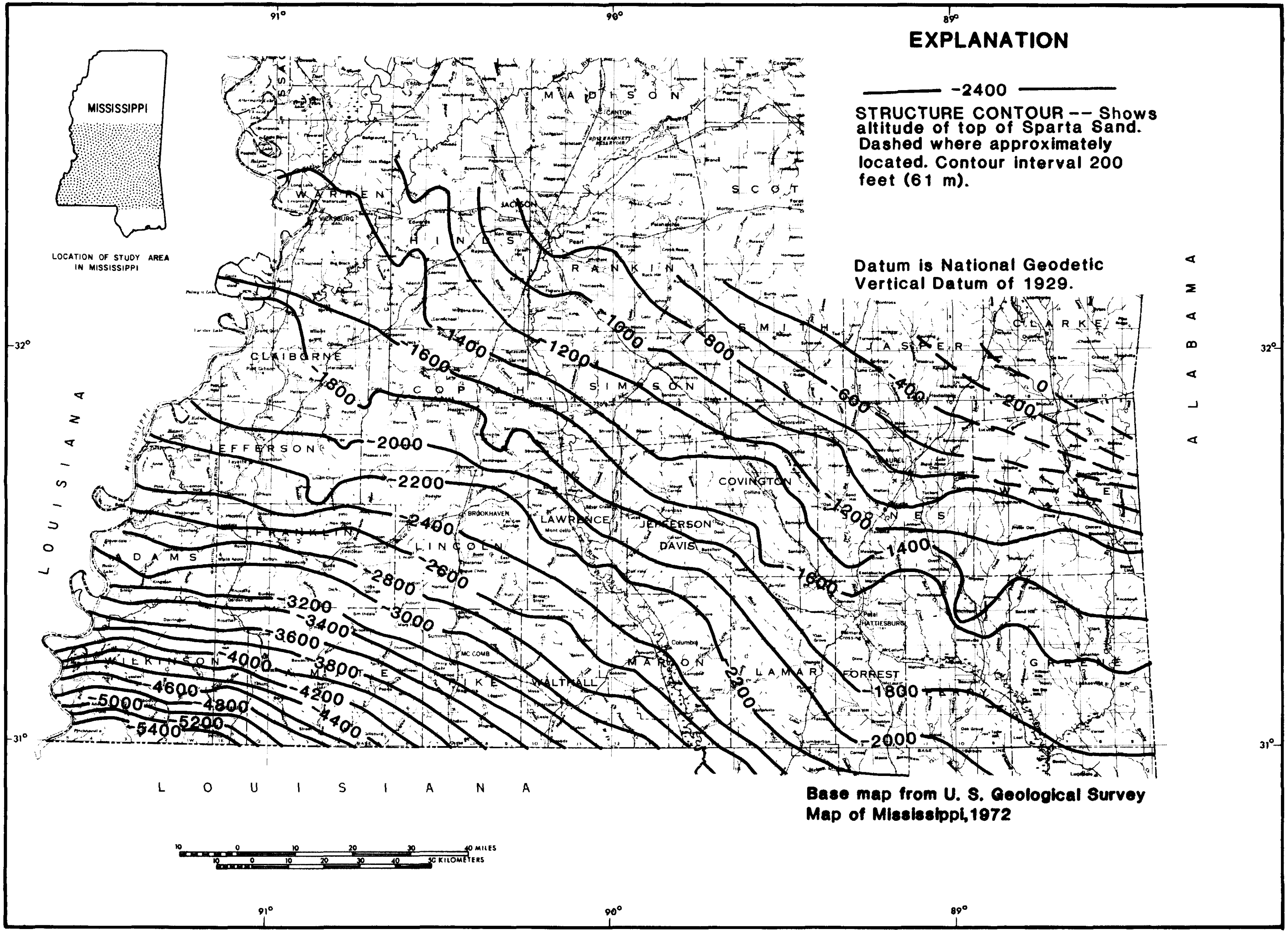


Figure 11.-- The configuration of the top of the Sparta Sand.

(1968) theorized that water in the Sparta is moving westward toward the trough of the Mississippi Embayment and upward through younger formations. The degree of flushing in the Sparta is related to permeability and thickness of the sand and to the altitude of the recharge areas that provide the hydraulic head.

Although much information about the Sparta in the freshwater area is available, nothing is known about the direction and rate (velocity) of movement of water in the salt-dome basin. Also, there is little information about the relation of water levels in the Sparta to water levels in other aquifers, especially in the southern half of the basin.

Water from the Sparta aquifer is a sodium-bicarbonate type and the increase in dissolved solids downdip to the limit of freshwater is mainly in those two constituents. Beyond the limit of freshwater, little is known about the chemical content of the water in the Sparta; however, analyses of water collected from oil test wells show that water from the Sparta in the salt-dome basin has dissolved-solids concentrations from 22,000 to 58,000 mg/L and is predominately the sodium-chloride type.

Cook Mountain Formation

The Cook Mountain Formation, known also as the "Camerina limestone," is a bioclastic limestone that contains some thin beds of bentonitic clay (Eargle, 1968). Updip, the Cook Mountain contains more clay and acts as a lower confining unit for the Cockfield and upper confining unit for the Sparta Sand. Downdip and in the southern part of the basin, the formation reaches a thickness of over 500 ft (152 m) and undergoes a facies change from clay to limestone (figs. 8-10).

Taylor, while studying the geohydrology near Tatum dome (Taylor and others, 1968), determined that the velocity of water movement in the Cook Mountain was 0.09 ft/year (2.7 cm/year) and the direction of movement near the dome was to the southwest; however, he believed the injection of brine from oil fields locally modified the movement of ground water in the Cook Mountain.

Elsewhere in the salt-dome basin no data are available to substantiate the velocity and direction of water movement in the Cook Mountain Formation. It should be stressed that the average velocity of native formation water should not be used for predicting the rate and distance of movement of substances introduced into the ground-water system (Lohman, 1972).

Little is known about the water quality in the Cook Mountain in the salt-dome basin except at Tatum dome where the sum of analyzed constituents exceeds 18,000 mg/L (table 2, Lamar County, well J005).

Cockfield Formation

The Cockfield, the youngest unit of the Claiborne group (table 1), consists of about 200 ft (61 m) of sand, lignite, and irregularly bedded sandy, carbonaceous, chocolate-brown or gray clay. It is thickest in the western part of the salt-dome basin and thins toward the east and southeast. The regional dip of the beds is about 30 ft/mi (570 cm/km) (fig. 12) toward the southwest.

The downdip limit of freshwater in the Cockfield is approximately the same as in the Sparta Sand (figs. 4-8), although the permeability of the formation is less.

There is little water-level information about the Cockfield aquifers in the salt-dome basin, and rate and direction of ground-water flow is indeterminate. As a result of facies changes there is little sand in the downdip part of the formation; therefore, the Cockfield is not considered an important aquifer in the salt-dome basin.

Jackson Group

The Yazoo Clay, the uppermost formation of the Jackson Group, is a distinctive clayey unit about 200 to 400 ft (61 to 122 m) thick in the subsurface in the northern half of the basin and is underlain by the 30 ft (9 m) thick Moodys Branch Formation. The Yazoo is a confining bed in the southern half of the basin. Northeastward in the salt-dome basin the Cocoa Sand Member of the Yazoo Clay is considered an aquifer. The Yazoo Clay dips 30 ft/mi (570 cm/km) toward the southwestern part of the basin (fig. 13).

No freshwater is found below the Yazoo in the south half of the salt-dome basin, and any vertical movement of saline water from deeper aquifers would be restricted by the clay.

Oligocene Aquifers

Aquifers of Oligocene age include the Forest Hill Sand (the updip lateral transition from the Red Bluff Clay), the Vicksburg Group, and the Chickasawhay Limestone.

Freshwater in Oligocene aquifers does not extend as far from the outcrop as does freshwater in the more permeable Sparta Sand and Cockfield Formation except in the east. At Tatum dome the direction of water movement in the Vicksburg Group was to the southwest, and the velocity of movement was 0.1 ft/yr (3.1 cm/yr) (Taylor, 1964).

In the southern half of the salt-dome basin there is only one chemical analysis for water from the Vicksburg Group. The water sample was taken at Tatum dome and the concentration of dissolved solids in the sample was 1,480 mg/L (table 2, Lamar County, Well J011).

Miocene Aquifers

Miocene deposits occur throughout most of the salt-dome basin (fig. 3). Miocene sediments form a wedge that thickens gulfward and has its base about 4,000 ft (1,220 m) below NGVD (National Geodetic Vertical Datum of 1929) in southern Wilkinson County (fig. 14). These sediments dip gulfward at a rate of 30 to 100 ft/mi (570 to 1,890 cm/km); the rate of dip is least in the near-surface zone.

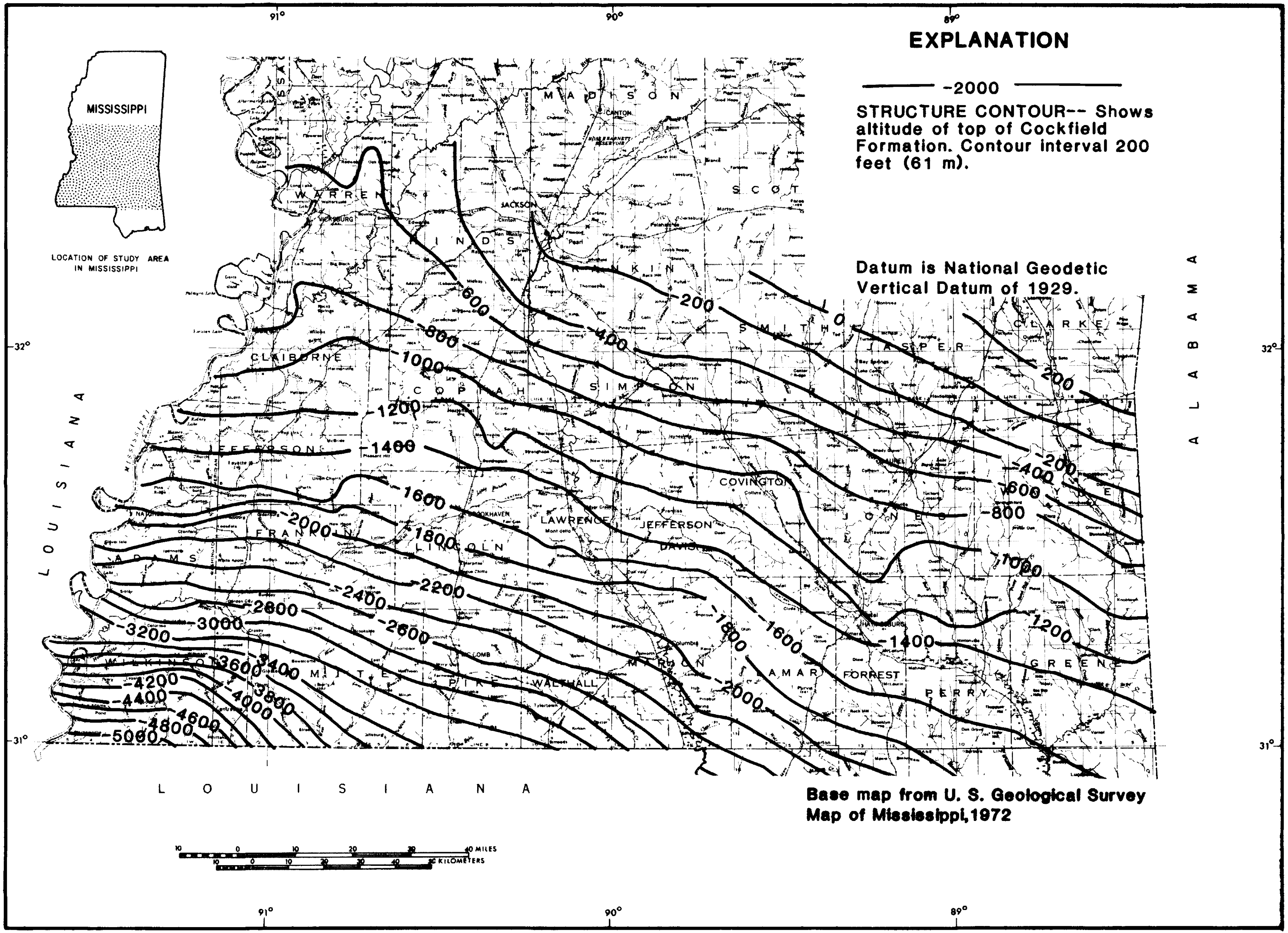


Figure 12.-- The configuration of the top of the Cockfield Formation.

