

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division



Fort Sumter and Fort Moultrie National Historical Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic
Data for Fort Sumter and Fort Moultrie National Historical Park

fosu_geology.pdf

Version: 6/21/2022

Geologic Resources Inventory Map Document for Fort Sumter and Fort Moultrie National Historical Park

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Geologic Resources Inventory Map Document



Fort Sumter and Fort Moultrie National Historical Park, South Carolina

Document to Accompany Digital Geologic-GIS Data

[fosu_geology.pdf](#)

Version: 6/21/2022

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Fort Sumter and Fort Moultrie National Historical Park, South Carolina (FOSU).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

- 1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.
- 2) **GRI Digital Maps and Source Map Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.
- 3) **Map Unit List** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.
- 4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.
- 5) **Geologic Cross Sections** – Geologic cross section graphics with source geologic cross section abbreviations.
- 6) **Ancillary Source Map Information** – Additional source map information presented by source map. For each source map this may include a stratigraphic column, index map, map legend and/or map notes.
- 7) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

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About the NPS Geologic Resources Inventory Program

Background

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI. The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. Many additional partners participate in the GRI process by contributing source maps or reviewing products.

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report. These products are designed and written for nongeoscientists.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: <https://www.nps.gov/articles/gri-geodatabase-model.htm>

Geologic Reports: GRI reports synthesize discussions from the original scoping meeting, follow up conference call(s), and subsequent research. Chapters of each report discuss the geologic setting of the park, distinctive geologic features and processes within the park, highlight geologic issues facing resource managers, and describe the geologic history leading to the present-day landscape. Each report also includes a poster illustrating these GRI digital geologic-GIS data.

For a complete listing of GRI products visit the GRI publications webpage: <https://go.nps.gov/gripubs>. GRI digital geologic-GIS data is also available online at the NPS Data Store: <https://irma.nps.gov/DataStore/Search/Quick>. To find GRI data for a specific park or parks select the appropriate park(s), enter "GRI" as a Search Text term, and then select the Search button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: <https://>

www.nps.gov/subjects/geology/gri.htm. At the bottom of that webpage is a “Contact Us” link if you need additional information. You may also directly contact the program coordinator:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division. Learn more about I&M and the 12 baseline inventories at the I&M webpage: <https://www.nps.gov/im/inventories.htm>.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps for Fort Sumter and Fort Moultrie National Historical Park, South Carolina (FOSU):

Digital Geologic-GIS Map of Fort Sumter and Fort Moultrie National Historical Park and Vicinity, South Carolina (*GRI MapCode FOSU*)

The GRI digital geologic-GIS map was produced from the following source maps. The full extent of the Weems et al., 1997 source map was used, and all geologic features within the extent were captured, however, only a portion of the Weems et al., 1993 source map was used, but then all features within this extent were captured.

Weems, Robert E., Lemon, Earl M. Jr., and Chirico, Peter G., 1997, Digital Geology and Topography of the Charleston Quadrangle, Charleston and Berkeley Counties, South Carolina: U. S. Geological Survey, Open-File Report OF-97-531, scale 1:24,000 ([Charleston Quadrangle \(Digital Geology and Topography\)](#)). (*GRI Source Map ID 5574*).

Weems, Robert E., and Lemon, Earl M. Jr., 1993 Geology of the Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles, Charleston and Berkeley Counties, South Carolina: U.S. Geological Survey, Map I-1935, 2 sheets, scale 1:24,000 ([Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)). (*GRI Source Map ID 2530*).

Additional information pertaining to each source map is also presented in the GRI Source Map Information (FOSUMAP) table included with the GRI digital geologic-GIS data.

Index Map

The following index map displays the extent of the GRI digital geologic-GIS map produced for Fort Sumter and Fort Moultrie National Historical Park (FOSU). The boundaries of Fort Sumter and Fort Moultrie National Historical Park (as of June, 2022) are outlined in green. The GRI digital geologic-GIS map extent is defined by the extent of the Charleston and Fort Moultrie 7.5' quadrangles. The GRI digital geologic-GIS map also covers Charles Pinckney National Historic Site.



Index map by Stephanie O'Meara (Colorado State University)

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Fort Sumter and Fort Moultrie National Historical Park, South Carolina (FOSU) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qaf - Artificial fill). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (FOSUUNIT) table included with the GRI digital geologic-GIS data. Unit symbols, names and ages in unit descriptions, and in a correlation of map units figure were not edited.

Cenozoic Era

Quaternary Period

[Qaf](#) - Artificial fill

[Qal](#) - Alluvium

[Qht](#) - Tidal-marsh deposits

[Qhs](#) - Beach and barrier-island sands

[Qhm](#) - Freshwater stream and swamp deposits

[Qhec](#) - Estuarine deposits

[Qhes](#) - Beach to barrier-island deposits

[Qwc](#) - Wando Formation, clayey sand and clay facies

[Qws](#) - Wando Formation, barrier sand facies (Mount Pleasant barrier system)

[Qwls](#) - Wando Formation, barrier sand facies (Awendaw barrier system)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. Unit descriptions were taken from both source maps. If a unit's descriptions differs between source maps, then each source map's unit description is presented and noted. Note that for units Qaf, Qal and Qht, these unit descriptions are identical between the two source maps, and thus the description is presented just once.

Qaf - Artificial fill (Holocene)

af - Artificial fill (Holocene)

Sand or clayey sand of diverse origin. Used as fill for roads, dams, and other construction. Ranges from 3 to 10 ft (1-3 m) thick. Deposits are less than 300 years old. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#) and [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qal - Alluvium (Holocene)

Qal - Alluvium (Holocene)

Sands presently migrating down drainage courses, frequently veneered by thin mucks and peats at the surface. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#) and [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qht - Tidal-marsh deposits (Holocene)

Qht - Tidal-marsh deposits (Holocene)

Clayey sand and clay, medium gray (N5) to black (N1), soft, organic rich. Dominant clay mineral is kaolinite, with significantly less illite/smectite and illite. Deposits 0 to 10 ft (0-3 m) thick and support marsh grass. Known ages less than 5 ka. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#) and [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qhs - Beach and barrier-island sands (Holocene)

Qhs - Beach and barrier-island sands (Holocene)

Quartz sand, very light gray (N8), fine grained, well sorted, shelly; dark, very fine grained heavy minerals abundant. Auger hole FM 5 includes typical section of this unit. Age less than 10 ka, and surface deposits probably less than 1 ka. Deposits 0 to 35 ft (0-11 m) thick. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qhs - Beach and barrier-island sands (Holocene)

Quartz sand, very light gray (N8), fine grained, well sorted, shelly; dark, very fine grained heavy minerals abundant. Age less than 10 ka, and surface deposits probably less than 1 ka. Deposits 0 to 35 ft thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qhm - Freshwater stream and swamp deposits (Pleistocene to Holocene (Wisconsinan glacial age))**Qhm - Freshwater stream and swamp deposits (Holocene to Pleistocene (Wisconsinan glacial age))**

Peat and muck, moderate brown (5YR 3/4) to black (N1), thin, soft, accumulating along impounded stream courses and in ovoid-shaped depressions mostly on Ten Mile Hill and Wando depositional surfaces. Deposits located mainly from aerial photographs and topographic base. Auger hole CA 20 (see Weems and Lemon, 1985) shows typical section of one of these features. Known ages range from modern to at least 34 ka. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qhm - Freshwater stream and swamp deposits (Holocene to Pleistocene (Wisconsinan glacial age))

Freshwater stream and swamp deposits (Holocene to Pleistocene (Wisconsinan glacial age)). Peat and muck, moderate brown (5YR 3/4) to black (N1), thin, soft, accumulating along impounded stream courses and in ovoid-shaped depressions mostly on Ten Mile Hill and Wando depositional surfaces. Deposits located mainly from aerial photographs and topographic base. Known ages range from modern to at least 34 ka. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qhec - Estuarine deposits (middle Holocene and Pleistocene (probably 6 to 7 ka, and between 33 and 85 ka))**Qhec - Estuarine deposits (Pleistocene, between 33 and 85 ka, and middle Holocene, probably 6 to 7 ka, and)**

Silty to sandy clay, and quartz sand, medium gray (N5) to dark gray (N3), fine grained, clayey. Kaolinite is dominant clay mineral with lesser amounts of illite/smectite and illite. Sediment is dewatered sufficiently to form firm ground. Auger hole NC 5 ([fig. 4](#)) includes typical section. Deposits 0 to 10 ft (0-3 m) thick. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qsbc - Silver Bluff beds (informal) Estuarine deposits (Pleistocene, between 33 and 85 ka)

Silty to sandy clay, and quartz sand, medium gray (N5) to dark gray (N3), fine grained, clayey. Kaolinite is dominant clay mineral with lesser amounts of illite/smectite and illite. Sediment is dewatered sufficiently to form firm ground. Deposits 0 to 10 ft (0-3 m) thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qhes - Beach to barrier-island deposits (Pleistocene (between 33 and 85 ka))**Qhes - Beach to barrier-island deposits (Holocene)**

Quartz sand, grayish orange (10YR 7/4), fine grained with a minor but persistent coarse-grained fraction, bimodally well sorted; dark, very fine grained heavy minerals abundant; prominently crossbedded. Auger hole CH 7 includes typical section. Deposits up to 10 ft (3 m) thick. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qsbs - Beach to barrier-island deposits (Holocene).

