UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY REPORT OF THE GEOHYDROLOGY NEAR CYPRESS CREEK AND RICHTON SALT DOMES, PERRY COUNTY, MISSISSIPPI

by

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UNITED STATES DEPARTMENT OF THE INTERIOR
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Multiply	By	To Obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
acre	2.471	hectometer (hm^2)
mile (mi)	1.609	kilometer (km)
cubic foot per day per square foot $(ft^3/d)/ft^2$	0.3047	cubic meter per day per square meter $(m^3/d)/m^2$
cubic foot per day per foot $(ft^3/d)/ft$	0.0929	cubic meter per day per meter $(m^3/d)/m$
micromho per centimeter at 25° Celsius (umho/cm at 25°C)	1.000	microsiemen per centimeter at 25° Celsius (uS/cm at 25°C)

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

DATUM

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in the text of this report.

PRELIMINARY REPORT OF THE GEOHYDROLOGY NEAR CYPRESS CREEK AND RICHTON SALT DOMES, PERRY COUNTY, MISSISSIPPI

by C.B. Bentley

ABSTRACT

Fresh ground water in the area of Cypress Creek and Richton domes occurs in discontinuous, lenticular sand deposits interbedded with clay, marl, and limestone, primarily of Miocene age. Saline water occurs in deeper aquifers and in the caprock of the domes. Estimates of transmissivity of the saline and fresh-water aquifers range from 410 to 28,000 cubic feet per day per foot, and horizontal ground-water velocity estimates range from 0.4 to 300 feet per year. The presence of saline water at relatively high altitudes in wells near the domes may indicate dissolution of salt around the domes or upward movement of saline water around the flanks of the domes.

INTRODUCTION

An investigation of the geohydrology near salt domes selected as possible repositories for storing radioactive waste is being conducted by the U.S. Geological Survey in cooperation with the U.S. Department of Energy (DOE). The investigation is part of the Nuclear Waste Terminal Storage (NWTS) program, which is administered for DOE by the Office of Nuclear Waste Isolation (ONWI), Battelle Memorial Institute, Columbus, Ohio. The program involves extensive geotechnical investigations, the results of which will assist DOE and their subcontractors in identifying suitable locations for permanent isolation of high-level nuclear wastes.

The disposal method that is receiving principal emphasis is the emplacement of radioactive wastes in mined geologic repositories located in stable rock masses deep underground (Interagency Review Group on Nuclear Waste Management, 1978; Klingsberg and Duguid, 1980). Rock types under investigation include bedded salt deposits and salt domes, basalt, granite, shale, and tuff. The geologic, geohydrologic, geochemical, and structural characteristics of the rock types and their contained fluids, and of the areas where they occur are being investigated to determine if nuclear waste can be isolated from the biosphere, the environment accessible by man, for at least a period of time sufficient for radionuclides to decay to safe levels of activity. The draft of the revised guidelines for evaluating the suitability of sites for radioactive-waste repositories has been finalized (DOE Task Force, 1983).

Purpose and Scope

The Geological Survey's responsibility in the Mississippi salt dome investigation is to describe the geohydrology of the salt-dome basin. Emphasis is placed on describing the physical and chemical characteristics of the geohydrologic system and on determining the rate and direction of ground-water movement. These factors 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 geohydrologic conditions in the Mississippi salt-dome basin in the area of the Cypress Creek and Richton salt domes. It incorporates data from the area characterization investigations in Mississippi and provides a foundation of technical information for subsequent, more detailed hydrologic investigations.

Background

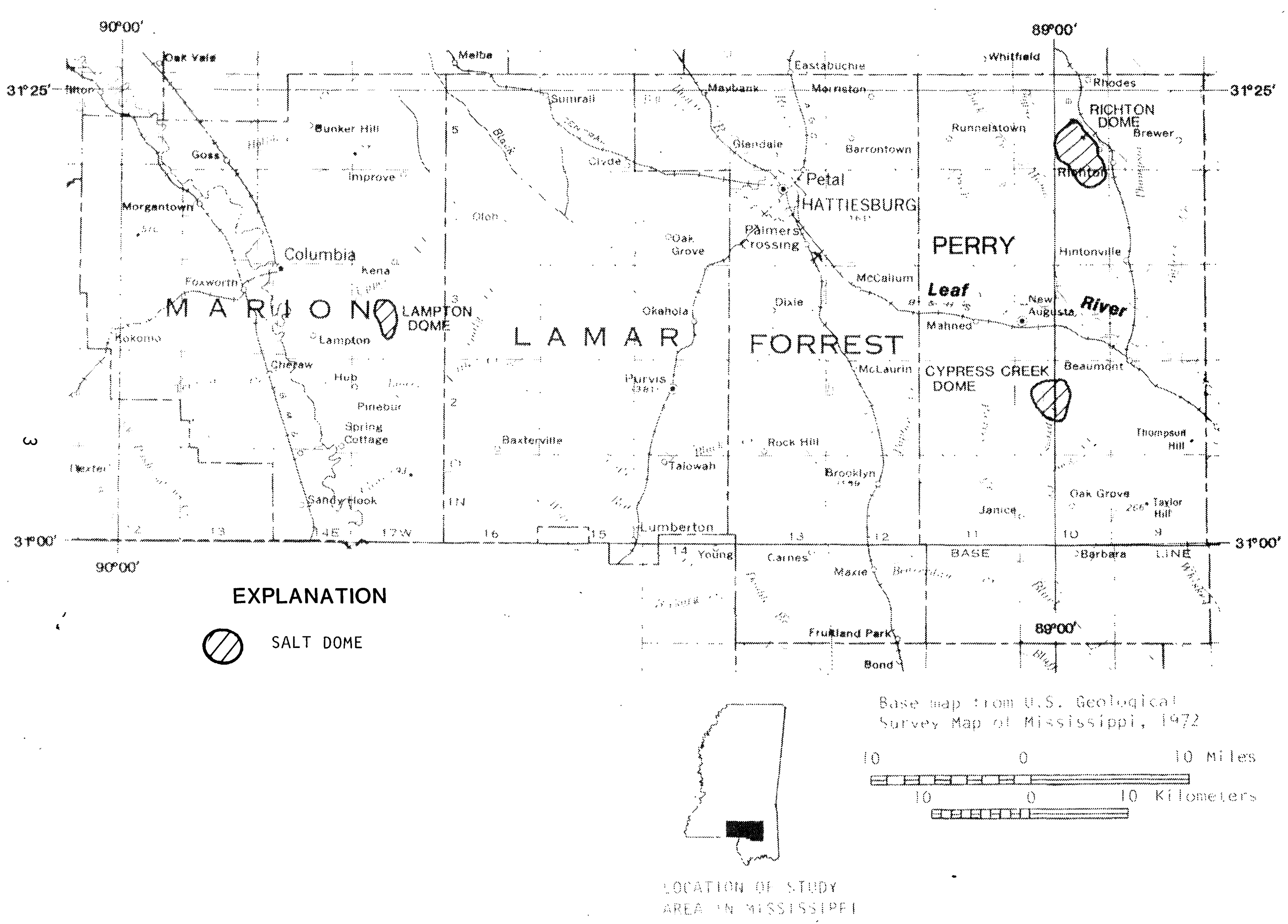
Investigations of the suitability of salt domes in Mississippi, Louisiana, and Texas for the storage of radioactive wastes have been proceeding since the early 1970's (Martinez and others, 1975, 1976; Hosman, 1978). Eight salt domes were identified in 1978 as having met minimum screening criteria for potential repository sites (ONWI, 1980). Three of the domes, Cypress Creek, Richton, and Lampton domes, are in Mississippi. Law Engineering Testing Company (LETCo), Marietta, Georgia, under contract to ONWI as Geologic Program Manager from 1977 to 1981, coordinated study activities and data aquisition in the Gulf Coast region. The activities included deep rotary drilling and coring, shallow borings, borehole geophysical logging, aquifer testing, water-quality testing, water-level monitoring in wells, gravity surveys, seismic and surface resistivity surveys, geologic surface mapping, and laboratory analysis of rock and water samples.

On the basis of area characterization reports of the Mississippi salt domes and reports of similar studies in Louisiana and Texas, ONWI recommended four of the eight previously selected domes to DOE as being acceptable for further study. They are from most to least favorable: Richton dome, Mississippi; Vacherie dome, Louisiana; Cypress Creek dome, Mississippi; and Oakwood dome, Texas (ONWI, 1982 p.75-78).

Description of Study Area

The Mississippi salt-dome basin has an oval shaped outline about 200 by 100 miles, and extends from northeastern Louisiana, east-southeasterly across southern Mississippi to approximately the Mississippi-Alabama State line. Cypress Creek and Richton salt domes are in Perry County near the eastern end of the basin (fig. 1). Cypress Creek dome is about 21 miles southeast of Hattiesburg in DeSoto National Forest and Camp Shelby Military Reservation. Richton dome is about 18 miles east of Hattiesburg. The area of this report includes the southeastern part of the salt-dome basin with emphasis on the area of the two domes. Because Lampton dome, about 25 miles west southwest of Hattiesburg, was initally considered as a potential repository site, considerable data were collected in that area in this investigation. Consequently, the Lampton dome area is considered as part of the study area.

The topography is characterized by alluvial plains and rolling hills of low relief. The altitude of the land surface ranges from about 50 ft along the Leaf River to more than 400 ft on some of the higher hills and ridges. The Pearl and Leaf Rivers are the principal streams in the area.


90°00'
89°00'
31°25'
31°00'
MARION
LAMAR
FORREST
PERRY
LAMPTON DOME
CYPRESS CREEK DOME
RICHTON DOME
Columbia
HATTIESBURG
Petal
Palmers Crossing
Leaf
River
Oak Vale
Melba
Whitfield
Eastabuchie
Maybank
Moriston
Rhodes
Brewer
Richton
Sumrall
Glendale
Barrontown
Runnelstown
Bunker Hill
Improve
Goss
Clyde
Morgantown
Oloh
Oak Grove
Hintonville
Foxworth
Kena
McCallum
New Augusta
Okahola
Dixie
Mahned
Kokomo
Lampton
McLaurin
Beaumont
Cheraw
Hub
Purvis
Pinebur
Spring Cottage
Baxterville
Rock Hill
Thompson Hill
Dexter
Talowah
Brooklyn
Oak Grove
Taylor Hill
Janice
Sandy Hook
Lumberton
Young
Carnes
Maxie
Barbara
Fruitland Park
Bond
BASE
LINE
EXPLANATION
SALT DOME
Base map from U.S. Geological Survey Map of Mississippi, 1972
10 0 10 Miles
10 0 10 Kilometers
LOCATION OF STUDY AREA IN MISSISSIPPI

Acknowledgments

Many of the illustrations and both numbered tables used in this report were prepared by Paul Dooley, former project leader. Both he and Charles Spiers, also formerly associated with the project, continued to provide advice and information to the author following their resignations from the U.S. Geological Survey.

REGIONAL GEOHYDROLOGY

Stratigraphy

Several thousand feet of sedimentary rock of various geologic ages deposited over a basement complex of Precambrian rocks underlie the surface of Mississippi. However, the Louann Salt of Jurassic age is the oldest geologic formation reached by deep oil test wells in the salt-dome basin of southern Mississippi. Tertiary rocks extend to depths in excess of 5,000 ft in the area, considerably below the maximum repository depth of 3,000 ft, and only formations of post-Cretaceous age are considered relevant to the present investigation.

Changing patterns in the sedimentary environment of the salt-dome basin have produced complex stratigraphic relationships including interbedded lenses of sand and clay with minor deposits of marl and limestone. Tongues of channel sands were deposited in numerous ancient river channels. A transition zone in the southern part of the basin separates predominantly sand deposits in the north from clay in the south and some relatively impermeable clay units in the north from water-bearing limestones in the south (Spiers and Gandl, 1980, p 4).

The regional stratigraphy has been described in detail by Eargle (1964, 1968) and Anderson and others (1973), and is summarized in table 1.

Structural Features

Folding and Faulting

The Mississippi salt-dome basin is a structural basin with little or no surface expression (fig. 2). It is bounded on the northwest by the Monroe-Sharkey uplift, a broad, relatively flat-topped structural feature in northeastern Louisiana, southeastern Arkansas, and west-central Mississippi (Murray, 1961, p. 114). The basin is bounded on the north and east by the Pickens-Gilbertown fault system, a series of normal faults which forms regional grabens across most of Mississippi (Murray, 1961, p. 186). On the south, the basin is bounded by the Wiggins uplift or anticline, an irregular, arcuate uplift, or series of uplifts, which trends westerly from southwestern Alabama across southern Mississippi (Murray, 1961, p. 105).

For more complete descriptions of the structural geology of the salt-dome basin and surounding area, the reader is referred to discussions by Murray (1961) and Anderson and others (1973).

Table 1.--Geologic units and their lithologic character in the Mississippi salt dome basin

(Modified from Eargle, 1968)

System	Series	Group	Unit	Lithologic Character
Quaternary	Holocene to Pleistocene		Alluvium Loess	Silt, sand, gravel. Calcareous silt with shells.
			Terrace deposits	Silt, sand, gravel.
Tertiary	Pliocene		Citronelle Formation	Silty clay, sand, gravel.
	Miocene ?		Pascagoula and Hattiesburg Formations, undivided	Silty clay, sand, gravelly sand.
			Catahoula Sandstone ?	Sand, silty clay, marl, glauconitic calcarenite.
	Oligocene		Chickasawhay Formation	Sandy limestone, calcareous clay, sand.
		Vicksburg	Bucatunna Formation Byram Formation Glendon Formation	Calcareous clay, sandy limestone, marl.
			Marianna Formation Mint Spring Formation	Sandy, glauconitic limestone, marl.
			Forest Hill Formation Red Bluff Formation	Sand, calcareous clay, calcarenite.
	Eocene	Jackson	Yazoo Clay	Calcareous clay, marl.
			Moodys Branch Formation	Sandy limestone, glauconitic and fossiliferous calcarenite.
		Claiborne	Cockfield Formation	Sand, silt, shale.
			Cook Mountain Formation	Sandy limestone, calcarenite, clay.
			Sparta Sand	Silty clay, sand, marl.
			Zilpha Clay Winona Sand Tallahatta Formation	Carbonaceous clay, sand. Marl, calcareous clay. Siltstone, clay, sand.
		Wilcox	Undifferentiated	Sand, siltstone, clay, marl, lignite.
	Paleocene	Midway	Porters Creek Clay	Silty, sandy clay.
			Clayton Formation	Silty, fossiliferous limestone, marl, clay.

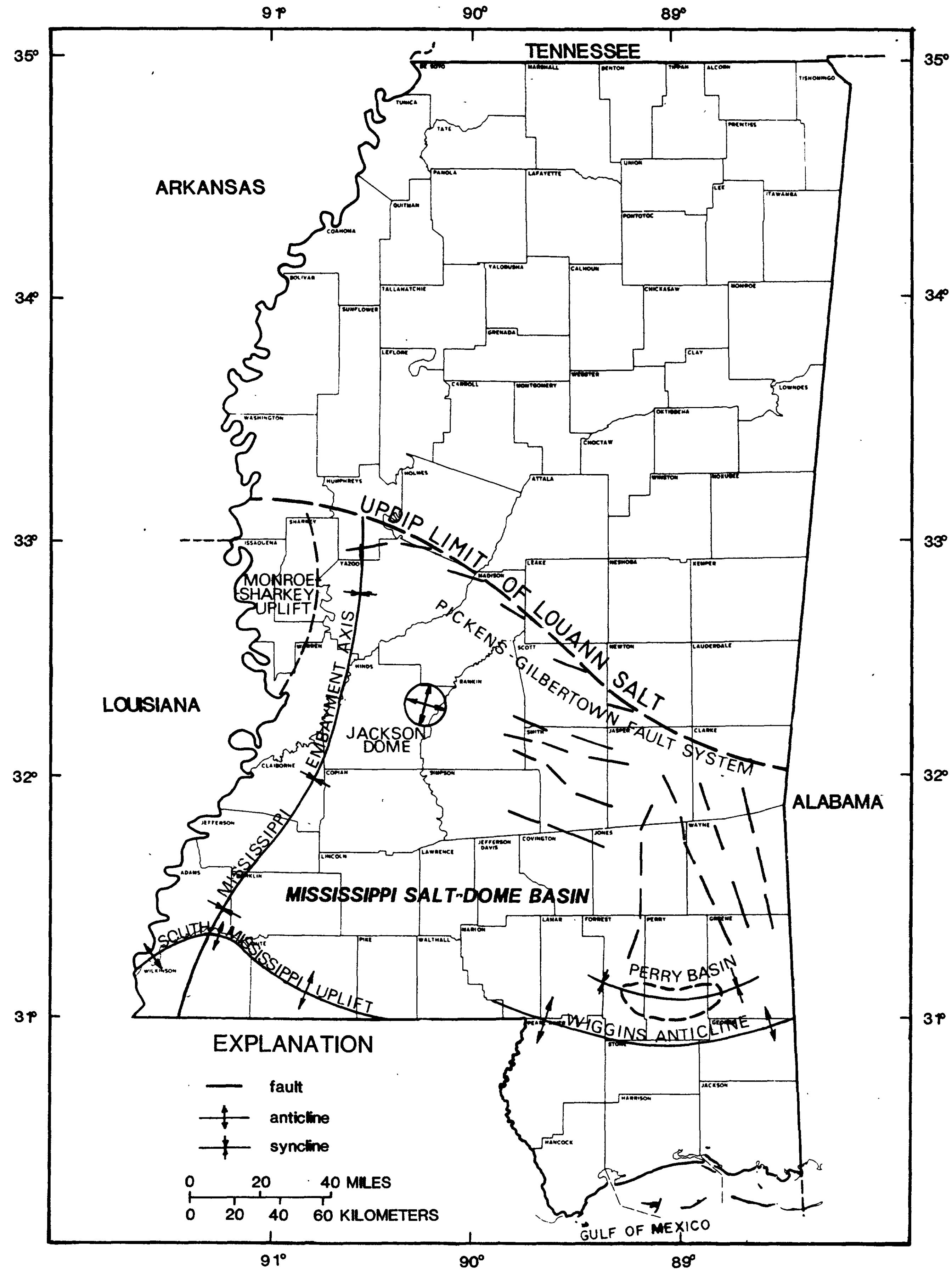


Figure 2.--Structural features in the Mississippi salt-dome basin.

