Permeable Thickness of the Miocene Upper and Lower Brunswick Aquifers, Coastal Area, Georgia

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INFORMATION CIRCULAR 103

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ABSTRACT

Eocene-Oligocene limestone of the upper Floridan aquifer provides voluminous quantities of ground water to the coastal counties of Georgia. However, ground-water withdrawals from the upper Floridan aquifer are inducing saltwater encroachment beneath developed communities of coastal Georgia. To offset demand from the upper Floridan, overlying clastic aquifers were investigated as possible alternative sources of ground water by estimating their permeable thickness and areal distribution. These aquifers, called the upper and lower Brunswick aquifers, and are composed of strata of the Miocene Hawthorne Group.

The lower Brunswick aquifer consists of sandy limestone and calcareous sand of the Parachucla Formation. The upper Brunswick aquifer consists mostly of gravelly sands of the Marks Head Formation. The aquifers can be identified on electric logs by prominent deflections in spontaneous potential and apparent resistivity. These deflections correspond to changes from clay to sand and vice versa. The aquifers can also be identified by their association with three marker horizons, which show up as prominent deflections on natural gamma ray logs. Typically, the electric log signatures of the aquifers show good correlation to lithologic descriptions from the same or nearby wells. The Brunswick aquifers are thickest under Glynn County, Georgia, and become thinner to the southwest and northeast.

INTRODUCTION

The upper Floridan aquifer is the principal source of freshwater supply in the 11-county coastal area of Georgia. Availability of freshwater supplies in the aquifer is threatened by saltwater encroachment in the Savannah area, and by upward migration of saline water in the Brunswick area. Because of the threat of saltwater contamination to the upper Floridan aquifer, alternative water supplies are being evaluated by the Georgia Geologic Survey as part of a five-year study to assess ground-water resources of the coastal area.

Miocene-age sediments of the coastal area of Georgia (Figure 1) contain the upper and lower Brunswick aquifers. Together, the upper and lower Brunswick aquifers make up the Brunswick aquifer system. This aquifer system is composed of mixed siliciclastic and carbonate sediments that overlie the carbonate rocks of the Floridan aquifer system (Figure 2). The Brunswick aquifer system is currently being studied to assess the viability for supplying supplemental ground water to coastal Georgia. Objectives of the present study are to map the permeable thickness and distribution of the upper and lower Brunswick aquifers, and to assess the possible use of ground water from the Brunswick aquifer system as a supplemental source of water to the upper Floridan aquifer.

Purpose and Scope

The purposes of this report are: 1) measure the permeable thicknesses of the upper and lower Brunswick aquifers; 2) to develop isopach maps of the aquifers over an eleven-county area; and 3) to provide a means by which the thickness of the permeable portions of the Brunswick aquifers may be estimated for a particular location. The

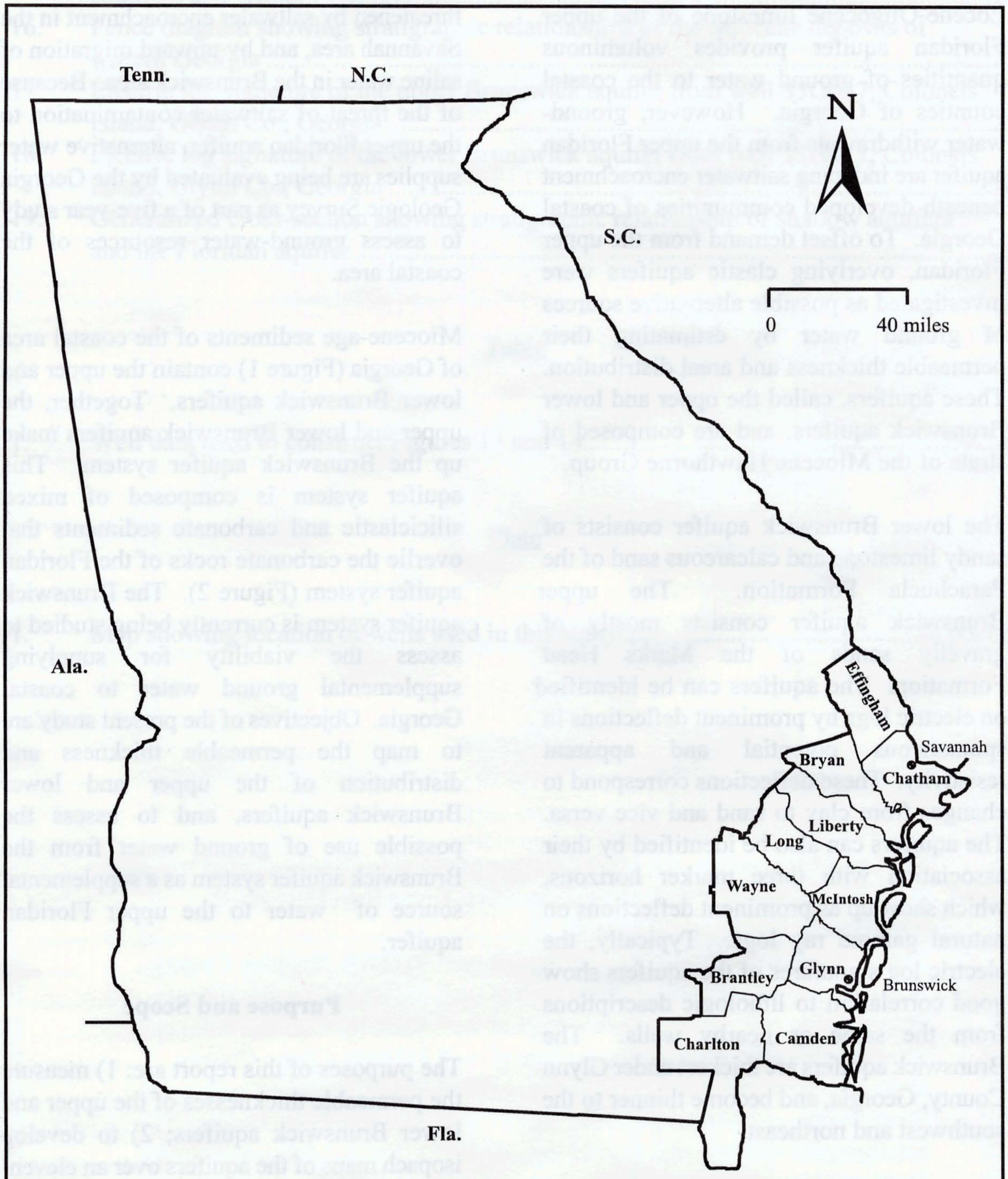


Figure 1: Location of study area.

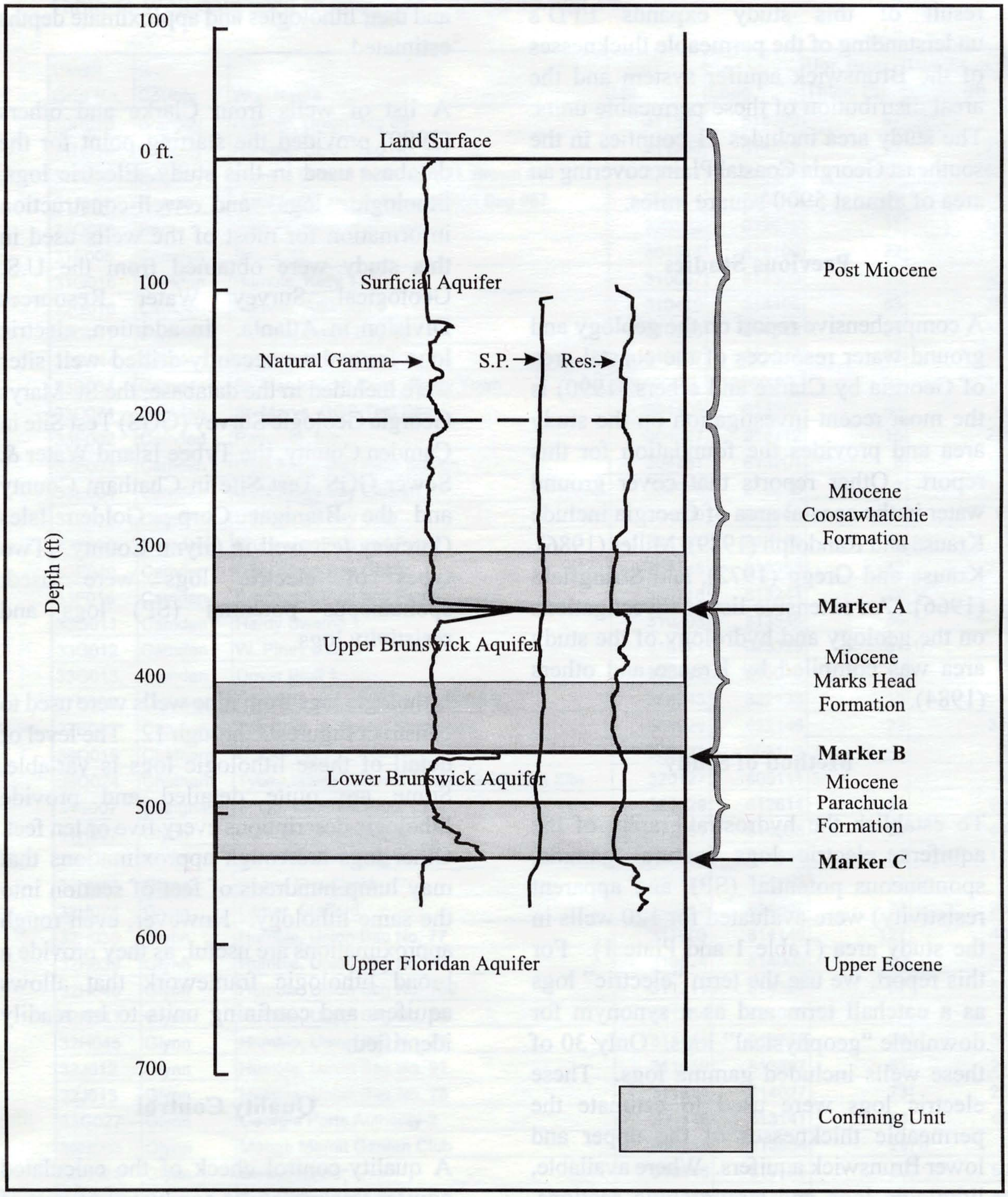


Figure 2: Stratigraphic position, thickness, and electric log expression of the upper Floridan, upper and lower Brunswick, and surficial aquifers, Kings Bay, Camden County. Modified from Clarke and others, 1990.

result of this study expands EPD's understanding of the permeable thicknesses of the Brunswick aquifer system and the areal distribution of these permeable units. The study area includes 11 counties in the southeast Georgia Coastal Plain, covering an area of almost 5900 square miles.

Previous Studies

A comprehensive report on the geology and ground-water resources of the coastal area of Georgia by Clarke and others (1990) is the most recent investigation on the study area and provides the foundation for this report. Other reports that cover ground water in the coastal area of Georgia include Krause and Randolph (1989), Miller (1986), Krause and Gregg (1972), and Stringfield (1966). An extensive list of investigations on the geology and hydrology of the study area was compiled by Krause and others (1984).

Method of Study

To establish the hydrostratigraphy of the aquifers, electric logs (natural gamma, spontaneous potential (SP), and apparent resistivity) were evaluated for 120 wells in the study area (Table 1 and Plate 1). For this report, we use the term "electric" logs as a catchall term and as a synonym for downhole "geophysical" logs. Only 30 of these wells included gamma logs. These electric logs were used to estimate the permeable thicknesses of the upper and lower Brunswick aquifers. Where available, lithologic logs and stratigraphic sections, obtained from the cores and cuttings available from the study area, were compared with the electric logs. Thus, the aquifers could be assigned to a formation, and their lithologies and approximate depths estimated.

A list of wells from Clarke and others (1990) provided the starting point for the database used in this study. Electric logs, lithologic logs and well-construction information for most of the wells used in this study were obtained from the U.S. Geological Survey Water Resources Division in Atlanta. In addition, electric logs from three recently-drilled well sites were included in the database; the St. Marys Georgia Geologic Survey (GGS) Test Site in Camden County, the Tybee Island Water & Sewer GGS Test Site in Chatham County and the Branigar Corp., Golden Isles Gateway test well in Glynn County. Two types of electric logs were used: spontaneous potential (SP) logs and resistivity logs.

Lithologic logs from nine wells were used to construct Figures 3 through 12. The level of detail of these lithologic logs is variable. Some are quite detailed and provide lithologic descriptions every five or ten feet. Other logs are rough approximations that may lump hundreds of feet of section into the same lithology. However, even rough approximations are useful, as they provide a broad lithologic framework that allows aquifers and confining units to be readily identified.

