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Late Holocene Sedimentation and Paleoenvironmental History for the Tidal Marshes of the Potomac and Rappahannock Rivers, Tributaries to Chesapeake Bay

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ABSTRACT

Instrumental tide gauge records indicate that the modern rates of sea-level rise in the Chesapeake Bay more than double the global average of 1.2-1.5 mm yr-1. The primary objective for this study is to establish a relative depositional history for the tidal marshes of the Potomac and Rappahannock Rivers that will help us improve our understanding of processes that influence sedimentation in the proximal tributaries of Chesapeake Bay. Marsh cores were collected from Blandfield Point VA, Tappahannock VA, and Potomac Creek VA. The sedimentary facies include: 1) a lower unit of organic-poor, grey clay with fine sand and silt layers and estuarine foraminifera; and 2) an upper unit of organic-rich clay and peat with abundant brackish to freshwater marsh foraminifera and thecamoebians. AMS 14C dating of bulk marsh sediments yield sedimentation rates at Potomac Creek ranging from 3.04-4.20 mm yr-1 for the past 2500 years. Rates of sedimentation calculated for Blandfield Point indicate 1.37-2.19 mm yr-1 in the basal clays and peat for the past ~3000 years. Foraminiferal census counts indicate a freshening upward trend with a transition from an estuarine Ammobaculites crassus assemblage to a marsh Ammoastuta salsa assemblage with abundant freshwater Thecamoebians. The late Holocene history of sedimentation for the marshes indicates that differential compaction, recent land use practices, and climate change have contributed to the resultant freshening-upward environmental trend and variability in sediment accumulation rates between coring sites.

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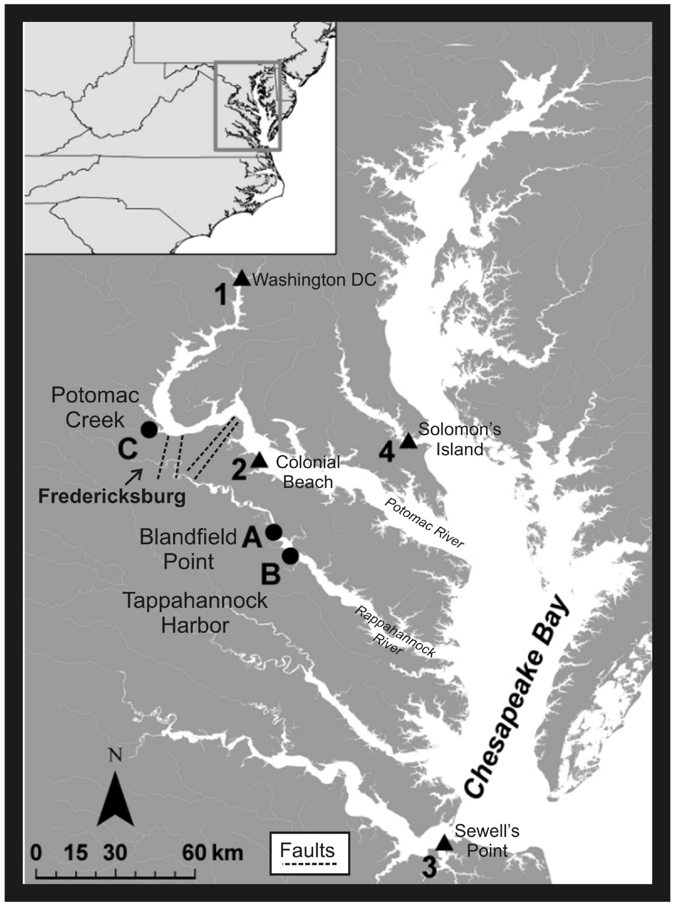

FIGURE 1. Location map for the tidal reaches of the Potomac and Rappahannock Rivers. Table1 lists the coordinates and detailed coring information for Sites A-C. Table 2 list coordinates and details for the tide gauge stations (Sites 1-4). Inset shows our location along the eastern Atlantic coast of the USA.

INTRODUCTION

The Chesapeake Bay watershed comprises numerous tributaries draining from the eastern Appalachian Mountains. The central axis to the Chesapeake has been evaluated in the context of decadal, centennial, and millennial climate changes (Cronin and others 2005, 2010). In the historic Northern Neck region of Virginia, the tidal reaches of the Rappahannock and Potomac Rivers (Fig. 1) have received little detailed study with respect to the nature of the sedimentary record spanning the past several thousand years. Recent estimates for eustatic sea level are estimated to be as high as 1.5-1.88 mm yr^{-1} (Church and White 2006, Nerem and others 2006) whereas the instrumental tidal

TABLE 1. List of sampling localities from the Potomac and Rappahannock tidewater region of Virginia and Maryland.