Quartz sand, grayish orange (10YR 7/4), fine grained with a minor but persistent coarse-grained fraction, bimodally well sorted; dark, very fine grained heavy minerals abundant; prominently crossbedded. Auger hole CH 7 includes typical section. Deposits up to 10 ft (3 m) thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qwc - Wando Formation, clayey sand and clay facies (Pleistocene (about 70-130 ka))

Qwc - Wando Formation, clayey sand and clay facies (Pleistocene (about 70-130 ka))

Clay, mottled pale grayish orange (10YR 7/4) and medium light gray (N6), silty to sandy; clayey quartz sand, mottled pale grayish orange (10YR 7/4) and medium light gray (N6). Fine to medium grained. Dominant clay mineral is kaolinite with illite and illite/smectite in variable proportions. Soil profile poorly developed compared to Ten Mile Hill beds and older terrace units; grayish-yellow (5Y 8/4) to dark-yellowish-orange (10YR 6/6) B-horizon; base of B-horizon usually 6 ft (1.8 m) deep. Unit covered, in places, by modern swamp deposits less than 3 ft (1 m) thick. Underlies Princess Anne terrace surface at altitudes below 20 ft (6 m). Wood and terrestrial vertebrate fossils indicate formation in estuarine to fluvial environments. Auger holes CA 21 and NC 11 include typical sections. Unit is up to 35 ft (11 m) thick. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qwc-Wando Formation (Pleistocene, about 70–130 ka) Clayey sand and clay facies.

Clayey sand and clay facies. Clay, mottled pale grayish orange (10YR 7/4) and medium light gray (N6), silty to sandy; clayey quartz sand, mottled pale grayish orange (10YR 7/4) and medium light gray (N6). Fine to medium grained. Dominant clay mineral is kaolinite with illite and illite/smectite in variable proportions. Soil profile poorly developed compared to Ten Mile Hill beds and older terrace units; grayish-yellow (5Y 8/4) to dark-yellowish-orange (10YR 6/6) Bhorizon; base of Bhorizon usually 6 ft (1.8m) deep. Unit covered, in places, by modern swamp deposits less than 3ft (1 m) thick. Underlies Princess Anne terrace surface at altitudes below 20 ft (6 m). Wood and terrestrial vertebrate fossils indicate formation in estuarine to fluvial environments. Unit is up to 35 ft (11 m) thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qws - Wando Formation, barrier sand facies (Mount Pleasant barrier system) (Pleistocene (about 70-130 ka))

Qws - Wando Formation, barrier sand facies (Pleistocene (about 70-130 ka))

Quartz sand, medium gray (N5) to light brown (5YR 6/4) where fresh, may be dark yellowish orange (10YR 6/6) to grayish orange (10YR 7/4) or humic dusky yellowish brown (10YR 2/2) in upper 7 ft (2 m); fine grained; dark, very fine grained heavy minerals abundant. Dominant clay mineral is vermiculite. Auger hole FM 7 includes typical section. Forms Mount Pleasant barrier system (Colquhoun, 1974), mostly at altitudes from 15 to 27 ft (4.5-8 m). Unit up to 25 ft (8 m) thick. Description from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Qws -Wando Formation (Pleistocene, about 70–130 ka) Barrier sand facies

Barrier sand facies. Quartz sand, medium gray (N5) to light brown (5YR 6/4) where fresh, may be dark yellowish orange (10YR 6/6) to grayish orange (10YR 7/4) or humic dusky yellowish brown (10YR 2/2) in upper 7 ft (2 m); fine grained; dark, very fine grained heavy minerals abundant. Dominant clay mineral is vermiculite. Forms Mount Pleasant barrier system mostly at altitudes from 15 to 27 ft (4.5-8 m). Unit up to 25 ft (8 m) thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Qwls - Wando Formation, barrier sand facies (Awendaw barrier system) (Pleistocene (about 70-130 ka))

Qwls - Wando Formation (Pleistocene, about 70–130 ka) Barrier sand facies.

Quartz sand, medium gray (N5) where fresh, may be dark yellowish orange (10YR 6/6) to grayish orange (10YR 7/4) or humic dusky yellowish brown (10YR 2/2) in upper 7 ft (2 m), fine grained; dark, very fine grained heavy minerals abundant. Dominant clay mineral is vermiculite. Auger hole CH 12 includes a typical section. Forms Awendaw barrier system mostly at elevations from 20 to 35 ft

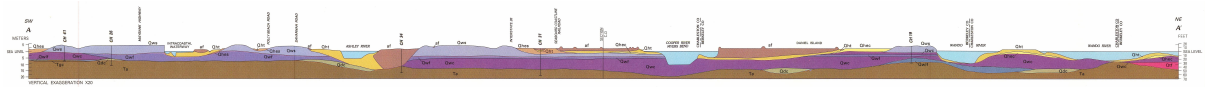
(641m). Unit up to 20 ft (6m) thick. Description from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Note, unit is not present on the [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#) source map.

Geologic Cross Section

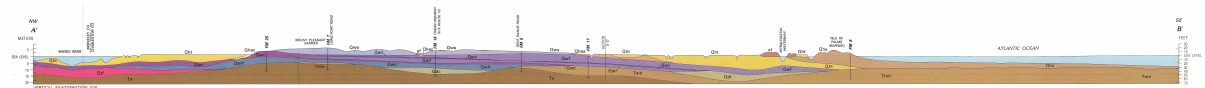
The geologic cross sections present in the GRI digital geologic-GIS data produced for Fort Sumter and Fort Moultrie National Historical Park, South Carolina (FOSU) are presented below. Cross section lines in the GRI digital geologic-GIS data retain their source map cross section abbreviations. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

Cross Section A-A'



Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Cross Section A'-B'



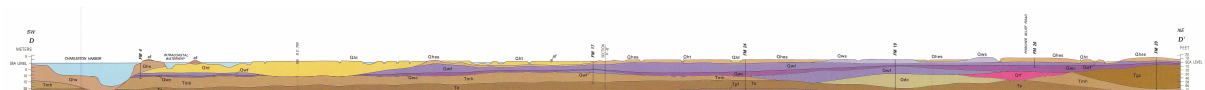
Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Cross Section A-B



Graphic from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

Cross Section D-D'



Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Ancillary Source Map Information

The following sections present ancillary source map information associated with sources used for this project.

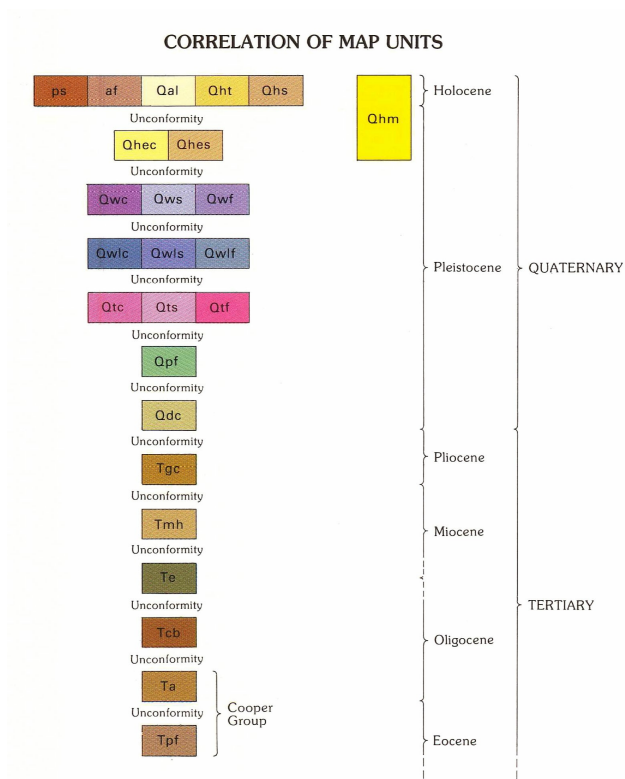
Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles

The formal citation for this source.

Weems, Robert E., and Lemon, Earl M. Jr., 1993 Geology of the Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles, Charleston and Berkeley Counties, South Carolina: U.S. Geological Survey, Map I-1935, 2 sheets, scale 1:24,000 (*GRI Source Map ID 2530*).

Prominent graphics and text associated with this source are presented below. Note that has the GRI digital geologic-GIS data used only a portion of the source map not all units, mapped features, graphics and text (Discussion) are relevant to this data.

Correlation of Map Units



Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Explanation of Map Symbols

EXPLANATION OF MAP SYMBOLS

	Contact —Located by changes in slope and by projecting drill-hole data to surface
	Structure contour —Drawn on base of Quaternary units. Contour interval 10 ft. Datum is mean sea level
	Updip limit of the Marks Head Formation beneath Pleistocene cover —Ticks point downdip
	Drill hole —Quadrangle abbreviations: <i>CA</i> , Cainhoy; <i>CH</i> , Charleston; <i>FM</i> , Fort Moultrie; <i>NC</i> , North Charleston. Value indicates elevation in ft above sea level of base of Pleistocene; n.d., no data. See Weems and Lemon (1985) and Weems and others (1985) for logs. Symbol designates beds penetrated:
	Chandler Bridge Formation
	Edisto Formation
	Marks Head Formation
	Goose Creek Limestone
	Daniel Island beds
	Outliers of Ten Mile Hill beds
	Location of selected outcrop —See Weems and Lemon (1985) and Weems and others (1985) for logs
	Location of borehole from unpublished Charleston area engineering company reports —Principally from Law Engineering Testing Company; Soil Consultants, Inc.; Moran, Proctor, Mueser, and Rutledge; and Mueser, Rutledge, Wentworth, and Johnston
	Location of drill hole from unpublished records —On file with the South Carolina Geological Survey, Columbia, S.C. Abbreviation used: <i>BC</i> , Berkeley County. Value indicates elevation in feet above sea level of base of Pleistocene; n.d., no data
	Location of earthquake-induced liquefaction features
	Sand and clay pits

Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Map of Pleistocene Terraces, Earthquake Epicenters and Quadrangle Index

