MINERALOGY AND HEAVY-MINERAL RESOURCE POTENTIAL OF SURFICIAL SEDIMENTS ON THE ATLANTIC CONTINENTAL SHELF OFFSHORE OF GEORGIA

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Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey

PROJECT REPORT 19

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Prepared in cooperation with
U.S. Minerals Management Service and the
U.S. Geological Survey
U.S. Department of the Interior
under MMS Agreement No. 14-12-0001-30496

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

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Atlanta, Georgia
1993

PROJECT REPORT 19

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ABSTRACT

Textural and mineralogical data for 83 grab samples from the Georgia shelf are used to determine the potential for placer heavy-mineral resources in the surficial sediments. The distribution of coarse-grained, feldspar-rich, immature, terrigenous, clastic sediments shows that the Piedmont-draining Savannah and Altamaha Rivers controlled shelf-wide sedimentation; common shallow-water processes such as sea-level changes, bottom currents, and major storms have not substantially modified this shelf-wide pattern. The relative abundance of heavy minerals that weather quickly outside the marine environment reflects either modern depositional loci of Piedmont-draining rivers or their seaward extension during times of lower sea level. Analyses of an additional 65 subsurface samples from offshore and onshore boreholes provide supporting data on the immature nature of the heavy-mineral suite provided to the Georgia shelf. Sea-level stillstands of significant duration are not supported by the mineralogic data except for one near the 14-m isobath.

The potential for deposits of heavy mineral placers is very low because the mineral suite provided from the Piedmont source terrane is immature. The lack of heavy-mineral placers is further indicated by the absence of beach-complex sediments, which tend to have mature assemblages, and the abundance of fluvial sediments, which tend to have immature assemblages.

INTRODUCTION

Background

Concentrations of heavy minerals, including those containing titanium, zirconium, and rare-earth elements, on the Atlantic Continental Shelf offshore of Georgia (the Georgia shelf) have been known for some years. A tract about 60 km long, extending from about Tybee Island to about Jekyll Island, and about 15 km wide, extending from the shoreline to about the 20 m isobath, was identified by U.S. Geological Survey scientists as prospective for heavy-mineral concentrations (Mining Journal, 1985). Exploration permits were subsequently granted to companies mining heavy minerals onshore in northeastern Florida; however, results of their sampling programs have not been made public.

The lack of adequate geologic, grade, and compositional data for the surficial sediments of the Georgia shelf have hindered analyses of heavy-mineral resource potential on the Georgia shelf. This study was conducted at the request of the State of Georgia - U.S. Department of the Interior Task Force for the Offshore to provide an assessment of the potential for commercial deposits of heavy minerals within a geologic, textural, and compositional framework. Surface sampling for heavy minerals may be effective only in locating surficial accumulations and may miss the more important non-eroded relict deposits. Geophysical techniques are required to locate buried placers, which must be confirmed by coring or relatively deep dredging. This study is based only on surface and core samples.

Physiography

The Georgia shelf is approximately 120 km wide; the shelf break is near the 60-m isobath. The shelf surface is generally smooth and outcrops of hard rocks are rare. Bathymetric expressions of southeast-trending remnants of the Savannah and Altamaha River channels are discernible on the shelf even though they are now submerged and have been modified by depositional and erosional processes. High-resolution seismic data for this region show the presence of fluvial channels in the shallow subsurface. The degree of fluvial sedimentation on the shelf can be inferred by the extensive "scalloping" of the 10-, 20- and 40- m isobaths shown in Figures 1 and 2. Supporting evidence for this interpretation is given by seismic stratigraphic studies of a feature called the Tybee Trough (located between sample sites 2295 and 1485 in

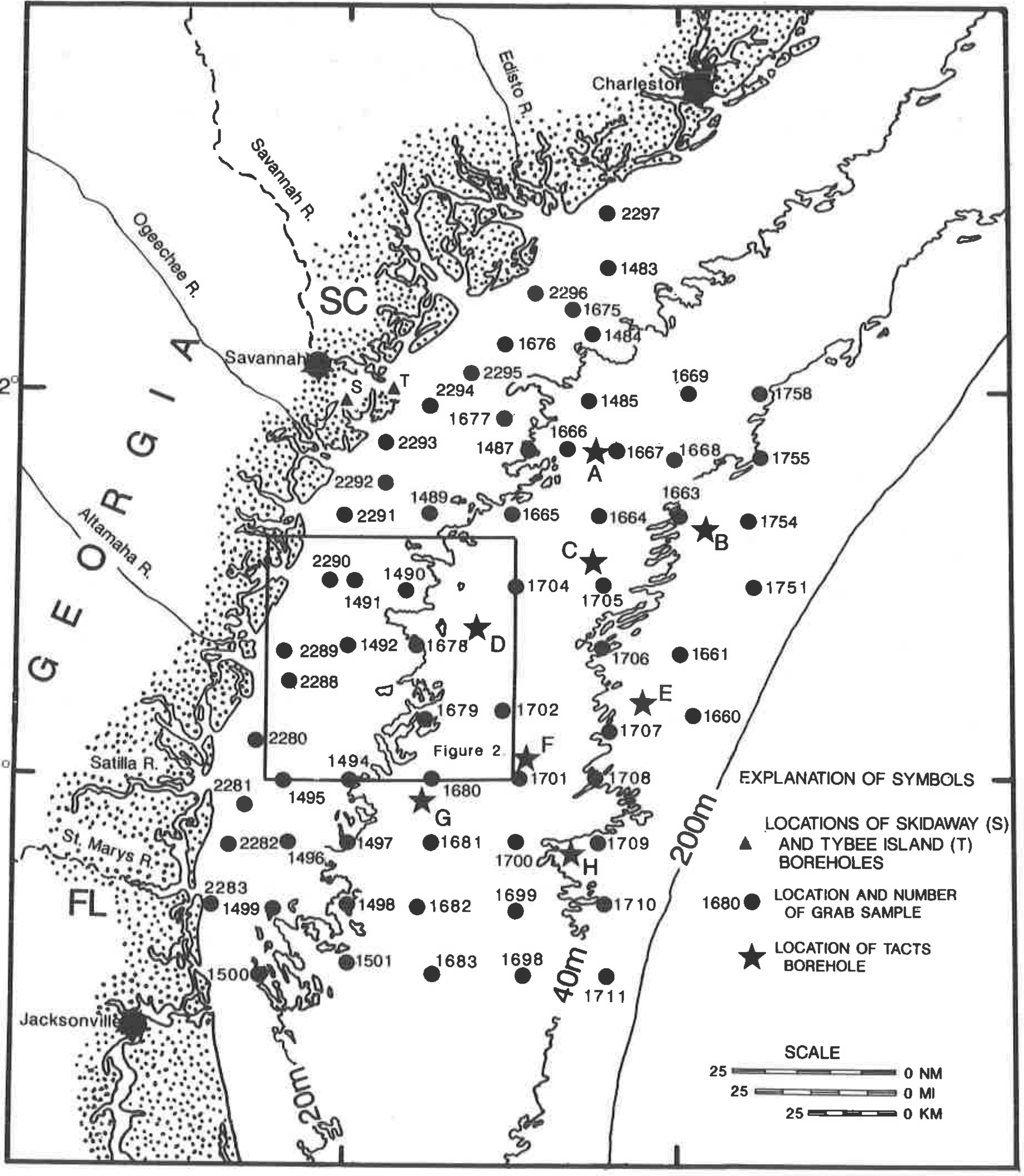

Figure 1.—Spatial distribution of samples from the Georgia shelf. Bathymetry in meters.

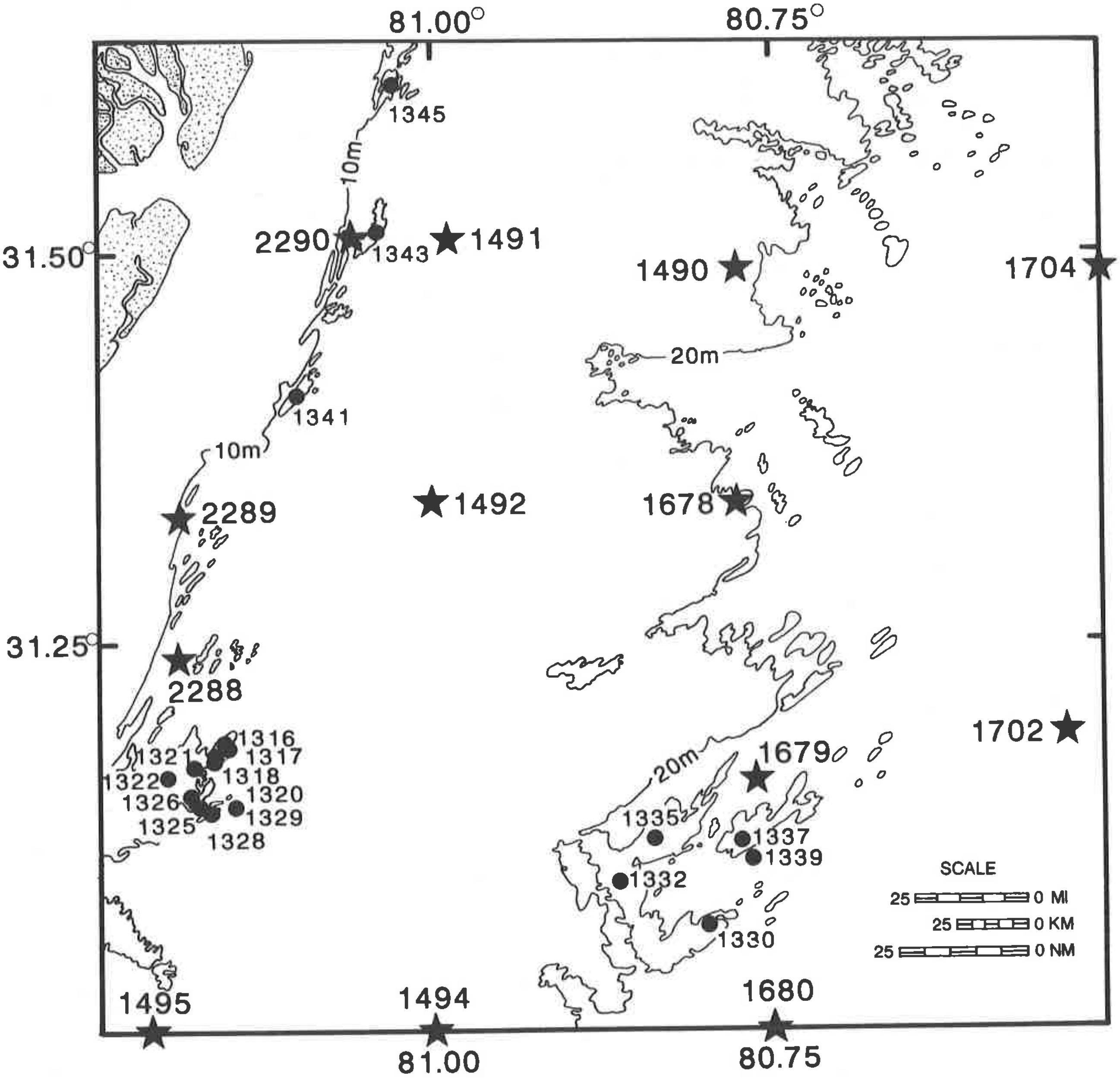

Figure 2.—Spatial distribution of 18 transect surface grab samples from the Georgia shelf. Transect samples indicated by solid circles; grid surface grab samples by stars. Latitude and longitude in hundredths of a degree to facilitate comparison with Table 4.

Figure 1) by Kellam and Henry (1987). Uchupi (1968) showed northeast- and southeast-trending sand swells radiating from near the mouth of the Altamaha River; he suggested that these features may be a response to wave-induced oscillatory currents generated during intense storms. Some of these features, however, may be fluvial levees (Uchupi, 1968). Seven escarpments thought to represent both accretional and erosional shorelines are approximately coincident with isobaths at 14, 20, 25, 30, 40, 45, and 60 m; they are identified on the basis of detailed bathymetric and high-resolution seismic transects (V.J. Henry, Jr., GSU, Atlanta, 1989, written communication).

Previous work

Previous studies of the surficial and shallow-subsurface sediments of the Georgia shelf have been regional in scope. Although they address small-scale textural distribution patterns and general compositional trends (Pilkey and Frankenberg, 1964; Milliman, 1972; Hollister, 1973) only limited heavy-mineral analysis was done in attempts to outline petrographic provinces. Pilkey (1963) and Gorsline (1963) referred to heavy minerals in eight very widely spaced samples (described by Moore and Gorsline, 1960) from the Georgia shelf and gave mineralogy only for narrow size fractions (<0.25 mm) of small samples.

Neiheisel (1965) studied the dispersion of Altamaha River sediments near Brunswick Harbor, GA, by use of hornblende separated from the sand-size fraction of the sediments. Carver and Kaplan (1976) discussed the distribution of hornblende on the Georgia shelf and concluded that the Altamaha and Savannah Rivers are the dominant sources of sediment.

Placer heavy-mineral distribution patterns in surficial sediments of the U.S. Atlantic Continental Shelf were discussed by Grosz and others (1987), and an assessment of the economic heavy-mineral resource potential was given by Grosz (1987) (Figure 3). Neither these nor the other studies, however, provide mineralogic data for the Georgia shelf.

The most recent analysis of heavy-mineral data for the Georgia shelf was done for the Task Force by the Zellars-Williams Company (1988). The analysis was conducted on non-opaque heavy-mineral data (from Hathaway, 1971) which are expressed as percentages of the sand-size fraction from which they were separated.

Thus, available literature provides heavy-mineral data that were generated for regional studies or for site-specific surficial sediment distribution patterns. Analyses limited to non-opaque mineral species of narrow size fractions of small sediment samples do not provide adequate information for an assessment of detrital mineral resource potential because many of the economic heavy minerals are opaque. In addition, the use of bulk samples weighing on the order of tens of grams creates a particle-sparsity-effect (Clifton and others, 1969) that makes it difficult to determine concentrations of scarce but highly valuable heavy minerals such as monazite accurately.

Gorsline (1963) and Henry and Hoyt (1968) identified two textural domains on the Georgia shelf: one characteristically fine grained in the nearshore and another coarser grained further offshore. Pilkey and Frankenberg (1964) placed the boundary between the two textural domains at the 11-m isobath; Henry and Hoyt (1968) proposed the 15-m isobath. Studies by Pilkey (1963), Neiheisel and Weaver (1967), and Bigham (1973) suggest that modern sediment deposition is limited largely to this narrow nearshore zone, where sediment is dispersed longshore in a southerly direction; little sediment is transported seaward.

PRESENT WORK

This study is based on 116 offshore sediment samples [83 surface grab samples and 33 samples from 8 Tactical Air Command Test Site (TACTS) boreholes] and 32 onshore sediment samples (from 2 onshore boreholes on Tybee and Skidaway Islands) (Figure 1). The 83 grab samples are located by a grid on the Georgia shelf with a sample density of about 1 per 250 km^2. This spacing allows only the definition of regional patterns. To expand coverage, 20 samples from areas north and south of the Georgia State line were included. Two types of grab samples were utilized in the study: (1) 65 surface grab samples collected on a grid (grid samples) and (2) 18 surface grab samples collected on transects of bathymetric features (transect samples). Sample coverage extends from the 6-m to the 64-m isobath, the approximate edge of the Georgia shelf. The variety of samples was assembled for this study to allow small- and large-scale surficial coverage as well as to probe patterns of mineral distribution in older, subsurface sediments both onshore and offshore.