Salt Domes

Halbouty (1979) reviewed the extensive literature on the origin, development, and description of salt domes in the Gulf Coast region. The following description is summarized from his work.

Domes in the Gulf region are circular to broadly eliptical. Their tops range in diameter from one-half to 4 miles. The composition of the domes is almost pure sodium chloride (halite) with minor amounts of anhydrite and traces of other minerals. Caprock, composed chiefly of granular anhydrite, overlies the top of most shallow piercement salt domes. Caprock is believed to be an accumulation of insoluble residues that precipitated from ground water acting on the salt. It usually is thickest, 300 to 400 ft, over the center of a dome, thinner toward the periphery, and very thin or absent on the flanks. At some caprocks, a calcite or limestone zone occurs above the anhydrite but separated from it by a transition zone containing calcite, anhydrite, sulfur, gypsum, and other minerals. In addition, many caprocks are overlain by a zone of hard, secondarily cemented sediments, known as false caprock, which may be gradational with the caprock. Faulting, predominantly normal, is common in the sediments over and around the domes (Halbouty, 1979, p. 27-85).

Ground Water

The major source of fresh ground water, water containing less than 1000 mg/L of dissolved solids, in the southern part of the Mississippi salt-dome basin is the Miocene aquifer system which consists of the Catahoula Sandstone and the Pascagoula and Hattiesburg Formations (table 1). The Citronelle Formation also is an important aquifer locally. Farther north in the basin the Wilcox Group, Sparta Sand, Cockfield Formation, and the Oligocene formations are important aquifers, but their water is saline in the area of this report. Two geohydrologic sections (fig. 3), one along the southern edge of the basin (fig. 4) and the other across the eastern end of the basin (fig. 5) show the generalized relationship between the base of freshwater and the various aquifers in the area. The base of freshwater generally ranges between 600 and 1400 ft below sea level in the southeastern part of the basin. The depth to the base of freshwater and the quality of water may be altered locally by withdrawals, oil-field injection wells, dissolution of salt domes, or upward movement of water from saline aquifers. The general movement of water in the Miocene aquifers is southward toward the Gulf.

The Catahoula Sandstone consists of sand, silt, silty clay, limestone, and marl. It has a maximum thickness of about 1,800 ft in the salt-dome basin (Spiers and Gandl, 1980, p. 25). The Pascagoula and Hattiesburg Formations cannot be differentiated on the basis of lithology in the subsurface of Mississippi, and generally are mapped as a single unit. Both formations consist of mostly silty clay and sand. Their maximum combined thickness in the basin exceeds 2,000 ft.

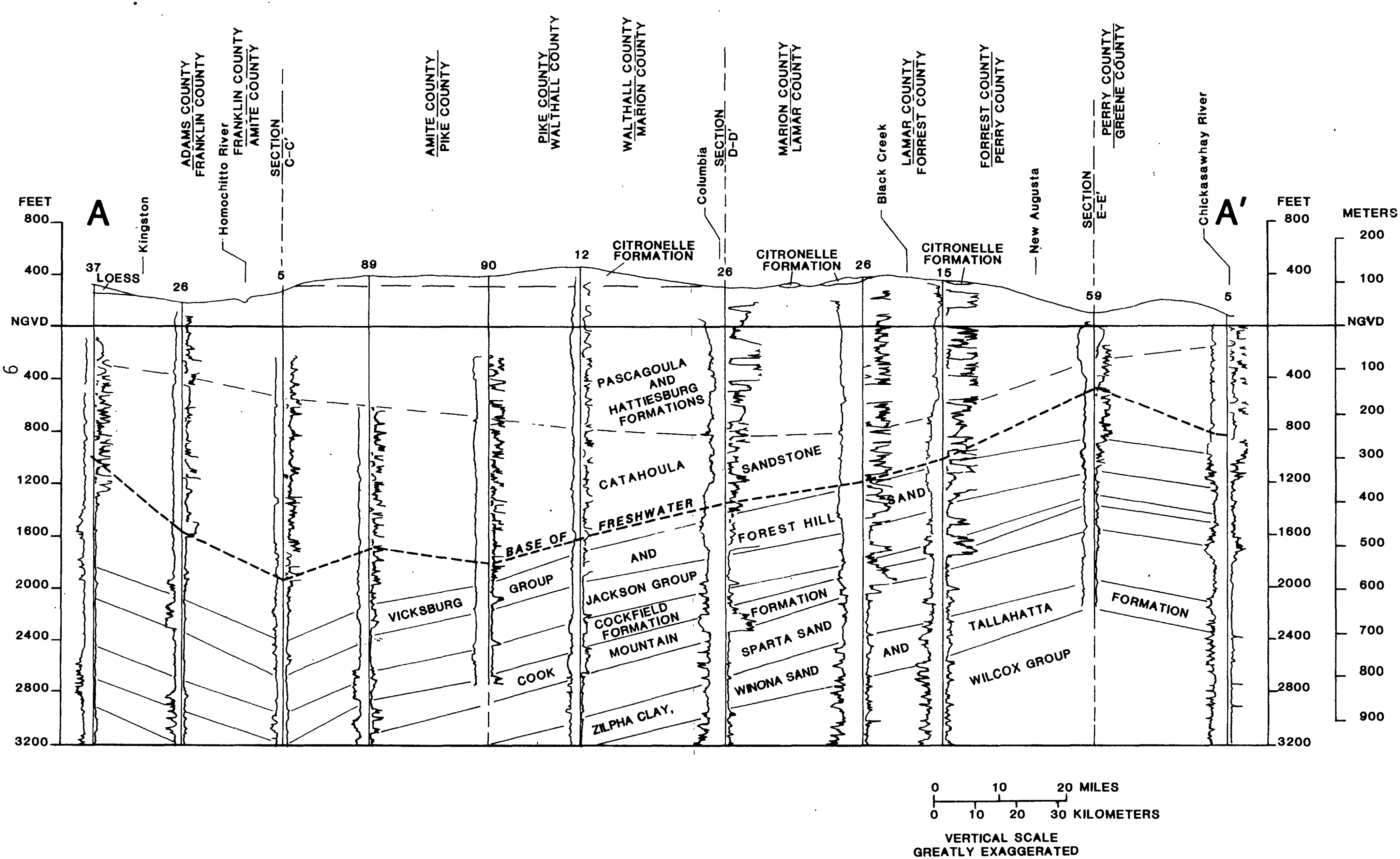


Figure 4.--Geohydrologic section A-A' from Adams to Greene County.

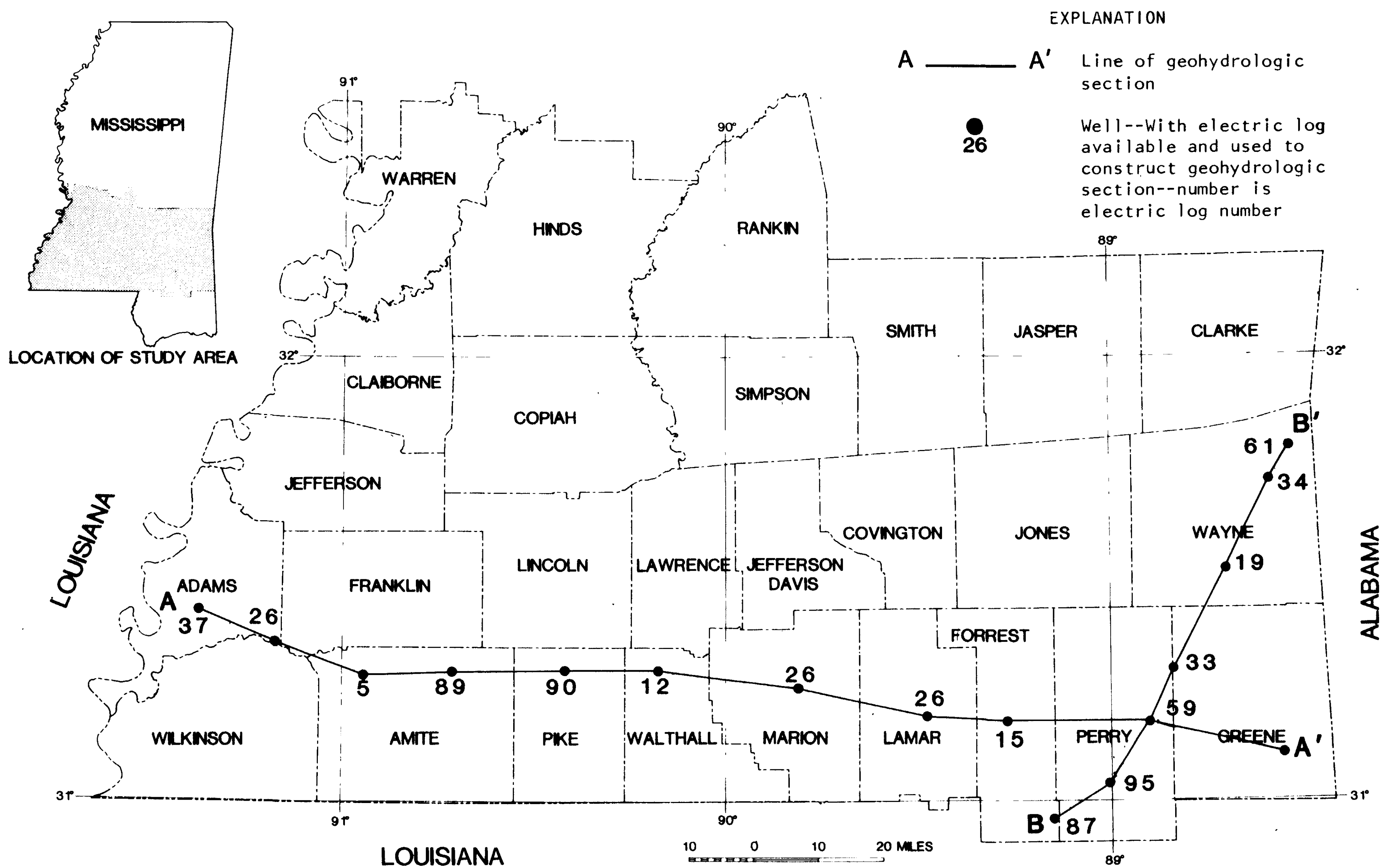


Figure 3.--Location of geohydrologic sections.

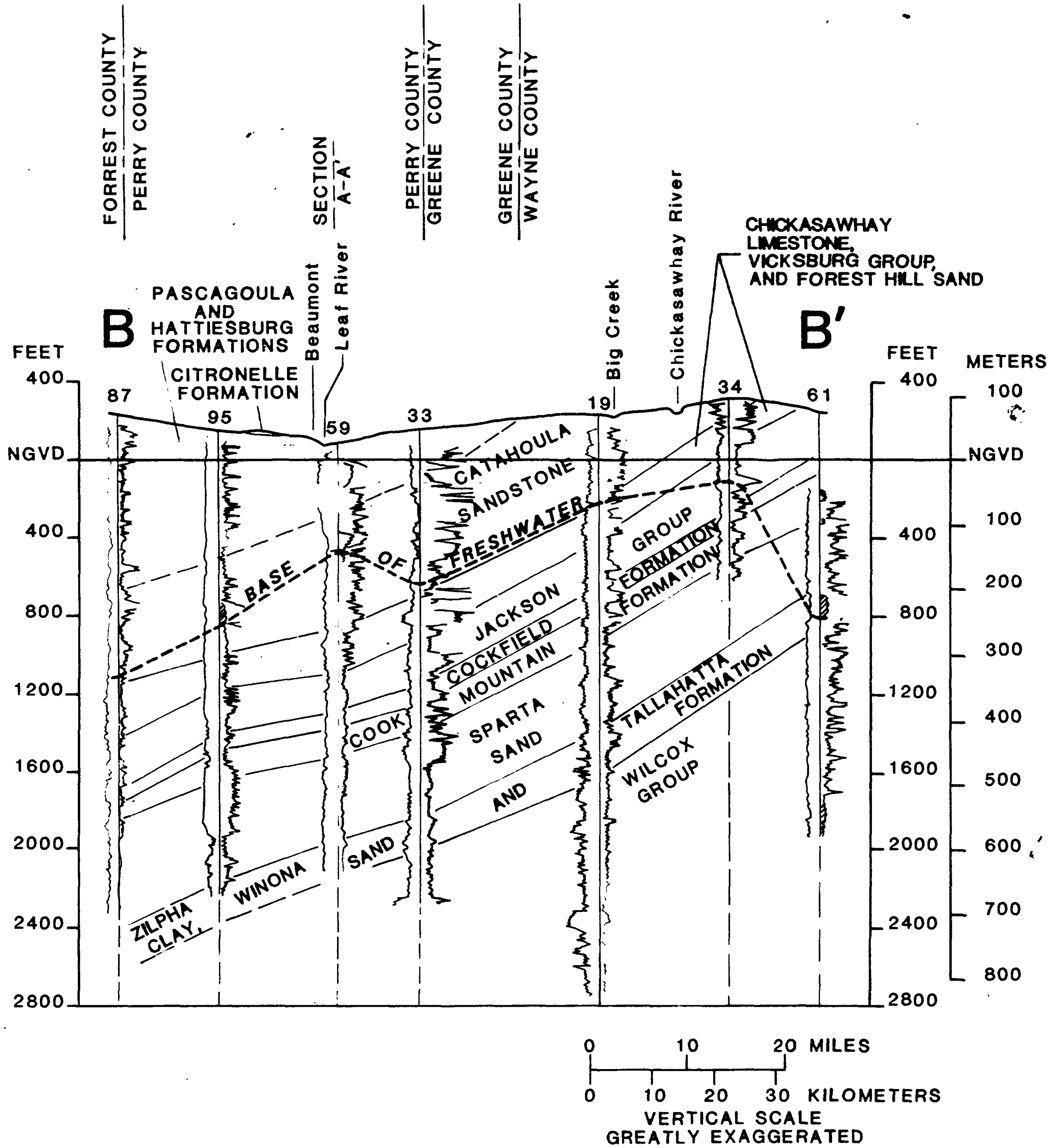


Figure 5.--Geohydrologic section B-B' from Forrest to Wayne County.

The Miocene aqufiers are highly permeable and a hydraulic conductivity of about 100 $(ft^3/d)/ft^2$ has been estimated from about 200 aquifer tests in southern Mississippi. Transmissivities may be as much as 120,000 $(ft^3/d)/ft$ based on the maximum cumulative thickness of sand in the aquifer system (Spiers and Gandl, 1980, p. 25).

CYPRESS CREEK AND RICHTON SALT DOMES AREA

Geologic Setting

Cypress Creek salt dome probably exceeds 1000 acres (1.0 x 1.5 miles) in area at a depth of 1,500 ft, as substantiated from gravity data and an exploratory oil test well that reportedly reached salt at a depth of 1,447 ft on the north edge of the dome (Spiers and Gandl, 1980, p. 33). Richton dome, with dimensions of 1.5 by 3.5 mi at a depth of 1,000 ft, is the largest and also the shallowest dome in the Mississippi salt-dome basin (Spiers and Gandl, 1980, p. 30). Data from sulfur exploration holes show the top of the caprock at 497 ft below land surface and the top of the salt to be 722 ft below the surface (Mellen, 1976).

