Open-file report

USGS-4339-2
1973

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

GEOLOGIC AND HYDROLOGIC SUMMARY OF SALT DOMES IN GULF COAST REGION OF TEXAS, LOUISIANA, MISSISSIPPI, AND ALABAMA

By

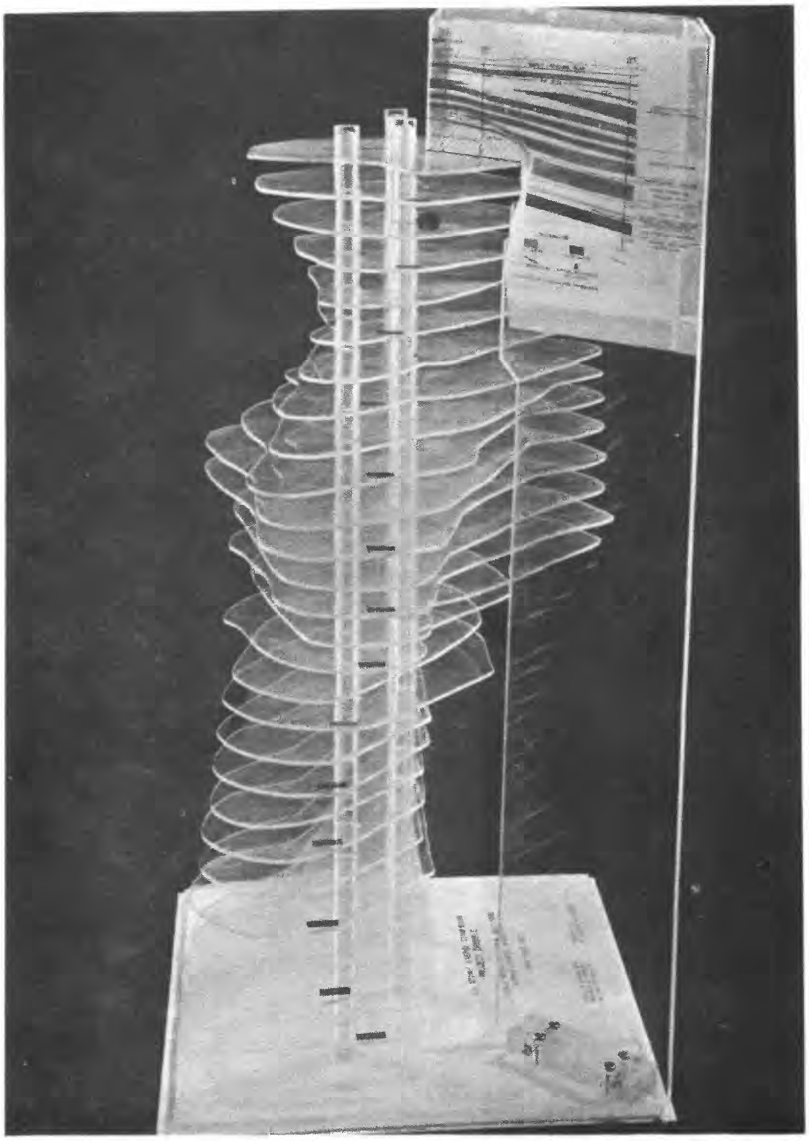
R. Ernest Anderson, D. Hoye Eargle, and Beth O. Davis

Open-file report
1973

73-7

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards or nomenclature.

**No pages with numbers 185 and 189.



Scale Model of Tatum Salt Dome

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

Appendix

TABLES

USGS-4339-2 UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY USGS-4339-2

Federal Center, Denver, Colorado 80225

GEOLOGIC AND HYDROLOGIC SUMMARY OF SALT DOMES IN GULF COAST REGION OF TEXAS, LOUISIANA, MISSISSIPPI, AND ALABAMA

By

R. Ernest Anderson, D. Hoye Eargle*, and Beth O. Davis

ABSTRACT

There are 263 known or suspected onshore salt domes in the Texas-Louisiana-Mississippi-Alabama portion of the Gulf Coast geosyncline. The top of the salt in 148 of them is probably deeper than desirable for a waste repository site, and 79 of those that are shallow enough are probably unavailable for a site because of present use by industry for gas storage or production of oil, salt, or sulfur. In this report we have compiled the available geologic and hydrologic background data pertinent to the evaluation of the remaining 36 known or suspected salt domes as potential sites for waste storage. There are three parts to this compilation: 1) summaries of the geology and hydrology of the salt-dome province as a whole; 2) summaries of the physiography, climate, geology, and hydrology of each of the five salt-dome basins that occur within the province; and 3) an appendix of background data for each of the 36 potentially acceptable domes.

* The compilation of salt-dome data included in this report is one of the last major efforts of D. Hoye Eargle, a highly competent geologist with a host of friends, who died on March 11, 1973.

The distribution of salt domes in the province is genetically related to areas of relative subsidence that formed basins or depocenters within the Gulf Coast geosyncline. In some cases, as in northeast Texas and south Louisiana, the locations of individual domes or groups of domes are related to deep movement of salt along axial trends. The salt domes in the interior salt-dome subprovince are probably more structurally stable than those of the coastal subprovince because salt diapirism is inferred to have ceased around Miocene time in the interior but may still be active in parts of the coastal subprovince. Although the size and shape of many domes is unknown or can only be roughly approximated, each of the five basins in the province appears to contain potentially acceptable domes of adequate size for a repository. We recognize no pattern to the distribution of salt-dome size. Caprock thicknesses vary greatly within each salt-dome basin, and we recognize no pattern to the variations. Among the potentially acceptable domes, the depths to the top of the salt are generally greatest in the Mississippi salt-dome basin, where all tops are more than 1,500 feet deep. Intermediate depths of about 1,000 feet are common in the east Texas-south Louisiana salt-dome basin. Depths to salt tops in the north Louisiana and northeast Texas basins are variable but most are less than 1,000 feet.

Available drilling records are generally adequate to determine the number of wells drilled on or in the vicinity of individual domes and also the well locations. The numbers of wells vary widely within each salt-dome basin. More salt domes are currently available for use as repository sites in the interior subprovince than in the coastal subprovince, where the pressure for industrial use of domes is high.

In the interior subprovince many of the potentially acceptable domes are located beneath hilly well-drained terrain that is not subject to flooding or other surface-water problems. Although topographic depressions occupied by shallow lakes, swamps, or "salines" occur over several of the domes, they are generally flanked by topographically high ground where surface facilities could be sited without complications. A few of the potentially acceptable domes are located beneath floodplains where surface facilities might face hazards from flooding.

In the coastal subprovince several of the potentially acceptable domes are located in relatively flat poorly drained terrain where surface flooding might constitute a potential hazard.

The availability of fresh to slightly saline ground water varies considerably within each salt-dome basin. We have outlined some of the factors that are responsible for the variations and have provided or referred to maps and geohydrologic cross sections that illustrate the general distribution of fresh to slightly saline water. The top of the salt in about half of the known potentially acceptable domes is below the regional base of the fresh to slightly saline ground-water system, but in a few of the domes the salt top rises far above that base.

Available geologic and hydrologic information is generally inadequate to fully evaluate the domes for use as repository sites. With the possible exception of Tatum dome, the unique hydrologic regimen at any dome would have to be defined by preliminary exploration and research.

INTRODUCTION

This report is one of a series prepared by the U.S. Geological Survey summarizing available geologic and hydrologic knowledge of certain salt deposits to help determine their suitability for waste emplacement. The report was prepared for the U.S. Atomic Energy Commission and the Defense Advanced Research Projects Agency.

The preparation of this series of reports has been expedited by the fact that two governmental agencies approached the U.S. Geological Survey with similar requests. In 1971 the Advanced Research Projects Agency, anticipating the difficulties Department of Defense agencies and their contractors might eventually face in finding safe underground sites for disposal of nonradioactive but chemically noxious wastes, asked the Geological Survey to evaluate potential subsurface sites in impermeable rocks, particularly salt deposits, in terms of their geologic and hydrologic suitability for emplacement of noxious wastes. Early in 1972 the U.S. Atomic Energy Commission asked the USGS to summarize the available geologic and hydrologic knowledge of selected areas and rock types, particularly salt, in regard to their suitability for the emplacement of radioactive wastes. Because the geologic and hydrologic factors involved in selecting sites for storage or disposal of wastes in subsurface salt deposits are much the same whether the wastes are highly radioactive or nonradioactive but highly toxic, the results of the Geological Survey's investigations for the Atomic Energy Commission are of parallel interest to the Advanced Research Projects Agency (now the Defense Advanced Research Projects Agency). This report is one of those that provide data needed by both agencies and is therefore being submitted to both.

The purpose of this study is to provide the geologic and hydrologic background data needed to evaluate salt domes of the Gulf Coast region as potential sites for waste emplacement. This report deals only with the onshore salt domes of the Gulf Coast region of the United States, because siting in offshore salt structures would add unnecessary complications to a plan that requires assurance of a dry repository including conventional shafts, conventional access, continuously reliable utilities, etc. (Bradshaw, 1970). The present report is therefore a summary of published background information on the geology, hydrology, and supplemental subjects pertaining to salt-dome basins within the northern Gulf Coast salt-dome province and to specific salt domes within those basins.

Areal subdivisions

The Gulf Coast region of the United States is herein referred to as the northern Gulf Coast salt-dome province to distinguish it from salt-dome provinces or basins that occur in other parts of the Gulf of Mexico region such as in Mexico and Cuba (Meyerhoff and Hatten, 1968).

There are approximately 263 known and suspected onshore salt domes in the northern Gulf Coast salt-dome province (fig. 1, in pocket). The province can be conveniently divided into interior and coastal subprovinces that can be further subdivided on the basis of the states or the geologic basins in which the domes occur. In order to conveniently describe general geologic and hydrologic factors that pertain to the domes we have based our subdivision on geologic basins as follows:

Interior subprovince:

northeast Texas salt-dome basin

north Louisiana salt-dome basin

Mississippi salt-dome basin

Coastal subprovince:

east Texas-south Louisiana salt-dome basin

south Texas salt-dome basin

The outlines of these salt-dome basins are shown in figure 1. The east Texas-south Louisiana salt-dome basin includes a large number of offshore domes that are not considered in this report.

Limitations

It would not have been possible to assemble comprehensive background information on all 263 onshore domes in the limited time available. A preliminary rejection process based on factors affecting potential suitability had to be applied to the large selection of domes in order to reduce the number of domes to be considered. Through consultation with personnel of the Oak Ridge National Laboratory it was agreed that we would preliminarily reject all domes whose tops are deeper than about 2,000 feet as well as all other domes that are presently being used by industry for petroleum production, gas storage, sulfur production, or brine production. The results of this preliminary rejection process, based on the depth and present usage factors, indicated that 227 of the 263 known and suspected domes would not be given further consideration at this time. The results are presented in tables 1, 2, and 3, beginning on page 9. The conditional nature of this rejection process should be emphasized because first, some domes that have had significant ongoing petroleum production may be potentially acceptable because they are nearing the depletion of their reserves. Second, some domes are only slightly deeper than 2,000 feet and a relaxation of the depth cutoff factor may render them potentially acceptable. Throughout the report we refer to the potentially acceptable domes as unrejected domes and to those that appear to be unacceptable, based on depth and present usage factors, as rejected domes.

There is undoubtedly much proprietary and presently unavailable gravity, seismic, and drill hole data that were acquired by petroleum and sulfur companies in the prospecting and exploration of domes found to be undesirable for further development; these domes are on our list of unused domes. If this geophysical and drill hole information were available, it would be especially useful in assessing the salt-mass dimensions and contact relationships that are critical to determining whether or not a dome is acceptable for waste emplacement. Of the 36 unused shallow domes on which we have compiled information, we have gravity and seismic data on only one--Tatum dome in Mississippi. In eight of the 36 unrejected domes salt has not been reached by the drill and in many of the others salt has been reached only in one or two drill holes.

The paucity of drill holes and drill hole data is a severe limitation from the standpoint of evaluating the geology and hydrology of a dome. However, the fewer the drill holes that have penetrated a salt dome, the fewer the manmade openings for potential ingress of ground water.

Our ability to assess the suitability of salt domes <u>in general</u> is somewhat limited by the fact that information sought by mineral and petroleum companies does not completely overlap information needed to evaluate suitability for waste emplacement. This is especially so in regard to recent salt movement and detailed hydrology (including dissolution) of salt domes, two topics that are of vital concern for waste emplacement. There are almost no specific data on these topics for the domes under consideration and very little data available for salt domes in general.

Kupfer (1970) has observed that ideas that represent advances in the understanding of salt domes are generally common knowledge in industrial circles long before they are published and heard elsewhere. Perhaps during more advanced phases of consideration of salt domes for waste emplacement some of these data and ideas will become available.

Table 1.--Distribution of rejected and unrejected domes by salt-dome basin

Salt-dome subprovince	Salt-dome basin	Rejected domes	Unrejected domes
Interior	Northeast Texas	13	7
	North Louisiana	11	8
	Mississippi	63	14
Coastal	South Texas	5	1
	East Texas-south Louisiana	135	6
	Total	227	36

Table 2.--Summary of reasons for rejecting domes arranged according to salt-dome basins

Salt-dome subprovince	Salt-dome basin	Too deep*	Multiple use**	Pet. prod.	Gas storage	Salt prod.	Total
Interior	Northeast Texas	6	0	3	3	1	13
	North Louisiana	6	0	1	4	0	11
	Mississippi	60	0	0	2	1	63
Coastal	South Texas	3	0	1	0	1	5
	East Texas-south Louisiana	73	30	29	2	1	135
	Total	148	30	34	11	4	227

* Many of the domes rejected on the basis of depth also have active production of petroleum.

** Includes domes that are being used by more than one of the three usage categories--petroleum production, gas storage, salt production.

Table 3.--Rejected domes

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
	Northeast Texas salt-dome basin	
Bethel	Anderson, Tex.	Petroleum production 1,969,600 bbls to 1964
Boggy Creek	Anderson and Cherokee, Tex.	Petroleum production 5,921,100 bbls to 1964
Brushy Creek	Anderson, Tex.	Too deep (3,570')
Butler	Freestone, Tex.	LPG Storage
Concord	Anderson, Tex.	Too deep (5,994')
Day	Madison, Tex.	Too deep (3,153' or 3,160')
East Tyler	Smith, Tex.	LPG Storage
Elkhart	Anderson, Tex.	Too deep (10,165')
Grand Saline	Van Zandt, Tex.	Brine production Salt production
Hainesville	Wood, Tex.	LPG Storage
Kittrell (Trinity)	Houston and Walker, Tex.	Too deep (3,855')
LaRue	Henderson, Tex.	Too deep (4,450')
Oakwood	Freestone and Leon, Tex.	Petroleum production 1,439,200 bbls to 1964
	North Louisiana salt-dome basin	
Arcadia	Bienville, La.	LPG Storage
Bistineau	Webster, La.	LPG Storage
Chester (Lonnie)	Caldwell and Winn, La.	Too deep (4,840')
Chestnut	Natchitoches, La.	Too deep (2,450' or 2,885')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
	North Louisiana salt-dome basin--Continued	
Coochie Brake	Winn, La.	Too deep (2,500' or 2,603')
Drakes	Natchitoches and Winn, La.	LPG Storage
Gibsland	Bienville, La.	LPG Storage
Lonnie	See Chester	
Milam	Winn, La.	Too deep (4,430')
Minden	Webster, La.	Petroleum production 1,289,500 bbls to 1964
Packton	Winn, La.	Too deep (6,425')
Sikes	Winn, La.	Too deep (4,931')
	Mississippi salt-dome basin	
Allen	Copiah, Miss.	Too deep (2,774')
Ashwood	See Somerset	
Baxterville	Lamar, Miss.	Too deep (14,000')
Brownsville	Hinds, Miss.	Too deep (4,686')
Burns	Smith, Miss.	Too deep (>11,310')
Carmichael	Hinds, Miss.	Too deep (2,966')
Carson	Jefferson Davis, Miss.	Too deep (3,086')
Caseyville	Lincoln, Miss.	Too deep (3,035')
Centerville	Jones, Miss.	Too deep (>3,000')
Chaparral	See Hiwanee	
D'Lo	Simpson, Miss.	Too deep (2,400')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
	Mississippi salt-dome basin--Continued	
Dont	Covington, Miss.	Too deep (2,300')
Dry Creek	Covington, Miss.	Too deep (2,300')
Duck Port	Madison, La.	Too deep (5,345')
Eagle Bend	Warren, Miss.	Too deep (4,425')
East Tallulah	See Walnut Bayou	
Edwards	Hinds, Miss.	Too deep (3,026')
Ellisville	Jones, Miss.	Too deep (14,075')
Eminence	Covington and Jones, Miss.	Too deep (2,440')
Eucutta	Wayne, Miss.	Too deep (11,804')
Foules	Catahoula, La.	Too deep (6,013')
Galloway	Warren and Claiborne, Miss.	Too deep (4,432')
Glass	Warren, Miss.	Too deep (4,030')
Glazier	Perry, Miss.	Too deep (7,685')
Grange	Jefferson Davis, Miss.	Too deep (15,274')
Gwinville	Jefferson Davis, Miss.	Too deep (>10,000')
Halifax	Hinds, Miss.	Too deep (3,995')
Heidelberg	Jasper, Miss.	Too deep (9,390')
Hervey	Claiborne, Miss.	Too deep (3,547')
Hiwanee (Chaparral)	Wayne, Miss.	Too deep (13,598')
Killens Ferry	See Snake Bayou	

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
	Mississippi salt-dome basin--Continued	
Kings	Warren, Miss.	Too deep (3,845')
Kola	Covington, Miss.	Too deep (3,048')
Laurel	Jones, Miss.	Too deep (12,304')
Learned	Hinds, Miss.	Too deep (4,437')
McBride	Jefferson, Miss.	Too deep (2,205')
McIntosh	Washington, Ala.	Brine production
Midway	Lamar, Miss.	Too deep (2,205')
Monticello	Lawrence, Miss.	Too deep (2,757')
Moselle	Jones, Miss.	Too deep (~2,200')
Newellton	Tensas, La.	Too deep (4,123')
New Home	Smith, Miss.	Too deep (2,595')
Newman	Warren, Miss.	Too deep (5,108')
North Tallulah (Tallulah)	Madison, La.	Too deep (4,537')
Oakley	Hinds, Miss.	Too deep (2,634')
Oak Ridge	Warren, Miss.	Too deep (5,062')
Oakvale	Jefferson Davis, Miss.	Too deep (2,696')
Ovett	Jones and Perry, Miss.	Too deep (13,156')
Petal	Forrest, Miss.	LPG Storage
Prentiss	Jefferson Davis, Miss.	Too deep (~2,800')
Raleigh	Smith, Miss.	Too deep (2,140') Petroleum production 9,807,400 bbls to 1964

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
Mississippi salt-dome basin--Continued		
Richton	Perry, Miss.	LPG Storage
Rufus	Rankin, Miss.	Too deep (12,485')
Ruth	Lincoln, Miss.	Too deep (2,700')
Singer	Madison, La.	Too deep (4,197')
Snake Bayou (Killens Ferry)	Tensas, La.	Too deep (5,989')
Somerset (Ashwood)	Tensas, La.	Too deep (4,073')
South Carleton	Clarke, Ala.	Too deep (11,176')
South Coleman	Madison, La.	Too deep (>3,352')
South Tallulah	See Tallulah	
Sunrise	Forrest, Miss.	Too deep (5,940')
Tallulah (South Tallulah)	Madison, La.	Too deep (3,023')
Tallulah	See North Tallulah	
Utica	Copiah, Miss.	Too deep (3,135')
Valley Park	Sharkey and Isaquena, Miss.	Too deep (12,424')
Vicksburg	Warren, Miss.	Too deep (4,386')
Walnut Bayou (East Tallulah)	Madison, La.	Too deep (2,740')
Wesson	Copiah, Miss.	Too deep (3,550')
Yellow Creek	Wayne, Miss.	Too deep (11,422')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
	South Texas salt-dome basin	
Dilworth Ranch	McMullen, Tex.	Too deep (7,645')
Moca	Webb, Tex.	Too deep (6,366')
Palangana	Duval, Tex.	Brine production
Pescadito	Webb, Tex.	Too deep (15,070')
Piedras Pintas	Duval, Tex.	Petroleum production 5,331,100 bbls to 1964
	East Texas-south Louisiana salt-dome basin	
Allen	Brazoria, Tex.	Petroleum production 137,100 bbls to 1964
Anse la Butte	St. Martin, La.	Brine production LPG Storage Petroleum production 48,086,200 bbls to 1964
Arriola	Hardin, Tex.	Too deep (3,929')
Avery Island	Iberia, La.	Petroleum production 50,545,400 bbls to 1964 Salt mine
Barataria	Jefferson, La.	Too deep (7,730')
Barbers Hill	Chambers, Tex.	Brine production LPG Storage Petroleum production 114,398,900 bbls to 1964
Batson	Hardin, Tex.	Too deep (2,050') Petroleum production 49,670,400 bbls to 1964

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Bay de Chene	Lafourche and Jefferson, La.	Too deep (7,950')
Bay Junop	Terrebonne, La.	Too deep (4,678')
Bayou Bleu	Iberville, La.	Too deep (2,801')
Bayou Bouillon	St. Martin and Iberville, La.	Petroleum production 2,239,500 bbls to 1964
Bayou Choctow	Iberville, La.	Brine production LPG production Petroleum production 19,743,200 bbls to 1964
Bayou Couba	St. Charles, La.	Too deep (6,294')
Bayou des Allemands	St. Charles and Lafourche, La.	Too deep (7,650')
Bayou des Glaizes	Iberville, La.	Too deep (3,219')
Bayou Wickoff	See North Crowley	
Bay Ste Elaine	Terrebonne, La.	Petroleum production 64,077,200 bbls to 1964
Belle Isle	St. Mary, La.	Petroleum production 9,284,900 bbls to 1964 Salt mine
Big Creek	Fort Bend, Tex.	Petroleum production 13,402,900 bbls to 1964
Big Hill	Jefferson, Tex.	LPG Storage
Big Lake	Cameron, La.	Petroleum production 6,519,200 bbls to 1964

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Black Bayou	Cameron, La.	Petroleum production 25,096,000 bbls to 1964
Blue Ridge	Fort Bend, Tex.	Brine production LPG Storage Petroleum production 21,765,800 bbls to 1964
Boling	Wharton and Fort Bend, Tex.	Petroleum production 30,699,900 bbls to 1964 Sulfur production
Bosco	Acadia and St. Landry, La.	Too deep (13,742')
Brenham	Washington and Austin, Tex.	Petroleum production 406,100 bbls to 1964
Brookshire	See San Felipe	
Bryan Mound	Brazoria, Tex.	Brine production
Bully Camp	Lafourche, La.	Petroleum production 20,945,700 bbls to 1964
Caillou Island	Terrebonne, La.	Too deep (2,850')
Calcasieu Lake	Cameron, La.	Too deep (2,345' or 2,369')
Cameron Meadows	Cameron, La.	Too deep (4,770')
Carlos	See Fergusons Crossing	
Chacahoula	Lafourche, La.	Brine production Petroleum production 20,635,100 bbls to 1964
Charenton	St. Mary, La.	Too deep (10,002')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Cheneyville	Rapides, La.	Too deep (6,709')
Clam Lake	Jefferson, Tex.	Too deep (8,156')
Clay Creek	Washington, Tex.	Too deep (2,400')
Clemens	Brazoria, Tex.	LPG Storage
Clovelly	Lafourche, La.	Petroleum production 13,451,300 bbls to 1964
Convent	See Hester-Vacherie	
Cote Blanche Island	St. Mary, La.	Petroleum production 14,812,300 bbls to 1964 Salt mine
Crowley	Acadia, La.	Too deep (14,892')
Cut Off	Lafourche, La.	Too deep (9,708')
Damon Mound	Brazoria, Tex.	Petroleum production 17,432,900 bbls to 1964
Danbury	Brazoria, Tex.	Too deep (5,040')
Darrow	Ascension, La.	Too deep (4,595')
Delta Duck Club	Plaquemines, La.	Too deep (9,214')
Dog Lake	Terrebonne, La.	Petroleum production 19,856,700 bbls to 1964
East Hackberry	Cameron, La.	Too deep (2,950')
Edgerly	Calcasieu, La.	Too deep (3,985')
Esperson	Liberty, Tex.	Too deep (6,150')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Fannett	Jefferson, Tex.	LPG Storage Petroleum production 36,833,800 bbls to 1964 Sulfur production
Fausse Point	Iberia and St. Martin, La.	Petroleum production 18,685,200 bbls to 1964
Fergusons Crossing (Carlos)	Grimes and Brazos, Tex.	Too deep (4,038')
Four Isle Bay	Plaquemines, La.	Petroleum production 5,567,000 bbls to 1964
Franklin	St. Mary, La.	Too deep (16,910')
Garden Island Bay	Plaquemines, La.	Too deep (2,014') Petroleum production 43,590,300 bbls to 1964 Sulfur production
Golden Meadow	Lafourche, La.	Too deep (15,344')
Good Hope	St. Charles, La.	Too deep (9,580')
Grande Ecaille	See Lake Washington	
Gueydan	Vermillion and Acadia, La.	Too deep (4,653')
Hankamer	Liberty and Chambers, Tex.	Too deep (7,582')
Hester-Vacherie (Convent)	St. James, La.	Too deep (6,780')
High Island	Galveston, Tex.	Petroleum production 83,052,800 bbls to 1964

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Hull	Liberty, Tex.	LPG Storage Petroleum production 153,211,700 bbls to 1964
Humble	Harris, Tex.	Petroleum production 147,959,500 bbls to 1964
Iberia (Little Bayou)	Iberia, La.	Petroleum production 54,131,000 bbls to 1964
Iowa	Jefferson Davis, La.	Too deep (7,902')
Jeanerette	St. Mary, La.	Too deep (8,000')
Jefferson Island	Iberia, La.	Petroleum production 4,472,900 bbls to 1964 Salt mine
Jennings	Acadia, La.	Too deep (2,512')
Lafitte	Jefferson, La.	Too deep (13,947')
Lake Barre	Terrebonne, La.	Petroleum production 64,421,100 bbls to 1964
Lake Chicot	St. Martin, La.	Too deep (12,780')
Lake Hermitage	Plaquemines, La.	Petroleum production 2,557,900 bbls to 1964
Lake Mongoulois	St. Martin, La.	Too deep (6,915')
Lake Pelto	Terrebonne, La.	Petroleum production 55,037,300 bbls to 1964 Sulfur production

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Lake Salvador	St. Charles, La.	Too deep (11,270')
Lake Washington (Grand Ecaille)	Plaquemines, La.	Petroleum production 95,473,400 bbls to 1964 Sulfur production
Lawson	Acadia, La.	Too deep (16,850')
Leeville	Lafourche, La.	Too deep (3,800')
Little Bayou	See Iberia	
Lockport	Calcasieu, La.	Too deep (7,207')
Lost Lake	Chambers, Tex.	Too deep (5,430')
Manvel	Brazoria, Tex.	Too deep (11,274')
Markham	Matagorda, Tex.	LPG Storage Petroleum production 16,698,900 bbls to 1964
Millican	Brazos, Tex.	Too deep (5,170')
Moss Bluff	Liberty and Chambers, Tex.	Petroleum production 1,745,600 bbls to 1964 Sulfur production
Mykawa	Harris, Tex.	Too deep (7,100')
Napoleonville	Assumption, La.	Brine production Petroleum production 9,479,000 bbls to 1964
Nash	Fort Bend and Brazoria, Tex.	Petroleum production 3,351,900 bbls to 1964

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
North Crowley (Bayou Wickoff)	Acadia, La.	Too deep (14,900' or 14,856')
North Dayton	Liberty, Tex.	Petroleum production 9,262,900 bbls to 1964
North Mallard Bay	Cameron, La.	Too deep (15,750')
North Starks	Calcasieu, La.	Too deep (9,031')
Orange	Orange, Tex.	Too deep (7,120')
Orchard	Fort Bend, Tex.	Petroleum production 12,717,600 bbls to 1964 Sulfur production
Paradis	St. Charles, La.	Too deep (13,538')
Pierce Junction	Harris, Tex.	Brine production LPG Storage Petroleum production 89,114,400 bbls to 1964
Pine Prairie	Evangeline, La.	LPG Storage Petroleum production 23,517,600 bbls to 1964
Plumb Bob	St. Martin, La.	Petroleum production 7,153,200 bbls to 1964
Port Barre	St. Landry, La.	Too deep (3,642')
Port Neches	Orange, Tex.	Too deep (6,948')
Potash	Plaquemines, La.	Petroleum production 12,402,600 bbls to 1964
Raccoon Bend	Orange, Tex.	Too deep (11,004')
Raceland	Lafourche, La.	Too deep (8,170')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Roanoke	Jefferson Davis, La.	Too deep (11,585')
St. Gabriel	Iberville, La.	Too deep (11,230')
St. Martinville	St. Martin, La.	Too deep (11,200')
San Felipe (Brookshire)	Austin and Waller, Tex.	Too deep (4,755')
Saratoga	Hardin, Tex.	Petroleum production 50,884,400 bbls to 1964
Section 28	St. Martin, La.	Petroleum production 20,053,600 bbls to 1964
Sorrento	Ascension, La.	Brine production LPG Storage Petroleum production 2,541,800 bbls to 1964
Sour Lake	Hardin, Tex.	LPG Storage Petroleum production 107,466,000 bbls to 1964
South Houston	Harris, Tex.	Too deep (4,662')
South Liberty	Liberty, Tex.	Petroleum production 59,175,600 bbls to 1964
South Section 28	St. Martin, La.	Too deep (14,061')
South Tigre Lagoon	Iberia, La.	Too deep (14,200')
Spindletop	Jefferson, Tex.	Petroleum production 140,347,500 bbls to 1964 Sulfur production

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Starks	Calcasieu, La.	Brine production Petroleum production 7,297,500 bbls to 1964 Sulfur production
Stella	Plaquemines, La.	Too deep (9,032')
Stratton Ridge	Brazoria, Tex.	Brine production LPG Storage Petroleum production 2,840,300 bbls to 1964
Sugarland	Fort Bend, Tex.	Too deep (4,280')
Sulphur Mines	Calcasieu, La.	Brine production LPG Storage Petroleum production 27,295,200 bbls to 1964
Sweet Lake	Cameron, La.	Too deep (8,500')
Thompson	Fort Bend, Tex.	Too deep (9,314')
Timbalier Bay	Lafourche, La.	Too deep (6,430')
Valentine	Lafourche, La.	Too deep (6,573')
Venice	Plaquemines, La.	Petroleum production 98,654,800 bbls to 1964
Vermilion Bay	Iberia, La.	Petroleum production 1,492,100 bbls to 1964
Vinton	Calcasieu, La.	Petroleum production 97,942,700 bbls to 1964
Webster	Harris, Tex.	Too deep (10,434')

Table 3.--Rejected domes--Continued

NAME	LOCATION (County or Parish, and State)	REASON FOR REJECTION
East Texas-south Louisiana salt-dome basin--Continued		
Weeks Island	Iberia, La.	Petroleum production 120,779,600 bbls to 1964 Salt mine
Welsh	Jefferson Davis, La.	Too deep (6,107')
West Bay	Plaquemines, La.	Too deep (8,260')
West Columbia	Brazoria, Tex.	Petroleum production 141,940,800 bbls to 1964
West Cote Blanche Bay	St. Mary, La.	Too deep (7,545')
West Hackberry	Cameron, La.	Brine production Petroleum production 76,110,300 bbls to 1964
White Castle	Iberville, La.	Too deep (2,313')
Woodlawn	Jefferson Davis, La.	Too deep (10,726')

Previous work

Le Grand (1962) furnished the Atomic Energy Commission with a report on the geology and ground-water hydrology of the Atlantic and Gulf coastal plains as related to disposal of radioactive wastes. The report is highly generalized however, and does not contain specific information on salt-dome geology or hydrology.

Pierce and Rich (1962) summarize the features of salt domes for the Gulf Coast and very briefly describe the interior and coastal subprovinces. They cite (1962, p. 70) the great thickness of the salt masses and their purity as favorable factors for radioactive waste storage.

The U.S. Bureau of Mines (1961) furnished the Atomic Energy Commission with a report listing the principal reasons why 261 of the 279 salt domes in the Gulf Coast region did not meet required criteria for use as nuclear-explosion sites. Appended to that report are summaries of the geology and hydrology of 18 salt domes that did meet the required criteria for such use. Twelve of the 18 domes are on our list of unrejected domes (table 4, in pocket) and therefore, the 1961 U.S. Bureau of Mines report is a valuable supplement to the present report for information concerning the following domes: Bruinsburg, Byrd, County Line, Lampton, Tatum, Prices, Rayburns, Davis Hill, Gulf, Hawkinsville, Brooks, and Hockley.

Information on industry's use of salt domes in the Gulf Coast region was compiled by Hawkins and Jirik (1966). We have relied heavily on their compilation in the preparation of table 3 and have attempted to update the records for some domes.

GEOLOGY, NORTHERN GULF COAST SALT-DOME PROVINCE

Extensive topical reviews of special aspects of salt-dome geology are found in published proceedings of several recent symposia and guidebooks of numerous field trips, most of which are referenced in the present report. Recent publications that, taken together, constitute a comprehensive review of the general salt-dome geology of the Gulf Coast region are available (Murray, 1961, 1968; Halbouty, 1967; Kupfer, 1970) and we, therefore, do not include a review herein. Instead, the paragraphs that follow focus on differences that appear to exist between the geology of the interior and coastal subprovinces in the hope of shedding some light on factors that affect the suitability of the two subprovinces for waste emplacement.

The present summary is abstracted largely from Kupfer (1970) who has outlined differences in age, depth, piercement distance, type of folding, competence, and purity of salt in the two subprovinces. We have enlarged on some of his topics and added comments on seismicity of the region and present usage of the domes.

Factors related to age

The Louann Salt, Jurassic(?) in age, is generally considered to mark the horizon of bedded salt from which the domes are derived in both subprovinces--interior and coastal. Whether or not salt was deposited in the domeless area between the subprovinces is not known, but if it was its thickness was probably much less than in the depocenters represented by the salt-dome subprovinces. The domes of the interior subprovince were probably emplaced from Late Cretaceous to Oligocene time and the coastal domes from Miocene to Pleistocene time (Kupfer, 1970). This difference in age has been schematically depicted by Hanna (1959) in a group of time-sequential cross sections through the Gulf Coast geosyncline (fig. 2). The cross sections show a four-stage depositional model for the development of the geosyncline and growth of the domes. Domes are supposedly formed by differences in static load of sediments at and ahead of a seaward migrating axis of principal deposition. It is important to emphasize that the model refers to the main episodes of diapirism and is not intended to preclude minor tectonic adjustments resulting from such processes as differential compaction or salt dissolution. Diapirism in the interior subprovince, according to this model, has been virtually inactive since Miocene time and is presently most active along the offshore axis of the geosyncline under the Gulf of Mexico.

Gera (1972) has summarized reported cases of present salt movement related to diapirism, and it is interesting to note that the three cases involving onshore Gulf Coast domes are from the coastal subprovince (Belle Isle, Jefferson Island, and Hoskins Mound, fig. 14, in pocket). Clark (1961, p. 3) states that many of the interior domes are known to be growing at the present time but we were unable to find evidence that would support his statement. What little evidence there is for present dome growth seems to be restricted to the coastal subprovince.

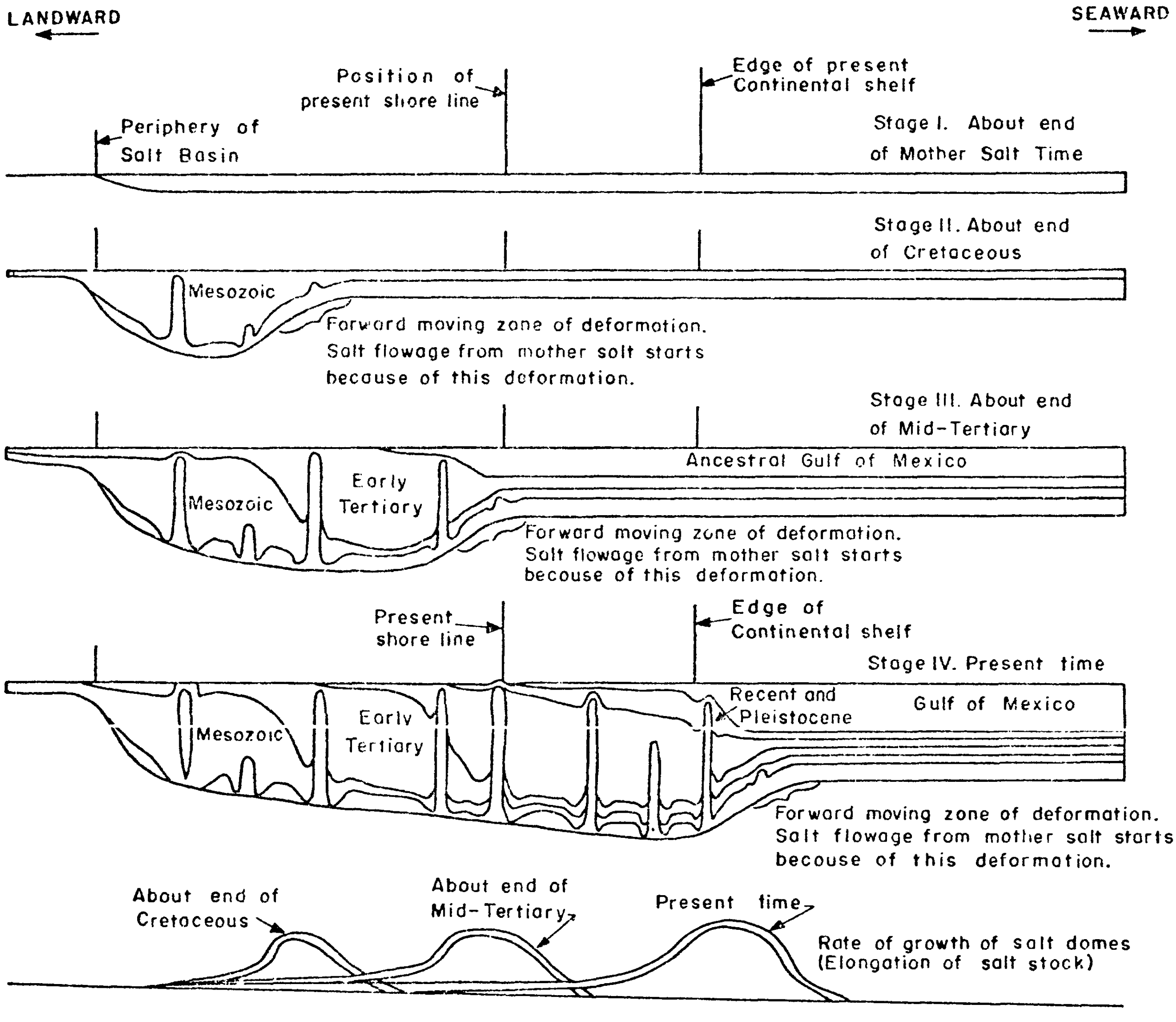


Figure 2.--Schematic time-sequential cross sections showing development of Gulf Coast geosyncline and growth of salt domes. (Modified from Hanna, 1959.)

DeWitt Van Siclen (written commun., 1972) has studied Holocene terraces along the Brazos River and found that along the portion of the river course that crosses the coastal salt-dome subprovince (south of the Clay Creek and Millican domes, fig. 14), the terraces have been "warped both regionally and over salt domes; and displaced by zones of en echelon normal faults which trend about parallel to regional strike, are mostly down-to-coast, and near the coast seem generally to connect salt domes." He notes that of the eight salt domes overlain by Holocene floodplain and deltaic deposits from the Raccoon Bend salt dome to the coast, five of the domes warp those deposits.

D. H. Kupfer and C. O. Durham (oral commun., 1972) make a strong contrast between the inactive interior domes, many of which are blanketed by undeformed Miocene and post Miocene sediments, and the domes within the active unstable coastal subprovince which Kupfer likens to a "shaking bowl of pudding" in which differential displacements related to several processes, including diapirism, are active. The apparent absence of surface indications of diapirism in the interior subprovince is, of course, no proof that diapirism is not occurring there. As Goldman (1931) stated the problem, "Have solution and upward movement balanced each other or has there been practically none of either [in the recent geologic past]?" We comment further on this problem under the heading Hydrology. As far as diapirism is concerned however, we conclude that the interior domes are more stable and therefore more suitable for waste-emplacement sites than the coastal domes.

Factors related to depth

One of the most significant differences between the interior and coastal subprovinces is the depth to the source bed of salt. In the interior the depth is generally less than 15,000 feet whereas in the coastal subprovince it is generally considered to be a minimum of 35,000 feet, more likely 40,000-45,000 feet, and possibly as much as 60,000 feet deep in parts of coastal Louisiana (Kupfer, 1970). Thus, the average piercement distance is much greater for the coastal domes which accordingly record a much more complex structural history that includes much folding, refolding, and attenuation of a type suggestive of plastic deformation and flow of fluids. One possible consequence of the greater piercement distance in the coastal domes is the refining or purification of the salt. Masses of halite have a lower bulk density and behave more plastically than mixtures of halite and anhydrite or masses of anhydrite. It seems reasonable that halite would rise preferentially in the diapiric column and anhydrite would lag behind. Thus, domes with the greatest piercement distance could consist of "purified" salt as a result of a combined rheological and gravitational refining process. The process may be aided by continual preferential recrystallization of the halite at progressively higher levels in the diapiric column. Meager data indicate that coastal domes consist of purer salt than interior domes (Kupfer, 1970).

Salt in interior domes tends to be more competent than in coastal domes. This difference could reflect any one or any combination of the following characteristics of interior domes (Kupfer, 1970): (1) a longer period of structural stability, (2) a simpler tectonic history (less recrystallization), or (3) a greater content of impurities.

The more complex structural history of coastal domes could be an important factor from a hydrologic standpoint if it is learned that discontinuous lenticular masses of highly sheared clastic sediments, such as those reported at Belle Isle and Avery Island domes by Kupfer (1970; oral commun., 1972), are common in the domes of the coastal subprovince. These masses of sediments are thought to be former wall rock incorporated into the main salt mass by continued large-scale upward movement. If they include permeable rock, these inclusions could provide channelways that would transmit water into the salt mass, appreciably increasing the probability that mined openings might reach saturated permeable rock within the central salt mass.

We conclude that the simpler internal structure of the interior domes is a factor in their favor for waste disposal because mined openings could be planned and constructed in them with greater predictability than in the coastal domes with their more complex internal structure.

Seismicity

Although the seismic risk of both subprovinces is estimated to be either minor or nonexistent (U.S. Environmental Science Services Admin., 1969), there is a record of slight to moderate damage caused by earthquakes in both subprovinces in the time interval from 1890 to

1965 (U.S. Geological Survey, 1970). Only one of the epicenters in the interior subprovince is located in a salt-dome basin (fig. 1). One earthquake that produced moderate damage and one that produced slight damage are reported east of the northeast Texas salt-dome basin, and a single quake with slight damage is reported from the south margin of the Sabine platform (fig. 1). Four additional epicenters are reported for the time period between December 31, 1966 and January 1, 1972, in the vicinity of the Sam Rayburn reservoir in east Texas (U.S. Environmental Science Services Admin., 1970), but they may be related to reservoir impoundment and are therefore not plotted on figure 1.

In the coastal subprovince seismic activity is limited to southeast Louisiana and has produced only slight damage (fig. 1). This seems surprising in view of the reported subsidence that has produced surface fracturing in the Houston area as a result of fluid removal (Sheets, 1971). Apparently strain release in that area is gradual and at a low level. We are not aware of any micro-seismic investigations either in the Houston area or elsewhere in the Gulf Coast region. It is not known whether the reported seismicity (fig. 1) is related in any way to salt domes. In fact, it is not known whether release of seismic energy is a characteristic feature of salt diapirism. Seismic studies seem to be desirable in areas of subsidence and would probably be very instructive if conducted near salt domes.

Use by industry

In 1964, production from salt domes amounted to about 74 percent of the elemental sulfur, about 41 percent of the salt, and about 12 percent of the total crude oil produced in the United States. Also, at that time salt domes provided for more than half of the nation's capacity for underground storage of liquefied petroleum gas (LPG) (Hawkins and Jirik, 1966). Industry uses many more salt domes in the coastal subprovince than in the interior subprovince. According to Clark (1961), 100 wells have been drilled on the domes of the coastal subprovince to every one drilled on domes of the interior subprovince. The data in table 2 indicate that about 90 percent of the shallow domes in the coastal subprovince are being used by the petroleum industry in contrast to about 35 percent in the interior subprovince. In 1964 (Hawkins and Jirik, 1966), only two of the 23 active salt mines were in the interior subprovince. The pressure for future use of salt domes by industry is probably reflected in these statistics. Thus, from the standpoint of noninterference with the petroleum and salt extraction industries, the interior subprovince appears to offer considerably more potential at present than the coastal subprovince.

HYDROLOGY, NORTHERN GULF COAST SALT-DOME PROVINCE

Surface water

Large differences in rainfall exist across the northern Gulf Coast region and are mainly responsible for climatic variability ranging from semiarid in the west to humid in the east. There is little temperature difference east-west across the region; it is characterized by long hot summers and mild winters. Contours representing eastward-increasing mean annual precipitation sweep fanlike across the Gulf Coast region. They trend northwest in the western, north in the central and northeast in the eastern part (U.S. Geological Survey, 1970). Annual rainfall ranges from about 20 inches in the western part of the south Texas salt-dome basin to about 64 inches in the Mississippi Delta area. Surface-water resources, therefore, range from minimal in the west to very abundant in the east where they are largely undeveloped. In most of the south Texas salt-dome basin average annual runoff ranges from 0.1 to 1.0 inches and can support only intermittent streams (U.S. Geological Survey, 1970). Average annual runoff in south Mississippi, by contrast, is as high as 30 inches.

Ground water

Ground-water resources are impressive almost everywhere across the northern Gulf Coast and locally, as in south Mississippi, they are of colossal proportions. This results from the almost ideal conditions that exist in the Gulf Coast geosyncline where the huge gulfward-dipping and thickening sedimentary prism consists predominantly of unconsolidated clastic sediments, the coarser (sand to conglomerate) fraction of which is generally highly permeable. A small portion of the precipitation that falls in the outcrop areas infiltrates these permeable sediments, moves down dip (generally gulfward) and, in short distances, is confined beneath finer grained, less permeable strata (mainly clays) where the water exists under artesian conditions. Thus, in the upper strata of the sedimentary prism the fresh ground water has displaced or flushed out a large part of the saline connate water that was entrapped in the sediments during their deposition. There is, however, an enormous quantity of saline connate water remaining in the subjacent strata.

The availability of fresh and slightly saline ground water in the Gulf Coast geosyncline is highly dependent on the mode of deposition of the strata and the resultant variations in lithofacies. Important factors are the locations of major ancient fluvial systems that not only shifted laterally with time but also were extended seaward during periods of slow geosynclinal subsidence or lowered sea level, and regressed landward during periods of rapid subsidence or high sea level. Thus, as the broad-scale depositional axis of the geosyncline shifted coastward with time there were complex smaller shifts in the position of the strand line and in the location of the major drainage systems. The result is a complex of interstratified marine, littoral, and continental deposits along ancient strand lines, and interlaced channel and interchannel deposits inland. Variation in composite thickness of sand interbeds is the most important lithologic factor in determining the availability of ground water in the aquifers of this complex sedimentary prism because hydraulic transmissivity is strongly dependent on the composite thickness of sands. The hydrologic significance of variations in composite thickness of sand interbeds has been demonstrated for the Sparta Sand of Eocene age by Payne (1968).

The distribution of fresh and slightly saline ground water is also dependent on other factors, some of which are outlined here.

1. The magnitude and direction of dip associated with subsidiary structures in the geosyncline, such as the east Texas embayment, Sabine platform, north Louisiana basin, Monroe platform, and Rio Grande embayment, have a strong effect on depth of flushing by influencing the hydraulic head and gradient of the aquifers. Fresh water generally extends to deeper levels in the basins, where the salt domes occur, than in the structurally elevated adjacent areas.

2. Flushing will generally not extend deeper (farther down dip) than a level at which the magnitude of counter pressure (static head) of the saline water equals the pressure head of the fresh-water part of the aquifer. Where this equilibrium occurs the fresh-water aquifer will generally discharge upward through its overlying confining beds, through fractures, or through the disturbed area around a dome. Farther downdip fresh water is present in a stratigraphically higher aquifer. Steeply inclined fresh-saline water interfaces or abrupt steps in those interfaces result, as in the Mississippi salt-dome basin. The depth at which caprock forms, and therefore the depth to salt, is probably influenced to some extent by these contrasting depths to salt water.

3. The location of major foci for discharge, such as broad alluvial valleys, may have a strong influence on the direction of ground-water movement and consequently can affect the depth to saline water. Payne (1968), for example, suggests that the Mississippi River alluvial valley is the major focus of discharge for most of Arkansas, Louisiana, and Mississippi and thereby exerts a major influence on the depth to salt water (fig. 3).

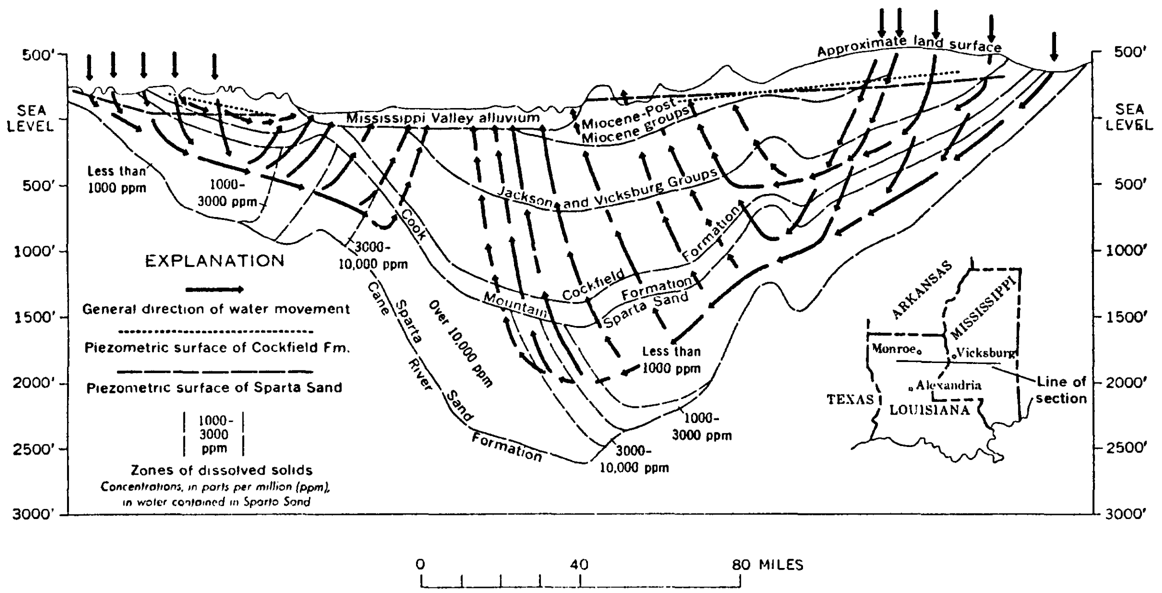


Figure 3.--Generalized east-west geohydrologic section through the Mississippi Valley showing movement of ground water as affected by reversals in level of the piezometric surface of the Cockfield and Sparta Formations as described by Payne (1968). Note the strong asymmetry of ground-water flow and contrast in depth of fresh water caused by the difference in depth to the two formations across the Mississippi Valley. Note also the extreme vertical exaggeration of the cross section. From Payne (1968, fig. 2).

4. On a more local scale the depth to saline water is strongly influenced by some faults which act as hydraulic barriers either because the fault zone itself has a low permeability or because it juxtaposes rocks of contrasting hydraulic properties.

5. On a very local scale many salt domes that have their tops close to or above the top of the regional saline ground-water surface have a pronounced influence on the depth to saline water, which tends to rise abruptly around and over the domes through hundreds of feet of stratigraphic section. Both structural and stratigraphic factors are involved in this influence. Some of the available information and speculations based on that information are summarized in the descriptions of the salt-dome basins that follow.

Lithofacies variations are common between the area over salt domes, the rim syncline area (if present), and the area outward from the rim syncline. These variations are generally interpreted as evidence of syndepositional doming of the surface, and they constitute the principal evidence for the process of salt diapirism being a slow and continuous one (Ferruccio Gera, written commun., 1970). These local facies changes at salt domes can have an important influence on the availability and possibly also the movement patterns of ground water near salt domes. In any case, they provide an added complexity which, together with the structural complications due to doming and the regional complexities noted above, makes the understanding of the hydrologic environment at salt domes very difficult. Available data are inadequate to formulate hydrologic principles that would be generally applicable to evaluating the effect of salt domes on the hydrologic system or vice versa. Only at Tatum dome has a systematic hydrologic study been made. Development of a repository site at any other dome would require a full-scale hydrologic investigation designed to define the unique hydrologic system at that dome.

The depth to salt at most salt domes is greater, and in most cases much greater, than the depth to saline water in the general vicinity of the domes. The saline water is generally conceded to be stationary and, therefore, cannot be participating in important salt dissolution after it becomes a saturated brine in contact with the salt mass. As judged from theories of caprock formation and from the distribution of caprock, most dissolution occurs when the upper part of the rising salt diapir intersects fresh to slightly saline water that is moving downdip in an aquifer (Bodenlos, 1970). Because fresh to slightly saline water is not found any deeper than about 3,500 feet in the province, and because there is no reason to assume that paleodepths were any greater than 3,500 feet, caprock that occurs below about 4,000 feet probably formed during earlier geologic periods when the sedimentary cover over the domes was less than it is now. In the north Louisiana and Mississippi salt-dome basins caprock has been reported from 18 of the 21 domes whose salt tops are deeper than 4,000 feet, whereas in the east Texas-south Louisiana salt-dome basin caprock has been reported from only eight of the 48 deep domes (Murray, 1961). These relationships seemingly support the suggestion made by Kupfer (1970) that the diapiric rise of the domes of the interior subprovince ceased a long time ago, perhaps in the Miocene.

Although the salt in most salt domes lies well below the base of the fresh and slightly saline ground water there are some exceptions where salt extends above it. Rayburns dome appears to be the only exception in the north Louisiana salt-dome basin, and Tatum and Lampton in the Mississippi salt-dome basin, but there are numerous exceptions in the coastal subprovince, including Hockley, Humble, and Pierce Junction domes in the Houston area; Batson, Saratoga, and Sour Lake domes in Hardin County in east Texas (Baker, 1964); and the Five Islands, Vermillion Bay, Pine Prairie, and Anse la Butte domes in south Louisiana. We are not aware of any systematic water-quality studies designed to determine if dissolved solids from these domes are contributed to the surrounding ground water. In the absence of such studies it is not known whether or not the salt in the domes is in contact with the moving ground water. It would be of special interest to conduct closely controlled water-quality studies at a dome like Hockley where nearby heavy withdrawal from wells has steepened the hydraulic gradient and presumably accelerated the coastward movement of ground water past the dome. Meager data indicates that dissolution may be occurring at some coastal domes. In an unpublished report on the ground water of Fort Bend County, Texas, southwest of Houston, J. B. Wesselman (written commun., 1972) noted that the quality of ground water is adversely affected in the vicinity of some salt domes in that county. Baker (1964) noted time-dependent increases in chloride content in wells near salt domes in Hardin County, about 60 miles northeast of Houston. At some of these domes the deterioration in quality of ground water may be related to oil field operations or other factors not related to dissolutioning. With the possible exception of inclusions of permeable wall rock in coastal domes, we do not recognize any hydrologic factors of subprovince scale that favor either the interior or the coastal subprovinces for waste emplacement. Special aspects of surface- and ground-water hydrology that pertain to the suitability for waste emplacement are described under the headings of the individual salt-dome basins that follow. A general evaluation of hydrologic factors that affect suitability is included under "conclusions."

NORTHEAST TEXAS SALT-DOME BASIN

The northeast Texas salt-dome basin includes a well-defined cluster of domes situated between the Mexia-Talco fault zone on the west and the Sabine platform on the east (figs. 1 and 4). From a geologic standpoint, two of the 20 domes included in the basin on figure 4 (Day and Kittrell domes) belong in the south Louisiana salt-dome basin. They are included with the northeast Texas domes in order to conserve on the area covered by figure 14 and thereby simplify the illustrations.

Of the 20 domes in the basin, 13 appear to be unfavorable from the standpoint of depth and present usage (table 2). Depth to salt in the seven unrejected domes ranges from 122 feet for Palestine to 2,009 feet for Whitehouse. Data for the seven unrejected domes are presented in table 4 (in pocket) and in the appendix. Of the seven domes, most is known about Palestine and Keechi.

Physiography and climate

The northeast Texas salt-dome basin is in an area of gently rolling topography that is crossed from northwest to southeast by three major drainages--the Sabine, Neches, and Trinity Rivers (fig. 4). Elevations range from about 175 to 700 feet and, except for local marshy areas along the major drainages, the area is well drained.

The climate is temperate with long mild summers. Average annual precipitation is about 44 inches.

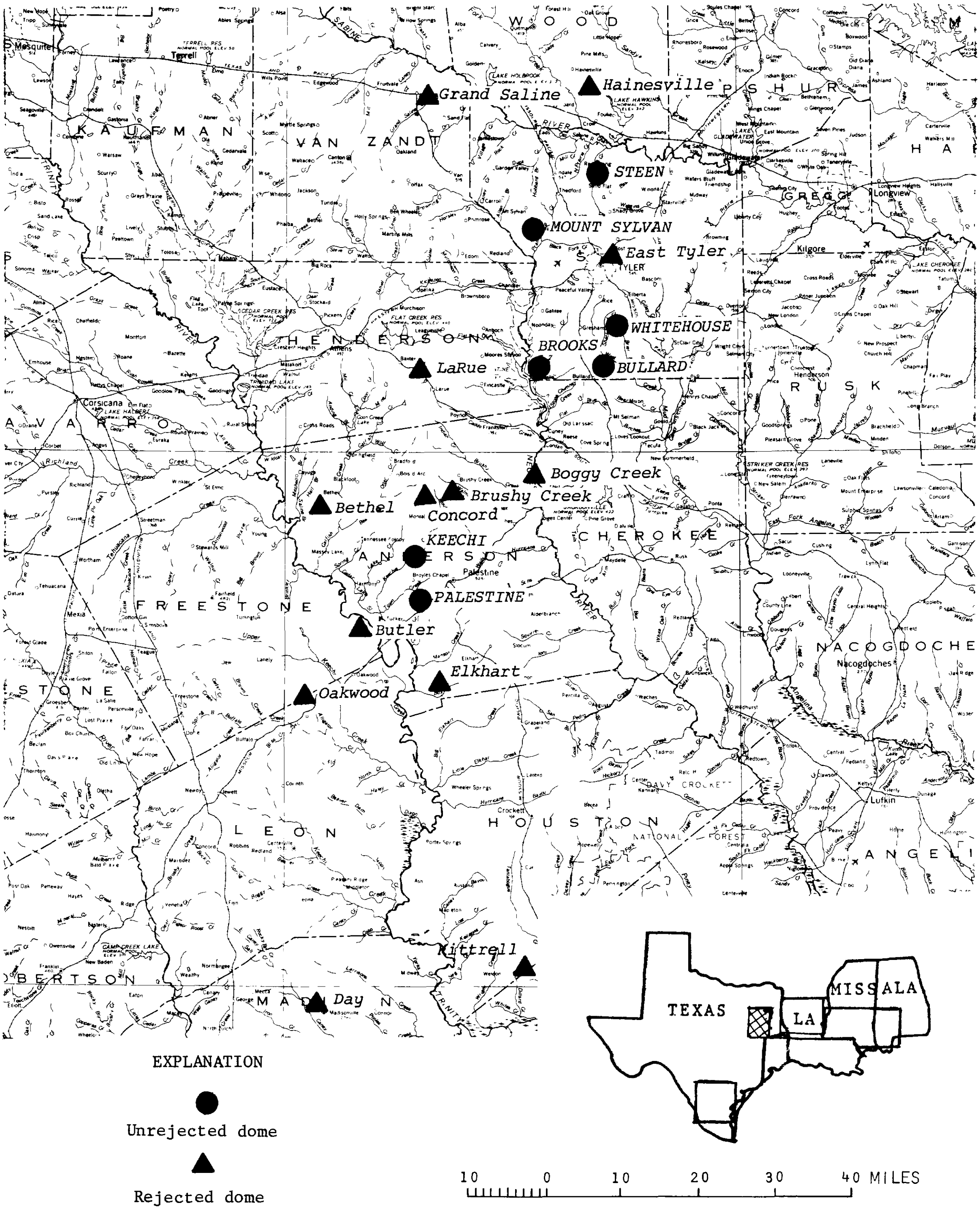


Figure 4.--Unrejected and rejected domes in northeast Texas salt-dome basin. (Base map, USGS 1:1,000,000; Texas.)

Geology

The northeast Texas salt-dome basin forms the northern part of the east Texas embayment--one of the three large embayments that modify the shape and structure of the Gulf Coast geosyncline. Exposed strata range in age from Cretaceous to Quaternary. A partial stratigtaphic section of Tertiary strata in the basin is shown on figure 5. Strata of Cretaceous age and those belonging to the Eocene Midway and Wilcox groups are exposed only in the deformed areas around some of the salt domes including Palestine, Keechi, Butler, Brooks, and Steen domes. Most exposures throughout the basin consist of post-Wilcox Eocene strata that have gentle dips into the basin. Quaternary materials consisting of Pleistocene fluviatile terrace deposits and Holocene alluvium are restricted to areas along the major and tributary drainage courses.

The upper parts of the seven unrejected domes are contained in, and overlain by, strata ranging from Upper Cretaceous to the Sparta Sand of Eocene age. The Upper Cretaceous rocks and the rocks of the Midway Group include limestone, mudstone, shale, clay, marl, and chalk that form complex uplifted blocks on Palestine, Keechi, Brooks, and Steen domes. The top of Whitehouse dome is probably contained in clays of the Midway Group. The tops of Bullard and Mount Sylvan domes are probably contained in the interbedded, poorly cemented quartz sand, silty shale, clay and lignitic clay of the Eocene Wilcox Group. The Wilcox is 1,000-2,000 feet thick and consists of about 40 percent sand. In ascending order, the important overlying Eocene strata include the

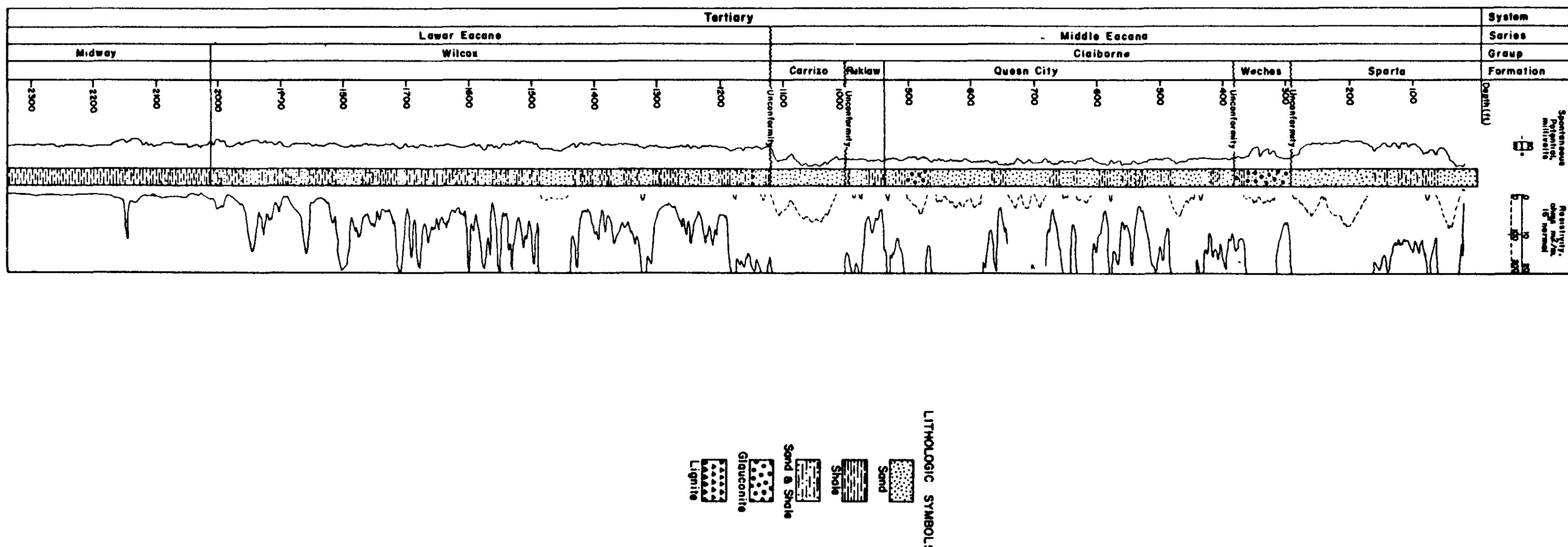


Figure 5.--Typical electric and lithologic log of some Tertiary strata in Smith County, Texas. From Dillard (1963, pl. 3). Additional typical electric and lithologic logs within the salt-dome basin are reported by Park (1950, p. 220-221) for the Maydelle field, and by Turner (1950, p. 365) for the South Tyler field. These logs include deeper strata than are shown here.

Carrizo Sand, the clay-rich Reklaw Formation, the interbedded sand and clay of the Queen City Sand and Weches Formation, and the Sparta Sand.

The Eocene strata are the most important from the standpoint of salt-dome geology of the basin. Eocene strata were deposited in alternating marine and continental environments that resulted from repeated transgression and regression of the sea. The marine strata consist mainly of clay and shale with minor sand, and the continental strata consist of near-shore sand and lesser amounts of clay, shale, and lignite.

From a structural standpoint, the northeast Texas salt-dome basin coincides with the Tyler basin, a north-northeast-trending, southward-opening structural depression that is separated from the southern part of the east Texas embayment by the Mt. Enterprise fault zone (fig. 1).

The top of the Louann Salt is at a depth of about 15,000 feet in the deeper parts of the salt-dome basin. The Ferry Lake Anhydrite of Early Cretaceous age shows about 2,500 feet of structural relief across the basin (Cohee, 1962). The base of the Wilcox Group descends into the basin from a depth of about 400 feet below sea level on the flanks to about 1,500 feet along the axis indicating structural relief of about 1,100 feet (fig. 6).

Eocene strata dip into the Tyler Basin at a rate of about 50 feet per mile but the dip increases to as much as 100 feet per mile in areas within the basin where salt flowage has produced arching and subsidence. Salt flowage has played an important role in localizing subsidiary structures that influenced deposition during the Tertiary. The subsidiary

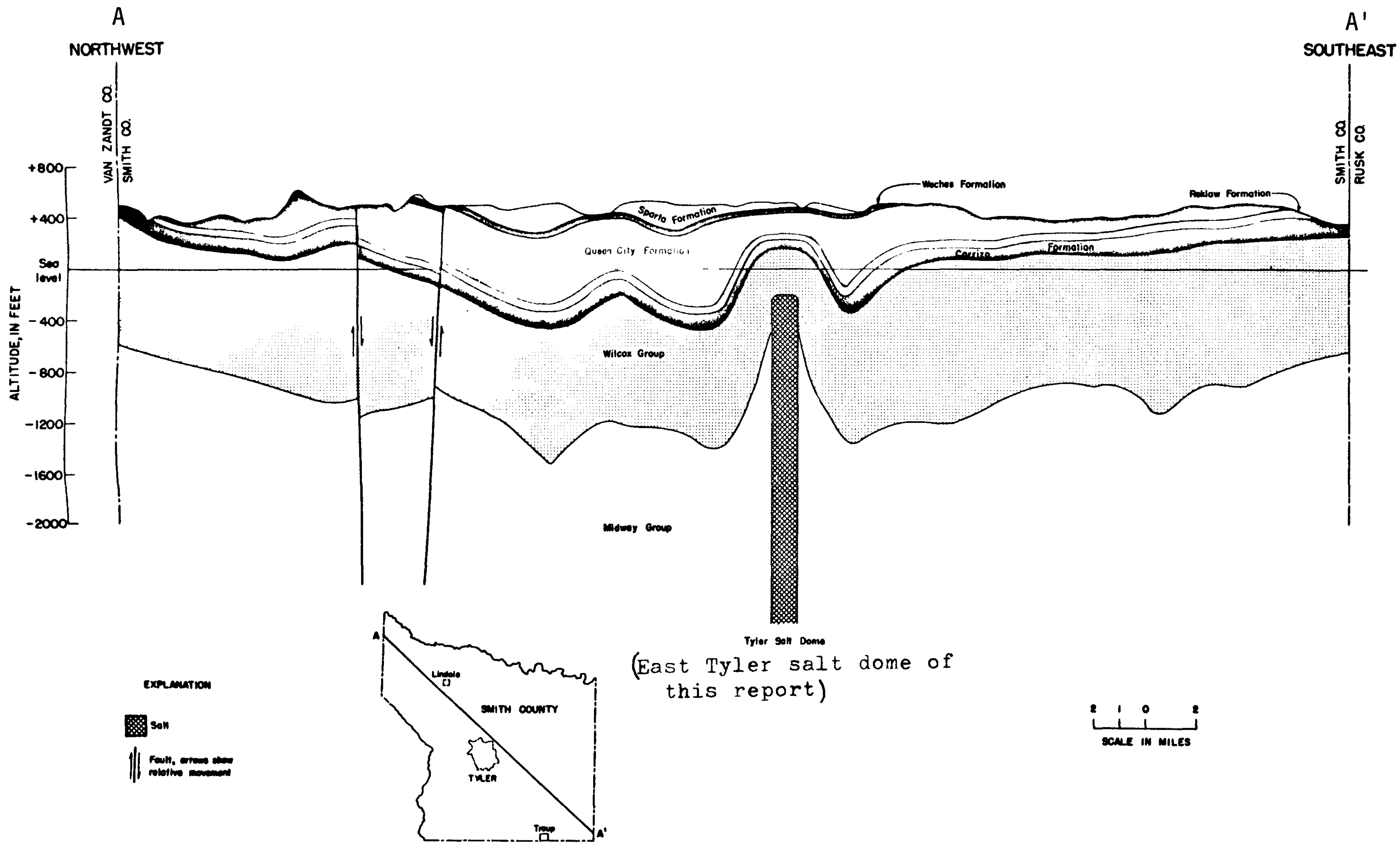


Figure 6.--Diagrammatic cross section trending northwestward through Smith County, Texas, showing the Tyler basin as expressed in Tertiary strata. Note vertical exaggeration. From Dillard (1963, pl. 4).

structures are ridges and troughs that trend northeast. The salt domes occur in the troughs. Sediments thicken and become more sandy in structural depressions where they collected preferentially. Uplift due to salt diapirism has produced steep dips and faults that have conspicuous surface expression at Palestine, Keechi, Brooks, and Steen domes. An example can be seen on the geologic map of Palestine dome provided in the appendix (fig. 22).

