Subsurface Geology of the A and M Areas of the Savannah River Plant, Aiken, South Carolina(U)

by

D. Jackson (Contact)

E. I. du Pont de Nemours and Company

Savannah River Site

Aiken, South Carolina 29808

W. C. Fallaw

K. A. Sargent

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AT THE SAVANNAH RIVER PLANT, AIKEN, SOUTH CAROLINA

by
W.C. Fallaw
and
K.A. Sargent

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E.I. duPont de Nemours & Company

Savannah River Plant

Aiken, South Carolina 29808

Geological Consulting Services

Rt. 7, 12 Kensington Road

Greenville, South Carolina 29609

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INTRODUCTION

A study of the subsurface geology of A and M areas at the Savannah River Plant was begun in the summer of 1984 with the establishing of a sedimentological laboratory at Building 704-U. Here, core samples, recovered during the drilling of selected A and M area monitoring wells, were examined by trained geologists under the supervision of Dr. W.C. Fallaw. This project was continued during the summer of 1985. The results of these studies were used, along with available borehole geophysics, to delineate the subsurface geology. This report is based on these investigations. The sedimentological data obtained are summarized by monitor well as a lithologic log and are presented along with the borehole geophysics in the Appendix.

The geological interpretation is presented in the form of structure contour maps, isopach maps, and cross-sections. The study is limited to existing data from A and M areas, and the interpretation may change as additional data become available.

GEOLOGY

STRATIGRAPHIC SECTION

The Cretaceous and Cenozoic sediments of the Coastal Plain are approximately 700 ft thick in A and M Area and regional dip is to the southeast (Siple, 1967; Colquhoun et. al., 1983). The sediments are mostly loose and partially indurated sands and clays, and they overlies Precambrian or Paleozoic metamorphic rocks of the Appalachian Province. Newark-type Triassic sediments occur between the Coastal Plain sediments and the Appalachian crystalline rocks in a part of the Savannah River Plant, but none are known in A and M

areas. The Cretaceous and Cenozoic deposits appear to have formed in fluvial, deltaic, and shallow marine environments.

Terminology used for the strata varies among the studies done in the SRP area. Among the more pertinent publications are Sloan (1908), Cooke (1936), Siple (1967), Nystrom and Willoughby (1982), Carter (1983), and Colquhoun et al. (1983). The terminology of this report, shown below, is based on a review of these studies, and on the usage of DuPont employees concerned with subsurface stratigraphy. Further study may result in revision.

Upland unit	Age unknown
Unconformity?	
Barnwell Group	Late Eocene (and younger?)
Tobacco Road Formation	
Dry Branch Formation	
Unconformity	
McBean Formation	Middle Eocene
Unconformity?	
Congaree Formation	Middle Eocene
Unconformity	
Ellenton Formation	Paleocene
Unconformity	
Black Creek Formation	Late Cretaceous
Unconformity	
Middendorf Formation	Late Cretaceous

METHODS

The core samples were acquired using either a split spoon or phosphate barrel sampler. The split spoon sampler retrieves a 1 7/8 in-diameter core in runs up to 24 in long. The phosphate barrel sampler retrieves a 3 7/8 in-diameter core in runs up to 10 ft in length but more commonly in unconsolidated sediments is restricted to less than 5 ft. Upon recovery, the cores were wrapped in aluminum foil or a polyvinyl plastic sheet and stored in core boxes marked to record the sampling interval and to distinguish top and bottom of

the core samples. Storage boxes were normally of waxed corrugated cardboard construction but on occasion wood boxes were used. Long-term storage was effected in a locked building.

The cores were examined megascopically and with binocular microscopes, and these properties were recorded:

Depth	Modal grain size
Recovery	Sorting
Color	Roundness
Clay color	Presence of sulphides
Sedimentary structures	Percentage muscovite
Percentages of pebbles, granules, sand, silt, and clay	Percentage glauconite
Percentage carbonate (detected by HCl)	Percentage lignite
Rock name	Presence of fossils
Maximum grain size	Fluorescence under ultra-violet light (for heavy minerals)

Grain sizes were estimated by comparing the core samples with sieved fractions of known size, and percentages were estimated by comparing the core samples with diagrams showing how various percentages would appear under the microscope (Terry and Chilingar, 1955). The Wentworth-Udden scale was used for grain sizes. This is shown below, and on the far right is shown the corresponding ϕ scale terminology, ϕ being the negative of the logarithm to the base 2 of the grain size diameter. The ϕ units were used in parameters (Folk and Ward, 1956) of size frequency distributions for samples which had been size analyzed by sieve and hydrometer:

<u>Grain Size</u>	<u>Diameter in mm</u>	<u>ϕ Scale</u>
Pebbles	4	-2
Granules	2 - 4	-1 - -2
Very coarse sand	1 - 2	0 - -1
Coarse sand	1/2 - 1	1 - 0
Medium sand	1/4 - 1/2	2 - 1
Fine sand	1/8 - 1/4	3 - 2
Very fine sand	1/16 - 1/8	4 - 3
Silt	1/256 - 1/16	4 - 8
Clay	1/256	8

In the formation descriptions, the average size fraction percentages and sorting are based on visual analysis. In the presentation of the results for the few samples which were sieved and analyzed by hydrometer, the sand percentage also includes granules and pebbles, these being present in only minute amounts in those samples.

Sorting, a measure of the degree to which all grains in a sample approach the same size, was estimated for sands according to this scale:

Well sorted	90% of sample within 2 sand size classes
Moderately sorted	90% of sample within 3 sand size classes
Poorly sorted	90% of sample within 4 sand size classes
Very poorly sorted	90% of sample within more than 4 size classes

In general, the core data were recorded at 2 ft intervals, but where there was an obvious lithologic break within the interval, smaller intervals were recorded. Lithologic logs (see Appendix) on a scale of 1 in to 10 ft were prepared from the coded data. Major features recorded on the logs are modal grain size, maximum grain size, pebble plus granule percentages, sorting, carbonate zones, dominant color, sedimentary structures, fossils, and content of muscovite, glauconite, lignite, and heavy minerals.

Of the 47 borings used in the stratigraphic study, 33 were cored. Some borings were cored continuously and some were cored 2 ft in every 5 ft of depth. Figure 1 shows the locations of the borings and Table 1 shows the amount of data available. In making correlations and describing formation lithologies, great reliance was placed on 13 borings which were cored continuously at least through the Eocene section: ASB-8, MSB-10, -11, -12, -13, -21, -29, -30, -31, -36, -40, -41, and -42.

Figure 1. Location map of borings used in geologic study.

Table 1. Data Used in Geologic study. Elevations relative to mean sea level

Well Cluster	CORES		Core Spacing*	GEOPHYSICAL LOGS	
	Elevations of Intervals Cored ft	Thickness of Interval Cored ft		Elevations of Intervals Logged ft	Thickness of Intervals ft
AC2	343-139	204	2/5	337-143	194
ASB 7	351-211	140	2/5		
ASB 8	349-11	338	Continuous	349-19	330
ASB 9	306-216	90	2/5		
MSB 9	357-263	94	Continuous		
MSB 10	353-104	249	Continuous	348-112	236
MSB 11	363-123	240	Continuous	357-123	234
MSB 12	346-(-313)	659	Continuous	338-(-309)	647
MSB 13	343-99	244	Continuous	337-98	239
MSB 14	346-143	203	2/5	340-147	193
MSB 15	365-163	202	2/5	359-165	194
MSB 16	365-163	202	2/5	359-167	192
MSB 17	266-154	112	2/5	350-156	194
MSB 18	248-141	107	2/5	332-138	194
MSB 19	298-96	202	2/5	292-98	194
MSB 20	262-150	112	2/5	346-152	194
MSB 21	354-16	338	Continuous	354-10	344
MSB 22	357-155	202	2/5		
MSB 23	370-54	316	2/5	370-44	326
MSB 24	379-127	252	2/5		
MSB 25	365-113	252	2/5		
MSB 26	359-156	203	2/5		
MSB 27	374-171	203	2/5	372-60	312
MSB 28	252-151	101	2/5		
MSB 29	364-47	317	Continuous	364-52	312
MSB 30	253-27	226	Continuous	348-33	315
MSB 31	246-12	234	Continuous		
MSB 32				247-40	207
MSB 33				251-7	244
MSB 34	381-(-279)	660	2/5	375-(-279)	654
MSB 35				348-34	214
MSB 36	340-38	302	Continuous	338-40	298
MSB 37	382-260	382	Cuttings	374-(-4)	378
MSB 38				352-32	320
MSB 39				338-40	298
MSB 40	321-9	312	Continuous	319-23	296
MSB 41	323-18	305	Continuous	323-12	311
MSB 42	376-36	340	Continuous	371-25	346
MSB 43				355-41	314
MSB 44				370-118	252
MSB 45				374-120	254
MSB 46				368-122	246
RWM 4				360-126	234
RWM 5				361-103	258
RWM 6				347-138	209
RWM 7				345-141	204
RWM 8				346-100	246

* 2/5 indicates well was cored 2 ft of every 5 ft

Table 2. Elevations of Tops of Stratigraphic Units. Elevations given are relative to mean sea level.

