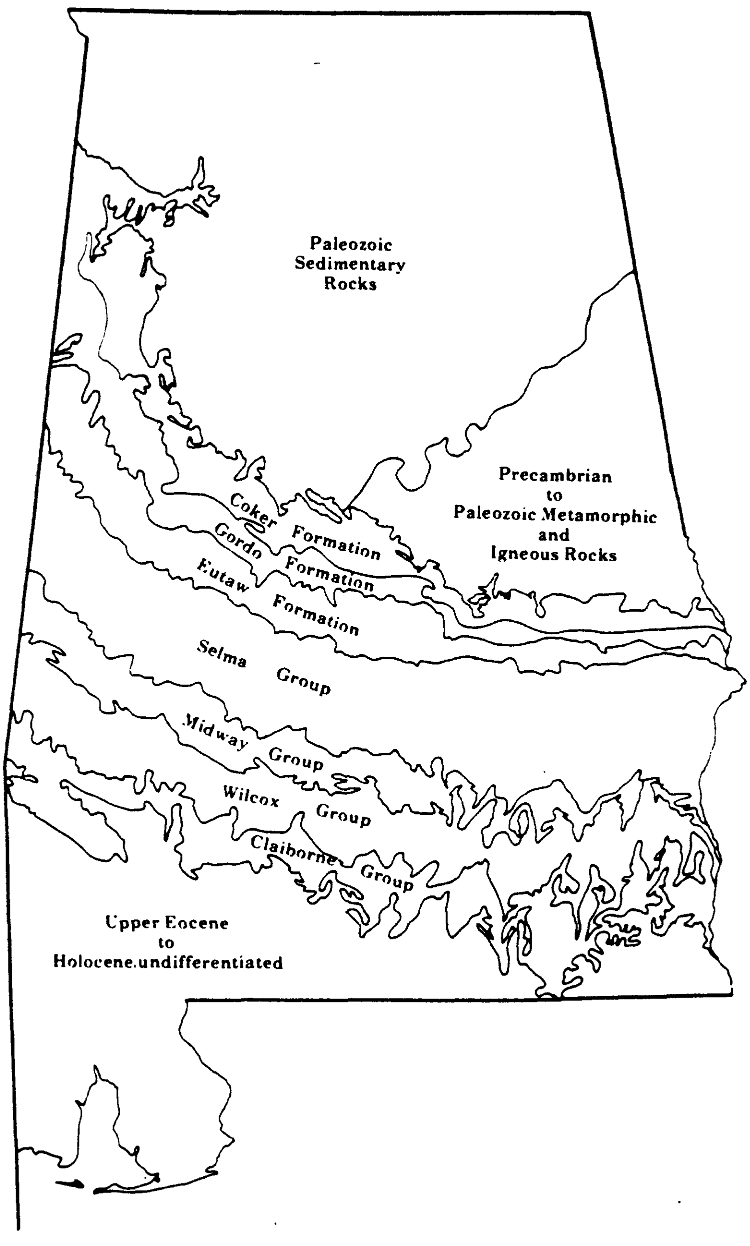
WATER-RESOURCES INVESTIGATIONS
REPORT 87-4112

STRATIGRAPHIC AND HYDROGEOLOGIC FRAMEWORK OF THE ALABAMA COASTAL PLAIN

By Marvin E. Davis



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

Regional Hydrologist
U.S. Geological Survey
75 Spring Street, S.W., Suite 772
Atlanta, Georgia 30303

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports
Box 25425, Federal Center
Denver, Colorado 80225

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

TABLE

PLATES
(Plates are in pocket)

STRATIGRAPHIC AND HYDROGEOLOGIC FRAMEWORK OF THE ALABAMA COASTAL PLAIN

By Marvin E. Davis

ABSTRACT

Tertiary and Cretaceous sand aquifers of the Southeastern United States Coastal Plain comprise a major multistate aquifer system informally defined as the Southeastern Coastal Plain aquifer system, which is being studied as part of the U.S. Geological Survey's Regional Aquifer System Analysis (RASA) program. The major objectives of each RASA study are to identify, delineate, and map the distribution of permeable clastic rock, to examine the pattern of ground-water flow within the regional aquifers, and to develop digital computer simulations to understand the flow system. The Coastal Plain aquifers in Alabama are being studied as a part of this system.

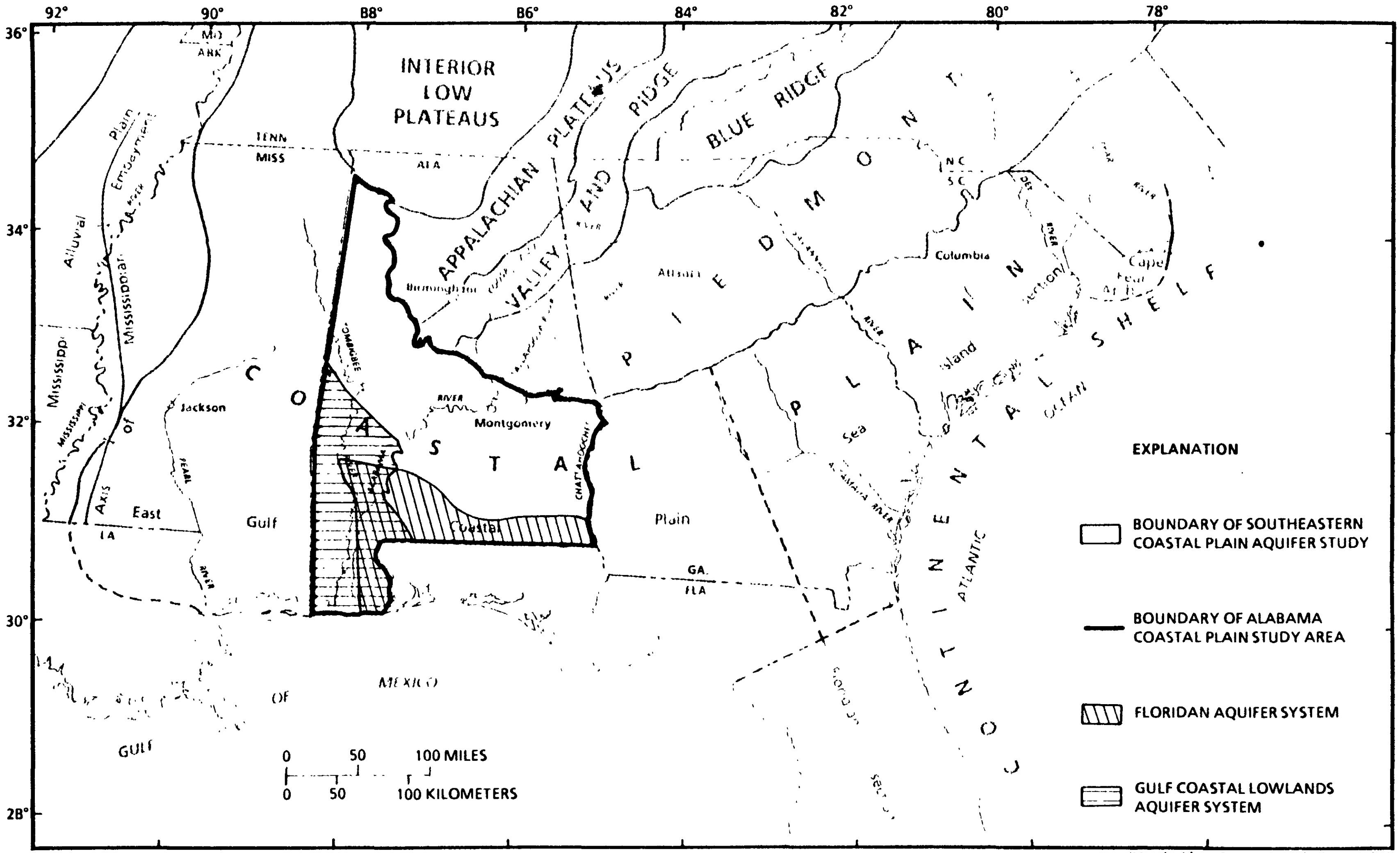
This report describes the stratigraphic framework of the Cretaceous, Tertiary, and Quaternary Systems in Alabama to aid in delineating aquifers and confining units within the thick sequence of sediments that comprises the Southeastern Coastal Plain aquifer system in the State. Stratigraphic units of Cretaceous and Tertiary age that make up most of the aquifer system in the Coastal Plain of Alabama consist of clastic deposits of Early Cretaceous age; the Coker and Gordo Formations of the Tuscaloosa Group, Eutaw Formation, and Selma Group of Late Cretaceous age; and the Midway, Wilcox, and Claiborne Groups of Tertiary age. However, stratigraphic units of late Eocene to Holocene age partially overlie and are hydraulically connected to clastic deposits in southern Alabama. These upper carbonate and clastic stratigraphic units also are part of the adjoining Floridan and Gulf Coastal Lowlands aquifer systems. The Coastal Plain aquifer system is underlain by pre-Cretaceous rocks consisting of low-permeability sedimentary rocks of Paleozoic, Triassic, and Jurassic age, and a complex of metamorphic and igneous rocks of Precambrian and Paleozoic age similar to those found near the surface in the Piedmont physiographic province.

Twelve hydrogeologic units in the Alabama Coastal Plain are defined--six aquifers and six confining units. Aquifers of the Coastal Plain aquifer system are composed of fine to coarse sand, gravel, and limestone; confining beds are composed of clay, shale, chalk, marl, and metamorphic and igneous rocks.

INTRODUCTION

Clastic sediments of Cretaceous and Tertiary age in South Carolina, Georgia, Alabama, Mississippi, and adjacent areas of northern Florida and southwestern North Carolina comprise a major aquifer system in the Southeastern United States Coastal Plain that is informally called the Southeastern Coastal Plain aquifer system. This aquifer system can be traced from the southwestern flank of the Cape Fear arch in North Carolina into the Mississippi embayment in northern Mississippi.

The uppermost hydrogeologic units of the Southeastern Coastal Plain aquifer system thicken and become part of the Floridan aquifer system (Miller, 1986) in southern Alabama, and of the Gulf Coastal Lowlands aquifer systems that are being studied by the Gulf Coast Regional Aquifer System Analysis (RASA) project (Grubb, 1986) in southwestern Alabama (fig. 1).



(Modified from Fenneman and Johnson, 1946)

Figure 1.--Alabama Coastal Plain study area, Southeastern Coastal Plain Regional Aquifer System Analysis study area, and parts of adjacent Regional Aquifer System Analysis study areas.

The Southeastern Coastal Plain aquifer system is being studied as part of the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) program, a series of investigations that present a systematic, unified, regional overview and assessment of the hydrogeologic and geochemical conditions of multistate aquifer systems. The major objectives of the Southeastern Coastal Plain aquifer system study are to identify, delineate, and map the distribution of permeable clastic rock; to examine the pattern of ground-water flow within the regional aquifer system, whose physical boundaries extend beyond political subdivisions; and to develop computer simulations to understand the flow system. The Coastal Plain aquifers in Alabama are being studied as a part of the Southeastern Coastal Plain RASA study.

The Coastal Plain of Alabama encompasses an area of about 32,000 square miles and is underlain by a wedge of unconsolidated to semiconsolidated deposits that thickens from its inner margin, the Fall Line, to the coast and consists of sand, gravel, clay, and limestone of Early Cretaceous to Holocene age. These deposits are underlain by pre-Cretaceous rocks that consist of sedimentary rocks of Paleozoic, Triassic, and Jurassic age and a complex of metamorphic and igneous rocks of Precambrian and Paleozoic age similar to those found near the surface in the Piedmont physiographic province of the State.

Purpose and Scope

The purpose of this report is to describe the stratigraphic and hydrogeologic framework of the Cretaceous, Tertiary, and Quaternary Systems in Alabama. The framework was used to aid in delineating aquifers and confining units within the thick, complex sequence of sediments that comprises the Coastal Plain aquifer system in the State. The stratigraphic framework described in this report consists of five geologic sections and nine maps that show the configuration of the top or base of formations, groups of formations, or stratigraphic systems. Although more detailed subdivision of aquifers and confining units is needed for local ground-water development, the simplification of the aquifer system described in this report by dividing it into a framework of discrete geologic units can aid significantly in understanding the hydrology of the aquifer system on a regional scale. This geologic framework is the basis for defining the aquifers used in potentiometric mapping, transmissivity mapping, geochemical analysis, and ground-water flow modeling for the Alabama section of the Southeastern Coastal Plain study.

The area described in this report is the Coastal Plain of Alabama (fig. 1). Data from Alabama and adjacent states were used. Figure 1 shows the area of study and its relation to the three regional aquifer system studies, of which Alabama Coastal Plain hydrogeologic units are a part. Only those portions of the Floridan and Gulf Coastal Lowlands aquifer systems that overlie and are a part of the Southeastern Coastal Plain aquifer system in Alabama are shown.

Previous Investigations

The first comprehensive and systematic work on the stratigraphy of the Coastal Plain in Alabama was done by Eugene A. Smith, State Geologist from 1873 to 1927, who was assisted by L. C. Johnson of the U.S. Geological Survey and, later, by D. W. Langdon of the Geological Survey of Alabama. The results of their investigations were published in 1887 and 1894. These reports laid the foundation for all future work in Coastal Plain stratigraphy by establishing the sequence of Cretaceous and Tertiary strata, by providing a detailed description of the beds and their guide fossils, and by instituting a classification and nomenclature of the formations. During this early period the eminent paleontologists Gilbert D. Harris and Truman H. Aldrich contributed much to the knowledge of Coastal Plain fauna.

Later, C. Wythe Cooke, L. W. Stephenson, J. E. Brantly, and others studied the Coastal Plain geology. Some of the most important of the later reports that contain information on the geology of the Coastal Plain are: "The Underground Water Resources of Alabama," by E. A. Smith, published in 1907; "The Mesozoic Rocks," by L. W. Stephenson, and "The Cenozoic Formations," by C. W. Cooke, in "Geology of Alabama," by G. I. Adams and others in 1926; "Notes on Deposits of Selma and Ripley age in Alabama," by W. H. Monroe in 1941; "Summary of the Midway and Wilcox Stratigraphy of Alabama and Mississippi," by F. S. MacNeil in 1946; and the guidebook of the tenth field trip of the Mississippi Geological Society on the Wilcox and Midway Groups of west-central Alabama, by P. E. LaMoreaux and L. D. Toulmin in 1953.

Many other recent and detailed geologic and hydrologic reports exist. Publications resulting from comprehensive and reconnaissance-type studies conducted by the U.S. Geological Survey have described the geologic units and water resources for each county in Alabama. Because of the statewide scope of this study, these reports are not discussed individually.