Quality Control

A quality-control check of the calculated aquifer thickness was conducted as part of this study. Ten percent of the wells listed in Table 1 (12 wells, 24 thickness estimates) were randomly selected for the quality-control check. A geologist familiar with

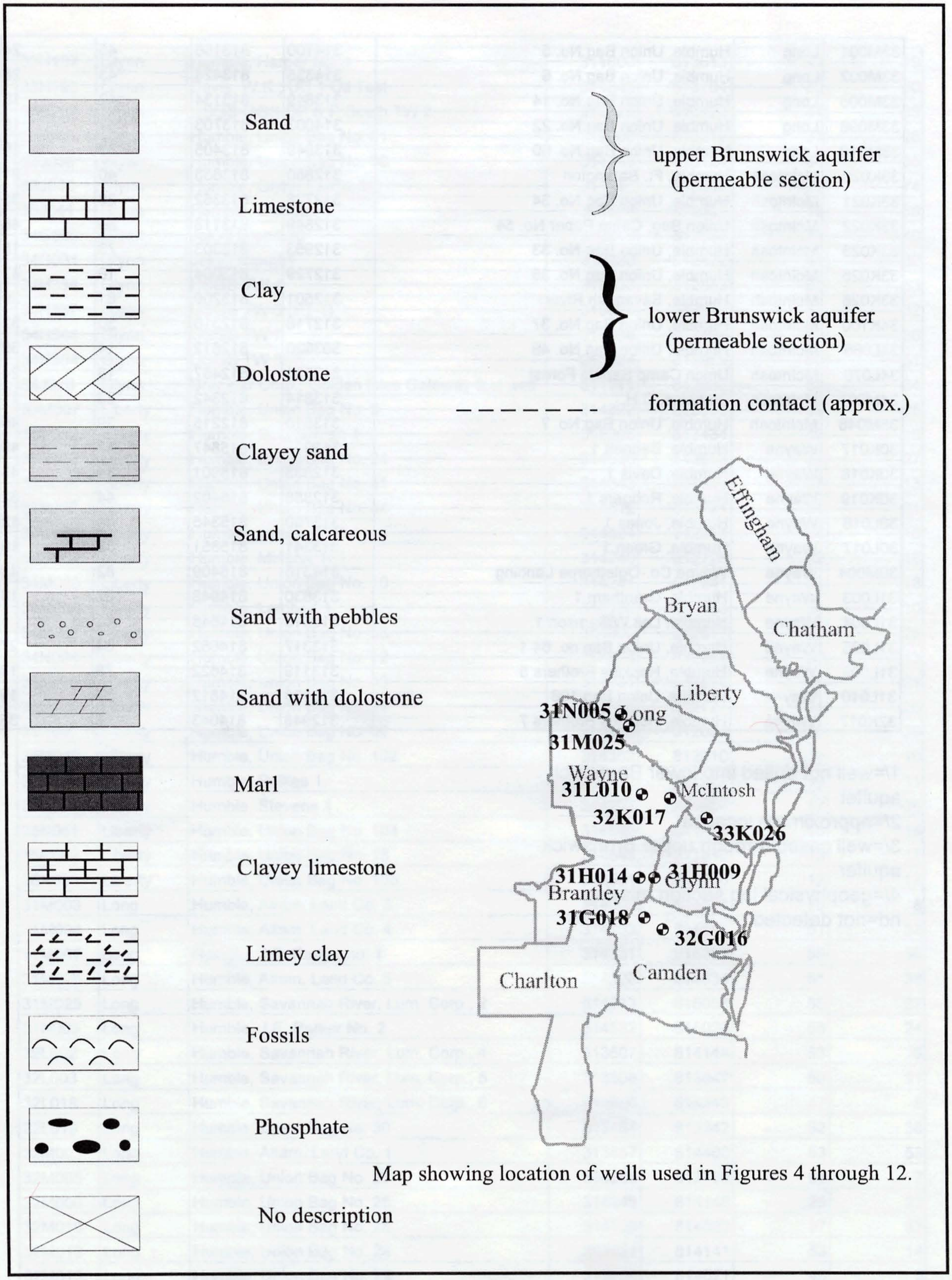
Table 1: Well data used to construct Figures 13 and 14.

USGS Grid No.	County	Well Name	Lat.	Long.	Upr. Brun. Thick. (ft)	Lwr. Brun. Thick. (ft)
30H010	Brantley	Humble, Union Bag 85	311352	815329	51	69
31H014	Brantley	Humble, Union Bag No. 99	311335	814819	83	31
31J002	Brantley	Humble Oil and Refining, WH. Brown #1	311931	815205	69	67
31J004	Brantley	Humble Oil and Refining, Union Bag #87	311534	815053	90	25
35Q001	Bryan	USA Ft. Stewart at river	320122	812016	41	13
31E005	Camden	Silcox, O.	304814	815109	22	0
31G018	Camden	Humble, Kelly 1	310657	814809	40	38
32G016	Camden	Humble, Atkinson 1	310419	814405	53	30
32G017	Camden	Humble, Union Bag 80	310658	814348	25	35
32G044	Camden	Humble, Union Bag 92	310627	813944	32	29
33D031	Camden	St. Marys Kraft Corp., Porgy Town	304400[2/]	813300[2/]	28	14
33D071	Camden	St. Marys, GGS Test Site	304406	813307	64	4
33E002	Camden	Rayonier, Inc.	304627	813712	15	20
33E003	Camden	USN Kings Bay Refill Station	304751	813201	8	14
33E004	Camden	USN Kings Bay Etowah	304910	813238	7	13
33E018	Camden	USN Kings Bay Club	304800	813105	4	9
33E038	Camden	Brunswick Pulp and Paper	305157	813156	12	1/
33E040	Camden	USN Kings Bay Obser.	304748	813353	33	37
33F016	Camden	Brunswick Pulp and Paper	305718	813244	22	1/
33G011	Camden	Hardy Swamp 1	310208	813546	36	1/
33G012	Camden	W. Piney Bluff 1	310111	813323	61	1/
33G013	Camden	Dover Bluff 1	310122	813049	12	1/
27E002	Charlton	USGS Okefenokee Swamp Well 8	304943	822138	10	8
27E003	Charlton	Ga. DNR, S. Foster State Park	304929	822146	22	33
39Q016	Chatham	USGS TW 7	320122	805102	3/	5
39Q024	Chatham	Tybee Island Water & Sewer, GGS Test Site	320127	805111	3/	8
34S007	Effingham	S. Ga. Minerals Prog. EF-1	322129	812611	34	10
31H007	Glynn	Humble, Union Bag 97	311051	814558	38	49
31H009	Glynn	Humble, Union Bag 96	311353	814536	56	12
32H017	Glynn	Roads End Camp	311155	814252	17	1/
32H024	Glynn	Lamar, Stafford	310918	814008	27	26
32H038	Glynn	Humble, Union Bag No. 77	311003	814149	127	40
32H039	Glynn	Humble, Union Bag No. 93	310924	814008	62	39
32H040	Glynn	Humble, Union Bag No. 100	311211	814324	57	55
32H041	Glynn	Humble, Union Bag No. 76	311254	814025	35	4/
32H045	Glynn	Humble, Union Bag No. 73	311444	813758	36	57
32J012	Glynn	Humble, Union Bag No. 91	311559	813837	52	21
32J013	Glynn	Humble, Union Bag No. 75	311644	814027	73	25
33G027	Glynn	Georgia Ports Authority-2	300519	813141	48	42
33H003	Glynn	Madge Merritt Garden Club	310759	813554	29	1/
33H021	Glynn	Blythe Island	310946	813325	29	59
33H134	Glynn	Ballard Fire Station	311212	813024	38	46
33H139	Glynn	O'Quinn, Wyllie, Jr.	310738	813327	0	16
33H184	Glynn	Humble, Union Bag No. 94	311353	813653	70	68
33H185	Glynn	Humble, Union Bag No. 74	311433	813046	54	44
33H186	Glynn	Humble, Bell No. 1	310817	813539	28	35

33H187	Glynn	Humble, Harper No. 1	311000	813613	43	49
33H192	Glynn	Davis, W.K., UC 1 Oil Test	311345	813704	30	50
33H207	Glynn	USGS-GGS-BP & P South TW 2	310925	813122	44	69
33J038	Glynn	Humble, Union Bag No. 61	312000	813212	37	26
33J039	Glynn	Humble, Union Bag No. 90	311748	813124	64	65
33J040	Glynn	Humble, Glynn Farms 1	311916	813509	20	74
33J041	Glynn	Humble, Schluter 1	311524	813607	15	69
34G006	Glynn	Jekyll Island 20	310249	812538	71	40
34G031	Glynn	Jekyll Island 1	310403	812422	41	32
34H334	Glynn	USGS TW 4	310938	812853	61	63
34H337	Glynn	USGS TW 5 (PT 1)	310824	812942	88	32
34H344	Glynn	USGS TW 7	310938	812852	69	86
34H354	Glynn	USGS TW 8	310924	812952	50	51
34J076	Glynn	Branigar Corp., Golden Isles Gateway test well	311711	812832	58	34
33M007	Liberty	Humble, Union Bag No. 9	314322	813033	39	25
33N092	Liberty	Humble, Quarterman 1	315206	813434	49	15
33N093	Liberty	Humble, Union Bag No. 24	314536	813653	37	27
33N096	Liberty	Humble, Union Bag No. 41	314643	813323	37	13
33N097	Liberty	Humble, Union Bag No. 44	314512	813121	51	21
34M083	Liberty	Humble, James, WM 1	314324	812513	24	18
34M084	Liberty	Humble, Minson, R 1	314240	812726	22	16
34M085	Liberty	Humble, Union Bag No. 10	314241	812241	33	18
34M086	Liberty	Humble, Lambert 1	314132	812433	34	10
34M087	Liberty	Humble, Union Bag No. 58	314000	812617	23	26
34N094	Liberty	Humble, Union Bag No. 12	314624	812244	26	13
34N095	Liberty	Humble, Union Bag No. 43	314731	812813	35	21
34N096	Liberty	Humble, Union Bag No. 11	314528	812727	24	26
34N097	Liberty	Humble, Union Bag No. 38	314915	812607	25	39
35M043	Liberty	Humble, Union Bag No. 103	314352	812210	25	10
35M044	Liberty	Humble, Reikes 1	314412	811901	19	11
35M045	Liberty	Humble, Stevens 1	314233	811655	17	36
35N061	Liberty	Humble, Union Bag No. 104	314530	811816	15	15
35N062	Liberty	Humble, Union Bag No. 13	314649	811812	13	17
35N063	Liberty	Humble, Union Bag No. 105	314531	812050	12	12
31M003	Long	Humble, Altam. Land Co. 3	314005	814523	75	8
31M004	Long	Humble, Altam. Land Co. 4	314203	814642	51	33
31M007	Long	Humble, J.E. Parker no. 1	314331	815223	55	56
31M025	Long	Humble, Altam. Land Co. 5	314223	814834	55	38
31M029	Long	Humble, Savannah River, Lum. Corp., 2	314233	815058	55	27
31N005	Long	Humble, J.E. Parker No. 2	314532	815020	58	24
32L002	Long	Humble, Savannah River, Lum. Corp., 4	313607	814144	53	6
32L003	Long	Humble, Savannah River, Lum. Corp., 5	313308	813847	50	11
32L018	Long	Humble, Savannah River, Lum. Corp., 6	313606	814343	47	8
32L019	Long	Humble, Union Bag No. 30	313454	813842	92	38
32M003	Long	Humble, Altam. Land Co. 1	313857	814400	53	53
32M005	Long	Humble, Union Bag No. 23	314235	813739	66	7
32M006	Long	Humble, Union Bag No. 25	314349	814146	25	23
32M010	Long	Humble, Union Bag No. 26	314109	814023	37	37
32M012	Long	Humble, Union Bag No. 28	313921	814141	53	14
32M013	Long	Humble, Union Bag No. 29	313734	814021	45	9
33L003	Long	Humble, Union Bag No. 59	313541	813535	39	22

33M001	Long	Humble, Union Bag No. 5	314100	813156	45	24
33M002	Long	Humble, Union Bag No. 6	314335	813424	43	25
33M005	Long	Humble, Union Bag No. 14	313849	813134	42	16
33M006	Long	Humble, Union Bag No. 22	314003	813703	60	19
33M010	Long	Humble, Union Bag No. 60	313949	813405	33	19
33K020	McIntosh	Humble, Ft. Barrington	312850	813653	40	21
33K021	McIntosh	Humble, Union Bag No. 34	312728	813352	28	35
33K022	McIntosh	Union Bag, Camp Paper No. 54	312849	813118	50	46
33K023	McIntosh	Humble, Union Bag No. 33	312953	813303	73	18
33K025	McIntosh	Humble, Union Bag No. 35	312729	813004	16	47
33K026	McIntosh	Humble, Savannah River	312501	813209	61	29
34K100	McIntosh	Humble, Union Bag No. 37	312718	812316	30	32
34L066	McIntosh	Humble, Union Bag No. 48	303620	812612	14	30
34L070	McIntosh	Union Camp Sapelo Forest	313531	812457	16	24
34M001	McIntosh	Stebbins, C.H.	313814	812342	23	11
35M046	McIntosh	Humble, Union Bag No. 7	313810	812215	39	45
30K017	Wayne	Humble, Bennett 1	312958	815847	47	49
30K018	Wayne	Humble, Davis 1	312533	815901	34	43
30K019	Wayne	Humble, Rodgers 1	312858	815402	44	62
30L016	Wayne	Humble, Jones 1	313700	815345	54	12
30L017	Wayne	Humble, Green 1	313341	815851	52	19
30M004	Wayne	Wayne Co.-Oglethorpe Landing	314316	815409	82	45
31L003	Wayne	Humble, Grantham 1	313630	814948	37	13
31L004	Wayne	Humble, Lee Williamson 1	313518	814646	45	nd
31L005	Wayne	Humble, Union Bag no. 64 1	313317	814652	84	27
31L009	Wayne	Humble, Hopkins Brothers 5	313119	814622	79	18
31L010	Wayne	Humble, Union Bag 106	313128	814812	37	19
32K017	Wayne	Humble, Hopkins Brothers 7	312948	814043	55	35

1/=well not drilled into lower Brunswick aquifer
2/=approximate location
3/=well cased through upper Brunswick aquifer
4/=geophysical log section missing
nd=not detected



Map showing location of wells used in Figures 4 through 12.

Figure 3: Explanation for Figures 4 through 12.

