Journal of Archaeological Science: Reports 5 (2016) 240–262

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

The archeology, sedimentology and paleontology of Gray's Reef National Marine Sanctuary and nearby hard bottom reefs along the mid continental shelf of the Georgia Bight

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ARTICLE INFO

Article history:
Received 7 June 2015
Received in revised form 28 October 2015
Accepted 4 November 2015
Available online xxxx

Keywords:
Archeology
Sedimentology
Paleontology
Georgia Bight
SEM-EDS
XRD
Petrography

ABSTRACT

Geoarcheological surveys undertaken over the past two decades at Gray's Reef National Marine Sanctuary, 32 km offshore Georgia, and nearby JY Reef have recovered archeological and paleontological materials dating from the Late Pleistocene, primarily Marine Isotope Stage (MIS) 3, 59–24 KYBP as well as the early-to-mid Holocene, 6000 BP. The paleontological materials include both invertebrate and vertebrate taxa from both the Pleistocene and Holocene while the archeological materials are Holocene age. Sediment coring has developed a more comprehensive picture of the inner-to-mid continental shelf sediment prism of the Georgia Bight. Optical petrography, scanning electron microscopy, electron dispersive spectroscopy (SEM-EDS) and wavelength dispersive X-ray diffraction (XRD) have been used to characterize Gray's Reef lithic artifacts and nearby outcrops which are both primarily Pliocene age calcareous sandstones. JY Reef is, by contrast, a coquina rich in fossil and subfossil materials but depauperate in any archeologic finds. Petrologic and geochemical data have been developed for both the outcrops and artifacts that are in good agreement with previous studies using optical petrography.

1. Introduction

The search for submerged archeological sites on the sea floor has taken on renewed importance in the U.S. with the debate over the timing and means of the prehistoric human colonization of the Western Hemisphere (Dixon, 2001; Haynes, 2003; Rick and Erlandson, 2009; Erlandson et al., 2011; Faught and Gusick, 2011; Evans et al., 2014). The Atlantic coastline of the southeastern United States has been identified as an area with good potential for preservation of archeological sites from the periods prior to the establishment of the modern shoreline (cf. Harris et al., 2013). The drowned continental shelves along this coastline are wide and comparatively shallow, vastly increasing the area available to prehistoric groups prior to marine transgression, as well as improving probabilities for chances of site preservation during episodes of rapid lateral marine transgression of the coastline (Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b). To these observations, we must add that the multiple paleoclimate studies showing that this region had much more favorable climate conditions than other regions of North America in the Late Pleistocene and into the Middle Holocene, during a period when the initial colonization of this hemisphere occurred (Russell et al., 2009).

We report here then, the results of our studies along the Georgia coast at Gray's Reef National Marine Sanctuary and nearby locations that have focused on exploring its potential for submerged prehistoric archeological and paleontological sites since 1996 (Fig. 1). The research has included sedimentological, geological/geophysical, chronological, archeological and paleontological investigations, all of which offer us both insight into the potential for deposition and preservation of both paleo-environmental proxy data as well as human activities along this now-drowned coastal plain. Initially the discovery of sites was the first priority of our research. Because the modern shoreline dates to only around 5000 BP, sites associated with any cultural period older than that are potentially present in the Georgia Bight and at Gray's Reef. In this report, first, we will outline the general geological, geomorphological, and sedimentological context of Gray's Reef. Next, we will briefly discuss the general outlines for each cultural period that could have deposited remains of their activities at Gray's Reef. Third, we will then discuss the sedimentology, paleontology and archeology as it is currently understood for these sites; Finally, we will synthesize these data into an analysis for overall significance.

2. The Georgia Bight and Gray's Reef

The Georgia Bight, also called the South Atlantic Bight, is a shallow embayment that stretches along the Atlantic coastline from South Carolina to the mouth of the St. John's River in northeastern Florida, along a tectonic low created by the Cape Fear and Ocala arches. It is a mixed energy coastline with a mesotidal range of around 2–3 m, and a minimal wave height of around 33 cm (Weaver, 2002: 16–17; Garrison et al.,

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http://dx.doi.org/10.1016/j.jasrep.2015.11.009
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Fig. 1. Gray's Reef and JY Reef within the Georgia Bight.

2008). Two large watersheds empty into the Bight along the Georgia coastline: The Savannah River and the Altamaha. These are sourced in the southern Appalachians and deposit sediment from this area, as well as from the piedmont and coastal plain. Smaller watersheds such as the Satilla and the Ogeechee drain the coastal plain alone. Compared to other coastlines, the Bight is a sediment-starved continental shelf (Weaver, 2002:18; Harris et al., 2013:8), with little to no finer grained (<63 nm, silt sized or smaller) fluvial sediment deposited past 10 km from the coast. These sediments instead are deposited within the extensive saltwater marshes associated with the barrier islands fringing the coastline. Beyond the inner continental shelf, sediments are medium to coarser grained, with carbonate increasing towards the slope (Pilkey et al., 1981; Weaver, 2002:18; Garrison et al., 2008).

The continental shelf off Georgia is broad, stretching seaward another 60 or more kilometers where it meets the shelf break and continental slope. At the last glacial maximum, the entirety of this shelf was exposed, while by the Paleoindian period the relative sea level was somewhere in the region of the −40 to −73 m isobaths (Garrison, 1992; Dunbar et al., 1989; Anuskiewicz and Dunbar, 1993; Anderson and Faught, 2000:165, Fig. 1; Faught, 2004a, 2004b; Basillie and Donoghue, 2004; Garrison et al., 2008, 2012a, 2012b; Harris et al., 2013). Rock outcrops appear to be mostly Pliocene in age until the shelf break, although there may be Miocene outcrops along the modern coastline (Huddlestun, 1988). Non-Pliocene outcrops offshore are currently undocumented but certainly are possible (see Popenoe, 1991; Poppe et al., 1995 for discussion of offshore stratigraphy older than the Pliocene formations currently outcropping at Gray's Reef and elsewhere in the Georgia Bight).

The Holocene islands fronting the Atlantic are welded onto Pleistocene islands (Booth et al., 1999:83; Linsley et al., 2008: 38–39; Turck, 2010). All of them are subject to the vagaries of sediment supply and both eustatic and relative sea level changes (Nichols, 2009: 203–205). The terrestrial archeological sites along the modern coastline tend to be located in back barrier locations as early as the Late Archaic sites ca. 5000 BP; these are often located on the Pleistocene barrier components, near marshes that allowed access to multiple highly productive resource patches. Behavioral ecological models have supported the argument that this tight clustering of resources did not require residential mobility to satisfy the needs of populations living on these islands because the handling costs for prey capture, transportation and processing were accordingly reduced, with the probable use of watercraft reducing handling costs even further (Thomas et al., 2008: 930–931, 1084, 1088; Reitz, 1982, 1988: 138–139, 2014).

Some current data suggest that conditions in the Georgia Bight supported the formation of barrier islands between the last glacial maximum and the establishment of the modern shoreline. Relatively slow transgression plus sufficient sediment load forms barrier islands in microtidal and mesotidal coasts (Dalrymple and Zaitlin, 1992: 1132–1133; Nichols, 2009:205). The Georgia coastline itself has the required sediment supply, along with the mesotidal range and wave action noted above. Rapid transgression (>33 cm/century) can overtop barriers, drowning them in place, while slower rates simply roll them back. Drowned barrier systems are visible to marine geophysical survey (Garrison, 1992; Locker et al., 1996:829, 830; Balsillie and Donoghue, 2011:63; Nichols, 2009:203), and have good potential for archeological materials when subject to rapid inundation and limited exposure to erosion. Where transgression rates are slower, only back barrier sediments tend to be preserved below open marine deposits (Locker et al., 2003:373), visible only to coring or other means of exposing these buried sediments.

Rates of marine transgression are key to formation of barrier islands as well as to the potential for site preservation (Dunbar et al., 1989; Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b; Stright, 1986a, 1986b, 1990, 1995; Stright et al., 2003). The relative sea level (RSL) positions for the Gulf of Mexico are relatively well understood, but RSL along the Georgia coast is less so (Fig. 2, adapted from Balsillie and Donoghue, 2011; Garrison et al., 2008, 2012a, 2012b; Harris et al., 2013). The Georgia Bight does not share the Gulf's tectonic or sedimentary characteristics and thus we expect relative sea level curves to differ somewhat. Current studies have shown that recent dates obtained from materials recovered from locations off the South Carolina coast are consistent with the earlier portion of the Gulf Coast curve; stumps from a submerged forest found under the modern sand sheet at the −19 m isobaths date to 11,500 BP, and an associated peat layer dates to 10,800 BP (Harris et al., 2013, p.11). However, dates reported by Garrison et al. (2008) derived from sediments and faunal materials at Gray's Reef do not agree with the Gulf Coast curve. These yielded dates of 6090 ± 60 BP, 8950 ± 70 BP, and 18,670 ± 140 BP (Garrison et al., 2008: Table 4, p. 132; Appendix, Table 3 this paper). The latter date was a carbon dated ophiomorpha and suspected of being anomalous. The youngest date of 6090 ± 60 BP, is from a bison bone (*Bison bison*). This item could be part of a lag deposit associated with a tidal inlet (Mallinson et al., 2010) and thus not evidence that Gray's Reef itself was still terrestrial, but even assuming taphonomic processes such as erosion and re-deposition for this item, the age rendered by 14C AMS dating argues that the coastline was not far from its Late Holocene terminus at this time. At present, the question remains unsettled. Radiocarbon dates on organic remains from back barrier marshes in Georgia do demonstrate that the modern shoreline arrived around 5000 BP (Booth et al., 1999:83; Linsley et al., 2008:38). Taken with the anomalous dates from Garrison et al. (2008), and Harris et al. (2013), we can comfortably say that the Georgia coastline was easily located at the −20 m isobaths by the Clovis Period (11,500 BP to 10,800 BP) but, if the *B. bison* date is correct, it may not have been submerged until around 6500 BP. during the Middle Archaic period.

It may be possible to infer coastline position and/or barrier formation prior to 5000 BP along the Georgia coast using bathymetric profile analysis. This has been done along five transects from the modern shoreline to the −45 m isobaths (the latter consistent with the late

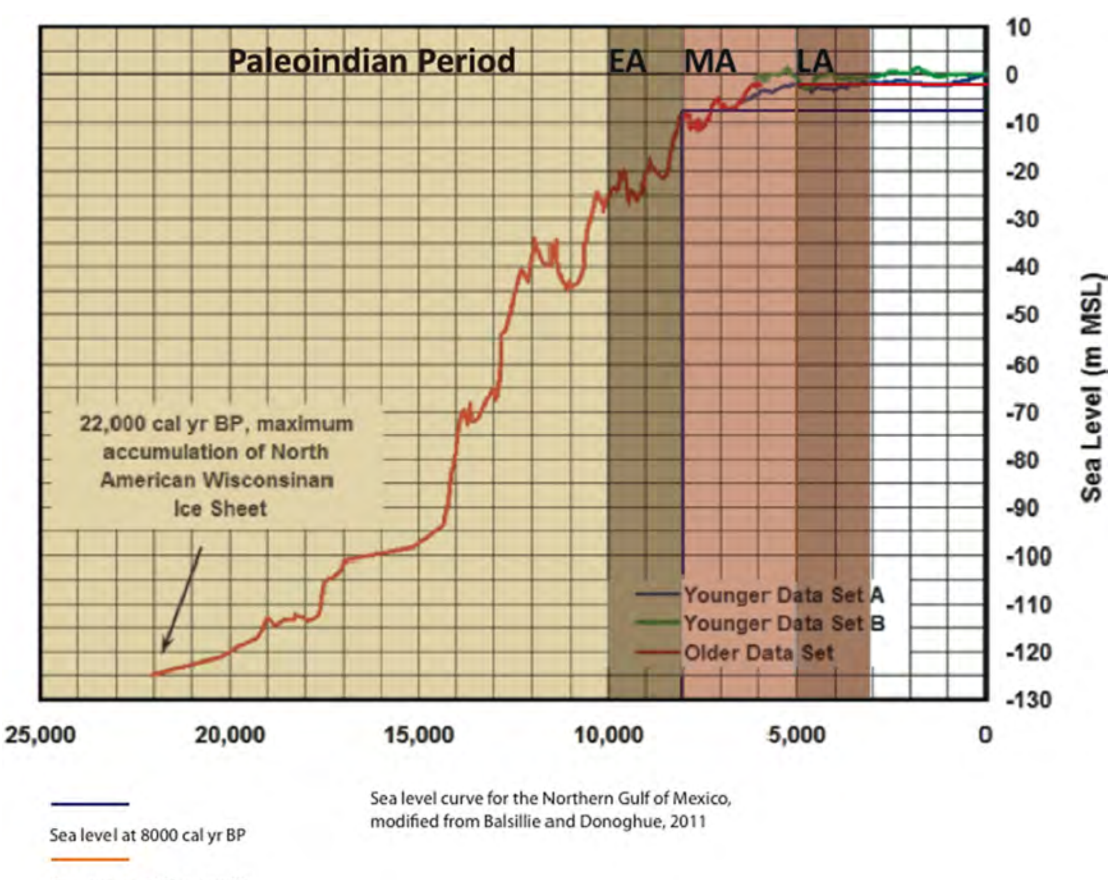


Fig. 2. General sea level curve for the Gulf of Mexico adapted from Balsillie and Donoghue (2011).

Paleoindian period shorelines) using a geographic information systems (GIS) database. This GIS database synthesizes sedimentological, geomorphological, palynological, archeological, paleontological data from the body of research dating to 1996 at these locations offshore, as well as with 3 arc sec resolution bathymetric data downloaded from the National Oceanographic and Atmospheric Administrations (NOAA)'s National Geophysical Database Center (NGDC) and regional paleoclimatological studies (Carver and Brook, 1989; Garrison et al., 2008, 2012a, 2012b; Ivester et al., 2001; LaMoreaux et al., 2009; Leigh, 2008; Littman, 2000; Russell et al., 2009; Weaver, 2002). These profiles suggest several topographic highs at roughly the same depths in a generally consistent manner along all profiles. They are also consistent with the appearance of drowned barriers derived from other geophysical surveys (e.g., Hoyt and Hails, 1967:1542; Locker et al., 1996). While remaining cautious in our interpretations of these bathymetric features, we do suggest that these locations should be high priority targets for site detection efforts given the potential for back barrier locations to be rapidly sealed over and preserved by overwash sediments during periods of rapid (>33 mm/year) periods of marine transgression or during storms. (Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b, 2008; Grøn, 2006, 2007:113; Harris et al., 2013:20; Kelley et al., 2013:1). Interestingly, Gray's Reef lies just to the west of one of these topographic highs (Fig. 3).