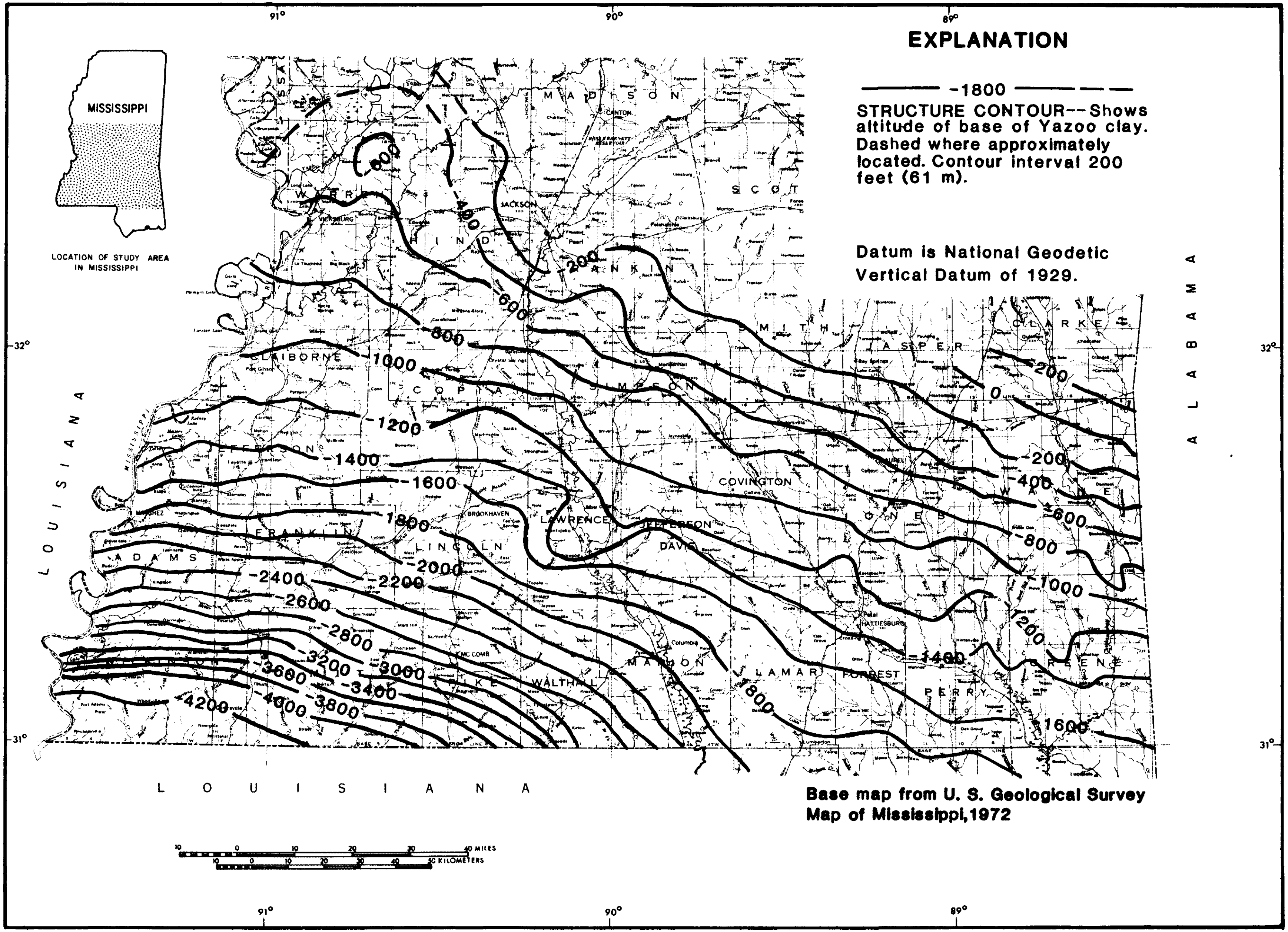


Figure 13.-- The configuration of the base of the Yazoo Clay.

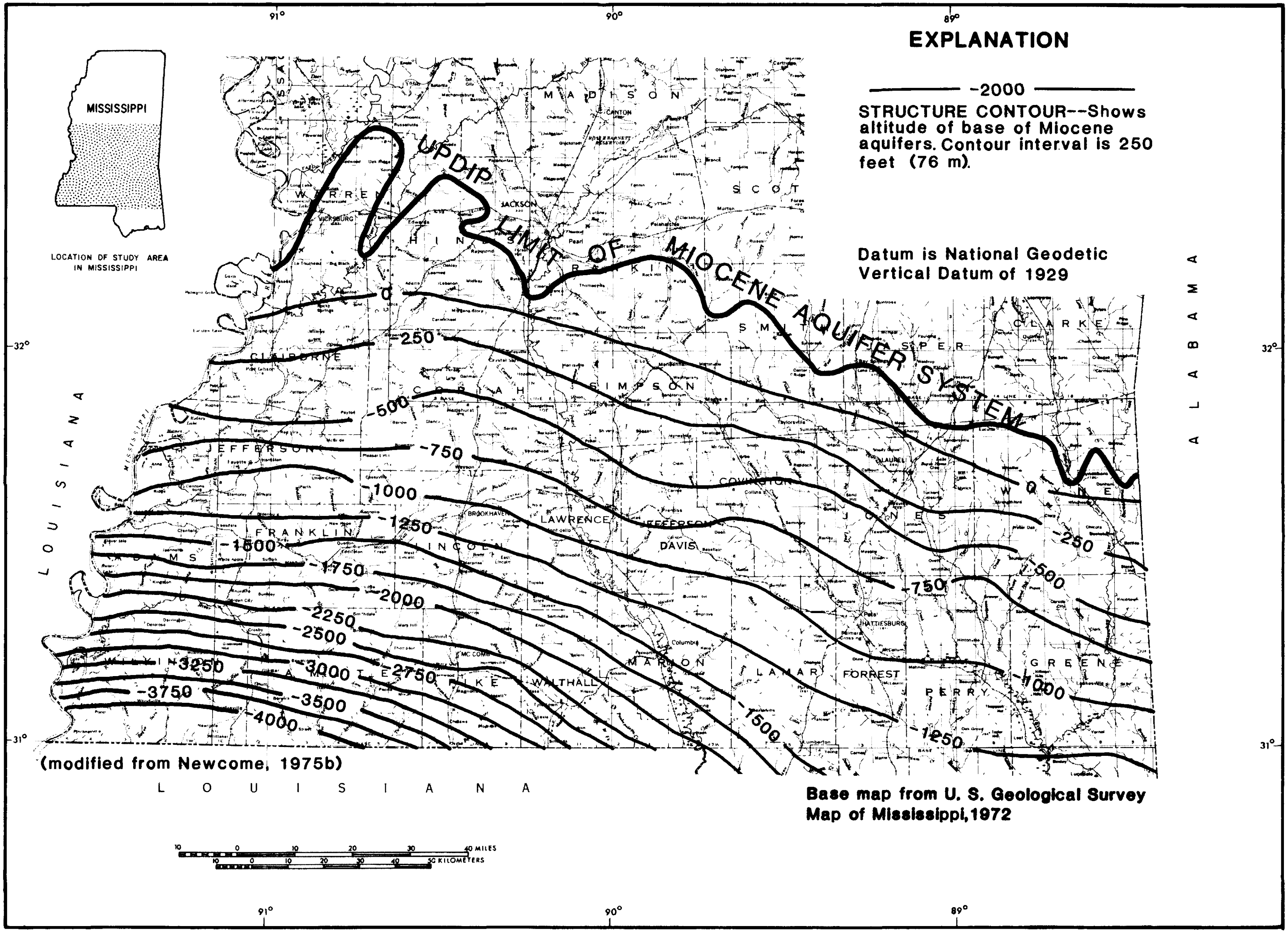


Figure 14.-- The configuration of the base of the Miocene aquifers.

Beds of Miocene age are divided into the Catahoula Sandstone and the undifferentiated Pascagoula and Hattiesburg Formations. The Catahoula Sandstone, gray-to-olive sand, silt, silty clay and white-to-gray limestone and marl, attains a maximum thickness of 1,800 ft (550 m) in the salt-dome basin. The Catahoula Sandstone dips south to southwestward at about 35 ft/mi (660 cm/km) (fig. 15).

The Pascagoula and Hattiesburg Formations are difficult to differentiate in Mississippi and some geologists do not separate the units. Both units consist of greenish-gray silty clay and sand. The maximum combined thickness is more than 2,000 ft (610 m).

In the northern part of the salt-dome basin, freshwater occurs below the base of the Miocene in the Oligocene aquifers, and in the Cockfield Formation, and the Sparta Sand.

Freshwater is available from the Miocene aquifers, but not everywhere from the entire thickness of Miocene section. In the Miocene, the base of the freshwater section dips southward to about 2,600 ft (790 m) below NGVD, but at a lower rate than the formational dip. As a result, the lower part of the Miocene Series contains saline water in much of southern Mississippi. The upper parts of Miocene aquifers are fresh everywhere in the salt-dome basin (table 2), but the quality of water may be altered locally by oil-field wastes, dissolution of salt domes, or by upward dispersion of saline water. The map showing the configuration of the base of freshwater (fig. 9) and the geohydrologic sections (figs. 4-8) illustrate the thickness of the freshwater section and its relation to the base of the Miocene Series.

Because of its thickness, areal extent, and permeability, the Miocene aquifer system is the largest potential source of ground water in the State. In much of the basin only the upper few hundred feet of the system have been significantly developed, and many thick aquifers remain untapped. Most of the public water supply and industrial wells that tap the Miocene are described by Callahan (1975).

The Miocene aquifers appear to have a greater water-transmitting capacity than do the deeper aquifers in the salt-dome basin. An average hydraulic conductivity of about 100 $(ft^3/d)/ft^2$ or 30 $(m^3/d)/m^2$ was estimated from 200 aquifer tests. With the substantial cumulative thickness of sand in the Miocene section (fig. 16), it may be possible for transmissivities to be as great as 120,000 $(ft^3/d)/ft$ or 11,000 $(m^3/d)/m$ in the extreme southern part of the basin.

The Miocene aquifers are recharged by rainfall directly on the outcrops, by infiltration from overlying surficial deposits (Citronelle Formation, and terrace and alluvial deposits), and by vertical movement through the clay and silt beds that separate sand units.

Figure 17 shows a generalized potentiometric surface in the upper part of the Miocene. Water in the western part of the basin is moving westward toward the Mississippi River, whereas in the east half of the salt-dome basin, ground water is moving toward the Pearl and the Leaf Rivers or into heavily pumped areas. Much of the flow in the upper part of the Miocene may be intercepted by streams or pumping well fields.