Sample acquisition

The 65 grid samples are part of about 3600 ocean-floor sediment grab samples collected from the Atlantic Continental Shelf through the joint efforts of the Woods Hole Oceanographic Institution and the U.S. Geological Survey (Hathaway, 1971). The sample collection was done between 1955 and 1970 by using several types of bottom samplers, including Campbell, Smith-McIntyre, and Van Veen. The samples used in this study were collected during

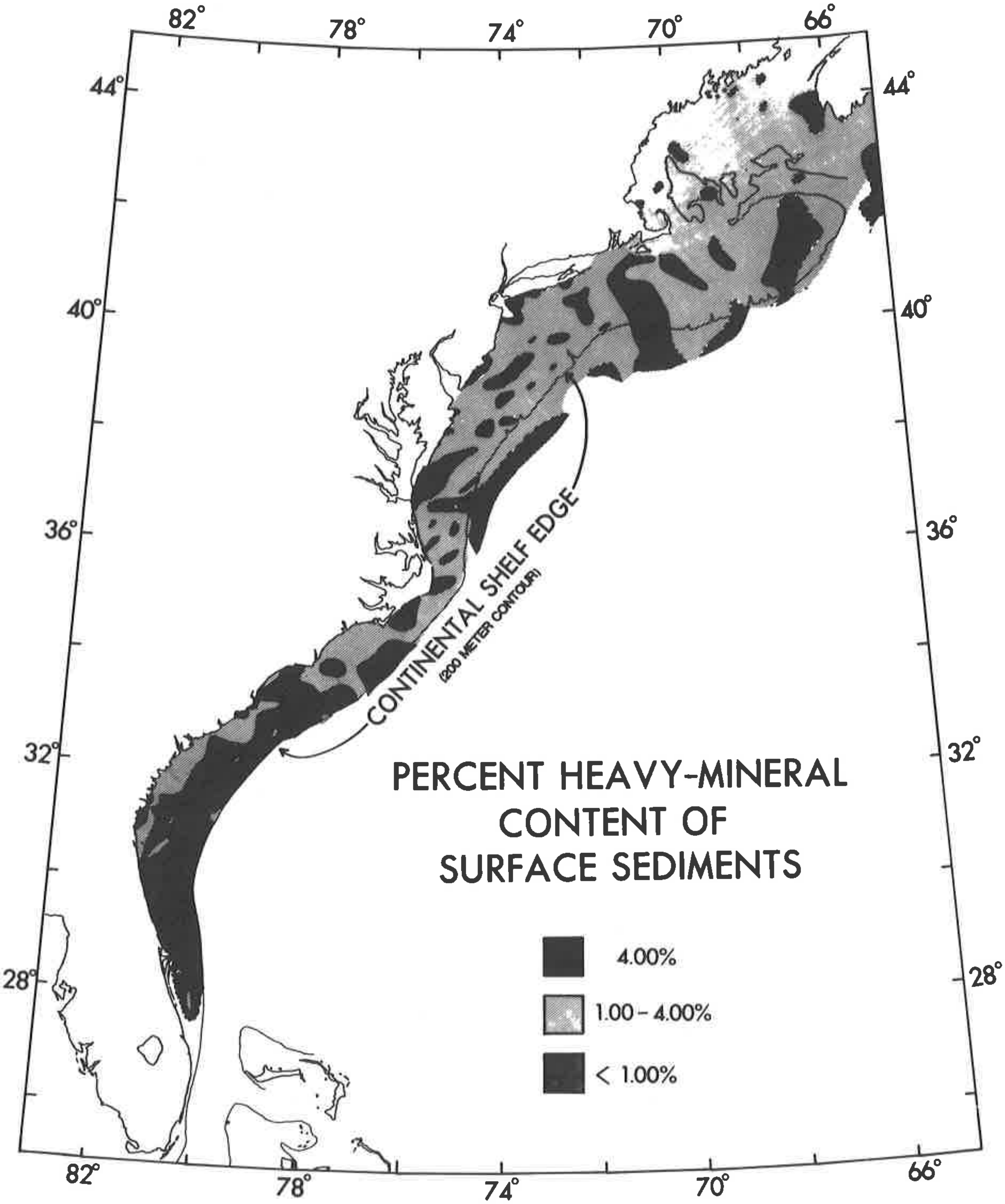

Figure 3.—Distribution of heavy minerals in surficial sediments of the U.S. Atlantic Continental Shelf. From Grosz and others (1987).

May and June of 1964 and May of 1965. Sample sites are approximately on a 20-km grid (Figure 1) the precision of the sample locations is estimated to be within about 2 km. However, these samples may not accurately represent bulk ocean-floor sediments, because part of the fine-grained material may have been lost from coarse-grained or gravelly sediments during collection.

The 18 transect samples were collected during June of 1985 by the U.S. Geological Survey from the R/V John Wesley Powell by use of a Van Veen grab sampler. They were acquired during sampling transects made on probable former fluviodeltaic deposits of the Altamaha River at what appear to be shoreline deposits near the 10- and 20-m isobaths. The precision of the locations of these samples (Figure 2) is estimated to be within about 30 m of the reported coordinates. The samples probably accurately represent the upper 10 to 15 cm of ocean-floor sediment because complete closure of the sampling device (no loss of fines) was noted for each of the samples. Bulk samples of about 10 liters each were collected in single drops of the Van Veen grab sampler.

Samples from eight TACTS boreholes (sites A-H; Figure 1) were drilled for the U.S. Navy for foundation evaluation purposes. The TACTS drill cores do not represent continuous coverage of penetrated strata (about 100 m). Core materials exist in three forms: pint Mason jars of artificially consolidated material left from physical properties tests such as triaxial compressive strength; intact core sections of a few to about 33 cm in plastic tubes of 6.5 cm inner diameter; and bags of loose material, generally from near-surface sections. The 33 samples from the TACTS drill holes are widely spaced, are generally of small volume, and represent sediment shallower than 25.5 ft (7.8 m) (Pleistocene and Holocene) beneath the ocean floor. Lithologic descriptions and phosphorite pellet content of TACTS cores B, D, and H were given by Manheim and others (1989).

The 32 onshore borehole samples were provided by the Georgia Geologic Survey. Boreholes on Tybee and Skidaway Islands were drilled to 167 and 191 feet, respectively. Samples representing approximately every 5-foot interval were collected from the Tybee Island borehole to a depth of 86.5 feet and from the Skidaway Island borehole to a depth of 71 feet. Complete sample (core) recovery of a 5 foot section yielded between 11 and 23 kg of sediment depending on texture and water content. However, as shown by the bulk weights in Table 7 complete recovery was seldom achieved and in sample recovery was generally poor.

Laboratory procedures

Each of the 65 grid samples was split and sieved into three size classes: (1) gravel and very coarse sand (>16 mesh, >1.18 mm), (2) coarse to very fine sand (from <16 to >325 mesh, <1.18 ->0.045 mm), and (3) silt and clay (<325 mesh, <0.045 mm). The heavy-mineral fraction of the coarse to very fine sand fraction was separated with bromoform. After the ferromagnetic minerals were removed from heavy-mineral concentrates heavier than 1.9 g by using a hand-held magnet, the heavy-mineral concentrates were further separated into three magnetic subfractions on a Frantz Isodynamic Magnetic Mineral Separator (0.0 - 0.5, 0.5 - 1.0, and >1.0 A). Each of the four magnetic separates was weighed and studied microscopically by transmitted and reflected light. The identification of some minerals was also confirmed by X-ray diffraction. Comparison charts for the visual estimation of percentage composition (Terry and Chillingar, 1955) and point-counting were done to estimate mineral abundances in each magnetic subfraction. The identification of zircon and monazite was aided by using long- and short-wave ultraviolet illumination. Abundances of individual mineral species in each magnetic subfraction were summed and calculated as weight percentages of the total heavy-mineral fraction without compensation for differences in densities of individual mineral species. The lithologic descriptions, results of the mineralogic determinations, and textural and limited mineralogic data compiled by Hathaway (1971), are given in Tables 1, 2, and 3. The mineralogic analyses are incomplete with respect to heavy minerals in the gravel and very coarse sand and the silt and clay fractions. Phosphorite is probably the only heavy mineral of importance in the coarse fraction. Silt and clay contents are very low except in one sample where this fraction is 8 percent; thus any heavy mineral in this size fraction would not substantially alter the overall mineralogic makeup of the heavy-mineral assemblages.

For the 18 transect samples, the procedures were different from those used for the grid samples. Only a brief description is provided here as details are given in Grosz and others (1990). An approximately 12.5 kg sample was wet sieved through a 10-mesh U.S. Standard stainless steel sieve to remove the gravel fraction. The entire sand-silt-clay fraction was then processed through a three-turn spiral concentrator to preconcentrate the heavy minerals. Heavy minerals were recovered from the preconcentrate by use of acetylene tetrabromide and subsequently were separated into five magnetic subfractions (magnetic at 0.20, 0.40, 0.60, 1.80, and nonmagnetic at 1.80 A) on a Frantz Magnetic Barrier Laboratory Separator after removal of the ferromagnetic particles by use of a Frantz Isodynamic Mineral

Table 1.--Location coordinates and lithologic descriptions of the 65 grid surface grab samples from the Georgia shelf. [Data from Hathaway (1971). Lithologic descriptions are modified]

SAMPLE NUMBER	LONGITUDE (WEST)	LATITUDE (NORTH)	LITHOLOGIC DESCRIPTION
1483	-80.22500	32.33334	GRAY, CLEAN, WELL-SORTED FINE SAND WITH SHELL FRAGMENTS.
1484	-80.26834	32.16000	GRAY-GREEN, FINE TO MEDIUM SAND, WELL SORTED, ABUNDANT DARK MINERALS, SHELL HASH.
1485	-80.24667	31.98002	BROWNISH-GRAY-GREEN, FINE TO MEDIUM VERY SHELLY SAND, ABUNDANT DARK MINERALS.
1487	-80.46001	31.85002	LIGHT-GRAY, POORLY SORTED, MEDIUM TO COARSE CLEAN SAND, LUMPS OF GRAY CLAY.
1489	-80.75002	31.68335	LIGHT GRAY, FINE TO MEDIUM, UNIFORM SAND.
1490	-80.76668	31.49001	GRAY, CLEAN, MEDIUM SAND WITH MANY SHELL FRAGMENTS.
1491	-80.98835	31.51168	LIGHT-GRAY, WELL-SORTED, FINE SAND WITH MANY SHELL FRAGMENTS.
1492	-81.01667	31.34001	LIGHT-BROWN, MEDIUM SAND, WITH APPRECIABLE MATERIAL IN FINE AND VERY COARSE SIZES.
1494	-80.99669	30.99169	LIGHT-BROWN, MEDIUM TO COARSE, CLEAN SAND. WORM TUBES, MANY SHELL FRAGMENTS.
1495	-81.22500	30.99169	LIGHT-GRAY, MEDIUM TO COARSE, CLEAN SAND WITH SHELLS.
1496	-81.22334	30.83502	BROWN, VERY FINE, UNIFORM SAND.
1497	-81.00000	30.83335	LIGHT-GRAY, MEDIUM TO COARSE, QUARTZ SAND WITH FEW SHELLS.
1498	-81.00333	30.67001	GRAY, FINE SAND, CLEAN AND WELL SORTED, WITH SHELL FRAGMENTS.
1499	-81.22834	30.66001	BROWN, VERY FINE SAND, WITH MUD BALLS OF VERY SOFT BLACK CLAY AND SILT.
1500	-81.25501	30.49334	LIGHT-GREENISH-GRAY, MEDIUM TO COARSE SAND WITH BLACK SILTY LUMPS, SHELL FRAGMENTS.
1501	-81.00000	30.48334	GRAY-GREEN, FINE SAND WITH SHELL FRAGMENTS.
1660	-79.96669	31.16834	BROWN, WELL-SORTED, CLEAN, COARSE, QUARTZ SAND.
1661	-80.00667	31.32667	LIGHT-GRAY, CLEAN, MEDIUM TO COARSE, QUARTZ SAND.
1663	-79.99502	31.67835	LIGHT-BROWNISH-GRAY, MEDIUM TO COARSE SAND.
1664	-80.24334	31.67335	LIGHT-BROWN TO YELLLOW-GRAY, MEDIUM TO COARSE SAND, SOME SHELL FRAGMENTS.
1665	-80.51001	31.68501	MEDIUM QUARTZ SAND.
1666	-80.34167	31.85002	MEDIUM QUARTZ SAND.
1667	-80.19167	31.84002	LIGHT-GRAY, MEDIUM SAND WITH SHELL FRAGMENTS.
1668	-80.01833	31.82335	LIGHT-BROWNISH-GRAY COARSE SAND WITH SHELLS.
1669	-79.98002	32.00833	GREEN-GRAY, VERY COARSE CLEAN SAND, SHELL FRAGMENTS, GLAUCONITE, HEAVY MINERALS.
1675	-80.32501	32.22500	GRAY, WELL-SORTED, FINE SAND.
1676	-80.47334	32.12667	GRAY, WELL SORTED, FINE SAND.
1677	-80.62001	31.94835	GRAY-GREEN, MEDIUM TO FINE SAND.
1678	-80.77168	31.34001	GRAY, COARSE SAND, SOME SHELLS.
1679	-80.76002	31.16000	LIGHT-GRAY, FINE SAND.
1680	-80.74668	31.00000	FINE, WELL-SORTED SAND, PELECYPODS.
1681	-80.75002	30.83002	FINE TO COARSE SAND, 20 % SHELL FRAGMENTS.
1682	-80.78668	30.66668	GRAY, FINE TO COARSE SAND, SOME SHELLS, ABUNDANT HEAVY MINERALS.
1683	-80.73335	30.49668	GRAY, FINE TO MEDIUM SAND, SHELLS, FORAMS.
1698	-80.47834	30.49168	GRAY-GREEN SAND WITH 20 % SHELL FRAGMENTS.
1699	-80.49668	30.66668	FINE SAND WITH BLACK SPECKS.
1700	-80.49668	30.83335	MEDIUM TO COARSE CLEAN SAND.
1701	-80.49168	31.00333	BROWN TO GRAY, FINE TO COARSE, QUARTZ SAND.
1702	-80.53334	31.18667	BROWN, MEDIUM TO VERY COARSE SAND.
1704	-80.50001	31.51334	GRAY-GREEN, MEDIUM TO COARSE SAND.
1705	-80.27501	31.50168	GREEN, FINE TO COARSE SAND.
1706	-80.23167	31.33334	LIGHT-GRAY, WELL SORTED, MEDIUM TO COARSE CLEAN SAND.
1707	-80.21000	31.15667	LIGHT-GRAY-BROWN, FINE TO COARSE, CLEAN SAND.
1708	-80.25001	31.00000	BROWN, FINE SAND.

Table 1.--Continued.

SAMPLE NUMBER	LONGITUDE (WEST)	LATITUDE (NORTH)	LITHOLOGIC DESCRIPTION
1709	-80.25501	30.83335	COARSE SAND WITH PHOSPHATE ROCK AND SHELLS.
1710	-80.22500	30.67501	TAN SHELL HASH, 60 %, WITH FINE, BROWN SAND, 40 %.
1711	-80.22834	30.49668	TAN SAND, WITH SHELL HASH.
1751	-79.77002	31.49834	GREEN, MEDIUM, CLEAN SAND, ABUNDANT HEAVY MINERALS.
1754	-79.75335	31.65668	LIGHT-GRAY MEDIUM TO COARSE, CLEAN QUARTZ SAND.
1755	-79.75668	31.83168	LIGHT-BROWNISH-GRAY, COARSE TO VERY COARSE, WELL SORTED, CLEAN QUARTZ SAND.
1758	-79.75335	31.99502	BROWNISH-GREEN, MEDIUM SAND WITH SOME SHELLS.
2280	-81.28167	31.09667	MEDIUM OLIVE GRAY, VERY WELL SORTED, VERY FINE CLEAN SAND, 1 % SHELL FRAGMENTS.
2281	-81.31501	30.93002	VERY WELL SORTED, VERY FINE SAND, FEW (<1%) SHELL FRAGMENTS, UPPER 3-4 CM MEDIUM OLIVE GRAY, MEDIUM BLACK-GRAY BELOW.
2282	-81.36834	30.81168	MEDIUM-OLIVE-GRAY, WELL SORTED SILT OR VERY FINE SAND, FEW SHELL FRAGMENTS.
2283	-81.40501	30.64335	WELL-SORTED, VERY FINE SAND, FEW SMALL SHELL FRAGMENTS, SOME LARGE, UPPER 4 CM MEDIUM OLIVE GRAY, GRAY BELOW.
2288	-81.18667	31.24167	LIGHT-OLIVE-GRAY, MEDIUM SORTED, MEDIUM SAND.
2289	-81.19667	31.32501	LIGHT-OLIVE-GRAY, WELL-SORTED, VERY FINE SILTY SAND, SOME SHELL FRAGMENTS.
2290	-81.06500	31.52001	LIGHT-OLIVE-GRAY, MODERATELY WELL SORTED, FINE SAND, FEW SHELL FRAGMENTS.
2291	-81.02167	31.67835	LIGHT-GRAY, WELL-SORTED, VERY FINE SAND.
2292	-80.89002	31.76502	MEDIUM SAND, MEDIUM-GOOD SORTING.
2293	-80.87335	31.86835	DARK GRAY, CLAYEY SANDY SILT.
2294	-80.75168	31.97169	DARK-GREENISH-GRAY, POORLY SORTED, COARSE SAND, MANY SHELLS, APPROACHING SHELL HASH.
2295	-80.62501	32.08500	WELL-SORTED, FINE SAND.
2296	-80.45001	32.26167	LIGHT-OLIVE-GRAY, MEDIUM TO WELL SORTED, FINE SAND.
2297	-80.22167	32.46668	LIGHT-GREENISH-GRAY, WELL-SORTED, FINE, QUARTZ SAND.

