CHAPTER 10
VIBRACORES AND VIBRACORE TRANSECTS: CONSTRAINING THE GEOLOGICAL AND CULTURAL HISTORY OF ST. CATHERINES ISLAND

Gale A. Bishop, David Hurst Thomas, Matthew C. Sanger, Brian K. Meyer, R. Kelly Vance, Robert K. Booth, Fredrick J. Rich, Donald B. Potter, and Timothy Keith-Lucas

Vibracoring is a subsurface sediment acquisition (sediment coring) technique (Pierce and Howard, 1969; Howard and Frey, 1975; Dreher et al., 2008) that returns sediment preserved within its stratigraphic and sedimentologic context. This process (see appendix 1) generates a continuous, contiguous sediment sample at a point by vibrating an aluminum core barrel vertically into the sediment (fig. 10.1). One advantage of vibracoring is that core depths (up to ~7.5 m) can be extracted preserving stratigraphic layering, sedimentary structures, fossils, and lithology in their natural context.

VIBRACORE PROTOCOLS ON ST. CATHERINES ISLAND

Our vibracore rig (fig. 10.1) consists of a 5.5 horsepower Briggs and Stratton gasoline powered engine, a cement vibrator, a clamping device to attach the vibrator onto 6 m (20 ft) segments of aluminum irrigation pipe 75 cm (3.0 in.) in diameter, with a wall thickness of 1.27 mm (0.050 in.), and an aluminum tripod and draw-works to extract the core barrel from the ground. The engine spins a flexible cable at high speed that causes the unevenly weighted head at its distal end to vibrate. The head, mounted by bolts to a weighted adapter that clamps to the aluminum core barrels, causes the pipe to vibrate into the substrate. Penetration of sediment and roots is enhanced by sharpening and filing serrations into the end of the aluminum pipe, producing a saw-toothed cutting edge. Because the adapter can easily be repositioned up the shaft as the core is vibrated into the substrate, the rig is capable of handling barrels of any length, although extraction of cores longer than 7.5 m becomes problematical. Six-meter (20 ft) core barrel lengths have been found to be optimal for our operation on St. Catherines Island. Once maximum penetration is accomplished (nearly to the length of core barrel available or until the vibracore no longer penetrates the substrate) drilling ceases. At this point, the depth to the top of the sediment surface inside the pipe is measured, the length of the pipe remaining above the ground is measured, and the former is subtracted from the latter to determine compaction of sediment inside the core barrel. The core's location and compaction and total depth measurements are recorded in a field notebook. The upper end of the pipe is plugged with a sewer plug and sealed with bolt compression or inflation of the air seal prior to pulling to create a partial vacuum inside the pipe to help hold the sediment in place. The core barrel is then extracted using a tripod with two lever hoists (known as come-a-longs) connected to the pipe with hemp rope tied into Prusik Knots. The come-a-longs are first used in tandem to overcome initial friction, then used in parallel, one after another, to more rapidly pull the core as friction decreases as the pipe is extracted. When the lower end of the tube appears, it, too, is plugged with a sewer plug (and if any sediment has fallen out, the tube should be packed with aluminum foil). The pipe is trimmed to approximate the core length (which is less than total depth due to sediment compaction and/or limited penetration) by cutting the pipe off with a hacksaw just above the top surface of sediment. The core is marked with catalog numbers and the core orientation is indicated by placing consistent arrows labeled “down” (or “up”) directly on the aluminum pipe. The location of the core is identified with global positioning system (GPS) data and the longitude and latitude, and elevation are recorded in the notebook or on a logging form (fig. 10.2B).

The core is transported to a laboratory or shelter and a straight line marked along the length of the core tube. An electric saw with a carbide blade set to slightly greater depth of the wall thickness is then used to saw along the straight line. The core tube is then squeezed into a holding trough (we use a trough constructed of rough lumber 5.08 × 10.16 cm and 5.08 × 20.32 cm [2 × 8 in. and 2 × 4 in.] to hold the core and track the saw) and taped with duct tape every half meter (about two feet) after it has been cut (fig. 10.2A), the core is then rotated 180° and cut a second time along its length, and retaped to hold the core tube shut as it is manipulated out of the cutting trough. Then a cut is made through the sediment and tape with a thin knife, coping saw or piano wire to separate the core into two hemicylinders. Holding the core with the cut vertical, the core is then allowed to split open laying each half with the cut surface horizontal. The surface of the exposed sediment core is then gently shaved with a sharp knife or trowel to prepare the core for description (fig. 10.2C). A metric tape or folding metric scale is laid on, or along, the length of the core and the core photographed, then described on a log form. Geologists normally log from the surface downward, starting at the surface as “0” and logging downward to total depth (TD) of the core. Sediment color, type, sorting and variation, layering, and sedimentary structures and “fossils” (if present) are noted. In the case of critically detailed work, the compaction of the sediment is proportioned along the length of the log to compensate for compaction.

Samples from the core are taken from critical zones for sedimentological study (grain size analysis and determination of mineralogy), to acquire organics for radiocarbon dating and palynology or to obtain macro and microfaunal records of the sedimentary environment. Samples to be processed by ^{14}C methods are collected, cut, and cleaned to insure lack of contamination, and wrapped in aluminum foil to be sent to a laboratory specializing in ^{14}C dating. Palynological samples are collected, cut, and cleaned to ensure lack of contamination of surface pollen and spores, and wrapped in aluminum foil to be sent to a laboratory specializing in palynological analysis (usually Rich’s or Booth’s laboratory).

The vibracoring procedure is simple and the equipment is relatively easy to maintain and transport. Penetration success and core recovery in the vibracoring process, however, are largely dependent on lithology and sediment pore water saturation. Pure, dry sand tends to attenuate the vibration of the barrel and slow its descent; mud, if saturated with water, is easy to penetrate, and rock or even semilithified sediment will stop penetration of the barrel. Humate cemented sand has proven to be an impediment to vibracore penetration on the Pleistocene core of the island. Dense clay can also be difficult to penetrate and may be very resistant to core barrel extraction. The vibration of the pipe can be translated to the core sample itself, and may compact the sediments or disrupt laminations or bedding in the sediment, especially along the edges of the pipe surface, causing drag structures.

In the case of geological exploration, sites to be drilled are often selected for their presumed stratigraphic value as single cores (figs. 10.3–10.5), or as a line of cores (a *transect*) that allows one to correlate laterally using Steno’s laws of stratigraphy; superposition, lateral continuity, and original horizontality (Steno, 1669) to generate a cross section (figs. 10.6–10.8). In geology, the linearity of transect lines is often sacrificed for necessity of being able to drill, potential stratigraphic value of slight offsets or convenience. In the case of archaeological exploration, linearity is more important and alignment with survey grids is critical. Sites may be selected to physically test stratigraphy, magnetic resistivity, or Ground Penetrating Radar (GPR) anomalies, providing a rapid and only minimally invasive peek into the buried cultural history of a site.

THE VIBRACORE EVIDENCE FROM ST. CATHERINES ISLAND

A series of stratigraphic cores were drilled on St. Catherines Island by several teams from Georgia Southern University, the University of the South, the University of Pittsburgh, and the American Museum of Natural History, forming what we informally call the SCI Geology Research Consortium. The drilling of vibracores has been facilitated by Royce Hayes and the St. Catherines Island Foundation staff since 1989 and a complete catalog of all known vibracores from the island is included as

Fig. 10.1. Components of the St. Catherines vibracore in use in the field. **A,** Georgia Southern University drill team vibracoring near Gator Pond in 2008, showing gasoline engine, vibrator cable clamped to aluminum pipe under tripod as clamp is being raised to continue drilling; **B,** close-up of vibrator head clamped to irrigation pipe at total depth as sewer plug is being inflated to seal core in pipe; **C,** core being extracted by come-a-longs as crew chief Vance records data; **D,** AMNH crew coring at St. Catherines Shell Ring as crew chief Bishop supervises forcing the pipe into dry ground; **E,** Island Ecology Program coring at Flag Lagoon supervised by crew chiefs Potter (on tripod) and Keith-Lucas (kneeling) attempting to pull a core. Photographs A, B, C, and E by Gale Bishop; D by Anna Semon.

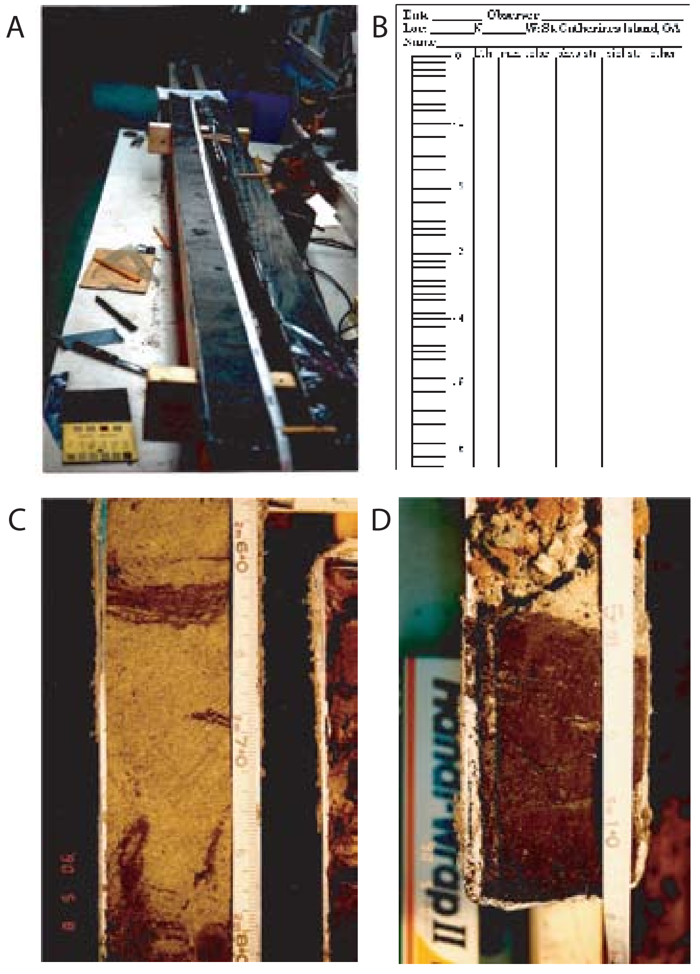


Fig. 10.2. Logging of vibracores is done under the roof of a shed. **A,** The core is placed into a trough constructed of two-by-fours cut lengthwise on two sides with a carbide disk on an electric saw, then cut through the sediment and laid open exposing the core to inspection (note the thin knife, Munsell Color Chart, sediment size chart, straight edge, pencils, hand lens, and tape measure; **B,** one example of a possible computer-generated logging form; **C,** Cracker Tom core, image of split core showing sand with mud flaser above and lined ghost shrimp burrow near bottom, and **D,** bottom of Cracker Tom Bridge (note foil cap) showing compact peat that stopped drilling. Photographs A, C, and D by Gale Bishop.

appendix 2, at the end of this volume. Initial drilling (table 10.1) was done by the SCI Geology Research Consortium to document lithology, stratigraphy, and sedimentary structures at points hypothesized to harbor interesting geological data. Initial coring was done at Mission Santa Catalina de Guale in 1989 (to test the equipment in the Island core). Subsequent efforts have focused on the following sites:

(1) Offshore at Yellow Banks Bluff to test the continuity of relict marsh mud exposed there (fig. 10.3);

(2) On Cracker Tom Causeway (fig. 10.7) to investigate stratigraphy of McQueen Marsh (Booth and Rich, 1999, Booth, Rich, and Bishop, 1999; Bishop et al., 2007; Linsley, Bishop, and Rollins, 2008);

(3) In State Road Pond in the Pleistocene core to test the Pleistocene stratigraphy (fig. 10.5);

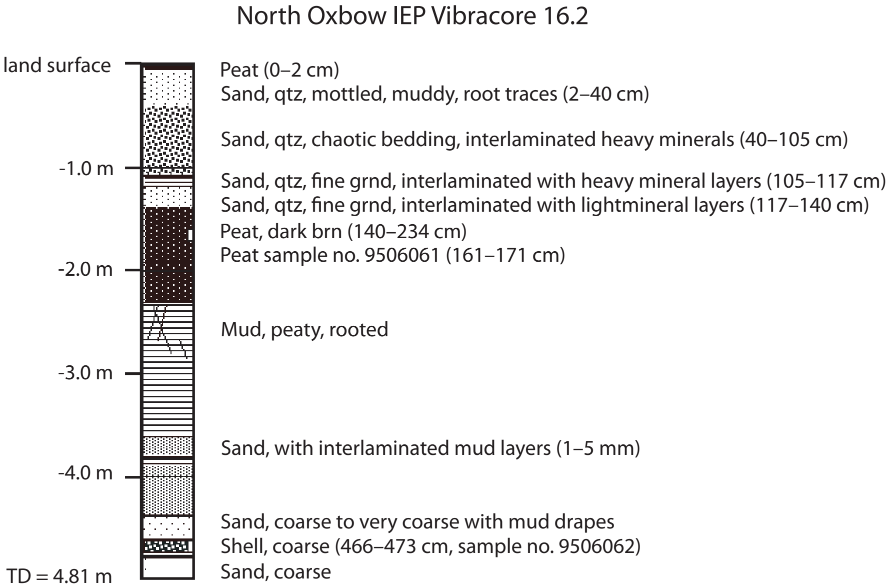


Fig. 10.3. Log of IEP vibracore 16.2 in North Oxbow south of Sand Pit Road showing stratigraphy underlying an ancient meander scar floored by a shell lag and overlying transgressive facies (sand, marsh, and freshwater peat) marking a still-stand at marsh level followed by a second transgression in overlying sequence of sand, backbeach, horizontally laminated heavy mineral sand, and overlying chaotically bedded heavy mineral-rich sand (perhaps a trample bed from cattle during the mid and late 1900s). Total depth = 4.81 m.