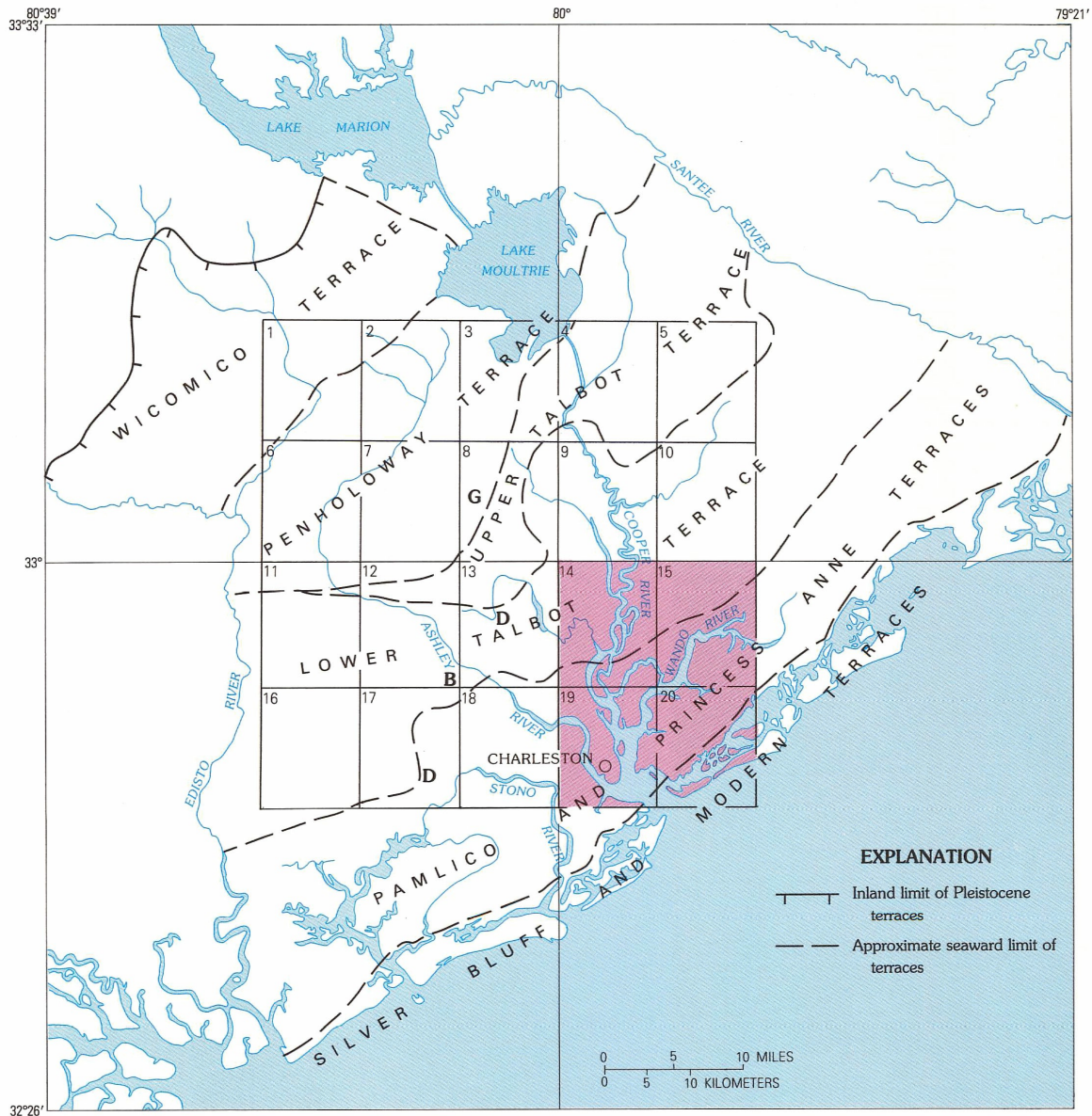


Figure 1.—Map of Pleistocene terraces, estimates of epicenters for earthquake of August 31, 1886, and index of 7.5-minute quadrangles covering the Charleston meizoseismal area. **B**, Estimate of epicenter (Bollinger, 1977); **D**, Estimate of two epicenters (Dutton, 1889); **G**, Estimate of epicenter (Gibbes and others, 1887). Geomorphic terrace nomenclature established by Cooke (1936) and Colquhoun (1974).

Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Environments of Deposition for Stratigraphic Units

Human influence		Freshwater		Backbarrier (estuarine/lagoonal)	Barrier island/marginal marine	Shallow marine shelf	Middle shelf	
ps	af	Qhm	Qal	Qht	Qhs			Holocene
				Qhec	Qhes			Pleistocene
				Qwc	Qws	Qwf		
				Qwlc	Qwls	Qwlf		
				Qtc	Qts	Qtf		
						Qpf		
				Qdc				
						Tgc		Pliocene
				Tmh				Miocene
						Te		Oligocene
				Tcb				
							Ta	Eocene
							Tpf	

Figure 2.—Environments of deposition for stratigraphic units.

Graphic from source map: [Cainho, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Isopach Map of Poorly Consolidated Quaternary Deposits

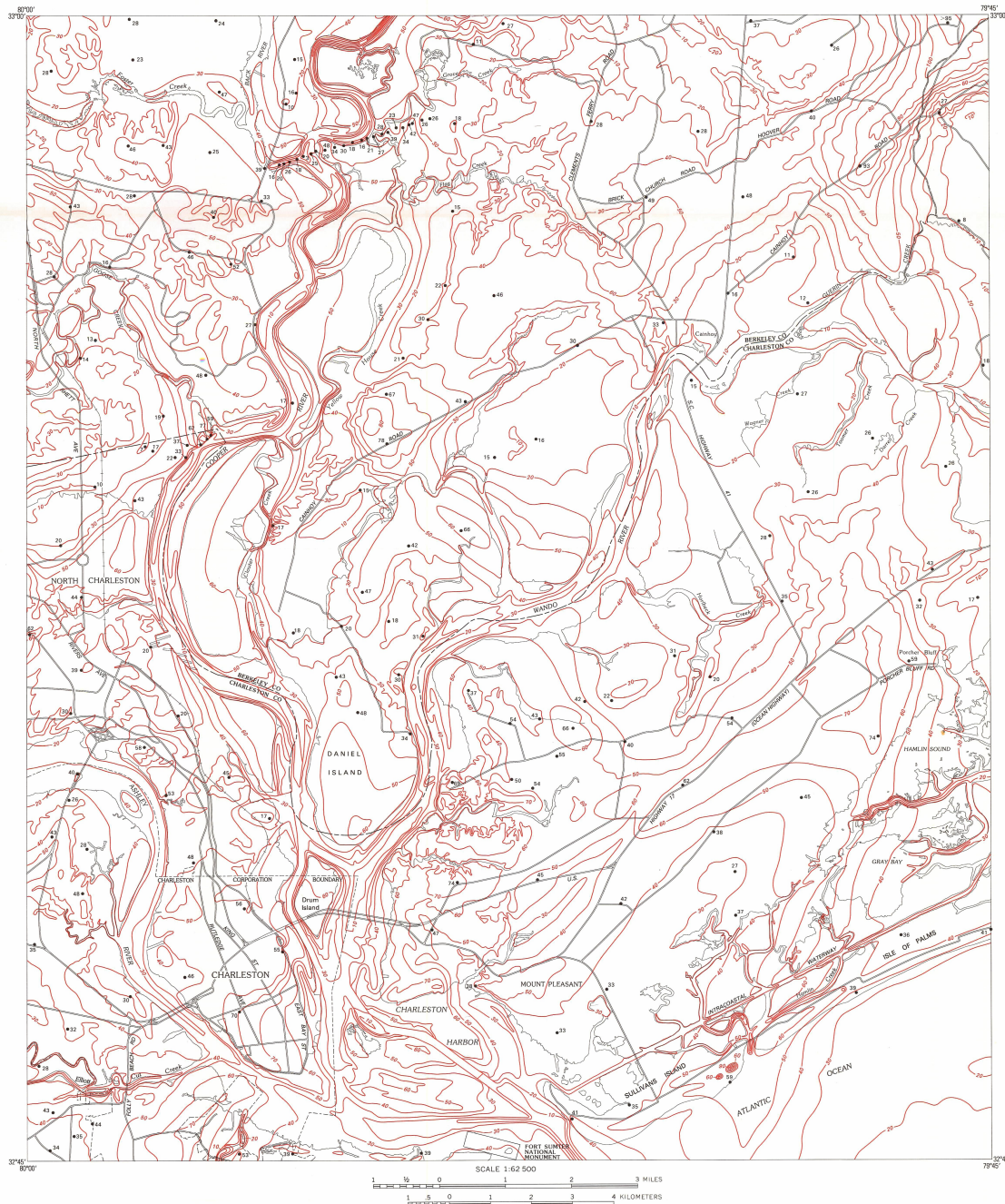


Figure 3.—Isopach map showing thickness of poorly consolidated Quaternary deposits. Isopach contours are shown in red. Contour interval 10 ft (~3 m). Drill hole localities are shown by solid dots; thicknesses are in feet.

Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

Auger Hole Logs

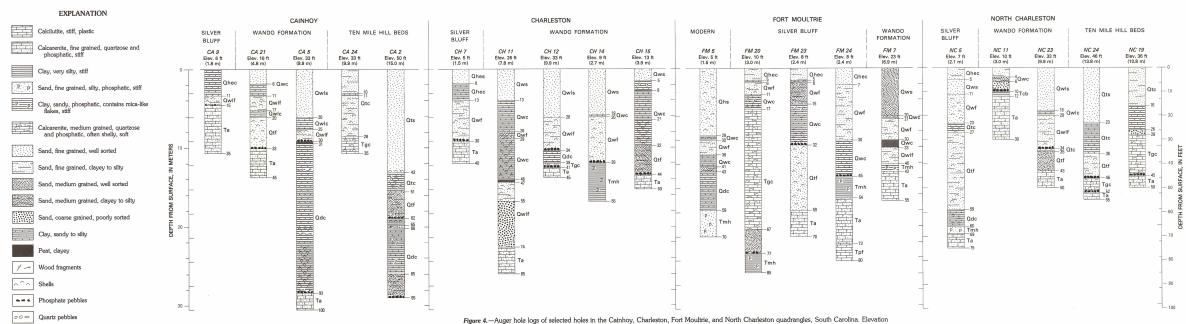


Figure 4—Auger hole logs of selected holes in the Cainhoy, Charleston, Fort Moultrie, and North Charleston quadrangles, South Carolina. Elevation values are given for ground surface at each auger hole site. Formation names are for surficial unit encountered at each site.

