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What is past is prologue: excavations at the Econfina Channel site, Apalachee Bay, Florida, USA

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ABSTRACT
Offshore submerged sites can retain valuable data concerning many questions of interest to archaeology, including what form coastal occupations may have taken during periods before the establishment of modern coastlines and late Holocene climate and ecological conditions. However, submerged offshore sites experience postdepositional forces entirely unlike those in terrestrial contexts, including erosion/deflation of sediments, and degradation of artifacts and/or features caused by the marine environment. Methodological and theoretical approaches to assessing submerged marine sites, versus terrestrial ones, must be adjusted accordingly to extract valuable data and interpretations from them. This study demonstrates the application of these different approaches at the Econfina Channel site (8TA139) in Apalachee Bay, Florida, USA. The site appears to contain significant evidence for coastally adapted occupation during the final part of the Middle Archaic period (~8600–5000 cal BP), but we needed to address marine site formation processes before we could assess human activities at the site. Sedimentological and archaeological traces of human activities can be teased out using geoarchaeological methods, which differentiate between nonhuman postdepositional processes and the cultural material remains left behind by those who used the site before it was abandoned and subsequently submerged.

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Submerged prehistoric archaeology; Florida archaeology; Archaic

Submerged sites on the inner continental shelf

While the challenges associated with identification and excavation of submerged prehistoric sites are considerable, they have the potential to offer us badly needed insight into human behaviors during periods when now-submerged landscapes were dry, including the use of coastal and marine resources during prehistory (Anderson and Faught 1998; Bailey and Flemming 2008; Bailey and Milner 2002; Dixon 2013; Erlandson and Fitzpatrick 2006; Faught 2004a, 2004b; Faught and Donoghue 1997; Garrison et al. 2012, 2016). Shell midden deposits that signal human exploitation of coastal resources become increasingly visible in the archaeological record by around 5000 BP but may simply mark stabilization of the modern coastline position, leaving earlier evidence for coastal occupations submerged offshore (Bailey 2014:293; Cunliffe 2001, 2011; Habu 2004; Jöns and Harff 2014; Thompson and Worth 2011). Scholars focused on coastal occupations increasingly call for investigation into these types of submerged sites (Erlandson and Fitzpatrick 2006; Grøn 2006, 2007; Reitz 1988, 2014; Thompson and Turck 2009; Thompson and Worth 2011; Turck 2010).

The call for additional investigations offshore is based on observations of multiple coastal groups who developed complex foraging economies with minimal mobility, raising anthropological questions about connections between subsistence, mobility, and social structures without domesticates. The southeastern United States is one area where groups established complex foraging by 4500 cal BP and possibly earlier (Andrus and Thompson 2012; Russo 1994; Thomas 2014; Thompson and Andrus 2011). To seek evidence for the development of coastal adaptations on the continental shelf that might shed light on these connections, we should first examine the most accessible sites of this type. In the Southeast, these are between 5,000 and 8,600 years old (the Middle Archaic period), in waters that are usually no deeper than 15 m (45 ft). Archaeologists documented sites in Apalachee Bay, Florida, from the Paleoindian to the Middle Archaic periods during the 1980s, 1990s, and early 2000s, with additional opportunities for research on this question (Dunbar 1988, 2006, 2012; Faught 1988, 2004a, 2004b; Faught and Donoghue 1997; Halligan et al. 2016).

The Econfina Channel site (8TA139) was one of the first sites within Apalachee Bay to be located and

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documented by researchers in 1986 (Faught 1988). However, it did not conform to the predictive model for submerged sites in Apalachee Bay, which correlated archaeological deposits with sinkhole features and prominent chert outcrops based on assumed upland occupations (Dunbar 2016; Faught 2004a, 2004b; Faught and Donoghue 1997). While Econfina Channel had prominent chert outcrops and a small spring, it contained no obvious sinkhole feature. Furthermore, while archaeological sites in the Aucilla and PaleoAucilla River watershed generally show continuity from the Paleoindian period into the Middle Archaic, the Econfina Channel site has only one documented cultural component: Middle Archaic (Faught 2004a, 2004b; Faught and Donoghue 1997). The site does show, however, the abundant use of coastal resources, making it ideal for a study of coastal adaptations prior to the late Holocene or Late Archaic period. The goal of our study is to outline our recent work at Econfina Channel in search of additional details on the nature of this coastal occupation.

Early coastal sites in the region

Florida is home to some of the oldest sites in North America, and the Big Bend of Florida around Apalachee Bay has a high density of prehistoric archaeological sites from the Pre-Clovis period forward (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar 1988; Faught 2004a, 2004b; Faught and Donoghue 1997:421; Halligan et al. 2016). Most of Florida's prehistoric sites represent upland occupations, however, with less clear evidence for coastal occupation prior to the Middle Archaic. Along the Atlantic shoreline where the continental shelf is narrower and paleoshorelines lie closer to the modern shoreline, sites such as Vero (8IR009) and Douglass Beach (8SL17) may represent visits to coastal regions by Paleoindian and Archaic groups from farther afield. Atlantic coastline lithic depositions are poor, and the appearance of exotic lithics in these locations suggests the movement of people or goods across significant distances (Cockrell and Murphy 1978; Hemmings et al. 2015; Murphy 1990). Along the Gulf of Mexico, the continental shelf is wider, with occupations older than the late Middle Archaic that are submerged farther away from the modern shore; Ray Hole Springs (8TA171), a site that dates to the terminal Early Archaic or early Middle Archaic, is over 30 km from the modern coastline (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar 1988).

By the end of the Middle Archaic period, shell mound sites arguing for the human use of aquatic resources and coastal occupations appear throughout Florida. Early examples may initially represent extraction sites for aquatic resources, but, over time, these sites show non-subsistence-oriented, ritual use of these sites and features (Mikell and Saunders 2007; Randall 2013; Randall et al. 2014; Russo 1988; Saunders 2010; Saunders and Russo 2011; Saunders et al. 2009). Terminal Middle Archaic shell mounds have been documented in the Mitchell River valley in northwestern Florida dating to as early as ~7200 cal BP, including the earliest documented appearance of exotic steatite bowls in the region and suggestions of potential year-round occupation at some base camps, though the latter point is still not completely resolved (Mikell and Saunders 2007:173–174, 193). Similar and slightly earlier (~7400 cal BP) shell mound deposits are also known within the St. Johns River valley (Randall 2013:204), with increasing evidence for lower degrees of mobility as well as long-range trade networks within which people and goods could move considerable distances (e.g., Quinn et al. 2008; Tuross et al. 1994). By the end of the Middle Archaic period, these shell mound sites appear to have taken on clear ritual purposes, specifically, mound construction and burials (e.g., Randall 2013:214; Russo 1994).

Throughout the peninsula and panhandle of Florida, the ritual landscape also exhibits clear diversity, with burials found in mortuary pond sites such as Windover (8BR246), Little Salt Springs (8SO18), and Warm Mineral Springs (8SO19) (Adovasio et al. 2001; Clausen et al. 1979; Doran 2002; Royal and Clark 1960; Tomczak and Powell 2003; Tuross et al. 1994; Wentz and Gifford 2007:330), and others in shell mounds such as those found along the St. Johns River. Offshore examples of mortuary pond sites also exist. A wooden stake, like those found at Windover dating to the Middle Archaic period, is known from Douglass Beach (8SL17) (Murphy 1990). In late 2015, archaeologists delineated a submerged pond burial site off Venice Beach, Florida, on the west coast south of Tampa (8SO7030), predating the arrival of the modern coastline ~5000–4500 cal BP (Duggins and Price 2016). Shell mounds, pond mortuary sites, and non-ritually oriented sites of all types are more archaeologically visible by the end of the Middle Archaic when relative sea levels approached the modern coastline, but they cannot be ruled out for earlier periods along older coastlines. Where, then, does the Econfina Channel site fit into this overall picture?

Our objectives for the Econfina Channel study were twofold: first, what activities are evident within this site; and second, how do they inform us about human behaviors and their coastal adaptations at this location? The first question must contend with site formation processes specific to submerged contexts. The second question can be answered by comparing our findings to trends for coastal sites in Florida and elsewhere. Geoarchaeological methods and behavioral archaeology provide the framework to discern natural processes from anthropogenic ones, placing cultural deposits within their environmental contexts (Gagliano et al. 1982; Garrison et al. 2016; Murphy 1990; Pearson et al. 2014; Stright 1986a, 1986b, 1995). Behavioral ecology has been used in various coastal regions to address questions of coastal site location choices, subsistence practices, mobility, and the development of social complexity (e.g., Bird et al. 2002; Bird and Bliege Bird 1997, 2000; Thomas 2008, 2014). We combine these multiple approaches to address our study objectives.

Geological and geomorphological background

Apalachee Bay possesses a low energy coastline with minimal wave, current, and tidal action, and which is defined by its karst terrain. Carbonate bedrock lies beneath Quaternary sediments, acting as both the primary aquifer and a major control on fluvial processes, particularly the Aucilla and Econfina rivers. The aquifer is unconfined, with upwelling springs throughout the region. Sediment loads within the rivers are minimal, and fluvial channels are often defined not by incision, but by collapse features and intermittent channels that only flow continuously once within a few miles of the coastline; thus, sediment loads entering the bay are minimal (Brooks et al. 2003; Goodbred et al. 1998; Hine et al. 1988).

Both the Aucilla and Econfina rivers rise within the coastal plain only, unlike the Apalachicola River that feeds the western side of Apalachee Bay. The Aucilla River headwaters lie north of the Cody Scarp, which consists of Pleistocene sediments overlying older Quaternary formations. The Econfina River rises below the toe of the Cody Scarp and may contain even less sediment load than the Aucilla, as the Aucilla passes through the Scarp proper where sediment cover is greater. Few sinkhole features are associated with the Econfina Channel itself, unlike the Aucilla, which is defined by them, suggesting a less direct connection with the aquifer. Abundant chert outcrops dot the Econfina Channel, making navigation challenging.