(4) On Terrain #6 (an east-west Holocene terrain) to document (fig. 10.4) its stratigraphy;

(5) In Long Marsh west of Hickory Hill to investigate its subsurface;

(6) The sediment underlying Beach Pond (Booth et al., 1999).

All members of the consortium have utilized the St. Catherines Island vibracore equipment to investigate geological conditions pertinent to their specific research program and to create real world, hands-on, field-based educational activities for their students. Cores drilled by the University of the South were often sited with consensus of Potter, Keith-Lucas, and Bishop; one core led to documentation of the North Oxbow (fig. 10.3) near Sand Pit Road (and the site of Bishop's hydrological study of sea turtle nests in 1996). Another consensus led to vibracore sites adjacent to the St. Catherines Shell Ring in Long Field, on the west side of the island; additions to these core sites produced the St. Catherines Shell Ring transect (fig. 10.6) (Bishop et al., 2007).

Yellow Banks Bluff and Seaside Spit

Twelve vibracores recovered from three transects have been described, analyzed, and interpreted by Linsley (1993), Bishop et al. (2007), and Linsley, Bishop, and Rollins (2008). Transects A and B are located on the northeastern portion of St. Catherines Island, and Transect C lies along Cracker Tom Causeway in the east-central portion of the island. The state of knowledge of the geological foundation of St. Catherines Island has been summarized by Bishop et al., 2007 and in chapter 3 of this volume. These summaries subdivide the island into at least three major geomorphic systems: the island core, beach ridge complexes, and salt marsh (Linsley, Bishop, and Rollins, 2008, fig. 3.1; this volume: fig. 3.2). The island core comprises the western portion of the island, has a relatively high elevation of ~4 to a maximum of 8.8 m (29 ft), is relatively level, and its vegetation consists of a mature, mixed deciduous–pine forest and fallow agricultural fields in various stages of succession.

Several series of parallel to subparallel, low-lying ridges (Bishop et al., 2007, fig. 57; average elevation of 1–4 m) comprise the accretionary terrain complexes located at the northern tip of the island (within which the "great dunes" have the maximum elevation on St. Catherines Island of 10.4 m [34 ft]), as well as bordering the south and southeast. Adjacent beach ridges are separated by swales containing intertidal to low supratidal creek and marsh meadows or ephemeral freshwater ponds (especially after heavy rains). The accretionary terrain complexes are vegetated primarily by cabbage palm, saw palmetto, hickory, pine, and live oak. The salt marsh fringes the island core on the east and the southwest and consists of meandering tidal creeks separated by marsh meadows vegetated by cordgrass (*Spartina alterniflora*) at the elevation of mean high tide (Bishop et al., 2007; Linsley, Bishop, and Rollins, 2008). On the eastern side of the island, extensive marsh meadows lie behind the beach barriers, Seaside Spit, Middle Beach, and in interdune swales behind South Beach.

The island core sediment consists of predominantly tan, fine- to medium-grained sand, intensively bioturbated by plant roots penetrating to a depth of 2–2.5 m. Below this depth some primary sedimentary structures are preserved, and the color changes to light gray. Primary sedimentary structures at this depth consist of horizontally laminated interbeds of quartz and heavy mineral sand, some cross-bedded units (see chap. 11, fig. 11.7), and occasional burrows of the Carolinian ghost shrimp (*Callichirus major)* (Frey, Howard, and Pryor, 1978). Heavy minerals are disseminated throughout the quartz sand body, but also occur concentrated in discrete laminae characteristic of backbeach facies (Bishop et al., 2007).

The accretional beach ridge complexes are Holocene features that formed as transverse dunes associated with a nearly modern mean sea level position (Bishop et al., 2007: figs. 38,

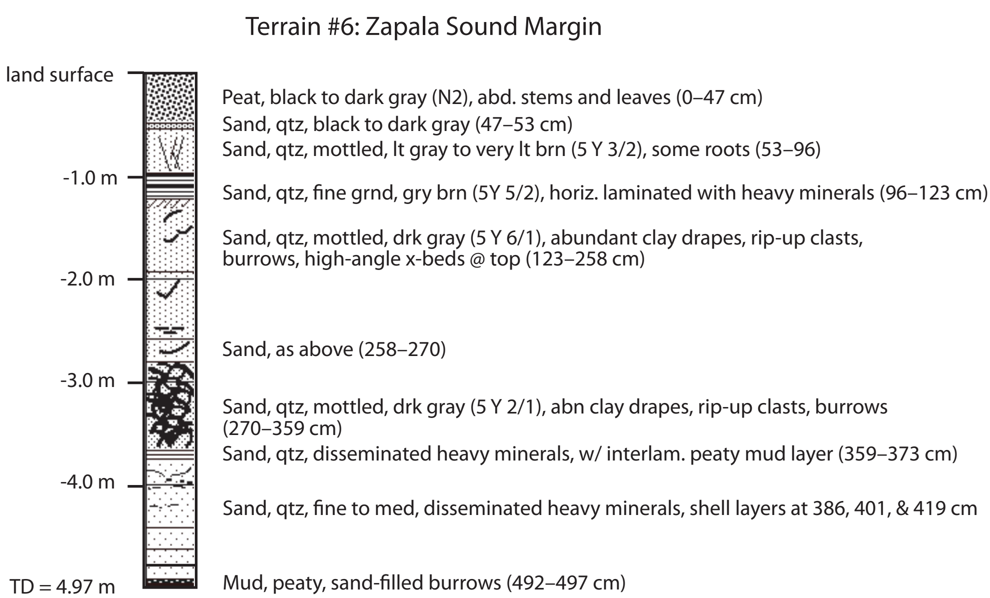


Fig. 10.4. Terrain #6 vibracore taken in swale pond in east-west terrain. This core has a muddy peat at its bottom (total depth = 4.97 m), overlain by a sand with three shell layers up to 4.0 m, then marked by a thin laminated sand overlain by a heavily mottled, burrowed, muddy sand from 3.66 to 2.70 m, in turn overlain by a sand with abundant clay drapes, burrows, and tabular cross-beds at its top from 2.70 to1.23 m, a thin horizontally laminated sand bed from 1.23 to 0.96 m, a fine-grained rooted sand from 0.96 to 0.47 m, and a very organic peat from 0.47 to 0.00 m.

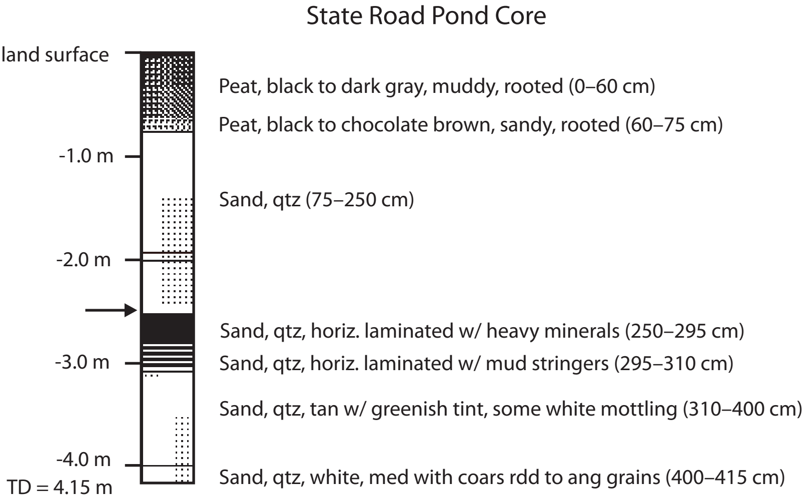


Fig. 10.5. State Road Pond core, located on the younger Pleistocene terrain, has interlaminated heavy mineral and quartz sand (2.50–3.10 m) indicating a sea level elevation of -2.50 m (arrow) when the top of this later Pleistocene layer was deposited.

41, and 59; Linsley, Bishop, and Rollins, 2008). Along the Georgia Bight, beach ridges are generally found on the northern and southern ends of the island cores or along the oceanward sides, where rates of fluvial sediment supply are high. Marked progradation of beach ridge accretionary terrains has occurred on islands fed by the deltas of the Savannah, Ogeechee, and Altamaha rivers (Oertel, 1979; Bishop et al., 2007: fig. 7; see Bishop et al., this volume, chap. 3: fig. 3.1). Because St. Catherines Island lacks nearby fluvial sources, sand for beach ridges must come from longshore transport of reworked continental shelf sand, erosion of the island core, or from islands, tidal deltas, or estuaries to the north (see chap. 8, this volume). The southeastern portion of the island consists of a sequence of discrete beach ridge "packages" that become progressively younger to the southeast and east. These sediment ''packages'' may represent periods of rapid accretionary activity during the Holocene punctuated with periods of erosion due to inlet mouth migration, major storm events, sea level changes, or pulses of sedimentation. They can be chronologically sequenced using crosscutting relationships (see Oertel, 1975b, 1979). Rollins, Beratan, and Pottinger (chap. 8, this volume) describes the deposition of three distinct beach ridges over a five-year interval at the north end of St. Catherines Island following Hurricane Hugo in 1989 (Linsley, Bishop, and Rollins, 2008; Pottinger, 1996).

At Yellow Banks Bluff, sand eroded from the base of the bluff by waves during nor'easters on spring high tides steepens and undercuts the slope with consequent slope re-equilibration by mass wasting. Blocks of soil, knit together by grasses, saw palmetto stems and roots, and trees tumble off the scarp face into the ocean below as the scarp migrates westward. Waves disaggregate the slump blocks at the base of the bluff, producing a beach "boneyard" of skeletal trees, and a heavy mineral placer along the base of the bluff (see Bishop et al., 2007: figs. 22–24). The rate of bluff retreat at Yellow Banks Bluff is 1.8 m/yr (5.9 ft) (Potter, Padgett, and Trimble, 2007; Bishop and Meyer, chap. 14: fig. 14.13; Potter, this volume, chap. 7). Approximately 5 m of sand are exposed for 0.8 km (0.5 mi) along this prominent bluff. There is general consensus that at least the lower portion of Yellow Banks Bluff is attributable to the Silver Bluff shoreline of Pleistocene age (Bishop et al., 2007; Martin and Rindsberg, this volume, chap. 5; Vento and Stahlman, this