Table 2.--Water depth, sampling equipment, texture, carbonate content, and gamma radiation activity data for the 65 surface grab samples from the Georgia shelf. [Sampling equipment: 1, Campbell grab with camera; 2, Campbell grab without camera; 5, Van Veen grab. NA, not applicable, not separated; ND, not determined; HM, heavy minerals; CPM/g, counts per minute per gram. Gravel, sand, silt, clay, CPM/g, and carbonate data from Hathaway (1971)]

SAMPLE NUMBER	WATER DEPTH (m)	SMPL EQPT TYPE	GRAVEL >2.00 mm (%)	SAND 2.00 TO 0.0625 mm (%)	SILT 0.0625 TO 0.0039 mm (%)	CLAY <0.0039 mm (%)	BULK WT (g)	WT % >16 MESH	WT % <16->325 MESH	WT % <325 MESH	NUMBER OF SIZE MODES	MEAN SIZE (mm)	WT % HM IN WHOLE SAMPLE	WT % HM IN CARBONATE-FREE SAMPLE	WT % F. MAG.	WT % 0-.5A	WT % .5-1A	WT % >1.0A	GAMMA ACTIVITY (CPM/g)	WT % CARBONATE OF SAND
1483	13	2	0.0	100.0	0.0	0.0	252.6	4.8	95.2	0.0	1	0.19	2.13	2.37	11.98	6.65	49.43	31.94	1.60	10.24
1484	15	2	0.0	100.0	0.0	0.0	272.2	7.3	92.7	0.0	1	0.27	1.90	2.86	18.43	13.14	27.45	40.98	ND	33.48
1485	21	2	0.0	100.0	0.0	0.0	238.6	3.5	96.5	0.0	1	0.26	0.58	0.71	NA	NA	NA	NA	0.80	18.11
1487	18	2	0.0	100.0	0.0	0.0	254.8	8.1	91.9	0.0	1	0.35	1.13	1.36	2.81	13.33	33.33	50.53	ND	17.20
1489	17	2	0.0	100.0	0.0	0.0	257.3	4.8	95.2	0.0	1	0.27	1.71	1.81	5.09	19.68	44.44	30.79	ND	5.69
1490	20	2	0.0	100.0	0.0	0.0	231.6	2.8	97.2	0.0	3	0.30	1.14	1.26	0.38	8.78	24.81	66.03	0.95	9.48
1491	13	2	0.0	100.0	0.0	0.0	242.7	13.3	86.7	0.0	1	0.32	1.25	1.39	9.97	15.28	34.55	40.20	ND	10.22
1492	15	2	0.0	100.0	0.0	0.0	221.1	16.0	84.0	0.0	1	0.49	0.38	0.40	NA	NA	NA	NA	0.34	5.01
1494	19	2	0.0	100.0	0.0	0.0	292.1	17.0	83.0	0.0	1	0.37	0.88	0.90	18.75	26.56	21.48	33.20	1.65	2.39
1495	16	2	0.0	100.0	0.0	0.0	249.2	6.6	93.3	0.1	1	0.45	0.17	0.19	NA	NA	NA	NA	ND	10.20
1496	15	2	0.0	100.0	0.0	0.0	276.4	0.2	99.8	0.0	1	0.14	2.42	2.51	5.74	24.02	40.79	29.46	2.06	3.42
1497	18	2	0.0	100.0	0.0	0.0	251.1	3.3	96.7	0.0	1	0.27	0.71	0.75	0.58	58.48	11.70	29.24	ND	5.34
1498	20	2	0.0	100.0	0.0	0.0	238.3	1.0	99.0	0.0	1	0.19	0.79	0.85	0.58	64.33	11.70	23.39	0.77	6.93
1499	19	2	0.0	100.0	0.0	0.0	187.1	1.1	98.9	0.0	1	0.13	1.85	1.97	2.33	26.16	46.51	25.00	ND	6.25
1500	17	2	0.0	100.0	0.0	0.0	207.0	5.7	94.3	0.0	1	0.34	0.48	0.54	5.43	41.30	10.33	42.93	0.48	11.41
1501	26	2	0.0	99.0	1.0	0.0	253.4	1.9	98.0	0.1	1	0.22	1.52	1.86	3.98	14.59	24.93	56.50	ND	18.09
1660	46	2	1.0	99.0	0.0	0.0	255.3	8.5	91.5	0.0	1	0.44	1.09	1.19	8.24	26.97	48.69	16.10	0.82	8.31
1661	41	2	0.0	100.0	0.0	0.0	241.0	1.0	99.0	0.0	1	0.38	0.33	0.35	NA	NA	NA	NA	0.22	6.12
1663	36	5	0.0	100.0	0.0	0.0	244.7	5.9	94.1	0.0	1	0.36	0.48	0.51	0.94	84.91	4.72	9.43	0.33	5.63
1664	28	5	0.0	100.0	0.0	0.0	301.0	6.1	93.9	0.0	1	0.43	0.70	0.73	3.85	24.04	60.58	11.54	0.37	3.94
1665	20	5	0.0	100.0	0.0	0.0	208.2	4.5	95.5	0.0	1	0.26	1.23	1.35	4.82	20.88	46.59	27.71	ND	8.92
1666	20	5	0.0	100.0	0.0	0.0	242.6	3.9	96.1	0.0	1	0.41	0.34	0.36	NA	NA	NA	NA	0.80	5.11
1667	22	5	0.0	100.0	0.0	0.0	274.2	15.8	84.2	0.0	1	0.40	0.92	1.04	10.53	12.15	24.29	53.04	1.58	11.19
1668	30	5	1.5	98.5	0.0	0.0	211.1	25.4	74.6	0.0	1	0.55	0.77	0.82	NA	NA	NA	NA	0.70	6.42
1669	27	5	0.0	100.0	0.0	0.0	242.9	9.7	90.3	0.0	1	0.43	0.54	0.62	NA	NA	NA	NA	0.35	12.44
1675	14	1	0.0	100.0	0.0	0.0	243.1	0.7	99.3	0.0	1	0.19	2.02	2.15	5.02	24.69	47.28	23.01	ND	6.00
1676	14	1	0.0	100.0	0.0	0.0	220.4	0.8	99.2	0.0	1	0.19	1.43	1.53	8.52	19.24	42.90	29.34	0.91	6.68
1677	17	1	0.0	100.0	0.0	0.0	249.1	3.6	96.4	0.0	1	0.31	1.28	1.44	3.72	18.58	47.68	30.03	ND	11.13
1678	22	1	0.0	100.0	0.0	0.0	252.1	12.5	87.5	0.0	1	0.49	0.74	0.80	0.53	32.62	13.37	53.48	ND	7.49
1679	19	1	0.0	100.0	0.0	0.0	255.0	5.9	94.1	0.0	1	0.36	0.58	0.61	2.03	50.00	11.49	36.48	0.41	5.04
1680	24	1	0.0	100.0	0.0	0.0	230.5	2.7	97.3	0.0	1	0.20	1.36	1.51	8.21	17.20	28.66	45.93	1.06	9.71
1681	24	1	0.0	100.0	0.0	0.0	218.8	12.6	87.4	0.0	1	0.38	0.84	0.96	1.65	40.98	13.11	44.26	0.68	12.67
1682	26	1	0.0	100.0	0.0	0.0	213.4	8.8	91.2	0.0	1	0.36	1.02	1.16	0.53	11.23	56.15	32.09	0.65	11.81
1683	32	1	0.0	100.0	0.0	0.0	253.8	3.2	96.8	0.0	1	0.21	0.57	0.69	2.08	57.64	11.81	28.47	0.74	17.82
1698	35	1	0.0	100.0	0.0	0.0	262.3	3.5	96.5	0.0	1	0.37	0.26	0.33	1.45	52.17	17.39	28.99	0.32	21.43
1699	38	1	0.0	100.0	0.0	0.0	217.8	11.8	88.2	0.0	1	0.40	0.78	1.01	1.78	47.93	14.79	35.50	0.50	22.88
1700	33	1	0.0	100.0	0.0	0.0	232.3	4.8	95.2	0.0	1	0.37	0.87	0.98	9.64	13.20	35.53	41.62	0.43	11.55
1701	31	1	0.0	100.0	0.0	0.0	285.2	10.9	89.1	0.0	1	0.40	0.88	0.97	9.54	11.20	33.61	45.64	0.58	9.69
1702	31	1	0.0	100.0	0.0	0.0	249.1	10.6	89.4	0.0	1	0.37	0.33	0.36	3.66	73.17	6.10	17.07	0.30	7.82
1704	24	1	0.0	100.0	0.0	0.0	260.5	7.6	92.4	0.0	1	0.41	0.74	0.79	1.56	69.43	10.88	18.13	0.41	6.52
1705	32	1	0.0	100.0	0.0	0.0	244.3	6.4	93.6	0.0	1	0.40	0.34	0.35	3.62	75.90	8.43	12.05	0.34	3.56
1706	36	1	0.0	100.0	0.0	0.0	213.8	5.6	94.4	0.0	1	0.35	0.94	1.01	13.57	20.60	45.23	20.60	0.40	7.10
1707	36	2	0.0	100.0	0.0	0.0	192.5	13.1	86.9	0.0	1	0.48	0.31	0.32	8.48	66.10	8.47	16.95	0.35	4.34
1708	36	2	0.0	100.0	0.0	0.0	193.0	2.6	97.4	0.0	1	0.44	0.42	0.44	3.66	74.39	7.32	14.63	0.30	5.56

Table 2.--Continued.

SAMPLE NUMBER	WATER DEPTH (m)	SMPL EQPT TYPE	GRAVEL >2.00 mm (%)	SAND 2.00 TO 0.0625 mm (%)	SILT 0.0625 TO 0.0039 mm (%)	CLAY <0.0039 mm (%)	BULK WT (g)	WT % >16 MESH	WT % <16->325 MESH	WT % <325 MESH	NUMBER OF SIZE MODES	MEAN SIZE (mm)	WT % HM IN		WT % F. MAG.	WT % 0-.5A	WT % .5-1A	WT % >1.0A	GAMMA ACTIVITY (CPM/g)	WT % CARBONATE OF SAND
													WHOLE SAMPLE	CARBONATE-FREE SAMPLE						
1709	37	2	0.0	100.0	0.0	0.0	186.9	11.7	88.3	0.0	1	0.26	0.44	0.54	3.66	78.05	4.88	13.41	0.35	18.97
1710	42	2	0.0	100.0	0.0	0.0	171.6	9.3	90.7	0.0	1	0.30	0.23	0.37	2.56	48.72	5.13	43.59	0.24	38.51
1711	43	2	0.0	100.0	0.0	0.0	245.6	11.1	88.9	0.0	3	0.54	0.31	0.53	0.69	7.48	36.73	55.10	0.32	42.04
1751	64	2	0.0	99.0	1.0	0.0	223.7	2.5	97.4	0.1	1	0.31	0.29	0.32	NA	NA	NA	NA	0.21	9.10
1754	45	2	0.0	100.0	0.0	0.0	203.7	0.6	99.4	0.0	1	0.39	0.28	0.30	NA	NA	NA	NA	0.28	5.71
1755	40	2	0.0	100.0	0.0	0.0	215.6	13.3	86.7	0.0	1	0.56	0.24	0.25	NA	NA	NA	NA	0.21	5.13
1758	32	2	0.0	100.0	0.0	0.0	269.2	4.8	95.2	0.0	1	0.40	0.49	0.53	NA	NA	NA	NA	0.36	7.14
2280	6	2	0.0	95.0	5.0	0.0	186.9	0.6	99.2	0.2	2	0.12	4.17	4.27	5.00	25.90	48.72	20.38	2.00	2.29
2281	7	2	0.0	93.0	7.0	0.0	182.7	2.0	97.6	0.4	2	0.14	4.28	4.41	7.16	28.90	37.98	25.96	4.83	3.02
2282	8	2	0.0	95.0	5.0	0.0	149.4	0.5	99.1	0.4	2	0.11	2.26	2.32	3.79	24.63	53.71	17.87	1.73	2.67
2283	8	1	8.0	90.0	2.0	0.0	323.0	9.0	90.8	0.2	2	0.15	2.03	2.09	1.23	23.66	46.56	28.55	0.51	2.81
2288	10	1	0.0	100.0	0.0	0.0	179.2	1.6	98.4	0.0	1	0.28	0.45	0.46	1.61	80.65	8.06	9.68	ND	2.30
2289	7	1	0.0	97.0	3.0	0.0	218.4	1.0	98.8	0.2	2	0.12	4.26	4.38	26.20	10.20	43.50	20.10	2.39	2.75
2290	9	1	0.0	100.0	0.0	0.0	196.6	4.6	95.2	0.2	2	0.22	1.17	1.26	20.09	9.82	40.63	29.46	ND	6.83
2291	8	1	0.0	92.0	8.0	0.0	198.0	0.4	99.3	0.3	1	0.10	3.84	4.09	27.89	8.82	48.55	14.74	1.80	6.08
2292	13	2	0.0	100.0	0.0	0.0	225.0	0.8	99.2	0.0	1	0.24	0.67	0.70	0.74	80.88	3.68	14.71	0.56	3.98
2293	9	2	0.0	94.0	6.0	0.0	139.6	0.0	92.0	8.0	2	0.15	3.15	3.33	27.10	6.50	46.34	20.05	2.10	5.27
2294	10	2	26.0	74.0	0.0	0.0	192.2	37.6	62.3	0.1	4	0.59	0.55	0.67	NA	NA	NA	NA	0.47	18.34
2295	8	2	0.0	100.0	0.0	0.0	147.2	0.2	99.8	0.0	1	0.14	2.62	2.68	21.04	15.84	41.30	21.82	1.19	2.17
2296	11	2	5.0	90.0	5.0	0.0	172.6	4.7	94.9	0.4	3	0.18	2.00	2.21	33.14	6.69	43.02	17.15	1.08	9.59
2297	11	2	0.0	100.0	0.0	0.0	202.1	1.4	98.6	0.0	1	0.17	3.95	4.13	18.68	18.56	37.11	25.65	3.20	4.35

Table 3.--Feldspar and heavy-mineral data for the 65 surface grab samples from the Georgia shelf. [SG, specific gravity; T; trace, less than 0.1 %]

