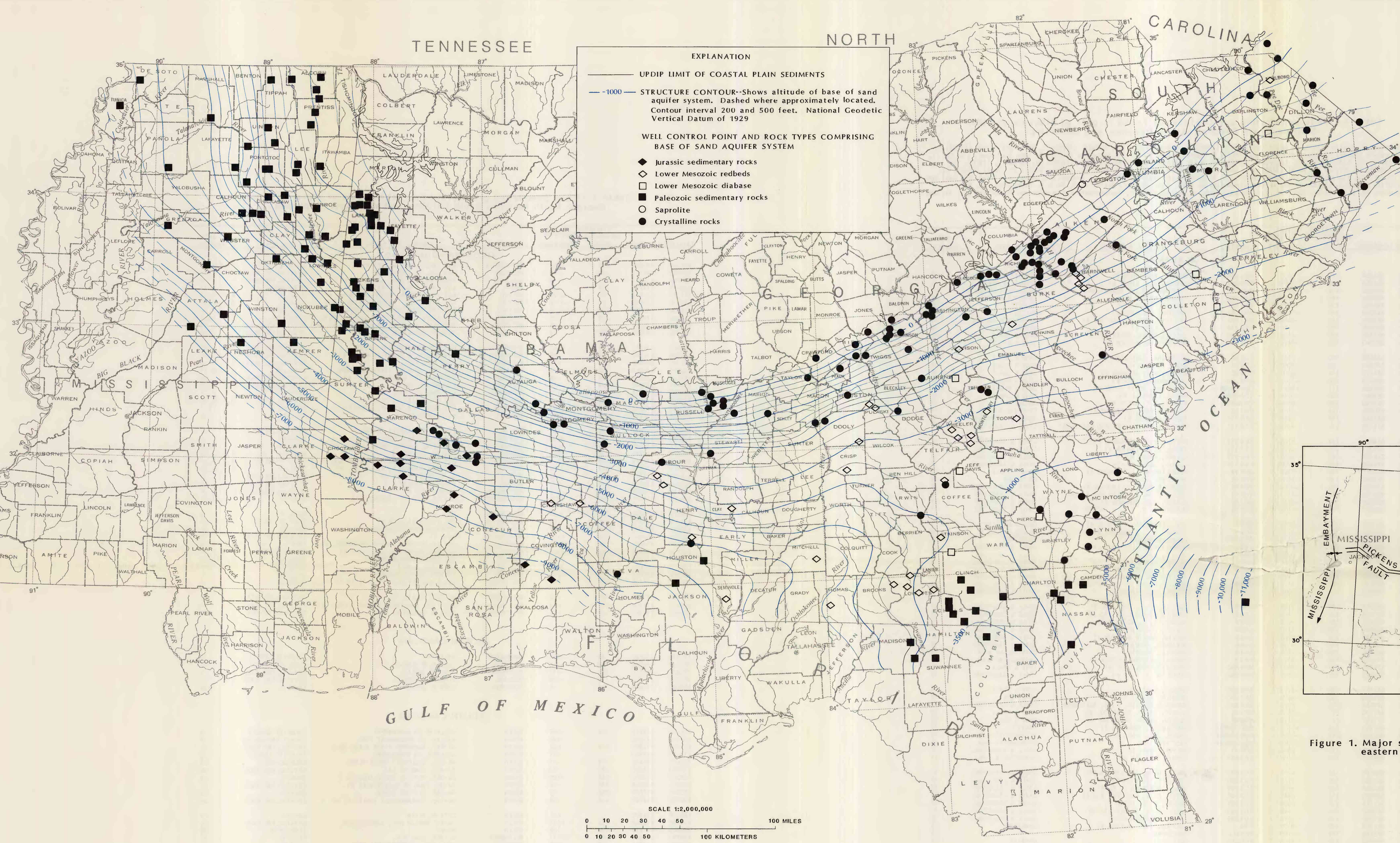

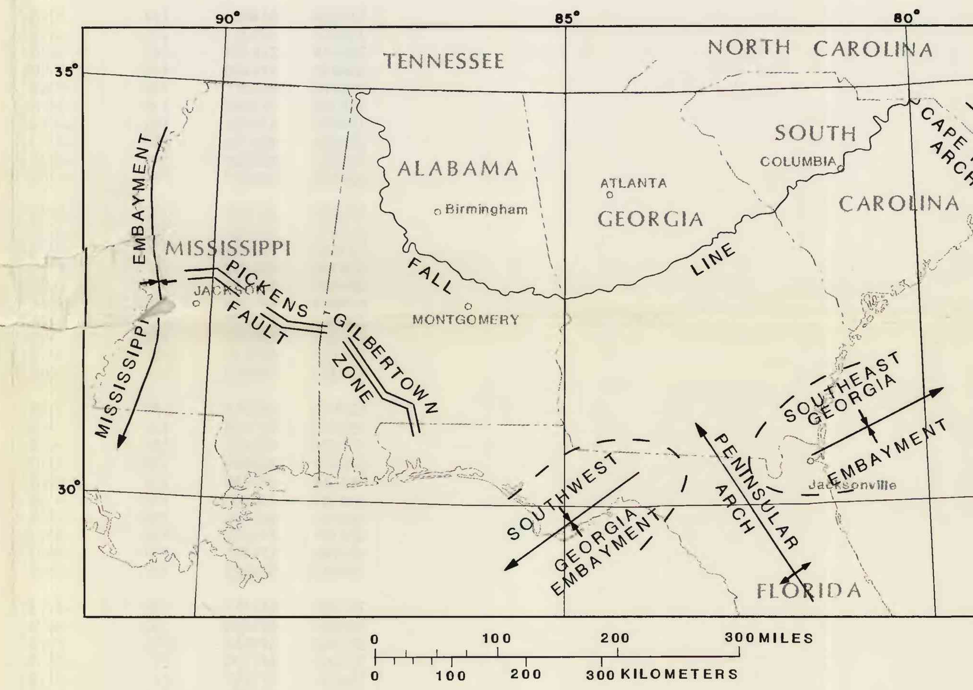

Figure 1. Major structural features in the Coastal Plain of the Southeastern United States, modified from Renken, 1984.

INTRODUCTION

The Southeastern Coastal Plain aquifer system is being studied as part of the U. S. Geological Survey's Regional Aquifer-Systems Analysis (RASA) program, which is designed to examine a number of the regional aquifers that provide a significant part of the country's water supply. The general objectives of each RASA study are (1) to describe the ground-water flow system as it exists today and as it existed before development, (2) to analyze changes between present and predevelopment systems, (3) to integrate the results of previous studies dealing with local areas or discrete aspects of the system, and (4) to provide some capability for evaluating the effects of future ground-water development on the system. These objectives can best be met by digital computer simulations of the aquifer system. Proper simulation requires knowledge of the hydrologic boundaries of the system, such as the system's base.

The base of the aquifer system, as shown here, consists of rocks ranging in age from Paleozoic to Jurassic, which are much less permeable than the overlying sand aquifers of Cretaceous and younger age.

Purpose and Scope