Graphic from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#).

Note that auger (drill) holes are present in the GRI digital geologic-GIS data if within the extent of the source map that was used.

Discussion

DISCUSSION

INTRODUCTION

The Cainhoy, Charleston, Fort Moultrie, and North Charleston quadrangles, comprising an area of about 200 mil (520 km²), are located in the outer Atlantic Coastal Plain about midway between the Cape Fear Arch (to the northeast) and the Southeast Georgia Embayment (to the southwest). Marine, marginal-marine, and fluvial-estuarine sediments, ranging in age from late Oligocene to Holocene, crop out or are present just beneath the land surface in these quadrangles. The area is generally low and flat, and much of it is crossed by the tidal estuaries of the Ashley, Cooper, and Wando Rivers. In the northern and northwestern portions of the area, older and topographically higher middle Quaternary deposits attain altitudes as high as 50 ft (15 m), but local relief seldom exceeds 10 ft (3 m). In contrast, submarine relief within the Cooper River estuary is much more pronounced than the onshore relief and ranges up to 70 ft (21 m). Most of the streams and swamps drain centrally from the west, east, and north toward the major rivers in the area. These in turn drain into Charleston Harbor in the vicinity of the city of Charleston ([fig. 1](#)). Only the short streams southeast of the Mount Pleasant barrier (Qws) in the Fort Moultrie quadrangle drain directly to the Atlantic by way of the salt marshes behind the presently accumulating barrier islands, Isle of Palms and Sullivan's Island.

In the shallow subsurface, there are eleven discrete depositional assemblages that record high stands of sea level during the last 40 Ma ([fig. 2](#)). Tertiary transgressions extended well to the northwest of this area; the original inland extent of these transgressions has not yet been determined. These deposits are all marine in origin and accumulated during the more recent stages of a prolonged interval of Coastal Plain subsidence during which the Charleston region subsided a total of about 3,000 ft (900 m) in Late Cretaceous and early Tertiary times (Gohn and others, 1977). The Charleston area has remained tectonically stable since the Oligocene, but the area to the north has continued to rise (Cape Fear Arch) and the area to the south has continued to subside (Southeast Georgia Embayment). As a result of this regional tectonism, Oligocene and older beds generally occur as wedge-shaped sequences that crop out updip in broad east-west-trending belts which dip and thicken toward the south. Because the Charleston area is near the axis of tilting, successive post-Oligocene transgressions of the Atlantic Ocean have induced extensive reworking of each previously deposited unit. This process has produced a mosaic of small remnants of Miocene to lower Pleistocene units distributed more commonly side by side than in superposition. In contrast, many deposits that formed at the same time farther updip to the north have been almost completely removed, whereas most deposits that formed farther downdip to the south have been little disturbed and form nearly continuous sheets.

TERTIARY DEPOSITS

Each Tertiary marine deposit in this area is lithologically distinct and is bounded above and below by disconformities. Basal disconformities commonly are recognized in auger holes by nodular phosphate and (or) glauconite-rich lag deposits that formed during part of the prolonged interval of nondeposition that each disconformity represents (Weems and Lemon, 1985; Weems and others, 1985, 1987). Burrows, filled with poorly sorted matrix and pebbles from the overlying unit, are concentrated in the upper 3 ft (1 m) of each deposit.

Cooper Group

The oldest units encountered by augering in this area are soft, impermeable limestones that were named the Cooper Marl by Tuomey (1848). Ward and others (1979) referred to this unit as the Cooper Formation and subdivided it into three members, the Harleyville, Parkers Ferry, and Ashley. These members were raised to formation rank and the Cooper was raised to group rank by Weems and Lemon (1984) to conform to the usage of formation and group ranks for rock units farther north in Virginia which are of similar diversity, thickness (around 500 ft or 150 m), and areal extent. Use of the term Cooper as a group also has been advocated by Colquhoun and others (1982). The Ashley and Parkers Ferry Formations occur at shallow depths in the map area.

Parkers Ferry Formation

This dense, sticky, moderate-yellowish-green to light-blue-green calcilutite was encountered only in auger hole **FM 24**. The Parkers Ferry formed in a soft-bottomed, open-marine-shelf environment as indicated by the abundant echinoid spines that it contains. A late Eocene (Priabonian) age (about 38 Ma) has been established on the basis of calcareous nannofossil assemblages characteristic of zone NP 20 (Hazel and others, 1977).

Ashley Formation

The most widespread unit in the shallow subsurface of this area is the Ashley Formation, which consists of tough, light-olive-brown, phosphatic and quartzose calcarenite that is only weakly cemented. The abundant marine fauna indicates that it accumulated in an open-marine-shelf environment (Hazel and others, 1977). The presence of sepiolite suggests that a much drier climate existed, at least locally, than at present. Remains of fish, reptiles, birds, and mammals are locally common. A late Oligocene (early Chattian) age (about 30 Ma) has been established on the basis of foraminifera characteristic of zones P20-21 and calcareous nannofossil assemblages characteristic of zone NP 24 (Hazel and others, 1977).

Chandler Bridge Formation

The medium-gray to dusky-green quartz and phosphate sands of the Chandler Bridge Formation accumulated in lagoonal to shallow-marine environments of deposition, as indicated by the admixture of marine vertebrate and terrestrial plant remains (Sanders and others, 1982). The flora suggests that deposition occurred in a warm, temperate climate comparable to the present. Vertebrate remains are common, diverse, and well preserved. A late Oligocene (middle Chattian) age (about 28 Ma) is inferred from the odontocete whale fauna collected from this unit and stored at the Charleston Museum. The Chandler Bridge is soft and erodes readily. For this reason it has been extensively stripped by erosion and persists mostly in thin patches in low areas overlying the Ashley Formation. It has been penetrated in the subsurface of these quadrangles only along the western margin of the North Charleston quadrangle (locality **NC 11**, [fig. 4](#)).

Edisto Formation

The olive-gray to greenish-gray, phosphatic, shelly, calcareous sands of the Oligocene and Miocene

Edisto Formation (about 24 Ma) were considered by Sloan (1908) to be the parent lithology for the "rock phosphate" which once was mined extensively in the Charleston area. This view was challenged by Malde (1959), who thought that the Ashley Formation was a more likely source for this material. Dinoflagellates recently found in a sample of the phosphate rock include species which appear later than Ashley or Chandler Bridge time, but all of the species are closely comparable to those known elsewhere from the flora of the Edisto and Marks Head Formations (L.E. Edwards, USGS, written commun., 1985). Therefore, we accept Sloan's view that the Edisto was the likely parent lithology for the phosphate formerly dredged from the bottom of the Wando River east of S.C. Highway 41 in the Cainhoy quadrangle (Penrose, 1888) and mined near the west border of the North Charleston quadrangle along Filbin Creek. Because the type specimen of *Dioplotherium manigaulti* Cope (a fossil dugong found near Cainhoy during phosphate dredging operations in the river) has matrix still clinging to it which is most comparable to that of the Edisto Formation, this also suggests that the Edisto formerly was present along the bottom of the Wando River near the town of Cainhoy. This formation, in an unphosphatized state, was penetrated only in two holes (**CA 26**, **CA 27**) in the southeastern part of the Cainhoy quadrangle.

Marks Head Formation

The Marks Head Formation, as used by Abbott and Huddlestun (1980), was penetrated at a number of localities within the confines of this map, especially in the Fort Moultrie quadrangle. The Marks Head consists of olive-gray to moderate-olive-brown quartz-phosphate sands and attapulgitic-rich clays. The presence of attapulgitic suggests that this unit accumulated in shallow, brackish-water coastal lagoons (Weaver and Beck, 1982). Although post-depositional alteration of the Marks Head in the Charleston area generally has destroyed all microfossils except pollen and dinoflagellates, farther south it has yielded foraminifera which suggest it is early Miocene (Burdigalian) in age (about 18 Ma) (Abbott and Huddlestun, 1980).

Because the basal contact of the lower Miocene Marks Head Formation drops steeply to the southeast in the Fort Moultrie quadrangle, this unit is exceptionally thick in the southeastern half of that quadrangle along a northeast and southwest trend (see sections **A'-B'** and **D-D'** in the Fort Moultrie quadrangle). The lower contact with the upper Oligocene Ashley Formation and the upper Eocene Parkers Ferry Formation, however, does not show any comparable break in slope across the same region (compare **FM 24**, **FM 17**, and **FM 25** in sections **A'-B'** and **D-D'**). For this reason, the Marks Head is assumed to fill an old erosional valley cut during the early Miocene when sea level was much lower in the Charleston area relative to the present land surface. There is no evidence to suggest that this slope anomaly along the Oligocene-Miocene contact is tectonic in origin.

Goose Creek Limestone

The white to very pale orange quartzose and phosphatic calcarenites of the Goose Creek Limestone were deposited in an open-shelf, shallow-marine environment that received very little clastic influx from the land (Weems and others, 1982). Vertebrate remains are locally abundant, as are shells of pectinids such as *Amusium mortoni*, *Argopecten eboreus*, and *Pecten hemicyclica*. Only calcitic shells have survived; aragonitic shells have been leached out, leaving only molds and casts. The Goose Creek is middle Pliocene in age (between 3 and 4 Ma) as indicated by the occurrence of the shark *Carcharodon carcharias* together with the calcareous nannoplankton, species *Reticulofenestra pseudumbilica* (Gartner, 1967) and *Sphenolithus abies* Deflandre, 1954. The Goose Creek normally is soft and easily excavated, but it can be locally indurated from calcite cementation. Ground water flows freely through this unit, and locally it is known as "the water sands." The Goose Creek is the oldest unit known to crop out naturally in this map area, and it can be seen at low tide at two localities (**NC 2**, **NC 4**) in the North Charleston quadrangle. The locality along Goose Creek near Yeamans Hall is the type section for this unit (Weems and others, 1982).