Site	Location	Longitude	Latitude	Geographic Info
Site A	Blandfield Point VA	76°54'40.436"W	38°0'6.911"N	Blandfield Marsh on Rappahannock River (proximal estuarine zone 0-5 ppt)
Site B	Tappahannock Harbor VA	76°51'15.368"W	37°55'16.723"N	Coleman's Island, Hoskin's Creek tributary to Rappahannock River (distal tributary to central estuarine zone)
Site C	Potomac Creek VA	77°20'7.619"W	38°21'6.972"N	Potomac Creek tributary to Potomac River (central estuarine zone 5-15 ppt)

records from the Chesapeake Bay indicate rates as high as ~3-4 mm yr^{-1} (Boon 2012). The disparity between global and regional base level change in the Chesapeake Bay is not well understood and likely reflects the combined effects of allogenic, autogenic, and anthropogenic processes in the region (Cronin 2012). The primary objective for this paper is to establish a late Holocene sedimentation and paleoenvironmental history for the tidal reaches of the Potomac and Rappahannock Rivers in the Northern Neck region of Virginia, USA. Our primary analytical tools include physical stratigraphy (loss on ignition, grain size, and magnetic susceptibility), foraminiferal paleoecology, and AMS ^{14}C geochronology applied to cores collected from the central estuarine region of the tidal Potomac and Rappahannock Rivers.

BACKGROUND

The Chesapeake Bay is the largest estuary in the United States, with shores bordering the states of Virginia, Maryland, and the District of Columbia. The watershed area of this coastal plain estuary is 167,000 km^2 that includes the following major tributaries: Susquehanna, Potomac, Rappahannock, York, and James Rivers (Boesh and others 2001). The Chesapeake Bay is the product of Holocene sea-level rise formed by fluvial incision coupled with the inundation of river valleys following the terminus of the last glacial maximum (Schubel and Pritchard 1986). The Chesapeake Bay is located in an apparently inactive tectonic region on the North American passive margin. However, many Cretaceous age faults have been identified in close proximity to our localities in the Fredericksburg, VA (Table 1) which marks the transition from the Piedmont region (west) to the coastal plain (east) in Virginia (Fig. 1) (Berquist and Bailey 1999). Lower Tertiary sedimentary deposits in the region include fine-to coarse glauconitic quartz sand and clay-silt of the Lower Tertiary Pamunkey Group (Brightseat, Aquia, Marlboro, Nanjemoy, and Piney Point formations) (Mixon and others 1989).

TABLE 2. Tidal gauge data for the Chesapeake Bay (NOAA, 2009).

Locality	Instrumental Records	SL Rate mm yr-1	YBP	Tidal Station & Data Set Info NOAA Monthly Mean
1	Washington DC	3.16±0.35	87	8594900 (1924-2006)
2	Colonial Beach VA	4.78±1.21	39	8635150 (1972-2003)
3	Sewells Point VA	4.44±0.27	84	8638610 (1927-2006)
4	Solomons Island MD	3..41±0.29	74	8577330 (1937-2006)
✷	Global average	1.5±0.5	0	

During the past several decades, the National Oceanic and Atmospheric Administration (NOAA, 2009) has maintained tidal gauging stations at Colonial Beach and Washington DC (Table 1). The sea level rates calculated from the instrumental records on the Potomac River range from 3.16-4.78 mm yr^{-1} from Washington DC and Colonial Beach respectively (Table 2), which are significantly higher than eustatic values of 1.0-1.5 mm yr^{-1} (Table 2) (NOAA 2009; Boon 2012). The instrumental records from the lower Rappahannock at Sewell's point record a relative sea-level rise of 4.44 mm yr^{-1} spanning the past 84 years.

Cronin and others (2000, 2005, and 2010) and Cronin and Vann (2003) reported microfossils from cores (~2-6 m in thickness) located at the mouths of the major tributaries in the central regions of the bay (e.g., Patuxent, Choptank, and the Potomac Rivers). Willard and others (2003) and Cronin and others (2003) reported a high-resolution historical microfossil record that apparently discriminates important anthropogenic events such as the Medieval Warm Period and deforestation of the bay region with the arrival of European settlers.

METHODS

Marsh cores were collected from the Rappahannock and Potomac Rivers that includes Blandfield Point (Site A), Tappahannock Harbor (Site B), and Potomac Creek (Site C) (Table 1) (Fig. 1). A square-rod piston coring device was used to collect continuous 1-meter long core drives down a single coring hole (Wright 1967). Individual core sections were split along a longitudinal axis to produce two equal halves. Potomac Creek cores were evaluated for microfossils at 10 cm intervals. Approximately eighty 1 cm^3 sediment samples were soaked in a beaker of warm water and mild detergent to disperse the clays (Scott and Leckie 1990). Samples were rinsed over a 63 µm sieved and picked wet using conventional microfossil methods (Scott and Medioli 1980). Each sample was then examined for foraminifera and relative abundances were calculated for species and select genera to simplify the trends. Exceptionally preserved specimens were examined on the scanning electron microscope (SEM) for identification and illustration purposes.

The total organic matter (TOM) was determined by using loss on ignition (LOI) (Dean 1974). Grain size analyses were conducted using methods modified from McManus (1988). Volume magnetic susceptibility was conducted on sediments using a Bartington MS2E surface scanner following the method of split-core logging of Last and Smol (2001). Select bulk sediment samples were pretreated for radiocarbon dating at the University of Pittsburgh following the methods outlined by Abbott and Stafford (1996). AMS ^{14}C analyses were performed at the University of Arizona's Accelerator Mass Spectrometry Laboratory and the dates calibrated using Calib 6.1.0 (Reimer and others 2009).