Acknowledgments

Special appreciation is extended to Charles W. Copeland, Jr., Chief Geologist, Geologic Division, Geological Survey of Alabama, who provided invaluable help in interpreting electric logs for many of the wells used for this report; and to colleagues of the U.S. Geological Survey, including James A. Miller, Chief of the Southeastern Coastal Plain RASA study, who provided encouragement and assistance with this report; and Sydney DeJarnette and Brenda Alan, who assisted in the preliminary preparation of the stratigraphic maps and cross sections.

Method of Study

Description of the generalized structure and stratigraphy of the Coastal Plain is based primarily on interpretation of electric logs of water wells and oil test holes. In areas where electric logs were not available, attempts were made to use drillers' and sample logs; generally, however, timed circulation of cuttings commonly is not considered and sample descriptions for these logs do not always correspond with the correct depths of lithologic changes in the well. Much of the geologic interpretation is based on previously established and generally recognized unit boundaries. Some microscopic and micropaleontologic examinations of well cuttings were made during this study to verify the interpretation of the drillers' and electric logs. Microscopic examination of well cuttings from oil test wells has been a normal procedure by the Geological Survey of Alabama upon completion of most of the wells.

Figure 2 shows two representative electric logs of oil test wells for western and eastern Alabama and the correlation of formation tops and lithologic changes between the wells. The interpretation of these particular logs as shown is in general agreement with most previous investigations in southwestern and

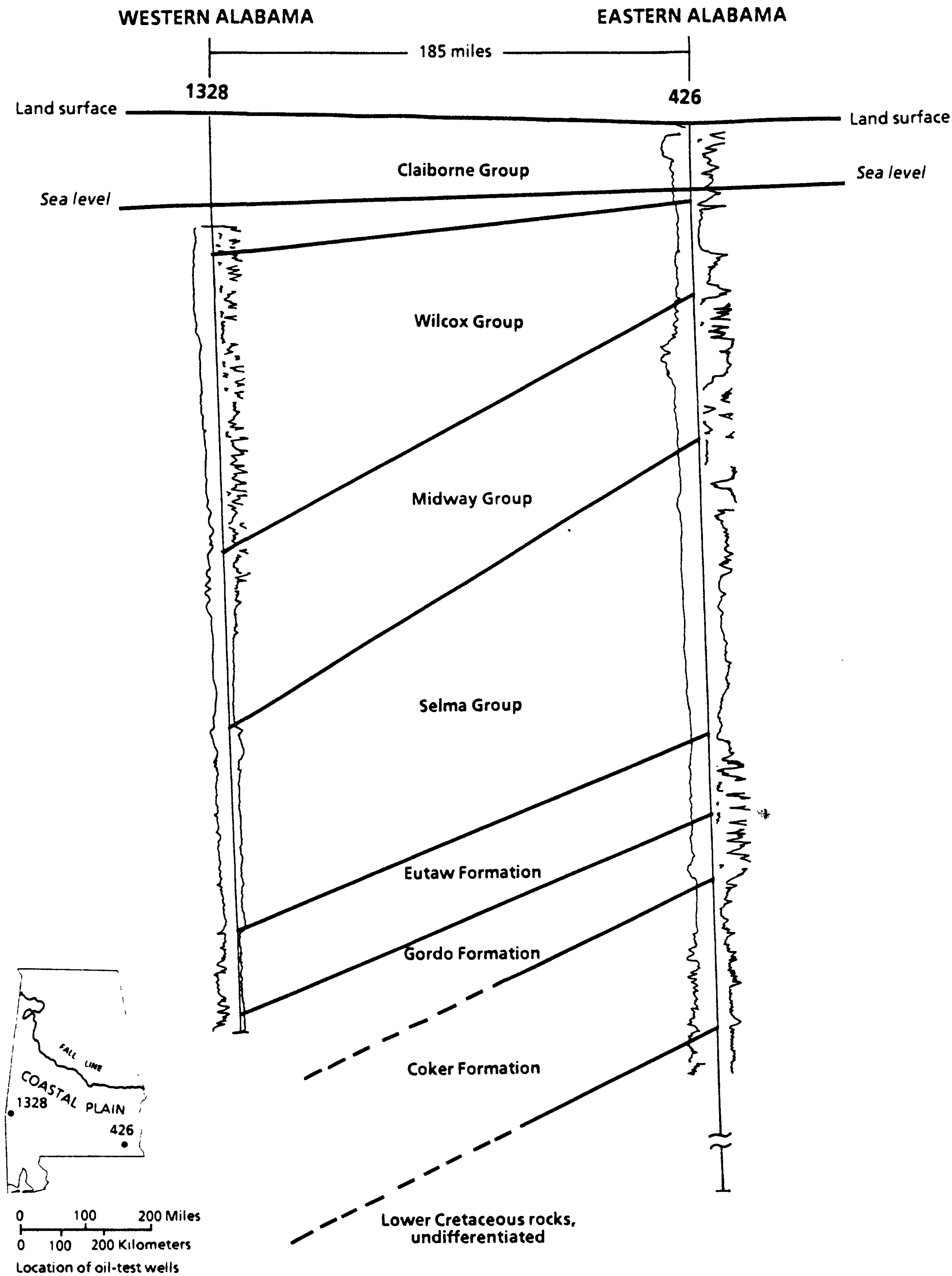


Figure 2.--Formation tops and changes in lithology between eastern and western Alabama.

southeastern Alabama. The "signatures" of the spontaneous potential (SP) and resistivity (R) curves on these logs have been used extensively to verify similar-shaped curves on the logs of other wells.

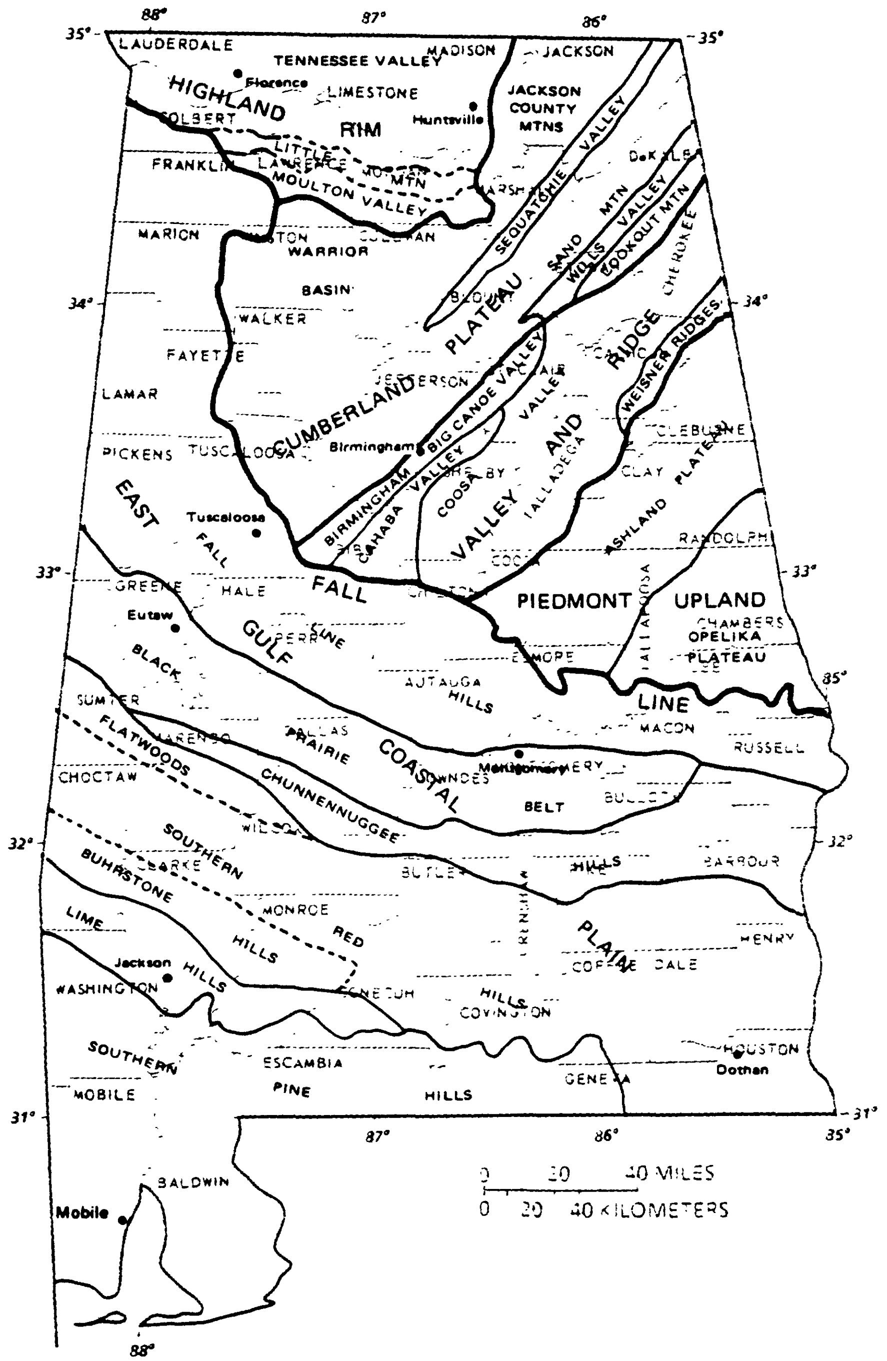
Facies changes in the Tertiary System appear to occur most drastically near the central and southeastern part of the Coastal Plain. In these areas, where the upper Tertiary parts of the logs appeared to be totally unlike, it was sometimes necessary to correlate the easily recognized contact of the Selma Group and Eutaw Formation for reasonable alignment of the logs and work upward into the Tertiary (fig. 2). Also, by correlating the logs of wells on a regional basis, rather than county by county, it is easier to detect facies changes and recognize resemblances of similar formation tops in wells separated by many miles.

During the study two stratigraphic sections parallel to the regional dip and three stratigraphic sections parallel to regional strike were constructed to illustrate the geology of the Coastal Plain of Alabama (pls. 2 to 6). Nine maps showing the configuration of the top or base of formations, groups of formations, or stratigraphic systems were prepared to portray the geometric relief relative to sea level (pls. 7 to 15). The locations of the 189 wells used in constructing the top maps and cross sections are shown on plate 1. On the cross sections (locations also shown on plate 1) and in table 1, each oil-test well used is designated by the sequential permit number assigned by the State Oil and Gas Board of Alabama upon application of intent to drill. A few wells shown on the cross sections were drilled specifically for water supply. These wells have been given the grid number assigned during inventory of the wells for a county water-resources investigation, such as K-13 in Dallas County, for example. The well data for each well in plates 2 to 6 are given in table 1 and include the well number, county, latitude, longitude, section-township-range grid, datum altitude and total depth.

The well data used for structural control are stored in U.S. Geological Survey computer files and may be obtained as a computer printout from the Water Resources Division, U.S. Geological Survey, 520 19th Avenue, Tuscaloosa, AL 35401.

Physiographic Features

Alabama is in parts of five primary physiographic provinces: the Highland Rim Section of the Interior Low Plateaus, the Cumberland Plateau section of the Appalachian Plateaus, the southernmost part of the Valley and Ridge, the Piedmont Upland section of the Piedmont, and the East Gulf Coastal Plain section of the Coastal Plain (fig. 3). Only parts of the East Gulf Coastal Plain section below the Fall Line are described in detail in this report. Descriptive information concerning the various divisions is from Adams (1926), Johnson (1933), Fenneman (1938), Monroe (1941), and Pierce (1967). The secondary divisions shown on figure 3 indicate the resistance or non-resistance to erosion of outcropping rocks. Thus, the outlines of the physiographic divisions follow very closely the pattern of the outcropping surface geology (pls. 9-15).



(Modified from Peirce, 1967)

Figure 3.--Physiographic provinces of Alabama.

Coastal Plain Province

East Gulf Coastal Plain Section

The East Gulf Coastal Plain Section is underlain by Mesozoic and Cenozoic sedimentary rocks which dip gently southward at about 20 to 40 feet per mile, increasing to as much as 50 feet per mile near the coast. Outcropping resistant beds form cuestas (asymetrical ridges) that gently slope southward forming a series of arcuate, hilly belts trending southeasterly to easterly across the State. The Coastal Plain is divided into the Fall Line Hills, Black Prairie Belt, Chunnennuggee Hills, Southern Red Hills, Lime Hills and Southern Pine Hills. The location of each physiographic subdivision is determined largely by the geologic character of the sediments that underlie it.

Fall Line Hills.--The Fall Line Hills is a dissected upland with a few broad, flat ridges separated by valleys ranging from 100 to 200 feet deep. The Fall Line Hills occupy a zone where streams descend from resistant Paleozoic sedimentary and Piedmont crystalline rocks to the less resistant sand and clay of pre-Selma age in the Coastal Plain. The zone has a maximum width in western Alabama of about 50 miles, and altitudes range from more than 700 feet above sea level in northwestern Alabama to about 250 feet along the northern edge of the Black Prairie Belt.

Black Prairie Belt.--The Black Prairie Belt lies to the south of the Fall Line Hills and occupies a narrow crescent-shaped area, extending from western Tennessee and northern Mississippi into central Alabama. The area is characterized by an undulating deeply weathered plain of low relief, developed mainly on chalk and marl of the Selma Group. Partly because of the impurity of the chalk and marl and partly due to other factors, typical karst features generally formed in carbonate-rock terranes are missing. In western and central Alabama, the interstream areas lie at altitudes of about 250 feet above sea level. The belt is not present in eastern Alabama because of facies changes; the dominant chalk lithologies of western Alabama are replaced by clastic sedimentary units to the east.

The Arcola Cuesta, supported by the resistant Arcola Limestone Member of the Mooreville Chalk, occurs near the middle of the belt and trends southeastward and eastward from the Alabama-Mississippi State line to a point southeast of Montgomery. The Arcola Cuesta is characterized by a line of hills rising 50 to 75 feet above the surrounding prairie floor.

Chunnennuggee Hills.--The Chunnennuggee Hills is a pine-forested series of sand hills and cuestas developed on the Ripley Formation and Prairie Bluff Chalk in western Alabama and the Blufftown Formation, Ripley Formation, and Providence Sand in eastern Alabama. This hilly belt extends eastward from Sumter County across most of the State. It widens in eastern Alabama as the chalk of the Black Prairie Belt intertongues with the more resistant clay, siltstone and sandstone of the Blufftown and Ripley Formations and Providence Sand. In western Alabama the Chunnennuggee Hills are bounded on the north by the Black Prairie Belt and in easternmost Alabama by the Fall Line Hills.

The more indurated beds of several of the Coastal Plain formations that underlie the Chunnennuggee Hills subdivision support prominent north-facing cuestas such as the Ripley Cuesta (Fenneman, 1938), and the Blufftown, Sand Fort, En'on, and Lapine Cuestas (Monroe, 1941).