As one approaches the coastline, the subtropical coastal woods are replaced by tidal marshes with increasingly sparse hammocks that retain some tree cover. Soils are dominated by fine sand and sandy loams in better-drained areas, with some sandy clay loams as well. Tidal marsh areas are composed of mucky mollisols overtopping mucky loamy sands and sands (USDA Web Soil Survey 2016).

Water depths from the mouth of the Econfina into Apalachee Bay are 1–2 m outside the paleochannel proper. Apalachee Bay is dotted with eelgrass beds, which provide habitat for a diverse suite of marine fauna, including scallops, sea turtles, and blue crabs (Mattson et al. 2007), but tend to obscure archaeological sites. The Aucilla's paleochannel has been traced offshore using geophysical methods, but no geophysical survey has been conducted for the Econfina (Faught 1988, 2004a, 2004b; Faught and Donoghue 1997). Recently, researchers associated with the Aucilla Research Institute (ARI) have gathered bathymetric lidar datasets for both paleochannels but they are still being interpreted.

During the late Pleistocene and early Holocene, rivers fed by the Floridan Aquifer dropped along with relative sea levels, leaving sinkholes dotting the landscape instead of flowing channels (Dunbar 2006; Faught and Donoghue 1997). The development of these sinkholes likely attracted fauna in search of food and water, and human groups followed them to these locations (Duggins 2012; Thulman 2009). Abundant chert outcrops provided access to stone tool source materials all across the landscape (Dunbar 2006, 2016; Halligan et al. 2016).

The local prediction model for offshore sites extrapolated these trends into Apalachee Bay with great success (Anuszkiewicz and Dunbar 1993:2–3; Faught and Donoghue 1997:422–423). More than two dozen offshore sites or activity areas were identified during initial surveys, including the Econfina Channel site. The Econfina Channel site is approximately 5 km offshore in water depths ranging from 2–5 m, depending on intrasite location and tidal gradient.[1] When archaeologists first documented the site, they observed a shell midden (trash) deposit and abundant lithic debitage deposits around abundant chert outcrops, but found no sinkhole features. Archaeologists initially interpreted the Econfina Channel site as an intermittent hunting camp (Faught 1988, 2004a, 2004b; Faught and Donoghue 1997).

The site is located on the south-southeastern side of the paleochannel that routes west-southwest along a quarry zone (Figures 1 and 2), and its most visible feature is the large shell deposit, located north of eelgrass beds along a roughly east to west axis. Reports during the 1980s surveys speculated that the deposit may extend into the eelgrass (Faught 1988). Today, eelgrass extends south and east of the site, and the bottom shoals up to water depths of 1.4–1.8 m east and south of the midden. Chert and dolomite bedrock outcrops lie north, east, and west of the midden surrounded by extensive lithic debitage. A freshwater seep/spring was detected within an

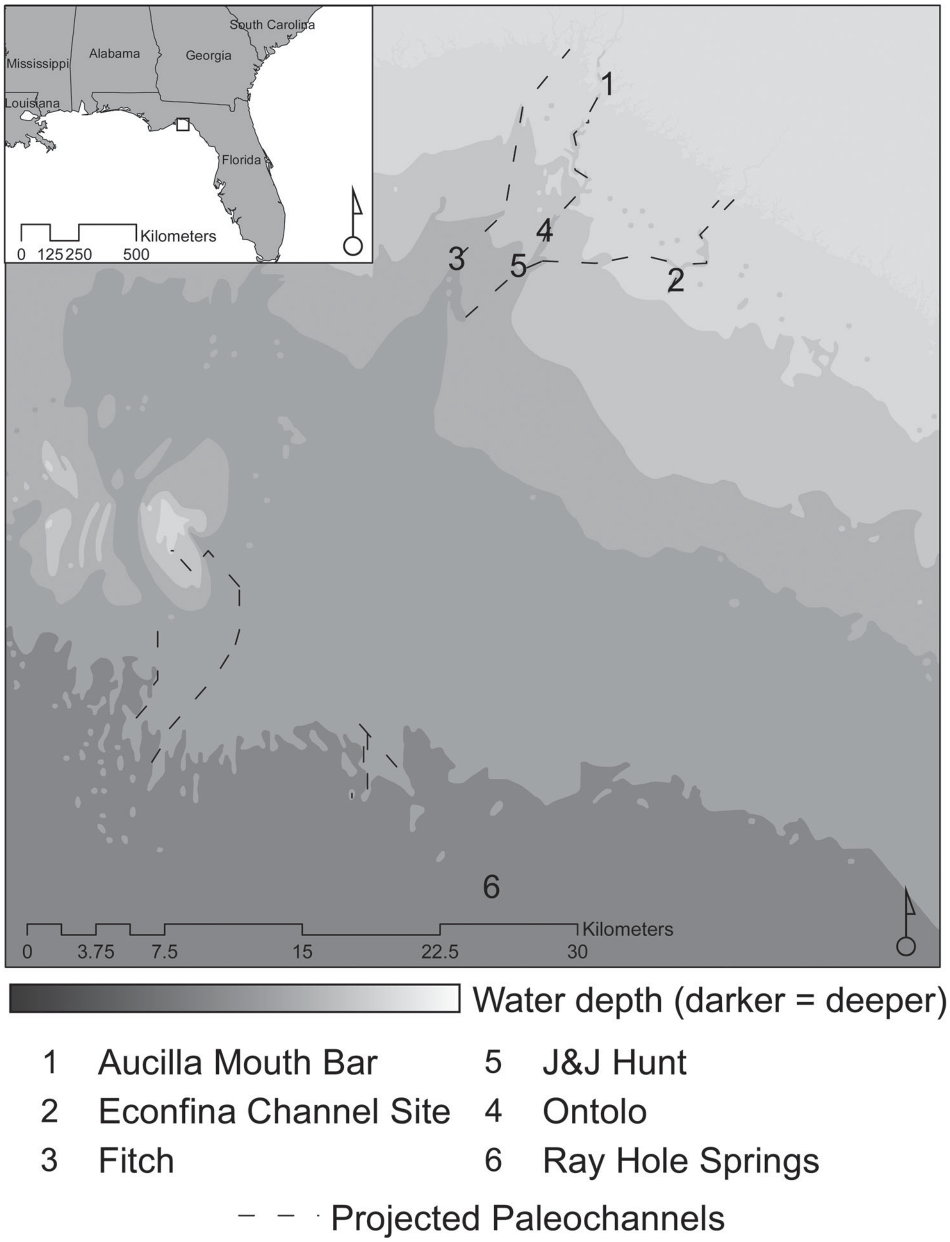

Figure 1. Econfina Channel and other associated sites.

Notes: Grayscale background shows water depths with darker shades representing deeper water and lighter shades showing shallower water. Depth range varies up to 1 m based on tides.

area of bedrock outcrops west of the midden, near the paleochannel.

Methods

Anthropogenic features are present at the site, but the full extent of those features was unclear prior to this study. Mapping, excavation, and subsequent sediment analyses offered the best potential for delineating activity areas, sediment depositional zones, the site's full extent, and whether marine transgression has impacted site sediments. Thus, the project relied on two primary tasks: first, relocating, excavating, and mapping the features first reported by Faught (e.g., Faught 1988); and second, recovering bulk sediment samples from across the site.

Field methods included mapping, bulk sediment sampling, and excavation units, while laboratory analyses included lithic analysis, radiocarbon dating of excavated materials, and particle size analysis (PSA). We conducted mapping by diver survey in August 2015, after which we placed four 1×1 m excavation units within the paleochannel, the quarry area outside the midden, the eelgrass, and the midden itself, and examined the midden's stratigraphic profile. Submerged

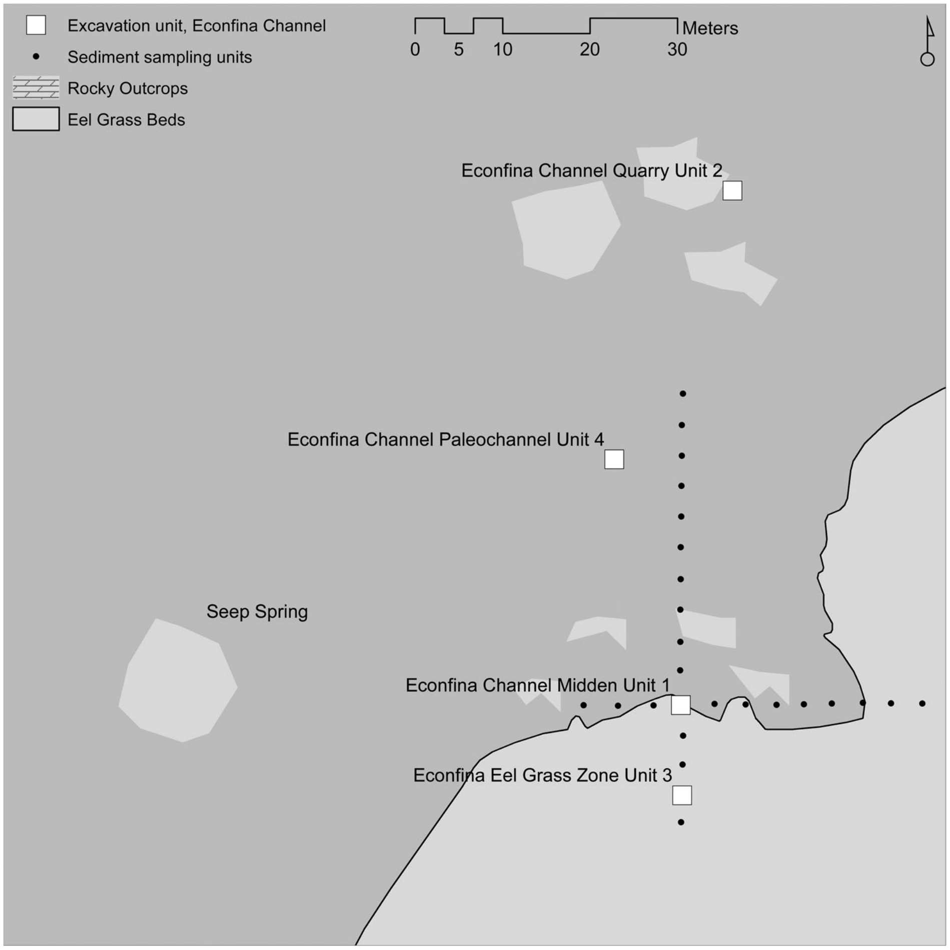

Figure 2. Map of excavation units and bulk sediment sampling stations at the Econfina Channel site.

excavation units in sandy marine sediments can be difficult to document because they tend to collapse, so we used photography to document plan views and profiles.