Hydrology

The mean annual precipitation in the northeast Texas salt-dome basin is about 44 inches. About 5 percent of this water is consumed in recharge to the exposed Eocene strata. Much is lost as runoff.

In general, the base of the Wilcox Group marks the base of the fresh-water aquifer system. The base of the Wilcox is at a depth of about 2,300 feet in the central part of the basin and, as noted above, has about 1,100 feet of structural relief across the basin. The lower beds in the Wilcox are transitional with the clay-rich beds of the underlying Midway Group, and locally they contain saline water similar to the Midway strata.

Almost all of the data on which this summary is based were acquired from a ground-water report of Smith County, Texas, by Dillard (1963). There are three main aquifers in the post-Midway Group strata of Eocene age. They are the Carrizo-Wilcox, Queen City, and Sparta aquifers. Within the 939-square-mile area of Smith County (which is believed to typify the rest of the basin) well fields could yield the following quantities of fresh water from the three aquifers, in million gallons per day:

Sparta	10
Queen City	3
Carrizo-Wilcox	36

Although far below the potential yields for Mississippi, these data indicate that very adequate supplies of fresh ground water are available throughout the basin. The average transmissivities for the three aquifers are as follows, in cubic feet per day:

Sparta	1,660
Queen City	430
Carrizo-Wilcox	2,670

In general, ground water is subjected to water-table conditions in areas of outcrop of the aquifers and to artesian conditions elsewhere. The direction of ground-water movement in the Carrizo-Wilcox aquifer is generally down the dip into the basin, but the greatest recharge area is in the west and thus the main movement of water is to the east and southeast. Ground-water-movement patterns in the other two aquifers are controlled by structural dip, topography, and local discharge to streams that have incised the aquifers. Natural rates of ground-water movement in the basin are slow--probably a few feet to a few tens of feet per year. Hydraulic gradients are typically about 10 feet per mile.

Dillard (1963, p. 17) has noted that the quality of water in the Carrizo-Wilcox aquifer may be adversely affected by salt domes in Smith County. An anomalously high chloride content in City of Tyler Well No. 6 may be a result of moving ground water coming in contact with the salt of the Tyler dome which, according to available data, penetrates the aquifer to a depth (890 ft below the surface) slightly above the pumping level in the well (898-1,032 ft below surface). A systematic study of water quality in other wells that are screened in aquifers penetrated by nearby salt would be very desirable. The published water-quality data for Smith County are inadequate for such a study.

The construction of a mined chamber for a waste emplacement site produces the secondary problem of how to dispose of the mined salt. Large quantities of oil-field brine are disposed of by injection into permeable intervals in the Woodbine Formation of Late Cretaceous age. These strata do not contain petroleum reserves in most of the salt-dome basin. Available surface or ground water could be used to produce a brine from the mined salt, and brine disposal into the deep formations would probably be feasible.

NORTH LOUISIANA SALT-DOME BASIN

The north Louisiana salt-dome basin is marked by a northwest-trending cluster of known and suspected salt domes situated between the Sabine platform on the west and the Monroe platform on the east (figs. 1 and 7). There are 15 known domes in which salt has been penetrated by the drill and at least 4 suspected domes in which salt has not been drilled.

The depth to salt in six of the 15 known domes is in the interval from about 2,500 to 6,425 feet thus indicating that the domes are too deep to be favorable for a repository site. Gas-storage facilities have been developed on four other domes and one dome (Minden) has active petroleum production. Therefore, only four of the 15 known domes are unrejected on the basis of depth and present usage--Vacherie, Kings, Rayburns, and Winnfield. Depth to salt is less than 1,000 feet for all four and is as little as 115 feet on Rayburns. Caprock has been found on the four domes but varies greatly in thickness from dome to dome and over individual domes (table 4).

There are at least four suspected salt domes that have surface structural and(or) topographic expression but in which the depth to salt is unknown--Castor Creek, Cedar Creek, Prices, and Prothro. These suspected domes are included in our list of potentially suitable domes because, by comparison with some of the known domes in the north Louisiana salt-dome basin, the depth to salt is probably not unreasonably great. For example, Castor Creek, Cedar Creek, and Prices domes have surface "salines" or salt licks similar to at least four of the shallow

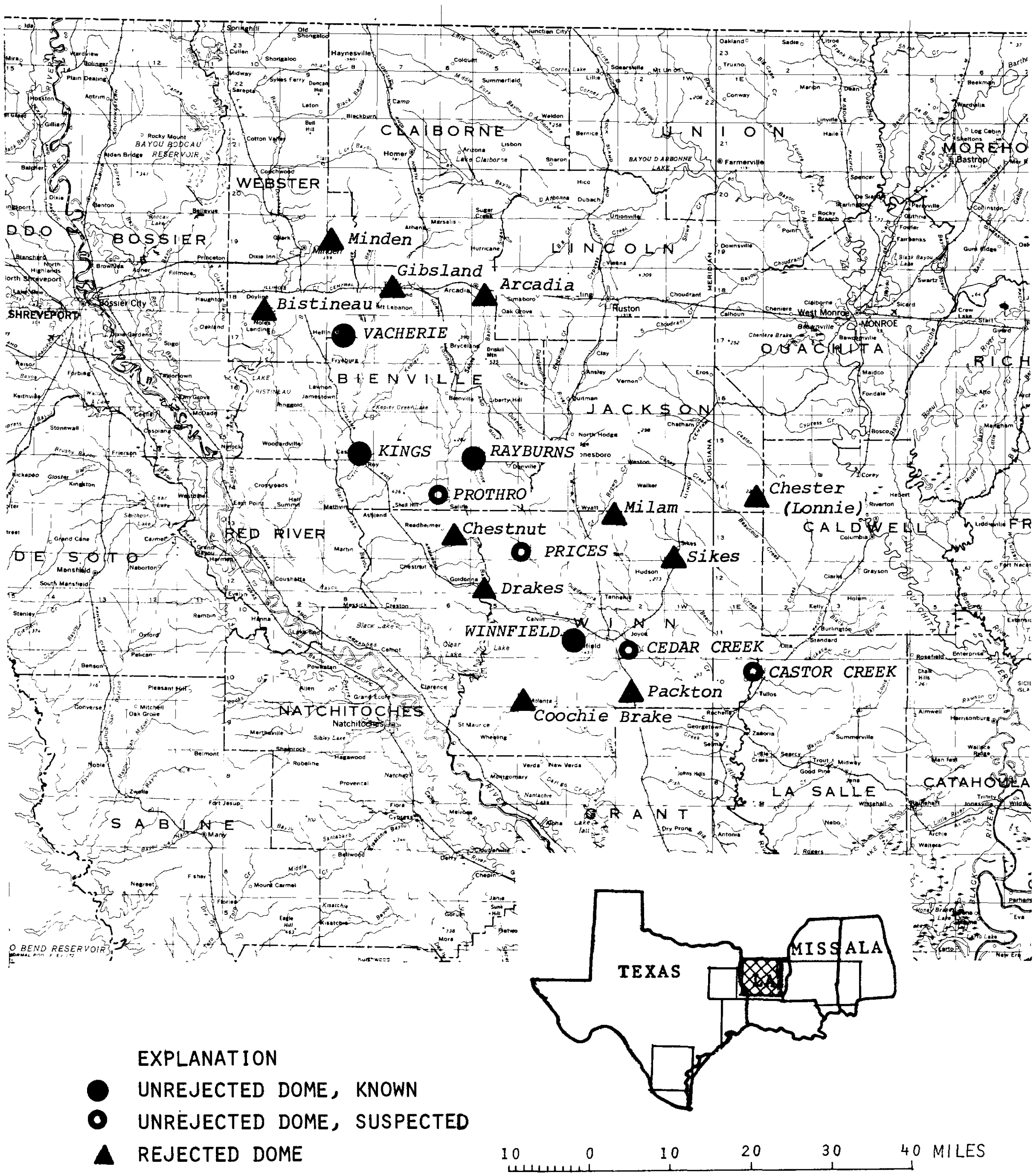


Figure 7.--Unrejected and rejected domes in north Louisiana salt-dome basin. (Base map, USGS 1:1,000,000; Louisiana and Texas.)

known domes in the basin--Bistineau (1,500 ft), Drakes (900 ft), Kings (172 ft), and Rayburns (115 ft). Also, exposed strata at Prothro dome are uplifted and tilted as a result of salt diapirism similar to at least five other known shallow domes in the basin--Arcadia (1,400 ft), Minden (1,912 ft), Gibsland (885 ft), Rayburns (115 ft), and Drakes (900 ft). The known deep domes in the north Louisiana salt-dome basin lack "salines" or surface structural expression.

The eight unrejected known and suspected domes are distributed throughout Winn and Bienville Parishes and one dome (Vacherie) is located at the north boundary of Bienville Parish where it adjoins Webster Parish (fig. 7).

The tops of two of the rejected salt domes, Coochie Brake and Chestnut, lie within 2,600 feet of the surface. Because economic development has not been reported on either dome they should be recognized as potentially suitable if future consideration is given to salt at a depth considerably greater than 2,000 feet. The Coochie Brake and Chestnut domes are located in Winn and Natchitoches Parishes, respectively.

Of the known domes only Winnfield has a mined opening. More is known about the geology and hydrology of the Winnfield dome than any of the others, but it probably would have to be rejected because of (1) a reported history of water encroachment problems in the mined openings, (2) a history of naturally occurring CO_2 outbursts in the mine, and (3) recent mine flooding and associated caprock subsidence. The mine and shaft are at present in a completely flooded condition as a result of a sudden inflow of water near the shaft on November 17-18, 1965. The mine did not collapse but minor subsidence and fracturing occurred at the surface, probably as a result of rapid dissolution by the inflowing water at the upper caprock-salt contact. A description and map of the surface fractures is available (Gulf Coast Association of Geological Societies, 1970).

Brine production from shallow wells, mostly during the Civil War, is reported for five of the shallow domes in the basin and three of those domes (Kings, Rayburns, and Prices) are on our list of unrejected domes.

Physiography and climate

The north Louisiana salt-dome basin is part of a broad dissected plain having a gentle gulfward slope. It is an area of gently rolling or hilly topography with elevations ranging from 250 to 400 feet. The hilly topography is interrupted locally by nearly flat valleys that are characteristic of the principal drainages of northern Louisiana. Four of these southward-flowing drainages cross the basin. From west to east they are Bayou Dorcheat, Black Lake Bayou, Saline Bayou, and Little River (fig. 7).

The climate is humid and characterized by long hot summers during which the average temperature is about 80° F. Winters are short and mild and average temperatures are about 50° F. Average annual precipitation is about 50 inches.

SYSTEM	SERIES		GROUP	FORMATION	THICKNESS IN FEET	LITHOLOGY
QUATERNARY	HOLOCENE			ALLUVIUM	0- 40	Gravel, sand, silt, and clay
	PLEISTOCENE			PRAIRIE	0- 40	Gravel, sand, silt, and clay
				MONTGOMERY	0- 90	Gravel, sand, silt, and clay
				BENTLEY	0- 80	Gravel, sand, and silt
				WILLIANA	0- 40	Gravel and sand
TERTIARY	EOCENE		CLAIBORNE	COCKFIELD	0- 40	Non-marine sand and silt
				COOK MOUNTAIN	0- 300	Marine to non-marine glauconitic sands and chocolate-brown clays, and sands and silts
				SPARTA SAND	0- 500	Massive sands, silts, and silty shales
				CANE RIVER	0- 280	Glauconitic greensand, clay-marl, and chocolate-brown silty clays
			WILCOX	(UNDIFFERENTIATED)	0-1000	Thin-bedded sands, silts, and silty clays
	PALEOCENE		MIDWAY	(UNDIFFERENTIATED)	500- 650	Gray-black shale--calcareous at base
CRETACEOUS	UPPER CRETACEOUS	GULFIAN		ARKADELPHIA MARL	50- 120	Gray, chalky marl
				NACATOCH SAND	250- 400	White to gray calcareous sand Gray, calcareous sandy shale
				SARATOGA CHALK	50- 75	White to gray chalk
				MARLBROOK MARL	170- 190	Gray chalky marl
				ANNONA CHALK	100- 120	White to gray chalk
				OZAN EQUIVALENT	150- 250	Marly shale and sand
				BROWNSTOWN MARL AND TOKIO EQUIVALENT	400- 525	Sand and shale
				EAGLE FORD	200- 400	Red and green tuffaceous sands. Dark shales
				WOODBINE	80- 160	Gray to dark shales and red waxy shales, interbedded in tan tuffaceous, chloritic, conglomeratic sands
	LOWER CRETACEOUS	COMANCHEAN	WASHITA AND FREDRICKSBURG	(UNDIFFERENTIATED)	0- 300	Gray shales and limes
			TRINITY	PALUXY	0-1525	Red and gray sands, sandy shales, shales and sandy limes
				MOORINGSPORT	450-1300	Shales and sandy shale; thin limes, anhydrite stringers
				FERRY LAKE ANHYDRITE	200- 585	Massive anhydrite--shales, lime stringers
				RODESSA	480- 550	Oolitic, coquinoid lime, black shale, thin sands, anhydrite stringer
				JAMES LIMESTONE	110- 200	Lignitic, silty, oolitic, porous, fossiliferous, slightly sandy lime.
				PINE ISLAND SHALE	300- 400	Dark gray to black shale and limy shale
				SLIGO	250- 450	Gray, oolitic lime and dark-gray, limy shale
		COAHUILAN		HOSSTON	1900-3025	Varicolored non-marine hard sands, sandy shales and shales
JURASSIC	UPPER JURASSIC		COTTON VALLEY	SCHULER	? -2150	Light-colored waxy shales and fine-to medium-grained sandstone, occasionally calcareous. Basal sands coarse grained to conglomerate.
				BOSSIER	530-1350+	Dark shales with fossiliferous limestone; fine-to coarse-grained light-colored sand; frequently a basal conglomerate.
				BUCKNER	0-1790	White to red, coarse-to medium-grained sands with some interbedded dark shales. Red to brown shale with pink anhydrite and light-colored sands, porous oolitic lime.
				SMACKOVER	0-1510	Gray to dark-gray oolitic limestone (Reynolds oolite of economic usage); interbedded limestone, shale and calcareous sandstone.
				NORPHLET	0- 150	Red and gray clays; reddish and gray sands; occasional gravel.
JURASSIC(?)				LOUANN SALT	? -3223+	Clear rock salt with occasional traces of white powdery anhydrite.

Figure 8.--Generalized stratigraphic section of Webster Parish, Louisiana; modified from Martin and others, 1954, pl. 3.

Geology

Comprehensive geologic reports that describe the physiography, stratigraphy, and salt-dome geology are available for Webster Parish (Martin and others, 1954) and Caldwell and Winn Parishes (Huner, 1939) but none is available for Bienville Parish. The generalized stratigraphic section for Webster Parish shown in figure 8 adequately represents the stratigraphy in the rest of the salt-dome basin. Most of the domes in the salt-dome basin are located in an area where beds of the Claiborne Group of Eocene age are at the surface, but the more westerly domes are located along the western limit of the Claiborne where the underlying Wilcox Group is exposed on the east flank of the Sabine platform. Three of the domes that lie along the western and southern margins of the basin (Bistineau, Coochie Brake, and Castor Creek) are in areas where the Tertiary strata are buried by a thin veneer of terrace deposits of Pleistocene age.

Some salt domes have surface expression. For example, the only Upper Cretaceous strata exposed in Louisiana occur at Rayburns and Prothro domes where they have been uplifted (Durham and White, 1960). Although not exposed, Cretaceous strata are reported at or near the surface of Kings and Bistineau domes (Spooner, 1926). At Vacherie dome Wilcox strata are exposed in an area where the normal surface strata are the overlying Claiborne Group. On top of the Arcadia, Minden, Gibsland, and Drakes domes, some exposed rocks of the Claiborne Group are older than the Claiborne rocks surrounding the domes.

The upper parts of the four known unrejected domes probably penetrate highly flexed Upper Cretaceous, Paleocene, and lower Eocene strata. It is common for the older strata to be uplifted about 2,000 feet at the domes. If any or all of the four suspected domes are as shallow as 2,000 feet their tops would be within the same stratigraphic range as those of the known domes. In general, Claiborne strata are flexed over, rather than penetrated by, the salt cores.

On the basis of subsurface data, rocks of Late Cretaceous age are at least 1,500 feet thick in the basin and consist mainly of marine shale and sandy shale, marl and clay-marl, chalk and impure chalk, and minor sand, limestone, and red clay (Spooner, 1926). The Midway Group of Paleocene age is about 550 feet thick and consists almost wholly of marine clay. The Eocene and Paleocene Wilcox Group thickens southward from 800 to 2,500 feet and is composed of interstratified sand and clay probably mostly of continental and deltaic origin. Although generally not in contact with the salt, the Claiborne Group of Eocene age is of special significance because it carries the important supplies of fresh ground water in the basin (Rollo, 1960). The Claiborne ranges from 1,800 to 2,400 feet in thickness and consists of four formations which are, in ascending order, Cane River Formation, Sparta Sand, Cook Mountain Formation, and Cockfield Formation. These strata record alternating marine and continental deposition. The Cane River and Cook Mountain are mainly clay and the Sparta and Cockfield are mainly sand and are the principal fresh-water aquifers.

The north Louisiana salt-dome basin is not a closed basin in the depth range with which this summary is concerned. It is a relatively shallow northwest-trending trough that plunges and opens to the southeast and plays out into the Gulf Coast geosyncline. The trough area subsided more rapidly and received thicker accumulations of Mesozoic and Tertiary sediments than the flanking Sabine and Monroe platforms. The Louann Salt is at a depth of about 11,000 feet in the north part of the basin and is probably more than 15,000 feet deep in the southern part. The Ferry Lake Anhydrite of Early Cretaceous age shows about 2,500-3,000 feet of structural relief across the northern part of the basin (Cohee, 1962).

As noted above, salt diapirism has produced strong local uplift, but little seems to be known about possible subsidiary deep structures in the basin that may be related to salt movement. Structure contours on the Ferry Lake Anhydrite show some irregularities including two small northeast-trending subsidiary troughs that are possibly related to salt withdrawal during dome formation (Cohee, 1962). The main structural irregularities in the basin are those related to salt diapirism.

Hydrology

There is considerable published general information concerning the availability of fresh ground water in Louisiana (Rollo, 1960; Winslow and others, 1968). Detailed reports concerning the surface- and ground-water resources are available for several of the parishes located west and south of the salt-dome basin but not for the parishes within the basin (Page and May, 1964; Page and others, 1963; Newcome and others, 1963). Much basic water-supply information including water quality data are available for municipal water supplies in the basin (Dial, 1970), and additional information is available from the offices of the U.S. Geological Survey in Baton Rouge (G. D. Cardwell, oral commun., 1972).

Surface water

The average annual precipitation in the basin as estimated from published reports on adjoining parishes, ranges from about 47 to 52 inches. About 35 percent is lost to runoff and a small percentage is consumed in recharging the aquifers.

The basin area is topographically high relative to the drainage courses of the Red and Ouachita Rivers between which it is situated (fig. 7). The basin is drained mainly by a dendritic system of streams that flow southward to Red River.

In general, the area is well drained with small local swamps and marshes restricted to some of the major stream courses and to the "salines" or areas of subsidence that are localized over some of the salt domes. Because the basin area is relatively high topographically and is well drained, flood hazards appear to be low for all of the unrejected domes except possibly Cedar Creek and Castor Creek near the Dugdomona River and Castor Creek, respectively. Records for peak runoffs are available from gaging stations near both domes (Sauer, 1964), and those data can be used to establish flood-frequency relationships.

Ground water

Fresh ground water is available throughout northwest Louisiana to depths ranging from more than 200 feet above sea level on the Sabine platform to 1,100 feet below sea level at Rayburns dome along the axis of the salt-dome basin (fig. 9). Locally, as at Rayburns dome, the base of the fresh-water system extends down into the sands of the Wilcox Group, but throughout most of the basin fresh ground water is restricted to the strata of the overlying Eocene Claiborne Group. Small amounts of fresh water are found in the valley and the terraced upland deposits of Quaternary age that form veneerlike belts along the major and tributary drainages. Deposits of Holocene age form thin mantles of sand, silt, and clay along stream valleys but do not constitute important aquifers.

Recharge to fresh-water aquifers is principally from rainfall. Discharge from the aquifers is by evapotranspiration, effluent seepage, interaquifer leakage, and pumping from wells. Total natural discharge far exceeds the total discharge from wells.

The depth to the base of fresh water broadly reflects control by regional structural and stratigraphic patterns. For example, the depth increases generally southward toward the Gulf Coast geosyncline and eastward toward the axis of the Mississippi structural trough. On a somewhat more restricted scale the Sabine platform in northwestern Louisiana has a pronounced effect on the position of the base of the fresh-water system. A thick clay section belonging to the Midway Group of Paleocene age is at or near the surface over much of the Sabine

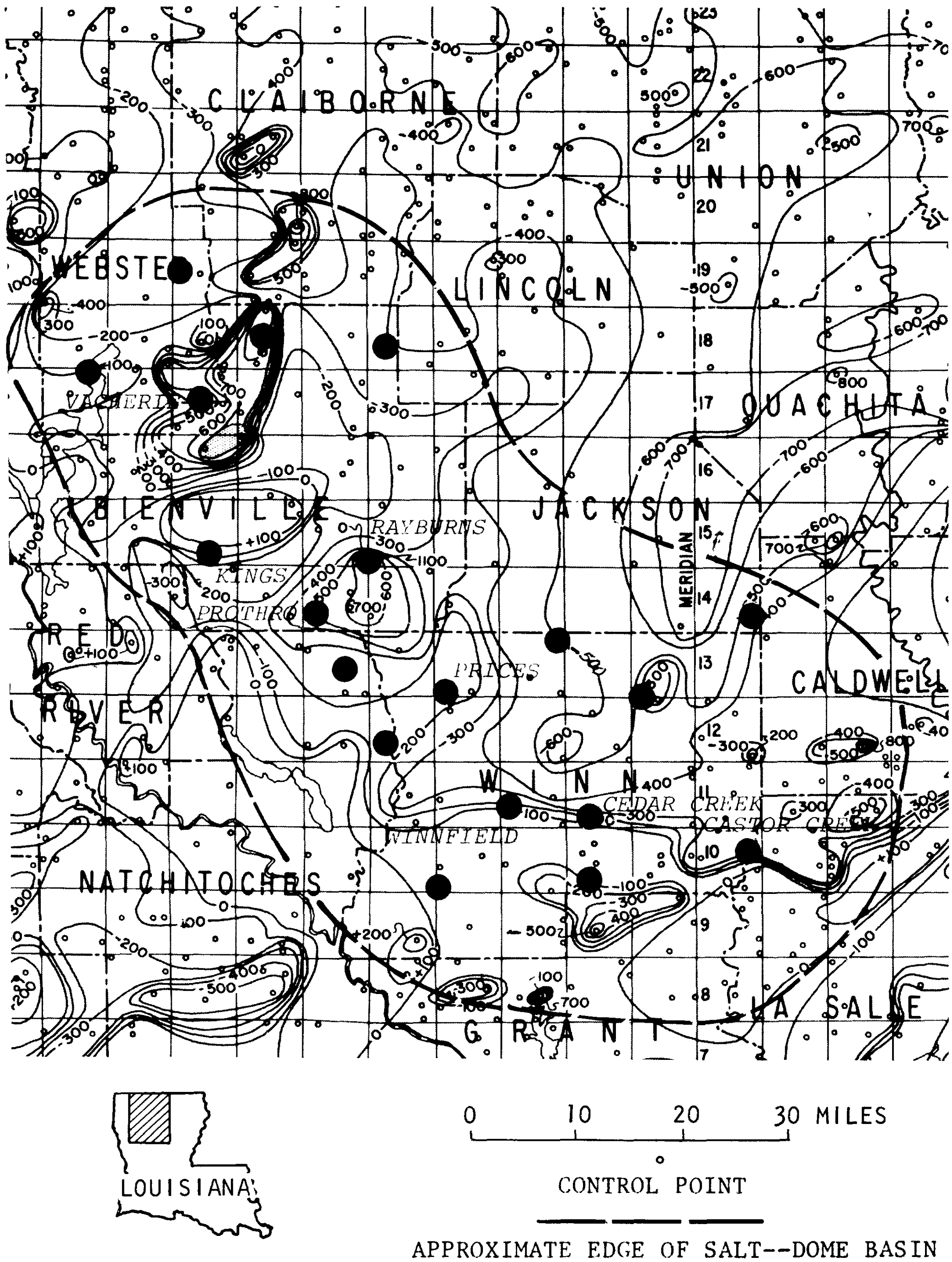


Figure 9.--Altitude of base of fresh ground water and location of domes in north Louisiana salt-dome basin. Chloride content of fresh water less than 250 parts per million. Contour map from Rollo (1960). Contour interval 100 feet, + above sea level, - below sea level.

platform. The clay prevents the circulation of fresh water into and out of the deposits of Cretaceous age so that the base of the fresh-water system is shallow over the platform but becomes deeper eastward in the north Louisiana salt-dome basin and becomes abruptly deeper southward where the dip off the platform adds to the southerly dip of the Gulf Coast geosyncline. Within the basin the base of the fresh-water zone (defined as 250 ppm chloride) is quite irregular (fig. 9), but generally it follows the base of the Sparta Sand of the Claiborne Group (Rollo, 1960). On the south side of the approximately east-west alinement formed by Winnfield, Cedar Creek, and Castor Creek domes (fig. 9), the base of the fresh-water zone rises abruptly through about 500 feet of section into younger strata of Oligocene and Miocene age. This abrupt step in the base of the fresh-water zone reflects the southern limit of flushing of connate saline waters from the Claiborne strata (Rollo, 1960). Where complications due to faulting or withdrawal from wells do not occur, ground-water movement is in the general direction of the regional dip of the strata. However, near the limit of flushing of an aquifer the major component of movement of fresh ground water will be upward either along faults, through the less permeable confining beds, or, if a salt dome is present, along the structurally disturbed strata that surround the salt mass. The possibility exists that accelerated upward movement of ground water related to the limit of flushing of the Claiborne strata at Winnfield salt dome contributed to the hydrologic problems encountered at that dome.

Based on a broadly consistent density of control points, the configuration of the basal surface of the fresh-water system is far more irregular in the north Louisiana salt-dome basin than in adjacent areas (fig. 9). Depressions and rises that range in area of closure from 2 to 100 square miles are common throughout the basin. Rollo (1960) has suggested that salt domes that penetrate to or near the land surface have a pronounced effect on the occurrence of fresh ground water and may be responsible for some of the erratic patterns in the basin. Two illustrations from Rollo's report are reproduced in the appendix. They show the ground-water conditions at Rayburns dome and are interpreted as follows by Rollo (1960, p. 12-15):

> "These illustrations indicate that fresh water reaches a greater depth on the flanks of the dome than in the surrounding area and that fresh water is absent altogether over the apex of the dome. The intrusion of the salt mass pushed older formations to the surface, where they crop out, ringlike, around the center of the dome. As the water level in these ringlike outcrop areas is higher than that in water-bearing beds of the Wilcox group adjacent to the dome, it appears that water entering the ringlike outcrops has flushed salt water from the flanks of the dome and consequently generally increased the depth to which fresh water occurs in the area. Ground-water conditions at Rayburns dome indicate that the occurrence of fresh water probably is very erratic in the immediate vicinity of other intrusive salt masses and consequently exploration for ground water near similar structures should be undertaken prior to development."

Consistent with these suggestions by Rollo, it is at least interesting to note that many of the salt domes in the central part of the basin are located where the base of the fresh-water zone is marked by locally oversteepened south to southeasterly slopes. Inasmuch as the normal hydraulic gradient and movement direction in the basin is south and southeast, these relationships seem to preclude the contribution of chloride ions to the aquifers from the salt domes within the limits of detectability of the sampling and analysis system used by Rollo (1960). In fact, some of these oversteepened slopes may be related to the flushing mechanism proposed by Rollo.

Seven of the known and suspected domes in the basin have surface "salines" or "salt licks." The depth to salt in the known domes of this group ranges from 115 to 1,500 feet. Because the detailed movement patterns of ground water around salt domes are not known, the source of salt in the surface "salines" is not known. It could either be leached from uplifted masses of strata that contain saline connate water or it could be derived from dissolution at the top of the salt mass and slow upward circulation of the resulting brine through pore spaces as suggested by Goldman (1931, p. 1110). However, as Bodenlos (1970, p. 83) has noted, the second process (upward circulation through pores) does not take into account the relatively low permeability of anhydrite caprock. Reported caprock thicknesses for the seven north Louisiana domes with surface "salines" range from 11 feet (Kings dome) to 650 feet (Drakes dome) indicating that the development of the salines (based on this small sample) is independent of the thickness of caprock. This factor together with the wide range in depth to salt noted above seems to argue against the derivation of salt in surface salines from dissolution of the top of the salt mass. In either case the "salines" indicate complex hydrologic patterns at salt domes.

MISSISSIPPI SALT-DOME BASIN

The Mississippi salt-dome basin extends in an east-southeast direction from northeastern Louisiana across Mississippi to southwestern Alabama--a distance of about 250 miles (figs. 1 and 10, in pocket). It averages about 60 miles wide and contains 77 known and suspected salt domes of which only 14 are unrejected based on the depth and usage criteria that we have applied (fig. 10, tables 1, 2, and 4). Salt has not been drilled in four of the 14 unrejected domes--Crowville, Sardis Church, Hazlehurst, and Cypress Creek (fig. 10). On the basis of meager drill-hole data, the depth to salt at Crowville and Sardis Church is probably greater than 2,000 feet, and at Hazlehurst and Cypress Creek it may be slightly less than 2,000 feet. The salt tops of four of the 10 known unrejected domes lie beneath, but close to, the 2,000-foot cutoff limit--Bruinsburg, 2,016 feet, Byrd, 2,058 feet, Leedo, 2,065 feet, and County Line, 2,169 feet. The depth to salt is greater than 1,300 feet in all the 10 known unrejected domes, and the tops of seven of them lie within 100 feet of the 2,000-foot cutoff limit.

Physiography and climate

The Mississippi salt-dome basin covers parts of two natural physiographic regions: (1) the Mississippi alluvial plain in the northwest, and (2) the Gulf Coastal Plain in the southeast. These two regions are separated by a narrow north-northeast-trending physiographic district east of the Mississippi River designated the loess or bluff hills.

The Gulf Coastal Plain is characterized by pine-forested hilly uplands traversed by alluviated stream valleys, whereas the Mississippi alluvial plain is nearly flat. Elevations in the Mississippi salt basin range from 250 to 600 feet along major divides and from about 50 to 150 feet along major streams.

Climate in the basin area is humid and characterized by long hot summers during which prevailing southerly winds carry the moist warm air and commonly generate afternoon thundershowers. Mean annual temperature is about 66° F. and ranges from a mean monthly low during January of about 50° F. to a mean monthly high during July of about 82°. Average annual precipitation ranges from about 52 inches in the south to about 64 inches in the Mississippi River Delta area where the climate could be classified as humid semitropical.

Geology

Surface exposures in the large southeastern part of the salt-dome basin are Tertiary deltaic sediments that are mantled locally by thin deposits of Pleistocene sand and gravel. A smaller northwestern part is entirely within the broad belt of Quaternary alluvium of the Mississippi Valley. This alluvium forms a thin mantle averaging about 200 feet thick above the Tertiary sediments. The tops of the 10 known unrejected salt domes are in Tertiary deltaic strata ranging from the Wilcox Group of Paleocene and Eocene age upward to the Catahoula Sandstone of Miocene age (fig. 12). These strata consist mainly of poorly lithified sandstones and interbedded shales with minor amounts of marl, limestone, and sandstone. The percentage of interbedded shale and clay in the Miocene and younger strata increases toward the Gulf of Mexico, as does the thickness of those strata. The southern part of the Mississippi salt-dome basin, where the unrejected domes are located, is situated near a transition zone where the stratigraphic section changes from predominantly sand to the north to predominantly shale to the south. Eargle (1968) described the stratigraphy and structure of the Tatum dome area which includes Lampton, McLaurin, and Richmond domes. Structure and isopach maps of that area show changing patterns of structural development and sedimentation since the end of Early Cretaceous time related to the formation of a middle Tertiary depocenter in the Mississippi embayment (Eargle, 1968). These changing patterns together with the overall position of the transition zone produce stratigraphic complexities in the area of the unrejected salt domes. Additional complexity is introduced by common 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 available for Tatum dome (see appendix) can be applied to neighboring domes.

The Mississippi salt-dome basin is a deep, west-northwest-trending, asymmetric depression that lies athwart the southwesterly projection of the buried Appalachian tectonic belt and the south-southeastward projection of the buried Ouachita tectonic belt (fig. 1). In its eastern part the basin trends westward, and an approximately north-south section across it (Williams, 1969) shows the top of the Louann Salt at depths ranging from 12,000 feet, beneath the north flank, to 27,000 feet, beneath the structural axis. Displacement of the structural axis to the south of the geographic axis (fig. 1) gives the basin a strongly asymmetric profile. The Louann Salt is inferred to be 6,000 feet thick beneath the axis in eastern Mississippi (Williams, 1969). Shallow crustal structure interpreted from reversed refraction data along a north-south line located about 40 miles west of Williams' cross section clearly shows the asymmetric depression, not only within the sedimentary prism, but also as a basement structure (Warren and others, 1966). To the west, the axis of the salt-dome basin swings slightly northward and trends across the axis of the Mississippi structural trough into Louisiana, where it apparently terminates against the Monroe platform (fig. 1). There is no indication of broadening of the basin where it crosses the trough. The salt-dome basin has little or no structural expression in the Tertiary strata in which the tops of the 10 known unrejected domes are located. These strata dip from 20 to 100 feet per mile. The dips are generally gulfward, and the strikes swing in a broad arc, convex to the north, that reflects the combined structural effects of the Mississippi structural trough, the Gulf Coast geosyncline, and, to a small degree, the Monroe platform. Although they are highly exaggerated vertically, the geohydrologic sections presented in figures 12 and 13 illustrate the generalized shallow stratigraphy and structure across the salt-dome basin.

The depth to salt in the domes of the Mississippi salt-dome basin ranges from 400 feet to more than 15,000 feet. The tops of 44 of the 77 domes lie between 2,000 and 4,000 feet deep; the tops of only two are less than 1,000 feet deep, and the tops of 12 are more than 10,000 feet deep. The areal distribution of the depths to salt in the domes is irregular, although the deeper domes occur in the northern part of the basin and the shallower domes occur in the southern part. This explains the fact that there are no potentially suitable domes in the northern part of the basin (fig. 1). They are all too deep. It is possible that an inadequate salt supply in the Louann Salt or some other factor regulating the diapiric process did not permit continued upward penetration by the several very deep salt diapirs in the northern part of the basin. Some of the variation in depth to salt of the shallower domes may be related to ground-water hydrology.

Hydrology

On the basis of availability and quality of surface and ground water the Mississippi salt-dome basin is one of the most richly endowed areas in the United States. In most parts of the basin individual wells could yield 1,000-3,000 gpm (gallons per minute) and well fields could produce as much as 25 mgd (million gallons per day) of good to excellent water. Appraisals of the hydrologic potential of multicounty areas covering most of the salt basin have been prepared cooperatively by the Water Resources Division of the U.S. Geological Survey and the Mississippi Industrial and Technological Research Commission as informal reports that are available from the State offices in Jackson. These reports contain a great deal of information on surface- and ground-water hydrology, only a small part of which will be summarized herein. Other informative reports include hydrologic appraisals of the Pascagoula (Newcome, 1967), Pearl (Lang, 1972), and Big Black (Wasson, 1971) River basins in Mississippi, all of which cover areas that traverse the Mississippi salt basin. None of these reports, however, contains specific information concerning the hydrology of salt domes.

Surface water

Annual rainfall varies from about 52 inches in the northwest part of the basin to about 64 inches in the southeast part. About 30 percent of this water is lost as runoff, a large percentage is lost consumptively through evapotranspiration, and a small part infiltrates to the ground-water reservoirs. Of special interest in this report is the water lost through runoff, because runoff determines, in part, erosion rates, and it produces flood hazards.

Severe floods have occurred in the Mississippi salt basin in recent years and can be expected in the future. Location of a storage facility in the basin would require a study of data from past floods in order to estimate maximum future flood hazards. Peak annual discharge data acquired at gaging stations have been used to construct flood-frequency curves for selected recurrence intervals of as much as 50 years for some of the major streams that drain the Mississippi salt basin (Wilson and Trotter, 1961). These curves, when manipulated by a shape coefficient for the drainage basin, can be used to estimate the magnitude of future floods for selected recurrence intervals of as much as 50 years at specific sites, according to a method outlined by Wilson and Trotter (1961). The curves could be projected, with appropriate caution, to make estimates for recurrence intervals greater than 50 years if consistent climatic conditions are assumed.

A rough approximation of erosion rates in the Mississippi salt basin can be obtained from data on rates of soil loss for various land-usage categories. Soil-loss data from several watersheds in the basin were acquired from Graham Renfro of the U.S. Soil Conservation Service in Fort Worth, Texas (oral commun., 1972). The acquired data pertain only to soil loss by sheet erosion, and specifically exclude losses due to critical erosion along stream banks, road cuts, road banks, gullies, etc. The data on sheet erosion are probably more readily applicable to siting a storage facility than are data on total erosion because it is assumed that the site area will be so managed as to minimize critical erosion. The data of the Soil Conservation Service are given in terms of tons per acre per year, and have been converted here to inches per year (table 5) by assuming a fixed specific volume for the soil. Soil losses for five watersheds within the Pearl River drainage basin are given in table 5. There are 56 tributary watersheds within the 8,760-square-mile Pearl River basin, and their average soil loss ranges from 0.024 to 0.1 inch per year. Thus, the limits of loss are approximately represented by Holliday and Silver Creeks (table 5).

Table 5.--Average soil loss in inches per year for five small watersheds in the Pearl River drainage basin; distribution of soil loss among the three principal-usage categories is also given for four of the watersheds. Modified from data from Soil Conservation Service (oral commun., 1972).

Watershed	Average soil loss	Soil loss for cultivated land	Soil loss for pasture land	Soil loss for forested land	Area (square miles)
Copiah Creek	0.06	0.1	0.03	0.006	200
Bahala Creek	.07	.1	.05	.012	50
Holliday Creek	.03	.07	.02	.006	100
Silver Creek	.09	.1	.05	.012	175
Big Creek	.05	---	---	---	---

The range of soil loss in the 9,700-square-mile Pascagoula River drainage basin is similar to that of the Pearl--cultivated land, 0.072 to 0.4 inch per year; land in pasture, 0.012 to 0.09 inch per year; and forested land, 0.003 to 0.012 inch per year. The data show that forested land has the least soil loss of the three, and, by proper forest management, soil loss on forested land could probably be kept as low as 0.002 inch per year--between 15 and 20 feet in 100,000 years.

Ground water

The resource potential of the fresh ground-water system in the Mississippi salt basin has received much study in recent years, and data are available in several reports (Newcome, 1967; Lang, 1972; Shows and others, 1966; Callahan and others, 1964; Newcome and Thomson, 1970; Taylor and others, 1968; Rollo, 1960; Winslow and others, 1968). Although less is known about the saline aquifer system than the fresh, the saline system has been utilized locally for brine disposal. At

Baxterville oil field near Tatum dome, for example, about 20 million barrels of brine are injected into the system each year, and the cumulative total is over 200 million barrels.

Fresh ground water is found in the Mississippi salt basin to depths ranging from less than 100 feet to more than 3,000 feet below sea level (fig. 11). Strata that contain important fresh water include the sands of the Wilcox Group, to a depth of 3,000 feet in a small area in the northeastern part of the basin; the Claiborne Group, especially the Sparta Sand (Payne, 1968); lenticular sands in a thick section of undivided Miocene beds; and, in the western part of the basin, blanket alluvial deposits in the Mississippi Valley.

The base of the fresh-water-aquifer system slopes generally southwestward, subparallel to the regional dip of the strata. It is characterized by at least two major discontinuities or steps across which the depth to salt water decreases abruptly to the south or southwest (fig. 11). These discontinuities reflect the southerly limits of flushing of certain aquifers or groups of aquifers as shown on the geohydrologic cross sections on figures 12 and 13. The northern discontinuity marks the limit of flushing of aquifers of the Wilcox Group, and the southern one the limit for aquifers in the Claiborne Group. All of the ten potentially suitable salt domes are located south of the southern discontinuity, in the area where fresh ground water does not exist beneath the Miocene beds. As noted above, the domes tend to be shallower in that area than elsewhere in the salt

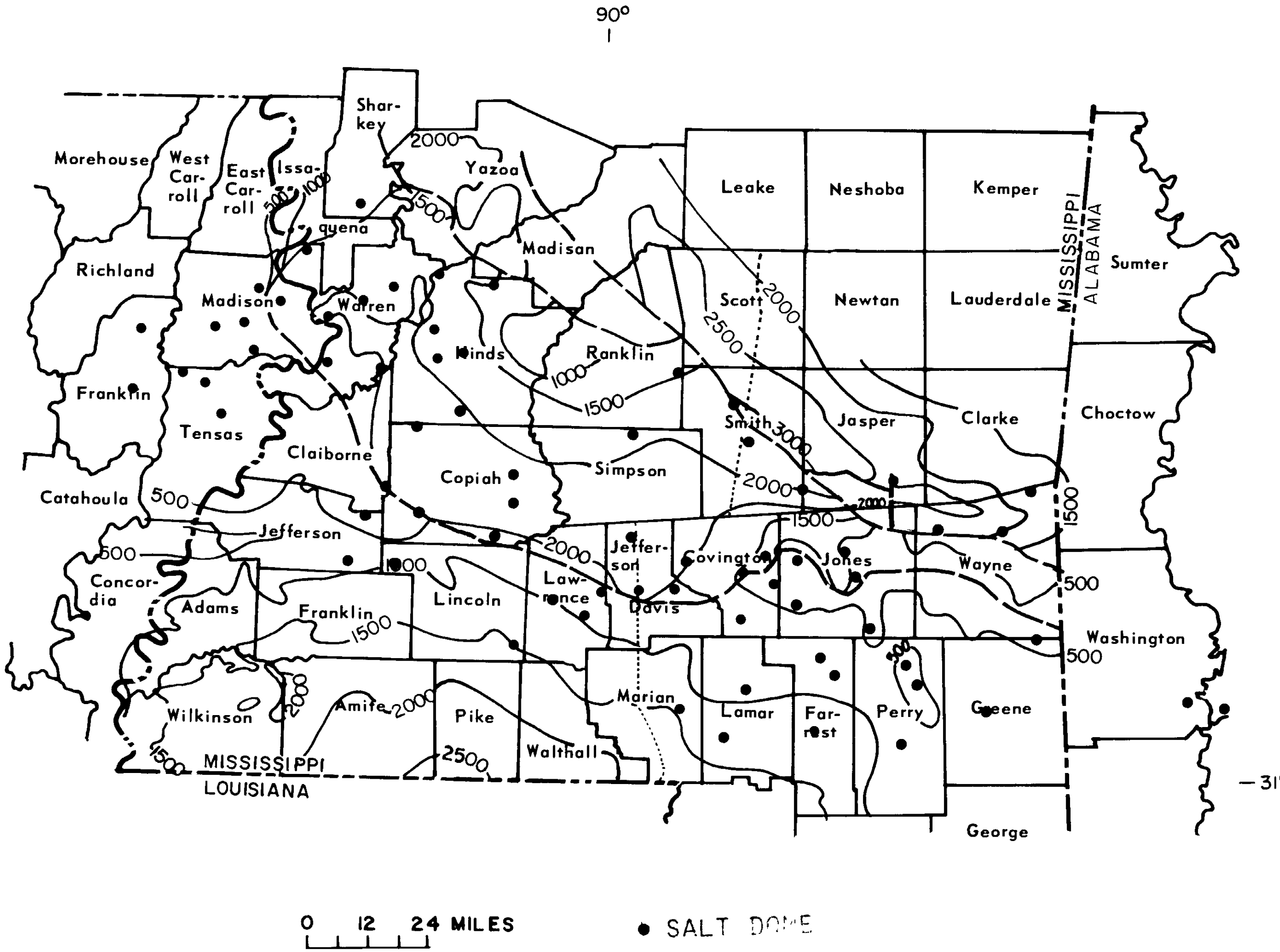


Figure 11.--Contour map showing base of fresh ground water, in feet below sea level, in the Mississippi salt-dome basin. Long-dashed lines show approximate trace of discontinuities in contoured surface, short-dashed lines show location of geohydrologic sections of figures 12 and 13. Modified from Newcome (1965, 1967); Lang (1972); Shows and others (1966); Callahan and others (1964); Newcome and Thomson (1970); and Taylor and others (1968). Contour interval 500 feet.

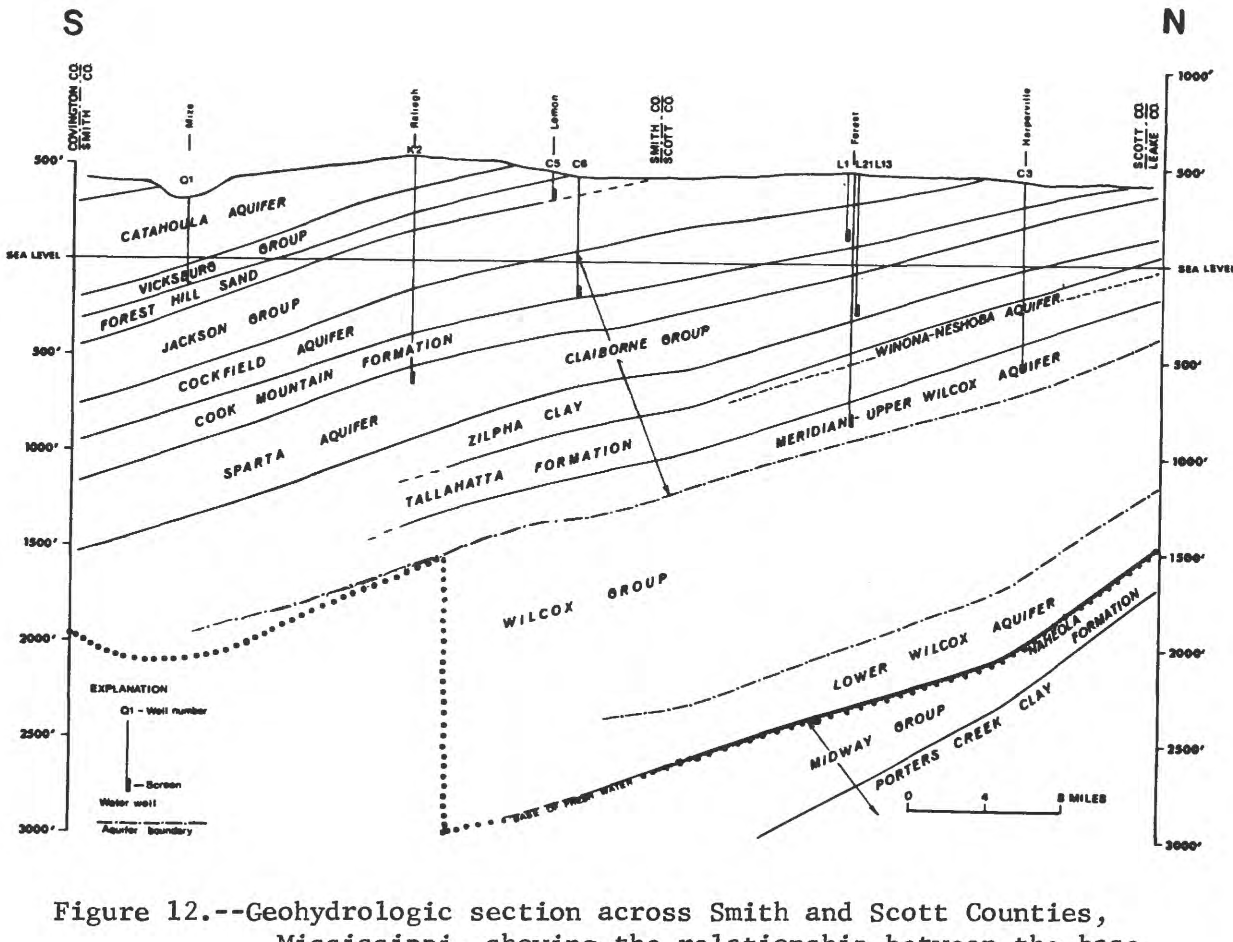


Figure 12.--Geohydrologic section across Smith and Scott Counties, Mississippi, showing the relationship between the base of the fresh water and the coastward-dipping aquifers; line of section shown on figure 11. Modified from Boswell and others (1970).

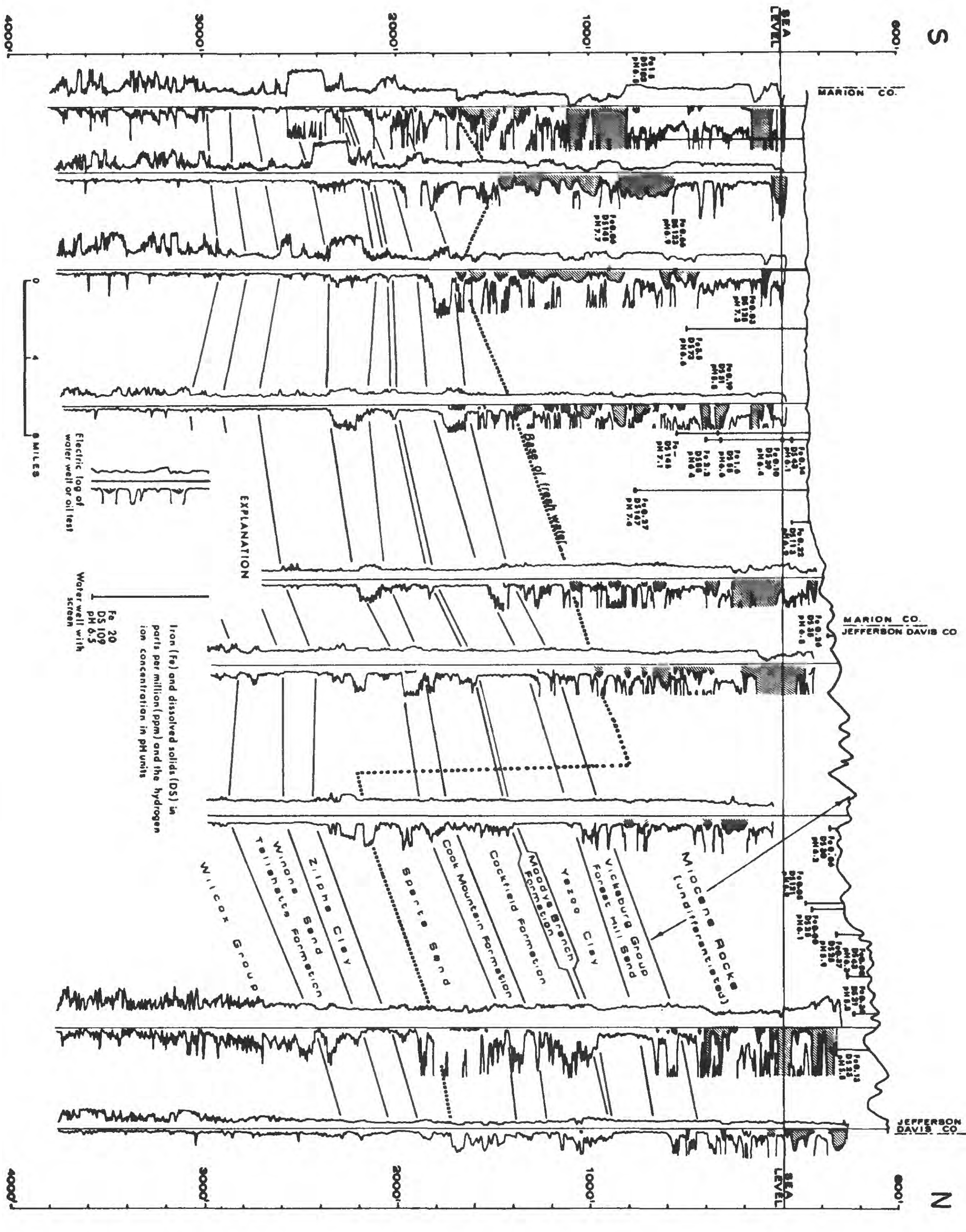


Figure 13.--Geohydrologic section across Marion and Jefferson Davis Counties, Mississippi, showing relationship between base of fresh water and coastward-dipping aquifers; line of section shown on figure 11. From Taylor and others (1968).

basin. The possibility exists that the depth to the tops of the salt diapirs is in part determined by movement of fresh ground water.

The upper parts of the two shallowest domes (Lampton, 1,305 feet, and Tatum, 1,460 feet) penetrate upward through the base of the fresh-water-aquifer system. Lampton dome appears to extend about 350 feet above the regional base of fresh water. Tatum dome extends about 300 feet above the regional base of fresh water, and approximately 800 feet above a local depression in the base of the fresh-water system that is related to the rim syncline. The direction and rate of movement of fresh water in the strata into which the upper parts of these domes penetrate is likely to be complicated on a local scale (1) by variable distribution of channel sands, (2) by variation in composite thickness of sand interbeds, (3) by structural disturbance related to diapirism (including the rim syncline), and (4) by pumping. Some of these factors have been evaluated in the Tatum dome area and are described in the appendix.

EAST TEXAS-SOUTH LOUISIANA SALT-DOME BASIN

There are 141 reported onshore domes in the east Texas-south Louisiana salt-dome basin of which only six are unrejected on the basis of the depth and usage factors that we have applied (tables 1 and 2). All six of the unrejected domes are in the western part of the basin west and southwest of the Trinity River-Galveston Bay area (fig. 14). The following summary only pertains to the Texas part of the east Texas-south Louisiana salt-dome basin--that part where the six unrejected domes occur, and subsequent use of the term "basin" refers only to that western part of the entire basin.

Depth to salt in the six unrejected domes ranges from 450 feet for Hawkinsville to 1,200 feet for Davis Hill. Thickness of caprock ranges from 275 feet for Gulf and as much as 910 feet for Hockley. Data on the six unrejected domes are presented in table 4 and in the appendix. Of the six domes, most is known about Hockley, which has been the site of salt mining and petroleum production.

Physiography

The land surface is nearly featureless and rises gently from sea level to an altitude of about 200 feet some 80 miles inland. Near the coast much of this surface is depositional on Pleistocene and Holocene formations, but it becomes progressively more eroded inland. The principal inland relief is caused by small streams that have carved youthful valleys. Most of these streams flow to the Gulf but some are tributary to the Brazos and Trinity Rivers, which flow across the basin in broad shallow valleys and deposit their sediment load in actively growing deltas. Extensive marshy areas occur in the bottom land of some of the major drainages. The coast is characterized by a system of barrier islands that protect numerous indentations and bays some of which have areas of several hundred square miles. Some of the bays are only a few feet deep and extensive marshy areas and tidal flats exist adjacent to and between them. The Colorado, Brazos, and Trinity Rivers are actively infilling the areas behind the barrier bars with deltaic sediments, and thus are producing additional marshy areas. Three of the unrejected domes (Gulf, Hawkinsville, and Hoskins Mound) are located in this coastal area (fig. 14).

Several of the salt domes are expressed at the surface by hills or mounds that rise several tens to more than 100 feet above the flat coastal plain. Examples are Davis Hill, Hoskins Mound, High Island, Barbers Hill, and Damon Mound.

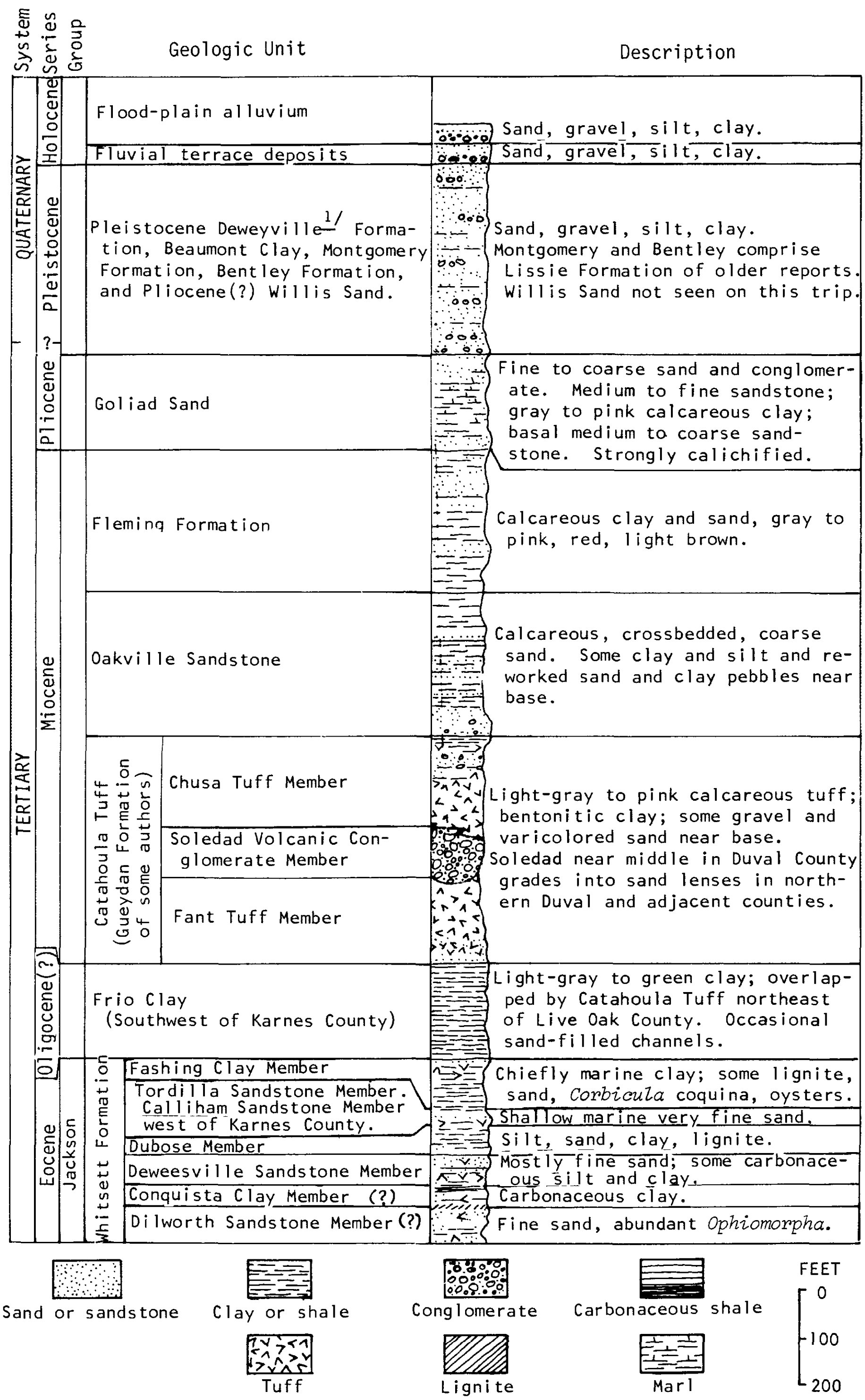
Geology

The east Texas-south Louisiana salt-dome basin, including its offshore portion in the Gulf of Mexico, embraces the active northern part of the Gulf Coast geosyncline where south- to southeast-flowing rivers are depositing huge quantities of sediment in deltas along the coast landward of the geosynclinal axis (not shown on figure 1). In its simplest sense this sedimentary process has been active since Cretaceous time, and the axis of principal sedimentation has shifted southward some 300 miles to its present position since then.

A representative stratigraphic section of the basin as we have outlined it (fig. 1) is shown in figure 15. The exposed strata are mostly continental deposits of fine to coarse sand and conglomerate of Pliocene age (Goliad Sand), and coastal and estuarine deposits of sand, gravel, silt, and clay of Pliocene(?) age (Willis Sand[1/]) and Pleistocene age (Bentley Formation, Montgomery Formation, Beaumont Clay, and Deweyville Formation in ascending order). The inland protrusion northwest of Houston includes exposures of rocks as old as the Jackson Group of Eocene age. Near the coast the cumulative thickness of Pliocene and Pliocene(?) strata is about 900 feet and of Pleistocene strata about 3,000 feet. All strata wedge out landward. The upper parts of the three domes located along the coast (Gulf, Hawkinsville, Hoskins Mound) are in the unconsolidated clay, silt, sand, and gravel of Pleistocene age, whereas the two inland domes, Hockley and Davis Hill, have their upper parts in clay and sand of the Miocene Fleming Formation and Oligocene(?) Frio Clay, respectively.

Normal faults that parallel the coast are related to the geosynclinal subsidence. They displace only the subsurface strata and generally have no surface expression. Faults related to salt domes are known but generally have little or no surface expression. It is possible, however, that the surface fractures resulting from subsidence related to ground water withdrawal in the Houston area may be associated

1/ Although heretofore considered Pliocene(?) in age, the Willis Sand is now generally considered Pleistocene, as in recent maps of the Geologic Atlas of Texas, Houston Sheet (Texas University, Bureau of Economic Geology, 1968).



1/Names used are not necessarily in conformity with U.S.G.S. standards.

Figure 15.--Schematic generalized stratigraphic section pertaining to the western part of the east Texas-south Louisiana salt-dome basin. From Eargle and others (1971, fig. 2).

with adjustments on the buried faults. Sheets (1971) has emphasized the potential hazards of surface fracturing in the Houston area. He recognizes that subsidence related to fluid withdrawal may trigger or accelerate surface movement above some of the buried faults, but he suggests that there is no relation between the location, age, or trend of those faults and the subsidence. He suggests that active surface fracturing in the Houston area is commonly the surface expression of larger buried faults that either belong to the regional system that parallels the coast or to systems related to salt domes.

Hydrology

The east Texas-south Louisiana salt-dome basin area has a moist subhumid climate with eastward-increasing mean annual rainfall ranging from 40 inches along the western edge of Matagorda County, west of Gulf dome, to about 50 inches in the vicinity of a line connecting Davis Hill dome with the eastern part of Galveston Bay (fig. 14). The highest monthly precipitation is during the warmer months between May and September when the precipitation is mostly from thunderstorms. Tropical storms also occasionally sweep in from the Gulf during those months and drop as much as 30 inches of rain in 24 hours. Flood hazards from these storms are severe. Higher water levels in poorly drained marshy areas along major stream courses and behind the barrier bars can persist for long periods following the storms. These areas would have to be avoided in locating surface facilities for a repository site. At several of the domes surface facilities could be located on the low hills or mounds and thereby reduce or eliminate hazards from flooding at the site although access to the site could be adversely affected by the flood conditions.

Urban, industrial, and agricultural development in the basin have stimulated several comprehensive investigations of the ground-water hydrology. Ground-water-resources reports are available for Matagorda (Hammond, 1969), Harris (Winslow and others, 1957), Liberty (Anders and others, 1968), and Galveston (Petitt and Winslow, 1957) Counties and a report is in progress for Fort Bend County (J. B. Wesselman, written commun., 1972). These reports contain data on the quantity and quality of usable water, water usage, and characterization of aquifers including their lithology, hydraulic properties, and potential for future development. Five of the six unrejected salt domes are located in the counties covered by these reports; the exception is Hoskins Mound in Brazoria County. Two regional hydrologic reconnaissance reports that include the basin area are also available (Wood and others, 1963; U.S. Study Commission, 1962).

The oldest strata that yield fresh ground water in the vicinity of the six unrejected domes are sands in the Miocene Fleming Formation in parts of Harris County. These sands are more deeply buried coastward where they are not flushed. The Pliocene Goliad Sand and overlying Pliocene(?) (or Pleistocene) Willis Sand are major fresh-water aquifers throughout a broad band 50-90 miles wide that crosses the basin parallel to the coast. In the northwestern two-thirds of the broad band the base of the Goliad approximately coincides with the base of fresh ground water which dips coastward. In the southeastern third of the band, the base of fresh water rises through the aquifers marking the limit to which they are flushed. They do not contain fresh water along the coast (Wood and others, 1963). The resulting configuration resembles an irregular fresh-water trough that parallels the coast with an axis 40-60 miles inland and along which fresh to slightly saline water occurs to depths ranging from 1,600 to 3,000 feet. Saratoga, South Liberty, and Pierce Junction domes lie approximately along this axis, whereas Long Point is located on the south flank of the trough and Davis Hill on the north flank (fig. 14). Prior to heavy pumping from wells in the fresh-water trough the movement of ground water was coastward down the dip of the aquifers and discharge was upward through the confining clay beds of low permeability in the southeastern third of the trough (Winslow and others, 1957). A state of dynamic equilibrium probably existed between fresh and saline ground water in the discharge area. That is, the landward-dipping fresh-saline water interface (actually a diffuse zone) probably had a stationary location. Heavy pumping in the Houston area (Winslow and others, 1957) and along the northeasterly extension of the trough in southwestern Louisiana (Harder and others, 1967) has caused acceleration of coastward ground-water movement in the northwest flank of the trough and reversals of movement in the southeast flank of the trough, the discharge area. This condition has created concern for possible landward saline-water encroachment and also for upward movement into the lower parts of fresh-water aquifers along the axis of the trough. Hockley dome is situated in the area of accelerated ground-water movement toward the coast. Fresh water is apparently absent over Hockley dome although it occurs to depths of about 2,000 feet surrounding the dome. Fresh and slightly saline water occurs over Davis Hill dome but at somewhat shallower depths than in the surrounding area where the interface with saline water occurs at about 1,700 feet. At Long Point dome the depth to saline water decreases from about 1,800 feet adjacent to the dome to less than 300 feet on top of the dome.

Other important aquifers in the basin are sands in the several Pleistocene formations noted above and in Holocene deposits that occur along the coast and in the delta area of the Colorado and Brazos Rivers (Hammond, 1969; Wood and others, 1963). The area in which the Pleistocene strata contain fresh to slightly saline water generally extends inland about 60 miles, overlapping the area in which Pliocene and Pliocene(?) strata contain fresh water. In general, fresh to slightly saline water is restricted to depths less than 1,000 feet in that area, and the depths decrease toward the coast where locally no fresh water is available. In the area of Gulf, Hawkinsville, and Hoskins Mound domes fresh water is found to depths of about 600 feet and slightly saline water to about 900 feet. Fresh and slightly saline water occur over these domes but at lesser depths.

In an unpublished report on ground-water resources of Fort Bend County, Texas, J. B. Wesselman (written commun., 1972) noted that the quality of ground water is adversely affected in the vicinity of salt domes. Chloride concentrations of more than 250 mg/l (milligrams per liter) were found in 14 of 226 wells in the county and 10 of them are near salt domes. Plumes of anomalously high total dissolved solids in intermediate sands of one aquifer extend outward from some domes (including Long Point) for several miles and are believed by Wesselman to be related to the domes. Winslow, Doyel, and Wood (1957) and Wesselman believe that the normal movement of ground water is upward around the domes, but Wesselman notes (written commun., 1972) that changed pressure relationships caused by heavy pumping near some domes may have reversed the movement. Baker (1964) reported increases with time in chloride contents of wells near three salt domes in Hardin County, Texas, about 60 miles northeast of Houston. The top of the salt in all three domes (Batson, Saratoga, and Sour Lake) is above the regionalized base of the fresh-water-aquifer system. The rates of increase range from 1.25 ppm (parts per million) per year to 77.6 ppm per year. These increases may be the result of lack of adequate circulation, lack of adequate protection of fresh water from oil-field operations, contamination from underlying salt-water sands, or contamination from the nearby salt domes.

Oil-field brine is widely disposed of by injecting it into deep saline aquifers in the basin. The potential for disposing of mined salt in the form of a brine at any of the six unrejected domes is good.

SOUTH TEXAS SALT-DOME BASIN

The south Texas salt-dome basin is a triangular area (fig. 1) encompassing the lower part of the Rio Grande embayment, a southeastward-plunging syncline tributary to the northeastward-trending Gulf Coast geosyncline. The salt-dome basin includes only six domes in which the drill has penetrated salt (fig. 16), although several additional domal structures in which salt has not yet been penetrated are known in the region. The basin includes Pescadito dome, believed to be the largest in the United States; it is the farthest west dome of the Gulf region and also one of the deepest known salt domes--more than 14,000 feet. The salt-dome basin also contains, at its southeastern end, the only structure in Texas in which gypsum caprock has been found at the surface--Gyp Hill dome. Domes of the basin, therefore, exhibit some of the qualities of both the interior and the coastal domes, as described in other sections of this report. Data on Gyp Hill dome are given in table 4 and the appendix.

Physiography

The surface of the south Texas salt-dome basin consists of two types of plains, a nearly flat depositional surface on late Tertiary and Quaternary coastal and fluviatile deposits, and an inland erosional surface, of somewhat more rolling submature topography developed on Tertiary formations. Between the two is the high west-facing Bordas Escarpment, the western limit and the highest elevations of the depositional surface.