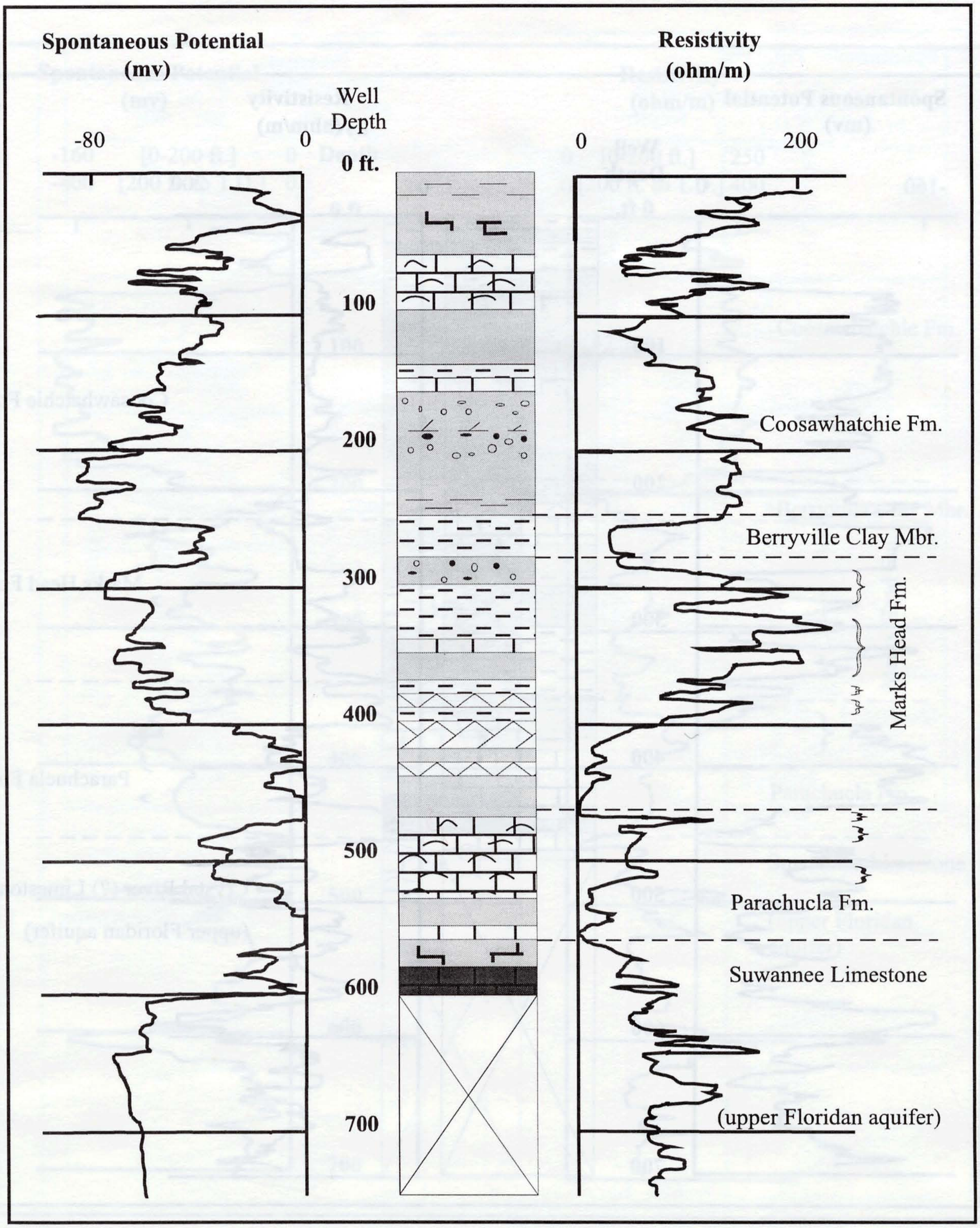


Figure 4: Stratigraphic column and electric logs of well 31H014, Brantley County.

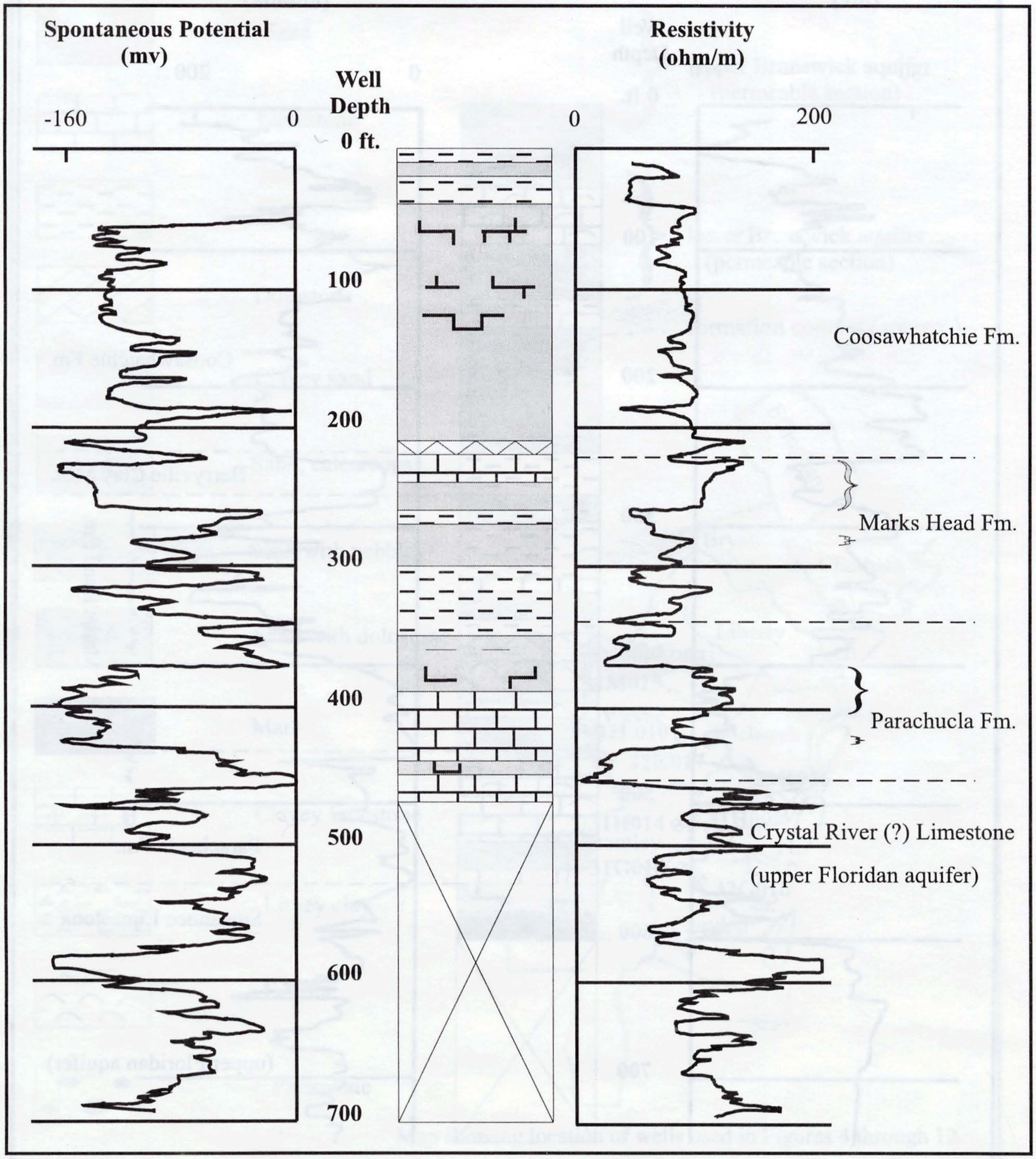


Figure 5: Stratigraphic column and electric logs of well 31G018, Camden County.

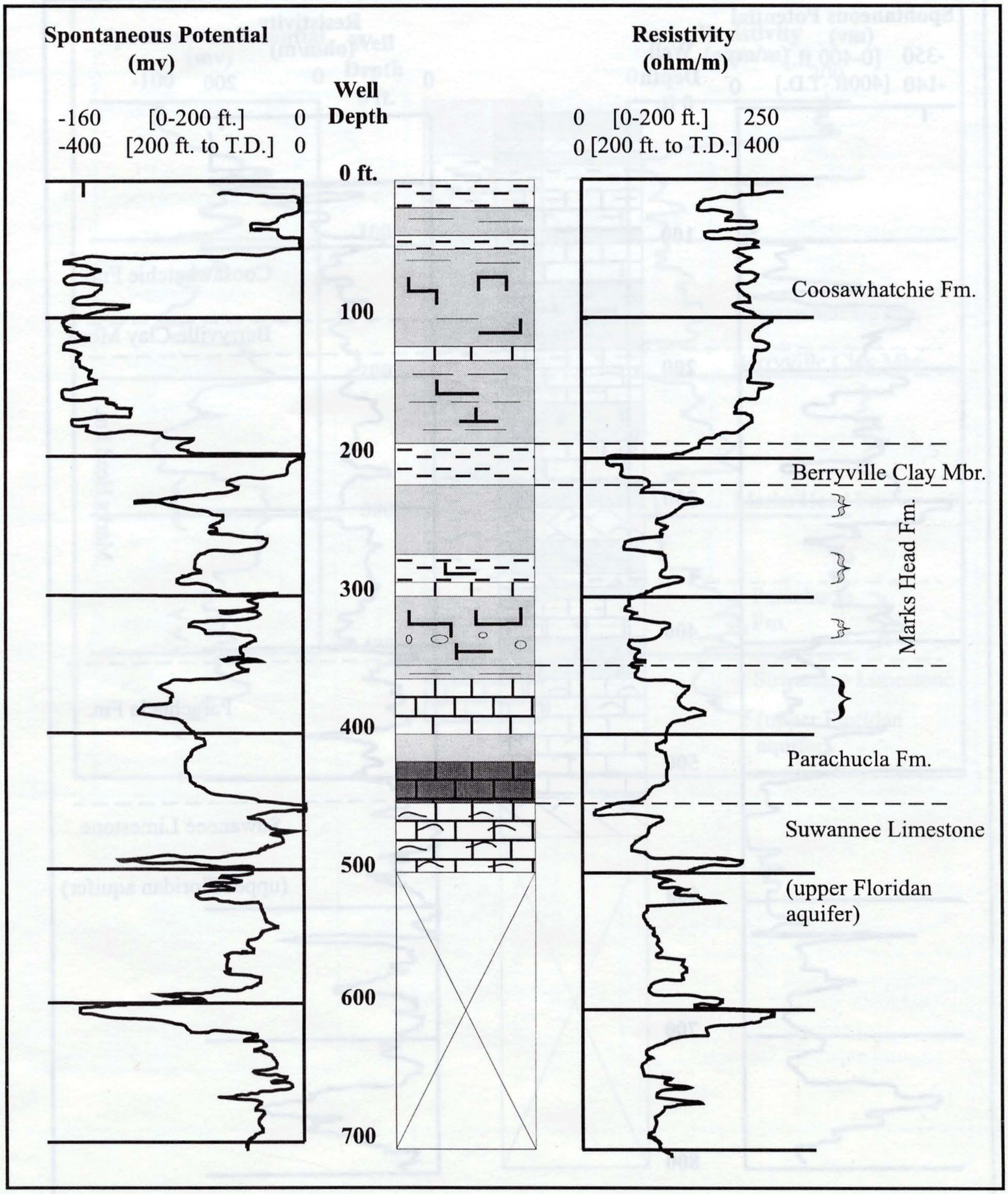


Figure 6: Stratigraphic column and electric logs of well 32G016, Camden County.

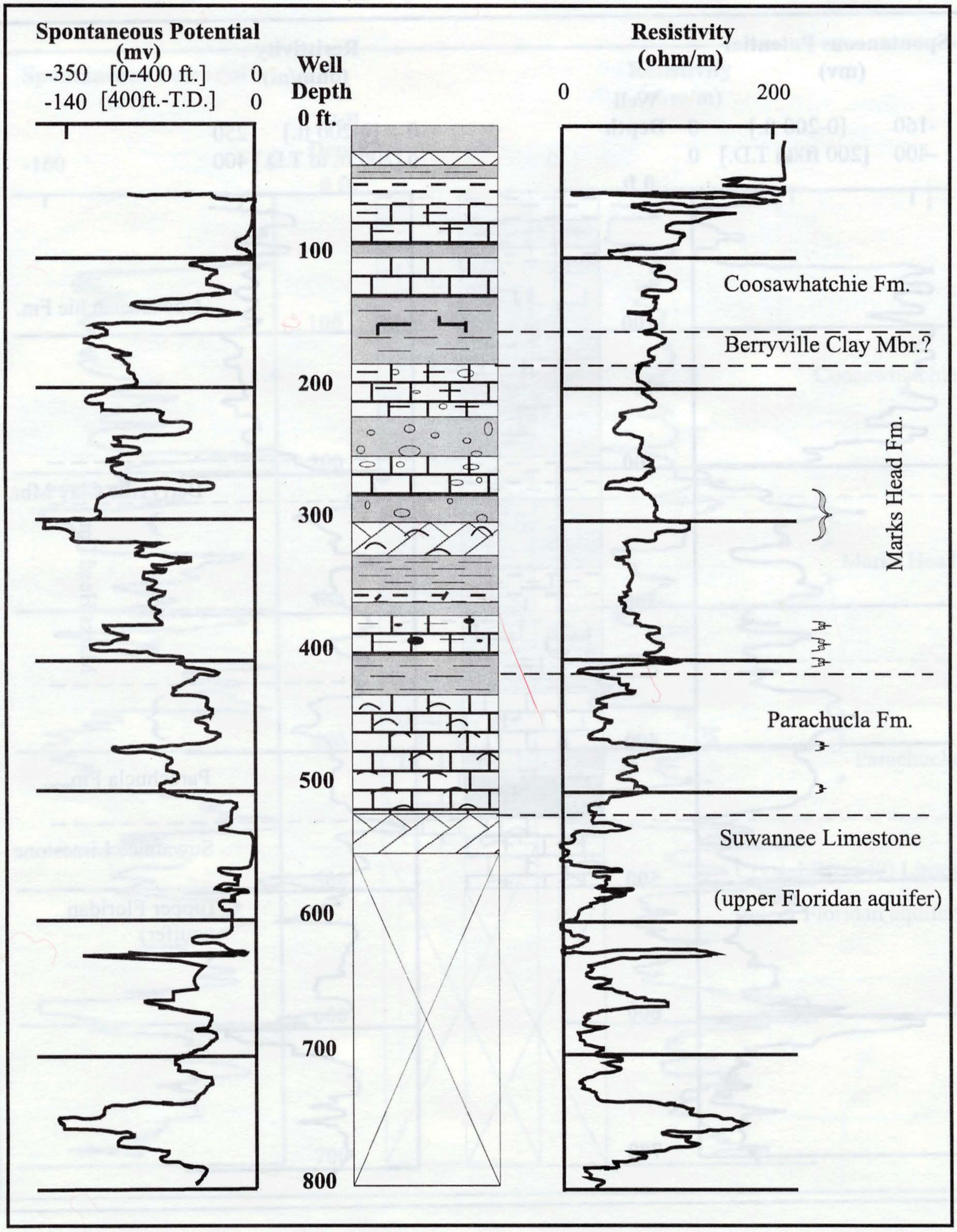


Figure 7: Stratigraphic column and electric logs of well 31H009, Glynn County.