We then collected bulk sediment samples across the site in late October 2015, and again in October 2016 and September 2017, after the passage of Hurricanes Hermine and Irma. The 2015 dataset contained 26 samples. Each sample was around 1 kg total and was composed of sediments collected by hand from the surface. We collected samples every 3 m for the north–south transect, every 3 m for the transect running from the midden to 30 m east into the eelgrass zone, and every 5 m on a 15-m transect running west from the midden into the quarry zone. Each transect was 15 m long. We reserved bulk sediments from 2015 only for PSA, charcoal analysis, and micro/macro-inclusion analysis for this study. Comparison with our results from 2016 and 2017 will be discussed elsewhere.

Laboratory methods included PSA, inclusion analysis, lithic analysis, and two radiocarbon dates. Sediment from each sample location was shaken in a mechanical shaker for 30 minutes using stacked sediment analysis screens. Screen mesh sizes were 4,000 μm (4 mm), 2,000 μm (2 mm), 1,000 μm (1 mm), 500 μm (0.5 mm), 250 μm (0.25 mm), 125 μm (0.125 mm), and 63 μm (0.0625 mm). Results for each sampling location were converted to weight percentages for each particle size and assessed using Gradistat software that assigns Folk Classifications to each sample, and statistical analysis using PAST3. We conducted point count analysis on select samples for inclusions such as charcoal, shell, and heavy minerals. Finally, we assessed lithic materials to determine what stages in lithic reduction sequences were present at the site, as well as for use wear that can suggest what tasks the lithic tools were used to perform.

We chose these methods because they falsify a null hypothesis that sediments from submerged contexts do not retain signatures diagnostic for human activities, such as burned bone, debitage, and geochemical traces for human activities. By demonstrating that sediments are anthropogenic, lines of evidence from materials such as inclusions can be used to distinguish evidence of human activities from natural marine processes. Bulk sediment sampling has a long history in geoarchaeology and archaeology (e.g., Butzer 1971; Hassan

1979), and Gagliano and others (1982) were among the first to suggest that sediments in submerged archaeological sites could be characterized by the presence or absence of anthropogenic inclusions and geochemistry (see also Murphy 1990; Pearson et al. 2014).

Results

Mapping

As noted above, we first mapped the site by diver survey. We performed surface collection for artifacts and debitage at the freshwater seep/spring area located west of the midden/quarry areas, recovering several flakes that were human-modified along with one partially exhausted core. We then mapped the extent of the midden. Using only visible shell deposits as a guide, the midden measured approximately 10 m across on a north–south outside the eelgrass zone, but closer to 25 m east-west. Finally, we determined that U2 within the quarry zone was 55 m and 15 degrees from the midden itself, and that the freshwater seep/spring was 50 m and 280 degrees from the midden (see Figure 2).

We also mapped for depth. The freshwater seep/spring depth was confirmed to be approximately 0.5–1 m deeper than the midden. Unit 2 compared to the midden was 1–1.25 m deeper, depending on proximity to the paleochannel area. The midden was approximately 0.75 m deeper at the drop point than at 30 m east from the midden. We concluded that the quarry zone and freshwater seep/spring were clearly downslope from the midden, which is itself downslope from the eelgrass zone, again consistent with Faught's observations during initial surveys (Faught 1988).

Excavations

Excavation unit locations and bulk sediment sampling stations are shown in Figure 2. Midden excavations (U1) recovered the following taxa: *Crassostrea virginica* (oyster), *Pecten* sp. (scallop), *Melongena corona* (crown conch), and Ampullariidae (apple snails), a freshwater taxon. The team did not perform formal zooarchaeological analysis on these taxa, opting instead to record their presence alone. A formal zooarchaeological study will be a critical aspect of future site studies.

Quarry zone excavations (U2) provided abundant lithic debitage. Stratigraphy in this unit matched Faught and Donoghue (1997) but lacked prominent midden debris. It consisted of marine shell hash underlain by dolomite bedrock and cobbles at a depth of around 50 cm. We recovered debitage, worked flakes, and carbonate rock samples. All debitage was found within the marine shell hash.

The eelgrass unit (U3) was excavated to ∼40 cm in the eelgrass, delineating fine to very fine sand sediments with midden visible to ∼30–35 cm below the seabed. Beneath the large shell hash was a level with finer shell hash, and finally a bed of articulated *Crassostrea* deposits that are most likely natural, not anthropogenic (Figure 3). We recovered one chert flake and some broken scallop shells. Stratigraphy was consistent with the stratigraphy reported by Faught and Donoghue (1997), with a top layer of a marine shell hash underlain by black, finer grained sediments in which copious shell was embedded.

The paleochannel unit (U4) was next to an iron rebar datum hammered into the dolomite substrate. This unit reached 60 cm below the seabed, and we recovered large debitage with prominent cortex but with minimal to no evidence for human modification. Surficial bedrock outcrops were minimal, with lower relief than those observed near U1 and U2. Stratigraphy was minimal as well, with a marine shell hash layer overlying dolomite boulders and cobbles similar to the quarry zone unit. The marine sediments were thicker in U4 than at U1 or U2.

Lithic analysis

No diagnostic bifacial projectile points were recovered during excavations, but five identifiable tools were found. One scraper was recovered from U2, and one scraper from the sediment bulk sampling at station N9. A blade tool and a scraper tool were recovered from the surface at U1 on the midden, and another scraper was recovered from the surface at the seep/spring (Figure 4). The lack of diagnostic tools is similar to earlier excavations that recovered primarily debitage and informal tools, with only a few Archaic stemmed points (Faught and Donoghue 1997).

We weighed and measured all tools and debitage to compare assemblages from each unit, including bulk sediment sample stations, to one another. The analysis included items recovered during hand excavation and surface sampling only, not micro-debitage recovered during PSA of bulk sediments. We used ANOVA tests to determine if the mean lengths and weights for lithics from each unit, bulk sediment sampling location, or surface collection were significantly different. We chose this test instead of chi-square or *t*-tests because lithic reduction sequences contain more than two stages that can in turn produce debitage and tools; ANOVA tests are appropriate when there is more than one independent variable and one dependent variable. Table 1 shows that mean weights varied significantly, but the mean weights for the quarry (U2), seep/spring (surface collection), and paleochannel zones (U4) were not significantly different, and that mean weights for debitage found in

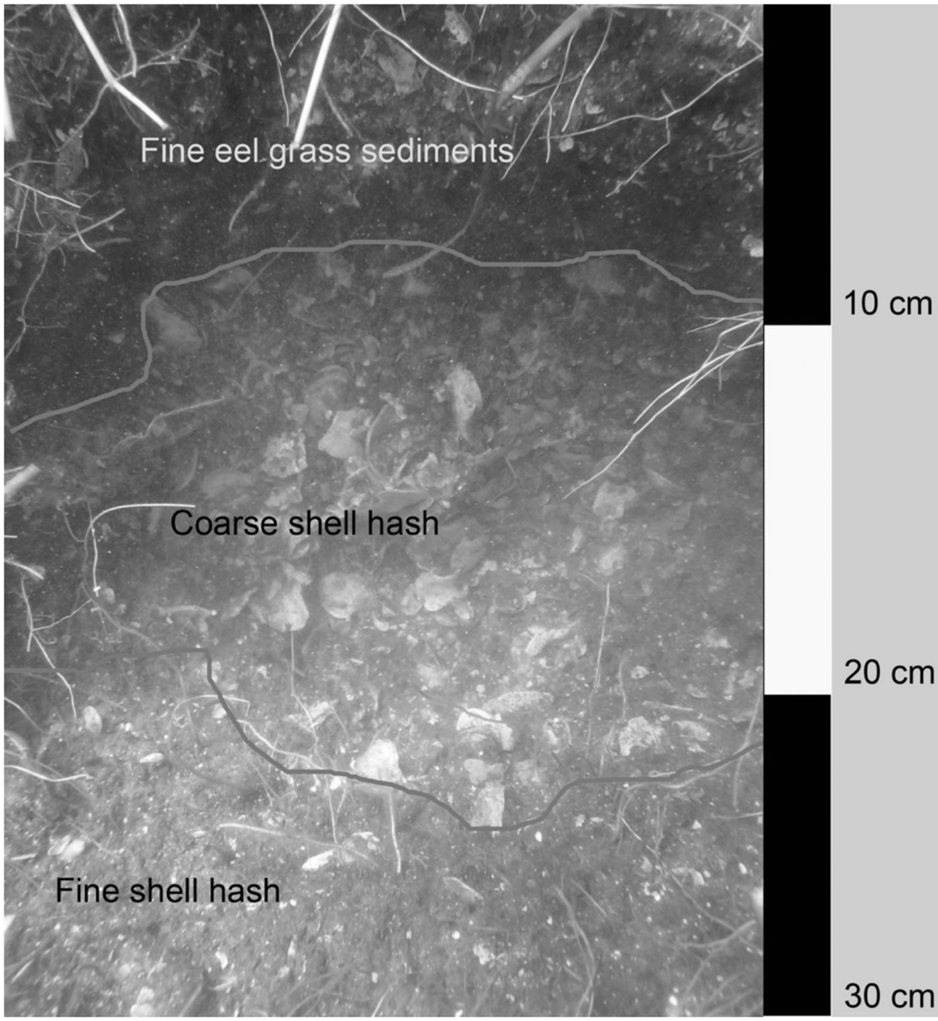

Figure 3. Stratigraphic profile, Econfina Channel site, eelgrass zone. Photograph by Ervan G. Garrison.

the midden (U1) and in the bulk sediment sample stations were also not significantly different. Table 2 shows that mean lengths varied significantly among all units, but that mean length was the same for debitage from the bulk sediment sample stations and midden unit (U1), while it differed between units from the quarry (U2), seep/spring (surface collection), and paleochannel (U4).