The Tertiary stratigraphy in the immediate area of the domes is shown by a geohydrologic section constructed through both domes (fig. 6) More than 20,000 ft of overburden was penetrated by the domes, which pierced the entire stratigraphic thickness above the Louann Salt to the base of the Catahoula Sandstone.

A corehole was drilled by a private contractor into each of the two domes (LETCo, 1980b, Appendix A-1). The Cypress Creek dome hole (MCCG-1), sec.9, T.2 N., R.10 W., reached the top of the Caprock at a depth of about 1170 ft below land surface. The cores showed the caprock at that location to consist of about 204 ft of finely crystalline anhydrite with abundant gypsum (selenite) veins and few beds of white, chalky limestone. About 230 ft of very fine to very coarse, friable sand overlies the caprock. About 510 ft of salt, consisting of clear, crystalline halite with zones of angular anhydrite fragments, was drilled. The caliper log indicated a gap of about 2 ft between the base of the caprock and the salt (Drumheller and others, 1981a, p. 9). The gap is presumed to be a "washout" in anhydrite sand caused by drilling fluid (Spiers, C. A., Law Engineering Company, oral commun., 1983). The top of the caprock in the Richton dome well (MRIG-9), sec.26, T.5 N., R.10 W., was reached at a depth of about 540 ft below land surface and is overlain by interbedded sand and clay with minor amounts of mudstone, siltstone, and lignite. The uppermost 23 ft of the caprock consists of microcrystalline, vuggy, limestone with calcite veins and is underlain by about 185 ft of fine to medium crystalline anhydrite with occasional gypsum viens, calcite crystals, and traces of sulfur. The lower 5 to 8 ft of caprock is unconsolidated anhydrite sand. The caliper log shows a 5-ft washout at that interval, similar to that at Cypress Creek dome (Drumhellar and others, 1981b, p. 11). The total thickness of caprock at the well site is 213 ft. The underlying salt consists of clear, crystalline halite with few disseminated anhydrite veins, vertical anhydrite bands, and angular anhydrite clasts up to 6 in. long. The upper 6 ft of salt contains considerable anhydrite sand, and the uppermost 1.5 ft is fractured. About 508 ft of salt was cored.

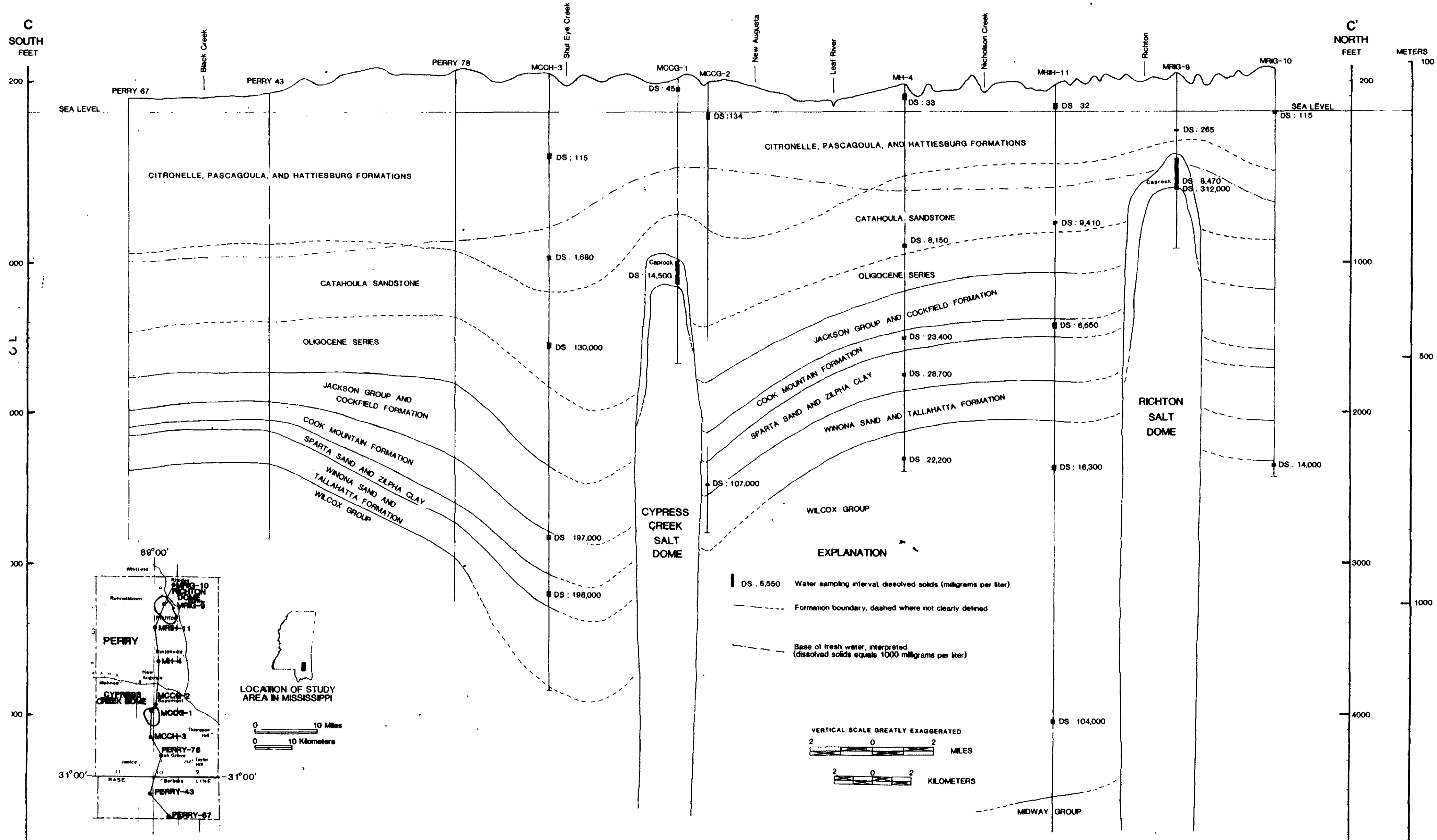


Figure 6.--Geohydrologic Section C-C' through Cypress Creek and Richton Domes.

Shallow boreholes and surface geologic mapping indicate that the Pascagoula, Hattiesburg and Citronelle Formations, terrace deposits, and alluvium are present at the surface in the areas of both domes. Detailed descriptions of the lithology and stratigraphy of the surface and subsurface geologic units in the area of both domes are presented in a technical report that characterizes the geology of the study area in Mississippi (ONWI, 1982b).

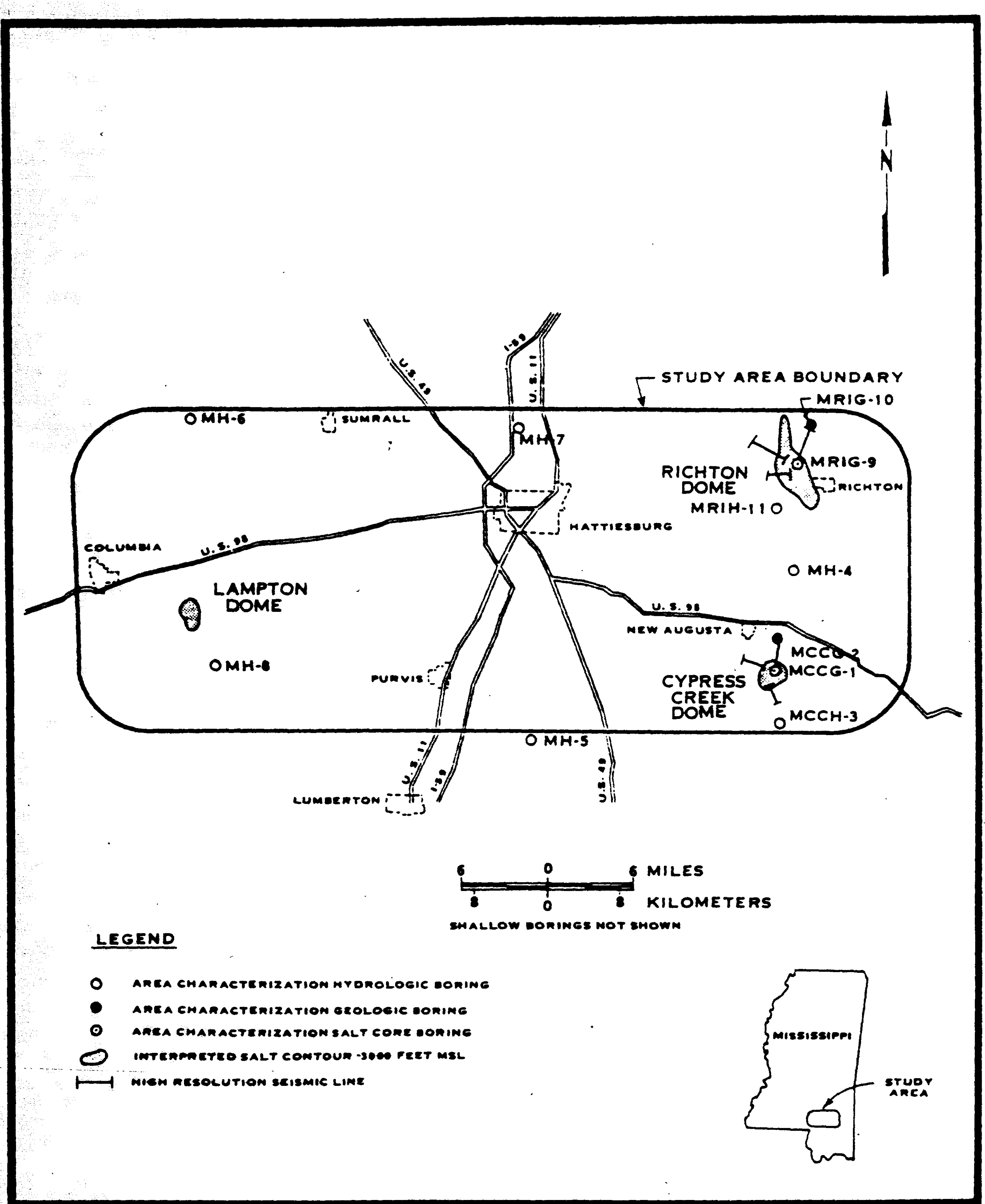
Occurrence and Movement of Ground Water

An extensive field data-collection program to collect regional and near-dome hydrologic data was conducted by LETCo in consultation with the U.S. Geological Survey (ONWI, 1982b, p. 14-1--14-141). The program included construction of 42 wells at seven hydrologic and four geologic data-collection sites (LETCo, 1982a-k) (fig. 7). Hydrogeologic data were collected at both types of sites. Five of the hydrologic sites were selected for collection of regional data, and two were selected for collection of near-dome data; one each at Cypress Creek (site MCCH-3) and Richton domes (site MRIH-11). One to four deep wells, completed at different depths, and a water-supply well were drilled at each site. Typical well construction is shown in figure 8. Hydrologic data collection included geophysical well logging to help define the vertical location of water-bearing zones, aquifer tests, water-level measurements, and collection of water samples at each site. The geologic data-collection sites consisted of one deep well and one water-supply well. Two of the sites were located near Cypress Creek dome (MCCG-1, MCCG-2) and two near Richton dome (MRIG-9, MRIG-10) (fig. 6). Side-wall cores were taken from wells at selected data-collection sites and analyzed by Core Laboratories, Houston, Texas, for porosity, permeability, grain density, and grain-size distribution.

Freshwater Aquifers

Fresh ground water occurs throughout the area of investigation in the upper two-thirds to one-half of the Miocene aquifer system and locally in the Citronelle Formation. Water in the Miocene aquifers is under artesian pressure, and flowing wells are common except in higher altitudes of the study area. The base of freshwater, 1000 milligrams per liter (mg/L) dissolved solids, ranges from about 400 ft below sea level in an area about midway between Cypress and Richton domes to more than 1200 ft below sea level southwest of Cypress Creek dome (fig. 9). Saline water occurs in aquifers below those depths.

Water levels in wells completed in the freshwater zone of the Catahoula Sandstone range from less than 80 ft above sea level in a cone of depression at Hattiesburg, a center of large withdrawals, to more than 160 ft at Richton dome, and even higher altitudes west of Hattiesburg. A smaller cone of depression centered at Purvis is caused by pumping for municipal and industrial water supplies (fig 10.). Ground-water movement in the Catahoula Sandstone at Richton dome is to the south and southeast, toward the Leaf River. Water-level data are insufficient to establish the direction of ground-water flow in the Cypress Creek dome area.



Modified from Law Engineering Testing Co., 1982a.

Figure 7.--Law Engineering Testing Co. (LETCO) field investigation plan.