The purpose of this report is to define the configuration and hydrology of the rock surface upon which the sand aquifers and confining beds of the Southeastern Coastal Plain aquifer system were deposited. The Southeastern Coastal Plain aquifer system, as defined here, consists of three regionally-extensive sand aquifers that underlie an area extending from the Cape Fear arch, near the North Carolina-South Carolina border, westward through South Carolina, Georgia, Alabama, and Mississippi to the Tennessee border. This investigation utilized data available in reports or as file data in the States mapped. These data are summarized in table 1, which lists the altitude and type of rock comprising the base of the aquifer system. Because the well control used was of insufficient density to depict faulted areas in the western Alabama-southeastern Mississippi area, no attempt was made to map the base of the system in these complexly faulted areas. The effect of faulting on the lithology, thickness, and hydrology of the aquifers present in these areas is largely unknown.

Location of Area

The area studied extends from the Fall Line marking the inland limit of Coastal Plain rocks eastward as far as the coast in South Carolina, southward to the Georgia-Florida border, and southwestward to the area of the Pickens-Gilbertown fault zone in western Alabama and Mississippi.

Previous Investigations

Many earlier works identified rocks they called "basement" in part of the area. "Basement rocks," a poorly defined term, includes both crystalline rocks and sedimentary rocks of early Mesozoic age as mapped by previous workers, particularly in South Carolina, most of Georgia, and near the Fall Line in Alabama.

