The Hydrologic and Taphonomic Implications of Oxide Mineralization along Calvert Cliffs, Maryland, USA

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Introduction

- The Calvert Cliffs represent a dynamic coastal environment along the western shore of the Chesapeake Bay
- The lithology and hydrology results in REDOX reactions and active oxide mineralization, which re-shapes the shoreline
- Oxide mineralization also results in diagenesis of Miocene fossils (i.e., active, observable taphonomic alteration)

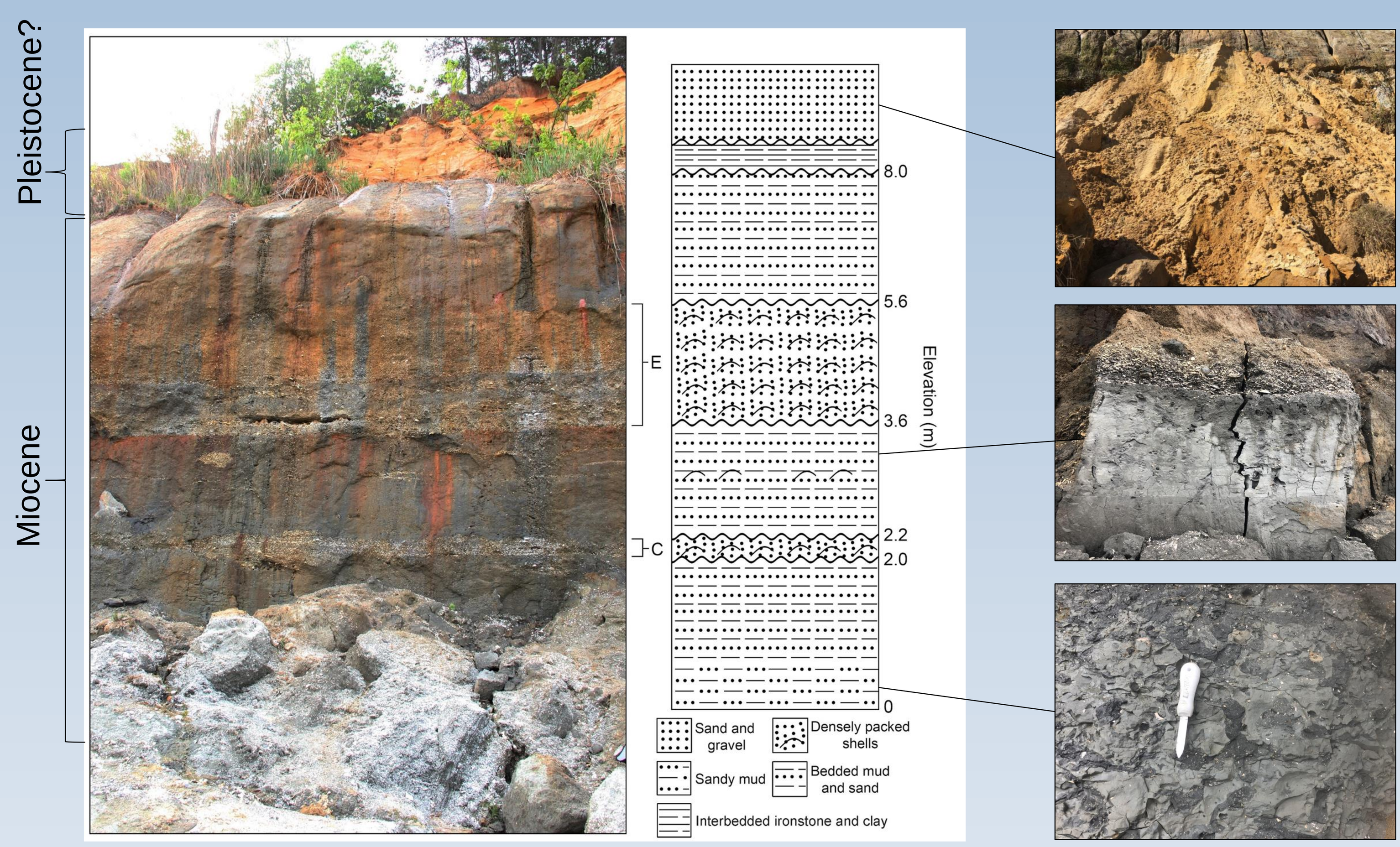

Fig. 1. Stratigraphy on the southern end of the Calvert Cliffs.[1,2] The basal marine Miocene unit is comprised of alternating clay-rich beds and shell beds. The overlying backshore to aeolian Plio-Pleistocene unit is comprised of coarse sands and gravel. Iron and manganese are leached out of the upper sandy unit.