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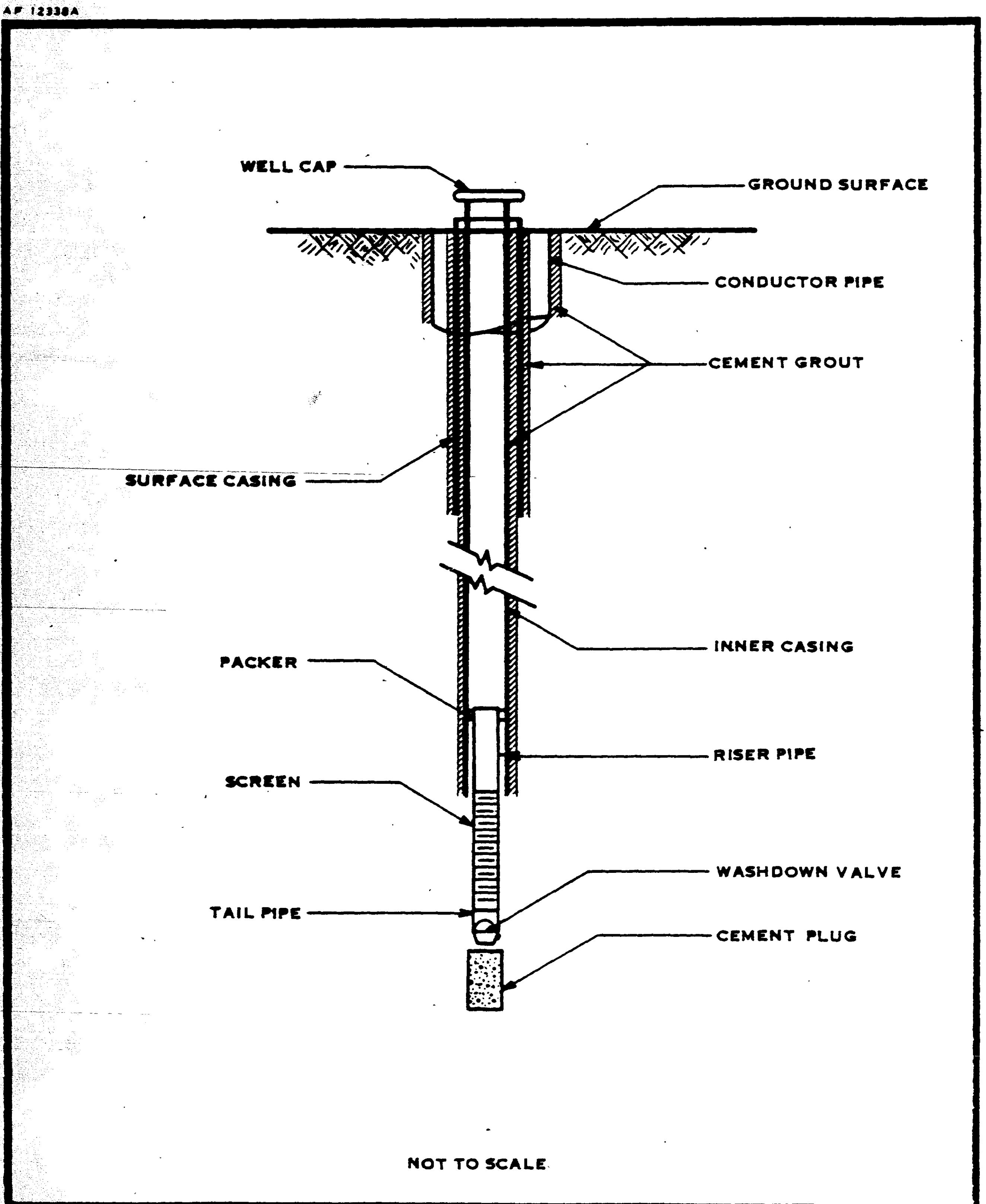
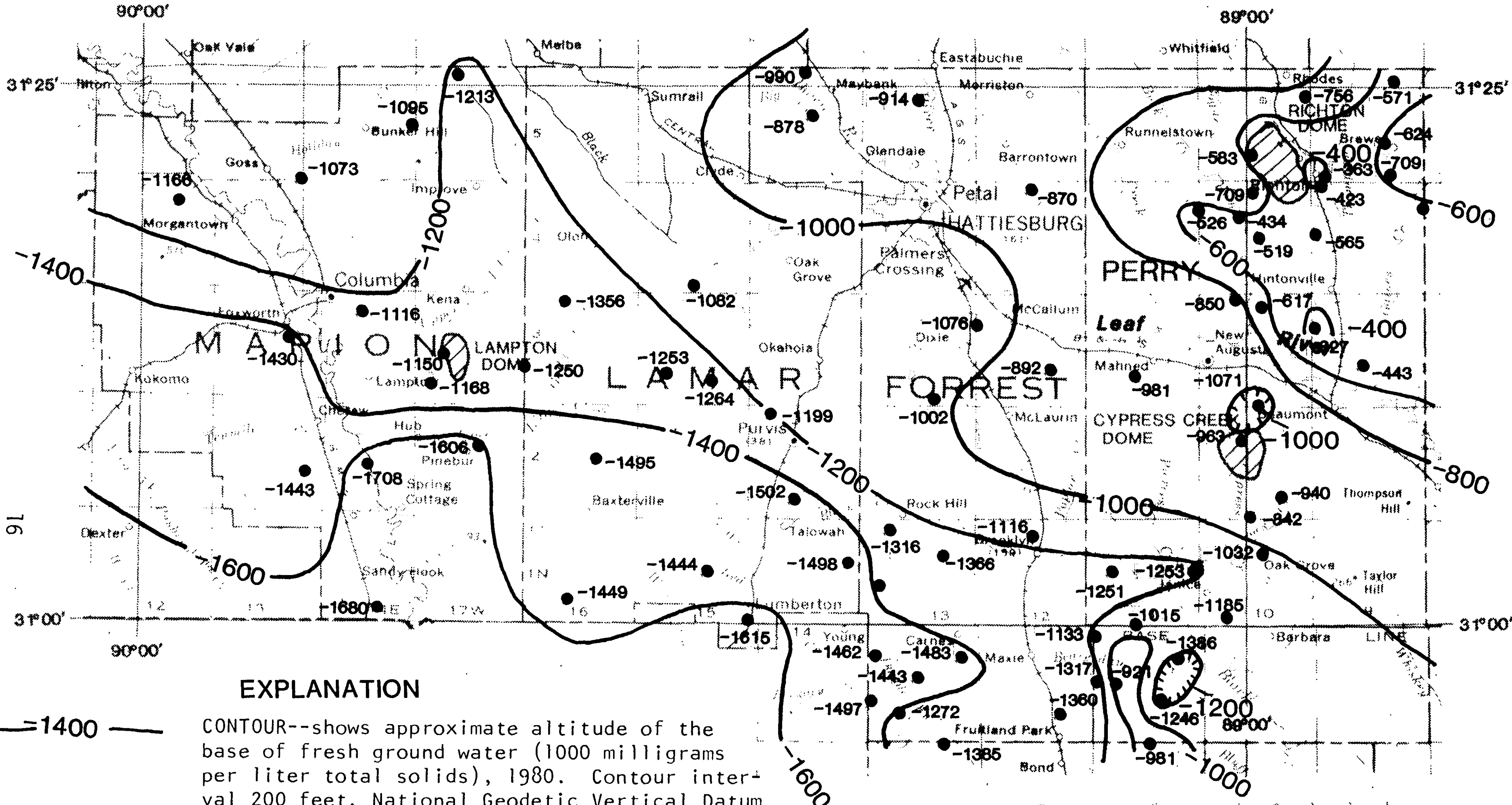


Modified from Law Engineering Testing Co., 1982 b .

Figure 8.--Typical construction of Law Engineering Testing Co., data collection well in the Cypress Creek - Richton dome area.

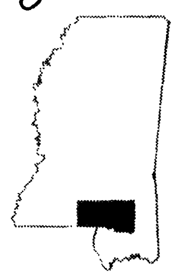


EXPLANATION

—1400— CONTOUR--shows approximate altitude of the base of fresh ground water (1000 milligrams per liter total solids), 1980. Contour interval 200 feet, National Geodetic Vertical Datum of 1929.

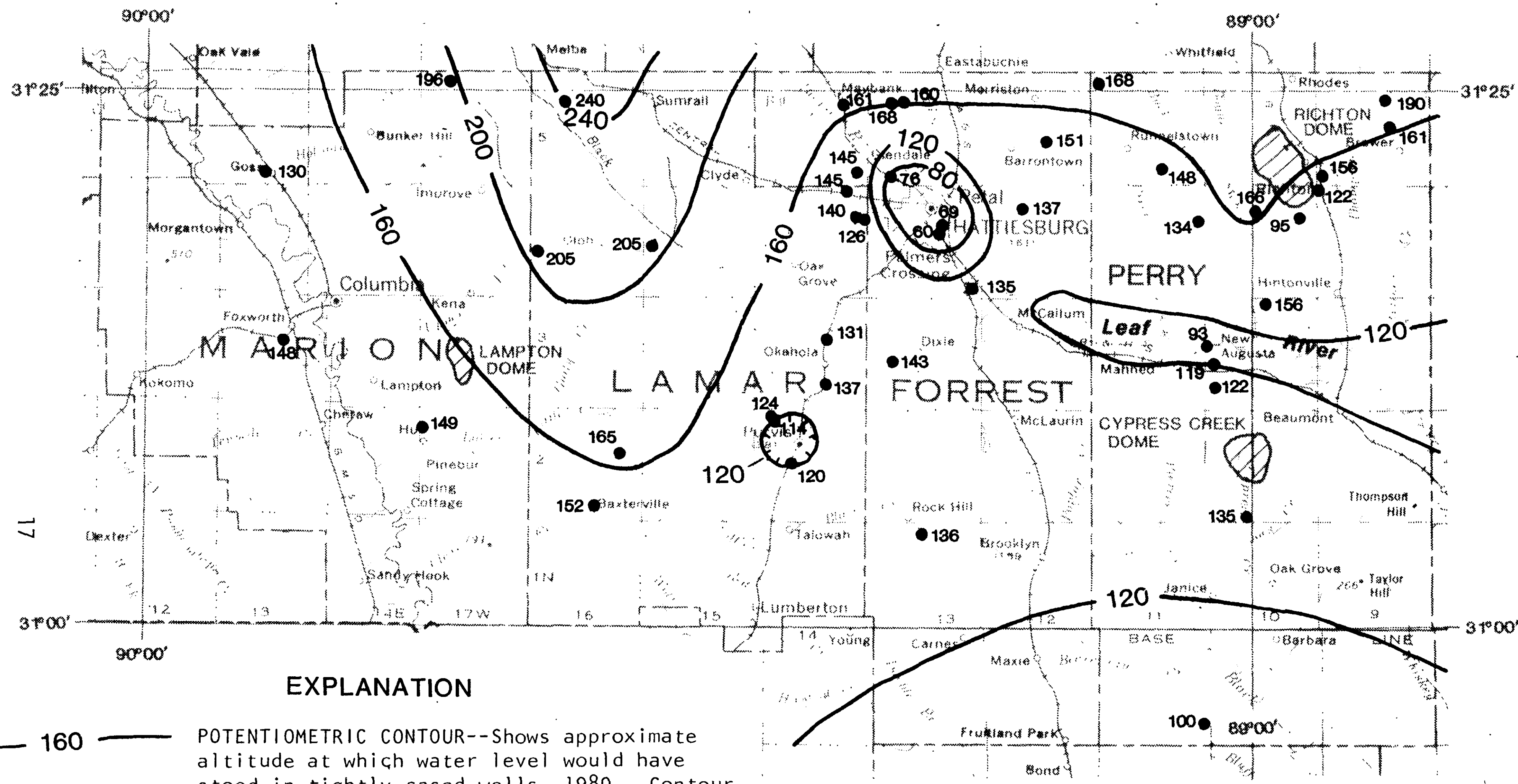
● -1680 DATA POINT--Water-well number is altitude of freshwater.

SALT DOME



LOCATION OF STUDY AREA IN MISSISSIPPI

Figure 9.--Base of fresh ground water in the Lampton-Cypress Creek-Richton domes

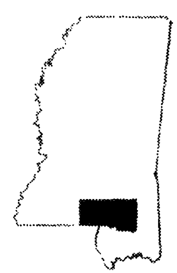


EXPLANATION

160 — POTENTIOMETRIC CONTOUR--Shows approximate altitude at which water level would have stood in tightly cased wells, 1980. Contour interval 40 feet, National Geodetic Vertical Datum of 1929.

●152 DATA POINT--Water well. Number is altitude at water level in feet.

SALT DOME



LOCATION OF STUDY AREA IN MISSISSIPPI

Figure 10.--Potentiometric surface of the Catahoula Sandstone

Water levels in wells in the Pascagoula and Hattiesburg Formations range from less than 80 ft above sea level along the Leaf River to more than 200 ft north of Richton dome and to the west in Forrest County (fig. 11). Water levels at both domes are about 120 ft to 160 ft above sea level. Ground-water movement at Richton dome is southward toward the Leaf River. A ground-water divide immediately south of Cypress Creek dome separates northward flowing water at the dome from southwesterly flowing water south of the dome. Limited data indicate that the movement of ground water over the top of the domes is not affected.

Because of the discontinous and lenticular nature of sand, clay, marl, and limestone deposits in the Catahoula Sandstone and Pascagoula and Hattiesburg Formations, both units are in fact aquifer systems consisting of many individual water-bearing zones. Poor to fair hydraulic connection exists between water zones at different depths; artesian pressure generally increases with depth in both formations. Consequently, potentiometric maps of the aquifers tend to be generalized, and the water level in a well at a given location may vary from that indicated on the map depending on the depth of the well.

Saltwater Aquifers

Problems with water-density determinations in association with water-level measurements in the deeper, saline aquifers do not permit determinations of ground-water movement other than very generalized assumptions. Water-level measurements converted to equivalent freshwater head estimates for the Wilcox Group (fig. 12) using a method described by Lusczynski (1961), range from about 230 ft above sea level between the domes, to more than 270 ft north of Richton dome, to 295 ft about 17 miles west southwest of Cypress Creek dome. Water at Richton dome appears to move southward. Equivalent freshwater head estimates for the Sparta Sand (fig. 13) range from 174 ft above sea level between the domes to 326 ft south of Cypress Creek dome. The movement of water at Cypress Creek dome appears to be northward. Head estimates for the Cook Mountain Formation (fig. 14) range from 215 ft above sea level south of Richton dome to 293 ft south of Cypress Creek dome. Water movement appears to be northward from Cypress Creek dome toward Richton dome. Water-level data from additional sites and more accurate pressure determinations are needed to describe the flow patterns in the deeper aquifers and to describe the effect of the salt domes on the ground-water flow.

Aquifer Characteristics

Estimates of an aquifer's ability to store and transmit water are essential to develop an understanding of the ground-water flow system. Aquifer tests to calculate the hydraulic characteristics of an aquifer, transmissivity, and hydraulic conductivity, were run at 41 wells at the eleven data sites (ONWI, 1982c, Appendix C-1) that were described in the previous section. The tests were performed by LETCo personnel in consultation with the U.S. Geological Survey.

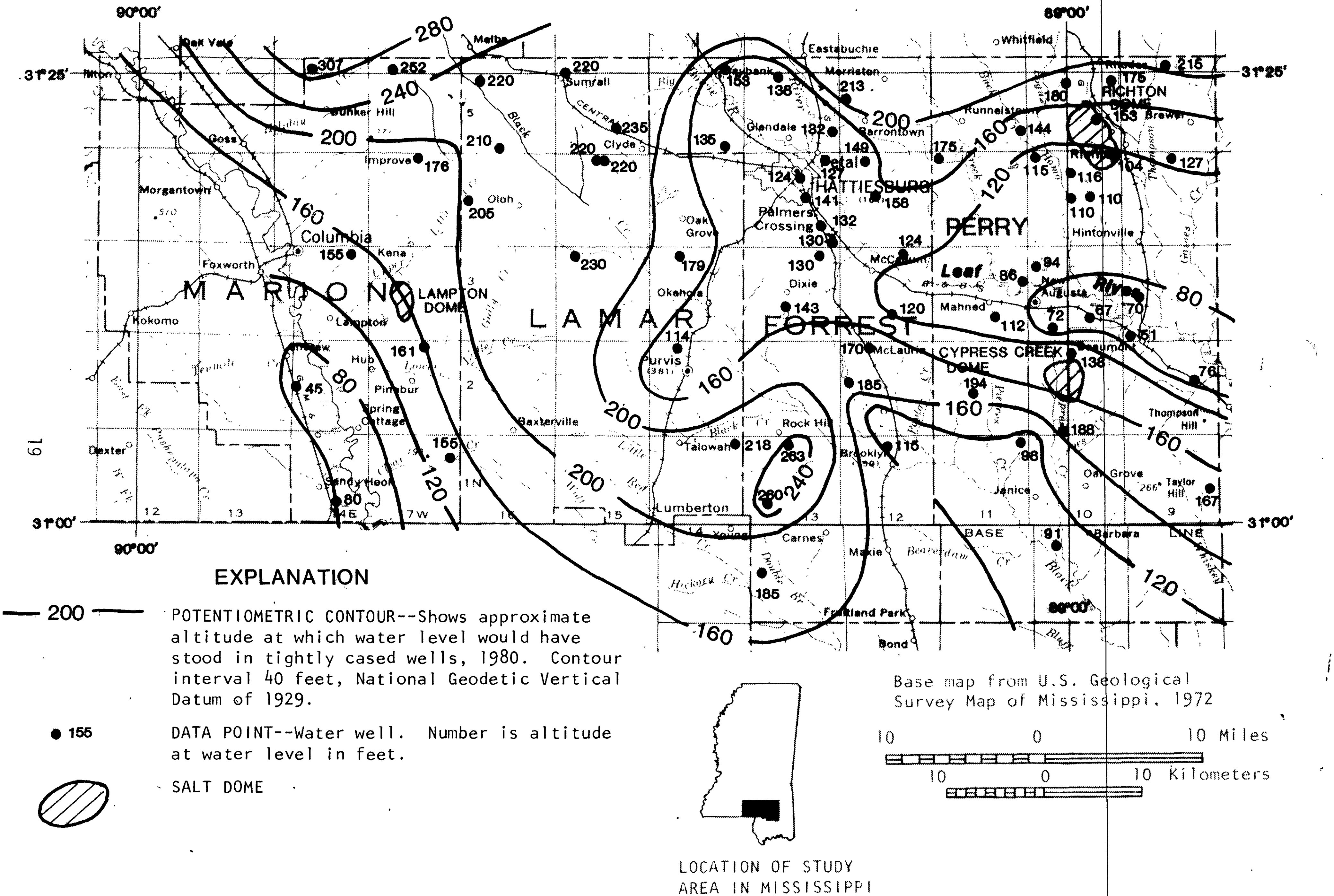
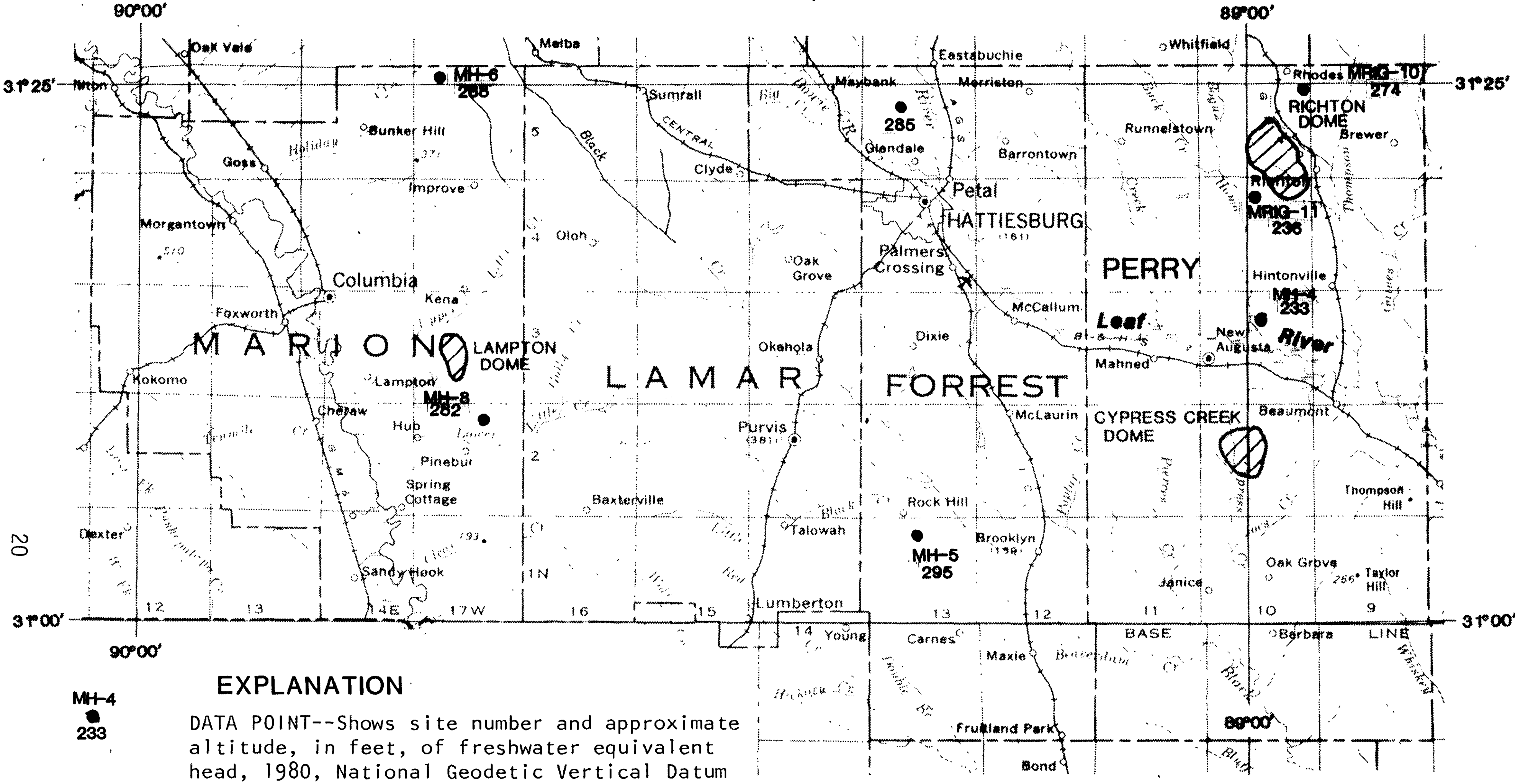


Figure 11.--Potentiometric surface of the Hattiesburg and Pascagoula Formations.