Well Cluster	Ground Elevation ft	Tobacco Road ft	Dry Branch ft	McBean ft	Upper Congree ft	Congree clay ft	Lower Congree ft
AC 2	343	305	251	206	183		
ASB 7	351	328					
ASB 8	349	328	266	231	197	169	146
ASB 9	306	274					
MSB 9	357	317					
MSB 10	353	315	269	227	198	183	158
MSB 11	363	307	253	220	197	161	155
MSB 12	346	300	248	210	184	156	136
MSB 13	343	291	260	223	195	177	146
MSB 14	346	308	264	218	194	154	
MSB 15	365	312	260	223	198		
MSB 16	365	308	265	227	197		
MSB 17	356		246	197	177		
MSB 18	338	290	243	210	189	175	
MSB 19	298	276	266	213	186		
MSB 20	352		255	207	184		
MSB 21	354	316	246	196	162	136	124
MSB 22	357	315	255	220	201		
MSB 23	370	343	270	233	215	167	152
MSB 24	379	350	267	234	214	149	
MSB 25	365	318	279	235	212	169	
MSB 26	359	331	266				
MSB 27	376	336	269	233	212	158	138
MSB 28	353						
MSB 29	365	345	264	220	198	167	154
MSB 30	353	306	259	205	185	133	123
MSB 31	346			222	198	152	146
MSB 34	253		236	204	187		
MSB 33	254		245	215	193		
MSB 34	381	356	262	220	201	150	138
MSB 35	350	326	259	214	190	152	150
MSB 36	340	324	266	226	202		
MSB 37	382	332	266	224	224	202	175 149
MSB 38	356	338	264	220	196	150	148
MSB 39	341	324	258	226	205	153	150
NSB 40	321	321	261	226	198		
MSB 41	323	295	255	223	205	175	159
MSB 42	376	348	266	232	210	179	136
MSB 43	357	339	270	234	213	159	141
MSB 44	375	352	255	214	192	152	144
MSB 45	379		278	231	204	173	152
MSB 46	370	346	275	233	208	152	148
RWM 4	364		263	224	194	150	142
RWM 5	365		277	232	216	174	169
RWM 6	347		265	220	201	154	150
RWM 7	347		263	218	200	157	154
RWM 8	346		252	220	198	183	142

Table 2. (continued)

Well Cluster	Upper clay ft	Upper sand ft	ELLENTON		BLACK CREEK	
			Middle clay ft	Lower sand ft	Lower clay ft	
AC 2						
ASB 7						
ASB 8			102	95	71	55
ASB 9						
MSB 9						
MSB 10			147	138	118	
MSB 11			148	143	129	
MSB 12	112	110	106	101	73	34
MSB 13			127	109		
MSB 14						
MSB 15						
MSB 16						
MSB 17						
MSB 18						
MSB 19			133	130	110	
MSB 20						
MSB 21	114	112	107	86	64	35
MSB 22						
MSB 23		125	122	111	95	66
MSB 24						
MSB 25			123			
MSB 26						
MSB 27			129	116	104	62
MSB 28						
MSB 29			133	129	113	101
MSB 30			117	113	93	37
MSB 31			140	128	114	68
MSB 32	118	114	112	110	97	53
MSB 33	147	141	132	113	82	55
MSB 34				116	103	67
MSB 35			140	134	117	67
MSB 36	143	140	134	114	90	80
MSB 37			130	123	104	87
MSB 38			140	124	114	67
MSB 39	140	137	132	119	101	86
MSB 40	142	137	135	131	99	47
MSB 41	126	125	123	121	81	62
MSB 42			120	118	98	74
MSB 43			128	126	108	72
MSB 44			130			
MSB 45			134			
MSB 46			144	139	120	
RWM 4						
RWM 5			134			
RWM 6						
RWM 7						
RWM 8	119	117	112			

FORMATION DESCRIPTIONS

Middendorf Formation

The two deepest borings in M area, MSB-12 and MS-34, cored into the Middendorf but did not drill through it. MSB-12, the deeper of the two, reached an elevation of -313. The top of the formation was picked at the top of a thick clay at -113 in #34 and -118 in #12. The assignment of this clay to the Middendorf rather than the Black Creek is arbitrary.