Darton (1896, 1902) was among the early workers who reported penetration of basement rocks in wells. Stephenson and Veatch (1915) listed several wells in Georgia that penetrated basement rocks including those previously listed by McCallie (1898, 1908). Herrick (1961) listed many wells that ended in crystalline rocks or other pre-Cretaceous rocks. Cooke (1936) and Siple (1946, 1958) reported data on basement rocks from South Carolina, and Siple (1959) presented a map of the pre-Cretaceous surface of South Carolina. Herrick and Vorhis (1963) showed a map of the pre-Cretaceous surface in Georgia. Brown and others (1979) mapped what they termed the pre-unit F(?) surface, representing Jurassic or older rocks in Georgia and South Carolina. Hurst (1960) and Milton and Hurst (1965) reported on basement rocks in Georgia and Florida. Applin (1951) mapped the buried pre-Mesozoic rocks in Florida and adjacent States. Neathery and Thomas (1975) described the types of basement rocks in Alabama but presented no contour map. Kidd (1976) mapped the top of the Pottsville Formation (Pennsylvanian) in northwest Alabama. A comprehensive study of the mineralogy and age of cores and drill cuttings in Georgia and part of South Carolina was made by Chowns and Williams (1983), who also used radioisotopes to date rocks.

Acknowledgments

The authors wish to acknowledge colleagues of the Geological Survey who have contributed to this report and compiled data from many sources for the map. Data from South Carolina were compiled by Walter Aucott; from Georgia, by Robert Faye and David Prowell; and from Alabama, Sydney S. DeJarnette. Robert A. Renken and Ernest Boswell provided data from wells in Mississippi, and James A. Miller provided data from Florida and Alabama.

CONFIGURATION OF THE SURFACE OF PRE-CRETACEOUS ROCKS

Structural features shown by the base of the aquifer system as mapped herein include the Cape Fear arch, the Southeast Georgia embayment, the Southwest Georgia embayment, the Peninsular arch and small grabens that are part of the Pickens-Gilbertown fault zone in western Alabama and Mississippi. The locations, trends, and axes of these tectonically-produced features are shown on figure 1.

The Cape Fear arch is a gentle broad arch in the crystalline rocks whose axis is north of and parallel to the South Carolina-North Carolina border and is oriented about North 60° West. Along its crest from the Fall Line to the coast, its axis plunges gently southeastward. The Cape Fear arch separates the Chesapeake-Delaware embayment (Murray, 1961, p. 92) on the north from the Southeast Georgia embayment on the south. Northeast of the arch the slope on the crystalline rocks is relatively steep; to the southwest, the slope is more gentle. The strike on the pre-Cretaceous rocks changes from about North 70° East on the south side of the arch to about North 30° East to the north of it. The sedimentation pattern across the Cape Fear arch indicates that it has periodically been a positive feature during parts of Cretaceous and Tertiary time (Cooke, 1936; Siple, 1959). Brown and others (1972, plate 3) showed that Early Cretaceous Unit F is the oldest unit that crosses the arch and that the succeeding Early Cretaceous Unit E is not present on top of the arch. They also showed that sediments of Midway, Sabine, and Oligocene age are missing over the arch and only thin patches of rocks of Claiborne and late Miocene age are preserved on the arch as erosional remnants, some of which lie near the Fall Line in North Carolina.

The Southeast Georgia embayment includes those counties eastward of a nearly linear, northwest-trending high in central Georgia that is a continuation of the Peninsular arch of Florida. The embayment is as much as 4,500 feet deep onshore in Glynn County, Ga., and becomes shallower westward to less than 3,500 feet in central Georgia along the extension of the Peninsular arch. One offshore well drilled 74 miles east of Jacksonville, Fla., penetrated metamorphosed sedimentary rocks and meta-igneous rocks at about 11,000 feet below sea level that are believed to be of Devonian age (Simonis, 1979). This is the greatest known depth to pre-Cretaceous rocks in the Southeast Georgia embayment.

The Peninsular arch (Applin, 1951) trends northwestward from Florida into Georgia and separates the Southeast and Southwest Georgia embayments. Sedimentation was not continuous across the arch in Georgia during Early Cretaceous time. The Southwest Georgia embayment trends southwestward into southeastern Alabama and western Florida and reaches a depth of about 13,000 feet in western Florida. Cretaceous sedimentary rocks are underlain by Paleozoic and Mesozoic rocks in this basin (Brown and others, 1979).

There is scant evidence for the Chattahoochee anticline named by Veatch and Stephenson (1911). The strike of the crystalline basement rocks changes from slightly north of east in Georgia to slightly north of west in Alabama in the vicinity of the Chattahoochee River but no distinctive arch is shown by contours representing the base of the Southeastern Coastal Plain aquifer system.