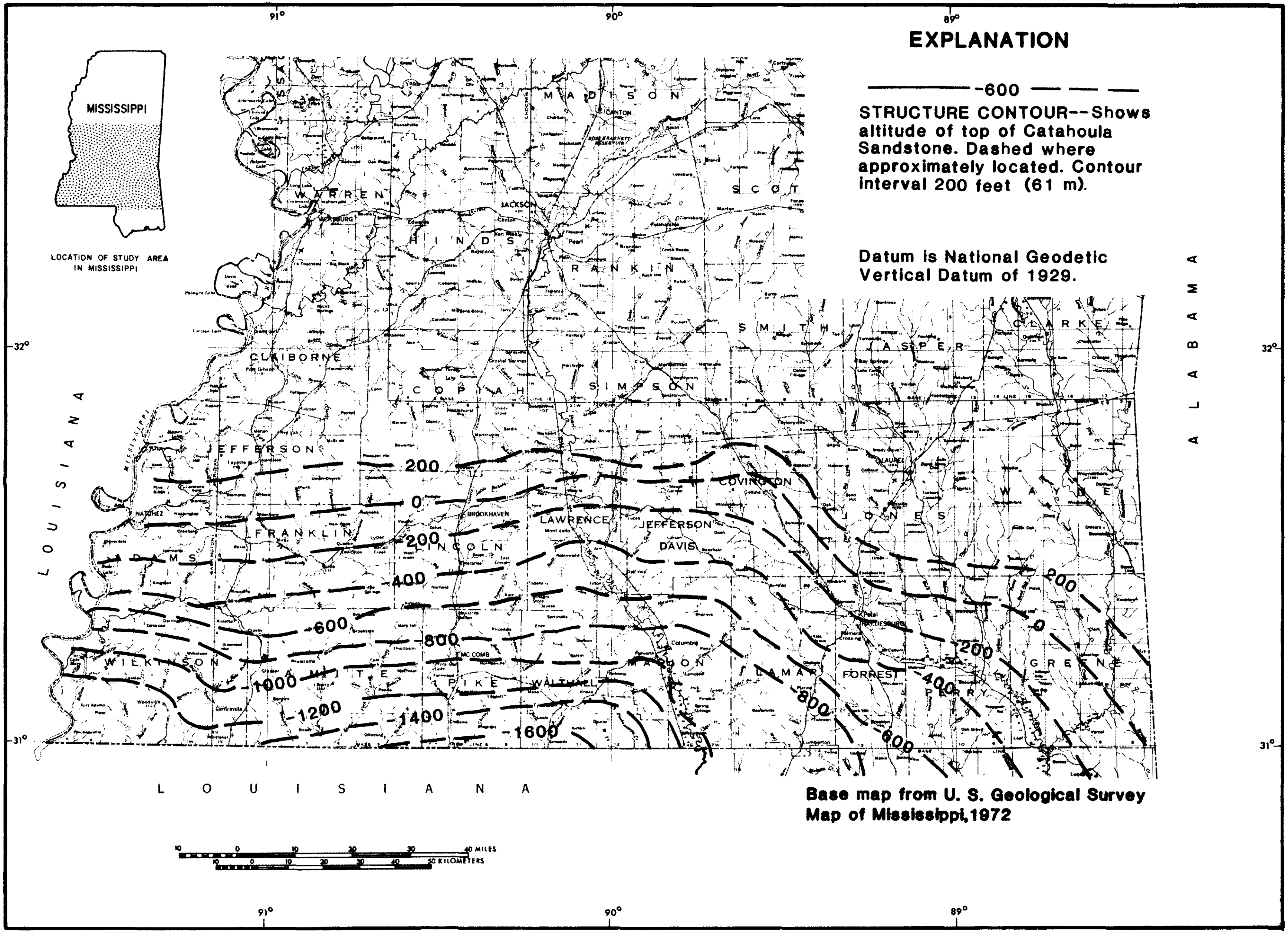


Figure 15.-- The configuration of the top of the Catahoula Sandstone.

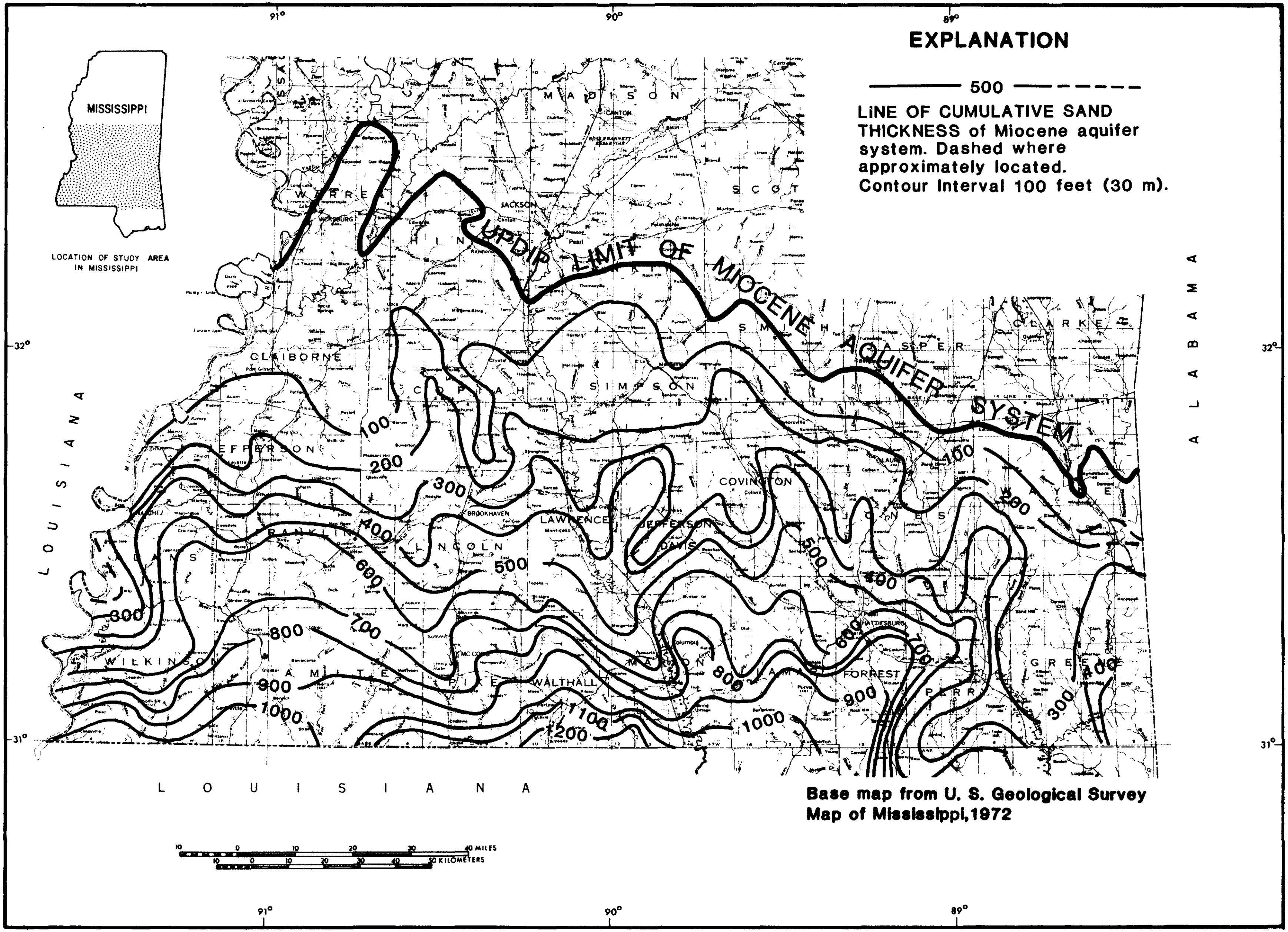


Figure 16.-- The cumulative sand thickness of Miocene aquifers.

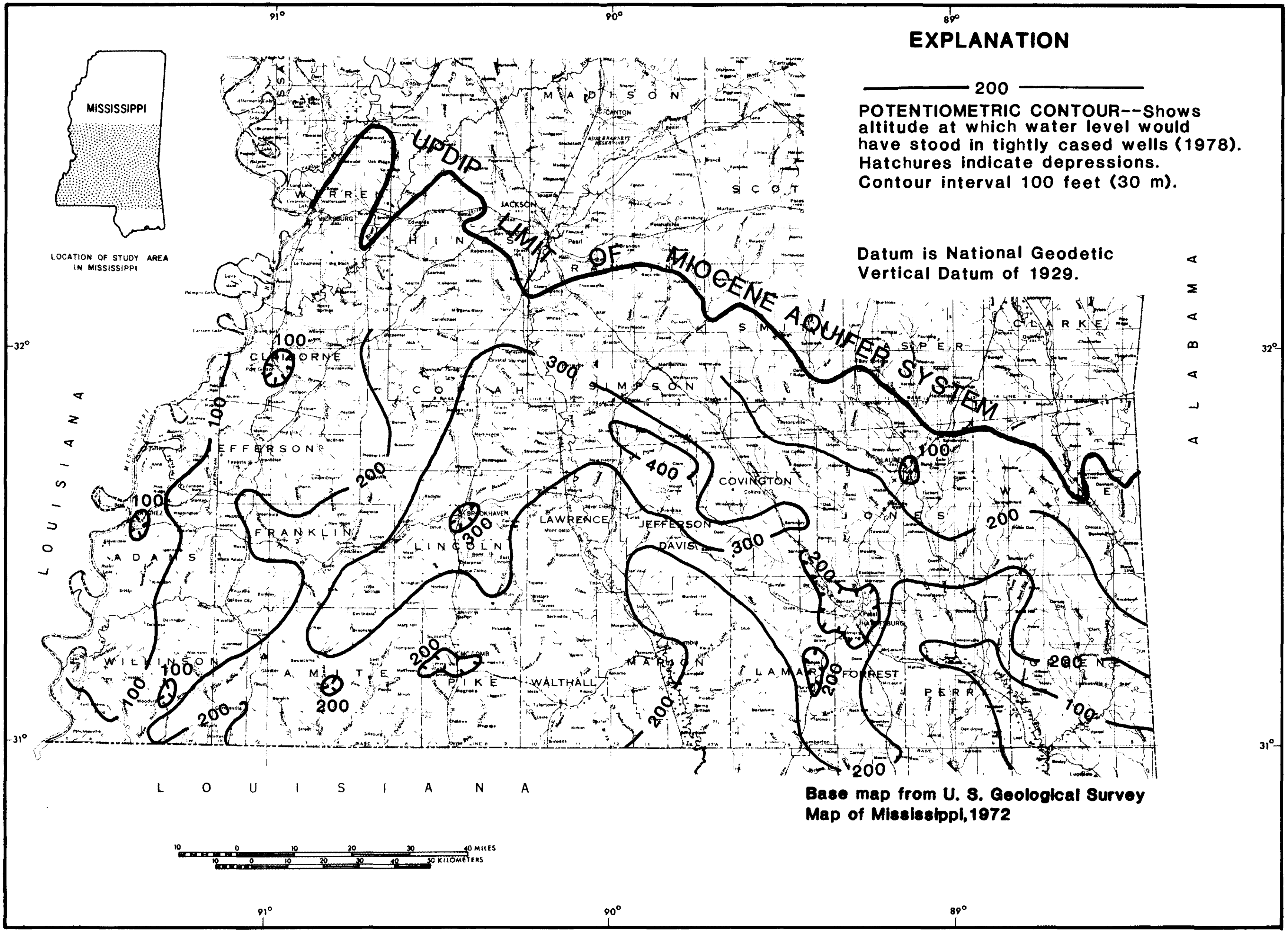


Figure 17.-- The generalized potentiometric surface of the Miocene aquifers, 1978.

It is difficult to delineate an accurate potentiometric surface for the Miocene. Many sand beds in the Miocene are discontinuous and there are head differences between sands in the aquifer. Also, difficulty in determining the potentiometric surface is compounded by the lack of head data at depth (below 1,000 ft or about 300 m).

The hydraulic gradient in the Miocene aquifers ranges from 5 to 15 ft/mi or 95 to 280 cm/km (figure 17). Assuming a porosity of 0.30 and a hydraulic conductivity of 100 $(ft^3/d)/ft^2$ or 30 $(m^3/d)/m^2$, the average velocity of water movement is 110 to 350 ft/yr (33 to 107 m/yr). The range of velocities determined for Miocene aquifers in the salt-dome basin does not fulfill the need for a more exact estimate of rates of water movement near individual domes. At Tatum dome the velocity of water movement in Miocene aquifers ranged from less than 0.1 ft/yr (.03 m/yr) to about 15 ft/yr (4.6 yr) (Taylor, 1964).

SALT-DOME GEOHYDROLOGY

Piercement Salt Domes

The Louann Salt, Jurassic in age, is generally believed to be the bedded salt from which domes in the salt-dome basin are derived. The domes of the Mississippi salt-dome basin were probably formed during Late Cretaceous to Oligocene time, and some investigators believe that no significant movement of the domes has occurred since Miocene time.

Although most salt domes in Mississippi are roughly circular in plan view and range in diameter from about 0.5 to 3.5 mi (0.8 to 5.6 km), great diversity exists in dome geometries, dome-to-caprock relations, and dome-to-flankrock orientations. The height of these salt domes above their base is not uniform and is dependent in part on the thickness of the parent salt layer, the amount of salt that is mobilized, and the thickness of overlying sediments that must be pierced. Upward movement of salt of domes is possible because the salt is plastic under great pressure and is less dense than surrounding compacted sediments. Heights above the Louann are known to range from 10,000 to 20,000 ft (3,000 to 6,000 m). Many of these domes spread outward at depth and are connected at the base with the parent salt layer. Other domes are more constricted at depth and, like an inverted teardrop, may be pinched off at the base and disconnected from the parent layer (Johnson and Gonzales, 1978).