QUATERNARY DEPOSITS

Quaternary deposits form terrace complexes which represent partially filled backbarrier, barrier-island,

and shallow-ocean-marine-shelf deposits ([fig. 2](#)). These deposits formed during interglacial ages, during which sea level was high due to extensive melting of the polar icecaps. They are very similar to the deposits forming along the Atlantic coastline today. This similarity suggests that each barrier-island deposit represents the position of the Atlantic shoreline at the time it was formed.

Regionally, there are five Pleistocene terrace complexes. Their ages have been established by using biostratigraphic methods, uranium-disequilibrium-series dates obtained from corals, and observations of the relative degree of weathering of clay and heavy minerals in each unit (McCartan and others, 1984). The ages and stratigraphic relations indicate that the terrace deposits record successive transgressive and regressive ocean shoreline movements caused by sea-level changes interacting with vertical tectonic uplift. Presumably the changes in sea level were the result of successive interglacial and glacial ages during the Pleistocene. Normally, on tectonically stable coasts, littoral erosion associated with successive high-sea-level stands removes nearly all deposits of previous high-sea-level stands. The preserved depositional record of many of the earlier Quaternary sea-level oscillations in the Charleston region attests to broad crustal uplift that has occurred in the Charleston region throughout the Quaternary (Cook, 1936). This uplift has carried older beach complexes upward, out of reach of later littoral erosion during subsequent high-sea-level stands. Present altitudes of successive deposits indicate that the average rate of this uplift has been approximately 0.7 in. (1.8 cm)/1,000 years (Cronin and others, 1981). Although barrier and backbarrier deposits are preserved, each succeeding transgression largely reworked the shallow shelf deposits seaward of each immediately older barrier ridge. Because of this, younger beach-ridge and lagoonal deposits lie immediately seaward of and at slightly lower altitudes than the next older coastal deposits. Fine-grained sediments of younger units also fill the bottoms of what were water-filled estuaries and lagoons during older transgressions (see cross section **C'-D'** in the Cainhoy quadrangle and **B-A'** in the North Charleston quadrangle).

The bases of the various Quaternary transgressive-regressive sediment sequences were located from shallow auger holes, excavations, and outcrops, which are numbered and shown on the map. These holes and localities serve as control for the structure contours drawn on the base of the Quaternary units on this map and for the smaller scale isopach map of the same area ([fig. 3](#)). This contoured horizon is of variable age, but it separates the unconsolidated Quaternary deposits from underlying well-compacted to partially lithified Tertiary deposits.

Quaternary map units used in this report correspond to numbered interglacial chronolithologic units of the South Carolina Coastal Plain in McCartan and others (1984). Each lithologic sequence is most commonly found beneath an associated recognizable terrace surface. Each lithologic sequence is never found beneath older terraces at altitudes above that of its normally associated terrace surface, but sporadic outliers are occasionally penetrated when drilling through younger deposits found beneath terraces which lie at lower altitudes. Colquhoun (1974) has applied the names shown in [figure 1](#) to the geomorphic terrace features associated with each lithologic sequence. Stratigraphic names are assigned herein to each coeval complex of facies which form a lithologic sequence because (1) each lithologic sequence is bounded both above and below by a recognizable unconformity, either in the form of a detrital lag deposit or a presently exposed subaerial or subaqueous surface, (2) the local and regional stratigraphic relations have been worked out from extensive new subsurface data, (3) biostratigraphic control for the lithologically subdivided units is now available, and (4) radiometric ages determined for these units show they vary widely in age.

Within each mapped Quaternary rock unit, three facies based on association of mineralogy, texture, and fossils are readily recognized and mapped separately. They correspond to fluvialestuary-backbarrier (c), barrier-island (s), and open-marine-shelf (f) depositional environments ([fig. 2](#); lagoonal (l), barrier (b), and ocean (o), respectively, in McCartan and others, 1984). These facies usually grade into each other over a vertical distance of 1 to 3 ft (0.3-1.0 m), although in places where barrier sands have migrated over backbarrier clays or where estuary channels have produced cut-and-fill structures, the contact may be quite sharp. Together, the three facies form a single facies complex or lithologic sequence. Usually coarse-grained, pebbly lag beds only occur at the base of each lithologic sequence and not between its constituent facies. The thickness of the Quaternary deposits ranges from 0 to 110 ft (0-33 m) ([fig. 3](#)) and is dependent on local variations in spatial relations between

paleochannels, barrier-island morphology, and postdepositional erosion.

Daniel Island beds

This name is applied informally to a subsurface unit composed of layers of dark-bluish-gray to dark-gray clay, mud, and sandy clay. These beds represent the inshore deposits of an extensive paleo-estuary system which has been traced from Daniel Island in the Charleston quadrangle northward to the Kittredge, Bethera, and Cordesville quadrangles and westward to the Ravenel quadrangle. Ostracodes in these deposits are early Pleistocene (Sharon Lyons, written commun., 1982), and the assemblages include only species tolerant of brackish water, even in the vicinity of Daniel Island. To the north, the ostracodes indicate increasingly freshwater environments of deposition and peat becomes more common. This evidence suggests that at the time of deposition of these beds, the shoreline lay at approximately the same position as the present shoreline. It seems probable that any associated terrace and barrier deposits were destroyed by erosion associated with middle and late Pleistocene transgressions which extended well to the west of this area. This unit is preserved only in deeply cut estuaries that were not completely scoured out during later transgressions. Drill holes penetrated these beds most often in the deep paleochannels that are concentrated along the eastern side of the Cainhoy and Fort Moultrie quadrangles. The interval of 32 to 43 ft (-22 to -33 ft elev) in auger hole **CH 21** on Daniel Island constitutes the reference locality and interval for this unit. Although it has not been dated more closely than early Pleistocene, it is assumed tentatively to be about 1,200 ka in age because the time gap between the Waccamaw Formation (unit Q6 of McCartan and others, 1984) and the Penholoway Formation (unit Q5 of McCartan and others, 1984) is the longest time gap present within the local Pleistocene section. The Waccamaw, not present in this map area, accumulated between 1,600 and 1,400 ka ago; the Penholoway accumulated between 970 and 730 ka ago.

Penholoway Formation

The Penholoway Formation, equivalent to unit Q5 of McCartan and others (1984), consists of sand, clayey sand, and clay deposited in shallow-marine to marginal-marine environments. Within the map area, the only possible Penholoway was penetrated at Marion Square in downtown Charleston. There, a bed containing Pliocene or early Pleistocene marine shells was encountered at a depth of 82 to 83 ft (25 m) during the drilling of a deep water well (Stephenson, 1914). Without more information, these sediments cannot be assigned unequivocally to the Penholoway. The basal beds of the Penholoway Formation in the vicinity of Summerville, S.C., have yielded sparse calcareous nannofossils, none of which suggest an age older than the upper part of the Quaternary Zone NN19 of Martini (1971) or no older than 970 ka (Laurel Bybell, USGS, written commun., 1984). The same beds also yielded a piece of coral with a U-Th disequilibrium age greater than 700,000 years (Szabo, 1985). Therefore, on the basis of the data from the Summerville area, the sediments tentatively correlated with the Penholoway in this map area are assigned an early Pleistocene age.

Ten Mile-Hill beds

The clays and clayey sands here included in the Ten Mile Hill beds were deposited in marginal-marine and lagoonal environments that existed adjacent to a barrier beach, the sands of which now constitute the Cainhoy barrier (Colquhoun, 1974). The lagoonal portions of these deposits formerly were included in the Ladson Formation (Malde, 1959) because they formed in similar environments, but they are mapped separately in this report because they record a younger transgression and regression of the sea than that recorded by the beds forming the type section of the Ladson Formation (not present in this map area). Made recognized the "sands on Ten Mile Hill" (a term previously used by Sloan, 1908) as a younger lithologic unit than the Ladson Formation, but not the associated lagoonal deposits. The name is modified here to the informal term "Ten Mile Hill beds" and expanded to include backbarrier and shallow-shelf deposits that formed coevally with the barrier beach that once occupied the present position of Ten Mile Hill in the Ladson quadrangle. The Ten Mile Hill beds, as here defined, underlie only the lower part of the Talbot terrace which is southeast of the Bethera barrier and scarp (Colquhoun, 1974). In this area, these deposits are equivalent to unit

Q3 of McCartan and others (1984). The Ten Mile Hill beds were deposited at the time when sea level in the Charleston area stood about 35 ft (11 m) above its present level relative to the land, as indicated by the present altitude of the top of the lagoonal deposits of this unit. The associated Cainhoy barrier system, which crests at about 50 ft (15 m) above sea level, is composed of the barrier-beach sand facies (Qts) of the Ten Mile Hill beds. This facies is extensively exposed in the Cainhoy and North Charleston quadrangles of the present map area and marks the southeast margin of the outcrop belt of this unit. Northwest of this barrier, clay-rich Ten Mile Hill deposits (Qtc) formed in backbarrier to estuarine environments. Corals recovered by the authors from marine deposits of the Ten Mile Hill beds in the Ravenel and Johns Island quadrangles yielded U-Th ratios which indicate that the unit accumulated between 200 and 240 ka ago (Cronin and others, 1981; McCartan and others, 1982; Szabo, 1985). This age corresponds to marine oxygen-isotope Stage 7 of Shackleton and Opdyke (1973). The Ten Mile Hill beds are poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. The Ten Mile Hill beds, especially the well-sorted sands around Ten Mile Hill, underwent extensive liquefaction during the 1886 Charleston earthquake.