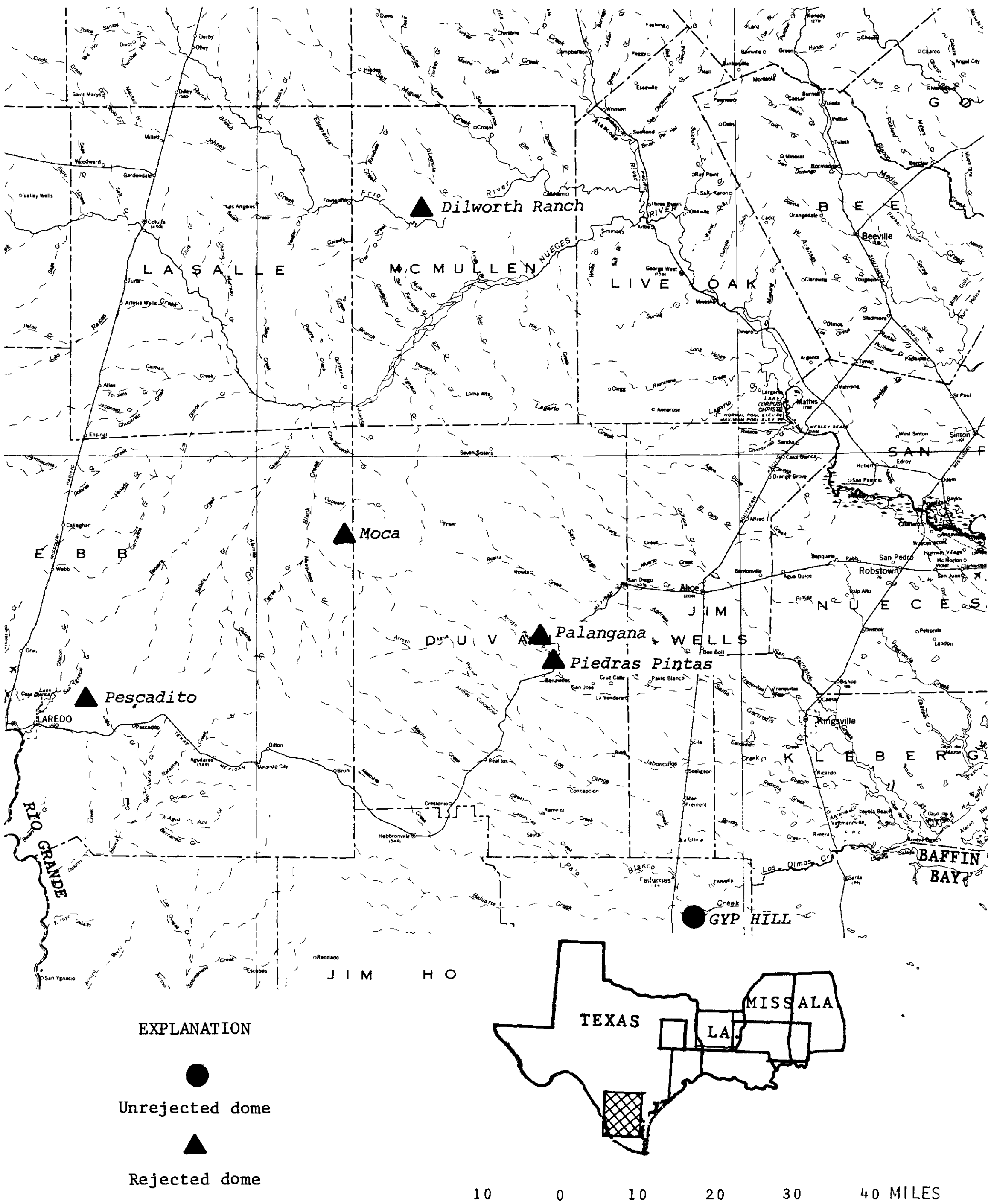


Figure 16.--Unrejected and rejected domes in south Texas salt-dome basin. (Base map, USGS 1:1,000,000; Texas.)

The lower eastern section of the depositional surface is a nearly flat terrace on Pleistocene deposits some 50 miles wide, sloping gently to the coast from about 100 feet above sea level. On the west it joins at a low angle the Bordas plain which is underlain by the Pliocene Goliad Sand. The Bordas plain is more steeply inclined than the coastal terrace and rises westward to an elevation of more than 900 feet along the crest of the Bordas Escarpment, about 100 miles from the Gulf. Stream valleys tributary to the bays and lagoons of the Gulf carry little water and trend southeastward across the depositional surface.

The erosional surface is 200-600 feet above sea level and its drainage is roughly at right angles to that of the Bordas plain--to the Nueces River to the north, and to the Rio Grande River to the south.

The deltas of the Nueces and the Rio Grande form part of the coastal terraces that characterize the region. The delta of the Nueces lies chiefly south of that river's present course and is made up primarily of sands and silts that form the terraces west of the Corpus Christi and Baffin Bays (figs. 1 and 16). The delta of the Rio Grande lies more on the United States, or northern, side of that river, and makes up an irrigated fertile plain of orchards and garden land known as the Rio Grande Valley. North of the Rio Grande River Delta, covering the coastal terraces inland from the focus of the parabolic Gulf Coast, is an extensive region of sand dunes and intervening swales known as the Sand Sheet. The general trend of the dunes, now generally fixed with a growth of brush and grasses, is west-northwest, and extends from the Gulf to at least 70 miles inland. Beyond this the depositional as well as the erosional plains are covered with aeolian silts to at least 200 miles inland. Some deposits are so thick as to resemble the loess in the Mississippi and Missouri River region.

Gyp Hill, the only salt dome not rejected at this time for storage of radioactive material, lies at the northern edge of the Sand Sheet, and is separated from the lagoonal area of the Gulf by very sparsely settled semiarid pasture lands of the King Ranch. In the area of the Sand Sheet, aeolian deposits cover the bedrock and choke most drainage lines. Very little trace of some previously carved valleys remains.

The physiography and soils as well as the bedrock of the south Texas region offer distinct evidence of a climate that has become hotter and drier since the Eocene. During the Pleistocene and Holocene, however, several cooler and more humid interludes have occurred. The most conspicuous feature of Pleistocene climatic fluctuations is the strong caliche cap that has developed during an arid climate in the near-surface few feet of the calcareous sands and silts of bedrock, terraces, and alluvium. The most recent arid climate, as shown by C^{14} dating of the caliche, occurred some 20,000 years ago; whether earlier periods of intensely arid climates with corresponding caliche development occurred is not definitely known. In all areas except perhaps the southernmost part of the region the carbonate caliche cap is being gradually destroyed by solution thus indicating a recent shift to a less arid and cooler climate. The climate of the region is now semiarid, and soils characteristic of this climatic type are being developed in the caliche and replacing it. Sink holes and an incipient karstlike topography are also forming in the caliche.

Geology

The outcropping rocks of the south Texas salt-dome basin range from middle Eocene in the western part to Holocene in the east. The stratigraphic section for the east Texas-south Louisiana salt-dome basin (fig. 15) is generally applicable to the south Texas basin and serves as a reference for the discussion that follows. The larger structural feature that includes the salt-dome basin is the Rio Grande syncline, and although only relatively few salt diapirs have penetrated the overlying rocks, salt is believed to extend beneath a much larger area than that encompassing the area of the domes. Most of the known domal structures produce petroleum.

The Cretaceous and Paleocene formations that crop out in the Rio Grande syncline are marine; they are succeeded upward by alternating marine and nonmarine beds reflecting tectonic movements involving the Gulf Coast geosyncline. We believe the geosyncline sank periodically, causing transgression of the coastline landward, but continuing sedimentation pushed the shoreline seaward again and the sediments became brackish to fresh water during the latter part of each cycle.

Sediments of Tertiary and Quaternary age thin and change their facies outward from the center of the Rio Grande basin, as they do shoreward from the Gulf Coast geosyncline. Wedgeshaped as they are, the units therefore range considerably in thickness and lithologic characteristics, so that both thickness and lithologic data given are averages only for the areas under consideration for the areal limits of the salt-dome basin of this report.

Formations that are associated with piercement domes in the south Texas region are, from oldest (Eocene) upward: Laredo Formation, chiefly fossiliferous sands interbedded with chocolate-colored fissile clay, 600-700 feet thick; the Yegua Formation, chiefly clay with minor beds of sandstone and layers rich in oyster shells, 600-800 feet thick; the Jackson Group (upper Eocene), about 1,200 feet thick, of montmorillonitic clay, volcanic ash, and sands grading upward into Frio Clay (Oligocene?) about 300 feet thick; the Miocene formations, Catahoula Tuff, Oakville Sand, and Fleming Formation, about 1,500 feet thick; the Pliocene Goliad Sand and Pleistocene coastal terraces, undivided--sands and clays--1,500-2,000 feet thick.

The center of the Rio Grande syncline, the large feature of which the south Texas salt-dome basin is a part, extends southeast from the vicinity of Cretaceous outcrops of southwestern Texas to the coast south of Corpus Christi Bay. In this region, therefore, the axis of the basin lies north of the present course of the Rio Grande, and its trend is parallel to and related more to that of the Nueces River than to the Rio Grande.

Faulting accompanied basin subsidence as is shown on the tectonic map of the northern Gulf Coast region (fig. 1). Principal faults nearly parallel the strike of the formations and are generally downthrown to the coast. They are accompanied, however, by compensatory upthrown-to-the-coast faults, forming grabens. The principal faults lie along the landward margin of the salt-dome basin, and movement of salt in the deep subsurface is believed to have assisted in, if not to have been the principal cause of, the faulting.

Two principal fault zones traverse the south Texas basin and trend much farther northeastward toward the east Texas-south Louisiana coastal basin: the Mirando-Provident City fault zone and the Sam Fordyce-Vanderbilt fault zone (fig. 1). Movement along the faults was taking place during the time the sediments were being deposited. Thus, the beds are spectacularly thicker on the downdip (gulfward) side of each fault.

Hydrology

Most of the statements that follow were abstracted from a report on the ground-water resources of Brooks County, Texas (Myers and Dale, 1967), and from a manuscript on the ground-water resources of Kleberg, Kenedy, and southern Jim Wells Counties, Texas (G. Shafer and E. T. Baker, written commun., 1972). The statements pertain mostly to the southeast part of the salt-dome basin where the only unrejected dome, Gyp Hill, is located. The climate is semiarid with average annual precipitation of about 23 inches and average monthly temperatures ranging from 58 during January to 86 during July and August. Sandy soils blanket the area and facilitate infiltration of rainwater, but extensive blankets of caliche hold much of the infiltrated water near the surface so that the water evaporates. The area is drained by small intermittent low-gradient streams that flow east and southeast in wide nearly flat valleys. The area is almost wholly dependent on its ground water for municipal and agricultural water supplies.

Tropical storms are known to strike the area and deposit in a few days a quantity of rainfall equal to or exceeding that of the mean annual precipitation. Torrential rainfall of record-breaking magnitude from hurricane Beulah in October 1967 produced flooding of a 3,000-square-mile area in south Texas (Baker, 1971). The Gyp Hill area received about 20 inches of rainfall much of which was ponded in numerous shallow depressions. Topographically high areas such as Gyp Hill were not inundated but highways were blocked for several days, ranching and oil-field operations were hampered for at least 6 months, and the hydrologic system had approached but had not returned to pre-Beulah conditions 2 years after the hurricane (Baker, 1971).

Aquifers are recharged by rainfall in outcrop areas to the west, and ground water moves eastward under artesian conditions at rates varying from tens of feet per year during periods of low rainfall to hundreds of feet per year during periods of high rainfall when the piezometric surface rises in the recharge area resulting in a steepening of the hydraulic gradient and an increase of hydraulic pressure. Usable ground water is found in several aquifers (Myers and Dale, 1967), but the Pliocene Goliad Sand is the principal aquifer because it is the most permeable and therefore the most completely flushed of the fresh-water-bearing strata. In some areas saline or slightly saline water is found in aquifers above Goliad beds that bear fresh water of good quality. Adequate supplies of undeveloped fresh ground water are available from the Goliad Sand in the vicinity of the Gyp Hill salt dome (fig. 17). The depths to which this water is found are outlined in the appendix (p. 243).

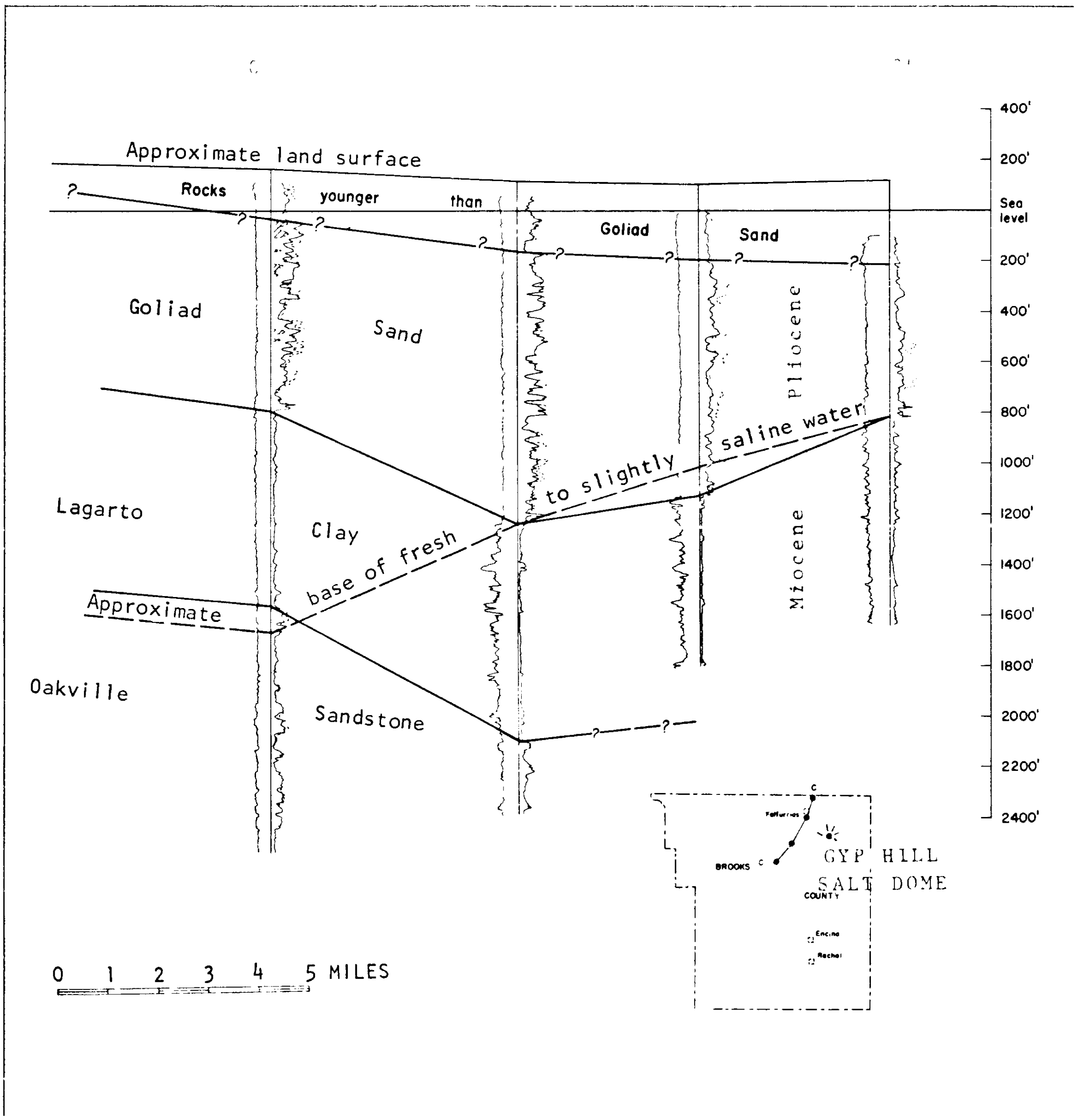


Figure 17.--Cross section C-C' through part of the south Texas region in the vicinity of Gyp Hill dome showing age and characteristics of aquifers. Modified from Myers and Dale (1967, fig. 17).

SUMMARY

Of the 263 known or suspected onshore salt domes in the Gulf Coast region, we believe 36 might prove to be acceptable sites for waste emplacement. These are the domes that are not being used by industry and that have relatively shallow tops--no more than about 2,000 feet of overburden. Favorable factors that all salt domes are assumed to share are the high purity of the salt and its great thickness. Other factors to be considered in assessing a salt dome's suitability for waste emplacement include size, long-range stability, and long-range hydraulic isolation.

In regard to diapirism, salt domes of the interior subprovince appear to be more stable than the domes of the coastal subprovince. We infer from limited geologic and hydrologic data that the diapiric rise of salt domes in the interior subprovince tended to stop in Miocene time, but diapirism is still active in the coastal subprovince. We need much more data on rates of diapirism. Detailed and integrated stratigraphic, microseismic, and leveling studies at carefully chosen locations might provide the needed data.

The internal structure of interior domes tends to be less complex than that of coastal domes. This results from the greater magnitude of the diapiric rise of the coastal domes. Some coastal domes contain large lenticular inclusions of wallrock that have been incorporated into the salt mass, possibly as a result of a complex dome-growth history. The chances of avoiding complications related to the presence of inclusions that could serve as undesirable hydraulic channelways

and of avoiding structural complexities that could render the salt environment around the mined opening less predictable seem to be better in the interior than in the coastal subprovince.

From the standpoint of noninterference with the petroleum and salt extraction industries and the availability of domes not being used by those industries, the interior subprovince appears to offer considerably more potential at present than the coastal subprovince. Potential complications arising from municipal and industrial use of ground water also seem to be fewer in the interior than in the coastal subprovince.

In spite of the extensive exploration for petroleum along the flanks of salt domes, we found a notable lack of published information on the structural, lithologic, and hydrologic conditions that exist at the sides of salt domes. This deficiency of information precludes reliable evaluation of such factors as amounts and rates of dissolutioning and structural coupling or decoupling of the salt. Because petroleum is commonly impounded in structural traps at the sides of salt domes, we infer that a tight hydraulic and possibly also structural seal generally exists between the salt mass and country rock. The quality of the hydraulic seal should be an important factor in determining whether or not dissolution will occur, especially in domes whose sides extend above the base of an active fresh-water aquifer system. Meager water-quality data around some domes (Tyler in the northeast Texas salt-dome basin and several domes in Fort Bend and Hardin Counties in the east Texas-south Louisiana salt-dome basin) show a contribution of chloride ion to the ground water, suggesting that the hydraulic seal at some domes is incomplete. Other factors being equal, we think such domes as Lampton, Vacherie, or Whitehouse, whose tops are below or near the base of fresh ground water, offer the most promise for waste-emplacement sites.

The supplementary data of the appendix and the selected data of table 4 are listed according to salt-dome basins, but the order in which the basins are presented does not reflect the relative favorability of the various basins for waste emplacement. Within each basin, however, domes are listed in order of decreasing favorability for waste emplacement based on our evaluation of the data presented in the appendix. An important fact to note is that the lack of adequate information on which to base a reliable evaluation was a primary consideration in giving many of the domes their low rankings.

APPENDIX

For convenience of reference the data in the appendix and text are color-coded according to salt-dome basins as follows:

Northeast Texas	blue
North Louisiana	pink
Mississippi	white
South Texas	yellow
East Texas-south Louisiana	green

NORTHEAST TEXAS

SALT-DOME BASIN

Index of salt domes

KEECHI DOME: Anderson County, Texas (figs. 18-20)

DEPTH TO CAPROCK: About 250 feet (Judson and Stamey, 1933, p. 1518). Not reported by Hawkins and Jirik (1966).

DEPTH TO SALT: About 300 feet (Judson and Stamey, 1933); 435 feet (Ebanks, 1965).

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Diameter of structure is 3 1/2 miles. Diameter of salt stock apparently increases with depth. Salt overhang, or ledge, on southeast side, drilled from 2,162 feet to 2,822 feet (660 feet); 79 feet of apparent salt stock drilled from 3,091 feet to 3,170 feet (TD). Sedimentary rocks drilled between overhang and apparent salt stock. Salt core at 500 feet is about 3,000 feet in diameter; at 2,000 feet, about 6,000 feet (Judson and Stamey, 1933), and at 3,000 feet it has a north-south diameter of about 11,900 feet and an east-west diameter of about 8,400 (Ebanks, 1965).

DESCRIPTION OF CAPROCK: Caprock not reported in discovery well nor in tests made in 1916 on southeast side of dome, but is 16-200 feet thick on northwest flank, and thins with depth (fig. 20) (Judson and Stamey, 1933, p. 1518; published log). In a well located on the dome (Navarro Oil Co. No. 2 Greenwood) 250 feet of gypsum and anhydrite caprock is reported (Ebanks, 1965) with salt at 435 feet.

DRILLING HISTORY: Producers Oil Co. 1 Barrett and Greenwood (discovery well) and 4 additional wells on southeast flank drilled in 1916.

KEECHI DOME: Continued

Since then three Navarro Oil Company wells drilled on northwest flank (fig. 20).

NEAREST POPULATION CENTER: Palestine, 6 miles southeast.

POPULATION: 14,500

GEOLOGIC DATA: Taylor Marl (Upper Cretaceous) upthrown about 3,500 feet to outcrop on southeast half of dome, placing Cretaceous rocks on the southeast against Wilcox rocks (Eocene) on the northwest. Dips are steep, as much as 45°, on surface rocks on all sides of dome, but dips are only 2° 1 1/2 miles from the center. Movement of road base on Texas Route 19 has been falsely reported to be result of shifting dome, but movement is in fact due to unstable clays of the Cretaceous (District Superintendent, Texas Highway Department, oral commun., 1972). Structure has a distinct rim syncline.

HYDROLOGIC DATA: Salt Fork of Keechi Creek (flood plain about 1,500 feet wide) crosses dome from northeast to southwest. Aquifers include sands of Wilcox on flanks of dome. Taylor Marl on southeast of dome center; center is reported to be subject to soil creep when wet. Salty patches in creek during summer.

GEOPHYSICAL DATA: No information, but region has been covered by seismic traverses. Texas Company shot area of Bethel dome, 15 miles northwest, resulting in oil production deep below salt overhang.

ECONOMIC DATA: Showings of oil in dome discovery well.

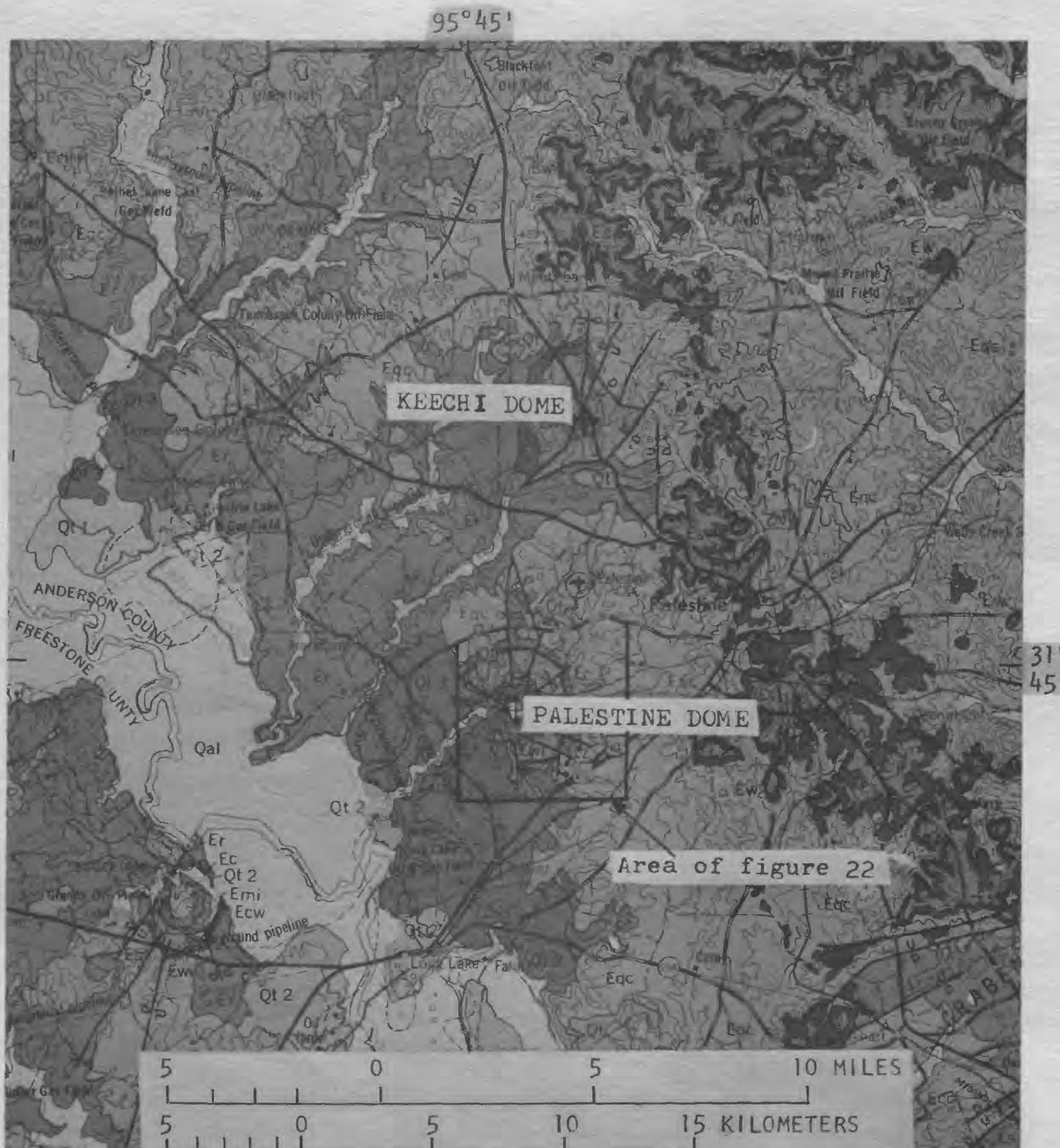


Figure 18.--Geologic map showing location of Palestine and Keechi salt domes, Anderson County, Texas. K, Cretaceous rocks, undivided (in vicinity of salt domes); Emi, Midway Group; Ewi, Wilcox Group, undivided; Ecw, Carrizo Sand and Wilcox Group, undivided; Ec, Carrizo Sand; Er, Reklaw Formation; Eqc, Queen City Sand; Ew, Weches Formation; Es, Sparta Sand; Ecm, Cook Mountain Formation; Qt 1, 2, 3, Fluviatile terrace deposits (in order of increasing age); Qal, Alluvium. From Univ. Texas Bur. Econ. Geology, Geologic Atlas of Texas, Palestine sheet (1967).

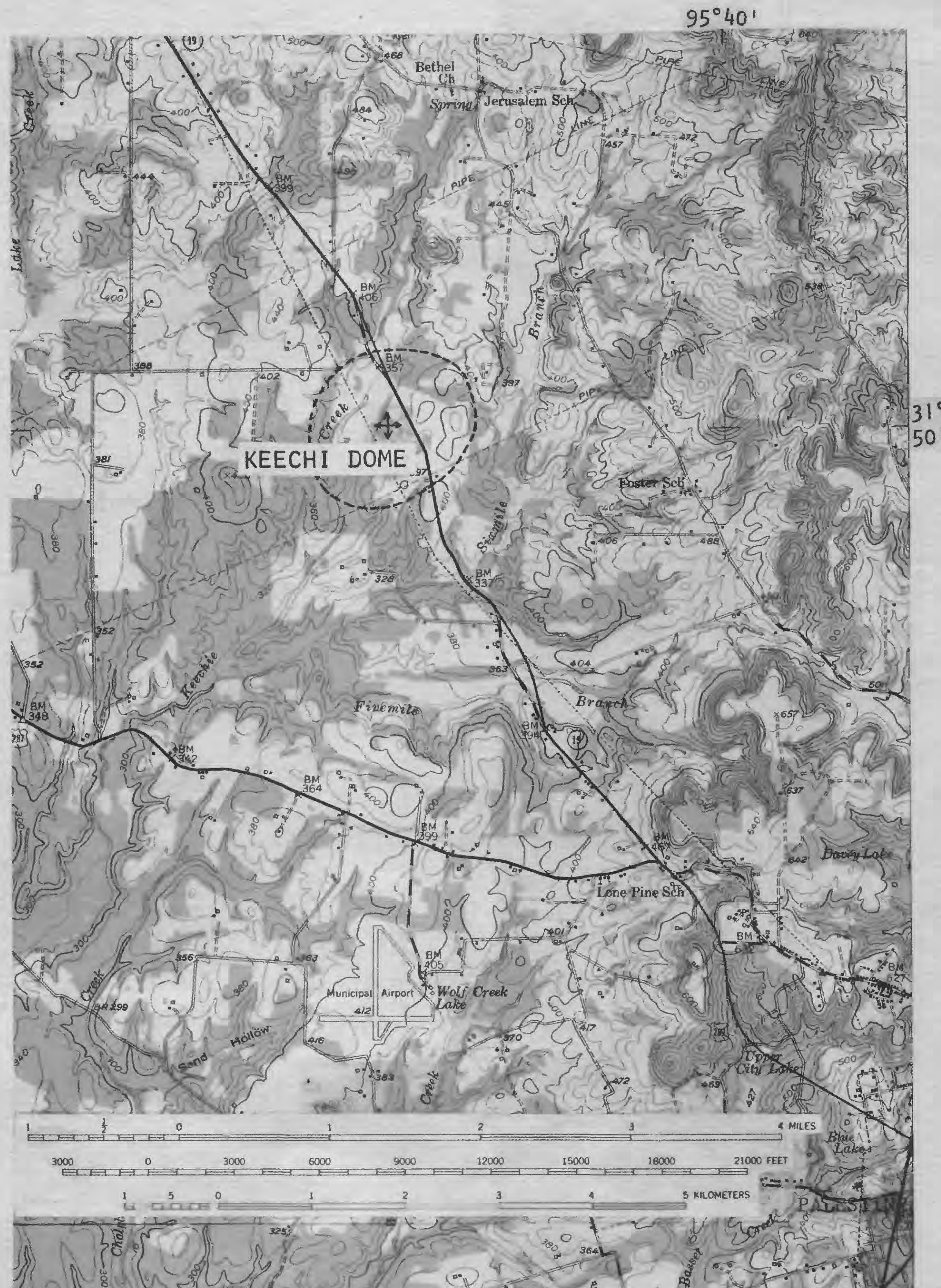


Figure 19.--Topographic map showing location of Keechi dome. Outline of dome from Powers (1926, p. 245). (Base map, USGS, 1:62,500; Palestine, Texas.)

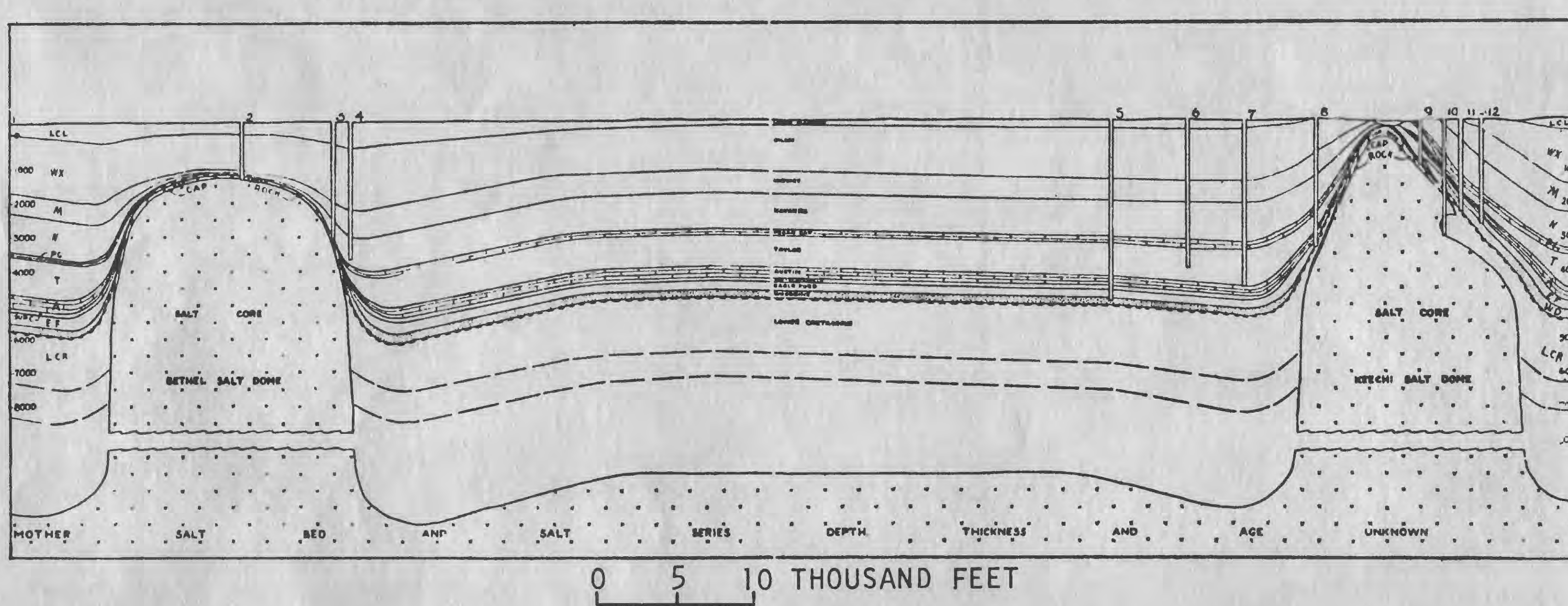


Figure 20.--Geologic cross section from northwest to southeast through Bethel and Keechi salt domes. LCR, Lower Cretaceous; W, Woodbine; EF, Eagle Ford; SUBC, Sub-Clarksville; A, Austin; T, Taylor; PG, Pecan Gap; N, Navarro; M, Midway; WX, Wilcox; LCL, lower Claiborne. Age and thickness of beds below Lower Cretaceous and above salt series unknown. Drill hole 5, Roeser 2 Auld; 6, Roeser 1 Via; 7, Cosden 1 Douglas; 8, Cosden 1 Adams; 9, Navarro 1 Greenwood; 10, Producers 1 Barrett and Greenwood; 11, Producers 3 Barrett and Greenwood; 12, Producers 5 Barrett and Greenwood. (From Wendlandt and Knebel, 1929, fig. 5.)

PALESTINE DOME: Anderson County, Texas (figs. 18, 21-24)

DEPTH TO CAPROCK: 120 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

DEPTH TO SALT: 122 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None; salt mine and salt wells abandoned.

DESCRIPTION OF CAPROCK: Hard limestone, 9 feet thick on western shore of Duggeys Lake, increasing to 32 feet thick in wells farthest away. Caprock limestone elsewhere is reported to be of varying thickness beneath 85 feet of gray to yellow water-bearing sand and 40 feet of dark-gray to black sandy clay.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Little is known. Well on west side of dome penetrated 500 feet of jumbled rock and shale without reaching salt; another on northwest side bottomed at 360 feet without reaching salt.

DRILLING HISTORY: Salt was produced from brine wells during Civil War. Well casings were set on rock and deepened through sand (anhydrite?) until salt was reached at 140 feet. When salt was dissolved, caprock and overlying formations caved in, forming large sinkholes (Hopkins, 1918). One well drilled at Little Saline, three-fourths of a mile northeast of the dome, reached salt at 200-225 feet. The well farthest northeast reached salt at 560 feet. Several wells were drilled into shallow rock salt about the year 1900. About 120 tons of salt per day were mined in the early 1900's, enough to cause as much as 2 inches of subsidence over an area of half a square mile. Texas 1 Wright shows thinning of Cretaceous and Tertiary beds over the dome, and several unconformities. A well drilled in 1923 south of the dome did not reach salt at 700 feet (TD). Wells a few hundred feet north reached salt at "normal depth." Salt was 400 feet thick in two wells drilled through a salt overhang, but the wells did not penetrate deeper salt. One well produced salt for 20 years; others, where caprock is thin, have caved in. Salt production in 1924 was from two wells at south end of lake. Well on west side of lake reached salt at 406 feet. A well north of this had no caprock.

NEAREST POPULATION CENTER: Palestine, 4.7 miles east-northeast.

POPULATION: 14,500

GEOLOGIC DATA: Bedding surrounding dome shows steep dips away from dome and radial and circumferential faults. Eight radial faults form triangular wedges pointing toward dome. Throw of faults decreases with distance from dome, and can't be recognized 2 miles away. Area affected by doming is 4 miles in diameter. Thinning of strata from Upper Cretaceous to present indicates movement from Cretaceous to Tertiary time. Cretaceous beds have risen as much as 5,500 feet. Displacement of a key bed near the base of the Eocene Reklaw Formation (Claiborne Group) shows Davey fault to have risen 1,400 feet near center of dome, but only 100 feet 1 1/2 miles from center of dome. Pleistocene terraces not affected by doming. Dips measure 45°-75°, but drilling away from dome shows a shoulder with less steep dips from 3,000 feet to 4,500 feet below surface. Total section affected by thrusting was about 3,200 feet of Upper Cretaceous, and 1,500 feet of Eocene beds, all of which have been removed from the center of the dome.

HYDROLOGIC DATA: Duggeys Lake, now called Old Salt Works Lake, is said to have a maximum depth of 4 feet, averages half a mile in length and three-eighths of a mile wide, is irregular in shape, and contains salt water. Elevation of the lake is 244 feet, of hills near lake, 340-350 feet. Wolf Creek, draining the domal area at about 240 feet above sea level, joins the Trinity River 5 miles downstream at about 200 feet above sea level. Maximum flood stage on the Trinity River, near Oakwood (about 10 miles southwest of dome), was 53 feet in May 1890; a stage of 52.2 feet was reached in June 1908, and 51.6 feet in April 1942. The gage is 175 feet above sea level. Thus, the highest stage in 80 years would not have flooded the dome.

Near the dome in the Wilcox Group (lower Eocene) and in the Woodbine Sand (Upper Cretaceous) are several sands capable of receiving brine injection. The base of the fresh water in the Wilcox is 1,400 feet below the surface north and west of the dome; 1,000 feet east of the dome, and 680 feet, south of the dome, where slightly saline water extends to 1,700 feet below the surface.

PALESTINE DOME: Continued

ECONOMIC DATA: Long Lake oil field extends to within 2 miles of the southwest flank of the dome. Production from that field to 1949 was more than 27 million barrels. Salt water produced from this field is injected into the Woodbine Sand below the oil-water contact. Through 1948, more than 1,908,000 barrels of water had been produced.

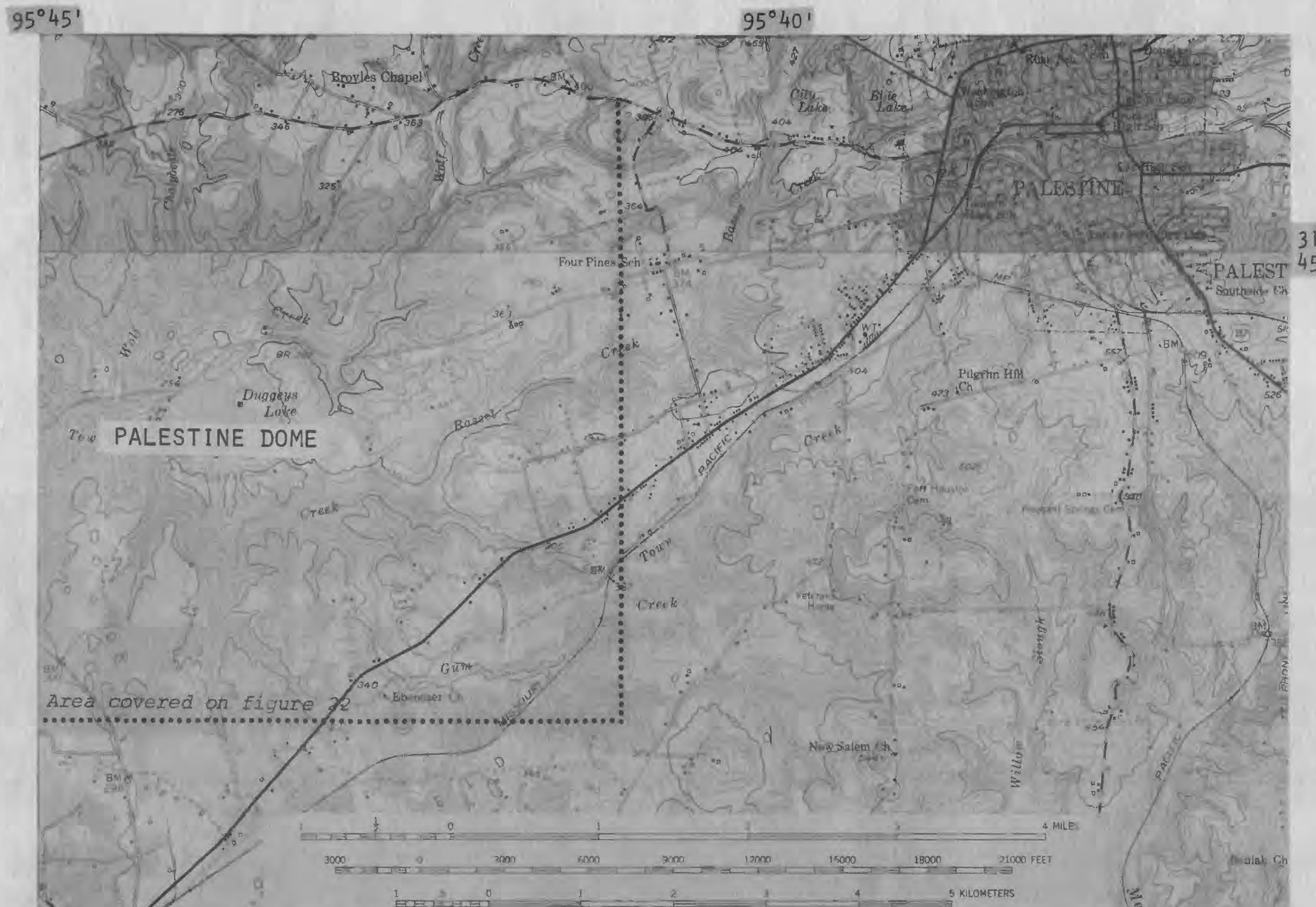


Figure 21.--Topographic map showing Palestine salt-dome area. (Base map, USGS, 1:62,500; P and Elkhart, Texas.)

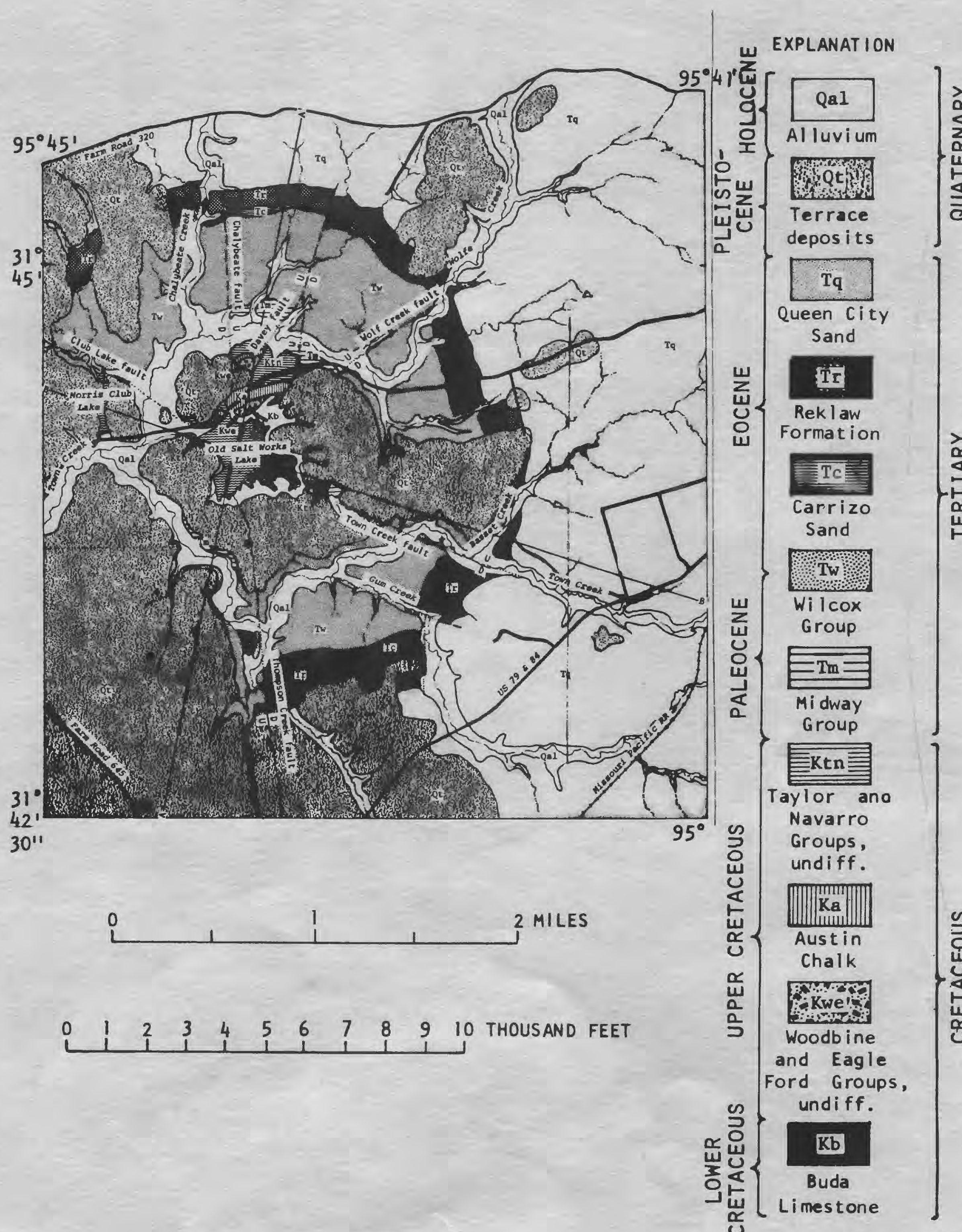


Figure 22.--Geologic map showing Palestine dome area. From Hightower (1958).

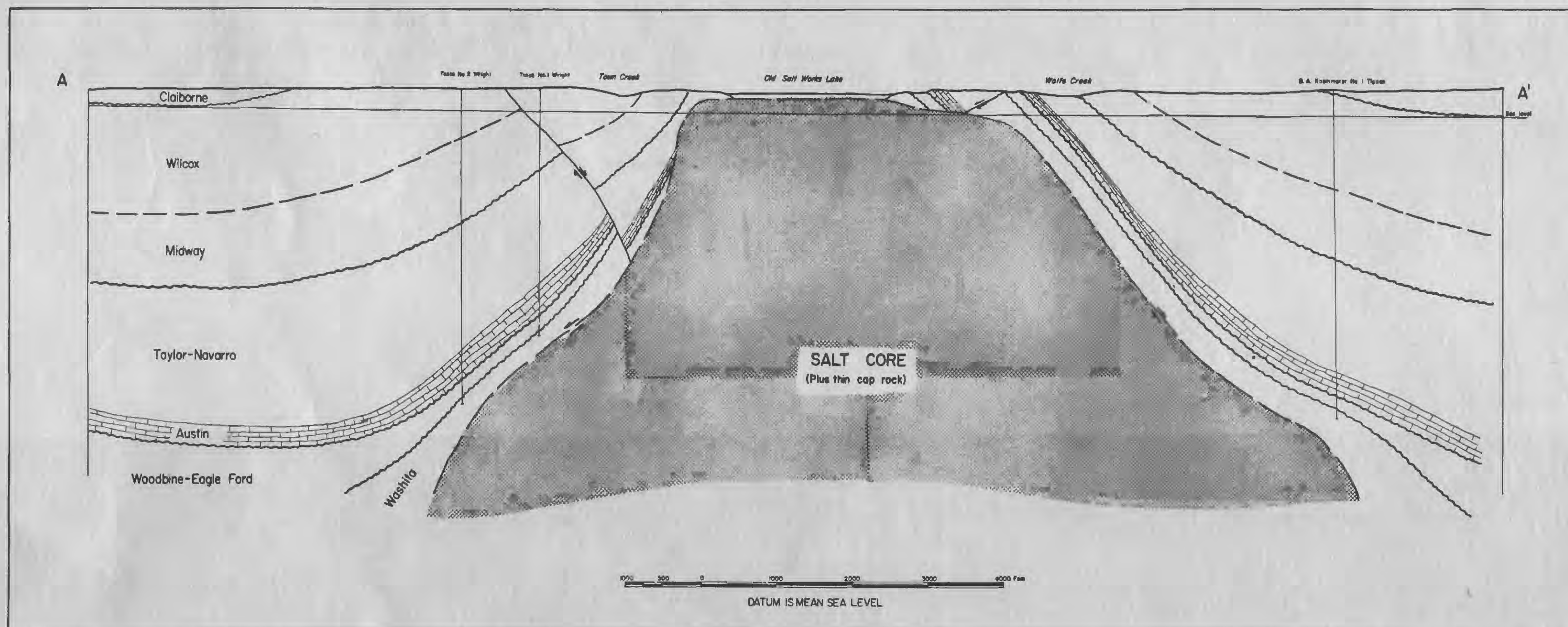


Figure 23.--Cross section A-A' through Palestine dome. For location of cross section see figure 22. From Hightower (1958).

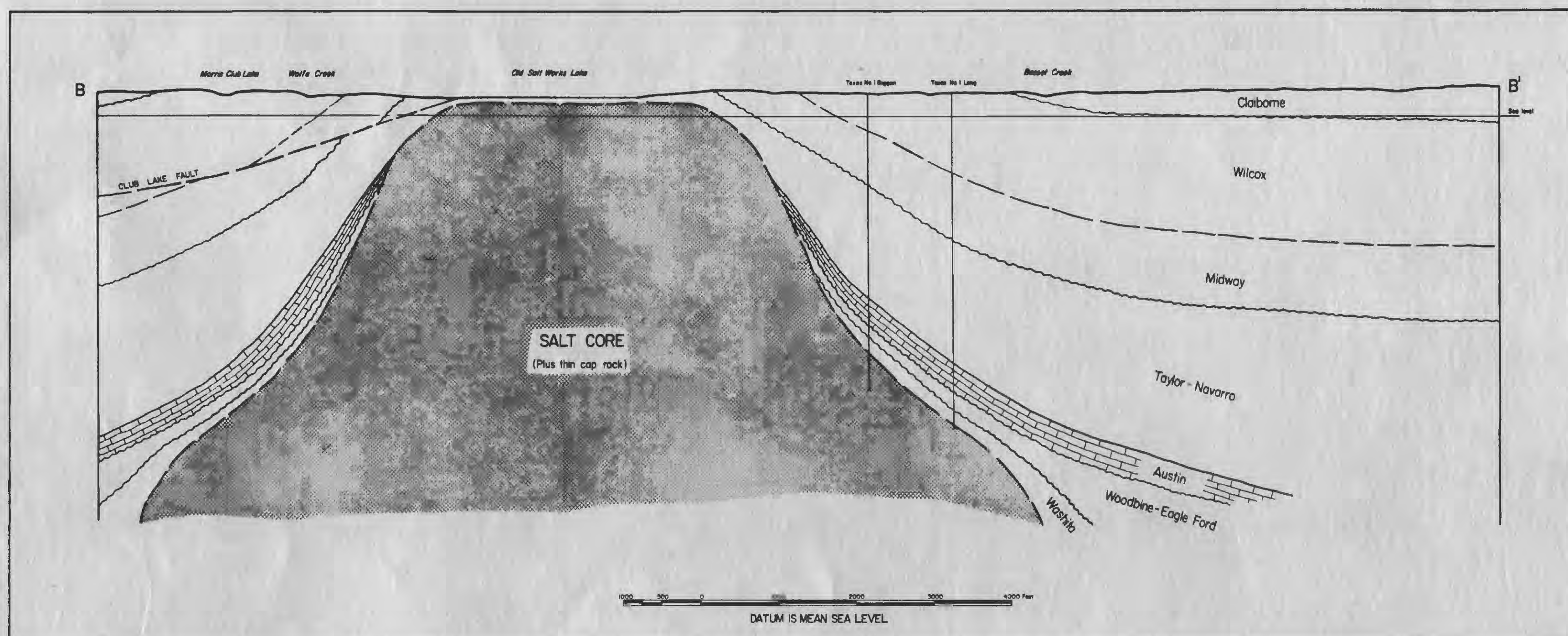


Figure 24.--Cross section B-B' through Palestine dome. For location of cross section see figure 22. From Hightower (1958).

BROOKS DOME: Smith County, Texas (figs. 25, 26)

DEPTH TO CAPROCK: 195 feet (Hawkins and Jirik, 1966)

DEPTH TO SALT: 220 feet (Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Hawkins and Jirik (1966) report 5 1/2 cubic miles above 10,560 feet. Dome is oval shaped, elongate from north to south. Salt overhang is present. At 500 feet below surface width is 1 1/2 miles; at 3,000 feet, 1 3/4 miles; at 2,000 feet area is at least 4 square miles.

DESCRIPTION OF CAPROCK: Thickness as encountered in three wells measures 20 feet, 114 feet, and 268 feet.

DRILLING HISTORY: Brine was produced from wells during the Civil War. Five shallow wells drilled for salt in 1903 and 1904, the deepest encountering gypsum from 200 feet to 220 feet, underlain by salt to 280 feet (TD). Four of seven oil tests in 1919 and 1920 encountered salt at 309 feet (TD 429), 840 feet (TD 850), 1,343 feet (TD 2,161), and 2,744 feet (TD 2,769). Humble 3 Wendlandt (1962) penetrated nearly 3,000 feet of salt overhang before reaching sediments, and produced 40 barrels a day from 8,046 to 8,054 feet below surface.

NEAREST POPULATION CENTER: Bullard, 7 miles east — POPULATION: 600
Tyler, 17 miles northeast — 58,000

PHYSIOGRAPHIC DATA: About half of the dome is covered by alluvium of Saline Creek, which flows from north to south across the center of the dome. Part of the alluvial area, about 320-340 feet above sea level, is a saline flat called Saline Prairie. Slightly below 320 feet and a mile downstream from the rim of the dome, Saline Creek joins the Neches River. As the flood plain of Saline Creek joins the flood plain of the Neches River near the dome, the alluvium-covered part of the dome is inundated in times of flood. The hilly parts of the domal area are as high as 420 feet above sea level, and are not subject to flooding.

GEOLOGIC DATA: The Cretaceous Austin Chalk and Taylor Marl have been thrust up to the surface around the dome, and outcrops there include also lower Tertiary formations up to the Eocene Queen City Sand. In the normal stratigraphic sequence for this area, the Wilcox Group (Paleocene(?) and Eocene) measures 1,200 feet, the Midway (Paleocene) and Navarro (Upper Cretaceous) Groups, 1,900 feet, and the Taylor Marl, 1,000 feet. The uplift of the Navarro and Taylor Cretaceous rocks measures 3,300 feet, and the uplift of the Austin Chalk, 4,300 feet.

HYDROLOGIC DATA: The Neches River is sometimes dry and cannot be considered an adequate source of water, therefore the underground water in the Carrizo and Wilcox sands (Paleocene) is the only reliable supply of fresh water in the vicinity of Brooks dome. The shallow Carrizo-Wilcox sands (combined thickness, more than 1,200 feet) are present over most of the area. Reports from several communities that have wells completed in these sands indicate that individual well capacities range from 100 to 700 gallons per minute.

The Layne Texas Company, which drills most of the fresh-water wells in east Texas, examined electric logs from four wells drilled near Brooks dome and estimated that water at 1,000-2,000 gallons per minute could be obtained by completing three to five supply wells in the Carrizo and Wilcox sands. However, it is the opinion of the district geologist of Humble Oil and Refining Company that the sands of the Carrizo and Wilcox thin near Brooks dome and probably pinch out against the salt plug (U.S. Bureau of Mines, written commun., 1961).

Sandstone of the Woodbine (Upper Cretaceous) is used for water disposal throughout the east Texas area. Examination of the Woodbine section on electric logs of four dry holes indicates that the Woodbine sand is well developed in the area and would be suitable for disposing of waste water.

GEOPHYSICAL DATA: Geophysical surveys were made prior to the drilling of Humble 3 Wendlandt in 1962.

ECONOMIC DATA: Wells drilled for oil have been noncommercial. Some lime has been quarried in the Austin Chalk.

Figure 25.--Topographic map showing vicinity of Brooks dome. For a map showing more recent road pattern see figure 26. (Base map, USGS, 1:62,500; Bullard, Texas.)

Figure 26.--Geologic map showing locations of Brooks, Bullard, Mount Sylvan, Steen, and Whitehouse domes. Ku, Upper Cretaceous rocks, undivided; Ewi, Wilcox Group, undivided; Ec, Carrizo Sand; Er, Reklaw Formation; Eqc, Queen City Sand; Ew, Weches Formation; Es, Sparta Sand, not including Etg, Tyler Greensand Member; Qt, Fluviatile terrace deposits, undivided; Qal, Alluvium. From Texas Univ. Bur. Econ. Geology, Geologic Atlas of Texas, Tyler sheet (1964).

MOUNT SYLVAN DOME: Smith County, Texas (figs. 26-29)

DEPTH TO CAPROCK: 650 feet (Wendlandt and Knebel, 1929)

DEPTH TO SALT: 1,050 feet (Wendlandt and Knebel, 1929); 613 feet (Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Information from seismic survey (Wendlandt and Knebel, 1929) shows the dome to be about 10,000 feet long by 9,000 feet wide (depth not indicated). Dome is egg shaped, elongate from north to south, nearly flat topped, with steep flanks.

DESCRIPTION OF CAPROCK: Streaks of anhydrite, salt, and sand.

DRILLING HISTORY: Eight wells drilled around flanks of dome. Humble A-1 Reese reached salt at 613 feet (Hawkins and Jirik, 1966).

NEAREST POPULATION CENTER: Tyler, 8 1/2 miles southeast

POPULATION: 58,000

GEOLOGIC DATA: Rim of low hills surrounds dome. Valley crosses dome. Surface formations are Queen City Sand, Weches Formation, Sparta Sand (all Claiborne Group, Eocene), and alluvium. Alluvium covers most of southeast third of dome. Saline Prairie and marsh on southeast of dome. Rim syncline almost completely encloses the dome.

HYDROLOGIC DATA: Salt water at 250 feet below surface and at 400 feet when well was abandoned. Alluvial valley of Black Fork Creek joins flood plain of Neches River near southwest margin of dome. Possibility of flooding during high water on Neches River.

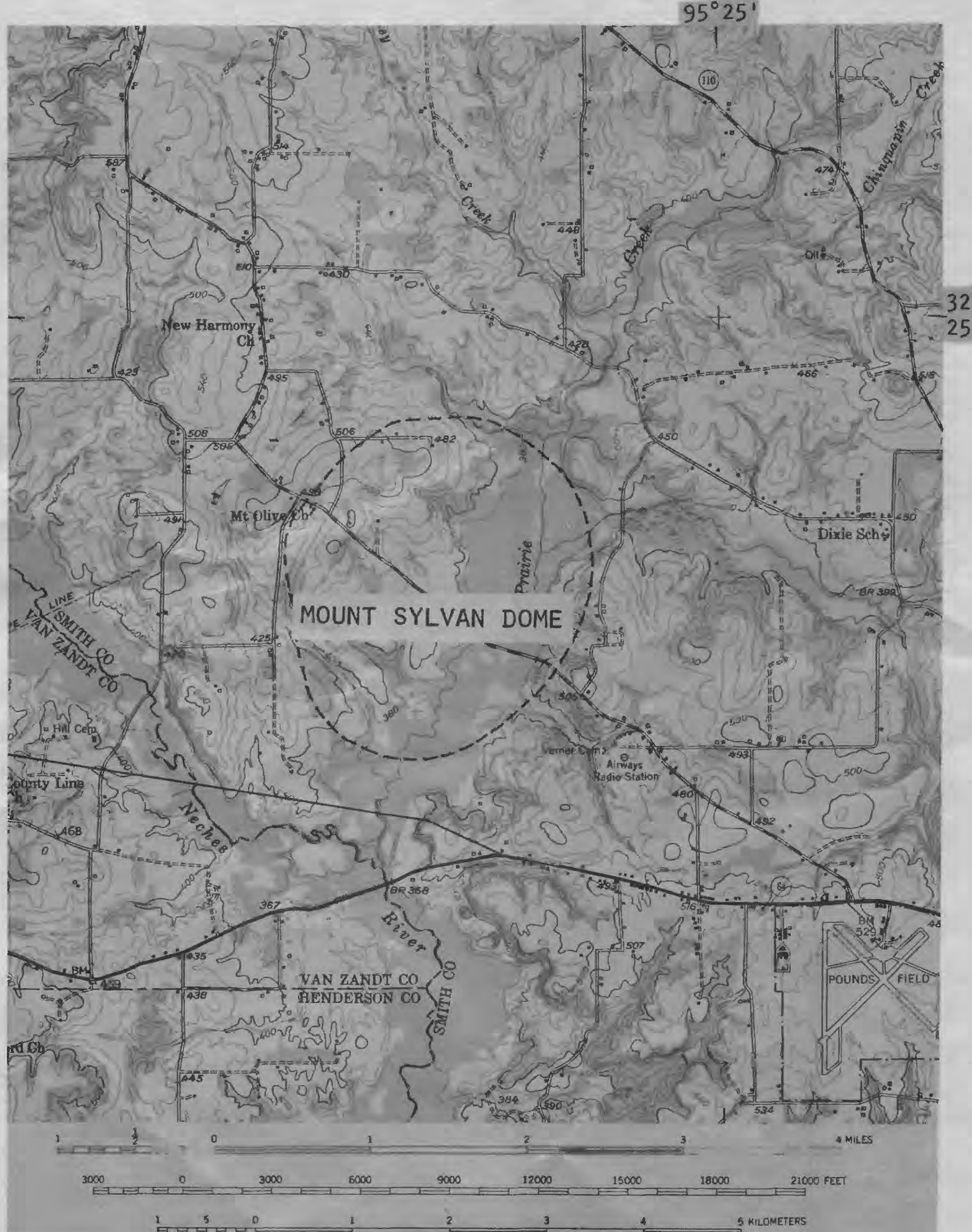


Figure 27.--Topographic map showing vicinity of Mount Sylvan dome. Dome outline from Wendlandt and Knebel (1929, p. 1363). (Base map, USGS, 1:62,500; Tyler, Texas.)

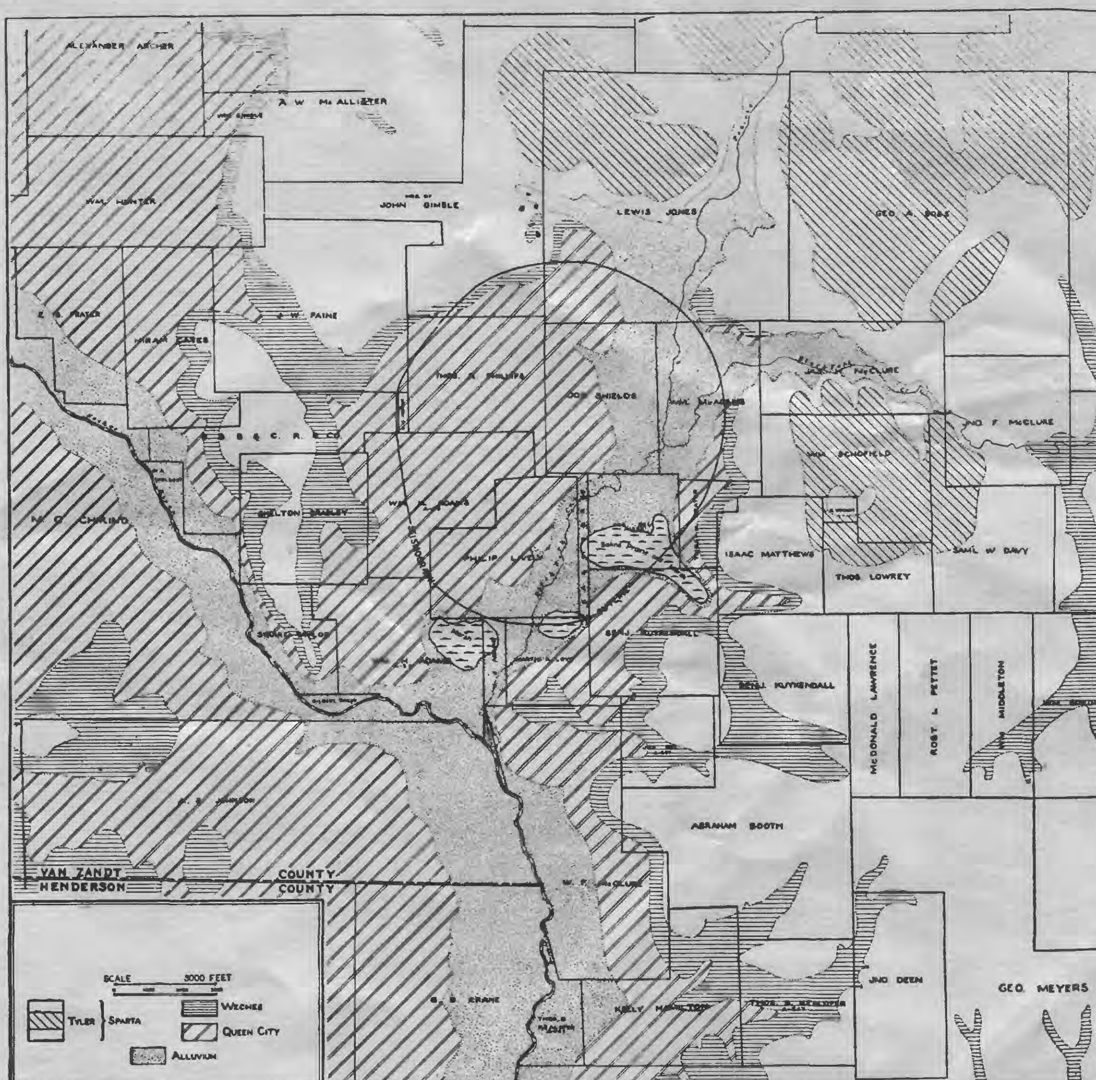


Figure 28.--Geologic map showing Mount Sylvan salt-dome area. From Wendlandt and Knebel (1929, p. 1363).

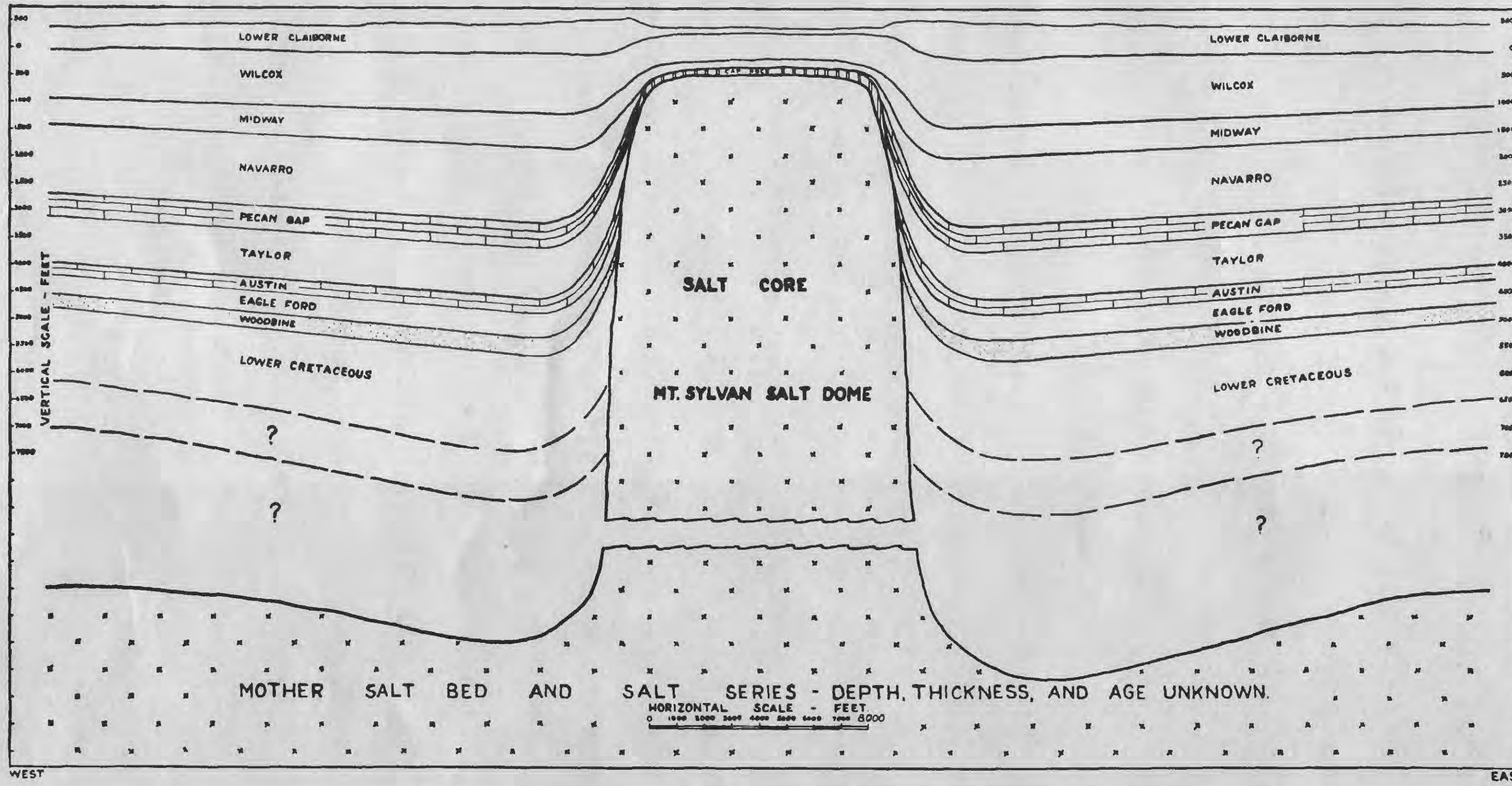


Figure 29.--Idealized diagrammatic cross section through Mount Sylvan dome, from west to east. From Wendlandt and Knebel (1929, p. 1367).