SAMPLE NUMBER	POTASSIUM FELDSPAR[1]	PLAGIOCLASE FELDSPAR[1]	TOTAL FELDSPAR[1]	ILMENITE	MAGNETITE	GARNET	STAUROLITE	EPIDOTE	PYROBOLES[2]	ALUMINO-SILICATES[3]	TOURMALINE	LEUCOXENE[4]
	AS A PERCENTAGE OF THE NON-CARBONATE 0.125-.250 mm FRACTION			EXPRESSED AS WEIGHT PERCENTAGES OF THE SG >2.85 FRACTION								
1483	5.0	8.0	13.0	27.0	1.3	0.9	2.8	20.1	9.9	10.5	6.9	6.3
1484	4.0	4.0	8.0	25.2	1.7	1.2	3.2	15.6	4.1	11.1	13.6	2.9
1485	4.0	2.0	6.0	44.0	1.0	T	3.0	15.0	5.0	7.0	15.0	5.0
1487	5.0	5.0	10.0	15.8	0.2	1.1	3.4	10.4	7.0	4.9	14.9	6.0
1489	6.0	4.0	10.0	20.0	0.3	0.7	4.3	19.4	5.9	11.3	7.7	2.6
1490	5.0	5.0	10.0	6.8	0.1	0.2	1.7	9.5	5.0	9.3	12.8	13.7
1491	3.0	3.0	6.0	19.9	1.2	1.1	3.8	14.1	8.5	9.5	5.7	4.7
1492	3.0	3.0	6.0	54.0	T	3.0	5.0	10.0	7.0	2.0	15.0	2.0
1494	6.0	2.0	8.0	36.7	0.8	2.4	4.4	10.4	3.2	9.6	5.4	3.0
1495	6.0	4.0	10.0	45.0	T	1.0	3.0	20.0	10.0	5.0	10.0	3.0
1496	8.0	2.0	10.0	16.0	1.6	1.3	4.7	20.5	13.0	12.7	3.7	3.8
1497	3.0	5.0	8.0	32.1	0.6	1.8	3.3	10.0	5.8	9.6	5.8	3.0
1498	3.0	3.0	6.0	20.0	0.7	1.3	2.3	18.0	16.3	8.7	4.7	1.7
1499	7.0	4.0	11.0	14.2	0.7	0.8	6.5	22.9	17.6	11.9	6.7	3.5
1500	3.0	3.0	6.0	17.9	0.5	2.2	3.1	20.0	2.9	7.2	7.5	4.7
1501	2.0	3.0	5.0	17.8	0.6	0.8	2.9	7.4	3.0	7.6	5.7	6.4
1660	5.0	5.0	10.0	26.8	1.1	6.0	12.2	16.0	3.2	4.2	8.4	3.9
1661	4.0	4.0	8.0	25.0	T	2.0	5.0	25.0	10.0	7.0	15.0	2.0
1663	4.0	2.0	6.0	26.4	0.9	2.5	6.3	31.5	8.5	4.6	5.1	1.7
1664	4.0	5.0	9.0	22.3	0.6	0.4	6.1	23.5	18.2	6.4	8.3	4.1
1665	4.0	5.0	9.0	11.0	0.7	1.1	5.1	24.1	17.1	10.6	6.8	3.2
1666	4.0	4.0	8.0	39.0	1.0	T	3.0	20.0	5.0	7.0	10.0	10.0
1667	2.0	2.0	4.0	12.2	0.7	1.7	5.0	13.6	7.9	6.0	4.5	10.9
1668	5.0	2.0	7.0	42.0	T	5.0	7.0	15.0	3.0	5.0	10.0	7.0
1669	4.0	3.0	7.0	34.0	T	5.0	7.0	15.0	7.0	10.0	7.0	10.0
1675	2.0	4.0	6.0	11.9	0.5	0.3	5.2	21.7	24.0	8.5	3.9	7.0
1676	4.0	2.0	6.0	14.1	0.6	0.4	4.0	20.5	18.4	10.1	4.5	5.9
1677	3.0	2.0	5.0	9.8	T	0.6	4.4	17.3	21.8	9.3	8.3	8.9
1678	3.0	1.0	4.0	6.1	0.3	1.6	2.3	6.7	1.0	2.9	3.6	9.0
1679	3.0	2.0	5.0	5.8	T	2.5	3.5	14.0	5.0	6.3	3.7	3.1
1680	5.0	2.0	7.0	10.5	0.4	0.6	4.1	9.2	13.8	6.8	7.9	9.9
1681	3.0	0.5	3.5	8.8	0.9	2.0	4.1	9.5	2.9	5.8	2.9	2.5
1682	2.0	0.5	2.5	9.6	T	0.6	4.7	12.4	7.3	3.9	6.3	6.0
1683	4.0	4.0	8.0	12.3	1.3	4.0	5.8	13.3	4.1	10.0	7.2	1.7
1698	5.0	3.0	8.0	5.9	0.6	2.6	8.0	12.4	2.8	7.2	2.9	7.8
1699	4.0	4.0	8.0	4.8	T	4.8	7.5	13.5	3.4	5.3	2.8	6.1
1700	3.0	3.0	6.0	12.3	0.1	0.9	5.0	12.6	11.0	2.7	4.8	12.9
1701	3.0	5.0	8.0	14.0	0.2	1.1	6.3	13.7	4.6	1.4	7.1	9.8
1702	3.0	1.0	4.0	7.9	0.9	7.5	5.2	18.4	11.1	13.3	7.7	2.0
1704	3.0	5.0	8.0	11.6	0.7	2.1	7.2	17.4	5.1	7.6	4.9	1.3
1705	5.0	3.0	8.0	10.6	0.9	1.6	11.5	16.3	11.8	10.2	6.3	1.6
1706	3.0	4.0	7.0	21.9	0.4	1.3	5.1	22.2	9.6	6.8	7.1	4.0
1707	3.0	1.0	4.0	17.0	1.6	3.5	7.3	21.8	6.8	9.0	4.2	1.7
1708	4.0	3.0	7.0	13.9	0.9	3.8	7.7	19.0	11.2	10.3	6.0	1.5

Table 3.--Continued.

SAMPLE NUMBER	POTASSIUM FELDSPAR[1]	PLAGIOCLASE FELDSPAR[1]	TOTAL FELDSPAR[1]	ILMENITE	MAGNETITE	GARNET	STAUROLITE	EPIDOTE	PYROBOLES[2]	ALUMINO-SILICATES[3]	TOURMALINE	LEUCOXENE[4]
	AS A PERCENTAGE OF THE NON-CARBONATE 0.125-.250 mm FRACTION			EXPRESSED AS WEIGHT PERCENTAGES OF THE SG >2.85 FRACTION								
1709	3.0	1.0	4.0	18.5	1.7	5.5	8.0	22.7	7.9	10.4	4.3	1.7
1710	2.0	2.0	4.0	5.3	0.1	1.5	5.0	21.0	4.9	29.2	3.5	4.1
1711	4.0	4.0	8.0	1.7	T	0.5	2.2	3.9	1.6	33.5	2.2	5.7
1751	4.0	4.0	8.0	34.0	T	2.0	3.0	15.0	7.0	5.0	15.0	15.0
1754	5.0	5.0	10.0	28.0	T	3.0	5.0	25.0	5.0	7.0	20.0	5.0
1755	4.0	3.0	7.0	33.0	T	3.0	5.0	30.0	3.0	7.0	15.0	3.0
1758	6.0	5.0	11.0	31.0	T	3.0	7.0	25.0	5.0	10.0	10.0	5.0
2280	3.0	2.0	5.0	12.2	1.1	0.9	5.3	27.6	21.3	11.7	5.5	4.7
2281	4.0	3.0	7.0	12.1	0.3	0.9	4.3	20.2	25.5	15.0	5.3	3.4
2282	4.0	2.0	6.0	5.6	0.9	T	2.8	24.7	34.1	14.2	5.3	3.4
2283	2.0	1.0	3.0	15.0	T	4.5	1.0	35.0	12.0	21.0	2.5	0.5
2288	6.0	3.0	9.0	13.9	T	0.8	2.9	20.3	34.1	10.7	2.5	0.2
2289	9.0	5.0	14.0	9.1	0.5	0.6	3.5	25.3	23.5	16.5	3.6	6.6
2290	5.0	4.0	9.0	15.9	0.5	0.9	2.8	22.6	15.4	10.2	4.7	4.5
2291	6.0	5.0	11.0	15.7	2.0	0.3	2.6	23.0	20.4	18.5	2.4	5.9
2292	7.0	5.0	12.0	17.8	0.8	2.4	4.1	24.3	20.5	8.1	4.2	1.8
2293	ND	ND	ND	22.2	0.4	0.4	2.5	10.9	23.5	16.8	3.0	13.3
2294	4.0	5.0	9.0	27.0	1.0	3.0	5.0	25.0	5.0	7.0	20.0	3.0
2295	6.0	5.0	11.0	19.9	0.6	0.6	4.4	15.4	19.7	11.7	4.7	6.6
2296	10.0	5.0	15.0	15.9	1.0	0.4	5.0	19.7	21.1	10.1	4.3	8.0
2297	8.0	5.0	13.0	13.1	1.3	1.1	6.0	15.4	23.8	14.8	4.4	7.2

Table 3.--Continued.

SAMPLE NUMBER	RUTILE	ZIRCON	MONAZITE	PHOSPHORITE	OTHERS[5]	WT % EHM/C[6]	WT % EHM/T[7]	WT % EHM/T CARBONATE-FREE[8]	WT % LABILES[9]	ZTR INDEX[10]	ILMENITE/ LEUCOXENE
	------EXPRESSED AS WEIGHT PERCENTAGES------ OF THE SG >2.85 FRACTION										
1483	T	0.3	0.5	11.2	2.3	44.6	0.95	1.06	32.2	13.9	4.3
1484	T	0.4	0.3	20.4	0.3	39.9	0.76	1.14	22.6	28.3	8.7
1485	T	T	T	2.0	3.0	56.0	0.32	0.39	21.0	33.3	8.8
1487	T	T	0.7	35.6	T	27.4	0.31	0.37	18.7	35.1	2.6
1489	T	0.3	1.3	26.2	T	35.5	0.61	0.65	26.3	15.7	7.7
1490	T	T	0.7	40.2	T	30.5	0.35	0.39	14.8	32.7	0.5
1491	1.2	1.2	1.0	28.1	T	37.5	0.47	0.52	24.9	17.6	4.2
1492	T	T	T	T	2.0	58.0	0.22	0.23	20.0	35.7	27.0
1494	1.7	10.0	1.7	10.7	T	62.7	0.55	0.56	16.8	35.0	12.2
1495	T	T	T	T	3.0	53.0	0.09	0.10	31.0	20.4	15.0
1496	2.1	0.9	3.5	16.2	T	39.0	0.94	0.97	36.4	10.7	4.2
1497	0.9	0.6	T	26.5	T	46.2	0.33	0.35	18.2	19.3	10.7
1498	0.7	0.2	T	24.8	0.6	31.3	0.25	0.27	36.3	10.7	11.8
1499	0.8	0.5	1.4	10.7	1.8	32.3	0.60	0.64	42.0	11.6	4.1
1500	0.9	T	T	32.7	0.4	30.7	0.15	0.17	25.6	19.2	3.8
1501	T	2.8	0.7	42.5	1.8	35.3	0.54	0.66	11.8	27.5	2.8
1660	0.3	0.5	1.5	15.9	T	37.2	0.41	0.45	26.3	17.6	6.9
1661	T	T	T	5.0	4.0	34.0	0.11	0.12	37.0	23.4	12.5
1663	0.7	0.5	T	11.3	T	33.9	0.16	0.17	43.4	10.6	15.5
1664	1.2	0.3	1.2	7.4	T	35.5	0.25	0.26	42.7	14.9	5.4
1665	0.3	0.8	1.4	17.7	0.1	27.3	0.34	0.37	43.0	11.7	3.4
1666	T	T	T	3.0	2.0	56.0	0.19	0.20	26.0	22.2	3.9
1667	T	1.1	0.7	35.7	T	30.9	0.28	0.32	23.9	13.8	1.1
1668	T	T	T	3.0	3.0	54.0	0.42	0.45	23.0	22.2	6.0
1669	T	T	T	2.0	3.0	54.0	0.29	0.33	27.0	13.7	3.4
1675	0.2	1.2	0.9	14.5	0.2	29.7	0.60	0.64	46.5	8.0	1.7
1676	0.6	1.3	2.1	16.8	0.7	34.1	0.49	0.52	39.9	10.3	2.4
1677	T	0.3	1.4	17.6	0.3	29.7	0.38	0.43	39.7	13.6	1.1
1678	T	T	T	66.5	T	18.0	0.13	0.14	9.6	19.9	0.7
1679	T	T	1.5	54.5	0.1	16.7	0.10	0.11	21.5	10.1	1.9
1680	0.9	0.5	1.4	32.9	1.1	30.0	0.41	0.46	24.0	20.6	1.1
1681	T	3.1	2.0	54.2	1.3	22.2	0.19	0.22	15.3	18.6	3.5
1682	0.6	T	1.7	46.8	0.1	21.8	0.22	0.25	20.3	18.4	1.6
1683	2.0	2.0	4.0	28.1	4.2	32.0	0.18	0.22	22.7	21.4	7.2
1698	T	0.9	5.2	43.7	T	27.0	0.07	0.09	18.4	9.0	0.8
1699	T	1.8	2.4	46.5	1.1	20.4	0.16	0.21	21.7	11.1	0.8
1700	T	T	2.5	35.2	T	30.4	0.26	0.29	24.6	12.2	1.0
1701	T	T	1.0	40.8	T	26.2	0.23	0.25	19.6	20.2	1.4
1702	1.8	1.2	5.6	17.3	0.1	31.8	0.10	0.11	37.9	14.9	4.0
1704	0.5	0.9	3.8	36.9	T	25.7	0.19	0.20	25.3	12.7	8.9
1705	0.8	0.8	5.3	22.2	0.1	29.3	0.10	0.10	30.6	12.2	6.6
1706	0.6	0.4	2.3	18.1	0.2	36.0	0.34	0.37	33.5	14.6	5.5
1707	1.7	2.5	2.5	20.3	0.1	34.4	0.11	0.11	33.7	14.2	10.0
1708	1.6	3.1	6.3	14.7	T	36.7	0.15	0.16	34.9	15.5	9.3

Table 3.--Continued.

SAMPLE NUMBER	RUTILE	ZIRCON	MONAZITE	PHOSPHORITE	OTHERS[5]	WT % EHM/C[6]	WT % EHM/T[7]	WT % EHM/T CARBONATE-FREE[8]	WT % LABILES[9]	ZTR INDEX[10]	ILMENITE/ LEUCOXENE
	------EXPRESSED AS WEIGHT PERCENTAGES------ OF THE SG >2.85 FRACTION										
1709	1.0	0.7	6.0	11.2	0.4	38.3	0.17	0.21	37.8	9.0	10.9
1710	3.1	4.4	4.6	13.3	T	50.7	0.12	0.19	27.5	14.2	1.3
1711	2.8	1.7	2.4	32.6	9.2	47.8	0.15	0.26	6.0	13.2	0.3
1751	T	T	T	3.0	1.0	54.0	0.16	0.18	24.0	31.9	2.3
1754	T	T	T	T	2.0	40.0	0.11	0.12	33.0	30.8	5.6
1755	T	T	T	T	1.0	43.0	0.10	0.10	36.0	23.8	11.0
1758	T	T	T	1.0	3.0	46.0	0.23	0.25	33.0	16.7	6.2
2280	1.4	0.4	2.4	5.4	0.1	32.8	1.37	1.40	50.9	9.5	2.6
2281	1.8	0.8	1.1	9.0	0.3	34.2	1.46	1.50	46.9	10.5	3.6
2282	0.2	0.9	1.6	5.9	0.4	25.9	0.59	0.61	59.7	7.6	1.6
2283	2.0	3.0	T	3.0	0.5	41.5	0.84	0.86	51.5	9.3	30.0
2288	0.3	0.3	T	14.0	T	25.4	0.11	0.11	55.2	4.3	69.5
2289	0.6	0.4	2.2	7.1	0.5	35.4	1.51	1.55	49.9	6.0	1.4
2290	0.8	0.3	1.2	20.2	T	32.9	0.38	0.41	39.4	9.8	3.5
2291	0.3	0.4	1.4	6.7	0.4	42.2	1.62	1.73	45.7	4.5	2.7
2292	0.3	0.3	T	15.4	T	28.3	0.19	0.20	48.0	7.5	9.9
2293	0.5	0.3	0.4	4.5	1.3	53.5	1.69	1.79	35.2	6.5	1.7
2294	T	T	T	T	4.0	37.0	0.20	0.24	34.0	30.8	9.0
2295	1.5	1.1	0.8	12.2	0.8	41.6	1.09	1.11	36.3	12.2	3.0
2296	1.2	0.5	2.2	10.2	0.4	37.9	0.76	0.84	42.2	9.3	2.0
2297	0.5	1.3	1.1	9.6	0.4	38.0	1.50	1.57	41.6	9.1	1.8

[1] Modified from Hathaway (1971).

[2] Undifferentiated pyroxenes and amphiboles.

[3] Sillimanite, kyanite, and andalusite.

[4] Altered ilmenite.

[5] May include undifferentiated opaque minerals, non-opaque minerals, glauconite, mica, apatite, spinel, corundum, gahnite(?), quartz.

[6] EHM/C = the sum of the economic heavy minerals ilmenite + leucoxene (altered ilmenite) + rutile + zircon + monazite + aluminosilicates expressed as a percentage of the heavy-mineral fraction.

[7] EHM/T = the sum of the economic heavy minerals expressed as a percentage of the bulk sediment sample.

[8] EHM/T on a calcium-carbonate-free basis.

[9] Sum of the labile minerals magnetite + epidote + pyroboles expressed as a percentage of the heavy-mineral fraction.

[10] ZTR index = sum of the resistant minerals zircon + tourmaline + rutile expressed as a percentage of the non-opaque heavy minerals.

Separator modified to allow free-fall separation. Magnetic fractions of the transect samples were weighed and studied in the same manner as the magnetic fractions of the grid samples were.

Use of heavy liquids, if properly done, results in the recovery of almost all the heavy minerals in a sample, whereas spiral concentration does not. On average, about 85 percent of the heavy minerals in a sample are recovered by the spiral; minerals with poor hydrodynamic shapes such as pyroboles (undifferentiated pyroxenes and amphiboles) and micas, and those with lower densities, such as phosphorite, highly altered ilmenite, and glauconite, compose the bulk of the heavy mineral rejected by the spiral. Location, textural, and mineralogic data for the transect samples are given in Table 4.