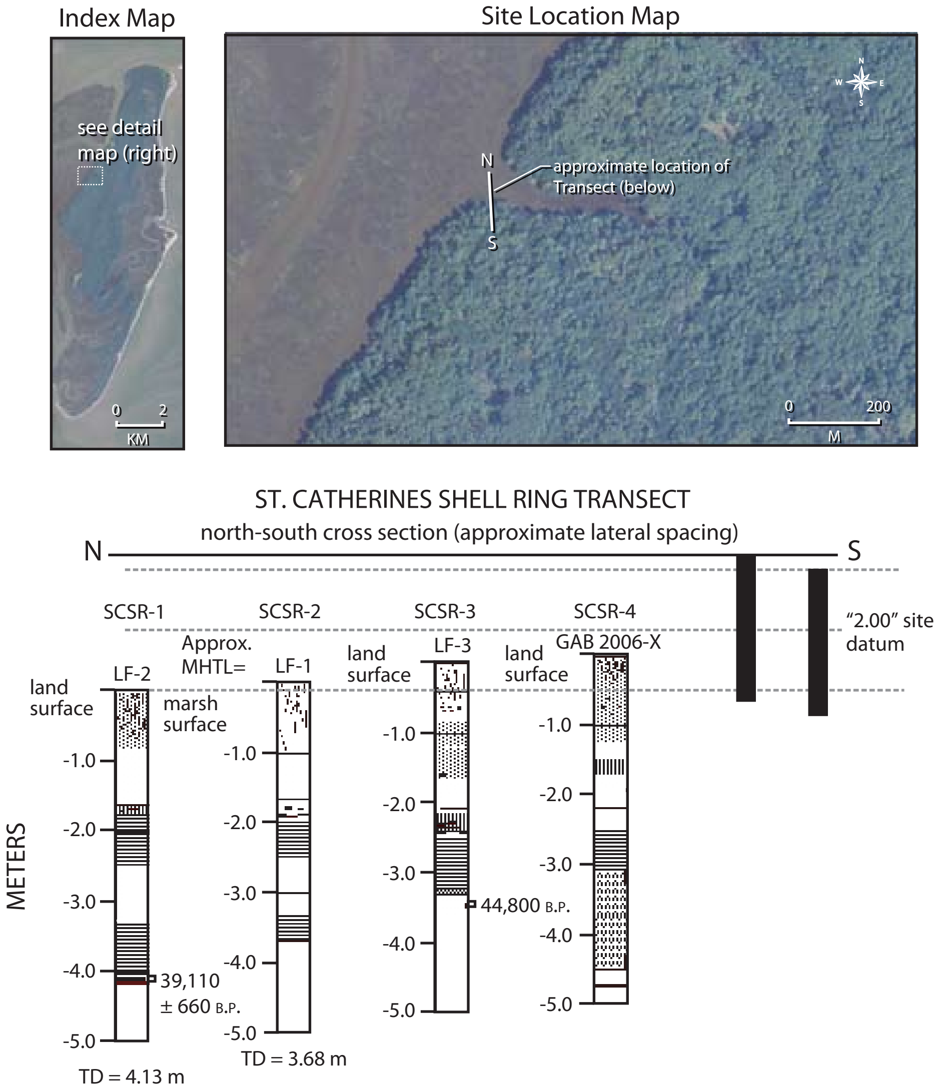


Fig. 10.6. Original St. Catherines Shell Ring Transect showing collaborative drilling effort by scientists to connect geology and archaeology. Three cores on left (SCSR LF #2, SCSR LF #1, and SCSR LF #3) drilled by faculty and students of the University of the South Island Ecology Program, fourth core from left (SCSR #4, GAB 20061102-1) drilled by team from Georgia Southern University, the St. Catherines Island Foundation, and archaeologists from the American Museum of Natural History, and a series of cores into the St. Catherines Shell Ring drilled by a GSU and AMNH team are represented by the two blank cores to the right. Aerial imagery from United States Department of Agriculture (USDA), National Agriculture Imagery Program (NAIP), 2006.

volume, chap. 4). Archaic archaeological sites near the bluff, rapidly being lost to progressive accelerating erosion, attest to the human appreciation and utilization of the scenic and functional values of this portion of the island for approximately 4000 years.

Two nearly continuous, intensively burrowed horizons have been mapped along the face of

Yellow Banks Bluff (see Bishop et al., 2007: fig. 10.23; Martin and Rindsberg, this volume, chap. 5). Burrows are short, unbranched, and are most apparent in darker gray sediment (Stapor and Mathews, 1983). These two burrowed zones are interpreted by Martin and Rindsberg (chap. 5) as washover fans burrowed by fiddler crabs and insects during the Silver Bluff portion of the Pleistocene. They may mark marine erosional terraces during the formation of the Silver Bluff shoreline. A horizontal maze of ghost shrimp burrows (*Callichirus major*) has been mapped beneath the former position of the bluff near its south end (Bishop et al., this volume, chap. 3: fig. 3.4). These two burrowed "erosional surfaces," marking former sea level highstands, occur at ~1.5 m (4.92 ft) above the base of the bluff near its north end (see Martin and Rindsberg, this volume, chap. 5).

Vibracores of a relict marsh mud at the south end of the bluff encountered 9.1 m (30 ft) of marsh sediment there, as previously mentioned. Seaside Spit is a wedge of sand deposited on top of the mud surface of Seaside Marsh. Seaside Spit lies immediately south of Yellow Banks Bluff and consists of a perched prism of beach sand and washover fans "parked" on top of Seaside Marsh (Bishop et al., 2007: figs. 25–27; Bishop et al., this volume, chap. 3: fig. 3.4). The sand, mobilized from Yellow Banks, is carried by the longshore drift that generally moved from north to south on the Georgia coast. During storms, sand is commonly washed over this spit, or berm, forming a series of washover fans (Bishop et al., 2007: figs. 26, 28, 29; see this volume, chap. 3; chap. 13: fig. 13.1) that constitute up to 80% of the 1.69 km (1.05 mi) length of Seaside Spit. This shoreline is currently in full retreat. Retreat of the shoreline at Seaside Spit was about 65 m (213 ft) from 1999 to 2002 (Potter, Padgett, and Trimble, 2007). Brian Meyer computed longer-term retreats as 6.5–9 m/yr (21–30 ft/yr) between 1979 and 2005, and nearly 21 m/yr (70 ft/yr) from 1999 to 2002 as measured from aerial photographs and storm high-tide positions over the interval 1999–2002. This retreat has obliterated Black Hammock, a wooded high area on the exposed beach that was present further east (now offshore), on Seaside Spit prior to 1971, "with enough vegetation to get lost in while hunting coons." (Royce Hayes, personal commun.). Prezant et al. (2002) report that "The southern half (about 1.5 km) of North Beach consists of fine-grained quartz sand and compacted semiconsolidated relict marsh mud representing the trailing edge of a rapidly migrating facies mosaic that has retreated at an average rate of 3.8–4.0 m per year for about the last 50 years (Oertel and Chamberlain, 1975; West, Rollins, and Busch, 1990; Goodfriend and Rollins, 1998). The relict marsh mud exposed almost continuously along Seaside Spit was extensively documented by Morris and Rollins (1977), who interpreted mud-dwelling organism associations as "holistic" communities of Kauffman and Scott (1976). Pemberton and Frey (1985), Rollins, West, and Busch (1990), and West, Rollins, and Busch (1990), described the palimpsest relict marsh mud surfaces and Glossifungites Ichnofacies exposed along North and Middle beaches.

To the north and south, the western margin of Seaside Marsh Meadow is a series of emarginated reentrants and points (see chap. 3, this volume), a feature named King New Ground Scarp. The view across Seaside Marsh Meadow toward North and Middle beaches emphasizes the great expanses of marsh meadows on the ocean side of St. Catherines Island that are now but a remnant of their former size.

North, Middle, and South beaches form a slightly concave, curved eastern boundary to this marsh, and abundant washover fans accommodate the westward transport of sand in response to rising sea level and easterly storms along its trace. Berms or beaches (Seaside Spit and Middle Beach) form as the turbulent waters of the ocean remove sand from the eastern beachfront, leaving behind the relict muds of the marsh. We anticipate that when we vibracore one of these meander scars (Bishop et al., chap. 3: fig. 3.6), we will encounter Pleistocene island core facies immediately beneath the Holocene meander plain sediments, as was discovered near Cracker Tom Hammock (Booth and Rich, 1999; Bishop et al., 2007: fig. 10.36).

Cracker Tom Hammock

The Cracker Tom vibracore transect of 1990 is parallel to and north of Cracker Tom Causeway, extending from the island core across the marsh to Cracker Tom Bridge. The intent of this transect was to investigate the stratigraphic foundation of the island (Bishop et al., 2007). Sediment lithology, stratigraphy, sedimentary structures, and trace fossils were logged (Bishop et al., 2007; Linsley, Bishop, and Rollins, 2008) and cores were correlated.

Booth and Rich (1999) extracted three additional cores called Cracker Tom Bridge (CTB), Cracker Tom Hammock (CTH), and Cracker Tom Rosetta (CTR) from the low ridge flanks in the marsh between Cracker Tom Hammock and the island core. After analyzing and evaluating samples collected from the three vibracores comprising the Cracker Tom Hammock Transect, Booth, Rich, and Bishop (1999) published *Palynology and Depositional History of the Late Pleistocene and Holocene Coastal Sediments from St. Catherines Island, Georgia, USA*.

The stratigraphic sequence (from bottom to top) in the Cracker Tom Transect consists of black-brown compact peat (CTB) and moderate yellow-brown consolidated sand (CTH) (unit A) underlying a sharp boundary, representing an erosional surface on top of the darker Pleistocene sediment. The formation of this erosional surface (disconformity) required subaerial exposure of ancient St. Catherines Island. Overlying this disconformity is a layer of very light gray to yellowish gray fine- to coarse-grained sand (unit B) with small clay-filled burrows with a basal shell lag of pale yellowish brown unconsolidated sand with abundant shells (gastropods and disarticulated bivalves) interpreted to be a transgressive sand deposited by a rising sea level. Overlying unit B is a light gray burrowed mud and sandy mud (unit C) with an eroded surface and carrying abundant oyster shells (*Crassostrea virginica*) in one core (CTH: 1.94–2.25 m) inferred to represent marsh facies. The upper surface is erosional and oxidized. Overlying the marsh sediment of unit C is another sandy unit, laminated with heavy mineral layers at its base giving way to mottled, organic sand above. Thus, the sequence is thought to represent a basal lithosome plus three sedimentary packets (fig. 10.7; see also chap. 3: fig. 3.3). A basal terrestrial Pleistocene lithosome is separated by a diastem from overlying Holocene nearshore marine, marsh, and shoreline deposits. The Holocene deposits consist of three sedimentary packets: (1) a basal transgressive nearshore sand body, overlain by (2) a marsh sequence with an erosional upper surface forming a second disconformity or diastem, and in turn overlain by (3) backbeach, shoreface, and marsh deposits.

Peat from 5.02–5.12 m in the Cracker Tom Bridge vibracore was radiocarbon dated and yielded a date of 47,620 ± 2500 yr B.P. (USGS WW1197) and was overlain by marine shells and charcoal, which were also dated. The charcoal yielded a date of 6020 ± 50 yr B.P. (USGS WW1198) and a shell, *Americardia,* yielded a date of 4060 ± 50 yr B.P. (USGS WW1262). An oyster bed entrained within a dark gray mud in the Cracker Tom Hammock core (CTH: 1.94–2.25 m) yielded an oyster shell (*Crassostrea virginica*) radiocarbon dated at 3200 ± 70 yr B.P. (UGA-6442). These dates firmly bracket the Pleistocene-Holocene disconformity representing approximately 40,000 years at Cracker Tom Hammock. The disconformity documented in the Cracker Tom vibracore transect represents one of the best Georgia barrier island records of a sea level lowstand and subsequent sea level rise. This sea level rise (marine transgression) resulted in the hypothesized destruction of Guale Island (see chap. 3: fig. 3.3), and the accumulation of sediment in the accretionary terrains to the south and east that make up the remainder of St. Catherines Island.

The Pleistocene peat below the disconformity contained a palynoflora consisting of 85% monolete pteridophyte spores of the fern *Woodwardia* and other hydrophyte taxa (Booth and Rich, 1999). Other taxa present in the Pleistocene sample included *Pinus*, *Quercus*, *Carya*, and Poaceae with northern temperate flora in smaller abundance (*Picea*, *Tilia*, *Fagus*, and *Tsuga*). The palynoflora association of the peat was used to infer that environmental conditions at the depositional site included a dense stand of ferns growing alongside characteristically southeastern floral elements dominated by the fern *Woodwardia virginica*. Holocene portions of the cores are derived from plants of nearshore marine, salt marsh, and tidal flat environments similar to those now found on St. Catherines Island (Booth et al., 1999, Rich and Booth, this volume, chap. 6).