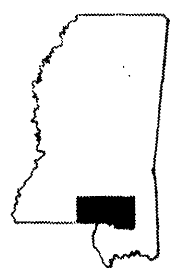


EXPLANATION

MH-4
233

DATA POINT--Shows site number and approximate altitude, in feet, of freshwater equivalent head, 1980, National Geodetic Vertical Datum of 1929.

SALT DOME



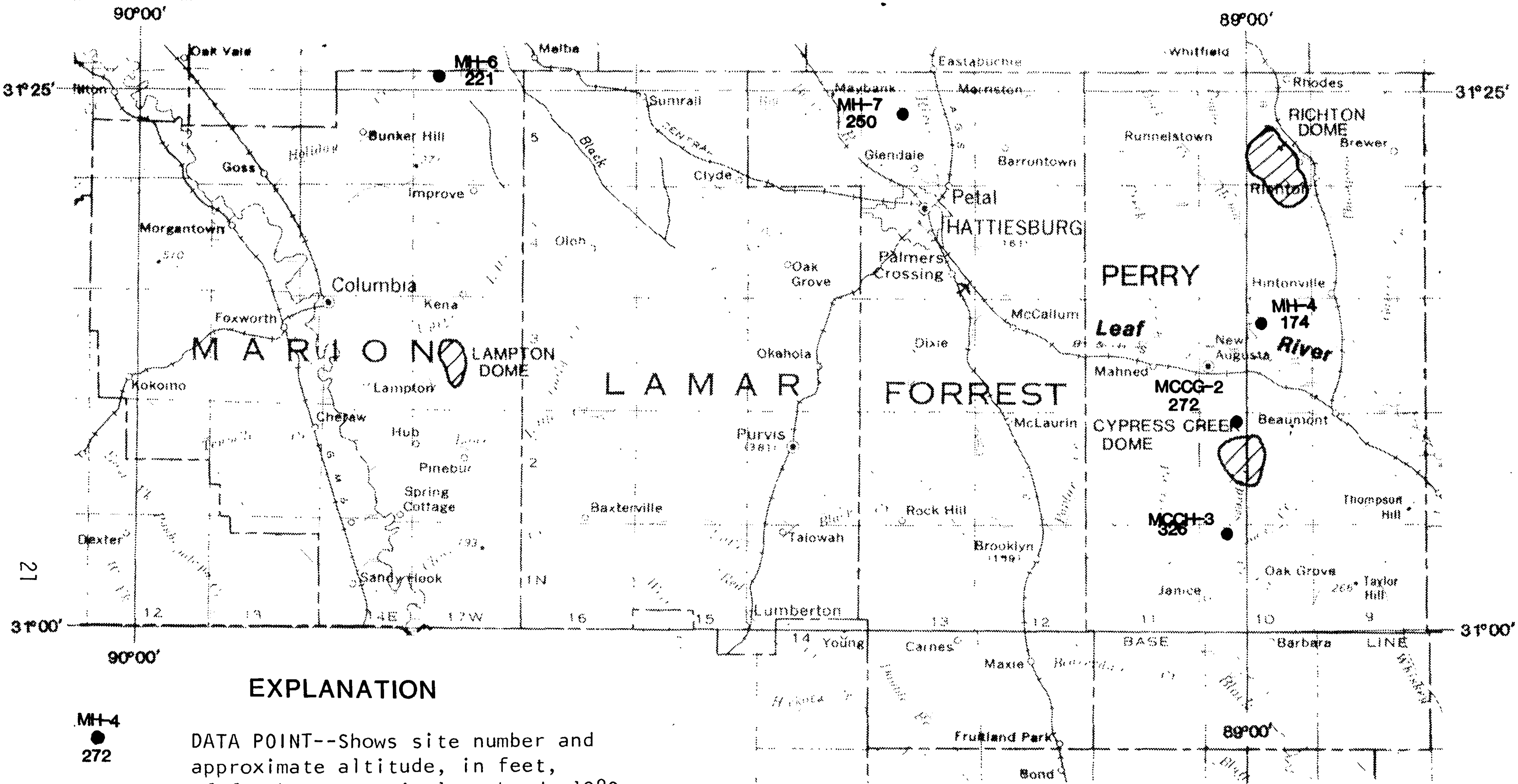
LOCATION OF STUDY AREA IN MISSISSIPPI

Base map from U.S. Geological Survey Map of Mississippi, 1972

10 0 10 Miles

10 0 10 Kilometers

Figure 12.--Equivalent freshwater head estimates for Wilcox Group.



EXPLANATION

MH-4
272

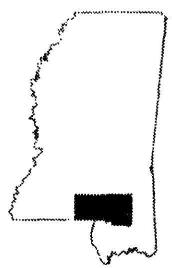
DATA POINT--Shows site number and approximate altitude, in feet, of freshwater equivalent head, 1980, National Geodetic Vertical Datum of 1929.

SALT DOME

Base map from U.S. Geological Survey Map of Mississippi, 1972

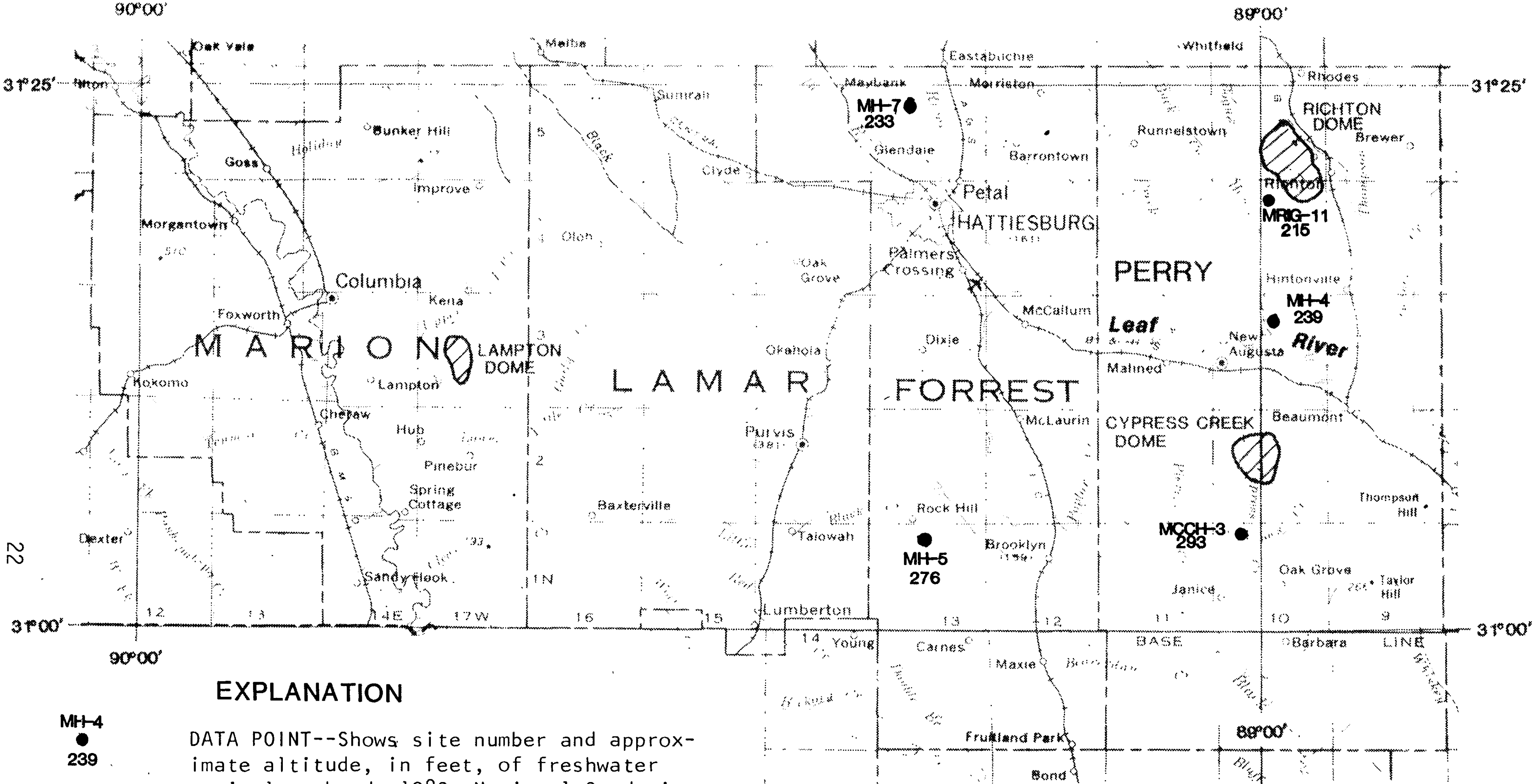
10 0 10 Miles

10 0 10 Kilometers



LOCATION OF STUDY
AREA IN MISSISSIPPI

Figure 13.--Equivalent freshwater head estimates for Sparta Sand.



EXPLANATION

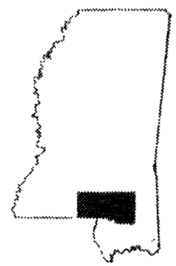
MH-4 239 — DATA POINT--Shows site number and approximate altitude, in feet, of freshwater equivalent head, 1980, National Geodetic Vertical Datum of 1929.

SALT DOME

Base map from U.S. Geological Survey Map of Mississippi, 1972

10 0 10 Miles

10 0 10 Kilometers



LOCATION OF STUDY AREA IN MISSISSIPPI

Figure 14.--Equivalent freshwater head estimates for Cook Mountain Formation.

Aquifer tests were performed by pumping a well at a constant rate for a period of time, generally about 24 hours, while observing the water-level changes in the well. Water levels also were monitored during the recovery period after pumping was stopped. No nearby wells completed in the same unit as the discharge wells were available for observation during the tests, and all water-level data are from the discharge wells. The modified Theis non-equilibrium formula and the Theis recovery formula were used to analyze the data (Ferris and others, 1962). Flowing wells were tested by holding drawdown constant and decreasing the discharge during the testing period. Equations by Jacob and Lohman (1952) were used to analyze the data from tests of flowing wells.

In some of the tests, temperature and salinity changes and the presence of hydrocarbon gases produced inconsistent test results. To reduce the level of uncertainty associated with the values derived from such tests, only the test data collected during periods when temperature, salinity, and gas concentrations were stabilized were selected for analysis.

The caprock-salt interfaces on the domes were tested with special techniques that were developed by the petroleum industry. A drill-stem test using a straddle-packer was used at Cypress Creek dome, and pressure build-up data were analyzed by methods described by Horner (1951). A swabbing test, also using a straddle-packer, was used at Richton dome, and water-level recovery data were analyzed by a method developed by Cooper and others (1967). The data were used to calculate estimates of the hydraulic conductivity of the caprock at both sites.

All aquifer test data were reviewed by Geological Survey hydrologists, and aquifer characteristics were estimated from the data. Rough estimates of hydraulic conductivity and transmissivity were computed from those tests that were considered to be the most reliable. The hydraulic conductivities that were computed for the caprock, caprock-salt interface, and several formations show large ranges in value for most of the geologic units (fig. 15). Field observations of hydraulic conductivity frequently vary over a wide range, especially for units such as the Catahoula Sandstone and Pascagoula and Hattiesburg Formations, which are composed of discontinuous, lenticular sand and clay lenses. Values determined for the deeper formations were affected by density differences of the saline water. Transmissivity determinations were similarly affected and were complicated further by the effects of partial penetration of the wells, which would tend to yield values lower than the actual transmissivities. The following transmissivity values are the highest values determined for each geologic unit tested. Presumably these values were less affected by partial penetration and may be representative of the actual values or at least may be in the same order of magnitude. However, they are rough estimates at best and should not be used for predictive purposes.

Geologic Unit	Transmissivity $(ft^3/d)/ft$
Pascagoula and Hattiesburg Formations	28,000
Catahoula Sandstone	23,000
Cook Mountain Formation	410
Sparta Sand	670
Wilcox Group	560
Caprock (Cypress Creek dome)	12
(Richton dome)	20

Storage coeficients were not determined for any of the geologic units because of the unreliable nature of the data and the unavailability of nearby wells for observation of water levels during the testing.

The velocity of ground water can be determined from the equation (Lohman, 1979, p. 10):

$$v = -\frac{Kdh/dl}{\theta}$$

where

$\bar{v}$ = average velocity, in ft/d,
K = hydraulic conductivity, in $(ft^3/d)/ft^2$,
dh/dl = hydraulic gradient, dimensionless (a negative value), and
θ = porosity, as a decimal fraction.

