Geologic Resources Inventory Scoping Summary
Canaveral National Seashore, Florida

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The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a Geologic Resources Inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRI scoping meeting for the park units of the Southeast Coast Network (SECN) during the week of April 20–24, 2009 at Jacksonville, Florida. These units included Canaveral National Seashore (CANA), Castillo de San Marcos National Monument (CASA), Cumberland Island National Monument (CUIS), Fort Caroline National Memorial (FOCA), Fort Frederica National Monument (FOFR), Fort Matanzas National Monument (FOMA), Fort Pulaski National Monument (FOPU), and Timucuan Ecological and Historic Preserve (TIMU). Canaveral National Seashore was discussed on April 20. Bruce Heise (NPS GRD) facilitated the meeting, presented an overview of the GRI program, and led the discussion regarding geologic processes and features at each NPS unit. Stephanie O'Meara (Colorado State University) led the discussion of map coverage relevant to each unit. Randy Parkinson (RWParkinson Consulting) presented an overview of coastal regional geology and barrier island geomorphology. Participants at the meeting included NPS staff from the park, Geologic Resources Division (GRD), and Southeast Coast Network (SECN) and cooperators from the U.S. Geological Survey (USGS), Florida Geologic Survey (FGS), University of West Georgia, Polk Community College, and Colorado State University (CSU) (see table 2).

Canaveral National Seashore is unique because a digital geologic map was provided to the park by RWParkinson Consulting in 2007 at the request of the National Park Service. This scoping summary for Canaveral National Seashore, therefore, highlights the geologic setting, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, and a record of meeting participants.

Park and Geologic Setting

Canaveral National Seashore, along with the entire state of Florida, lies on the Floridian Plateau, a physiographic province approximately 800 km (500 mi) long and 400 – 640 km (250 – 400 mi) wide. The plateau, which has existed for millions of years, includes both emergent land and submerged continental shelf. Areas on the plateau have been alternately covered by seawater and exposed as dry land many times in the past so that marine and terrestrial deposits have been deposited one on top of the other.

With its approximately 23,000 ha (58,000 acres) of barrier island, open lagoon, coastal hammock, and pine flatwoods, Canaveral National Seashore represents an excellent example of a relatively stable barrier-beach complex backed by a productive lagoon system. Elongated north to south, the park shares its western border with Merritt Island National Wildlife Refuge and is southern border with the John F. Kennedy Space Center. Mosquito Lagoon lies between the barrier island on the east and an isthmus of the mainland to the west. The Indian River lies to the west of Canaveral National Seashore. About 24 km (15 mi) southeast of Canaveral National Seashore, Cape Canaveral juts out into the Atlantic. Similar to Cape Hatteras in North Carolina, Cape Canaveral forms a cuspate foreland where northern and southern ocean currents merge.

Mosquito Lagoon contains numerous islands and many small, intertidal oyster reefs in the northern portion. The 1.6 km (1 mi) wide lagoon is shallow, averaging 1.2 m (4 ft) deep. Mosquito Lagoon is connected to the Atlantic Ocean by the Ponce de Leon Inlet, located 16 km (10 mi) north of the park, and to the Indian River by the artificial Haulover Canal. Little flushing occurs in the lagoon and tides are measured in inches. The Intracoastal Waterway extends through the northern two-thirds of Mosquito Lagoon and then crosses over to the Indian River through the Haulover Canal.

Multiple sea level rises and falls over an estimated 240,000 years resulted in today's barrier island complex at Canaveral National Seashore. The barrier-island and tidal-inlet system of Florida's east coast extends for approximately 550 km (342 mi), making it the longest in the United States. South of Matanzas Inlet, Florida's east coast is wave-dominated, rather than tide-dominated, the sand supply is low, and the resulting barrier islands are long and narrow with widely spaced tidal inlets (Davis 1997). Unlike many barrier islands, Canaveral National Seashore has only one single dune ridge that forms the backbone of the island. The ridge averages 4 m (12 ft) high and serves to intercept wave action, wind abrasion, and salt spray. The dune shelters inland plant communities and provides valuable habitat for a variety of protected species. The 40 km (24 mi) of shoreline at Canaveral National Seashore is the longest stretch of undeveloped public beach on the east coast of Florida.