Using Tringham and others' (1974) criteria we also analyzed debitage and tools for potential uses and use wear. Several tools showed over-steepened working edges consistent with working durable materials such as bone, antler, or shell (Scott Jones, personal communication 2016). Others showed evidence of detachment and other breakage. Smaller lithic remains recovered from bulk sediment samples were assessed for use wear using a dissecting microscope. Again, we saw evidence consistent with working durable materials, as well as evidence for woodworking and working softer materials such as hides or textiles. Results for the debitage analysis is summarized in Table 3.

Lithics showed signs of staining or corrosion (Figures 4 and 5), which may be tannic staining from freshwater contexts, or the result of pyrite or other sulfide production during submergence in organic-rich, anoxic tidal salt marshes (Cook Hale 2018; Garrison et al. 2016; Lowery and Wagner 2012). Lithics impacted by this sulfidization process undergo the reverse of the initial reaction once oxygenated conditions are restored. This reaction, termed sulfuricization, produces new minerals within the lithic item's fabric, including iron oxides, and sulfuric acid as a byproduct of the reaction, which degrades the item's surface. Since recovery from the site, a powdery white coating has developed on some of the debitage. This suggests that at least some of the samples are stained due to sulfidization, and that sulfuricization is now occurring. This presents a significant curation challenge that should be considered for lithics from submerged contexts. We are currently working with personnel at the Florida Bureau of Archaeological Research (FBAR) to develop

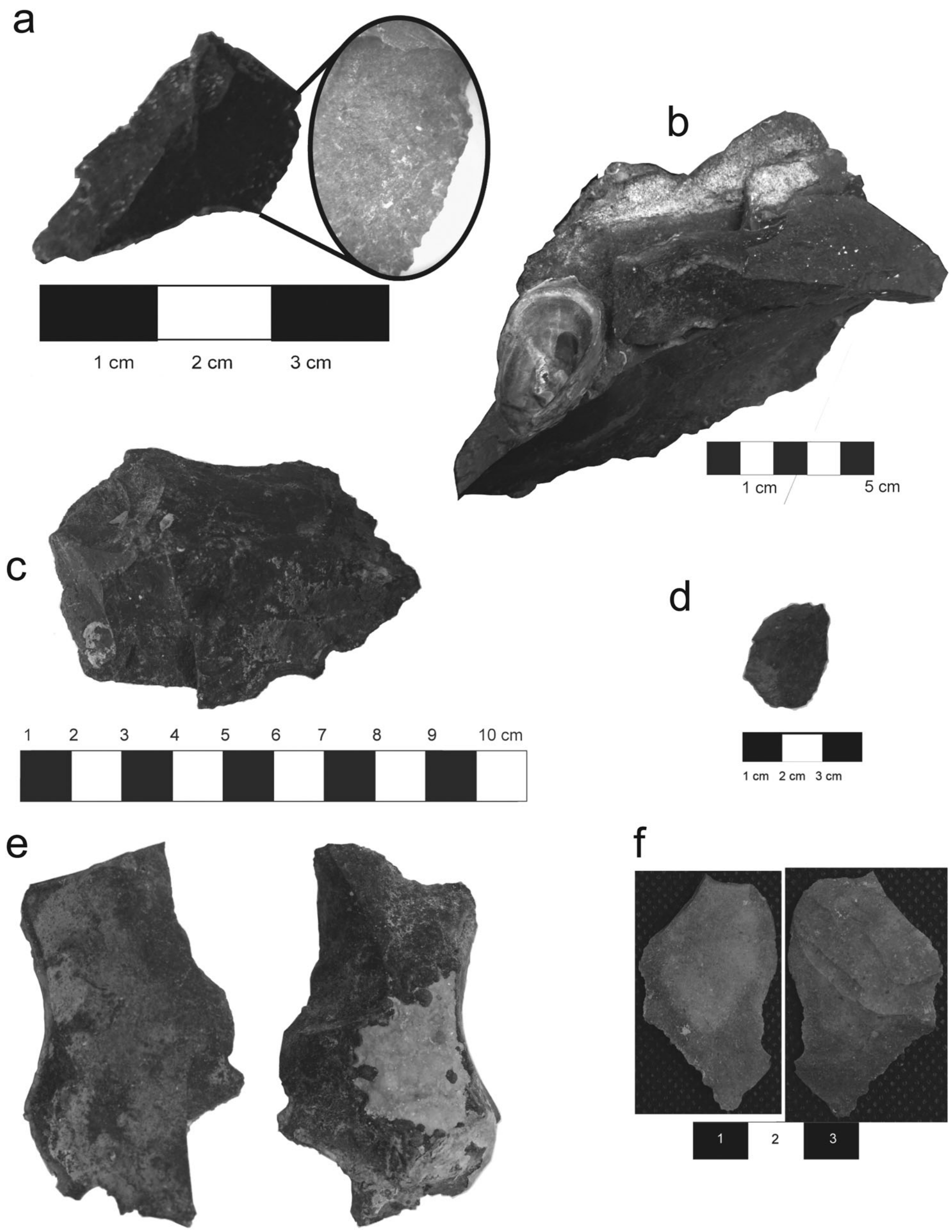

Figure 4. Tools recovered during excavation and bulk sampling: (a) debitage from E3, bulk sediment sampling station, showing edge damage; (b) core from seep/spring feature with refitted blade tool recovered from U1; (c) multiuse unifacial tool recovered from N3, bulk sediment sampling station; (d) thumb scraper from N9, bulk sediment sampling station; (e) scraper tool from N3, bulk sediment sampling station; (f) scraper tool recovered from surface of midden, near U1.

appropriate conservation protocols for lithics subjected to these geochemical changes.

Sediment analysis

Further sediment analysis is needed to delineate the extent of various depositional zones; for example, we observed clearly in the field that *Crassostrea* shell was common in the eelgrass beds around U3, which began 6 m south of and 18 m east of the drop point (U1), while the quarry zone area (U2) appeared to grade into the midden zone. We used PSA to delineate human activities areas from natural depositional zones.

Gradistat assigned five different Folk Classifications to the sediments: (1) a fine gravelly fine sand; (2) sandy fine gravel; (3) sandy very fine gravel; (4) very fine gravelly coarse sand; (5) slightly very fine gravelly fine sand (see supplementary materials for detailed GRADISTAT report). Combined with visual observation, it appears that the midden remains correlate with the sandy fine gravel and possibly the sandy very fine gravel. The sediments beyond the midden within the quarry zone were composed of the sandy very fine

Table 1. ANOVA lithic weights for all samples.

ANOVA: Single factor, all units/locations

Groups	Count	Sum	Average	Variance
Unit 2 2015	22.00	1,455.00	66.14	4,123.65
Unit 3 2015	21.00	1,152.00	54.86	3,581.23
Unit 1 2016	4.00	30.00	7.50	123.00
Unit 2 2016	5.00	381.00	76.20	3,879.70
Seep	3.00	397.00	132.33	6,220.33
Bulk sediments	11.00	17.06	1.55	1.89

Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	62,773.59	5.00	12,554.72	4.04	0.00	2.37
Within groups	186,568.50	60.00	3,109.48			
Total	249,342.09	65.00		Means are significantly different		

ANOVA: Single factor, quarry, seep/spring, and paleochannel zones
SUMMARY

Groups	Count	Sum	Average	Variance
Unit 2 2015	25.00	1,586.38	63.46	3,777.48
Unit 3 2015	24.00	1,268.11	52.84	3,235.13
Unit 2 Quarry zone 2016	8.00	520.07	65.01	2,918.30
Seep	6.00	609.54	101.59	5,357.72

Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	11,447.17	3.00	3,815.72	1.06	0.37	2.76
Within groups	212,284.34	59.00	3,598.04			
Total	223,731.51	62.00		Means are not significantly different		

ANOVA: Single Factor, bulk sediments and midden zone
SUMMARY

Groups	Count	Sum	Average	Variance
Bulk sediments	11.00	17.06	1.55	1.89
Unit 1 2016	4.00	30.00	7.50	123.00

Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	103.82	1.00	103.82	3.48	0.08	4.67
Within groups	387.87	13.00	29.84			
Total	491.69	14.00		Means are not significantly different		

gravel also, and the very fine gravelly coarse sand. The very fine gravelly coarse sand appears to correlate best to the paleochannel. Clear separation between midden, quarry, and even some of the eelgrass zone samples was not obvious. This was not an unexpected finding given the visual appearance of the site.

To further delineate sediments, we correlated sediment $CaCO_3$ and fraction sizes on the assumption that the gravel components represented shell from the midden. The 1,000 µm (1 mm) and 2,000 µm (2 mm) fractions align with the $CaCO_{3,}$ while finer sands (125 and 62.5 µm) fractions have a negative correlation with $CaCO_3$ (Table 4) and with coarser sand/fine gravel fractions. We completed point count analysis for inclusions on selected samples and tested for correlations as well, including charcoal and quartz. Charcoal positively correlates to "other minerals" and "heavy minerals." Quartz demonstrates negative correlations to "other minerals," charcoal, feldspar, and heavy minerals (Table 5).