Research Questions

1. How do oxide minerals form along the Calvert Cliffs and what minerals are present?
2. How does oxide mineralization affect fossil preservation?
3. How does oxide mineralization affect the local hydrology and cliff erosion?

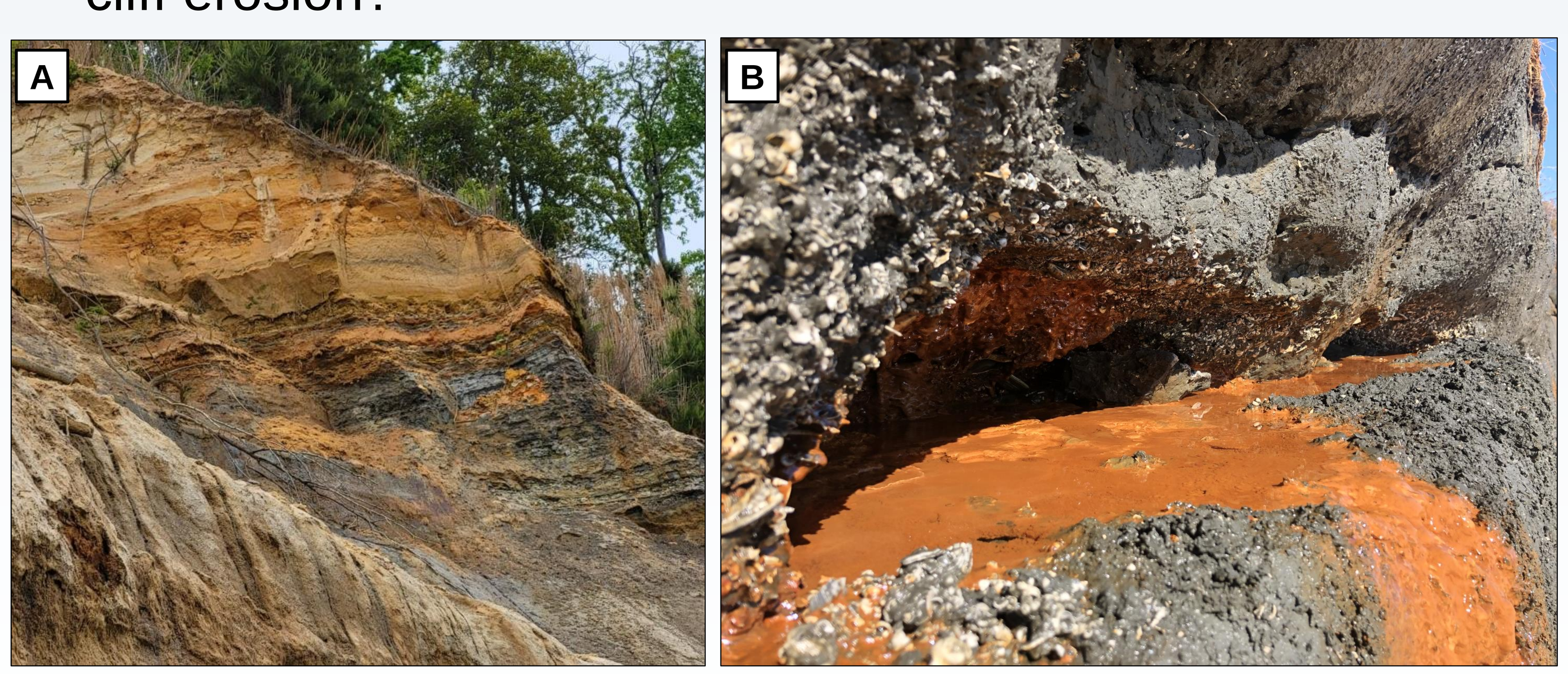

Fig. 2. Oxide mineralization occurs as Fe-Mn reduced fluids accumulate: **(A)** at the interface between the Pleistocene sands and Miocene clays and **(B)** on terraces formed due to differential weathering within the Miocene clay and shell beds.