Surface exposures at Canaveral National Seashore include deposits of Pleistocene (1.8 million years ago) Anastasia Formation, Pleistocene and Holocene (10,000 years ago to present) beach ridge and dune sediments, and Holocene sediments deposited in beach, swamp, dune, and shallow marine environments (Tweet et al. 2009). The Anastasia Formation formed in beach and shallow-water nearshore environments where sand grains and mollusk shells cemented together to form a sedimentary rock called a "coquina." The Anastasia Formation typically anchors Florida's east coast barriers, and in some areas, high foredunes develop that prevent overwashing and landward migration. The coquina was used in the construction of Fort Matanzas at Fort Matanzas National Monument, north of Canaveral National Seashore.

Pleistocene – Holocene marine terraces at Canaveral National Seashore document ancient shorelines and consist of a layer of marine sediments at their base followed by a thicker sequence of coastal terrestrial sediments, such as beach sands, barrier island deposits, estuarine or back-barrier sands and clays. Floodplain deposits left behind by receding shorelines typically form the uppermost layer. Talbot, Pamlico, and Silver Bluff marine terraces are present in or near the park. The Talbot terrace rises 7.6 – 12.8 m (25 – 42 ft) above sea level, the Pamlico terrace is 1.8 – 7.6 m (6 – 25 ft) above sea level, and the Silver Bluff terrace is 0 – 3.1 m (0 – 10 ft) above sea level (Tweet et al. 2009).

Regional Geology and Barrier Island Geomorphology (Randy Parkinson)

Fort Pulaski National Monument, Fort Frederica National Monument, and Cumberland Island National Seashore are part of Georgia's Coastal Plain, one of five major northeast-southwest trending geologic zones that define the landscape in the southeastern United States. From northwest to southeast, these geologic zones include the Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain provinces. The Coastal Plain is a broad and gently sloping landscape that consists of nearly horizontal sedimentary layers that were deposited, eroded, and modified over the past 100 million years and continues to be modified even today. Barrier islands, tidal creeks, and extensive marshlands mark the eastern edge of the province. To the west, the "Fall Line" represents the boundary between the Coastal Plain and Piedmont provinces. The Fall Line, identified on topographic maps by a series of waterfalls, marks an abrupt change in elevation between the low-lying plains and the rolling topography and foothills of the Piedmont. The Piedmont and the other elevated provinces formed from tectonic events spanning 250 million to 1 billion years ago. The provinces continue to undergo erosion and supply sediment via rivers and streams to the Coastal Plain and its barrier islands.

Linear features identified on the Coastal Plain represent previous coastlines and barrier islands associated with major fluctuations of sea level over the past 400,000 years. Sea level fell during periods of glacial advance and rose during interglacial periods when glaciers melted. Sea level began to rise about 20,000 years ago and rose rapidly until about 6,000 years ago when the present barrier islands along the eastern seaboard formed. The rapid rise in sea level drowned previously existing barrier islands. About 3,000 years ago, coastal features stabilized so that although sea level continues to rise and the coastline continues to retreat landward, the barrier islands, wetlands, lagoons, and other coastal features have maintained their geomorphic integrity.

Barrier islands require an abundant sediment supply, moderate to high wave energy, micro- to meso-tidal ranges of less than 4 m (13 ft), rising sea level, and a broad continental shelf. Barrier island morphology is controlled by both tidal range and wave height. Wave dominated barrier islands, such as those along the east coast of Florida, are long and straight. Short, crenulated barrier islands along the Florida panhandle and southwest coast are tide dominated. The short barrier islands along the Georgia coast result from a mixed wave and tidal energy.