Wando Formation

The Wando Formation is defined by McCartan and others (1980) as only slightly weathered beds of sand, clayey sand, and clay which underlie the Pamlico and Princess Anne terraces of Colquhoun (1974). This unit was mapped as unit Q2 by McCartan and others (1984). The Wando Formation encompasses sediments deposited during three minor but distinct late Pleistocene high-sea-level pulses (Corrado and others, 1986), all of which fall within the major high-sea-level stand defined as Stage 5 by Shackleton and Opdyke (1973). In many places in the Charleston and Fort Moultrie quadrangles, the high-sea-level stand accumulations during these three transgressive pulses are separated by clay beds (Qwc) which were deposited in lagoonal environments present during the intermediate minor regressions (see cross section **A-B'** in the Fort Moultrie quadrangle). Because these lagoonal clay beds are nearly flatlying (their immediately underlying beds are not channelled) and do not include basal lag deposits of coarse sand or gravel, they do not seem to represent regressions that extended far enough east of the present coastline to significantly interrupt deposition during Wando time.

The oldest Wando facies complex was deposited when sea level in the Charleston area stood about 25 ft (7.5 m) above its present level relative to the land, as indicated by the Pamlico terrace. A later (probably the third) Wando facies complex was deposited when sea level in the Charleston area stood about 15 ft (4.5 m) above its present level relative to the land, as indicated by the Princess Anne terrace. The second facies complex cannot be associated with any terrace surface, so its deposits may have been overridden completely by the transgression that deposited the third facies complex. Probably the second complex accumulated when sea level was between present sea level and 15 ft (4.5 m) above present sea level relative to the land. Wando deposits from all of these high-sea-level stands are present in the map area.

The early Wando sea transgressed inland as far as the central Cainhoy, southern North Charleston, and northern Charleston quadrangles. There it laid down the Awendaw barrier system (Qwls). Unlike earlier and later Pleistocene transgressions, extensive salt marshes did not form landward of this barrier. Rather, the beach and marginal-marine sediments (Qwls, Qwlc) were deposited directly against the adjacent mainland in the same manner as the beaches around Myrtle Beach, S.C., are forming today. Marine deposits of the early Wando transgression (Qwlf) are exposed along the northern edge of the Wando River near the town of Cainhoy. This classic exposure has been known from the earliest days of geologic exploration in the Charleston area (Holmes, 1849) and presently constitutes one of the reference sections for the Wando Formation (McCartan and others, 1980). A coral from this bluff along the Wando River yielded a U-Th disequilibrium age of 130 ± 10 ka (Szabo, 1985), suggesting that this transgression corresponds to stage 5e of Shackleton and Opdyke (1973). This portion of the Wando Formation may be equivalent in age to the Socastee Formation of the Myrtle Beach area (DuBar, 1971) because some corals from the Socastee also have yielded U-Th ages of 120 to 130 ka (Szabo, 1985).

After this initial Wando transgression, the sea probably withdrew to slightly below present sea level

and then transgressed again. Marine deposits (Qwf), lithologically very similar to the deposits of early Wando age (Qwlf) but containing corals that have yielded much younger U-Th disequilibrium ages of 80 to 90 ka (Szabo, 1985), were extensively laid down across the Charleston and Fort Moultrie quadrangles. There are now known correlative barrier-island deposits for these sediments. Barrier islands associated with this minor transgression (stage 5c of Shackleton and Opdyke, 1973) probably were destroyed during the third (stage 5a) transgression, which overrode the medial Wando deposits and formed the Mount Pleasant barrier deposits (Qws). The Mount Pleasant barrier sands are very similar in lithology to the early Wando Awendaw barrier sands (Qwls). Behind the Mount Pleasant barrier, which probably formed during stage 5a of Shackleton and Opdyke (1973), an extensive system of estuaries formed which were drained by the ancestral Wando River estuary. These estuaries became partly filled with clay and clayey sand (Qwc) to altitudes as high as 15 ft (4.5 m) above present sea level. These deposits lithologically are very similar to the analogous early Wando lagoonal to estuarine deposits (Qwlc). The Wando is poorly consolidated, easily excavated, and readily eroded. Clay-rich intervals may be quite sticky. Wando sand beds underwent extensive liquefaction to the south and west of this area during the 1886 Charleston earthquake (Dutton, 1889), but liquefaction features are relatively rare within this map area.

Wisconsinan to Holocene deposits

Materials that have accumulated within the last 35 ka are not formally named. Some of these deposits (Qhec) formed in tidal marshes that formerly extended up the Cooper and Wando River estuaries farther than the modern tidal marshes. These deposits can be associated, at least in part, with the Silver Bluff terrace of Colquhoun (1974). Recent tidal-marsh deposits, presently forming in and around the modern Cooper and Wando River estuaries, are mapped as Qht. Round to ellipsoidal depressions (the largest of which could be considered "Carolina bays") commonly are filled with peat and carbonaceous clay (muck) deposits, which date from the Wisconsinan glacial age to the present (Thornbury, 1965; Kaczorowski, 1977). These and other peat and muck deposits which accumulated along slack stream courses have been mapped as Qhm. Should the drainage system in these areas become better established naturally or artificially in the future, the peaty deposits can be expected to be destroyed by oxidation. Areas where sandy sediment seems to be actively prograding along stream courses have been mapped separately as Qa I. Thin deposits of very fine grained, wind-blown sand exist also but are localized and too poorly exposed to be mapped. Wisconsinan to Holocene tidal-marsh, estuary, swamp, and alluvial deposits constituted unit Q1 of McCartan and others (1984). Materials beneath the Silver Bluff terrace are compacted moderately well; Holocene deposits are unconsolidated and saturated with water.

The deposits beneath the Silver Bluff terrace (Qhec, Qhes) previously have been assigned either to the uppermost Sangamon stage (marine oxygen-isotope Stage 5A) or the middle Wisconsinan stage (marine oxygen-isotope Stage 3) (Colquhoun, 1974). The bulk of this deposit is probably middle Wisconsinan in age because a radiocarbon date of $33,070 \pm 1830$ years was obtained from surf-polished wood chips found near the base of this unit in the sand pit between localities **FM 24** and **FM 17** (Beta Analytic Laboratory Report B-20188, 1987) in the Fort Moultrie quadrangle. However, other samples of woody material recovered by augering 5 ft (1.5 m) below this terrace surface in the Fort Moultrie quadrangle (locality **FM 23**), have yielded carbon-14 ages of only $7,860 \pm 80$ years (U.S. Geological Survey Radiocarbon Laboratory Report W-5038, 1982) and of $6,960 \pm 200$ years (U.S. Geological Survey Radiocarbon Laboratory Report W-5322, 1984). This suggests that some local deposits of early Holocene age also are present within this terrace complex.

Materials from beneath the modern marshes surrounding the Cooper River (Qht) yield ages only as old as 5 ka (Brooks and others, 1979; Cinquemani and others, 1982). Peat and muck deposits (Qhm) are thin, but many were deposited as long ago as middle or early Holocene time. For example, a core taken in the northeastern quarter of the Cainhoy quadrangle at locality **CA 20** yielded 5 ft (1.5 m) of peat, the basal few inches of which yielded a carbon-14 age of $6,260 \pm 200$ years (U.S. Geological Survey Radiocarbon Laboratory Report W-5282, 1983). A few of these deposits could be much older, because at least one peat bed locality in the nearby Ladson quadrangle (see [fig. 1](#)) has yielded wood with a carbon-14 age of $34,000 \pm 700$ years BP (U.S. Geological Survey Radiocarbon Laboratory

Report W-5388, 1984).

GEOLOGIC HISTORY

The area of this map has been inundated repeatedly by marginal-shelf seas of the Atlantic Ocean since Late Cretaceous time. A summary of the lithostratigraphy and biostratigraphy of the materials which accumulated during Late Cretaceous and early Tertiary marine transgressions is presented by Gohn and others (1977) and Hazel and others (1977). These older deposits occur in this map area only in the subsurface (65-3,300 ft or 20-1,000 m below sea level).

The oldest unit penetrated by auger drilling within 75 ft (23 m) of the surface is the late Eocene Parkers Ferry Formation. At the time of deposition of this unit, the map area was located on the continental shelf under open-marine waters, but the fine texture and restricted fossil assemblage of the Parkers Ferry indicate that the ocean bottom was soft and covered with calcareous ooze which was foraged and extensively bioturbated by echinoids. The Parkers Ferry contains the zeolite mineral clinoptilolite, which is considered to be an alteration product of volcanic ash (Gohn and others, 1977). No younger unit has yielded this mineral, although it does occur in older local units throughout the late Paleocene. Following deposition of the Parkers Ferry, the sea withdrew eastward beyond the position of the present coastline.

The next known major transgressions of the sea across the map area occurred in late Oligocene time, when the Ashley and Chandler Bridge Formations were deposited. The Ashley accumulated well offshore in an open-marine shelf environment. During the deposition of the Ashley, in contrast to the Parkers Ferry, fine carbonate sand with subordinate quartz and phosphate sand accumulated on the sea bottom. Foraminifera tests are abundant; mollusk, coral, and vertebrate remains are sparsely distributed. By the end of Ashley time, the sea briefly withdrew to the east. Soon after, perhaps 1 to 2 Ma later, it readvanced across the largely undissected surface of the Ashley to deposit the marginal-marine to shallow-shelf quartzose and phosphatic sands of the Chandler Bridge Formation (Sanders and others, 1982). This unit represents a shallower and more clastic shelf deposit than the Ashley. The Chandler Bridge once contained abundant mollusk shells, but these have been largely leached out and only their casts and molds remain. Phosphatic vertebrate remains, which were not so affected by leaching, are abundant.