RESULTS

Sedimentary Facies

Grey Clay Facies: The basal sediments at all coring sites comprise clay and sparse interbeds of silt and sand (Fig. 2). The grey clay facies ranges in thickness from ~7.5-4.25 m at Potomac Creek to ~5.5-2.5 at Tappahannock Harbor (Fig. 2). TOM values in the organic-rich clay range from ~8-28%. Magnetic susceptibility values are relatively low with positive excursion peaks in the silt-rich layers. Grain size analyses at Tappahannock Harbor indicate a coarsening-up trend from mud-to-silt and fine sand (Fig. 2). Foraminifera in the organic-rich grey clay are dominated by *Trochammina inflata*, and *Ammobaculites* spp. in association with sparse *Ammoastuta salsa* and *Miliammina fusca*. (Fig. 3).

Peat & Clay Facies: All cores contain an upper unit of alternating peat and grey clay with TOM values that range from ~20% to 85% (Fig. 2). Magnetic susceptibility values are relatively low with little variability. Microfossil populations in this facies are dominated by *Ammoastuta salsa* and *Miliammina fusca*. *Trochammina inflata* and *Jadaminna macrescens* are also common while *Haplophragmoides* is the least abundant (Fig. 3). Sedimentary cores from Blandfield Marsh and Potomac Creek (Fig. 2) are capped with an uppermost rooted zone of the grass *Phragmites* and the freshwater thecamoebian *Arcellacea* sp. (Figs. 2, 3).

Core Chronology & Sedimentation Rates

Accelerator Mass Spectrometry (AMS) ^{14}C dates obtained from Blandfield Point, Tappahannock Harbor, and Potomac Creek are listed in Table 3. Blandfield Point (Site A) yielded a basal age of 3100 ±50 ybp. Tappahannock Harbor and Potomac Creek yielded basal ages of 2658±43 and 2725±25 2430±25 ybp respectively. The uppermost samples at Potomac Creek (Site C) and Tappahannock Harbor (Site B) were determined to be post-bomb and are therefore excluded from our sediment accumulation rate analysis. Rates of sedimentation were calculated using the cal BP ^{14}C dates and the respective core depths (Fig. 4). Potomac Creek yielded the highest rates of 3.04-4.20 mm yr^{-1} for the past 2430±25 years. Both Blandfield Point and Tappahannock Harbor yield sedimentation rates that were relatively consistent during the past several thousand years (1.48-1.65 mm yr^{-1}) approaching those for estimates for late Holocene sea-level rise (Table 3). ^{137}Cs dates obtained in contiguous estuarine cores at Potomac Creek (Site C) and Blandfield Point (Site A) yielded sedimentation rates of 5.4 mm yr^{-1} and 4.5 mm yr^{-1} respectively (Tibert and others 2013).

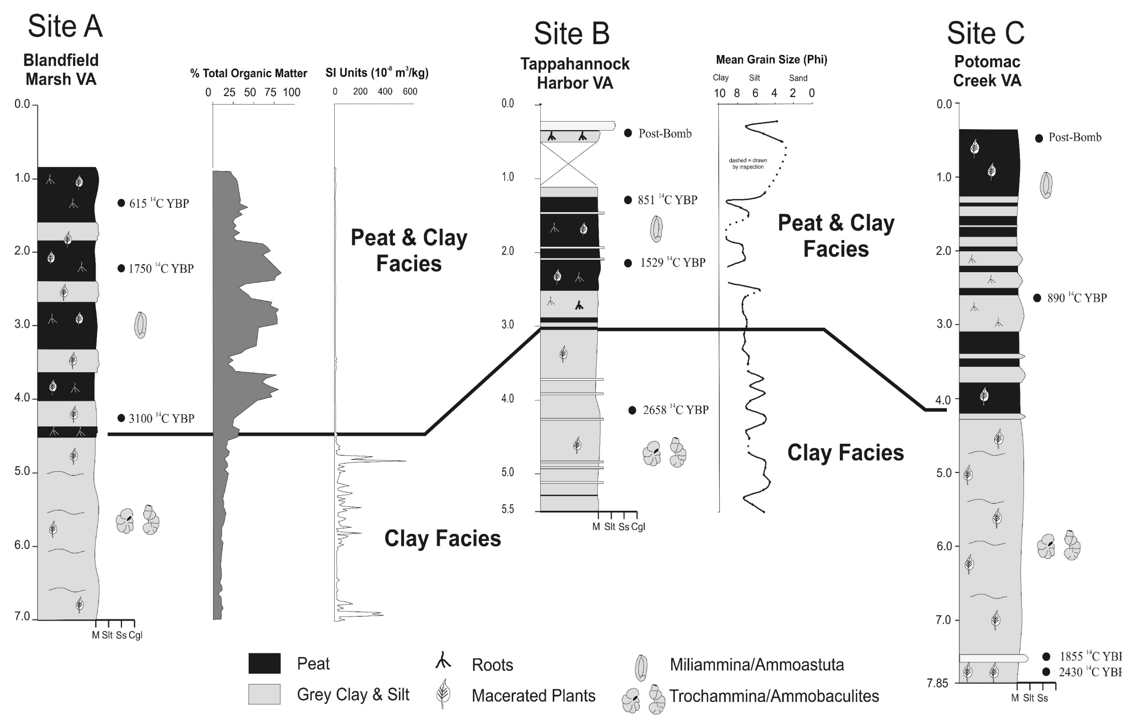

FIGURE 2. Physical stratigraphy of the sedimentary cores collected from the Rappahannock River (Site A Blandfield Point; Site B Tappahannock Harbor) and the Potomac River (Site C Potomac Creek VA). Locality information is listed in Table 1. Details on the AMS Carbon 14 radiometric dates are listed in Table 3.