Finally, we turned to multivariate analysis to differentiate sediment types in a quantitatively robust manner. We used the following steps:

1. We completed summary statistics using percentage measures for each sediment size to assess for variation coefficients. The 500 µm, 250 µm, and carbonate size fractions each had coefficients of variation below 50% and thus we removed them from multivariate analysis.
2. We then normalized the remaining particle size weight percentages using *z*-scores.
3. Each sampling station received a group classification based on its resemblance to the excavation units: midden (most like U1), quarry (most like U2), eelgrass (most like U3), or paleochannel (most like U4).
4. Principal Components Analysis (PCA) determined which particle sizes defined these hypothetical groups (Table 6).
5. We then tested our visual classifications using Linear Discriminant Analysis (LDA) (Figure 6). LDA predicted these classifications with reasonable accuracy (Table 7).
6. Finally, we interpolated raster images in ArcMap using mean phi for each sampling station in ArcMap to show the general distribution of particle sizes

Table 2. ANOVA analysis lengths, all lithics.

ANOVA: Single factor

Groups			Count	Sum	Average	Variance
Unit 2 2015			22.00	1,371.20	62.33	625.03
Unit 3 2015			21.00	1,272.30	60.59	498.15
Unit 1 2016			4.00	90.50	22.63	72.64
Unit 2 2016			5.00	325.20	65.04	564.24
Seep			3.00	343.90	114.63	1,020.80
Bulk sediments			11.00	172.70	15.70	61.60
Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	34,146.21	5.00	6,829.24	14.52	0.00	2.37
Within groups	28,221.18	60.00	470.35			
Total	62,367.39	65.00		Means are significantly different		

ANOVA: Single factor
SUMMARY

Groups			Count	Sum	Average	Variance
Unit 2 2015			23	1,433.52	62.32	596.61
Unit 3 2015			22	1,332.88	60.58	474.431
Unit 2 Quarry zone 2016			6	390.24	65.04	451.39
Freshwater seep/spring			4	458.53	114.63	680.53
Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	10,417.50	3	3,472.50	6.46	0.00	2.783
Within groups	27,387.20	51	537.01			
Total	37,804.71	54		Means are significantly different		

ANOVA: Single factor
SUMMARY

Groups			Count	Sum	Average	Variance
Bulk sediments			11	172.7	15.7	61.61
Unit 1 midden datum 2016			4	90.5	22.62	72.64
Source of variation	SS	df	MS	*F*	*p*-Value	*F* crit
Between groups	140.67	1	140.66	2.19	0.16	4.67
Within groups	833.97	13	64.15			
Total	974.63	14		Means are not significantly different		

across the site, and three more rasters showing particle sizes with the three highest coefficients for variation: 4,000 µm (4 mm), 2,000 µm (2 mm), and 63 µm (0.0625 mm), as they appeared to be most diagnostic for the midden, quarry, and eelgrass zones as shown by PCA and LDA (Figure 7).

Two radiocarbon dates were extracted from shell excavated from the upper and lower stratigraphic portions of the midden, but they have significant limitations. *Crassostrea* shell is a problematic material for dating due to environmental influences on the ^{14}C content, such as old carbon dissolved from local/regional carbonate bedrock, and water salinity in estuarine environments – both of which are significant concerns at this site. Calibration can take these reservoir effects into account, but only when used at a highly local level (Hadden and Cherkinsky 2017). However, we recovered no non-shell organic materials suitable for radiometric dating.

Table 3. Use wear patterns debitage, bulk sediment samples.

Activity	Locations
Reduction/finishing	E3, E12, E15
Primary reduction	E15, W9, N6
Retouch	E12, W3
Wood working	E3
Durable material working (bone, antler)	E9, E12
Soft materials such as hide or textiles	N6

Dates were obtained using standard practices at the University of Georgia's Center for Applied Isotope Studies using their AIS 0.5 MeV accelerator mass spectrometer. The sample $^{13}C/^{12}C$ ratios were measured separately using and expressed as $\delta^{13}C$ with respect to PDB. The dates have been corrected for isotope fractionation. The uncalibrated date for the lower level was 4490 ± 25 RCYBP (UGAMS 27919; shell; $\delta^{13}C$ −5.04‰) and the uncalibrated date for the upper level was 3010 ± 25 RCYBP (UGAMS 27918; shell; $\delta^{13}C$ −2.87‰).

We then calibrated the dates. This was a two-step process. First, we had to obtain a correction for the marine reservoir effects. We calculated this value using Calib which uses the Intcal 2004 marine calibration dataset to account for marine reservoir values (Reimer et al. 2004) (http://calib.org/marine/). The marine reservoir correction we used was calculated using an average of

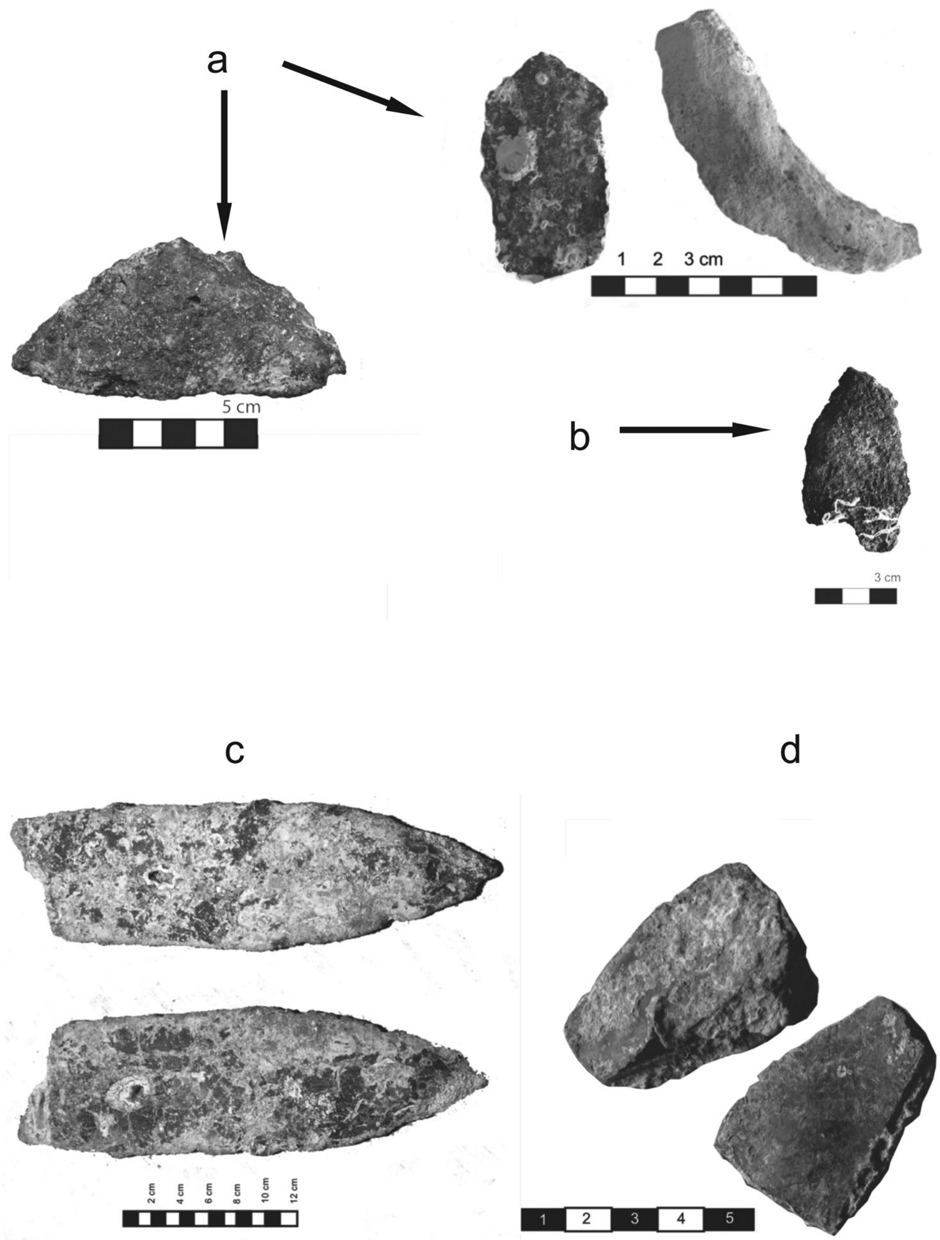

Figure 5. Corrosion sequence showing examples from multiple sites: (a) possible scrapers from Ray Hole Springs (8TA171), highly corroded; (b) possible bifacial projectile point from Ray Hole Springs, highly corroded; (c) Suwannee bifacial projectile point from Douglass Beach (8SL17), moderately corroded; (d) decortification flake from Econfina Channel site (8TA139), highly corroded.

136 ± 100 years, taken from two datasets from the Apalachee Bay area (Hadden and Cherkinsky 2015). Next, we calibrated our dates using these marine reservoir values in Oxcal 4.2, which uses IntCal 2013 (Bronk Ramsey 2009; Reimer et al. 2013). After calibration in Oxcal to 2σ using the marine reservoir correction obtained from Calib, the age range for the older, lower level was 5465–3546 cal BP at 95.3% confidence, with a mean date of 4510 cal BP and a standard deviation of 461. The age range for the younger, higher level was 3450–1784 cal BP at 95.4% confidence, with a mean date of 2621 cal BP and a standard deviation of 423 (Figure 8).

There is also some question about whether sulfide reduction and pore water diffusion occurring in sediments during and after submergence can create significant reservoirs of inorganic carbon (Sivan et al. 2001); however, had this been the case, the $^{13}C/^{12}C$ ratios for these samples should also reflect this reservoir and deviate from the typical range of a tidal salt marsh environment. These two samples yielded $^{13}C/^{12}C$ ratios consistent with tidal marsh conditions, however, arguing against an additional reservoir effect introduced by sulfide reduction (see Andrus and Crowe 2000; Andrus and Thompson 2012).

Table 4. Correlation analysis particle size fractions and carbonate components.