The Pickens-Gilbertown fault zone in western Alabama is near the downdip limit of mapping, and also coincides approximately with the downdip limit of the occurrence of freshwater in Cretaceous rocks. Because hydrologic data are unavailable in the area, and because the fault zone consists of numerous, complex, small-scale structures, the pre-Cretaceous surface is unmapped in or south of this fault zone.

Triassic grabens or half-grabens are present in South Carolina (Marine and Siple, 1974). Olivine diabase believed to be of Triassic age was identified at Florence (Siple, 1959) but the extent and thickness of Triassic rocks there is not known. In the Aiken-Barnwell County area, Siple (1967) defined a Triassic basin which was subsequently named the Dunbarton basin by Marine and Siple (1974). This basin is bounded on the north by a normal fault known to have a displacement of at least 1,590 feet. The boundary of the south side of the basin is undetermined but the basin is inferred to be 6 to 7 miles wide on the basis of aeromagnetic and seismic data. Small-scale faulting has been found within the Dunbarton basin.

Basalt flows have been found in southwestern and northwestern Dorchester County, S.C., some of which lie atop the reddish brown, silty clay of Triassic age. Basalt or similar rocks have also been found in wells in southwest Georgia intruded into sedimentary rocks believed to be of Triassic age that underlie an extensive area (Chowns and Williams, 1983). The relation of these rocks with those found in the Dunbarton basin and at Florence is unclear. Locally, in southeast Alabama, sedimentary rocks and basalt flows thought to be of Triassic age have been reported (Neathery and Thomas, 1975).

The pre-Cretaceous surface is largely erosional and exhibits local relief in addition to its overall seaward slope. Siple (1967) indicated relief of as much as 150 feet on crystalline rocks in the Aiken-Barnwell County area of South Carolina and suggested that peneplanation of the crystalline rock surface was not complete prior to subsequent deposition. Stephenson and Monroe (1940) estimated that the relief on the Paleozoic rocks in Tishomingo County, Miss., is 100 feet or more. The slope of the crystalline rocks along the axis of the Cape Fear arch from the Fall Line to the Coast is about 14 feet per mile (ft/mi). Northeast of the arch, in the vicinity of Cape Hatteras, N.C., the slope increases to about 60 ft/mi (Brown and others, 1972). Southwest of the arch, from Columbia to Charleston, S.C., the slope on the pre-Cretaceous surface is about 20 ft/mi. Slopes of about 25 to 35 ft/mi occur near the Savannah River and westward to the vicinity of Macon, Ga. From Macon, Ga., southeastward to northern Coffee County, Ga., the slope is about 50 ft/mi. A flat area or saddle with less than 500 feet of relief occurs from Coffee County southward to the Georgia-Florida line. The slope of the pre-Cretaceous surface steepens between Columbus and Bainbridge, Ga., being about 60 ft/mi into the Southwest Georgia embayment. As noted by Prouty (1946), the slope in many places steepens below an elevation of -2,500 feet, as shown by the slope of about 73 ft/mi between Brunswick, Ga., and a well offshore from Jacksonville, Fla.

In west-central Alabama in the vicinity of Montgomery, Tuscaloosa, and Selma, the slope of the pre-Cretaceous surface ranges from about 90 to 110 ft/mi. In northeast Mississippi, the slope is less, about 38 ft/mi. Faulting in southwestern Alabama and in Mississippi appears to account in part for the increase in slope toward the Gulf coast.

HYDROLOGY OF PRE-CRETACEOUS ROCKS

The rocks that underlie the Cretaceous sedimentary rocks of the Southeastern Coastal Plain aquifer system can be grouped into five general categories. Depending upon lithology, ground water may occur in these rocks in either primary (intergranular) or secondary (fractures) pore spaces. Porosity and permeability of all the rocks mapped herein are much lower than that of the aquifer system that overlies them. Details on the type of porosity and hydraulic characteristics of each mapped category of rocks are discussed below.

Crystalline Rocks

Ground water occurs mainly in the fractures and joints of crystalline rocks. Where faulting has occurred and shear zones have developed, large fractures may be present and chemical weathering of the mylonite in fracture zones may enlarge them at some places or cause sealing at others. Stewart and others (1964, table 9) reported the hydraulic conductivity of four samples of crystalline rock (quartz biotite schist) in Dawson County, Ga., ranged from $1.3x10^{-5}$ to $5.0x10^{-6}$ feet per day (ft/d) and porosity ranged from 2.5 to 6.1 percent. The permeability of some rock samples was so low it could not be determined after 2 months under high pressure and vacuum. Stewart (1962a) reported on hydraulic conductivity studies near Jonesboro, Ga., to determine the suitability of quartz biotite-feldspar gneiss for storing liquid petroleum products. Tests were made of core samples to determine their conductivity to air. The tests gave values of $1.46x10^{-4}$ to 0.14 ft/d for horizontal conductivity and $1.7x10^{-6}$ to $6.8x10^{-4}$ ft/d for vertical conductivity. The conductivity to water would be less than these values. In most cases, the porosity values of these cores were less than 1 percent.