WHITEHOUSE DOME: Smith County, Texas (figs. 26, 30, 31)

DEPTH TO CAPROCK: 483 feet in Humble 1-A Van Hovenberg et al.; 1,950 feet in Humble 1 Pruett, a flank well

DEPTH TO SALT: 2,009 feet in Humble 1 Pruett

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Estimated to be slightly less than 4 square miles at depths below 2,000 feet.

DESCRIPTION OF CAPROCK: Driller's log of Humble 1-A Van Hovenberg et al. shows 2 feet of anhydrite from 483 feet to 485 feet; hard sand from 485 feet to 492 feet; anhydrite from 492 feet to 550 feet (TD).

DRILLING HISTORY: Discovery well, Humble 1-A Van Hovenberg et al. Humble 1 Pruett, elevation 491 feet, drilled in 1928 on flank of dome; caprock at 1,950 feet (1,459 subsea). Coring (?) 1,996 to 2,005 feet anhydrite with shales and sand; anhydrite dips 70 degrees from 2,008 to 2,009 feet. Salt at 2,009 feet (1,518 subsea), TD 2,017 feet. (Information from Humble Oil and Refining Company, Tyler, Texas.)

NEAREST POPULATION CENTER:		POPULATION:
	Tyler, 8 miles north	58,000
	Whitehouse, 3 miles east	<1,000

GEOLOGIC DATA: No specific data available, but geologic setting is similar to nearby domes Brooks and Bullard.

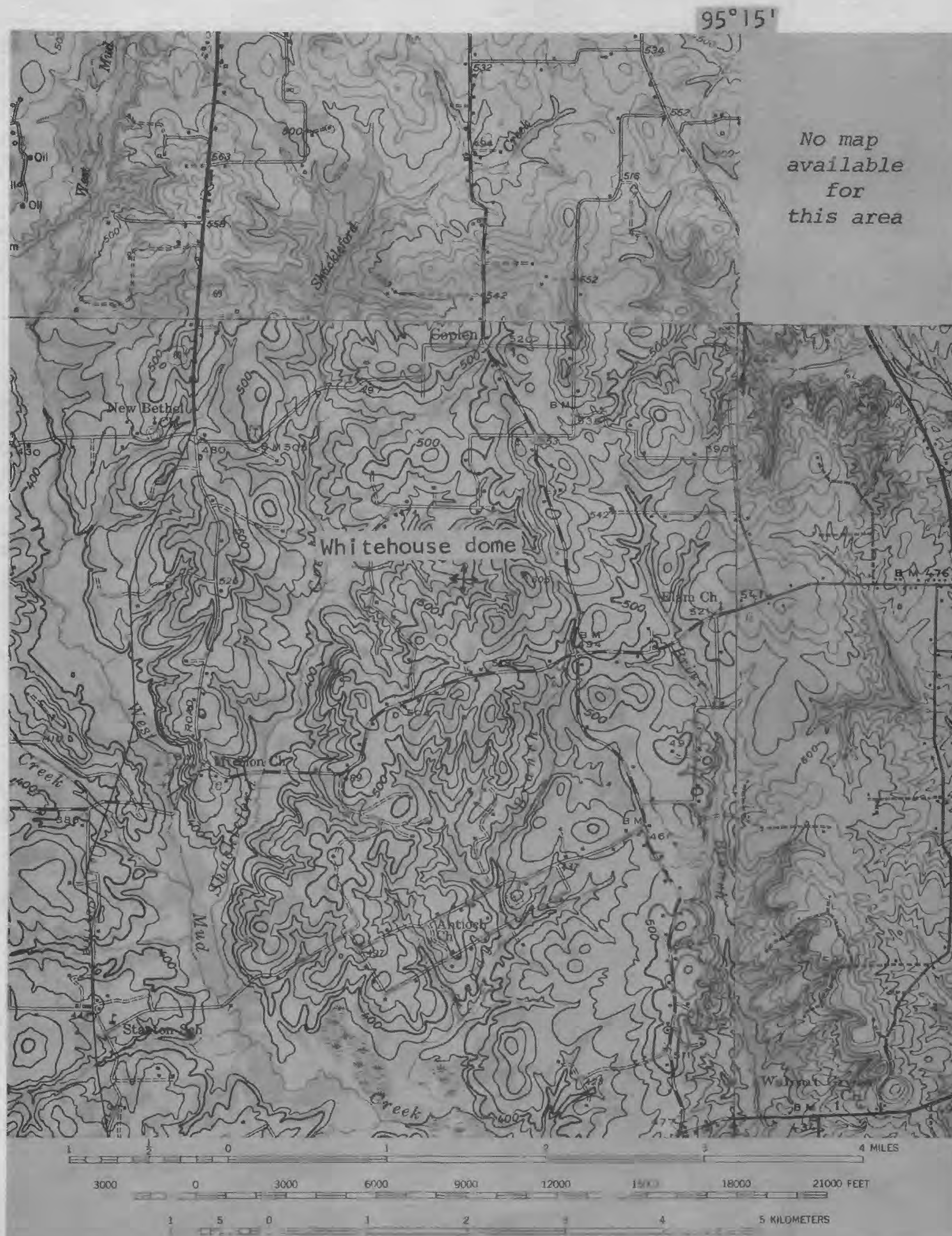


Figure 30.--Topographic map showing Whitehouse dome area. (Base map, USGS, 1:62,500; Tyler, Bullard, and Troup, Texas.)

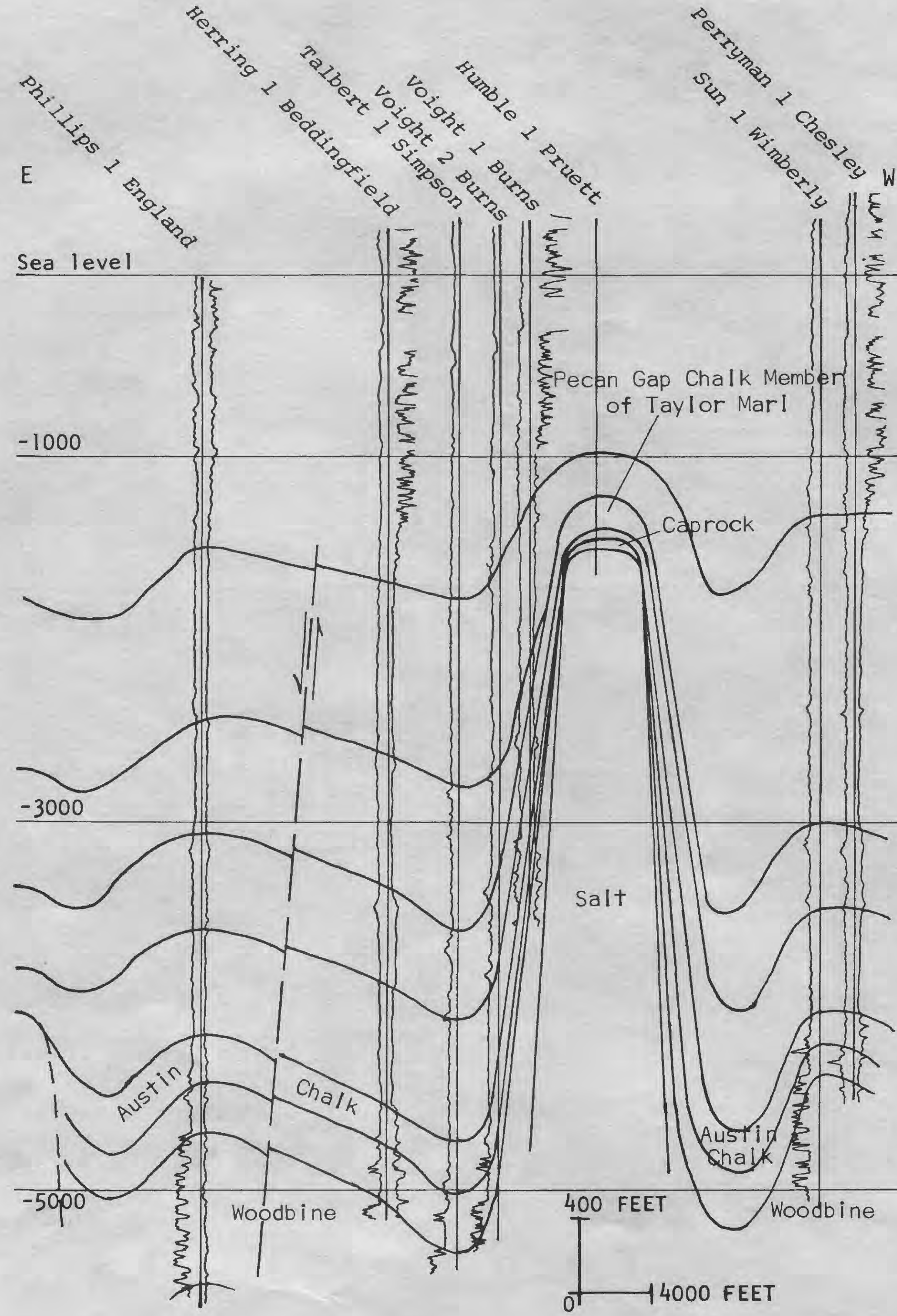


Figure 31.--Geologic cross section from east to west through Whitehouse dome. From J. K. Rogers, written commun. (1972).

BULLARD DOME: Smith County, Texas (figs. 26, 32, 33)

DEPTH TO CAPROCK: 375 feet

DEPTH TO SALT: 527 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: The dome contains an estimated 1 1/2 cubic miles of salt above 10,560 feet below the surface. Available information (fig. 33) indicates that the radius of the dome at 1,000 feet below the surface is about 2,500 feet, and at 2,000 feet, about 3,500 feet, but these radii can not be used to estimate the area of the dome. The salt mass probably has less than half the area of Brooks dome (4 square miles) at 2,000 feet below the surface.

DESCRIPTION OF CAPROCK: Crystallized gypsum with streaks of shale and limestone, 152 feet thick.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Wells drilled on flank of dome show Cretaceous limestones in contact with caprock, dipping away from dome at about 45°.

DRILLING HISTORY: Four wells drilled for oil on northwest flank of dome; one in northeast quarter on top of the dome; one in rim syncline northeast of the dome. Discovery well drilled 152 feet of caprock (from 375 feet to 527 feet) and 4 feet of salt (from 527 feet to 531 feet, TD). Salt was drilled in another well from 2,943 feet to 2,950 feet (Judson, 1929, p. 613).

NEAREST POPULATION CENTER:		POPULATION:
	Bullard, 1 1/2 miles southeast	600
	Tyler, 12 miles north	58,000

BULLARD DOME: Continued

GEOLOGIC DATA: On surface are Queen City Sand and Weches Formation (Claiborne Group), steeply dipping near dome. Thickness of formations and general hydrology at Bullard dome are similar to Brooks dome.

Figure 32.--Topographic map showing location of Bullard salt dome, Smith County, Texas. (Base map, USGS, 1:62,500; Bullard, Texas.)

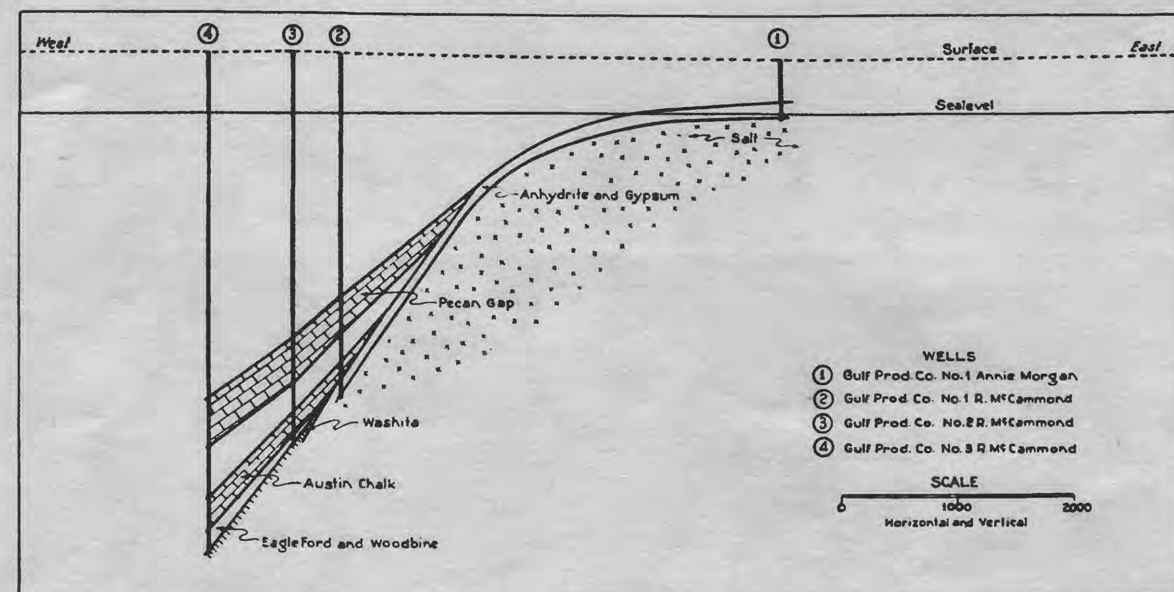


Figure 33.--Diagrammatic geologic cross section through west flank of Bullard dome. From Hanna (1934, p. 673).

STEEN DOME: Smith County, Texas (figs. 26, 34)

DEPTH TO CAPROCK: 75 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

DEPTH TO SALT: 300 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None. Salt well abandoned.

SIZE AND SHAPE OF SALT MASS: Oval shaped, 7,500 feet long, 4,600 feet wide, elongate north to south.

DESCRIPTION OF CAPROCK: No information

DRILLING HISTORY: Brine wells produced salt during Civil War. Several wells drilled on flanks and in rim syncline, and at least three drilled on crest of dome. Deepest test drilled to 2,630 feet below surface.

NEAREST POPULATION CENTER:	Lindale, 4.5 miles west	POPULATION:	1,600
	Tyler, 9.3 miles south		58,000

GEOLOGIC DATA: At surface, Eocene Queen City Sand (Claiborne Group) surrounds undivided Cretaceous, uplifted over domal area. Over half of dome covered with prairie and swamp (330 feet above sea level) of Saline Creek, which crosses dome from south to north. Hills rise to 380 feet on each side. A fault cuts red sandstone on north flank of Todd Mountain.

HYDROLOGIC DATA: Springs in swamp represent artesian waters from sands of Wilcox(Paleocene and Eocene) along joints and faults in rocks overlying caprock. Sulfur spring on northeast part of dome.

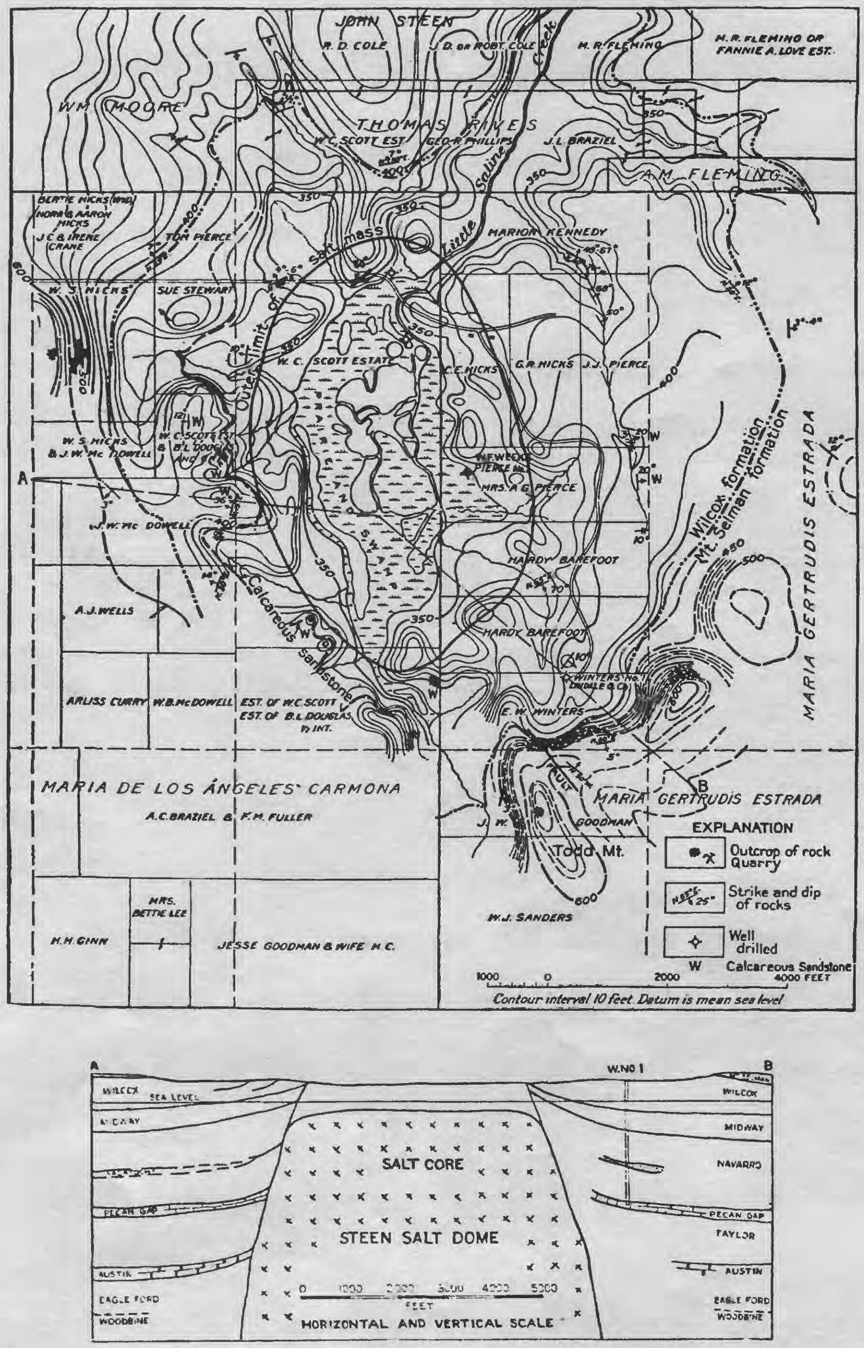


Figure 34.--Topographic map and section showing surface trace of outer limit of Steen salt dome and diagrammatic geologic cross section through the dome. From Powers (1926, figs. 5 and 6).

NORTH LOUISIANA

SALT-DOME BASIN

Index of salt domes

VACHERIE DOME: Bienville and Webster Parishes, Louisiana (figs. 35-40)

DEPTH TO CAPROCK: 658 feet (U.S. Bureau of Mines, 1961)

DEPTH TO SALT: 777 feet (U.S. Bureau of Mines, 1961); 799 feet (Louisiana Geological Survey) in Hull, 1925, p. 904-905.

SIZE AND SHAPE OF SALT MASS: Upper part of salt mass is possibly as much as 2 miles wide from east to west at 2,000 feet below the surface. Approximate size and shape are shown on figure 40.

DESCRIPTION OF CAPROCK: 90-120 feet thick (Spooner, 1926), white and dark-gray anhydrite, with irregular dark-gray and blue banding, similar to caprock on Winnfield dome.

DRILLING HISTORY: (fig. 40) Standard Oil Company of Louisiana 1 Jordan, 1922, drilled anhydrite and gypsum from 709 feet to 799 feet; salt from 799 feet to 897 feet. Standard Oil Company of Louisiana 1 Stephens, 1922, drilled salt from 777 feet to 788 feet. Great Western 1 Moore, 1961, reached salt at 7,380 feet (TD 7,580 feet). Montgomery 1 Woodward-Walker, 1967, drilled salt from 4,260 feet to 4,289 feet (TD); anhydrite from 4,170 to 4,260 feet. Pan American 1 Smith reached salt at 5,410 feet. Lion 1 Woodward reached caprock at 1,506 (by Schlumberger), salt at 1,585±, (by Schlumberger).

NEAREST POPULATION CENTER:		POPULATION:
	Heflin, 3.6 miles west	300
	Gibsland, 9.8 miles northeast	1,400

VACHERIE DOME: Continued

GEOLOGIC DATA: Inliers of Cane River Formation (Claiborne Group, Eocene) and Wilcox Group (Paleocene(?) and Eocene) in both Webster and Bienville Parishes evidence the domal structure in the outcrop of the Sparta Sand (Claiborne Group). Spooner reports Arkadelphia Marl (Navarro Group, Upper Cretaceous) and Midway (Paleocene) beneath alluvium of Bashaway Creek. Some hydrogen sulfide encountered in drilling caprock. Dome rises out of the Minden syncline; evidence that dome did not rise until end of Early Cretaceous time.

HYDROLOGIC DATA: Bushaway Creek flows eastward across southern part of dome. Same aquifers as in other salt domes in this basin. Depth to base of fresh water about 500 feet, and to slightly saline water, about 800 feet.

GEOGRAPHICAL DATA: Central area is low, but does not have a saline. Discovered by field work of Standard Oil Company of Louisiana in 1921, drilled in 1922. Hills of Sparta Sand rise 150 feet above flanks of dome.

ECONOMIC DATA: Most of area around dome forested; scattered farm land; no production from dome.

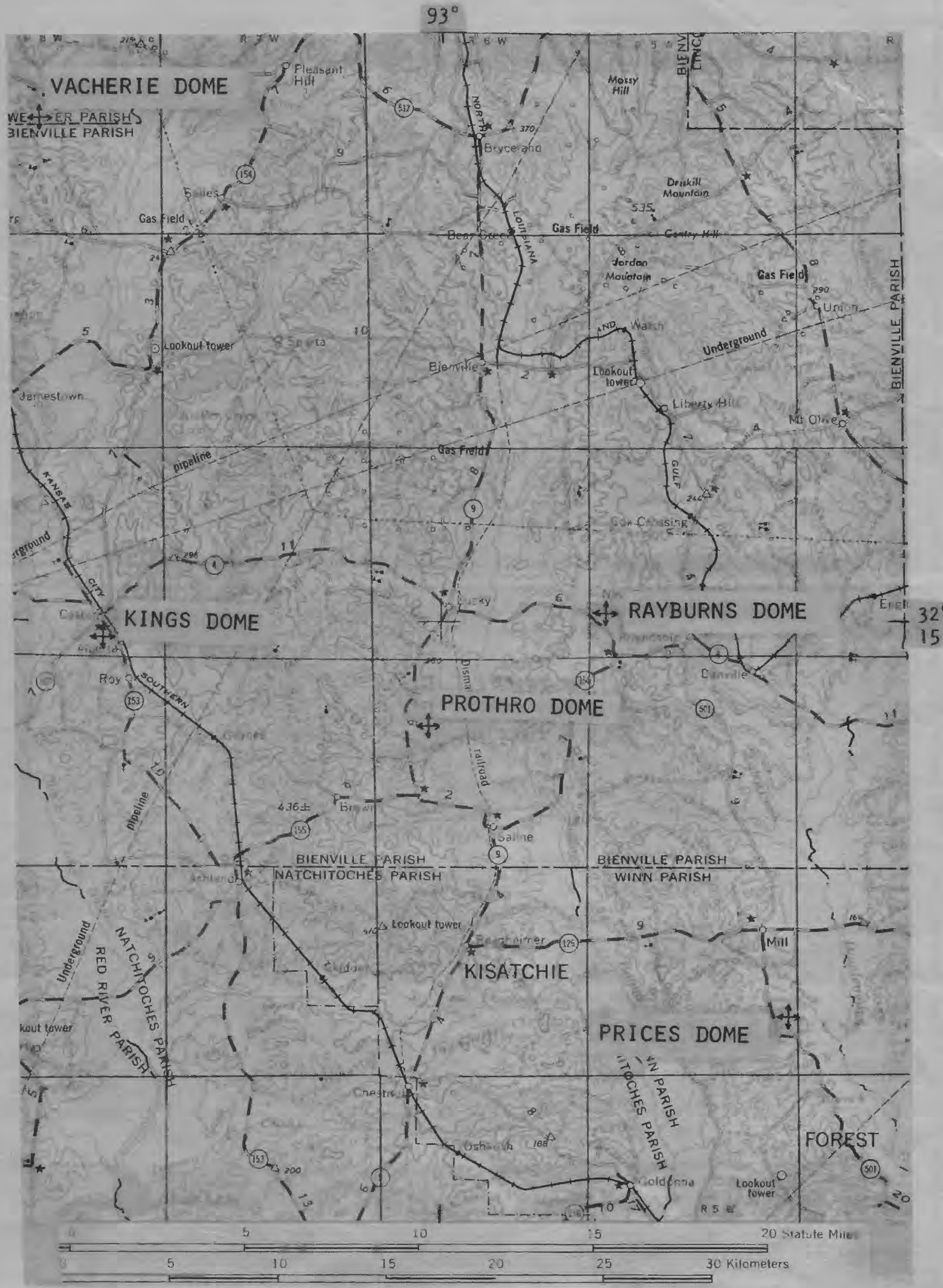


Figure 35.--Topographic map showing Kings, Prices, Prothro, Rayburns, and Vacherie domes. (U.S.A.M.S., Shreveport)

Figure 36.--Topographic map showing Vacherie dome. Dashed line is outline of gravity anomaly, from J. K. Rogers (written commun., 1972). (USGS, 1:62,500, Gibsland and Jamestown, La.)

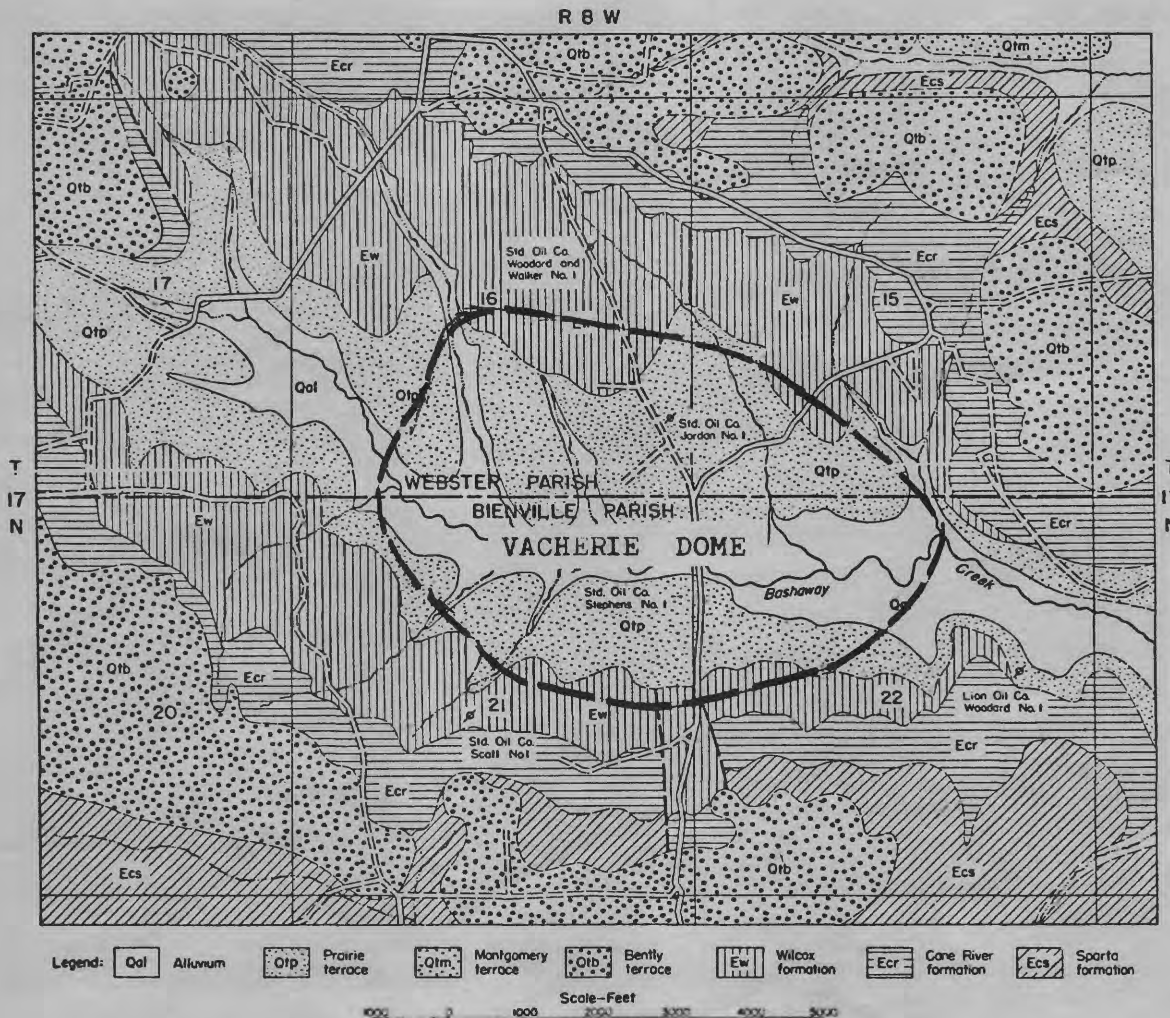


Figure 37.--Geologic map showing Vacherie dome area. From Martin and others (1954, pl. 12). Dashed line is outline of gravity anomaly, from J. K. Rogers (written commun., 1972).

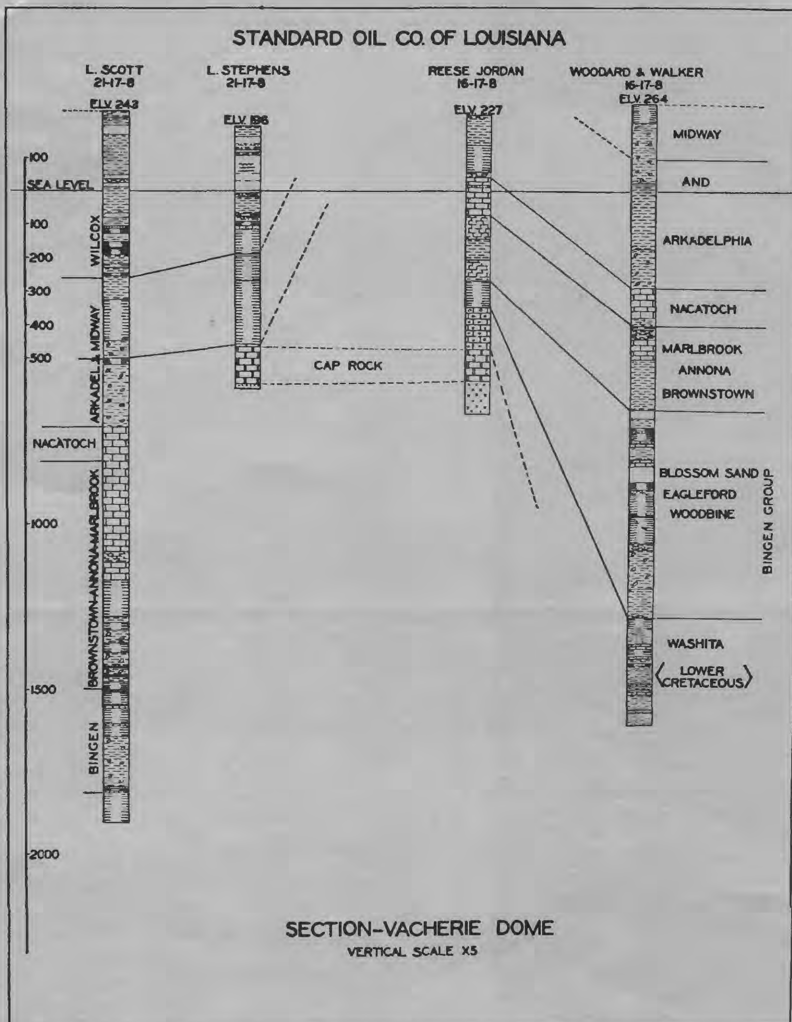


Figure 38.--Stratigraphic correlation across Vacherie dome. For location of drill holes see figure 37. From Spooner (1926, fig. 9).

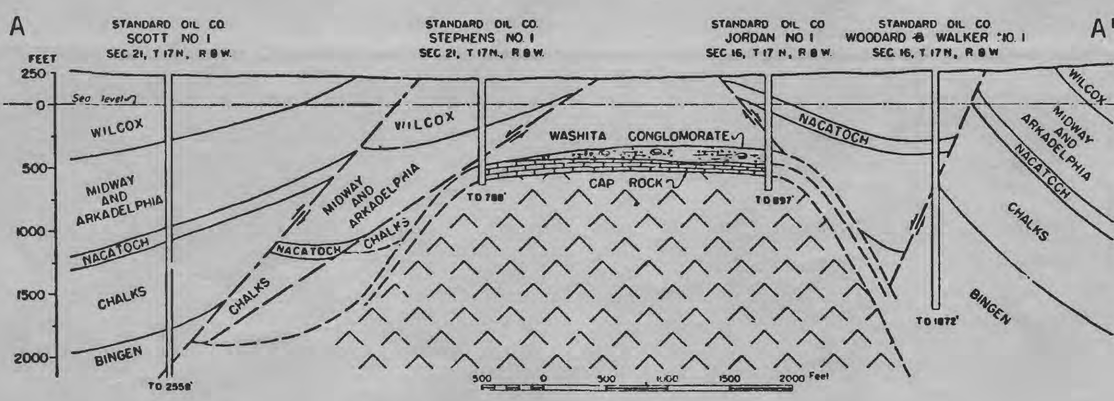


Figure 39.--Diagrammatic geologic cross section from north to south through Vacherie dome. For location of cross section see figure 40. From Martin and others (1954, fig. 9).

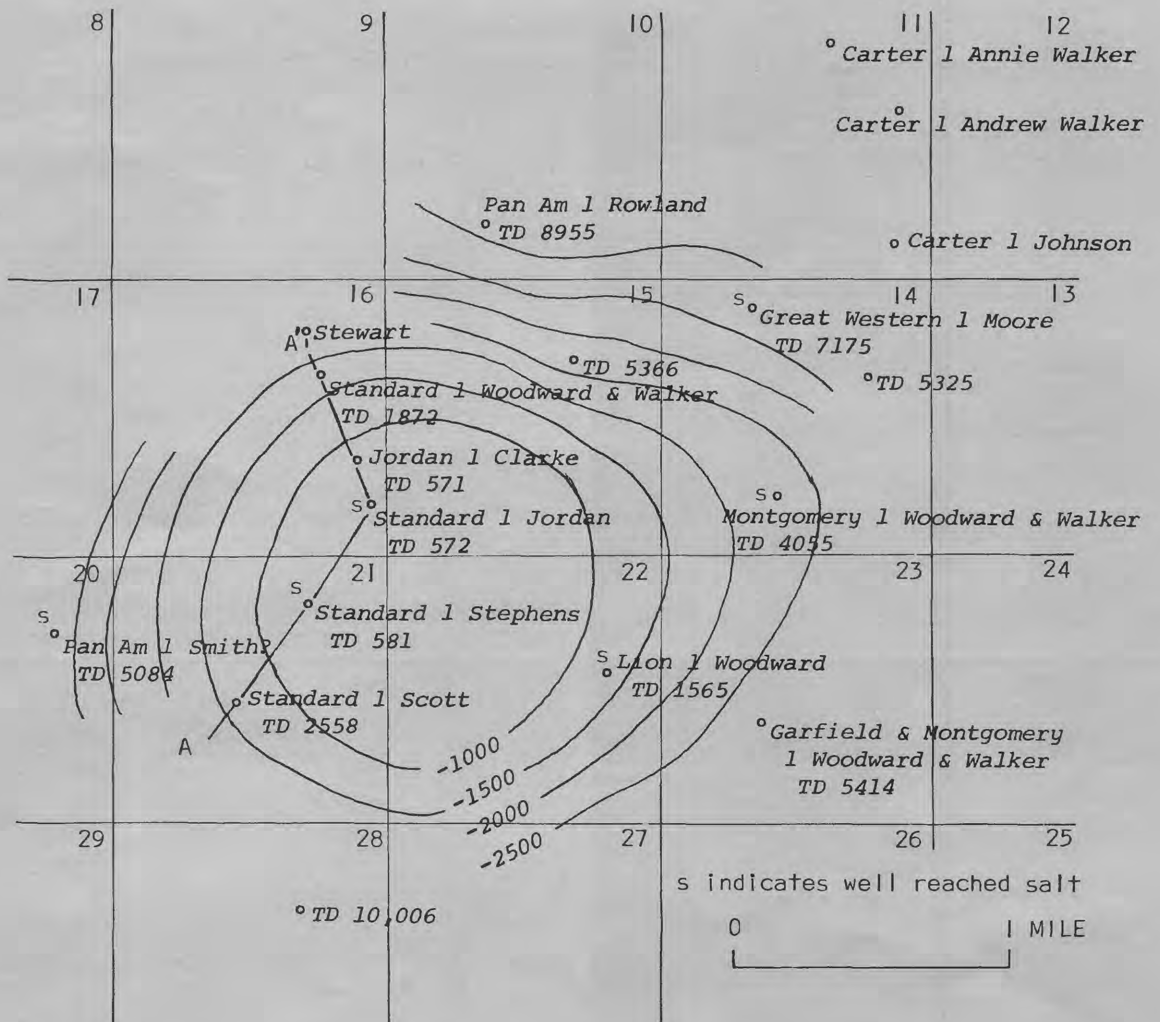


Figure 40.--Subsurface contour map showing the top of the salt, Vacherie dome (T. 17 N., R. 8 W.). From unpublished data. Cross section shown in figure 39.

PROTHRO DOME: Bienville Parish, Louisiana (figs. 35, 41, 42)

DEPTH TO CAPROCK: Not available. Prothro is in an area of shallow domes.

DEPTH TO SALT: Not available.

PRESENT ECONOMIC USE: None.

SIZE AND SHAPE OF SALT MASS: Estimated to be about 1 mile by 1 1/4 miles. Diameter of uplifted area is 2 1/2 miles (Powers, 1926, p. 222). Elongate from north to south.

DRILLING HISTORY: Vuci 1 Evans reached salt (J. Braunstein, oral commun., 1972). No further data available.

NEAREST POPULATION CENTER:		POPULATION:
	Brown	<1,000
	Saline	300
	Jonesboro, 16.8 miles east-northeast	5,000

GEOLOGIC DATA: The Eocene Sparta Sand (Claiborne Group) is the normal formation exposed in the area surrounding the dome. The Sparta Sand and underlying glauconitic sand of the Eocene Cane River Formation (Claiborne Group) form cuestas surrounding a central depression that is interrupted by low hills in which sands of the Wilcox Group (Paleocene and Eocene) are exposed. Strata as old as Late Cretaceous are found at the surface in the central depression (Durham and White, 1960). The older strata have been uplifted at least 2,800 feet and dip steeply to vertically in the area of the central topographic depression. In center of dome is abandoned limestone quarry in

Saratoga Chalk(?) (Cretaceous). A north-south cross section (fig. 42) showing the near-surface relations over the dome has been published (Durham and White, 1960).

HYDROLOGIC DATA: Prothro dome is surrounded by the same aquifers that surround Prices and Rayburns domes. The aquifers apparently do not come in contact with salt mass. Fresh ground water is apparently sparse beneath the central topographic depression, but occurs to depths of from 500 feet to 700 feet around the dome.

GEOGRAPHIC DATA: State Route 9 crosses dome from north to south. East half of dome covered by large swamp about 180 feet above sea level, drained by Sprawls Mill Creek into Saline Bayou, 1 1/2 miles east, at about 160 feet.

ECONOMIC DATA: Most of dome covered by forested lowland. On hilly west side is some cultivated land and a few houses.

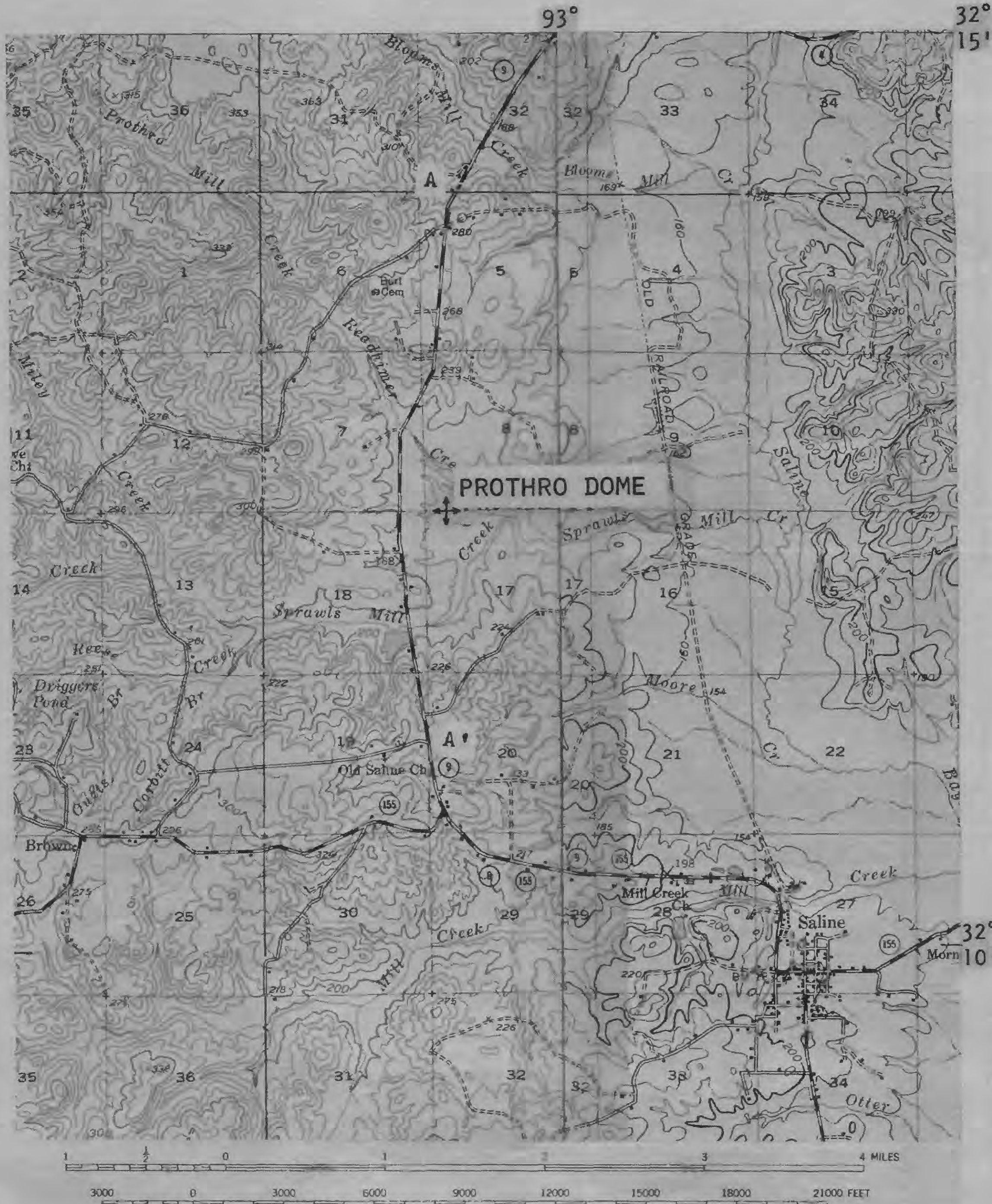


Figure 41.--Topographic map showing location of Prothro dome. Geologic cross section, figure 42, follows Route 9 from A in the north to A' in the south. (USGS, 1:62,500, Ashland and Goldonna, La.)

RAYBURNS DOME: Bienville Parish, Louisiana (figs. 35, 43-45)

DEPTH TO CAPROCK: 0 (Hawkins and Jirik, 1966); 85 feet (Blanpied, 1960).

DEPTH TO SALT: 115 feet (Hawkins and Jirik, 1966)

SIZE AND SHAPE OF SALT MASS: Estimates by U.S. Bureau of Mines (written commun., 1972) give width at top of salt, about 2,300 feet across; at 500 feet subsea, about 2,600 feet across; at 1,000 feet subsea, about 3,000 feet; at 2,000 feet subsea, 3,500 feet across. Saline outlines salt core. Top of salt is eroded.

DESCRIPTION OF CAPROCK: Said to be 130 feet thick by U.S. Bureau of Mines (written commun., 1972), white and gray banded calcite rock at top, gypsum and anhydrite in old brine wells.

DRILLING HISTORY: Hodge-Hunt 3 Fee reached top of caprock at 85 feet; top of salt at 115 feet (Spooner, 1926); TD 277 feet; drilled in 1923. Hodge-Hunt 3 Continental Can (center NE 1/4 NE 1/4 sec. 36, T. 15 N., R. 6 W.), TD 709 feet in salt. Hodge-Hunt 3 Fee; top of salt at 120 feet; TD 257 feet (615 feet east and 570 feet north of SW. cor. sec. 31, T. 15 N., R. 5 W.). Five wells drilled about 1 mile from the center of the dome (one to 3,003 feet, others below 4,000 feet) did not reach salt.

NEAREST POPULATION CENTER:		POPULATION:
	Saline, 6 miles southwest	300
	Hodge, 11 miles east	900
	Jonesboro, 11 miles east	5,000

GEOLOGIC DATA: Cretaceous limestone exposed at center(?) of dome, uplifted at least 2,200 feet. Saratoga Chalk and Blossom Sand (both

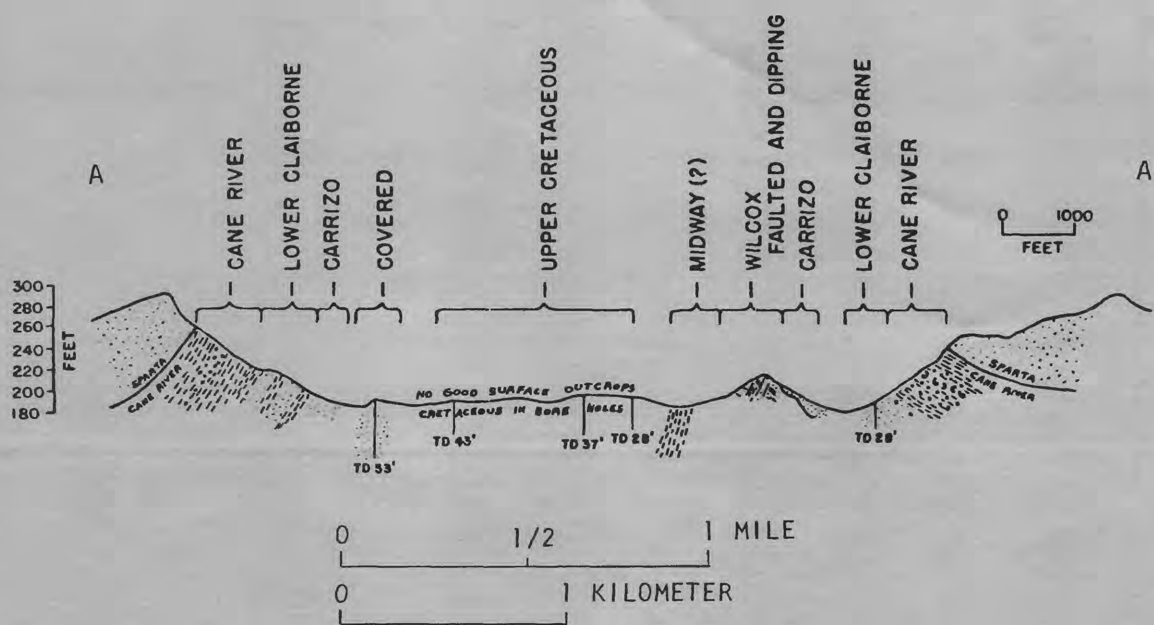


Figure 42.--Diagrammatic geologic cross section A-A' from north to south through Prothro dome. Cross section follows Route 9 on figure 41. From Shreveport Geological Society (1960, Pl. A-1074).

RAYBURNS DOME: Continued

Upper Cretaceous), unconformable Tertiary formations strongly dipping and faulted; Eocene Sparta Sand (Claiborne Group) in hills surrounding dome.

HYDROLOGIC DATA: Radial streams and springs feed into salines from all sides. Aquifers are Sparta Sand and Wilcox Group (Paleocene and Eocene) sands. Fresh water not present over dome, but present to depths of 1,000 feet in cone of depression around dome (figs. 44, 45).

GEOGRAPHIC DATA: Top of dome, 180 feet above sea level, has small lake and marshy saline 2,000 feet long and 1,500 feet wide, circled by hills 60-100 feet higher. Wooded country, some cultivated land. State Route 4 crosses dome area. United Gas 24-inch pipeline is 6 miles northwest.

ECONOMIC DATA: Limestone quarry in center (?) of dome in Saratoga Chalk (Cretaceous). Liberty Hill and Lucky gas fields about 3 1/2 miles north and northwest of dome center produce from reservoirs not associated with Rayburns structure.

Figure 43.--Topographic map showing location of Rayburns dome. (USGS, 1:62,500, Bienville and Goldonna, La.)

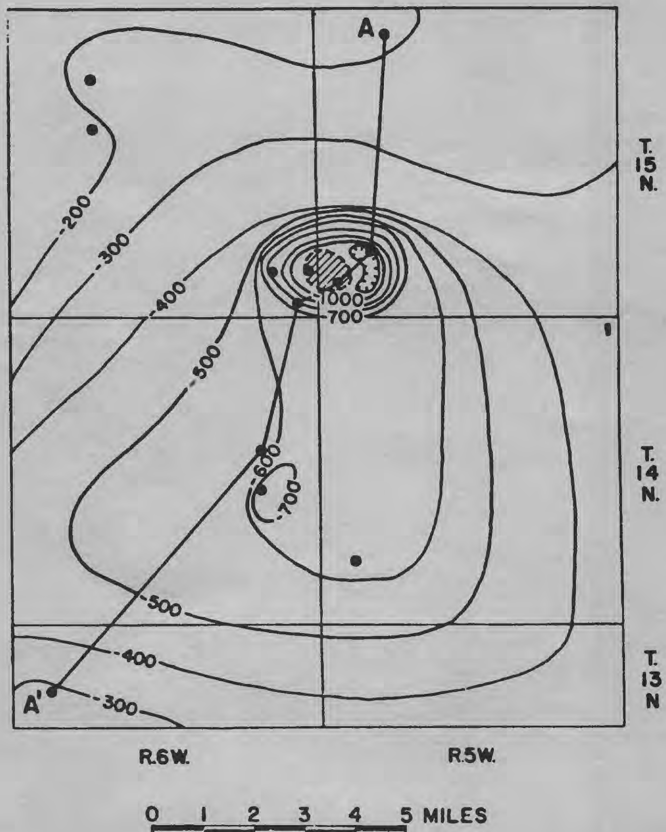


Figure 44.--Subsurface map of Rayburns dome area contoured on the base of the fresh-water zone. Black dots are control points; hatched area is approximate extent of salt plug; contour interval 100 feet; datum, mean sea level. From Rollo (1960).

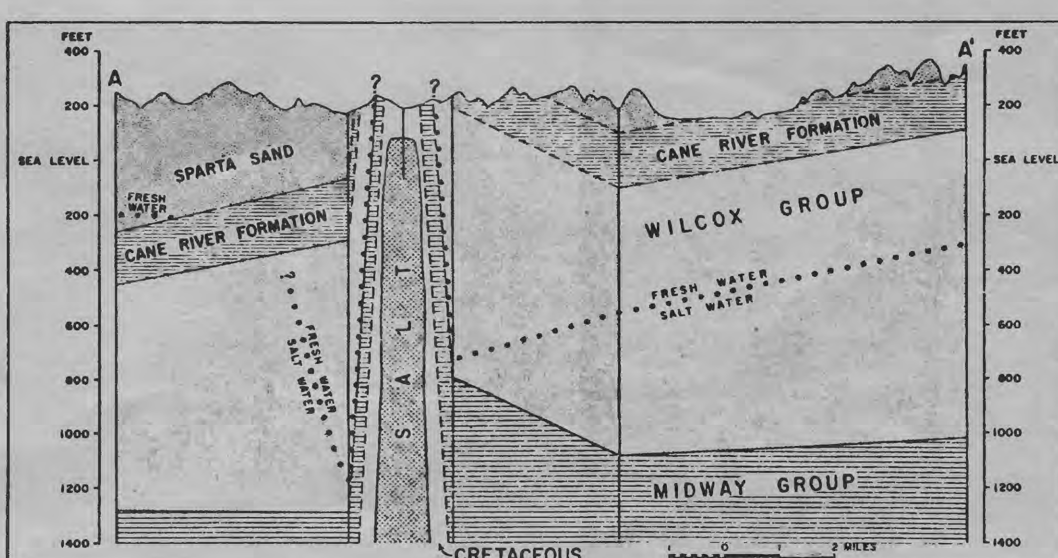


Figure 45.--Geologic cross section A-A' through Rayburns dome. For location of cross section see figure 44 above. From Rollo (1960).

PRICES DOME: Winn Parish, Louisiana (figs. 35, 46)

DEPTH TO CAPROCK: 1,100 feet (U.S. Bureau of Mines, Powers)

DEPTH TO SALT: 1,300(?) feet (from geophysical data)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Diameter, three-fourths of a mile; uplifted area, 2 miles. Amount of uplift is 1,500 feet (Powers, 1926, p. 222).

DRILLING HISTORY: Vivian Oil Co. 1 Bodcaw drilled in 1916 on northwest flank, 2,000 feet from center, bottomed at 2,134 feet in Cretaceous rocks. No recent drilling.

NEAREST POPULATION CENTER:		POPULATION:
	Jonesboro, 12.2 miles north-northeast	5,000
	Mill, 2.8 miles north	<1,000

GEOLOGIC DATA: Ferruginous sandstone in hills that surround the dome area, which is Eocene Sparta Sand (Claiborne Group). Regional dip is southeast. Surface expression of dome structure is less pronounced than either Prothro or Vacherie, suggesting that the salt plug at Prices is deeper or smaller or both.

HYDROLOGIC DATA: Fresh water is apparently absent over dome. Principal ground-water-bearing formations surrounding dome are Wilcox (Paleocene(?) and Eocene) in northwest, and Sparta Sand in southeast. In well 3 miles southeast, Sparta extends to 480 feet and contains fresh water throughout entire thickness. Well 4 miles northwest shows fresh water in Wilcox from 400 feet to 575 feet beneath surface. Brine disposal would be possible in the Wilcox southeast of dome where there is a saline aquifer.

PRICES DOME: Continued

GEOGRAPHIC DATA: State Route 50 half a mile southwest of dome; logging road terminates a fourth of a mile from the center of the dome. Kansas City Southern (Louisiana and Arkansas) Railroad is 6 miles southwest. Several pipelines 2 1/2 to 3 miles from dome.

PHYSIOGRAPHIC DATA: Central hill (Lick Hill), 96 feet high, between salines or flat barren sandy areas surrounding the hill. Radial drainage; Dugdemona Bayou, principal drainage of the region, is 1 1/4 miles east, separated from the salines by a 55-foot fill that is broken by streams that drain the salines. Some depressions are apparently sinkholes.

ECONOMIC DATA: Early production of salt from shallow wells in the salines, now abandoned.

Figure 46.--Topographic map showing location of Prices dome. (USGS, 1:62,500, Goldonna, La.)

KINGS DOME: Bienville Parish, Louisiana (figs. 35, 47-49)

DEPTH TO CAPROCK: 161 feet

DEPTH TO SALT: 172 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Core is one-half to three-fourths of a mile in diameter. Top of salt is eroded.

DRILLING HISTORY: Pardee Co. Fee No. 1 (TD 404 feet) in salt at 161 feet (fig. 48). Center of dome beneath NW 1/4 sec. 35, T. 15 N., R. 8 W. (fig. 47). Five wells drilled as of 1926. Louisiana Oil and Refining Corp. 2 Huckaby (sec. 27, T. 15 N., R. 8 W.) drilled salt at 2,228 feet on flank of dome (TD 2,505 feet).

NEAREST POPULATION CENTER:		POPULATION:
	Castor, on dome	178
	Ringgold, 8.2 miles northwest	1,000

GEOLOGIC DATA: No central depression. Syncline on southeast flank, near contact of Wilcox Group (Paleocene(?) and Eocene) and Eocene Cane River Formation (Claiborne Group). Vertical uplift of area more than 2,000 feet in 3-mile area. Sparta Sand (Claiborne) is youngest formation exposed on surface; oldest is Marlbrook Marl (Late Cretaceous).

HYDROLOGIC DATA: Presence of salt licks on surface suggest that no fresh ground water exists over the dome. In area surrounding dome the base of the fresh-water-bearing sands is only about 150 feet below the surface, and beneath it is a zone 500 feet thick containing moderately saline water. Sand thicknesses in the fresh and slightly

KINGS DOME: Continued

saline water zone are about 250 feet, and estimated potential yields from individual wells range from 100 to 500 gallons per minute.

GEOGRAPHIC DATA: State Routes 4, 153, and 507, and the Kansas City Southern Railroad traverse the dome. The Tennessee Eastern Transmission Company 24-inch pipeline crosses the dome from northeast to southwest. A saline drained by Bayou Castor is on top of the dome (150 feet above sea level). Hills around dome as much as 300 feet high. Dome has no central basin.

ECONOMIC DATA: Lucky gas field is 8 miles northeast. Salt well is abandoned.

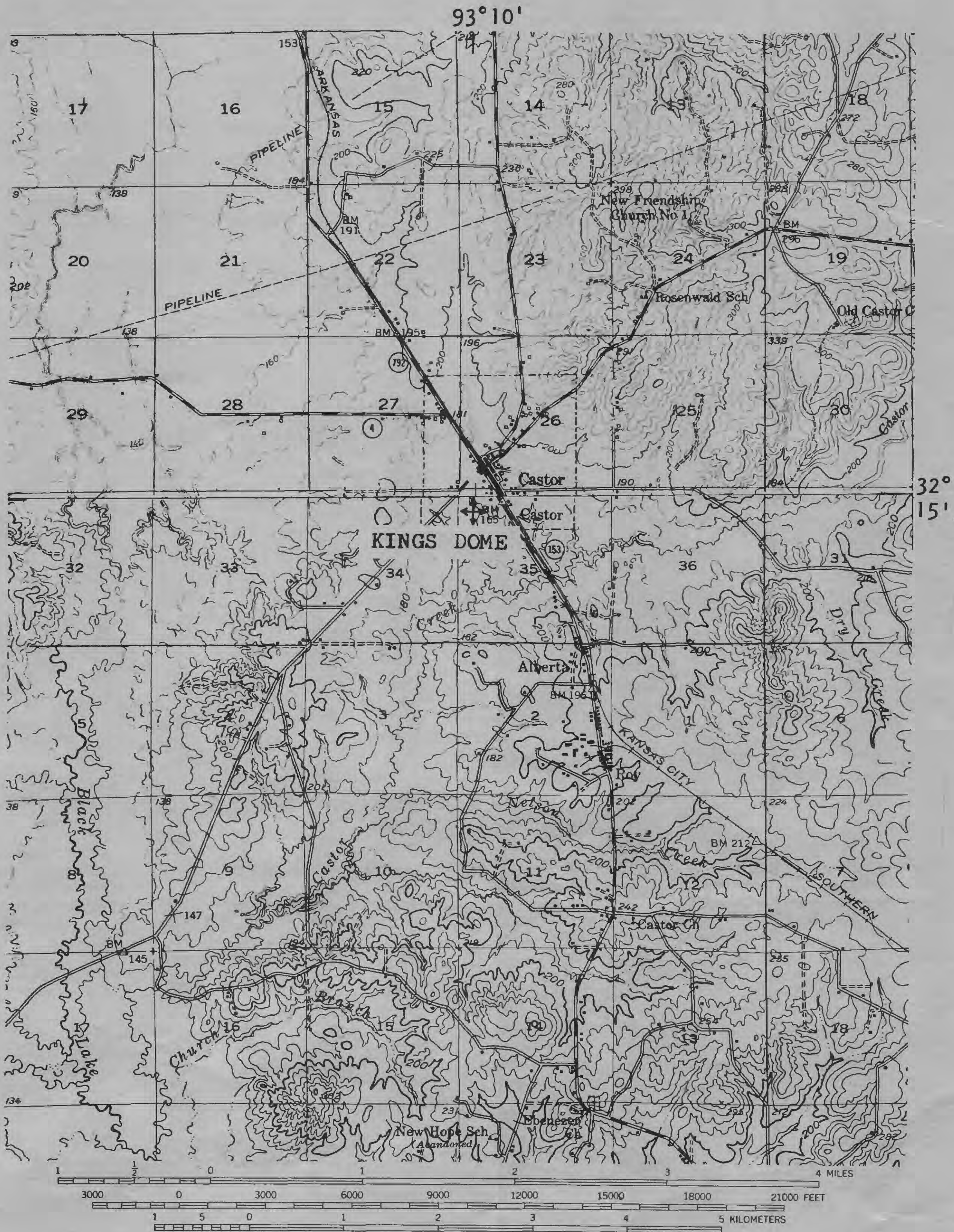


Figure 47.--Topographic map showing location of Kings dome. (USGS, 1:62,500, Jamestown and Ashland, La.)

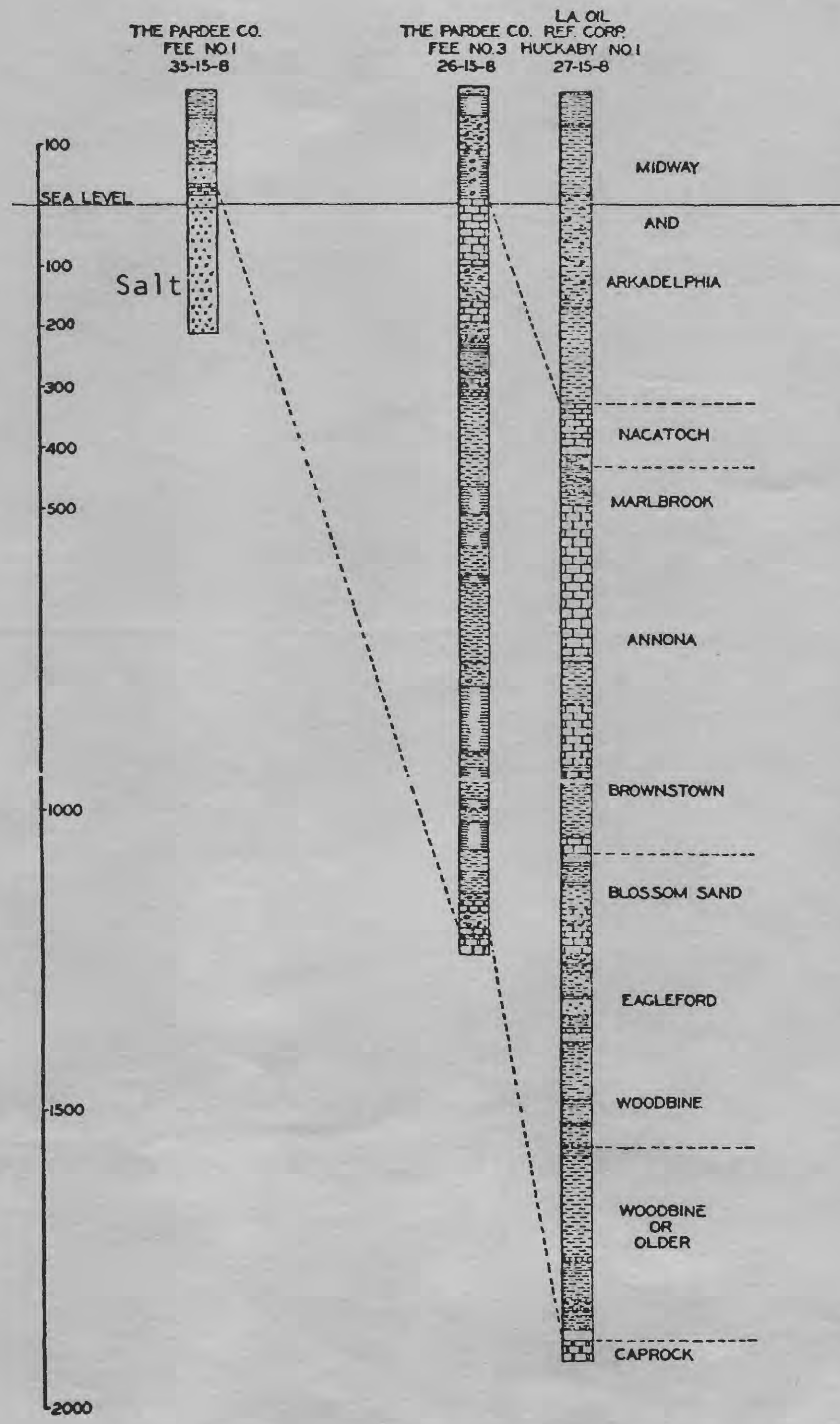


Figure 48.--Diagrammatic stratigraphic cross section through part of Kings dome. For locations of wells see figure 49. From Spooner (1926, fig. 14).

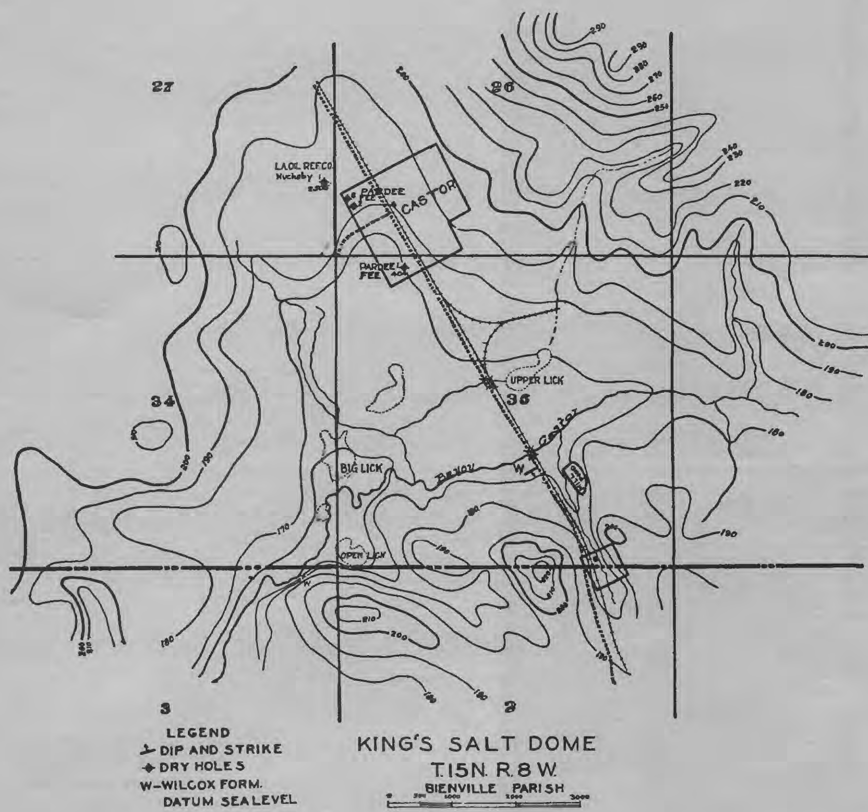


Figure 49.--Well location map, Kings dome area. From Spooner (1926, fig. 13).

CEDAR CREEK DOME: Winn Parish, Louisiana (figs. 50-52, 54)

DEPTH TO CAPROCK: 500 feet

DEPTH TO SALT: 750 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Long axis is northeast-southwest. Salines indicate dome to be eight-tenths of a mile long and half a mile wide. Uplifted area has diameter of 3 miles.

DESCRIPTION OF CAPROCK: Hard, contains much pyrite; similar to caprock at Winnfield, white and gray banded calcite (Spooner, 1926). At 714 feet subsea in Pardee Co. 1 Winnfield; at 469 feet subsea in Pace Oil Co. 1 Winnfield.

DRILLING HISTORY: Three wells drilled in 1907 to 1,000 feet or more. Three wells drilled in 1914, two to 1,000 feet; caprock at 804 feet. No additional drilling on flanks (figs. 51, 52).

NEAREST POPULATION CENTER: Winnfield, 1.7 miles northwest

POPULATION: 7,000

GEOLOGIC DATA: Eocene Cook Mountain Limestone (Claiborne Group) exposed on dome. Eocene Yegua Formation (Claiborne Group) exposed in upper part of encircling hills. Amount of uplift of strata over dome estimated by Spooner (1926) from Cretaceous rocks drilled to be 3,000 feet; by Huner (1939), 2,200 feet. Eocene Cockfield Formation (Claiborne Group) at surface, underlain by Cook Mountain Limestone.

CEDAR CREEK DOME: Continued

GEOGRAPHIC DATA: See figure 50 for location of dome relative to nearby features. Flood plain of Cedar Creek is about 2,000 feet wide, contains salines and marshes, crosses dome from northeast to southwest. Elevation about 100 feet above sea level, hills on each side as much as 150 feet high. U.S. 79 crosses dome from northwest to southeast. Kansas City Southern Railroad crosses west flank of dome from northwest to southeast.