Oxide Mineral Formation

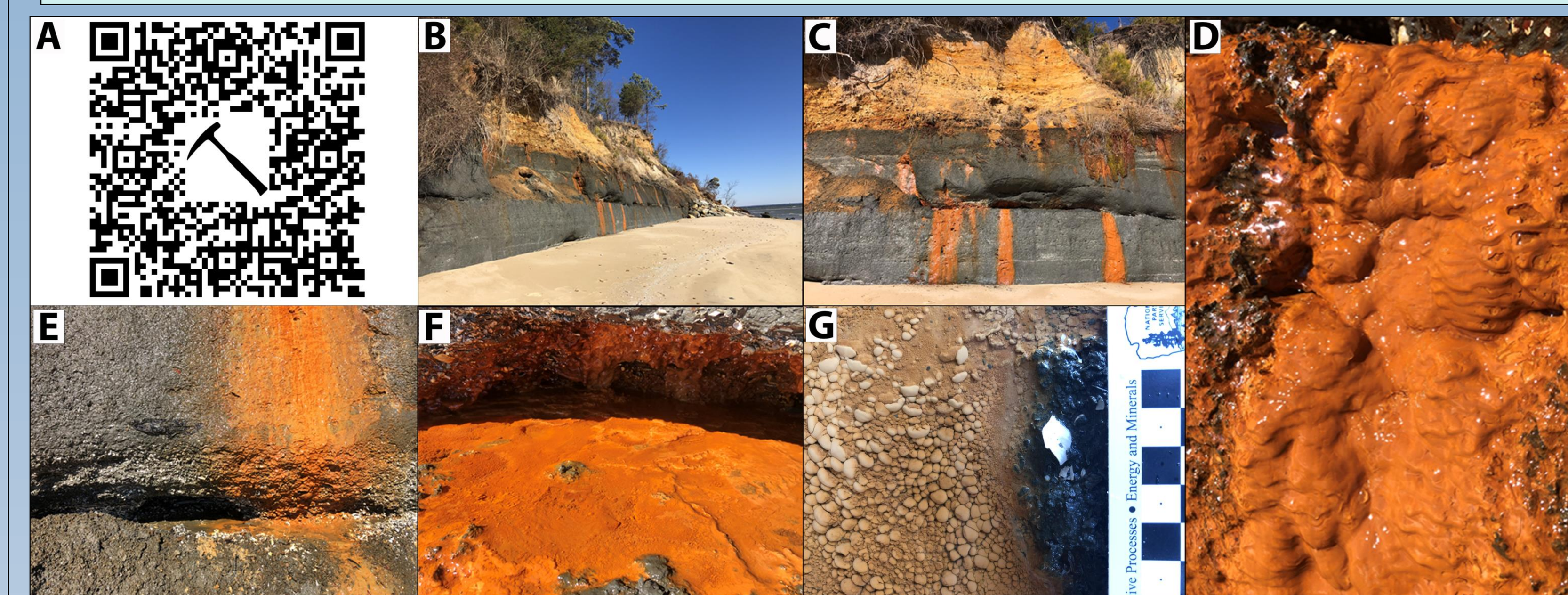

Fig. 3. As an active, ongoing process, oxide mineralization is observable.[3] **(A)** short video showing the cliff face; **(B)** the cliff face and sandy shoreline; **(C)** cliff face highlighting the contrasting lithology and vibrant iron streaking; **(D)** vertical flow structure forming; **(E)** terrace formed due to freeze-thaw eroding out the shell bed; **(F)** hydrous oxide precipitation; **(G)** close-up of the botryoidal precipitation.