Marine (1967) determined the hydraulic conductivity of fractured crystalline rock at the Savannah River Plant near Aiken, S.C. Laboratory results on core samples showed conductivities ranged from $1.07x10^{-7}$ to $2.67x10^{-4}$ ft/d and averaged $6.68x10^{-5}$ ft/d. Twenty-five swab tests made of test holes in low-permeability rock showed hydraulic conductivities ranged from $2.67x10^{-6}$ to $1.07x10^{-4}$ ft/d. Additional tests were made by pumping the wells and observing water-level changes. The transmissivity ranged from about 13 to about 34 feet squared per day (ft^2/d) on drawdown tests and from about 13 to about 41 ft^2/d on recovery tests. An average conductivity determined from these tests was $4x10^{-2}$ ft/d. The zones from which fractures yielded water were determined to have a transmissivity of about 21 ft^2/d and an average hydraulic conductivity of about $1.0x10^{-1}$ ft/d.

The head in crystalline rocks near Barnwell, S.C., was found by Siple (1964) to be about 20 feet higher than that in the overlying sand. There appears to be some vertical movement of water from the crystalline rocks into the overlying Coastal Plain sediments; however, the amount probably is negligible.

Saprolite

Saprolite is defined as chemically weathered crystalline or sedimentary rock composed mostly of clay but which maintains the original texture of the parent rock. Saprolite develops primarily on the top of crystalline rocks, is often a deep red color due to the oxidation of iron, and occasionally contains large amounts of quartz. If present in appreciable thickness, saprolite can be defined by its distinctive electric log character; a low resistivity and strongly positive spontaneous potential. Unweathered crystalline rock beneath the saprolite exhibits a high resistivity and strongly negative spontaneous potential. Saprolite may be as much as 100 feet thick; however, thicknesses of 5 to 10 feet are more common. Where saprolite is present, it acts as a confining bed overlying the crystalline rock and inhibits the circulation of water from the crystalline rock into the overlying sediments.

Stewart (1964) reported on a metamorphic rock terrain near Dawsonville, Ga., where pumping tests were made in wells completed in saprolite and crystalline rock (biotite schist) and infiltration tests were made in pits dug in the saprolite. The hydraulic conductivity of the saprolite as determined from laboratory tests made on cores ranged from 0.01 to 7.6 ft/d, and porosity ranged from 31 to 59 percent (Stewart, 1964). Aquifer tests made of saprolite in Dawson Co., Ga., indicate its transmissivity ranged from about 96 to about 280 $ft/^2/d$ and the storage coefficient ranged from 0.00094 to 0.0083. These test results showed the hydraulic conductivity was greatest along the direction of strike. At two other sites, the hydraulic conductivity of saprolite core samples ranged from 0.00027 to 0.13 ft/d at one site and from 0.001 to 1.20 ft/d at the other site.

Siple (1964) noted that in Aiken and Barnwell Counties, S.C., a marked difference in head and quality of water existed between confined water in the crystalline rocks and water in the overlying Coastal Plain sediments. Freshwater occurred in the crystalline rocks in and near the outcrop, but highly mineralized water occurred where the crystalline rocks were deeply buried. By contrast, the overlying Cretaceous sedimentary rocks contained freshwater everywhere. Siple attributed this to the discontinuous nature of the saprolite in the outcrop area versus its impermeable character downdip and stated (p. C181), "Downgradient from the 'lip' of the continuous sheet of saprolite, little or no escape of water from the crystalline rocks is possible and the water in these rocks is stagnant or nearly so." These data indicate saprolite becomes compacted and very impermeable where buried, but near the Fall Line may contain and transmit small amounts of freshwater.