	$CaCO_3$	4,000 microns	2,000 microns	1,000 microns	500 microns	250 microns	125 microns	62.5 microns	CATCH PAN
$CaCO_3$	1.00								
4,000 μm	0.34	1.00							
2,000 μm	0.68	0.44	1.00						
1,000 μm	0.58	0.27	0.89	1.00					
500 μm	0.20	0.02	0.59	0.78	1.00				
250 μm	−0.50	0.13	−0.25	−0.14	−0.22	1.00			
125 μm	−0.53	0.06	−0.55	−0.50	−0.43	0.79	1.00		
62.5 μm	−0.66	−0.29	−0.66	−0.68	−0.53	0.56	0.81	1.00	
CATCH PAN	−0.59	−0.22	−0.55	−0.59	−0.51	0.45	0.64	0.83	1.00

Table 5. Point count and correlation analysis.

Slide	Quartz	Shell, etc.	Other minerals	Charcoal	Feldspar	Heavy minerals
S12	289.00	8.00	25.00	5.00	3.00	0.00
N3	265.00	10.00	22.00	2.00	0.00	0.00
N18	208.00	7.00	49.00	9.00	7.00	6.00
N30	249.00	4.00	44.00	4.00	3.00	1.00
W15	270.00	7.00	26.00	10.00	0.00	0.00
E30	306.00	5.00	9.00	1.00	1.00	0.00
Mean	264.50	6.83	29.17	5.17	2.33	1.17
Std.	31.05	1.95	13.53	3.34	2.43	2.19

Correlation analysis, point counts

	Quartz	Shell	Other minerals	Charcoal	Feldspar	Heavy minerals
Quartz	1.00	−0.03	−0.92	−0.56	−0.72	−0.87
Shell	−0.03	1.00	−0.19	0.06	−0.20	−0.07
Other minerals	−0.92	−0.19	1.00	0.56	0.76	0.75
Charcoal	−0.56	0.06	0.56	1.00	0.38	0.50
Feldspar	−0.72	−0.20	0.76	0.38	1.00	0.90

The dates suggest the midden deposition lasted from the end of the Middle Archaic period into the Late Archaic period, and possibly even into the Early Woodland period. Faught and Donoghue (1997:444) reported broken bifaces from the Econfina Channel site that are probably Marion or Putnam type. Bullen classified Marion and Putnam as lasting from the Middle Archaic into the Late Archaic; Farr, however, argued that Marion is part of the Florida Archaic Stemmed point tradition spanning the entire Middle Archaic and into the Late Archaic (~8600–4000 cal BP), while Putnam is classified by some as a separate type with a shorter use period of ~7250–6250 cal BP (Farr 2006:107, 111). Our late dates do not clarify that situation, and it is possible that the unusually young Woodland date is erroneous.

Table 6. PCA loadings and scores.

PC	Eigenvalue	% variance
1	2.56	61.56
2	1.14	27.35
3	0.34	8.25
4	0.12	2.84

	PC 1	PC 2	PC 3	PC 4
4,000 μm	−0.26	0.84	−0.36	0.30
2,000 μm	−0.55	0.20	0.81	−0.06
125 μm	0.53	0.48	0.18	−0.68
62.5 μm	0.59	0.13	0.42	0.67

Discussion

The Econfina Channel site contains multiple features showing varying preservation: a shell midden, a quarry with every stage of lithic reduction and manufacture, and a freshwater spring. First, we will discuss what activities we can infer from the evidence recovered from these features, and then we will discuss the shortcomings of preservation.

Identification of the shell midden as anthropogenic relies on multiple lines of evidence. First, the shell deposit is composed of *Crassostrea* sp. (oyster), with some examples of *Pecten* sp. (scallop), *M. corona* (crown conch), and Ampullariidae (apple snail) (Figure 9). All taxa except for the apple snail are found in estuarine and open marine contexts, and do not argue for human intervention to create this deposit. However, the apple snail is a freshwater species that would have been deposited before the paleochannel became brackish or saline. Modern salinity in Apalachee Bay averages around 28 g/L (Bianchi et al. 1999:39), which is the upper end of the salinity range tolerated by *C. virginica* (NOAA Fisheries Eastern Oyster Review 2007). It is more likely a natural oyster deposit would form when salinities were brackish or closer to modern marine conditions. A natural estuarine oyster deposit could form only above a freshwater apple snail deposit. The intermingling of two taxa from very different

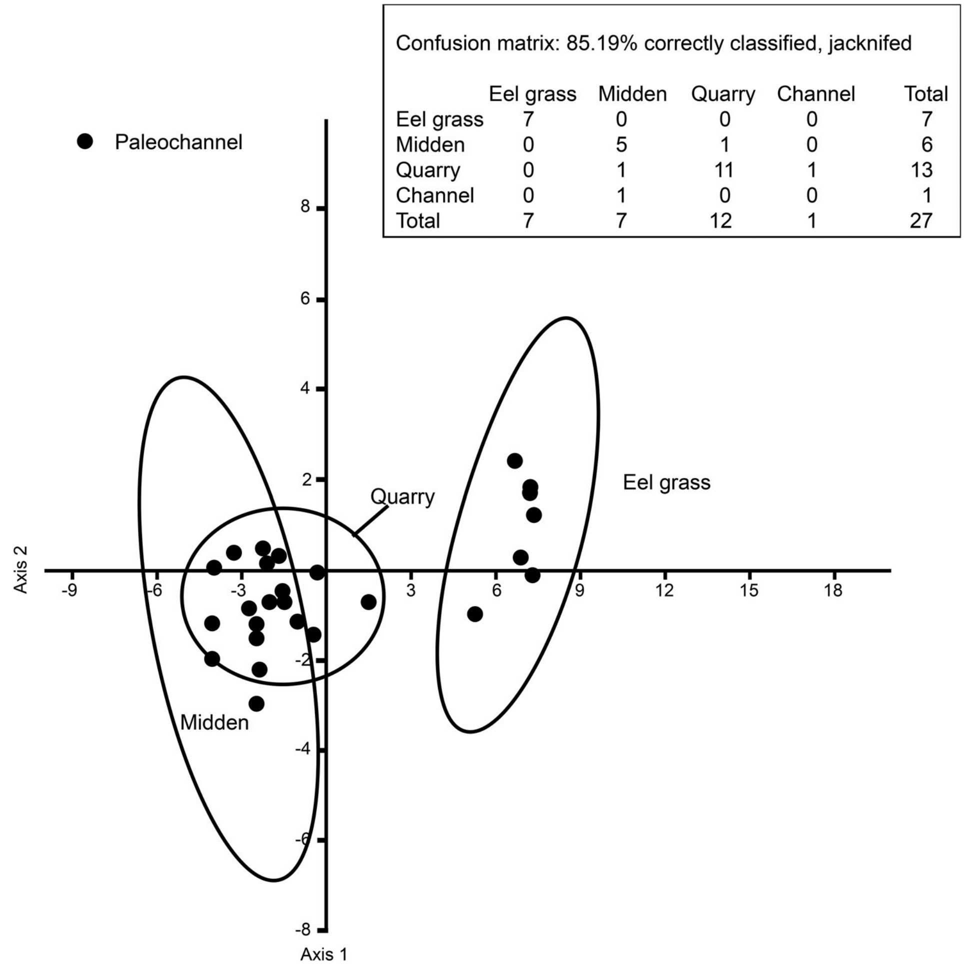

Figure 6. LDA of bulk sediments and carbonate components.

Table 7. Sediment classes according to LDA, 2015 samples, 81.48% correct classification using jackknifing.

Point	Given group	Classification	Jackknifed
S12	Eelgrass	Eelgrass	Eelgrass
S9	Eelgrass	Eelgrass	Eelgrass
S6	Eelgrass	Eelgrass	Eelgrass
S3	Midden	Midden	Midden
N3	Midden	Midden	Midden
N6	Quarry	Quarry	Quarry
N9	Quarry	Quarry	Quarry
N12	Quarry	Quarry	Quarry
N15	Quarry	Quarry	Quarry
N18	Quarry	Channel	Channel
N21	Quarry	Quarry	Quarry
N24	Quarry	Quarry	Quarry
N27	Quarry	Channel	Channel
N30	Channel	Channel	Quarry
W15	Quarry	Quarry	Quarry
W10	Midden	Midden	Midden
W5	Midden	Midden	Quarry
E3	Midden	Midden	Midden
E6	Quarry	Quarry	Quarry
E9	Quarry	Quarry	Quarry
E12	Quarry	Quarry	Quarry
E15	Midden	Midden	Midden
E18	Quarry	Quarry	Midden
E21	Eelgrass	Eelgrass	Eelgrass
E24	Eelgrass	Eelgrass	Eelgrass
E27	Eelgrass	Eelgrass	Eelgrass
E30	Eelgrass	Eelgrass	Eelgrass

salinity environments and the occurrence of human-modified lithics among them argue that this shell deposit resulted from human subsistence activities carried out when the fluvial channel was a freshwater environment (Garrison et al. 2013:73). Furthermore, all of the oyster valves are disarticulated, and show no signs of intergrowth as is commonly seen in natural oyster reefs.