Oxide Mineral Characterization

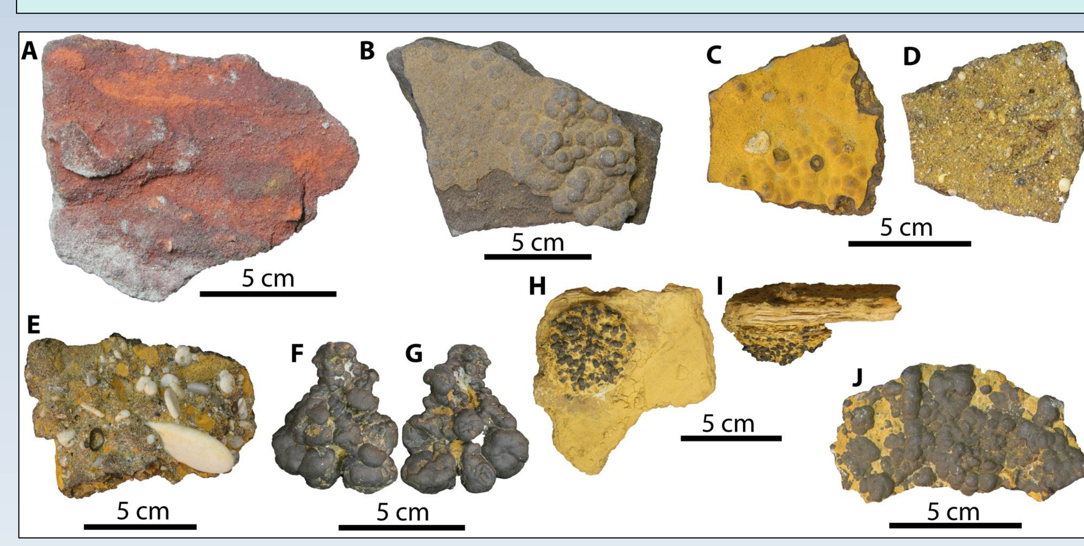

Fig. 4. Iron and manganese oxides. **(A)** clastic iron sandstone (mostly hematite and quartz); **(B)** well-cemented ironstone with botryoidal precipitation; **(C-D)** botryoidal limonite cemented onto clastic sandstone; **(E)** iron-supported conglomerate; **(F-G)** vertical botryoidal/nodular manganese oxide precipitation; **(H-I)** vertical manganese oxide precipitation within orange clay; **(J)** lateral botryoidal manganese oxide precipitation.

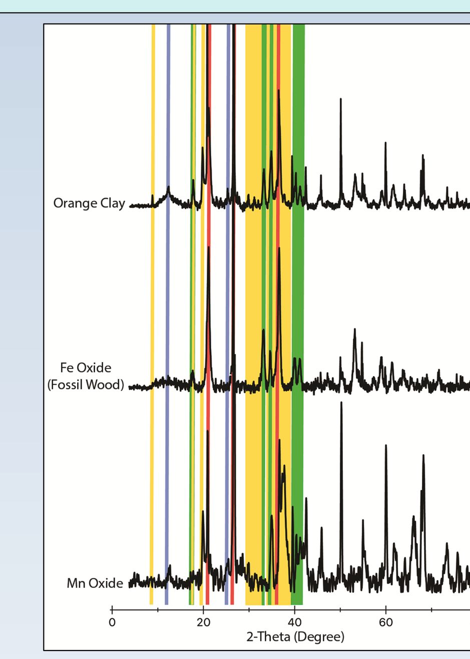

Fig. 5. XRD plot of three powdered samples. Regions in yellow are indicative of Fe-bearing mica/illite, blue are birnessite, green are goethite, and red are quartz.