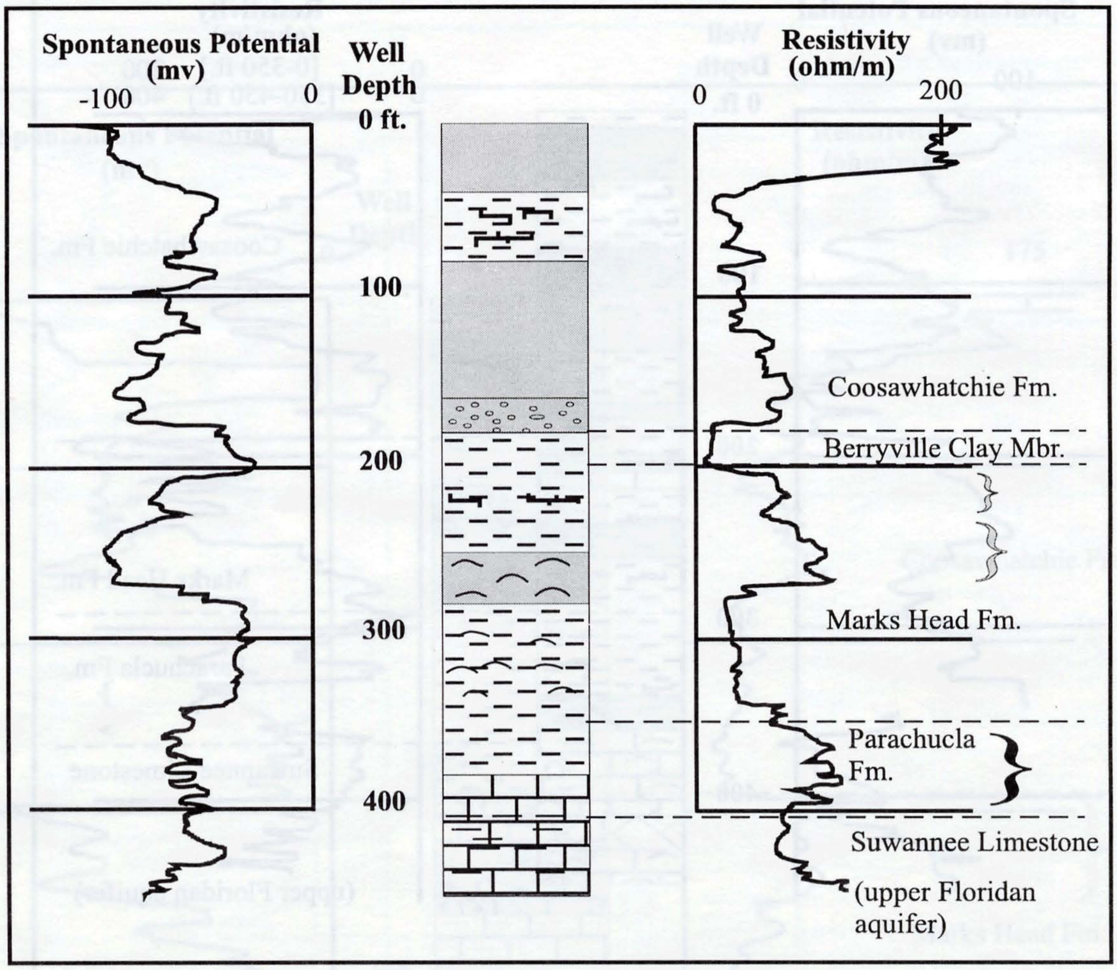


Figure 8: Stratigraphic column and electric logs of well 31M025, Long County.

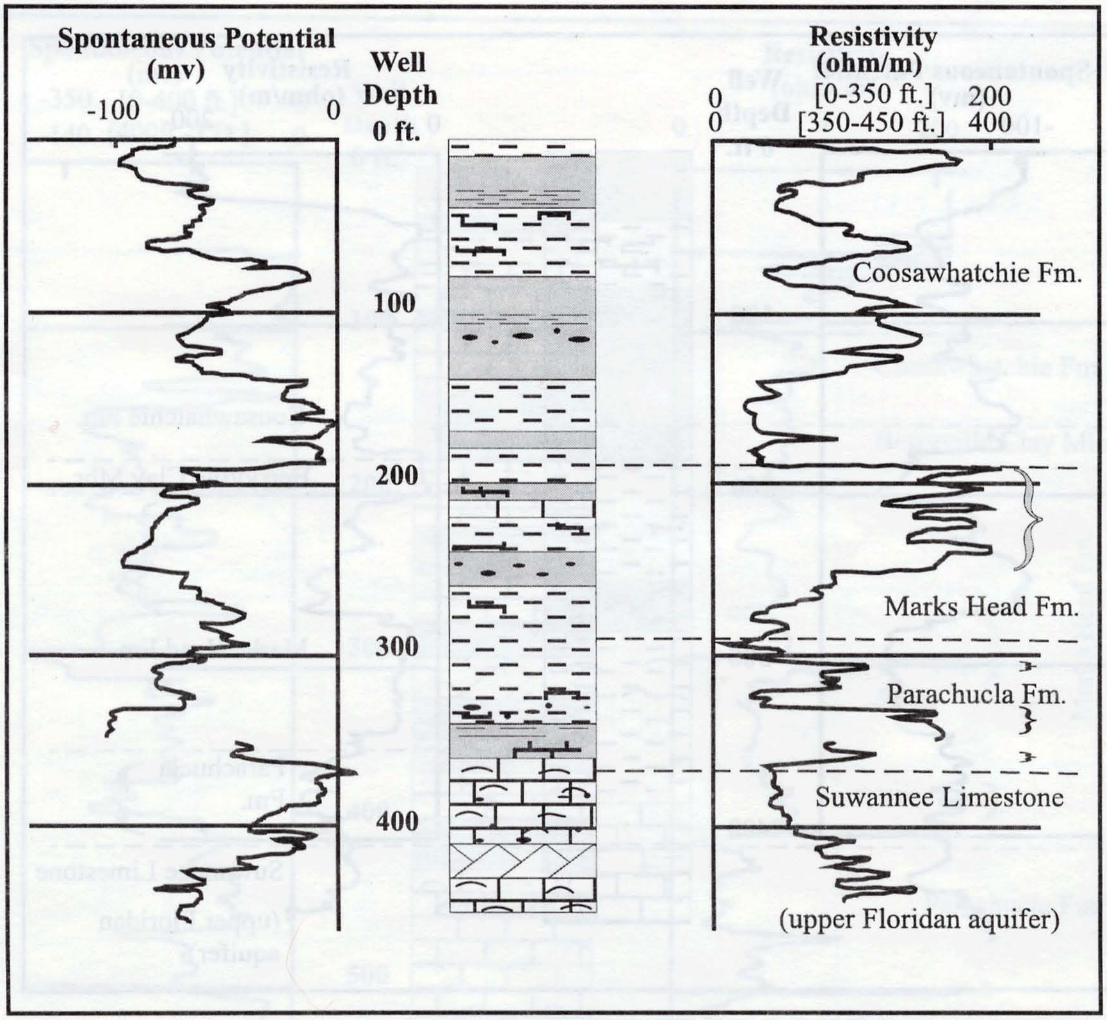


Figure 9: Stratigraphic column and electric logs of well 31N005, Long County.

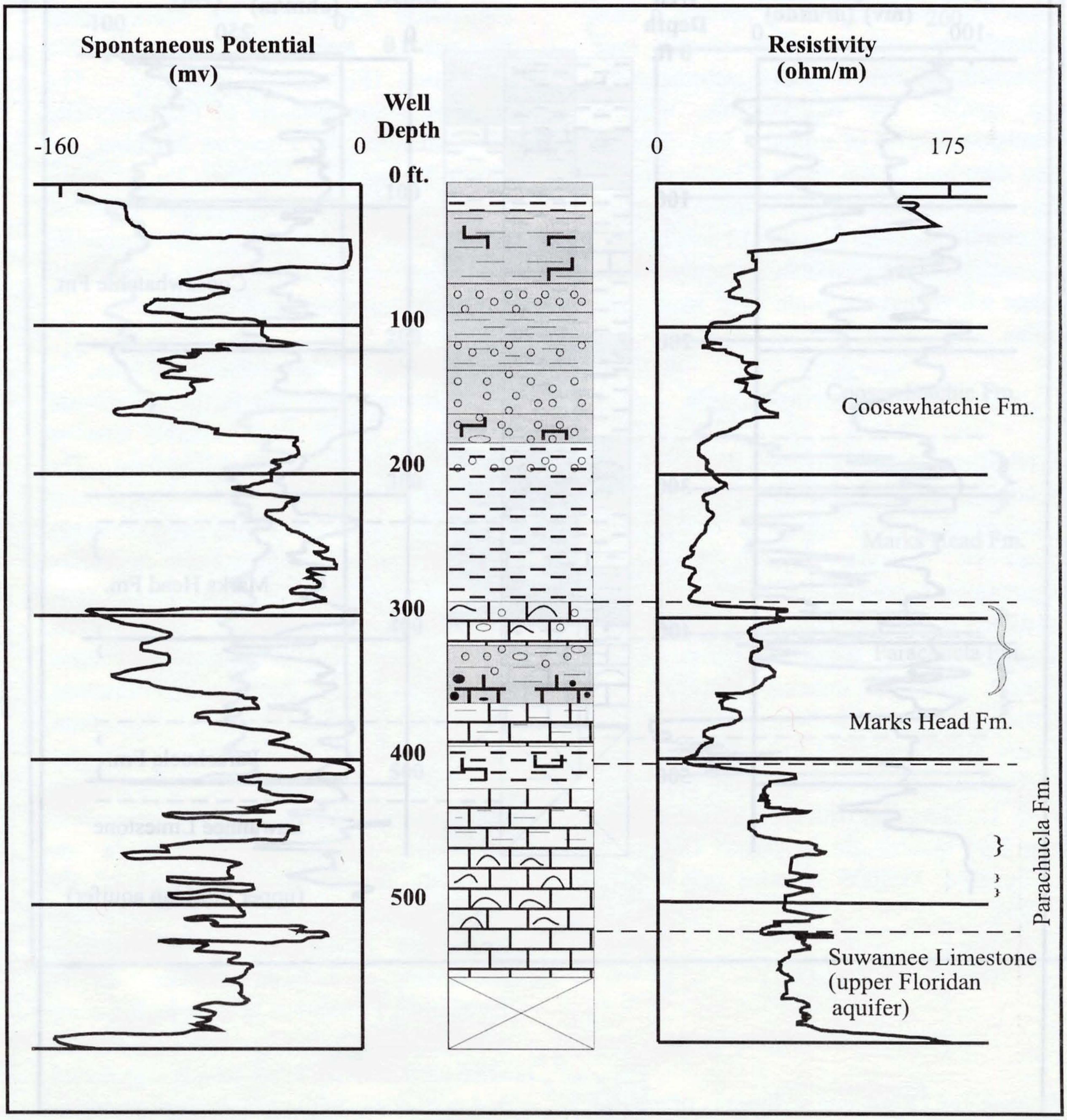


Figure 10: Stratigraphic column and electric logs of well 33K026, McIntosh County.

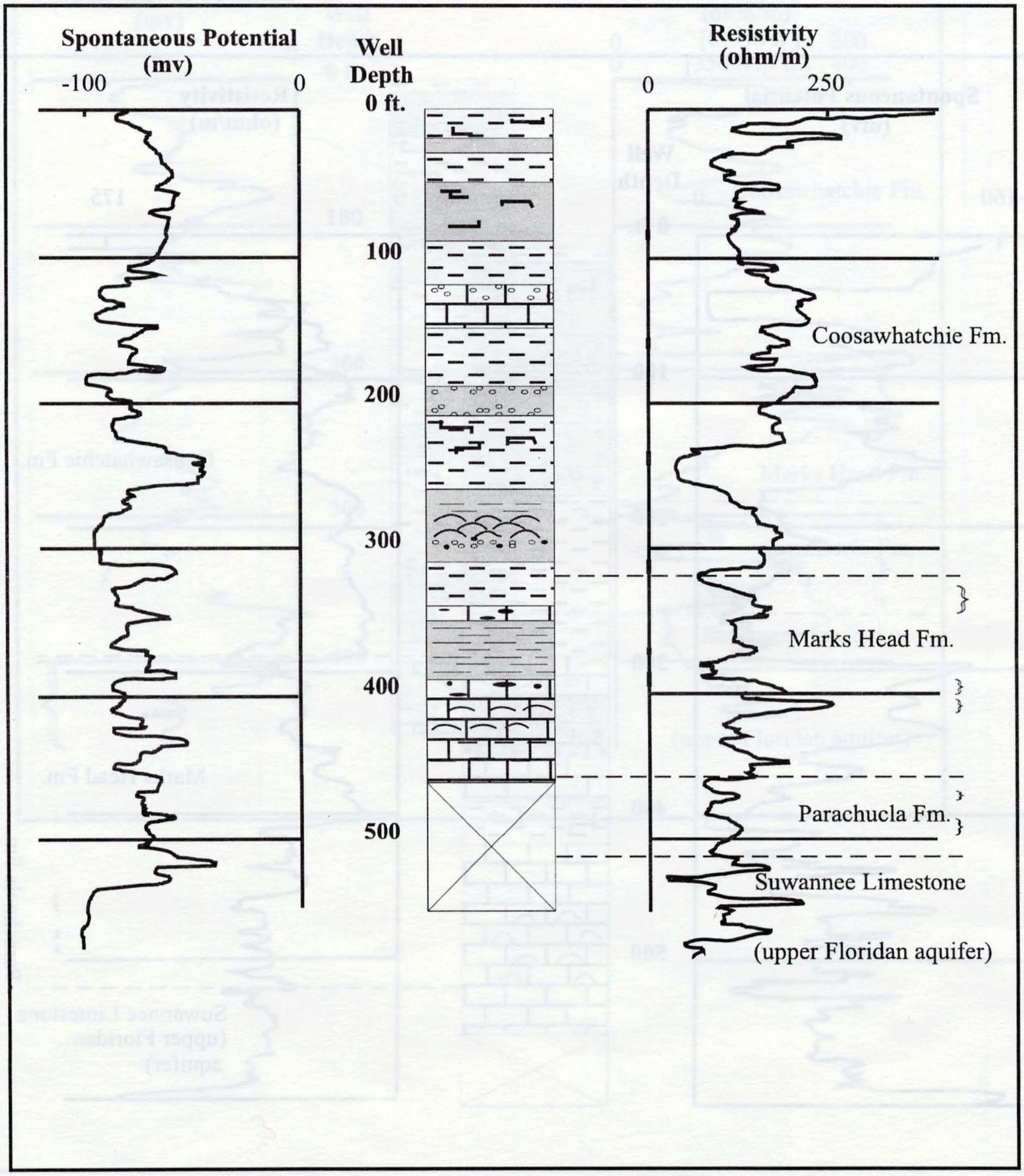


Figure 11: Stratigraphic column and electric logs of well 31L010, Wayne County.