The sea withdrew again from the Charleston area during late Oligocene time to east of the present coastline and next transgressed across the outer Coastal Plain during very late Oligocene or very early Miocene time. During this transgression, the Edisto Formation was deposited. The Edisto Formation is an impure, quartz-rich limestone (Ward and others, 1979), which in some areas was extensively altered to rock phosphate. In most areas, only blocks of rock phosphate remain, reworked into the basal lag beds of younger units. This sort of material was dredged from the bottom of the Wando River east of S.C. Route 41 for commercial phosphate (Penrose, 1888). Small remnant patches of unaltered Edisto were encountered at only two localities (**CA 26, CA 27**).

During early Miocene (Burdigalian) time, the area was inundated by marginal-marine lagoons, in which were deposited phosphatic, fine-grained, attapulgite-rich, clayey sands and clays of the Marks Head Formation. This unit is widespread in the Fort Moultrie and southeastern Charleston quadrangles, where it appears to occupy a large erosional channel that trends northeast to southwest. The size and depth of this channel suggests that a major regression, accompanied by extensive erosion, must have occurred between Edisto and Marks Head time.

A late Miocene or early Pliocene transgression is suggested for the Charleston area on the basis of phosphatized vertebrate remains of late Miocene or early Pliocene ziphiid whales, present in the Pleistocene lag gravels in this region (Leidy, 1876, 1877). No deposits of this age have been discovered so far in either surface outcrops or auger holes.

A regional middle Pliocene transgression occurred which deposited the Goose Creek Limestone in a shallow-marine shelf environment. Goose Creek sediment is abundant only east of the Cooper River in the map area, but probably once occurred as an extensive continuous cover of limestone over the

entire area. The Goose Creek usually lies directly over the Ashley Formation. This suggests that the Miocene units mostly were stripped away in latest Miocene or earliest Pliocene time prior to deposition of the Goose Creek. Thus, by inference, a regression of the sea eastward beyond the present coastline occurred during late Miocene and (or) early Pliocene time. Similarly, because the Goose Creek was eroded from wide areas before deposition of the lower Pleistocene Waccamaw Formation, a late Pliocene to early Pleistocene regression must have occurred.

No deposits equivalent to the Waccamaw(?) Formation (unit Q6 of McCartan and others, 1984) were discovered in this area, but the wide extent of this unit northwest of the map area beneath the Wicomico terrace indicates that deposits of a regional transgression about 1.5(?) Ma ago once were present but have been stripped away. Younger Pleistocene deposits (the Daniel Island beds, the Penholoway Formation(?), the Ten Mile Hill beds, and the Wando Formation) still occur in this area. These are associated with interglacial Pleistocene marine transgressions about 1,200(?) ka, 850 ka, 200 ka, and 100 ka ago, respectively.

In Daniel Island time, perhaps around 1,200 ka ago, the sea probably transgressed inland only to about the present coastline because no fully marine deposits of this age have been found. During this time, an extensive estuary system formed across most of the map area. Small patches of the Goose Creek Limestone occasionally are found immediately beneath the Daniel Island beds at depths much greater than where the Goose Creek is found in nearby areas where the Daniel Island beds are absent. This suggests that the Daniel Island estuary system occupies an older Goose Creek channel system, from which the Goose Creek sediment was largely scoured out in late Pliocene and (or) early Pleistocene time.

After Daniel Island time, the sea withdrew to the east. The sea again transgressed entirely across the map area about 850 ka ago to deposit the Pinopolis/Summerville barrier to the northwest of the map area. Most beds of this age have been stripped from the map area, but one small outlier in the Charleston quadrangle possibly is equivalent to this unit (Qpf). The sea withdrew eastward and then transgressed again across this area about 450 ka ago to deposit the Bethera barrier system north and northwest of the map area (Colquhoun, 1974). If deposits of this age once were present in the quadrangles mapped here, they have been stripped away by later erosion, for no deposits formed during this transgression were found.

The sea withdrew to the east and transgressed again about 200,000 years ago to form the Cainhoy barrier system (Qts) across the Cainhoy and North Charleston quadrangles. Northwest of this barrier, an extensive series of marginal-marine deposits (Qtc) accumulated in a large backbarrier lagoon. When sea level dropped after this transgression, the old tidal estuaries within this lagoon were transformed into the streams that presently drain most of the map area northwest of the Cainhoy barrier (Qts).

The next transgression in early Wando time, about 120 to 130 ka ago, left a narrow shoreline deposit (Qwls) parallel to and abutting the seaward edge of the Cainhoy barrier. About 75 ka ago, after a minor regression, the late Wando sea transgressed inland only far enough to deposit the Mount Pleasant barrier system across the Fort Moultrie quadrangle. The extensive backbarrier marsh deposits (Qwc) between the Cainhoy (Qts) and Mount Pleasant (Qws) barriers all represent deposits which accumulated during this late Wando transgression. The area that was then occupied by tidal channels became the ancestral Wando River and its tributaries. At the end of Wando time, about 70 ka ago, the sea withdrew to the east of the Charleston area as the Wisconsin ice sheet formed and locked up water from the world's oceans.

Evidence for a middle Wisconsinan high-sea-level stand slightly above present sea level recently has been found in the Fort Moultrie area of this map. Surf-rounded bits of wood, found near the base of the Silver Bluff deposits at present sea level, yielded a radiocarbon age of $33,070 \pm 1,830$ years (Beta Analytic Laboratory Report B-20188, 1987). Supporting evidence for this high-sea-level stand is provided by grossly similar radiocarbon dates of around 23 to 27 ka reported from *Anadara brasiliensis* shells collected on Edisto Beach about 30 mi (50 km) to the southwest of Charleston (Mathews, 1978). Similarly, evidence has been cited for a middle Wisconsinan high-sea-level stand in Maryland

and Delaware (Field and others, 1979; Owens and Denny, 1979) and along the south coast of Long Island, N.Y. (Rampino and Sanders, 1981). After this middle Wisconsinan high-sea-level stand, sea level dropped to at least 200 ft (60 m) below its present level by 16 to 17 ka ago (Blackwelder and others, 1979).

Near Porcher Bluff, in the northeastern corner of the Fort Moultrie quadrangle, there is a reentrant marsh deposit formed of clayey sands and clays (Qhec), which directly overlies wood fragments (recovered by augering) dated at about 7 ka (U.S. Geological Survey Radiocarbon Laboratory Reports W-5038, 1982, and W-5322, 1984). This marsh deposit lies behind a middle Wisconsinan spit-and-beach deposit composed of broadly crossbedded, fine- to coarse-grained waterlaid sands (Qhes). The ponding of water in this depression may indicate that sea level, and with it the ground-water table, has risen to approximately its present level about 6 to 7 ka ago during the middle Holocene. This evidence for a middle Holocene high-sea-level stand is equivocal, but evidence for a transgression of this age has been found in Australia (Fairbridge, 1961), Brazil (Delibrius and Laborel, 1971; Suguio and Martin, 1982), Britain (Godwin and others, 1958; Chisholm, 1971; Sissons and Brooks, 1971; Tooley, 1974; Cullingford and others, 1980; Paterson and others, 1981), France (Ters, 1973), the Gulf of Mexico (Beard, 1973), Japan (Fuji, 1966), Madagascar (Battistini and others, 1976), Mauretania (Einselee and others, 1974), and Taiwan (Lin, 1969; Hashimoto, 1972). If this transgression occurred, it must have been followed by a minor regression between 5 and 6 ka ago, because freshwater diatoms have been reported from samples dated as being 2 to 5 ka old from beneath the modern salt marshes (Cinquemani and others, 1982). Additionally, Native American shell middens of this age have been found beneath the salt marshes to the south along the coast of Georgia (DePratter and Howard, 1981). In the last 2 Ma, the sea has been rising and transgressing landward (Tuomey, 1848; Brooks and others, 1979); the presence of wood only 950 years old beneath the back edge of the modern marsh at locality **FM 28** (U.S. Geological Survey Radiocarbon Laboratory Report W-5039, 1982) indicates that the modern salt marshes have reached their present landward extent in less than the last thousand years.

GEOMORPHOLOGY

The geomorphology of this area has been strongly influenced by recent geologic history. Virtually all of the features which can be seen in this area resulted from the deposition of sediment along the Atlantic shoreline during interglacial intervals around 240 to 200 ka ago, 120 to 70 ka ago, during the middle Wisconsinan high-sea-level stand, and within the last 7 ka. Only minor modification by erosion along the larger river valleys has occurred during the intervening glacial intervals, so most deposits are well preserved and look nearly the same as when they formed. During glacial intervals, sea level was down 200 ft (60 m) or more below its present level (Blackwelder and others, 1979) and the presently sluggish streams in this area had gradients sufficiently steep to actively erode their streambeds. The results of this stream erosion mostly are buried now beneath the modern tidal estuaries, but a few streams are still actively downcutting into the Cainhoy barrier in the vicinity of the town of Cainhoy.

The portion of the Cooper River flowing through this area north of the Cainhoy barrier (Qts) probably originated as a middle Pleistocene tidal estuary connecting tidal marshes (Qtc) to the northwest with the Atlantic Ocean between two coastal barrier islands (Qts). The Wando River probably had a similar origin, but formed at a later time in the late Pleistocene when it constituted the major backbarrier tidal estuary behind the Mount Pleasant barrier (Qws). The prominent bend in the Wando River at Cainhoy just west of the S.C. Route 41 bridge in the Cainhoy quadrangle seems to have been accentuated by the presence of a deep, crosscutting, much older Pleistocene channel filled with soft sediment. Where the Wando channel cut into the tough Ashley Formation during the Wisconsin glaciation, it now can only migrate laterally with great difficulty. Where the Wando channel cut into soft Pleistocene sediments, however, the modern estuary tidal currents readily can scour into the soft sands and clays along the edge of the channel to enlarge a preexisting bend. This tendency for the river to migrate laterally, where its channel is not firmly constrained, locally has allowed the course of the river to deflect strongly to the northwest in the vicinity of the town of Cainhoy so that it has formed a bluff in that vicinity. The cutting of this bluff also has steepened the gradients of the local streams so that they have become competent to locally cut into the Cainhoy barrier. In contrast to the Cooper and Wando

Rivers, the trend of the Ashley River (southeast) seems to cut across the regional depositional trends (northeast to southwest). For this reason, the location of the Ashley River is suspected to be, in part, of tectonic origin and may be related to the Ashley River fault zone of Talwani (1982).