Salt domes in Mississippi, on a regional basis, do not significantly affect ground-water flow across the salt-dome basin, but locally they affect flow patterns in aquifers affected by the dome. If aquifers adjacent to the dome are tilted upward or faulted by movement of the dome, then possible avenues of ground-water flow occur. Ground water could move in the upturned beds along the flanks of the dome causing dissolution of the salt. Also, faulting could allow ground water to move from deeper saline aquifers upward into freshwater aquifers provided there were sufficient head differences between aquifers.

The caprock occurs not only on the top of many domes but occurs also along the flanks of the dome. Caprock may be the result of dissolution of the salt over long periods of geologic time. The thickness of the caprock, therefore, may provide a measure of the amount of dissolution that has occurred.

The presence of a salt-water plumes in aquifers adjacent to the domes would be another indication of dissolution of the salt. However, in Mississippi there is no direct evidence from water wells that salt domes are in contact with moving ground water. The reason for this lack of evidence may be the limited number of water wells near the domes and the lack of information about the relation of the salt and the caprock to adjacent aquifers. Also, water-level information is available only for the upper part of the freshwater aquifers. Information on water levels for the deeper saline aquifers near domes is not available.

Selected Domes

In 1977, Union Carbide Corporation, Nuclear Division, OWI (Office of Waste Isolation) contracted with Law Engineering and Testing Co. to coordinate the geologic investigations and testing services for the Gulf Coast salt basins. Late in 1977 Battelle Memorial Institute, ONWI (Office of Nuclear Waste Isolation) assumed the responsibilities of Union Carbide for directing the nuclear waste repository studies for the Department of Energy. From criteria established by ONWI and its predecessor OWI, three salt domes in Mississippi were selected for more intensive geohydrologic studies; Richton and Cypress Creek in Perry County and Lampton in Marion County (fig. 1). Criteria used to select these three domes from the 50 domes in the salt-dome basin were:

1. size (greater than 1,000 acres or 2,470 hm^2),
2. depth (less than 2,000 ft or 610 m to the top of the dome),
3. the absence of mines or solution cavities,
4. proximity of surface waters (lakes or streams),
5. the distance from large population areas.

Richton Dome

Richton dome, located in northern Perry County (fig. 18) about 15 miles (24 km) east of Hattiesburg, is the largest and shallowest dome in the Mississippi salt-dome basin. The dome lies beneath the drainage divide between the Bogue Homo River and Thompson Creek. Altitudes of land surface over the dome range from 160 to 280 ft (49 to 85 m). In plan section it is an elliptical structure with its long axis oriented northwest to southeast (fig. 19). At a depth of 1,000 ft (305 m) the long axis of the section is about 3.5 mi (5.6 km), the short axis is about 1.5 mi (2.4 km), and the area is about 4,000 acres (9,880 hm^2).

During the 1930's, 34 exploratory test holes for sulfur were drilled on or near the dome. Data from these holes delineated the geometry of the dome and the altitude of surrounding strata. Caprock was reached at depths as shallow as 497 ft (151 m), and the top of the salt was as shallow as 722 ft (220 m) (Mellen, 1976). Salt may have penetrated to the base of the Oligocene Forest Hill Sand, but this

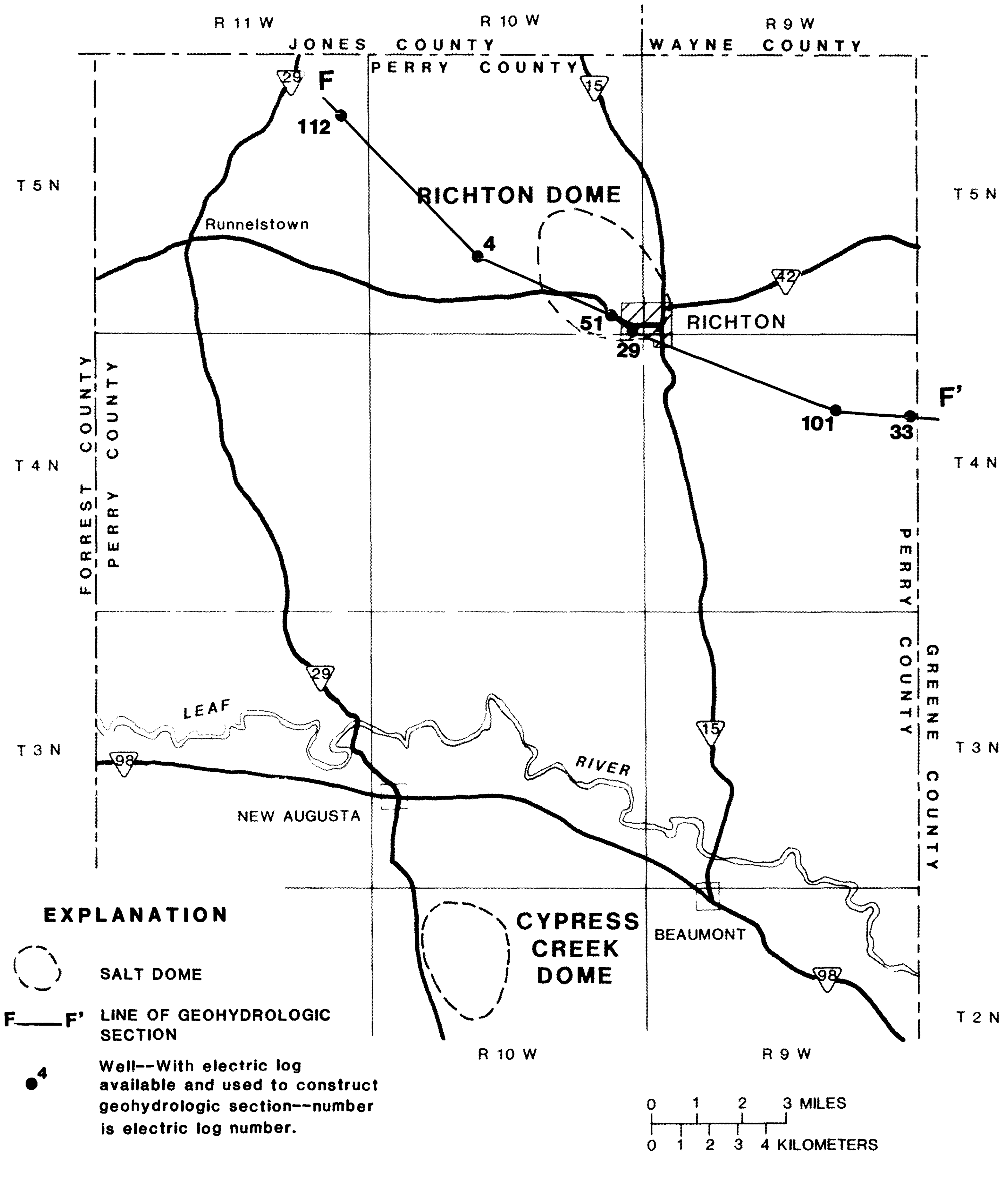


Figure 18.--The location of Richton and Cypress Creek domes and geohydrologic section F-F'.

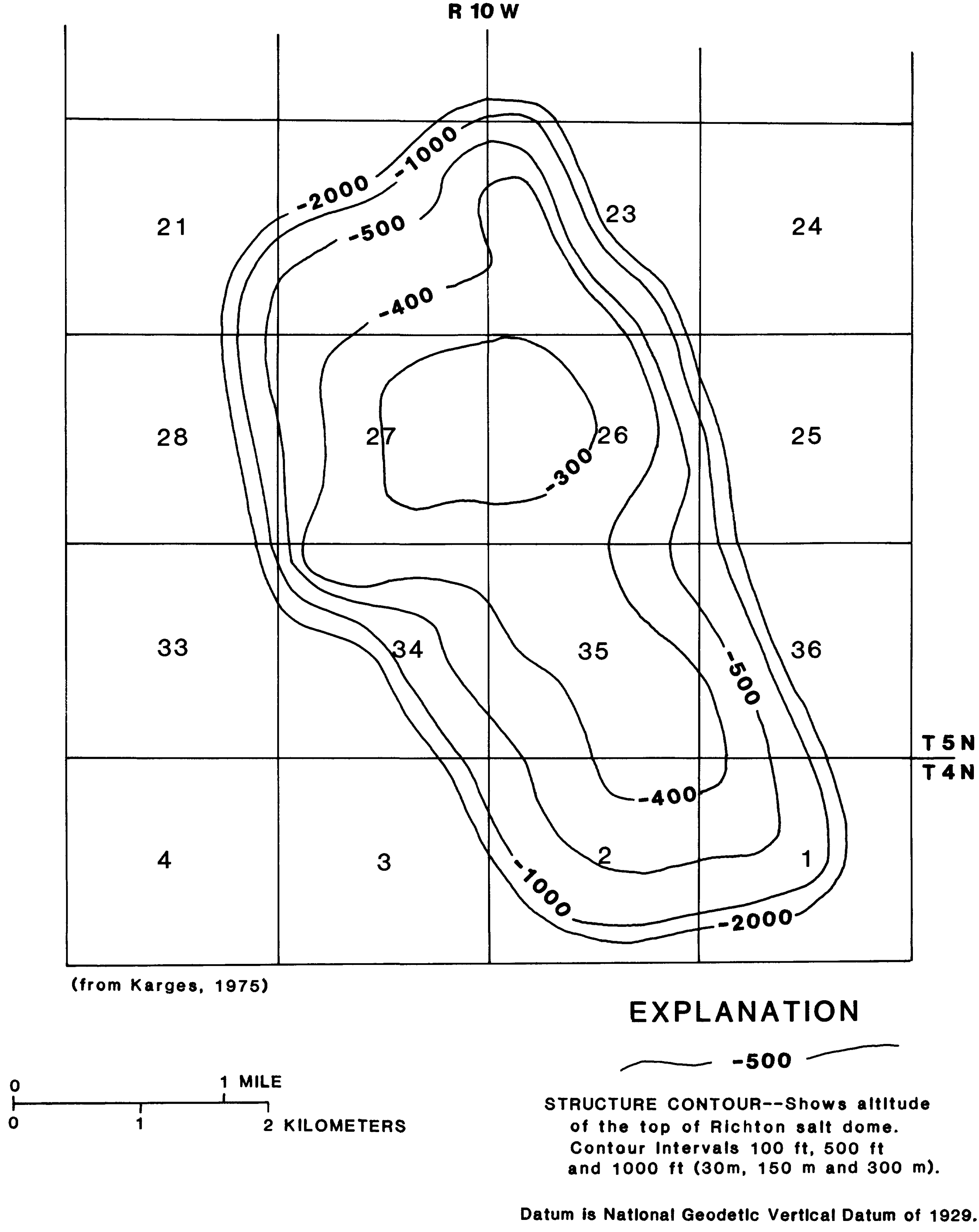


Figure 19.--The configuration of the top of Richton dome.

cannot be substantiated without further test drilling. The approximate positions of geohydrologic units shown in figure 20 illustrate how these units are affected by upward movement of the dome.

Water levels in Miocene freshwater aquifers near the dome range from 200 ft (61 m) above NGVD to about 110 ft (34 m) near the Leaf River south of the dome. Data from water wells in Perry County indicate that recharge to freshwater aquifers might be occurring locally near the dome, and that aquifer discharge areas might be located near the Leaf River. Flowing wells near the town of New Augusta (fig. 18) indicate that water levels in the confined aquifers are higher than the land surface near the Leaf River (Shows and others, 1966), and that ground water is discharging upward through the alluvial deposits near the river.

Although the base of freshwater near Richton dome appears to occur near the base of the Catahoula Sandstone (about 400 ft or 122 m below NGVD, fig. 20), some electric logs indicate that the Vicksburg Group might also contain freshwater. South of the dome (downdip) the base of freshwater appears to be much higher in the geologic section than elsewhere in Perry County. This might be evidence of (1) a saline plume originating from the dome, or (2) the possibility of saline water moving upward to replace freshwater discharged near the Leaf River basin, or (3) unflushed saline water remaining in the aquifers.

Some well drillers have reported slightly saline water in water wells west of and northwest of the town of Richton over the shallowest part of the dome. Also, chemical analyses of water taken from wells in the town of Richton show chloride concentrations more than 100 mg/L higher than the average for the Miocene aquifers that might be a result of ground water that has been in contact with the salt. Other analyses of water taken from water wells south of Richton dome near Beaumont and New Augusta also show chloride concentrations more than 60 mg/L higher than average.