The TACTS borehole samples were weighed and wet sieved through a 10-mesh U.S. Standard stainless steel screen (>2.00 mm) to remove the gravel fraction. The sand-silt-clay (<2.00 mm) fraction was repeatedly washed to decant the clay-size fraction; a small amount of silt may have been lost during this procedure. The heavy-mineral fraction of the sand-silt fraction was separated in acetylene tetrabromide. The separates were fractionated magnetically and analyzed optically in the same manner as the transect samples. Textural and mineralogic data for the TACTS samples are given in Table 5.

Samples from Skidaway and Tybee Islands were dried, weighed, and wet sieved through a 10-mesh sieve to remove the gravel fraction. The clay fraction was elutriated from the sand-silt fraction, and large samples were processed by the spiral/heavy-liquid process described for the transect samples. Smaller samples were processed in heavy liquid after clay removal. Heavy minerals were recovered in acetylene tetrabromide and then were magnetically fractionated and optically analyzed in the same manner as the transect samples. Textural and mineralogic data for the Skidaway and Tybee Island borehole samples are given in Table 6.

RESULTS

Texture

The surficial sediments on the Georgia shelf are predominantly unimodal and well-sorted sands (data in Hathaway, 1971). The sand-size fraction (2.00-0.0625 mm) in the grid samples ranges from 74 to 100 percent by weight (henceforth %) and averages about 99%; gravel and silt contents average 0.6% and 0.7%, respectively. The sand fraction is dominantly quartz, which averages about 90% (range from 67%-96%). The mean grain size of the surficial sediments is 0.31 mm (medium sand) in a range from 0.10 to 0.59 mm (very fine to coarse sand).

A trend of increasing grain size from inner to outer shelf is shown in Figure 4. A narrow belt of largely fine-grained sediment occurs in a zone (7 to 15 km wide; defined by the 0.2-mm contour) extending from near the Savannah River south to the St. Marys River, where it broadens about 50 km seaward. The zone extends north of the Savannah River also. Lobate seaward extensions of the fine-grained sediment zone are also located offshore of the Ogeechee and St. Marys Rivers; each has headwaters in the Coastal Plain. This pattern may reflect southward nearshore sediment dispersal. Coarse grained sediment trains (outlined by the 0.4-mm contour) extend due eastward from the Savannah and Altamaha Rivers and probably outline drowned ancestral river channels that spanned the shelf when sea level was near the shelf edge.

The change in sediment texture at the 11-m isobath is proposed by Pilkey (1963), Pilkey and Frankenberg (1964), and Bigham (1973) to be the modern/relict sediment boundary. Henry and Hoyt (1968) proposed the 15-m isobath as this boundary. If the lobes of fine-grained sediment are derived from the Savannah and Altamaha Rivers (Figure 4) then modern sediment is not limited to a narrow nearshore zone as suggested by Pilkey (1963), Neiheisel and Weaver (1967), and Bigham (1973). Neither is the boundary at Pilkey and Frankenberg's (1964) 11-m isobath, or Henry and Hoyt's (1968) 15-m isobath. Instead it is outlined by the 1.0% or 1.5% heavy-mineral isopleth of this study (Figure 7); both are irregularly shaped and range from water depths less than about 10 m to depths of about 26 m.

Carbonate content

Although the sediments are dominantly quartz, carbonate content, principally in the form of shells, shell fragments, foraminiferal tests, and phosphate rock, averages about 10% of the sand-size fraction. The gravel fraction is composed entirely of carbonate. A general increase in carbonate content of the sand-size fraction with water depth is evident in Figure 5. The high carbonate content (exceeding 16%) at the 40-m isobath near the St. Marys River may represent an area of high shell productivity, but the presence of phosphate rock in the sample suggests that carbonate-rich Miocene(?) outcrops may be present at or near the surface in this area.

Feldspar content

The total feldspar content of the sand fraction of the sediments averages about 8% (ranges from about 3% to

Table 4.--Location coordinates, water depth, gravel content, and heavy-mineral data for the transect surface grab samples from the Georgia shelf. [Column heads as in Table 3]

SAMPLE NUMBER	LONGITUDE (WEST)	LATITUDE (NORTH)	WATER DEPTH (m)	BULK WEIGHT (g)	WT % GRAVEL >2.0mm	WEIGHT % RHM	WT % ILMENITE	WT % MAGNETITE	WT % GARNET	WT % STAUROLITE	WT % EPIDOTE	WT % PYROBOLES
1316	-81.15600	31.18450	5.8	10559	2.9	0.37	34.1	0.7	1.4	4.5	16.8	6.0
1317	-81.15717	31.18050	5.4	12392	3.9	0.51	16.4	0.1	0.6	4.9	17.9	5.7
1318	-81.16117	31.17917	6.8	14011	3.4	0.34	25.9	0.2	1.1	4.2	15.8	12.9
1320	-81.16434	31.17500	12.3	10190	2.6	0.73	33.2	0.0	1.4	4.9	13.3	6.6
1321	-81.17750	31.17284	6.7	12968	3.8	0.61	29.9	1.3	1.0	5.0	13.6	8.9
1322	-81.18767	31.16917	6.5	9561	2.1	0.67	21.5	1.3	1.4	5.5	19.8	10.5
1325	-81.18400	31.15667	5.0	11972	1.6	0.59	18.2	2.0	0.6	5.9	20.9	13.3
1326	-81.17517	31.16300	6.2	10718	2.7	0.70	27.3	0.9	0.9	4.5	11.5	6.6
1328	-81.17500	31.15134	5.0	10315	2.8	0.58	25.4	1.7	1.4	5.1	8.9	8.1
1329	-81.15167	31.15384	6.8	13286	4.0	0.19	29.0	0.8	1.7	6.6	7.2	11.0
1330	-80.80018	31.06733	16.7	13044	4.2	0.41	26.1	0.9	3.1	7.7	10.2	7.1
1332	-80.86252	31.09734	14.3	13204	3.6	0.29	23.8	1.1	3.5	5.7	8.5	9.5
1335	-80.83785	31.12967	14.3	14793	5.7	0.42	21.0	0.8	3.5	8.4	8.0	8.9
1337	-80.77735	31.12850	16.1	14555	3.8	0.29	23.6	0.7	3.2	11.0	10.8	7.7
1339	-80.76285	31.11567	20.0	13644	1.2	0.18	17.0	1.1	0.3	5.7	20.7	18.5
1341	-81.09334	31.38601	7.6	12064	0.7	0.57	19.4	0.8	0.4	8.6	13.2	5.6
1343	-81.03917	31.51401	5.0	14774	5.9	1.00	18.4	1.8	1.4	10.7	12.3	6.3
1345	-81.03117	31.61701	5.0	20216	0.9	3.27	21.2	3.2	1.7	4.4	11.1	8.7

SAMPLE NUMBER	WT % ALUMINO-SILICATES	WT % TOURMALINE	WT % LEUCOXENE	WT % RUTILE	WT % ZIRCON	WT % MONAZITE	WT % OTHERS	WT % EHM/C	WT% EHM/T	ILMENITE/ LEUCOXENE	ZTR INDEX	WT % LABILES
1316	25.9	6.4	2.5	0.7	0.3	T	0.9	63.4	0.23	13.5	11.9	24.8
1317	42.0	8.5	2.8	0.3	0.4	T	0.5	61.8	0.32	6.0	11.3	24.3
1318	28.2	6.2	1.0	3.5	0.3	T	0.7	59.0	0.20	25.9	13.9	29.9
1320	31.3	5.1	1.6	1.3	0.3	T	1.0	67.7	0.49	21.0	10.5	21.3
1321	31.9	4.3	2.4	1.2	0.3	T	0.3	65.6	0.40	12.6	8.7	24.8
1322	29.2	7.9	1.4	1.3	T	T	0.3	53.4	0.36	15.0	12.1	33.0
1325	27.0	9.0	1.4	1.5	T	0.0	0.2	48.1	0.28	12.9	13.4	36.8
1326	33.6	7.1	3.8	3.7	T	0.0	0.1	68.5	0.48	7.1	16.0	19.9
1328	28.5	8.7	6.7	4.5	0.3	0.1	0.5	65.6	0.38	3.8	20.7	20.1
1329	24.3	7.2	5.9	5.5	0.3	T	0.5	65.1	0.12	5.0	20.4	20.7
1330	21.6	11.3	7.5	3.9	0.3	0.4	0.1	59.7	0.24	3.5	23.7	21.2
1332	16.0	14.7	11.0	5.1	0.3	0.1	0.9	56.2	0.16	2.2	31.9	22.5
1335	16.7	18.0	9.2	4.1	0.3	0.4	0.9	51.7	0.22	2.3	32.9	21.2
1337	17.4	11.4	6.6	6.6	0.3	0.0	0.6	54.6	0.16	3.6	26.7	22.4
1339	13.9	15.8	5.6	1.0	0.1	T	0.5	37.5	0.07	3.1	22.3	40.4
1341	25.9	18.3	4.1	2.6	0.4	T	0.8	52.3	0.30	4.8	28.3	20.1
1343	7.5	32.6	5.4	2.5	0.1	0.4	0.7	34.3	0.34	3.4	47.8	21.7
1345	20.0	17.5	5.1	5.7	0.7	0.1	0.7	52.7	1.72	4.2	34.3	24.7

Table 5.--Texture and heavy-mineral content of the TACTS samples. [Heads as in Table 3 except: WT % HM, SG greater than 2.96; Fe-OXIDES, limonite-goethite]

SAMPLE NUMBER	DEPTH (m)	BORE-HOLE	SAMPLE INTERVAL (m) FROM	SAMPLE INTERVAL (m) TO	BULK WEIGHT (g)	WT % GRAVEL >10 MESH	WT % SAND+ SILT	WT % CLAY	WT % HM	WT % MAGNETITE	WT % ILMENITE	WT % GARNET	WT % PYROBOLES	WT % STAUROLITE
A3.2	3.2?	A	3.2	?	1520.1	28.8	54.2	17.0	0.12	17.1	6.2	1.9	7.1	2.4
A5.8	5.8	A	5.8	6.1	110.5	20.8	65.7	13.5	0.18	20.0	4.4	0.6	6.6	0.8
A8.5	8.5	A	8.5	9.1	1106.8	24.2	56.4	19.4	0.05	1.5	22.7	2.7	6.2	11.9
A16.1	16.1	A	16.1	16.8	1017.0	22.1	56.3	21.5	0.08	12.4	11.1	1.2	3.4	6.6
B3.2	3.2	B	3.2	?	652.9	5.1	87.0	7.9	1.39	0.8	9.9	2.2	12.5	8.5
B5.5	5.5	B	5.5	5.9	386.2	43.1	43.0	13.9	0.18	7.9	10.2	1.8	5.0	3.5
B12.2	12.2	B	12.2	12.4	222.6	4.0	87.4	8.5	0.22	2.0	17.8	2.0	17.4	1.7
C1.5	1.5	C	1.5	2.1	1732.1	4.5	95.0	0.5	0.70	1.3	17.7	1.6	24.4	3.7
C11.0	11.0	C	11.0	11.6	565.9	51.2	44.2	4.6	0.19	72.0	0.8	T	T	T
C17.7	17.7	C	17.7	17.9	640.8	0.0	3.4	96.6	0.02	49.5	T	T	0.5	0.5
D1.5	1.5	D	1.5	3.5	220.8	5.6	85.4	9.0	0.50	1.8	13.6	0.6	6.4	2.1
D9.4	9.4	D	9.4	9.6	1467.1	13.4	72.3	14.2	1.02	11.8	3.2	T	5.7	0.8
D10.8	10.8	D	10.8	?	482.9	17.4	58.4	24.2	0.31	56.0	2.1	0.2	2.4	0.4
E4.6	4.6	E	4.6	5.2	585.5	3.2	88.4	8.4	0.60	2.8	24.7	3.3	6.0	3.5
F3.4	3.4	F	3.4	<5.8	294.2	4.9	93.0	2.2	0.41	4.1	17.4	0.8	13.8	2.6
F5.8	5.8	F	5.8	?	601.4	5.4	85.2	9.5	0.28	6.1	20.8	1.2	7.3	3.3
F6.7	6.7	F	6.7	6.9	149.0	3.2	91.3	5.6	0.40	6.3	15.0	1.1	12.9	2.8
F10.1	10.1	F	10.1	<12.0	207.9	0.0	68.4	31.6	0.10	0.2	0.4	0.2	3.0	8.0
F12.0	12.0	F	12.0	12.4?	232.4	11.2	67.9	20.9	0.04	24.8	24.3	T	2.5	1.5
F18.9	18.9	F	18.9	<20.6	315.7	0.0	3.3	96.7	0.03	19.8	12.4	0.2	1.6	0.4
F20.6	20.6	F	20.6	<23.8	472.4	0.0	24.6	75.4	0.17	4.7	10.4	T	3.1	1.3
G0.9	0.9	G	0.9	2.5	292.7	3.1	90.1	6.7	0.51	1.7	20.5	0.4	6.3	3.7
G2.7	2.7	G	2.7	4.8	403.6	2.7	92.5	4.9	0.82	0.2	20.0	1.5	9.3	5.1
G5.0	5.0	G	5.0	<5.2	820.3	0.0	33.2	66.8	0.73	0.1	27.0	T	11.1	2.3
G5.6	5.6	G	5.6	6.3	234.9	12.8	53.4	33.8	0.51	0.6	29.8	4.7	5.0	3.9
G7.6	7.6	G	7.6	8.4	308.5	16.9	64.5	18.6	0.32	2.5	26.2	1.8	8.0	4.5
G8.5	8.5	G	8.5	11.2	310.0	24.3	66.5	9.2	0.39	5.0	24.6	2.5	6.3	3.0
G11.3	11.3	G	11.3	17.0	218.1	0.0	83.5	16.5	0.78	0.5	31.7	T	5.2	4.5
G17.1	17.1	G	17.1	19.7	184.7	0.0	85.7	14.3	0.65	6.6	28.8	T	2.7	4.8
G19.8	19.8	G	19.8	22.8	232.7	0.0	96.0	4.0	0.86	0.6	23.1	T	4.3	6.5
H1.2	1.2	H	1.2	?	948.6	1.6	96.7	1.7	0.53	1.5	13.9	2.5	5.5	6.1
H14.6	14.6	H	14.6	<15.8?	350.3	31.3	64.0	4.7	0.17	15.0	15.2	1.0	2.8	4.7
H18.9	18.9	H	18.9	25.5	115.5	18.4	64.8	16.7	0.26	30.0	3.0	T	4.7	2.0

Table 5.--Continued.