From this we infer one specific instance of subsistence activity: shellfishing consistent with other Archaic shell middens along the northern Gulf Coast (Hadden 2015; McFadden 2016; Saunders and Russo 2011). We recovered the same suite of invertebrate taxa as Faught and colleagues did during initial investigations (Faught 1988; Faught and Donoghue 1997). Significantly, the possible midden zone extends south and east into the eelgrass zone as Faught suspected, and appears to have two lobes based on sediment size analysis, suggesting either multiple contemporary shellfish processing areas, or two different shellfish processing episodes and/or possible occupations. Additional ^{14}C dates could resolve this issue and offer more insight into depositional history at the site. Additional dating methods should also be

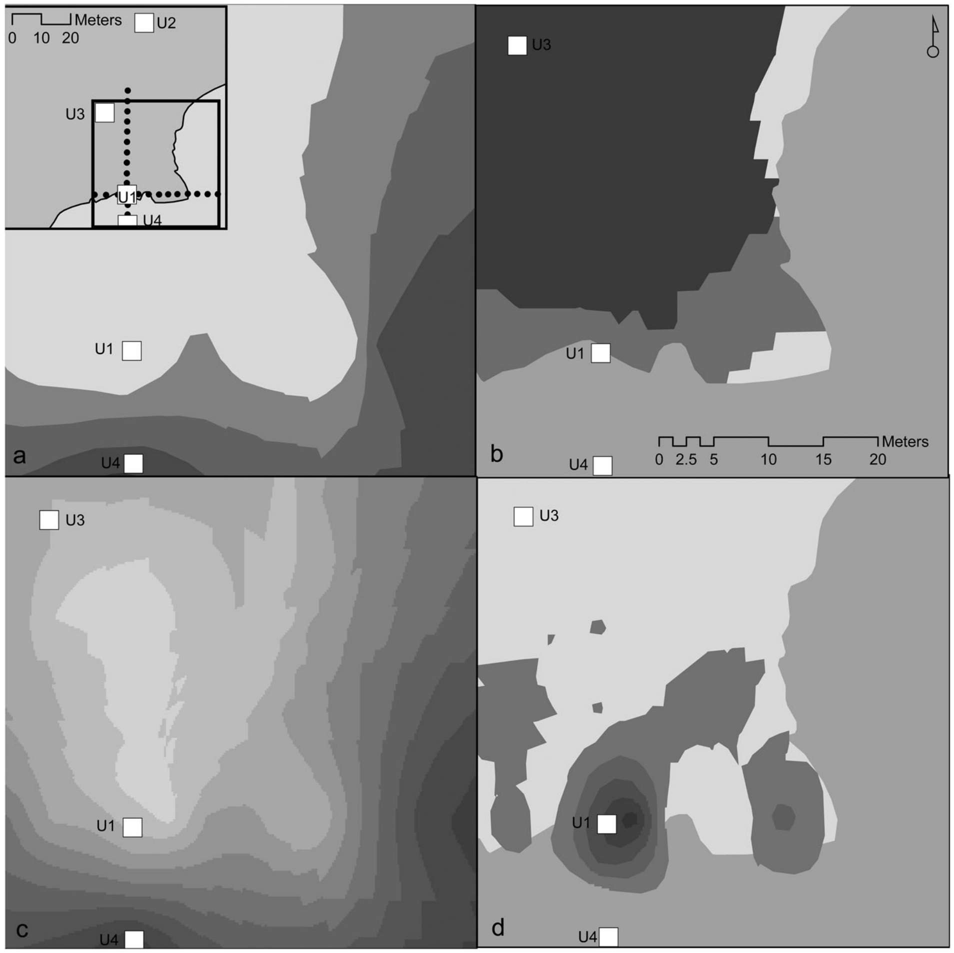

Figure 7. High-resolution map, Econfina Channel site, showing distribution of sediments and depositional zones: (a) darker zones show increasing amounts of sediments associated with eelgrass zone; (b) deflated quarry sediments (darkest gray, north and northwestern area of map) and deflated midden sediments (second darkest gray, directly south and southwest of deflated quarry sediments); (c) average sediment particle sizes, with darker grays denoted smaller grain sizes; (d) midden area and eelgrass sediments, with midden area denoted in darker grays.

considered to minimize the large reservoir effects from dating shell. Amino acid racemization would be an additional method that could provide relative dates on the shell to assess the degree of vertical transport and disturbance within the midden (Koppel et al. 2016, 2017).

The $\delta^{13}C/^{14}C$ ratios become less negative in the younger levels, indicating the water salinity was lower for the lower stratigraphic layer but increased in the younger layer (Andrus and Crowe 2000:39). The most reasonable explanation is that the *Crassostrea* in the lower levels were collected farther inland, in somewhat fresher water than the younger ones. This is consistent with sea levels shifting landward as the coastline approached its modern position. The appearance of *Pecten* in the midden could indicate that this taxon from a fully marine environment may have been consumed here as well, though this is equivocal; if true, these items imply the use of watercraft despite the lack of direct evidence for them.

The ANOVA results suggest all stages of lithic reduction sequences are represented in the assemblage from Econfina Channel based on sizes ranging from large (>5 cm) primary reduction debitage to small (<2 cm) debitage suggestive of breakage and retouch. Spatial patterning is also apparent for different reduction stages. The partially exhausted blade core from the freshwater seep/spring area was refitted with a blade tool recovered from the midden over 50 m away (see Figure 2). Multiple examples of cobble testing, primary reduction debitage, and scraper/flake/blade tools were seen at the quarry zone, at the freshwater seep/spring, and close to the paleochannel itself, while smaller flakes were recovered from the midden and eelgrass area. The occupants at this location apparently made, used, and discarded tools within specific zones around the site, though the contemporaneity of these episodes cannot be securely demonstrated at this time (see Andrefsky 2007).

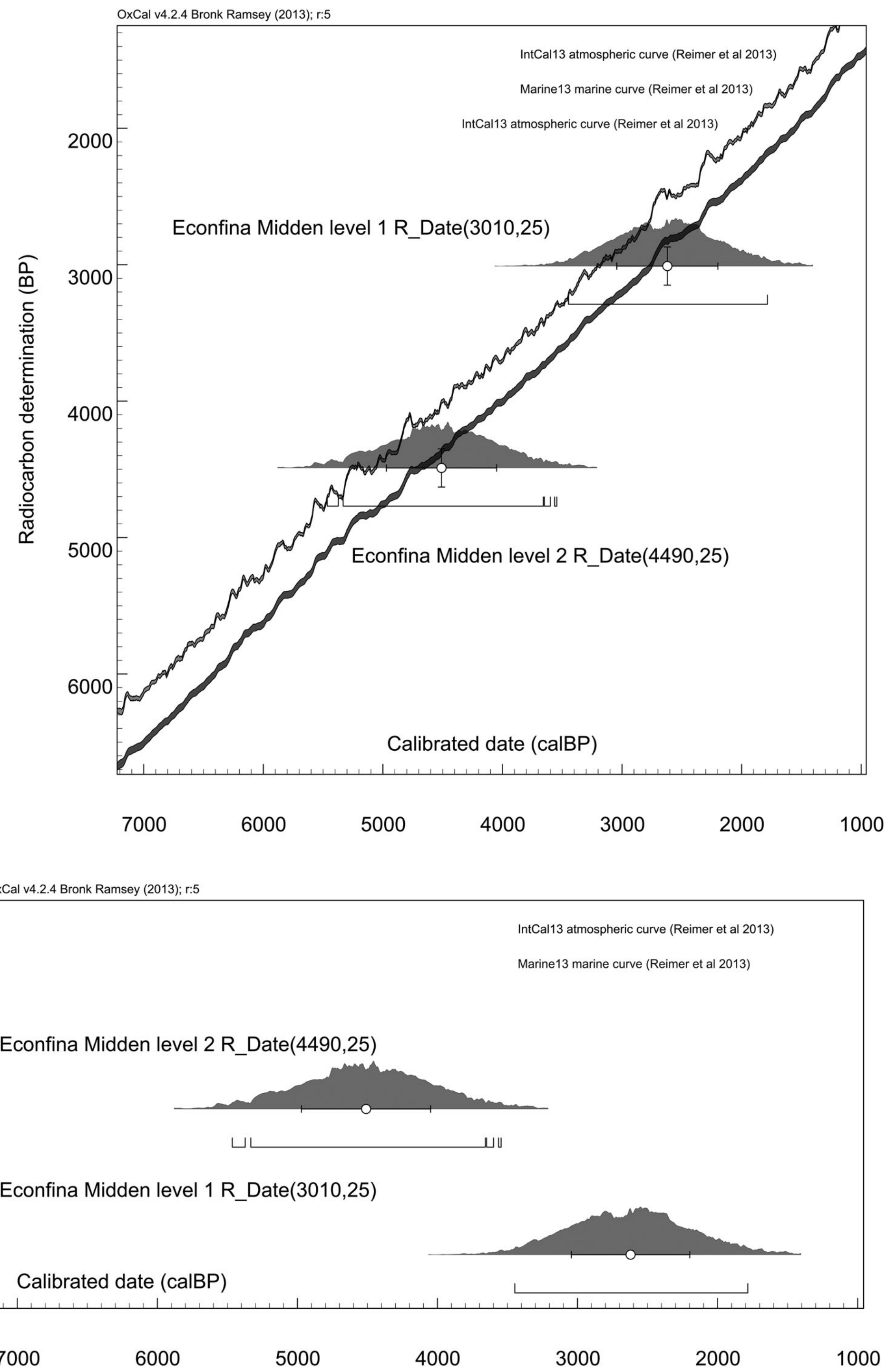

Figure 8. Calibrated ^{14}C dates from the Econfina Channel site midden.