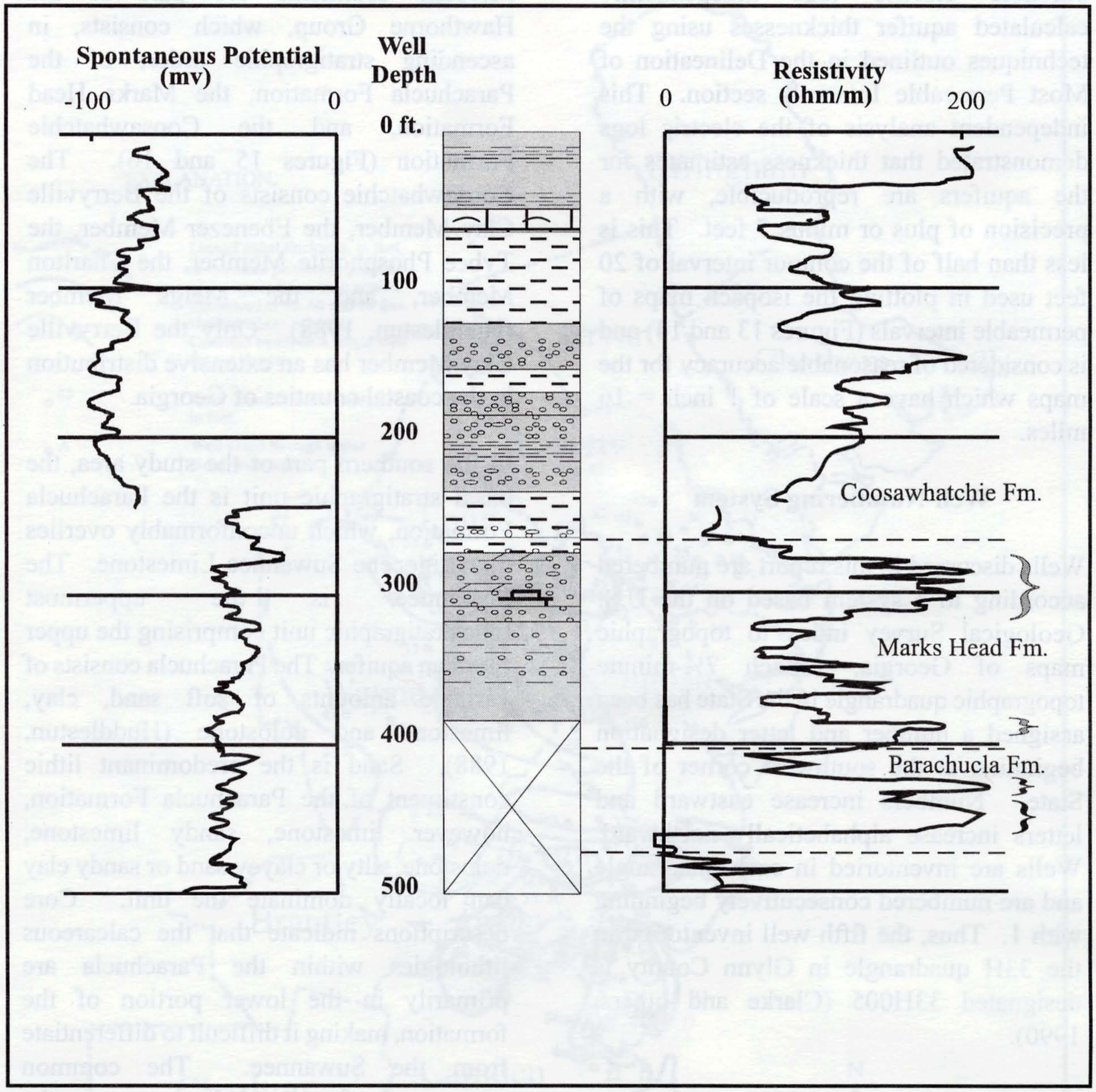


Figure 12: Stratigraphic column and electric logs of well 32K017, Wayne County.

borehole electric logs independently calculated aquifer thicknesses using the techniques outlined in the Delineation of Most Permeable Intervals section. This independent analysis of the electric logs demonstrated that thickness estimates for the aquifers are reproducible, with a precision of plus or minus 7 feet. This is less than half of the contour interval of 20 feet used in plotting the isopach maps of permeable intervals (Figures 13 and 14) and is considered of reasonable accuracy for the maps which have a scale of 1 inch = 16 miles.

Well-Numbering System

Wells discussed in this report are numbered according to a system based on the U.S. Geological Survey index to topographic maps of Georgia. Each 7½-minute topographic quadrangle in the State has been assigned a number and letter designation beginning at the southwest corner of the State. Numbers increase eastward and letters increase alphabetically northward. Wells are inventoried in each quadrangle and are numbered consecutively beginning with 1. Thus, the fifth well inventoried in the 33H quadrangle in Glynn County is designated 33H005 (Clarke and others, 1990).

GEOLOGY

Miocene Stratigraphy

Eocene and Oligocene sediments of coastal Georgia are mostly carbonates, and constitute the Floridan aquifer (Figure 2). Miocene sediments unconformably overlie these units, and are dominantly siliciclastic or mixed clastic and carbonate. The Miocene sediments are part of the Hawthorne Group, which consists, in ascending stratigraphic order, of the Parachucla Formation, the Marks Head Formation, and the Coosawhatchie Formation (Figures 15 and 16). The Coosawhatchie consists of the Berryville Clay Member, the Ebenezer Member, the Tybee Phosphorite Member, the Charlton Member, and the Meigs Member (Huddlestun, 1988). Only the Berryville Clay Member has an extensive distribution in the coastal counties of Georgia.

In the southern part of the study area, the basal stratigraphic unit is the Parachucla Formation, which unconformably overlies the Oligocene Suwannee Limestone. The Suwannee is the uppermost lithostratigraphic unit comprising the upper Floridan aquifer. The Parachucla consists of variable amounts of soft sand, clay, limestone and dolostone (Huddlestun, 1988). Sand is the predominant lithic constituent of the Parachucla Formation, however limestone, sandy limestone, dolostone, silty or clayey sand or sandy clay can locally dominate the unit. Core descriptions indicate that the calcareous lithologies within the Parachucla are primarily in the lower portion of the formation, making it difficult to differentiate from the Suwannee. The common occurrence of a basal limestone in the Parachucla Formation is seen in the study area, particularly in Figures 5, 7, 8, and 10. Shell casts and molds are widely distributed, and may occur in discrete beds or zones.

Overlying the Parachucla is the Marks Head Formation (Figures 15 and 16). The dominant lithology is sand, but the Marks Head is also variably calcareous and

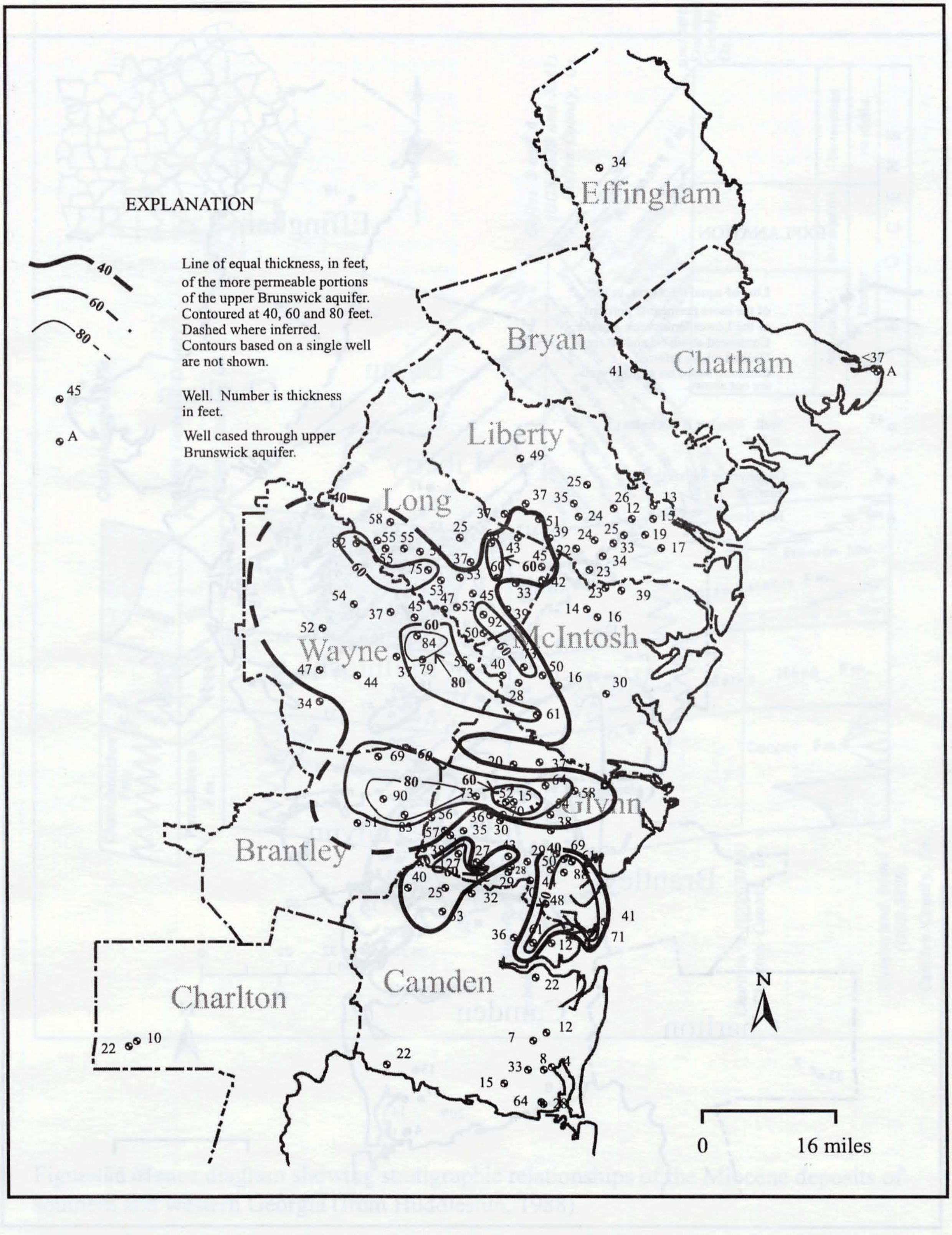


Figure 13: Isopach map of the more permeable portions of the upper Brunswick aquifer.

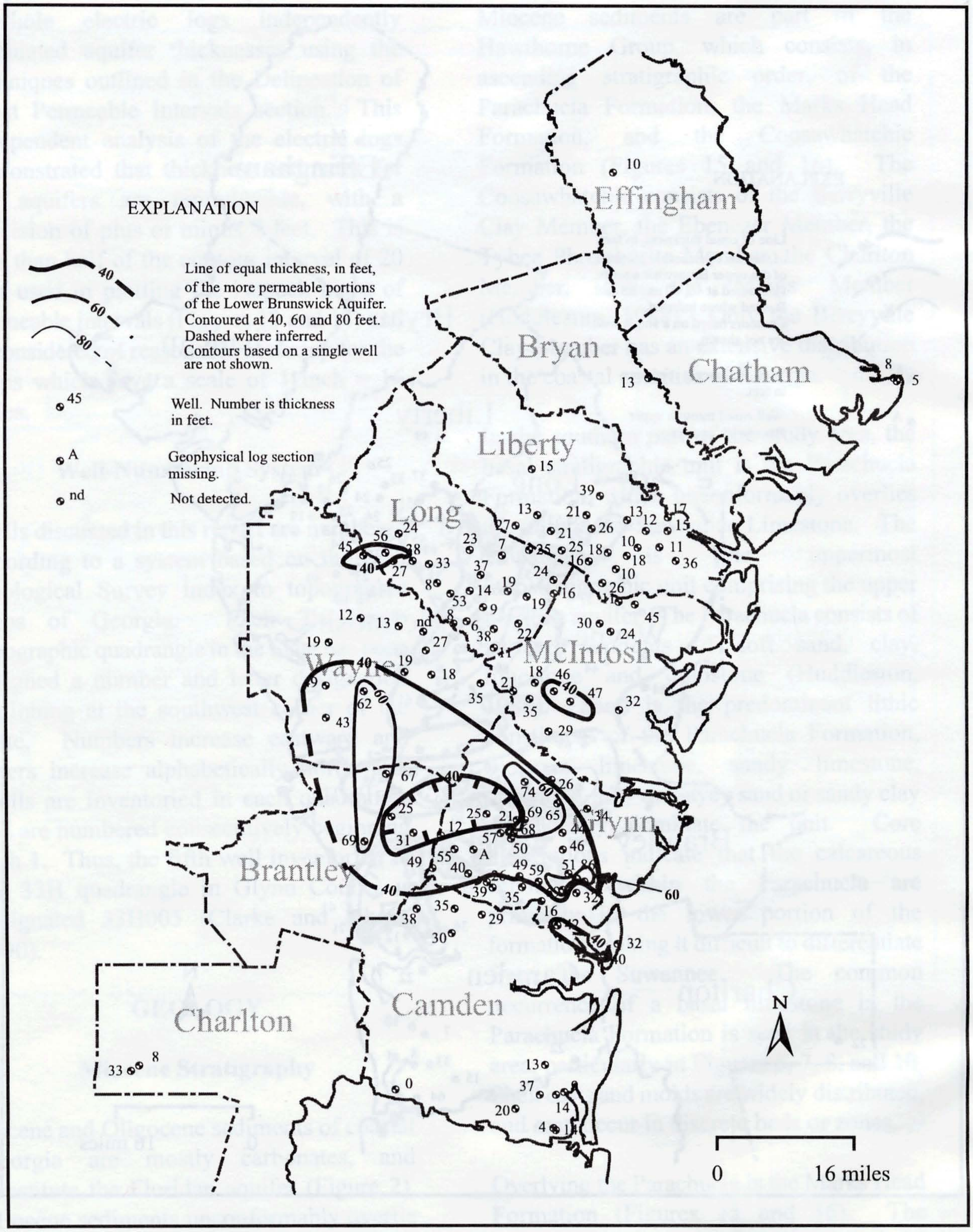


Figure 14: Isopach map of the more permeable portions of the lower Brunswick aquifer.