As we will discuss in more detail below, at Gray's Reef and other hard bottom ledges nearby, geological and geophysical mapping, together with sediment coring studies have demonstrated that the sediments are relatively shallow, 0–6 m thick, and consist of unconsolidated, palimpsest, medium sands rich in shell debris (Garrison et al., 2008; Littman, 2000; Weaver, 2002). The reef rock outcrops in this portion of the continental shelf at depths ranging from −15 m below mean sea level (bmsl) to −20 m bmsl. Dates have been obtained from the sediment samples using optically stimulated luminescence (OSL), and from bone and shell inclusions using accelerated mass spectrometry (AMS) radiocarbon and uranium/thorium (U/TH) methods (Table 3). These analyses have rendered dates ranging from the Pleistocene (Marine Isotope Stage 3, MIS3, 59–26 KYBP) to the early Holocene from the surface of the sediment down to −4 m below subsurface.

These data strongly argue that the sites that have already yielded artifacts and faunal materials at Gray's Reef are clearly heavily eroded and reworked into lag deposits retained by hard bottom sandstone ledge outcrops (see Fig. 4 for idealized representation of these features). Adding to these observations is the failure of pollen and sedimentological studies to detect evidence for the Younger Dryas reversal (Garrison et al., 2008: 137–139). The depths of the reef and sea floor at the find spots are below fair weather wave base, but are not below storm wave base generated by tropical systems that may cross the site. Diurnal tides also produce currents, this drowned coastal plain to prehistoric populations inhabiting the Bight prior to inundation, archeological materials at these locales are unlikely to be found in situ. This does not preclude the ability to interpret them but must be taken into consideration when doing so.

3. Potential cultural associations for submerged prehistoric sites within the Georgia Bight

The assessment of the meaning of the prehistoric archeology of the sea-floor depends upon an integrated understanding of the archeology on the adjacent hinterland. Pearson et al. (2008) and Benjamin (2010), among others, have stressed this methodological approach and we agree with this robust approach to research design for surveys of submerged landscapes. A brief review of regional chronologies and occupation patterns will place the surveys in the Georgia Bight within this context.

Known Paleoindian sites in the Southeast in general represented by Clovis and closely related cultural variants are few in relation to other periods; these may simply be under-represented in the archeological

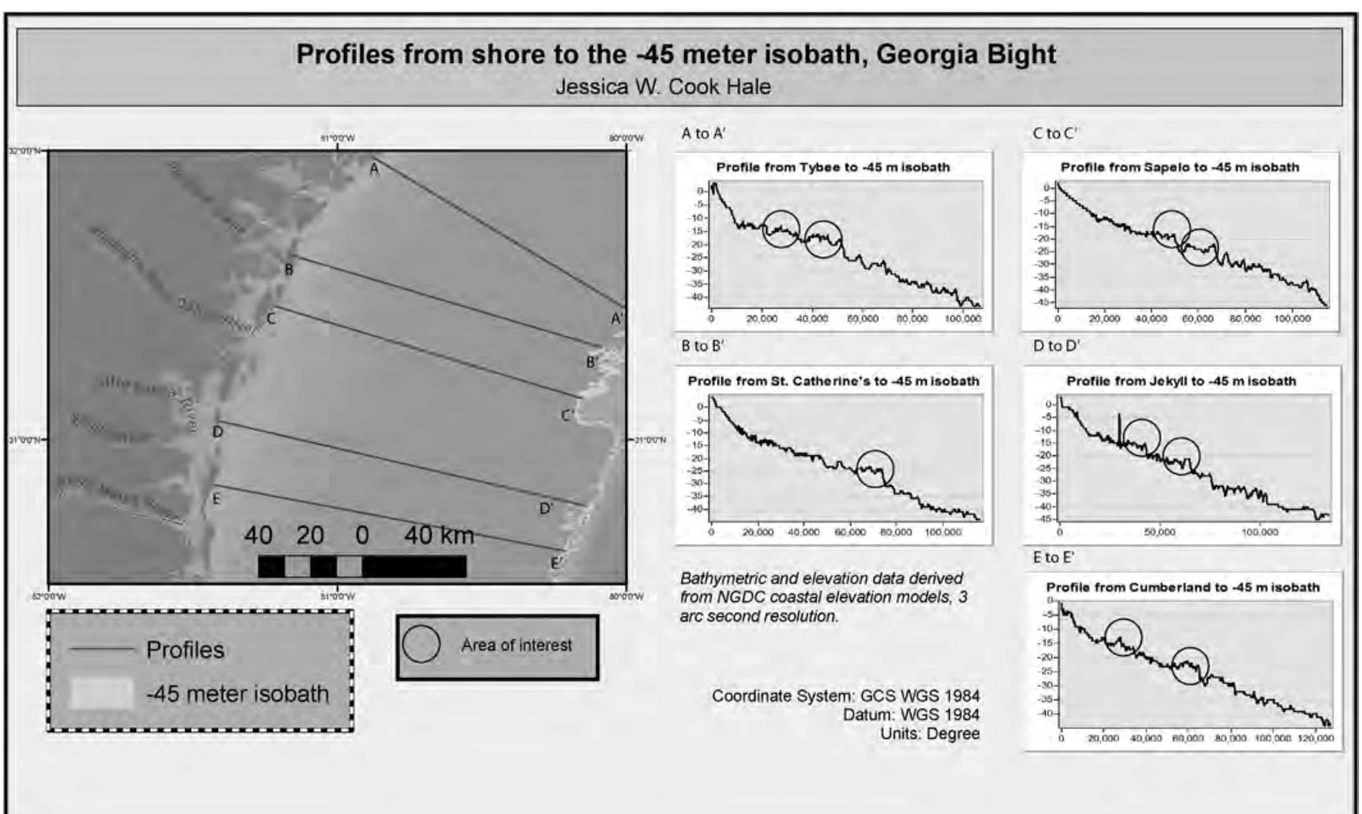


Fig. 3. Bathymetric highs suggested by GIS analysis.

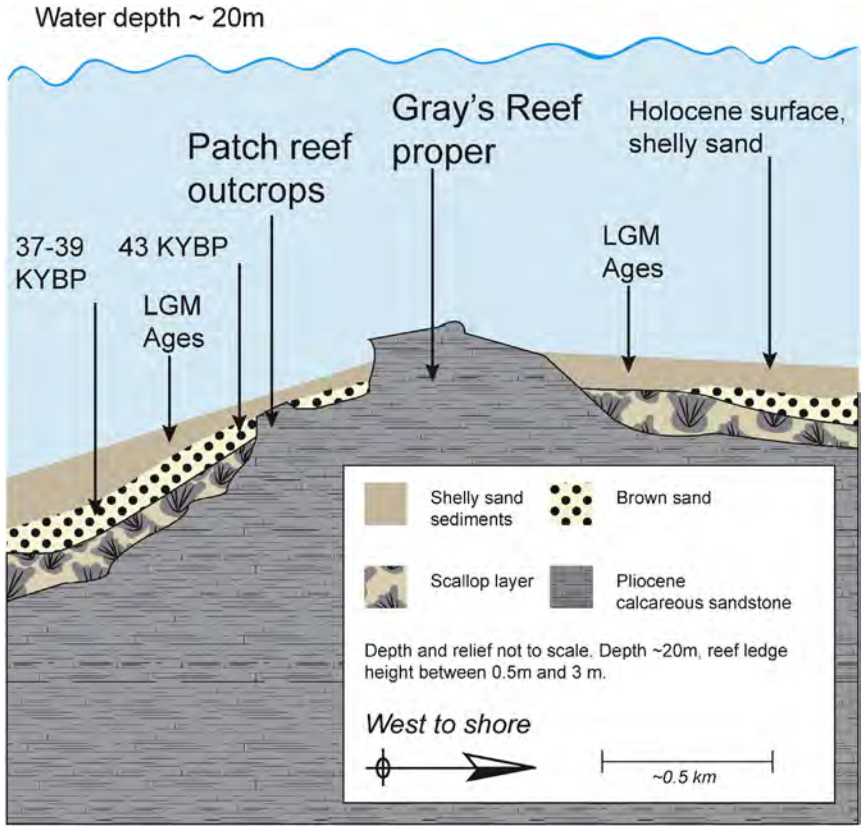


Fig. 4. Top — generalized diagram of hard bottom outcrops in profile, Gray's Reef and associated areas. Adapted from Weaver (2002).

record (Anderson and Schuldenrein, 1983; Anderson, 1995; O'Steen et al., 1986; Goodyear and Steffy, 2003; Hemmings, 2004; Faught, 2004a, 2004b). By the end of Marine Isotope Stage (MIS) 3 at around 25,000 14C BP, the submerged portion of the Georgia Bight/Atlantic Coastal Plain was subaerially exposed and available for human colonization. Models from the Big Bend in Florida for submerged sites along fluvial channels at sinkholes, near high quality chert outcrops, have proven successful in identifying sites in the offshore area of Apalachee Bay (Faught and Donoghue, 1997; Faught, 2004a, 2004b) but it is unclear how well this model translates to the Georgia Bight, where the bedrock consists of sandstone and not chert nodule bearing carbonates dissected into karst topography by disappearing rivers controlled by water table height.

The Paleoindian period is best known, of course, for its lanceolate point technology, specifically Clovis points. Paleoindian groups are thought to have been highly mobile, and the density of sites in the Southeastern United States strongly suggests that if Clovis didn't actually originate in this region, it certainly attained a remarkable fluorescence when it arrived (Anderson and Faught, 2000). The debate about the nature of Clovis subsistence is ongoing, with some scholars such as Meltzer remaining skeptical that Clovis peoples targeted megafauna (Cannon and Meltzer, 2004, 2008; Hemmings, 2004; Bradley et al., 2010) and other scholars citing the sheer volume of Clovis sites associated with megafaunal remains (Webb et al., 1984; Haynes, 2003). As noted above, the Southeastern United States was a climate refugium during the last glacial maximum and during the warming period that followed (Russell et al., 2009), and its comparatively mild climate compared to the rest of North America should have made it a very attractive region to early foraging groups; indeed, the density of Paleo-Indian points documented within the online Paleo-Indian Database of the Americas (PIDBA, http://pidba.utk.edu) appears to support this hypothesis for the terrestrial components of the Paleoindian occupation of the Southeast, as well as lending credence to Anderson and Faught's (2000) argument that Clovis may well have been invented here.

Early Archaic Period sites after 10,000 14C BP on the coastal plain, were most probably small, highly mobile populations (Griffin, 1952:354–355; Anderson and Hanson, 1988; Anderson and Sassaman, 1996). The most inclusive Early Archaic settlement model is commonly referred to as the Band–Macroband model (Anderson and Hanson, 1988) wherein macro-bands organized their territories along major watersheds, dispersing during the winter, traveling to the coast during the spring, following the rivers back to the upper coastal plain during summer. Alternate models have proposed that watersheds had permeable boundaries and that bands crossed them routinely using other water sources such as ox bow lakes and Carolina bays on the coastal plain (Daniel, 2001). Models of coastal Archaic sites diverge from those of the interior and riverine settings (Thompson and Turck, *supra*; Turck, 2012), being concentrated on the back sides of barrier islands in close proximity to diverse and highly productive ecological zones such as tidal marshes and maritime forests, but these observations are based on Late Archaic examples and it is currently unclear how well these models predict earlier coastal adaptations before 4500 BP.

The Middle Archaic period is even more poorly understood, at least in the Georgia Coastal Plain (Kirkland, 1994). For the Middle Archaic Period, some researchers postulate a general depopulation of the area (Faught and Waggoner, 2012; Thomas et al., 2010; Turck, 2012). Others argue that Middle Archaic projectile points have yet to be identified in the region (Elliott and Sassaman, 1995:26–38). It is likely that patterns of social relationships changed even in areas not characterized by intensive occupations, especially if Middle Archaic settlement expanded into new areas. The period is characterized by increasing territorial circumscription, even as evidence for continued high mobility remains (Saunders and Russo, 2011; Custer, 1990:36). Some workers have argued there is a discernible growth in population (Peros et al., 2010:663), with a parallel decrease in population ranges (Sassaman, 2010). Exploitation of aquatic resources clearly is ongoing during this period, not only inland, but along the coastlines as well; submerged shell middens from this period have been documented in Apalachee Bay, Florida (Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b).It has also been argued that this period sees the beginning of sedentary occupations along the coastline, if not actual sedentism itself (Bailey, 2014; Bailey and Flemming, 2008; Faught and Donoghue, 1997; Faught, 2004a, 2004b; Faught and Gusick, 2011). Regionally, shellfishing was a critical component of subsistence strategies practiced during this period, and long range trade patterns can be easily detected even as the first examples of monumental architecture make an appearance on the continent of North America in the form of large shell mounds, shell rings, and earthworks as Poverty Point, that reflect, at least in part, intentional, ritual behaviors. (Delcourt and Delcourt, 2004; Mikell and Saunders, 2007; Russo, 1994; Sassaman, 2004, 2010; Saunders and Russo, 2011; Thomas et al., 2008; Turck, 2010, 2012; Williams, 1994, 2000). A Middle Archaic pattern of subsistence dependent on shellfish should be visible in submerged sites from this period, and the lack of coastal Middle Archaic on modern Georgia coastline strongly suggests that the sites lie offshore. This has already been demonstrated to be the case in the Big Bend (Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b).

By the Late Archaic (5000 BP to 3000), sea levels had transgressed Gray's Reef (cf. Fig. 2) and that latter period is beyond the scope of inquiry of this study.

3.1. Methods in underwater prehistoric site detection and excavation

The earliest approaches to detection of submerged sites in drowned portions of the continental shelf of North America employed seismic data gathered by oil and gas companies in the Gulf of Mexico. Researchers examined them for features such as Pleistocene river terraces buried by Holocene estuarine sediments. Cores were taken from identified targets and examined for geochemical and/or sedimentological markers for human activities such as charcoal, bone, burnt shell, and lithic debitage, and elevated Mn, Zn, and inorganic phosphate (Gagliano et al., 1982; Pearson et al., 1989; Stright, 1986a, 1986b, 1990, 1995; Stright et al., 2003). In Europe, seismic data have also been used in a larger scale, regional landscape reconstruction of so-called Doggerland, now submerged within the southern North Sea (Fitch et al., 2005; Gaffney et al., 2007). Models predicated on sea level position in tandem with regional hydrology and locations of lithic resources have been employed successfully in the Big Bend of Florida (Dunbar et al., 1989; Anuskiewicz and Dunbar, 1993; Faught, 2004a, 2004b). Recently, the use of less expensive "fish finder" type sonar equipment has been deployed in the Gulf of California to map general bathymetry and more detailed targets such as possible rock shelter sites and shell midden deposits (Faught and Gusick, 2011). Benjamin proposes a generalized methodology for underwater research, known as the "Danish Model" (Benjamin, 2010, 2012). It is extremely effective, with over a 80% success rate in locating underwater sites in Denmark where it was developed (Benjamin, 2010, p. 258, citing Fischer, 1995, 2011).