Three conceptual models have been proposed for the origin of barrier islands: 1) dune drowning, 2) spit elongation, and 3) shoal emergence. Dune drowning occurs with a relative rise in sea level, which may inundate a mainland ridge of coastal dunes so that a lagoon develops between the most seaward dune ridge and the mainland. Stable sea-level conditions and/or an abundant sand supply are conducive to the development of barrier islands by spit elongation. In the spit elongation model, longshore currents transport sand along the coast, and the sand is deposited on the flanks of headlands or at the downdrift ends of existing barrier islands. As these relatively thin spits of sand elongate, they form barriers that block embayments and form lagoons. Eventually, tidal inlets may separate the spits from the headland, forming a barrier island. Shoal emergence results when erosion and redistribution of sediment on the sea floor promotes the upward growth of a submerged sand bar. Shoal emergence is aided by a relative fall in sea level and a local surplus of sand that can maintain the barrier above the ocean's surface.

Barrier islands can be subdivided into a back barrier region, dune system, and beach (fig. 1). A lagoon or estuary separates the barrier island from the mainland. Flood-tidal deltas form on the incoming tide while the outgoing tide produces ebb-tidal deltas. During storms, washover fans distribute sediment into the back barrier and push the barrier island landward.

Sea level rise is a major driving force with regards to barrier island sustainability. With a relative sea level rise (transgression), barrier islands migrate landward. Vertical cross-sections through present barrier island systems show this landward migration over time. Buried beneath today's beaches, for example, are yesterday's lagoon and mainland environments. Currently, the margins of North America are being subjected to coastal erosion. Understanding barrier island morphology and its dynamic association with sea level rise, tides, and wave energy may be used to project future coastline patterns.

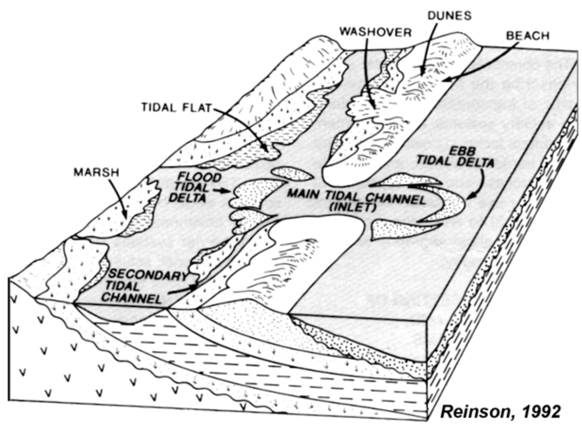

Figure 1. Common coastal environments associated with barrier islands. Schematic from Reinson (1992).

Geologic Map of Canaveral National Seashore

RWParkinson Consulting Inc. constructed the geologic map of Canaveral National Seashore at a scale of 1:24,000. Mapping units were generated based on the following morphogenetic features typically associated with a barrier island system and cuspate foreland (Parkinson and Schaub 2007).

Table 1. Hierarchical scheme of Canaveral National Seashore morphogenetic units.

LEVEL 1	LEVEL 2	LEVEL 3
BARRIER ISLAND	Continental Shelf	Inner shelf
	Open Ocean	Shoreface
		Beach
		Dune
	Platform	Upland
		Wetland
LAGOON	Island	Upland
		Wetland
	Island – Part Spoil	Upland
		Wetland
	Island - Spoil	Upland
		Wetland
	Subtidal	Seagrass – continuous
		Seagrass – continuous
		Barren
CUSPATE FORELAND	Relict Beach Ridge Complex	Ridge
		Swale
		Undifferentiated

The GRI converted the Parkinson and Schaub 2007 geologic map to the NPS GRI data model and GIS format in 2008 and the completed digital map is available at http://science.nature.nps.gov/nrdata/quickoutput.cfm?type=ds&cat=geology&key=GRE&parkcode=CANA.