The depositional environments of the original Cracker Tom Transect were previously interpreted (Bishop et al., 2007: fig. 36), but not correlated. This correlation is presented to link and summarize the depositional and temporal relationships and environments represented in the Cracker Tom Transect (fig. 10.7). Dates obtained from organic constituents in the cores precisely constrain the basal disconformity (Booth and Rich, 1999; Booth et al., 1999; Linsley, Bishop, and Rollins, 2008; Thomas, 2008). The dates also provide an average rate of deposition on the southeastern Holocene accretional terrains. Laminated sand of a transgressive beach and a small fan delta accumulated by erosion of an ancient scarp and reworking of sediment (Cracker Tom Scarp core –2.0–0.0 m) forming a continuous backbeach facies. The underlying forebeach sediment (Cracker Tom Scarp core –2.0–4.0 m) marks a rapid transgression between 6020 and ~3200 yr B.P. A period of stasis may have allowed formation of a small marsh protected by a beach ridge on the east, prior to a rise in sea level.

Beach Pond

Booth et al. (1999) described a core from Beach Pond, a freshwater pond and marsh, then located 50–100 m behind the active beach scarp in the mid-southern portion of St. Catherines Island. They recovered a 4.5 m sediment core from the pond to reconstruct the paleoecology of the site. Sediment was Holocene in age (<10,000 years), and the palynoflora record suggests cyclic deposition. Until 1999, the modern vegetation of Beach Pond was dominated by freshwater flora, including *Pluchea* and other composites, *Typha*, Cyperaceae, and Poaceae. This flora contrasts with palynology of the core, revealing dynamic changes in depositional environments and plant communities during sediment accumulation. Sediments from the lower portion of the core represented nearshore marine environments and probable accumulation in a shallow lagoon, characterized by the abundant pollen of *Pinus* with a high percentage of broken grains. Wood recovered from the uppermost lagoonal sediments yielded a radiocarbon date (AMS) of 1210 ± 40 B.P. (Beta-115910). The lower layers are overlain by tidal-flat-derived sediments, which are overlain by a thin peat layer derived from an interdunal swale community dominated by *Myrica*. A return to brackish marsh conditions is indicated by the presence of *Limonium*, Cheno-Am type (e.g., *Salicornia*), and abundant Poaceae pollen. The modern freshwater pond plant community was established as the salinity decreased; this is indicated by the abundance of freshwater plant taxa (i.e., *Azolla*, *Typha*, Cyperaceae). At this time (2010), Beach Pond is being invaded by saltwater, and the freshwater flora is dying as the beach shifts westward and the pond cycles back to salt marsh conditions.

The Scarps of St. Catherines Island

A comprehensive overview of the origins of the Georgia barrier islands and specifically St. Catherines Island was published by Bishop et al. (2007). They reviewed the ages, characteristics, and history of the sediments constituting the island, and the characteristics and distributions of island plant, animal, and human communities. Deposits of heavy minerals on St. Catherines Island were also documented, and the source rocks, transport, and concentration of the minerals on the coast as backshore placers, stranded during times of rapid recession were described (Pilkey, 1963; Woolsey, Henry, and Hunt, 1975; Bishop, 1990; W.A. Pirkle and F.L. Pirkle, 2007; Pirkle et al., 2007; Vance and Pirkle, 2007). The dynamic and rapid changes recorded in the sedimentary record of St. Catherines Island still confound and obscure the record and continue to perplex geologists and ecologists today (part of the reason for the Fourth Caldwell Conference and this volume). In 1989, Bishop had postulated that immediately before the last lowstand (i.e., ~18,000 yr B.P.), St. Catherines was an island doublet, similar to the Sapelo Island/Blackbeard Island pair today (Bishop et al., 2007, 2009; Linsley, Bishop, and Rollins, 2008; Thomas, 2008; see this volume, chap. 3: figs. 3.2 and 3.6).

Salient portions of the 2007 GSA field trip guidebook (Bishop et al., 2007) document aspects of the geology of St. Catherines Island that we wish to reemphasize here. The northern end of St. Catherines is most illustrative in terms of the development of the island's geological history, being comprised of the island core, accretional terrains to the north, northwest, and northeast (see Bishop et al., this volume, chap. 3: figs. 3.4–5). The scarps previously documented (Bishop et al., 2007: fig. 10.6) for St. Catherines Island are modified here to include two additional scarps. We now define four scarps bounding the north end of St. Catherines Island—Walburg Scarp, Northwest Scarp, Engineers Scarp, and St. Catherines Scarp. Walburg Scarp forms the northwest boundary of ancient St. Catherines Island, along with a newly recognized Northwest Scarp. The newly renamed Engineers Scarp, formerly included as part of St. Catherines Scarp, forms the boundary between the island core and the accretional terrains deposited by fluctuation of St. Catherines Sound to the north. The newly restricted St. Catherines Scarp forms Yellow Banks Bluff (this volume, chap. 3: fig. 3.2).

The present dynamic Atlantic margin of St. Catherines Island is formed by North Beach, Middle Beach, and South Beach. North Beach is developed on accretional terrains of the northeast shoulder of the island, on the detritus of Yellow

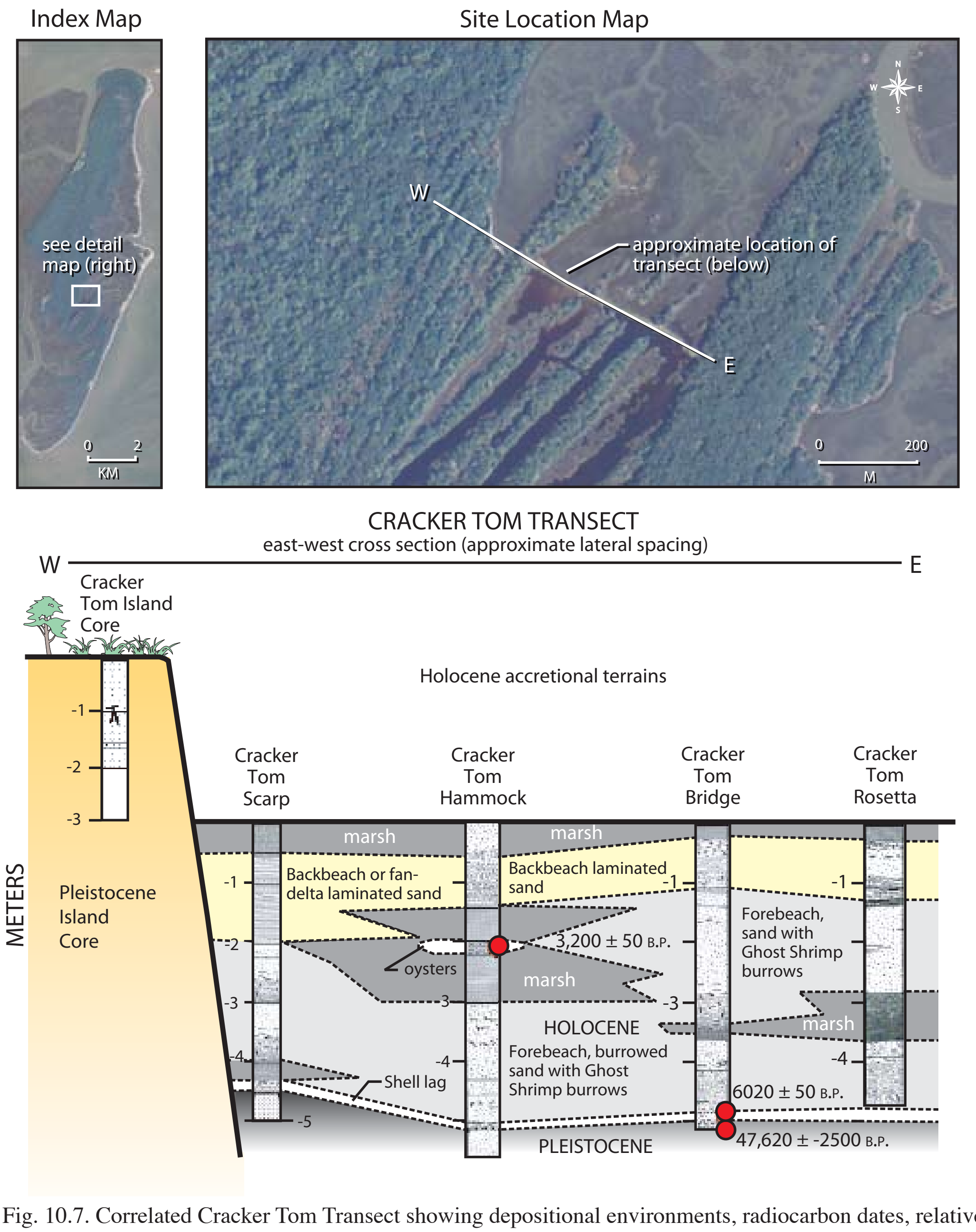


Fig. 10.7. Correlated Cracker Tom Transect showing depositional environments, radiocarbon dates, relative ages, and geomorphology in cross section. Note especially the disconformity at the bottom of the accretionary terrains with the fern peat at total depth dated at 47,620 ± 2500 ^{14}C yr B.P. and immediately overlain by charcoal dated at 6020 ± 50 ^{14}C yr B.P. bracketing the Pleistocene-Holocene disconformity. The dated oyster shell at -2.0 m in Cracker Tom Hammock core (3200 ± 50 ^{14}C yr B.P.) roughly correlates to the *elevation* of disconformity #2 in the St. Catherines Shell Ring Transect (redrafted after Bishop et al., 2007: fig. 36; and Booth et al., 1999: fig. 8). Aerial imagery from United States Department of Agriculture (USDA), National Agriculture Imagery Program (NAIP), 2006.

Banks Bluff, and on the surface of Seaside Marsh as washover fans from the berm of Seaside Spit. Middle Beach is a remnant of older accretional terrains formed and destroyed as sediment from Guale Island was transported southward. These terrains have all eroded away except for a small hammock near McQueen Inlet. Except for this small hammock, surface evidence of past exposure history is largely lacking, but evidence may lurk in the subsurface or within the geomorphology of McQueen and Seaside Marsh meadows. South Beach is developed on the eroding edge of Holocene accretionary terrains that may be composed of sand derived from the destruction of Guale Island (Bishop et al., 2007: fig. 70; see Bishop et al., this volume, chap. 3: fig. 3.3, and Bishop and Meyer, this volume, chap. 14: fig. 14.7).

The history of St. Catherines Island is recorded in the position of the scarps, accretional terrains, and island stratigraphy (Bishop et al., 2007). The features that document a Holocene highstand include backbeach sediment on Sand Pit Road ~2 m above normal high-tide level (see Bishop et al., 2007: fig. 11; this volume, chap. 3: fig. 3.4) and an erosional surface cutting into Yellow Banks Bluff about 1.5 m from its base (Bishop et al., 2007: figs. 23, 24). Evidence for lower than current sea level lies in the lower strata of a series of topographically subdued, accretionary swale and ridge terrains overlain by dunes (see Vance et al., this volume: fig. 11.4). A lowstand is also indicated by geology at Sand Pit Road southward; where the beach is underlain by marsh mud and peat at about –1.17 m, forming an aquitard (fig. 10.3) that perches the water table (see this volume, chap. 3: fig. 3.4). Behind the beach ridges just south of where Sand Pit Road runs onto the island core is an ancient oxbow pond with a second oxbow present immediately north of Yellow Banks Bluff, now all but eroded away by beach retreat. All of the known archaeological sites on the northern end of St. Catherines Island are restricted to the Pleistocene island core. These sites range in age (fig. 10.9) from the Late Archaic period (3000–1000 cal B.C.) to the Irene period (cal A.D. 1300–1580; Thomas, 2008: chap. 15; see also chap. 1, this volume).

Back Creek Scarp forms part of the ancient Atlantic margin of St. Catherines Island along Back Creek Road south of Cracker Tom Causeway. This scarp runs along the edge of the ancient shoreface along Back Creek Road (this volume: figs. 3.2 and 3.4). The high-standing Pleistocene island core on which the road is constructed stands in marked contrast to the forested beach ridges of the ancient low-lying Holocene ridge and swale terrains to the east. This boundary is prominent and can be traced for 2.0 km (1.2 mi) along Back Creek Road to its junction with South Beach Road, where the road exits the Pleistocene island core onto a high Holocene beach ridge.

St. Catherines Shell Ring

The St. Catherines Shell Ring (9Li231) was first recorded in 1979 during the systematic survey of the island (Thomas, 2008, 2010; Sanger and Thomas, 2010). Chester DePratter and two archaeologists from the American Museum of Natural History excavated three test pits at this site, recovering diagnostic Late Archaic ceramics. Radiocarbon dates processed from these test pits were the oldest cultural dates from the island (Thomas, 2008, chaps. 14–16, 20). The American Museum of Natural History team returned to this site in 2006, renaming the locality the "St. Catherines Shell Ring" and initiating multiyear excavations: a large-scale mapping project, an extensive geophysical survey of the site (see figs. 10.10, 10.11, and 10.12), and the vibracore transect described in this chapter.