SAMPLE NUMBER	WT % ALUMINO-SILICATES	WT % LEUCOXENE	WT % EPIDOTE	WT % TOURMALINE	WT % MONAZITE	WT % RUTILE	WT % ZIRCON	WT % PHOS-PHORITE	WT % Fe-OXIDES	WT % OTHERS	WT % EHM/C	WT % EHM/T	ILMENITE/ LEUCOXENE	ZTR INDEX	WT % LABILES
A3.2	5.4	T	3.8	1.3	T	T	T	47.3	6.2	1.4	11.5	0.014	NA	5.9	34.6
A5.8	5.0	T	7.4	1.8	T	T	T	26.2	17.0	10.2	9.4	0.017	NA	8.1	26.9
A8.5	9.2	2.6	16.5	1.0	T	T	0.2	14.1	0.5	10.9	34.6	0.016	8.8	2.5	24.7
A16.1	12.0	15.3	7.7	0.8	T	T	T	24.1	0.8	4.7	38.4	0.030	0.7	2.6	34.8
B3.2	9.9	1.6	19.3	1.2	0.1	0.2	0.2	23.8	0.2	9.6	21.9	0.305	6.4	3.1	27.5
B5.5	4.1	0.3	12.7	2.9	T	0.6	0.6	39.5	0.2	10.6	15.8	0.029	39.2	13.3	35.4
B12.2	17.6	0.2	14.0	1.6	T	0.2	0.4	21.5	1.2	2.4	36.2	0.081	89.0	4.0	45.9
C1.5	14.2	0.1	18.7	1.7	T	0.1	0.8	14.1	T	1.7	32.9	0.232	147.6	3.9	72.0
C11.0	T	T	T	T	T	T	T	T	25.3	1.9	0.8	0.002	NA	N/A	50.0
C17.7	T	T	T	T	T	T	T	T	39.5	10.0	0.0	0.000	NA	0.0	25.6
D1.5	7.3	T	16.8	1.1	T	T	0.2	47.1	1.8	1.2	21.1	0.105	NA	3.8	34.2
D9.4	5.0	0.1	16.7	2.8	T	T	0.1	21.5	21.8	10.4	8.5	0.086	46.1	9.4	67.3
D10.8	3.8	0.1	8.8	0.6	T	T	T	6.0	15.9	3.8	6.0	0.019	19.5	3.8	44.0
E4.6	7.4	0.2	31.9	1.9	T	T	0.6	15.0	0.3	2.6	32.8	0.196	145.1	4.5	51.0
F3.4	14.3	0.6	32.3	3.3	T	T	0.1	9.5	T	1.1	32.3	0.132	27.6	5.0	44.4
F5.8	14.3	0.7	29.8	1.8	T	T	0.6	11.9	0.1	2.3	36.3	0.103	30.1	4.1	46.4
F6.7	11.8	T	26.2	1.2	T	T	0.8	15.8	0.1	6.1	27.7	0.111	NA	3.5	5.4
F10.1	2.5	T	2.0	2.0	T	T	T	11.5	11.7	58.6	2.9	0.003	NA	11.3	28.0
F12.0	T	T	0.8	2.5	T	T	T	10.0	33.8	0.0	24.3	0.010	NA	34.5	21.6
F18.9	6.0	T	T	0.8	T	T	T	8.4	36.0	14.4	18.4	0.006	NA	8.9	33.2
F20.6	20.1	0.9	25.4	1.6	T	T	0.5	11.1	15.9	5.0	32.0	0.054	11.0	4.0	39.6
G0.9	13.9	1.3	31.3	1.3	T	T	0.9	17.7	0.2	0.8	36.7	0.188	15.4	3.9	38.3
G2.7	13.0	0.8	27.4	1.1	T	T	0.9	16.8	0.5	3.7	34.7	0.283	24.4	3.3	36.3
G5.0	17.7	2.3	25.1	0.6	T	T	T	8.9	0.6	4.4	46.9	0.343	11.6	1.0	35.7
G5.6	11.8	6.4	25.4	0.7	T	T	0.4	10.6	0.8	T	48.4	0.247	4.6	2.1	38.5
G7.6	10.8	6.9	26.2	1.7	T	T	0.7	9.5	0.9	0.3	44.6	0.145	3.8	4.5	41.3
G8.5	6.1	0.3	27.5	1.4	T	T	0.6	20.3	1.6	0.8	31.5	0.122	98.3	4.2	32.1
G11.3	14.0	6.3	26.4	0.8	T	T	0.7	9.1	0.9	T	52.7	0.411	5.0	2.7	35.1
G17.1	9.4	12.9	25.7	0.8	T	T	0.2	7.3	0.7	T	51.3	0.333	2.2	2.3	37.5
G19.8	6.0	16.6	32.6	0.7	T	T	T	7.6	0.3	1.7	45.7	0.393	1.4	1.5	43.7
H1.2	18.5	1.4	34.2	1.2	T	T	0.5	14.2	0.1	0.6	34.2	0.180	10.2	2.4	47.7
H14.6	11.5	1.7	28.8	1.5	T	T	0.5	15.0	0.7	1.7	28.8	0.049	9.1	3.9	34.7
H18.9	T	T	T	T	T	T	T	T	1.0	59.3	3.0	0.008	N/A	0.0	0.0

Table 6.--Texture and heavy-mineral content of the Tybee (GAT prefix) and Skidaway Island (GAS prefix) borehole samples. [Column heads as in Tables 2, 3, and 5]

SAMPLE NUMBER	DEPTH INTER-VAL (ft)	BULK WEIGHT (g)	WT % GRAVEL	WT % CLAY	WT % HM	WT % ILMENITE	WT % GARNET	WT % PYROBOLES	WT % STAUROLITE	WT % ALUMINO-SILICATES	WT % EPIDOTE
GAT- 1	0-5	5044	1.2	ND	1.06	11.5	T	13.5	1.5	9.3	23.4
GAT- 2	5-10	5109	1.2	ND	0.86	11.3	1.8	14.1	2.8	7.9	43.0
GAT- 3	10-15	6568	1.2	ND	0.46	11.2	0.3	20.8	1.6	11.5	37.1
GAT- 4	15-20	7873	1.8	ND	0.49	7.2	0.2	27.1	1.7	8.0	34.3
GAT- 5	20-25	1343	3.0	ND	0.93	8.7	T	38.8	1.2	4.5	24.7
GAT- 6	25-31	578	14.5	63.9	0.81	3.8	T	18.4	T	19.2	29.2
GAT- 7	31-36	303	14.1	30.3	0.56	6.7	T	24.0	T	10.5	36.4
GAT- 8	36-41	388	5.5	11.1	0.98	7.0	T	22.3	T	7.5	41.2
GAT- 9	41-46	486	13.4	70.3	0.37	11.7	0.2	18.3	T	13.8	33.6
GAT-10	46-51	918	6.0	10.3	1.17	12.8	0.5	16.6	1.5	4.3	33.1
GAT-11	51-56	808	3.4	11.5	0.80	12.1	0.1	15.1	1.6	13.6	27.1
GAT-12	56-61	2135	2.6	ND	0.71	18.7	1.9	11.3	6.0	9.2	20.6
GAT-13	61-66	383	7.7	13.1	0.57	18.8	2.5	11.4	4.5	7.5	22.4
GAT-14	66-71	2425	2.4	ND	0.75	25.2	1.5	5.4	3.9	7.2	11.8
GAT-15	71-76	2943	4.6	ND	0.93	24.8	2.1	1.6	6.9	4.4	9.7
GAT-16	76-79	1755	14.8	ND	0.48	27.4	1.5	2.9	10.5	1.5	9.7
GAT-17	82.5-84	1076	1.9	17.4	0.17	24.8	1.9	0.4	12.5	5.0	11.3
GAT-18	84-86.5	1726	2.2	ND	0.15	22.9	1.6	0.3	8.9	7.7	10.5
GAS- 1	0-5	6849	0.3	ND	0.77	18.5	0.5	5.7	5.5	13.2	38.3
GAS- 2	5-10	22856	0.4	ND	0.70	18.7	0.6	10.4	3.9	11.2	33.5
GAS- 3	10-14	11330	0.2	ND	0.59	8.9	0.6	18.1	2.1	5.8	34.5
GAS- 4	16-21	2291	27.2	48.2	0.27	27.7	0.5	5.9	1.7	7.3	33.0
GAS- 5	21-26.5	3286	1.9	ND	1.05	22.8	1.2	6.5	2.9	15.6	30.2
GAS- 6	26.5-30	895	7.8	28.7	0.55	26.5	1.5	5.8	3.6	9.7	30.2
GAS- 7	30-35	1680	8.8	ND	0.60	19.1	1.3	5.5	3.9	9.0	30.1
GAS- 8	35-39	844	6.1	19.4	0.90	16.2	1.4	2.8	1.1	17.2	21.0
GAS- 9	39-40.5	929	24.8	ND	0.49	13.1	0.3	2.7	1.0	5.9	10.9
GAS-10	40.5-44	1088	11.4	13.9	0.88	29.3	1.6	4.1	2.7	6.7	27.7
GAS-11	44-50	2138	1.4	ND	0.97	6.8	0.1	2.2	0.9	13.5	19.4
GAS-12	50-55	2734	2.5	ND	0.51	12.9	0.3	13.9	0.4	6.6	23.2
GAS-13	55-62	776	0.2	58.2	0.49	18.5	0.2	12.0	0.9	6.5	18.2
GAS-14	64-71	3083	11.2	ND	0.86	13.1	3.1	0.4	4.7	2.9	6.1

Table 6.--Continued.

SAMPLE NUMBER	WT % TOURMALINE	WT % MONAZITE	WT % RUTILE	WT % ZIRCON	WT % PHOS-PHORITE	WT % Fe-OXIDES	WT % OTHERS	WT % EHM/C	WT % EHM/T	ZTR INDEX	WT % LABILES
GAT- 1	0.1	T	2.1	3.8	T	17.1	17.6	26.8	0.28	11.2	36.9
GAT- 2	0.5	T	1.4	2.1	0.1	2.5	12.4	22.7	0.20	5.5	58.9
GAT- 3	0.4	T	1.2	2.0	1.0	0.2	12.7	25.9	0.12	4.7	58.3
GAT- 4	0.2	T	1.1	1.3	1.8	0.1	16.8	17.6	0.09	3.5	61.7
GAT- 5	0.1	T	0.5	0.6	0.6	0.1	20.1	14.3	0.13	1.6	63.5
GAT- 6	T	T	0.2	2.2	0.2	T	26.9	25.4	0.21	3.5	47.5
GAT- 7	T	T	2.3	3.7	T	T	16.4	23.1	0.13	7.7	60.4
GAT- 8	T	T	1.3	2.9	0.7	T	17.1	18.7	0.18	5.5	63.5
GAT- 9	0.6	T	1.7	3.9	T	T	16.1	31.1	0.12	8.6	52.2
GAT-10	1.6	T	1.1	0.9	T	T	27.5	19.2	0.22	6.1	50.2
GAT-11	T	T	0.1	6.0	1.1	0.1	23.0	31.8	0.26	9.6	42.3
GAT-12	0.6	T	2.2	1.6	15.8	0.4	11.9	31.6	0.23	8.2	33.8
GAT-13	0.1	T	4.1	2.7	1.0	0.1	25.2	32.9	0.19	12.4	36.3
GAT-14	1.0	0.1	2.6	6.0	22.2	0.3	12.8	41.1	0.31	24.2	18.7
GAT-15	1.2	0.1	6.6	1.4	19.1	0.4	21.5	37.4	0.35	27.2	13.5
GAT-16	1.5	T	2.1	3.0	24.4	0.5	14.9	34.1	0.16	20.2	14.0
GAT-17	1.7	0.1	1.9	7.6	23.2	T	9.7	39.5	0.07	26.5	13.5
GAT-18	4.2	T	0.8	2.5	24.5	0.7	15.4	34.0	0.05	20.5	12.4
GAS- 1	2.6	T	2.5	2.8	T	0.7	9.7	37.0	0.28	11.1	44.5
GAS- 2	0.3	T	1.8	2.9	T	0.5	16.2	34.6	0.24	7.7	44.5
GAS- 3	0.5	T	0.6	1.0	3.4	0.6	23.9	16.3	0.10	3.3	53.2
GAS- 4	0.5	T	2.4	3.4	T	0.4	17.2	40.8	0.11	11.5	39.4
GAS- 5	2.3	T	6.6	1.0	T	0.1	10.8	46.0	0.48	14.9	37.9
GAS- 6	1.5	T	3.4	3.6	3.7	T	10.5	43.2	0.24	14.3	37.5
GAS- 7	0.6	T	2.0	2.7	15.5	0.1	10.2	32.8	0.20	9.6	36.9
GAS- 8	3.1	T	1.4	3.9	17.1	T	14.8	38.7	0.35	16.2	25.2
GAS- 9	0.7	T	0.2	1.6	28.0	0.9	34.7	20.8	0.10	10.7	13.9
GAS-10	1.1	T	<0.1	1.7	10.8	T	14.3	37.7	0.33	6.1	33.4
GAS-11	0.3	T	0.2	0.3	27.9	0.4	28.0	20.8	0.20	2.2	21.7
GAS-12	0.9	T	1.1	1.9	21.1	T	17.7	22.5	0.11	8.1	37.4
GAS-13	0.4	T	0.2	1.1	12.1	0.1	29.8	26.3	0.13	4.3	30.4
GAS-14	0.2	T	1.5	3.3	53.7	0.1	10.9	20.8	0.18	22.5	9.6

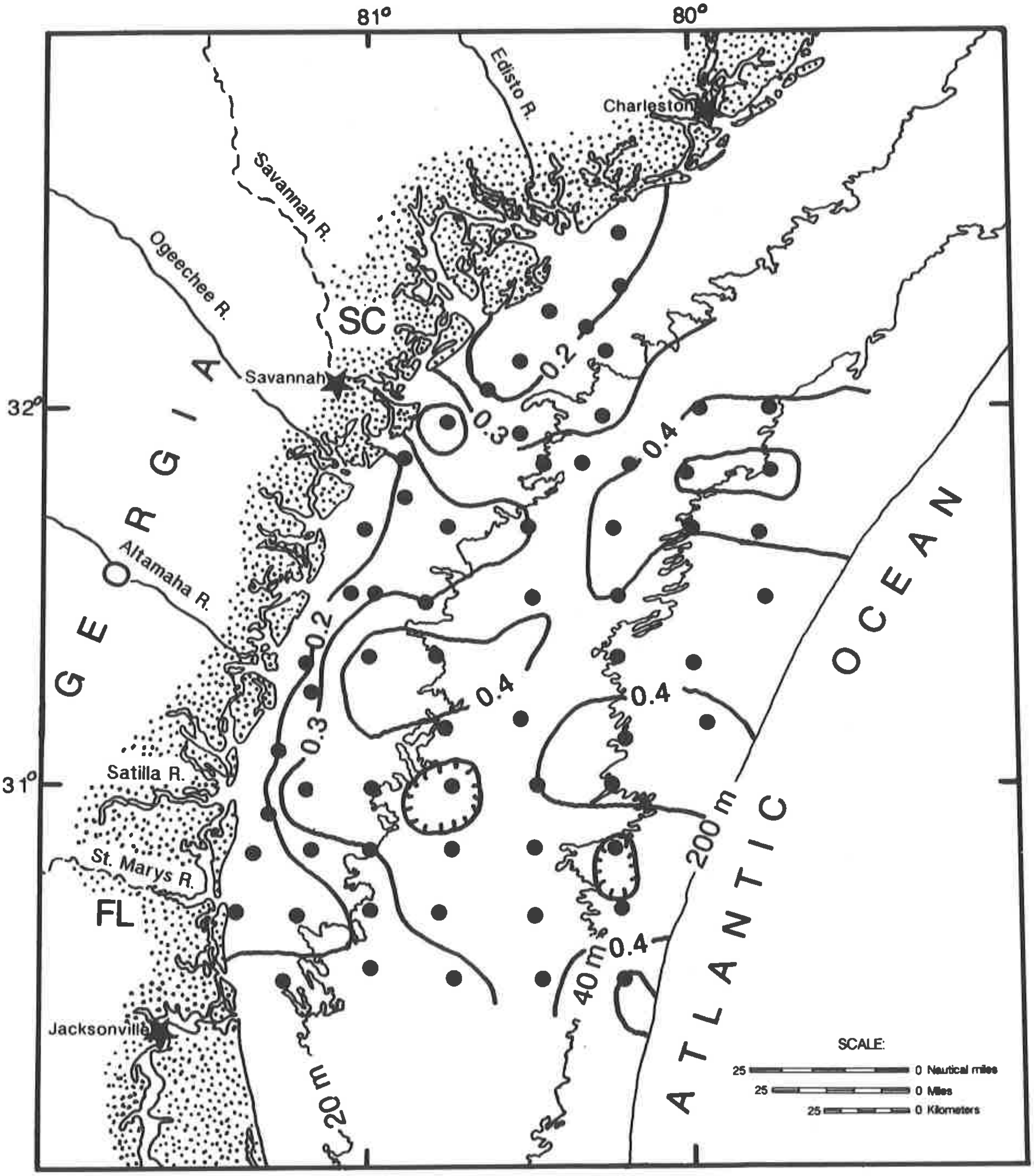

Figure 4.—Contour plot of the mean grain size of sediments in 65 surface grid samples from the Georgia shelf. Contour interval 0.1 mm.