The Middendorf consists mostly of medium- and coarse-grained, moderately and well-sorted quartz sand, averaging 17% silt and clay. Pebbly layers are common. Muscovite is common in some places, but not as abundant as in the overlying Black Creek Formation. Tan is the most common color, with gray, white, purple, orange, and yellow occurring. In addition to the clay at the top of the unit, clay and silt layers are interbedded with the sand. Roughly 20% of the sand section underlying the upper clay is composed of silt and clay beds. These fine-grained beds appear to be discontinuous, but the thick upper clay seems to be extensive within SRP. The upper clay is 38 ft thick in MSB-34. In MSB-12, the upper clay is divided into two parts by a 14 ft thick layer of sand. The upper layer of clay is 9 ft and the lower 10 ft thick.

The depositional units appear to be discontinuous, except perhaps the top clay. The irregular bedding, variation in sorting, and clay balls suggest that the Middendorf was deposited in fluvial environments. Most of the sands are probably point bar and channel deposits. The thin clays and silts were probably formed in overbank environments.

Black Creek Formation

Thirteen A and M borings are cored into the Black Creek Formation and seven others were logged geophysically. Only MSB-12 and MSB-34 drilled through it. The formation is 152 ft thick in #12 and 180 ft thick in #34. The upper contact is picked at the bottom of a thick clay immediately below

the poorly sorted, dark sands of the Ellenton Formation. The boundary is distinct on both lithologic and geophysical logs. Figure 2 is a structure contour map of the top surface of the Black Creek Formation. The lower contact is picked at the upper surface of the thick clay at the top of the Middendorf. Both contacts are probably unconformable (Colquhoun et al., 1983).

Most of the Black Creek consists of medium and coarse sands. Sorting is quite variable, ranging from well sorted to very poorly sorted, with the former being more common. Pebbly beds occur throughout, and clay balls are common. The sands are generally micaceous, more so than in the Middendorf, and feldspar and pyrite are rare. Tan, white, and yellow sands are most common, and the top of the sand is black in several borings, perhaps stained by the overlying Ellenton in some cases. Sands average 18% silt and clay. The upper part of the sand is massive, but clay beds occur in the lower part in the two deep borings. About 5% of the section is composed of silt and clay beds. Within the upper 30 ft, a zone penetrated by 10 continuously cored borings, 22% of the sediment is clay and silt. The deposits are similar to those of the Middendorf and appear to be fluvial.

Ellenton Formation

Parts of the Paleocene Ellenton Formation are dark gray or black, poorly sorted, fine to coarse, clayey, silty sand and dark, kaolinitic clay and clayey silt. Muscovite, feldspar, iron sulfide and lignite are common in these sediments. In other places in the A and M areas the Ellenton sands and clays are tan, purple, or orange, are better sorted, and tend to lack the sulfide and lignite found in the dark sediments. Both dark and light deposits contain pebbly zones. Some borings have both dark and light sections. A crude pattern seems to exist, however. Light deposits tend to occur in the northeastern part of the study area which is structurally low, and near a

Figure 2. Structure contour map of top surface, Black Creek Formation

structural high which is located near MSB-11. It is possible that some of the lighter sediments were deposited in post-Ellenton time. Their muscovite and feldspar content is more similar to that of the typical Ellenton than to the Eocene sands, and the shape of the modal size curves is similar to that of the dark Ellenton. The light color may have developed secondarily by leaching and oxidation of sulfides, and lignite. For the Ellenton as a whole, clay and silt beds make up 59% of the unit, and 62% of all sediments are clay and silt. Table 3 gives the results of size analysis of some of the lighter, better sorted sands. The lower boundary of the Ellenton is picked at the contact between a thick clay and the thick Black Creek sand section. The upper contact is picked at the base of a thick Eocene sand section which is usually a lighter color and much better sorted than the Ellenton. An indurated iron oxide layer marks this boundary in several borings. In Figure 3 is a structure contour map of the top surface of the Ellenton.