Paleozoic Rocks

Little is known of the hydrology of the Paleozoic rocks beneath the Coastal Plain. In a study done along the Tennessee-Tombigbee waterway, Brahana and others (1974) noted that water was obtained where weathering had occurred on the surface of the Mississippian rocks. Wells penetrating weathered chert at Iuka, Burnsville, and Corinth, Miss. show transmissivity values as great as 8,500 ft^2/d (Brahana and others, 1974), but according to Wasson (1980) chert transmissivities generally average about 400 ft^2/d. Data from Wolff (1982) shows Paleozoic rocks tested have a hydraulic conductivity ranging from $2.5x10^{-7}$ to 311.8 ft/d and a porosity range of from 0.44 to 30 percent.

Most of the water in Paleozoic rocks occurs in fractures or solution cavities. In northeastern Mississippi, water occurs in siliceous rocks equivalent to the fractured Fort Payne Chert of Mississippian age and is believed to move downward into the chert from overlying Cretaceous sedimentary rocks. In most places, however, small amounts of water are believed to move upward from Paleozoic rocks into the overlying Coastal Plain sediments. In the area downdip of the Fall Line, salty water usually occurs in the Paleozoic rocks. However, there is no chemical evidence to support the hypothesis of upward flow into Coastal Plain rocks from either salty or freshwater zones in the Paleozoic rocks.

Triassic Rocks

Marine and Siple (1974) reported that Triassic sedimentary rocks in the Dunbarton basin in Barnwell County, S.C., are characterized by extremely low hydraulic conductivity, ranging from $1.48x10^{-3}$ to $3.3x10^{-7}$ ft/d.

Triassic basalt and sedimentary rocks underlie part of South Carolina and were cored in a test well drilled for the Southeastern Coastal Plain RASA study in Dorchester County. No cavernous basalts were found, only solid flows, and no hydraulic test was made. However, data listed by Wolff (1982) indicate values of porosity for basalts tested elsewhere range from 0.1 to 33 percent and hydraulic conductivity values range from $5.4x10^{-6}$ to about 822 ft/d. It is assumed that the hydraulic conductivity of the basalt in Dorchester County, S.C., is similar to the lower range reported by Wolff. Minute healed fractures were seen in the core samples obtained from the test well. The basalt is interpreted as a nearly impermeable continuous cap, overlying the Triassic sedimentary rocks beneath it.

Bain and Brown (1981) used a slug test to determine the transmissivity of a zone in Triassic sandstone in a test well near Raleigh, N.C., in the Triassic Durham basin and found it to be $1.28x10^{-2}$ ft^2/d in the 810- to 866-foot interval. A swabbing test made of this zone obtained a transmissivity value of $4.7x10^{-2}$ ft^2/d. A slug test was made in the 3,310- to 3,750-foot interval at the bottom of the well and obtained a transmissivity of $9.1x10^{-4}$ ft^2/d.

Jurassic Rocks

Rocks that are part of the Upper Jurassic Cotton Valley Group are known to be present in western Florida, southern Alabama, and Mississippi. Miller (1982) discussed the sedimentation pattern and structural control of Jurassic rocks in this area, attributing the structural control to wrench faulting that caused foreshortening and folding. In the gentle downwarped synclinal areas he noted thickening of all Jurassic units. The Cotton Valley Group in this area consists of red, pink, and white, coarse-grained sandstones and minor maroon and brown shales. The subsurface extent of the Cotton Valley is not exactly known, especially in its updip area. No data exist on the hydrologic properties of these rocks, but they are excluded from the Southeastern Coastal Plain aquifer system because they contain saltwater everywhere, and are therefore assumed to have low permeabilities.

SUMMARY AND CONCLUSIONS

The base of the Southeastern Coastal Plain aquifer system consists of crystalline rocks, saprolite, Paleozoic rocks, Triassic sedimentary rocks (some of which are intruded by basalt), and Jurassic sedimentary rocks. The permeability of these rocks is extremely low and little exchange of water occurs upward to the overlying Cretaceous aquifers. Porosity values are in the range of 10 per cent or less in some of the rocks, indicating little water is stored in them. The transmissivity values are extremely low, indicating very slow movement of water in these rocks. The small volume of water moving at a very slow rate has a long residence time and is usually mineralized to a greater degree than water in the more permeable overlying sediments.

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BASE FROM U.S. GEOLOGICAL SURVEY DIGITAL LINE GRAPHS FROM 1:2,000,000 SCALE MAPS

CONFIGURATION AND HYDROLOGY OF THE PRE-CRETACEOUS ROCKS UNDERLYING THE SOUTHEASTERN COASTAL PLAIN AQUIFER SYSTEM

By
Robert L. Wait and Marvin E. Davis