The crests of the Cainhoy and Mount Pleasant barriers (Qts and Qws), which were similar in origin to the modern barrier islands presently forming along the coast in the Fort Moultrie quadrangle (Qhs), are the topographically highest areas in this region and have been deliberately chosen for highway routes (U.S. Route 17, Cainhoy Road, Rifle Range Road) because they are relatively well drained, level, not prone to flooding, and require minimal bridge construction. A prominent sag 10 ft (3 m) deep occurs along the crest of the Mount Pleasant barrier northwest of Porcher Bluff in the northeast quarter of the Fort Moultrie quadrangle. A similar sag (15 ft or 4.5 m deep) occurs in the Cainhoy barrier in the southeast corner of the North Charleston quadrangle. Both of these sags overlie deep Pleistocene channels filled with poorly compacted sediment. These particular sags probably resulted from great compaction and dewatering of sediments in the old channels relative to the compaction and dewatering in the less thick Pleistocene sediment stacks present to the northwest and southeast of these channels.

The approximate inland limits of Charleston Harbor may have been constrained by the inland limit of the Marks Head Formation subcrop belt, which runs roughly around the back edge of the harbor. The Marks Head, although sticky, is much softer than the Ashley Formation, which is a tough and cohesive sediment. Therefore, the rounded and open contours of Charleston Harbor could be readily scoured from the relatively soft Marks Head Formation by stream and marine erosion, while the tidal estuaries of the Ashley, Cooper, and Wando Rivers remained narrow and more confined because they are rooted in the much tougher and less easily scoured Ashley Formation.

The modern barrier islands and the sediment collecting in the marshes behind them are excellent examples of geologic features still in the process of forming. At a future date, if sea level drops again, the marsh clays ("pluff clay" of Tuomey, 1848, p. 187) and associated deposits will come to resemble the sediments mapped here as Qtc and Qwc, while the barrier islands will become a sand ridge similar to the Cainhoy barrier (Qts) and the Mount Pleasant barrier (Qws).

The coastal geography of the cities of Charleston and North Charleston has been extensively modified by the addition of artificial fill to remove or reduce areas of swampy and (or) easily flooded land, as can be seen by a comparison of older with more recent maps of the city (see, for example, Barboh, 1884, which was used for this report to estimate the extent of artificial fill in Charleston and North Charleston). Additionally, periodic dredging and deepening of the Charleston Harbor area has resulted in the accumulation of extensive spoil heaps of poorly compacted mud over large areas at the south end of Daniel Island and across most of Drum Island. Continued economic development in the area will add to the area occupied by artificial fill.

TECTONICS

The area covered by this map lies southeast of the meizoseismal zone of the Charleston 1886 earthquake. Even so, extensive damage due to that earthquake was reported and photographed in the city of Charleston, largely because the city is built on a thick layer (30-70 ft or 10-21 m) of soft, easily liquefied upper Pleistocene sand and mud. Disruption of this poorly compacted material during the earthquake produced widespread ground failure and broken foundations within the city. Liquefaction features from the 1886 earthquake have been found as far east as Mount Pleasant in the Charleston quadrangle and as far south as the southwestern corner of the Charleston quadrangle on the Charleston gold course. Liquefaction features which appear to be older than 1886 have been found in the other quadrangles; this suggests that seismicity has occurred in the past throughout this region. Tremors have been reported in the area around Sullivans Island on December 19, 1857 (McCrary, 1859) and November 19, 1952 (Coffman and von Hake, 1973, p. 33), but no historic seismicity has been reported from the Cainhoy or North Charleston quadrangle areas.

A very unusual feature is present in the northwest portion of the North Charleston quadrangle which cannot be easily explained as a depositional or erosional feature. This area, north of Red Bank Road

and south of Foster Creek, is bounded by two relatively steep scarps dropping down from the backbarrier surface of the Ten Mile Hill beds to the backbarrier surface of the Wando Formation. These scarps are nearly straight and meet each other at nearly a right angle. Erosion of these scarps by a laterally migrating stream or by estuary wave action should not have produced a nearly right-angle juncture of these two scarps, but subsidence along two intersecting fractures could produce such a juncture and also would explain why the small stream entering this flat area from the west flows almost along the strike of the north-facing scarp. This feature, therefore, might be tectonic in origin. If it is tectonic, it formed within the last 200,000 years because its bounding scarps are formed by the 200,000-year-old Ten Mile Hill beds.

ECONOMIC GEOLOGY AND WATER RESOURCES

Phosphate, chiefly concentrated as a lag bed at the base of the Wando Formation, was widely mined about 5 mi (8 km) to the west of this map area in the Johns Island and Ladson quadrangles from 1867 to 1937 (Ma1de, 1959). Except for the small area strip mined along Clouter Creek in the North Charleston quadrangle, the only records of mining in the map area indicate that portions of the Wando River in the central Cainhoy quadrangle were dredged for detrital rock phosphate that was concentrated on the river bottom (Penrose, 1888). No known economic potential is acknowledged for this resource in the area at the present time. Only slight potential exists regionally for extracting uranium from the phosphate-rich lag gravels at the base of the various Quaternary units (Force and others, 1978). The Edisto Formation is the probable parent lithology for most of the rock phosphate (Sloan, 1908).

Sand and earth fill are the only mineral resources presently exploited in the area (Long and others, 1980; Miller and others, 1971). The barrier sands contain the purest sands, while the backbarrier deposits contain variable amounts of clay. Both deposits are excavated by strip mining. Locations of many borrow pits are mapped, but others probably exist which escaped detection during mapping.

The Quaternary units and the Goose Creek Limestone (which is locally known as the "water sands") are generally saturated with water and are occasionally tapped by wells where the water is not too brackish. The major aquifers in this area, located within the Santee Limestone (middle Eocene) and the Black Mingo Group (Paleocene), are all below the depths shown in this report. Occasionally the water in these units is under sufficient artesian pressure to force it up to the land surface. This is probably the case at the locality on the eastern border of the Cainhoy quadrangle labeled "spring."

POSTSCRIPT

Before this map could be published, coauthor Earl M. Lemon, Jr., met an untimely death from a heart attack at age 39. The remaining author is extremely grateful for the hard work and keen insights that Mr. Lemon contributed to this and other Charleston area U.S. Geological Survey maps and papers. The completeness and accuracy of these works have been enhanced greatly by Mr. Lemon's effort and dedication; he and his expertise will be sorely missed.

Text from source map: [Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles](#)

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Charleston Quadrangle (Digital Geology and Topography)

The formal citation for this source.

Weems, Robert E., Lemon, Earl M. Jr., and Chirico, Peter G., 1997, Digital Geology and Topography of the Charleston Quadrangle, Charleston and Berkeley Counties, South Carolina: U. S. Geological Survey, Open-File Report OF-97-531, scale 1:24,000 (*GRI Source Map ID 5574*).

Relevant text associated with this source is presented below.

Digital Metadata Explanation

Abstract:

This geologic map represents the geographic information system (GIS) digital files of the geology and topographic features of the Charleston Quadrangle, Charleston and Berkeley Counties, South Carolina. These files were produced from a previously published map at 1:24,000 scale: Geology of the Cainhoy, Fort Moultrie, Charleston and North Charleston Quadrangles, Charleston and Berkeley Counties, South Carolina, by Robert Weems and Earl Lemon (1994). In addition to the geology layer all other basemap features are represented in digital form, including the hypsography, hydrography, and transportation (roads and railroads).

The original published map was constructed using data from numerous auger holes drilled throughout the quadrangle. The data from these auger holes were used to identify the number and types of units and their distribution throughout the quadrangle. The surficial units represented have geomorphic expressions in the Charleston area, and these expressions were used in construction of the geologic map.

The hydrography and transportation layers are USGS 1:24,000 DLG's which have been imported into Arc/Info GIS software to provide the base for the digital geologic map. The hypsography (topographic contours) and the geology were scanned from map separates provided on film. These layers were scanned at 600 dpi using an Anatech Eagle 4080ET scanner. The raster layers were then vectorized in GTX OSR raster to-vector conversion software. The resultant DXF files were imported into Arc/Info, transformed and then registered to the basemap coverages. The scanned hypsography coverage was attributed, edited and corrected using the hydrography coverage as the master or 'boss' layer. Digital geology was overlaid and corrected in a similar manner with the hydrography and hypsography as boss layers. Although USGS Digital Line graphs do carry quantified accuracy statements the geology and topography coverages shown here have been passed through a quality control check to validate use at 1:24,000 scale.

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Graphical depictions of this data are intended to be used within the map scale limits applicable to the source data. Although a geographic information system enables the user to show data at various scales, the user is reminded to refer to the appropriate map scale limitations.

References Cited

Weems, Robert E., and Lemon, Earl M., 1993, Geology of the Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles, Charleston and Berkeley Counties, South Carolina

Text from source map: [Charleston Quadrangle \(Digital Geology and Topography\)](#)

GRI Digital Data Credits

This document was developed and completed by Stephanie O'Meara (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Ron Karpilo (Colorado State University).

The information in this document was compiled from GRI source maps, and is intended to accompany the digital geologic-GIS maps and other digital data for Fort Sumter and Fort Moultrie National Historical Park, South Carolina (FOSU) developed by Stephanie O'Meara and Georgia Hybels (Colorado State University; see the [GRI Digital Map and Source Map Citations](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps).

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