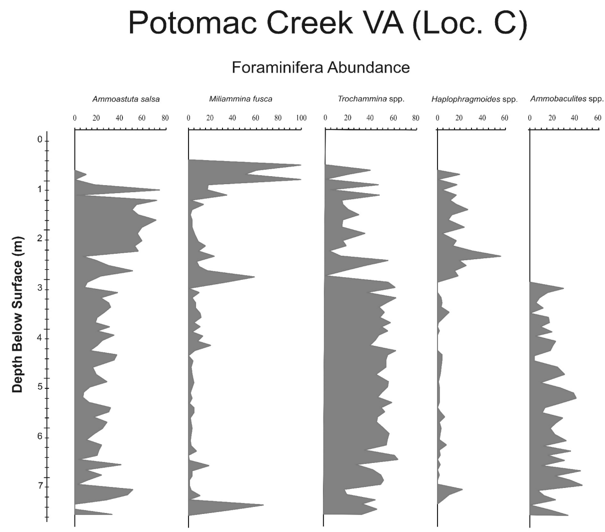

FIGURE 3. Relative abundance plots for the foraminifera recovered from Site C at Potomac Creek, VA.

TABLE 3. AMS ^{14}C dates and calculated rates of sedimentation for the Rappahannock and Potomac River marshes. Calibrations were performed using Calib 6.1.0 (Reimer and others, 2009).

Location	Sample #	Strat. Hgt (cm)	AMS ^{14}C	1σ cal. age ranges	unc. 14C Sed. Rate mm yr^{-1}	cal. ^{14}C Sed. Rate mm yr^{-1}
Blandfield Point VA	RA-07-C2-132	132	615±20	cal BP 557-648	2.15	2.19
	RA-07-C3-231	231	1750±20	cal BP 1623-1703	1.32	1.39
	RA-07-C5-456	456	3100±50	cal BP 3263-3377	1.47	1.37
Tappahannock VA	RA-05-C1-0.37	37	post-bomb	NA	NA	NA
	RA-05-C@-1.31	131	851±58	cal BP 692-894	1.54	1.65
	RA-05-C3-2.29	229	1529±41	cal BP 1359-1511	1.50	1.60
	RA-05-C5-4.12	412	2658±43	cal BP 2743-2838	1.55	1.48
Potomac Creek VA	PT-08-PC1	50	post-bomb	NA	NA	NA
	PT-08-PC1	263	890±20	cal BP 744-897	2.96	3.21
	PT-08-PC1	747	1855±20	cal BP 1737-1824	4.03	4.20
	PT-08-PC1	762	2430±25	cal BP 2361-2648	3.14	3.04

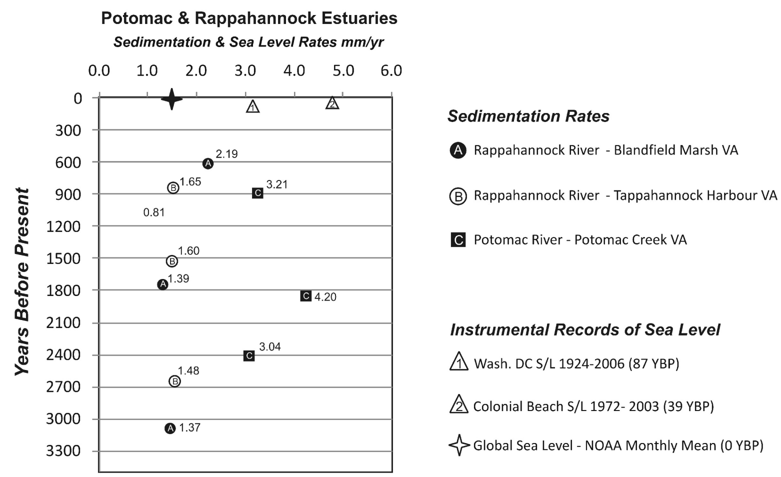

FIGURE 4. Sedimentation rates for the Potomac and Rappahannock marshes in Virginia and Maryland. Tables 1 and 2 list the coring site details and the tide gage station information (NOAA). Sites A-B from the Rappahannock River sedimentation rates match closely late Holocene rates of sea-level rise until ~600 YBP; rates increase sharply during the past several hundred years. Sedimentation rates at Rappahannock Sites A-B differ from Potomac Creek Site C that suggests differential compaction in the larger Potomac River catchment basin.