Southern Red Hills.--The Southern Red Hills includes the Flatwoods, a lowland generally about 5 to 8 miles wide that extends from Sumter County to just east of the Alabama River. The flat-lying, relatively smooth surface of the Flatwoods is at an altitude of about 200 feet above sea level and is developed on the dark clay of the Porters Creek Formation. The Flatwoods are bordered to the south by a range of hills that rise 200 to 400 feet above the area to the north. In this area the hills are underlain by formations of the Wilcox Group, but farther east, the Clayton Formation of the Midway Group forms the boundary ridge south of the Chunnennuggee Hills. The northern edge of the Southern Red Hills lies at a nearly accordant altitude of 600 feet above sea level and local relief of several hundred feet is common. Considerably large areas of "red levels," or undissected uplands, remain, especially at the outer edge of the belt. Along the southern edge of the Southern Red Hills, a cuesta known as the Buhrstone Hills rises 300 to 400 feet above the nearby streams and is considered to be the most rugged topographic region in the Alabama Coastal Plain. This hilly belt is 10 or more miles wide, extends from the Pearl River in Mississippi across Alabama to about the middle of the State, and is developed on the indurated resistant siliceous claystone and sandstone of the Tallahatta Formation.

Lime Hills.--The Lime Hills extend eastward in a belt 5 to 8 miles wide from near the Alabama-Mississippi State line across southwestern Choctaw County into Conecuh County. This rugged topography approaches that of the Buhrstone Hills in places, and is caused partly by the reappearance of the highly resistant Tallahatta Formation in the Hatchetigbee anticline in Choctaw, Washington and Clarke Counties, and partly by facies changes from soft clay, sand, and marl to resistant limestones in the upper Eocene and Oligocene deposits.

The Hatchetigbee anticline affects an area at least 50 miles long and 20 miles wide and stratigraphic displacement at the land surface is at least 600 to 700 feet. The southern flank of the anticline lies in the Lime Hills and the northern flank in the Southern Red Hills. The topography in the western part of the Lime Hills is attributed to the resistant beds in the Tallahatta Formation and resistant limestones of the upper Eocene and Oligocene deposits. Relief of 200 to 250 feet from valley floors to ridge crests is common.

The eastern part of the belt in Monroe and Conecuh Counties is less rugged and the hills are approximately 100 to 150 feet above the valley floors. The sand, clay, and marl of the upper Eocene and Oligocene deposits have been almost entirely replaced by more resistant limestones.

Southern Pine Hills.--The Southern Pine Hills, a cuesta-like, elevated, southward-sloping dissected plain, is developed on Miocene estuarine deposits to the north and on sand and gravel of the Pliocene Citronelle Formation to the south. The plain ranges in altitude from about 400 feet above sea level near the northern border in Monroe County to about 100 feet a few miles inland from the Gulf of Mexico. Relief is greatest in the northern part where streams draining eastward to the Tombigbee River and westward to the Alabama River drop to base level in relatively short distances. The relief is as much as 250 feet in this area. To the south the topography is more subdued, being characterized by low rounded hills.

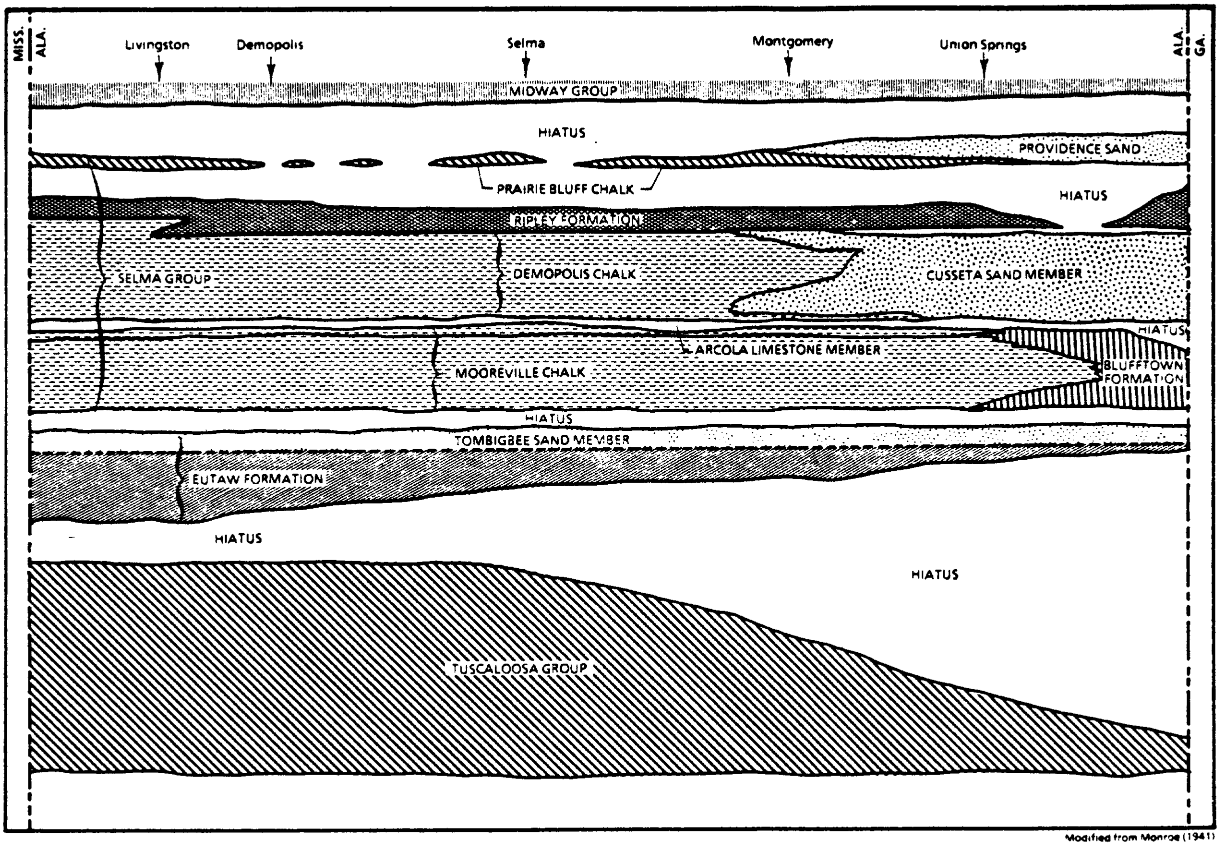


Figure 4.--Stratigraphic relations of Upper Cretaceous formations in Alabama.

GEOLOGY

Regional Setting

The geologic units that are part of the Southeastern Coastal Plain aquifer system and crop out in the Coastal Plain of Alabama are shown individually on the structure contour maps (pls. 9-15). The deposits are of sedimentary origin; consist mainly of sand, gravel, silt, chalk, limestone, and sandstone; and range in age from Late Cretaceous to middle Eocene. The outcropping units include, in ascending order: the Coker Formation and Gordo Formation of the Tuscaloosa Group, Eutaw Formation, Selma Group, Midway Group, Wilcox Group, and Claiborne Group. Outcropping geologic units of late Eocene to Holocene age are not shown because they are exposed at the surface in all of the area south of the outcrop of the Claiborne Group (pl. 15) in Alabama. The units are designated as upper Eocene to Holocene, undifferentiated, on the cross sections (pls. 4 and 5). Rocks of Early Cretaceous age do not crop out in Alabama.

A diagrammatic geologic section and a correlation chart of the outcropping Upper Cretaceous formations from east to west across the upper part of the Coastal Plain in Alabama are shown on figure 4 and figure 5, respectively. Zones of hiatus and facies change are shown for several of the formations in this part of the Coastal Plain. The chart on plate 16 gives a generalized correlation of stratigraphic units in western and eastern Alabama by era, system, series, groups and formations.

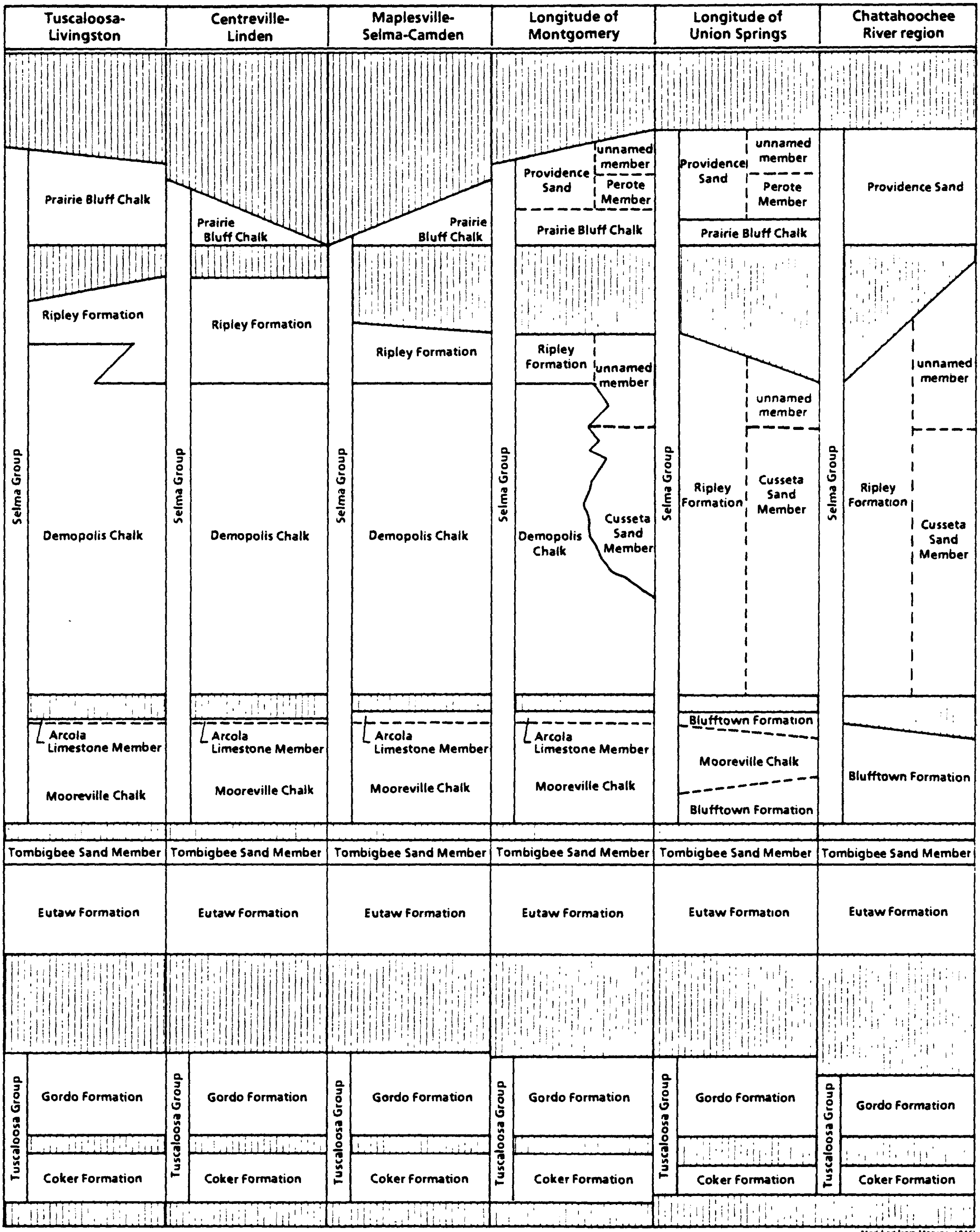


Figure 5.--Outcropping stratigraphic units of Late Cretaceous age in the upper part of the Coastal Plain in Alabama.

Detailed descriptions of the geology were compiled principally from "Correlation of subsurface Mesozoic and Cenozoic rocks along the Eastern Gulf Coast" (Maher and Applin, 1968), "Geology of the Alabama Coastal Plain" (Copeland, 1968), "Hydrogeologic framework of the Floridan Aquifer System in Florida and in parts of Georgia, Alabama, and South Carolina" (Miller, 1986), and numerous county reports prepared by the U.S. Geological Survey and the Geological Survey of Alabama.

Structural Features in the Coastal Plain

The easternmost extension of the Mississippi Interior Salt Dome basin is in southwestern Alabama (fig. 6). Most of the geologic structures observable in Early Cretaceous or younger sediments in this basin are the result of movement of the underlying Louann Salt of Jurassic age. Salt at depth responds as a plastic medium and will move into zones of weakness in response to sediment loading. Structures formed as positive features by salt swells or domes and as collapse-type features (such as grabens) where salt was removed occur in southwestern Alabama. Salt movement associated with these structures was sporadic with alternating dormant and active periods. Isopach maps of geologic units overlying the salt reflect the periods of salt-movement activity with thickening of the units where subsidence resulted from salt removal and thinning of the units where positive or domal movement occurred (Andrews, 1960).

The most prominent structural features within the salt basin in southwestern Alabama are the Hatchetigbee anticline, the Jackson fault-Klepac dome, the Mobile graben, and the Gilbertown, Coffeeville-West Bend, Pollard and Bethel fault zones (fig. 6). Other important structures are the domal anticlines at Citronelle, South Carlton and Chatom and the piercement salt dome at McIntosh. A more subtle, less defined feature with possible regional significance is the Wiggins uplift.

Outside of the salt basin, structural development is mainly dependent on basement movement such as readjustment along faults, downwarping in response to sediment load, and igneous intrusions. Only a few wells in southern Alabama have been drilled to basement and related interpretations are based mainly on geophysical data or projections from north of the Fall Line. A major structural feature outside the salt basin is the Southwest Georgia embayment, which trends southwestward across part of southeastern Alabama and is the result of subsidence and deposition during the Cretaceous Period. A smaller feature also located outside of the salt basin is the Livingston fault zone, which trends southeastward across Sumter County, and is composed of a series of parallel horsts and grabens separated by reverse faults that have displacements ranging from a few inches to about 100 feet (Monroe and Hunt, 1958).

Gravity anomalies of high magnetic intensity that represent either basement highs or intrabasement events occur in the Coastal Plain in Dallas, Clarke, Baldwin, and Geneva Counties and along the western boundary of Covington County. The anomaly in Geneva County, which trends northward, is the only one reflected in sediments overlying the basement. Upper Cretaceous and Tertiary formations thin across this anomaly, indicating uplift during deposition. The other anomalies are possibly inactive basement highs that were gradually onlapped and finally covered by Jurassic or younger sediments.