Cypress Creek Dome

Cypress Creek dome is located in south-central Perry County about 5 mi (8 km) west of Beaumont and 5 mi (8 km) southeast of New Augusta (fig. 18). The dome is located in a part of Camp Shelby Military Reservation that includes a part of DeSoto National Forest.

Cypress Creek dome is thought to be larger than 1,000 acres (2,470 hm^2) at a depth of 1,500 feet (460 m), but only gravity data substantiate this. An oil-company test hole is reported to have penetrated salt at 1,447 ft (441 m) on the north edge of the dome. A marsh located over the top of the dome may have formed in a lowland caused by dissolution of salt and collapse of overlying sediments. If so, a saline plume may have formed during the dissolution process. The plume, if it exists, will probably be elongated in the direction of ground-water flow. Present water-level data near the dome are too sparse to indicate the direction and rate of ground-water flow.

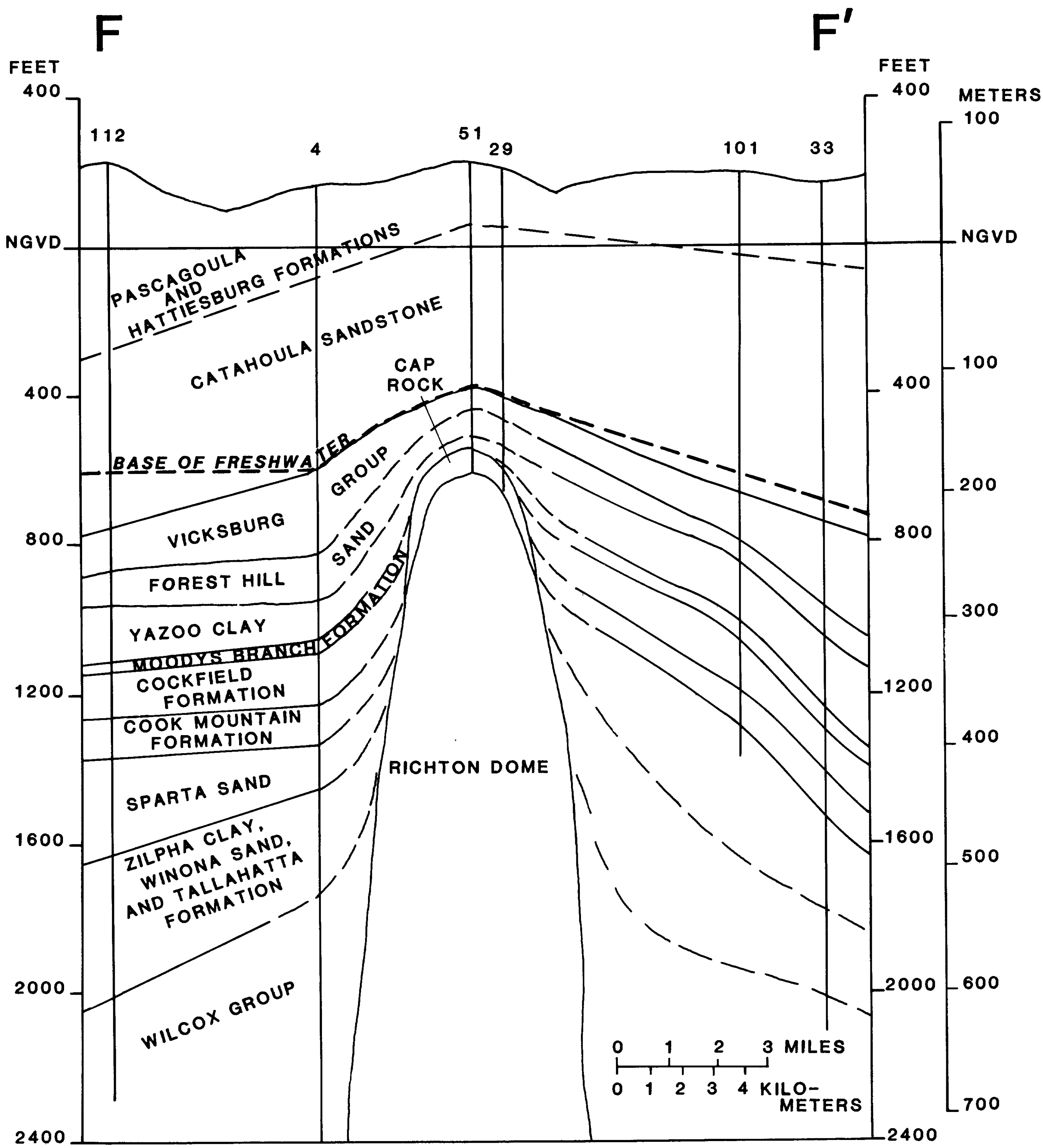


Figure 20.-- Geohydrologic section F-F′ through Richton dome.

Lampton Dome

The Lampton salt dome is located 7 mi (11 km) southeast of Columbia in east-central Marion County (fig. 21). The dome lies beneath the east-west trending drainage divide between Upper Little Creek and Lower Little Prong Creek. The altitude of land surface near the dome ranges from 200 to 370 feet (61 to 113 m). The shape of the dome is circular to slightly elongated in a north-south direction (fig. 22). The area of the dome at a depth of 3,000 ft (914 m) is 1,400 acres (3,460 hm^2) (Law Engineering, 1978). The cap rock is about 1,200 ft (366 m) below NGVD, and the base of freshwater is approximately 200 ft (61 m) above the caprock.

Thin surficial deposits of sand and gravel of the Citronelle Formation overlie the Pascagoula and Hattiesburg Formations in the immediate vicinity of the dome (fig. 23). Freshwater sands of the Pascagoula and Hattiesburg overlie the Catahoula Sandstone, the basal unit of the sedimentary beds that extend across the dome. The base of the freshwater is in the lower part at the Catahoula Sandstone.

The freshwater section reaches a maximum thickness of 1,200 ft (366 m) in the dome area. Chemical analyses of water from nearby water wells show no evidence of saline water near the dome, and the base of freshwater, interpreted from electric logs, is 1,000 ft (305 m) below NGVD over the dome and as much as 1,400 ft (427 m) below NGVD on the flanks.

Existing water wells near the dome are too few to supply sufficient water-level information to indicate the rate and direction of ground-water flow.

ADDITIONAL DATA NEEDS

To evaluate the geohydrology of Richton, Lampton, and Cypress Creek domes as possible sites for storage of radioactive waste the following tasks are necessary:

1. determine more accurately direction and rate of regional and local ground-water flow
2. determine hydrologic relations between aquifers and domes
3. describe character, configuration, and permeability of the caprock
4. determine hydrologic stability of the domes (dissolution of the salt)
5. determine water quality in the aquifers.

To obtain this information, an intensive drilling and testing program near these domes will be necessary. Test holes should be drilled near the domes so that all major aquifers can be investigated and sampled. Additional test holes drilled into the caprock can determine the salt-caprock and caprock-aquifer hydrologic relationships. Selected test wells can be completed as permanent observation wells in a water-quality and water-level monitoring network. The wells can monitor head changes in aquifers that might be affected by nearby pumping, and they can be used to determine potentiometric gradients near the domes.

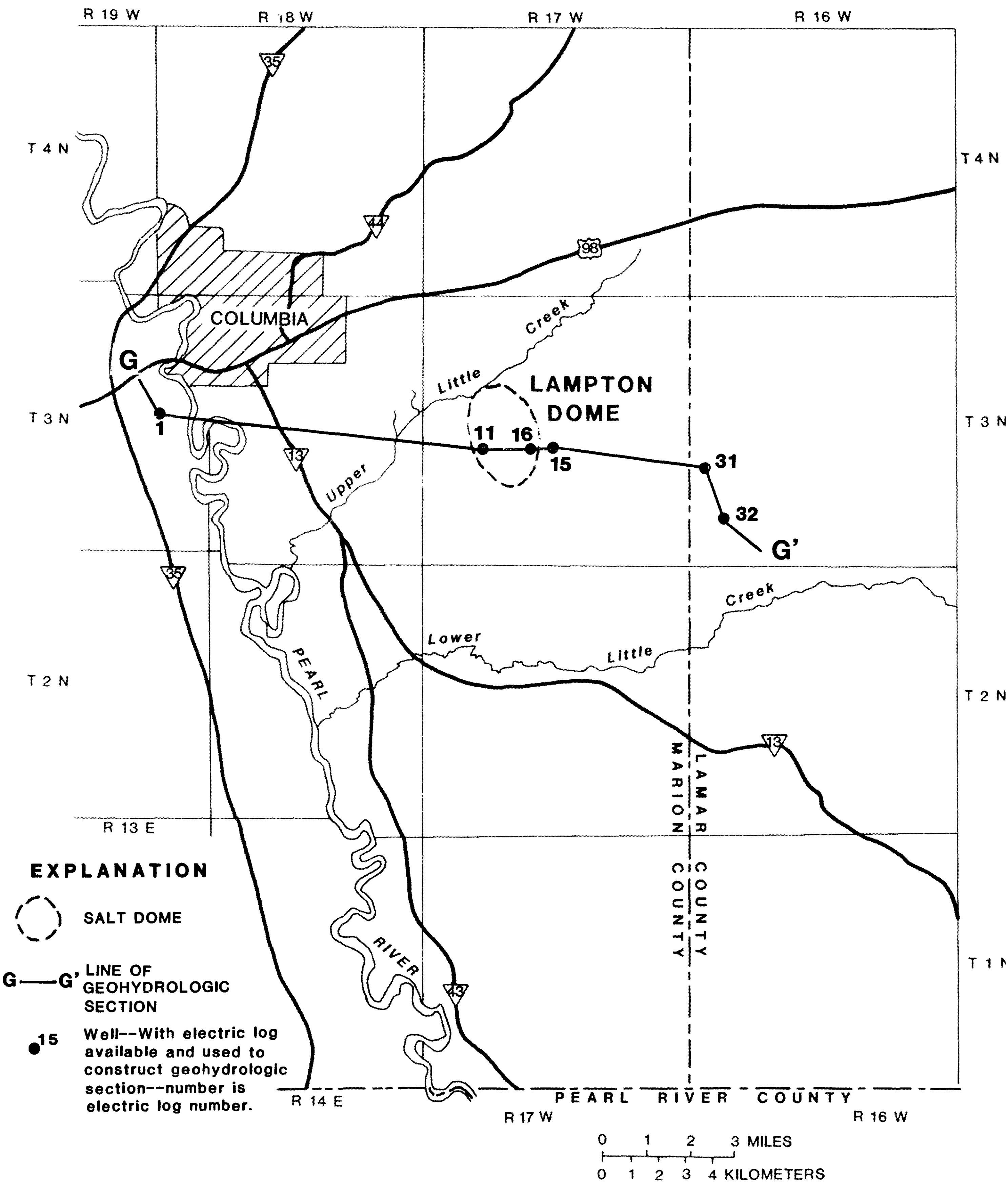
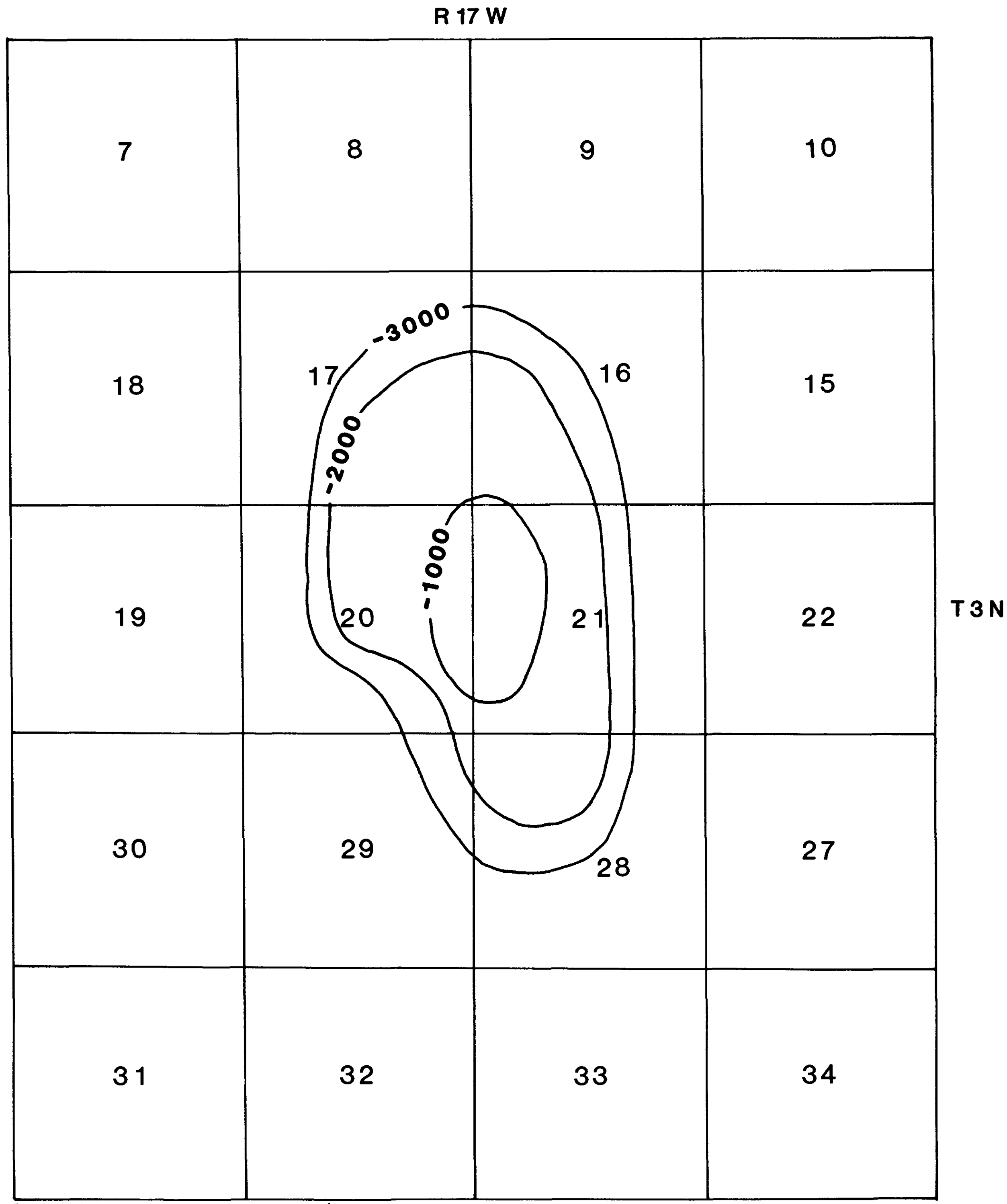
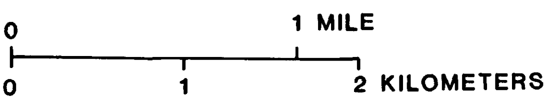