DISCUSSION

Paleoenvironmental Trends

Ellison and Nichols (1976) documented vertical zonation of foraminifera along a transect extending from the lowest low water-to highest high water positions at nearby Belle Isle on the Rappahannock River. Following this ecological model, we identify three primary foraminiferal assemblages (Figs. 5, 6) that includes an upland thecamoebian assemblage, a low-to high marsh *Ammoastuta salsa* and *Miliammina fusca* assemblage, and an estuarine *Ammobaculites* spp. assemblage (e.g., Ellison 1972). The grey clay facies of the Potomac Creek core (Figs. 2, 3) records an initial deep central estuarine environment with deposition of clay in association with the *Ammobaculites* assemblage (Figs. 2, 3). The overlying peat and clay facies contain abundant *Ammoastuta salsa* and *Miliammina fusca* that is consistent with peat accumulation that was likely influenced by differential compaction due to autogenic fluvial processes. The uppermost marsh deposits contain abundant macerated plant detritus and *in situ* roots from the plant *Phragmites*. Foraminiferal abundances in the uppermost sediments are low (no. < 10) and thecamoebians are relatively abundant which records the recent development of an upland, freshwater marsh. Ellison and Nichols (1976) also reported foraminiferal trends and radiocarbon results from nearby

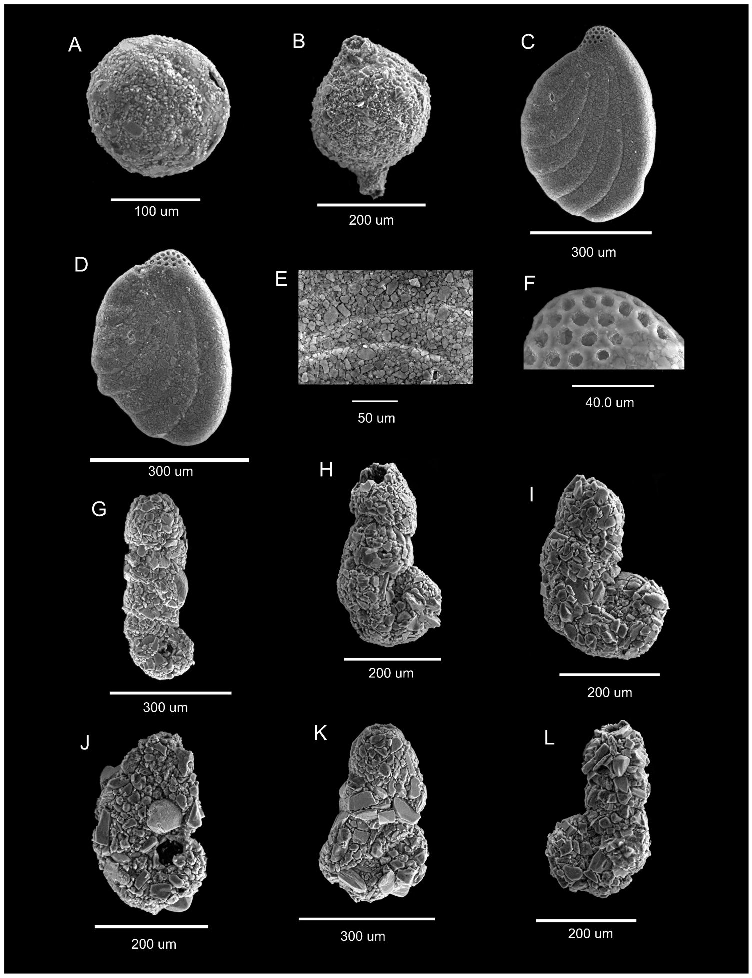

FIGURE 5. Agglutinated foraminifera and thecamoebians from Potomac Creek, Virginia (Site C). A-B. *Arcellacea* sp.; C-F. *Ammoastuta salsa* Cushman and Brönniman; G. *Ammobaculites crassus* Warren; H-K. *Ammobaculites dilatatus* Cushman and Brönnimann; L. *Ammobaculites exiguus* Cushman and Brönnimann.

Hunter Marsh on the Rappahannock River that indicates an approximate uncorrected ^{14}C age of 5780 ybp at the base of the core (9.22 m). Their biotic synthesis was that the fossil populations of the foraminifera changed from domination of open bay (more saline species) to less saline species (freshwater) up core. Considering this previous study and the trends reported herein, we interpret the sedimentary bay-filling sequence in the tidal reaches of the Northern Neck as a product of gradual and steady Holocene sea-level rise with both regional and global processes impacting sedimentation rates as discussed below.