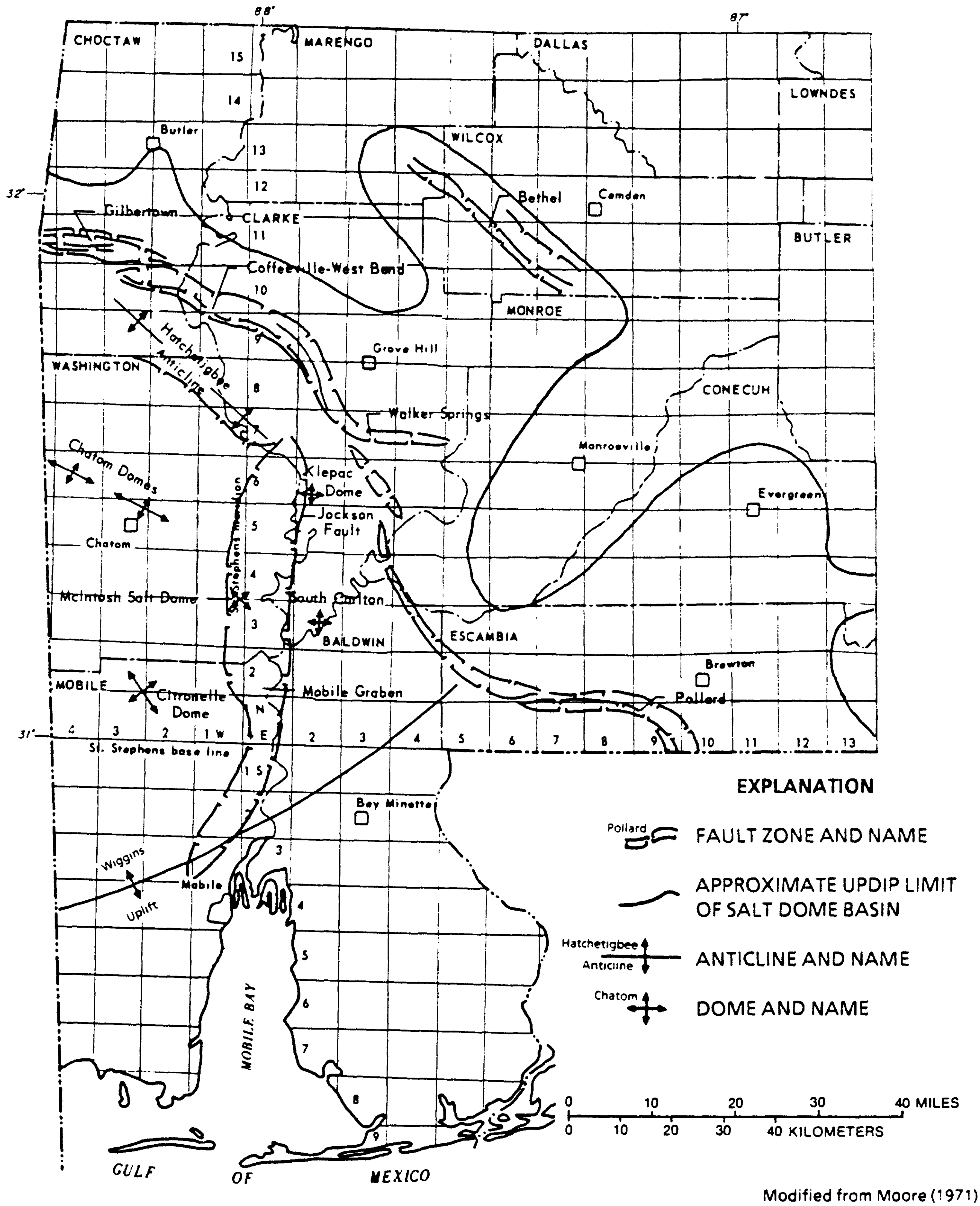


Figure 6.--Location of prominent salt-related structural features in the Alabama Coastal Plain.

STRATIGRAPHY

The Coastal Plain deposits in Alabama form a thick wedge of unconsolidated to poorly consolidated clastic and carbonate rocks that dip generally south to southwestward from the Fall Line toward the Gulf of Mexico at about 20 to 40 feet per mile, increasing to as much as 50 feet per mile near the coast. The deposits range in thickness from a featheredge at the Fall Line to as much as an estimated 6,000 feet near the coast (pl. 7). They are underlain in places by metamorphic and igneous rocks of Precambrian and Paleozoic age and in other places by sedimentary rocks of Paleozoic and early Mesozoic age. The rocks underlying the Coastal Plain sediments are, in part, a southern and southwestern extension of the Piedmont Province and, in part, a southwestern extension of the Appalachian Mountains. These rocks of Precambrian to early Mesozoic age, combined, constitute the pre-Cretaceous Coastal Plain floor or base of the Southeastern Coastal Plain aquifer system as used in this report.

Coastal Plain rocks are the product of the cyclic invasion and retreat of ancient seas and were deposited from early Mesozoic to Holocene time under marine, marginal marine, and nonmarine conditions. Deeply buried sedimentary rocks of Triassic and Jurassic age are found in parts of the subsurface of Alabama; however, they are not considered to be part of the geohydrologic framework described in this report. These rocks were excluded from examination because they are not known to contain water with a dissolved-solids content of less than 10,000 milligrams per liter (mg/L). They are therefore considered part of the Coastal Plain floor.

Coastal Plain sediments of Alabama are parts of three regional aquifer systems (fig. 1). The principal part of the Southeastern Coastal Plain aquifer system in Alabama consists of clastic deposits of Early and Late Cretaceous, Paleocene, and early and middle Eocene age (pl. 16). Carbonate rocks of late Eocene and Oligocene age, overlying the clastic deposits in southern Alabama, are an upper part of the Coastal Plain aquifer system and are also part of the Floridan aquifer system (Miller, 1986). Overlying the Floridan aquifer system in the southwestern part of the State are clastic deposits of Miocene to Holocene age that also comprise a part of the Gulf Coastal Lowlands aquifer system studied by the Gulf Coast Regional Aquifer System Analysis (Grubb, 1986).

Pre-Cretaceous System

Relatively impermeable rocks of Precambrian to Jurassic age form the base for the Cretaceous System and the Coastal Plain aquifer system (pl. 7). Gneiss, schist, quartzite, and granitic rocks of Precambrian and Paleozoic age crop out in the Piedmont area and underlie the Coastal Plain sediments in the eastern part of the State. Updip, Coastal Plain deposits in the western part of the State are underlain generally by alternating sequences of sandstone and shale of Pennsylvanian age. Locally, near the Fall Line in west-central Alabama, the Pennsylvanian rocks have been uplifted and eroded and the Coastal Plain deposits are underlain by limestone of Ordovician age.

A sequence of continental clastic beds, at places separated by flows and intrusions of basic igneous rock, underlies the Cretaceous System in southeastern Alabama. These beds have been assigned to the Triassic System (Maher and Applin, 1968). The Triassic beds are composed chiefly of hard, dark-red and greenish-gray, mottled, micaceous shale interbedded with partly conglomeritic and arkosic sandstone with poorly sorted, angular grains. Igneous bodies separating and cutting the sedimentary beds are flows, sills, and dikes of basalt and diabase.

Sedimentary rocks of Jurassic age are the principal units underlying the Cretaceous System in southwestern Alabama. These rocks have been penetrated by many oil test wells in southwestern Alabama where oil reservoirs occur in several formations of Jurassic age. Rocks of the Cotton Valley Group of Late Jurassic age directly underlie the Cretaceous System and consist of pink and gray sand and gravel; red, purple, and green mottled shale; green waxy shale; and some carbonaceous material. The Louann Salt of Middle and Late Jurassic age has greatly influenced geologic structure in southwestern Alabama. Major fault zones (fig. 6) were formed by movement of the Louann Salt in the subsurface in response to sediment loading.

Cretaceous System

Lower Cretaceous Series

Rocks of Early Cretaceous age do not crop out in Alabama; rather, they thin northward and pinch out in the subsurface south of the Fall Line (pls. 5, 6, 7, and 8). Updip, these deposits overlie Paleozoic sedimentary rocks and metamorphic and igneous crystalline rocks of the Piedmont. Downdip, they overlie rocks of Triassic and Jurassic age. Near the coast in southern Alabama, Lower Cretaceous rocks are composed of lithologically similar successions of alternating shale and sandstone as much as 7,000 feet thick, containing minor amounts of marine fossiliferous limestone. The regional facies distribution has been complicated by structural features (fig. 6 and pl. 8) but generally the largely marine rocks near the coast grade rather abruptly northward and eastward into a sequence of alternating marine and nonmarine beds, and then into a completely nonmarine clastic facies. Subdivisions of the fossiliferous Lower Cretaceous rocks at the coast are lost as the marine units thin and disappear inland. The upper beds of this unit at the coast locally contain the foraminifera Reophax minuta Tappan, Dicyelina schlumbergeri Munier-Chalmas, several species of Quinqueloculina and Massilina, and many specimens of Nummoloculina heimi Bonet.

Pink nodular limestone fragments and red and green shale, sometimes found near the top of the Lower Cretaceous rocks, distinguish them from the massive sand of the overlying Coker Formation of Late Cretaceous age. In places, Lower Cretaceous rocks contain massive beds of coarse to very coarse sand and fine gravel in their upper part.

Upper Cretaceous Series

Tuscaloosa Group

The Tuscaloosa Group, the basal unit of the Upper Cretaceous Series in Alabama, crops out in a cresent-shaped belt that extends through the central and northwestern part of the State adjacent to the Fall Line. Outcrop widths range from about 25 miles in western Alabama to about 5 miles in eastern Alabama. The beds dip about 30 to 50 feet per mile except in northwestern Alabama where the dip is about 15 to 20 feet per mile. Direction of dip is southward in the eastern part of the State, southwestward in the western part, and westward in the northwestern part.

The Tuscaloosa Group unconformably overlies Precambrian and Paleozoic igneous and metamorphic rocks of the Piedmont that extend southwest of the Fall

Line to central Perry County. Westward from Perry County to the Alabama-Mississippi State line, the Tuscaloosa Group unconformably overlies Paleozoic sedimentary rocks. Southward toward the coast, the Tuscaloosa Group unconformably overlies rocks of the Lower Cretaceous Series.

The Tuscaloosa Group generally is divided into the Coker and Gordo Formations in the central and western part of the State. Most investigators indicate that the two formations cannot be separated at the surface east of Elmore County because of the similarity of beds. In this report, the Coker Formation has been separated from the Gordo Formation on the basis of eastward correlation of a diagnostic marine shale bed in the upper part of the Coker.

Coker Formation.--The Coker Formation, the lower unit of the Tuscaloosa Group, crops out adjacent to the Fall Line (pl.9). The Coker generally ranges from about 250 to 500 feet thick near the Fall Line but may be as much as 900 feet thick downdip. Updip, it consists of massive, nonmarine, medium- to coarse-grained sand beds with some chert gravel in the basal part. The upper part of the Coker consists of a thick section of dense, gray, light purple, and red micaceous clay, the top of which generally is interpreted on electric logs as the top of the Coker in most of Alabama. In places, the upper part of the formation may include also a lenticular bed of fine- to medium-grained sand, which is of hydrologic importance for public water supplies in Dallas and Montgomery Counties (Knowles and others, 1963, p. 22; Scott and others, 1981, p. 23).

Downdip, near the coast, the Coker is a marine facies consisting of dark gray shale beds with an abundance of crushed chalky microfossils in the upper part, and thin siltstone lenses and sandstone beds at the base.

The geologic sections on plates 2, 3, 4, and 6 show the Coker extending into the eastern part of the State. Interpretation of electric logs shown on the cross sections suggests that, although the dominant upper clay beds of the Coker become thinner in the eastern part of the State, they are generally present and can be correlated between wells (pls. 2 and 6).

Gordo Formation.--The Gordo Formation overlies the Coker Formation and consists of nonmarine lenticular beds of gravel, sand, and clay (pl. 10). Thick basal beds of coarse, gravely, poorly-sorted sand containing thin lenses of carbonaceous, clayey sand rest directly on clay or fine sand of the Coker. The upper part of the Gordo consists of lenticular, red mottled, nonmarine clay and in places, lenses of crossbedded, fine- to coarse-grained sand. The Gordo can be distinguished from the underlying Coker by its consistently darker and more reddish sands or purple mottled clays that contrast with the red mottled clays of the Coker. Near the outcrop, where it is often in sharp unconformable contact with the Coker, the Gordo is generally about 300 feet thick. It thickens downdip tc as much as 500 feet.

Eutaw Formation

The Eutaw Formation crops out in a belt parallel to, and immediately south of, the Gordo Formation (pl. 11). The Eutaw Formation ranges in thickness from about 250 to 500 feet throughout the State but generally is about 400 feet thick. The lower part of the formation consists of thin to massive beds of fine- to coarse-grained glauconitic sand, interbedded with layers of light to dark gray laminated clay. The middle part consists chiefly of light greenish-gray, cross-laminated, fine- to medium-grained, well sorted, micaceous, fossiliferous, very glauconitic sand that is interbedded with greenish-gray, micaceous, glauconitic clay. The Tombigbee Sand Member, the upper part of the formation, consists of about 100 feet of gray, massive, very fine-grained, very glauconitic, fossiliferous sand locally containing layers of calcareous sandstone and sandy chalk. A thin bed of sand at the base of the formation commonly contains shark teeth. Locally, Eutaw beds are fossiliferous throughout the section, one place in eastern Alabama having as much as 100 feet of sand packed with the shells of Ostrea cretacea, according to Monroe (1946).

Selma Group

The Selma Group crops out across the State in a band ranging from about 20 to 40 miles wide (pl. 12). The Selma unconformably overlies the Eutaw Formation and is overlain unconformably by the Clayton Formation of Paleocene age (pl. 16). The lithology of the Selma Group in western Alabama is principally chalk and the Selma contains relatively little clastic material. The top and base of the chalk is easily picked on electric logs (fig. 2); the Selma is used as a marker bed wherever it is found in the Coastal Plain of Alabama. Eastward from central Alabama, however, the rocks grade from predominantly fossiliferous chalk to fossiliferous sand and clay and the clastic materials become progressively coarser to the east. Figure 4 shows the stratigraphic relations of individual units within the Selma Group across the upper part of the Coastal Plain. Plate 17 shows columnar profiles with facies changes in outcropping formations in the Selma Group in the northeastern part of the Coastal Plain. The location of the described sections in Barbour, Bullock, Macon, Montgomery, and Russell Counties are shown on plate 17.

The formations of the Selma Group in eastern Alabama show evidence of cyclic deposition. The basal deposit of each cycle usually is coarse sand or gravel, which grades upward into fine sand, clayey sand, and silt. The last phase of such a cycle is calcareous or carbonaceous clay, apparently deposited in a quiet embayment or shallow sea. Some phases of the cyclic sequence may be missing, and some types of lithology may attain greater thicknesses in some cycles than in others.

Mooreville Chalk and Blufftown Formation.--The Mooreville Chalk, basal unit of the Selma Group in central and western Alabama, interfingers with and gradually merges into the sand and clay of the Blufftown Formation near the southwestern part of Macon County and western Bullock County (fig. 4 and pl. 17). The Mooreville Chalk consists of gray silty chalk and calcareous clay interbedded with thin layers of limestone and calcareous sandstone. The thickness of the Mooreville ranges from about 350 feet in Sumter County to about 600 feet in Montgomery County. The Mooreville is about 500 feet thick in the western part of Bullock County but rapidly thins toward the east and is completely replaced by the Blufftown Formation in Russell County. The Arcola Limestone Member, a series of resistant limestone beds separated by sandy clay about 6 to 10 feet thick, is present at the top of the Mooreville from western Alabama to southeastern Montgomery County.