The average velocity of the water in the formations in the area of investigation is estimated by (1) selecting the average hydraulic conductivity for the respective unit from figure 14, (2) computing the hydraulic gradient from figures 9-13, and (3) using an estimated porosity of 0.30 for the Catahoula Sandstone and Pascagoula and Hattiesburg Formations, and 0.20 for the deeper formations as follows:

Formation	K	dh/dl	θ	$\bar{v}$	$\bar{v}$(ft/year)
Pascagoula and Hattiesburg Formations	140	9/5280	0.30	0.8	300
Catahoula Sandstone	180	7/5280	.30	.8	300
Cook Mountain Formation	.86	3.6/5280	.20	.003	1.0
Sparta Sand	.11	11/5280	.20	.001	.4
Wilcox Group	4.1	3.3/5280	.20	.01	4.0

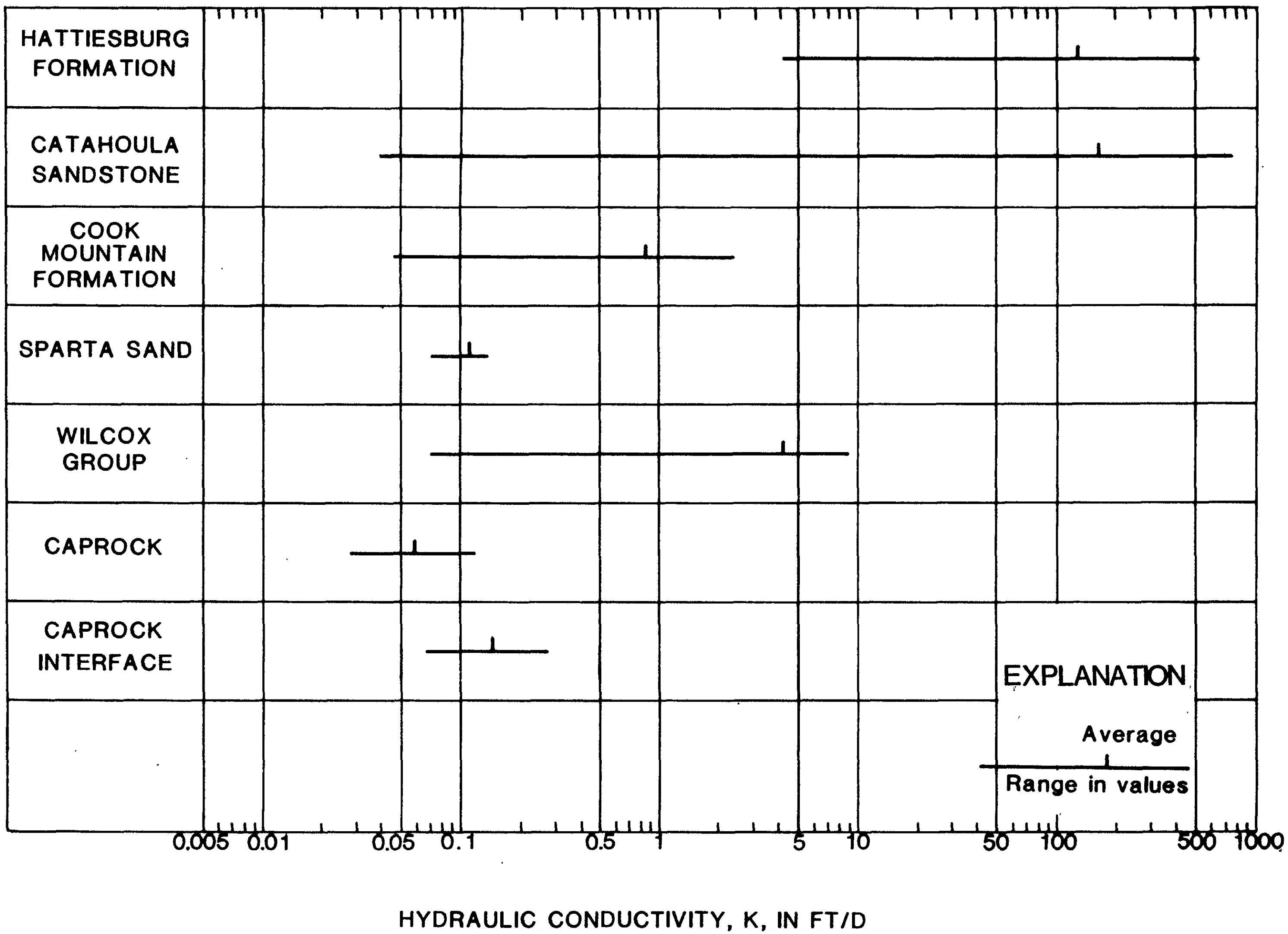


Figure 15.--Hydraulic conductivities for selected geologic units in the Cypress Creek-Richton domes area.

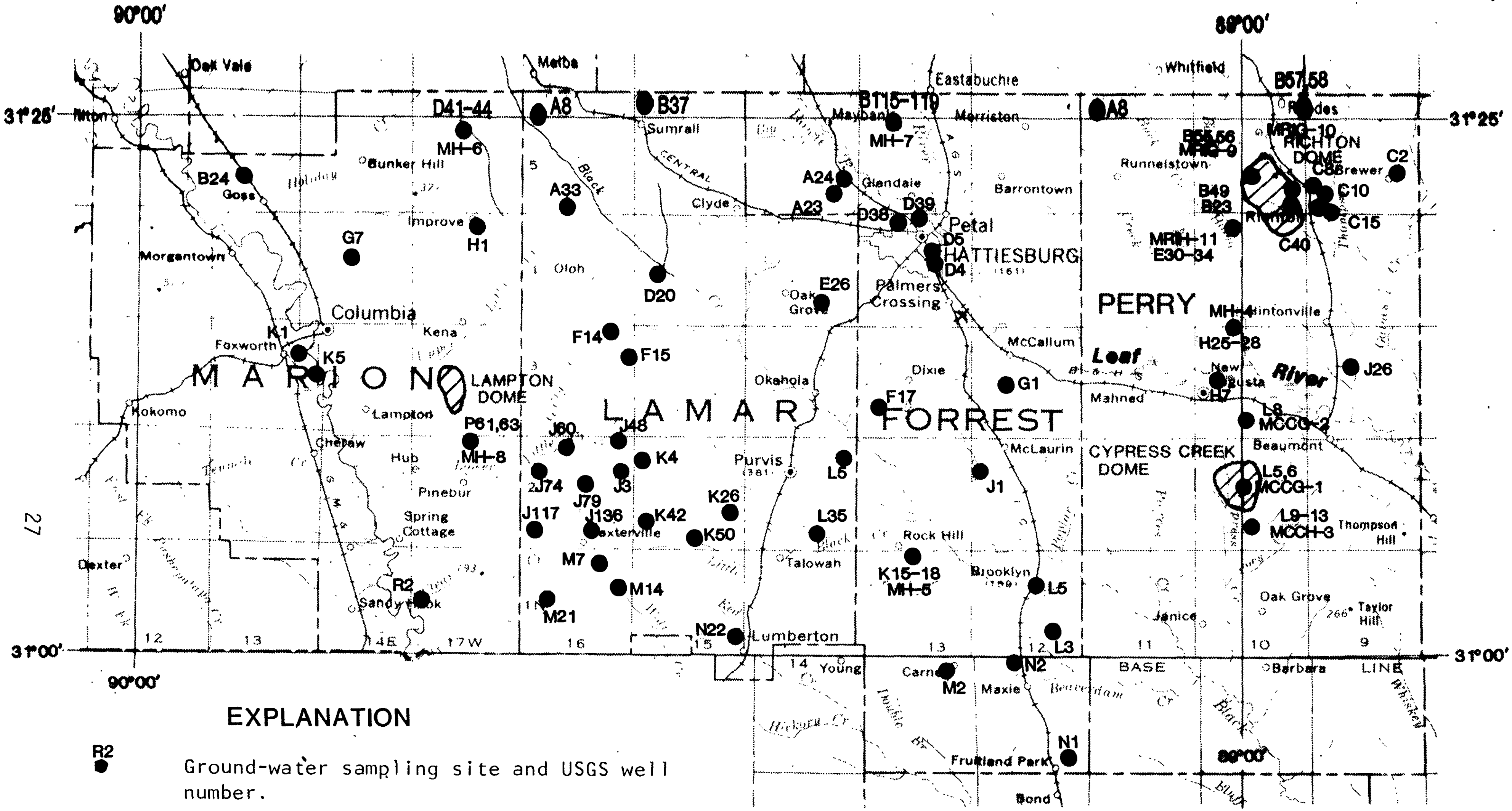
It must be emphasized again that these are rough estimates, and, further, the values are average velocities and do not necessarily equal the actual velocity between any two points in a given formation, which may be greater or less than the average velocity, depending on the flow path.

Slaughter (1981, p. 26-30), using aquifer-test data and laboratory analyses of the sidewall cores, estimated vertical velocities and flow times for water to move from various depths upward to the base of freshwater at Cypress Creek and Richton domes. At Cypress Creek dome he computed periods of 49,000 years for water to so move from a point in the Vicksburg Group, 118,000 years from a point in the Cockfield Formation, 234,000 years from a point near the base of the Zilpha Clay, and 300,000 years from a point in the Tallahatta Formation. At Richton dome, periods of 52,000 years from a point at the base of the Bucatunna Formation, 127,000 years from a point near the base of the Cook Mountain Formation, 250,000 years from a point in the Tallahatta Formation, and 332,000 years from a point near the top of the Wilcox Group, similarly were computed.

Quality of Ground Water

Water samples were collected from all of the wells drilled by LETCo for the DOE investigation and analyzed for chemical quality by the U.S. Geological Survey (fig. 16 and table 2). In addition, analyses of water from selected water wells in the area of investigation were used in this study. Most of the additional analyses are from the shallower freshwater aquifers. All of the samples from the Wilcox Group, Sparta Sand, and Cook Mountain Formation were saline, and mineral concentrations of some samples were several times that of seawater. Water samples from the caprocks of Cypress Creek and Richton domes also were saline. As would be expected, the most mineralized water sample (312,000 mg/L) in the area came from the salt-caprock interface--DOE well MRIG-9 at Richton dome.

Water in the Catahoula Sandstone generally is fresh and of suitable chemical quality for most uses, although many of the samples from the area of investigation had high concentrations of iron (table 2). Samples from three DOE wells--MRIH-11D, a mile southwest of Richton dome (fig. 6); MH-4D, midway between the domes; and MCCH-3C, about 2 mi south of Cypress Creek dome--had high concentrations of sodium and chloride. The latter sample was extremely salty and had a higher dissolved solids concentration than did a sample from the Sparta Sand at site MCCG-2 on the north side of the dome (figs. 5 and 6). Water sampled in 1979 from one (table 2, well C15) of three private wells in the town of Richton, about a mile east of Richton dome, had relatively high concentrations of sodium and chloride; whereas the other two wells, one of a similar depth and the other nearly 400 ft deeper (table 2, wells C10 and C8), sampled in 1955, had low concentrations of those minerals. All of the samples that had high chloride concentrations also had high concentrations of boron and strontium, both of which are common in seawater and brine.



EXPLANATION

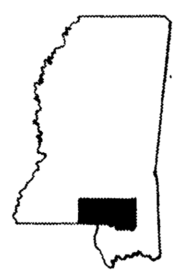
R2 ● Ground-water sampling site and USGS well number.

SALT DOME

Base map from U.S. Geological Survey Map of Mississippi, 1972

10 0 10 Miles

10 0 10 Kilometers



LOCATION OF STUDY

Table 2.--Chemical analyses of water from selected wells

Well number	Location Sec.	Location T.	Location R.	Supplemental location data	Date of collection	Screened interval or well depth (depth in feet)	Temperature (°C)	Boron (B), dissolved	Iron (Fe), dissolved	Manganese (Mn), dissolved	Strontium (Sr), dissolved	Silica (SiO_2), dissolved	Calcium (Ca), dissolved	Magnesium (Mg), dissolved	Sodium (Na), dissolved	Potassium (K), dissolved	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4), dissolved	Chloride (Cl), dissolved	Flouride (F), dissolved	Bromide (Br), dissolved	Iodide (I), dissolved	Nitrate (NO_3), dissolved	Solids, sum of constituents, dissolved, calculated	Hardness, dissolved as ($CaCO_3$)	Specific conductance (umho/cm at 25°C)	pH
								Micrograms per liter				Milligrams per liter																
WILCOX GROUP																												
035/B116	9	5N	13W	DOE MH-7A	03-13-80	2,651-2,673	23.0	3,500	370	10	1,700	6.9	1.8	14	4,100	23	1,390	400	36	5,300	1.8	29	1	-	10,600	64	17,200	8.9
035/K016	4	1N	13W	DOE MH-5A	10-12-79	3,521-3,542	40.0	3,200	3,700	500	103,000	16	490	340	21,000	71	300	0	-	31,000	.4	140	8.2	-	53,200	2,700	77,000	7.3
091/D041	4	5N	17W	DOE MH-6A	11-05-79	3,266-3,286	21.0	3,300	7,100	60	2,800	13	21	13	4,600	27	1,200	0	-	6,000	1.6	65	1.4	-	11,400	130	18,500	8.5
091/P061	10	2N	17W	DOE MH-8A	12-13-79	3,180-3,190	38.5	3,000	3,100	190	40,000	16	260	170	14,000	100	420	0	140	23,000	.6	71	5	-	38,000	1,400	59,000	7.4
111/B058	12	5N	10W	DOE MRIG-10	11-09-79	2,615-2,636	32.0	3,500	1,400	40	3,700	23	37	32	5,300	49	670	0	12	8,200	1.6	20	1.4	-	14,000	230	20,000	7.5
111/E031	9	4N	10W	DOE MRIH-11A	11-16-79	4,205-4,226	47.0	3,400	18,000	950	350,000	15	1,500	620	39,000	100	190	0	-	63,000	.3	370	.6	-	104,000	6,700	130,000	6.9
111/E032	9	4N	10W	DOE MRIH-11B	11-20-79	2,523-2,555	33.0	3,100	990	40	8,200	19	55	47	6,400	36	1,070	0	-	9,100	.9	98	1.9	-	16,300	340	27,000	7.4
111/H026	3	3N	10W	DOE MH-4A	07-25-79	2,505-2,525	22.0	4,000	8,500	200	130,000	1.1	140	90	8,500	49	660	0	40	13,000	.2	4.9	.9	0.2	22,200	740	-	8.0
					Median	-	32.5	3,400	3,400	130	24,000	16	98	69	7,400	49	670	0	38	11,000	.8	68	1.4	-	19,200	540	27,000	7.4
					Minimum	2,505-2,525	21.0	3,000	370	10	1,700	1.1	1.8	14	4,100	23	190	0	12	6,000	.2	4.9	.6	.2	10,600	64	17,200	6.9
					Maximum	4,205-4,226	47.0	4,000	18,000	950	350,000	23	1,500	620	39,000	100	1,390	400	140	63,000	1.8	370	8.2	.2	104,000	6,700	130,000	8.9
SPARTA SAND																												
035/B117	9	5N	13W	DOE MH-7B	12-05-79	1,940-1,962	21.0	3,000	1,400	100	2,500	5.9	34	23	4,100	30	600	0	-	6,000	1.2	17	.6	-	10,500	180	17,000	8.3
035/K017	4	1N	13W	DOE MH-5B	03-12-80	2,496-2,526	24.0	3,300	310	510	51,000	1.1	290	220	14,000	79	77	0	91	22,000	.4	69	7.1	-	36,900	1,700	58,200	7.6
091/D042	4	5N	17W	DOE MH-6B	11-01-79	2,724-2,756	27.0	3,200	350	20	1,500	14	13	11	2,900	20	1,540	0	28	3,300	1.4	27	.6	-	7,080	79	12,400	8.1
111/H027	3	3N	10W	DOE MH-4B	03-11-80	1,945-1,965	22.0	3,300	220	180	2,400	4.8	200	150	11,000	74	170	0	75	17,000	.6	51	3.9	-	28,700	1,100	46,500	7.7
111/L008	33	3N	10W	DOE MCCG-2	09-27-79	2,669-2,677	30.0	4,000	8,500	200	130,000	8.9	390	600	41,000	100	240	0	580	64,000	.3	99	7.9	-	107,000	3,600	128,000	7.1
111/L011	33	2N	10W	DOE MCCH-38	10-22-79	3,450-3,490	25.0	1,000	2,100	1,600	84,000	.8	510	520	76,000	320	70	0	1,600	119,000	0	230	8.2	-	198,000	3,500	222,000	8.4
					Median	-	24.5	3,200	880	190	38,000	5.4	240	180	12,000	76	200	0	91	20,000	.5	60	5.5	-	32,000	1,400	52,400	7.9
					Minimum	1,940-1,962	21.0	1,000	220	20	1,500	1.1	13	11	2,900	20	70	0	28	3,300	0	17	.6	-	7,080	79	12,400	7.1
					Maximum	3,450-3,490	30.0	4,000	8,500	1,600	130,000	14	510	600	76,000	320	1,540	0	1,600	119,000	1.4	230	8.2	-	198,000	3,600	220,000	8.4