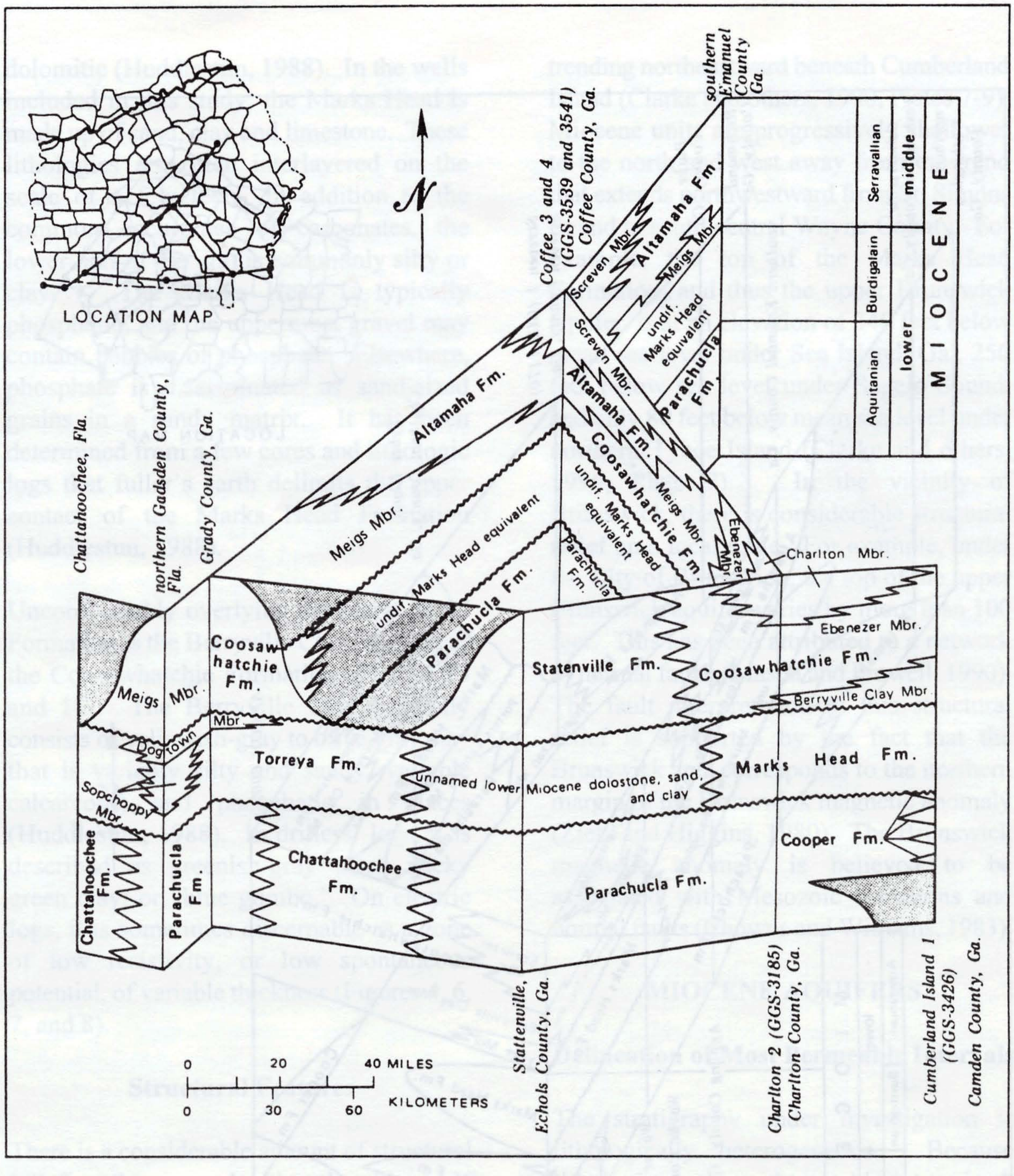


Figure 15: Fence diagram showing stratigraphic relationships of the Miocene deposits of southern and western Georgia (from Huddlestun, 1988).

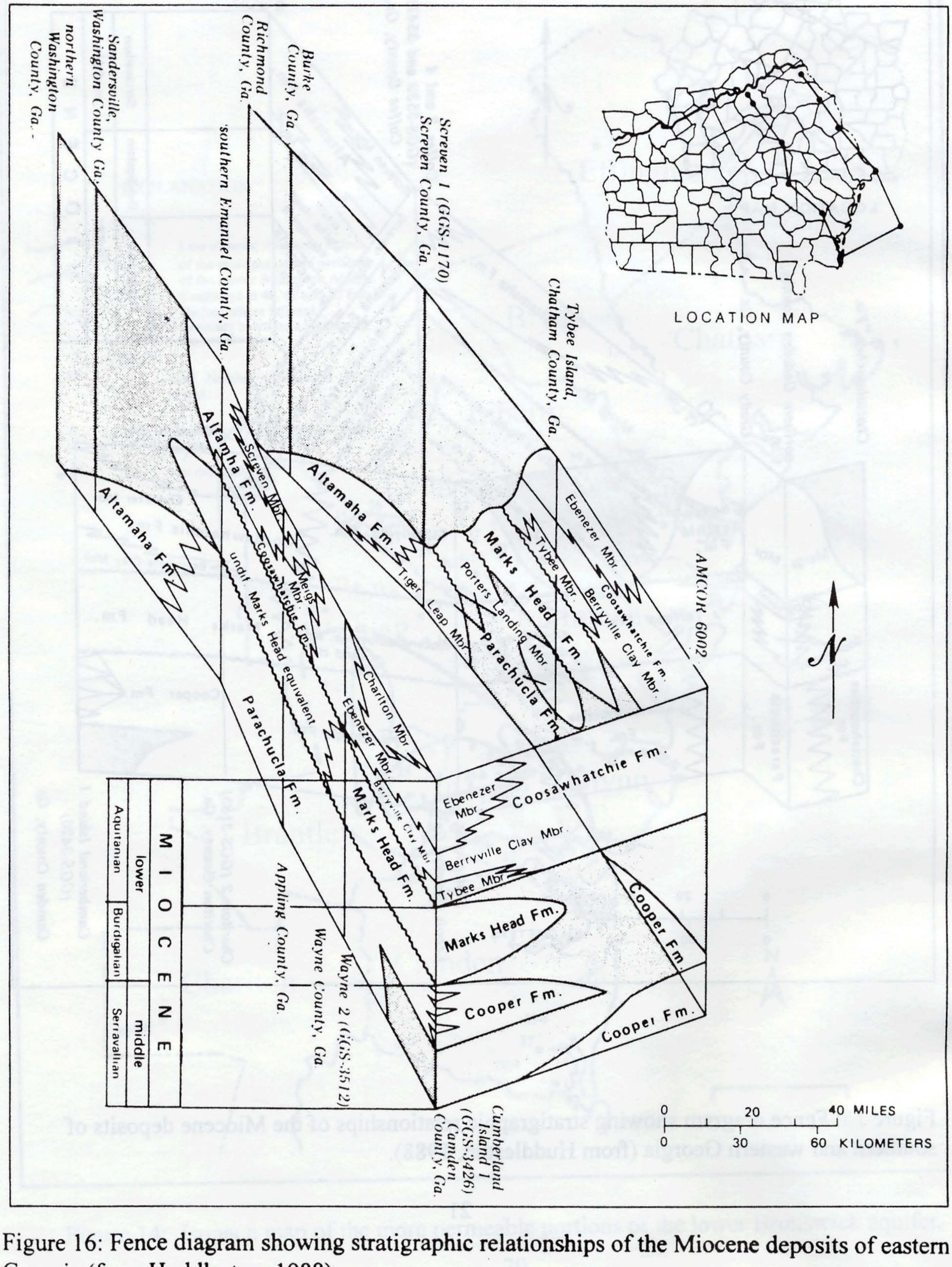


Figure 16: Fence diagram showing stratigraphic relationships of the Miocene deposits of eastern Georgia (from Huddlestun, 1988).

dolomitic (Huddlestun, 1988). In the wells included in this study, the Marks Head is made up of sand, clay and limestone. These lithologies are often interlayered on the scale of a few feet. In addition to the common occurrence of carbonates, the lower half of the unit is commonly silty or clayey. The Marks Head is typically phosphatic, and the uppermost gravel may contain pebbles of phosphate. Elsewhere, phosphate is disseminated as sand-sized grains in a sandy matrix. It has been determined from a few cores and lithologic logs that fuller's earth delimits the upper contact of the Marks Head Formation (Huddlestun, 1988).

Unconformably overlying the Marks Head Formation is the Berryville Clay Member of the Coosawhatchie Formation (Figures 15 and 16). The Berryville Clay generally consists of yellowish-gray to olive-gray clay that is variably silty and sandy, variable calcareous, and phosphatic in places (Huddlestun, 1988). In drillers' logs, it is described as greenish-gray marl, sticky green clay, or "blue gumbo." On electric logs, it is sometimes discernable as a zone of low resistivity, or low spontaneous potential, of variable thickness (Figures 4, 6, 7, and 8).

Structural Features

There is a considerable amount of structural relief on the maps showing the altitude of the markers that frame the Brunswick aquifers (Clarke and others, 1990, Plates 7-9). All the Miocene units discussed here are generally deepest along a broad trend extending northwestward from St. Simons Sound to south-central Wayne County (Watson, 1979). There is also a deep zone trending northeastward beneath Cumberland Island (Clarke and others, 1990, Plates 7-9). Miocene units are progressively shallower to the north and west away from the trend that extends northwestward from St. Simons Sound to south-central Wayne County. For example, the top of the Marks Head Formation, and thus the upper Brunswick aquifer, is at an elevation of 340 feet below mean sea level under Sea Island, Ga., 250 feet below sea level under Sapelo Sound, and only 80 feet below mean sea level under northern Tybee Island (Clarke and others, 1990, Plate 7). In the vicinity of Brunswick, there is considerable structural relief on a local scale. For example, under the City of Brunswick, the top of the upper Brunswick aquifer varies by more than 100 feet. This has been attributed to a network of normal faults (Maslia and Prowell, 1990). The fault interpretation of this structural relief is supported by the fact that the Brunswick area corresponds to the northern margin of the Brunswick magnetic anomaly (Zietz and Higgins, 1980). The Brunswick magnetic anomaly is believed to be associated with Mesozoic intrusions and normal faults (Chowns and Williams, 1983).

MIOCENE AQUIFERS

Delineation of Most Permeable Intervals

The stratigraphy under investigation is lithologically heterogeneous. Because lithologies were so thoroughly intermixed, natural gamma logs were ineffective for distinguishing individual lithologies. However, gamma logs were critical in locating the stratigraphic position of the upper and lower Brunswick aquifers in any given area. In the Miocene units of coastal Georgia, there are three markers that are prominent on natural gamma logs. These are called, from bottom to top, markers C, B, and A (Figure 2). They represent highly phosphatic layers in which uranium has been incorporated into the crystal lattice of the phosphate minerals (Clarke and others, 1990). The lowest marker, 'C', approximates the base of the Miocene-age sediments and the top of the Floridan aquifer. Marker 'B' is near the top of the Parachucla Formation and the base of the Marks Head Formation, and marker 'A' is near the top of the Marks Head Formation. The upper Brunswick aquifer occurs within the Marks Head Formation; therefore, marker 'A' represents the approximate top of the upper Brunswick aquifer. For well data that did not include gamma logs, Plates 4, 5, 7, 8 and 9 of Clarke and others (1990), which are cross sections and maps that show the elevations of the three marker horizons, were used to estimate the depths of the three marker horizons. The depths of the markers were projected onto the electric logs or lithologic logs, and the permeable thicknesses of the aquifer units were estimated. Such estimates of the position of the marker horizons were required for 90 wells. In general, the precision of aquifer boundaries is greater for wells with both electric and gamma logs than for wells with only electric logs.

Clarke and others (1990) used gamma logs to delineate the total thicknesses of the upper and lower Brunswick aquifers. This study uses electric logs (spontaneous potential (SP) and resistivity) along with gamma logs to estimate the most permeable thicknesses of these aquifers.

SP logs generally appear on the left side of an electric log chart and resistivity logs on the right, as shown on Figures 17 and 18. SP logs measure direct current voltage differences between an electrode in the well bore and an electrode at the surface. Voltage differences are largely a result of differences in salinities of borehole drilling mud and naturally occurring formation water. If the borehole fluid is fresher than the formation water, a negative (leftward) SP deflection occurs opposite sand beds (Keys, 1988). For this reason, SP logs can be used to identify permeable and impermeable zones. For permeable zones, salinity differences are greater for a water-saturated sand than for a clay or shale, and a sand will tend to create a greater SP deflection than a clay or shale. A clean sand will create a larger deflection than a clayey sand. This is because drilling mud will penetrate further into a more permeable sand than into a clay or clayey sand.