The Blufftown Formation consists of yellowish-orange to dark gray calcareous, sandy clay, carbonaceous clay, and fine-grained, micaceous, silty sand with thin layers of limestone and sandstone; the basal part changes eastward from a chalky sand to a gravelly sand. The thickness of the Blufftown ranges from a featheredge in the western part of Bullock County to as much as 500 feet near the Alabama-Georgia State line.

Demopolis Chalk.--The Demopolis Chalk of the central and western parts of Alabama interfingers with, and merges eastward into, the upper part of the Blufftown Formation and most of the Ripley Formation, including all of its basal Cusseta Sand Member. The Demopolis ranges in thickness from about 200 to 500 feet and consists of massive, light-gray, silty, fossiliferous chalk.

Ripley Formation.--The Ripley Formation consists of an upper unnamed member, which extends across the entire width of the State and ranges in thickness from about 150 to 250 feet, and a lower Cusseta Sand Member, which is confined to the eastern part of the State and is about 100 to 200 feet thick. The upper unnamed member consists of fine-grained sand, sandy calcareous clay, and thin indurated beds of sandstone in western Alabama. In the eastern part of the State, it consists of alternating thick beds of fine- to coarse-grained, micaceous, glauconitic sand and calcareous clay. The basal Cusseta Sand Member of the Ripley interfingers with and replaces the Demopolis Chalk near the central part of the State and extends eastward. The Cusseta consists chiefly of beds of calcareous sandstone, sandy chalk, calcareous silty clay, and fine- to coarse-grained, micaceous sand.

Prairie Bluff Chalk and Providence Sand.--The Providence Sand, upper unit of the Selma Group, interfingers with and replaces the Prairie Bluff Chalk near the central part of Alabama and extends eastward into Georgia. The Providence Sand increases in thickness from less than 50 feet in Lowndes County to about 300 feet at the eastern boundary of Alabama. The upper part of the Providence consists of crossbedded, fine- to coarse-grained sand and white, black, and purple clay, with some lignite and kaolin. The basal Perote Member consists chiefly of dark-gray, laminated, silty clay and very fine- to fine-grained sand that is abundantly micaceous and carbonaceous. The Prairie Bluff Chalk unconformably overlies the Ripley Formation in much of western and central Alabama, but locally interfingers with the Ripley (pl. 17). The Prairie Bluff is about 50 to 100 feet thick and consists mainly of massive, compact, white chalk and calcareous, sandy clay.

Tertiary System

Tertiary formations in the Southeastern Coastal Plain aquifer system in Alabama overlie the Cretaceous rocks and crop out across the southern part of the State. Plates 13, 14, and 15 show the outcropping geologic units of the Midway, Wilcox, and Claiborne Groups; the outcrops of younger units are not shown. Where units younger than the Claiborne Group are shown on the cross sections on plates 4 and 5, they are designated as upper Eocene to Holocene, undifferentiated. The Tertiary formations range in age from Paleocene to Pliocene, consist predominately of marine clastics, and are transitional in character between clastic, mostly nonmarine sediments in Mississippi and the carbonate rocks of Florida. Descriptions of the Tertiary formations are taken largely from Copeland (1966).

Paleocene Series

Midway Group

The Midway Group of Paleocene age constitutes the oldest Tertiary deposits in Alabama and rests disconformably on rocks of the Cretaceous System. This disconformity represents a relatively long lapse of time, as indicated by a great faunal change at the base (Copeland, 1966). The contact is marked by a basal conglomerate or sand with large glauconite grains and reworked Cretaceous fossils at the base of the Tertiary deposits.

The Midway Group consists of marl, limestone, fine-grained sand, silt, sandstone, and black, marine clay in western Alabama. Eastward from central Alabama, the rocks grade by facies change into a relatively pure limestone underlain by coarse-grained sand. The Midway ranges in thickness from about 300 feet in Houston County to as much as 1,200 feet in Mobile County.

The Midway Group is divided into the Clayton, Porters Creek, and Naheola Formations in western Alabama. However, because the Porters Creek and Naheola grade eastward into thin beds of silt, marl, and limestone, they are included with the Clayton Formation in eastern Alabama.

Clayton Formation.--The Clayton Formation is about 5 to 20 feet thick in western Alabama and consists principally of chalky marl, limestone, and conglomerate. A thin basal sand bed is commonly present. Argillaceous beds above the basal sand contain the lower Paleocene fossil Ostrea pulaskensis Harris (Copeland, 1966). Eastward from about the middle of the Coastal Plain in Alabama, the Clayton thickens abruptly and becomes the dominant formation in the Midway Group. The Clayton thickens to about 125 feet in Barbour County and as much as 175 feet in Dale County. Plate 13 shows the configuration of the top of the Midway Group, which is also the top of the Clayton Formation in eastern Alabama and the top of the Naheola Formation in the western part of the State.

At outcrops in Barbour, Pike, and Bullock Counties the Clayton consists of a basal sand that is overlain by relatively pure limestone. This limestone is in turn overlain by sandy limestone and sandy clay that comprise the upper part of the formation. The lithologic character of the Clayton downdip in the subsurface of Dale County is similar to that of the outcrops. Analysis of drill cuttings from test wells in this downdip area indicates that the basal sand is 10 feet thick or more and is colorless to light gray, medium to very coarse, subangular to subrounded, quartzose, and very clean.

Porters Creek Formation.--The Porters Creek Formation reaches a maximum thickness of about 450 feet in the western part of the State. It consists mostly of dark-brown to black, massive, marine clay that breaks with a subconchoidal fracture and about 5 feet of glauconitic shell marl (Matthews Landing Marl Member) at the top (Copeland, 1966). The black marine clay contains little calcareous material and forms the tough clay soil of the Flatwoods belt that extends from Mississippi eastward into Alabama as far as the Alabama River. The lower part of the Porters Creek thins and contains much calcareous material eastward in Butler and Conecuh Counties. The upper part grades eastward into calcareous, micaceous silt and fine-grained sand in Butler County. The Matthews Landing Marl Member increases in thickness to about 15 feet in Butler County and consists mostly of fossiliferous brownish-gray, calcareous, silty clay. According to Copeland (1966, p. 23), "The total thickness of the Porters Creek Formation in Conecuh and Butler Counties is about 150 feet. The Porters Creek becomes increasingly calcareous and, in Crenshaw County, prominent limestone is present in the middle and upper parts of the formation. East of Crenshaw County, beds correlative with the Porters Creek, if present, are included in the Clayton Formation because of similar lithologies."

Naheola Formation.--The Naheola Formation is divided into lower and upper parts, the Oak Hill Member and the Coal Bluff Marl Member, respectively. Copeland (1966, p. 23) reports that, "The lower member, consisting of brownish-gray laminated sandy silt and silty clay and beds of greenish-gray fine-grained sand, generally is about 80 to 150 feet thick in western Alabama. Lignite, ranging in thickness from 1 to 7 feet, is present in places at the top of the member. The upper member, consisting of glauconitic sand and sandy marl with thin-bedded, silty clay in the upper part, is variable in thickness. The thickness of the member in west-central Alabama commonly ranges from about 15 to 30 feet. The Coal Bluff Marl contains Cucullaea macrodonta Whitfield and other mollusks, most of which are Paleocene in age, and some ostracods and foraminifers indicative of the Paleocene." The Naheola, because it is thin and lithologically similar to underlying beds, is included as part of the Porters Creek or Clayton Formations east of Wilcox and Conecuh Counties. Following Copeland (1966) in this report the Midway-Wilcox boundary is placed between the Coal Bluff Marl and the Nanafalia Formation, which contains Ostrea thirsae (Gabb), a lower Wilcox guide fossil.

Wilcox Group

The Wilcox Group, of Paleocene and early Eocene age, rests disconformably on rocks of the Midway Group and consists principally of deposits of silt, medium- to coarse-grained sand, clay, sandstone, and sandy limestone. The Wilcox ranges in thickness from about 400 feet in Houston County to as much as 1,500 feet in Mobile County. The Wilcox Group is divided into the Nanafalia, Tuscahoma, Bashi, and Hatchetigbee Formations. In eastern Alabama, the middle and upper parts of the Nanafalia grade laterally updip into the Baker Hill Formation.

Nanafalia Formation and Baker Hill Formation.--The Nanafalia Formation overlies the Naheola Formation in the western part of Alabama and the Clayton Formation in the eastern part. In western Alabama, the Nanafalia consists of three members. The basal, or Gravel Creek Sand Member, according to Copeland (1966), consists of coarse-grained, crossbedded, fluvial, or beach sand that contains some fine quartz gravel and clay pebbles and rests disconformably on the Coal Bluff Marl Member of the Naheola Formation. The Gravel Creek Sand Member, as stated by Copeland (1966, p. 24), "is thicker updip, is absent locally, and pinches out downdip. The middle unnamed member of the Nanafalia consists of glauconitic quartz sand and glauconitic sandy marl filled with the Nanafalia guide fossil, Ostrea thirsae. The upper Grampian Hills Member consists of marine glauconitic sandy clay and dark-gray massive clay with glauconitic sand beds in places. Some of the beds contain numerous fossil casts and molds."

In eastern Alabama, the base of the Nanafalia consists of white, crossbedded, medium- to coarse-grained, micaceous, very fossiliferous sand. The upper and middle parts of the Nanafalia in eastern Alabama grade laterally updip into the Baker Hill Formation (Gibson and others, 1982), a sequence of interbedded micaceous sand and kaolinitic, bauxitic, and carbonaceous clay. The Nanafalia is about 80 to 160 feet thick in the eastern part of the State and more than 400 feet thick in the western part.

The Salt Mountain Limestone, a downdip facies of the Nanafalia, locally separates the Midway and Wilcox Groups in southern Alabama. The Salt Mountain is characterized by one or more discontinuous limestone beds containing the foraminifera Pseudophragmina stephensoni Vaughan and Discocyclina weaveri Vaughan.

Tuscahoma Formation.--The Tuscahoma Formation overlies the Nanafalia Formation and crops out across the central part of the Coastal Plain in Alabama. The Tuscahoma in western Alabama ranges from 250 to 600 feet thick. In Choctaw County, the basal part of the formation consists of about 60 feet of gray, carbonaceous clay, overlain by about 400 feet of light gray, very fine- to medium-grained, micaceous, fossiliferous sand. The upper part consists of lignite, silty carbonaceous clay, and fine- to medium-grained, fossiliferous, glauconitic sand.

In the eastern part of the State, the Tuscahoma Formation is about 80 to 200 feet thick. The basal part consists primarily of crossbedded, medium- to coarse-grained, glauconitic, fossiliferous sand. The upper part consists of silty, calcareous, carbonaceous clay.

Eocene Series

Wilcox Group

Hatchetigbee Formation and Bashi Formation.--The updip Hatchetigbee Formation and the coeval, downdip Bashi Formation overlie the Tuscahoma Formation and crop out across the central part of the Coastal Plain. Plate 14 shows the configuration of the top of the Wilcox Group, which is also the top of the Hatchetigbee. The Hatchetigbee Formation ranges in thickness from about 25 feet in Butler County to about 400 feet in Choctaw County. The Hatchetigbee resembles the Tuscahoma lithologically and is difficult to separate from the Tuscahoma except where it intertongues with the Bashi Formation, a fossiliferous, glauconitic, calcareous sand and marl. The Bashi is easily recognized in outcrop and on electric logs where it underlies the base of the Hatchetigbee, and generally ranges in thickness from about 6 to 35 feet in southern Alabama.

Claiborne Group

The Claiborne Group, of middle Eocene age, rests disconformably on rocks of the Wilcox Group and consists of silty sand, calcareous sandstone, carbonaceous shale, sandy clay, and fine- to coarse-grained sand. The Claiborne ranges in thickness from about 300 feet in Escambia County to as much as 550 feet in Mobile County. The Claiborne Group is divided into the Tallahatta, Lisbon, and Gosport Formations.

Tallahatta Formation.--The Tallahatta Formation disconformably overlies the Hatchetigbee and varies in thickness and lithology. The formation ranges from about 20 to 125 feet in thickness and consists generally of pale-green to olive-gray, marine, locally siliceous claystone with a few beds of fine to coarse, glauconitic, calcareous sand and sandstone. According to Copeland (1966, p. 25), "The glauconitic, calcareous sand beds at the top of the formation are very fossiliferous and contain *Discocyclina advena*, *Protoscutella mississippiensis* (Twitchell), *Ostrea johnsoni* Aldrich, and *Ostrea perplicata* Dall." In central and eastern Alabama the Tallahatta consists chiefly of sand and sandy clay and beds of "buhrstone" or massive siltstone are present near the bottom and top of the formation.

Lisbon Formation.--Copeland (1966, p. 26) states "The Lisbon Formation consists chiefly of marine calcareous glauconitic sand, marl, and sandy clay more or less fossiliferous throughout, but it interfingers westward in western Choctaw County with some nonmarine beds. . . . From the bottom up it consists of glauconitic sand, brown carbonaceous clay and sandy clay, crossbedded sand, and fossiliferous glauconitic marl and nonfossiliferous clay with some lignite. . . . Several beds in the formation contain the large Ostrea sellaeformis Conrad, and O. lisbonensis Harris is common in the lower beds." The Lisbon is as much as 200 feet thick in this area. In eastern Alabama, the Lisbon is as much as 150 feet thick and consists of fine- to very coarse-grained, quartzose sand, sandy limestone, and calcareous sandy clay.

Gosport Sand.--The Gosport Sand disconformably overlies the Lisbon Formation. Plate 15 shows the configuration of the top of the Claiborne Group, which is also the top of the Gosport. In western Alabama, the Gosport consists of about 50 feet or less of fine- to coarse-grained, glauconitic, fossiliferous sand, with minor lenses of dark, carbonaceous shale. Because the basal contact of the Gosport with the underlying Lisbon Formation generally cannot be readily distinguished, the two units are usually classified as Gosport Sand and Lisbon Formation, undivided, a convention that is followed in this report (pl. 16). This author agrees with Copeland (1966) that the Gosport is not recognizable east of the Alabama River.

Jackson Group

In western Alabama, the Jackson Group of late Eocene age is separated from the underlying Claiborne Group by an indistinct disconformity that is locally marked by phosphate pebbles and large glauconite grains (Copeland, 1966). The Jackson consists of fossiliferous, calcareous, glauconitic sand, sandy marl, calcareous clay, and white porous, conquinoidal limestone. The Jackson Group is divided into the Moodys Branch Formation and Yazoo Clay in southwestern Alabama. The Yazoo Clay becomes more calcareous eastward and grades into the Ocala Limestone in southeastern Alabama.