Thickness of the Ellenton in A and M area borings is from 32 to 95 ft. (See Figure 4). The upper part of the Ellenton is absent in some borings which are generally in a zone trending north-south through A and M areas. (See Figures 11 and 13) This zone corresponds crudely to structurally high trends, but some borings with a missing section occur off structure. In a complete section, the Ellenton consists of five units. These are, from bottom to top: a thick clay, a thick sand, a medium-thickness clay, a thin sand, and a thin clay. The clay at the bottom of the formation is from 10 to 56 ft thick, and generally thins toward structural highs. (See Figures 5 and 6). In most borings, the clay is gray, greenish gray, or black. In other borings oxidized colors are common, such as red, purple, orange, and yellow. Some borings which have dark clay also have an oxidized zone at the top, and some borings have interbedded light and dark layers.

Figure 3. Structure contour of top surface, Ellenton Formation.

Figure 4. Isopach map of the entire Ellenton Formation.

Figure 5. Structure contour map of top surface, lower Ellenton clay.

Figure 6. Isopach map, lower Ellenton clay.

A sandy zone from 2 to 8 ft thick was encountered in a few borings about 15 to 20 ft above the base of the clay. Iron sulfide occurs in some borings, lignite in a few, and fissility was observed in a small section of core in one boring. In MSB-36, a section of core from the base of the clay layer was seen to expand in diameter by perhaps 25% when removed from the core barrel. X-ray analysis revealed only kaolinite and quartz in this material. Pebbles occur in parts of the clay, but in general the largest particle size is medium or coarse sand.

Dinoflagellates and pollen from the lower clay yielded Eocene(?) dates from MSB-12 and MSB-34, Paleocene(?) in MSB-42, and Early Paleocene in MSB-36. Steele (1985) assigned this clay in M area to the Paleocene, using a gamma ray kick at the base as a Cretaceous-Paleocene Contact.

The lower Ellenton sand is generally coarse to very coarse, micaceous, feldspathic, and poorly sorted, although light-colored, cleaner sands occur in some borings. Average size fractions of this sand are 77% sand size and larger, and 23% silt and clay. Several clay beds, 1 to 2 ft. thick, are interbedded with the sand in most borings. The sand is from 10 to 40 ft thick and thins toward structural highs (See Figures 7 and 8).

The middle clay attains a thickness of more than 20 ft off structure and tends to thin toward highs (See Figures 9 and 10). It appears to be missing in MSB-34, allowing the lower Ellenton sand to be in contact with Eocene sand. Dinoflagellates and pollen indicate an Eocene age for the clay in MSB-21.

The upper Ellenton sand is up to 9 ft thick and tends to be missing in some borings (See Figures 11 and 12). It is medium and fine grained, silty and clayey, poorly sorted, and micaceous. Size fractions average 66% sand size and larger, and 34% silt and clay. Dinoflagellate and pollen dates from this unit are Early Paleocene in MSB-23 and MSB-36.

Figure 7. Structure contour map of top surface, lower Ellenton sand.

Figure 8. Isopach map, lower Ellenton sand.

Fig. 9. Structure contour map of top surface, middle Ellenton clay.

Figure 10. Isopach map, middle Ellenton clay.

Figure 11. Structure contour map of top surface, upper Ellenton sand.

Fig. 12. Isopach map, upper Ellenton sand.

Table 3. Ellenton Size Analysis Data (better sorted sands)

Well Cluster	Elevation ft	Sand %	Silt %	Clay %	Median ϕ	Mean ϕ	Sorting ϕ	Skewness
MSB-10	119	65	20	15	2.7	3.5	2.5	0.4
MSB-11	132	88	6	6	1.4	1.6	2.5	0.3
MSB-11	130	91	6	3	1.2	1.3	1.9	0.2
MSB-19	117	95	2	3	0.5	0.7	1.3	0.4

Table 4. Lower Congaree Size Analyses Date

Well Cluster	Elevation ft	Sand %	Silt %	Clay %	Median ϕ	Mean ϕ	Sorting ϕ	Skewness
MSB-10	152	88	7	5	2.6	2.7	1.5	0.37
MSB-10	150	88	11	1	2.2	2.2	1.0	0.02
MSB-13	134	89	2	9	2.4	2.5	2.1	0.45
MSB-13	132	88	6	6	0.9	1.5	2.9	0.47
MSB-13	130	89	5	6	1.2	1.5	2.3	0.38