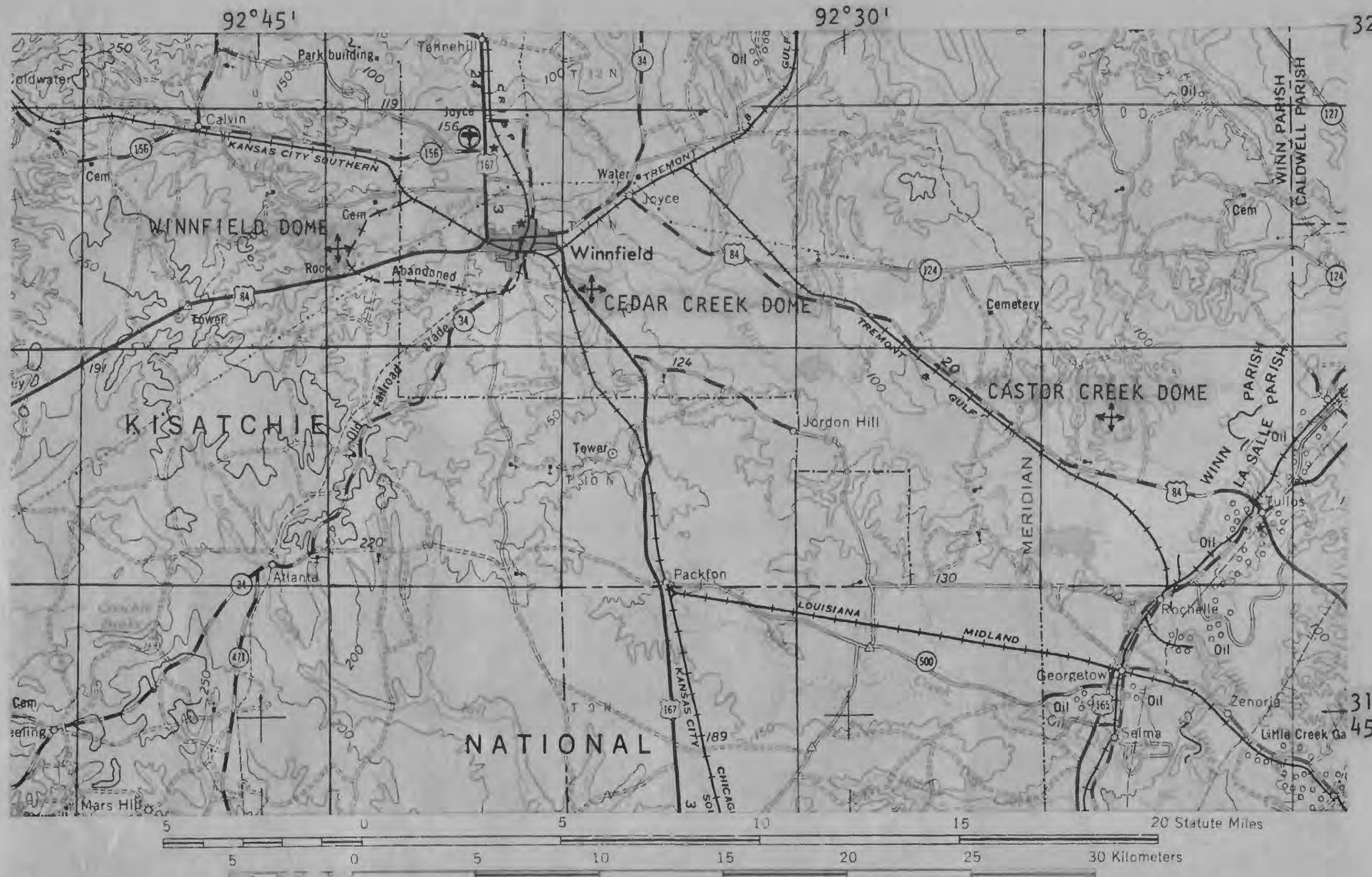


Figure 50.--Topographic map showing Winnfield, Cedar Creek, and Castor Creek domes. (U.S.A.M.S., 1:250,000, Alexandria)

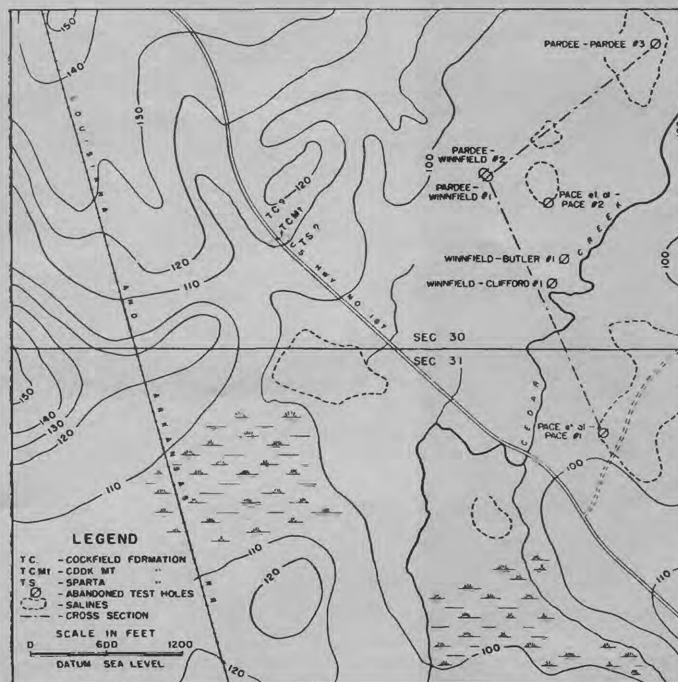


Figure 51.--Topographic map of Cedar Creek dome area. From Huner (1939, fig. 20).

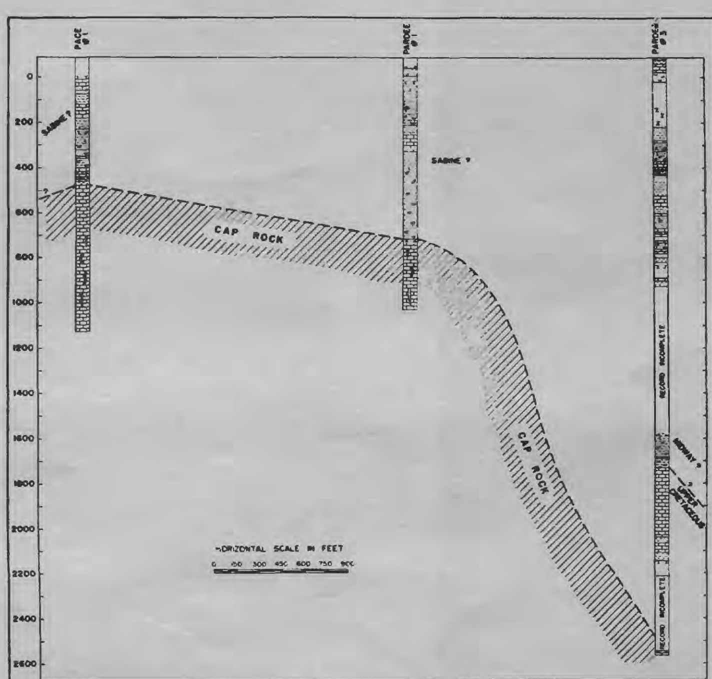


Figure 52.--Diagrammatic cross section through part of Cedar Creek dome. For location of cross section see figure 51. From Huner (1939, fig. 22).

CASTOR CREEK DOME: Winn Parish, Louisiana (figs. 50, 53)

DEPTH TO CAPROCK: Not available

DEPTH TO SALT: Not available

PRESENT ECONOMIC USE: None

NEAREST POPULATION CENTER: Tullos, Louisiana, 3.3 miles southeast

POPULATION: 600. See figure 50 for location of dome relative to nearby features and figure 53 for detailed topography of dome area.

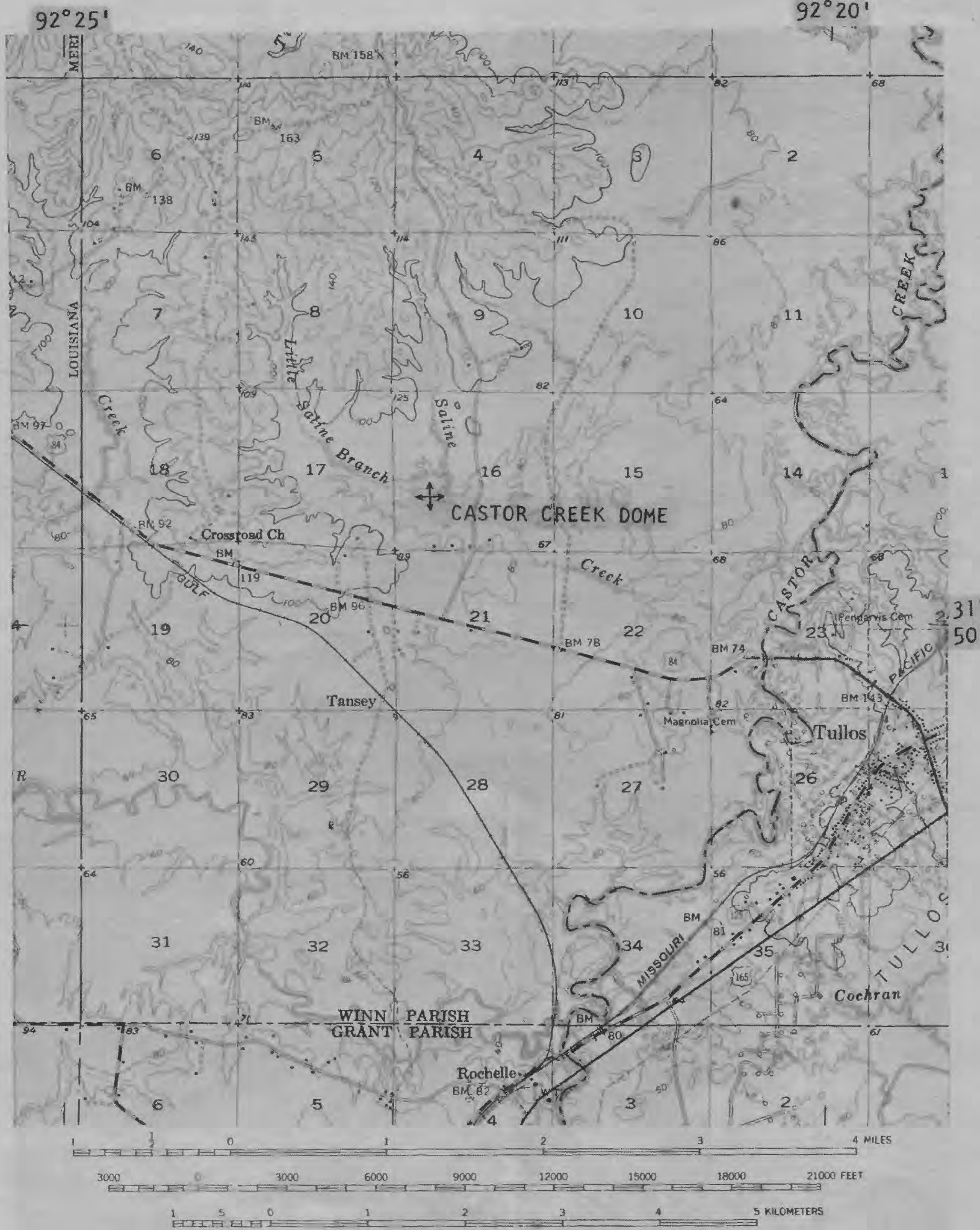


Figure 53.--Topographic map showing location of Castor Creek salt dome, Winn Parish, Louisiana. (USGS, 1:62,500, Tullos, La.)

WINNFIELD DOME: Winn Parish, Louisiana (figs. 50, 54-58)

DEPTH TO CAPROCK: 0 (Hawkins and Jirik, 1966)

DEPTH TO SALT: 200 feet (Hawkins and Jirik, 1966); 999 feet (Blanpied, 1960).

PRESENT ECONOMIC USE: Caprock is quarried.

SIZE AND SHAPE OF SALT MASS: About a mile in diameter, nearly circular. Top of salt is nearly level at 280 feet subsea. Salt is intricately folded banded halite and anhydrite.

DESCRIPTION OF CAPROCK: Calcite caprock on surface, crystalline, banded horizontally, 20-75 feet thick. Gypsum layer is 20-50 feet thick. Caprock contains some barite and sulfides. Sinkholes in caprock area. Anhydrite ranges from a few feet thick to more than 300 feet thick; contact is very irregular.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Cavity at the salt-anhydrite contact had a surface outlet: grout forced into the cavity that was made when the shaft was sunk appeared in a seepage hole in the quarry a quarter of a mile away. Large solution channels contain flowing water.

DRILLING HISTORY: In 1922, Cady Petroleum Co. 1 Southern Mineral Co. hit salt at 999 feet. In 1931, Carey Salt Co. shaft was sunk on west side of dome, struck salt at 838 feet.

NEAREST POPULATION CENTER: Winnfield, 3.5 miles east

POPULATION: 7,000

WINNFIELD DOME: Continued

GEOLOGIC DATA: Dome surrounded by Cook Mountain and Yegua Formations (Claiborne Group, upper middle Eocene). Tertiary rocks dip as much as 40° away from dome. Interstitial brine and carbon dioxide especially abundant in the salt in west and south parts of mine (near edge of salt). Stalactites formed by seepage from mine ceilings. Gas forms bubbles. These features appear chiefly after mine openings are made and tend to heal after several years. Nine holes drilled to 600 feet in floor of mine; gas and saturated brine flowed from these under high pressure (Belchic, 1960). Some gas blowouts cause breaking of thousands of tons of salt. Gas is trapped in crystalline salt at pressures of 500-1,000 atmospheres at 0° C.

HYDROLOGIC DATA: Peripheral drainage around dome. Low interior depression occupied by lake, but hills surround dome. Dome located in area of abrupt southward decrease in depth to salt water indicating that deep movement of water may be upward around dome. Fresh water in shallow aquifers known to be hydraulically connected with caprock at upper salt contact. Surface fractures were caused by subsidence after mine was abandoned in 1960's following overnight flooding that resulted from penetration of water into the shaft area.

ECONOMIC DATA: Mine opened in 1932 to 811 feet below surface; abandoned in 1960's. Quarry in caprock for limestone from 1936 to 1948, and for anhydrite and gypsum since 1951. One abandoned section of the mine was used for Project Cowboy of the Atomic Energy Commission.

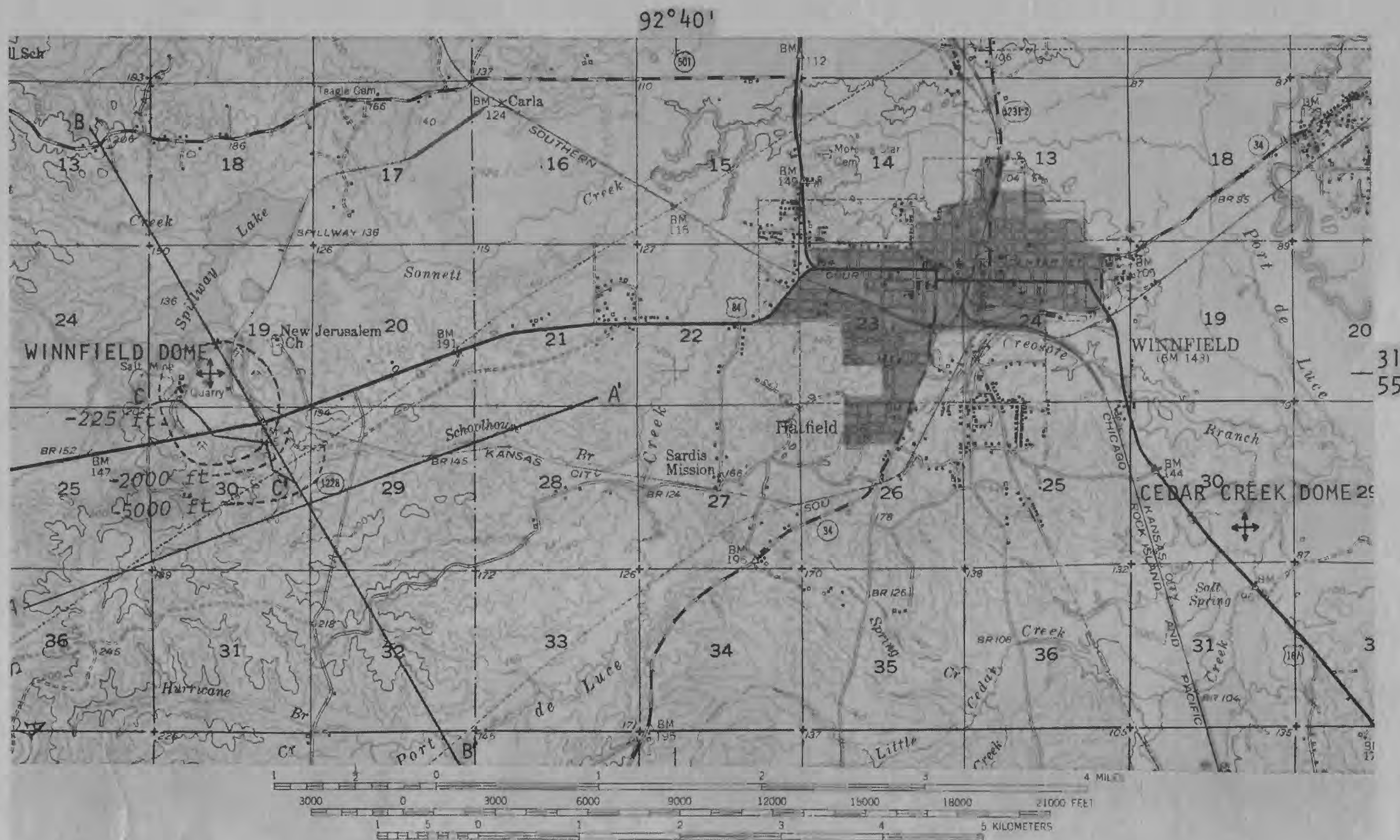


Figure 54.--Topographic map showing vicinity of Winnfield and Cedar Creek domes. Location of cross sections A and B from Huner (1939, fig. 14); location of cross section C and outlines of salt (dashed lines) from Belchic (1960, p. 42). Cross sections A and B continue beyond margins of the map. (USGS, 1:62,500, Winnfield, La.)

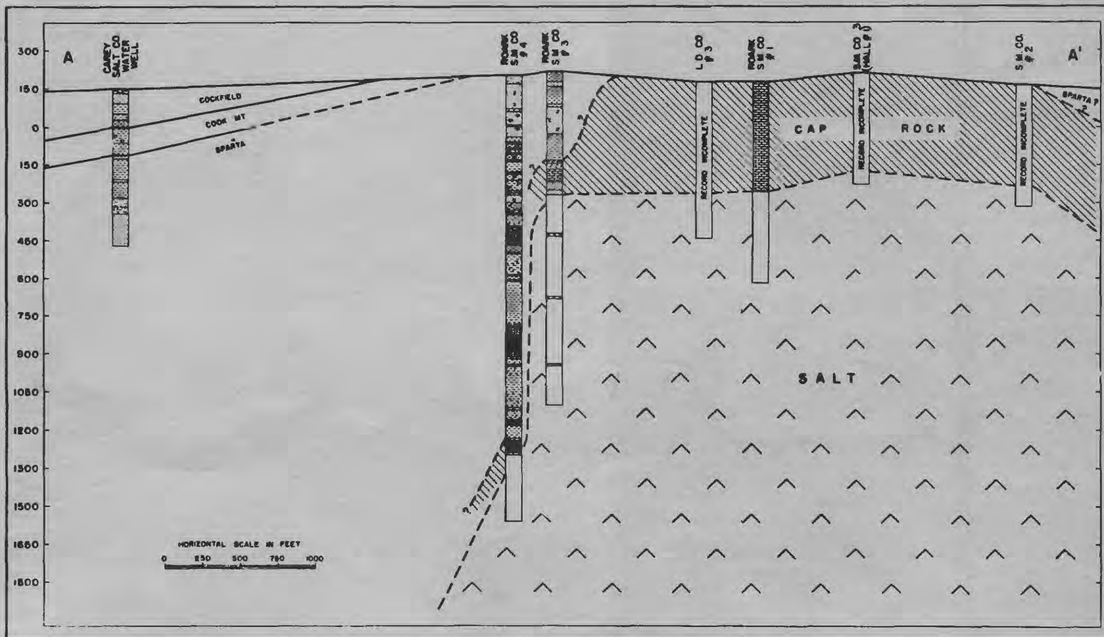


Figure 55.--Geologic cross section A-A' through Winnfield dome. For location of cross section see figure 54. From Huner (1939, fig. 11).

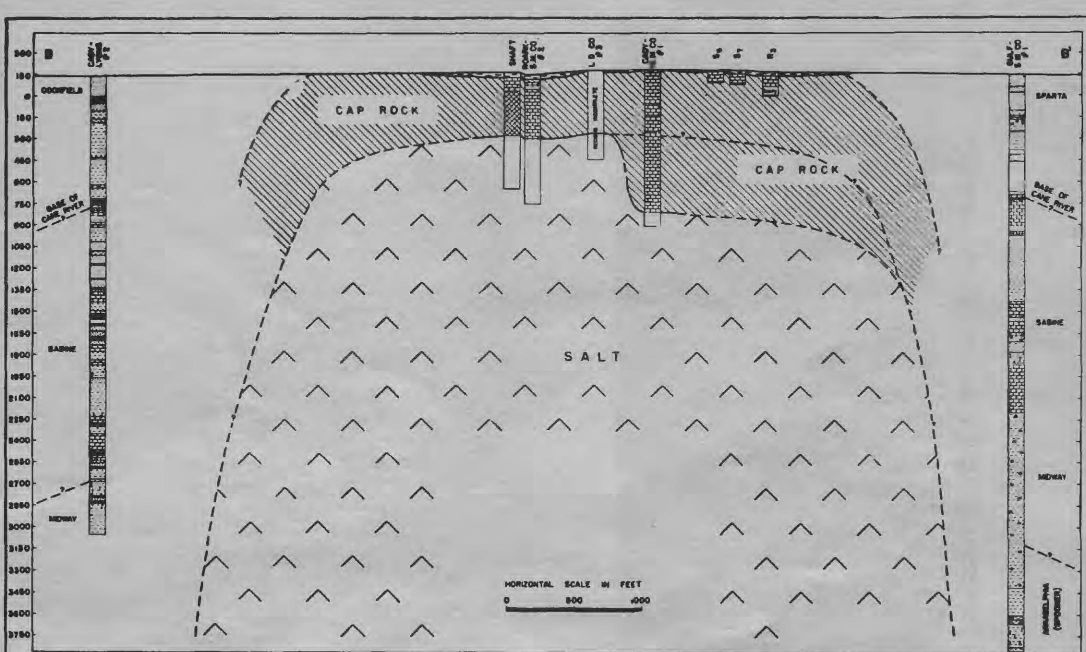


Figure 56.--Geologic cross section B-B' through Winnfield dome. For location of cross section see figure 54. From Huner (1939, fig. 12).

Figure 57.--Plan of Winnfield salt mine showing structure of salt as exposed at 811-foot level of Carey Salt Company mine. From Hoy and others (1962, fig. 5, p. 1450 and 1451).

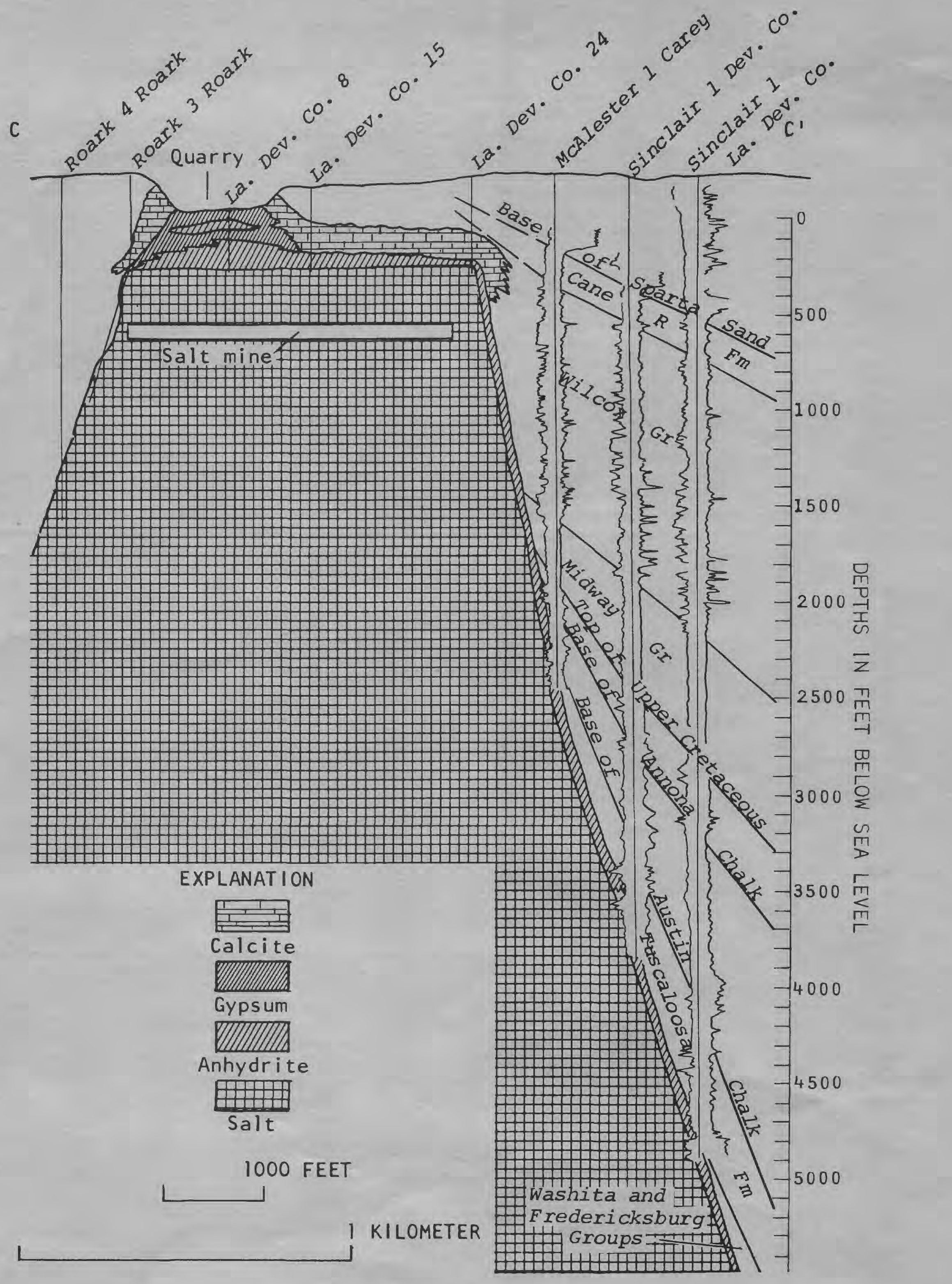


Figure 58.--Geologic cross section through Winnfield dome. From Belchic (1960, fig. 2, p. 43). For location of line of section see figure 54.

MISSISSIPPI

SALT-DOME BASIN

Index of salt domes

TATUM DOME: Lamar County, Mississippi (figs. 59-67)

DEPTH TO CAPROCK: Irregular, averages 930 feet (range: 855-962 feet). Caprock thickness range: 530 to possibly 675 feet. Surface elevations over structure range from 230 to 275 feet.

DEPTH TO SALT: About 1,460-1,605 feet, depending on surface elevations. Top of salt is 1,230 feet subsea, nearly flat.

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Measures 5,500 feet from north to south, 5,000 feet from east to west; nearly circular, except for a rounded salient projecting 500 feet to the north (fig. 60). Its surface is nearly flat (figs. 62, 67). Geophysical data show that the salt stock is nearly vertical and irregularly cylindrical and is connected with the mother bed at about 32,000 feet subsea. The stock is slightly constricted for several hundred feet (from 2,500 to 3,500 feet subsea), but expands with depth.

DESCRIPTION OF CAPROCK: Ranges in thickness from 530 to 675 feet. Zones are 1) limestone (fig. 62), 70-130 feet thick, highly cavernous, rich in strontium and water; 2) gypsum layer, a few inches to about 7 feet thick; 3) anhydrite; 60-480 feet thick, massive, solid, hard, except lower 432 feet is loose anhydrite sand. Broken by many diagonal fractures, along which are gypsum zones. Caprock overhangs the west side of the structure (fig. 62).

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Contact with overlying anhydrite caprock is sharp and nearly horizontal. Contacts on flanks are nearly vertical, presumably covered with sheath of gouge, possibly diapiric shale and(or) anhydrite.

DRILLING HISTORY: Wells drilled on the dome. The following wells penetrated the caprock or overlying beds:

Petroleum exploration (figs. 61, 62)

Willmut Oil & Gas Co. 1 Tatum (discovery well)

Sulfur exploration (figs. 61, 62)

Freeport Sulphur Co. 1, 3, 4, 5, 6, 8, 9, and 10 Tatum

Hydrologic testing (USAEC) (fig. 63)

CH-1, 2, and 3 (Caprock hydrology tests)

HT-1, 3a, 3b, 3c, 4, 4a, 4b, 5, 5a, and 5b (Aquifers above caprock)

Definition of salt (USAEC) (figs. 63, 64)

E-1, 2, 3, 4, 5, 6, 7, and 9

Coring (USAEC) (figs. 61, 62)

WP-1 and 4

Placement of atomic device (figs. 61, 62)

1-A, emplacement hole, at ground zero for Salmon event.

Instrumentation (USAEC) (figs. 61, 62)

E-11, 12, 13, 14, 15, and 16

Postshot holes (locations not available)

1) Several holes for determining cavity size and fractured zones.

2) Placement holes for post-Salmon events.

Sixteen of the wells listed above (all drilled before the Salmon event) penetrated the salt. They are:

	Hit salt at (feet)	Total depth (feet)	Salt drilled (feet)
Willmut Oil & Gas Co. 1	1503	1695	192
Freeport Sulphur Co. 1	1534	1595	61
Freeport Sulphur Co. 3	1533	1548	15
Freeport Sulphur Co. 6	1512	1554	42
Freeport Sulphur Co. 9	1503	1570	67
USAEC WP-1	1510	3510	2000
USAEC WP-4	1484	3507	2023
USAEC E-1	1510	4517	3007
USAEC E-2	1495	1690	195
USAEC E-3	1493	1549	56
USAEC E-4	1488	4524	3036
USAEC E-5	1494	3521	2027
USAEC E-6	1480	2299	819
USAEC E-7	1495	3553	2058
USAEC E-9	1494	3525	2031

Following is a description (Rawson and others, 1966) of the cavity created in the salt stock of Tatum dome by the Salmon event (fig. 65); "...a nearly spherical cavity of radius 17.4±0.6 m [meters]... Radioactive melt injected into cracks was observed as far as 37 m from the shot point, and radioactivity increased above background as far as 64 m. The wall rock was highly microfractured and contained some macrofractures. The most broken portion of the rock surrounding the cavity was observed...39 to 50 m below shot point....It is concluded that the resulting cavity is stable...however, the material surrounding the cavity is less competent than it was before the shot, and the present strength and stress distribution of the rock are not known."

Wells drilled near but not on the dome:

. . .

Petroleum exploration (figs. 61, 62)

Willmut Oil & Gas Co. 2, 3, and 4 Tatum

Humble Oil & Refining Co. 1 Hibernia

Shell Oil Co. 1 Hibernia

Plains Production Co. 1 Tatum (not on maps; near Humble 1 Hibernia)

Sulfur exploration (figs. 61, 62)

Freeport Sulphur Co. 2 and 7 Tatum

Geophysical research (Project Dibble, USAEC) (fig. 63)

E-8

Hydrologic testing (USAEC) (figs. 63, 64)

HT-1, 1a, 1b, 2, 2a, 2b, 6, 6a, 7, 7a, 7b, 8, 8a, 9, 9a, 9b, 10, 10a, 11, 11a, 12, 13, and 14

NEAREST POPULATION CENTER:		POPULATION:
	Baxterville, 4 miles south	1,000
	Purvis, 8 miles east	1,860
	Hattiesburg, 18 miles northeast	41,000

TATUM DOME: Continued

GEOLOGIC DATA: The salt spine penetrates all strata up to the base of the Miocene (fig. 62). Overlying the caprock are the following formations, not including thin local deposits of alluvium:

Age	Formation	Minimum thickness (in feet)	Maximum thickness, near flanks (in feet)
Miocene	Pascagoula and Hattiesburg, undivided. Clays and sands.	650	950 (East) 1050 (West)
Miocene(?) and Oligocene	Catahoula Sandstone. Mostly sands.	200	650 (includes some Oligocene)

The center of the rim syncline is about a mile from the edge of the salt (fig. 66). The pre-Miocene beds around the flanks of the dome are tilted and faulted, but no faults are known to cut the beds on top of the structure.

In the rim syncline the Miocene, covered by about 150 feet of gravelly sand of the Citronelle Formation (Pliocene), is about 600 feet thicker than on top of the dome. There, Tertiary beds have been drilled in normal succession down to the Claiborne Group (Eocene) at about the regional thickness.

The beds are domed up at least 400 feet from the center of the rim syncline to the crest of the dome. Holocene erosion has removed the Citronelle, which is arched upward 100-150 feet on the flanks, from the top of the structure.

HYDROLOGIC DATA: Overlying the dome, four aquifers have been defined and tested (fig. 64), and surrounding the structure are at least three additional ones, consisting chiefly of more or less calcareous sands or sandy limestones. The Miocene sands above the caprock, at depths of 100-900 feet, are loose, fine- to coarse-grained sands; some are gravelly and are prolific suppliers of fresh water. From the crest of the dome the sands dip gently away into the rim syncline about 400 feet below, and thence, regionally to the southwest. The cavernous calcareous caprock contains fresh water and is in hydraulic connection with the porous permeable Tatum Limestone Member of the Catahoula Sandstone (Oligocene(?), Miocene) (fig. 64) and with aquifers in the Vicksburg Limestone (Oligocene). Around the structure fresh water extends as deep as 2,000 feet subsea. In the normal sedimentary sequence this aquifer is confined by an overlying 350-foot clay bed that allows little transfer of saline water to the fresh-water aquifers above, in spite of a head differential of about 75 feet. Heavy use of water in Purvis and Hattiesburg, northeast of the dome (fig. 59), has reversed the normal regional gradient of ground-water movement in several of the fresh-water aquifers. The rate of water movement in most aquifers is 10 feet per year. The highest rate, 160 feet per year, was recorded for a gravelly sand several hundred feet above the caprock. Some ground water moves upward at about 100-200 gallons per minute from the Vicksburg Limestone into the calcareous caprock and the Miocene sands above. The other aquifers, separated by apparently effective clayey confining beds, do not seem to be connected.

The transmissibility of the 100-foot basal aquifer of the Miocene, tested at HT-1, northeast of the dome (figs. 61, 62, 63, 64), measured 70,000 gallons per day per foot. The upper part of the same aquifer tested at HT-2, southwest of the dome, measured 166,000 gallons per day per foot. Other aquifers measured 1,500-7,000 gallons per day per foot at HT-1, and 2,000-8,300 gallons per day per foot at HT-2.

The coefficient of permeability of the basal Miocene aquifer measured 700 gallons per day per square foot at HT-1 and more than 1,000 gallons per day per square foot at HT-2; other aquifers measured from 10 to 70 gallons per day per square foot at these sites.

GEOPHYSICAL DATA: Seismic traverses radiating for about 10,000 feet in eight directions from the caprock margins show that the salt mass is roughly cylindrical to at least 5,000 feet subsea. The upper 1,000 feet of the salt spine bulges outward. At 2,000 feet subsea its diameter is about 4,300 feet; at 3,500 feet subsea, in the narrower part of the spine, its diameter is about 3,600 feet. Below this level the spine expands gradually. The top of the mother bed (Jurassic(?) Louann Salt) is believed to be at about 25,000 feet subsea. A pre-Salmon seismic traverse made by the U.S. Geological Survey through this region puts the base of the Louann at about 30,000 feet subsea.

PROJECT DRIBBLE: Tatum dome has been used by the Department of Defense and the U. S. Atomic Energy Commission for scientific and defense purposes, including underground atomic detonation. Project Dribble of the Vela Uniform Program was concerned chiefly with the detection of underground nuclear explosions. The Salmon event of Project Dribble served to determine the effects of a coupled (tamped-in; as opposed to decoupled, set off in a cavity) nuclear device of 5 kt (kilotons) capacity (equivalent in energy released to 5,000 tons of TNT). The salt in the vicinity of the shotpoint has been contaminated by the Salmon event, but beyond 280-380 feet the condition of the rock approaches preshot status (fig. 65) (Rawson and others, 1966, p. 3516). Thus, by far the larger part of the salt stock of Tatum dome has not been affected by the Salmon explosion.

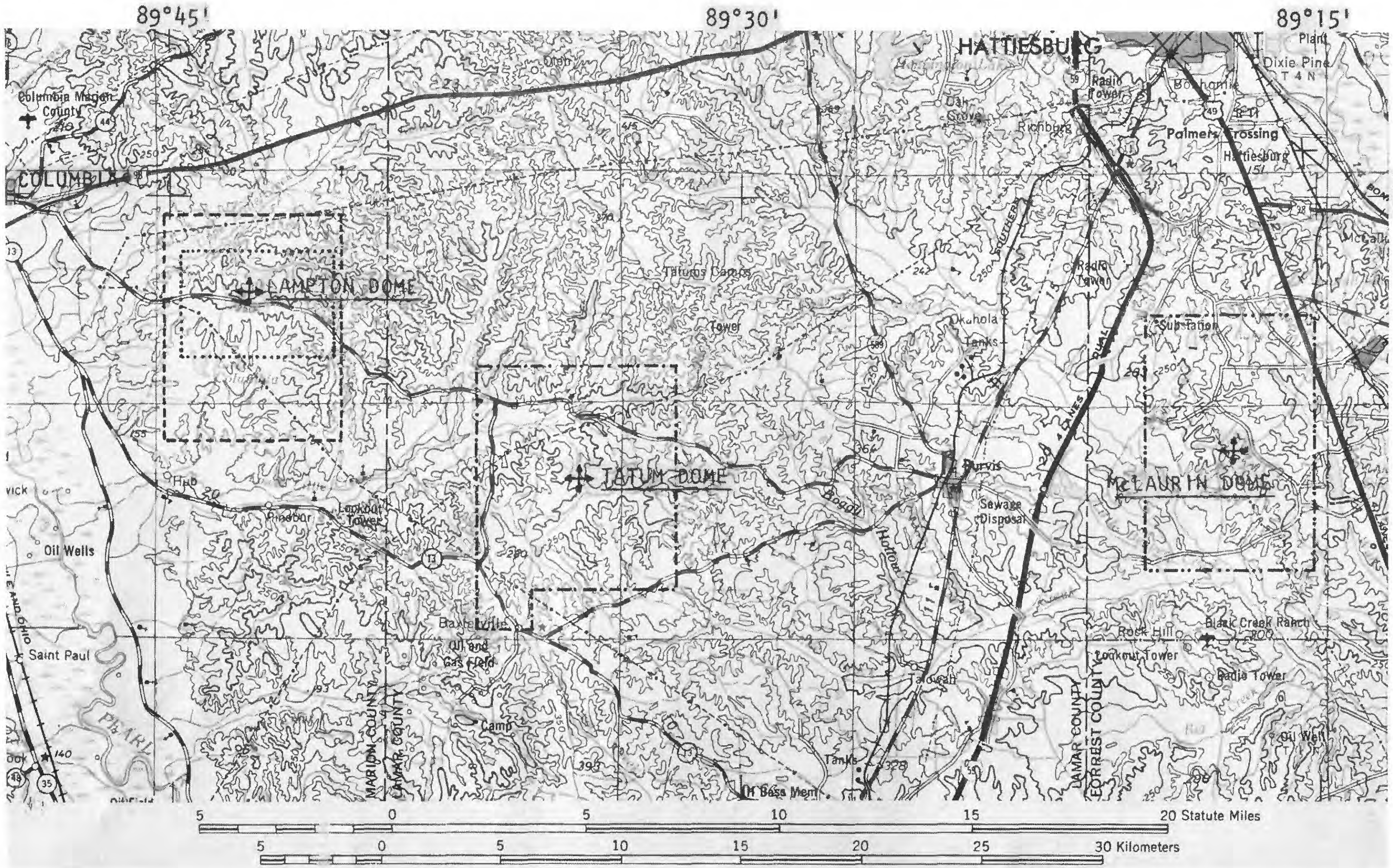


Figure 59.--Topographic map showing locations of Lampton, McLaurin, and Tatum domes.•••••••• encloses area covered on figure 68;━ ━ ━ encloses area covered on figure 68;━·━·━ encloses area covered on figure 60;━··━·· encloses area covered on figure 73. (U.S.A.M.S., 1:250,000, Hattiesburg, Miss., Ala., La.)

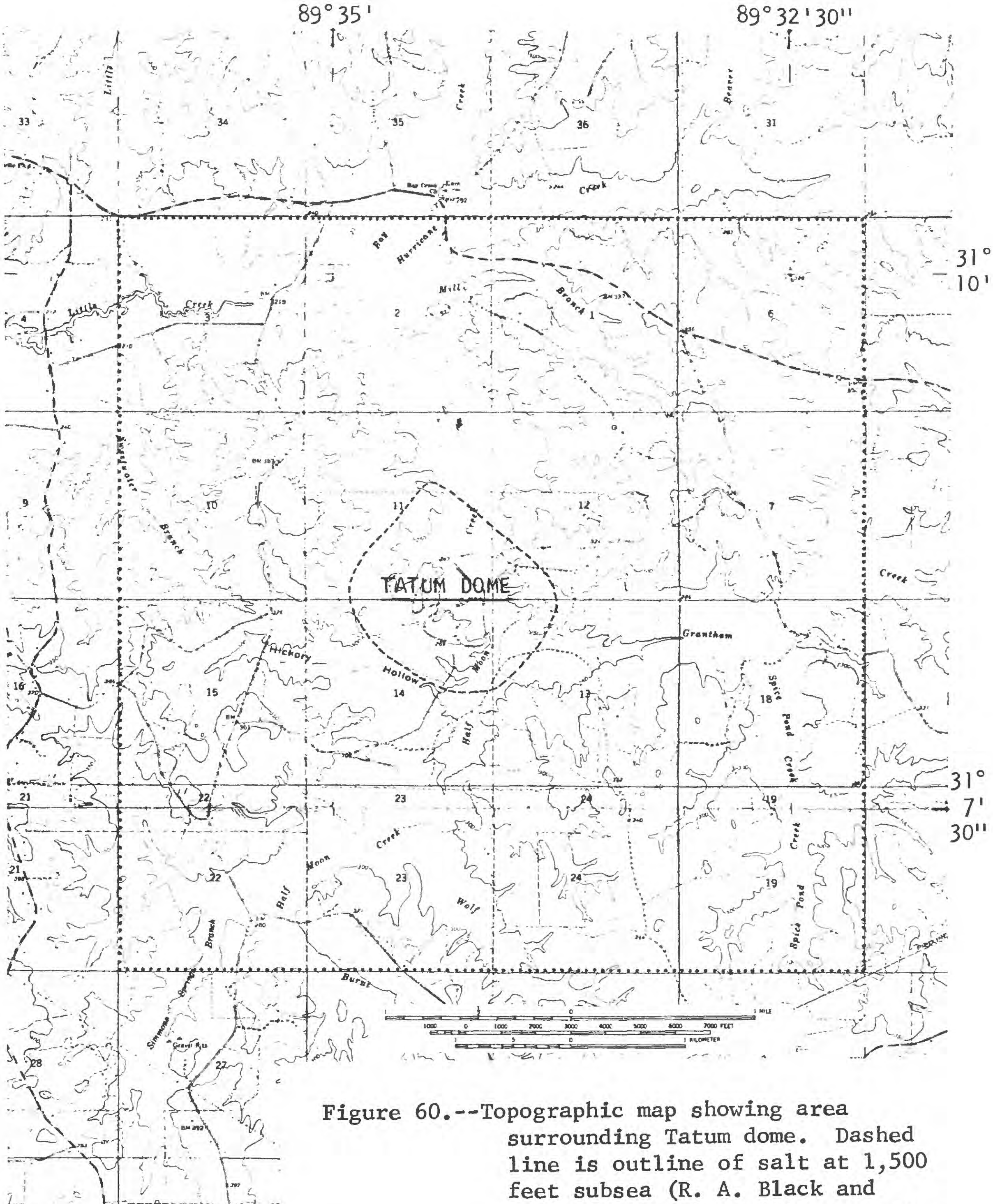
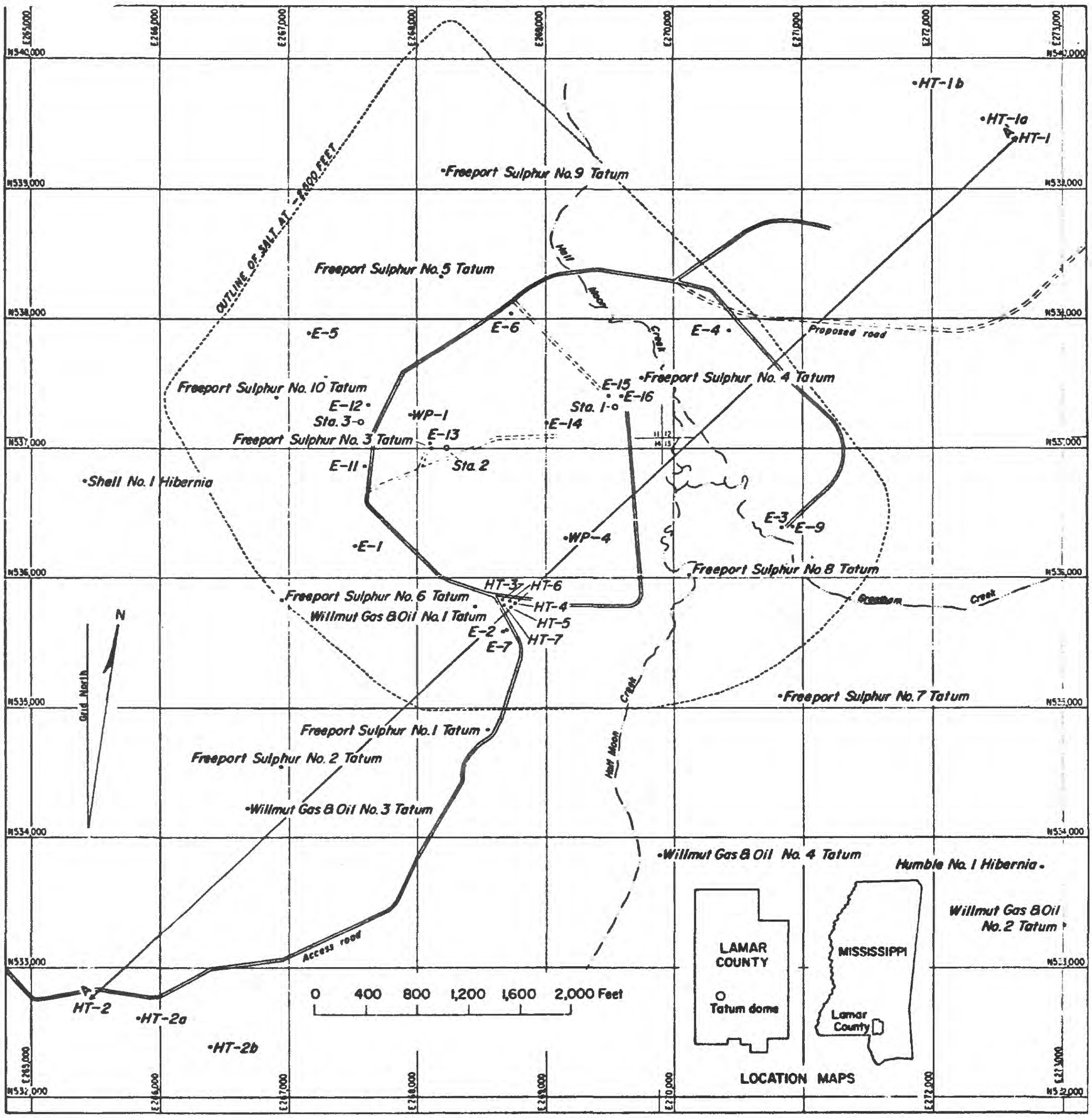


Figure 60.--Topographic map showing area surrounding Tatum dome. Dashed line is outline of salt at 1,500 feet subsea (R. A. Black and W. S. Twenhofel, written commun., 1962). Dotted line encloses area covered in subsurface map, figure 66. (USGS, 1:24,000, Baxterville NE and Baxterville, reduced in scale)

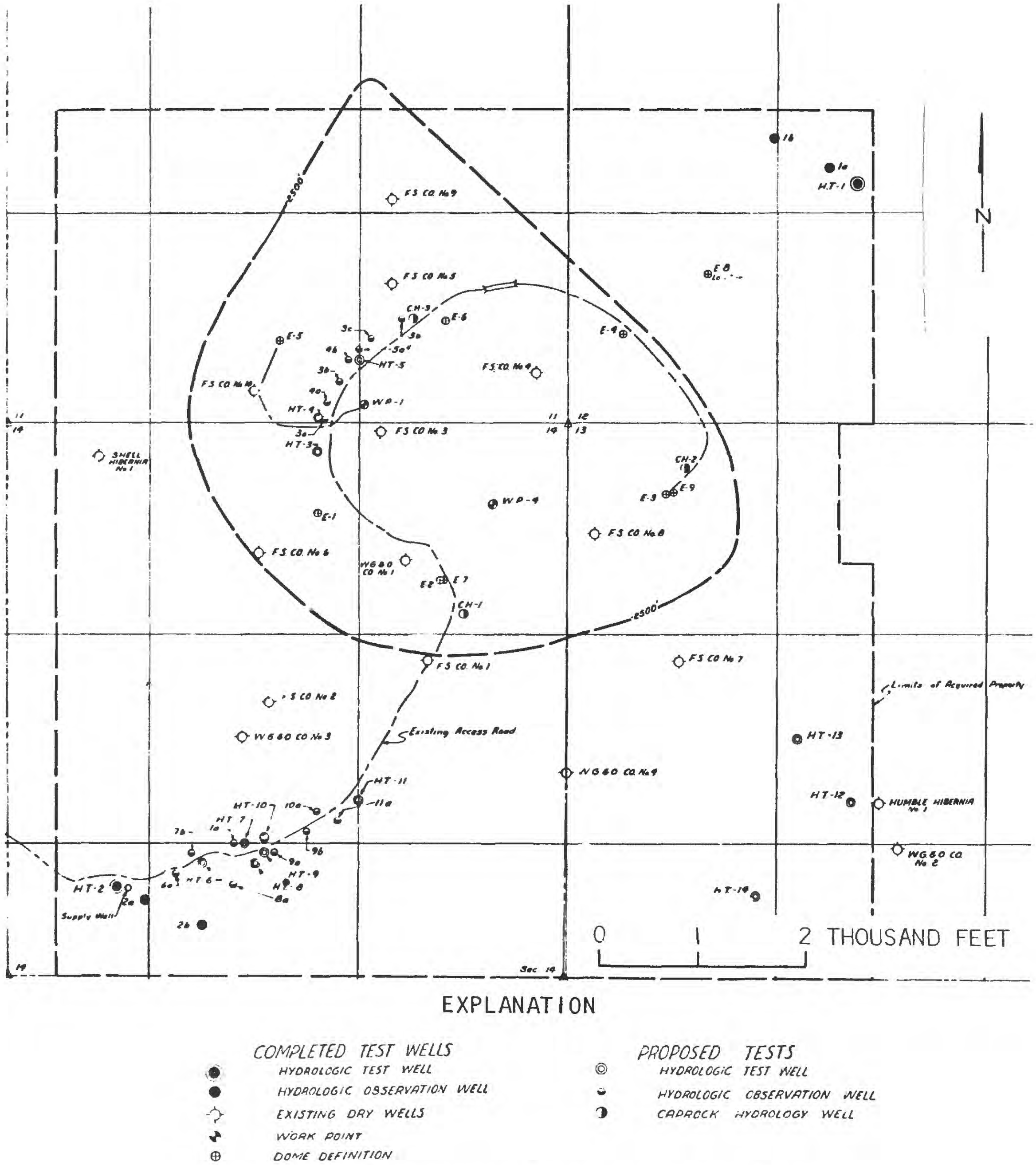


Note: Sta. 1-A, ground zero for the Salmon event, is 30 feet north of Sta. 1. Hole P.S. 1 in vertical cross section B-B' (fig. 65) is a few feet west of Sta. 1-A.

Figure 61.--Plan of Tatum dome showing cross section A-A'. From Eargle (1971, fig. 1).

This page intentionally left blank.

No page 184



Locations of proposed tests are approximate

Figure 63.--Plan of Tatum dome showing locations of test wells. From Lang (1971).

This page intentionally left blank.

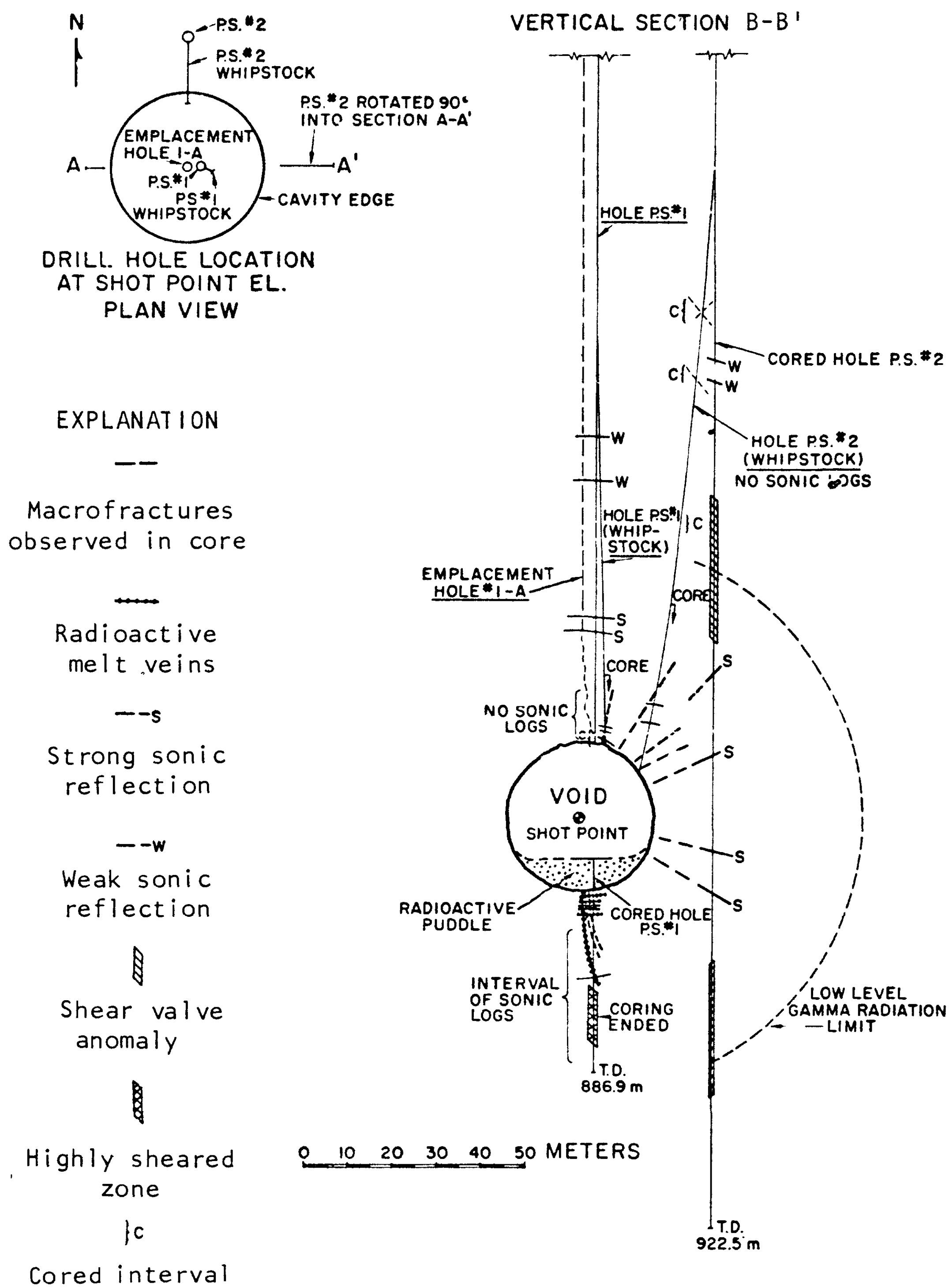


Figure 65.--Cross section B-B' showing the Salmon postshot environment, with plan view showing locations of drill holes. For location of cross section, see figure 61. From Rawson and others (1966, fig. 1, p. 3508).

(no page #189)
#188

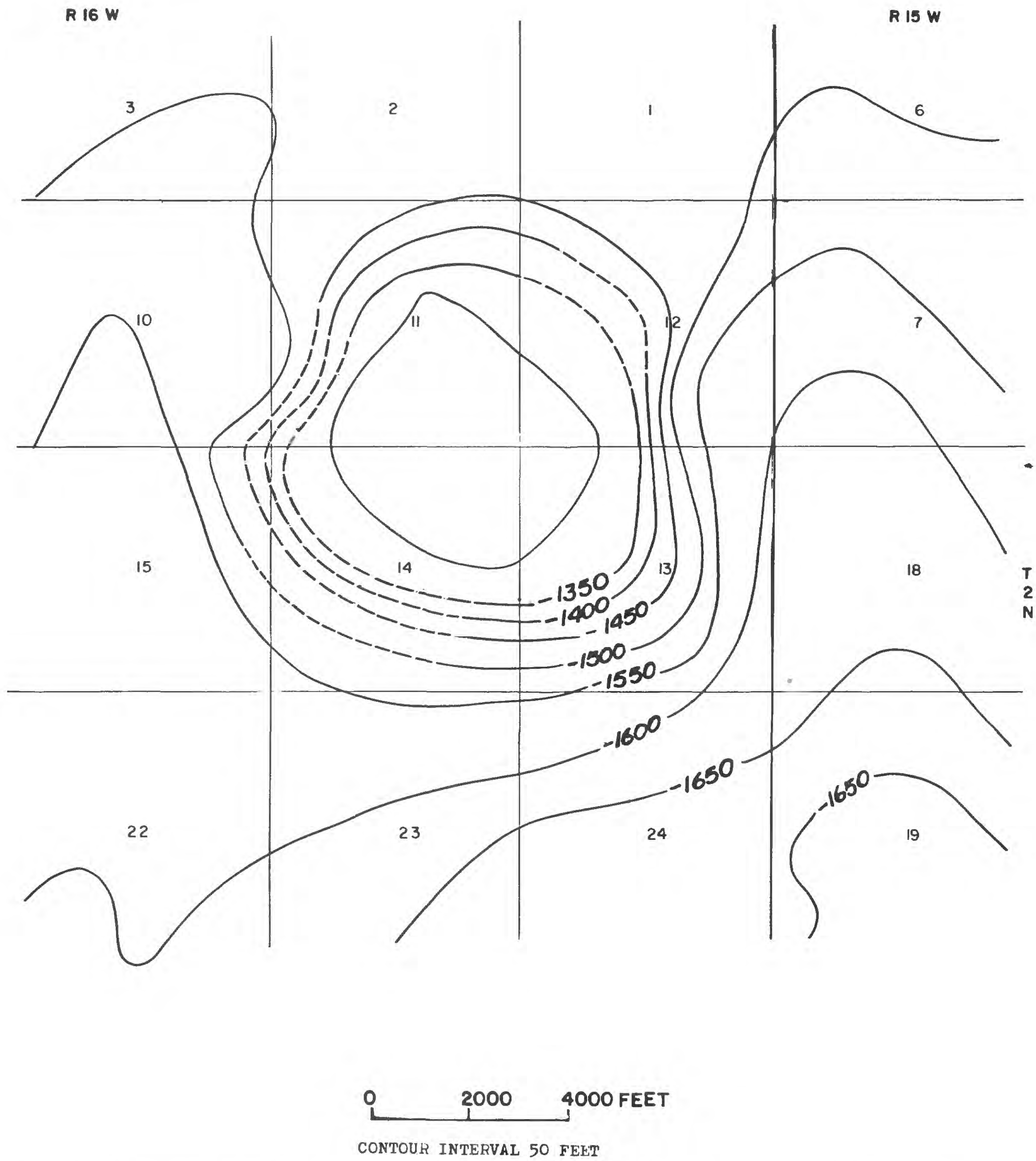


Figure 66.--Subsurface contour map of Tatum dome on the reflecting horizon in the Vicksburg Group (Oligocene), showing rim syncline and tilted beds around the dome. Structure contours interpreted from seismic data provided by Humble Oil and Refining Company. From Black and Twenhofel (1962).

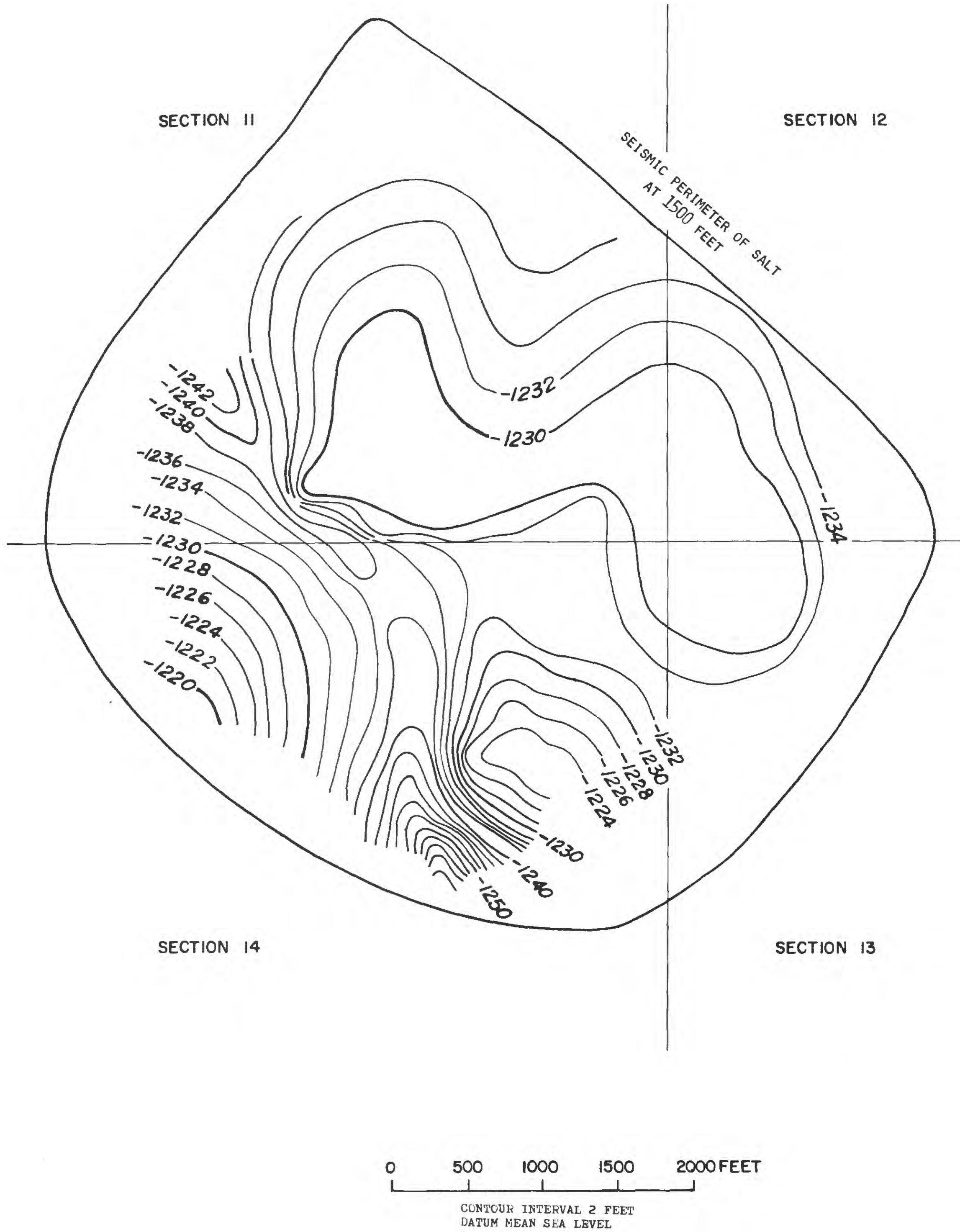


Figure 67.--Subsurface contour map of Tatum dome showing configuration of the top of the salt. (Unpublished map, USGS, Jackson, Mississippi)

LAMPTON DOME: Marion County, Mississippi (figs. 59, 68)

DEPTH TO CAPROCK: 1,305 feet in Gulf 3 Bradshaw; some reports give 1,365 feet.

DEPTH TO SALT: 1,647 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Unpublished data indicate that dome is large.

DESCRIPTION OF CAPROCK: Thickness, 342 feet (one source gives 282 feet). Electric log indicates upper 50± feet is porous (calcareous caprock?), grades down into about 90 feet of massive (anhydrite caprock?) rock.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Much shale intruded diapirically, and faulted and steeply dipping beds surround dome. Caprock has irregular surface, nearly flat contact with salt. Flank well reached salt at 5,635 feet, indicating salt flares outward with depth.

DRILLING HISTORY: Of 16 exploratory wells, eight reached caprock, two reached salt, three bottomed in sediments of Cretaceous or Tertiary age, and for three there are no data.

Gulf 4 Bradshaw (fig. 68) penetrated 1,565 feet of salt, from 5,635 to 7,200 feet.

Gulf 5 Bradshaw farther from dome than Gulf 4 Bradshaw, penetrated 94 feet of anhydrite from 6,734 to 6,828 feet (TD).

LAMPTON DOME: Continued

NEAREST POPULATION CENTER:		POPULATION:
	Columbia, 6.7 miles northwest	7,587
	Pinebur, 5.3 miles south	<1,000
	Hub, 5.1 miles south-southwest	<1,000

GEOLOGIC DATA: On the surface are sand and gravel of Citronelle Formation (Pliocene) and clay and fresh-water sands of Pascagoula and Hattiesburg Formations (Miocene). Salt has penetrated to base of Eocene Claiborne Group. Well information shows beds with steep dips and diapiric clay surrounding salt stock. Tatum Limestone Member of Catahoula Sandstone (Miocene) is the basal unit of sedimentary beds that are believed to extend across the domal structure.

HYDROLOGIC DATA: Fresh-water aquifers more than 200 feet thick occur in dome area, indicating prolific water production. In the upper 930 feet of one well, three aquifers total at least 460 feet in thickness. In nearby Tatum dome, these aquifers consist of sand and gravelly sand with high fresh-water production.

GEOPHYSICAL DATA: None available.

ECONOMIC DATA: Structure is considered nonproductive for petroleum; several unsuccessful petroleum tests drilled as deep as Lower Cretaceous; one test drilled to salt on flanks. Caprock explored for sulfur (Exploro Corporation drilled nine tests in 1944, fig. 68); no significant showings.

LAMPTON DOME: Continued

Surface of area of the structure is rolling pinewoods land with a few farms. Relief is 150 to 200 feet. Well drained, no obvious reflection of structure on surface. Country resembles Tatum dome area, 10 miles southeast.

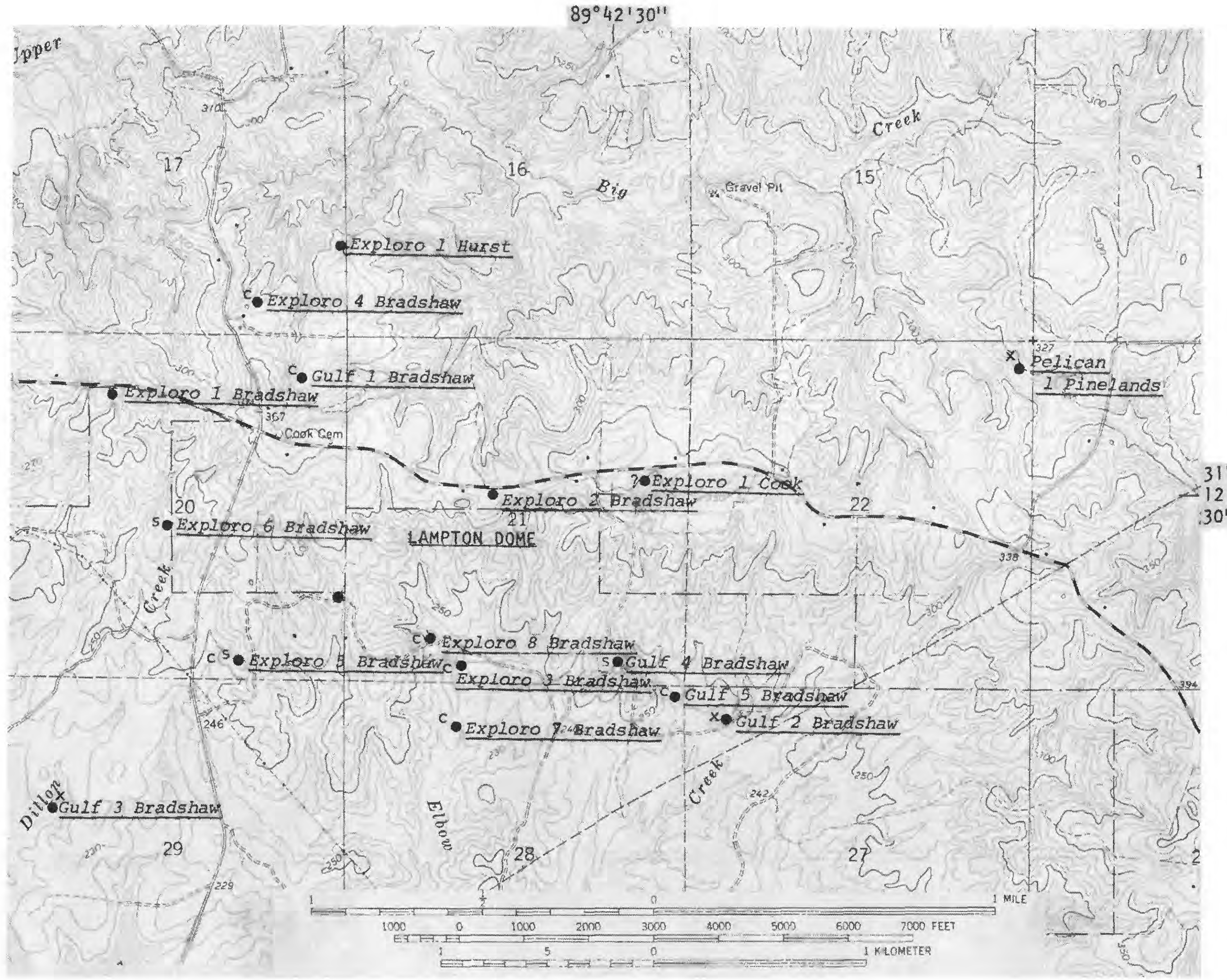


Figure 68.--Topographic map showing wells drilled in vicinity of Lampton dome. c, well reached caprock; s, well reached salt; x, well reached neither caprock nor salt. (USGS, 1:24,000, Pinebur, Miss.)