Figure 21.--The location of Lampton dome and geohydrologic section G-G'.



(from Law Engineering, 1978)



EXPLANATION

-2000

STRUCTURE CONTOUR--Shows altitude of the top of Lampton salt dome Contour interval 1000 ft (300m).

Datum is National Geodetic Vertical Datum of 1929.

Figure 22.--The configuration of the top of Lampton dome.

The types of information that should be obtained in this drilling program are:

1. geophysical logs
2. lithologic and hydraulic characteristics of aquifers and confining beds
3. lithologic and hydraulic characteristics of the salt and the caprock
4. chemical analyses from the freshwater and saltwater aquifers
5. water levels in each aquifer.

These data will answer many questions about the geohydrology of salt domes. The studies will provide part of the information necessary for decisions about utilizing domes as possible repositories for radioactive waste.

SUMMARY

The geohydrology of the Mississippi salt-dome basin is complex. Regional stratigraphic facies changes and discontinuous sand beds in many aquifers make determination of potentiometric surfaces in aquifers difficult. Domes were formed by salt that penetrated upward through aquifers in the basin. The geohydrology near domes is complex owing to the effect of the dome on surrounding aquifers. This activity caused upturned, faulted, and deformed beds adjacent to the domes that might affect ground-water flow near the domes.

Little is known about the ground-water hydrology adjacent to the three domes selected for more intensive geohydrologic studies (Richton, Cypress Creek, and Lampton). Although a significant amount of geologic and hydrologic data was acquired at Tatum dome, comparable data have not been obtained at other domes.

To evaluate the geohydrology of Richton, Lampton, and Cypress Creek domes as possible sites for storage of radioactive waste, an intensive drilling and testing program is needed. This comprehensive program for the collection of geologic and hydrologic data will be necessary to provide the information needed for decisions about utilizing domes as possible repositories for radioactive waste.

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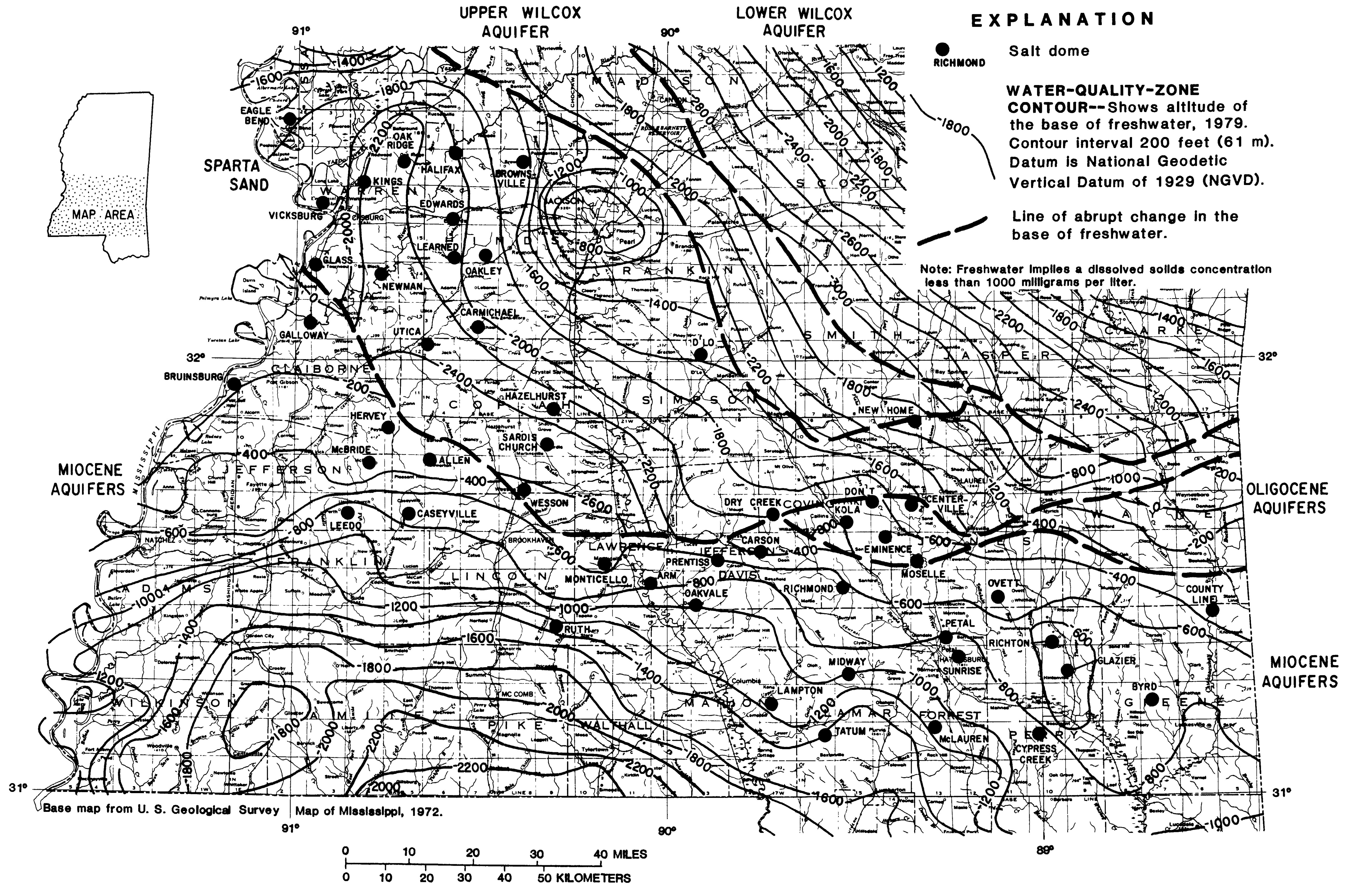

Figure 9.--The base of freshwater in the salt-dome basin.

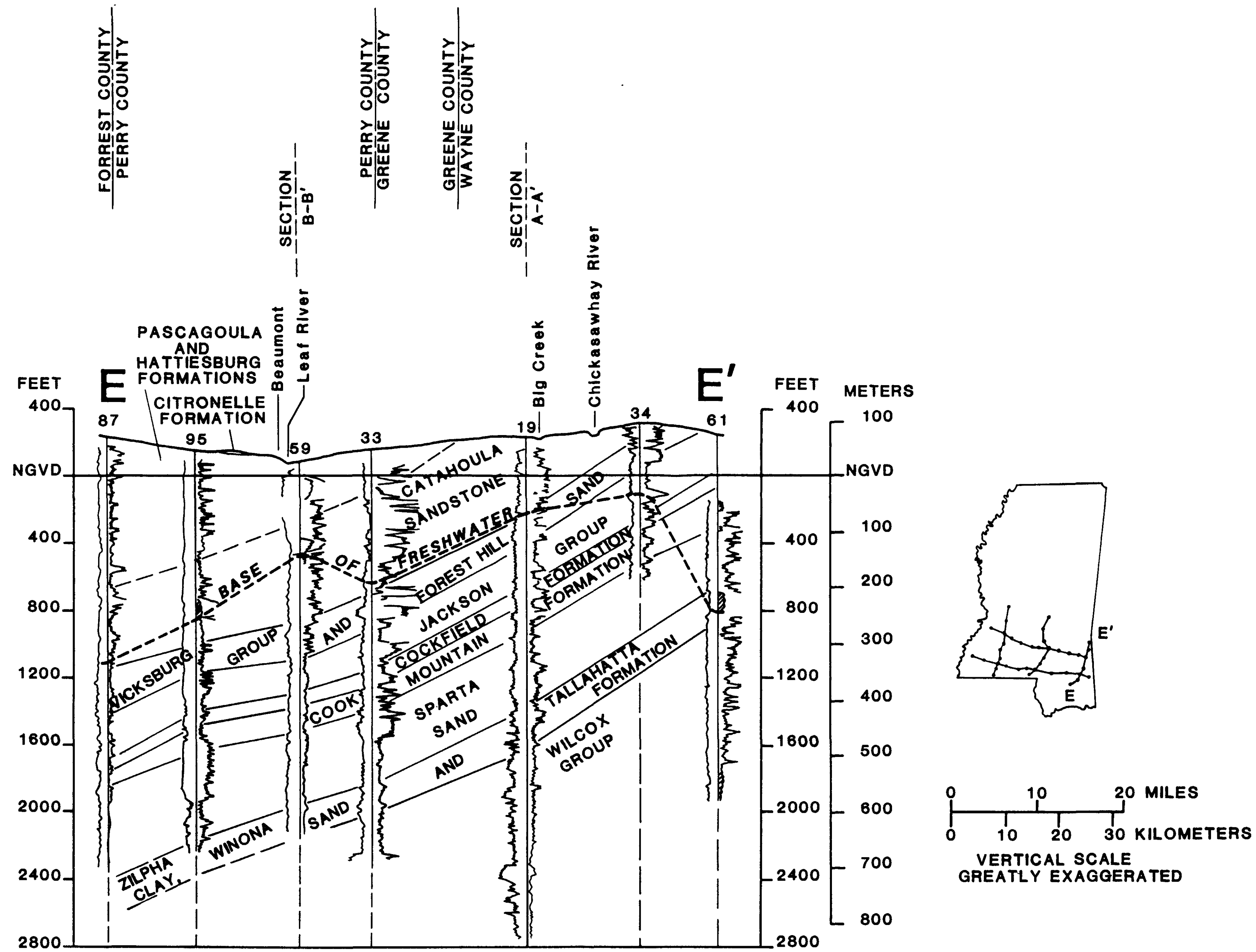

Figure 8.-- Geohydrologic section E-E' from Forrest to Wayne County.