Moodys Branch Formation.--The Moodys Branch Formation consists of about 10 to 20 feet of greenish-gray, fossiliferous, calcareous, glauconitic sand and sandy marl (Copeland, 1966). Basal beds contain the guide fossil Periarchus lyelli (Conrad) and have been referred to as the "Scutella bed" in early reports. The "Scutella bed" is about 28 feet thick in south-central Alabama and is overlain by about 20 feet of glauconitic, sandy, argillaceous limestone that forms the upper part of the Moodys Branch (Copeland, 1966).

Yazoo Clay and Ocala Limestone.-- The Moodys Branch Formation is conformably overlain by the Yazoo Clay, which consists of a lower tongue of greenish-gray, calcareous, sparsely fossiliferous clay (North Twistwood Creek Clay Member), overlain by loose, yellow, calcareous, locally fossiliferous sand (Cocoa Sand Member), which is succeeded by yellow limestone and white chalky marl (Pachuta Marl Member), that is in turn overlain by an upper tongue of fossiliferous, greenish-gray, calcareous clay and marl (Shubuta Member). The Yazoo Clay becomes more calcareous eastward and grades into limestone in central Alabama (Copeland, 1966). In the eastern part of the State, the Ocala Limestone is the stratigraphic equivalent of the Yazoo. The Ocala in southern Alabama is a white, porous, coquinoidal limestone, composed mainly of specimens and fragments of several species of Lepidocyclina and Operculinoides.

Oligocene Series

Red Bluff Formation and Bumpnose Formation

The Red Bluff Formation is about 60 feet thick in southwestern Choctaw County, where Copeland (1966, p. 27) states "the formation consists of yellow glauconitic limestone containing Ostrea vicksburgensis Conrad and Spondylus dumosus (Morton) overlain by greenish-gray, glauconitic calcareous clay and by gray silty nonfossiliferous clay with thin beds of sand." In Clarke County, the upper clay is missing and the lower limestone becomes greenish-gray and chalky (Copeland, 1966). The equivalent eastward extension of the Red Bluff Formation has been called the Bumpnose Limestone. The Bumpnose extends eastward through southern Alabama into Florida.

Vicksburg Group

The Vicksburg Group of early and middle Oligocene age overlies the Red Bluff Formation and Bumpnose Formation in southwestern Alabama and consists of soft, porous limestone; fossiliferous, calcareous sand; fossiliferous marl; and carbonaceous clay. The Vicksburg is divided into the Mint Springs-Marianna, Glendon, Byram, and Bucatunna Formations.

Mint Springs Formation and Marianna Formation.--The Marianna Formation consists of white to cream, soft, highly fossiliferous, glauconitic limestone. According to Copeland (1966), the Marianna is about 40 to 60 feet thick in southwest Alabama and contains the guide fossils Lepidocyclina mantelli (Morton), Clypeaster rogersi (Morton), and Pecten poulsoni (Morton). The Marianna grades northwestward across southwest Alabama into the Mint Spring Formation, a thin, fossiliferous, glauconitic sand or clayey sand that represents the base of the Vicksburg Group in western Alabama.

Glendon Formation.--According to Copeland (1966) the Glendon Formation is a thin, cream-colored, irregularly-indurated, coquinoidal and crystalline limestone in western Alabama. The Glendon is about 20 feet thick in Clarke County and contains the fossil Lepidocyclina supera (Conrad).

Bryam Formation.--The Bryam Formation in western Alabama consists of thin beds of gray to tan, sandy, fossilferous, glauconitic marl and calcareous clay. The clay beds in the Bryam may merge with the Bucatunna Formation in the shallow subsurface.

Bucatunna Formation.--The Bucatunna Formation consists of massive, medium-gray, bentonitic, carbonaceous, fossiliferous clay with traces of fine-grained, yellow sand. The Bucatunna is generally less than 100 feet thick and is an excellent marker bed for interpreting stratigraphic position on electric logs. It acts as a confining bed separating the Upper and Lower Floridan aquifers of the Florida aquifer system in the Florida panhandle and southwestern Alabama.

Chickasawhay Formation

The Chickasawhay Formation, which overlies the Vicksburg Group, consists of bluish-gray, glauconitic, soft, sandy calcareous clay, and layers of hard white limestone. The Chickasawhay is about 20 feet thick in southwest Alabama. It contains the fossil Kuphus incrassatus Gabb (Copeland, 1966).

Paynes Hammock Formation

The Paynes Hammock Formation is a thin, calcareous, fossiliferous sand and clay sequence that overlies the Chickasawhay. The formation cannot be distinguished from the Chickasawhay Formation in the subsurface.

Miocene Series

The Miocene Series crops out in the southwestern part of the State, except where it is covered by coastal deposits of Pliocene age and younger. The Miocene is composed of undifferentiated, highly interbedded layers of light-colored sand, gray clay, and fossiliferous marl in the upper part. A unit occurring locally at the base, the Catahoula Sandstone, consists of grayish-yellow sand and gray sandy clay (Copeland, 1966). The Miocene beds dip southwestward at about 30 to 100 feet per mile and are at least 3,000 feet thick at the southwestern corner of Mobile County.

Pliocene Series

Citronelle Formation

The Citronelle Formation is exposed at the surface over most of its limited area of occurrence in southwestern Alabama and is present primarily on hilltops and uplands. Along stream valleys it has been eroded to expose the underlying Miocene beds. The Citronelle Formation is composed of discontinuous layers of medium to coarse quartz sand, chert gravel, and lenses of clay. The formation is thickest and least dissected near the coast but rarely exceeds 100 feet in thickness.

Quaternary System

Pleistocene and Holocene Series

The alluvium and terrace deposits of Pleistocene and Holocene age consist of silt, clay, sand, and gravel deposited along the valleys of Alabama streams. The deposits generally are less than 50 feet in thickness. The sand beds are very lenticular and can be traced only short distances laterally.

RELATION OF GEOLOGIC UNITS TO AQUIFERS AND CONFINING UNITS

A regional hydrogeologic framework was developed for the Southeastern Coastal Plain based on the concept of a regional aquifer system. This concept recognizes the interconnection of aquifers and associated confining units and provides guidelines for model simulations that aid in understanding the ground-water flow system on a regional scale where a geologic unit may be an aquifer in one area and a confining unit in another. Designated aquifers may not consist of the same formations in all areas but are hydraulically connected in varying degrees and can be treated as a single flow unit.

A subregional hydrogeologic framework and computer model was developed in each State concurrently with the regional framework and model to simulate the ground-water flow and evaluate the long-term effects of pumpage at a subregional scale. These subregional models also provide alternative solutions for local ground-water management.

As a preliminary stage in the study of the hydrologic system in the Coastal Plain of Alabama, a series of stratigraphic sections and maps showing the top or base of geologic formations were prepared to aid in delineating aquifers and confining units in the hydrogeologic framework (pls. 2-15). The correlation chart on plate 16 shows the relation of geologic formations to aquifers and confining units in western and eastern Alabama. The hydrogeologic units are delineated to include formations or parts of formations containing regionally extensive permeable zones of sand or limestone as aquifers or relatively impermeable zones of clay or chalk as confining units. Because the boundaries between aquifers and confining units do not always conform to stratigraphic boundaries, a separate classification was used to delineate the hydrogeologic units. Regionally extensive permeable or relatively impermeable zones having a wide distribution and a large degree of interconnection, similar lithology, and similar hydraulic characteristics were considered to act as a single aquifer or confining unit. The letter A in the parenthesis after each aquifer name is to indicate the geohydrologic unit as an aquifer and the letter C indicates a confining unit. A sequential number is assigned to indicate the relative position of each unit in the hydrogeologic column. These letters and sequential numbers are used in model simulations and in discussions of the relation between the model-simulated layers and the hydrogeologic units in this report. For example, the uppermost aquifer unit (Gulf Coastal Lowland and Floridan aquifer systems) shown in the correlation chart (pl. 16) is designated A1 and the underlying confining unit is designated C1. Confining units are given a sequential number only, without proper names.

Twelve hydrogeologic units were selected to constitute the Coastal Plain aquifer system in Alabama--six aquifers separated by six confining units. The confining unit (C6), which forms the base for the Coastal Plain aquifer system in Alabama, consists of low-permeability metamorphic and igneous rocks of Precambrian to Paleozoic age in the northeastern part of the Coastal Plain. Sedimentary rocks of Paleozoic and Early Mesozoic age underlie the aquifer system in the remainder of the Coastal Plain.

Tuscaloosa Aquifer

The Tuscaloosa aquifer (A6) includes sand and gravel beds in the Coker Formation and basal sand beds in the Gordo Formation throughout the Coastal Plain where the aquifer contains water with a dissolved-solids content of less than 10,000 mg/L. The Tuscaloosa aquifer also locally includes freshwater-bearing coarse sand and gravel beds of Early Cretaceous age in western Alabama.

Because of the availability of water from shallower aquifers, Lower Cretaceous rocks are not tapped by wells in Alabama. However, according to interpretation of electric logs, sample cuttings, and analyses of water from test wells, the sand beds are very permeable and contain freshwater in updip areas. The water in these strata becomes progressively more saline downdip.

Large quantities of freshwater are available from sand and gravel beds in the Coker and Gordo Formations within and several miles south of their outcrop areas (pls. 9, 10). West of Elmore County, individual wells tapping the basal sands and gravels of each of the formations are capable of producing from 0.5 to 1 million gallons per day (Mgal/d) (Lines, 1975). East of Elmore County, many of the municipal wells are screened opposite the sand and gravel beds of both the Coker and Gordo Formations. Water within the sand and gravel beds in and near the outcrop areas is under water table conditions, whereas water in downdip parts of the Coker and Gordo is confined. Wells tapping sand beds in lowland areas commonly flow.

The quality of water from the Coker and Gordo Formations generally is suitable for most uses and is soft to moderately hard. Locally, the water may contain objectionable amounts of iron and hydrogen sulfide (iron content greater than 300 micrograms per liter (μg/L) and hydrogen sulfide greater than 0.05 mg/L). The dissolved-solids content of the water generally increases with depth and distance from the area of outcrop. Locally, however, in northern Sumter County and western Green County, an anomalous condition occurs. The water in the Coker there is fresher than in the overlying Gordo or Eutaw Formations. Data from files of the U.S. Geological Survey show that sand beds in the Gordo and Eutaw Formations in parts of these counties locally contain water with concentrations of chloride as great as 400 mg/L, whereas water in the underlying Coker locally contains chloride concentrations as small as 24 mg/L.

The overlying confining unit (C5) is a nonmarine clay bed in the upper part of the Gordo Formation. Electric logs of wells indicate the occurrence of the clay bed eastward from the Mississippi State line almost across the upper Coastal Plain (pl. 2). Some electric logs in eastern Alabama do not indicate a significant confining bed but, because of the high clay content of the upper aquifer material, some hydraulic separation of the permeable zones is generally present.

Eutaw Aquifer

The Eutaw aquifer (A5) consists of medium- to coarse-grained sand beds in the lower part of the Eutaw Formation in west-central Alabama. In the eastern part of the State, the Eutaw aquifer consists principally of a basal sand zone in the unit. Sand beds in the basal part of the Blufftown Formation of the Selma Group are included with the Eutaw aquifer in the northeastern part of the Coastal Plain.

Large quantities of water are available from sand beds in the Eutaw Formation within and several miles south of the outcrop area (pl. 10). Except for small supplies from the alluvium in the valley areas, the Eutaw is the shallowest source of water for large supplies in the outcrop area and slightly downdip, where the Eutaw passes beneath the Selma Group in central and western Alabama. Flowing wells tapping the Eutaw are commonly found in lowland areas in the central and western parts of the State. Municipal wells are generally screened opposite only the lower part of the formation, because the sand there is coarser and thicker and because water in the upper part of the Eutaw generally contains excessive concentrations of iron. Yields from municipal wells that tap the Eutaw Formation range from about 0.5 to 1.0 Mgal/d (Davis, 1980).

The quality of water from the Eutaw generally is suitable for most uses and ranges from soft to very hard. Locally, the water may contain iron in excess of 300 μg/L, particularly in the upper part of the formation. Dissolved-solids and chloride concentrations of the water increase with depth and distance from the area of outcrop.

The overlying confining unit (C4) includes the relatively impermeable Mooreville Chalk and Demopolis Chalk eastward from the Mississippi State line to about Bullock County where the chalks grade into sands and clays of the Blufftown Formation. The clay beds in the upper part of the Blufftown continue eastward to the Georgia State line and act as a confining unit.

Providence-Ripley Aquifer

The Providence-Ripley aquifer (A4) consists of sand beds in the Ripley Formation in west central Alabama and the Providence Sand and Ripley Formation, including the Cusseta Sand Member, in the eastern part of the Coastal Plain.

The Ripley Formation is developed for water supplies downdip from its outcrop area from about Greenville in Butler County to the eastern boundary of Alabama. Sand beds in the Ripley yield only small quantities of water in the western part of the State, where much of the aquifer is composed of clay. A well at Ozark in Dale County, screened solely in the Ripley, produced as much as 750 gallons per minute (gal/min) in 1968 (Newton and others, 1968). Water from the Ripley Formation ranges from soft to hard and locally has an excessive iron content.

The Providence Sand, where of sufficient thickness, generally is developed in conjunction with the underlying Ripley Formation or the overlying Clayton and Nanafalia Formations. A municipal well at Dothan, screened wholly in the Providence, produced 876 gal/min in 1974 (Scott and others, 1984). Water from the Providence Sand generally is soft but may contain iron in excess of 300 μg/L.

The overlying confining unit (C3) consists of chalk and clay beds in the Prairie Bluff Chalk, Clayton Formation, and Porters Creek Formation in the western part of the State and a marine clay bed in the lower part of the Clayton Formation in the eastern part. This clay bed may be only partially confining and is intermittently absent in eastern Alabama.

Nanafalia-Clayton Aquifer

The Nanafalia-Clayton aquifer (A3) consists of basal sands of the Tuscahoma Formation and the Nanafalia and Naheola Formations in the western part of the State. In the eastern part, the aquifer is composed of the basal sands of the Tuscahoma Formation, the Nanafalia and Baker Hill Formations, and limestone and sand beds in the Clayton Formation. The Clayton consists of about 5 to 20 feet of chalky marl and limestone in western Alabama, thickening abruptly near the middle of the Coastal Plain to as much as 175 feet in Pike County (Shamburger, 1968).

The Clayton Formation is a major aquifer in some parts of southeastern Alabama east of Conecuh and Butler Counties. The Clayton generally is screened with the overlying Nanafalia Formation and underlying Providence Sand. Except for local domestic use, the Clayton is not a source for water supplies in western Alabama. A well developed solely in the Clayton in Coffee County pumped 112 gal/min for 24 hours in 1968 (Scott and others, 1984). Water from the Clayton generally is moderately hard to hard and locally contains excessive iron.