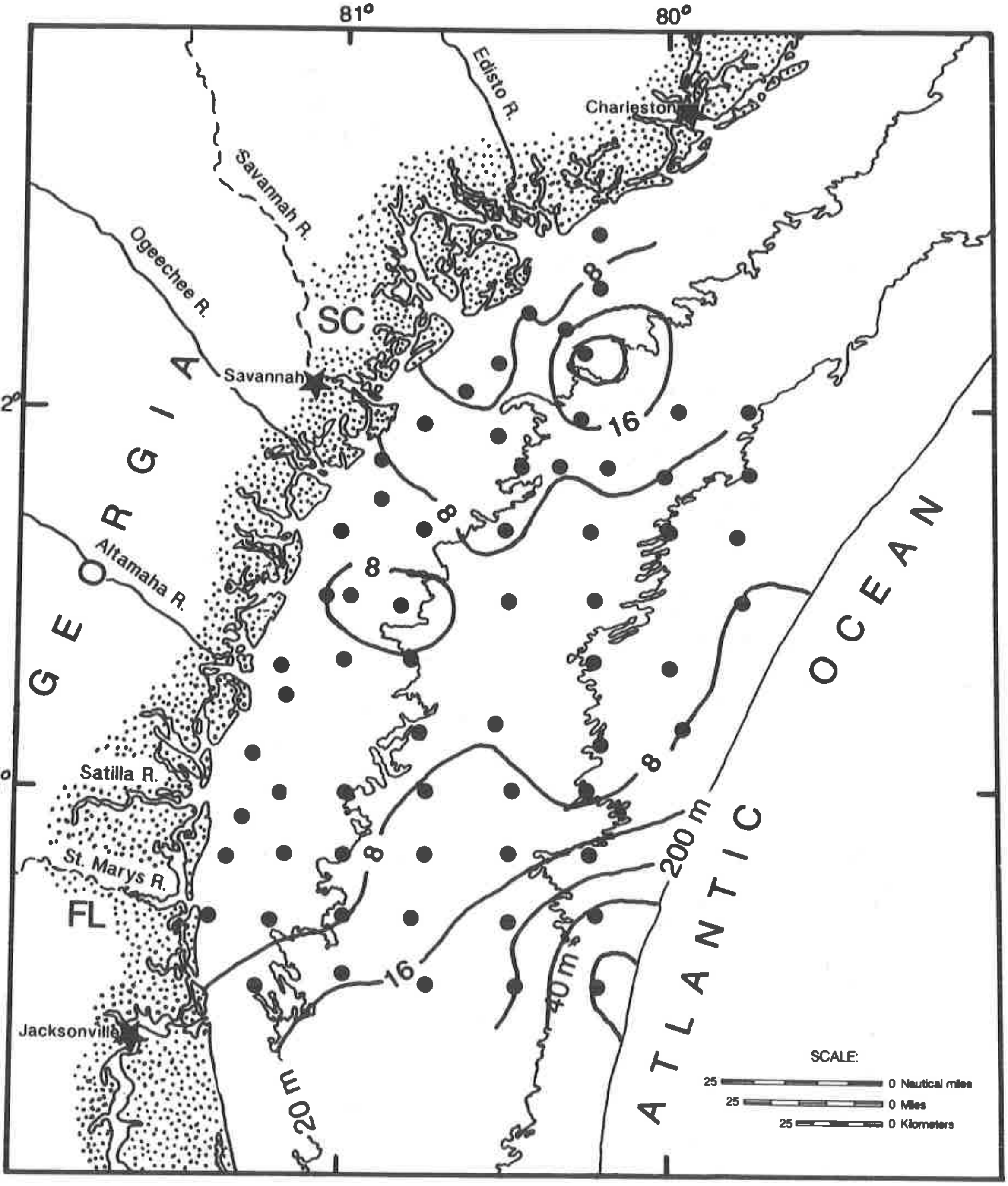

Figure 5.—Contour plot of the $CaCO_3$ content of sediments in 65 grid surface grab samples from the Georgia shelf. Contour interval 8 percent.

15%); potassium feldspar is somewhat more abundant than plagioclase. Feldspar concentrations occur in two zones perpendicular to the coast as defined by the 8% contour interval (Figure 6). The northern coast-perpendicular zone is a continuation of the Savannah River, and the southern zone is a seaward continuation of the Altamaha River. Both river-associated feldspar-rich zones extend to the shelf edge. Although locally diffuse, the pattern of feldspar distribution emphasizes the enduring effects of fluvial sedimentation on the Georgia shelf.

Heavy minerals

Mineralogic data are reported and discussed as weight percentages of the heavy-mineral assemblage unless otherwise noted. The heavy-mineral data in this report do not include the <325-mesh and the >16-mesh fractions; however, only 13 of the 65 grid samples had any <325-mesh size fraction and only 15 of the samples had >16-mesh fractions in excess of 10%. In general, the frequency of occurrence (in decreasing order of abundance) of heavy minerals in the sample population are phosphorite, ilmenite, epidote, pyroboles, aluminosilicates, tourmaline, leucoxene, staurolite, monazite, garnet, zircon, rutile, and magnetite.

Heavy-mineral content

The surficial sediments average 1.21_1.06% heavy minerals on a bulk sample basis. Inner shelf samples average 1.86_1.24% heavy minerals, middle shelf samples average 0.73_0.32% heavy minerals, and outer shelf samples average 0.40_0.29% heavy minerals. A contour plot of these data (Figure 7) reveals that the high heavy-mineral values are restricted to inner shelf sediments as previously shown elsewhere on the Atlantic Continental Shelf by Grosz (1987). However, two lobes correspond to the fine-grained textural lobes offshore of the Ogeechee and St. Marys Rivers (Figure 4). These results suggest that the fine-grained sediments contain the larger concentrations of heavy minerals.

Transect samples from the 10- and 20-m isobaths show the same trend of decreasing heavy-mineral content with depth; the nearshore (10 m) and midshore (20 m) groups average 0.78% and 0.32% heavy minerals respectively. However, it should be noted that values vary widely, particularly within the nearshore group. The distribution of heavy minerals on the Georgia shelf appears to be related to the distribution of fine-grained sediment lobes associated with fluvial deposition extending offshore from the Savannah-Ogeechee and Satilla-St. Marys River pairs.

Heavy-mineral resource potential

The detrital minerals (exclusive of sand and gravel) of commercial interest on the Georgia shelf consist of ilmenite, leucoxene (altered ilmenite), rutile, zircon, monazite, and aluminosilicates (sillimanite, kyanite, and andalusite). The variable EHM/T (sum of the economic heavy minerals mentioned above expressed as a percentage of the bulk sample, T) is used as a measure of economic viability of heavy-mineral deposits.

For the grid samples, EHM/T averages 0.44_0.42% and exhibits an inverse relationship to water depth (Figure 8). Data for the transect samples show that within the inner shelf the nearshore samples have a higher, but much more variable average EHM/T (0.43_0.39%) than the midshore samples (0.17_0.06%). The distribution pattern of EHM/T values (Figure 9) is similar to that of total heavy minerals (Figure 7). High EHM/T values are confined to nearshore sediments and to lobate seaward extensions near the mouths of the rivers from the Savannah south to the Satilla (Figure 9). The 20-m-isobath region offshore of the Altamaha River (Figure 2) is notably depleted in economic heavy minerals; however, ilmenite, the most abundant economic heavy mineral, is preferentially concentrated there (Figure 10). The abundance of ilmenite is also high offshore of the Altamaha River and in a broad zone trending south-southeast across the shelf from near the Edisto River. The ilmenite concentration near the Altamaha River is approximately coincident with what is probably a 14-m sea-level stillstand beach-complex deposit.

High-resolution seismic data show that, in places, at least the upper 20 m of sediment contains extensive channels to the shelf edge and that channel thalwegs have migrated considerably over time. Cross-shelf-trending coarse-grained fluvial sediments (Figure 4) are not coincident with anomalous EHM/T concentrations (Figure 9) as predicted by the inverse relationship between mean grain size and heavy mineral content (Figure 11).

Factors limiting the potential for significant concentrations of economic heavy minerals in channel deposits include (1) the absence of significant amounts of heavy-mineral-bearing, fine-grained sediments in channels (see the relationship in Figure 11), (2) the juvenile nature of the heavy-mineral assemblage provided by the rivers, and (3) the low overall abundance of heavy minerals in the sediments on the Georgia shelf. The potential for placer deposits of heavy minerals in beach-complex deposits seems to be equally limited because (1) the heavy-mineral assemblage provided to the Georgia shelf is ubiquitously juvenile, (2) upgrading of the assemblages by weathering does not appear to be significant or areally extensive, and (3) textural and mineralogic data do not provide supporting evidence for significant sea level stillstands (necessary for the formation of large placer deposits) at water depths other than the 14-m

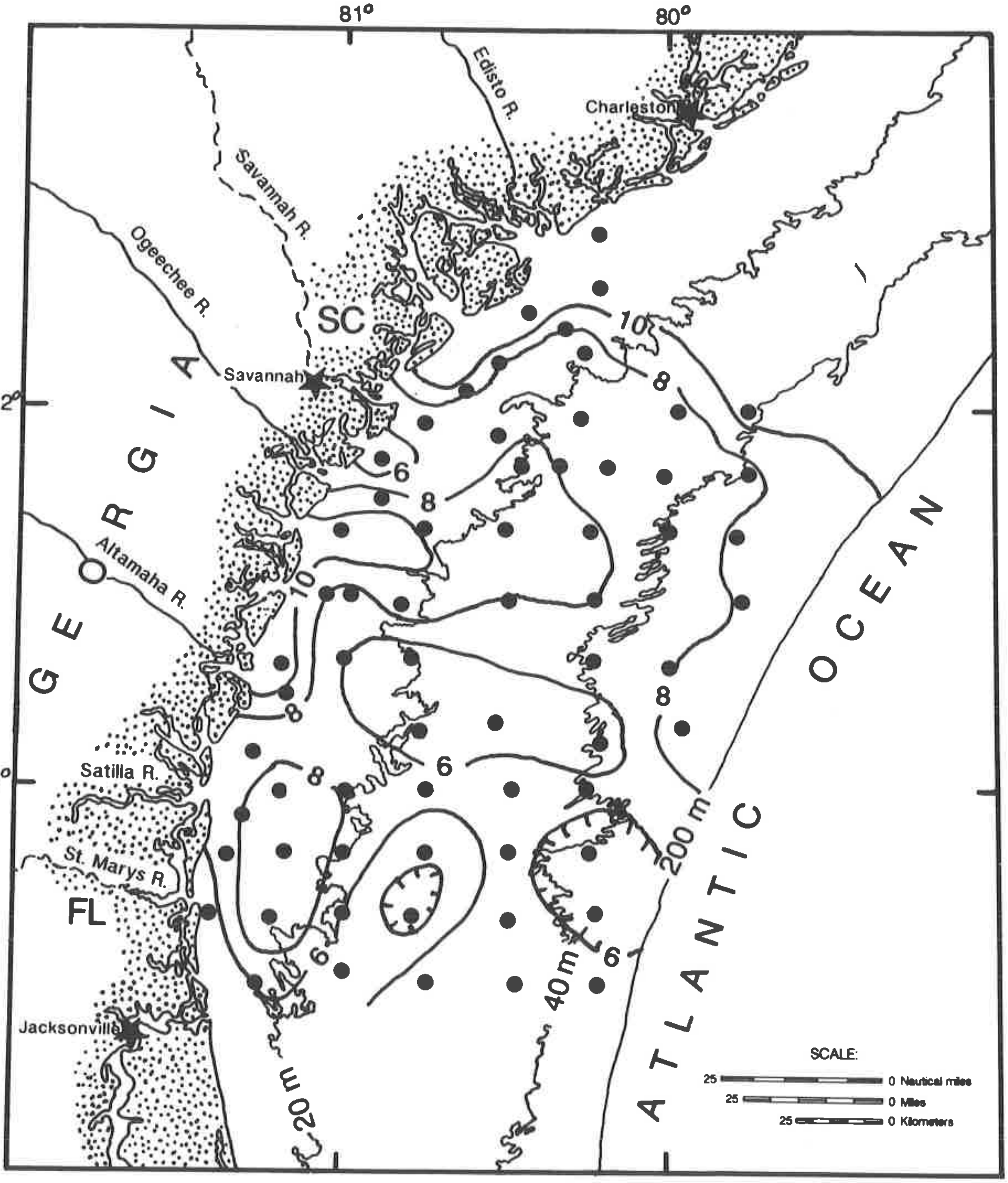

Figure 6.—Contour plot of the feldspar content of the sand fraction in 65 grid surface grab samples from the Georgia shelf. Contour interval 2 percent.

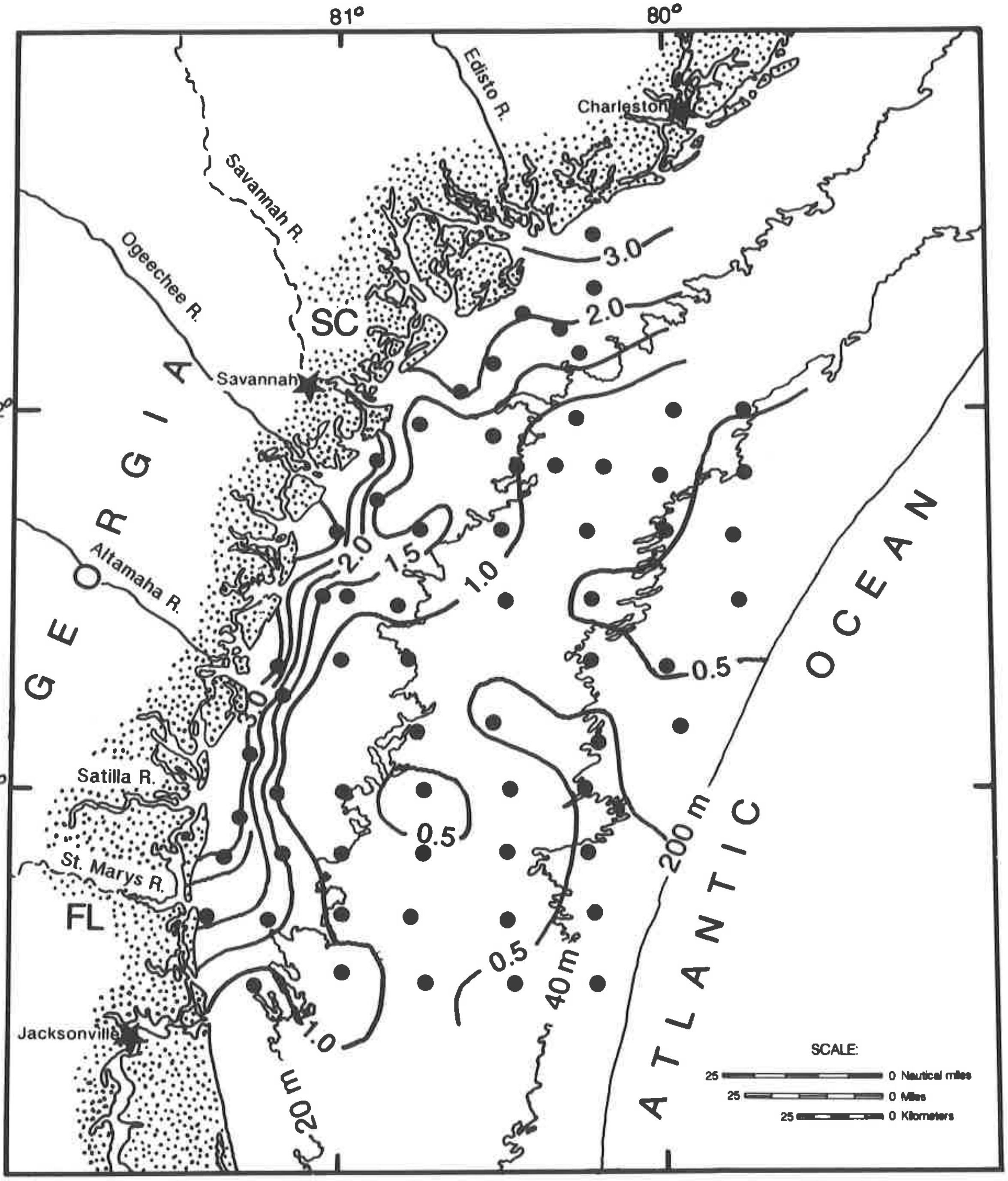

Figure 7.—Contour plot of the percentage of heavy minerals in 65 grid surface grab samples from the Georgia shelf. Contour interval 0.5 percent.