BRUINSBURG DOME: Claiborne County, Mississippi (figs. 69-72)

DEPTH TO CAPROCK: 1,629 feet

DEPTH TO SALT: Ranges from 1,881 feet to 2,236 feet

PRESENT ECONOMIC USE: A shaft for salt mining reportedly in planning stage.

SIZE AND SHAPE OF SALT MASS: Nearly circular; slightly elongate from northwest to southeast. Northwest to southeast diameter is 5,400 feet; northeast to southwest diameter is 4,800 feet. Area enclosed by the 2,000-foot subsea contour on limestone caprock is about 230 acres. Salt core estimated by U.S. Bureau of Mines (written commun., 1961) to be 8,000 feet in diameter.

DRILLING HISTORY: Four exploratory wells drilled by Sun Oil Co. on western part of the dome.

Sun Oil Co. 1 Hammett in northeast part of section 2, 1,758 feet (TD).

Sun Oil Co. 1-A Hammett just west of Sun 1 Hammett; dry-gas potential of 1.2 million cubic feet per day from Eocene Moodys Branch Limestone (Jackson Group) from 846 to 850 feet subsurface. Well had a gas blowout during coring of the Moodys Branch, but it was controlled and well was drilled to 3,599 feet subsea (TD) and abandoned as nonproductive; has been shut-in since 1944. Apparently gas came from a small fault block on west side of dome. Freeport Sulphur Co. drilled five wells on dome, all nonproductive of sulfur.

BRUINSBURG DOME: Continued

Sun Oil Co. 2 and 3 Hammett were directionally drilled beneath slight overhang on west flank of dome; Sun 2 Hammett drilled to 4,437 feet in steeply dipping Wilcox (Paleocene and Eocene) rocks. Sun 3 Hammett drilled to salt at 5,646 feet (5,545 feet subsea).

Freeport Sulphur Co. 1 Hamett drilled Miocene, Oligocene, and Eocene rocks to the Eocene Tallahatta Siltstone (Claiborne) at 1,544 feet; reached limestone caprock at 1,629 feet (penetrated 384 feet of limestone caprock); hit anhydrite at 2,013 feet, and salt at 2,063 feet; TD in salt at 2,068 feet.

Freeport 2 Hammett limestone caprock at 2,055 feet (1,970 feet subsea); salt at 2,065 feet (1,980 feet subsea); TD in salt at 2,090 feet.

Freeport 3 Hammett Claiborne at 964 feet (882 feet subsea); false caprock from 1,973 to 2,007 feet.

Freeport 4 Hammett limestone caprock at 1,802 feet (1,721 feet subsea); salt at 2,020 feet (1,939 feet subsea).

Freeport 5 Hammett Claiborne from 911 to 1,776 feet; limestone caprock at 1,776 feet (240 feet of limestone); salt at 2,016 feet (1,942 feet subsea).

NEAREST POPULATION CENTER: St. Joseph, Louisiana, 4.8 miles west-southwest

POPULATION: 2,000

BRUINSBURG DOME: Continued

GEOLOGIC DATA: Dome area is covered with alluvium of the Mississippi River and Bayou Pierre.

Early in 1961 the USAEC drilled a test to determine the suitability of the dome for experiments in decoupled atomic explosions (Project Dribble of the Vela Uniform Program). The following stratigraphic identifications were made by D. H. Eargle from geophysical logs of this well and from examination of cores: top Vicksburg Group (Oligocene), 600 feet; top Cook Mountain Limestone (Claiborne), 1,130 feet; top Sparta Sand (Claiborne), 1,200 feet; top false caprock(?), 1,750 feet; top limestone caprock, 1,770 feet; top salt, 2,040 feet (total salt drilled, 1,366 feet); TD, 3,406 feet. Underlying the Claiborne Group, slightly lower than the top of the salt, is a profound structural unconformity. The beds above the unconformity are arched slightly over the dome and are broken by at least one fault, along which gas has accumulated. The block is faulted downward toward the top of the dome and trends a few degrees west of north. Below the unconformity, rocks including beds from the Wilcox Group down to the Upper Cretaceous are tilted vertically and overturned. Directional drilling has indicated a slight overhang of the salt that projects from the top of the western flank. The eastern and southern parts of the dome are mainly unexplored (J. W. Lang, written commun., 1960, chiefly from data from the Sun Oil Co.)

BRUINSBURG DOME: Continued

The caprock of the dome is chiefly limestone; a thin layer of anhydrite has been found only on the crest of the dome. Apparently the only caprock that exists on the western crest of the dome near the faulted overlying beds is a false caprock. The false caprock consists of hard sandy limestone, brecciated limestone, calcite, and pyrite. (J. W. Lang, written commun., 1960, chiefly from data of the Sun Oil Co.).

Available drilling data indicate that the top of the salt is nearly flat, ranging from 2,000 to 2,300 feet in depth. The data are not sufficiently detailed for postulation of the configuration of the salt mass (J. W. Lang, written commun., 1960, chiefly from data from the Sun Oil Co.).

The salt is clear and free from anhydrite sand. Sodium chloride content is 99.37 percent; traces of magnesium and potassium are present.

GEOPHYSICAL DATA: The dome was discovered by gravity-meter surveys, followed by refraction seismograph work in 1941 by the Sun Oil Co. The exploration drilling for sulfur was carried out in 1944 by the Freeport Sulphur Co., and the tests for petroleum were made by the Sun Oil Co. in 1944. Directional drilling on the flanks was carried out by the Sun Oil Co. in 1946 (J. W. Lang, written commun., 1960, chiefly from data from the Sun Oil Co.).

BRUINSBURG DOME: Continued

GEOGRAPHIC DATA: Dome is apparently confined to the flood plain of Bayou Pierre, 3 miles northeast of its junction with the Mississippi River. Area is subject to flooding from the Mississippi and Bayou Pierre. Bluffs 100 feet high adjoin the dome area.

HYDROLOGIC DATA: Fresh-water aquifers in the area are 200-1,000 feet below the surface. Electric logs indicate a permeable sand 100 feet thick, about 300 feet below the surface. The aquifers could supply about 2,000 gallons per hour from four wells; however, very much larger supplies could be obtained from Bayou Pierre or the Mississippi River.

Brine could be disposed of in salt-water aquifers 1,500-3,500 feet deep that are indicated on logs of wells drilled near the dome and in oil fields 12 miles south of the dome.

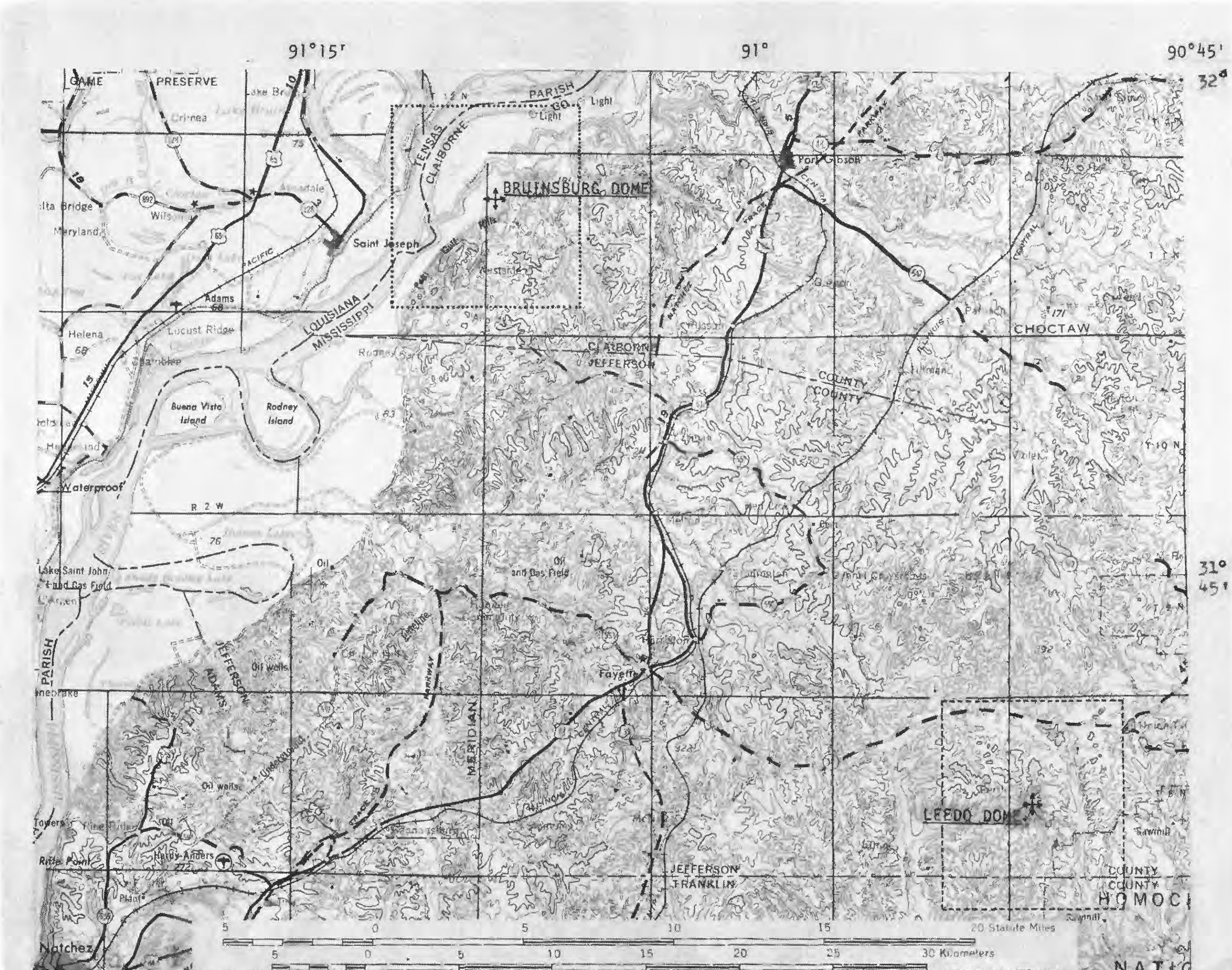


Figure 69.--Topographic map showing locations of Bruinsburg and Leedo domes. Dotted line encloses area covered by figure 70; dashed line encloses area covered by figure 74. (U.S.A.M.S., 1:250,000, Natchez)

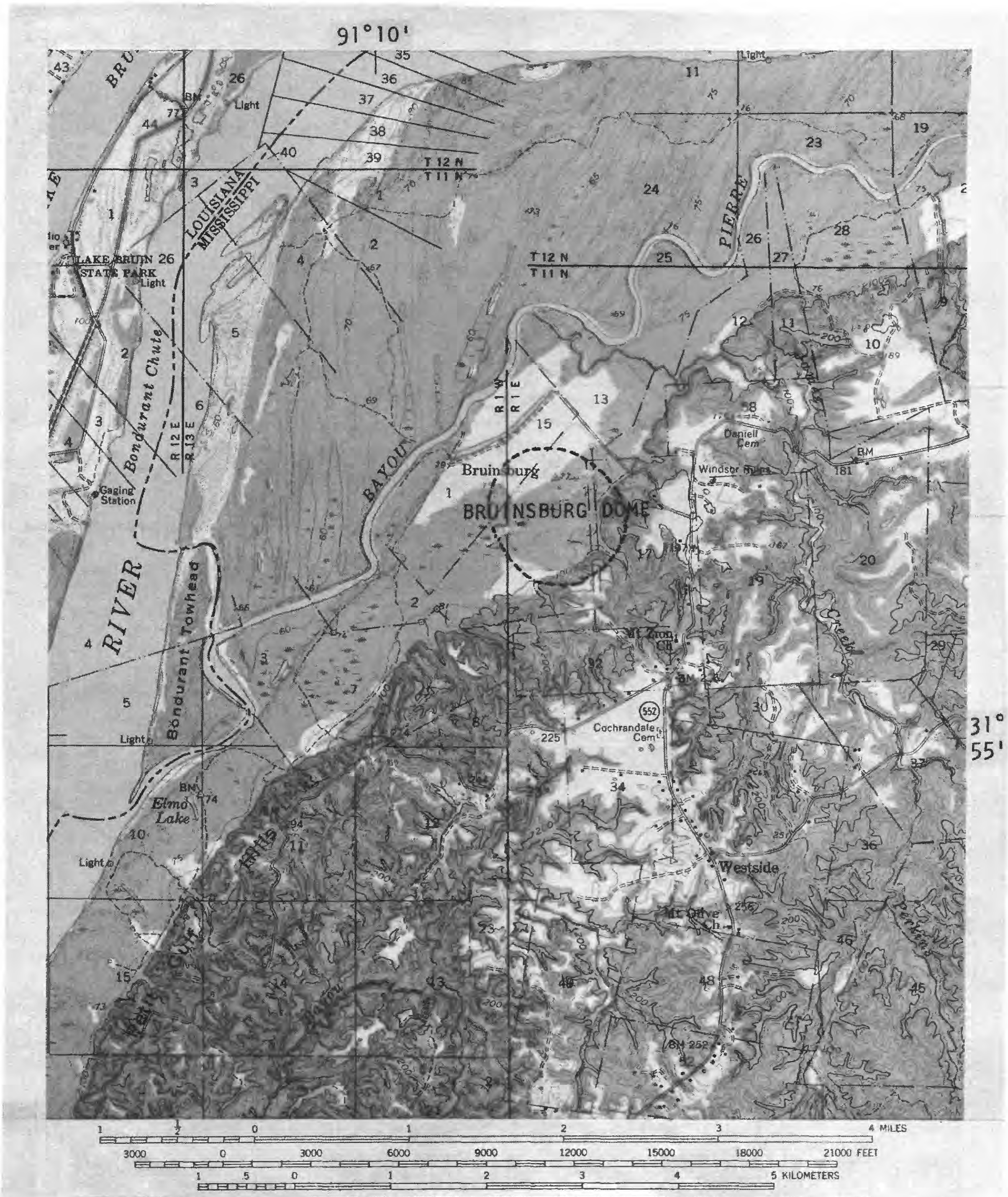
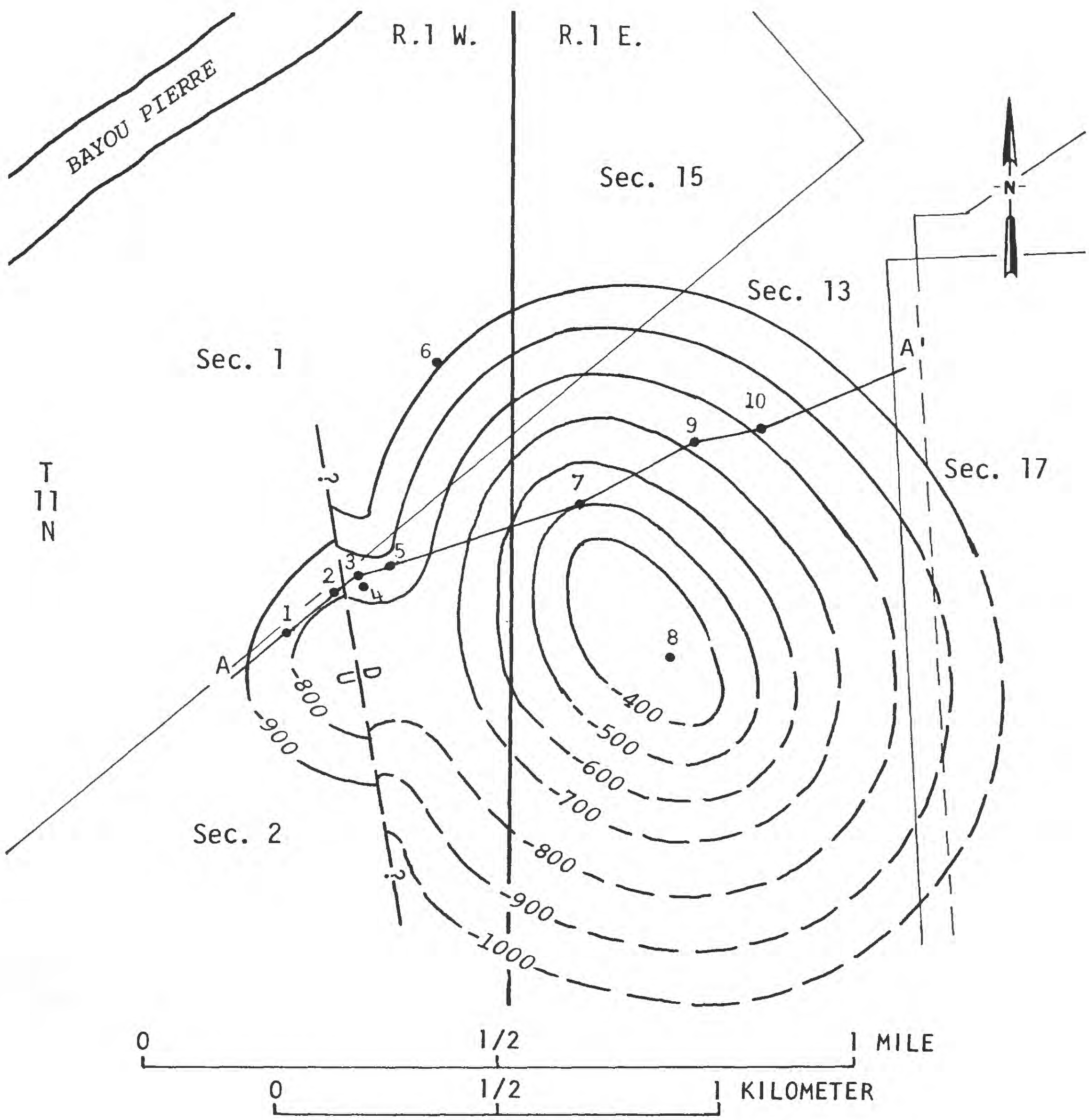


Figure 70.--Topographic map showing vicinity of Bruinsburg dome, Claiborne County, Mississippi. Dashed line shows estimated limits of salt. (USGS, 1:62,000, St. Joseph, Miss.-La.)



KEY TO WELLS

1 Sun 2 Hammett
2 Sun 3 Hammett
3 Sun 1-A Hammett
4 Sun 1 Hammett
5 Freeport Sulphur 3 Hammett
6 Freeport Sulphur 2 Hammett
7 Freeport Sulphur 1 Hammett
8 Freeport Sulphur 4 Hammett
9 AEC Test
10 Freeport Sulphur 5 Hammett

Figure 71.--Subsurface map showing contours on top of the Claiborne Group (Eocene), Bruinsburg dome (J. W. Lang, written commun., 1960).

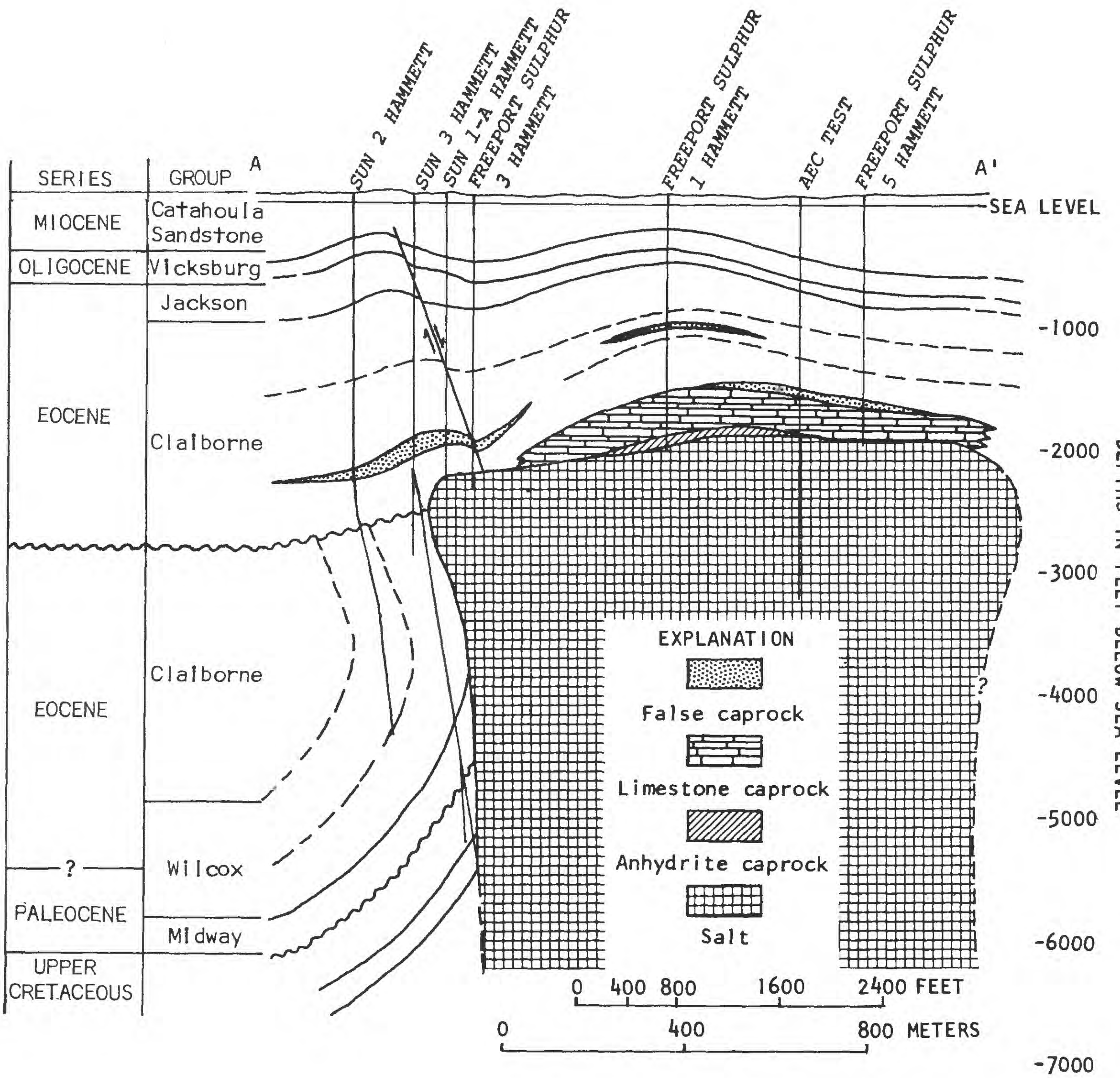


Figure 72.--Geologic cross section A-A' through Bruinsburg dome (J. W. Lang, written commun., 1960). For location of cross section, see figure 71.

McLAURIN DOME: Forrest County, Mississippi (figs. 59, 73)

DEPTH TO CAPROCK: 1,705 feet

DEPTH TO SALT: 1,930 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Unknown; salt is white according to core description, probably massive.

DESCRIPTION OF CAPROCK: Electric log indicates sharp transition from overlying sedimentary beds to presumed anhydrite caprock, with only 20± feet of calcareous caprock intervening. Anhydrite caprock 225 feet thick, chiefly massive and hard. Some penetration by ground water along fractures to 80 feet below top of caprock. Massive anhydrite interpreted to top of salt, but lower 50 feet may be softer and brine saturated.

DRILLING HISTORY: Dome discovered in June 1948.

Danciger 1 Love, discovery well; elevation 363; top salt 1,929 (scout card), salt from 1,930 to 1,981 feet, two sidewall cores and three conventional cores in salt between 1,963 and 1,981 feet; electric log run from 320 to 1,960 feet; 12 sidewall cores in sediments above caprock, six in caprock (no recovery); base fresh water 775 feet; top Eocene Ocala Limestone (Jackson Group) 1,038 feet, interbedded sand and clay; top Wilcox (Paleocene(?) and Eocene) and indurated shale caprock 1,700 feet.

McLAURIN DOME: Continued

Skelly Oil Co., Murray, and Varnado 1 Love; Elevation estimated 363; top anhydrite 1,737; top salt (from electric log) 1,933; TD 1,939; 39 feet of anhydrite and 3 feet of salt from core taken from 1,897 to 1,939 feet.

NEAREST POPULATION CENTER:		POPULATION:
	Purvis, 6.8 miles west-southwest	1,860
	McLaurin, 4.6 miles east-northeast	<1,000
	Hattiesburg, 10.5 miles north	41,000

GEOLOGIC DATA: Citronelle Formation (Pliocene), sand and gravel, about 50 feet deep, on surface. From about 50 feet to 550 feet, Pascagoula and Hattiesburg Formations (Miocene), chiefly sand (little gravel), about 10 percent clay partings. From 550 feet to 933 feet, Catahoula Sandstone (Oligocene and Miocene), Chickasawhay Limestone (Oligocene), and Vicksburg Group (Oligocene); sand, clay, and porous limestone. From 933 to 1,348 feet, Yazoo Clay (Jackson Group, Eocene), Cook Mountain Limestone (Claiborne, Eocene); sand, clay, and cavernous limestone. From 1,348 to 1,705 feet, Sparta Sand and Zilpha Clay, Winona Marl, and Tallahatta Siltstone (all Claiborne Group); chiefly clay with very little glauconitic marl. From 1,705 to 1,930 feet, caprock, chiefly massive anhydrite.

HYDROLOGIC DATA: Upper 930 feet of sediments overlying dome are fresh-water sands and sandy marls; upper 450 feet especially indicative of prolific water production; lower 480 feet less permeable, but highly productive of fresh water. Saline water zone is from 930 to

1,705 feet (top of caprock); from 930 to 1,348 feet, 50 percent clay of low porosity and 50 percent porous marly limestones, some brackish water production indicated; from 1,348 feet to the top of the caprock is mostly marine clay, with practically no water production believed possible.

GEOPHYSICAL DATA: None available. Lack of surface structure indicates that dome has been stable since Miocene time.

ECONOMIC DATA: Chiefly pine-forested land; some cultivated fields, 3 miles west of four-lane U.S. 49, 4 miles southwest of entrance to Camp Shelby, National Guard training center.

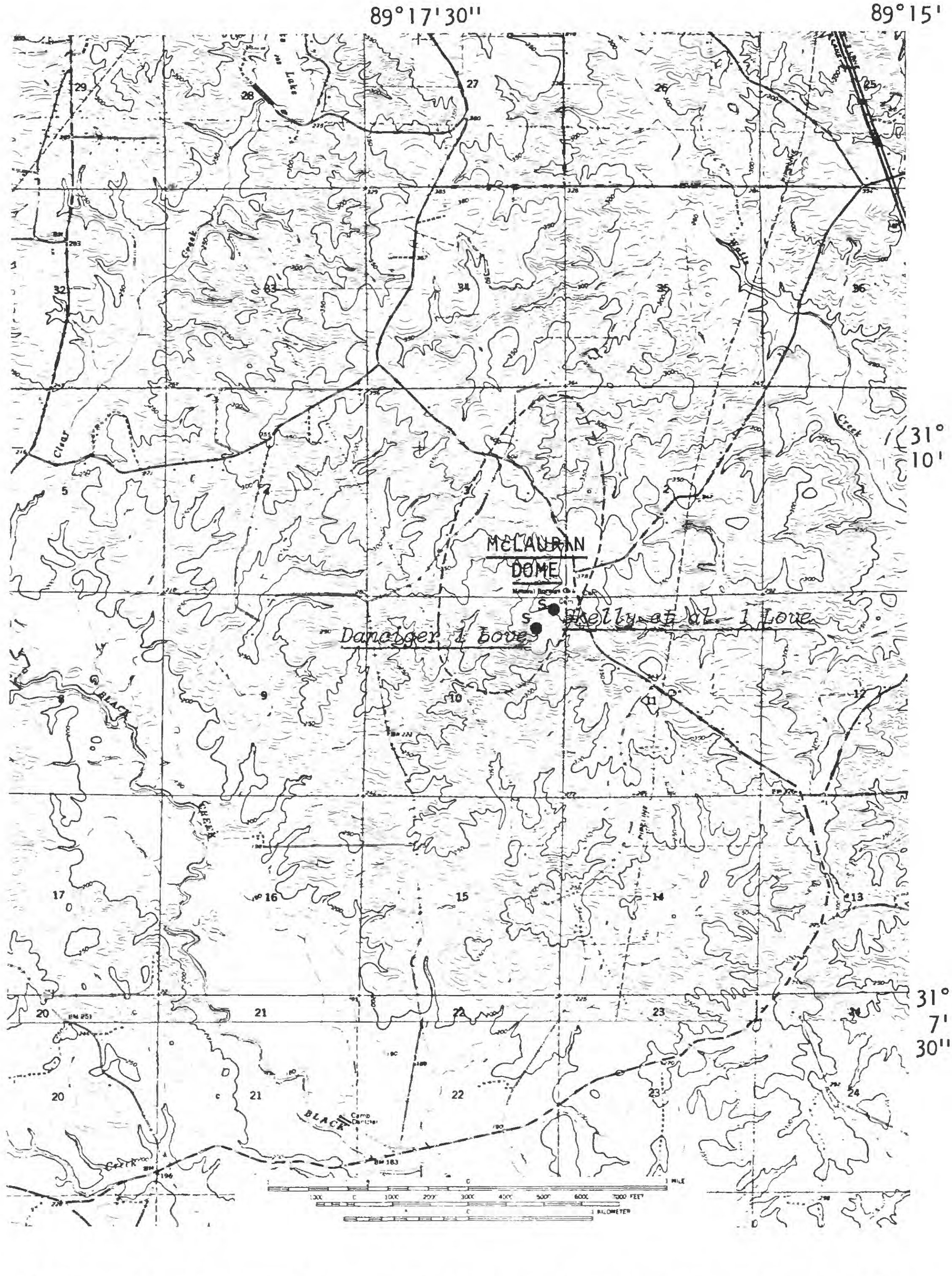


Figure 73.--Topographic map showing area surrounding McLaurin dome. Dashed line indicates limits of gravity anomaly (from oil company data). S indicates well reached salt. (USGS, 1:24,000, Dixie and Rock Hill, reduced in scale)

LEEDO DOME: Jefferson County, Mississippi (figs. 69, 74)

DEPTH TO CAPROCK: 1,359 (Hawkins and Jirik, 1966); 1,428 (Halbouty, 1967); 1,612 (Mellen, 1959).

DEPTH TO SALT: 2,065 (Hawkins and Jirik, 1966; Halbouty, 1967; Mellen, 1959).

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF CAPROCK: Drill-hole data are inadequate for reliable estimates but indicate that dome may be as much as a mile in diameter between 2,100 and 3,000 feet subsea.

DRILLING HISTORY:

Gulf 1 S. V. Cupit: Elevation 478, TD 2,071. Interbedded clay and sand to 1,609 feet; bottomed in salt; year 1943.

Gulf 2 Cato: Elevation 485; TD 8,028; top caprock 7,818; top salt 7,892; base fresh water 1,000; year 1945.

Gulf 1 Cato: Elevation 472; TD 10,920; base fresh water 990; no caprock or salt; year 1943.

Exploro 1 J. Cupit: Elevation 519; TD 2,106 in sand; top caprock 1,847 (scout card); top caprock 1,405 (D. H. Eargle, interpretation of electric log); base fresh water 570.

Exploro (Texas Gulf Sulphur Co.) 3 J. Cupit: Elevation 518; top caprock 144 (scout card); top anhydrite 2,035; base fresh water 580; TD 2,076 in anhydrite. Log indicates sediments 10-20 feet below top of caprock.

LEEDO DOME: Continued

Exploro 1 S. Cupit: Elevation 510; top caprock (limestone) 1,823; base fresh water 571; TD 2,130; year 1944.

Note: Owing to several interpretations of the locations of highly resistive sections above the definite caprock or salt points, opinions as to the elevation of the top of the caprock differ.

NEAREST POPULATION CENTER: Fayette, 7 miles northwest

POPULATION: 1,600

GEOLOGIC DATA: Surface strata are clays and sands of the Pascagoula and Hattiesburg Formations (Miocene) overlain locally by sand and gravel of Pliocene age. Stratigraphic section on edge of dome is abbreviated.

HYDROLOGIC DATA: Dome is near a drainage divide and therefore is well drained. Base of fresh water is about 520 feet deep over dome and 700-1,000 feet deep surrounding the dome.

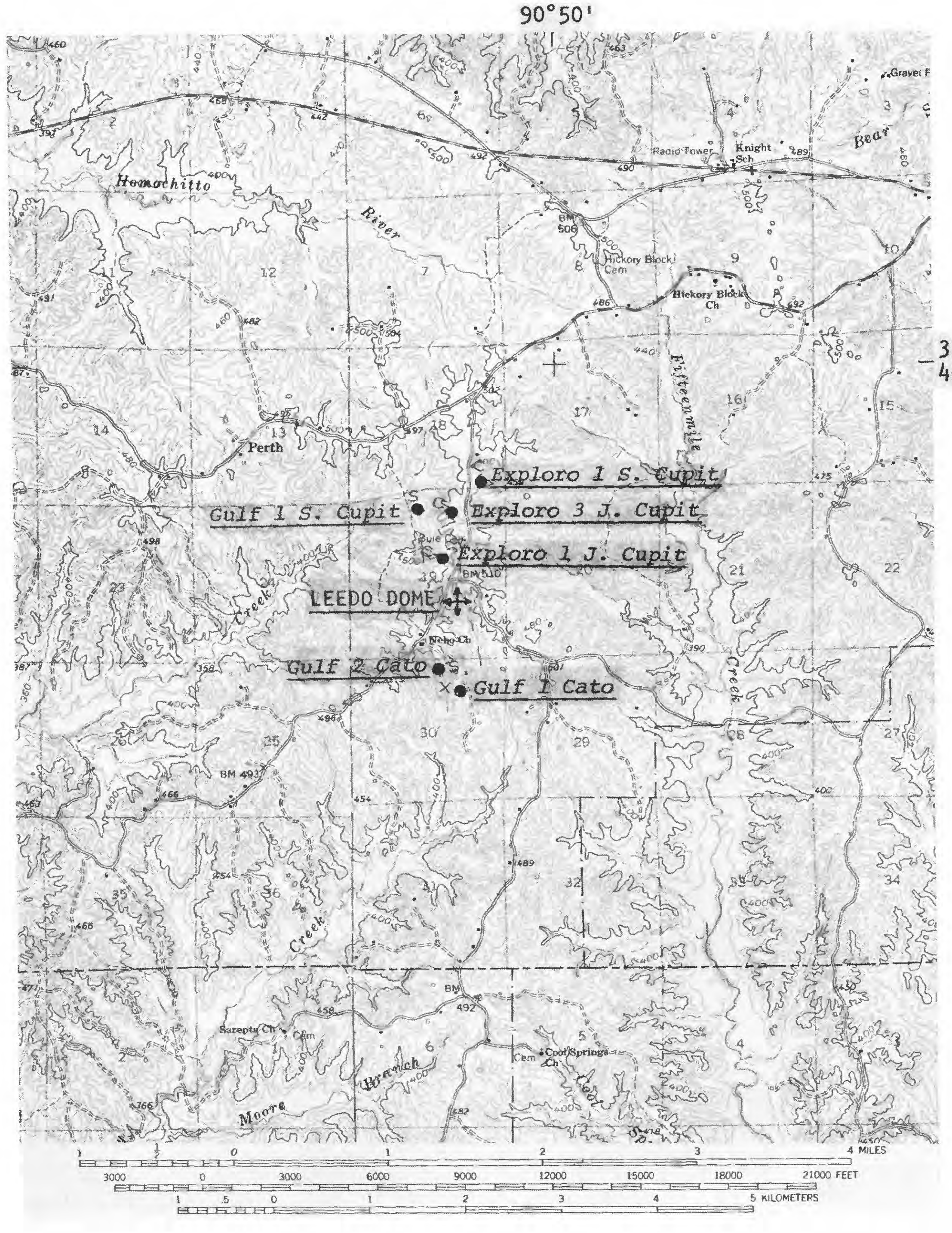


Figure 74.--Topographic map showing wells drilled in vicinity of Leedo dome. S, well reached salt; c, well reached caprock; X, well reached neither salt nor caprock. (USGS, 1:62,500, Union Church, Miss.)

RICHMOND DOME: Covington County, Mississippi (figs. 75, 76)

DEPTH TO CAPROCK: 1,910(?) in Freeport Sulphur Co. 1 Scarborough; 1,610 feet in Freeport Sulphur Co. 1 Beasley; 1,710 feet in Freeport Sulphur Co. 1 Wade.

DEPTH TO SALT: Reported at 1,954 feet in Freeport Sulphur Co. 1 Scarborough, but probably 200-300 feet shallower in vicinity of Freeport 1 Beasley.

SIZE AND SHAPE OF SALT MASS: Not known from available data.

DESCRIPTION OF CAPROCK: All data on caprock are from Freeport 1 Beasley, which penetrated 130 feet of caprock and was abandoned in anhydrite caprock. Alternating high and low resistivity on electric log of Freeport 1 Scarborough well indicates false caprock 60 feet thick, above which may be true caprock, perhaps only 44(?) feet thick if true caprock was encountered at 1,910 feet as electric log indicates.

DRILLING HISTORY:

Freeport Sulphur Co. (Exploro Corp.) 1 Beasley: Elevation 231; top Vicksburg Group (Oligocene); top caprock (discovery well) 1,609; top anhydrite 1,650; TD 1,740 in anhydrite. Electric log to 1,624 feet. Year 1944.

Freeport Sulphur Co. 1 Scarborough: Elevation 272; top broken (false) caprock 1,725; top calcareous caprock 1,842; top gypsum 1,857; top shale 1,913; TD 2,070 in salt. Year 1944. Schlumberger

RICHMOND DOME: Continued

logged to 1,910 feet; top caprock 1,918; top anhydrite 1,940; top salt 1,954. Fresh water to 800 feet, possibly to 1,050 in carbonates.

Freeport Sulphur Co. 1 Watts: Elevation 214; top caprock 1,708; top anhydrite 1,740; TD 1,808 in anhydrite.

NEAREST POPULATION CENTER:		POPULATION:
	Sumrall, 3.3 miles south	1,000
	Collins, 11.2 miles north	2,000
	Hattiesburg, 15 miles southeast	41,000

GEOLOGIC DATA: On surface is upper 400-500 feet of Pascagoula and Hattiesburg Formations, undivided (Miocene); chiefly clay, little sand. Lower Miocene and Oligocene beds beneath have fresh-water sands and limestone to about 1,200 feet. Chiefly clay to caprock, 1,610-1,910 feet, in Claiborne (Eocene). About 60 feet of false caprock indicated above true caprock in Freeport 1 Scarborough well.

HYDROLOGIC DATA: Catahoula Sandstone (Oligocene(?), Miocene(?), and Miocene) has 170-foot fresh-water aquifer. Tatum Limestone Member of the Catahoula Sandstone beneath, about 45 feet thick, is porous marly limestone; mostly porous sands and limestones from 400 to 1,200 feet; mostly impervious clays beneath to caprock.

ECONOMIC DATA: Three tests for sulfur, oil, and gas have had no showings.

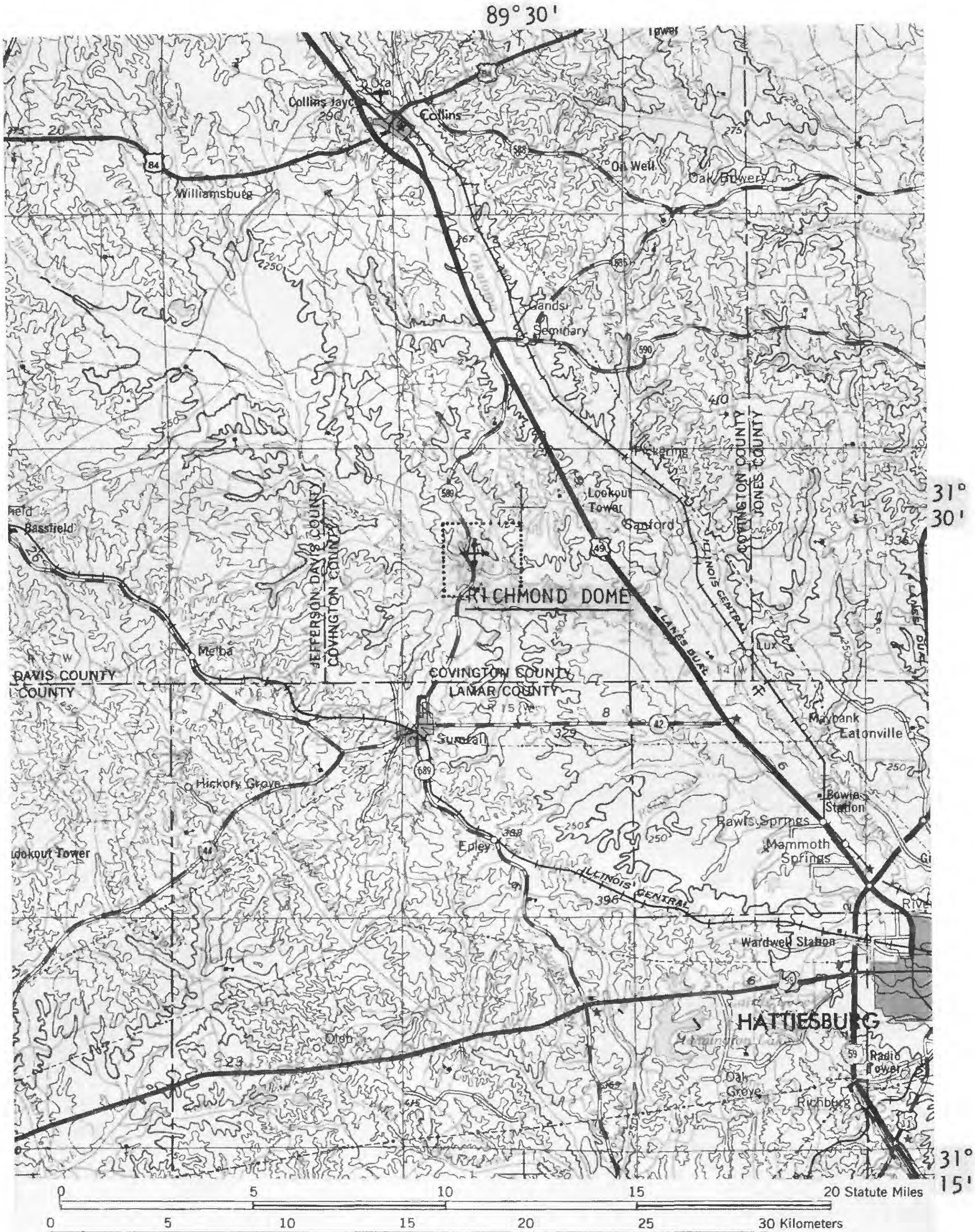


Figure 75.--Topographic map showing location of Richmond dome. Dotted line encloses area shown on figure 76. (U.S.A.M.S., 1:250,000, Hattiesburg)

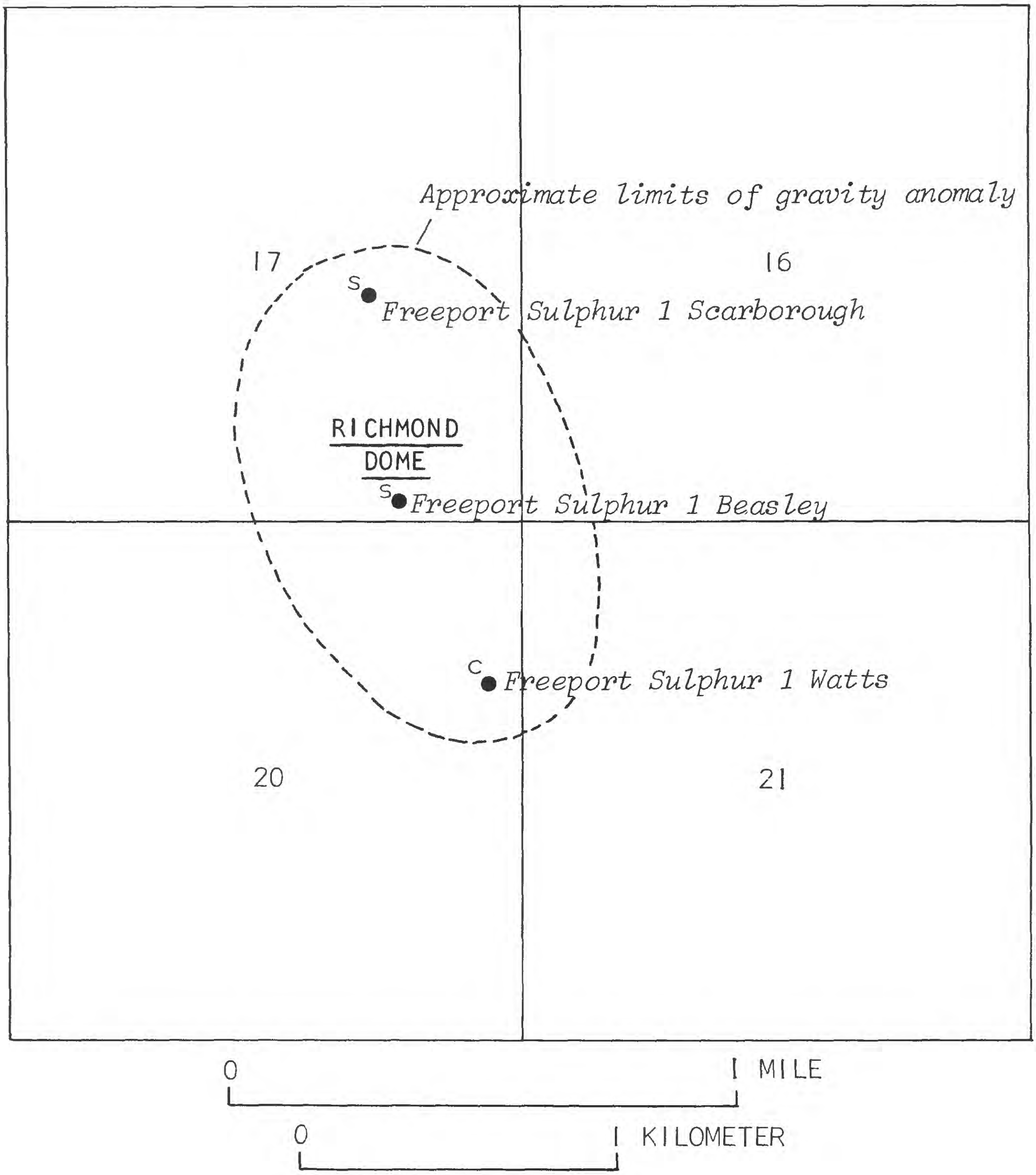


Figure 76.--Plan of Richmond dome area showing gravity anomaly (dashed line) and locations of wells drilled on the dome. s, well reached salt; c, well reached caprock. Gravity anomaly from oil company data.

ARM DOME: Lawrence County, Mississippi (figs. 77, 78)

DEPTH TO CAPROCK: 1,218 feet, 1,516 feet (Mellen, 1959); 1,412 feet (Halbouty, 1967)

DEPTH TO SALT: 1,930 feet (Mellen, 1959)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: At least 1 mile in diameter, determined by caprock wells.

DRILLING HISTORY:

Humble 1 Nelson is only well to hit salt; top salt 1,930; TD in salt, 7,625; drilled 5,695 feet of salt, probably near flank of dome; base of fresh water at 775 feet. Top caprock 1,218; gypsum 1,410-1,420; top anhydrite 1,420.

Gulf 1 Hickman, elevation 211; base fresh water 1,170 in Chickasawhay (Oligocene) (clay with thin aquifers). Aquifers as thick as 40 feet in basal Miocene above; TD 9,276.

Humble 1 Parkman interbedded sands and shales to 940 feet near base of Miocene; top Yazoo Clay at 1,200; base fresh water at 1,040 in Chickasawhay; elevation 210; TD 8,761 feet.

Sippiala 3 Nelson, elevation 196; TD 1,283; year 1946.

Sippiala 1 Sutton, elevation 195; TD 1,880; year 1946.

Sippiala 1 Foote, elevation 184; TD 1,654.

NEAREST POPULATION CENTER:		POPULATION:
	Arm, 1.6 miles northeast	<1,000
	Monticello, 6.2 miles northwest	1,800
	Prentiss, 12.5 miles northeast	1,800

ARM DOME: Continued

GEOLOGIC DATA: Surface is in center of 4-mile-wide flood plain or low terrace of Pearl River. Bedrock is clays of Pascagoula and Hattiesburg Formations (Miocene) with interbedded water-bearing sands.

HYDROLOGIC DATA: Conditions similar to Tatum structure and others of south-central Mississippi.

GEOPHYSICAL DATA: Original seismic shooting by Gulf Refining Co. Seismic work done in Humble 1 Nelson after it was drilled to 7,625 feet to select a deep flank test (Humble 1 Parkman).

OTHER DATA: Forested flood-plain surface over dome is about 10-20 feet below gage high of flood of April 1, 1949, at Monticello, 6 miles upstream. Flood-plain surface about 30 feet above Pearl River channel.

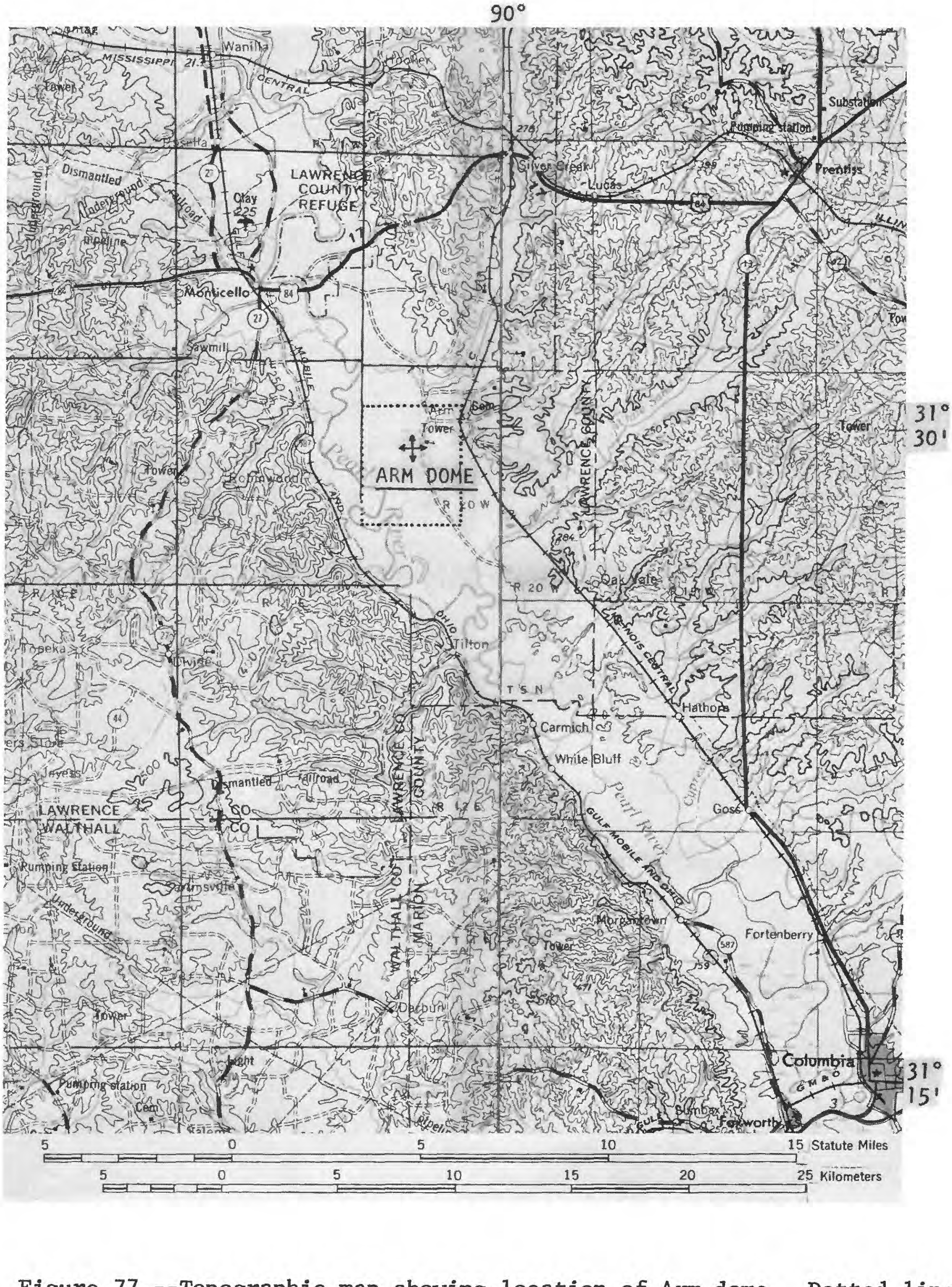


Figure 77.--Topographic map showing location of Arm dome. Dotted line encloses area covered on figure 78. (U.S.A.M.S., 1:250,000, Natchez and Hattiesburg)

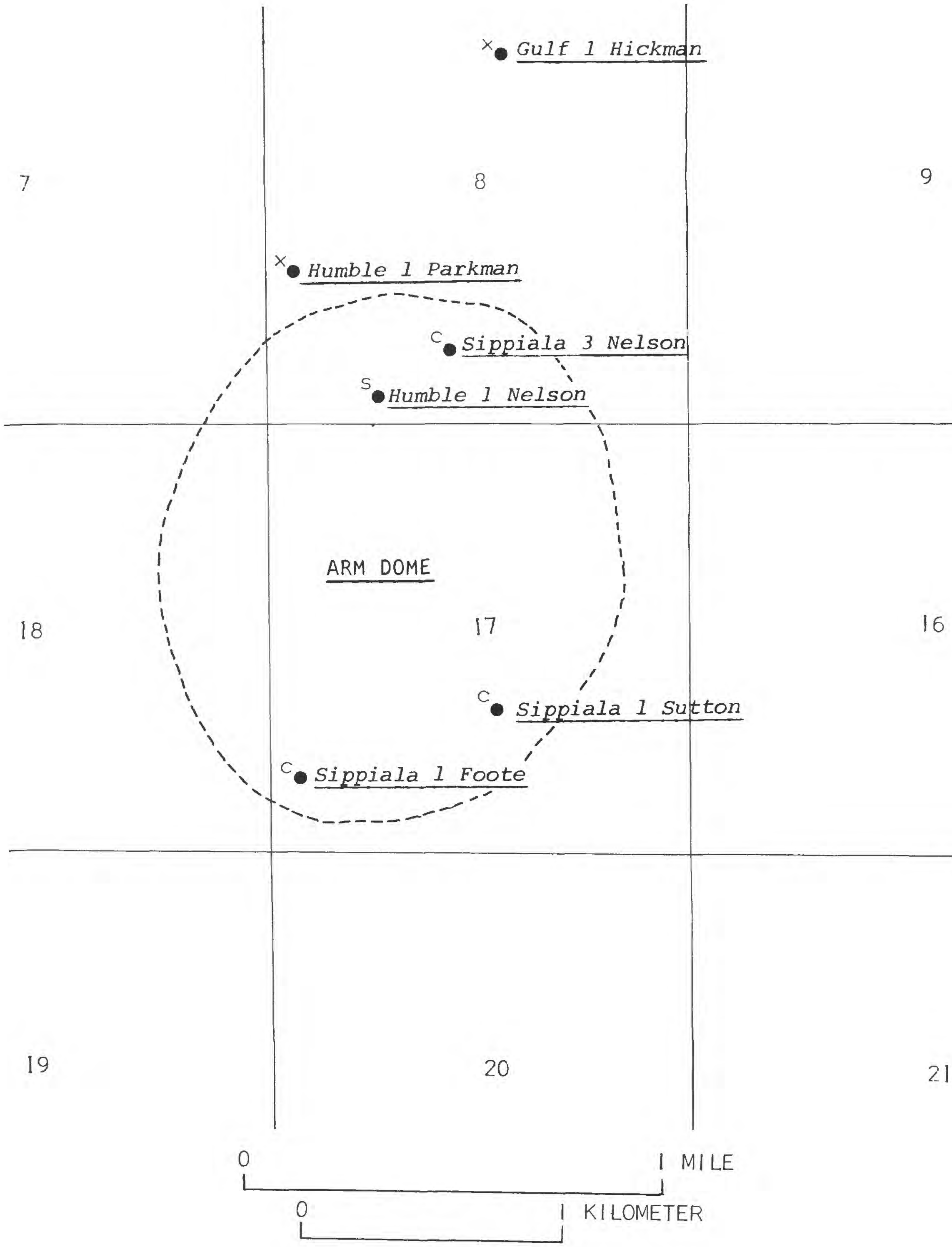


Figure 78.--Plan showing wells in vicinity of Arm dome. s, well reached salt; c, well reached caprock; x, well reached neither salt nor caprock. Dashed line shows approximate limits of caprock.

GILBERT DOME: Franklin Parish, Louisiana (figs. 79, 80)

DEPTH TO CAPROCK: 1,425

DEPTH TO SALT: 1,770. There is a difference of 2,175 feet in the elevation of the top of the salt in two wells, 2,200 feet apart, that have encountered salt.

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Little information published.

DESCRIPTION OF CAPROCK: Thickness, 345 feet in Continental 1 Sherrouse; 195 feet of anhydrite in Continental 1 Carroll.

DRILLING HISTORY:

Continental 1 Sherrouse, top salt 1,778; TD 1,839; year 1939.

Continental 1 Carroll, top salt 3,953.

Diamond B. Oil and Gas 1 J. Ernest, TD 3,460; year 1921.

NEAREST POPULATION CENTER: Winnsboro, 7 miles northwest POPULATION: 4,500

Gilbert, 3 miles southwest 500

GEOLOGIC DATA: Surficial deposit is Mississippi River alluvium, about 175 feet thick, which forms a broad terrace beneath which are sedimentary rocks of Eocene to perhaps Miocene age judged on stratigraphic information extrapolated from a map of the alluvial valley of the Mississippi River (Fisk, 1944).

OTHER DATA: Area is mostly farm land; a forested drainageway, Deer Creek, about 15 feet deep, crosses the area of the dome. Very few homes in the area of the structure or nearby. Bayou Macon, as close as 2 miles east, is a meandering sluggish stream at the western edge

GILBERT DOME: Continued

of a generally forested and swampy area that extends 25 miles eastward to the Mississippi River natural levees. The dome, however, is beneath a wide terrace 25 feet above the low-lying natural flood plain of the Mississippi (average elevation in this reach is 60 feet), and is not believed to be subject to flooding.

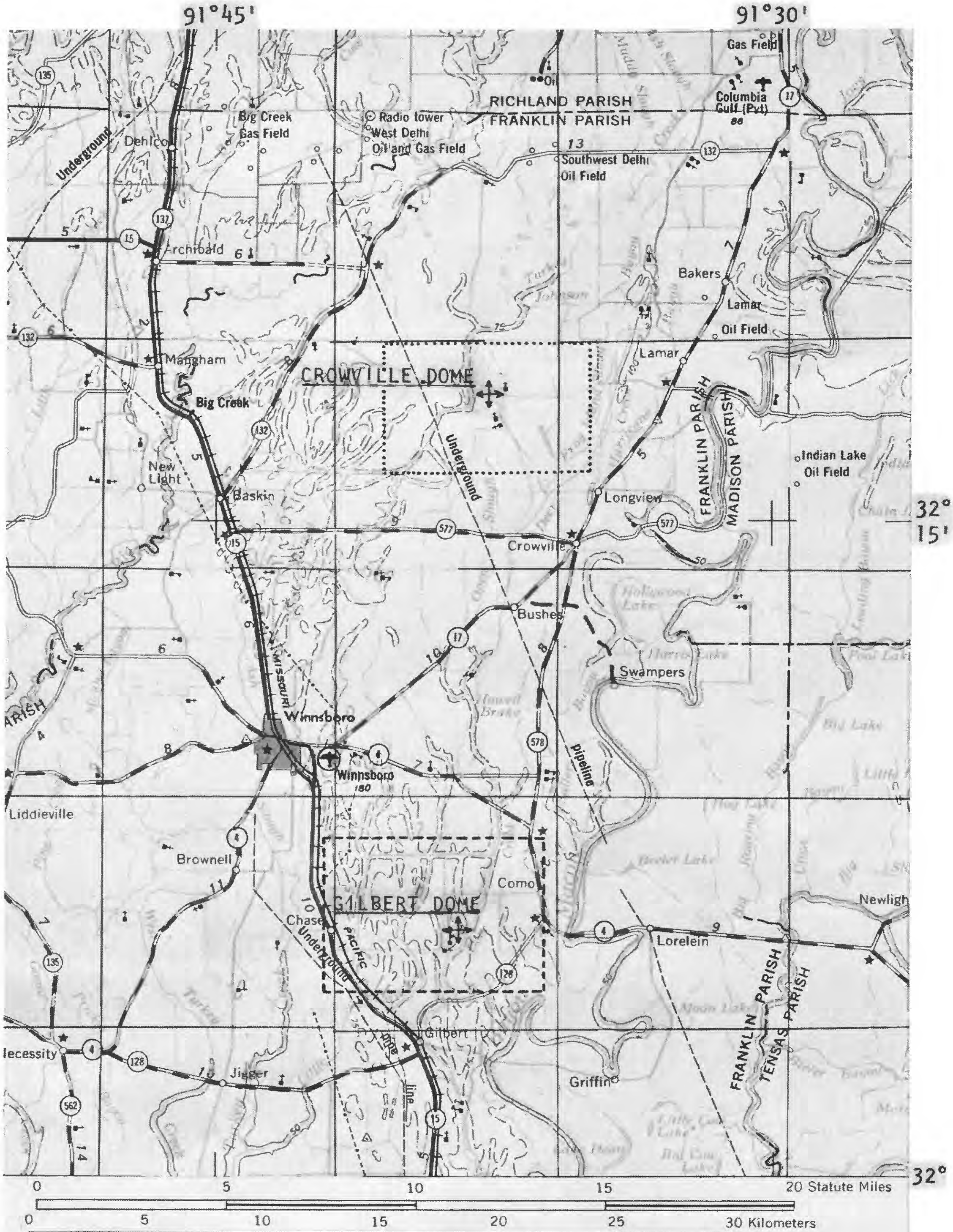


Figure 79.--Topographic map showing locations of Crowville and Gilbert domes. Dotted and dashed lines enclose areas covered in figure 80. (U.S.A.M.S., 1:250,000, Jackson)

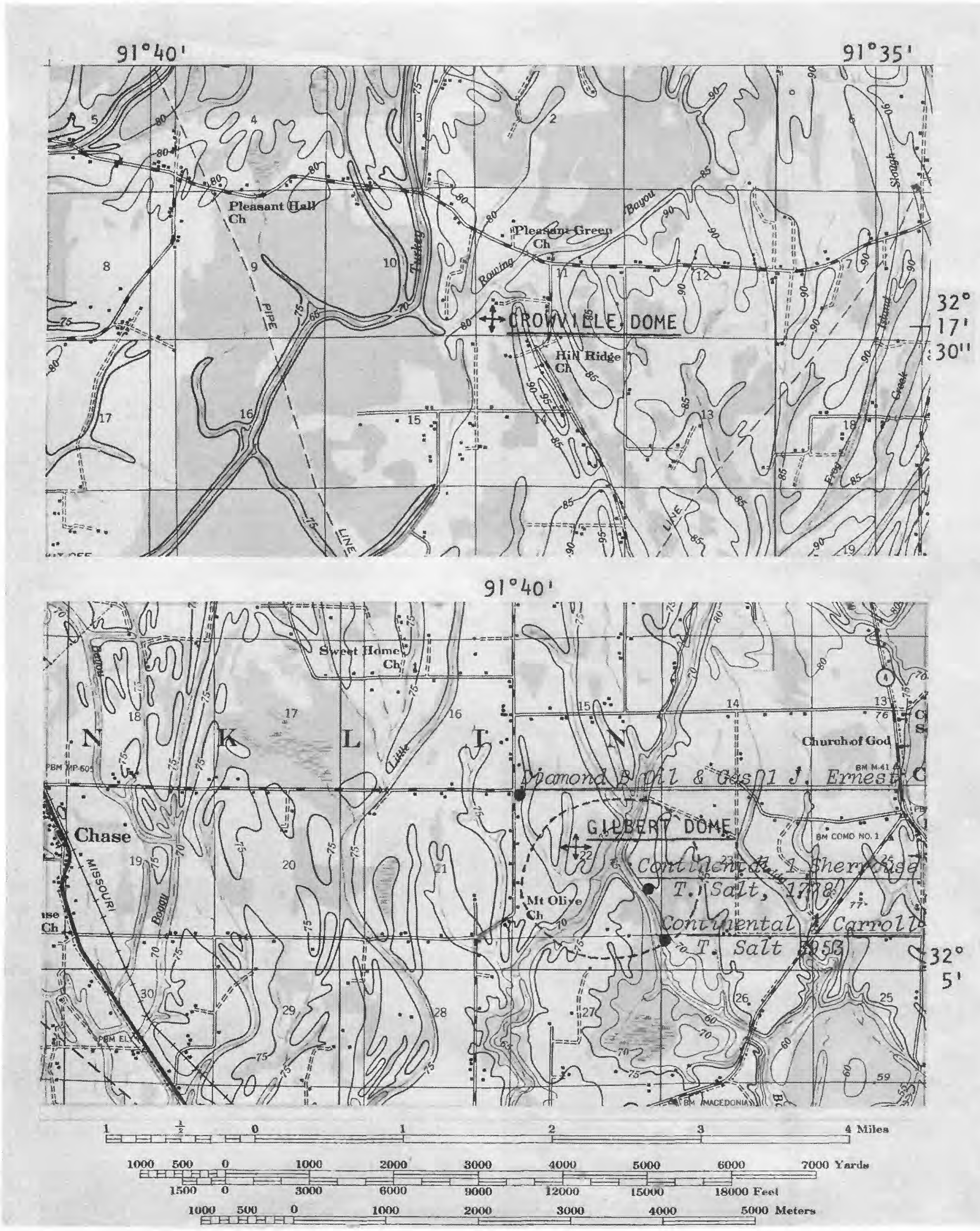


Figure 80.--Topographic maps showing Crowville (top) and Gilbert (bottom) domes. Dashed line is assumed outline of salt. (USGS, 1:62,500, Baskinton [Crowville] and Winnsboro [Gilbert])

COUNTY LINE DOME: Greene and Wayne Counties, Mississippi (figs. 81, 82)

DEPTH TO CAPROCK: 1,239 feet (Hawkins and Jirik, 1966); 1,288 (Halbouty, 1967).

DEPTH TO SALT: 2,169 feet

PRESENT ECONOMIC USE: None

DRILLING HISTORY: Sun Oil Co. 1 and 2 Gaines drilled on dome.

Sun 1 Gaines, elevation 140 feet; fresh water above 580 feet; top Jackson Group (Eocene) 590 feet; top Moodys Branch Limestone (Jackson Group) 825 feet; top Cockfield Formation (Claiborne, Eocene) 840 feet; top broken caprock 1,239 feet; top anhydrite 1,305 feet; top salt at 2,169 feet; TD 2,176 feet; shows of oil in sidewall cores from 1,085 to 1,270 feet.

Sun 2 Gaines, elevation 140 feet; fresh water above 500 feet top Moodys Branch 757 feet; top Cockfield 782 feet; top Cook Mountain 815 feet; top caprock 1,302 feet; top anhydrite 1,322 feet; TD 1,343 feet.

NEAREST POPULATION CENTER:		POPULATION:
	Leakesville, 22 miles south	900
	Waynesboro, 22 miles north-northwest	4,000
	State Line, 3 miles east	650

GEOLOGIC DATA: Beds at surface are from near top of Catahoula Sandstone (Miocene).

HYDROLOGIC DATA: Fresh water in aquifers over the dome to about 500 feet below surface. Apparently the stratigraphic section containing aquifers is greatly shortened over the dome. Miocene beds (Catahoula Sandstone) and Oligocene beds (Vicksburg Limestone) contain abundant ground water in this region.

GEOGRAPHIC DATA: State Route 42, going north to south, passes a mile east of dome. State Route 57 is 3 miles east, and U.S. Route 45 is 4 miles east. Dome is beneath flood plain and low terrace of Chickasawhay River, about 3 miles wide at about 100-150 feet above sea level.

ECONOMIC DATA: Shows of oil in beds above caprock have not led to commercial production. Surrounding country is chiefly forested, some small farms and houses near highways.