Geologic Resource Management Issues

The principal geologic resource management issues discussed during the scoping session involved both natural and man-made processes affecting aeolian (windblown) and coastal features and impacts from a changing climate. Erosion and shoreline retreat are critical issues at Canaveral National Seashore. Minor issues included restoring disturbed lands and groundwater quality.

Aeolian Issues

Visitors, storms, overwash events, restoration efforts, and stabilization projects may compromise the integrity of the dune system at Canaveral National Monument and threaten the habitat of threatened and endangered (T&E) species. Stabilized, continuous dunes help protect vegetation growing on the landward side of the dunes, but storms may decrease the continuity of the dunes by producing blowouts. Boardwalks and dune fences have been constructed to help protect and stabilize the dunes, but storms wash away the boardwalks. Storms may destroy cultural sites in the dunes such as old archaeology sites, middens, and modern shipwrecks, also. Studies have shown that lighting through the slats of the boardwalks affects vegetation growth. Plant roots and foliage act to stabilize and trap the shifting sand. Visitors who trample vegetation destabilize the dunes. During high tide, visitors to the beach may back up into the dunes, threatening turtle nesting sites.

Coastal Issues

Natural processes such as storms, waves, tides, and longshore currents cause erosion and redistribution of shoreline sediments. These processes may become management issues if they impact infrastructure and/or T&E habitat. Human activities that may impact the coastline include dredging, commercial fishing, and pleasure fishing. Dredging primarily occurs along the Intracoastal Waterway in the Mosquito Lagoon, Haulover Canal, and Indian River and is associated with the commercial oyster industry. Ditches have been dredged for mosquito control. Dredging has impacted submerged aquatic vegetation (SAV), and dredging spoil islands have changed the local hydrology. Boat wake causes shoreline erosion and increased turbidity, which negatively impacts oyster beds because oysters require relatively sediment-free water. Meandering tidal creeks may erode onshore resources. A wide range of salinity values are found in the various impoundments in the coastal zone.

Potential Impacts from a Changing Climate

With climate change, storm intensity is expected to increase, and this will potentially impact dune stability, roads, boardwalks, NASA camera pads, and other man-made structures (the new Visitor Center will not be on the barrier island, where the present one is currently located). Rising sea level and storms will increase the potential for storm washover events and erosion of the foreshore, dunes, and riverbanks. Habitat for threatened and endangered species may be altered and exotic species introduced into the area. Whether or not the marsh is keeping pace with water rise is a management concern. Modeling is being done on rainfall, salinity changes in the lagoon, impacts to

SAV, and exotic species of plants and animals. Climate change has already caused an overall temperature shift so that the area is becoming warmer. This change has enabled more tropical plants to become established in central Florida.

Other Issues

Disturbed lands. Disturbed lands needing restoration include impoundments, dikes scraped down to connect to Mosquito Lagoon, spoil islands, man-made ditches dug for orange groves (Bill's Hill), and areas impacted by activities designed to stabilize dunes against overwash.

Groundwater. Mosquito Lagoon receives a freshwater influx from rainfall and seeps. The lagoon is shallow, wide, and wind-driven so that salinity is not uniform throughout the lagoon. The upper part of the lagoon contains a significantly higher salinity than the lower part of the lagoon. The higher salinity affects fishing behavior; for example, redfish stay in the inlet because of high salinity. If a storm opened a new inlet to Mosquito Lagoon, the chemistry of the lagoon would dramatically change. Groundwater and surface water quality and monitoring is a function of the NPS Water Resources Division.