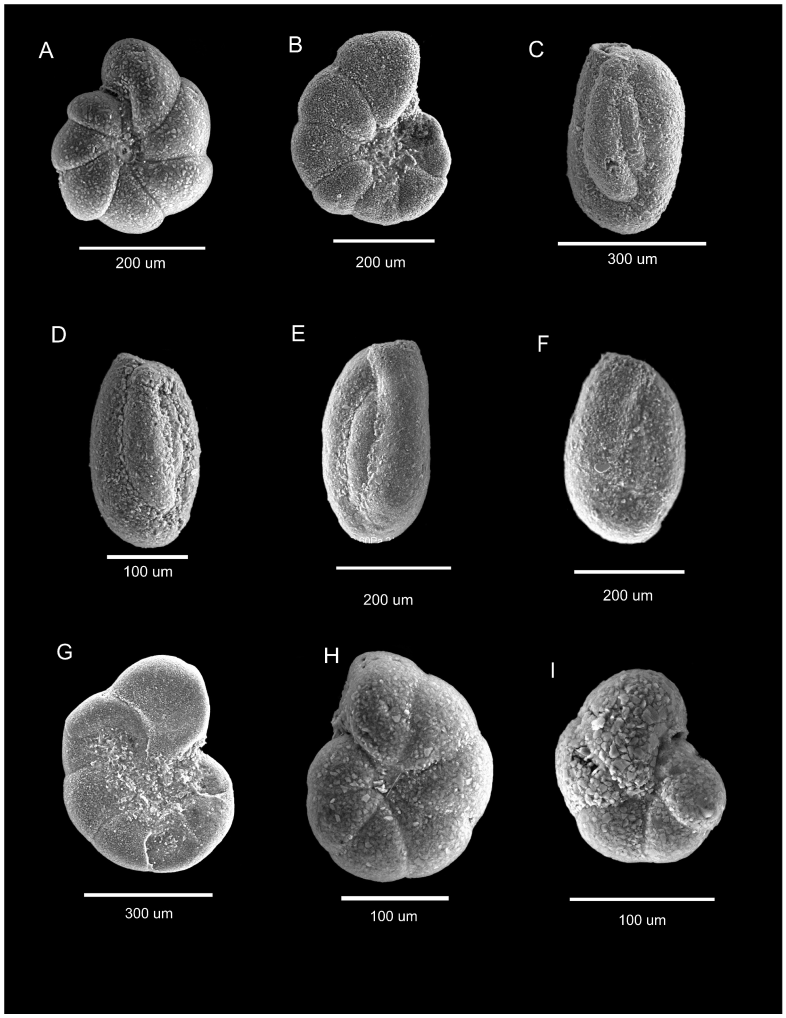

FIGURE 6. Agglutinated foraminifera from Potomac Creek, Virginia (Site C). A, I. *Haplophragmoides manilaensis* Andersen; B, G. *Jadammina macrescens* Brady; C-F. *Miliammina fusca* Brady; H. *Haplophragmoides wilberti* Andersen.

Late Holocene Compaction & Subsidence

The Chesapeake Bay region (Salisbury Embayment) is generally regarded as tectonically stable sedimentary basin (Mixon and others 1989) and should therefore be an ideal region to establish sea level baselines for global comparison. Microtidal marshes like those in the Chesapeake Bay region are also thought to present the highest potential for precise sea level predictions (Barlow and others 2013). Accurate predictive models, however, must take into account the role of glacial isostatic adjustment (GIA) in response to northern hemisphere deglaciation, regional compactional effects, and watershed specific sediment distribution patterns that complicate sea level studies (Barlow and others in press).

Rates for Holocene relative sea level change in nearby coastal Delaware and New Jersey may have been influenced significantly by GIA spanning the past 4000 years (Engelhart and others, 2011). These studies indicate that rates of relative sea-level rise for middle Atlantic marshes are on average higher (~1.7 yr^{-1}) than the baseline Holocene rate (~1.5 mm yr^{-1}). Although our results from Potomac River for the past ~2500 ybp support this assertion (2.96-4.03 mm yr^{-1}), the significantly lower rates at Rappahannock River (0.44-1.50 mm yr^{-1}) suggest that differential compaction due to the natural fluvial process might have contributed to the variable, longer term millennial rates of sedimentation in each basin. In this context of regional compaction, Horton and Shennan (2009) estimated that compaction in United Kingdom coastal marshes and estuaries may have contributed to as much 0.4-0.6 mm yr^{-1}, especially in the larger estuaries. The geographically large size of the Potomac River catchment basin, therefore, may have supplied a higher volume of sediment and in due course a higher rate of compaction due to sediment loading.

Late Holocene Climate Change

There is reasonable evidence to speculate that late Holocene temperature variability contributed to the abrupt environmental shift from estuarine clay to marsh peat and clay recorded in all cores between ~1500-800 ybp time interval. The Medieval Warm Period (MWP) has been reported from the main axis of the Chesapeake Bay as a relatively strong warmth signal that includes MWP I (1600-1100 ybp) and MWP II (1000-700 ybp) (Willard and others 2003; Cronin and others 2003, 2005, 2010). The marked change in foraminiferal assemblages from estuarine (*Ammobaculites* spp.) to marsh (*Ammoastuta salsa*) at Potomac Creek (Fig. 7) indicates a potential base level change on the order a meter or more that superimposed the late Holocene record for the middle Atlantic region (Engelhart and others 2011). The associated increased atmospheric warmth and humidity during the MWP maxima potentially contributed to the transgressive facies shift from grey clay to peat. With respect to 20th century climatic variability, Cronin and others (2005, 2010) have documented decadal and centennial intervals of extended warmth and humidity for the late 19th and 20th centuries that exceed the Medieval Warm Period by as much as 2-3^{o}C. In North Carolina, rates of relative sea-level rise from marsh records indicate a 3.0-3.3 mm yr^{1} sea-level rise that has been attributed to increased thermohaline expansion and/or mass loss from the Greenland Ice Sheet due to rising global temperature (Kemp and others 2009). The apparent freshening trends observed in the tidal reaches of the Potomac (Fig. 7) and Rappahannock suggest that regional sedimentary processes forced by climate change are confounding foraminiferal sea level studies in the recent sedimentary record.