While the AMNH team was excavating in May 2006, G.A. Bishop noted that several of the archaeological excavations approached the water table (at a depth of ~2 m below ground surface). He suggested the site would provide a perfect place for a vibracore transect to tie the archaeological evidence into the deeper geological record of strata beneath the St. Catherines Shell Ring. This concept was explored on June 7, 2006, with Bran Potter and Tim Keith-Lucas of the Island Ecology Program at the University of the South (Sewanee, Tennessee). The professors and their students obtained and logged three vibracores along a north-south transect in the marsh immediately adjacent to the archaeological investigations in the shell ring. Bishop also logged the three cores and recognized the presence of potentially significant sediments in two of them—a peat in the bottom of one core, perhaps correlative with the Cracker Tom peat (Booth, Rich, and Bishop, 1999; Booth et al., 1999) and a "trampled" shell lens from a core recovered close to the island.

In November 2006, Bishop worked with the American Museum of Natural History archae-

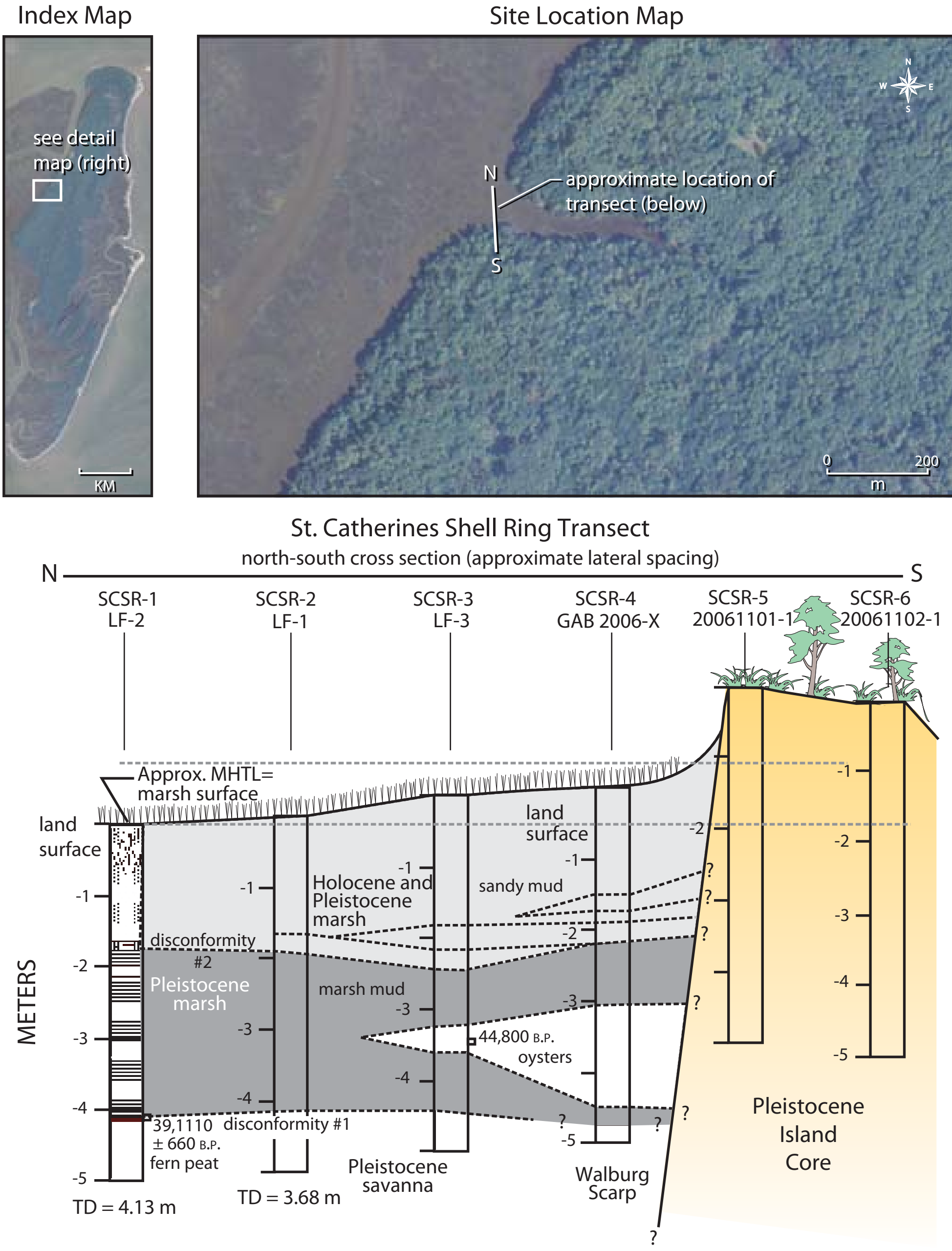
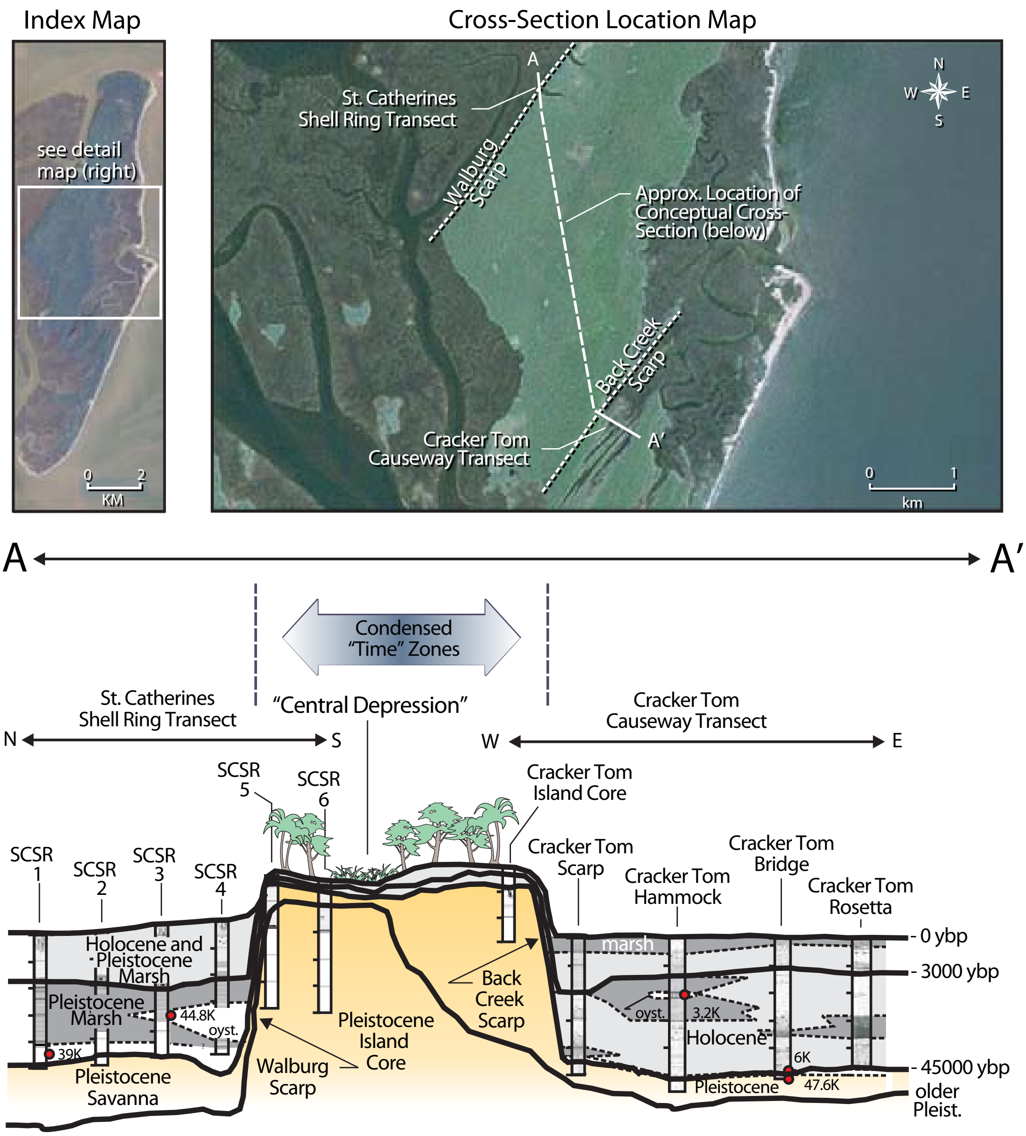


Fig. 10.8. Correlated geology at St. Catherines Shell Ring Transect showing depositional environments, radiocarbon dates, relative ages, and geomorphology in cross section. The lower disconformity marks an erosional boundary between the older Pleistocene terrestrial and overlying younger Pleistocene marsh facies. The upper disconformity is thought to mark the boundary between the younger Pleistocene and Holocene marsh facies on the west side of the island. The composition of Walburg Scarp and the Pleistocene marsh facies has not yet been determined by vibracoring. Aerial imagery from United States Department of Agriculture (USDA), National Agriculture Imagery Program (NAIP), 2006.



Note: The scale of the island core has been compressed laterally for presentational purposes.

Fig. 10.9. Cross section of St. Catherines Island integrating St. Catherines and Cracker Tom transects into an interpretive model including the geology. Note the "condensed zone" as isochrons cross from the geological realm to the archaeological realm.

ologists to extend the St. Catherines Shell Ring vibracore transect to the south (fig. 10.1D). This research connected the Island Ecology Program cores in the marsh via three new geology cores drilled by Bishop's team (fig. 10.8) into the archaeology of the St. Catherines Shell Ring.[1]

The upper component of the cores at the St. Catherines Shell Ring is constrained by the overlying archaeological deposits. The culturally constructed shell ring is a nearly perfect circle, mea-

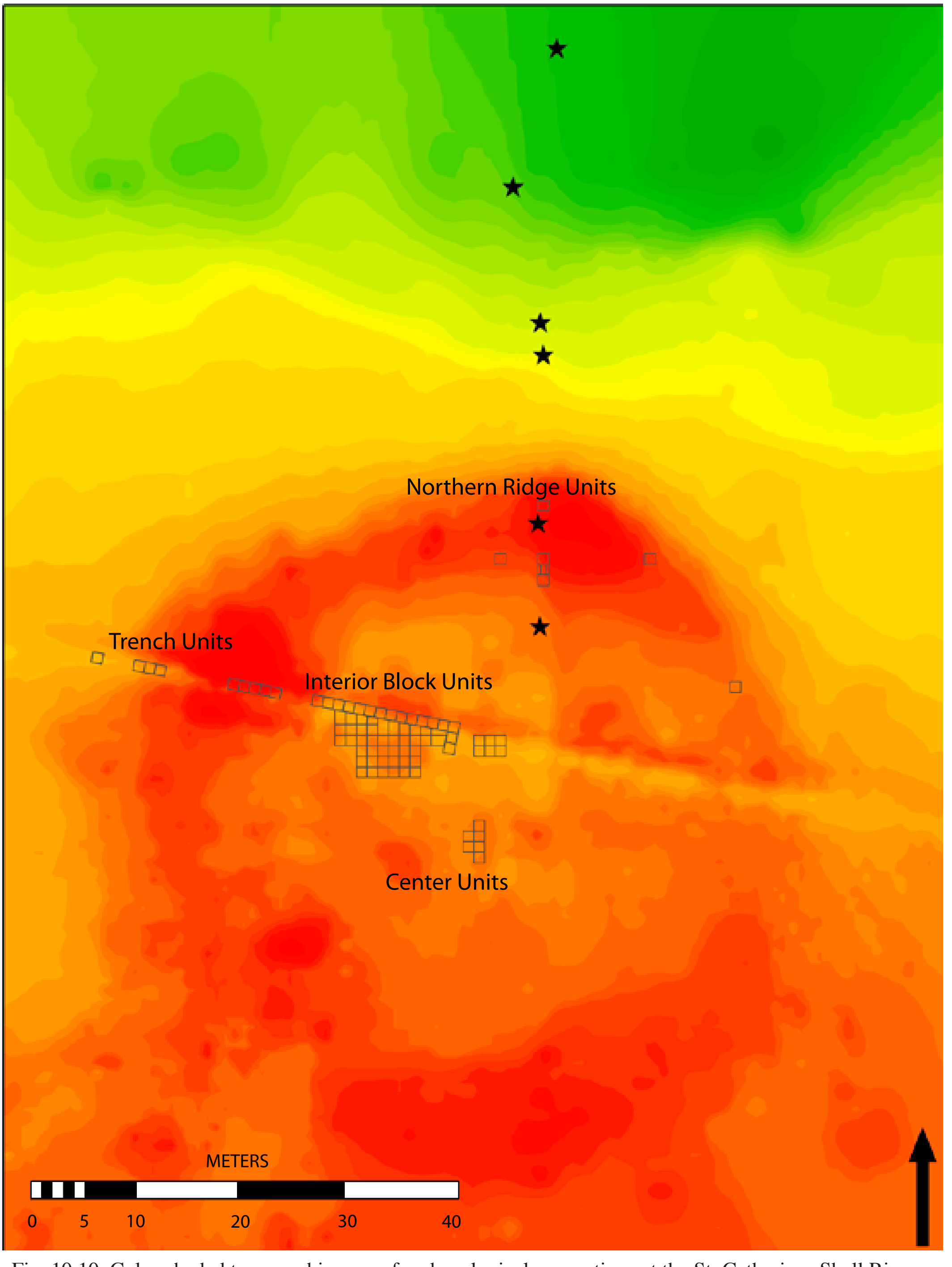


Fig. 10.10. Color-shaded topographic map of archaeological excavations at the St. Catherines Shell Ring; areas of higher elevation are indicated in red.. The diagonal line running approximately east-west is the antebellum boundary ditch defining the northern extent of Long Field. The St. Catherines vibracore transect extends northward under the "R" in words "Northern Ridge Units." Black stars represent vibracore locations.