Features and Processes

The scoping session for Canaveral National Seashore provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRI report. Please note that the National Park Service monitoring manual (R. Young and L. Norby, editors. *Geological Monitoring*. Special paper. Geological Society of America, Boulder, CO.) is currently in press and will contain information on monitoring of geologic features and processes found in NPS coastal units. These features at Canaveral National Seashore include:

- *Aeolian*. One primary dune ridge forms the backbone of the island. Back dune environments. Overwash deposits. Blowouts. Freshwater ponds.
- *Lacustrine (lake)*. Brackish to freshwater swales and mosquito control impoundments provide habitat for darters, herps, and birds. Mosquito control impoundments along the edge of Mosquito Lagoon are manipulated for a variety of water levels. At times, they are dry and other times, they are flooded. CANA and Merritt Refuge are major migratory stopover and key breeding and wintering areas for a variety of bird species.
- *Coastal*. Coastal features include the beach berm, beach face, low-tide terrace, ebb tide and tide delta shoals. An offshore trough and sand bar develop in the surf zone. Mosquito Lagoon, wetlands, tide marshes, and tidal creeks exist along the coast landward of the dune ridge. Changes in longshore transport may distribute different sediment types to micro-environments that form in different parts of the park.
- *Marine (submerged resources)*. The boundary of Canaveral National Seashore extends 0.8 km (0.5 mi) offshore.
- *Seismic*. Deep-seated structural lineaments may be buried beneath this part of Florida's coast, but no seismic activity is present at the surface. A historic earthquake in Charleston, South Carolina rang the bell in St. Augustine and was probably felt in the Canaveral area.
- *Paleontological resources*. Vertebrate and invertebrate fossils have been found in CANA and from surrounding areas. Larry West (NPS SECN) suggested consulting the recently published *Paleontological Resource Inventory and Monitoring* report for the SECN to

review the paleontological resources in Canaveral National Seashore (Tweet et al. 2009). The following information is from that report.

Teeth and small bone fragments from a mastodon have been recovered from Merritt Island National Wildlife Refuge, about 91 m (300 ft) outside Canaveral National Seashore. These fossils are kept at CANA because the Refuge does not have the facilities to store them. Because they came from outside the park, they are not catalogued.

The Anastasia Formation (Upper Pleistocene) underlies Cape Canaveral and is exposed in the area of Canaveral National Seashore west of Mosquito Lagoon and north of Merritt Island (Scott et al. 2001). Fossils known form the Anastasia Formation, although not recovered at CANA, include mollusks, foraminifera, coral, ghost crabs and their burrows, echinoids, and a variety of vertebrates such as cartilaginous fish, bony fish, frogs, salamanders, turtles, lizards, snakes, alligators, birds, armadillos, cricetid rodents, lagomorphs, camelids, deer, and *gomphotheriid proboscideans*.

Three fossil specimens from Canaveral National Seashore are stored at the Southeast Archeological Center (SEAC). A turtle bone (CANA 14817) came from the Kars Park location. The Aerial Map J4 location (CANA 15056) produced unidentified specimens as did the Haulover Canal Midden location (CANA 15088) (Tweet et al. 2009).

At least 129 sites of prehistoric cultural remains are known at Canaveral National Seashore, and fossils may be found associated with these cultural resources. Notable sites potentially containing fossils include Turtle Mound, Seminole Rest, and Castle Windy. Another notable site, about 18 km (11 mi) southwest of Canaveral National Seashore, is Windover Pond where human remains have been preserved in a swampy, peat pond. In some cases, preserved brain tissue dates from 8,290 to 7,790 years ago (Tweet et al. 2009).

- *Mineral exploration*: In the past, shell middens were mined for road fill, and abandoned borrow pits for aggregate exist on Merritt Island. Turtle Mound, a turtle-shaped mound located north of the Visitor Center, contains oysters and refuse from the prehistoric Timucuan people. Rising to an approximate height of 15 m (50 ft), the mound is the largest shell midden on the mainland United States and was added to the U.S. National Register of Historic Places in 1970.
- *Age dates*. Participants thought that Jack Rink (McMaster University) has optically stimulated luminescence (OSL) dates for the area. Carbon-14 dates may be available, also.
- *Type sections*: CANA has no type sections, but the type section for the Anastasia Formation is on Anastasia Island, near Fort Matanzas National Monument. Exposures of Anastasia coquina at Haulover Canal show the character of this Pleistocene limestone.

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Table 2. Scoping Meeting Participants

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