The Georgia Bight survey sites were selected based on their proximity to potential paleochannels and hard bottom outcrops capable of trapping lag sediments and thus any entrained artifacts. The fieldwork component of this study focused on diver survey and recovery of sediment cores, and did not deploy heavier excavation equipment such as dredges. Instead, divers were deployed at each of the surveyed sites, where visual survey, hand fanned test pits, and surface collections were gathered to characterize the sediments, fossil assemblages, and artifacts. The locations of collected items were plotted using Cartesian coordinates centered on a local datum point that is in turn tied established at the site's central GPS coordinates. Measuring tapes suitable for use in salt water environments were brought to the datum and extended out along compass coordinates; when an artifact or fossil item was located, it's spatial relationship to the closest tape was recorded. For example, a sub-fossil bone fragment might be recovered 7.2 m (23 ft) from the datum, along an eastern bearing transect. The fossil's position relative to the tape – how far it was located from the tape, and in which direction, north or south – was recorded, along with the distance from the datum. So, a hypothetical artifact would be noted as having been collected 7 m east of the datum, and 1 m north of the tape.

3.2. Geology and the site locations

Gray's Reef lies within a National Marine Sanctuary of 59 km^2 centered at 31° 23′ 30″, 80° 52′ 30″ (Fig. 1). It is located 32 km offshore of Sapelo Island, Georgia, and is composed of low relief (1–2 m) siliciclastic sandstones of Pliocene age (Huddlestun, 1988; Harding and Henry, 1994) that are exposed in the form of "live bottom" or "hard bottom" reef ledges. These ledges are very different from sub-tropical and tropical reefs in that they are not composed of live coral, but of rock outcrops upon which invertebrate organisms construct their niches. The depth averages about 16 to 19 m, making the area very accessible for diver survey using either regular air mixtures or NITROX mixtures (breathing gas mixtures that contain higher than normal percentages of oxygen to reduce the risk of decompression sickness). The marine sanctuary has been surveyed at high (<2 m) resolution using side scan sonar and videography to map the different sediment types and habitations (Fig. 5). These are partitioned into flat sand, rippled sand, sparsely colonized hard bottom outcrops, and densely colonized hard bottom outcrops. All of the survey locations are located near hard bottom outcrop ledges.

4. Sedimentology

Sediment cores were recovered from both Gray's Reef and nearby JY Reef in order to characterize the depositional histories of the site locations. All but Core 1B from the northeastern portion of the sanctuary have been discussed in other publications (e.g., Garrison et al., 2008, 2012a, 2012b) and so here we will confine our study to Core 1B only.

4.1. Core 1B from GRNMS

Core 1B from Gray's Reef was analyzed for grain size in 10 cm increments (Fig. 6). No bedding surfaces were observed. Particle size analysis was performed to characterize each section of the core by grain size as well as sediment sorting. Sorting is gauged by calculating the standard deviation of the sediments, while skew and kurtosis offer insight into the range of average sediment size. The results below show that these sediments are well sorted to very well sorted, skewed towards fine to very fine, with a very leptokurtic kurtosis, supporting the characterization that these sediments are well sorted to very well sorted. Total particle size distribution shows that the majority of the core is dominated by 2ϕ, or fine sand until the last 20 cm or so of the core, at which point the very fine sand becomes the dominant component. See Fig. 7

Three dates were taken from the core: One date of 43,770 ± 470 BP from 160 to 170 cm down, and two dates of 39,265 ± 5692, 37,481 ± 372 from 210 to 220 cm. The anomalously younger date from lower in the core is most likely a result of bioturbation caused by the obvious *krotovinas* observed in the core. The "Brown sand" component of the core dating to older than 43,770 ± 470 BP is thought to represent a back barrier environment where finer grained sediments can be deposited (Leporte, 1976; Garrison et al., 2008:137), while the shell-enriched sediments denoted as "shelly sand" are more typical for shoreface environments This characterization of the "brown sand" sediments is supported by the recovery of an Atlantic gray whale mandible recovered from similarly aged, poorly lithified rock at JY Reef (Noakes et al., 2009). The shell enriched sediments overlying this find appear to be deflated and reworked lag deposits dating from the Late Pleistocene into the Middle Holocene.

The pattern of dates obtained from material from Gray's Reef displays a prominent gap between dates that are late MIS 3/early MIS

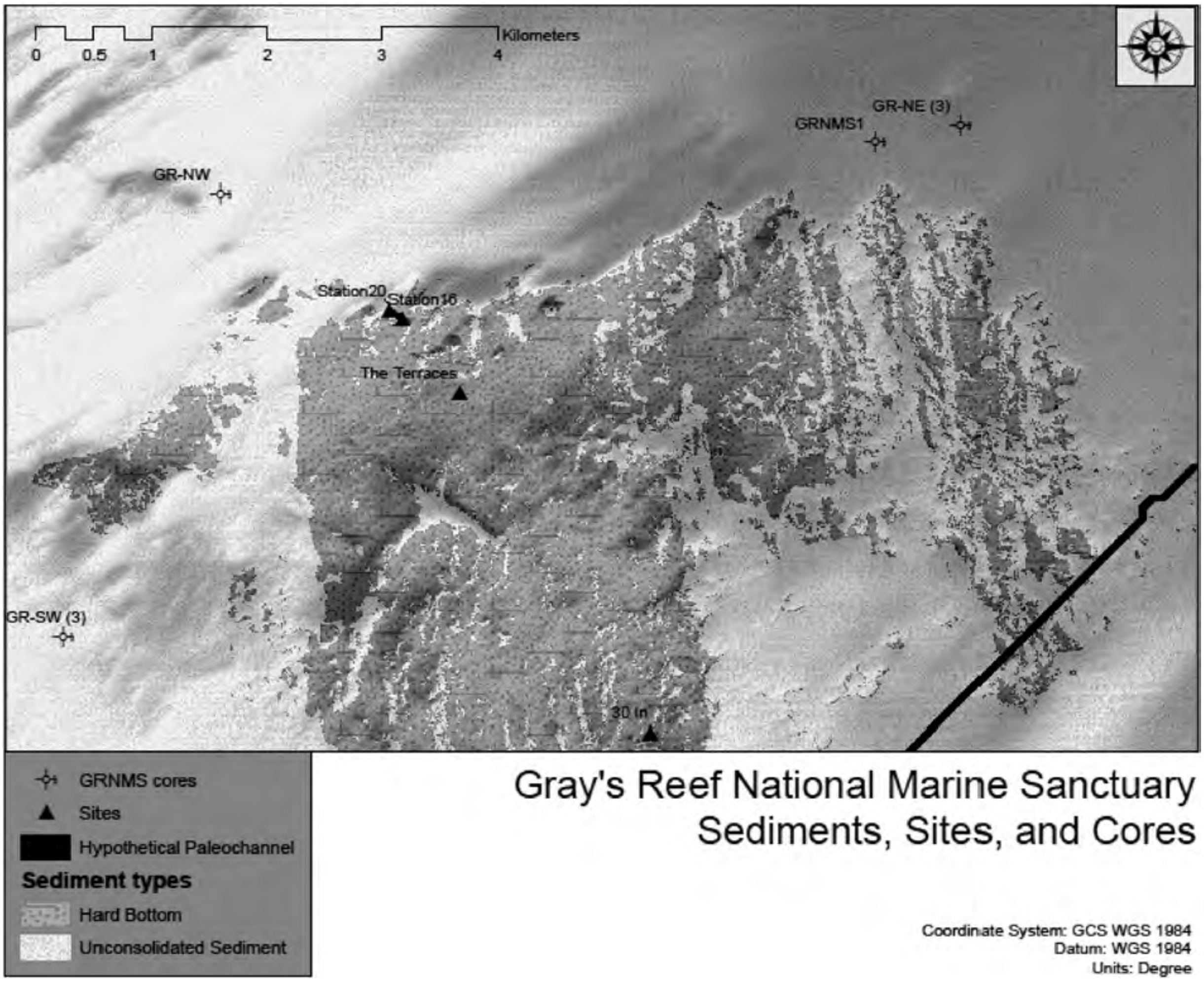


Fig. 5. Map of Gray's Reef showing sites (triangles), coring locations (stars) and bottom types.

2, to mid-Holocene (Garrison et al., 2008, Table 4 this report's Appendix). Several cores from St. Catherine's Island along the Georgia Coast have confirmed an erosional unconformity between mid-Holocene depositional sequences and lower-lying sequences of peat that are "dead carbon" in age; that is to say, older than radiocarbon methods, even AMS, can detect (Booth et al., 1999:84). This is also consistent with the rest of the coastal plain, where dates from the Sandy Run creek south of Macon, Georgia, in the central coastal plain reveal an erosional unconformity between 25,000 and 13,000 BP (LaMoreaux et al., 2009:310). Further north, Mallinson et al. (2008) obtained OSL dates from the North Carolina barrier system that displayed a similar cessation in deposition, similar to the lacuna in dates for MIS 2 and the early Holocene along the Georgia Bight paleo-coastlines (Mallinson et al. (2008):104).

While a few faunal remains date to the early and Middle Holocene, as well as MIS 2, at Gray's Reef, the sediments overwhelmingly date to MIS 3. A basic review of sequence stratigraphic principles for flooding surfaces further explains the lag deposits' characteristics at Gray's Reef. As noted by Scarponi et al. (2013), one of the primary means by which a transgressive tract system can be recognized is by the amount of condensation within the resulting section. As sea level transgresses, the erosion of deposited sediments deflates the sequences deposited during the low stand prior to the transgression. This results in a highly condensed section due to the loss of sediments, particularly the finer silt and clay fraction. This results in time compression and time averaging for the sediments that are left. If we look at the characteristics of the sediment at Gray's Reef itself, we can see that this indeed is a highly condensed section that, just as Scarponi, et al., predict, contains a heightened density of fossil remains (Scarponi et al., 2013: 239). The implications for archeological materials are clear: in situ deposits are extremely unlikely, and artifacts from any of the three potential cultural periods are likely to be co-mingled. In order to identify occupations by different cultural groups, materials will either have to be directly datable using radiometric dating techniques, or they will have to be diagnostic in morphology.

5. Paleontology

Table 1 summarizes all of the paleontological and organic materials recovered during the surveys (cf. Fig. 7). Only number of individual specimens (NISP) is given due to the highly fragmentary condition of much of the assemblage, and all interpretations are highly conservative in nature due to the comparatively poor preservation of identifiable faunal remains.

5.1. JY Reef and the scour nuclei associated with the A.B. Daniel wreck

JY Reef is a coquina deposit in excess of 2 m thickness dominated by valves of the sea scallop, *Placopecten magellanicus*. Embedded the coquina sediments and in lag deposits are extensive terrestrial faunal remains, both fossilized and sub-fossil. Much of what was collected was unidentifiable (UID) but large mammalian long bones, including ribs and possible femur/fibia/tibulae were recovered. The largest find to date has been a nearly complete dentary of the extinct Atlantic gray

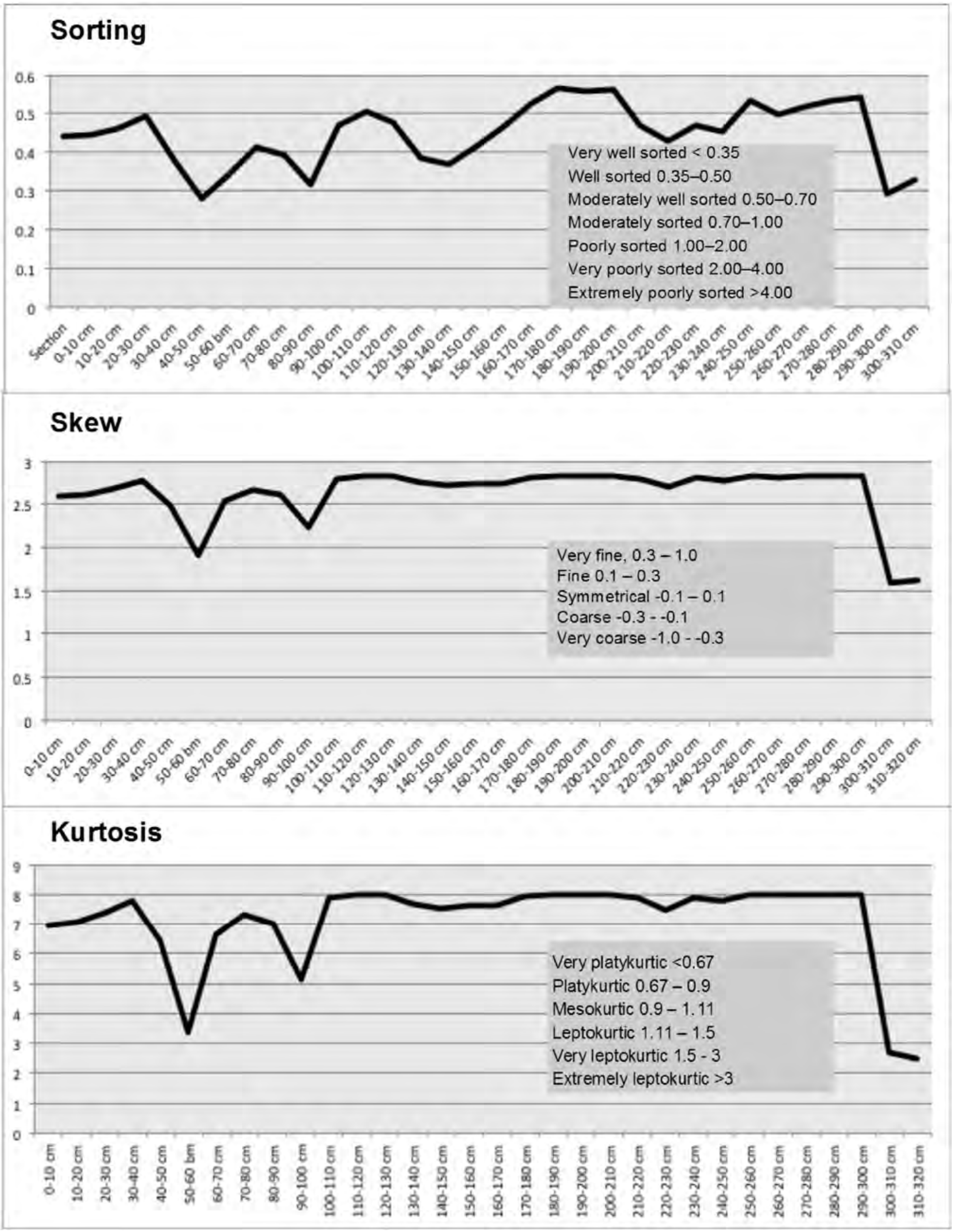


Fig. 6. Core B, GRNMS. Particle size analysis includes sorting to calculate the standard deviation of the sediment sizes and skew and kurtosis to assess the range of average sediment sizes. Core B illustrates the contact at −170 cm and contrast in sediments of the upper Raysor Shelly-Sand member of the Satilla Formation (Huddlestun, 1988) and that of the lower provisionally named "Brown Sand" member.