Post Colonial Landuse History

Instrumental tide-gauge records from the Potomac River at Washington DC (upstream) and Colonial Beach (downstream) yield relative sea level values of

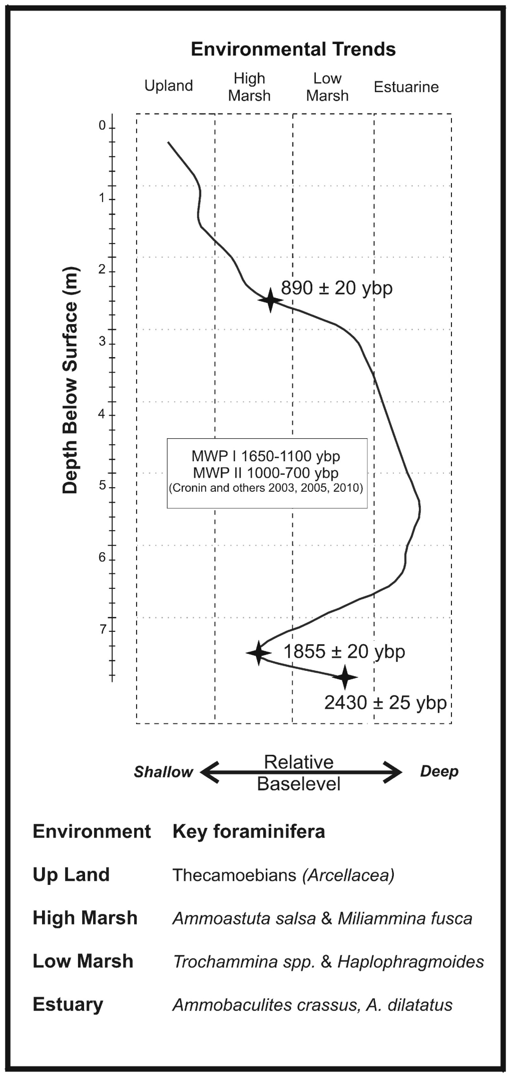

FIGURE 7. A simplified model to demonstrate the past ~2500 years of relative base level change at Potomac Creek. The onset of peat accumulation was preceded by a brief rapid rise in sea level that was broadly synchronous with the timing of Medieval Warm Period climate events recorded in adjacent Chesapeake Bay cores (Cronin and others 2003, 2005, 2010).

3.16±0.35 and 4.78±1.21 mm yr^{-1} respectively (NOAA 2009; Boon 2012) (Fig. 1, 5) (Tables 1, 2). Most studies clearly show that the rates of sedimentation for the Chesapeake Bay have increased significantly since initial European land clearance in 1760 CE (Cooper and Brush 1991, 1993; Colman and Bratton 2003). During the past

400 years, humans have altered the watershed of the Chesapeake Bay, by clearing land and creating impervious drainage surfaces that increase runoff, which ultimately increases erosion. A high abundance of fresh water thecamoebians and low abundances of foraminifera living in the modern marshes support this assertion. Consequently, the higher sedimentation rates observed in the uppermost sediments of all cores are attributed to increased erosion resulting from anthropogenic land use modification in the Rappahannock and Potomac watersheds. Our results indicate that localized sediment loading and regional compactional processes may have contributed to the apparent rates of accelerated rates of sea-level rise for the middle Atlantic region during the late 19th century (Kemp and others 2009, 2011; Tibert and others in press). The anthropogenic loading combined with the predicted increased humidity due to global warming combined with anomalous rate of sea-level rise could potentially exacerbate the coastal erosion problem in the Virginia tidewater region.

CONCLUSIONS

Marsh cores from tidal reaches along the shores of the historic Northern Neck region of Virginia record a complex sedimentation history for the past ~2500 years. We highlight five major sedimentological and paleoenvironmental trends as follows:

1. Grey clay rich with estuarine foraminifera (*Ammobaculites* spp.) characterize the basal facies in the marsh cores (~4-7 m);
2. Alternating peat and grey clay associated with marsh foraminifera (*Miliammina fusca* and *Ammoastuta salsa*) characterize the upper intervals of the cores (~1-4 m);
3. The uppermost rooted zones (~0.5 m) are dominated by freshwater grass *Phragmites* and microfossil populations dominated by freshwater thecamoebians;
4. The discordance in the ages observed at the base of the cores in the Rappahannock River and Potomac River marshes indicates that autogenic compactional processes have contributed to the variable rates of sedimentation during the past ~2500 ybp;
5. The sharp increase in sedimentation rates and upward freshening environmental trends at the top of the cores indicate that the combined influences of anthropogenic land use modification and climate change have contributed to high sediment volumes, increased freshwater influx and salt marsh deterioration, and variable fluvial compaction in the proximal tributaries of the Chesapeake Bay.