suring 70 m between the two exterior edges of the shell ring. The shell that makes up the circle varies in thickness from roughly 1 m to 25 cm in a heavily plowed area. This distinctive shell ring defines an interior, shell-free plaza that is 34 m across. To date, we have processed 41 ^{14}C dates from the St. Catherines Shell Ring, employing a variety of sampling strategies in selecting samples for radiocarbon dating (Sanger and Thomas, 2010).[2] The earliest known cultural event at the St. Catherines Shell Ring is the construction of several small, shell-filled pits, which date to 2540–2290 cal B.C. A century later, 2230–2030 cal B.C., the vast majority of the shell used in constructing the circular ring was deliberately deposited across the site, burying the preexisting shell-filled pits. Sometime during this sequence, cal 2410–2210 cal B.C., a large number of circular, straight-walled, flat-bottomed pits were excavated within the interior space created by the shell ring (Sanger and Thomas, 2010).[3]

The marsh cores were integrated into the transect, and that transect has been correlated (fig. 10.8) to show the stratigraphic relationships of the site. In one of the first cores logged (SCSR 1; LF #2), a basal peat was encountered and sampled for dating (SCSR core 1; LF #2: 410–413 cm). Sample splits of the peat and shell samples

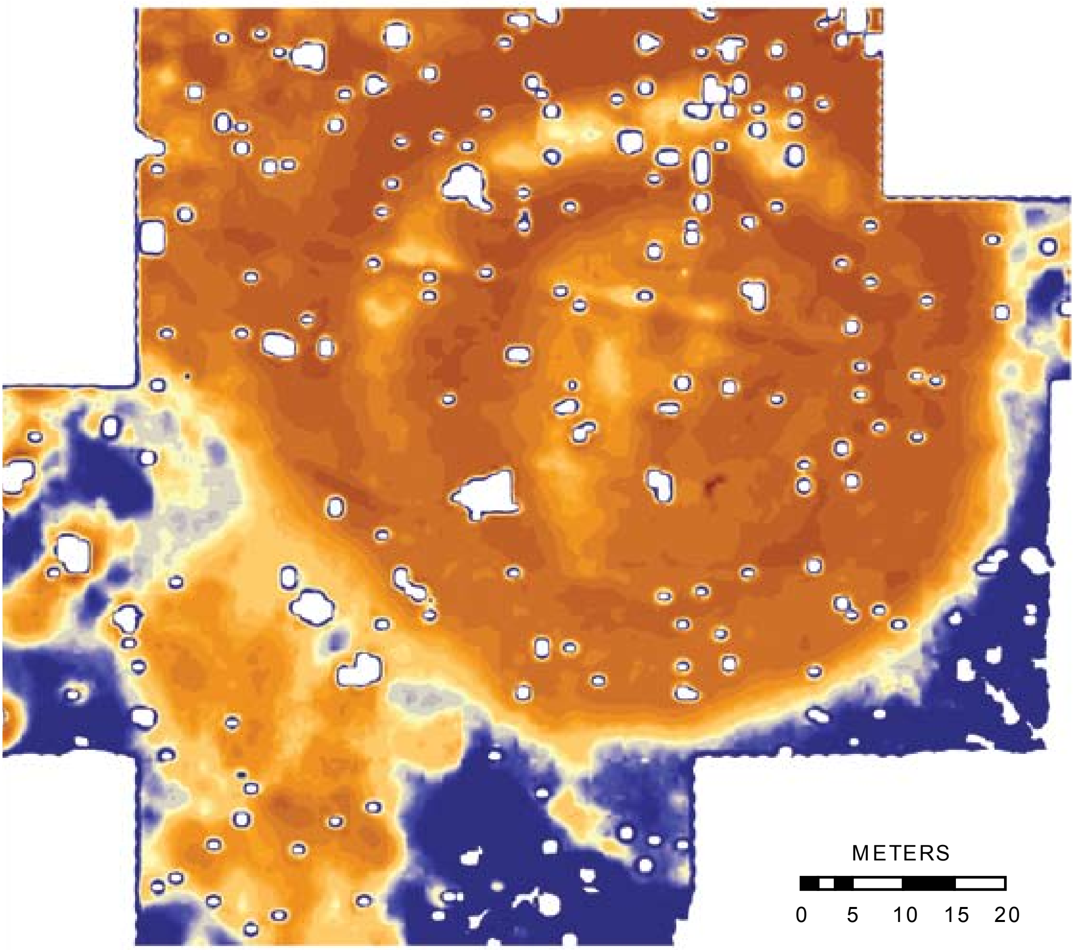


Fig. 10.11. Soil resistance map of the St. Catherines Shell Ring. The color scale ranges from dark orange (low resistance) to yellow (median resistance) to dark blue (high resistance). White areas indicate gaps in data collection due to obstructions such as living trees and vegetation, or excavation areas. The shell ring is clearly defined here as a lower resistance signature than the high resistance signature of the surrounding area.

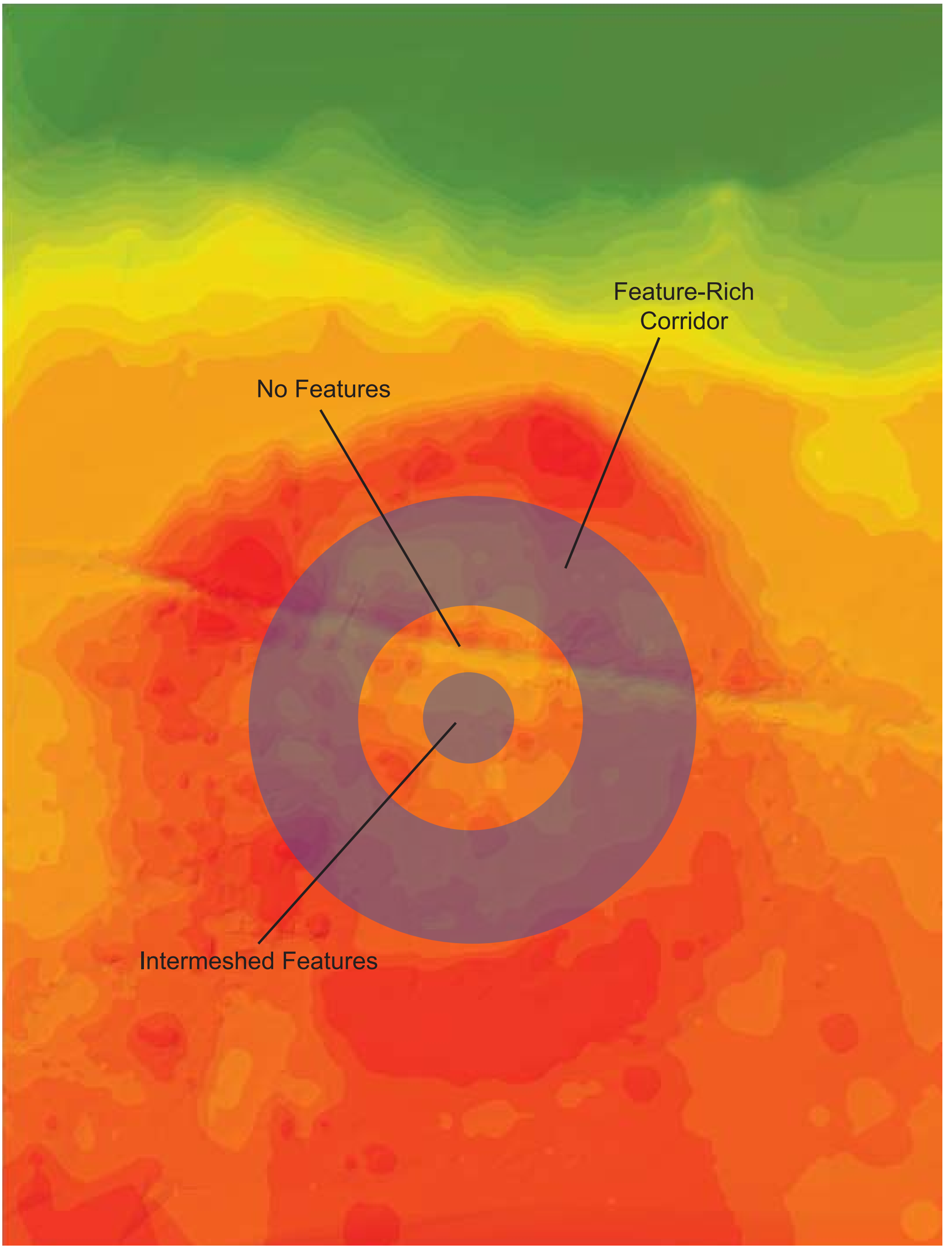


Fig. 10.12. Color-coded topographic interpretive diagram showing the internal structure of the St. Catherines Shell Ring (after Sanger and Thomas, 2010: fig. 3.12).

were sent to Thomas, who submitted them to Beta Analytic for ^{14}C dating. The dates from St. Catherines Shell Ring peat (>44,800 [Beta-217823] 39,110 ± 660 B.P. [Beta-217824]), are similar to the peat date from the core at Cracker Tom Bridge (47,620 ± 2500 B.P. [USGS WW1197]). These are among the oldest dates from St. Catherines Island and appear to mark a time when sea level dropped, exposing the flanks of St. Catherines Island to colonization by a maritime forest with a fern-dominated understory (see chap. 3, fig. 3.3F).

Correlation of the St. Catherines Shell Ring Transect (fig. 10.8) shows that horizontal marsh deposits of the north and western side of St. Catherines Island continue uninterrupted into Vibracore SCSR–4. The St. Catherines Shell Ring is perched on the edge of the Pleistocene island core, constraining the age of the habitation surface at ~5000 yr B.P. These sediments bracket Walburg Scarp and indicate that it has been a relatively stable core feature for ~5000 years. It would be useful to extend a core deeper into the subsurface beneath the SCSR-5 and SCSR-6 sites to test whether or not the ancient stratigraphy extends underneath the west side of the island, dating the earlier history of Walburg Scarp (fig. 10.8).

Two interruptions in sedimentation are seen in the cross section (fig. 10.8), a lower disconformity marked by transgression of marsh sediments onto a freshwater fern peat at approximately –4 m and a change from deposition of marsh mud to sandy mud of a higher marsh at approximately –2 m. The lower disconformity is bracketed by a date on the peat (39,110 ± 660 B.P. [Beta-217824]) and a date on the oyster shells in the overlying marsh mud (>44,800 B.P. [Beta-217823]). Both dates approach the limits of the ^{14}C methods, necessitating a return to relative dating by superposition. The dates indicate that the marsh hosting the oyster bioherm was situated on the bank of a tidal river some 44,800 yr B.P. It is not yet clear whether Walburg Scarp is part of the lower disconformity, or whether it is even older than the lower disconformity and antedates deposition of the lower sequence of marsh sediment.