Debitage showing use wear for multiple activities was found throughout the midden, as well. These activities include processing durable materials such as bone or antler, possibly shell, moderately durable materials such as wood, and soft materials such as meat or hides. Neither our study nor earlier excavations by Faught and colleagues (Faught 2004b; Faught and Donoghue 1997) detected bone from terrestrial taxa. This could be a preservation issue, but it is unclear to what degree given the recovery of bone from other nearby submerged sites such as J&J Hunt (8JE740). The debitage could be a secondary deposit but the distribution of the 4-mm particle size fraction does not support this. Statistical analysis correlates it well with the midden deposit, suggesting that this size fraction (and anything larger, such as debitage) has not been significantly remobilized during and

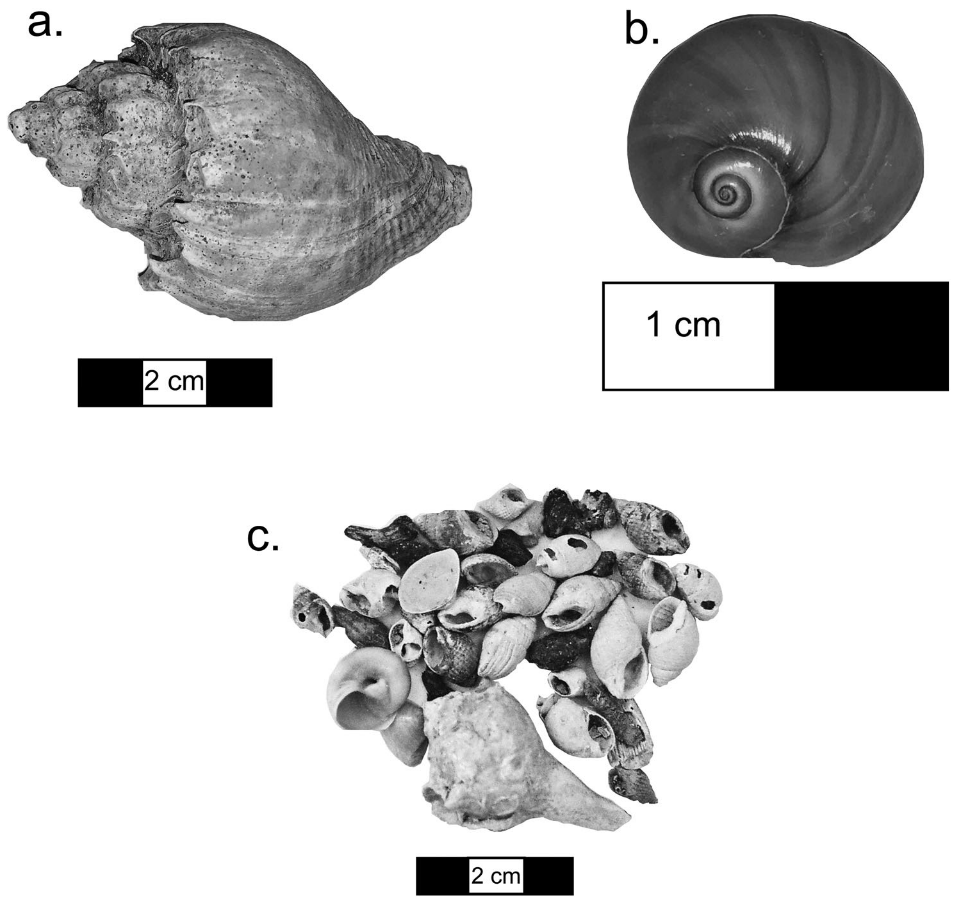

Figure 9. Apple snail and crown conch from midden deposit, Econfina Channel site, compared to gastropods from a suspected submerged midden from the Georgia coast: (a) *M. corona* (crown conch) from Econfina Channel Midden; (b) Ampullariidae (apple snail) from Econfina Channel site midden; (c) gastropods from probable submerged midden (target SB49, near Jekyll Island, Georgia, see Garrison et al. 2013 for comparison).

after submergence. Instead, the most parsimonious explanations are that either terrestrial faunal bone was systematically deposited elsewhere in the site, or that the use wear from working durable materials was created by manufacturing shell tools. Shell tool manufacture and use remains an area of emergent scholarship; the Econfina Channel site and other coastal sites like it present good opportunities to explore this topic further (see Allen et al. 1997; Arnold and Rachal 2002; Lammers 2008; Nigra and Arnold 2013; Szabo and Koppel 2015).

Mobility patterns cannot be directly inferred from our data, but several of our findings support informed speculation. According to FBAR inventories, Faught and colleagues recovered three bifaces, including one used as a scraper; one biface preform; and two flake tools. We recovered no bifacial tools; three flake tools; and three unifacial tools (see Figure 4). This gives a ratio of 4 total formal bifacial projectile points or preforms to 8 total flake or unifacial, informal tools. High ratios of informal to formal tools is considered suggestive by some of lower mobility but the relationship between tool type and mobility is not linear and can be complicated by other variables such as raw material availability or the nature of environmental risk in the local environment (Andrefsky 1994; Kelly 1992; Odell 1998). The dominance by shellfish in the midden as opposed to higher ranked prey is also suggestive of lower mobility. Additionally, lower ranked resources such as shellfish are less likely than higher ranked resources to undergo field processing, and this is especially the case when children or other physiologically limited members of a group are foraging (Bird and Bliege Bird 2000:471–472). The lack of terrestrial faunal remains may indicate terrestrial prey were processed elsewhere and brought to the site (Bird and Bliege Bird 1997; Bliege Bird et al. 2009:467). It could also indicate that terrestrial fauna simply was not consumed at this location when it was in use, which would argue against year-round occupation but does not rule out range circumscription within the watershed itself. The large marine reservoir correction required for radiocarbon dates on shell in this region makes it difficult to pinpoint when midden deposition began more precisely than the calibrated age of 4510 ± 461 cal BP, which falls in the Late Archaic, not Middle Archaic period. Despite this shortcoming, we can say that midden deposition occurred while Florida Stemmed Archaic points were produced, based on the dates from the midden. The younger date on the top level of the midden, recovered from an apparently anthropogenic context, returned a mean ^{14}C date of 2621 ± 423 cal BP, which is at least 1,400 years after the beginning of the Late Archaic period and well into the Woodland period, and also well after the shoreline was thought to have reached its roughly modern position in Florida (Balsillie and Donoghue 2011). While this date may be erroneous, it still raises questions about the relative sea-level curve in this area because the midden deposit averages 2–3 m below the modern sea level position. This discrepancy cannot be explained by glacial rebound (not a factor in this region), and these dates are much younger than the late Pleistocene and early Holocene sea level rises caused by meltwater pulses. The continental shelf in Apalachee Bay has an extremely low gradient, and even minor sea level changes can affect wide swaths of the bay; the most productive inference to be drawn from this data is that additional radiometric dating is needed in this region to clarify middle Holocene coastline positions. The site has undergone significant postdepositional erosion to different degrees within the site. Sediment analyses suggest fine sands in the quarry/midden zones experienced greater erosion and deflation since submergence than the same fractions in the eelgrass zones. PSA also cannot completely distinguish between midden versus quarry. Particle size analyses using PCA and LDA show significant overlap between midden and quarry sediments, even while the eelgrass zone clearly separates from the two. Charcoal appears in midden, quarry, and channel samples, suggesting either non-anthropogenic fire, or charcoal from anthropogenic fire that has been reworked by fluvial and marine processes, which is more consistent with marine processes. We interpret the overlap between the midden and the quarry zones as either postdepositional fluvial and marine processes conflating the midden and quarry zone sediments, or that these areas graded into one another during initial deposition. Nevertheless, interpolations using results from multivariate analyses correlate well with the zones mapped during visual survey.

While there was no serious argument against the anthropogenic nature of these features, following Gagliano and others (1982) we have falsified a hypothesis that they are natural. Our findings parallel Murphy's at the Douglass Beach site (8SL17) (Murphy 1990), arguing that individual components within the sediments are better suited to delineating intrasite areas, while the totality of all sediment components appears to best distinguish the site from the surrounding areas. In this case, shell, lithics, macro-debitage, and smaller debitage are the individual components separating the intrasite zones, while taken together they support the argument that these sediments experienced first anthropogenic alternation and then natural alteration after deposition. Even submerged sites disturbed by postdepositional processes yield useful data on human activities, but these taphonomic factors must be assessed before inferences can be made about them.

Conclusions

Although the Econfina Channel site does not contain the high degree of preservation often seen in onshore submerged sites such as Page Ladson (8JE591A), evidence for multiple activity areas can still be discerned, including exploitation of distinctly coastal resources by people who may have operated with lower mobility across the landscape than earlier cultural groups. We obtained useful datasets capable of supporting our interpretations by combining diver survey and mapping with limited excavation, bulk sediment sampling, and multiple geoarchaeological laboratory methods designed to tease out evidence for human activities. This maximized our limited underwater time at the site while still allowing us to characterize and interpret evidence for anthropogenic activities in this location.

Our findings have several important implications for future work on submerged offshore prehistoric sites with mixed preservation. First, while protected sites such as submerged sinkholes with intact stratigraphy remain ideal for submerged prehistoric studies, it is likely that disturbed sites such as Econfina Channel are more common than better-preserved ones. Scholars concerned with human activities on submerged continental shelves will have to contend with these less-than-ideal site conditions, and our study demonstrates how alternate approaches can still render useful data. Second, despite the shortcomings of preservation, we have good evidence that Econfina Channel is more akin to sites such as the Mitchell River, west of Apalachee Bay, which was first used during the Middle Archaic, and occupied into the Late Archaic (Mikell and Saunders 2007:172–174). Our study thus extends patterns for coastal resource use into the offshore zone, bringing the now-submerged continental shelf back into the wider archaeological picture for this region as climate, ecology, and human landscape interactions changed from the late Pleistocene into the beginning of the late Holocene. Third, these findings expand upon the predictive model that has been used to search for submerged sites in Apalachee Bay since the 1980s, demonstrating a site type different from Page Ladson inland or J&J Hunt offshore. This adds nuance to predictive modeling efforts that will allow future studies to target a variety of high probability zones for multiple different site types. Finally, our study furthers the argument that testing for intensively occupied, older coastal sites should continue out on the continental shelf. Without the incorporation of the submerged, formerly terrestrial prehistoric landscapes into their wider regional archaeological contexts, we cannot reliably interpret the full suite of human behaviors during prehistory.

Note

1. Tidal range in Apalachee Bay is approximately 0.7 m (2 ft), on a 12-hour cycle, and depth ranges vary based on the cycle. The net effect is that a feature can be found at 2.7 m (9 ft) in depth at one point in the day, or closer to 1.8 m (6 ft) when the slack tide is at its lowest point.

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Data availability statement

Lithic materials are curated with the Florida Bureau of Archaeological Research (FBAR). Shell and sediments are curated at the University of Georgia Geoarchaeology Laboratory. The data collected during this study can be accessed from the institutions at which they are curated or by contacting the authors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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