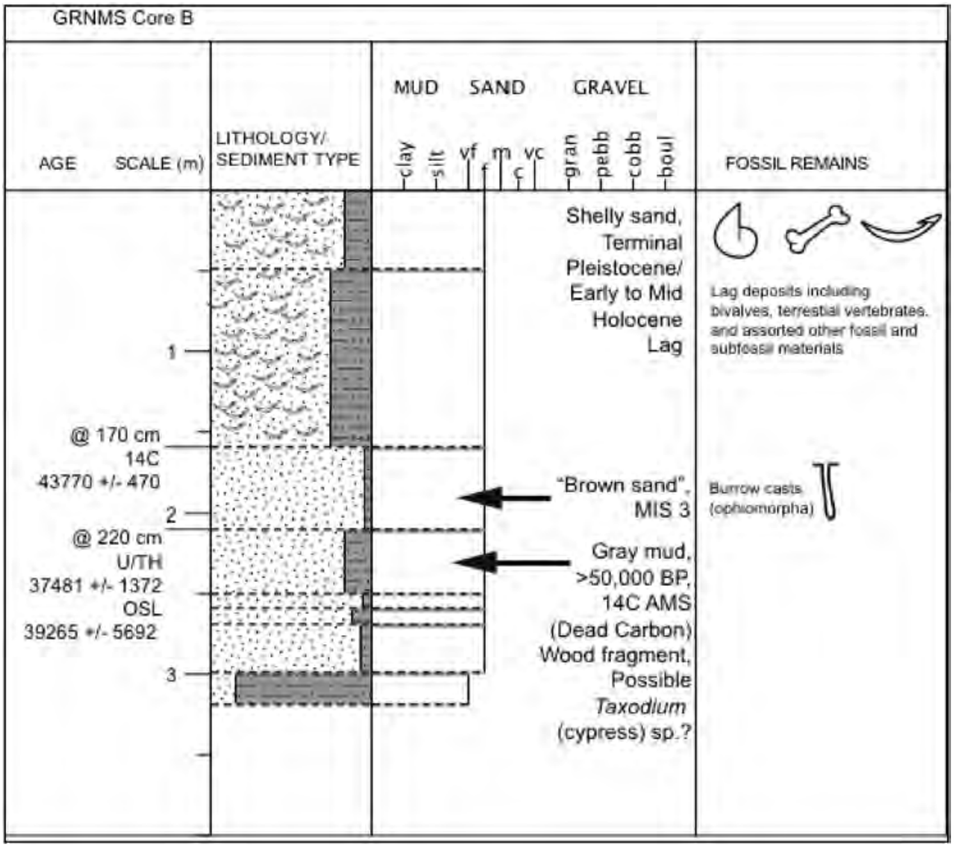


Fig. 6 (*continued*).

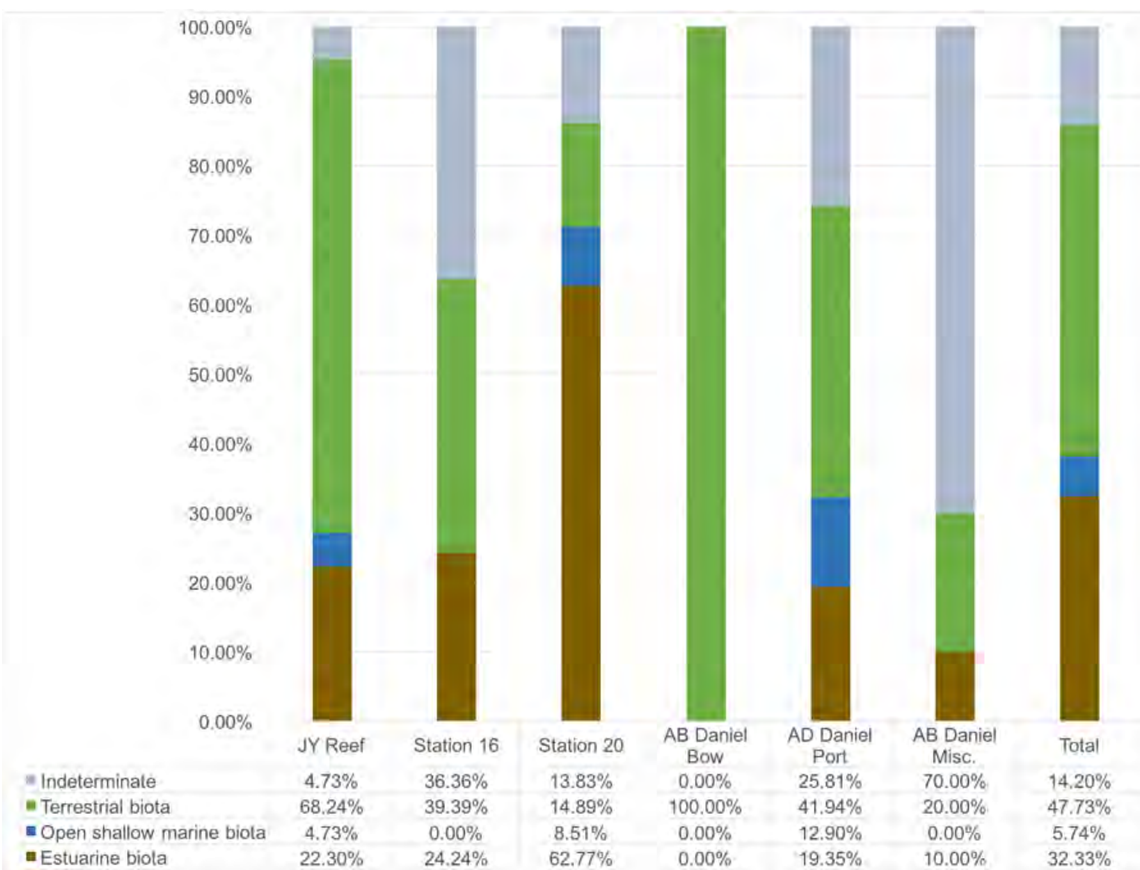


Fig. 7. Percentages of taxa in the paleontological and organic assemblages calculated for Table 1.

Table 1
Summary of all of the paleontological and organic materials recovered. Number of individual specimens (NISP) is given due to the highly fragmentary condition of much of the assemblages.

Taxon	JY Reef	Station 16	Station 20	AB Daniel Bow	AD Daniel Port	AB Daniel Misc.
Oyster NISP	1	5	37	0	0	0
Scallop NISP	7	0	8	0	4	0
Clam	1	0	8	0	0	0
Bone NISP	80	9	3	11	10	1
Wood NISP	15	3	11	1	3	1
Fossil	5	7	11	0	0	0
UID NISP	2	5	2	0	8	7
Ophiomorpha NISP	31	3	14	0	6	1
Tooth NISP	4	0	0	1	0	0
Horn NISP	2	1	0	2	0	0
All items	148	33	94	15	31	10

whale, *Eschrichtius robustus* (Noakes et al., 2009, 2013; Garrison et al., 2012b). 15 samples of wood were also collected at JY Reef, suggesting the potential for better preservation of organic materials than at other survey sites in this study.

The artificial reef emplacement of the Liberty Ship A.B. Daniel has developed several scour nuclei that expose the stratigraphy near JY Reef, as well as ample fossil materials. Most of what has been collected at the three logged survey locations at the bow, the port side, and at randomized collection points is dominated by bone, teeth, and horn remains, suggesting that terrestrial fossils constitute the bulk of the assemblage here. This is consistent with the materials collected at JY Reef.

5.2. GRNMS — Station 16 and Station 20

The invertebrate faunal assemblage from Station 20 is dominated by estuarine/shallow marine taxa such *Crassostrea* (oyster) and *Mercenaria* (surf clam) (Table 1; Fig. 7). Shell remains varied from entire disarticulated valves, to fragments and no valves were found still articulated. All of the finds are allogenic, that is to say, transported to their find spots from other locations. It is important to note the different natures of the invertebrate assemblages at the Gray's Reef and JY Reef. At JY Reef the sea scallop, a marine species, predominates whereas at Gray's Reef Station 20 the allogenic materials are estuarine taxa with some nearshore taxa.

The assemblage from Station 16, however, contains fewer estuarine species and more bone, as well as one horn item (Station 20 has 53 total items from estuarine contexts, while 16 has 5) (Table 1; Fig. 7). This is an intriguing finding given their extremely close proximity to one another; Station 16 is less than 150 m from 20. This finding calls for additional investigation in future studies, as it is suggestive that forces beyond those that create time transgressive, deflated deposits, could be in play.

Both suites of invertebrates provide crucial paleoenvironmental information for the Late Pleistocene to mid-Holocene Georgia Bight. *Crassostrea* – oysters – live at depths ranging from the intertidal zone to ranging from 0 to −12 m below sea level, with an average depth of 0 to −4 m in the Gulf of Mexico, and 0 to −8 m in Chesapeake Bay (NOAA Fisheries Eastern Oyster Biological Review Team, 2007). Once included in fine-grained sediments, oyster shells have a good chance of becoming preserved, especially if they are thick and consist of calcite rather than aragonite, and are thus particularly durable. Because of their local abundance, sizable shell accumulations of considerable extent occur in intertidal and shallow subtidal realms, usually in the vicinity of major tidal inlets. The accumulations, which form lenticular bodies of varying lateral extent, are interbedded with detrital sediments. Oyster beds of Late Pleistocene and mid-Tertiary ages in Georgia are similar to the recent ones (Weideman, 1972). Assuming that RSL is consistent with the Gulf Coast curves (a problematic assumption at best), then given the current depth of ~−18 m below sea level for Station 20, we arrive at a terminus post quem for the oyster deposits when the shoreline was −6 m below its present position. This occurred in the Gulf of Mexico between 8000 and 5000 BP, making many of these oysters Middle Holocene/Middle Archaic age at the youngest.

By contrast, the modern range for the sea scallop is temperature dependent with no shallow water beds appearing south of Cape Hatteras, North Carolina. Direct dates of the sea scallops and the sediments and inclusions of the coquina (Table 3, Appendix) place the death assemblage fully within Marine Isotope Stage (MIS) 3 or 59–24 ka (Garrison

Fig. 8. Representative vertebrate fossil/subfossil finds at Gray's Reef and JY Reef. Upper left, a fossil long bone/rib fragment (*Mammuthus*?), scale bar is 20 mm; upper right, a cast of the bison metapodial, scale bar is 20 mm; lower left, molar, *Mammuthus*, no scale; lower right, subfossil mandible, Atlantic gray whale, scale bar is 20 cm.

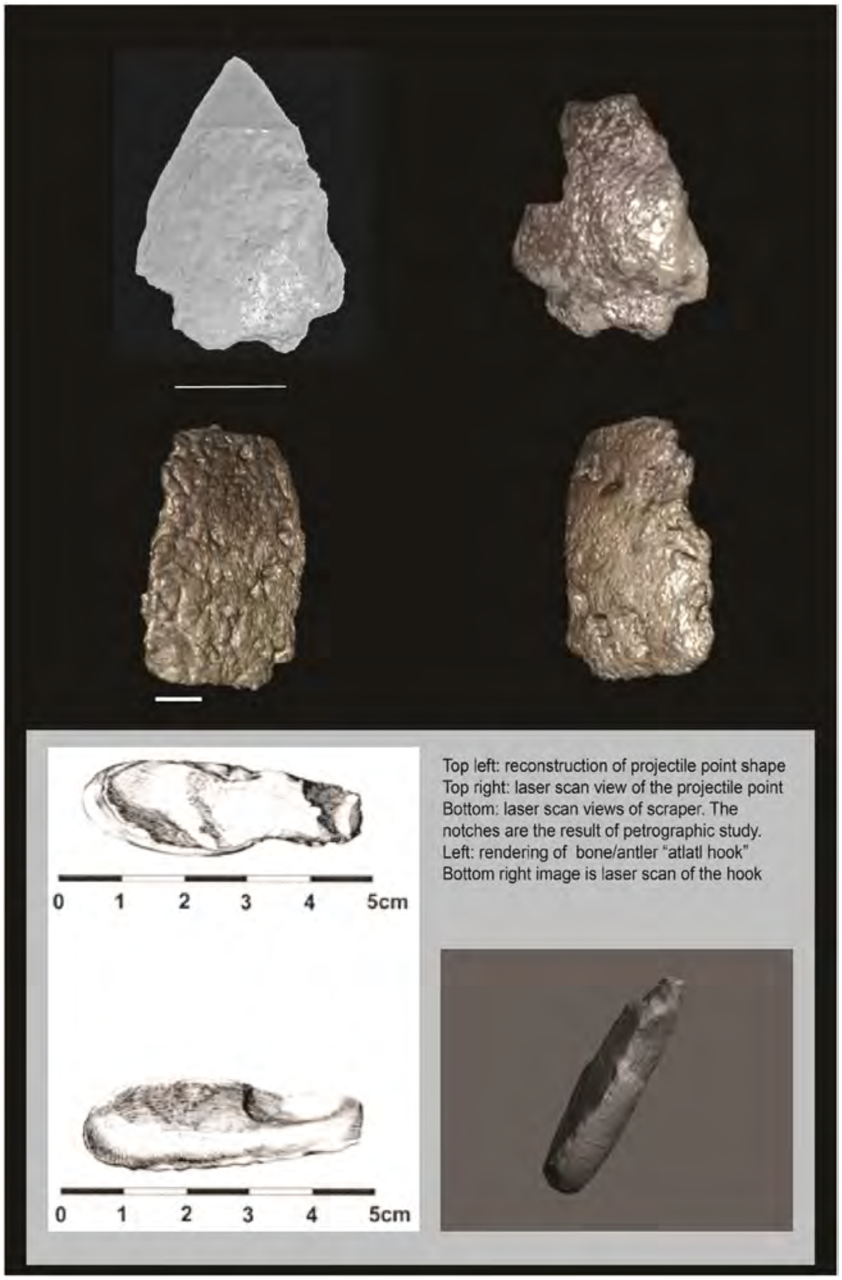


Fig. 9. Laser scans of Gray's Reef artifacts. Scale bars for projectile point and scraper are 10 mm respectively. Laser scans furnished by the Laboratory of Archeology, University of Georgia.

et al., 2008, 2012a). The coquina has been identified at Gray's Reef but in a thin (<1 m) and highly eroded state. Scallop valves at Gray's Reef are highly pyritized indicating burial in anaerobic, sulfur-rich sediments, which are most typical for back barrier tidal marshes along the present day Georgia coast. This is consistent with a marine transgression sequence, with open marine shoreface conditions shallowing upward to tidal marsh. The shoreline only moved seaward towards the shelf break after MIS 3, and the pyritization of the scallop valves at Gray's Reef is thus most likely to have occurred during the Early to Middle Holocene when transgression overtopped these deposits.

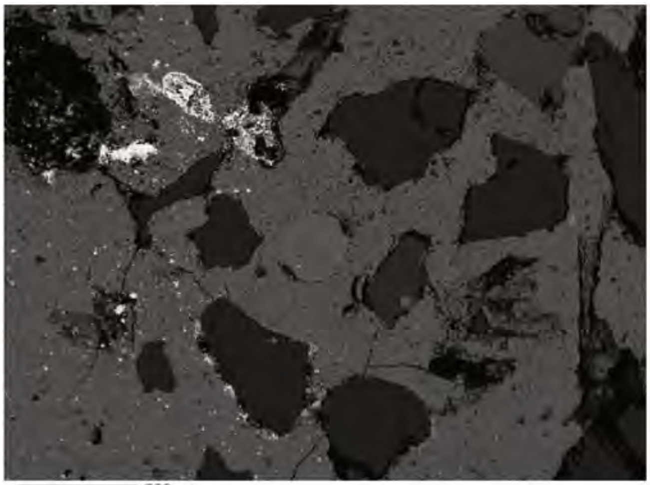
The vertebrate assemblage at Gray's Reef resembles that of JY Reef in species richness and diversity. Both assemblages include fragmentary remains of terrestrial and marine taxa in varying proportions to one another. While fewer in overall number than JY Reef, the number of finds at Gray's Reef exceeds one hundred individual fossil and subfossil bone. Gray's Reef provides the only directly dated faunal material, a *B. bison* metapodial (Fig. 8), whose AMS-radiocarbon age of 6090 ± 60 years BP. Other terrestrial mammals identified in the assemblage include Pleistocene horse; camel; as well as deer/antelope.