Ichnology & Taphonomy

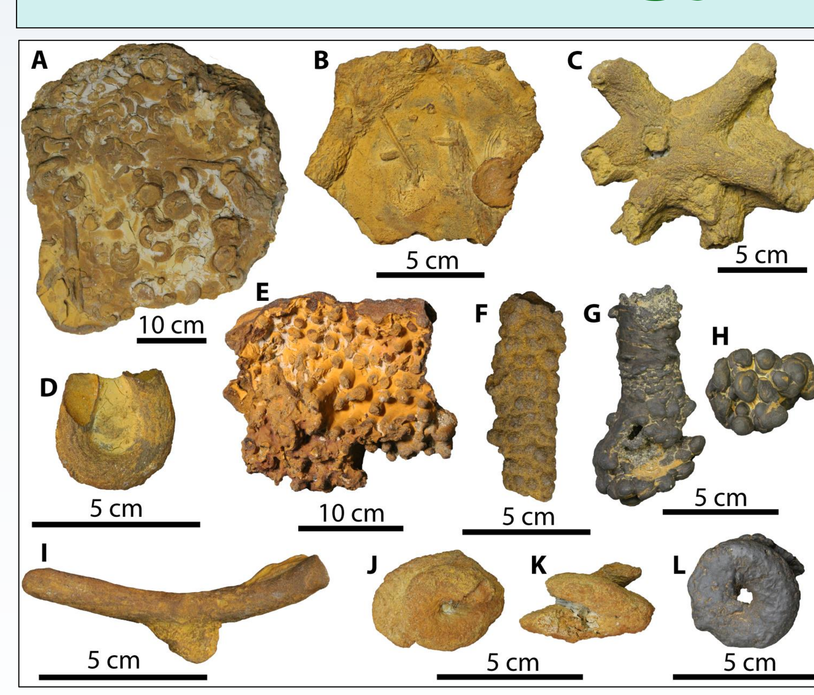

Fig. 6. Miocene burrows: **(A)** a complex network (*Diplocriterion*, *Thalassinoides*, *Gyrolithes*, etc.); **(B)** *Cruziana* and *Palaeophycus*); **(C)** *Palaeophycus*; **(D)** *Rhizocorallium/Diplocraterion*; **(E)** *Cylindricum/Skolithos*; **(F-H)** *Ophiomorpha* (*Callianassa*); **(I)** *Planolites*; **(J-L)** *Gyrolithes*.

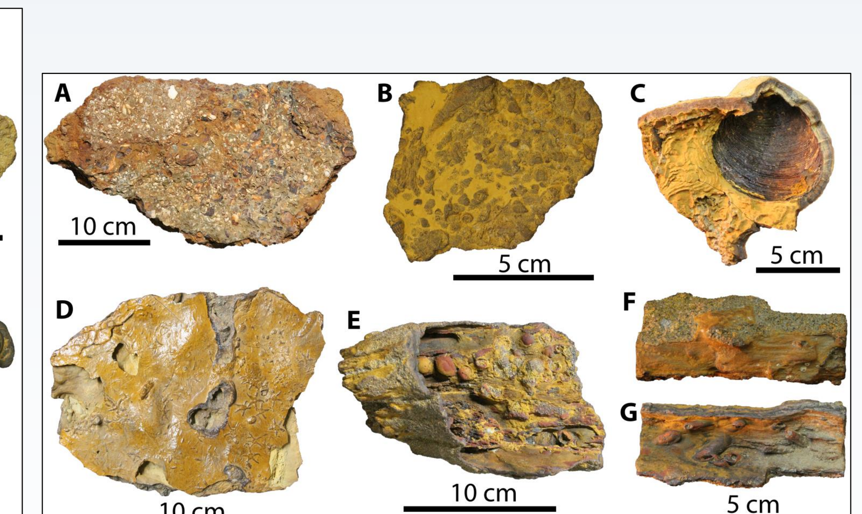

Fig. 7. Iron permineralized Miocene fossils: **(A)** mollusks with varying states of preservation in hematite matrix; **(B)** gastropod steinkerns (mostly mud snails *Nassarius peralta*); **(C)** quahog clam *Mercenaria cuneata*; **(D)** brittlestars *Ophiura marylandica* (ichnotaxon *Asteriacites*); **(E-G)** wood with *Teredo* burrows.

Hydrology & Erosion

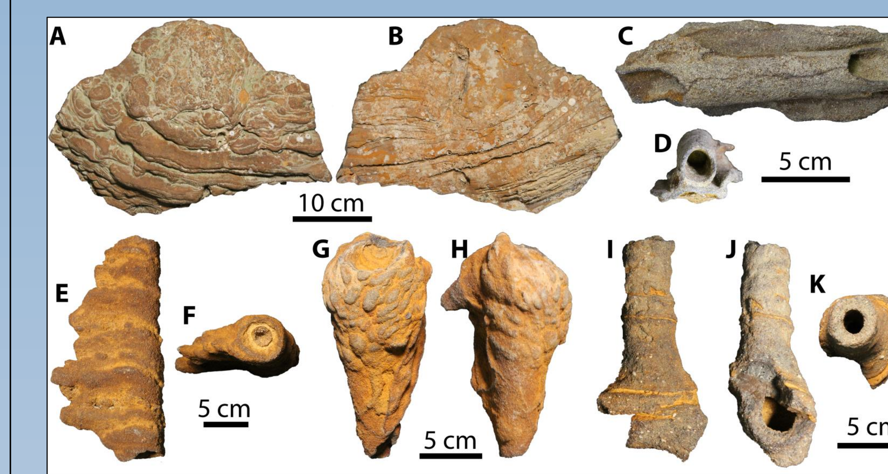

Fig. 8. As oxide minerals form around fossil burrows, they create sedimentary flow structures and a rigid plumbing system for continued water flow.