Resistivity logs graphically represent the ability of a formation to transmit an electric current. Such transmission is usually a function of the fluid in the formation pores and the degree to which the formation has been penetrated by drilling muds. Such penetration is a function of the permeability of the sediment. Therefore, a fresh-water-bearing formation will usually generate a stronger resistivity curve deflection than a tight, impermeable unit. An exception to this response is dense rocks such as granites or dense dolostones which are highly resistive and of very low permeability. Most of the resistivity logs used in this study were single-point resistance logs. A few, from more recently drilled wells were 16-64 inch normal resistivity logs (Chatham Co., well 39Q024; Glynn Co., well 33G027; Glynn Co. Well 34J076, for example). For the water-bearing, Miocene-age sediments

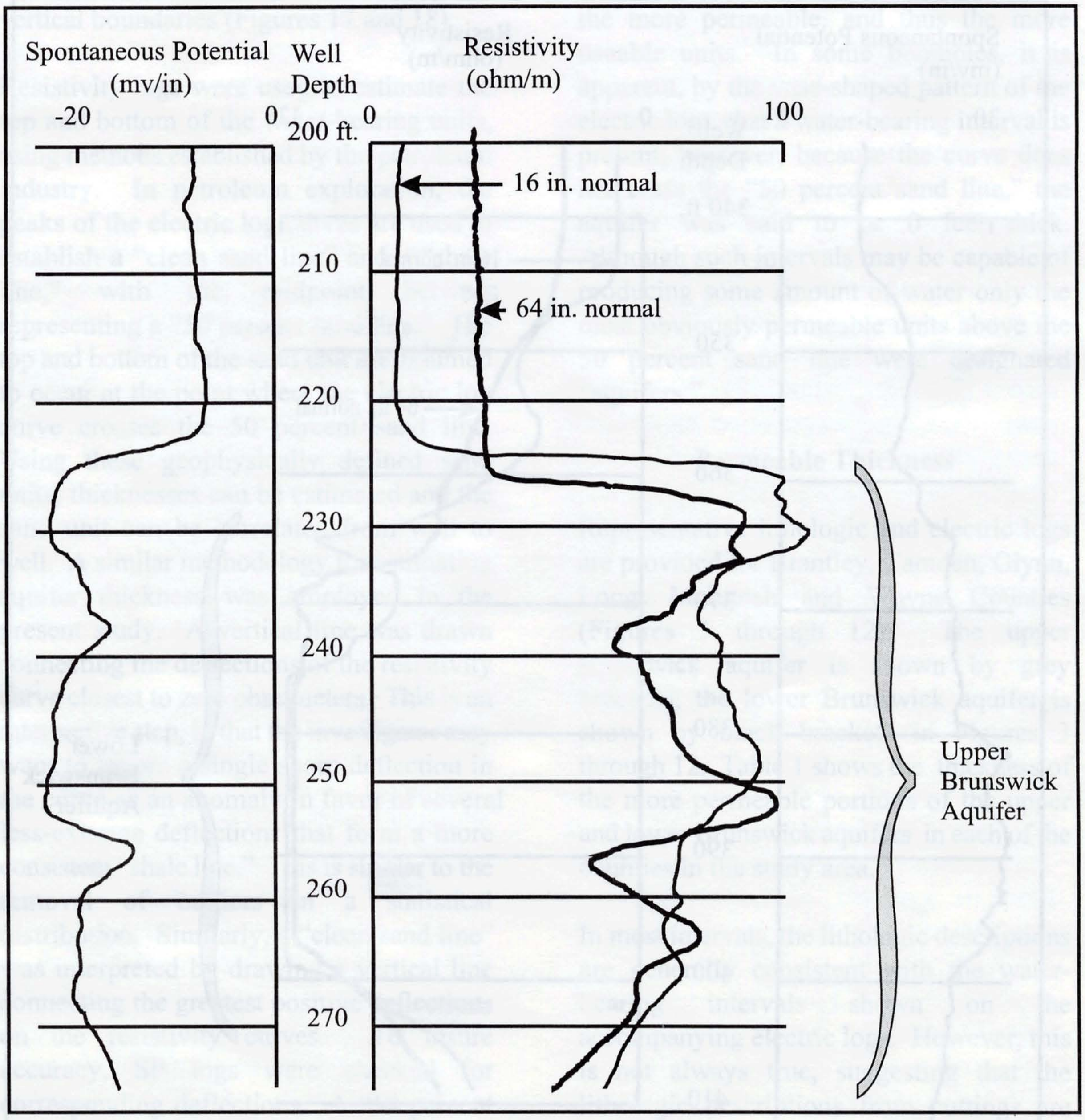


Figure 17: Electric log signature of the upper Brunswick aquifer from well 33G027, Colonels Island, Glynn Co.

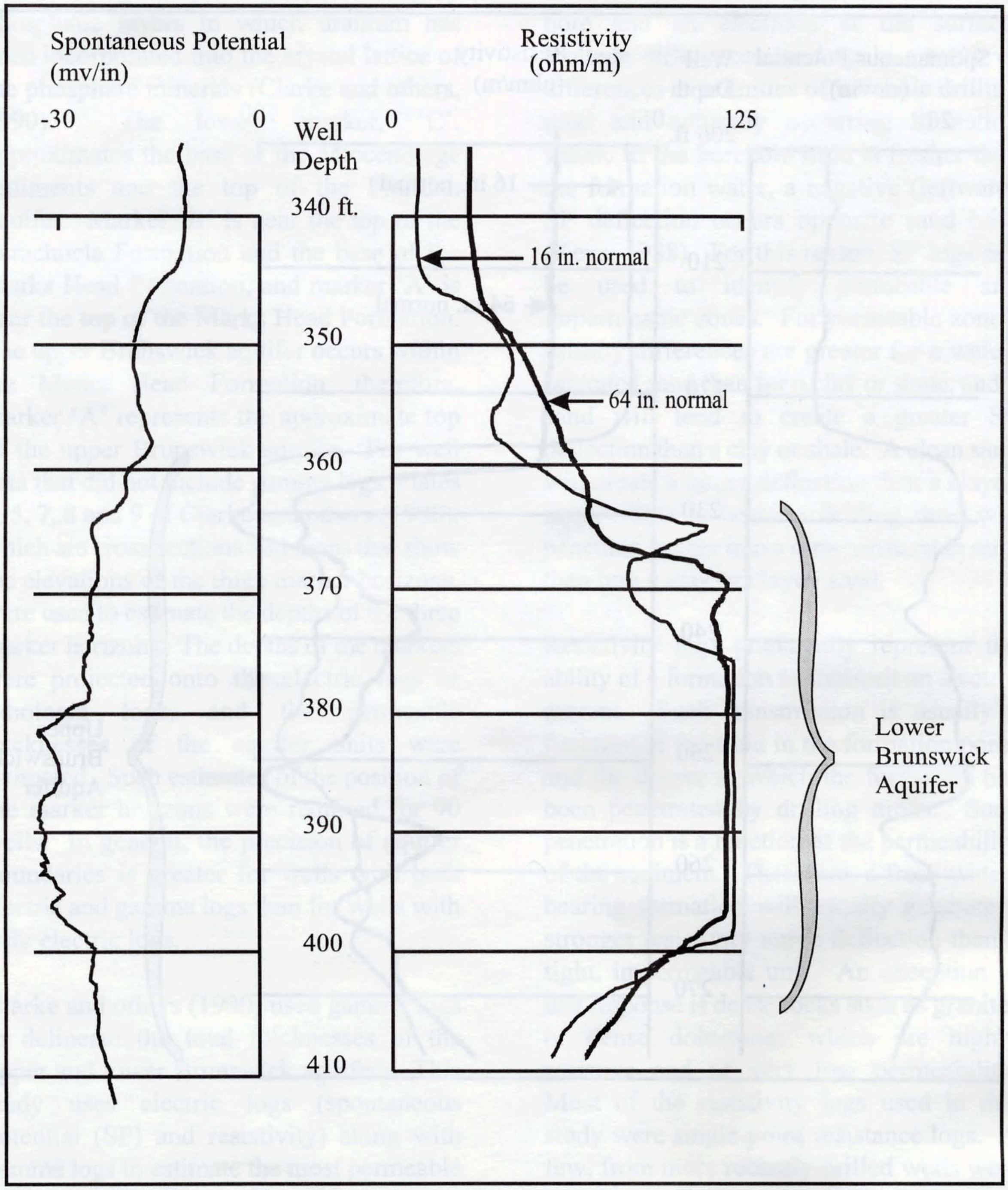


Figure 18: Electric log signature of the lower Brunswick aquifer from well 33G027, Colonels Island, Glynn Co.

of coastal Georgia, the pairing of SP logs and resistivity logs creates a vase-shaped pattern that delineates the aquifers and their vertical boundaries (Figures 17 and 18).

Resistivity logs were used to estimate the top and bottom of the water-bearing units, using methods established by the petroleum industry. In petroleum exploration, the peaks of the electric log curves are used to establish a "clean sand line" and a "shale line," with the midpoint between representing a "50 percent sand line." The top and bottom of the sand unit are assumed to occur at the point where the electric log curve crosses the 50 percent sand line. Using these geophysically defined sand units, thicknesses can be estimated and the sand unit can be correlated from well to well. A similar methodology for estimating aquifer thickness was employed in the present study. A vertical line was drawn connecting the deflections of the resistivity curve closest to zero ohm meters. This is an interpretive step, in that the investigator may want to ignore a single sharp deflection in the curve as an anomaly in favor of several less-extreme deflections that form a more consistent "shale line." This is similar to the removal of outliers in a statistical distribution. Similarly, a "clean sand line" was interpreted by drawing a vertical line connecting the greatest positive deflections on the resistivity curves. To insure accuracy, SP logs were checked for corresponding deflections. A "50 percent sand line" is defined as lying half way between the "shale line" and the "clean sand line" on the resistivity log curves. The thickness of each water-bearing interval was interpreted as the interval in which the resistivity curve lies above the 50 percent sand line. It is important to note that this operational definition does not reflect the total thickness of water-bearing units in the Miocene section, but rather the thickness of the more permeable, and thus the more useable units. In some boreholes, it is apparent, by the vase-shaped pattern of the electric logs, that a water-bearing interval is present; however, because the curve does not cross the "50 percent sand line," the aquifer was said to be 0 feet thick. Although such intervals may be capable of producing some amount of water only the most obviously permeable units above the 50 percent sand line were designated "aquifers."

Permeable Thickness

Representative lithologic and electric logs are provided for Brantley, Camden, Glynn, Long, McIntosh and Wayne Counties (Figures 3 through 12). The upper Brunswick aquifer is shown by grey brackets; the lower Brunswick aquifer is shown by black brackets in Figures 3 through 12. Table 1 shows the thickness of the more permeable portions of the upper and lower Brunswick aquifers in each of the counties in the study area.

In most intervals, the lithologic descriptions are generally consistent with the water-bearing intervals shown on the accompanying electric logs. However, this is not always true, suggesting that the lithologic descriptions from cuttings are imprecise, or that the clayey intervals have secondary permeability (i.e., fractures). Because electric logs are strongly affected by the formation permeability, it seems more likely that the lithologic logs from cuttings are not particularly accurate in defining the aquifer. This inaccuracy may be the result of sandy zones being missed when well cuttings are sampled. Elsewhere, a thick sand interval may not necessarily contain a thick water-bearing zone. This is especially apparent in Charlton County and southern Camden County, where thick sandy intervals may be cemented by clay and are therefore of low permeability.

The type locality for the Brunswick aquifers is beneath the Brunswick Pulp and Paper Co. USGS well cluster site (well 33H207) in Glynn County. The upper and lower Brunswick aquifer was delineated and named by Clarke and others (1990). These zones were also encountered beneath the Georgia Ports Authority facility on Colonels Island (well 33G027), also in Glynn County. These zones were designated "upper Hawthorn aquifer" and "basal Miocene aquifer" in a report by Soil and Material Engineers (1986). In the Glynn County area, the upper and lower Brunswick aquifers are conspicuous on electric logs as shown on Figures 17 and 18.

A generalized cross section of the Brunswick aquifers is shown in Figure 19. The increase in thickness near the Altamaha River is apparent, as is the northward thinning of the host rocks containing the aquifers.

Upper Brunswick Aquifer

Correlation of electric logs with gamma logs indicates that the upper Brunswick aquifer is directly underneath marker horizon 'A'. Lithologic logs show that the upper Brunswick is composed of sand, gravel, and sandy carbonate beds of the Marks Head Formation. The correlation of the uppermost permeable zone with marker horizon 'A' probably is the result of a layer of phosphatic gravel at the top of the Marks Head.

The upper Brunswick aquifer is confined above by the Berryville Clay. It is confined below by clayey or silty layers in the lower Marks Head or by the underlying Parachucla Formation.

In the southern part of the study area, the Marks Head is very coarse grained, and easily identifiable on most well logs (Figures 4 through 7 and 12). However, north of the Altamaha River, the Marks Head becomes progressively finer grained, and is almost entirely sandy silt or clay beneath Chatham and Effingham Counties (Huddlestun, 1988). As a result, the upper Brunswick aquifer tends to become progressively thinner north of the Altamaha River. It is best-defined underneath the Brunswick area. The upper Brunswick aquifer also thins to the south of the Brunswick area. In Camden and Charlton Counties, the upper Brunswick aquifer is thin but clearly identifiable on electric logs.