Table 5. Upper Congaree Size Analysis Data

Well Cluster	Elevation ft	Sand %	Silt %	Clay %	Median ϕ	Mean ϕ	Sorting ϕ	Skewness
MSB 11	178	56	20	24	3.5	4.8	4.1	0.42
MSB 11	163	89	4	7	2.1	2.4	1.6	0.73
MSB 11	162	30	27	43	7.0	7.1	4.1	0.05
MSB 12	183	92	5	3	0.7	1.1	1.5	0.52
MSB 12	181	93	6	1	0.5	0.9	1.4	0.48
MSB 12	179	93	6	1	0.5	0.8	1.4	0.20
MSB 12	161	92	6	2	0.9	1.3	1.6	0.44
MSB 12	159	84	1	15	2.4	2.6	2.7	0.44
MSB 12	157	55	7	1	3.3	6.0	4.9	0.65
MSB 14	190	92	7	1	2.3	2.2	1.2	0.01
MSB 17	160	86	3	11	1.8	2.1	2.1	0.61

Figure 13. Structure contour map of top surface, upper Ellenton clay.

Figure 14. Isopach map, upper Ellenton clay.

The upper clay is up to 6 ft thick and is missing in some borings (See Figure 14). An Eocene age determination was made from microfossils in MSB-21.

The contradictory paleontological age determinations from Ellenton samples in A and M areas may be caused by the paucity of fossils and by ignorance of the true stratigraphic ranges of the taxa. The lower clay had one Early Paleocene date and two questionable Eocene dates. The middle clay yielded one Eocene date. The upper sand had two Early Paleocene determinations, and the upper clay had a single Eocene date. Pollen dates from boring FC-5, several miles southeast of the study area, were Early Paleocene in deposits similar to the Ellenton in A and M areas. Further paleontological study is in progress on A and M cores.

The dark color, pyrite, and lignite, indicative of a reducing environment, suggest a deltaic or lagoonal environment for the Ellenton. The decrease in grain size upward of the lower Ellenton sand would be expected in a deltaic distributary channel. The Ellenton clays may have been deposited in quieter environments between distributaries and seaward of the delta shoreline.

Congaree Formation

The Middle Eocene Congaree Formation is a sandy unit with a clayey zone in the lower middle part in most borings. The lower unconformable contact is picked where the dark clays of the Ellenton Formation meet the clean, yellowish sands of the Congaree. An iron oxide-cemented zone marks the contact in some borings. MSB-36 displays the contact very well. Gamma ray readings are generally high in the Ellenton and low in the Congaree. The upper boundary of the Congaree is picked where the Congaree sands meet the clay beds and clayier sands of the McBean Formation.

Figure 15. Structure contour map of top surface, lower Congaree sand.

The lower Congaree sand (Figure 15) is brown, tan, and yellow; medium-grained; and moderately well sorted. An average of 17% of the entire unit is composed of clay and silt, and 6% of the section is made up of clay and silt beds. Clay laminae and heavy mineral zones occur in places. Pebbly layers are common, especially near the base. Thickness is from 4 to 44 ft. (See Figure 16). Table 4 gives data from size analyses.

The clayey zone in the Congaree (Figure 17) is a clay layer in some borings, and in others occurs as alternating sands and clays. A moderate gamma ray high and a low resistivity are usually logged through the interval. The zone is very thin or missing in the southern part of A and M areas (See Figures 17 and 18). The clayey zone appears to vary in stratigraphic position, sometimes appearing very low in the Congaree and sometimes higher. It is possible that there is more than one clayey zone. The interval is gray, tan, and, rarely, green, orange, brown, or purple. An average of 70% of the zone is composed of clay and silt beds, and 72% of all sediments are clay and silt. The sands in the zone are medium- to fine-grained and well sorted. Thickness varies from 0 to 43 ft. (See Figure 18). Middle Eocene pollen occurs in MSB-18.

The upper Congaree sand (Figure 19) is yellow, tan, and brown, medium- and fine-grained, well-sorted sand. Heavy mineral zones are common, as are pebbly zones and clay balls. Clay and silt beds make up an average of 7% of the section, and 16% of all material in the unit is clay and silt. Clay laminae occur in most borings and micaceous zones occur in some. The unit is from 14 to 60 ft thick. (See Figure 20) Table 5 shows size frequency distribution data.

Figure 16. Isopach map, lower Congaree sand

Figure 17. Structure contour map of top surface, Congaree clayey zone.