6. Archeology

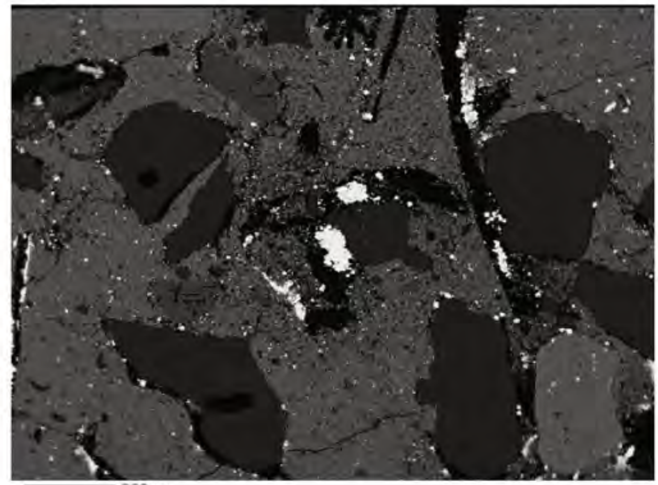
6.1. Tools from GRNMS: basic descriptions and hand sample analysis

All items were recovered during diver surveys executed between 1997 and 2010. Surveys were conducted by diving on study locations identified using GPS coordinates; during each dive, a bearing was taken from the datum point and a tape was extended along each directional heading. Dive personnel swam along each transect, performing hand fanning tests, which function similarly to shovel testing in terrestrial contexts.

The subfossil bone/antler artifact was found in a shallow excavation. The excavation unit was 8 m, 130° southeast of a reference station (#16), established by NOAA, for research at the Sanctuary (Fig. 9). The

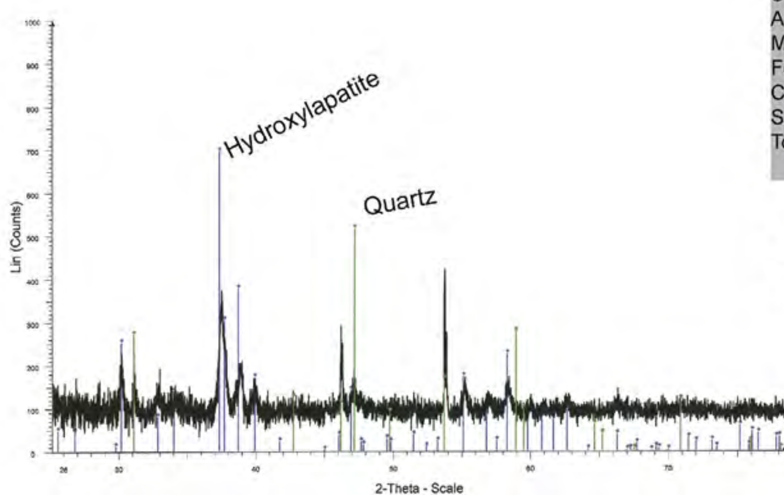


Projectile point. At this magnification, the quartz grains can be seen to have a low density. The strange round mark in the middle was thought to be the cross-section of an intrusion of a worm or gastropod. One of the many potassium feldspar inclusions can be seen in the top right.



Though this shows projectile point's matrix's compositional nature, a secondary electron image exposes the darkest lines and regions as morphological features (most clearly evident at the cleft in the top right). The white spot in the middle of the image was revealed to be pyrite.

Stochiometric Formula	Matrix (%)	Pyrite Inclusion(%)
SiO2	1.072	
Al2O3	1.064	
MgO	0.4487	
FeO	0.7388	44.22
CaO	31.41	
S		51.21
Total	50.68	94.43



XRD analysis showed peaks for hydroxylapatite (blue peaks) and quartz (green peaks). Hydroxylapatite is a major mineral component of bone and teeth. The quartz can easily be seen in the micrite matrix shown in SEM analysis.

Fig. 10. Summary data, SEM/EDS and XRD for the projectile point.

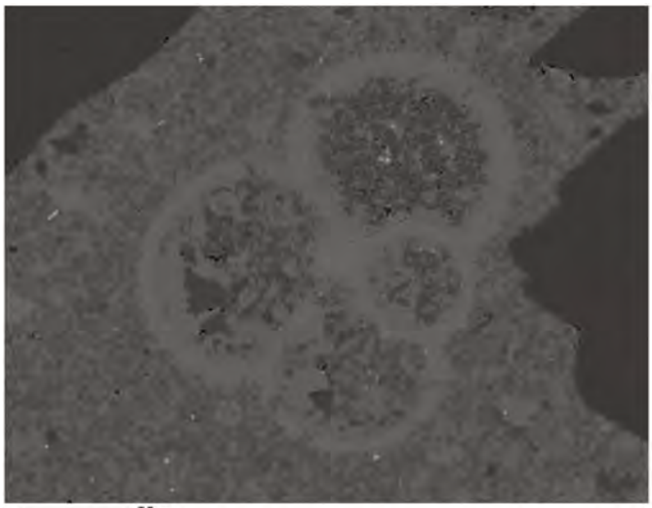
second artifact, a stone projectile point (Fig. 9) was found by a survey team at 34 m south (210°) of reference Station 20. They were within 100 m of each other along the reef's outcrop. The flake scraper was the last to be found during surveys carried out in 2009, in a different locale, in the Sanctuary, known as the "Terraces". This area has a relief of over 4 m and, as the name implies, consists of a series of three outcrops sequentially higher than the next. The upper terrace or ledge is 16 m from the second or middle terrace and over 40 m separates the middle and lower ledges. Both lithic items have obviously experienced extensive abrasion and rounding, due to marine processes, destroying any original flaking or usage scars (Fig. 9).

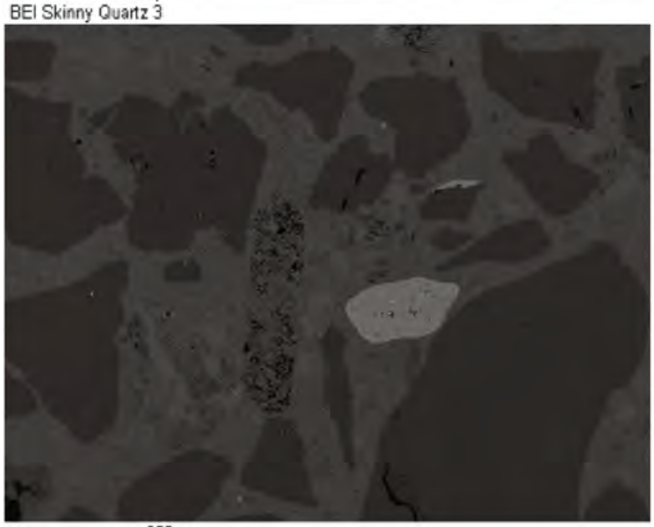
The bone/antler artifact shown in Fig. 9 measures 43 mm in overall length and has a maximum diameter of 14 mm. One end of the find is beveled while the other is rounded. The beveled end shows more tapering than the other, which is more rounded. The rounded end is the base. The tapered or distal end was prepared in such a way that suggests human modification. While the artifact is heavily mineralized, this appears to the result of diagenesis, after burial in sediments such as anaerobic muds; this would allow crystalline mineral substitution into the collagen matrix. The black coloration suggests pyritization in a sulfate-rich, oxygen-poor environment enriched in organic materials (Billon et al., 2002). No bioencrustation was observed on the item, however, arguing against direct marine deposition. Anoxic muds are typical of estuaries and marshes and it is reasonable to assume Gray's Reef experienced estuarine conditions during the last sea level (RSL) cycle. Taken together, all of these characteristics suggest that this artifact was deposited in a marsh or estuarine environment.

Classification of the bone/antler fragment as a tool was based on the step-like fracture on its tip as well as the basal rounding. Neither of these attributes is typical of natural antler or antler fragments "cast" or shed by animals. Similarly worked bone items have been found in both Paleo-Indian and Archaic Period assemblages and have been identified as atlatl "hooks" (Bradley et al., 2010).

6.2. Petrographic analyses

In 2010, optical and petrographic instrumental analyses were begun in an attempt to assess the artifacts at a microscopic scale. This was





Top two images show what appear to be infilled foraminifera tests. Bottom left image shows subangular quartz grains with a single pyrite grain in a calcium carbonate matrix. WDS data also who the presence of phosphate.

Stochiometric Formula	Matrix (%)
P_2O_5	13.38
CaO	36.92
NA_2O	0.8061
Cl	0.579
F	4.19
O	31.29
Total	87.39

!

XRD analysis confirms the presence of quartz grains, calcium carbonate matrix, and the presence of pyrite, which overlaps with ankerite, a carbonate within which Fe replaces Mg.

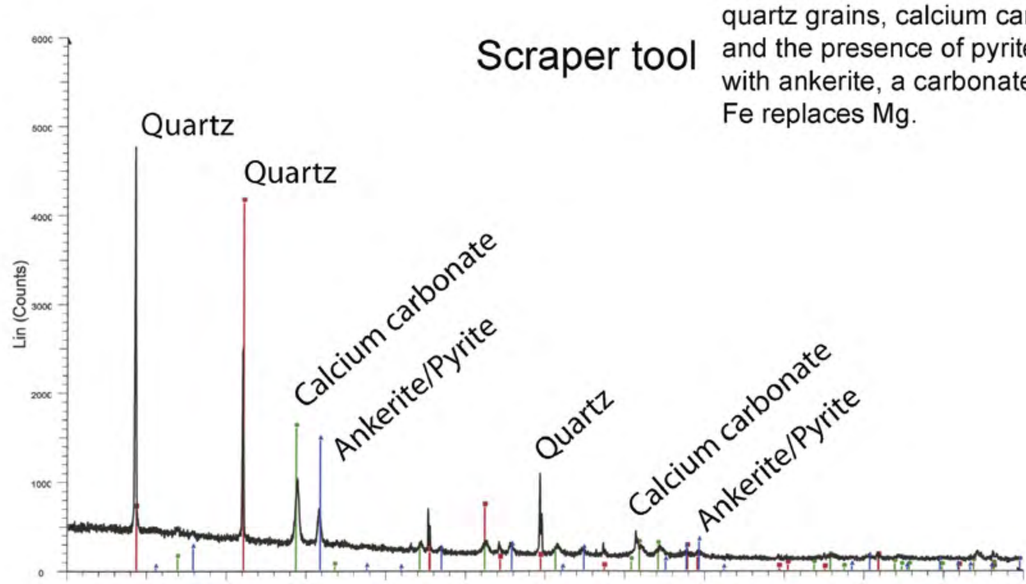


Fig. 11. Summary data, SEM/EDS and XRD for the flake scraper.

done to better elucidate their compositions and to compare them to non-artifact rock samples from their find spot locations. These techniques elucidate an artifact's composition as well as the taphonomic changes it has undergone after deposition. Composition is the key to separating putative artifacts from the natural rock formations at their find spots and is one critical line of evidence to establish transport by humans from a different location. Taphonomic changes are usually detected by identifying areas within the artifact that have undergone re-mineralization or transformation of some sort from its original composition. Utilizing these techniques, we can determine qualitative assessments of the samples' mineralogical composition as well as quantitative measures of geochemical composition within the samples.

Optical petrography was done first to initially characterize polished thin sections of the materials of the artifacts as well as potential tool stone resources. The thin sections were examined with an Olympus B-20 petrographic research microscope equipped with both transmitted/reflected polarized and Nomarski Differential phase contrast optics. The thin sections were first scanned with the 10X objective in plane polarized light (PPL). Then, selected areas on the thin section were examined using cross polarized light (XPL). Photomicrographs were taken with a digital camera equipped with a ScopeTronix ocular adapter.

After optical methods were performed, samples were prepared for SEM/EDS analysis at the Georgia Electron Microscopy Center (GEM) at the University of Georgia (UGA) and electron microprobe analysis (EMPA) at the University of Georgia Geology Department. The Leica 1750 SEM/EDS at GEM consists of a sample chamber pumped down to about 10–3 mbar ($9.87 \times 10–7$ atm) to prevent atmospheric backscatter noise, with the electron beam and detector situated above. Representative SEM images were taken, and areas of interested were scanned with the EDS. The EDS system was an Oxford Instruments Field Emission-SEM (FE-SEM) system, equipped w/both electron backscatter detectors (EBSDs) and EDS capability.

A JEOL 8600 scanning electron microprobe (EMPA) is one of the UGA Department of Geology's cornerstone analytical instruments. The electron microprobe, in comparison to the SEM-EDS systems, uses a finely focused beam of high-energy electrons, typically 1–2 μm in diameter, to excite a small volume of material (1–10 μm^3). The interaction of the electron beam with the atoms in the excited volume generates secondary and backscattered electrons used to image the sample, and characteristic X-rays measured to produce high precision, accurate quantitative analyses of the sample. Secondary electrons ejected from the surface atoms and backscattered electrons scattered out of the sample, reveal fine scale morphologic feature and compositional variation among the different constituents of the sample together with fine scale compositional zoning within individual mineral grains. The energy dispersive (EDS) X-ray detector detects a wide portion of the X-ray spectrum (Na–U) simultaneously, providing virtually instantaneous determination of elements present in the sample and rapid identification of the mineralogical phases present. Four wavelength dispersive (WDS) X-ray detectors were used to analyze elements ranging from F–U, and elements as light as B. Under ideal conditions, element concentrations as low as 100 ppm could be measured. EMPA is more reliable than SEM-EDS in making accurate quantification of minor and trace elements (Holton, 2012).

Finally, X-ray diffraction (XRD) was done in order to provide additional data on the mineralogical analysis of the samples. The XRD system used in this study is a Bruker D8-Advance at the University of Georgia Geology Department. This X-ray diffractometer is a versatile tool for phase and structural analysis of powders, analysis of liquid samples (capillary and transmission modes) and reflectometry of thin layers. The system includes: (a) Vertical Theta–Theta Goniometer control with stepper motors and optical encoders providing smallest selectable stepsize; (b) a short ceramic Cu X-ray tube with fine long focus; (c) two exchangeable detectors of scattered X-rays: NaI scintillator type detector with low background (0.4 cps) and high dynamic range (up to 2×106) together with a Braun position-sensitive detector; (d) rotation–transmission, capillary and reflectometry stages.