The most areally extensive occurrence of a thick sequence of the upper Brunswick aquifer occurs in Brantley, western Camden, Glynn, Long and western McIntosh and Wayne Counties (Figure 13). This isopach axis corresponds to the St. Simons Sound-Wayne County structural trend. The axis of this thick sequence of the upper Brunswick also generally coincides with the Altamaha River and may represent an ancestral Altamaha Miocene-aged delta. North of a line corresponding to the Satilla River, the permeable portions of the upper Brunswick aquifer thickens to greater than 40 feet and achieves a thickness of over 80 feet in

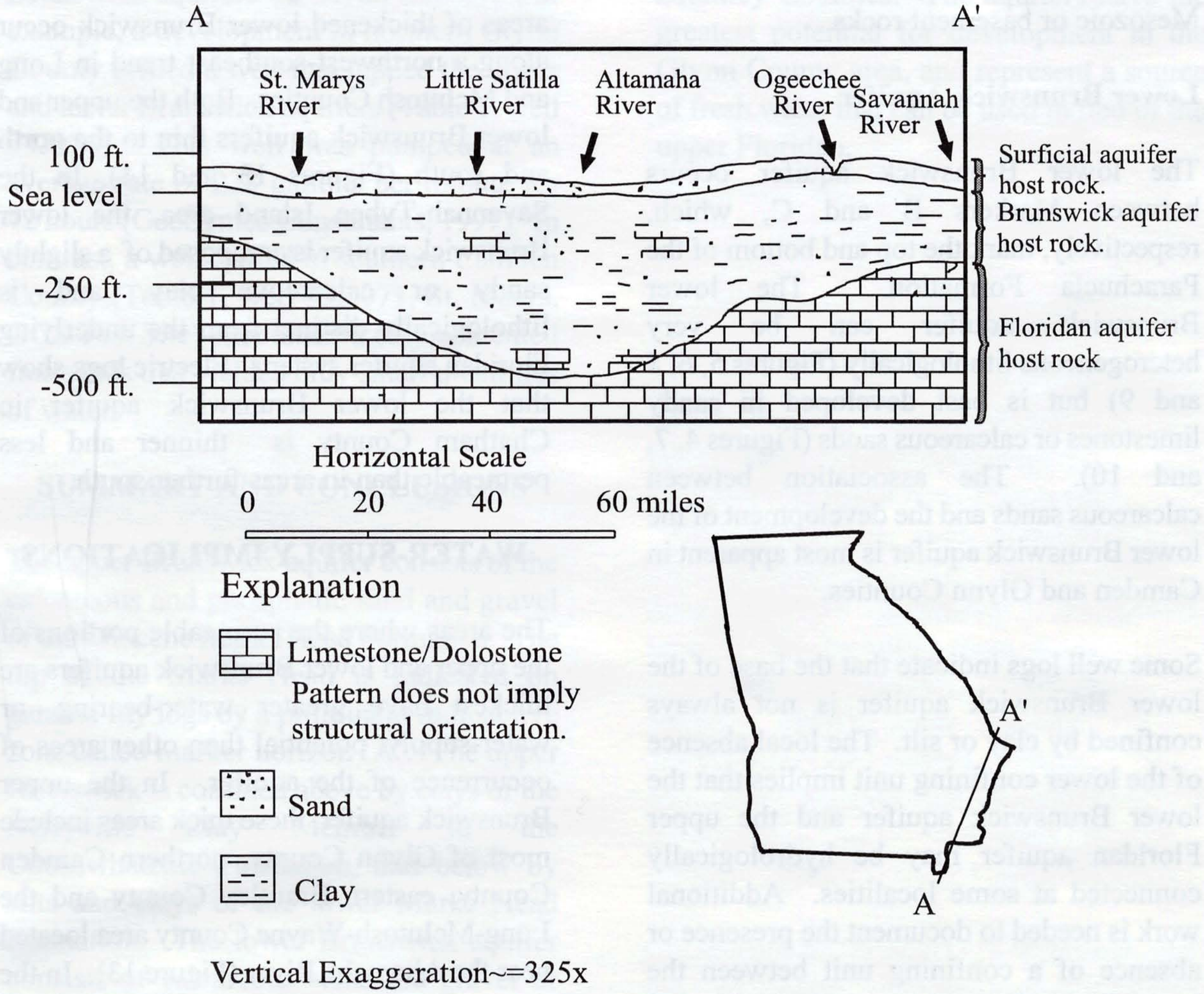


Figure 19: Generalized cross section showing stratigraphic relationship of shallow aquifers and the Floridan aquifer (modified from Watson, 1979). Depositional dips are not shown.

southeastern Glynn County. This thickening of the upper Brunswick aquifer corresponds to an increase in transmissivities in the Floridan aquifer and changes in other geologic and geophysical parameters. This line has been referred to as the "Satilla Line" (McLemore, oral communication, 1995; EPD, 1996). The origin of the Satilla Line remains uncertain, but the line may reflect structural features in Mesozoic or basement rocks.

Lower Brunswick Aquifer

The lower Brunswick aquifer occurs between Markers B and C, which, respectively, mark the top and bottom of the Parachucla Formation. The lower Brunswick aquifer can be very heterogeneous lithologically (Figures 5, 6, 8 and 9) but is best developed in sandy limestones or calcareous sands (Figures 4, 7, and 10). The association between calcareous sands and the development of the lower Brunswick aquifer is most apparent in Camden and Glynn Counties.

Some well logs indicate that the base of the lower Brunswick aquifer is not always confined by clay or silt. The local absence of the lower confining unit implies that the lower Brunswick aquifer and the upper Floridan aquifer may be hydrologically connected at some localities. Additional work is needed to document the presence or absence of a confining unit between the lower Brunswick and upper Floridan.

The geographic distribution of the lower Brunswick aquifer is similar to that of the upper Brunswick aquifer. A thick sequence of the more permeable portions of the lower Brunswick aquifer lies beneath the central Brantley, Glynn and Wayne county area (Figure 14). This also generally corresponds to an area of thickening of the upper Brunswick aquifer. The most permeable portion of the lower Brunswick is thickest in central Glynn County (Figure 14). The thickening of the upper and lower Brunswick aquifers may be related to the faulting thought to occur in this area or to paleo-Altamaha deposition. Two small areas of thickened lower Brunswick occur along a northwest-southeast trend in Long and McIntosh Counties. Both the upper and lower Brunswick aquifers thin to the north and south (Figures 13 and 14). In the Savannah-Tybee Island area, the lower Brunswick aquifer is composed of a slightly sandy or calcareous clay, and is lithologically distinct from the underlying Floridan aquifer system. Electric logs show that the lower Brunswick aquifer in Chatham County is thinner and less permeable than in areas further south.

WATER-SUPPLY IMPLICATIONS

The areas where the permeable portions of the upper and lower Brunswick aquifers are thickest have greater water-bearing, or water-supply, potential than other areas of occurrence of the aquifer. In the upper Brunswick aquifer, these thick areas include most of Glynn County, northern Camden County, eastern Brantley County and the Long-McIntosh-Wayne County area located near the Altamaha River (Figure 13). In the lower Brunswick aquifer, the thicker permeable units occur in central Glynn County, northern Brantley-southern Wayne County, and a northwest-southeast trend near the Altamaha River, from Long to McIntosh County (Figure 14). The areas of greater permeable thicknesses described above have the potential to supply larger volumes of water. Glynn County may have the greatest potential for development of the upper and lower Brunswick aquifers because of thicker permeable units and economic growth in the Brunswick area. Several developments are currently in the process of constructing water-supply test wells that tap the upper and lower Brunswick aquifers in Glynn County. For example, a development in northern Glynn County drilled a well that tapped the upper and lower Brunswick aquifers (Table 1, well 34J076). This well was pumped at an average rate of 238 gallons per minute for 72 hours (GeoSyntec Consultants, 1997). In contrast, a well drilled in southern Camden County (Table 1, well 33D071, St. Marys, GGS Test Site) encountered clay-cemented fine sands that yielded only small quantities of water.

SUMMARY AND CONCLUSIONS

The upper Brunswick aquifer consists of the calcareous and phosphatic sand and gravel of the Miocene Marks Head Formation. The top of the Marks Head is indicated on gamma-ray logs by a prominent radioactive zone called marker horizon 'A'. The upper Brunswick is confined above by clays of the Berryville Clay Member of the Coosawhatchie Formation, and below by silts and clays of the lower Marks Head Formation. The lower Brunswick aquifer consists of calcareous sand and gravel or sandy and gravelly limestone of the Miocene Parachucla Formation. The lower Brunswick exists between marker horizons 'B' and 'C', and is commonly, but not everywhere, hydrologically separated from the underlying carbonates of the Floridan aquifer system by silt and clay or calcareous silt. The Brunswick aquifers can be clearly delineated on electric logs as zones of low spontaneous potential and high resistivity. Application of the oil-industry techniques of defining clean sand and shale lines was used to interpret the thickness of the permeable intervals of the aquifers. Both aquifers are best developed in the central part of the study area under Glynn, Wayne, Long, and Brantley Counties. The aquifers have the greatest potential for development in the Glynn County area, and represent a source of fresh water that can be used in lieu of the upper Floridan.

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Appendix: Depth and Thickness Measurement of the Brunswick Aquifers

The following steps were taken in interpreting the stratigraphic position, depth, lithology and permeable thickness of the upper and lower Brunswick aquifers of Miocene age. This same methodology can be used by future investigators in coastal Georgia.

- Step 1: Plot the location of an existing or planned well as precisely as possible on a U.S. Geological Survey 7.5 minute topographic map.

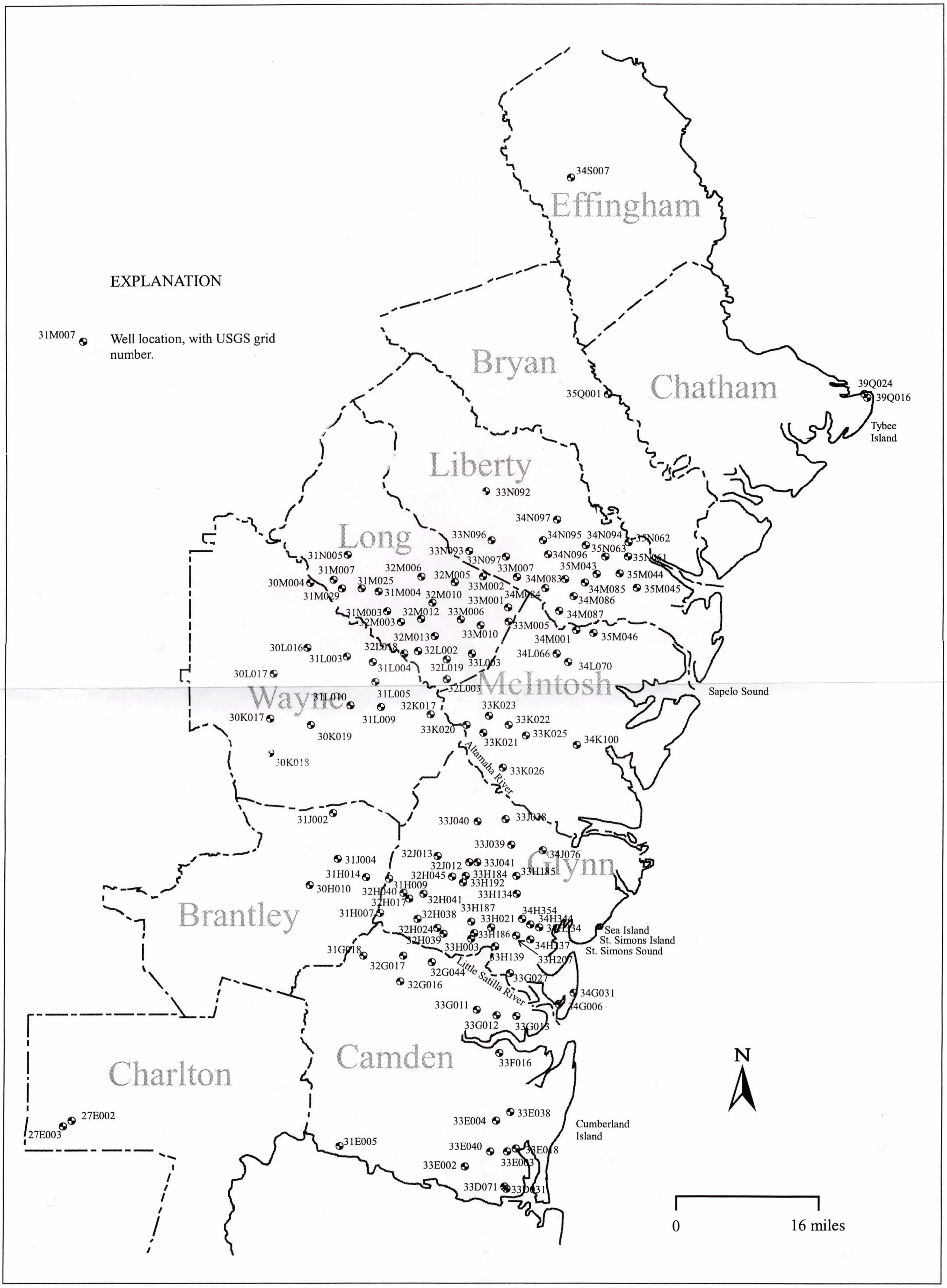
- Step 2: If resources are available, a test well should be drilled on the property and geophysical logs should be run at the landowner's or developer's expense. If it is not possible to drill a test well, Steps 3 through 5 should be followed.

- Step 3: If there is an existing well at the site, find out whether or not electric logs have been collected. The Georgia Geologic Survey and U.S. Geological Survey periodically run electric logs on wells for research purposes. Private concerns may also run electric logs to evaluate the ground-water potential of a development site. If logs are available, these agencies or businesses should be contacted and copies of logs requested.

- Step 4: Find the location of the well nearest the existing or planned well that has a natural gamma log. Plate 1 and Appendix B of Clarke and others (1990) can be used to facilitate this step. If there is no well with a natural gamma log within a reasonable distance from the existing or planned well, refer to Plates 4, 5, 7, 8, and 9 of Clarke and others (1990). These Plates are cross sections and maps of the coastal area of Georgia showing the elevations of Markers A, B, and C. Use the closest natural gamma log or cross section to estimate the depth to marker horizons A, B, and C in the existing or planned well. Account for elevation differences between the existing or planned well and the well with a natural gamma log or cross section from Clarke and others (1990).

- Step 5: Find the location of the well nearest the existing or planned well that has an electric log. This may be the same well that was used in Step 3. Aquifer units will appear on electric logs as symmetrical deflections of spontaneous potential and resistivity curves. Plot a "clean sand line" and "shale line" on the electric log, as described in the Delineation of Most Permeable Intervals section. Plot a "50 percent sand line," half way between the "clean sand line" and the "shale line." The permeable thickness of the aquifer is interpreted to be that portion of the resistivity log that is greater than the "50 percent sand lines."

- Step 6: If available, compare lithologic logs with the electric logs to confirm that the picks made from electric logs are accurate. If there is no lithologic log or stratigraphic column from the well with electric logs, obtain a lithologic log or stratigraphic column for the nearest available well.



Map showing location of wells used in this study.

Editor: William M. Steele

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