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Environmental Changes Based on a Multi-Proxy Analysis of a 1500-year Tidal Marsh Core from Benedict, MD.

Kathryn Howard, Casey Card, Mason Chandler, Annie Geoly, Chloe Harper, Zachary Kapus, Emme Kasprzyk, Audrey Lumsden, and Kristen St John. James Madison University, Harrisonburg, VA, United States.

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Background

This research focuses on sediment core B1A, a 300 cm tidal marsh core collected from a Chesapeake Bay marsh in Benedict, MD located in the Patuxent River watershed. Tidal marshes and estuaries are sensitive to changes in sea level and sediment influx from natural and anthropogenic influences.

Figure 1. From Left to Right: Tidal marsh field location where the core was retrieved from. Core retrieval process. Harper, Chloe vertically bisecting the core to create an archive and working half.

Purpose

The research aim was to characterize the sediment record and lithologic facies present in the core via a multi-proxy approach, and to infer environmental changes and anthropogenic impact throughout the last 1500 years.

Site Location

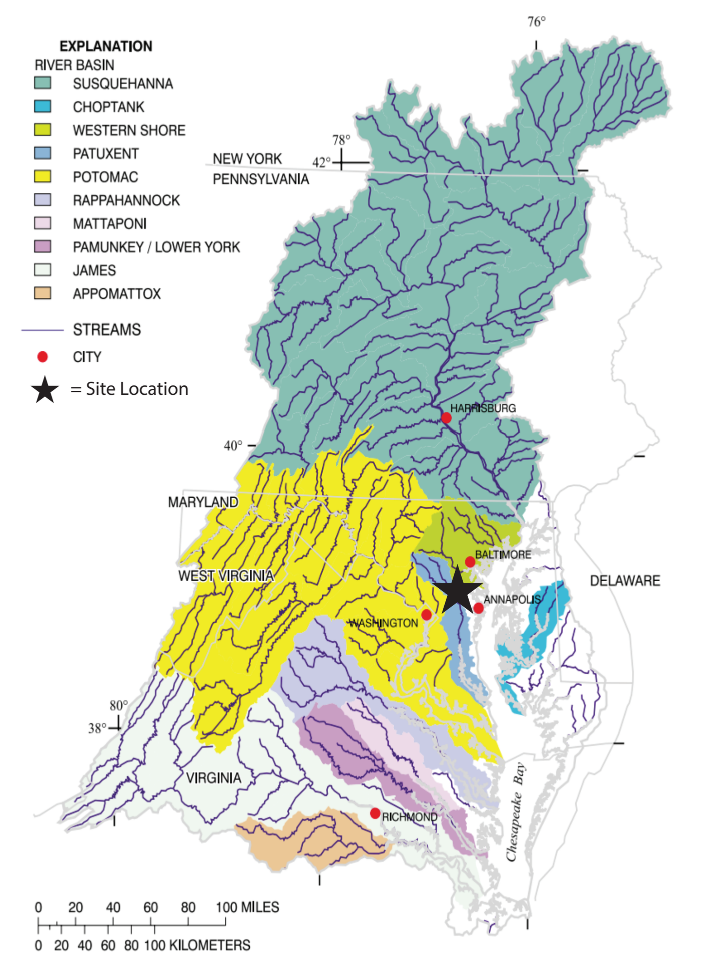

Figure 2: Map of Chesapeake Bay watershed and estuary. (Langland and Cronin, 2003) Site is located in the Patuxent river basin.