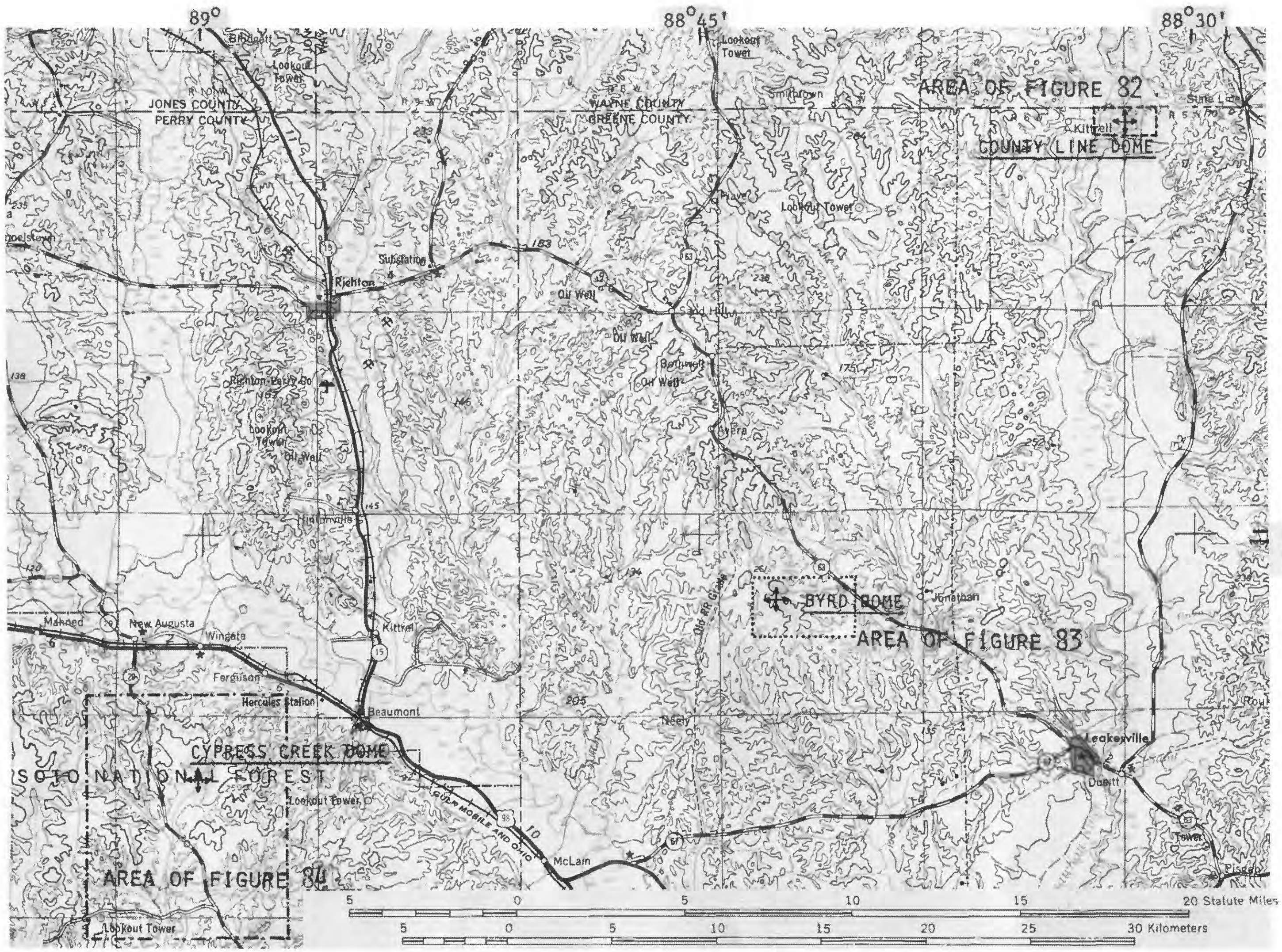


Figure 81.--Topographic map showing approximate locations of Byrd, County Line, and Cypress Creek domes. (U.S.A.M.S., 1:250,000, Hattiesburg, Miss., Ala., La.)

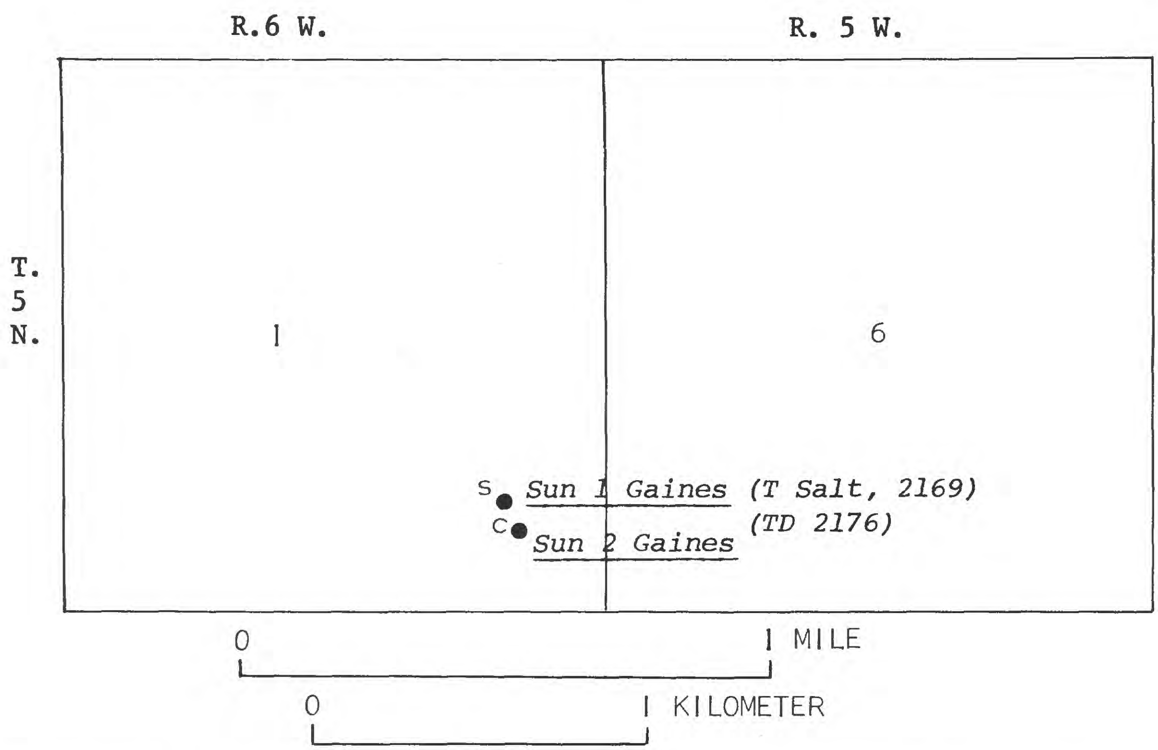


Figure 82.--Plan showing location of wells in vicinity of County Line dome. c, well reached caprock; s, well reached salt.

BYRD DOME: Greene County, Mississippi (figs. 81, 83)

DEPTH TO CAPROCK: 1,440 feet (Hawkins and Jirik, 1966)

DEPTH TO SALT: 2,058 feet

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Drilling information suggests that dome is either strongly asymmetric or is less than 1 mile in diameter between 2,000 feet and 3,000 feet subsea.

DESCRIPTION OF CAPROCK: 618 feet thick (Hawkins and Jirik, 1966); 494 feet thick (Mississippi Geological Society, 1944). Two hundred and twenty-nine feet of caprock drilled on flank, but true thickness may be less.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Flanking sheath is less than half as thick as caprock.

DRILLING HISTORY: Ten wells drilled in vicinity of dome (fig. 83).

Gulf A-1 School Land, elevation 250; top caprock 1,625; top anhydrite 1,720; top salt 2,119 feet. Mississippi Geological Society (1944) gives top caprock 1,480; lost circulation, 1,517; top anhydrite 1,530; top salt 2,058; TD 2,135 feet; year 1943.

Exploro Corporation drilled four unsuccessful tests for sulfur in 1944.

Exploro 1 School Land, elevation 244; reached anhydrite; TD 2,793 feet.

Exploro 2 School Land, reached caprock(?); TD 1,520(?).

Exploro 3 and 4 School Land; no information available.

BYRD DOME: Continued

Humble 1 School Land, TD 5,573 feet, in salt; drilled as part of seismic survey for planning of flank tests, Stover 1, 2, and 3.

Humble 1 Stover, shows faulted top of Cretaceous at 4,822 feet; top caprock at 5,620; top salt 5,849 feet. Well plugged back and whipstocked toward dome; abandoned at 6,850 feet, probably in Eutaw Formation (Upper Cretaceous).

Humble 2 Stover, drilled full section, from Miocene to Lower Cretaceous.

Humble 3 Stover; no information available.

NEAREST POPULATION CENTER: Leakesville, 10 miles southeast

POPULATION: 900

GEOLOGIC DATA: Beds at surface are from near the middle of the Pascagoula and Hattiesburg Formations, undivided (Miocene).

HYDROLOGIC DATA: Dome is located on divide between the Leaf River, 10 miles southwest, and the Chickasawhay River, 10 miles east. Both are tributaries of the Pascagoula River, principal drainage of southeastern Mississippi. Wells near Leakesville, 400-500 feet deep, flow about 600 gallons per minute per well. Saline aquifers of Eocene Cook Mountain Limestone (Claiborne Group) and Wilcox Group (Paleocene(?) and Eocene) are permeable according to electric logs (Hawkins and Jirik, 1966).

GEOPHYSICAL DATA: Geophysical study made by Gulf Oil Co. prior to their drilling Gulf 1 School Land well.

BYRD DOME: Continued

ECONOMIC DATA: Pine woods and few farms in vicinity of structure. United Gas pipeline crosses county 4 miles west of structure. Gulf, Mobile, and Ohio Railroad is 11 miles southwest. Mississippi Route 63 is 1.5 miles east of estimated center of dome.

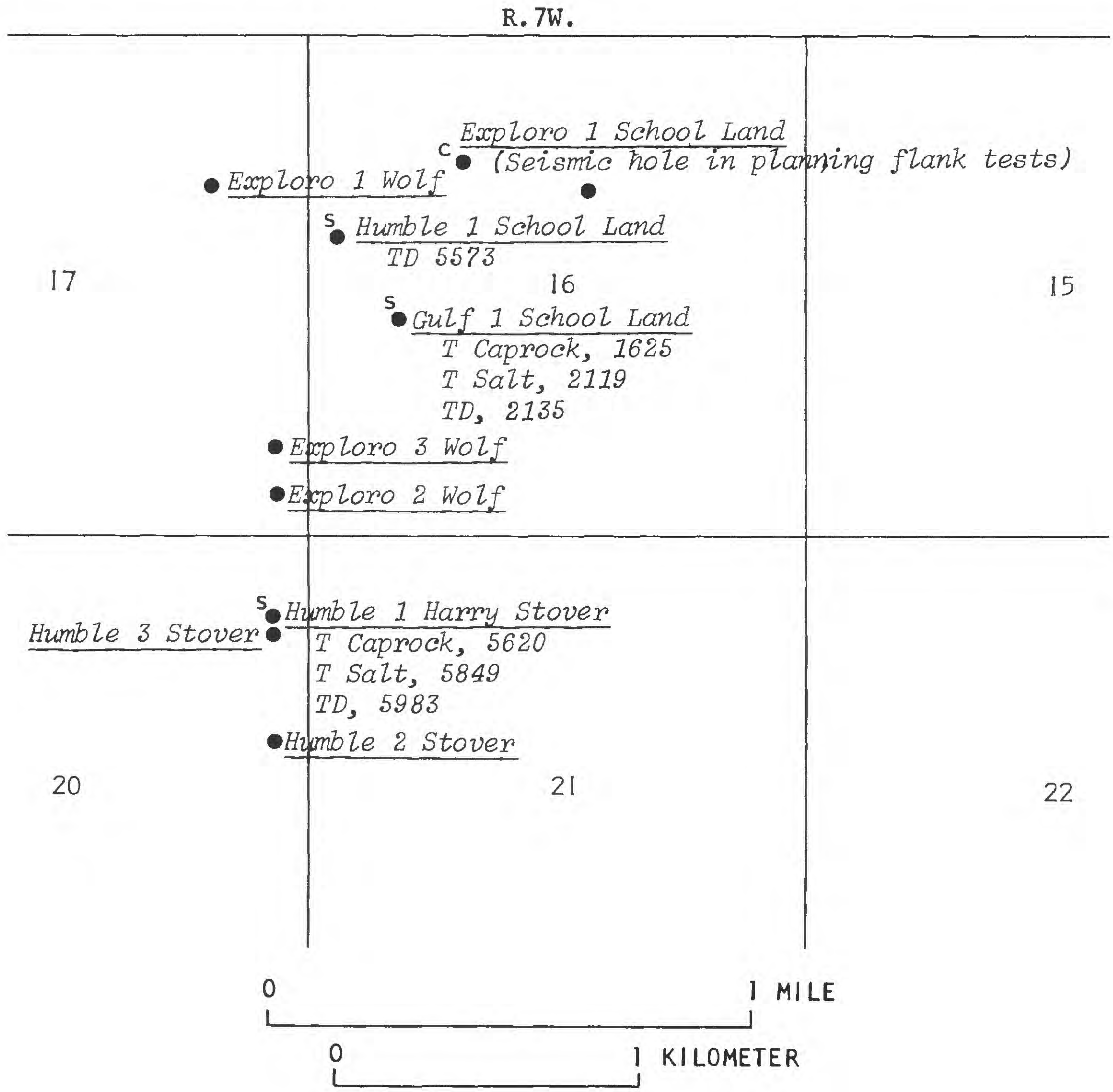


Figure 83.--Plan showing location of wells in vicinity of Byrd dome. c, well reached caprock; s, well reached salt.

Suspected Domes

At least four structures thought to be salt domes are located in the Mississippi salt-dome basin--Cypress Creek, Crowville, Sardis Church, and Hazlehurst (fig. 10). We have very little information on any of them and are therefore describing them as a group. Geophysical information exists in the files of exploration companies for at least three of these structures--Crowville, Sardis Church, and Cypress Creek.

Published information on the Cypress Creek structure is almost lacking. Neither salt nor caprock has been drilled in two wells (fig. 84) near the structure that reached depths of 8,434 feet and 15,352 feet. However, we have learned of extensive geophysical exploration by Humble Oil and Refining Company that indicates the salt dome is slightly smaller than Tatum, and salt seems to be at greater depth than at Tatum. The suspected dome is located (figs. 81, 84) in a poorly drained swampy area along Cypress Creek about 4.5 miles south-southeast of New Augusta (pop. 275). Surrounding hills rise to 50 feet or more and are capped with sand and gravel of the Citronelle Formation (Pliocene), underlain by clay and sand of the Pascagoula and Hattiesburg Formations (Miocene).

Humble has acreage on the south part of the structure and Sun Oil Company has acreage in section 16 over the structure (fig. 84).

The Sardis Church structure is located (figs. 85, 86) in a well-drained hilly area 5.5 miles southeast of Hazlehurst (pop. 4,577). It is located in the southern part of the broad outcrop belt of the

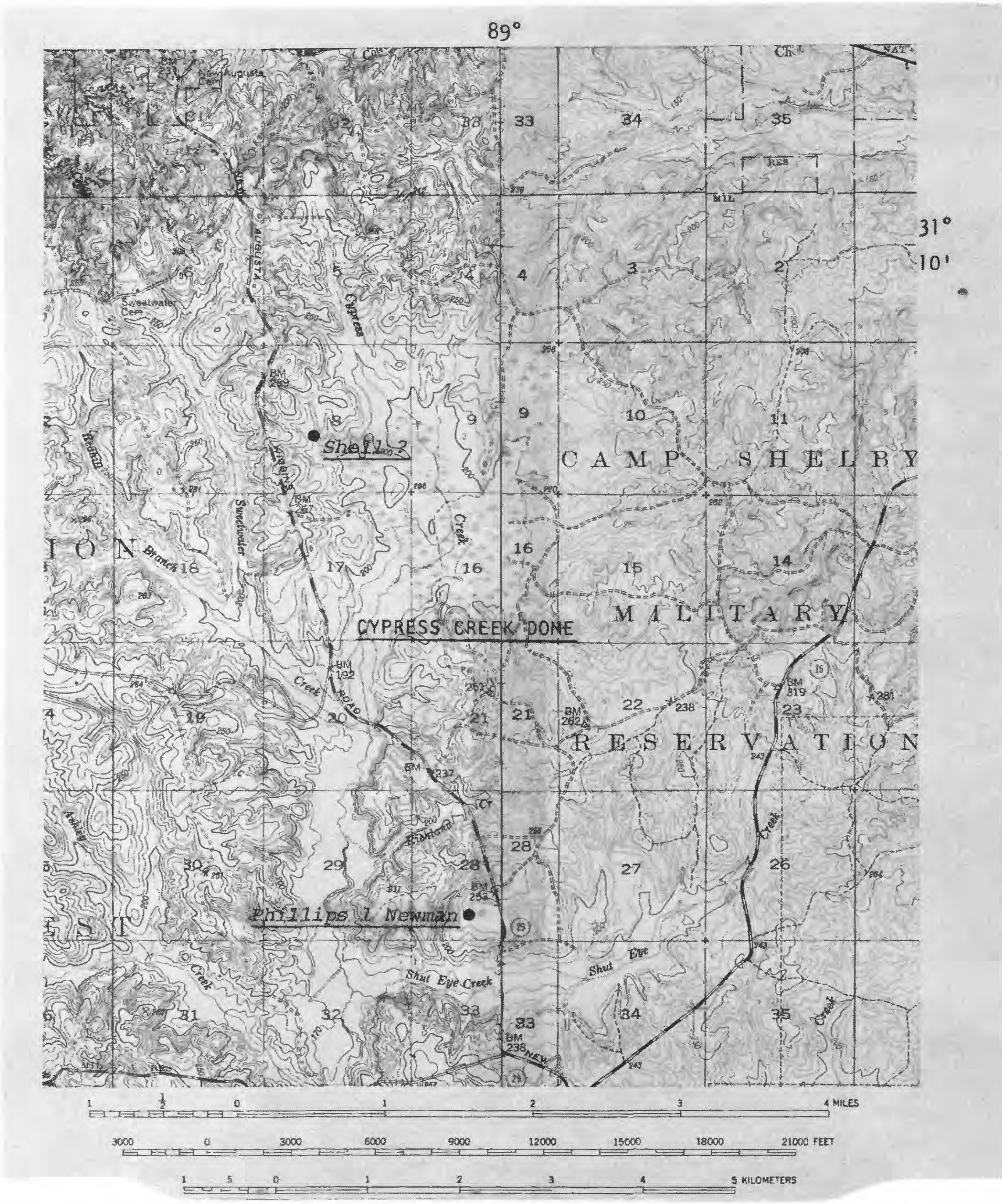


Figure 84.--Topographic map showing wells drilled in vicinity of Cypress Creek dome. (U.S.G.S., 1:62,500, New August and Beaumont, Miss.)

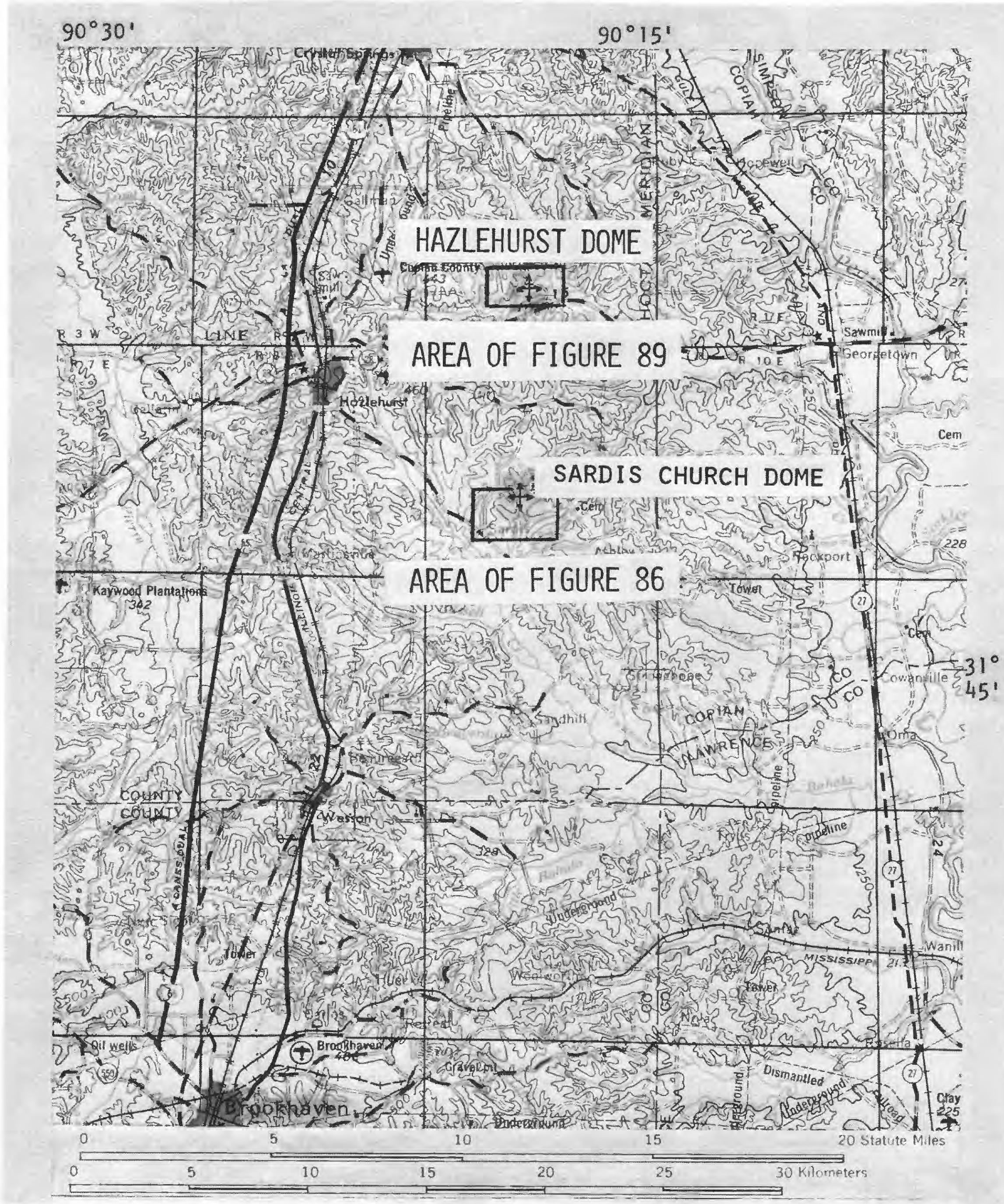


Figure 85.--Topographic map showing location of Hazlehurst and Sardis Church domes. (U.S.A.M.S., 1:250,000, Natchez)

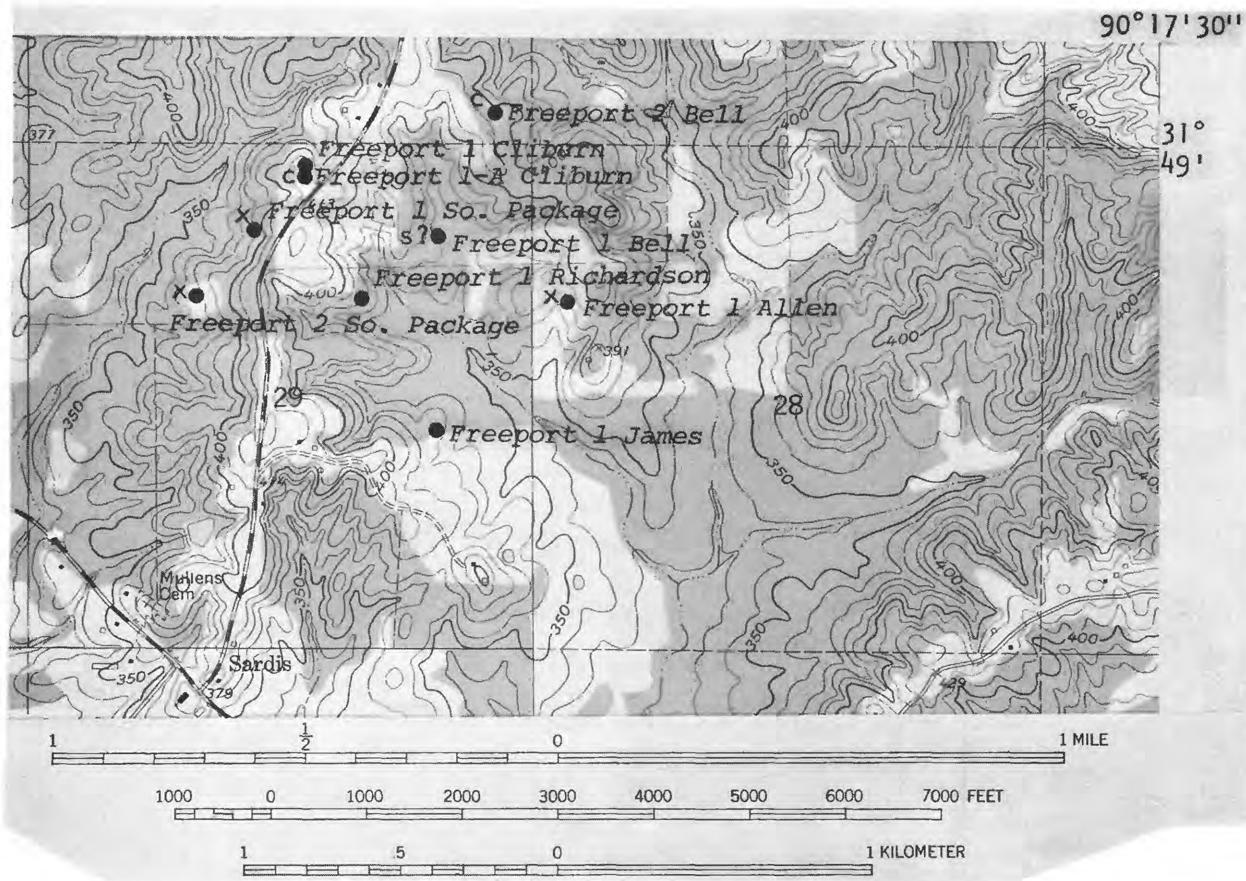


Figure 86.--Topographic map showing wells drilled in vicinity of Sardis Church dome. s, well reached salt; c, well reached caprock; x, well reached neither salt nor caprock. (U.S.G.S., 1:24,000, Shady Grove, Miss.)

sands and clays of the Miocene Catahoula Formation. The higher ground in the area is underlain by sand, gravel, and clay of the overlying Citronelle Formation. The Catahoula is about 600 feet thick. The structure was found as a result of geophysical work by the Sun Oil Company, but we do not have the geophysical data. Drill-hole data are available from six wells that have been drilled in the vicinity of the suspected salt structure. Their locations are shown on figure 86. Three of these wells, located within 2,000 feet of one another, penetrated caprock but not salt to depths in excess of 2,000 feet as follows:

Freeport Sulphur Co. 1 C. Bell; elevation 381; TD 2,267, logged to 1,478; massive limestone with calcite (no sulfur) from 1,483 to 1,543.

Freeport Sulphur 1A Cliborn; year 1943; elevation 412; TD 2,330; caprock from 1,915 to 2,315; anhydrite from 2,315 to 2,330.

Freeport Sulphur 2 Bell; elevation 410; TD 2,025; log to 1,630; calcite.

The three other wells were drilled to depths of 1,460 feet, 2,020 feet, and 2,188 feet and none encountered caprock. These data are not adequate for estimating the size or shape of the dome but tend to suggest that salt is present at depths not greatly in excess of 2,000 feet.

Fresh water was found to depths of about 500 feet in the two easternmost holes and to 1,000 feet and 1,500 feet in the Freeport Sulphur 1 South Package and Freeport Sulphur 2 South Package, respectively. The average depth of the base of fresh water in the area of the dome is about 2,000 feet. The lesser depths encountered in the wells probably reflect the influence of the dome.

The Crowville structure is located beneath a broad terrace (figs. 79, 80) fashioned on about 175 feet of unconsolidated alluvial deposits of the Mississippi River (Fisk, 1944). The alluvium is underlain by sedimentary rocks of Eocene to perhaps Miocene age. The terrace stands about 25 feet higher than the floodplain of the Mississippi River. The west margin of the floodplain is about 6 miles to the east. The area is partly farmland and partly forested and contains very few homes on or near the structure. Winnsboro (pop. 4,437) is located about 10 miles to the southwest (fig. 79).

The Crowville structure was located by gravity and refraction-seismograph surveys by the Gulf Research and Development Company. We do not have the geophysical data but have acquired an unpublished structure contour map on the top of the Lower Cretaceous rocks (fig. 87) that shows the location of the structure. Drill-hole data from the two wells on the structure (fig. 88), together with the structure contour map, indicate that the salt mass (not shown on fig. 88) is probably small and deep. Neither well penetrated salt. The Gulf George Washington 1A penetrated limestone caprock between 572 feet and its total depth of 911 feet, and the Gulf George Washington 2A penetrated anhydrite caprock from 2,977 feet to its total depth of 3,129 feet. These sparse data suggest that the salt mass may be considerably deeper than 2,000 feet and may be considerably less than 1 mile in diameter.

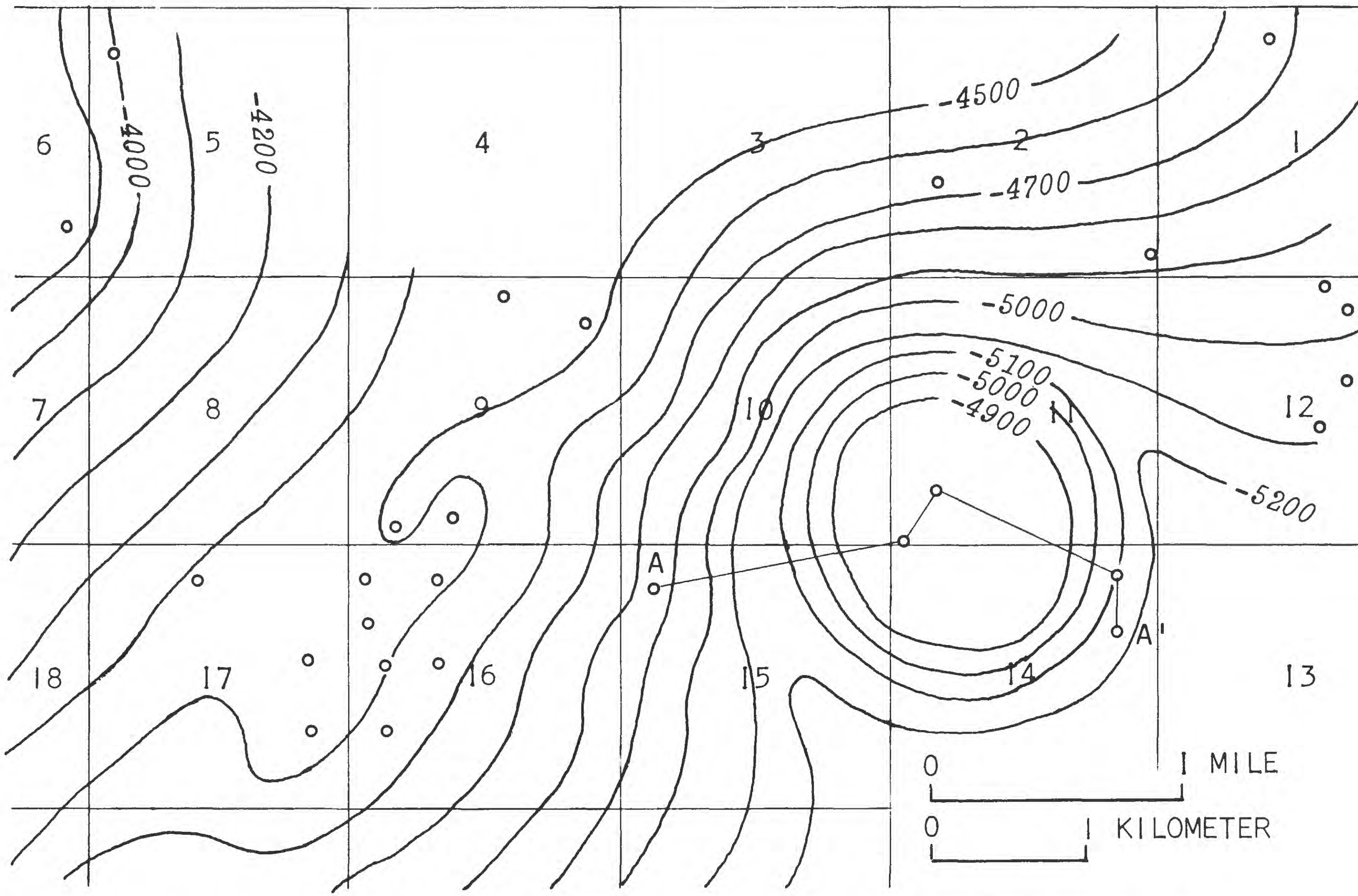


Figure 87.--Subsurface map showing contours on top of Lower Cretaceous rocks at Crowville dome. Circles are drill holes. From J. K. Rogers (written commun., 1972).

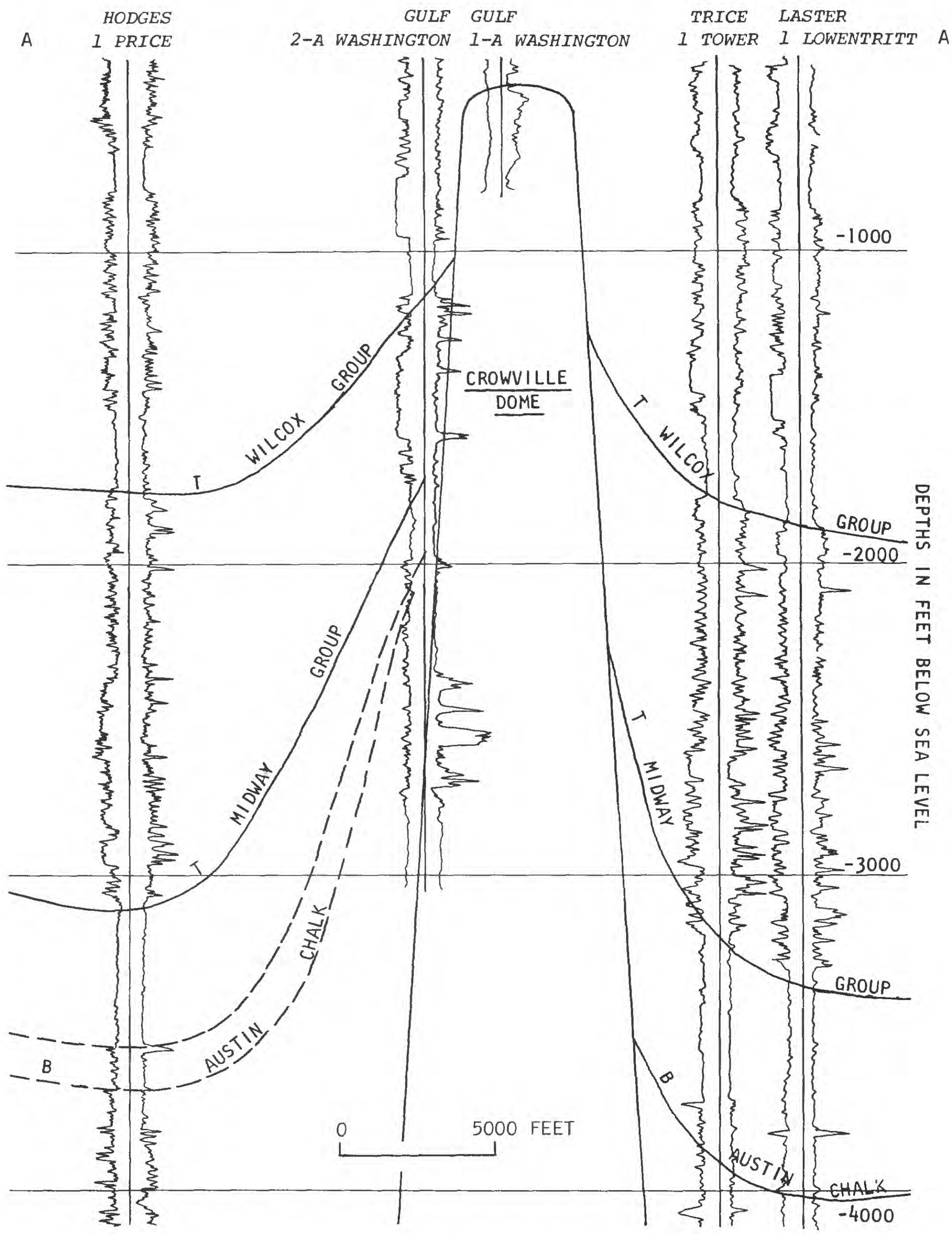


Figure 88.--Geologic cross section A-A' through Crowville dome. Trace of cross section on figure 87. From J. K. Rogers (written commun., 1972).

Fresh water is probably not available below the alluvial materials of the Mississippi Valley--approximately 175 feet. Surface water is available from Turkey Creek, which flows past the dome on the west.

Very little information is available on the Hazlehurst structure. Its approximate location, 5.1 miles northeast of Hazlehurst (pop. 4,577), is shown on figure 85. The general geologic and hydrologic setting is similar to that of the Sardis Church structure. Salt has not been drilled but caprock was found in the only well for which we have data as follows (fig. 89):

Stanolind Oil and Gas Co. 1 Huntington; year 1946; elevation 320 feet; TD 1,650 feet; limestone(?) caprock at 1,460 feet; anhydrite at 1,640(?) feet; cored 1,575-1,580 feet, and received 1 1/2 feet of hard broken limestone.

The suspected structure is located in a well-drained, partly wooded, hilly area along Copiah Creek.

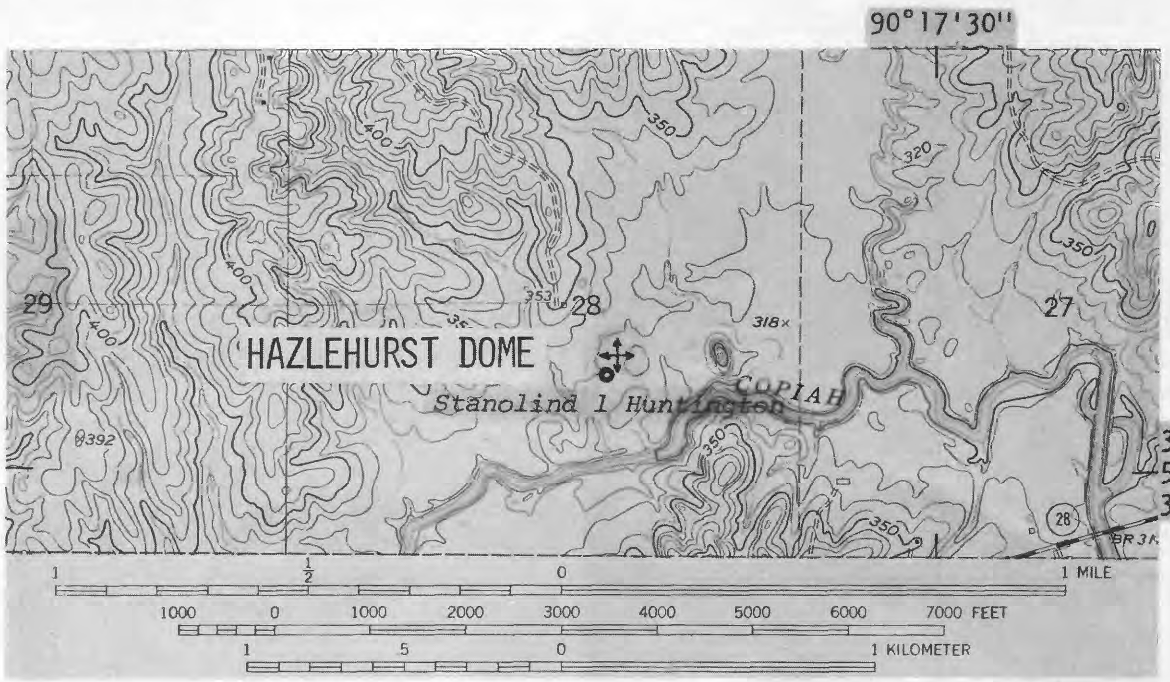


Figure 89.--Topographic map showing vicinity of Hazlehurst dome. (U.S.G.S., 1:24,000, Crystal Springs, Miss.)

SOUTH TEXAS

SALT-DOME BASIN

Index of salt domes

GYP HILL DOME: Brooks County, Texas (figs. 90, 91, 92, 92a)

DEPTH TO CAPROCK: 0; gypsum caprock exposed at surface.

DEPTH TO SALT: 831 feet (Sun and Humble 2-B Lasater); 4,992 feet (Sun and Humble 4-A Lasater).

PRESENT ECONOMIC USE: Small oil field on southeast flank; gypsum quarry at surface.

SIZE AND SHAPE OF SALT MASS: At 1,000 feet subsea, diameter is 3,600 feet. At 2,000 feet subsea, diameter is 4,500 feet. Surface elevation, 100-125 feet. Slightly asymmetric; steeper on southwest side.

DESCRIPTION OF CAPROCK: Gypsum caprock exposed at surface. Crystals of selenite 1-8 inches in diameter and 6-18 inches long form layers a few inches thick; layers dip slightly with the topography of the hill. Clusters of crystals form hexagonal prismatic columns. Gypsum is at least 400 feet thick in a well drilled on the southwest slope of Gyp Hill. One well in this area drilled to 1,000 feet below surface and abandoned in gypsum-anhydrite.

DRILLING HISTORY: Producers Oil Company drilled three wells on the south flank in 1911. Several wells were drilled from 1911 to 1945.

Texas 3 Lasater, in 1945, was completed for 1,820 million cubic feet of gas and 28 barrels of distillate from the Frio Clay (Oligocene?) at 6,651-6,653 feet.

Sun Oil Co. 4-B Lasater was completed for 42 barrels of oil per day from the Frio at 4,070-4,075 feet.

GYP HILL DOME: Continued

Finley, Gardner, et al. 1 Lasater produced 339 barrels of oil per day from the lowermost part of the Frio.

Sun & Humble 2-B Lasater encountered salt at 831 feet.

Sun & Humble 4-A Lasater encountered salt at 4,992 feet, in southwest quarter of the dome.

About 45 wells have been drilled within a mile of the dome, but only the two listed above have reached salt.

NEAREST POPULATION CENTER: Falfurrias, 6 miles north-northwest

POPULATION: 6,500

GEOLOGIC DATA: In cross section, dome is apparently bell shaped, but it is steeper on the southwest flank than elsewhere. Sedimentary rocks above the salt are radially and tangentially faulted (fig. 92). Surface sediments consist of alluvial sands overlying Pleistocene coastal terraces (all shown as rocks younger than the Goliad Sand on fig. 15). The Goliad Sand (Pliocene), Lagarto Clay (Miocene), and Oakville Sandstone (Miocene) extend to several thousand feet below the surface (fig. 15). There is no evidence of uplift of Pleistocene age around the dome.

HYDROLOGIC DATA: Shallow sand-filled valleys in this region usually carry flows only after hurricanes. Some fresh and brackish-water lakes exist in the region. Fresh to slightly saline ground water is produced chiefly from the Goliad Sand for local use, and downdip it is used for the cattle of the King Ranch. Locally, water is produced from several thousand feet below the surface in the Pleistocene coastal terraces.

Slightly saline water occurs to depths of as much as 2,500 feet below the surface in the area around Gyp Hill dome, but rises abruptly east of the dome to less than 1,000 feet. Contours representing the base of the fresh-water aquifer system indicate that the dome is located a few miles west of the axis of a north-trending rise of the fresh water/slightly saline water interface. The interface occurs at a depth of about 900 feet near the dome and slopes to the west at about 125 feet per mile and to the east at about 25 feet per mile. The interface rises sharply at the dome where fresh water is not found below about 300 feet.

Brine could be disposed of at the surface in Laguna Madre.

GEOGRAPHICAL DATA: Gyp Hill rises about 60 feet above a nearly flat brush-covered pasture-land surface that averages about 100 feet above sea level. The hill, composed of gypsum, partly covered with windblown sand, is rounded, about a mile in diameter, and has an abandoned gypsum quarry near the top. Laguna Salada, a shallow, brackish-water lake about 3 miles long and a mile wide extends from east to west, north of Gyp Hill (fig. 90). The lake, about 80 feet above sea level, occupies a valleylike depression that has no surface outlet, but joins an arm of Baffin Bay in Laguna Madre about 20 miles east-northeast. The area between Gyp Hill and Laguna Madre (the lagoon of the Gulf of Mexico that lies between Padre Island and the mainland) is very sparsely settled

GYP HILL DOME: Continued

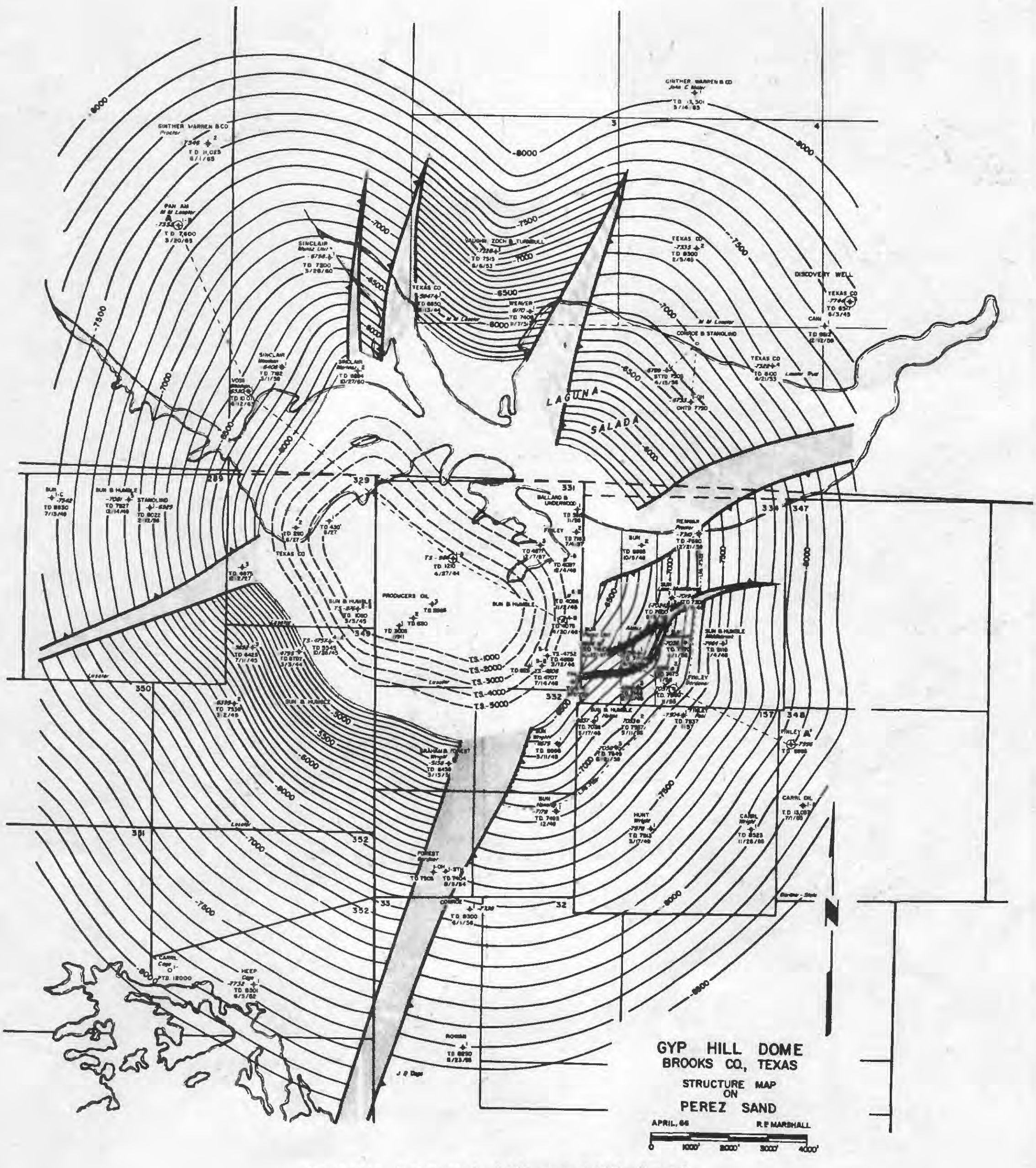
pasture land, brush land, and open grass-covered stabilized-dune country, all within the King Ranch. The Southern Pacific Railroad route from Corpus Christi to Brownsville and U.S. Route 281 pass 3 miles west of the dome.

ECONOMIC DATA: Small oil field is in a radially faulted and tilted block on the southeast flank of the dome about 7,000 feet southeast of the center. Total production of Gyp Hill field through 1956 was 223,272 barrels. Some gas was also produced from the field. The field then consisted of seven oil wells and eight oil and gas wells.

Gypsum has been produced from an open-pit mine (now abandoned) in the caprock exposed on the crest of the dome.

Figure 90.--Topographic map showing location of Gyp Hill salt dome. (U.S.A.M.S., 1:250,000, Laredo and Corpus Christi)

Figure 91.--Topographic map showing vicinity of Gyp Hill dome. (U.S.G.S., 1:24,000, Flowella, Tex.)



Contour interval 100 and 1000 feet

Figure 92.--Subsurface map of Gyp Hill dome. Dashed lines are contours on top of salt from Corpus Christi Geological Society (1967). White wedge-shaped areas represent fault surfaces.

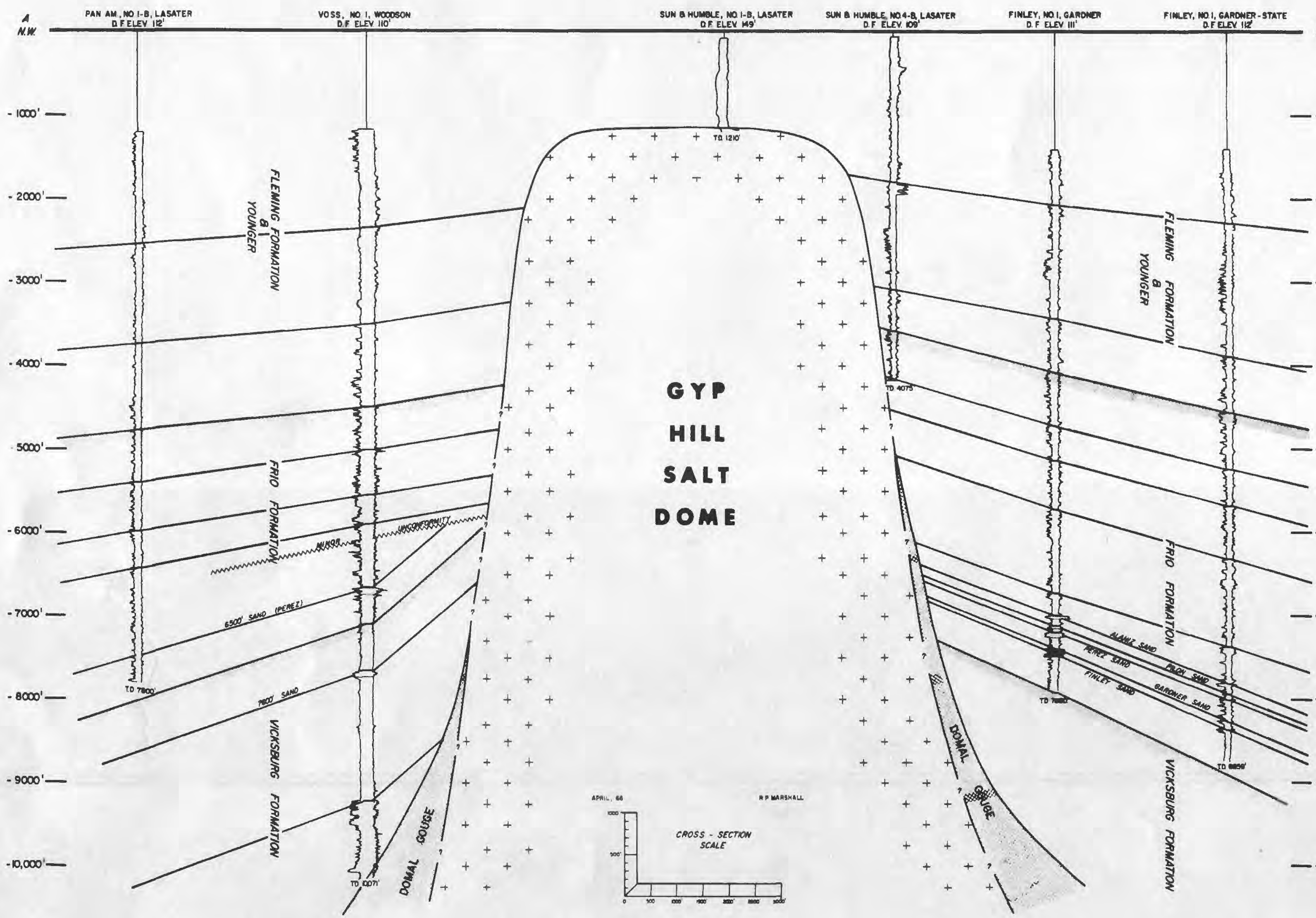


Figure 92a.--Cross section through Gyp Hill dome. Line of section shown on figure 92 from Corpus Christi Geological Society (1967).

EAST TEXAS-SOUTH LOUISIANA

SALT-DOME BASIN

Index of salt domes

HOCKLEY DOME: Harris County, Texas (figs. 93-97)

DEPTH TO CAPROCK: 74 feet (Hawkins and Jirik, 1966); 99 feet (Canada, 1953); 76 feet at mine shaft. Slopes downward near edge of dome.

DEPTH TO SALT: 1,010 feet (Hawkins and Jirik, 1966); 1,109 feet (Canada, 1953).

PRESENT ECONOMIC USE: Salt mine; small petroleum production.

SIZE AND SHAPE OF SALT MASS: 5.9 cubic miles of salt above 10,560 feet below surface (estimate). Salt mass as outlined by domal material is egg shaped, elongate from north to south, widest at the north, 17,000 feet long, 13,000 feet wide (Canada, 1953).

DESCRIPTION OF CAPROCK: Thickest in northeast (995 feet); 934 feet thick at mine shaft; in gypsum mine shaft a gypsum layer 18 feet thick lies between a 31-foot-thick calcite layer and an 885-foot-thick anhydrite layer. Anhydrite has many slickensided fractures; gypsum layer is vuggy, containing gypsum crystals and water; no gypsum layer is present where caprock is more than 400 feet below the surface. Calcite layer is cavernous.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Upper contact between salt and caprock is almost level, very sharp. Flanking sheath produces oil in two places. Dome is undercut from about 4,000 feet to 6,000 feet subsea, at position of sands of Eocene Yegua Formation (Claiborne Group). Caprock is thicker beneath and above the undercut, but not at the undercut. Anhydrite sheath is absent at many places as shown on cross section (fig. 96).

HOCKLEY DOME: Continued

DRILLING HISTORY: Unknown number of holes drilled for salt; 109 exploratory wells for petroleum or sulfur drilled through 1952 (Canada, 1953). Freeport Sulphur Co. drilled 17 wells for sulfur; 41 wells drilled for oil or gas before first production (noncommercial); 69 additional ones drilled before small oil field was brought in in 1945. Some wells drilled through salt overhang to produce from porous anhydrite sheaths and from sediments in undercut beneath overhang. Well just west of center of dome drilled to more than 10,000 feet.

NEAREST POPULATION CENTER:		POPULATION:
	Hockley, 4 miles north	300
	Houston, 25 miles southeast	1,000,000

GEOLOGIC DATA: Surface is capped with gently dipping Pleistocene terrace deposits. A few outcrops of possible Catahoula Sandstone (Miocene). Sediments beneath are tilted upward near dome. Dome has conspicuous rim syncline. Surface almost flat, 165-200 feet above sea level.

HYDROLOGIC DATA: Fresh water can be found down to 1,050 feet subsea on northwest side, to 800 feet on south side, and to depths of as much as 2,000 feet a few miles away from the dome. Aquifer shows "banner" of salty water on downdip side of dome at shallow depths; may be due to incomplete leaching of connate water on leeward side of dome from recharge areas or to yielding of salt from the dome to the aquifer. Dome discovered in 1906 by same man who discovered Spindletop dome, from sulfur water and gas seepage.

GEOPHYSICAL DATA: Has been thoroughly explored, but no records available. Magnolia Petroleum Co. determined configuration of salt mass by refraction shooting.

ECONOMIC DATA: Production brought in in part by deviated wells. First commercial production from beneath overhang in sands of Eocene Yegua Formation (Claiborne Group) in 1945, from 6,352 to 3,362 feet subsea. Oil production in 1966 from three wells in Hockley reservoir, 8,531 barrels. Cumulative production to January 1, 1967, 671,637 barrels. No gas production recorded. Oil production from one well in Hockley Y-2 FB-2 reservoir in 1966, 1,247 barrels. Cumulative production to January 1, 1967, 6,012 barrels. No gas production recorded.

Gypsum was produced from caprock in World War II, now abandoned. Salt mine now producing.

BRINE DISPOSAL: Mobil Oil Co. is disposing of brine from oil wells into sands in the following intervals: 2,125-2,145; 2,740-2,760; 2,860-2,884; 2,950-2,964; 3,050-3,067 feet.

These sands accept no more than 500 barrels of water per day at pressures of less than 600 pounds per square inch. Well records indicate a zone of lost circulation at about 3,800 feet that might accept more water. Electric logs of dry holes east of dome indicate highly permeable sands that might accept large quantities of water between 4,820 and 4,940; 5,110 and 5,140; 6,920 and 7,600 feet.

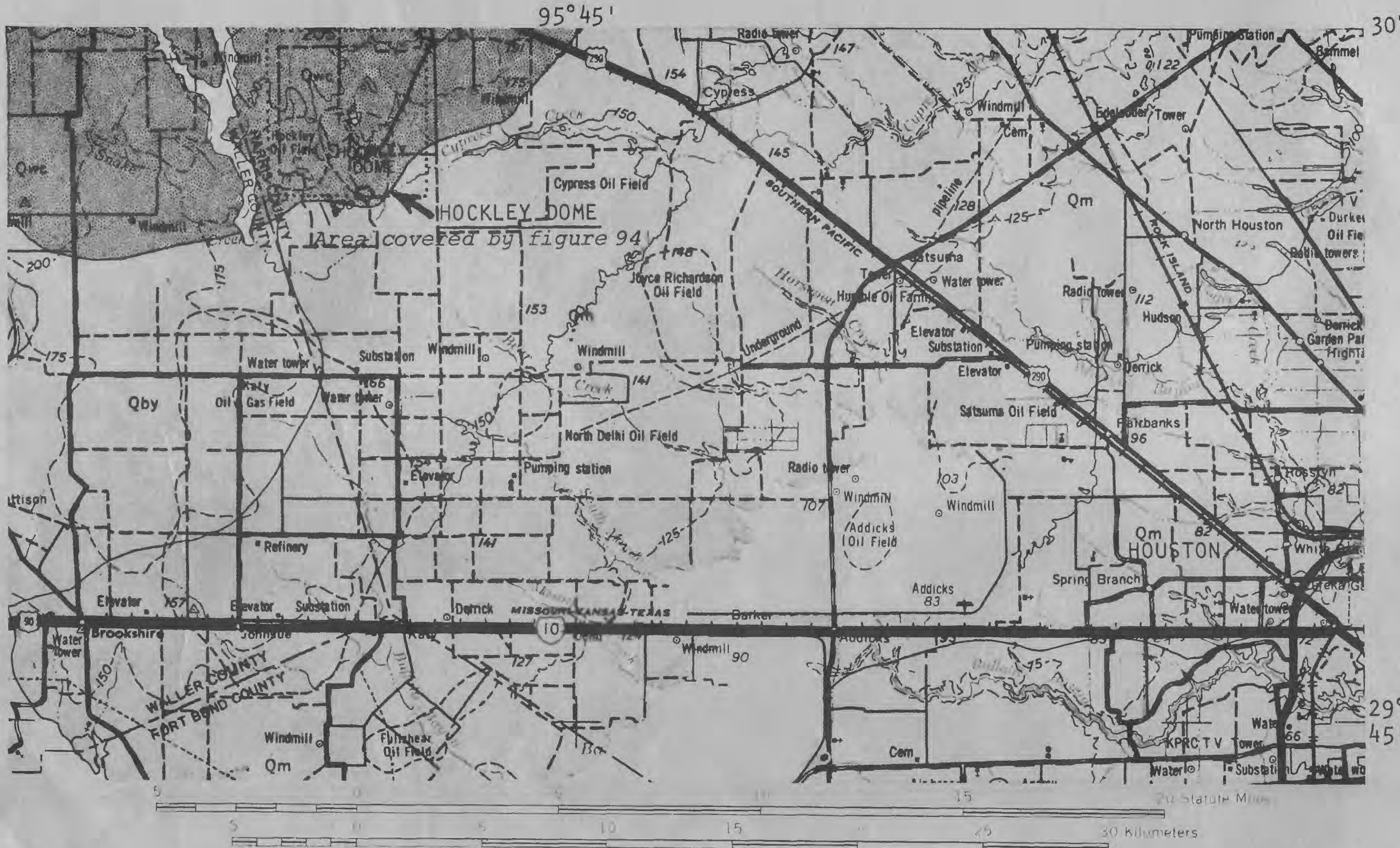


Figure 93.--Geologic map showing location of Hockley salt dome. T, Tertiary rocks; Qwc, Willis Formation; Qby, Bentley Formation; Qm, Montgomery Formation; Qb, Beaumont Formation; Qal, alluvium. From Texas University Bureau of Economic Geology (1968).

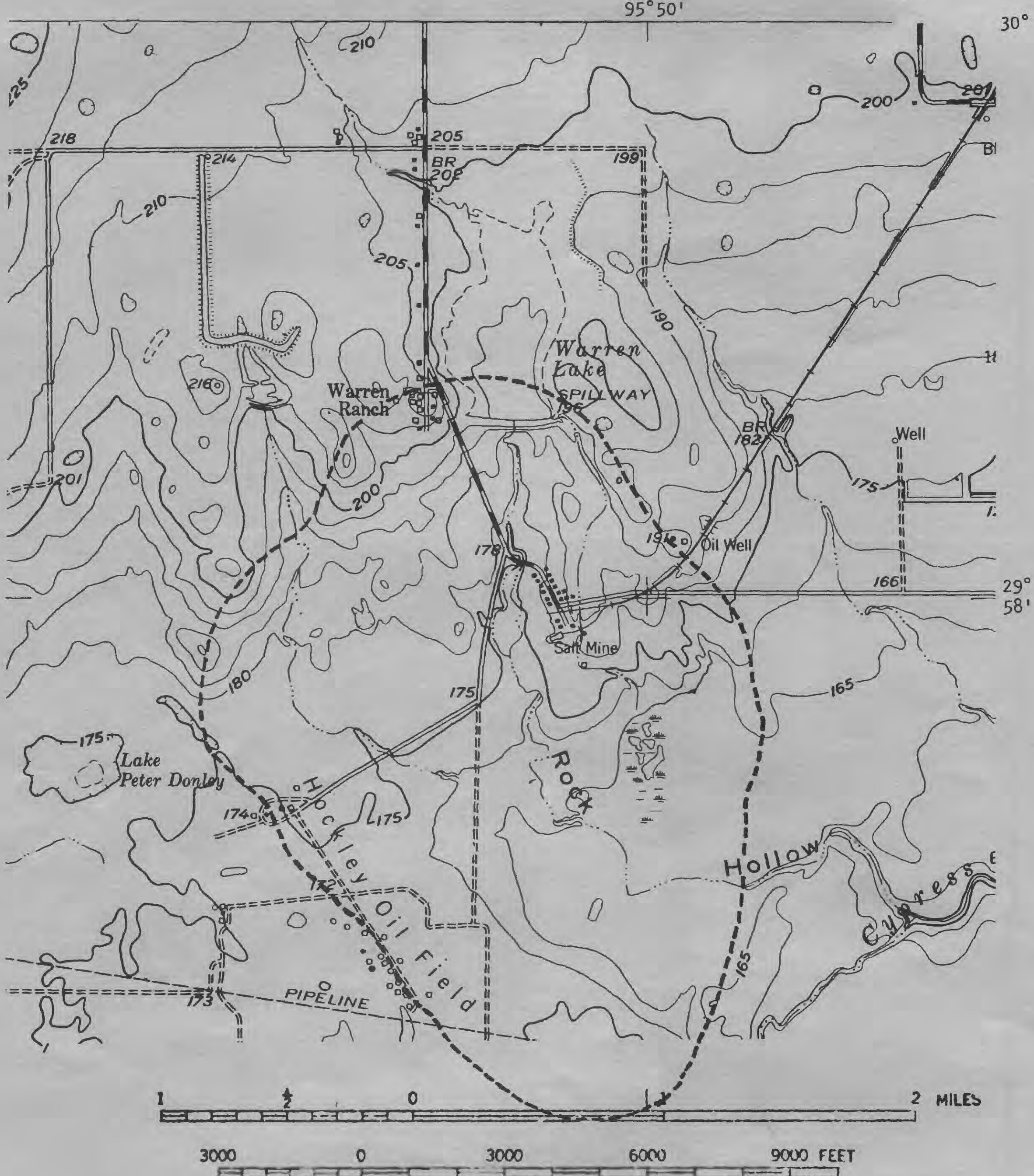


Figure 94.--Topographic map showing Hockley salt-dome area. Dashed line shows top of salt at 1,000 feet below sea level. Top of salt from American Association of Petroleum Geologists and others (1953, p. 126). (U.S.G.S., 1:62,500, Brookshire, Tex., enlarged in scale)

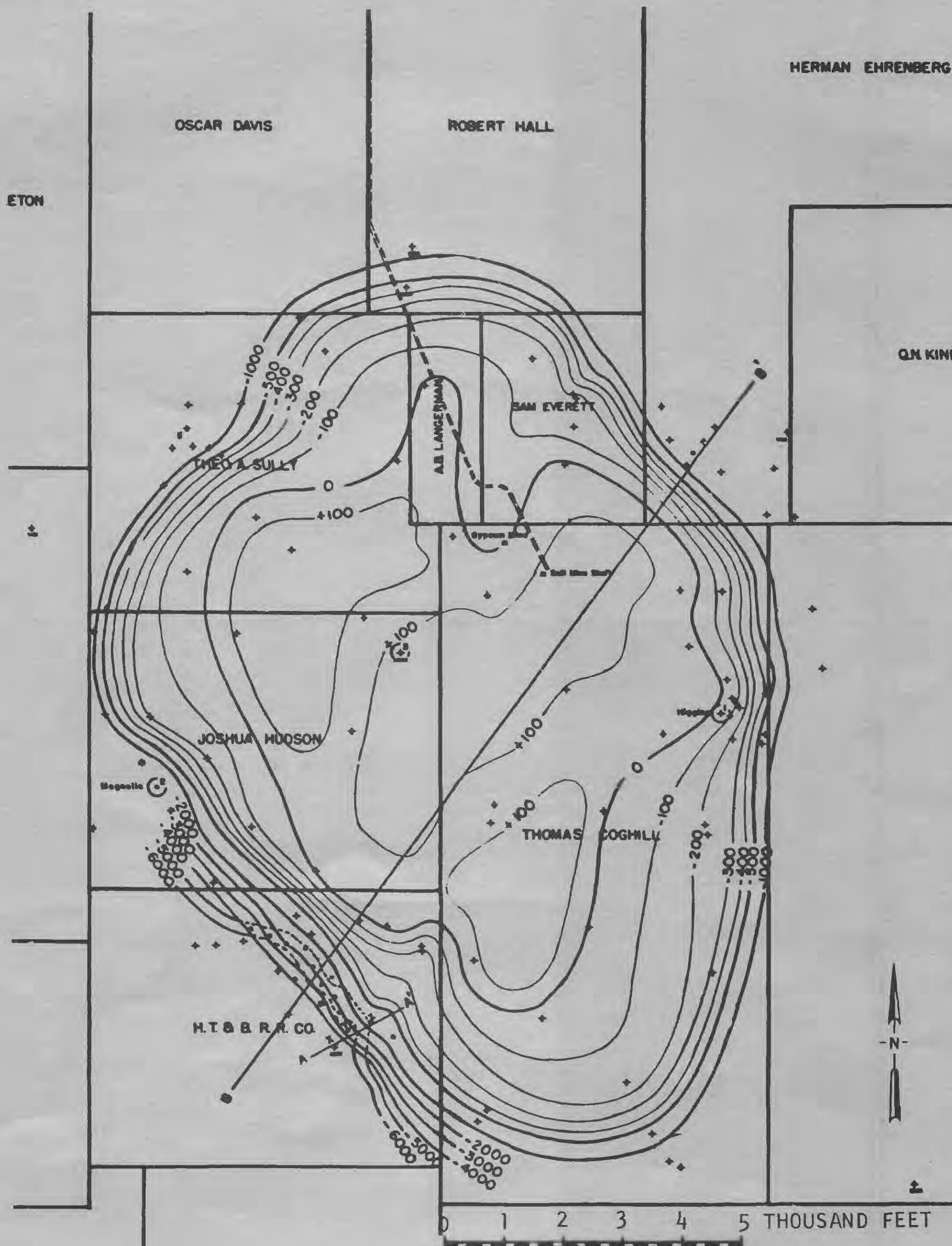


Figure 95.--Subsurface map showing contours on top of domal material, Hockley salt dome. From American Association of Petroleum Geologists and others (1953, p. 126).