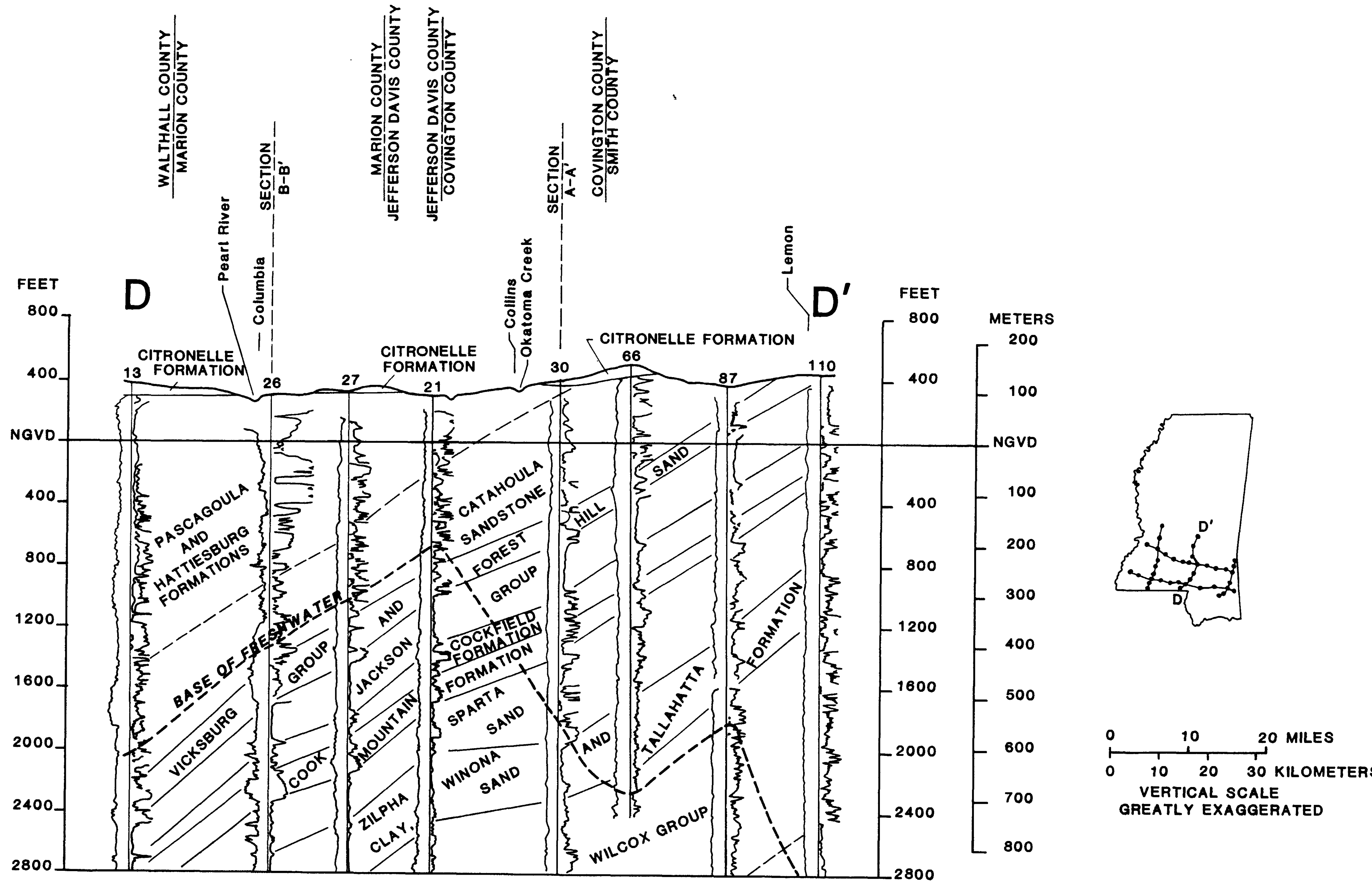

Figure 7.-- Geohydrologic section D-D' from Walthall to Smith County.

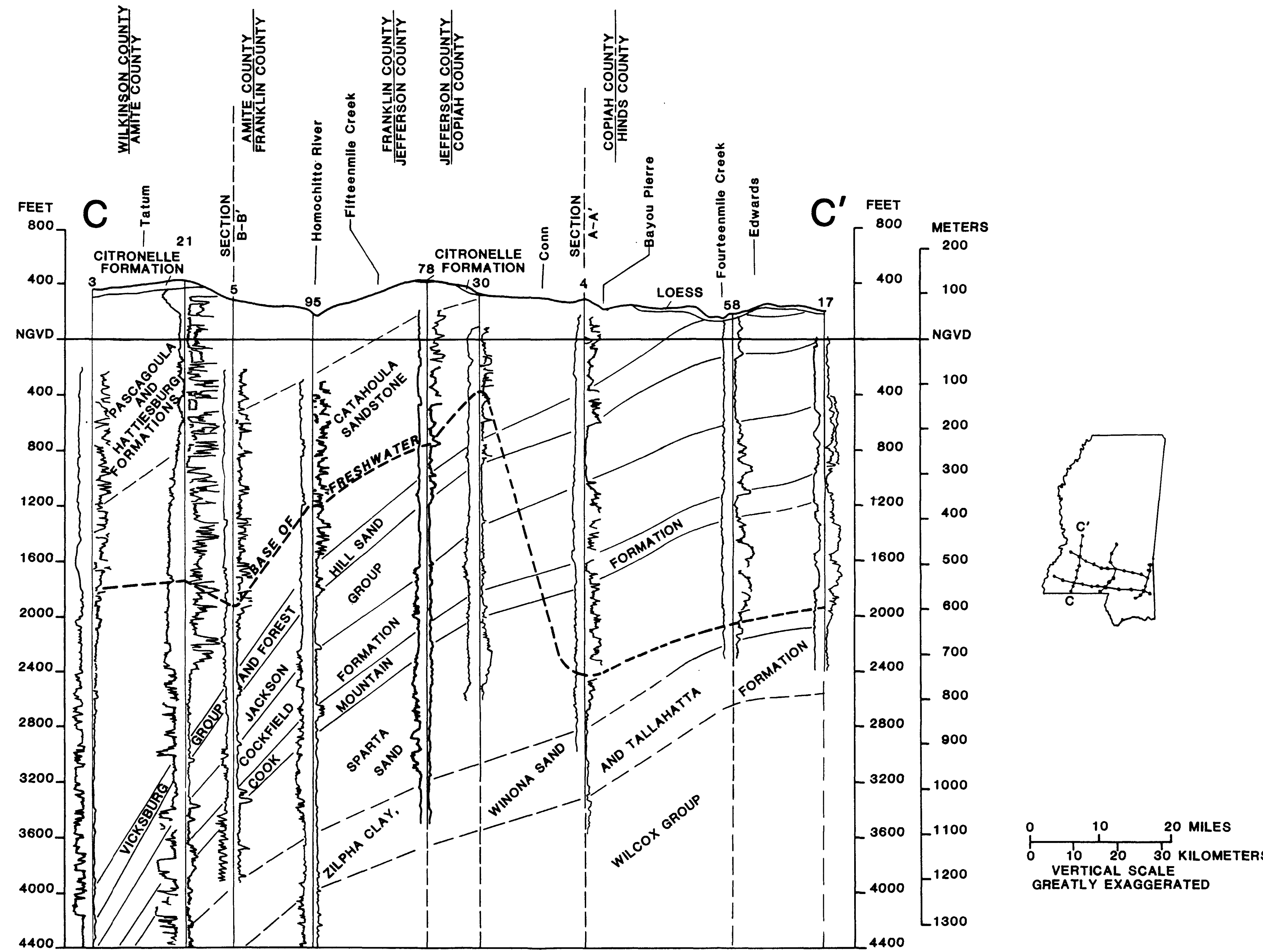

Figure 6.-- Geohydrologic section C-C' from Wilkinson to Hinds County.

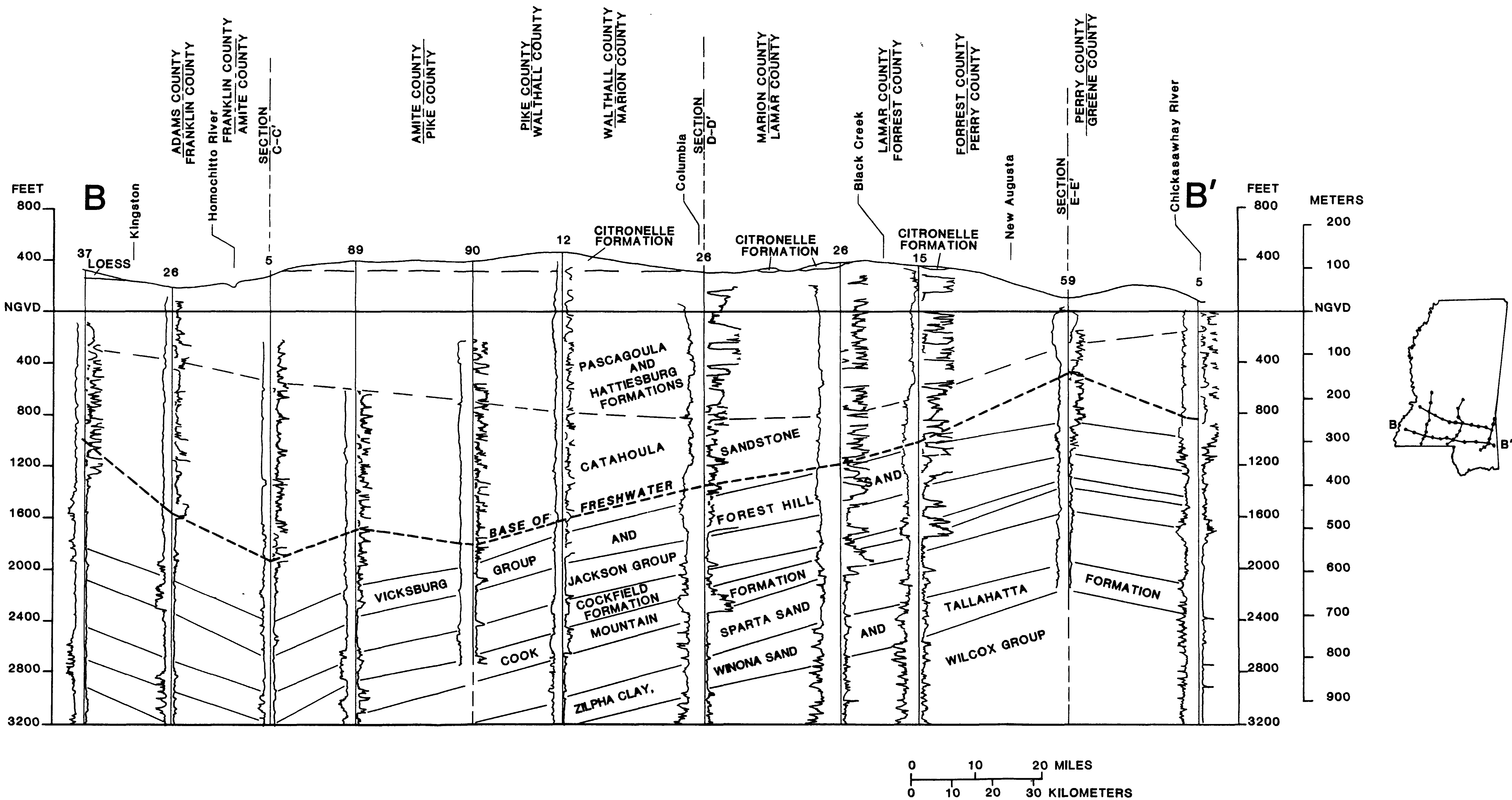

Figure 5.-- Geohydrologic section B-B′ from Adams to Greene County.