Table 2.--Chemical analyses of water from selected wells — Continued

Well number	Location Sec.	Location T.	Location R.	Supplemental location data	Date of collection	Screened interval or well depth (depth in feet)	Temperature (°C)	Boron (B), dissolved (Micrograms per liter)	Iron (Fe), dissolved (Micrograms per liter)	Manganese (Mn), dissolved (Micrograms per liter)	Strontium (Sr), dissolved (Micrograms per liter)	Silica (SiO_2), dissolved (Milligrams per liter)	Calcium (Ca), dissolved (Milligrams per liter)	Magnesium (Mg), dissolved (Milligrams per liter)	Sodium (Na), dissolved (Milligrams per liter)	Potassium (K), dissolved (Milligrams per liter)	Bicarbonate (HCO_3) (Milligrams per liter)	Carbonate (CO_3) (Milligrams per liter)	Sulfate (SO_4), dissolved (Milligrams per liter)	Chloride (Cl), dissolved (Milligrams per liter)	Flouride (F), dissolved (Milligrams per liter)	Bromide (Br), dissolved (Milligrams per liter)	Iodide (I), dissolved (Milligrams per liter)	Nitrate (NO_3), dissolved (Milligrams per liter)	Solids, sum of constituents, dissolved, calculated (Milligrams per liter)	Hardness, dissolved as ($CaCO_3$) (Milligrams per liter)	Specific conductance (µmho/cm at 25°C)	pH
COOK MOUNTAIN FORMATION																												
035/B118	9	5N	13W	DOE MH-7C	3-13-80	1,625-1,656	22.0	3,200	360	70	660	19	4.2	5.3	1,400	23	1,140	84	10	1,600	3.9	4.0	.6	-	3,620	33	6,460	8.6
035/K018	4	1N	13W	DOE MH-5C	3-12-80	2,244-2,287	24.0	3,400	110	30	8,700	1.2	26	52	6,000	49	250	15	42	9,500	2.2	40	2.2	-	15,900	290	27,000	8.8
091/0043	4	5N	17W	DOE MH-6C	3-12-80	2,389-2,419	22.0	3,100	940	10	500	29	1.9	1.0	1,200	34	1,130	150	29	1,100	4.7	4.5	.7	-	3,120	9	5,250	9.4
091/D063	10	2N	17W	DOE MH-8C	1-22-80	2,458-2,501	32.0	3,300	2,800	100	3,100	16	230	150	13,000	64	290	0	120	20,000	16	50	11	-	33,800	1,200	50,000	7.5
111/E033	9	4N	10W	DOE MRIH-11C	11-26-79	1,579-1,610	20.0	3,300	30	30	860	2.7	37	9.1	2,600	24	1,080	9	17	3,300	4.9	11	.9	-	6,550	130	11,600	9.4
111/H028	3	3N	10W	DOE MH-4C	3-11-80	1,697-1,717	19.0	3,200	230	460	19,000	.2	140	130	8,900	65	110	0	58	14,000	1.8	36	3.8	-	23,400	910	39,000	9.0
111/L010	33	2N	10W	DOE MCCH-3A	10- 5-79	3,070-3,101	29.0	5,000	2,700	1,000	68,000	3.9	410	440	73,000	260	78	0	2,600	120,000	.8	220	8.7	-	197,000	2,900	200,000	8.1
					Median	—	22.0	3,300	360	70	3,100	3.9	37	52	6,000	49	290	9	42	9,500	3.9	36	2.2	-	15,900	290	27,000	8.8
					Minimum	1,579-1,610	19.0	3,100	30	10	500	.2	1.9	1.0	1,200	23	78	0	10	1,100	.8	40	.6	-	3,120	9	5,250	7.5
					Maximum	3,070-3,101	32.0	5,000	2,800	1,000	68,000	29	410	440	73,000	260	1,140	150	2,600	120,000	16	220	11	-	197,000	2,900	200,000	9.4
SALT DOME CAPROCK																												
111/B056	26	5N	10W	Richton salt dome DOE MRIG-9	12- 7-79	569-750	31.0	1,100	250	30	270	14	240	4.6	3,000	6.7	300	0	650	4,400	0	.2	.2	-	8,470	620	14,000	7.6
111/L006	9	2N	10W	Cypress Creek salt dome DOE MCCG-1	10- 2-79	1,247-1,369	32.5	2,000	240	80	8,500	23	550	72	4,600	19	260	0	2,400	6,700	1.3	13	.3	-	14,500	1,700	22,500	7.1
SALT-CAPROCK INTERFACE																												
111/B056	26	5N	10W	Richton salt dome DOE MRIG-9	12- 4-79	750-770	27.0	1,300	5,500	10	30,000	31	1,100	170	120,000	60	500	0	5,890	185,000	-	460	1.9	-	312,000	3,400	162,000	6.4

Table 2.--Chemical analyses of water from selected wells — Continued

Well number	Location Sec.	Location T.	Location R.	Supplemental location data	Date of collection	Screened interval or well depth (depth in feet)	Temperature (°C)	Boron (B), dissolved	Iron (Fe), dissolved	Manganese (Mn), dissolved	Strontium (Sr), dissolved	Silica (SiO_2), dissolved	Calcium (Ca), dissolved	Magnesium (Mg), dissolved	Sodium (Na), dissolved	Potassium (K), dissolved	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4), dissolved	Chloride (Cl), dissolved	Flouride (F), dissolved	Bromide (Br), dissolved	Iodide (I), dissolved	Nitrate (NO_3), dissolved	Solids, sum of constituents, dissolved, calculated	Hardness, dissolved as ($CaCO_3$)	Specific conductance (umho/cm at 25°C)	pH
								Micrograms per liter				Milligrams per liter																
												CATAHOULA SANDSTONE																
035/A023	35	5N	14W	-	3- -65	752	23.3	-	490	-	-	11	10	2.9	23	3.8	96	0	9.8	2.0	.1	-	-	.1	106	37	187	7.0
035/A024	25	5N	14W	-	1- -67	705	21.1	-	180	-	-	35	7.5	2.2	32	4.2	114	0	9.8	1.8	.2	-	-	.2	120	28	200	7.2
035/B119	9	5N	13W	DOE MH-7D	1- 3-80	770-800	23.0	70	40	4	60	38	3.0	.7	51	2.2	140	0	11	2.8	.2	0	0	-	178	10	230	8.2
035/D004	15	4N	13W	-	2- -64	485	21.6	-	910	-	-	26	5.3	2.6	9.2	3.4	43	0	8.8	2.5	.4	-	-	.1	80	24	97	6.2
035/D005	15	4N	13W	-	2- -64	678	22.2	430	420	-	-	12	7.0	3.5	30	3.7	108	0	8.8	1.6	.2	-	-	0	121	32	184	7.1
035/D038	4	4N	13W	-	9- -65	687	22.2	-	520	-	-	1.4	8.1	4.1	22	3.4	90	0	8.6	2.0	.1	-	-	.1	108	37	177	6.9
035/D039	3	4N	13W	-	10- -65	353	-	-	210	-	-	39	6.5	3.0	7.4	4.2	42	0	9.8	2.6	0	-	-	.1	94	30	100	6.7
035/K019	4	1N	13W	DOE MH-5D	10-25-79	1,500-1,540	30.0	960	60	5	100	13	1.4	.6	230	2.8	590	20	3.2	8.0	4.7	.2	0	-	573	6	922	8.9
073/D020	20	4N	15W	-	1- -62	400	14.4	0	8,900	-	-	43	9.6	2.2	9.4	2.3	63	0	.6	3.0	.1	-	-	0	126	33	120	6.8
073/J003	12	2N	16W	-	5- -61	1,310	28.8	-	290	-	-	9.2	14	1.7	126	3.9	226	0	99	21	.9	-	-	0	420	42	675	7.4
091/D044	4	5N	17W	DOE MH-6D	1- 7-80	1,375-1,395	25.0	70	140	7	30	60	2.5	.2	52	.8	140	4	9.7	2.3	.2	0	0	-	202	7	240	8.5
091/G007	17	4N	18W	-	5- -74	790	24.0	-	170	-	-	19	4.2	1.7	38	4.7	122	0	8.8	1.7	.1	-	-	-	151	17	215	7.6
091/K005	11	3N	13E	-	7- -66	713	23.3	-	0	-	-	15	2.9	.2	50	2.3	128	0	9.2	2.1	.3	-	-	.1	134	8	214	7.1
111/A008	6	5N	11W	-	9- -64	658	22.2	-	650	-	-	6.4	11	5.0	35	2.7	129	0	11	4.4	.1	-	-	0	144	48	232	7.2
111/C002	23	5N	9W	-	6- -65	390	-	-	7,900	-	-	24	3.9	2.0	7.8	2.9	34	0	5.2	2.7	0	-	-	0	66	18	81	6.0
111/C008	31	5N	9W	-	9- -55	1,119	21.1	-	0	-	-	-	3.0	2.0	5.2	1.0	9	0	2.0	8.5	.2	-	-	8.8	60	8	64	5.7
111/C010	31	5N	9W	-	9- -55	728	23.0	-	540	-	-	-	1.3	.2	43	1.4	111	0	1.6	5.0	.2	-	-	0	157	4	200	7.4
111/C015	31	5N	9W	-	10-18-79	736	23.0	200	2,000	120	260	12	13	1.8	160	2.6	130	0	20	180	.2	.4	0	-	457	40	824	6.9
111/E034	9	4N	10W	DOE MRIH-11D	11-27-79	909-930	26.0	3,000	2,400	20	3,700	20	37	23	3,800	23	1,580	0	-	4,700	1.6	13	.4	-	9,410	190	15,000	7.5
111/H007	19	3N	10W	-	8- -78	721	23.0	-	10	0	-	12	.4	.1	120	1.1	210	-	1.9	66	.4	-	-	-	321	1	530	8.9
111/H029	3	3N	10W	DOE MH-4D	3-11-80	1,090-1,110	21.5	3,200	50	20	3,500	3.8	10	22	3,200	2.3	750	95	20	4,400	1.0	21	1.1	-	8,150	120	14,600	9.0
111/L012	33	2N	10W	DOE MCCH-3C	10- 8-79	1,791-1,833	30.0	2,600	2,800	200	1,500	16	290	150	4,000	160	310	0	2,300	73,000	1.2	86	.9	-	130,000	1,300	150,000	6.9
					Median	-	23.0	430	360	14	260	17	7.0	2.1	40	2.9	120	0	9.2	2.9	.2	.4	0	.1	150	29	214	7.2
					Minimum	353	14.4	0	0	0	30	1.4	.4	.1	5.2	.8	9	0	.6	1.6	0	0	0	0	60	1	64	5.7
					Maximum	1,791-1,833	30.0	3,200	8,900	200	3,700	60	290	150	54,000	160	1,580	95	2,300	73,000	4.7	86	1.1	8.8	130,000	1,300	150,000	9.0

Table 2.--Chemical analyses of water from selected wells — Continued

Well number	Location Sec.	Location T.	Location R.	Supplemental location data	Date of collection	Screened interval or well depth (depth in feet)	Temperature (°C)	Boron (B), dissolved (Micrograms per liter)	Iron (Fe), dissolved (Micrograms per liter)	Manganese (Mn), dissolved (Micrograms per liter)	Strontium (Sr), dissolved (Micrograms per liter)	Silica (SiO_2), dissolved (Milligrams per liter)	Calcium (Ca), dissolved (Milligrams per liter)	Magnesium (Mg), dissolved (Milligrams per liter)	Sodium (Na), dissolved (Milligrams per liter)	Potassium (K), dissolved (Milligrams per liter)	Bicarbonate (HCO_3) (Milligrams per liter)	Carbonate (CO_3) (Milligrams per liter)	Sulfate (SO_4), dissolved (Milligrams per liter)	Chloride (Cl), dissolved (Milligrams per liter)	Flouride (F), dissolved (Milligrams per liter)	Bromide (Br), dissolved (Milligrams per liter)	Iodide (I), dissolved (Milligrams per liter)	Nitrate (NO_3), dissolved (Milligrams per liter)	Solids, sum of constituents, dissolved, calculated (Milligrams per liter)	Hardness, dissolved as ($CaCO_3$) (Milligrams per liter)	Specific conductance (umho/cm at 25°C)	pH
PASCAGOULA AND HATTIESBURG FORMATIONS																												
035/B115	9	5N	13W	DOE MH-7WS	7-12-79	335-376	23.0	10	1,200	70	80	22	8.2	2.6	10	3.6	54	0	8.8	2.2	.1	.2	0	.2	86	31	125	6.4
035/F017	30	3N	13N	-	6- -65	340	20.5	-	5,900	-	-	5.3	9.9	2.0	16	2.8	68	0	7.0	4.7	.1	-	-	.3	129	33	142	6.4
035/G001	29	3N	12W	-	4- -70	400	-	-	80	-	-	58	9.4	2.1	15	3.9	71	0	5.0	5.6	.1	-	-	.1	143	32	136	6.8
035/J001	18	2N	12W	-	8- -61	333	-	0	0	-	-	14	2.1	.9	2.8	2.1	17	0	.2	3.0	0	-	-	.6	30	8	36	6.6
035/K015	4	1N	13W	DOE MH-5WS	5-31-79	163-185	21.0	20	30	10	20	18	1.3	.8	2.8	1.3	7	0	.9	4.8	0	-	0	0	33	7	27	5.8
035/L003	26	1N	12W	-	11- -67	740	22.0	-	2,200	-	-	52	4.8	.5	3.5	1.2	101	0	6.4	3.5	.1	-	-	.1	160	14	189	6.9
035/L005	10	1N	12W	-	9- -64	525	22.7	-	200	-	-	30	.1	.2	54	.8	130	0	9.4	3.4	.4	-	-	0	172	1	238	7.4
035/M002	2	1S	13W	-	9- -64	688	21.6	-	1,500	-	-	38	2.2	1.6	33	1.3	95	0	.6	3.4	.2	-	-	.1	143	12	174	6.9
035/N001	26	1S	12W	-	6- -65	250	-	-	30	-	-	16	9.2	2.9	40	1.6	127	0	7.8	2.8	.3	-	-	.2	143	31	233	6.8
035/N002	4	1S	12W	-	6- -65	529	-	-	230	-	-	41	5.0	.9	39	1.1	113	0	1.2	3.6	.2	-	-	-	148	16	205	6.9
073/A008	8	5N	16W	-	1- -62	396	15.0	0	6,000	-	-	15	4.6	2.6	5.5	1.6	41	0	.8	1.2	.1	-	-	0	62	22	110	6.2
073/A033	33	5N	16W	-	1- -62	255	18.8	0	5,600	-	-	52	5.3	2.1	8.5	2.0	49	0	.6	1.3	.2	-	-	0	120	22	89	6.2
073/B037	7	5N	15W	-	3- -64	382	20.0	40	50	-	-	27	2.5	.9	3.0	2.0	17	0	0	3.2	.1	-	-	.1	80	10	47	6.7
073/E026	26	4N	14W	-	12- -61	420	20.5	0	1,200	-	-	2.0	1.0	.6	6.7	1.2	12	0	5.6	2.9	.4	-	-	0	45	5	64	6.1
073/J074	8	2N	16W	-	8- -64	280	22.8	-	1,400	50	-	58	22	6.1	25	2.2	147	0	0	9.2	.1	-	-	-	194	80	260	7.1
073/J117	32	2N	16W	-	8- -34	454	25.0	-	1,500	-	-	52	17	3.8	28	2.5	132	0	0	7.2	.1	-	-	-	179	58	230	7.0
073/L005	12	2N	14W	-	5- -66	406	21.6	-	190	-	-	44	8.5	1.4	23	1.9	89	0	3.4	3.6	.1	-	-	1	132	27	167	6.8
073/L035	35	2N	14W	-	1- -62	250	20.0	0	50	-	-	32	1.8	.4	5.5	1.8	20	0	.8	2.0	.2	-	-	0	64	6	41	6.7
091/B024	27	5N	19W	-	8- -78	134	19.5	-	10	0	-	14	1.3	.5	2.7	.7	10	0	.3	3.7	0	-	-	-	31	5	29	5.5
091/D040	4	5N	17W	DOE MH-6WS	10- 4-79	297-327	21.0	60	20	20	10	18	1.7	1.7	2.3	1.4	25	0	.4	2.6	0	0	0	-	40	11	60	6.5
091/H001	4	4N	17W	-	10- -66	195	19.4	-	190	-	-	6.9	.8	.8	3.1	1.0	3	0	.6	4.0	0	-	-	5.2	30	5	32	5.4
091/K001	11	3N	13S	-	8- -66	522	21.6	-	190	-	-	23	2.7	.8	3.9	2.3	128	0	9.2	2.1	.3	-	-	0	134	8	214	7.1
091/D060	10	2N	17W	DOE MH-8WS	1-25-80	220-281	21.0	0	180	160	240	63	17	3.0	15	2.4	89	0	2.3	10	.1	0	.1	-	157	55	170	6.5
091/R002	19	1N	17W	-	1- -62	850	24.0	0	1,500	-	-	47	2.0	.5	18	1.7	44	0	7.6	2.9	.2	-	-	0	115	7	106	6.5
111/B023	25	5N	10W	-	11-27-79	412	19.0	80	30	20	40	7.6	1.4	.3	52	1.1	110	0	13	11	.1	.1	0	-	149	5	242	8.0
111/B049	25	5N	10W	-	11-27-79	325	17.0	50	30	9	100	14	4.8	1.1	36	1.6	100	-	4.5	4.9	.1	.1	0	-	122	17	182	8.8
111/B055	26	5N	10W	DOE MRIG-9WS	2- 2-80	368-378	25.5	220	10	10	340	12	4.8	.7	96	1.9	180	0	5.7	54	.3	.1	0	-	265	15	440	7.9
111/B057	12	5N	10W	DOE MRIG-10WS	2- 5-80	280-290	23.8	-	10	100	180	11	15	3.6	20	2.9	92	0	7.2	9.6	.1	0	0	-	115	52	180	7.9
111/C040	31	5N	9W	-	10-18-79	660	23.0	70	540	20	140	12	4.9	1.8	36	2.6	83	0	9.5	10	.1	.4	0	-	119	20	176	6.6
111/E030	9	4N	10W	DOE MRIH-11WS	7-31-79	120-160	21.0	10	40	9	20	13	.9	.4	4.8	1.1	10	0	1.5	5.0	0	0	0	.5	32	4	50	5.6
111/J026	8	3N	9W	-	8- -78	123	22.0	-	140	0	-	13	.7	.2	2.4	1.1	5	0	.7	2.0	0	-	-	-	26	3	25	5.9
111/L005	9	2N	10W	DOE MCCG-1WS	4-12-79	54-76	21.5	6	40	10	20	22	2.1	.8	4.8	1.8	11	0	1.3	6.5	0	.1	0	.4	45	9	50	5.7
111/L007	33	3N	10W	DOE MCCG-2WS	3-27-79	206-248	21.0	30	70	70	60	35	7.1	1.4	32	1.7	100	0	4	3.3	.1	0	0	0	134	24	175	8.8
111/L009	33	2N	10W	DOE MCCH-3WS	4-10-79	306-346	21.0	-	130	10	660	64	.3	.3	21	.5	46	0	1.7	3.0	0	0	0	0	115	3	90	6.5
111/L013	33	2N	10W	DOE MCCH-3D	6-13-79	1,219-1,250	27.5	1,400	30	10	270	12	9.2	1.0	660	5.6	420	0	110	670	3.2	1.7	0	.1	1,680	27	3,020	8.2
					Median		21.0	10	140	10	90	22	4.6	.9	16	1.8	71	0	2.3	3.4	.1	.1	0	.1	120	14	142	6.7
					Minimum	54-76	15.0	0	0	0	10	2.0	.1	.2	2.3	.5	3	0	0	1.2	0	0	0	0	26	1	25	5.4
					Maximum	1,219-1,250	27.5	1,400	6,000	160	660	64	22	6.1	660	5.6	420	0	110	670	3.2	1.7	.1	5.2	1,680	80	3,020	8.8