The high rates of sedimentation and patterns of deposition in the Potomac and Rappahannock region underscore the potential for significant coastal erosion and land management problems with the threat of further sea-level rise in the decades to come.

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ABBREVIATED TAXONOMY

Ammoastuta salsa Cushman and Brönnimann 1948
Figure 5 C, D, E, F

Ammoastuta salsa (Cushman and Brönnimann) 1948, p.17, pl. 3. – ELLISON and NICHOLS 1970, p. 15, pl. 2, fig. 3.

Remarks: *Ammoastuta salsa* has elongate chambers whereas the later formed chambers increase in size progressively. *Ammoastuta salsa* has a distinct aperture consisting of numerous perforated openings.

Ammobaculites crassus Warren 1957
Figure 5 G

Ammobaculites crassus WARREN 1957, p. 32, pl. 3, figs. 5,6,7. – ELLISON and NICHOLS 1970, p. 15, pl. 2, fig. 4.

Remarks: *Ammobaculites crassus* has a large test with progressively increased inflation of the chambers. The terminal aperture is large and circular.

Ammobaculites dilatatus Cushman and Brönnimann 1948
Figure 5 I, H, K

Ammobaculites dilatatus CUSHMAN and BRÖNNIMANN 1948, p.39, pl. 7, figs. 3, 4.
Ammobaculites cf. A. dilatatus Cushman and Brönnimann. – ELLISON and NICHOLS 1970, p. 15, pl. 2, fig. 5.

Remarks: *Ammobaculites dilatatus* has a compressed test with 2 or 3 chamber s in a serial array. The final chamber is truncated in appearance a terminal aperture.

Ammobaculites exiguus Cushman and Brönnimann 1948
Figure 5 L

Ammobaculites exiguus CUSHMAN and BRÖNNIMANN 1948, p.38, pl. 7, figs. 7, 8.
Ammobaculites cf. A. exiguus Cushman and Brönnimann. – ELLISON and NICHOLS 1970, p. 15, pl. 2, fig. 6.

Remarks: *Ammobaculites exiguus* has a broad initial coil region that uncoils into a parallel and even uniserial array. The chambers and sutures are relatively indistinct with a terminal aperture that is small and circular.

Haplophragmoides manilaensis Andersen 1953
Figure 6 A, I

Haplophragmoides manilaensis ANDERSEN 1953, p. 22, pl. 4, fig. 8. – ELLISON and NICHOLS 1970, p.16, pl. 1, fig. 6. – SCOTT AND OTHERS 1991, pp. 385, pl. 1, figs. 18, 19.

Remarks: *Haplophragmoides manilaensis* has a small, deep umbilicus with inflated chambers that increase in size with growth. Sutures are etched deeply, straight, and protrude in a radial direction outward from the center. An elongate aperture is located below a rim-like protrusion on the terminal chamber.

Haplophragmoides wilberti Andersen 1953
Figure 6 H

Haplophragmoides wilberti ANDERSEN 1953, p. 21, pl. 4, fig. 7. – ELLISON and NICHOLS 1970, p.16, pl. 1, fig. 7.

Remarks: *Haplophragmoides wilberti* has slightly inflated chambers with tight, planispiral coiling. Sutures are straight to slightly sigmoidal.

Miliammina fusca (Brady 1870)
Figure 6 C, D, E, F

Quinqueloculina fusca BRADY 1870, p. 47, pl. 11, figs. 2, 3l
Miliammina fusca (Brady). SCOTT and others 1991, pp. 386, pl. 1, fig. 14. – ELLISON and NICHOLS 1970, p.16, pl. 1, fig. 4. – SCOTT and MEDIOLI 1980, p. 40, pl. 2, figs. 1-3.

Remarks: *Miliammina fusca* has elongate chambers that vary in size. The aperture is located at the terminal end of the final chamber.

Trochammina inflata (Montagu 1808)

Nautilus inflata MONTAGU 1808, p. 81, pl. 18, fig. 3.
Trochammina inflata (Montagu) – SCOTT and others 1991, pp. 388, pl. 2, figs. 7, 8. – ELLISON and NICHOLS 1970, p.16, pl. 1, figs. 8, 9. – SCOTT and MEDIOLI 1980, p. 44, pl. 4, figs. 1-3.

Remarks: *Trochammina inflata* is a relatively large and robust trochospiral taxon with prominent inflation of the chambers.

Jadammina macrescens (Brady 1870)
Figure 6 B, G

Trochammina inflata (Montagu) var. *macrescens* BRADY 1870, p. 290, pl. 11, figs. 5a-c.
Jadammina polystoma BARTENSTEIN and BRAND 1938, p. 381, figs. 1a-c, 2a-1.
Trochammina macrescens Brady. – ELLISON and NICHOLS 1970, pp.14, pl. 1, figs. 10, 11. – SCOTT and MEDIOLI 1980a, p. 44, pl. 3, figs. 1-8.
Jadammina macrescens Brady. – SCOTT and others 1991, pp. 388, pl. 2, figs. 10, 11.

Remarks: *Jadammina macrescens* has a thin, trochospiral test with numerous pores in the terminal aperture.

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