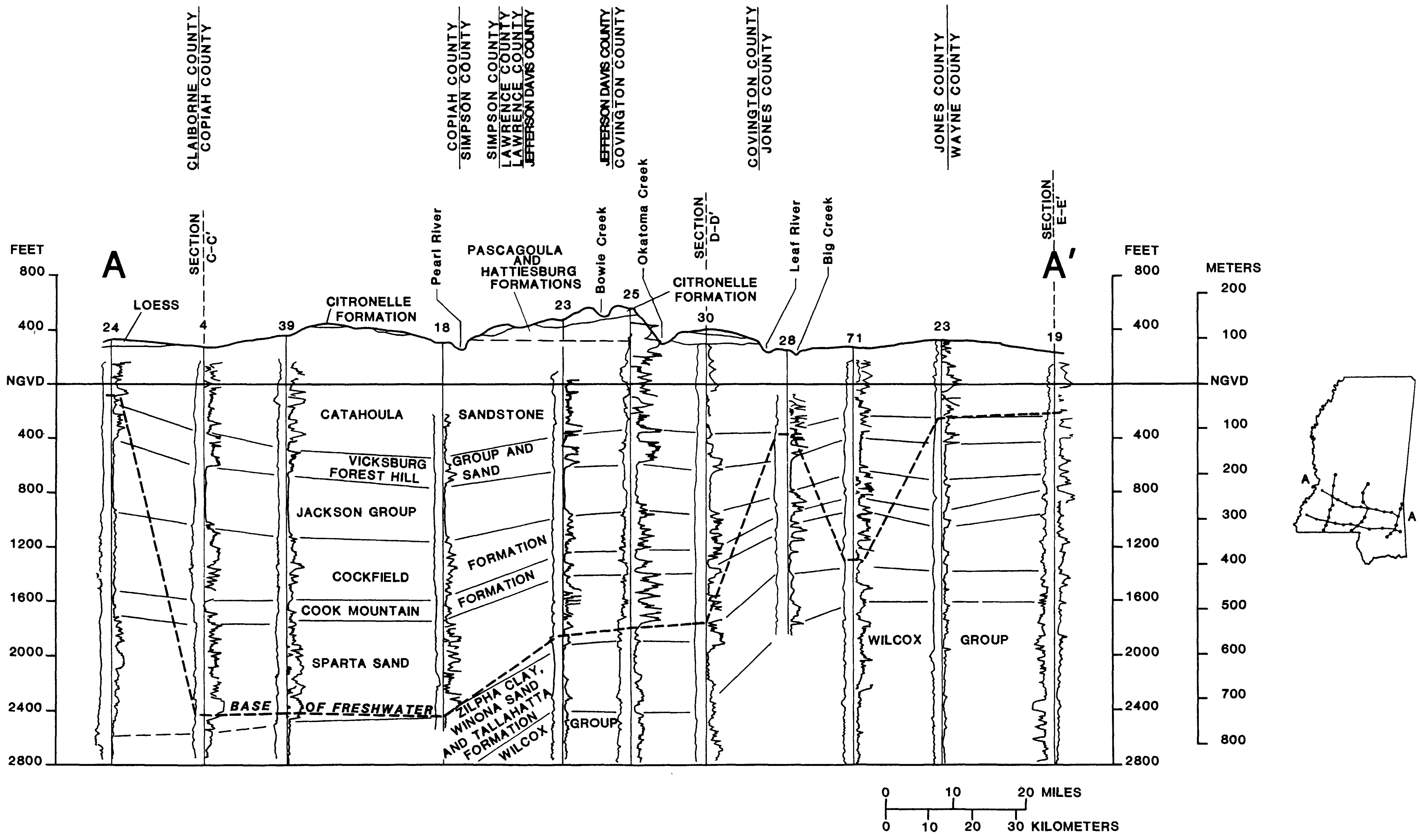

Figure 4.-- Geohydrologic section A-A′ from Claiborne to Wayne County.

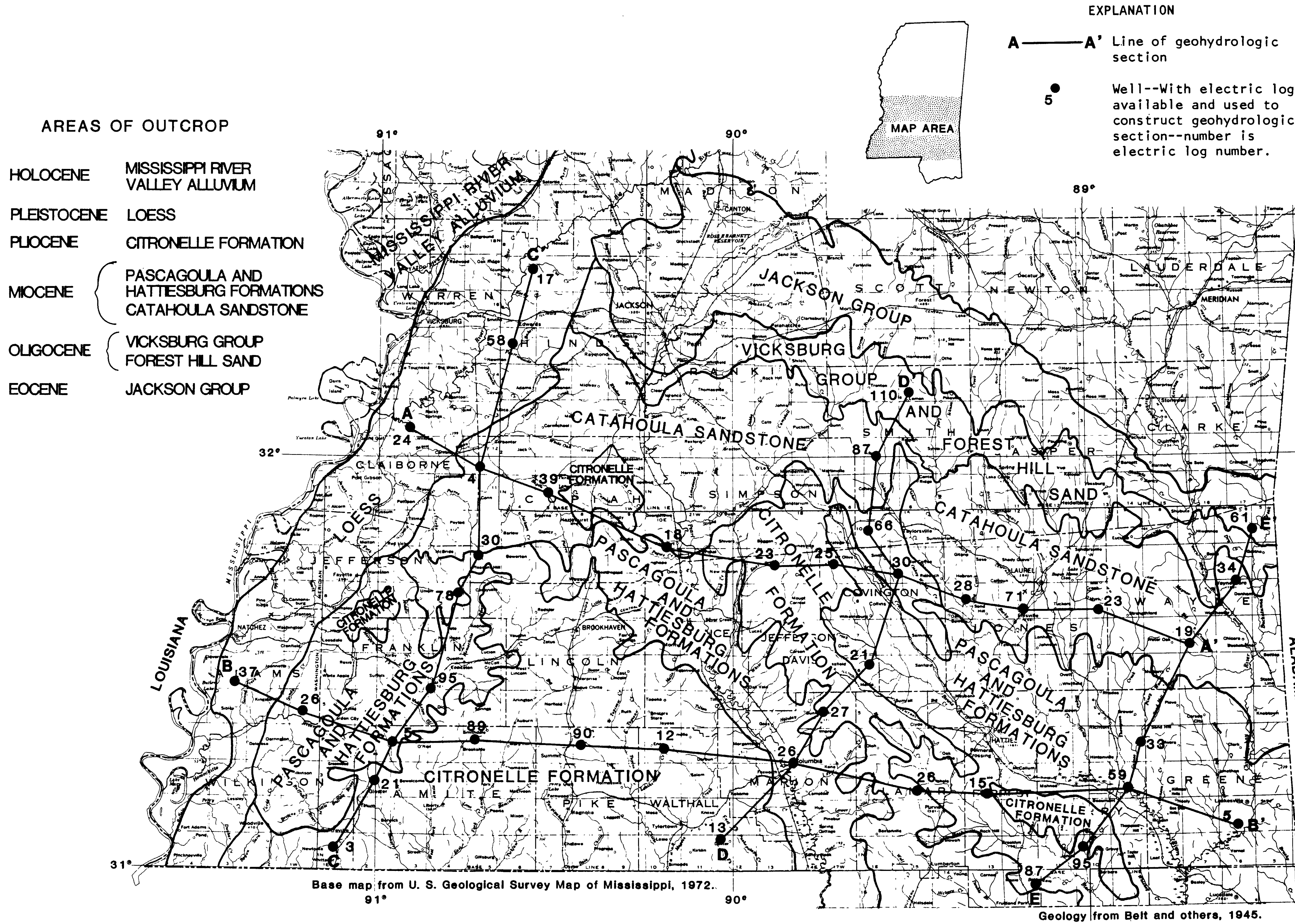

Figure 3.-- Geologic units and the location of the geohydrologic sections.

Table 1.--Geologic formations and their water-bearing characteristics.

(Modified from Eargle, 1968)

System	Series	Group	Unit	Maximum thickness (feet)	Lithologic character	Water-bearing characteristics
Quaternary	Holocene to Pleistocene		Alluvium	200	Clay, silt, sand, and gravel.	Deposits in stream valleys furnish water supplies for small domestic wells. Supplies large irrigation along the Mississippi River.
			Loess	50	Brown calcareous silt with shells.	Not an aquifer in this area.
Tertiary	Pliocene		Citronelle Formation	150	Gray to mottled red-orange silty clay, sand, and gravel.	Not an important aquifer. Supplies shallower domestic wells.
	Miocene		Pascagoula and Hattiesburg Formations undifferentiated	1,800	Greenish-gray silty clay, sand, and gravelly sand.	Important aquifers. Largest potential source of ground water in the State. Estimated hydraulic conductivity of 100 $(ft^3/d)/ft^2$. Supplies many municipal and industrial water users in the salt-dome basin.
			Catahoula Sandstone	2,800	Gray to olive sand, silt, and silty clay. Downdip--white to gray sandy limestone and marl; glauconitic, calcareous sand.	
	?		?			
	Oligocene	Vicksburg	Chickasawhay Limestone	470	Gray to white sandy limestone and fossiliferous sandstone and clay.	Not an aquifer in this area.
			Byram Formation/ Bucatunna Clay Member		Calcareous clay and white to gray sandy limestone, marl (Glendon Limestone Member).	Not an important aquifer. Supplies some domestic wells in the northern part of the salt basin. Contains slightly saline water in the southern parts of the basin.
			Marianna Limestone	300	White to gray sandy limestone, marl.	
			Forest Hill Sand/ Red Bluff Clay		Gray, fine sand and clay interbedded and soft fossiliferous limestone.	
		Jackson	Yazoo Clay (Cocoa Sand Member)	550	Oliver to gray calcareous clay.	Not an aquifer in this area. Cocoa Sand Member of Yazoo Clay is considered minor local aquifer in northeastern part of salt-dome basin.
			Moodys Branch Formation (Ocala Limestone to the south)		White sandy limestone, fossiliferous, glauconitic.	
	Eocene	Claiborne	Cockfield Formation	550	Lignitic clay and fine sand.	An important freshwater aquifer in northern half of salt-dome basin. Contains saline water in the south-half.
			Cook Mountain Formation	280	Hard to soft white calcareous sand and glauconitic, bentonitic clay.	Not a freshwater aquifer in this area. When limestone is present, contains saline water.
			Sparta Sand	1,000	Gray shale and thin siltstone, interbedded.	An important aquifer with moderate to large yields to industrial, municipal and domestic wells in the north-half of salt-dome basin. Contains saline water in the south-half.
			Zilpha Clay	500	Glauconitic marl, green sand, and shale.	Not aquifers in this area.
			Winona Sand Tallahatta Formation			
		Wilcox	Undivided	3,200	Gray, fine-grained sandstone and green to gray shale, interbedded. Chalky white fossiliferous limestone.	Important freshwater aquifer north of Jackson, but contains saline water in salt-dome basin.
Tertiary	Paleocene	Midway	Naheola Formation Porters Creek Clay	1,050	Gray shale.	Not an aquifer in this area.
			Clayton Limestone	25	Limestone	Not an aquifer in this area.
Cretaceous	Upper Cretaceous	Selma Group	Eutaw and McShan Formations undifferentiated	1,500	White chalk to gray marl, shale, and calcareous sandstone at base.	Contains saline water.
		Tuscaloosa	Gordo Formations and Coker Formation (includes marine Tuscaloosa and lower Tuscaloosa of oil geologists with "massive sand" at base	1,160	Shale and some sandstone, mostly marine deposits (includes thick sand, containing few shale lenses at base, and some gravel.	Contains saline water
	Lower Cretaceous		Dantzler Formation	1,150	Red to gray mottled shale, buff, red and green sandstone and stone.	Not an aquifer.
			Andrew Formation	1,880	Limestone, sandstone, and gray to green shale.	Not an aquifer.
			Paluxy Formation	1,450	Sandstone and shale, buff, pink, white, micaceous.	Not an aquifer.
			Mooringsport Formation	1,000	Marine shale, some sandstone.	
			Ferry Lake Anhydrite	240	Anhydrite, shale, limestone.	
			Rodessa Formation, James Limestone, and Pine Island Shale, undifferentiated.	750	Limestone, shale, sandstone, anhydrite (hard calcareous sandstone, gray to red limy micaceous shale, oolitic to finely crystalline limestone).	Not an aquifer.
			Sligo Formation	300	Sandstone, shale, mudstone, reddish, to greenish gray.	Not an aquifer.
			Hosston Formation	2,650	Sandstone, red shale conglomerate.	Not an aquifer.
Jurassic	Upper Jurassic		Cotton Valley Formation	2,900	Sandstone, shale, mudstone, red to purple, and green.	Not an aquifer.
			Haynesville Formation (includes Buckner Member)			Not an aquifer.
			Smackover Formation	3,450	Sand, sandstone, shale (red beds), oolitic limestone.	Not an aquifer.
			Norphlet Formation			Not an aquifer.
Jurassic			Louann Salt	6,000	White coarsely crystalline halite.	Not an aquifer.