Methods

Categories		Utility	Process
Non-Destructive	Troels Smith (T-S) Core Description and Smear slides	To characterize core sediments and create a detailed and standardized description of core lithologies by describing compositions, identifying event horizons, boundaries where lithological units change, and interpreting depositional environments.	Documented observations via spreadsheet and sketch, noting composition (mineralogical and organic) and physical properties (Munsell color classification, darkness, stratification, dryness, elasticity, facies boundaries). From this information, lithofacies boundaries were identified.
	Access to Previous Core Imaging	High-definition photos of the cores showing their color and features.	Core scanning and imaging at the USGS in Reston, VA in Fall 2023 (see Harper, 2024)
	X-ray Fluorescence (XRF)	To obtain elemental data about the core. XRF data can be used as geochemical proxies to determine stratigraphic changes, infer past changes in environmental and climate conditions, and anthropogenic influences. Additionally, the horizon with anomalously high lead (Pb) levels was used as an age-depth marker.	Using the MCS-1000E Core Scanner and BRUKER XRF analysis gun, the archive core half was measured and scanned. Data collected during scanning was processed through Artax software to refine, identify key elements, create a model of the results, and export to Excel for further normalizing and analysis
Sampling	Access to previous Radiocarbon Dating	To create an age model for the core allowing conversion from depth to age and for sedimentation rates to be calculated.	Completed by Harper and St John in Fall 2023 (See Harper, 2024) Four samples (3 of plant material and one of sediment organic carbon) were taken from the working half of the core and sent to the NOSAMS lab. One plant sample was omitted because of very high uncertainty in results. Data were calibrated using Calib 8.2 and IntCal 20.14c curve.
	Loss on Ignition	To get information on the percent total organic carbon (% TOC), useful for determining stratigraphic changes from more carbon-rich marshes to those of lower-carbon estuary settings.	A total of 15 approximately 10 cc samples were collected at random from each core section. Samples were divided in half into "A" and "B" sections. "B" section samples were set aside for future use. "A" section samples were dried in an oven on low heat and then disaggregated using mortar and pestle. They were weighed and roasted in a 550°C oven for 1.5 hours and reweighed to determine the mass of organics lost during roasting. These values were then converted to a percentage to represent % of lost organics.
	Grain Size Analysis (LDSPA)	To obtain average grain size abundances to determine stratigraphic changes in grain size.	Samples used for Loss on Ignition to determine %TOC were re-used for grain size analysis. Roasted samples were re-hydrated and disaggregated using 10% Calgon solution. After resting, samples were placed in an ultrasonic bath (BRANSON Bransonic® Ultrasonic Bath), further aerated, and stirred. Samples were then run through the Laser Diffraction Size Particle Analyzer, (LDSPA) Beckman Coulter, LS 13 320. Data was then collected, graphed, and interpreted.
	Smear Slides	Supplemented the Troels Smith method to determine lithology by examining the composition and texture of select samples using a petrographic microscope.	Sediment was transferred from the core to a glass cover using a wooden toothpick, mixed with a drop of DI water, and spread evenly before drying on a hot plate. Norland optical adhesive was placed on a glass slide, and the assembled slide was cured under UV light to set the adhesive.
	Wet Sieving & Binocular Microscope Analysis	To determine the general composition of the sand fractions, and analyze for paleo-environmental indicators such as benthic foraminifera.	A total of 15 approximately 10 cc samples were collected at random from each core section. Samples were divided in half into "A" and "B" sections. The "B" section samples previously set aside were soaked in 10% Calgon solution to disaggregate. Samples were washed through 2 mm, 250 um, and 63 um sieves. Using a Leica M125 High-Resolution Trinocular Microscope, the sand and large size fraction (>2 mm and 250um-2mm) wet samples were examined and described underneath magnification with a binocular microscope. Samples were examined specifically for benthic foraminifera as paleoenvironmental indicators.

Age Model

An age model was established using three carbon dates from Harper et al (2024), as well as an excursion in lead from XRF data marking the year 1974, providing a historical marker. Sedimentation rates increase upcore, from 1.4 mm/yr between 474 CE and 1763, to 2.6 mm/yr between 1763 and 1974. A much higher rate of 10.4 mm/yr since 1974 is attributed to the lack of compaction of recent marsh vegetation. Sedimentation rates for older intervals are similar to that of published rates (0.17-0.2 cm/yr; Cronin et al 2019) for regional marshes.