Fig. 9. Large ironstone boulders erode in substantial rockfalls. [Credit: S. Godfrey]

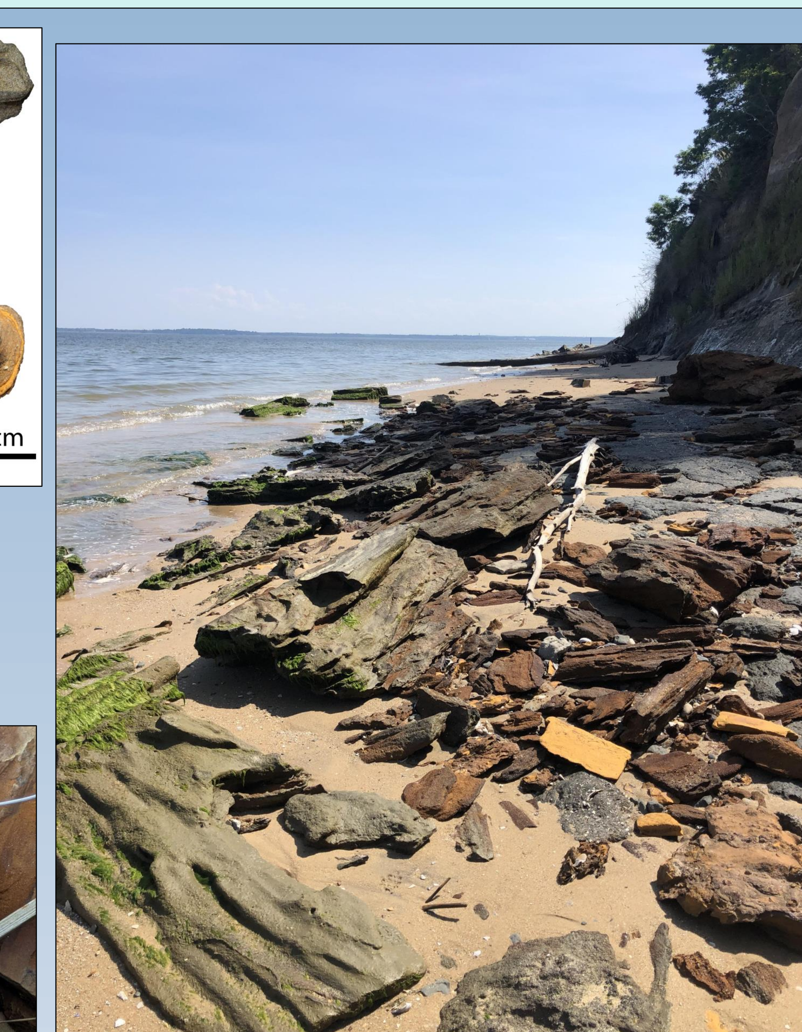

Fig. 10. The resistant rocks accumulate along the shoreline, providing a hard substrate to support intertidal life, such as barnacles, bryozoans, and mussels.

Conclusions & Future Research

- As water flows through the upper cliff face, soluble transition metals such as iron and manganese are leached out and accumulate upon contact with the relatively impermeable Miocene clays
- Oxide mineralization may alter or destroy the Miocene fossils through permineralization or dissolution
- Mineralization of the Miocene burrows creates a rigid plumbing system for continued water flow
- Oxide mineralization leads to rockfalls, which create a hard substrate for organisms living in the intertidal zone
- A major question that remains is the possible roles of microbial biomineralization in the oxide precipitation

References

1. Kidwell et al. 2015. Miocene stratigraphy and paleoenvironment of the Calvert Cliffs. GSA Field Guide.
2. Ward & Andrews. 2008. Stratigraphy of the Calvert, Choptank, and St. Marys formations (Miocene) in the Chesapeake Bay area, Maryland and Virginia. Virginia Museum of Natural History Publications.
3. Parenteau & Cady. 2010. Microbial biosignatures in iron-mineralized phototrophic mats at Chocolate Pots hot springs, Yellowstone National Park, United States. Palaios, 25(2).