The instrument is equipped with a wide range of crystallographic software for pattern simulations (NEWMOD, CrystalDiffract, and Wildfire), cell refinements (Rietveld refinement), crystal structure presentation (CrystalMaker), and the ICDD PDF-2 data base. The raw diffractograms were processed using the DIFFRACplus EVA software by Bruker AXS. The $K\alpha 2$ peaks and background noise were stripped and threshold sensitivity adjusted prior to performing a peak search to identify the major peaks in the diffractogram. Any significant peaks missed by the automated peak search were manually selected and added to the diffractogram record. Finally, potential mineral matches for each peak were identified with a general search option within the EVA software. Suspected minerals not included by the automated search were checked by conducting manual EVA searches for individual minerals. Peak intensity, 2θ, and d-spacing were used to identify the most likely mineral(s) responsible for each peak. The 2θ and d-spacing of suspected mineral matches were then compared to known index values, and thereby verified or disqualified as a match, using Powder Diffraction Database Search software by Scintag, Inc.

7. Results

7.1. Projectile point

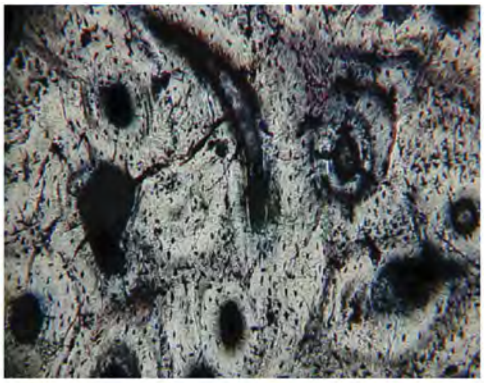
The projectile point sample contained nearly pure quartz grains throughout its matrix; the grains were angular to subangular and equally spaced throughout the rock as shown in thin section (Fig. 10). This sample contained potassium feldspar and pyrite, in small quantities as well. The entirety of the sample was bereft of fossils. Several WDS measurements of the matrix accounted for only roughly half of the weight (Table inset in Fig. 10). The subsequent conclusion was that the matrix was composed of $CaCO_3$ in micrite form (i.e., grain sizes smaller than 4 μm). The sample also contained abundant hydroxylapatite, an unexpected finding. The hydroxylapatite was extremely prominent in XRD analysis.

7.2. Flake scraper

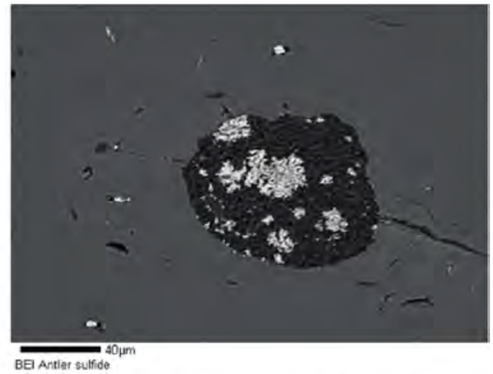
The quartz grains within the flake scraper were high density and subangular. Interspersed between these grains were inclusions of higher density (brighter on the backscatter images) that were determined to be apatite (Fig. 11). SEM analyses revealed that the tool was nearly devoid of potassium feldspar, and a superficial glance using the WDS configured for aluminum revealed no obvious potassium feldspar ($KAlSi_3O_8$) inclusions; a closer inspection of the entirety of the sample revealed that there were a mere two granules present in the entire surface of the sample. Ankerite was detected by XRD but the spectrum overlaps with pyrite, making secure identification of either element problematic. Ankerite is a carbonate containing iron, while pyrite, is composed of iron and sulfur. The matrix seemed to be primarily composed of micrite, though a small amount of MgO was present. Like the previous sample, the matrix analysis yielded very low totals: 55.86% in this case. Several microfossils were visible in the cross-section. They are characteristics for the phylum Foraminifera.

7.3. Bone/antler "Atlatl Hook"

The bone/antler artifact's thin section images (Fig. 12) show clear evidence of osteon structures confirming that it is composed of bone or antler. Mineralogically the tool contained distinct inclusions of quartz and pyrite in addition to apatite. The initial WDS data gathered from this item yielded high amounts of P2O5, CaO, F, and O in the matrix along with other trace elements. These elements are members of apatite, and are also consistent with bone or antler.



Thin section, 150 X, showing infilled osteon structures.



A backscatter electron image of pyrite infill of an osteon. The pyrite - mineralogically marcastite - is the small, white, snowflake-shaped portions of the darker inclusion.

Stochiometric Formula	Matrix %	Infill %
SiO2		15.19
P2O5	17.89	
TiO2		0.8417
Al2O3		9.53
MgO		1.7253
FeO		24.71
CaO	37.88	
K2O		8.53
Na2O		0.1179
Ba		0.0417
Cl	0.4787	1.219
F	3.33	
O	36.71	36.09
Total	96.28	97.9

Fig. 12. Summary data, micrographic and SEM/EDS for the atlatl hook.

8. Characterization of possible source rock

8.1. Gray's Reef overview

The rock of Gray's Reef has been extensively characterized, in thin section, by Hunt (1974) and, again, by Harding and Henry (1994). This study has only confirmed those studies findings though it has added additional spectroscopic data, rendering further details concerning the composition of the reef rock. Harding and Henry (1994) presented petrological findings from hand samples collected in 1987 (4 samples) and another set of 9 hand samples taken by Georgia Department of Natural Resources (DNR) divers. The 1987 samples were from outcrops in the southern and southwestern areas of Gray's Reef National Marine Sanctuary while the DNR samples were concentrated in the northeast, northwest and southwest portions of the sanctuary. By comparison, our samples were collected in the northwest of the sanctuary (cf. Fig. 5).

Harding and Henry (1994) characterized the rocks in their study as slight-to-compact in terms of cementation and induration. They described the lithology as a calcareous dolomitic sandstone. Hunt (1974) differed by identifying the rock as a type of sandy biomicrite, with the difference apparently being the respective proportions of clastic and carbonate present in the specific rocks. In calcareous sandstone, the quartz and feldspars tend to dominate (Kendall and Schager, 1981). Hunt, Harding and Henry could only offer conjecture about the specific nature of the carbonate cements and mineralization e.g. dolomitization, whereas our results are more specific thanks to the instrumental detail available to this study. The projectile point appears to be more arkosic, meaning that it can contain up to 25% feldspar, while the flake scraper is more arenitic, containing 90% or more quartz, suggesting that these tools can be sourced to rock outcrops composed of two different sandstone types (Folk, 1974).

8.2. Station 20 outcrop

The rock is composed of dispersed, angular grains of predominately quartz (Fig. 13). Some feldspar was observed in thin section as well as with XRD/WDS. The carbonate cement is clearly birefringent and agranular, indicating a micrite. Both apatite and pyrite were observed in thin section and spectrographic results. The opacity observed in thin section is attributed to phosphatic minerals such as apatite.

8.3. The Terraces

This rock sample displays high porosity and relative abundance of poorly sorted quartz and feldspar grains that are angular-to-subangular embedded in a sparite (Fig. 14). Grain size is that of a fine sand texture (>63 μm) X-ray mapping of selected areas of the thin sections indicated magnesium in the cement suggesting the presence of dolomitization. XRD spectra show magnesium just “upfield” of the ubiquitous quartz peak at 3.2464 Å (32°). Apatite is present but no pyrite was observed. XRD results reveal the presence of orthoclase and ankerite, which is closely related, mineralogically to dolomite, but which also contains Fe — a curious finding given the lack of visible pyrite. At the Lower Ledge, shell fragments – molluscs or gastropods – and foraminifera were commonly observed in samples Some feldspar (in the form of laths) is cemented

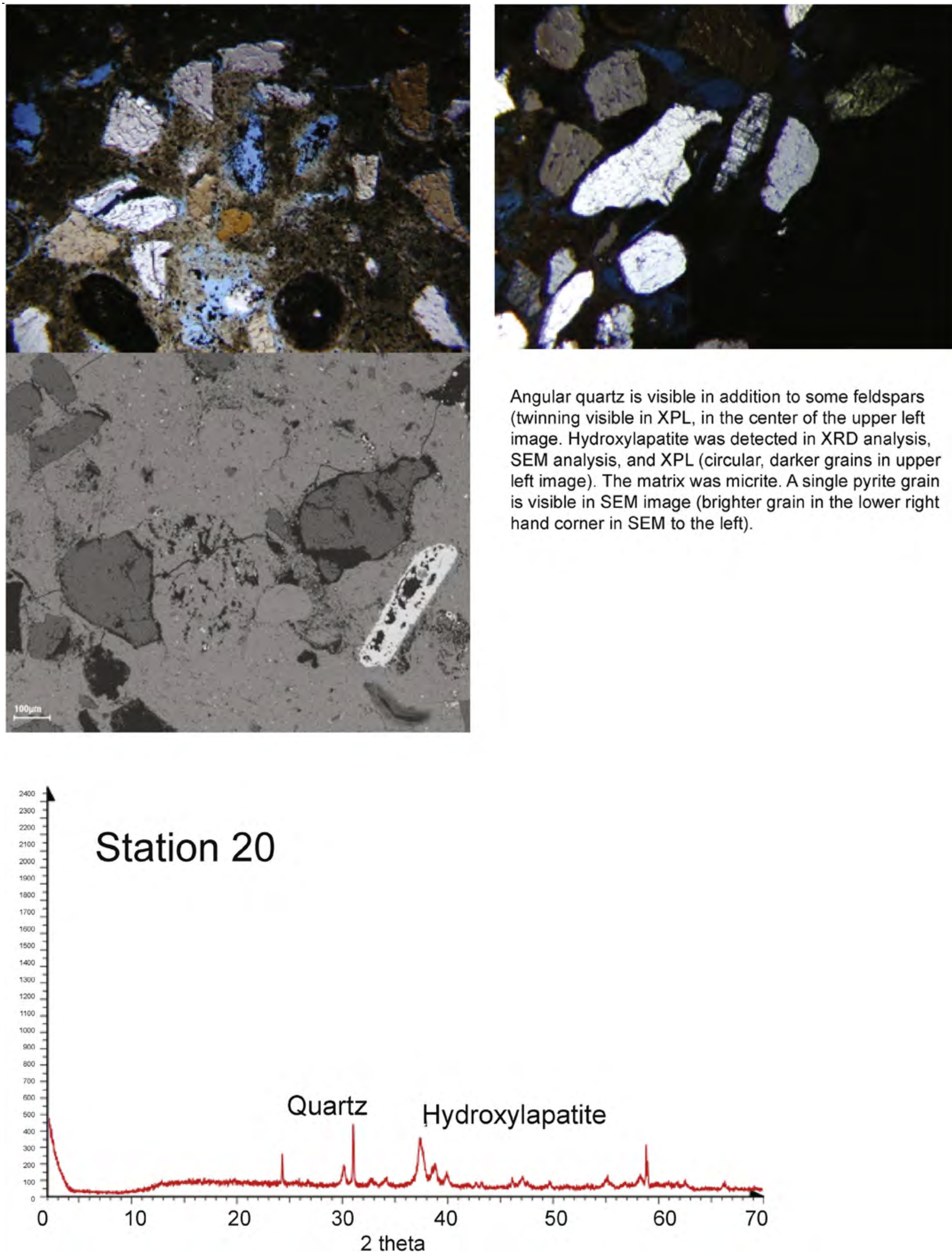
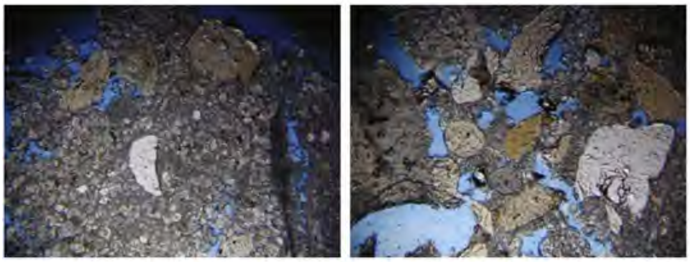
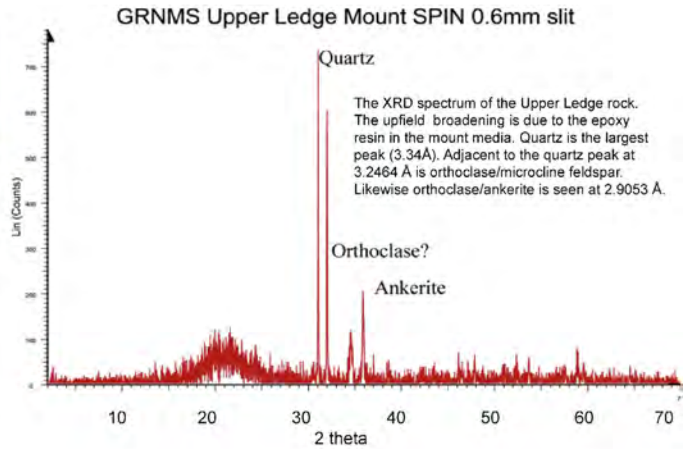


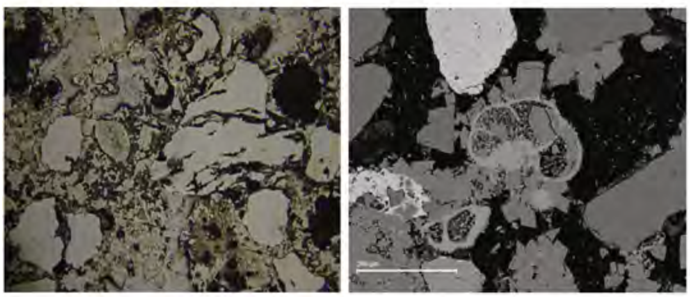
Fig. 13. Summary data, SEM/EDS and XRD for Station 20 outcrop.



Upper Ledge, The Terraces. (L) Blocky sparite matrix; (R) typical low density of grains showing significant porsity of this rock. More grain rounding is seen in this rock. The prevalence of quartz and feldspar is apparent. The calcite is dominated by sparite. It appears the quartz grains have undergone some dissolution or mechanical abrasion/weathering.

Element	Weight%	Oxide	Weight %
Mg	6.2	MgO	10.28
Si	20.3	SiO2	43.43
P	0.98	P2O5	2.25
Ca	31.48	CaO	44.05
Totals	100		99.99





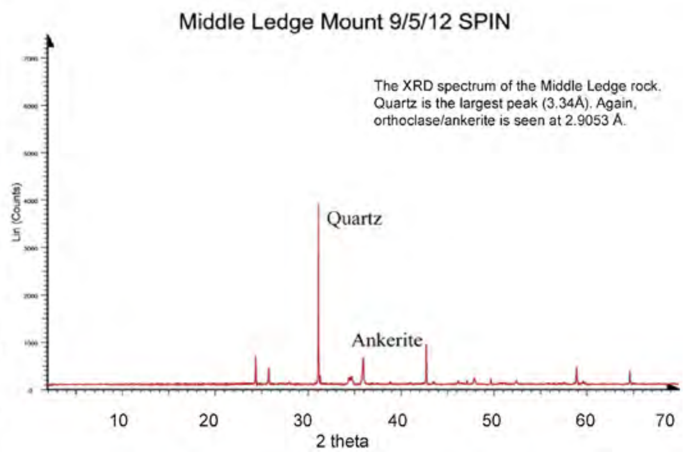
Middle Ledge, The Terraces, showing sub angluar to sub rounded quartz grains within dolomitized calcite matrix. Microfossils (possibly foraminifera) are visible in the SEM image on the left. XRD confirms presence of quartz and ankerite or pyrite. Grain density is again low.