Figure 18. Isopach map, Congaree clayey zone.

Figure 19. Structure contour map of top surface, Congaree Formation

Figure 20. Isopach map, upper Congaree sand.

McBean Formation

Limestone occurs at the type locality of the Middle Eocene McBean Formation across the Savannah River in Georgia. Calcareous deposits are found in the Middle Eocene section above the Congaree in many SRP borings. MSB-40, on the southern edge of A and M areas contains 7 ft of limestone in a 28 ft section composed mostly of glauconitic, poorly-sorted sand, with a thin clay at the top. (See Appendix Figure A36). Other borings in the study area lack the limestone, but a gamma ray high in MSB-40, corresponding to the section of glauconitic sand, limestone, and clay, can be found in most borings. Silicified mollusks were found in MSB-11. In most borings, the section contains more clay, either as clay layers or as matrix in sands, than in the underlying upper Congaree sand and the overlying Dry Branch Formation (Table 6). It also is more micaceous. An unconformity may separate the McBean from the underlying Congaree.

The McBean section is usually orange and yellow. Clay and silt beds average 14% of the unit, and clay and silt make up 25% of all sediments. In the northern part, the formation appears to be more permeable than elsewhere in A and M areas (Figure 22). The sands are fine-grained and well, moderately, and poorly sorted. Pebbles and clay balls occur in some borings, and muscovite is found in most. There does not appear to be an extensive, continuous layer of green clay at the bottom nor a tan clay at the top, as has been reported elsewhere in SRP, but clay layers of gray, green, tan, and other colors occur at various stratigraphic horizons within the McBean. Thickness of the formation is from 16 to 34 ft in borings (See Figure 23). Dinoflagellates and pollen from MSB-19 yielded a Middle Eocene date. Table 7 shows size data from sieve and hydrometer analysis.

Figure 21. Structure contour map of top surface, McBean Formation.

Figure 22. Percentage of silt and clay in the McBean Formation.

Figure 23. Isopach map for the McBean Formation.

Figure 24. Structure contour map of top surface, Dry Branch Formation.

Table 6. Average Clay and Silt Content from Visual Analysis

Stratigraphic Unit	As matrix in sands and as beds %	As beds %
Upland unit	52	49
Tobacco Road	13	2
Dry Branch	18	11
McBean	25	14
Upper Congaree	16	7
Congaree clayey zone	72	70
Lower Congaree	17	6
Ellenton	62	59
Black Creek (upper 30 ft)	22	5

Table 7. McBean Size Analysis Data

Well Cluster	Elevation ft	Sand %	Silt %	Clay %	Median ϕ	Mean ϕ	Sorting ϕ	Skewness
MSB 10	210	77	10	13	2.8	3.1	3.2	0.29
MSB 10	208	82	10	8	1.7	2.1	2.5	0.46
MSB 10	206	93	6	1	1.5	1.6	1.2	0.27
MSB 11	208	79	16	5	3.4	3.7	1.3	0.57
MSB 11	206	54	38	8	3.8	4.3	2.1	0.39
MSB 11	204	71	21	8	3.1	3.3	2.5	0.29
MSB 17	190	47	43	10	4.2	4.7	2.1	0.39
MSB 17	185	85	4	11	2.0	2.6	2.8	0.58

Dry Branch Formation

The Dry Branch (Figure 24) is the lower formation in the Late Eocene Barnwell Group and unconformably overlies the McBean. The sands of the Dry Branch are coarser and cleaner than those in the McBean, and a pebbly layer occurs at the base in some borings. The top of the unit is picked where the yellower sands with clay laminae meet the redder sands of the Tobacco Road which tend to lack clay laminae. The Dry Branch is composed of orange, brown, and yellow, medium-grained, moderately- and well-sorted sand. Clay and silt beds compose an average of 11% of the formation, and clay and silt constitute 18% of all the sediments. Clay laminae are common. There does not appear to be an extensive layer of tan clay anywhere in the formation. Clay layers, however, usually tan, occur at various stratigraphic horizons within the Dry Branch. Pebbly layers are common. Thickness of the formation is from 30 to 55 ft (See Figure 25).