Table 2.--Chemical analyses of water from selected wells — Continued

Well number	Location Sec.	T.	R.	Supplemental location data	Date of collection	Screened interval or well depth (depth in feet)	Temperature (°C)	Boron (B), dissolved	Iron (Fe), dissolved	Manganese (Mn), dissolved	Strontium (Sr), dissolved	Silica (SiO_2), dissolved	Calcium (Ca), dissolved	Magnesium (Mg), dissolved	Sodium (Na), dissolved	Potassium (K), dissolved	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4), dissolved	Chloride (Cl), dissolved	Flouride (F), dissolved	Bromide (Br), dissolved	Iodide (I), dissolved	Nitrate (NO_3), dissolved	Solids, sum of constituents, dissolved, calculated	Hardness, dissolved as ($CaCO_3$)	Specific conductance (umho/cm at 25°C)	pH
								Micrograms per liter				Milligrams per liter																
CITRONELLE FORMATION																												
073/F014	24	3N	16W	-	5- -61	112	21.1	-	4,700	-	-	38	12	1.7	7.8	3.0	62	0	1.0	4.7	0	-	-	0	133	37	122	6.4
073/F015	25	3N	16W	-	5- -61	80	21.1	-	1,400	-	-	7.0	1.1	.1	2.5	.8	4	0	1.2	3.5	0	-	-	.1	20	3	18	5.3
073/J048	1	2N	16W	-	6- -61	29	20.0	-	20	-	-	4.8	1.3	.7	2.8	.6	6	0	.6	3.6	0	-	-	2.9	25	6	28	5.7
073/J060	4	2N	16W	-	8- -64	19	22.2	-	2,800	-	-	7.5	1.1	1.3	17	2.0	16	0	0	20	0	-	-	3.3	96	8	118	5.8
073/J079	10	2N	16W	-	1- -62	43	16.6	50	920	100	-	5.1	.9	.2	2.1	.7	7	0	.6	1.6	0	-	-	0	21	3	22	6.0
073/J136	34	2N	16W	-	3- -67	200	20.5	-	570	-	-	52	9.0	2.1	15	4.5	70	0	6.2	4.3	.2	-	-	.2	138	31	138	6.5
073/K004	7	2N	15W	-	1- -62	90	14.4	0	0	-	-	7.1	1.0	.6	2.5	.9	6	0	.6	3.0	.1	-	-	2.3	34	5	29	6.0
073/K026	26	2N	15W	-	9- -61	90	23.3	280	1,600	-	-	4.2	3.5	2.3	2.3	.9	0	0	.2	1.0	.4	-	-	1.0	46	18	249	3.3
073/K042	31	2N	15W	-	5- -61	70	21.1	20	5,800	-	-	8.4	1.5	.8	4.6	.3	17	0	0	2.5	0	-	-	0	37	7	40	5.9
073/K050	33	2N	15W	-	5- -61	22	20.5	-	220	-	-	3.8	4.4	6.6	9.0	2.8	5	0	.4	27	0	-	-	24	109	38	147	5.5
073/M007	2	1N	16W	-	9- -61	173	20.5	10	150	-	-	5.3	3.3	1.4	1.5	.4	18	0	.8	2.0	0	-	-	.6	26	14	34	6.7
073/M014	11	1N	16W	-	9- -61	98	21.1	0	240	-	-	6.2	1.4	1.0	2.2	.6	9	0	.4	3.2	0	-	-	2.3	36	8	38	6.4
073/M021	17	1N	16W	-	1- -62	185	15.0	30	730	-	-	9.1	1.6	.5	1.8	.5	6	0	.2	3.0	.1	-	-	1.2	35	6	26	6.0
073/N022	22	1N	15W	-	1- -62	132	17.7	0	210	-	-	8.7	1.5	.8	3.9	1.0	14	0	.4	2.9	.1	-	-	.4	40	7	47	6.2
111/H025	3	3N	10W	DOE MH-4WS	6- 6-79	83-122	20.5	7	60	20	10	17	.7	.3	3.6	1.1	10	0	1.6	2.9	0	0	0	.2	33	3	34	5.3
					Median	-	20.5	10	570	60	-	7.1	1.5	.8	2.8	.9	9	0	.6	3.0	0	-	-	6	36	7	38	6.0
					Minimum	19	14.4	0	0	20	10	3.8	.7	.1	1.5	.3	0	0	0	1.0	0	0	0	0	20	3	18	3.3
					Maximum	200	23.5	280	5,800	100	10	52	12	6.6	17	4.5	70	0	6.2	27	.4	0	0	24	138	38	249	6.7

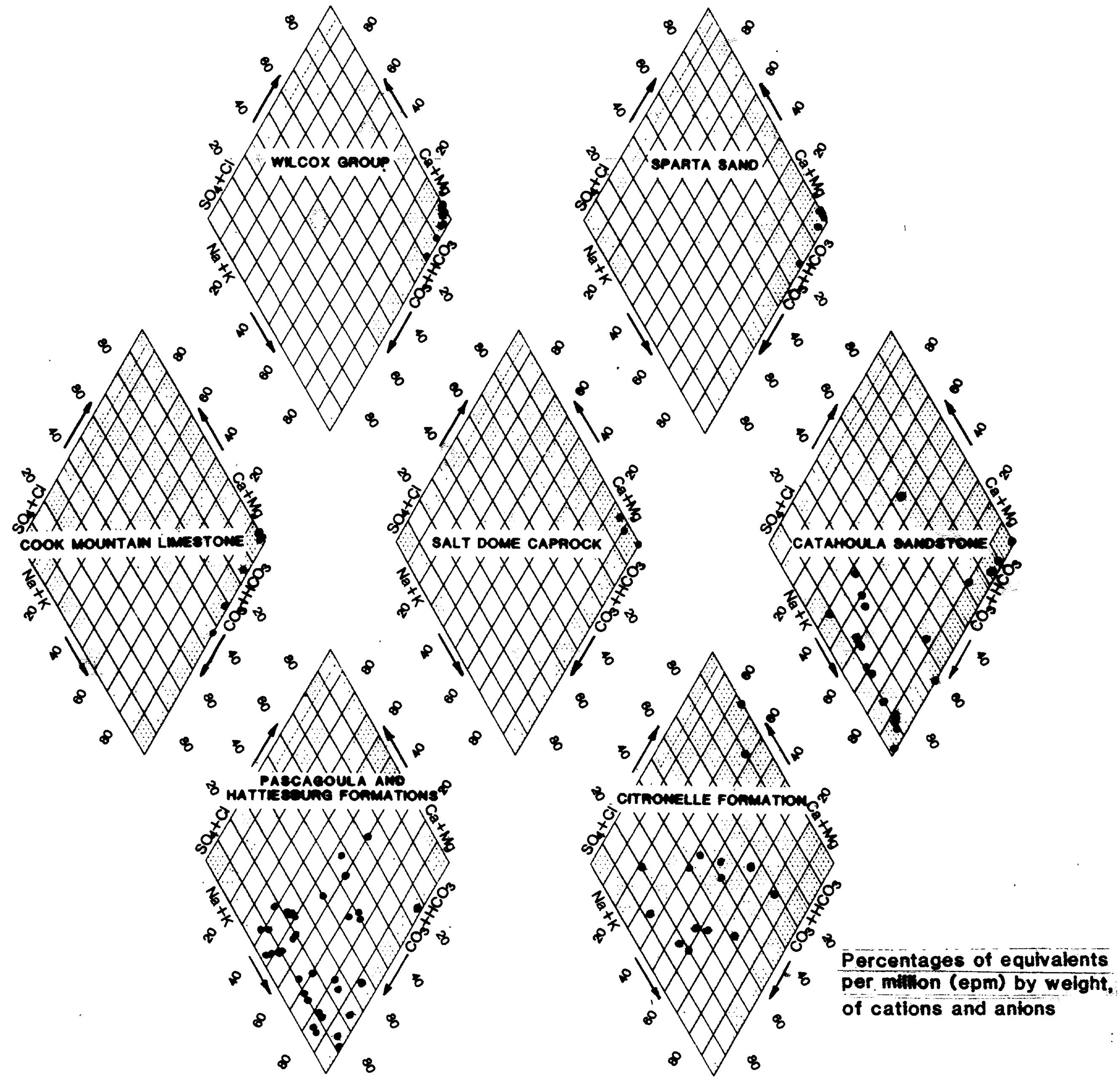


Figure 17.--Chemical character of water from salt-dome, caprock, and Tertiary formations near Cypress Creek and Richton salt domes.

Water in the Pascagoula and Hattiesburg Formations in the study area is somewhat similar to that in the Catahoula Sandstone but generally less mineralized. Only one water sample, that from DOE well MCCH-3, 2 mi south of Cypress Creek dome (fig. 6), had fairly high concentrations of sodium, chloride and boron, but the sample interval in the well was much deeper than that in any other wells in the Pascagoula and Hattiesburg Formations.

Water in the Citronelle Formation is generally similar to that in the Pascagoula and Hattiesburg Formations, although generally slightly less mineralized. Only one DOE well, the water supply well at site MH-4, between the domes, was sampled for water from the Citronelle Formation. The other analyses shown for comparison in table 2 are from water wells 30 to 40 mi to the west. The water in the DOE well appears to be representative of water elsewhere in the Citronelle Formation.

Water in the Catahoula Sandstone and the Pascagoula and Hattiesburg Formations is of a sodium bicarbonate type, and that in the Citronelle is a calcium-sodium bicarbonate (fig. 17). The deeper aquifers in the area of investigation and the salt-dome caprock contain water that is predominantly of a sodium chloride type. Water from a few deep wells in the Catahoula Sandstone and one in the Pascagoula and Hattiesburg Formations also is of the sodium chloride type.

The depth to the base of freshwater in the area of investigation (figs. 6 and 9) generally appears to coincide with the base of freshwater throughout the salt-dome basin and southern Mississippi. Saltwater appears to occur at higher altitudes in the immediate area of Cypress Creek and Richton domes than in the surrounding area. This could be due to either dissolution of salt around the domes or upward migration of water from the deeper saline-water aquifers through possible near-dome faults and permeable zones along the flanks of the domes. Gandl and Spiers (1980, p. 15) point out that other sources of the chlorides in the area might result from improper disposal of oil well brines, unplugged or leaky oil test wells that could be leaking saltwater up and into the Miocene aquifers, and disposal of industrial or municipal wastes. However, no disposal of wastes or brines in the vicinity of either dome has been identified.

ADDITIONAL DATA NEEDS

Many of the findings of the present investigation have not been verified, and many quantitative values are rough estimates at best. A primary concern of the following data needs, therefore, is to evaluate and better define the existing data.

1. The lenticular and discontinuous nature of the water-bearing zones in the Miocene aquifers will present a problem in modeling studies. Any subsurface mapping of individual water zones over a very large area and determining their hydraulic characteristics and the interconnection between zones will be expensive and may not be feasible. However, such studies would be of value in simulation studies.

2. Aquifer tests using discharge and observation wells that fully penetrate, within practical limits, the hydrologic unit being tested, are needed to calculate reliable hydraulic characteristics, including storage coefficients for use with quantitative or predictive analyses. Multiple-well tests in shallow caprock would be useful to determine the existence and extent of hydraulic connection over the domes.

3. Additional water-level data from the saline-water aquifers could provide more reliable data for both potentiometric surface mapping and aquifer test analysis.

4. Saline water from deep aquifers under high artesian pressure may be leaking upward through faults or permeable channels around the flanks of the domes. Accurate water-pressure and water-level data are needed to determine if the difference in head between water in the Wilcox aquifer and that in the shallower aquifers maintains itself toward the flanks of the domes, or if communication between aquifers is demonstrated by a decreasing pressure difference.

5. The observations of saline water at relatively high altitudes needs to be verified, and if correct, the source of the salt (natural or of manmade origin) identified. The presence of a saltwater plume down gradient from a salt dome might indicate either upward movement of saltwater from depth, the occurrence of which would need to be verified (see proceeding paragraph), or dissolution of salt from around the flanks of the dome.

6. Estimates of the travel time for water to move vertically through the various stratigraphic units were based on vertical hydraulic conductivity estimates determined from inspection of sidewall cores. Such determinations are inexact because of the rearrangement of grains and intergranular porosity by the physical impact of taking the core, and also because of the small vertical section of the formation that the core represents. Conventional cores, especially through the clays and other semi-permeable units, would be more useful for accurate determinations of vertical hydraulic conductivities and in estimating travel times from the Wilcox and other deep aquifers to the biosphere.

7. The caprock may play an important role in retarding dissolution of salt by fresh ground water from around the upper part of the dome. Additional water-quality data, including variations of quality with depth, and vertical and horizontal hydraulic conductivities will be useful in defining the transmissive properties of the materials throughout the caprock.

SUMMARY

Complex stratigraphic relationships exist in the post-Cretaceous rocks of the Mississippi salt-dome basin. Lenses of semiconsolidated sandstone are interbedded with clay, marl, and limestone. Tongues of channel sands were deposited in numerous ancient river channels. Throughout the basin, salt domes were formed when salt pushed its way up from a deep, bedded-salt deposit through thousands of feet of overlying sedimentary materials. Cypress Creek and Richton domes are composed of nearly pure, crystalline halite and are overlain by caprock as much as 200 ft thick composed primarily of anhydrite.

Fresh ground water in the Cypress Creek and Richton domes area occurs in the Catahoula Sandstone and the Pascagoula and Hattiesburg Formations, all of Miocene age, and the Citronelle Formation of Pliocene age. Water in the underlying aquifers is saline. Because of the lenticular character of the sedimentary deposits, the units in reality are aquifer systems made up of individual water-bearing zones. Aquifer tests were performed by LETCo at 41 wells and packer tests at two wells, drilled at 11 data-collection sites. All were single-well tests in partially penetrating wells, and density corrections were applied to water-level measurements in the deeper saline-water aquifers. Estimates of transmissivity for three saline-water and two freshwater-bearing formations, range from 410 to 28,000 $(ft^3/d)/ft$. Horizontal ground-water velocity estimates range from 0.4 to 300 ft/year.

Water in the freshwater aquifers is of the sodium bicarbonate and calcium-sodium bicarbonate types. Water samples from a few deep wells in the Miocene rocks, and all samples from deeper formations, the caprock, and salt-caprock interface were highly mineralized and of the sodium chloride type. Saltwater, which appears to occur at relatively high altitudes in the immediate areas of Cypress Creek and Richton domes, may be due to dissolution of salt from around the domes or to upward movement of water from saline-water aquifers around the flanks of the domes.

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