From a geological perspective, the juxtaposition of intervals of time represented by packets of sediment in the marshes surrounding St. Catherines Island and the equivalent, but thinner sediment within the island core would represent a sort of "condensed interval," where time lines converge and island history is compressed into a thin interval across the island. This concept has been explored by attempting to draw isochrons across the island (fig. 10.9).

Booth (personal commun.) has conducted palynological analysis on two samples taken from the St. Catherines Shell Ring. The two strata beneath the St. Catherines Shell Ring have been dated, as previously discussed. He also pointed out that both dates approach the maximum range of ^{14}C dating.

Two samples were taken in SCSR #4 and a palynological analysis of the peat sample in [LF #1: –4.10 m] was done by Booth at Lehigh University and he reported (Booth, personal commun.; Rich and Booth, chap. 6):

> SAMPLE 20061102-1, 322 cm, SHELL BED: The pollen assemblage from the shell bed was dominated by *Pinus* (pine) and *Quercus* (oak); these occurred in approximately equal percentages.… Other arboreal types that were likely present in the region include *Carya* (pecan/hickory), *Liquidambar* (sweet gum), *Nyssa* (tupelo/black gum), *Betula* (birch), Cupressaceae/Taxodiaceae (probably cypress), and *Ulmus* (elm). Abundant nonarboreal types included Chenopodiaceae/Amaranthaceae type (likely salt marsh chenopods) and Poaceae (grasses), consistent with deposition in or near a salt marsh environment. The palynology of the sample is quite similar to that of the lowermost sample from the Cracker Tom Hammock core (CTH559), which is presumably also late Pleistocene in age and characterized by codominance of *Pinus* and *Quercus*, and significant amounts of *Carya*, *Liquidambar*, Cupressaceae/Taxodiaceae, Poaceae, and Chenopodiaceae/Amaranthaceae type. Trace amounts of *Fagus* (beech) also occurred in both the shell bed sample and the lowermost Cracker Tom Hammock sample.

> SAMPLE SCSR-1, 406 cm, PEAT: The lowermost peat is dominated by *Pinus*.… Other common arboreal types include *Quercus*, Cupressaceae/Taxodiaceae, *Carya*, *Betula*, *Fagus*, *Liquidambar*, and *Nyssa*. The relatively high *Fagus* percentage (3%) suggests the local presence of

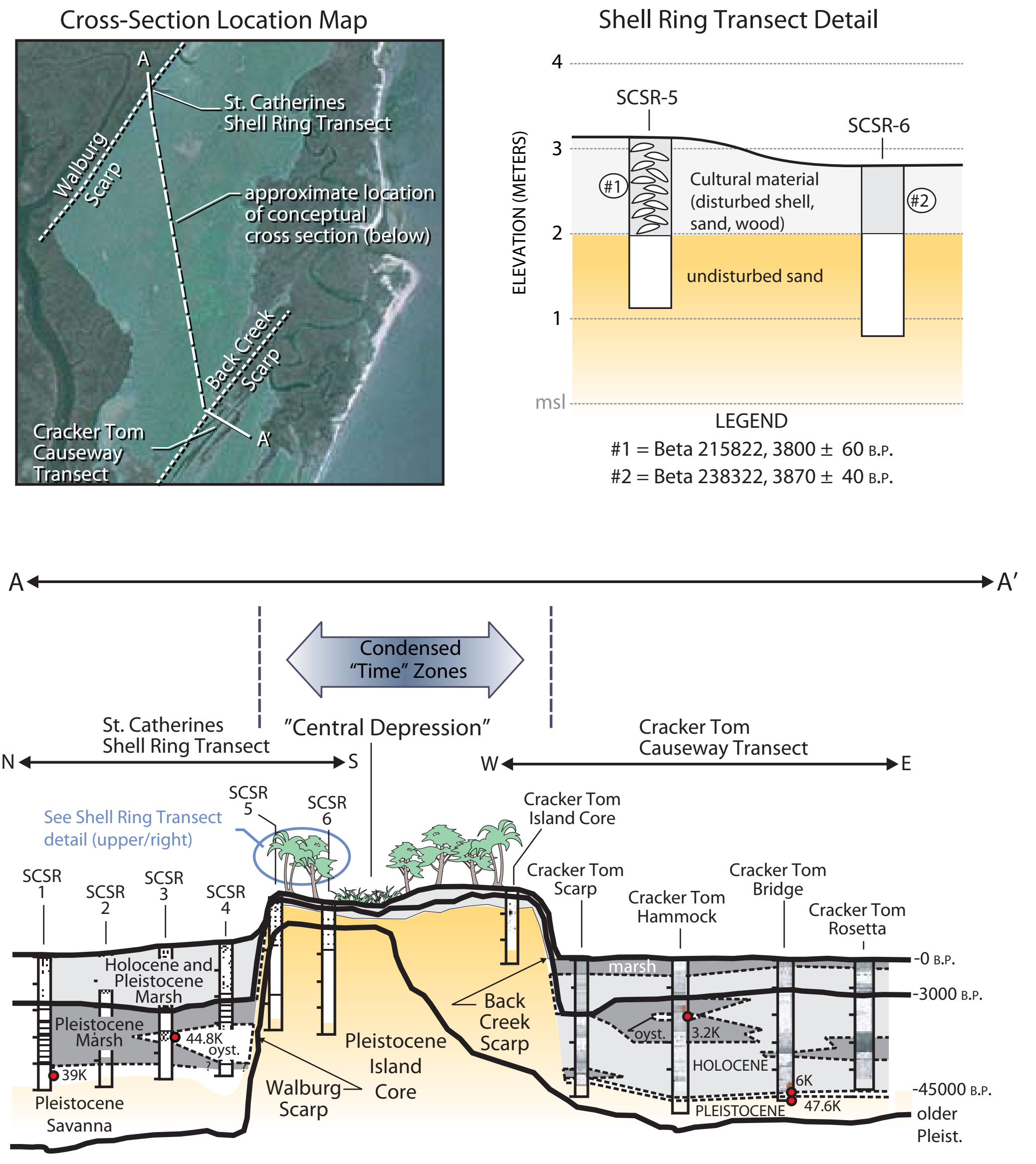


Fig. 10.13. Integrative model of St. Catherines Island geoarchaeology into which the authors hope to add additional detail in future collaborative studies. Note: The scale of the island core has been compressed laterally for presentational purposes.

beech populations. Beech currently does not occur in coastal Georgia, except for some disjunct populations on north-facing bluffs of the Savannah River. The nonarboreal pollen of the peat indicates deposition in a freshwater peatland environment, dominated by ferns (*Osmunda*, *Woodwardia*-type), grasses, and sedges. The palynology, and particularly the abundance of *Woodwardia*-type ferns, is relatively simi-

> lar to the palynology of the basal peat of the Cracker Tom Bridge core (CTB511), which was also late Pleistocene in age.

Correlation of the geology into and under the St. Catherines Shell Ring (fig. 10.8) shows a massive oyster bioherm thickening toward the island core, a perched water table indicated by limonite concretions, and a layer of "beach rock" underlying St. Catherines Shell Ring. Beach rock (a limonite or humate cemented sandstone) is often found underlying parts of the older Pleistocene parts of St. Catherines Island. Thom (1967) described humate occurrences in Australia, South Carolina, and on Sapelo Island. It is a dark brown or black cemented sand, often exceeding 3 m (20 ft) in thickness derived from Fe and the humic acids of decaying plant material and carried below ground in true solution or colloidal suspension. Thom thought humate deposits marked former water table positions.

The upper disconformity is marked by the top of the aforementioned ancient marsh with its oyster bioherm and the overlying sandy mud of more recent marsh sediments (yet undated) and a pervasive zone of limonitic concretions at its base just above the marsh mud. This concretionary zone is thought to be the result of, and marks the position of, freshwater outflow from the island core, i.e., a perched water table. It remains unclear whether the marsh mud underlying disconformity #2 forms a seal against Walburg Scarp or extends eastward under the St. Catherines Shell Ring beneath Walburg Scarp; either way it holds a perched water table. This relationship will be essential to understanding the evolutionary history of Walburg Scarp and, consequently, the configuration of the ancient St. Catherines geometry on the west side of the island.

The Terrain #6 vibracore (fig. 10.4) was taken in a swale pond in an east-west terrain. This core had a muddy peat at its bottom (TD 4.97 m), which was overlain by a sand with three shell layers up to 4.0 m, then was marked by a thin laminated sand overlain by a heavily mottled, burrowed, muddy sand from 3.66 m to 2.70 m. This was, in turn overlain by a sand with abundant clay drapes, burrows, and tabular cross beds at its top from 2.70 to1.23 m, with a thin horizontally laminated sand bed from 1.23 to 0.96 m, a fine-grained rooted sand from 0.96 to 0.47 m. Finally, there was a very organic peat from 0.47 to 0.00 m. This sequence of sediment and sedimentary structures is interpreted to represent the channel margin facies of the north edge of ancient Zapala Sound. The mottled muddy sand from 3.66 to 2.70 m is interpreted as a tidal mud flat on the channel margin with its surface at, or near midtide level, putting sea level at half the tidal range, or approximately at –1.70 m. The core is floored at total depth by a peaty mud, perhaps marking the disconformity seen at Cracker Tom and St. Catherines Shell Ring and described by Vance et al. (chap. 11, this volume).

Gator Pond

In 2008, Kelly Vance led three Georgia Southern University undergraduate students (Ferguson et al., 2009) in exploration of a sag structure at Road Junction 61 on the southwest side of Gator Pond Marsh (see Vance et al., chap. 11: fig. 11.14A). This subsurface structure was discovered by Vance and Bishop in 2007 during GPR profiling with a 100 MHz antenna. This exploration effort resulted in the recovery of 10 cores ranging in depth from 2.2–5 m in a zigzag traverse from road junctions 10 to 61 to 60 to the active excavation site of the pond at the old Crane Yard. Cores obtained from higher, well-drained areas were characterized by essentially structureless, medium- to fine-grained, subangular to subrounded, quartz sands with <1% disseminated dark, heavy minerals in the uppermost 1.5–2.5 m. Among these were two cores (our cores 8 and 9) from sites on topographically high, dry ground on the east and west sides of the drainage extending from Gator Pond to the Crane Yard site. These short cores (2.3 and 2.1 m) did not penetrate the base of these upper structureless sands. The relatively structureless uppermost sands are probably Holocene eolian sands (see Vento and Stahlman, chap. 4). Underlying sands (of Pleistocene age) are also largely fine- to medium-grained, but are distinct from the upper sands by the presence of inclined laminations defined by 4% to 12% concentrations of dark, heavy minerals. The laminated heavy mineral-rich sands are fine to very fine grained and similar strata have been attributed to a back beach depositional environment. Excavation of a new pond at the Crane Yard site in 2008 allowed construction of a composite section by utilizing strata exposed in the excavation wall plus vibracore samples. The excavation exposed an indurated humate-cemented sand (a vibracore impediment) at 1 to 1.5 m depth. The vibracore rig was erected in the bottom of the excavation where the indurated sand had been removed. The composite section is sand-dominated but includes some scour structures and lenses of finer sediment in the upper meter. Below the humate-cemented sands (1–1.5 m depth), heavy mineral sand concentrations (3%–5%) defined faint bedding in tan, fine- to medium-grained, subangular to subrounded, mica-bearing, quartz sands at 2.0 to 2.7 m depth. Thin (1 cm) lenses of red-brown, very fine, micaeous quartz sand and heavy minerals with traces of clay were observed at 3.7 m depth. Ghost shrimp burrows were identified (Gale Bishop) in fine- to medium-grained, subangular quartz sand at 3.9 to 4.6 m depth. The burrows were 1–2 cm in diameter with dark, clay-rich walls and a sand-filled interior. The core terminated in an iron oxide–cemented horizon at a depth of 4.9 m below the ground surface.