Sand beds in the Nanafalia Formation are a major source of water south of its outcrop. The Nanafalia may be developed by itself for water supplies in western Alabama, but it is usually developed in conjunction with the overlying Tuscahoma Formation and the underlying Clayton Formation and Providence Sand in the eastern part of the State. Sand beds in the Nanafalia may yield as much as 500 gal/min in northern Choctaw county (Newton and McCain, 1972). Water from the Nanafalia is of the sodium bicarbonate type and is soft, basic, and low both in iron and chloride content.

The overlying confining unit (C2) consists of about 100 to 250 feet of silt, clay, and clayey sand near the middle part of the Tuscahoma Formation.

Lisbon Aquifer

The Lisbon aquifer (A2) consists of upper sand beds in the Tuscahoma Formation, the Bashi, Hatchetigbee, and Tallahatta Formations, the Gosport Sand and Lisbon Formation, undivided, and the Moodys Branch Formation. Because some of these formations occur only as erosional remnants in eastern Alabama, one or more of these formations may be absent or may not be part of the aquifer at any one location.

The Lisbon Formation, combined with the underlying Tallahatta formation, is a principal source of ground water south of its outcrop. Wells developed in this aquifer commonly produce 0.5 to 1.0 Mgal/d in southeast Alabama (J.C. Scott, U.S. Geological Survey, oral commun., 1986). In southern Houston County, the Lisbon is developed in conjunction with the overlying Ocala Limestone for irrigation and public water supplies.

The overlying confining unit (C1) is formed by the Yazoo Clay in the southwestern part of the State. In the south-central and southeastern parts, however, the Yazoo Clay grades eastward into the Ocala Limestone. In these parts of the State, this confining unit is a soft, dense, gray clay, about 50 feet thick, directly underlying the fossiliferous limestone of the Ocala Limestone. This confining clay is correlative either with the upper part of the Moodys Branch Formation or the lower part of the Ocala Limestone.

Floridan and Gulf Coastal Lowlands Aquifer Systems

The Floridan and Gulf Coastal Lowlands aquifer systems (A1) constitute the uppermost hydrogeologic unit in the Coastal Plain of Alabama. The lower part of this unit consists of upper Eocene- and Oligocene-age carbonate rocks, which includes the highly-permeable Ocala Limestone in southeastern Alabama, that are referred to as the Floridan aquifer system (Miller, 1986). The upper part is composed of Miocene to Holocene clastic rocks, in southwestern Alabama, that are referred to as the Gulf Coastal Lowlands aquifer system of the Gulf Coast RASA study (Grubb, 1986). Geologic units constituting this aquifer are shown on plates 4 and 5 as upper Eocene to Holocene, undifferentiated.

The Ocala Limestone is a high-yielding aquifer in southeastern Alabama. It is tapped by irrigation wells in Geneva and Houston Counties, where it yields as much as 500 gal/min (J.C. Scott, U.S. Geological Survey, oral commun., 1986). In southern Houston County, the Ocala is usually developed in conjunction with the overlying Lisbon Formation. The Floridan and the Gulf Coastal Lowlands aquifer systems are being treated in more detail by adjacent RASA studies.

The Miocene deposits of the Gulf Coastal Lowlands aquifer system are a prolific source of ground water and are the principal source for public supplies at several towns in Baldwin, Mobile, and Washington Counties where the Miocene deposits yield as much as 500 gal/min. Wells developed in the Miocene deposits usually tap only the upper sand beds because abundant water is available at shallower depths. Downdip near the coast, water in the deeper sand beds is saline. Heavy pumping in the coastal areas of Baldwin and Mobile Counties has caused vertical and lateral movement of saline water toward the freshwater sands.

The Citronelle Formation of the Gulf Coastal Lowlands aquifer system is a water-table aquifer with water levels that vary in depth from place to place because of the discontinuous nature of the sand beds. Recharge is from rainfall directly on the outcrop, and water moves rapidly both vertically and laterally to recharge the underlying Miocene deposits and to sustain local streams. Large wells can be developed locally in the Citronelle, but a more productive source is available in the underlying deposits of Miocene age. Sand beds in the Citronelle generally are tapped for domestic supplies, although some public-supply wells, such as at Atmore in southwestern Escambia County, tap the Citronelle.

SUMMARY

This report describes the Cretaceous to Quaternary stratigraphic framework that was used to delineate the aquifers and confining units in Alabama as part of the Southeastern United States Coastal Plain aquifer system study. The subsurface stratigraphy of the Coastal Plain rocks that comprise the framework was delineated and mapped principally on the basis of data from sample and electric logs from deep oil-test wells. Five stratigraphic sections are presented to illustrate the regional relations among the geologic units both downdip and along strike. The sections show, by interpretation of electric logs, the distribution, arrangement, and lithic character of sand, clay, and limestone bodies that comprise the aquifers and confining units. Seven structural contour maps of outcropping geologic units, that are part of the Southeastern Coastal Plain aquifer system, portray the geometric relief of the surface of the units relative to sea level. Two structural contour maps are included that show the top of undifferentiated deposits of Early Cretaceous age and the base of the Cretaceous System. The base of the Cretaceous System also is the base of the Coastal Plain aquifer system in Alabama. Rocks of Early Cretaceous age do not crop out in Alabama.

Stratigraphic units of Cretaceous and Tertiary age that make up most of the aquifer system in the Coastal Plain of Alabama consist of clastic deposits of Early Cretaceous age; the Coker and Gordo Formation of the Tuscaloosa Group, Eutaw Formation, and Selma Group of Late Cretaceous age; and the Midway, Wilcox, and Claiborne Groups of Tertiary age. Stratigraphic units of late Eocene to Holocene age partially overlie and are hydraulically connected to the clastic deposits in southern Alabama. The upper carbonate and clastic stratigraphic units also are part of the adjoining Floridan and Gulf Coastal Lowlands aquifer systems.

Formations illustrated regionally by the stratigraphic framework were studied to delineate regionally extensive permeable zones of sand or limestone as aquifers and relatively impermeable zones of clay or chalk as confining units. Because the boundaries between aquifers and confining units do not always conform to stratigraphic boundaries, a separate classification was used to delineate the extensive hydrogeologic units. Regionally extensive permeable or relatively impermeable zones having a wide distribution and a large degree of interconnection, similar lithology, and similar hydraulic characteristics were considered to act as a single aquifer or confining unit.

Twelve statewide hydrogeologic units were selected to constitute the Southeastern Coastal Plain aquifer system in Alabama--six aquifers separated by six confining units. Low-permeability crystalline and sedimentary rocks of Precambrian to early Mesozoic age form the base of the aquifer system. The overlying Tuscaloosa aquifer consists of sand and gravel beds in undifferentiated deposits of Early Cretaceous age, the Coker Formation, and basal sand beds in the Gordo Formation. The overlying confining unit is a nonmarine clay bed in the upper part of the Gordo Formation, which is present throughout most of the Coastal Plain. The Eutaw aquifer consists of medium- to coarse-grained sand in the lower part of the Eutaw Formation in the west-central Coastal Plain and the Eutaw and basal sand beds in the Blufftown Formation in the eastern part. The overlying confining unit includes the Mooreville and Dempolis Chalks eastward from the Mississippi State line to about Bullock County where the chalks grade into sands and clays of the Blufftown Formation. Clay beds in the upper part of the Blufftown act as the confining unit eastward from Bullock County. The Providence-Ripley aquifer consists of sand beds in the Ripley Formation in west-central Alabama and the Providence Sand and Ripley Formation, including the Cusseta Sand Member, in the eastern part. The overlying confining unit consists of the Prairie Bluff Chalk, Clayton Formation, and Porters Creek Formation in the western part of the State and a marine clay bed in the lower part of the Clayton Formation in the eastern part.

The Nanafalia-Clayton aquifer consists of basal sands in the Tuscahoma Formation and the Nanafalia and Naheola Formations in the western part of the State. In the eastern part, the aquifer is composed of basal sands of the Tuscahoma Formation, the Nanafalia and Baker Hill Formations, and limestone and sand beds in the upper part of the Clayton Formation. The overlying confining unit is composed of silt, clay, and clayey sand near the middle of the Tuscahoma Formation. The Lisbon aquifer consists of the upper sand beds in the Tuscahoma Formation; the Bashi, Hatchetigbee, and Tallahatta Formations; the Gosport Sand and Lisbon Formation, undivided; and the Moodys Branch Formation. The overlying confining unit is formed by the Yazoo Clay in the southwestern part of the State. In the south-central and southeastern parts, however, the Yazoo grades into the Ocala Limestone. In these parts of the State, this confining unit is a soft, gray clay, which is correlative either with the upper part of the Moodys Branch Formation or the lower part of the Ocala Limestone.

The Floridan and Gulf Coastal Lowlands aquifer systems constitute the uppermost hydrogeologic unit in the Coastal Plain of Alabama. The lower part consists of upper Eocene and Oligocene carbonate rocks that are referred to as the Floridan aquifer system. The upper part is composed of Miocene- to Holocene-age clastic sediments that are referred to as the Gulf Coastal Lowlands aquifer system.

SELECTED REFERENCES

Adams, G.I., Butts, Charles, Stephenson, L.W., and Cooke, C.W., 1926, Geology of Alabama: Alabama Geological Survey Special Report 14, 312 p.

Aldrich, T.H., 1886, Preliminary report on the Tertiary fossils of Alabama and Mississippi: Alabama Geological Survey Bulletin 1, part 1, p. 15-60.

Andrews, D.I., 1960, The Louann Salt and its relationship to Gulf Coast salt domes: Gulf Coast Association of Geological Societies, Transactions, v. 10, p. 215-240.

Applin, P.L., and Applin, E.R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: American Association of Petroleum Geologists Bulletin, v. 28, p. 1673-1753.

----- 1947, Regional subsurface stratigraphy and correlation of middle and early Upper Cretaceous rocks in Alabama, Georgia and north Florida: U.S. Geological Survey Oil and Gas Investigations (Preliminary), Chart 26.

Boswell, E.H., 1963, Cretaceous aquifers of northeastern Mississippi: Mississippi Board of Water Commissioners Bulletin 63-10, 202 p.

----- 1976a, The lower Wilcox aquifer in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 60-75, 3 sheets.

----- 1976b, The Meridian-upper Wilcox aquifer in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 76-79, 3 sheets.

----- 1977, The Eutaw-McShan aquifer in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 76-134, 2 sheets.

----- 1978a, The Tuscaloosa aquifer system in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 78-98, 3 sheets.

----- 1978b, The Coffee Sand and Ripley aquifers in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 78-114, 1 sheet.

----- 1979, The Citronelle aquifer in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 78-131, 1 sheet.

Boswell, E.H., Moore, G.K., MacCary, L.M., and others, 1965, Cretaceous aquifers in the Mississippi embayment, with a discussion on the quality of the water by H. G. Jeffery: U.S. Geological Survey Professional Paper 448-C, 37 p.

Cederstrom, D.J., Boswell, E.H., and Tarver, G.R., 1979, Summary appraisals of the nation's ground-water resources - South Atlantic - Gulf Region: U.S. Geological Survey Professional Paper 813-0, 35 p.

Copeland, C.W., ed., 1966, Facies changes in the Alabama Tertiary: A Guidebook for the Fourth Annual Field trip of the Alabama Geological Society, 103 p.

----- 1968, Geology of the Alabama Coastal Plain - a guidebook: Alabama Geological Survey Circular 47, 97 p.

----- 1968, Facies changes in the Selma Group in central and eastern Alabama, in Scott, J. C., Chairman, Facies changes in the Selma group in central and eastern Alabama: Alabama Geological Society Guidebook for the Sixth Annual Field Trip, p. 2-26.

Copeland, C.W., Newton, J.G., and Self, D.M., eds., 1976, Cretaceous and Tertiary faults in southwestern Alabama: Alabama Geological Society Guidebook for the Fourteenth Annual Field Trip, 114 p.

Cushing, E.M., Boswell, E.H., and Hosman, R.L., 1964, General geology of the Mississippi embayment: U.S. Geological Survey Professional Paper 448-B, 28 p.

Cushing, E.M., Boswell, E.H., Speer, P.R., Hosman R.L., and others, 1970, Availability of water in the Mississippi embayment: U.S. Geological Survey Professional Paper 448-A, 13 p.

Davis, M.E., 1980, Ground-water levels in Alabama - for observation wells measured periodically August 1952 through July 1977: Alabama Geological Survey Circular 105, 74 p.
Davis, M.E., Sanford, T.H., Jr., and Jefferson, P.O., 1980, Water availability and geology of Sumter County, Alabama: Alabama Geological Survey Map 158, 69 p.
----- 1975, Water availability and geology of Hale County, Alabama: Alabama Geological Survey Map 136, 51 p.
Davis, M.E., Sparkes, A.K., and Peacock, B.S., 1983, Results of a test well in the Nanafalia Formation near Melvin, Alabama: U.S. Geological Survey Water-Resources Investigations Report 82-4108, 17 p.
Eargle, D. Hoye, 1950, Geologic map of the Selma Group in eastern Alabama: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 105, 1 sheet.
Fenneman, N.M., 1938, Physiography of the eastern United States: New York, McGraw Hill, 714 p.
Fenneman, N.M., and Johnson, D.W., 1946, Map of physical division of the United States: U.S. Geological Survey Map 7-C.
Gibson, T.G., 1982, Revision of the Hatchetigbee and Bashi Formations (lower Eocene) in the Eastern Gulf Coastal Plain: U.S. Geological Survey Bulletin 1529-H, p. H33-H41.
Gibson, T.G., Mancini, E.A., and Bybell, L.M., 1982, Paleocene to Middle Eocene stratigraphy of Alabama: Gulf Coast Association of Geological Societies, Transactions, v. 32, p. 449-458.
Grubb, Hayes F., 1986, Gulf Coastal Plain regional aquifer-system study, p. 152-161, in Sun, R. J., ed., Regional aquifer system analysis program of the U.S. Geological Survey, summary of projects, 1978-84: U.S. Geological Survey Circular 1002.
Harris, G.D., 1896a, The Midway stage: Bulletins of American Paleontology: v. 1, no. 4, p. 115-270.
Joiner, T.J., and Moore, D.B., 1966, Structural features in south Alabama, in Alabama Geological Society 4th Annual Field Trip Guidebook, 1966: p. 11-19.
Johnston, W.D., Jr., 1933, Ground water in the Paleozoic rocks of northern Alabama: Alabama Geological Survey Special Report 16, 414 p.
Knowles, D.B., Reade, H.L., and Scott, J.C., 1963, Geology and ground-water resources of Montgomery County, Alabama: U.S. Geological Survey Water-Supply Paper 1606, 76 p.
LaMoreaux, P.E., and Toulmin, L.D., 1953, The Midway and Wilcox Groups in central and western Alabama: Mississippi Geological Society Guidebook, 10th Field Trip, p. 5-29.
Lines, G.C., 1975, Water availability, Elmore County, Alabama: Alabama Geological Survey Special Map 138, 40 p.
MacNeil, F.S., 1946, Geologic Map of the Tertiary Formations of Alabama: U.S. Geological Survey Preliminary Oil and Gas Investigations Map no. 45, scale 1:500,000, 1 sheet.
MacNeil, F.S., 1946b, Summary of the Midway and Wilcox stratigraphy of Alabama and Mississippi: U.S. Geological Survey Mineral Investigations Preliminary Report 3-195, 29 p.
MacNeil, F.S., 1947, Correlation chart for the outcropping Tertiary Formations of the Eastern Gulf Coastal Plain, U.S. Geological Survey Oil and Gas Investigations Chart OC 29, 1 sheet.
Maher, J.C., 1965, Correlations of subsurface Mesozoic and Cenozoic rocks along the Atlantic Coast: American Association of Petroleum Geologists, Cross Section Publication 3, 18 p.