Tobacco Road Formation

The upper unit of the Barnwell Group, the Tobacco Road Formation (Figure 26) is characterized in many outcrops by a concentration of flat quartz pebbles at its base. In MSB-15 and -24, (See Appendix Figures A11 and A19) flat quartz pebbles were found at an obvious lithologic change. A gamma ray kick occurs there. The base of the formation was picked in other borings either by lithology or by a gamma ray kick. The upper contact was picked where the fairly well-sorted sands of Tobacco Road change to clayey, silty, sandy, pebbly, and poorly-sorted beds of the Upland unit.

The Tobacco Road is brown, orange, yellow, red, and purple. Medium and fine sands, moderately and well sorted, compose nearly the entire formation. An average of 13% of all the sediments are clay and silt. Clay and silt layers make up only 2% of the section. Pebbly layers are common, especially near the base. Clay balls occur in some borings.

The thickness, controlled partly by erosion accompanying deposition of the overlying Upland unit, and partly by post-Upland unit erosion, varies from 0 in stream valleys to about 97 ft. (See Figure 27). Both the Tobacco Road and the Dry Branch were probably deposited during the Late Eocene marine transgression. The latter formation with its clay layers formed during the transgressive phase and the younger Tobacco Road was deposited during the regressive phase.

Upland Unit

Capping the higher areas in SRP is a deposit of coarse-, medium- and fine-grained, poorly sorted, pebbly and cobbly material with extreme lateral and vertical variation. The South Carolina Geological Survey has been mapping it as the informally named "Upland unit." It partially corresponds to sediments previously mapped in SRP as the Hawthorn Formation.

In A and M areas, the unit is orange, brown, red, and tan. Sorting is very poor. Clay and silt make up about 50 % of the deposits. Pebbly zones are abundant. Feldspar grains occur in places. Thickness is from 0 to 57 ft. (See Figure 28). It was probably deposited in high energy fluvial channels, point bars, flood plains, and abandoned channels. The channels seem to have cut down into the Tobacco Road in places, forming a very irregular surface at its top.

Figure 25. Isopach map, Dry Branch Formation.

Figure 26. Structure contour map of top surface, Tobacco Road Formation.

Figure 27. Isopach map, Tobacco Road Formation.

Figure 28. Isopach map, Upland unit.

STRUCTURE

Cross-sections through the area (Figure 29) were prepared using the structure contour maps as a guide. The highs and lows between borings on the cross-sections (Figures 30-34) were inferred from the structure contour maps. Dips are up to about 260 ft/mi (3°) for the Black Creek Formation and generally decrease going up the stratigraphic section. A plausible sequence of events leading to the development of the structures is:

Deposition of sediment

Erosion during unconformity development, probably caused by drop in sea level

Deposition on irregular erosion surface, with thicker sediments being deposited in topographic lows

Differential compaction causing thicker sediments and clayey sediments to subside more than thinner sediments and sandier sediments

Erosion during unconformity development

This process would be modified by lateral changes in patterns of sedimentation during deposition of each formation. A barrier island, for example, would cause sediments to build higher than the adjacent shallow sea floor.

The structural grain (trends of highs and lows) shown on the structure contour maps (Figures 2,3,5,7,9,11,13,15,17,19,21,24,25) is generally northwest-southeast, parallel to regional slope. An exception to this is the top of the Tobacco Road Formation which is also the lower surface of the Upland unit (See Figure 26). This surface shows a grain which generally trends northeast-southwest. Erosion here may have been controlled by streams flowing toward the Savannah River rather than toward the Atlantic Ocean.

SUMMARY

The stratigraphic units beneath A and M areas are mostly sands. Extensive clays occur at the top of the Cretaceous Middendorf Formation, within the Paleocene Ellenton Formation, the Eocene Congaree Formation, the Eocene McBean Formation, and the Upland unit (age unknown). Carbonates were found in only the southern part of the study area.

Cross-sections, structure contour maps, and isopach maps show that stratigraphic units change in thickness, contacts are irregular rather than planar, and local dips vary in direction.

The coring and geophysical logging that will accompany future monitor well installation in the A and M areas will greatly aid in the refining of the stratigraphic and structural model presented here. Of especial help would be the expansion of the drilling effort towards Tims Branch which would enable this study to be correlated with studies in the F and H areas.

Further detailed sedimentological investigations of the available cores and the obtaining of additional age determinations should also be considered. During the summer of 1986, an investigation of the so-called "calcareous zone" is being conducted at SRP and should provide answers to many questions concerning the age and correlation of these sediments.

Figure 29. Location map for the cross-sections in Figures 30-34.

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