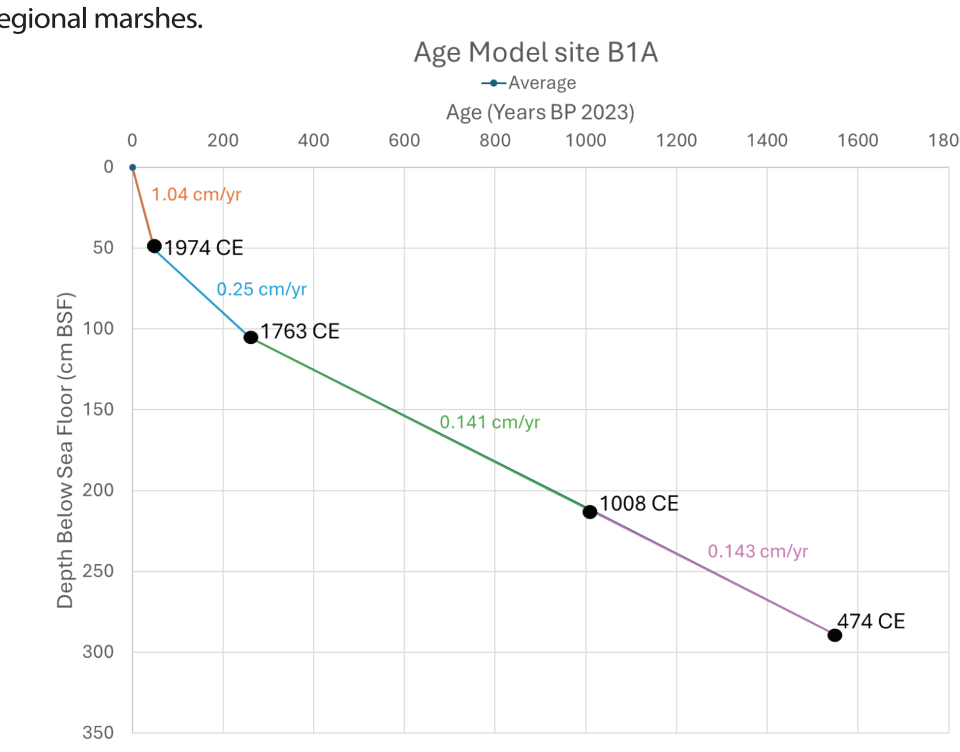

Figure 3: Age-Depth model and calculated sedimentation rates

Results and Interpretations

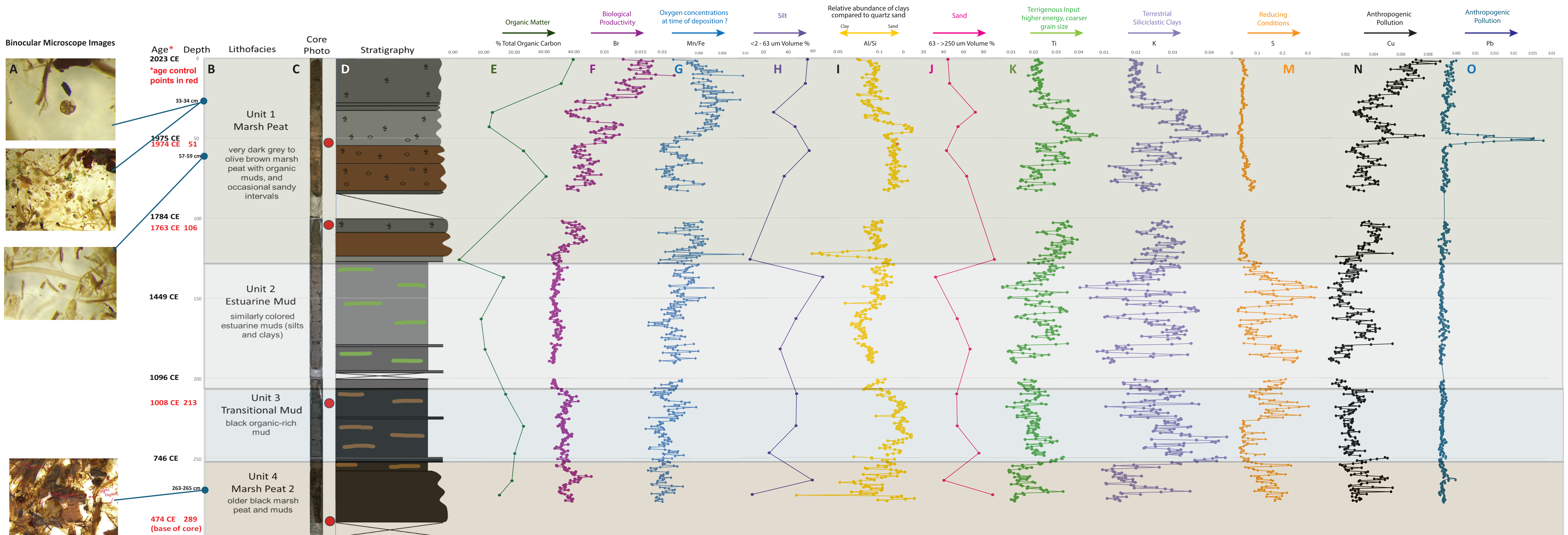

Figure 4. Summary diagram of A) Binocular Microscope Images, B) Lithofacies, C) Core photo, showing the archive half of the core, D) Stratigraphy, core drawing synthesizes information collected by Troels Smith core description method. Legend: = plant material, = vesicles, lines of green or brown represent mottled coloring on the cut surface of the core. E) % Total Organic Carbon, F) Br (Bromine) elemental data, G) Mn/Fe (Manganese/Iron) ratio elemental data, H) Silt %Volume, I) Al/Si (Aluminum/Silicon) ratio elemental data, J) Sand %Volume, K) Ti (Titanium) elemental data, L) K (Potassium) elemental data, M) S (Sulfur) elemental data, N) Cu (Copper) elemental data, O) Pb (Lead) elemental data. Elemental interpertations indicated with labeled arrows above each graph based on Rothwell and Croudace 2015.

Key Takeaways

1. Four lithologic facies (Units) were identified: (Unit 1) marsh peat with organic muds and occasional sandy intervals (Unit 2) estuarine muds, (Unit 3) a transitional mud, and (Unit 4) an older marsh peat and mud. Each facies contains lenses of fine quartz sand, indicating brief periods of high erosion due to storms and other events from the watershed.
2. Marsh Units (1 & 4): In Unit 1 High TOC and Br reflect organic-rich, productive conditions with reducing environments indicated by low Mn/Fe and high S. Unit 4, contradictorally, has much lower TOC and Br, despite being made up of decomposing plant matter and marsh peat. Layers and lenses of quartz sand and higher Ti indicated periods of high erosion due to storms and other events from the watershed
3. Estuarine Mud Unit (2): Low TOC and Br, paired with high silt content, Ti, K, and Al/Si, indicate fine-grained sediment deposition in a low-energy estuarine environment. Elevated Mn/Fe suggests more oxygenated conditions.
4. Transitional Mud Unit (3): Moderate TOC, variable silt and sand percentages, along with transitional values in Mn/Fe and S, suggest fluctuating depositional energy and mixed sediment sources.