Maher, J.C., and Applin, E.R., 1968, Correlation of subsurface Mesozoic and Cenozoic rocks along the eastern Gulf Coast: American Association of Petroleum Geologists, Cross Section Publication 6, 29 p.
Maher, J.C., and Applin, E.R., 1971, Geologic framework and petroleum potential of the Atlantic Coastal Plain and Continental Shelf: U.S. Geological Survey Professional Paper 659, 98 p.
Marsh, O.T., 1966, Geology of Escambia and Santa Rosa Counties, western Florida panhandle: Florida Geological Survey Bulletin 46, 140 p.
Miller, J.A., 1982a, Geology and configuration of the base of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Open-File Report 81-1176, scale 1:1,000,000, 1 sheet.
----- 1982b, Geology and configuration of the top of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Open-File Report 81-1178, scale 1:1,000,000, 1 sheet.
----- 1986, Geohydrologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama and South Carolina: U.S. Geological Survey Professional Paper 1403-B, 91 p.
Monroe, W.H., 1941, Notes on deposits of Selma and Ripley age in Alabama: Alabama Geological Survey Bulletin 48, 150 p.
----- 1946, Correlation of outcropping Upper Cretaceous Formations in Alabama and Texas, modified from chart by Stevenson, King, Monroe, and Imlay: U.S. Geological Survey Oil and Gas Investigations (Preliminary), Chart no. 23.
Monroe, W.H., Conant, L.C., and Eargle, D.H., 1946, Pre-Selma Upper Cretaceous stratigraphy of western Alabama: American Association of Petroleum Geologists Bulletin, v. 30, no. 2, p. 187-212.
Monroe, W. H., and Hunt, J.L., 1958, Geology of the Epes Quadrangle, Alabama: U.S. Geological Survey Geologic Quadrangle Map GQ-113.
Moore, D.B., 1971, Subsurface geology of southwest Alabama: Alabama Geological Survey Bulletin 99, 80 p.
Moore, D.B., and Joiner, T.J., 1969, A subsurface study of southeast Alabama: Alabama Geological Survey Bulletin 88, 33 p.
Newton, J.G., Golden, H.G., Avrett, J.R., and Scott, J.C., Water availability map of Dale County, Alabama: U.S. Geological Survey Map 64, 26 p.
Newton, J.G. and McCain, J.F., 1972, Water availability of Choctaw County, Alabama: Alabama Geological Survey Special Map 125, 23 p.
Paulson, Q. F., Miller, J. D., and Drennen, C. W., 1962, Ground-water resources and geology of Tuscaloosa County, Alabama: Geological Survey of Alabama County Report 6, 97 p.
Peirce, L. B., 1967, 7-day low flows and flow duration of Alabama streams: Alabama Geological Survey Bulletin 87, pt. A, 114 p.
Planert, M., and Sparkes, S.L., 1985, Estimation of vertical hydraulic conductivity of the clay layer between the Eutaw and Gordo aquifers in the vicinity of Faunsdale, Marengo County, Alabama: U.S. Geological Survey Water-Resources Investigations Report 85-4083, 23 p.
Poe, R.M., Wilson, G.V., and Tolson, J.S., 1979, Oil and gas wells in Alabama: Alabama Geological Survey Oil and Gas Report 2, 344 p.
Renken, R.A., 1984, The hydrogeologic framework for the Southeastern Coastal Plain aquifer system of the United States: U.S. Geological Survey Water-Resources Investigations Report 84-4243, 26 p.
Scott, J.C., 1962, Ground-water resources of Bullock County, Alabama: Alabama Geological Survey Information Series, no. 29, 120 p.
Scott, J.C., Golden, H.G., and Newton, J.G., 1981, Geology and water availability of Dallas County, Alabama: Alabama Geological Survey Map 180, 94 p.

Scott, J.C., Law, L.R., and Cobb, R.H., 1984, Hydrology of the Tertiary?-Cretaceous aquifer system in the vicinity of Fort Rucker Aviation Center, Alabama: U.S. Geological Survey Water-Resources Investigations Report 84-4118, 221 p.

Scott, J.C., McCain, J.F., and Avrett, J.R., 1967, Water availability map of Houston County, Alabama: Alabama Geological Survey Map 59, 1 sheet.

Shamburger, V.M., 1968, Geologic map of Pike County, Alabama: Alabama Geological Survey Map 72, 1 sheet.

Smith, E.A., 1907, The underground water resources of Alabama: Alabama Geological Survey Monograph 6, 388 p.

Smith, E.A., and Johnson, L.C., 1887, Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama Rivers: U.S. Geological Survey Bulletin 43, 189 p.

Smith, E.A., Johnson, L.C., and Langdon, D.W., Jr., 1894, Report on the geology of the Coastal Plain of Alabama, with contributions to its paleontology by T.H. Aldrich and K.M. Cunningham: Alabama Geological Survey Special Report 6, 759 p.

Sutcliffe, H., Jr., and Newton, J.G., 1957, Interim report on the geology and ground-water resources of Marengo County, Alabama: Alabama Geological Survey Information Series No. 4, 64 p.

Wahl, K.D., 1965, Ground-water resourcs of Pickens County, Alabama: Alabama Geological Survey Bulletin 83, 84 p.

Wait, R.L., and Davis, M.E., 1986, Configuration and hydrology of the Pre-Cretaceous rocks underlying the Southeastern Coastal Plain aquifer sytem: U.S. Geological Survey Water-Resources Investigations Report 86-4010, 1 sheet.

Williams, J.S., DeJarnette, S.S., and Planert, M., 1986, Potentiometric surface and water-use map of the Tuscaloosa aquifer in Alabama, fall 1982: U.S. Geological Survey Water-Resources Investigations Report 85-4174, 1 sheet.

----- 1986, Potentiometric surface, ground-water withdrawals, and recharge area for the Nanafalia-Clayton aquifer in Alabama, fall 1982: U.S. Geological Survey Water-Resources Investigations Report 86-4119, 1 sheet.

Williams, J.S., Planert, M., and DeJarnette, S.S., 1986, Potentiometric surface, ground-water withdrawals, and recharge area for the Eutaw aquifer in Alabama, fall 1982: U.S. Geological Survey Water-resources Investigations Report 86-4121, 1 sheet.

----- 1986, Potentiometric surface, ground-water withdrawals, and recharge area for the Providence-Ripley aquifer in Alabama, fall 1982: U.S. Geological Survey Water-Resources Investigations Report 86-4118, 1 sheet.

----- 1986, Potentiometric surface, ground-water withdrawals, and recharge area for the Lisbon aquifer in Alabama, fall 1982: U.S. Geological Survey Water-Resources Investigations Report 86-4120, 1 sheet.

Table 1.--Well data for stratigraphic sections in the Coastal Plain of Alabama

(Well numbers correspond to section wells on plates 1-6)

A-A´

Well number	County	Latitude	Longitude	Location S.	T.	R.	Altitude above sea level (feet)	Total depth (feet)
399	Lamar	33 48' 15''	88 02' 10''	32	14S.	14W.	532	3,320
1634	Pickens	33 19' 05''	88 10' 49''	14	20S.	16W.	336	10,995
1087	Pickens	33 01' 40''	88 16' 31''	26	24N.	3W.	212	10,250
E-19	Sumter	32 49' 59''	88 18' 31''	32	22N.	3W.	135	2,317
537	Sumter	32 40' 01''	88 10' 37''	34	20N.	2W.	195	4,586
177	Sumter	32 30' 12''	88 00' 25''	29	18N.	1E.	100	3,754
501	Marengo	32 26' 21''	87 35' 47''	17	17N.	5E.	282	2,675
K-13	Dallas	32 24' 49''	87 00' 24''	31	17N.	11E.	125	1,460
658	Autauga	32 24' 36''	86 33' 41''	33	17N.	15E.	273	1,250
L-36	Montgomery	32 20' 25''	86 28' 47''	29	16N.	16E.	146	1,219
597	Montgomery	32 14' 58''	86 23' 37''	30	15N.	17E.	265	2,083
92	Bullock	32 05' 31''	85 56' 20''	22	13N.	21E.	430	2,523
162	Barbour	31 56' 38''	85 25' 53''	9	11N.	26E.	640	3,384
V-2	Barbour	31 52' 30''	85 09' 14''	5	10N.	29E.	252	1,860

Table 1.--Well data for stratigraphic sections in the Coastal Plain of Alabama--continued

B-B'

Well number	County	Latitude	Longitude	Location S.	Location T.	Location R.	Altitude above sea level (feet)	Total depth (feet)
1241	Choctaw	32 14' 17''	88 23' 13''	28	15N.	4W.	274	6,009
1716	Choctaw	32 09' 08''	88 17' 43''	28	14N.	3W.	157	7,286
1570	Marengo	32 08' 40''	88 00' 01''	32	14N.	1E.	238	6,188
1557	Marengo	32 01' 45''	87 47' 04''	9	12N.	3E.	259	7,610
93	Wilcox	31 57' 33''	87 35' 51''	32	12N.	5E.	189	8,250
1432	Wilcox	31 51' 12''	87 27' 07''	10	10N.	6E.	100	8,879
1352	Monroe	31 42' 57''	87 17' 51''	30	9N.	8E.	213	10,367
549	Conecuh	31 43' 32''	86 57' 15''	27	9N.	11E.	390	3,756
145	Crenshaw	31 38' 20''	86 25' 39''	26	8N.	16E.	396	10,830
416	Pike	31 38' 04''	86 08' 24''	27	8N.	19E.	328	6,748
489	Coffee	31 35' 41''	85 51' 49''	8	7N.	22E.	365	3,160
F-20	Dale	31 29' 57''	85 39' 28''	17	6N.	24E.	440	908
631	Henry	31 20' 56''	85 10' 23''	6	4N.	29E.	192	6,610

Table 1.--Well data for stratigraphic sections in the Coastal Plain of Alabama--continued

C-C´

Well number	County	Latitude	Longitude	Location S.	T.	R.	Altitude above sea level (feet)	Total depth (feet)
366	Mobile	31 02' 09''	88 20' 10''	24	1N.	4W.	288	8,075
844	Mobile	31 05' 38''	88 13' 00''	31	2N.	2W.	305	19,206
292	Mobile	31 05' 28''	88 01' 44''	36	2N.	1W.	220	11,014
242	Baldwin	31 04' 08''	87 56' 54''	43	1N.	1E.	24	10,008
1334	Baldwin	31 04' 58''	87 51' 05''	43	1N.	2E.	118	10,809
160	Baldwin	31 05' 20''	87 43' 17''	36	2N.	3E.	202	6,817
593	Baldwin	31 09' 20''	87 37' 03''	12	2N.	4E.	285	6,812
464	Escambia	31 10' 55''	87 20' 02''	35	3N.	7E.	313	6,180
396	Escambia	31 14' 26''	87 11' 23''	8	3N.	9E.	329	5,950
398	Escambia	31 13' 20''	86 48' 04''	18	3N.	13E.	205	5,224
452	Covington	31 11' 34''	86 24' 40''	25	3N.	16E.	257	4,518
555	Geneva	31 04' 02''	86 02' 31''	9	1N.	20E.	176	4,600
1414	Geneva	31 05' 18''	85 50' 51''	4	1N.	22E.	137	8,792
615	Geneva	31 03' 03''	85 35' 19''	13	1N.	24E.	262	3,881
186	Houston	31 00' 05''	85 20' 47''	20	7N.	11W.	140	8,100
238	Houston	31 09' 40''	85 07' 29''	10	2N.	29E.	210	4,012

Table 1.--Well data for stratigraphic sections in the Coastal Plain of Alabama--continued

D-D´

Well number	County	Latitude	Longitude	Location S.	T.	R.	Altitude above sea level (feet)	Total depth (feet)
545	Mobile	30 22' 07''	88 15' 20''	8	8S.	2W.	12	9,008
313	Mobile	30 32' 00''	88 00' 00''	Mobile Bay			22	11,020
1219	Baldwin	30 46' 12''	87 57' 00''	-	3S.	1E.	22	13,005
528	Baldwin	30 58' 06''	87 49' 39''	12	1S.	2E.	137	7,503
160	Baldwin	31 05' 20''	87 43' 17''	36	2N.	3E.	202	6,817
593	Baldwin	31 09' 20''	87 37' 03''	12	2N.	4E.	285	6,812
538	Monroe	31 22' 56''	87 30' 10''	19	5N.	6E.	204	5,280
466	Monroe	31 32' 48''	87 30' 13''	36	7N.	6E.	413	5,238
1352	Monroe	31 42' 57''	87 17' 51''	30	9N.	8E.	213	10,367
668	Monroe	31 44' 42''	87 15' 32''	15	9N.	8E.	164	4,011
107	Wilcox	31 58' 09''	87 05' 43''	32	12N.	10E.	186	5,780
658	Autauga	32 24' 36''	86 33' 41''	33	17N.	15E.	273	1,250

Table 1.--Well data for stratigraphic sections in the Coastal Plain of Alabama--continued

E-E´

Well number	County	Latitude	Longitude	Location S.	Location T.	Location R.	Altitude above sea level (feet)	Total depth (feet)
1414	Geneva	31 05' 18''	85 50' 51''	4	1N.	22E.	137	8,792
417	Coffee	31 21' 03''	85 59' 04''	6	4N.	21E.	408	3,830
489	Coffee	31 35' 41''	85 51' 49''	8	7N.	22E.	365	3,160
443	Pike	31 59' 52''	85 55' 32''	23	12N.	21E.	480	2,015
92	Bullock	32 05' 31''	85 56' 20''	22	13N.	21E.	430	2,523
86	Bullock	32 11' 18''	85 52' 52''	18	14N.	22E.	270	1,715
M-1	Macon	32 24' 01''	85 54' 08''	1	16N.	21E.	356	580

☆U.S. GOVERNMENT PRINTING OFFICE 1988—549-975