One of the goals of this vibracore traverse was to explore low areas that may have preserved layers of sediment rich in organic components that could be used in palynological investigations. Organic matter was a minor component in topsoils in the upper 20 to 30 cm of core from the higher, well-drained sites. One core (our Core 2), from the southwest margin of Gator Pond Marsh, contained ~30 cm (compacted thickness) of plant debris and significant amounts of organic material mixed with fine to very fine sand to depths of 1 m. The upper meter of strata exposed in the walls of the Crane Yard pond excavation also contained substantial concentrations of organic components to a depth of 1 m. The organic-rich upper meter in the Gator Pond Marsh core is underlain by relatively structureless fine- to medium-grained, subangular quartz sand to a depth of 3.9 m, where a sharp oxidized contact was observed with underlying sands characterized by heavy mineral laminations. The east wall of the excavation at the Crane Yard site exposed 15 cm of dark gray to black organic topsoil grading downward into white, fine- to medium-grained sand. The white sand was underlain by chocolate-brown, fine- to medium-grained sand that graded downward into a zone of black fine sand, silt and organic components at a depth of 75 to 95 cm. A thin gray-to-brown sand below the second organic sediment layer gave way to an underlying sandy clay layer characterized by Liesegang banding at ~1.2 to 1.4 m depth. Small springs (perched water table?) were observed at this depth and the water smelled strongly of hydrogen sulfide. The exposure in the west side of the pit revealed small lenses and troughs of finer sediment within the upper meter of sands and a larger trough or scour cross-section bearing dark, laminated sand at 0.9 to 1 m depth. Older topographic maps and current Lidar topographic terrain models (Brian Meyer) indicate that the former, more extensive Gator Pond marsh drained into the area of the new Crane Yard pond.

Fred Rich and Shannon Ferguson conducted a palynological evaluation of core samples from the Gator Pond marsh area and the Crane Yard pond excavation. This research indicates these areas were dominated by freshwater wetlands during the deposition of the upper meter of sediment (Ferguson, Rich, and Vance, 2010). The analyses also indicate an increase in diversity of the floral community with depth and the presence of an open freshwater wetland that was gradually taken over by shrubs and trees. Nine wetland taxa identified in samples taken at 70 cm to 100 cm depth include *Sphangnum, Botryococcus, Myriophyllum, Nuphar, Nymphaea, Ovoidites, Polygonum, Taxodium, and Utricularia*. The diversity and open nature of the interpreted environment are compatible with the conditions described by Jonathan Bryan in 1753 as "a perfect Meadow…finely watered with Springs…" (Hayes and Thomas, 2008). Additional coring in the interior of Gator Pond marsh and some of the ephemeral wetlands in the low interior of the island should penetrate deeper horizons of organic matter to extend this wetland record. The GPR profiles can provide some guidance in core site selection by indicating the extent of basin development. The present profile inventory suggests the ephemeral wetlands near the present Windmill Pond would be good candidates for additional vibracoring sites (see chap. 11, fig. 11.8A).

St. Catherines and Sapelo Sounds

Accretionary beach ridge complexes at both ends of St. Catherines Island, oriented perpendicular to the present-day northeast-southwest trending beaches, represent Holocene changes in the channel margins of St. Catherines Sound and Sapelo Sound (Linsley, Bishop, and Rollins, 2008). This indicates that the sounds and

Pleistocene cores of the Georgia Sea Islands are stable core features, but the unconstrained mouths of the sounds are historically active and act like loose fire hoses, whipping rapidly back and forth along the coastline, generating the erosional boundaries and accretionary packages of the beach ridge complexes. Oertel (1975, 1979), Kana, Hayter, and Work (1999), and Rollins, Beratan, and Pottinger (chap. 8, this vol.) discussed the dynamics associated with beach ridge complexes adjacent to inlets. Most St. Catherines Island beach ridges are parallel linear features hundreds of meters long and 2–4 m high seen forming as longitudinal dunes on the leading edge of accretional terraces on North and South beaches (Bishop et al., 2007: fig. 16).

Marsh system facies tracts are dominated by tidal creeks, rivers, and sounds. Lateral migration of the tidal creeks and rivers incises the sounds (Farrell, Hoffman, and Henry, 1993; Bishop et al., 2007: figs. 31, 32; this volume, chap. 3: figs. 3.4–5) an average of 10–15 m (Henderson and Frey, 1986). The rate of lateral migration is often 1–2 m per year (Letzsch and Frey, 1980b) with erosional depths depending upon channel depth. Large tidal rivers may also cut channels to depths exceeding 10 m (Duc and Tye, 1987), while small tidal creeks cut channels to lesser depths.

SUMMARY AND CONCLUSIONS

Vibracores and vibracore transects provide stratigraphic control to establish relative dating and access to materials for radiocarbon dating within a stratigraphic context. Vibracoring documents the erosional surfaces (disconformities) bracketing sedimentary packets and defines the lateral and vertical limits of sedimentary packets that record past depositional environments. The sequences of facies deposited through time establish the geological history of St. Catherines Island. Vibracore techniques have been applied to tie three of the archaeological sites into a geologic framework. At all three sites the vibracore data demonstrate the presence of marine conditions in proximity to the sites when they were occupied.

From the geological and geoarchaeological data presented above, we can surmise the following:[4]

(1) St. Catherines Island is comprised of an older Pleistocene island core surrounded by Holocene sediment.

(2)The island core appears to be comprised of at least two ages of Pleistocene sediment, an older one forming the western part of the island and a younger one forming the part of island to the east; these components are separated by a central depression.

(3) The easternmost part of the island core is slightly higher and has a less mature topography, with surficial strata that may consist of dunes built of sand blown from the beaches to the east.

(4) Underlying the Holocene sediment on the east and west sides of the island are one or two disconformities bracketed by basal shell beds above and peat beds beneath. The upper disconformity on the west side is marked by limonite concretions and "beach rock."

(5) Peat beds penetrated by vibracores in the Cracker Tom and St. Catherines Shell Ring transects are Pleistocene, ^{14}C dated at 47,620 ± 2500 B.P. (USGS WW1197) and 39,110 ± 660 B.P. (Beta-217824), respectively; microfossils consist predominantly of spores and fragments of the fern *Woodwardia*.

(6) A peat bed penetrated by an Island Ecology Program vibracore 16.2 on North Beach (~27,000 B.P.) is also Pleistocene, but is significantly younger than the peat beds from Cracker Tom and St. Catherines Shell Ring transects.

(7) Charcoal and a marine bivalve, *Americardia*, shell lying immediately above the 44,000 B.P. peat at Cracker Tom were dated at 6020 ± 50 B.P. (USGS WW1198) and 4060 ± 50 B.P. (USGS WW1262) respectively, bracketing the major disconformity between the Pleistocene core and younger strata surrounding St. Catherines Island.

(8) High elevations of ghost shrimp burrows and laminated heavy mineral sand layers in vibracores (SRP 1, 2.50 2.95 m) indicate a sea level approximately 2–5 m above today's sea level when that part of the island core was deposited.

(9) Backbeach and marsh facies deposited above the basal disconformity in the Cracker Tom Transect and St. Catherines Shell Ring Transect record sea level rising against the island.

(10) The upper disconformity on the west side of the island at St. Catherines Shell Ring is the lower boundary for the overlying sedimentary packet, marking a probable still-stand at –2.0 m.

(11) The uppermost lagoonal sediments in

the Beach Pond vibracore contained a wood clast that yielded a radiocarbon date of 1210 ± 40 B.P. (Beta-115910).

These primary data can, in turn, be synthesized into several conclusions about the geology of St. Catherines Island:

(1) Vibracore transects indicate that St. Catherines Island formed during the Pleistocene in two major cycles of sedimentation at an elevation of some 4.0 m above current sea level.

(2) An island doublet, St. Catherines Island and Guale Island, formed during the latest cycle (see Bishop et al., this volume, chap. 3).

(3) St. Catherines Island was subject to subaerial exposure at least twice during formation of the island core, most recently in the Wisconsin period.

(4) While sea level was down during the Wisconsin glaciation, shorelines were situated far to the east (near Gray's Reef) and St. Catherines Island was a forested ridge on the mainland with significant fern communities in (low) spots.

(5) As sea level began to rise after the Wisconsin, preexisting (legacy) tidal creeks and rivers were reflooded as shorelines transgressed onto the ridge, laying down a record of transgressive shoreline and marsh facies above one or more disconformities. Erosion of Guale Island began and sand was transported southward along the east face of St. Catherines Island, forming a series of accretional terrains (see Bishop et al., this volume, chap. 3: fig. 10.7).

(6) As Guale Island eroded, the northern end of St. Catherines Island was exposed to erosion, forming an "erosional marine terrace" at ~1.5 m above current sea level (Martin and Rindsberg, 2008). Tidal creeks cut meander scars into the ocean side of St. Catherines Island, forming the North Oxbows and initial phases of meander scars cut into King New Ground Scarp.

In summary, we can see that the historical evolution of St. Catherines Island that was originally developed largely on the basis of geomorphology (Bishop et al., 2007; Linsley, Bishop, and Rollins, 2008, Thomas, 2008) is now being constrained by stratigraphy. Vibracoring around the island has been instrumental in documenting its geological foundation by providing sedimentological, stratigraphical, and palynological data that must be consistently integrated and interpreted. In addition, organic inclusions extracted from the vibracores provide radiocarbon dates that further constrain the evolutionary history of St. Catherines Island and build an absolute temporal framework for the geology and archaeology. These methods also provide the data to test new hypotheses (Chowns et al., 2008) of island formation, evolution, and of its contingency (Gould, 1989). New geophysical techniques like ground penetrating radar have become available to investigate the geological underpinning of St. Catherines Island (Vance et al., this volume, chap. 11). It will be interesting to note whether optical thermal luminescence methods will provide additional dates on the quartz sand that comprises so much of St. Catherines Island.

So, which way forward? What pertinent problems can be best investigated by future vibracoring on St. Catherines Island? Several obvious vibracore problems are already apparent due to past coring and GPR surveys (see chap. 11, this volume):

(1) What is the age and history of Northwest Marsh and how does it constrain Walburg, Northwest, Engineers and St. Catherines scarps?

(2) Can the hypothesized modification of King New Ground Scarp by erosional emargination of tidal creeks be documented and, if so, what is its timing?

(3) What is the nature of the GPR-identified sag structures within the island core (see Vance et al., this volume, chap. 11)? What are the implications of these structures for past hydrology and the future?

(4) Does the Central Depression really mark an ancient erosional scarp between older and younger Pleistocene sedimentary packages, and if it does, can the underlying disconformity be documented by vibracoring or GPR methods?

(5) Can Back Creek Scarp be documented by vibracore methods and will there be heavy mineral sand placer deposits at its base?

(6) What do Gardeners Peninsula, the arcuate meander scarp on the south side of McQueen Marsh meadow, and lineations within McQueen Marsh meadow tell us about island evolution?

(7) What is the relationship of the island's fringing marsh to the history of sea level fluctuation?

(8) What is the circular structure south and east of South End Settlement: a Carolina Bay, an old meander scar, or a sinkhole?

(9) What is the nature of the inclined strata beneath South End Field?

These and many other questions await resolution through the use of geophysical methods

(GPR, shallow seismic, resistivity), and Lidar terrain modeling used with vibracoring for ground truth and access to samples for geochronological, palynological, and sedimentological study.

NOTES

1. The AMNH archaeology crew then expanded the vibracore testing to investigate Back Creek Village and McQueen Shell Ring sites on the front of the island core in 2008.

2. We have calibrated these results according to the established protocols already established for St. Catherines Island (Thomas, 2008), namely using the CALIB 5.0.1 Radiocarbon Calibration Program (as initially presented by Stuiver and Reimer, 1993, and updated by Stuiver et al., 2005). For terrestrial samples, we used the IntCal04 curve (Reimer et al., 2004) and for marine samples, we employed the Marine04 curve, which takes into account the "global" ocean effects (Hughen et al., 2004). We also used the reservoir correction of $\Delta R = -134 \pm 26$ specific to St. Catherines Island (as derived in Thomas, 2008: chap. 13).

3. A prominent muddy oyster/mussel bed was observed to thicken southward and disappear under the edge of the island core. In subsequent excavations, archaeologists now routinely use vibracore sampling to complement conventional archaeological excavation.

4. Thomas et al. (2008) combined the available stratigraphic and geomorphologic evidence from St. Catherines Island with the known distribution of archaeological ceramics recovered from the more than 200 sites to develop a scenario of island evolution. A reconstruction of the shape of St. Catherines Island at various points through time was made and is inherent in the observations and conclusions of this chapter and volume. In (Thomas, 2008: table 29.1) the 41 "noncultural" ^{14}C dates are presented that have been processed to interpret the geomorphic evolution of St. Catherines Island and combine it with historical documents (see also appendix 1, this volume).