5. Shifts in lithofacies are likely controlled by regional sea level rise (RSLR), smaller-scale intra-marsh dynamics (e.g., drainage shifts), sediment transport processes, and high energy events (e.g., river input; storms).
6. Overall sedimentation rates increased from 0.141 cm/yr around 1008 CE to 1.04 cm/y rafter 1974, indicating ongoing but variable sediment accumulation. Given current rates of sea level rise in the Chesapeake Bay of 3.1-4.5 mm/year (Cronin et al 2019) these findings suggest that the marsh's ability to keep pace with modern rising sea levels is unlikely.

Next Steps

- Pollen analysis will be used an additional proxy for this core. Samples from 10cm intervals throughout the core were taken and processed, creating 16 slides. These pollen slides are currently being counted for species/floral abundances. This can be used as a proxy for temperature and humidity throughout the core.
- Integrate current data on core with ongoing work by Glenn Havelock at Kingston University, UK with diatoms to create a proxy record of salinity gradients.
- Preform clay minerals analyses using XRD to determine the relative abundances of major clay minerals (illite, chlorite, kaolinite, and smectite), which could help to interprete the XRF elemental data (e.g., K, Al/Si)

Acknowledgements & References

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Balascio N., et. al, 2019, A high-resolution mill pond record from eastern Virginia (USA) reveals the impact of past landscape changes and regional pollution history, Anthropocene.
Cronin, T.M. et al., 2019, Holocene sea-level variability from Chesapeake Bay Tidal Marshes, USA: The Holocene.
Harper, C., 2024, Lithofacies and Elemental Stratigraphy of a 1500-year Tidal Marsh Core, Benedict MD.
Rodysill, J., 2022, X-Ray Fluorescence Elemental Abundance Data Quality Assessments and Post-Processing Analyses:U.S. Geological Survey.
Troels-Smith, 1955, Brief guide to Troels-Smith sediment description scheme.
Croudace, I., Rothwell, R., 2015, Micro-XRF Studies of Sediment Cores: Applications of a non-destructive tool for the environmental sciences