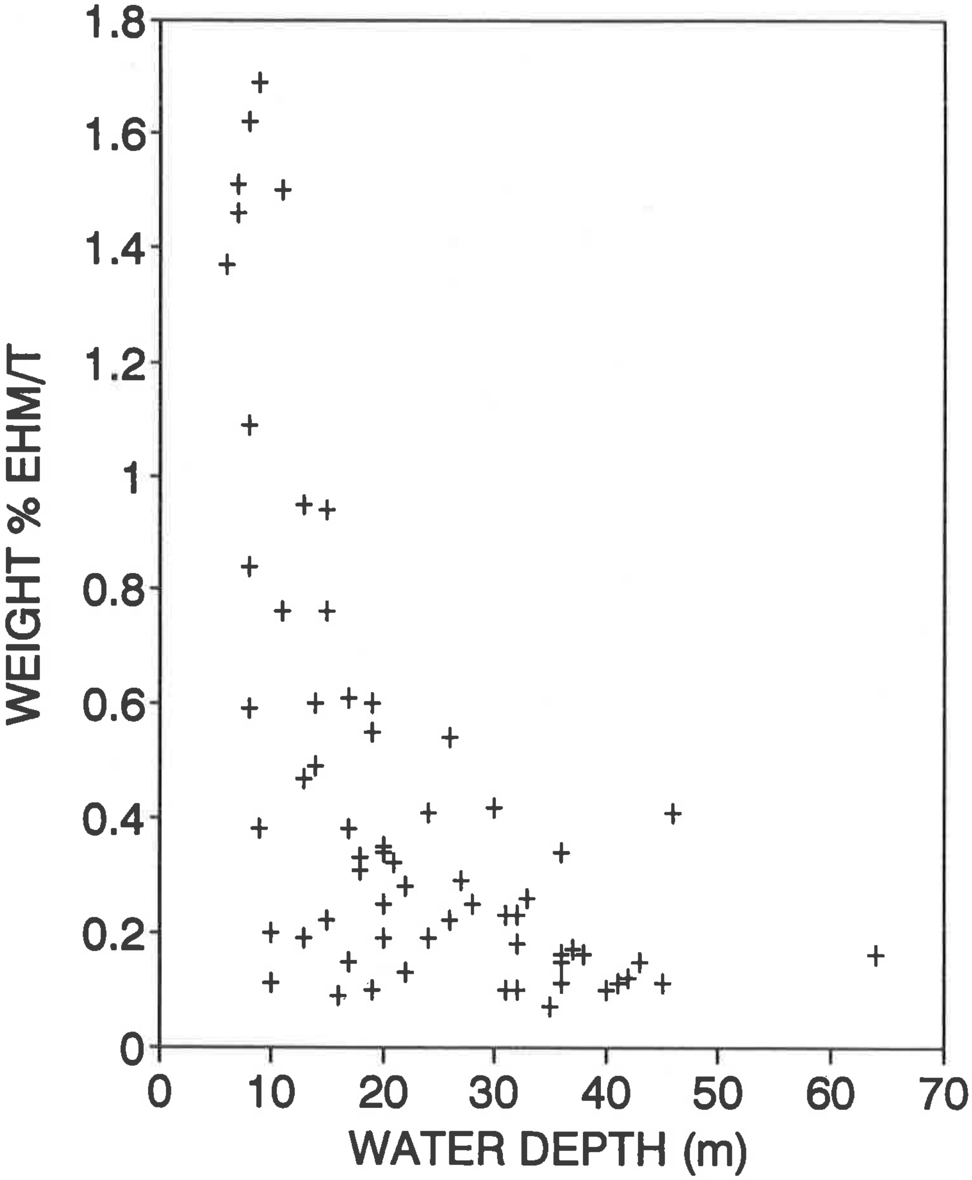

Figure 8.—Plot of the EHM/T (economic heavy minerals/bulk sample) versus water depth for the 65 grid surface grab samples from the Georgia shelf.

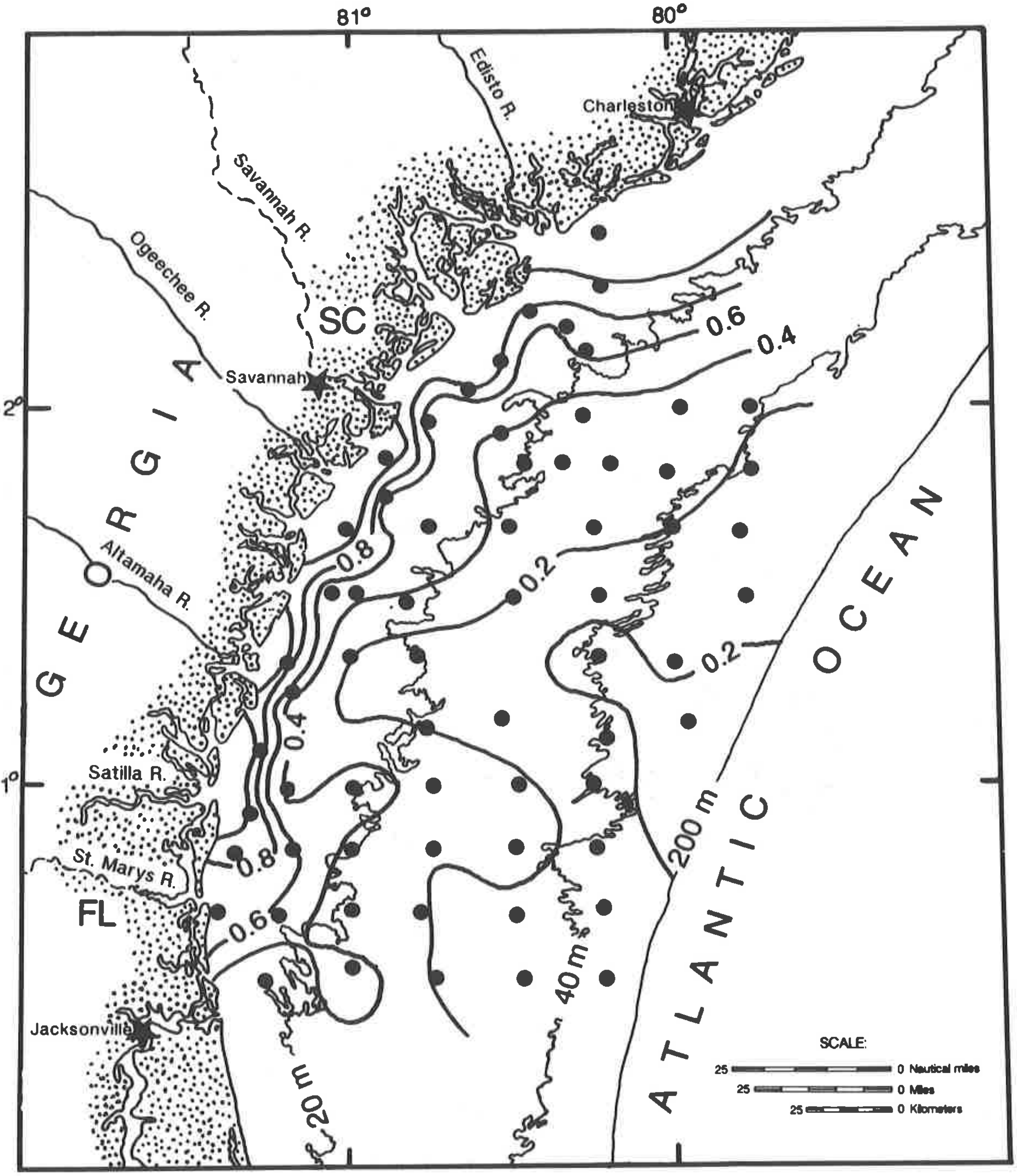

Figure 9.—Contour plot of the EHM/T of sediments in 65 grid surface grab samples from the Georgia shelf. Contour interval 0.2 percent.

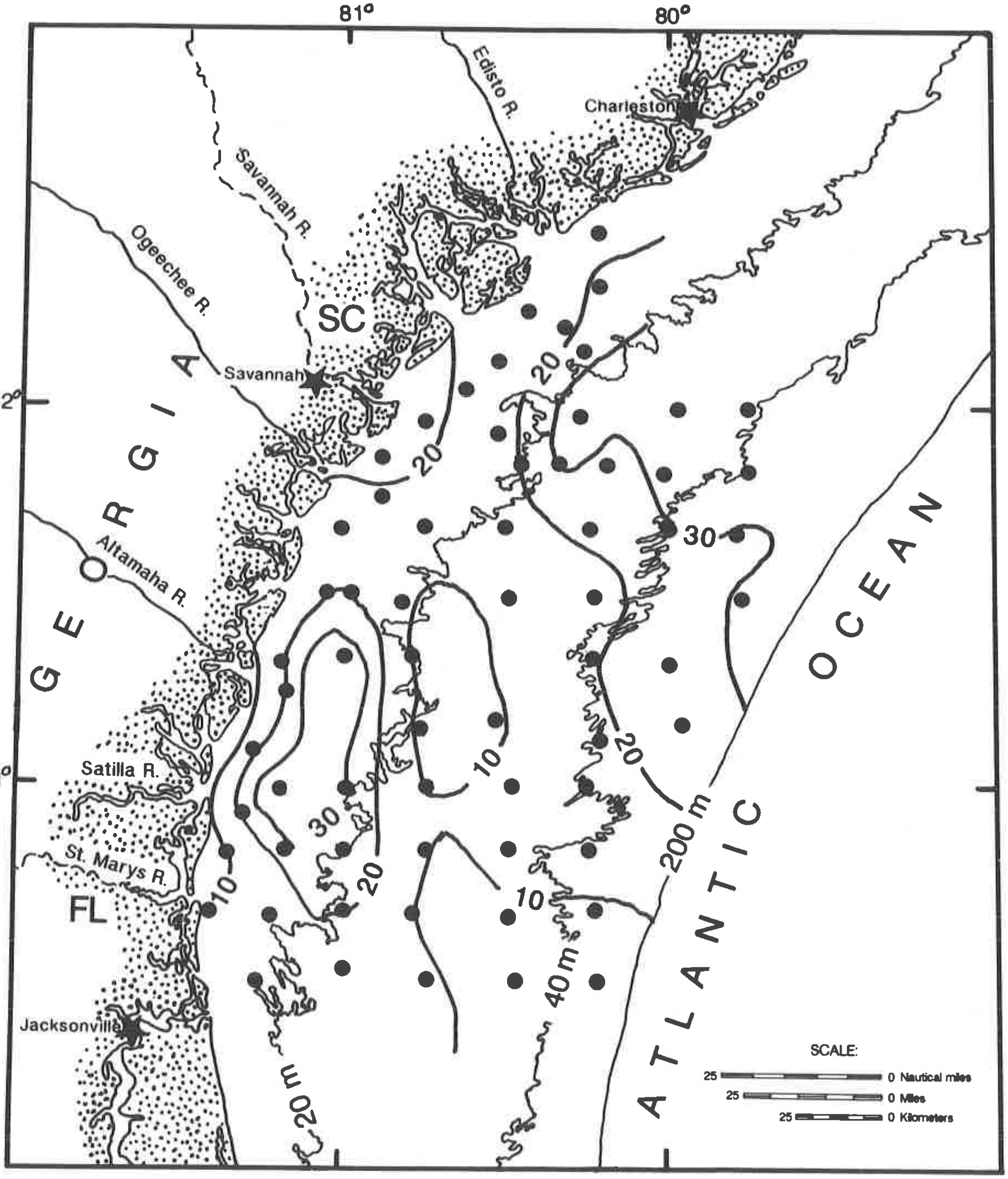

Figure 10.—Contour plot of the percentage of ilmenite in 65 grid surface grab samples from the Georgia shelf. Contour interval 10 percent.

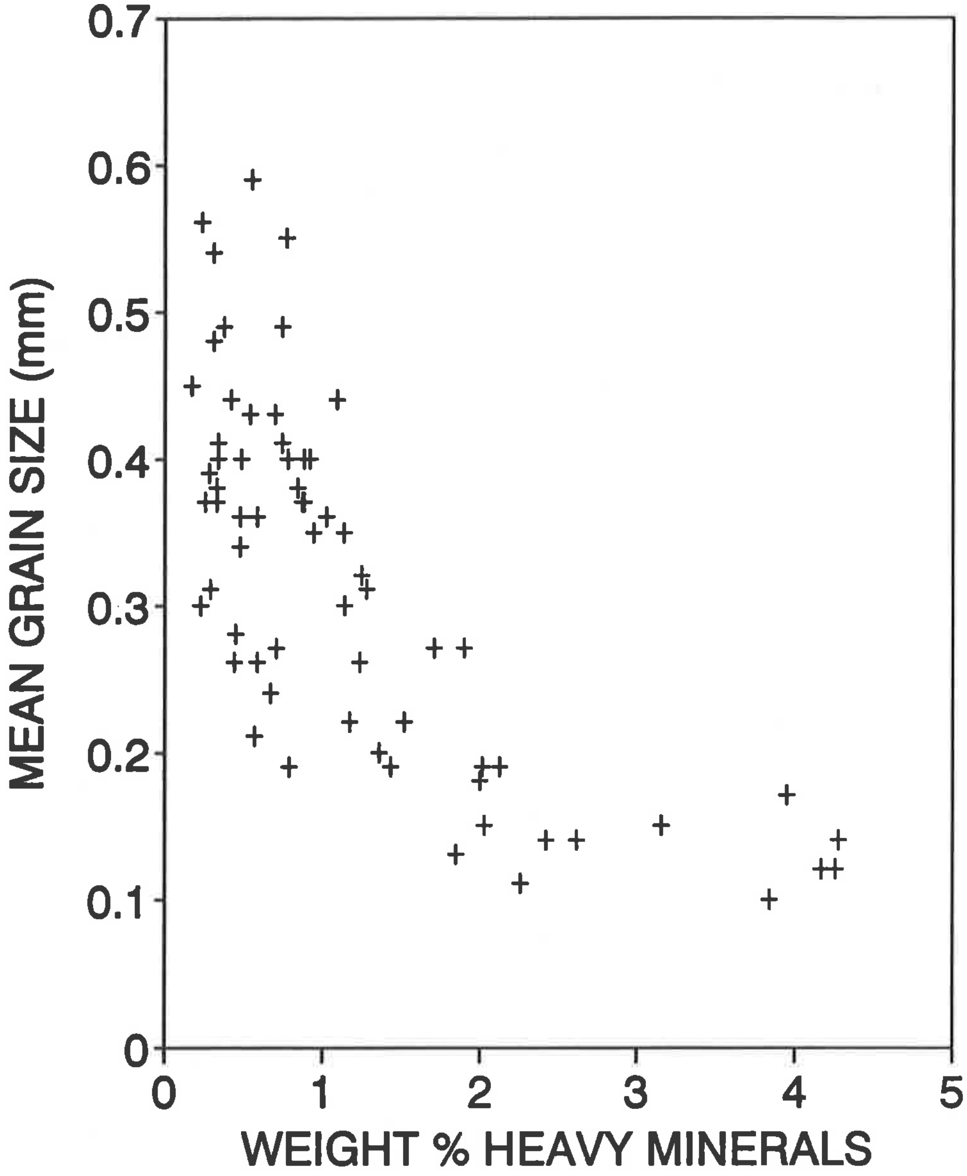

Figure 11.—Plot of the mean grain size versus the percentage of heavy minerals.

isobath. As marine transgressions may be effective dispersing agents of beach-complex sands, the preservation potential of beach-complex-associated deposits of heavy minerals on the Georgia shelf is very low. It is possible that small remnants of basal portions of larger deposits (beach-complex and fluvial) may exist; however, their expression would be difficult to detect with regional grab sampling grids; sampling at depth is necessary.

CONCLUSIONS

The terrigenous clastic component of surficial sediments on the Georgia shelf has been derived predominantly from Piedmont Province source rocks and carried to the sea by rivers having headwaters extending into the Piedmont. The Altamaha and Savannah Rivers are important conduits for these mineralogically immature sediments, and, along with the St. Marys River, they have had a pronounced effect on the texture and mineralogy of the surficial sediments. Beach-complex sediments are not important, except locally at the outer edge of the inner shelf approximately coincident with the 14-m isobath.

The heavy-mineral resource potential of the surficial sediments on the Georgia shelf is limited by a number of factors, the most profound and controlling one being the immature heavy-mineral suite that has been provided from the Piedmont. Additional constraints are the absence of beach-complex sediments, which tend to have a mature assemblage, and the abundance of fluvial sediments, which tend to have immature assemblages.

Indications are that the best potential, low as it is, for titanium-bearing placer deposits of heavy minerals occurs in a zone between the 14 and 20 m in depth offshore of the Altamaha River where concentrations are coincident with a probable sea- level still stand.

ACKNOWLEDGMENTS

John C. Hathaway of the U.S. Geological Survey (USGS) at Woods Hole, MA, supervised the heavy-liquid separation and magnetic fractionation of some of the samples. Ricardo Lopez of the USGS, Reston, VA, performed heavy-liquid and magnetic fractionation of the transect samples and conducted mineralogic determinations of individual magnetic fractions. James R. Herring of the USGS, Denver, CO, provided samples from the TACTS cores for analyses. Kathleen Farrell of the Georgia Geologic Survey collected the samples from the Tybee Island borehole. W. Jason Greenwood and Arjün R. Gadgil, Volunteers for Science at the USGS in Reston, VA, helped with the compilation of data and the drafting of figures. This study was conducted under a joint funding agreement between the Georgia Department of Natural Resources and the U.S. Geological Survey.

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