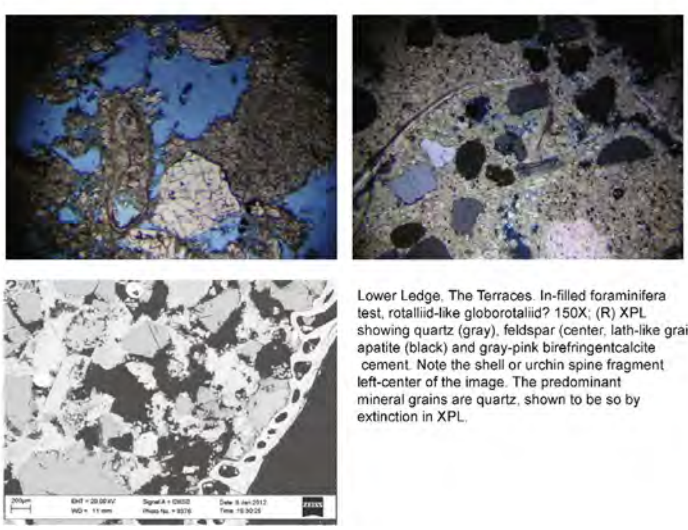
Element	Weight%	Oxide	Oxide %
C	11.18	CO2	40.95
Mg	1.55	MgO	2.57
CaK	40.37	CaO	56.48
O	46.91		
Totals	100.00	100.00	

Matrix of Middle Ledge sample

Element	Weight%	Oxide	Weight %
C	10.49	CO2	38.43
Mg	13.35	MgO	22.14
Ca	28.19	CaO	39.44
O	47.98		
Totals	100.00		100.00

Suspect dolomite "rhomb", Middle Ledge sample





Lower Ledge, The Terraces. In-filled foraminifera test, rotalliid-like globorotaliid? 150X; (R) XPL showing quartz (gray), feldspar (center, lath-like grain), apatite (black) and gray-pink birefringentcalcite cement. Note the shell or urchin spine fragment left-center of the image. The predominant mineral grains are quartz, shown to be so by extinction in XPL.

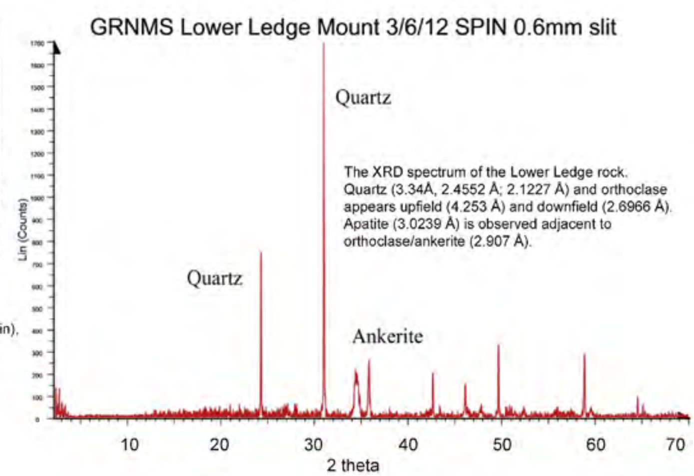


Fig. 14. Summary data, SEM/EDS and XRD for The Terraces outcrops.

with angular quartz and apatite grains. Rutile was observed. Potassium feldspar is indicated by XRD. The XRD spectrum of the Lower Ledge rock. Quartz (3.34 Å, 2.4552 Å; 2.1227 Å) and orthoclase appears upfield (4.253 Å) and downfield (2.6966 Å). Apatite (3.0239 Å) is observed adjacent to orthoclase/ankerite (2.907 Å).

9. Discussion

Without instrumental data generated by the electron/X-ray methods none of the artifacts would provide a definitive clue to geological origin nor that of their archeological provenance. The lithology of the two

Table 2
Summary of petrographic and mineralogic results — artifacts and source rock.

Sample	Grain rounding	Sorting	Grain density	Matrix	Mineral inclusions	Fossil material
Projectile point	Angular to sub-angular	Moderately well sorted	Low density, evenly spaced	Micrite	Quartz, pyrite, K-spar, hydroxylapatite	None
Station 20	Angular	Moderately poorly sorted	Low density, evenly spaced	Micrite	Quartz, pyrite, K-spar, hydroxylapatite	None
Scraper	Angular to sub-angular	Moderately well sorted	High density, evenly spaced	Micrite with MgO	Quartz, apatite, ankerite/pyrite	Yes, foraminifera
The Terraces	Angular	Poorly sorted	Low density	Sparite with MgO	Quartz, K-spar, hydroxylapatite, rutile, ankerite/pyrite	Yes, abundant, with foraminifera and shell

stone artifacts as well as that of the outcrop rock examined, in some cases are similar but not convincingly alike enough to assign a tool source to an outcrop.

Below is a table summary (Table 2) of each sample's characteristics according to grain rounding, sorting, density, matrix, mineral inclusions, and fossil materials. So how do we summarize our examination of the outcrop rocks? Alike, but not alike. No silicate cements were observed in any of the rocks and none of the rock types rise to the category of "quartzitic" or "orthoquartzite" either in cementation or hardness. With the exception of the scraper, all samples exhibited low grain density and angular to sub-angular grain rounding. The projectile point and the sample from Station 20 have many similarities, including grain rounding, density, matric, mineral inclusions, and lack of fossil materials. However, the projectile point shows grains that are moderately well sorted while Station 20 has grains that are more poorly sorted and could support an argument that the stone from the which the projectile point was made was deposited in a different depositional environment than that of Station 20, further suggesting that the projectile point was not made from rock sourced to this location.

The scraper and the rock samples from its location at The Terraces are much more obviously different. While the scraper has moderately well sorted high density grains with angular to sub-angular rounding in a micrite matrix containing MgO, the rock samples from all three Terrace ledges were poorly sorted low density angular grains in a sparite matrix with MgO. The presence of rutile in samples from The Terraces was not replicated in the scraper. In fact, the only commonality between the scraper and the outcrops at The Terraces was appearance of fossil material, and even then, there are differences, with the scraper showing only foraminifera taxa, while The Terraces samples contained both foraminifera and larger shell fragments potential left behind by larger marine or estuarine taxa. The presence of ankerite in the XRD spectra suggests the both rocks can be sourced to a clay and calcite rich sediment (Botbol and Evenden, 1989:H15), but the samples from The Terraces show much lower grain density than the scraper. Ankerite forms much later in the course of diagenesis than pyrite (Botbol and Evenden, *supra*), and this fact taken together with the higher porosity of the samples from The Terraces suggests that the iron containing mineral (pyrite) detected by XRD of these samples may be, in fact, created by pyrite not detected in visual analysis. Additional analysis of the scraper and the samples from The Terraces is needed to state with certainty.

Interpretation of the presence of sulfides should be done cautiously. While pyrite formation is typically associated with organic rich brackish tidal marshes, it can also occur in localized patches with metabolizable organic matter even where the overall environment is aerobic and comparatively depauperate in organic materials (Berner, 1966, 1984; Raiswell et al., 1988). This can occur when decaying organic matter within closed shells or burrows forms local, sulfidic microenvironments in otherwise organic-poor sediments (Reaves, 1986). Rapid incorporation of organic matter into sediments that are otherwise organic-poor also may result in the development of localized pyrite steinkerns (Brett and Baird, 1986). Thus, the appearance of pyrite in these samples does not necessarily imply or indicate "marsh or mud" in a past estuarine or marsh environment — just decaying gastropods or mollusks. That being said, the presence of ankerite in the samples from The Terraces does suggest a clay matrix that underwent more diagenetic changes than those that contain pyrite alone.

The projectile point and flake tool are typologically less ambiguous than the bone/antler artifact in terms of cultural provenance. The shape and size of the stemmed point suggest its origin within the Archaic period (Whatley, 2002). Flake scrapers were, likewise, ubiquitous in Archaic period assemblages. Antler tools were used extensively in a North American prehistory as points, flakers, atlatl components, etc., in not only the Archaic Period but that of preceding Paleo-Indian Period as well (Jennings, 1974; Bradley et al., 2010). Since the reef was submerged in the early mid-Holocene, it is logical to rule out an association of this artifact with later portions of the Archaic Period or that of the following Woodland Period. This leaves open the possibility that these artifacts date from as early as the Paleoindian period, or possibly as late as the Middle Archaic prior to establishment of the coastline at its modern position. Faught (2004a, 2004b:276) has identified a relative stillstand in the Big Bend of Florida along the Gulf Coast, at the −20 m isobath at 8000 BP, and Ray Hole Springs, which lies is −12 m of water, was submerged by 7500 BP or thereabouts (Anuskiewicz and Dunbar, 1993), which is consistent with the terminal Early to early Middle Archaic. This suggests a terminus post quem of around 8000 BP.

Garrison et al. (2008) previously characterized the geochronology of these same sites and their findings are supported by the current instrumental analysis. The upper sediments at Gray's Reef were dated to 8–9000 YBP using OSL, and inclusions of bone and shell. These shell-rich, medium sands contained Pleistocene and Holocene faunal remains of horse, mammoth and bison in an allogenic assemblage of materials from deflated coastal sediments eroded by rising, post-LGM sea level. An extensive shell assemblage of *Crassostrea* and *Mercenaria* is mixed with a Rancholabrean vertebrate assemblage present in the reef sands, and as noted in the discussion of the faunal remains from Station 20, *Crassostrea* prefers depths of −12 m or shallower, supporting our proposed terminus post quem of 7500 BP following Faught (2004a), Anuskiewicz and Dunbar (1993), and Balsillie and Donoghue (2011). The radiocarbon age for a *B. bison* metapodial, 6080 ± 60 YBP (Table 3), is not consistent with the timing of sea level rise proposed by Faught and others for the Big Bend, however. Given the much higher sedimentation rates for the Georgia Bight, we must also consider the possibility that the RSL curves for the Gulf are inappropriate for application along the Georgia Bight. Additional absolute dates are required in order to clarify the date for the submergence of Gray's Reef.

The arenitic sandstone projectile point's stratigraphic association with this temporal and faunal context is consistent with typological classification as Archaic but beyond this general category it is equivocal. This type is a thick point with an excurvate blade and weakly bifurcated base nearly as wide as the blade. An Early-to-Middle Archaic age (ca. 10,000–8000 YBP) cannot be ruled out as the base is weakly bifurcate. The general morphology of the projectile point is not at all consistent with the lanceolate points of the Paleo-Indian period. Studies by Chapman and others, suggest the bifurcate point/knife technology was introduced or invented in Eastern North America in the Early Archaic and disappears in the Late Archaic (ca. 5500 YBP) (Chapman, 1975;

Table 3
Chronology of sediment facies at Gray's Reef and JY Reef.

Method	Facies	Material	Location	Age (YBP) 1950[a] 2003[b]
AMS	Gray shelly sand	Bone	Surface sediment, Gray's Reef	6090 ± 60[a]
AMS	Gray shelly sand	Carbonate	Surface sediment (ophiomorpha)	18,970 ± 140[a]
AMS	Gray shelly sand	Shell	Surface, −0/cm Gray's Reef	8950 ± 70[a]
OSL	Gray shelly sand	Quartz sand	Core 4, −30/cm Gray's Reef	24,023 ± 4954[b]
AMS	Gray shelly sand	Shell	Core 4, −30/cm Gray's Reef	29,120 ± 680[a]
AMS	Gray shelly sand	Shell	Core 4, −170/cm Gray's Reef	24,640 ± 460[a]
OSL	Gray shelly sand	Quartz sand	Core 4, −170/cm Gray's Reef	23,702 ± 5411[b]
AMS	Gray shelly sand	Shell	Core 1, −170/cm Gray's Reef	43,770 ± 470[a]
OSL	Brown sand	Quartz sand	Core 1, −220/cm Gray's Reef	39,265 ± 5692[b]
U/TH	Brown sand	Sediment	Core 1, −220/cm Gray's Reef	37,481 ± 1372[b]
AMS	Gray shelly sand	Reef facies	Reef front, −15 cm Gray's Reef	44,370 ± 1530[a]
AMS	Gray mud	Wood	Core 1, −220/cm JY Reef	>50,290[a]
AMS	Gray mud	Wood	Core 4, −220/cm JY Reef	>48,020[a]

[a] Radiocarbon age
[b] OSL age.

Hranicky, 2002). Again, additional investigation is badly needed in order to add to the artifact assemblage; we cannot adequately address the issue of cultural association given the ambiguity of the date of submergence for the site and the equivocal classification of this projectile point beyond placing it in the Archaic period before 6000 BP but after 11,000 BP, due to the loss of manufacturing and use wear flaking scars.

Scrapers made on flakes have been found in tool assemblages going far back in to the Paleolithic (Bordes, 1973). These simple tools are easily fashioned, intentionally, or simply resulted from the opportunistic use of flakes made in the course of the manufacture of another type of tool. Whatever their genesis, flake scrapers have been shown to have been a multi-purpose implement. Their use has been inferred, replicated or observed in hide and meat processing, wood working and any other activity that required a “blunt dissection” type of tool for the task at hand. These tools did not have to be “sharp” in the sense of knives, projectile points, etc. Their utility was in large part due to their ability to hold an “edge” and not damage the materials on which they were used. Because of this requirement, a scraper made on a coarse-grained material such as calcarenite would have been useful.