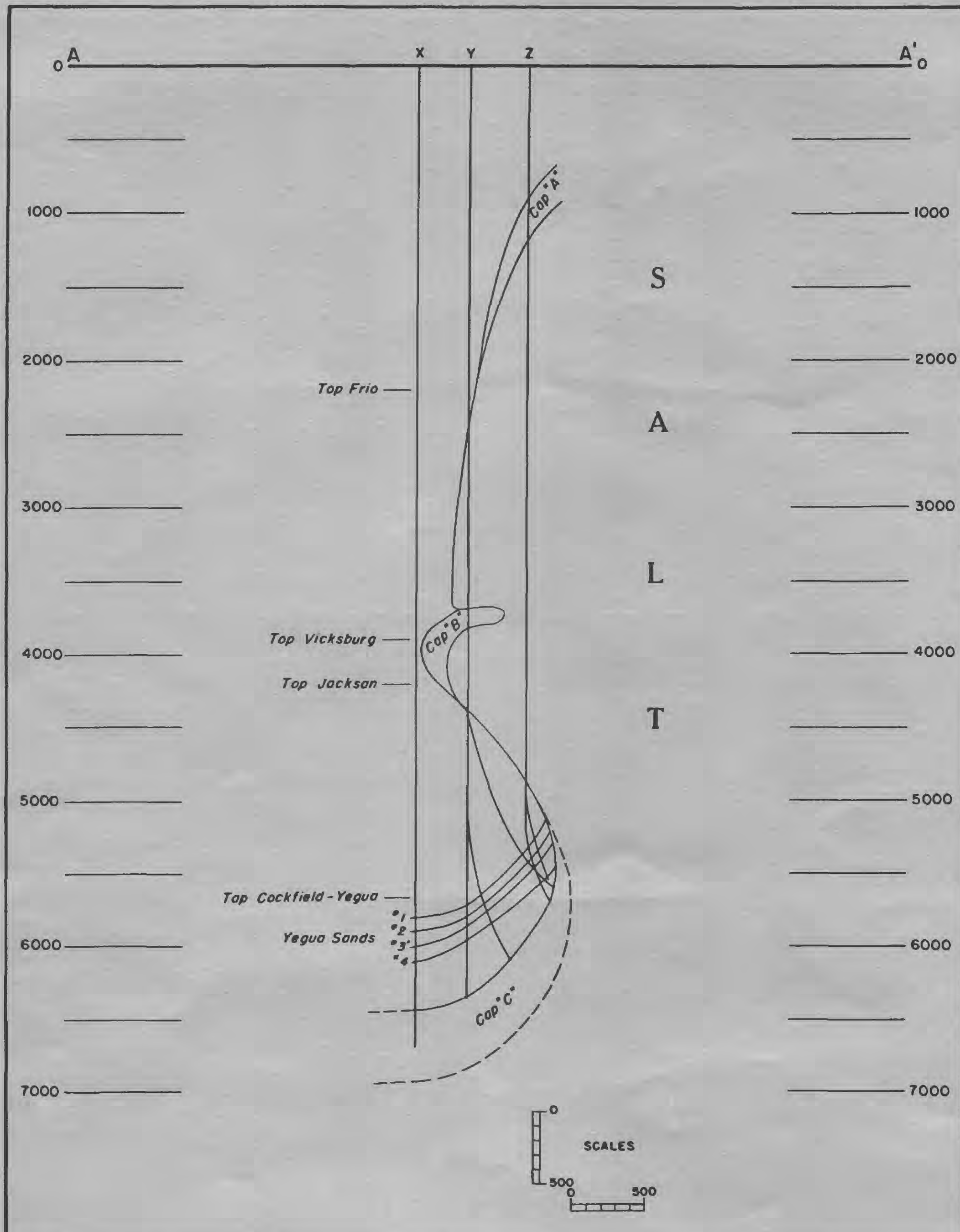


Figure 96.--Diagram showing type cross section on southwest flank of Hockley dome. For location of cross section and drill holes x, y, and z, see figure 95. From American Association of Petroleum Geologists and others (1953, p. 127).

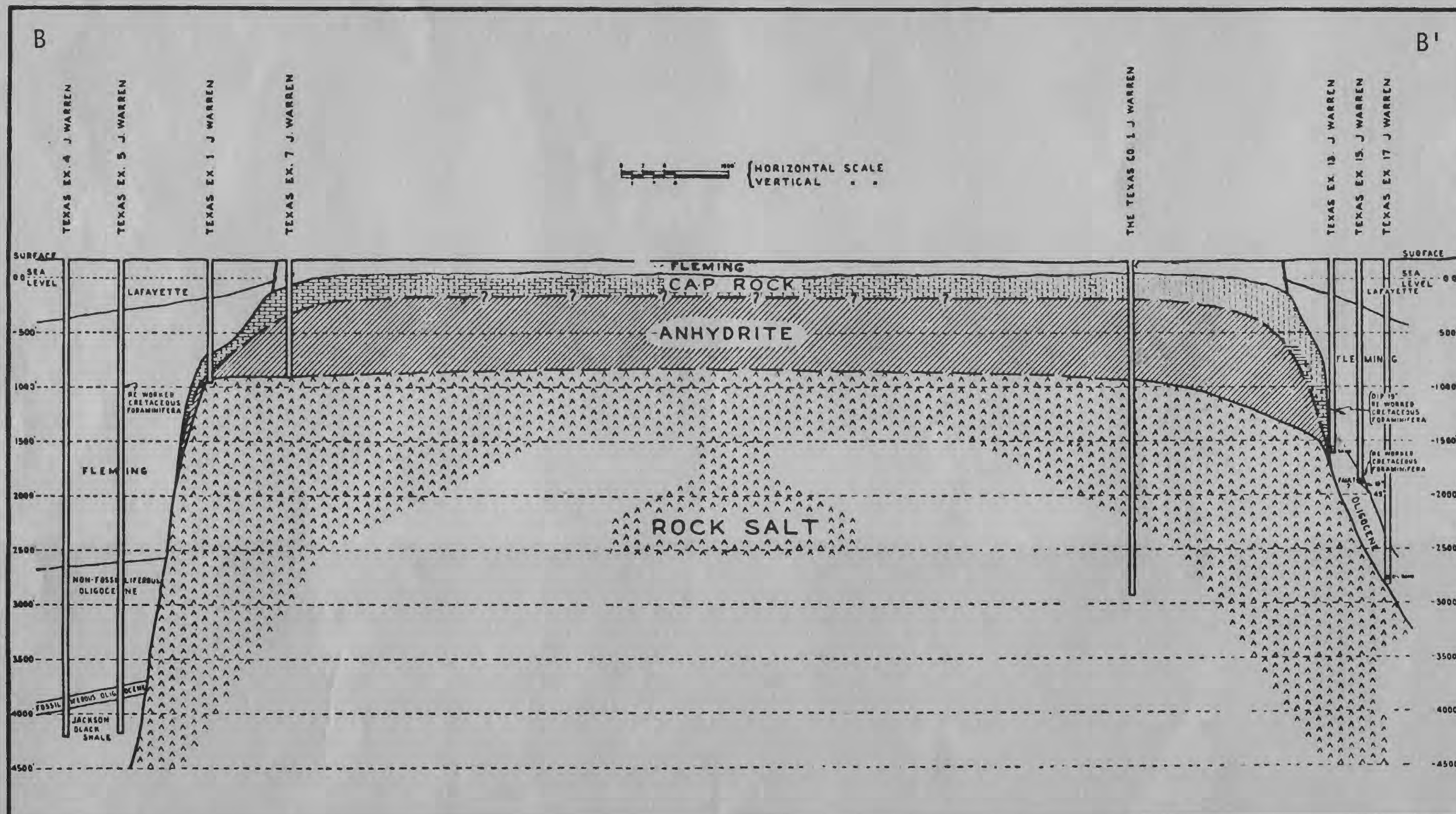


Figure 97.--Cross section B-B' through Hockley dome. For location of section, see figure 95. From Deussen and Lane (1925, fig. 3).

DAVIS HILL DOME: Liberty County, Texas (figs. 98-100)

DEPTH TO CAPROCK: 800 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

DEPTH TO SALT: 1,200 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Hawkins and Jirik (1966) estimate 5.5 cubic miles above 10,560 feet below surface. Salt area at 5,000 feet is 5.7 square miles.

DESCRIPTION OF CAPROCK: Records from well drilled on dome show 135 feet of pyrite, salt, gumbo, sand, and gypsum, with a show of oil and gas. Caprock is probably discontinuous.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Top of salt slopes downward toward edges of dome.

DRILLING HISTORY: Humble Oil and Refining Co. used one or two wells for seismic surveys.

Texas C-4 Davis produced petroleum.

Texas 1 Harvard, deepest well near dome, TD 5,160 feet.

Several other wells drilled.

NEAREST POPULATION CENTER: Cleveland, 14 miles west

POPULATION: 6,000

GEOLOGIC DATA: Discovered by surface geologic mapping. Miocene(?) rocks on surface of dome, surrounded by Pleistocene coastal terrace. Alluvium of Trinity River adjacent to dome on east side. Area of Frio Clay (Oligocene?) uplifted over 19-square-mile area.

HYDROLOGIC DATA: Trinity River 2 1/2 miles east. Davis Bayou near aquifer at 600 feet subsea around dome, now used for rice farms in area.

DAVIS HILL DOME: Continued

GEOGRAPHICAL DATA: High hill (fig. 99) over domal area. Surrounded by flat coastal terrace and alluvium of Trinity River to east.

ECONOMIC DATA: Oil wells abandoned. Texas C-4 Davis produced 21,912 barrels of oil, was converted in 1956 to a small gas well (3,000 cubic feet per day), shut in.

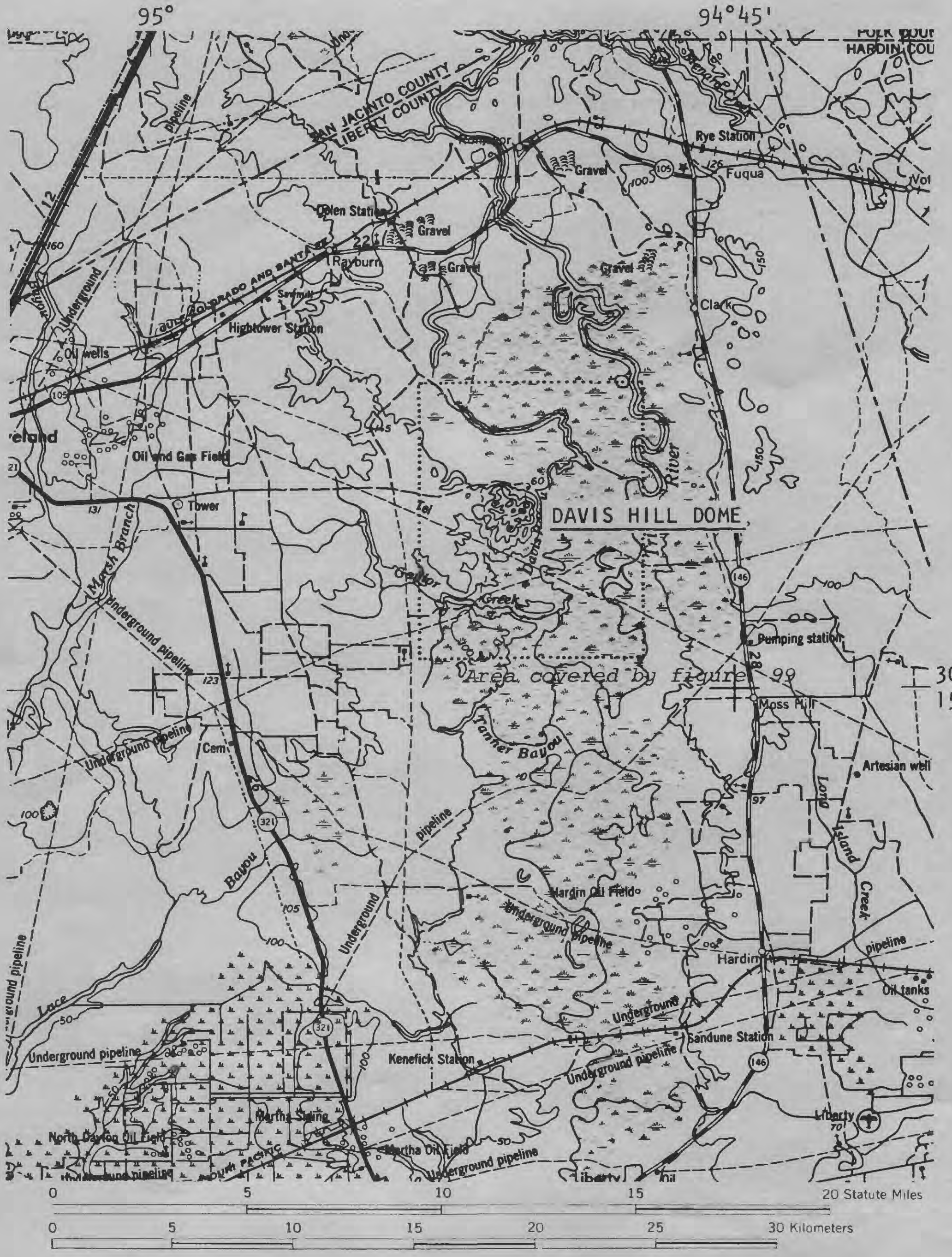


Figure 98.--Topographic map showing location of Davis Hill salt dome. (U.S.A.M.S., 1:250,000, Beaumont)

Figure 99.--Topographic map showing vicinity of Davis Hill dome. (U.S.G.S., 1:62,500, Rayburn, Tex.)

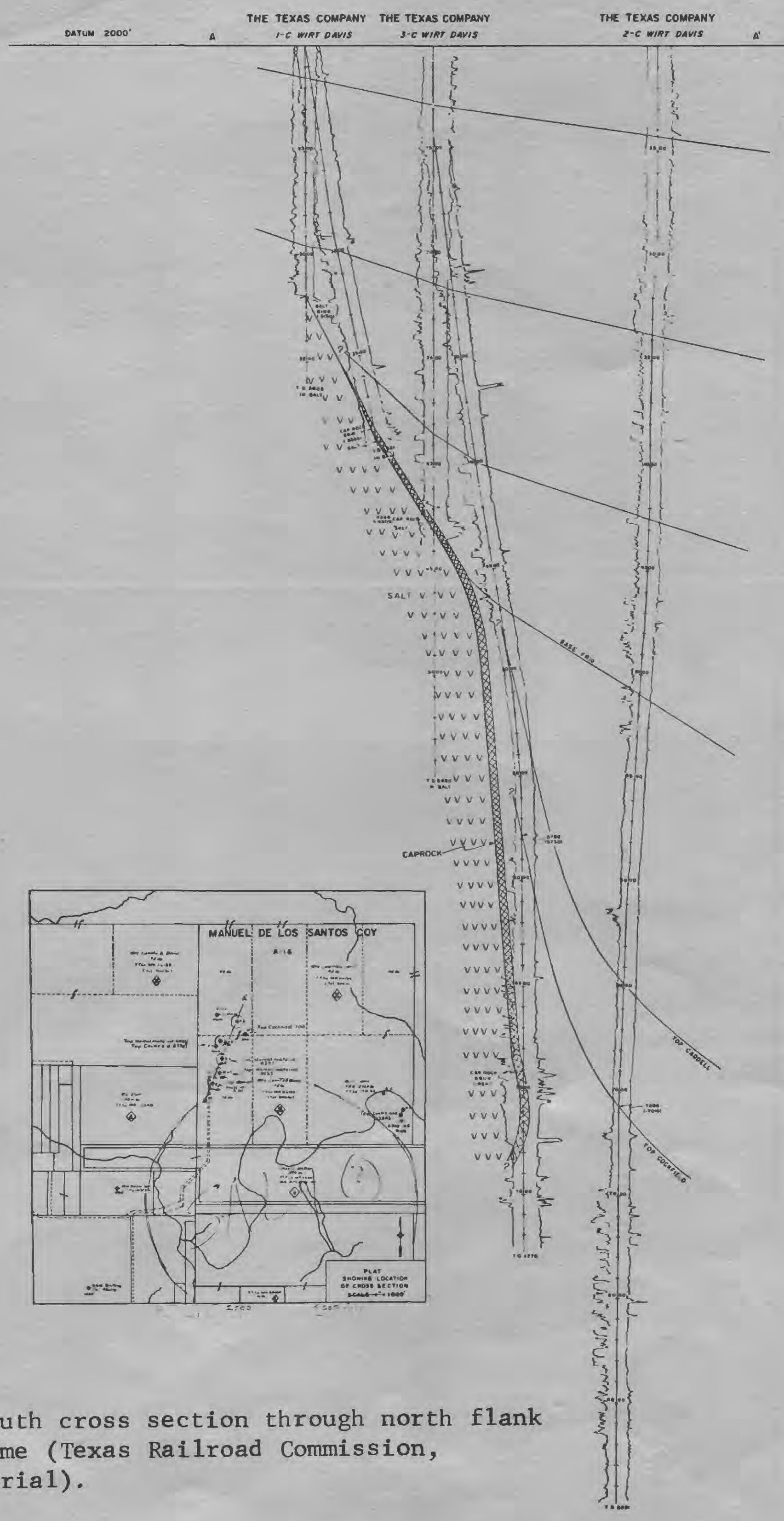


Figure 100.--North-south cross section through north flank of Davis Hill dome (Texas Railroad Commission, unpublished material).

HAWKINSVILLE DOME: Matagorda County, Texas (figs. 101-103)

DEPTH TO CAPROCK: 95 feet

DEPTH TO SALT: 450 feet near eastern edge; 614 feet near center

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: 4.4 cubic miles above 10,500 feet below surface. About 840 acres enclosed by the 1,500-foot subsurface top-of-salt contour.

DESCRIPTION OF CAPROCK: Thickness ranges from a few feet on the gently sloping west flank to 400 feet on the crest. Layers are, from top down, 1) limestone and sulfur, 2) anhydrite and gypsum, 3) massive anhydrite (Hanna, 1939).

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Dome is asymmetric, overhang on east side.

DRILLING HISTORY: Sun Oil Co. 1 Craig drilled salt overhang on east edge of dome from 677 feet to 1,055 feet. Overhang confirmed by two wells drilled by Sun south of Craig well. Fourteen wells drilled on top of dome, 15 wells drilled around dome (U.S. Bureau of Mines, written commun., 1961).

NEAREST POPULATION CENTER: Sweeney, 9.8 miles north

POPULATION: 3,000

GEOLOGIC DATA: Surface is low flat Pleistocene coastal terrace, shows little or no rise in elevation in dome area.

HAWKINSVILLE DOME: Continued

HYDROLOGIC DATA: Caney Creek west of dome. Estimated flow on September 15, 1959, was 150,000 gallons per minute of fresh water (U.S. Bureau of Mines, written commun., 1961). Aquifers of Pliocene and Pleistocene age surround dome. Possible brine disposal areas are Miocene(?) sands east of dome from 3,500 to 3,700 feet and from 4,185 to 4,300 feet; south of dome from 2,210 to 2,260 feet, from 3,870 to 4,000 feet, and from 4,500 to 4,600 feet.

GEOGRAPHICAL DATA: Surface nearly flat, 10 feet or less above sea level. Several drainage lines a few feet deep cross area. Dome area mostly grass- and brush-covered pasture. Cedar Creek just east of area and Caney Creek just west of area are nearly at sea level.

ECONOMIC DATA: Total petroleum production was 2,000 barrels; abandoned. Sun Oil Co. 2 Craig reportedly found oil at 5,150-5,160 feet, but no oil-production record available. Surface casing set to top of caprock or, in overhang area, through the salt (U.S. Bureau of Mines, written commun., 1961). Sulfur reported in limestone caprock (Hanna, 1939), but not considered commercial. Salt contains 5 percent anhydrite sand.

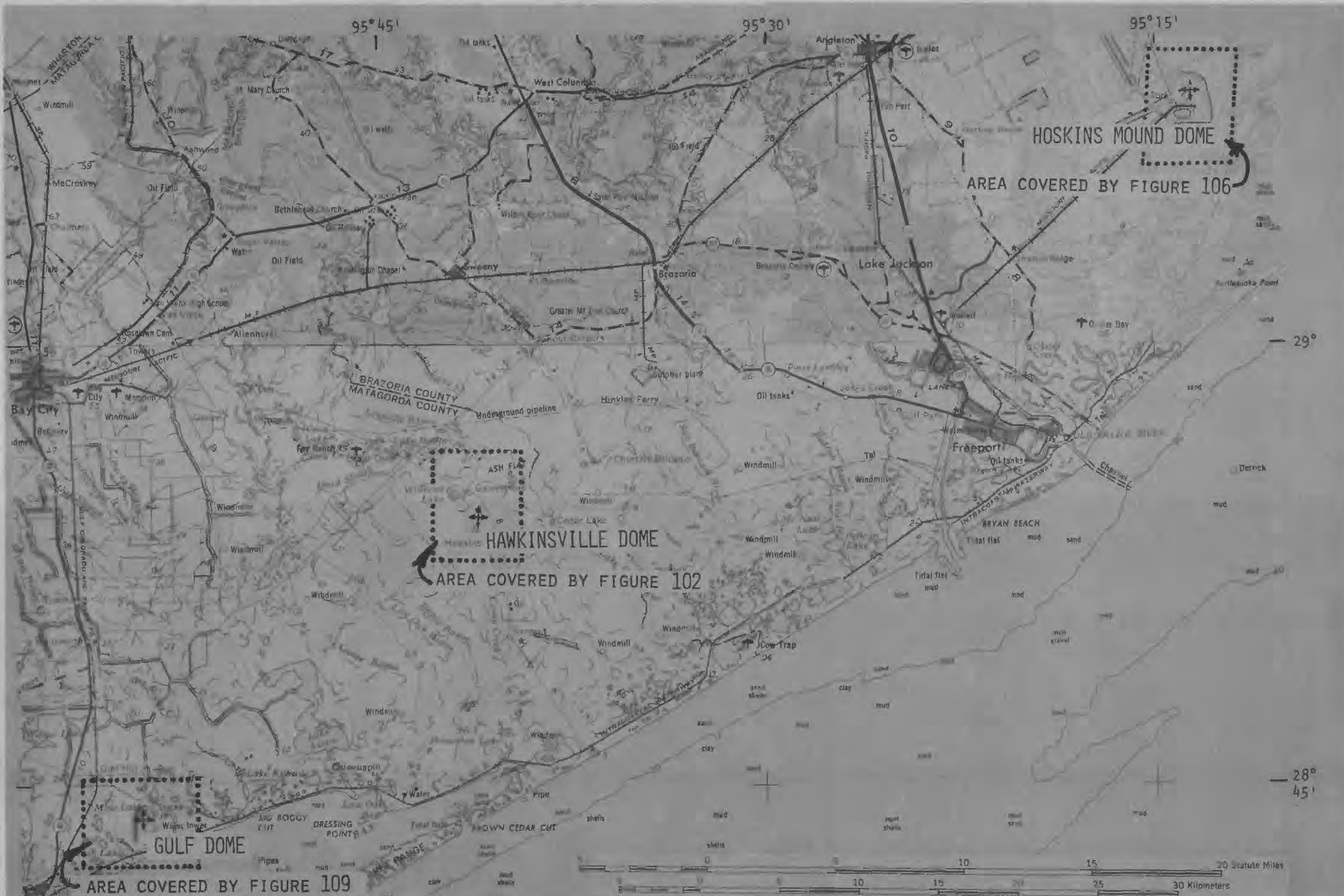


Figure 101.--Topographic map showing locations of Gulf, Hawkinsville, and Hoskins Mound domes. (U.S.A.M.S., 1:250,000, Bay City and Houston)

Figure 102.--Topographic map showing vicinity of Hawkinsville dome. (U.S.G.S., 1:24,000, Cedar Lane and Sargent, reduced in scale)

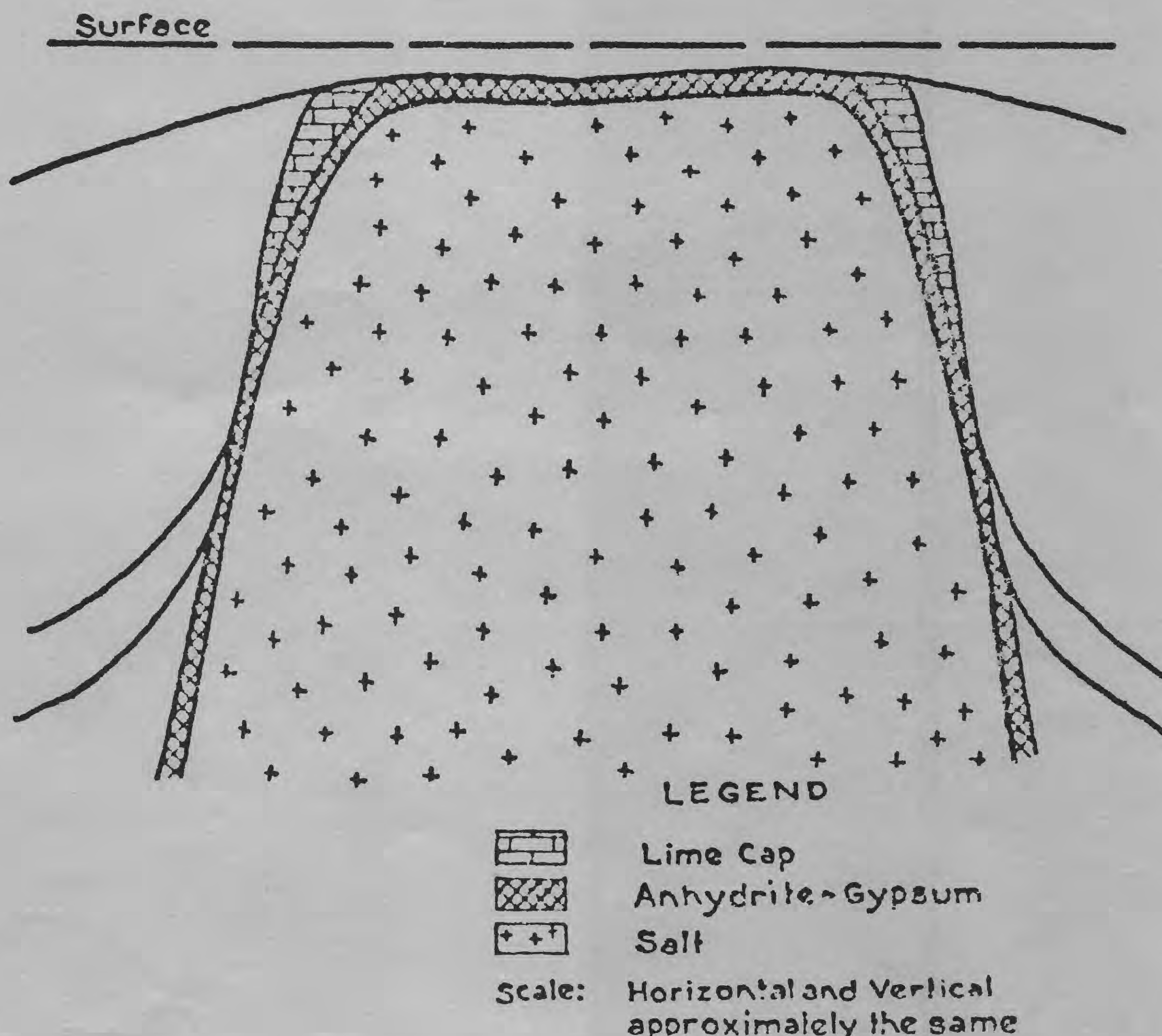


Figure 103.--Diagrammatic cross section believed to be representative of the Hawkinsville dome. From Hanna (1939, fig. 2).

LONG POINT DOME: Fort Bend County, Texas (figs. 104, 105)

DEPTH TO CAPROCK: 550 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

DEPTH TO SALT: 930 feet (Halbouty, 1967; Hawkins and Jirik, 1966)

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: 2.8 cubic miles above 10,560 feet; 3.1 square miles at 5,000 feet. Area of uplift on Frio Clay (Oligocene?) is 10 square miles; uplift on Frio is 800 feet.

DRILLING HISTORY: Gulf 1 Davis and Gulf 1 Wolf encountered caprock, produced oil and(or) gas from Fleming(?) (Miocene), 1953. Goldston 1 Zwahr produced gas from Vicksburg (Oligocene) at 5,186, TD 5,940, 1962.

NEAREST POPULATION CENTER:	POPULATION:
Rosenberg, 12 miles northwest	6,000
Houston, 25 miles northeast	1,000,000

GEOLOGIC DATA: Small amount of production (oil) from the Oligocene near the dome from 5,200 to 5,550 feet subsea.

HYDROLOGIC DATA: Dome located near coastward limit of flushing of Pliocene aquifers, depth to saline water about 1,800 feet surrounding dome and about 300 feet over dome. Ground-water movement possibly complicated by heavy pumping.

GEOPHYSICAL DATA: Torsion balance and refraction survey in 1924.

ECONOMIC DATA: Production of oil to 1964, 44,600 barrels (Halbouty, 1967; Hawkins and Jirik, 1966). Sulfur production, 380,000 long tons to January 1, 1938.

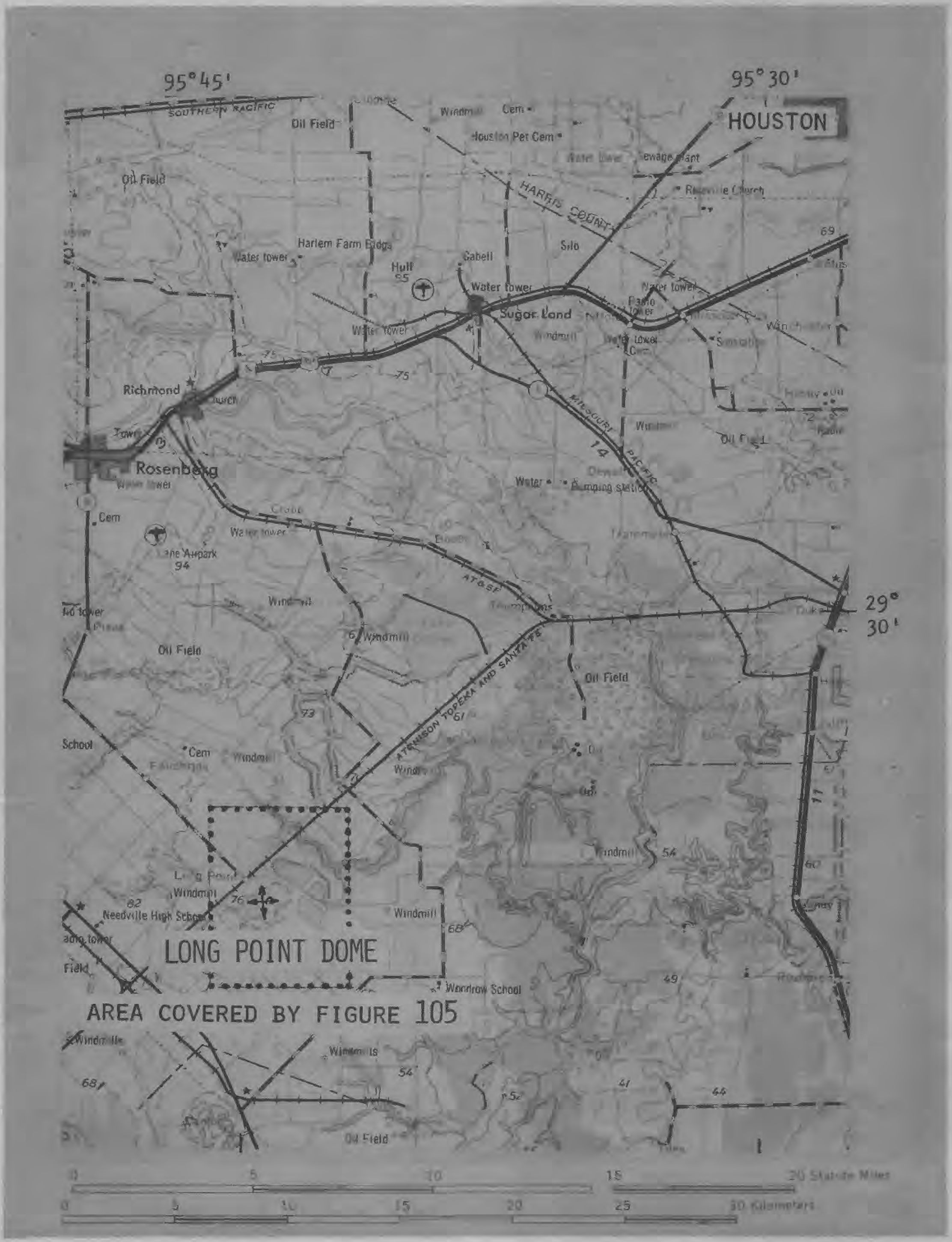


Figure 104.--Topographic map showing location of Long Point dome. (U.S.A.M.S., 1:250,000, Houston)

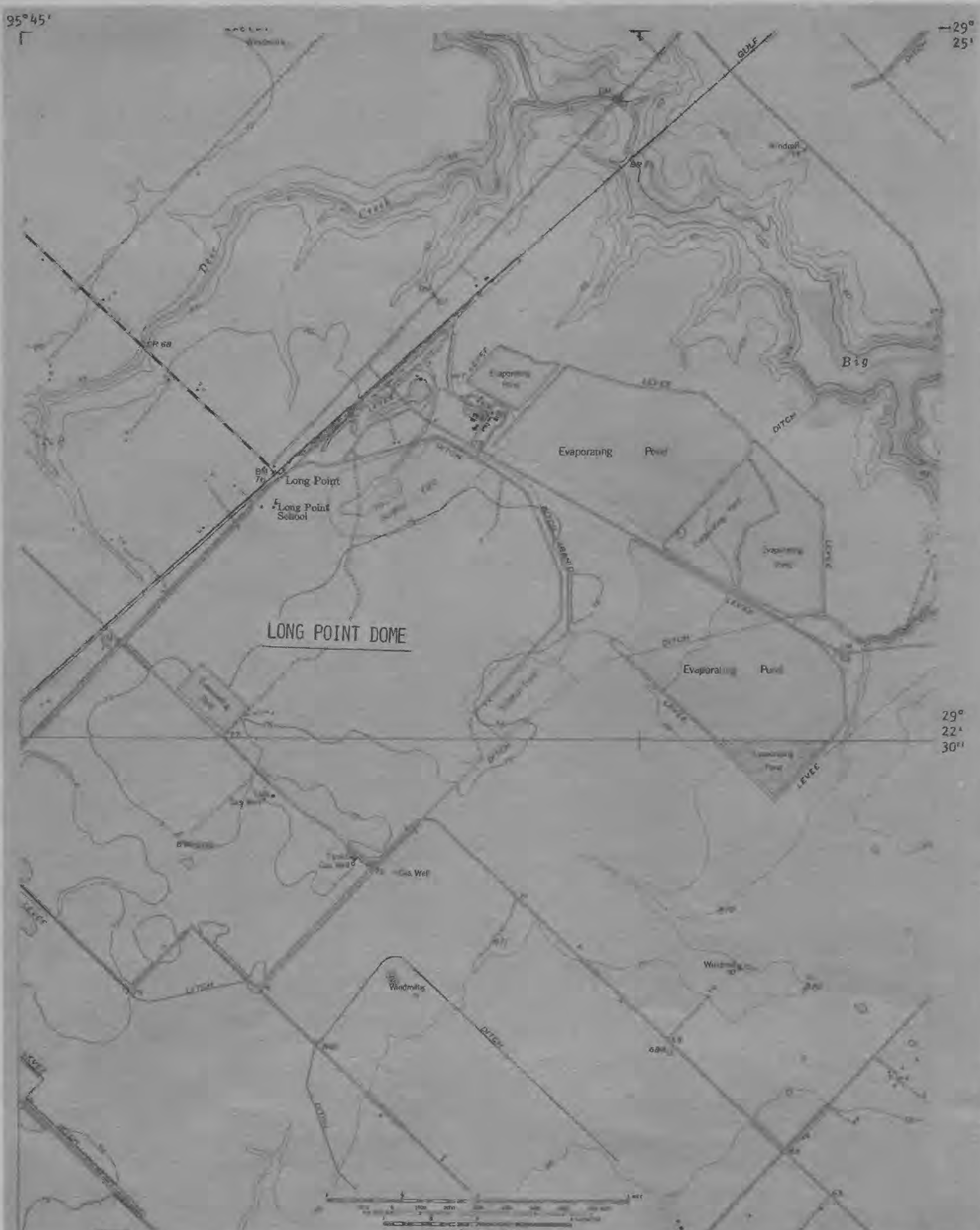


Figure 105.--Topographic map showing vicinity of Long Point dome. (U.S.G.S., 1:24,000, Damon and Lake George, reduced in scale)

HOSKINS MOUND DOME: Matagorda County, Texas (figs. 101, 106-108)

DEPTH TO CAPROCK: 574 feet

DEPTH TO SALT: 1,100 feet (Halbouty, 1967); 1,150 feet (Hawkins and Jirik, 1966); cross section shows salt up to about 500 feet subsea (Marx, 1936).

SIZE AND SHAPE OF SALT MASS: Eight-tenths of a cubic mile from 10,560 feet subsea to surface; diameter of salt estimated to be about 4,000 feet at 2,000 feet below surface, nearly circular in plan, with oversteepened southwest flank.

DESCRIPTION OF CAPROCK: (1) Limestone, barren of sulfur across entire structure, 25-200 feet thick, overlies (2) sulfur-bearing caprock from 0 to 250 feet thick; (3) anhydrite 350-450 feet thick. Caprock is very irregular.

DRILLING HISTORY: Three wells drilled for oil in 1904 and 1905 to sands above the caprock; 28 tests drilled between 1905 and 1910 on the mound to 400-1,600 feet; three of these were less than 900 feet deep. Oil was produced from six wells, all less than 710 feet deep, from sands above caprock; one of 14 sulfur tests drilled 400 feet into the salt. deepest test near dome is 4,126 feet deep. Before sulfur was produced, 45 oil tests were drilled.

NEAREST POPULATION CENTER:		POPULATION:
	Danbury, 9 miles northwest	800
	Freeport, 15 miles southwest	12,000
	Angleton, 13 miles west	10,000

HOSKINS MOUND DOME: Continued

GEOLOGIC DATA: Evidence of uplift in Pleistocene and probably in Holocene time. Beaumont Clay (Pleistocene) covers dome; originally stood as high as 35 feet above surrounding prairie, 10 feet above sea level. Now a lake occupies center of dome; subsidence owing to sulfur production from caprock.

HYDROLOGIC DATA: Gulf Coast aquifers around dome. Chocolate Bayou to north, Austin Bayou to southwest.

ECONOMIC DATA: From 1905 to 1915, about 500,000 barrels of oil produced from sands above the caprock; 32,000 barrels produced from flanks up to 1964; now abandoned. Sulfur wells mined by Freeport Sulphur Co. since 1923, from limestone on flanks of dome; 5 million long tons of sulfur produced.

Figure 106.--Topographic map showing vicinity of Hoskins Mound dome. (U.S.G.S., 1:24,000, Christmas Point and Hoskins Mound, reduced in scale)

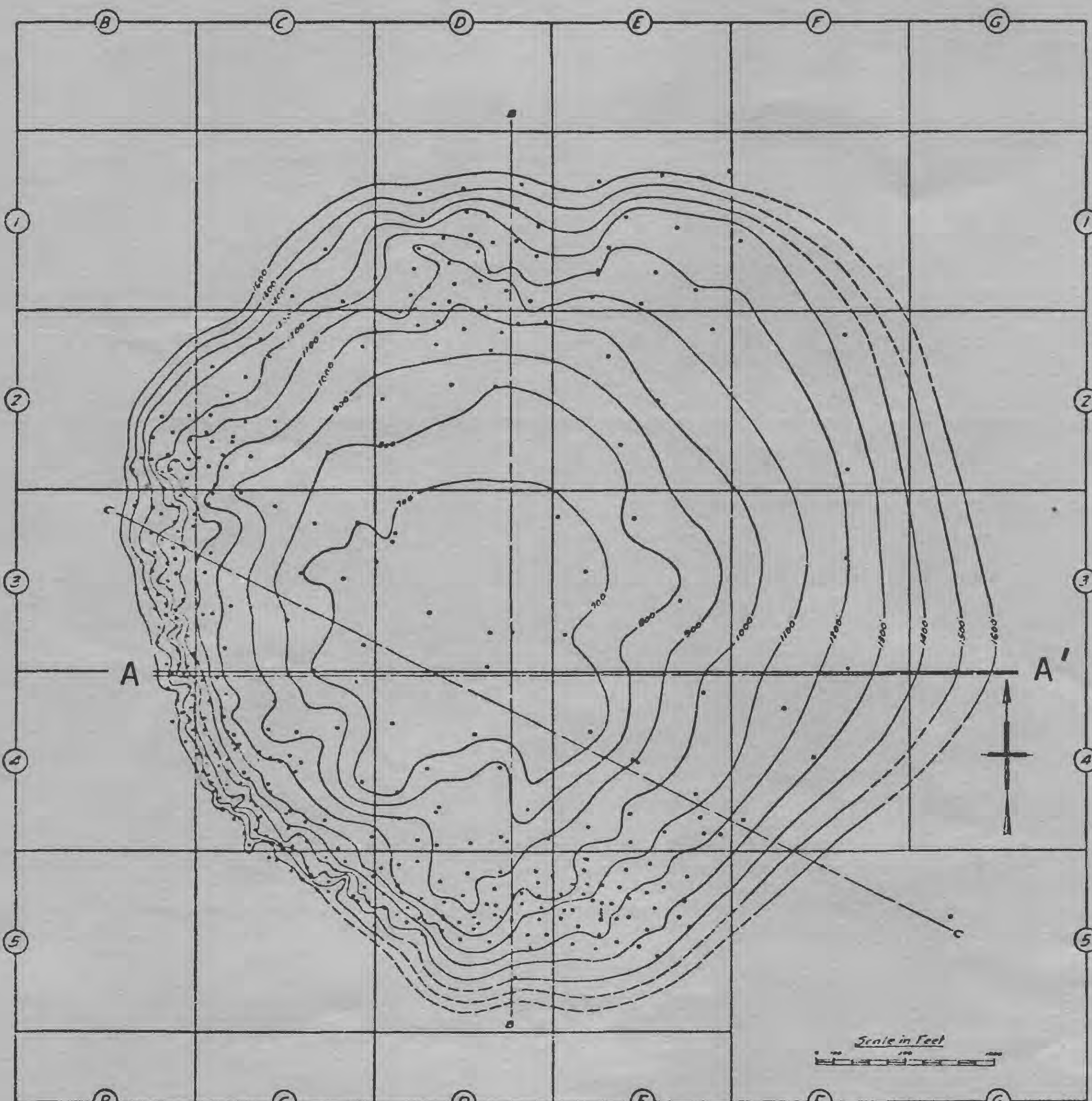


Figure 107.--Map showing subsurface contours on top of the caprock, Hoskins Mound dome. From Marx (1936, fig. 2).

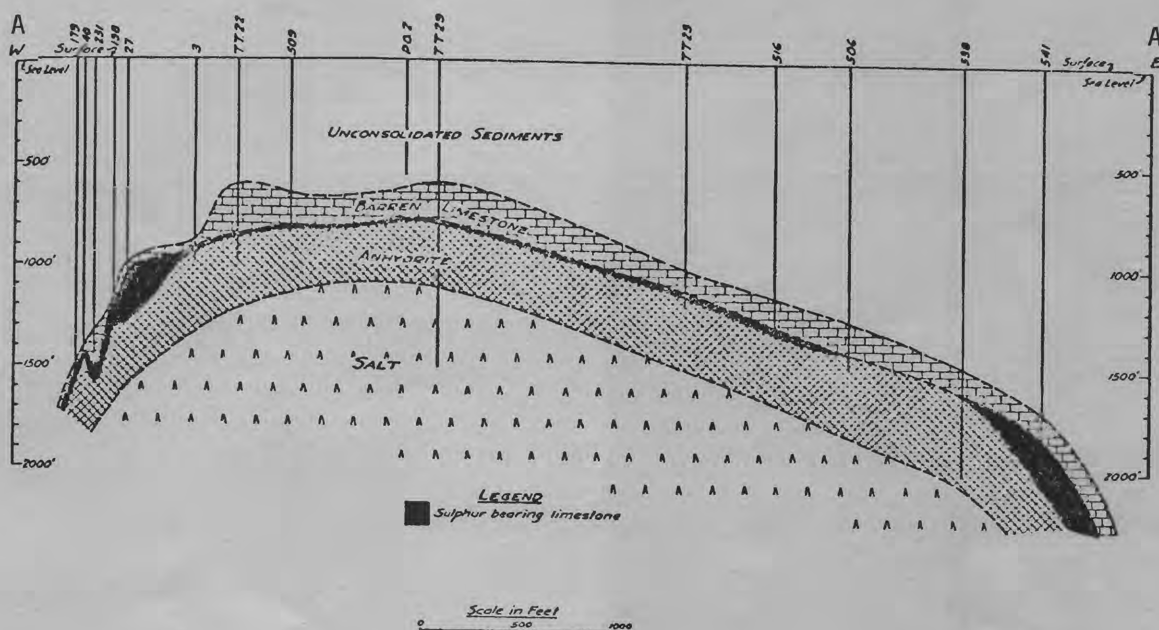


Figure 108.--Geologic cross section A-A' from west to east through Hoskins Mound dome. For location of cross section, see figure 107. From Marx (1936, fig. 3).

GULF DOME: Matagorda County, Texas (figs. 109, 110)

DEPTH TO CAPROCK: 825 feet (Halbouty, 1967; Hawkins and Jirik, 1966), west side; 886 feet at center.

DEPTH TO SALT: 1,100 feet (Halbouty, 1967; Hawkins and Jirik, 1966) at center, 1,340 feet.

PRESENT ECONOMIC USE: None

SIZE AND SHAPE OF SALT MASS: Above 10,560 feet measures seven-tenths of a cubic mile. Area enclosed by salt at 1,500 feet is about 620 acres. Salt overhangs northeast edge of dome. Salt is 95 percent halite at 1,800 feet subsea; 88 percent halite at 3,000 feet. Anhydrite is impure.

DESCRIPTION OF CAPROCK: Contains strontium minerals; celestite and strontianite, magnesium limestone, barite, sulfides; galena, pyrite, sphalerite, quartz as double pyramidal crystals.

CONTACT RELATIONS BETWEEN SALT WALLS AND COUNTRY ROCK: Caprock extends over flattened salt core and down the flanks a short distance (Wolf, 1925, p. 716).

DRILLING HISTORY: Shallow drilling in 1904; some oil produced, well abandoned in 1930; since then several wells drilled around flanks of dome. Texas Gulf Sulphur Co. completed a gas well at 4,500 feet a mile southeast of the dome in 1956; production, 3 million cubic feet.

NEAREST POPULATION CENTER:		POPULATION:
	Matagorda, 5 miles southwest	500
	Palacios, 19 miles west	4,000
	Bay City, 17 miles north	12,000

GULF DOME: Continued

GEOLOGIC DATA: Some evidence of movement since Beaumont (Pleistocene) time.

HYDROLOGIC DATA: Mine Lake situated over part of dome; Matagorda Bay less than a mile southeast of dome. Gulf Coast aquifers present, depth to saline water about 600 feet in vicinity of dome, but probably less over dome.

GEOGRAPHIC DATA: At surface, dome is an oval hill 5-30 feet above sea level; 37 feet high before sulfur mining began; once was small lake on north part of dome; swamp on east and west sides. Land is pastured. Gulf, Colorado, and Santa Fe Railroad passes 2 1/4 miles west of dome.

GEOPHYSICAL DATA: Texas Gulf Sulphur Co. defined dome to 6,000 feet by seismographic method.

ECONOMIC DATA: Petroleum production to 1964, 211,000 barrels; abandoned. Produced sulfur by Frasch process; 12,350,000 tons between 1919 and 1936. Plant reopened for short time in 1939, after which it was abandoned and permanently dismantled.

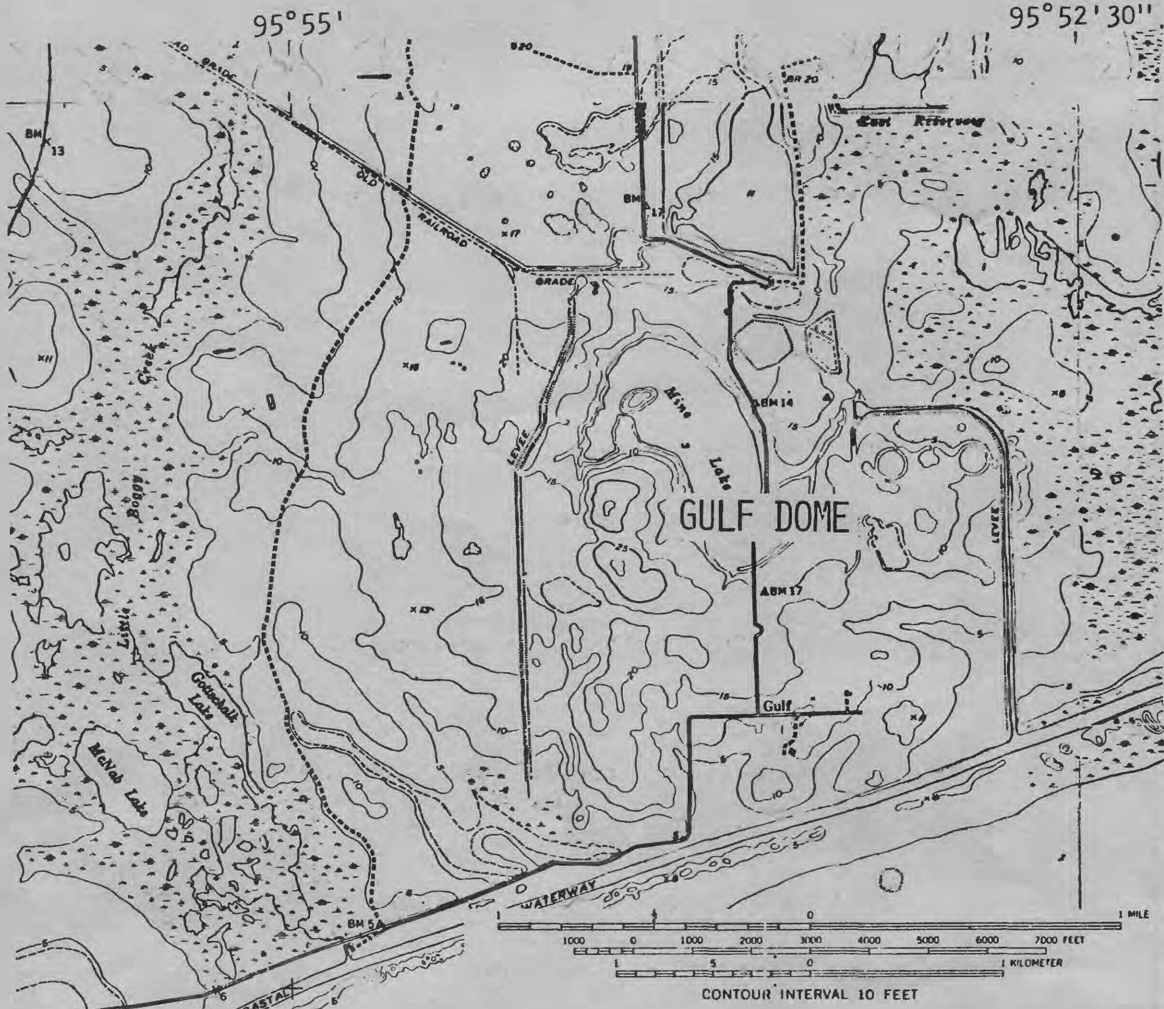


Figure 109.--Topographic map showing vicinity of Gulf dome. (U.S.G.S., 1:24,000, Dressing Point, Lake Austin, Matagorda, and Wadsworth, Tex., all reduced in scale)

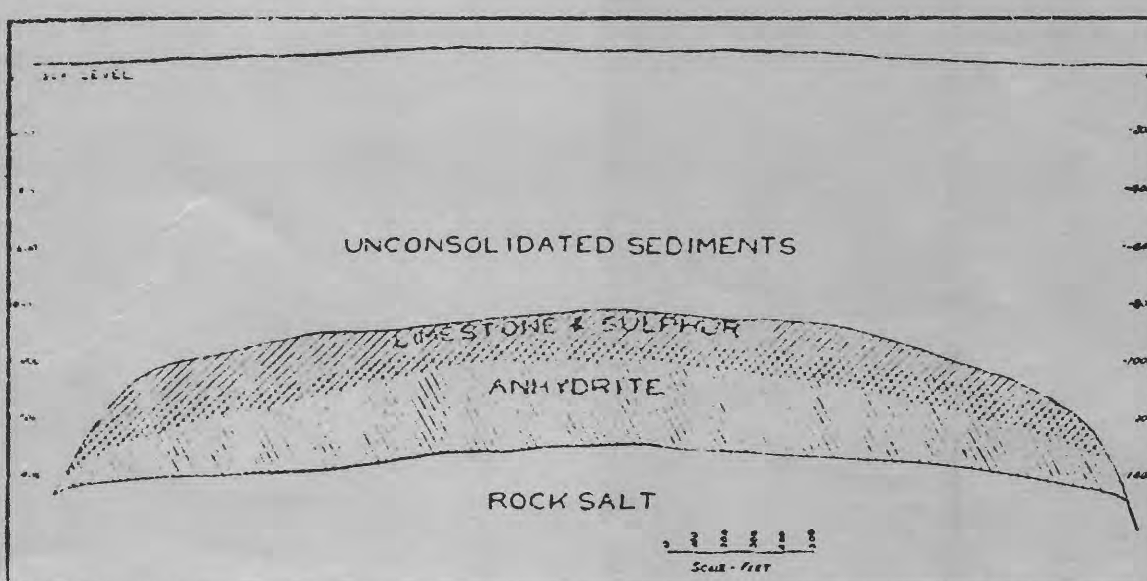


Figure 110.--Diagrammatic cross section through Gulf salt dome. From Wolf (1925, fig. 2).

REFERENCES CITED

American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, and Society of Economic Geologists, 1953, Guidebook, field trip routes, oil fields, geology, joint annual meeting, Houston, Texas, March 1953: 167 p.

Anders, R. B., McAdoo, G. D., and Alexander, W. H., Jr., 1968, Ground-water resources of Liberty County, Texas: Texas Water Devel. Board Rept. 72, 140 p.

Baker, E. T., Jr., 1964, Geology and ground-water resources of Hardin County, Texas: Texas Water Comm. Bull. 6406, 179 p.

______1971, Relation of ponded floodwater from Hurricane Beulah to ground water in Kleberg, Kenedy, and Willacy Counties, Texas: Texas Water Devel. Board Rept. 138, 33 p.

Belchic, H. C., 1960, The Winnfield salt dome, Winn Parish, Louisiana, in Interior salt domes and Tertiary stratigraphy of north Louisiana, 1960 Spring field trip guidebook: Shreveport, La., Shreveport Geol. Soc., p. 29-47.

Blanpied, B. W., 1960, Tabulation of north Louisiana salt domes, in Interior salt domes and Tertiary stratigraphy of north Louisiana, 1960 Spring field trip guidebook: Shreveport, La., Shreveport Geol. Soc., p. 57-60.

Bodenlos, A. J., 1970, Cap-rock development and salt-stock movement, in Geology and technology of Gulf Coast salt--A symposium, May 1-2, 1967, Louisiana State Univ., Baton Rouge, La.: Louisiana State Univ., School of Geoscience, p. 73-86.

Boswell, E. H., Thomson, F. H., and Shattles, D. E., 1970, Water for industrial development in Clarke, Jasper, Lauderdale, Newton, Scott, and Smith Counties [Mississippi]: Jackson, Miss., Mississippi Research and Devel. Center, 62 p.

Bradshaw, R. L., 1970 [Comments made during] Panel discussions, D. H. Kupfer and R. E. Taylor, moderators, in Geology and technology of Gulf Coast salt--A symposium, May 1-2, 1967, Louisiana State Univ., Baton Rouge, La.: Louisiana State Univ., School of Geoscience, p. 172.

Callahan, J. A., Skelton, John, Everett, D. E., and Harvey, E. J., 1964, Available water for industry in Adams, Claiborne, Jefferson, and Warren Counties, Mississippi: Mississippi Indus. and Tech. Research Comm. Bull. 64-1, 45 p.

Canada, W. R., 1953, Hockley field, Harris County, Texas, in Am. Assoc. Petroleum Geologists, Soc. Econ. Paleontologists and Mineralogists, and Soc. Econ. Geologists, Guidebook, field trip routes, oil fields, geology, joint annual meeting, Houston, Texas, March 1953: p. 125-128.

Clark, G. D., 1961, Interior salt domes of Texas, Louisiana and Mississippi, in Interior salt domes and Tertiary stratigraphy of north Louisiana, 1960 Spring field trip guidebook: Shreveport, La., Shreveport Geol. Soc., p. 3-16.

Cohee, G. V., chm., and others, 1962, Tectonic map of the United States: U.S. Geol. Survey and Am. Assoc. Petroleum Geologists, scale 1:2,500,000.

Corpus Christi Geological Society, 1967, Typical oil and gas fields of South Texas, 212 p.

Deussen, Alexander, and Lane, L. L., 1925, Hockley salt dome, Harris County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 9, no. 7, p. 1031-1060.

Dial, D. C., 1970, Public water supplies in Louisiana: Louisiana Dept. Public Works Basic Records Rept. 3, 460 p.

Dillard, J. W., 1963, Availability and quality of ground water in Smith County, Texas: Texas Water Comm. Bull. 6302, 150 p.

Durham, C. O., Jr., and White, W. S., Jr., 1960, A guided geological tour through north and central Louisiana, in Interior salt domes and Tertiary stratigraphy of north Louisiana, 1960 Spring field trip guidebook: Shreveport, La., Shreveport Geol. Soc., p. 83-88.

Eargle, D. H., 1968, Stratigraphy and structure of the Tatum salt dome area, southeastern Mississippi and northeastern Washington Parish, Louisiana, in Saline deposits--Internat. Conf. Saline Deposits, Houston, Tex., 1962, Symposium: Geol. Soc. America Spec. Paper 88, p. 381-405.

______ 1971, Southwest-northeast cross section, Tatum dome, Lamar County, Mississippi: U.S. Geol. Survey rept. USGS-474-114, 2 p. [1963]; available only from U.S. Dept. Commerce, Natl. Tech. Inf. Service, Springfield, Va. 22151.

Eargle, D. H., Hinds, G. W., and Weeks, A. M. D., 1971, Uranium geology and mines, south Texas: Texas Univ. Bur. Econ. Geology, Guidebook No. 12, 59 p.

Ebanks, J. K., 1965, Structural geology of the Keechi salt dome, Anderson County, Texas: unpublished M.A. thesis, The University of Texas at Austin, 83 p.

Fisk, H. N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Vicksburg, Miss., Mississippi River Comm., Dec. 1, 1944, 78 p.

Gera, Ferruccio, 1972, Review of salt tectonics in relation to the disposal of radioactive wastes in salt formations: Geol. Soc. America Bull., v. 83, p. 3551-3574.

Goldman, M. I., 1931, Bearing of cap rock on subsidence on Clay Creek salt dome, Washington County, Texas, and Chestnut dome, Natchitoches Parish, Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 15, no. 9, p. 1105-1113.

Gulf Coast Association of Geological Societies, 1970, Guidebook, north central Louisiana salt domes, 20th Ann. Mtg., Oct. 28, 29, 30, 1970: Shreveport, La., 23 p., 15 plates.

Halbouty, M. T., 1967, Salt domes--Gulf region, United States and Mexico: Houston, Tex., Gulf Publishing Co., 425 p.

Hammond, W. W., Jr., 1969, Ground-water resources of Matagorda County, Texas: Texas Water Devel. Board Rept. 91 [173 p.].

Hanna, M. A., 1934, Geology of the Gulf Coast salt domes, in Problems of petroleum geology (Sidney Powers memorial volume): Am. Assoc. Petroleum Geologists, p. 629-678.

______ 1939, Evidence of erosion of salt stock in Gulf Coast salt plug in late Oligocene: Am. Assoc. Petroleum Geologists Bull., v. 23, no. 4, p. 604-607; corrections, no. 10, p. 1576, October 1939; v. 27, no. 1, p. 85-86, January 1943.

Hanna, M. A. (compiler), 1959, Salt domes--favorite home for oil: Oil and Gas Jour., v. 57, no. 6, p. 138-142.

Harder, A. H., Kilburn, Chabot, Whitman, H. M., and Rogers, S. M., 1967, Effects of ground-water withdrawals on water levels and salt-water encroachment in southwestern Louisiana: Louisiana Geol. Survey and Dept. Public Works Water Resources Bull. 10, 56 p.

Hawkins, M. E., and Jirik, C. J., 1966, Salt domes in Texas, Louisiana, Mississippi, Alabama, and offshore tidelands--A survey: U.S. Bur. Mines Inf. Circ. 8313, 78 p.

Hightower, M. L., 1958, Structural geology of the Palestine salt dome, Anderson County, Texas: Unpublished M.A. thesis, The University of Texas at Austin, 83 p.

Hopkins, O. B., 1918, Palestine salt dome, Anderson County, Texas: U.S. Geol. Survey Bull. 661-G, p. 253-270.

Hoy, R. B., Foose, R. M., and O'Neill, B. J., Jr., 1962, Structure of Winnfield salt dome, Winn Parish, Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 8, p. 1444-1459.

Hull, J. P. D., 1925, Prothro salt dome, Bienville Parish, Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 9, no. 5, p. 904-906.

Huner, John, Jr., 1939, Geology of Caldwell and Winn Parishes: Louisiana Dept. Conserv. Bull. 15, 356 p.

Judson, S. A., 1929, Résumé of discoveries and developments in northeastern Texas in 1928: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 6, p. 611-616.

Judson, S. A., and Stamey, R. A., 1933, Overhanging salt on domes of Texas and Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 12, p. 1492-1520.

Kupfer, D. H., 1970, Mechanism of intrusion of Gulf Coast salt, in Geology and technology of Gulf Coast salt--A symposium, May 1-2, 1967, Louisiana State Univ., Baton Rouge, La.: Louisiana State Univ., School of Geoscience, p. 25-66.

Lang, J. W., 1971, Hydrologic studies, Project Dribble, Tatum salt dome, Lamar County, Mississippi: U.S. Geol. Survey rept. USGS-474-128, 15 p. [1961]; available only from U.S. Dept. Commerce, Natl. Tech. Inf. Service, Springfield, Va. 22151.

______1972, Geohydrologic summary of the Pearl River basin, Mississippi and Louisiana: U.S. Geol. Survey Water-Supply Paper 1899-M, p. M1-M44.

LeGrand, H. E., 1962, Geology and ground-water hydrology of the Atlantic and Gulf Coastal Plain as related to disposal of radioactive wastes: U.S. Geol. Survey open-file report TEI-805, 169 p.

Martin, J. L., Hough, L. W., Raggio, D. L., and Sandberg, A. E., 1954, Geology of Webster Parish: Louisiana Geol. Survey Geol. Bull. 29, 252 p.

Marx, A. H., 1936, Hoskins Mound salt dome, Brazoria County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 2, p. 155-178.

Mellen, F. F., 1959, Mississippi mineral resources: Mississippi State Geol. Survey Bull. 86, 100 p.

Meyerhoff, A. A., and Hatten, C. W., 1968, Diapiric structures in central Cuba, in Diapirism and diapirs--A symposium: Am. Assoc. Petroleum Geologists Mem. 8, p. 315-357.

Mississippi Geological Society, 1944, Mississippi oil-field and salt-dome names: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 7, p. 1046-1049.

Murray, G. E., 1961, Geology of the Atlantic and Gulf coastal province of North America: New York, Harper and Brothers, 692 p.

______1968, Salt structures of Gulf of Mexico basin--A review, in Diapirism and diapirs--A symposium: Am. Assoc. Petroleum Geologists Mem. 8, p. 99-121.

Myers, B. N., and Dale, O. C., 1967, Ground-water resources of Brooks County, Texas: Texas Water Devel. Board Rept. 61, 87 p.

Newcome, Roy, Jr., 1965, Configuration on the base of the fresh-ground-water section in Mississippi: Mississippi Board Water Commissioners Water Resources Map 65-1, scale about 1 inch to 16 miles.

______1967, Ground-water resources of the Pascagoula River basin, Mississippi and Alabama: U.S. Geol. Survey Water-Supply Paper 1839-K, p. K1-K36.

Newcome, Roy, Jr., Page, L. V., Sloss, Raymond, 1963, Water resources of Natchitoches Parish, Louisiana: Louisiana Geol. Survey Water Resources Bull. 4, 189 p.

Newcome, Roy, Jr., and Thomson, F. H., 1970, Water for industrial development in Amite, Franklin, Lincoln, Pike, and Wilkinson Counties, Mississippi: Jackson, Miss., Mississippi Research and Devel. Center, 61 p.

Page, L. V., and May, H. G., 1964, Water resources of Bossier and Caddo Parishes, Louisiana: Louisiana Geol. Survey Water Resources Bull. 5, 105 p.

Page, L. V., Newcome, Roy, Jr., and Graeff, G. D., Jr., 1963, Water resources of Sabine Parish, Louisiana: Louisiana Geol. Survey Water Resources Bull. 3, 146 p.

Park, N. R., 1950, Maydelle field, Cherokee County, Texas, in Occurrence of oil and gas in northeast Texas: Texas Univ. Bur. Econ. Geology in coop. with East Tex. Geol. Soc., p. 219-222.

Payne, J. N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas: U.S. Geol. Survey Prof. Paper 569-A, p. A1-A17.

Petitt, B. M., Jr., and Winslow, A. G., 1957, Geology and ground-water resources of Galveston County, Texas: U.S. Geol. Survey Water-Supply Paper 1416, 157 p.

Pierce, W. G., and Rich, E. I., 1962, Summary of rock salt deposits in the United States as possible storage sites for radioactive waste materials: U.S. Geol. Survey Bull. 1148, 91 p.

Powers, Sidney, 1926, Interior salt domes of Texas: Am. Assoc. Petroleum Geologists Bull., v. 10, no. 1, p. 1-60; Geology of salt dome oil fields, p. 209-268.

Rawson, D., Randolph, Philip, Boardman, C., and Wheeler, V., 1966, Post-explosion environment resulting from the Salmon experiment: Jour. Geophys. Research, v. 71, no. 14, p. 3507-3521.

Rollo, J. R., 1960, Ground water in Louisiana: Louisiana Geol. Survey Water Resources Bull. 1, 84 p.

Sauer, V. B., 1964, Floods in Louisiana--Magnitude and frequency, 2d ed: Baton Rouge, La., Louisiana Dept. Highways in coop. with U.S. Geol. Survey, 402 p.

Sheets, M. M., 1971, Active surface faulting in the Houston area, Texas, 1971: Houston Geol. Soc. Bull., v. 13, no. 7.

Shows, T. N., Broussard, W. L., and Humphreys, C. P., Jr., 1966, Water for industrial development in Forrest, Greene, Jones, Perry, and Wayne Counties, Mississippi: Jackson, Miss., Mississippi Research and Devel. Center, 72 p.

Shreveport Geological Society, 1960, Interior salt domes and Tertiary stratigraphy of north Louisiana, Shreveport Geological Society guidebook, 1960 Spring field trip: 147 p.

Spooner, W. C., 1926, Interior salt domes of Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 10, no. 3, p. 217-292.

Taylor, R. E., 1971, Water levels in observation wells in the Tatum salt dome area 1961-65, Lamar County, Mississippi: U.S. Geol. Survey rept. USGS-474-118, 27 p. [1966]; available only from U.S. Dept. Commerce, Natl. Tech. Inf. Service, Springfield, Va. 22151.

Taylor, R. E., Humphreys, C. P., Jr., and Shattles, D. E., 1968, Water for industrial development in Covington, Jefferson Davis, Lamar, Lawrence, Marion, and Walthall Counties, Mississippi: Jackson, Miss., Mississippi Research and Devel. Center, 114 p.

Texas University Bureau of Economic Geology, 1964, Geologic atlas of Texas, Tyler sheet--John T. Lonsdale Memorial Edition: Austin, Univ. Texas Bur. Econ. Geology, scale 1:250,000.

______1967, Geologic atlas of Texas, Palestine sheet--Sidney Powers Memorial Edition: Austin, Tex., Univ. Texas Bur. Econ. Geology, scale 1:250,000.

______1968, Geologic atlas of Texas, Houston sheet--Paul Weaver Memorial Edition: Austin, Tex., Univ. Texas Bur. Econ. Geology, scale 1:250,000.

Turner, G. L., 1950, South Tyler field, Smith County, Texas, in Occurrence of oil and gas in northeast Texas: Texas Univ. Bur. Econ. Geology in coop. with East Texas Geol. Soc., p. 364-366.

U.S. Bureau of Mines, 1961, An investigation of salt domes for potential nuclear test sites: U.S. Bur. Mines Admin. Rept., 104 p.

U.S. Environmental Science Services Administration/Coast and Geodetic Survey, 1969, Seismic risk map for conterminous United States: U.S. Dept. Commerce map.

U.S. Environmental Science Services Administration/Coast and Geodetic Survey, National Earthquake Information Center, 1970, Seismicity of the United States, 1st ed.: U.S. Dept. Commerce map NEIC 3012.

U.S. Geological Survey, 1957, Surface water supply of the United States, 1955, Pt. 8, Western Gulf of Mexico basins: U.S. Geol. Survey Water-Supply Paper 1392, 443 p.

______1970, The National atlas of the United States of America: Washington, D. C., 417 p.

U.S. Study Commission, 1962, The report of the U.S. Study Commission--Texas--Pt. 3, The eight basins: Houston, Tex., U.S. Study Comm., 217 p.

Warren, D. H., Healy, J. H., and Jackson, W. H., 1966, Crustal seismic measurements in southeastern Mississippi: Jour. Geophys. Research, v. 71, no. 14, p. 3437-3456.

Wasson, B. E., 1971, Water resources of the Big Black River basin, Mississippi: U.S. Geol. Survey Water-Supply Paper 1899-F, p. F1-F29.

Wendlandt, E. A., and Knebel, G. M., 1929, Lower Claiborne of east Texas, with special reference to Mount Sylvan dome and salt movements: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 10, p. 1347-1375.

Williams, C. H., Jr., 1969, Cross section from Mississippi-Tennessee state line to Horn Island in Gulf of Mexico: Mississippi Geol. Survey, scale 1:250,000.

Wilson, K. V., and Trotter, I. L., 1961, Floods in Mississippi, magnitude and frequency: Jackson, Miss., Mississippi Highway Dept., Traffic Plan Div., 326 p.

Winslow, A. G., Doyel, W. W., and Wood, L. A., 1957, Salt water and its relation to fresh ground water in Harris County, Texas, in Contributions to the hydrology of the United States, 1955: U.S. Geol. Survey Water-Supply Paper 1360-F, p. 375-407.

Winslow, A. G., Hillier, D. E., and Turcan, A. N., Jr., 1968, Saline ground water in Louisiana: U.S. Geol. Survey Hydrol. Inv. Atlas HA-310, 4 sheets, scale 1:750,000.

Wolf, A. G., 1925, Big Hill salt dome, Matagorda County, Texas: Am. Assoc. Petroleum Geologists Bull., v. 9, no. 4, p. 711-737.

Wood, L. A., Gabrysch, R. K., and Marvin, Richard, 1963, Reconnaissance investigation of the ground-water resources of the Gulf Coast region, Texas: Texas Water Comm. Bull. 6305, 114 p.