The flake scraper of this study is unifacial and has at least one edge that would have been effective. The more steepened edge could have been useful as well depending upon the task for which it was being utilized, though we cannot infer directly uses to which this particular tool was devoted. Microscopic inspection of the edges of the scraper show little evidence of its use. This is not surprising given the degree of

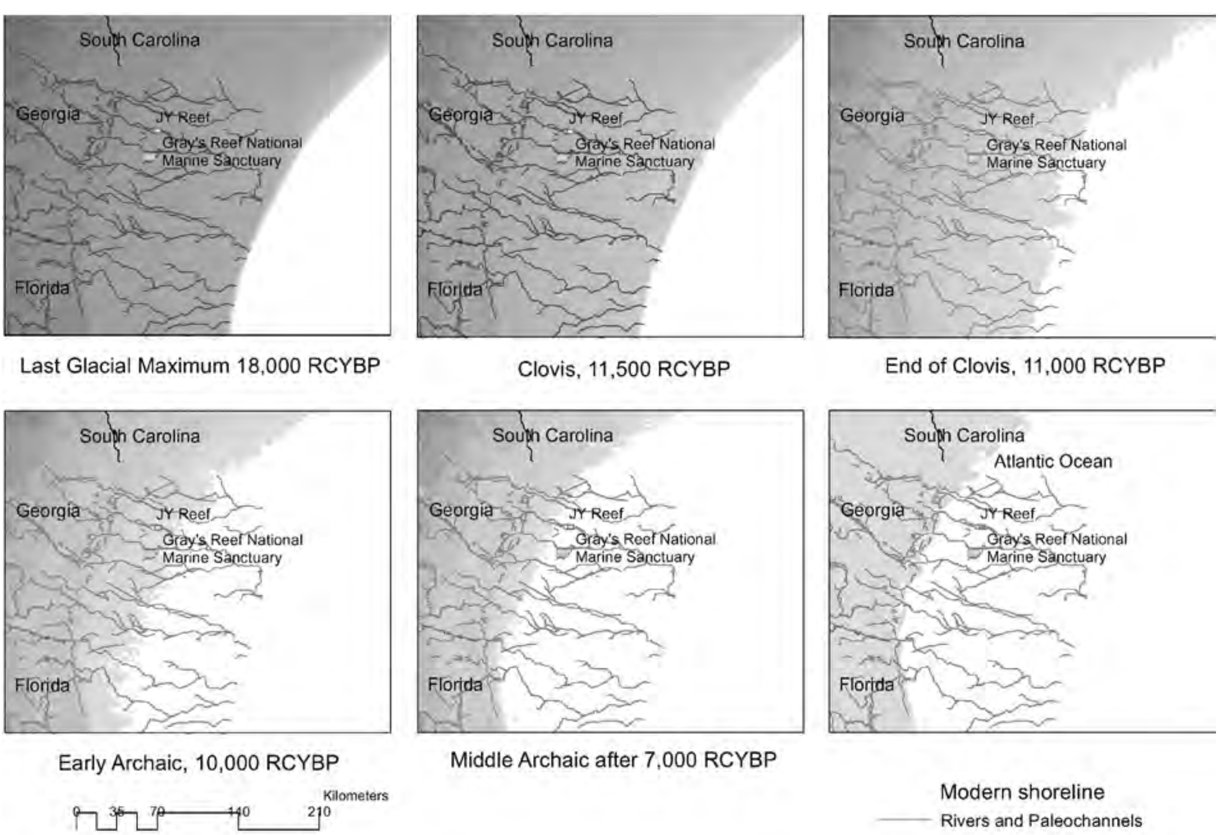


Fig. 15. Time slices showing paleoshorelines from the last glacial maximum to the present.

corrosion experienced by this item. Along the blunted, non-utilized edge, the arenite's quartz grains would show little or no "rounding" nor "edge damage" such as is commonly seen on more crystalline tool materials such a flint/chert (and even quartzite) if it was, in fact, not in use. We do observe a certain unevenness in the tool's edge but that could be as much an artifact of manufacture as actual use. Assignment of this item to the category of a flake scraper is based almost entirely on form or morphology.

Comparison of the scraper's lithology with that of the projectile point immediately showed disparity between the two items however. The scraper's material contained no pyrite, along with ankerite which suggests a different diagenetic history than the projectile point. The projectile point contained no microfossils whereas foraminifera and shell was observed in the scraper. There is a clear higher density of quartz (and feldspar) in the scraper than that of the projectile point. While we cannot source either of these items definitely to specific outcrops, we can say with confidence that they did not come from the same outcrop, and that they were not fashioned from rock sourced to The Terraces site, which is much more poorly lithified.

The antler hook is also not diagnostic for a specific cultural period, unfortunately. Antler and bone artifacts are common components of prehistoric assemblages in North America (Byrd, 2011; Dixon, 2001; Dunbar and Webb, 1996; Hranicky, 2002). As early as the Paleo-Indian Period, organic artifacts of bone, antler or ivory were in use (Hranicky, 2002). Frison and Zeimens, reported bone projectile points in the Folsom component levels of the Agate Basin site in Wyoming (Frison and Zeimens, 1980; Jennings, 1974). By the Archaic Period, thousands of bone and antler fragments found in sites across the Southeast showed use as tools (Byrd, supra; Jennings, supra). Increasing exploitation of deer in the Holocene is documented in Florida, Alabama, Kentucky and Tennessee (Hranicky, 2002; Dunbar and Webb, 1996; Frison and Zeimens, 1980). In Florida elaborate tools, made from both megafauna and deer, are reported from submerged sites (Dunbar and Webb, 1996; Dunbar, 1991). The increasing reliance on deer as a staple led to its expanded use for a variety of tools, solid bone awls and points; antler for atlatl hooks/tips, handles, flaking implements and points (Dunbar and Webb, 1996). At the Eva site, Lewis and Lewis listed 26 antler projectile points and 63 antler flaking tools from two Archaic Period levels (Lewis and Lewis, 1961).

Because of mineralization, reduced size and modification/use the antler tool is difficult to assign to a specific animal species or even to be 100% sure it is not ivory. One possible parameter that would suggest a species is the Ca:P (calcium:phosphorus) ratio. Pathak et al. (2001) in a study of the mineral composition of antlers from three deer species, examined the chemical composition and macro-mineral contents. Following Kay et al. (1982), Pathak, et al. reported a calcium:phosphorus ratio of 1.95 ± 0.08. Kay et al. had reported values of 2.02 ± 0.2. Our value for the C:P ratio based on WDS measurement is 2.05 making this material closest to the values for deer antler.

The natural density of horn and tusk material, plus diagenetic change, make it difficult to differentiate between the two materials horn and ivory. No Hunter-Schreger Banding was observed. As seen in Fig. 12, the specimen has distinct canal/tubule structures that are typical of cortical bone and not tusk/ivory (Tolksdorf et al., 2015). As noted by MacGregor (1985) the density and ratio of mineral to organic matter in antler is comparable to skeletal bone making antler tissue effectively coarsely-woven bone (supra). What we can say in regard to this artifact is that it is not made from tusk/ivory but we cannot differentiate whether it is bone or antler given the caveats just mentioned. Moreover, one must be convinced the distal end damage is basal rounding and not the result of natural processes. Thanks to extensive analytical, experimental and replicative studies on organic artifacts, it is possible to assign certain types of damage on bone and antler to human use (Olsen, 1989; Gaudzinski, 1999; Knecht, 1991, 1997; Pokines, 1998) The results of these studies on artifacts, replicates and natural materials gives one a clearer picture of the type and range of damage one should observe on organic artifacts particular that of antler used in pressure, perforative or penetrative roles, e.g. flaking, leather working or elements for hunting such as spears and atlatls.

In order to classify the antler item as an artifact, we must be able to disprove that observed modifications rule out natural processes. The distal fractures observed on the antler item are consistent with both terminal fractures that occur on the tips of awls or projectile points, and on naturally damaged antlers smoothed and/or rounded by the deer itself (Olsen, 1989). Sediment abrasion can also mimic the rounding or smoothing produced by deer rut behavior (Olsen and Shipman, 1988). In this case, the tip damage to this antler item is more consistent with that seen in antler points. This damage is generally more substantial than breakage of a small fraction off the tip, even factoring in rounding from natural processes (Knecht, 1997). It is also more consistent with the types of damage caused by pressure – faceting and pitting – that blunt the tool over time (Dunbar, 1991). Impact damage seen on upper Paleolithic projectile points (Knecht, 1997; Pokines, 1998) is likewise distinctive from not only that produced naturally, but from that produced by pressure alone. Basal rounding such as that which can be seen on this item can also result from natural processes (Stright et al., 2003). In the case of this artifact, though, the presence of basal rounding without similar abrasion or rounding on the distal end argues for a non-impact origin of the modification observed, while the damage to the tip appears to be more consistent with damage incurred by use as a tool. The similarity of the artifact to atlatl hooks found elsewhere in early prehistoric assemblages in America, suggests that this item was most likely used in this capacity (Bradley et al., 2010).

10. Conclusions

The survey sites at Gray's Reef and JY Reef have yielded extensive paleontological evidence of MIS 3 to Holocene age megafaunal remains, including extinct horse, bison, mammoth, deer/elk and various other taxa. In addition to these terrestrial taxa, he invertebrate paleontology constitutes a diverse suite of nearshore-to-estuarine species that, taken together with the vertebrate finds, allow for an informed speculation on paleoenvironments of the Georgia Bight from MIS 3 to the mid-Holocene. At approximately 38,000 14C BP, the area was shoreface, during which time an Atlantic gray whale died and was buried in the sediment dubbed "brown sand" during this study (Noakes et al., 2009). Subsequent to this period, as the climate cooled during the beginning of MIS2 and the last glacial maximum, the shoreline retreated towards the shelf break, reaching that point by 18,000 14C BP. The "brown sand" sediments underwent partial lithification. Relative sea levels began to rise again and by the end of the Clovis cultural period around 11,000 14C BP, the coastline was east of Gray's Reef and JY Reef at around the −40 m isobaths. Additional meltwater pulses drowned this shoreline and by the Early Archaic, between 10,100 14C BP and 9400 14C BP, stumps from a cypress forest have been documented by Harris et al. (2013), placing the shoreline somewhere around the −20 m isobaths, slightly to the east of Gray's Reef (Harris et al., 2013: 13–14). After this point the rise in relative sea level is not as clear given the very late date on the *B. bison* from Station 16. The rate and timing of transgression after 10,000 14C BP is best tested by future studies that seek for preserved organic remains and, if possible, intact stratigraphic profiles containing materials suitable for absolute dating techniques. At present the question of transgression after 10,000 14C BP remains unsettled, but we have developed sufficient data to offer the time slices below showing paleo-shorelines from the last glacial maximum to the present; the only time slice that lacks clarity is the one for the Middle Archaic after 7000 14C BP. For this time slice we infer shoreline position to be at the −12 m isobaths following the Gulf of Mexico RSL curves with the caution that this conclusion is subject to change (Fig. 15).

While the Gray's Reef materials are unusual prehistoric artifacts, in that they are not manufactured from the more typical cherts usually found during the Early to Middle Archaic periods in the Southeast. Both stone items are also typologically and technologically consistent with others from these periods in the U.S. Southeast. Their discovery is a positive result with regard to future archeological studies of the Continental Shelf. The bone/antler atlatl hook is, likewise consistent with those found in this cultural period. The recovery of this assemblage, however minimal and equivocal cultural associations might be, in tandem with an unclear date of final submergence for the site, argue strongly for additional investigations at Gray's Reef and associated locations.

One of the most common arguments leveled against acceptance of items such as these from submerged lag deposits is the simple question: How can you tell it's a tool, not just a fortuitously shaped scrap of reef rock? The presence of corrosion and rounding that obscures flake scars and other signs of human modification further complicate the question. However, identification of the projectile point and the scraper as made from materials that do not appear to have been local to their find spots argues for their transport to those locations, with human transport being the most straightforward explanation. Petrography, EDS and WDS data indicate that the two stone artifacts are calcareous sandstone, but that the projectile point is more arkosic, the scraper more arenitic, with pyrite and hydroxylapatite present in the point, but neither of these minerals present in the scraper. The presence of benthic foraminifera in the scraper tool but not in the projectile point also support an argument for different depositional environments for the lithic source materials. The rock from Station 20 could be the source for the projectile point, but the sorting and grain rounding appears dissimilar. The antler item shows evidence for fracturing consistent with impact damage or use wear on its distal end, but the rounding of the basal end without concomitant rounding on the distal end does not support the hypothesis that rounding was the result of natural processes. The morphology of all items is consistent with the gross morphologies of the basic artifact types, as well. Adding to the assemblage of artifacts will elucidate this issue.

Finally, the faunal assemblages across all sites shows signs of considerable differences. Station 20 yielded far more estuarine taxa than Station 16, JY Reef, or any of the scour nuclei around the A.B. Daniel. The proximity of 20 to 16 (less than 150 m) makes this finding particularly interesting. Without more data it would be unwise to speculate on the source of this dissimilarity but this finding also argues for more study. The results from sedimentological investigations confirm that the sediments within which artifacts and faunal remains are embedded are a deflated, condensed stratigraphic section that has been subject to erosion and ravinement as marine transgression overtopped the survey locations, sometime after 10,000 14C BP.

In Masters and Flemings' 1984 volume, C.W. Meighan concluded that investigation of submerged coastal sites was unlikely to yield evidence of "Early Man" (Meighan, 1984). This study, together with studies on the Gulf of Mexico, Atlantic and Pacific shelves (Anuskiewicz, 1988; Stright et al., 2003; Anderson and Faught, 2000; Faught, 2004a, 2004b) has shown the inaccuracy of this statement, and has provided new archeological data on Late Pleistocene–Holocene settlement within a now inundated coastal plain landscape. While it is clear that these surveys had serious challenges created by marine transgression, it has nevertheless proven them to be useful in demonstrating the potential for the Georgia Bight/South Atlantic Bight to assist in adjudicating questions of specific maritime and coastal adaptations by prehistoric hunting and gathering societies as well as those questions bearing on early aboriginal North America (Dixon, 2001; Haynes, 2003; Josenhans et al., 1997; Arnold, 1996; Smith, 2001; Faught, 2004a, 2004b).

Acknowledgments

The authors would like to recognize the various contributions and assistance given them over the course of this research. First and foremost are the colleagues from the National Oceanic and Atmospheric Administration (NOAA), who, over several years, provided vessel time, breathing gases, equipment and financial support to this research. NOAA personnel made many of the finds, primarily paleontological, listed in the tables and figures. Mr. Greg McFall and Mr. Reed Bohne, Gray's Reef National Marine Sanctuary, thorough their administrative roles, facilitated much of the invaluable support. Other NOAA personnel, too numerous to list, are thanked for their generous assistance offshore and on. Coastal Carolina University's Dr. Paul Gayes, and Rice University's Dr. John Anderson, made their marine vibracoring equipment available to the project and graduate studies conducted therein. Dr. Clark Alexander and the Skidaway Institute of Oceanography provided advice and analytical support to the principals and students most notably in terms of the sediment and geological studies. The late Professor Vernon James Henry, Georgia Southern University, was a valued friend and advisor for much of the early geological and geophysical research conducted at Gray's Reef by the principal author. Dr., John Shields and past principals at the Georgia Electron Microscopy Center of the University of Georgia provided their skills and instruction for the SEM/EDX instrumentation used on many of the lithic samples. Dr. Paul Schroeder and Mr. Chris Fleischer performed a similar assistance with the Department of Geology's XRD and Electron Microprobe facilities. In terms of recognition for their kind advice on paleontological finds we especially thank Dr. Nicholas Pyensen, Dr. David Webb, Dr. Jonathan Geisler, Mr. Gary Morgan, Dr. Elizabeth Reitz. The chronological results – AMS, OSL, U/TH – benefited primarily from the expertise of Dr. Alexander Cherkinsky and late Dr. Mike Neary, Center for Applied Isotope Studies, the University of Georgia and Dr. George and Ms. Brook, OSL Laboratory, Department of Geography, the University of Georgia. Dr. Tommy Jordan, Geospatial Research Center Department of Geography, the University of Georgia, provided guidance and instruction for the GIS portion of the study. We thank our friend and colleague, Dr. Scott Noakes, University System of Georgia Dive Officer, for all of his valued diving and scientific support over the course of this research. We wish to thank the anonymous reviewers whose comments and suggestions greatly improved the manuscript, and note that any mistakes are the authors' alone.

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