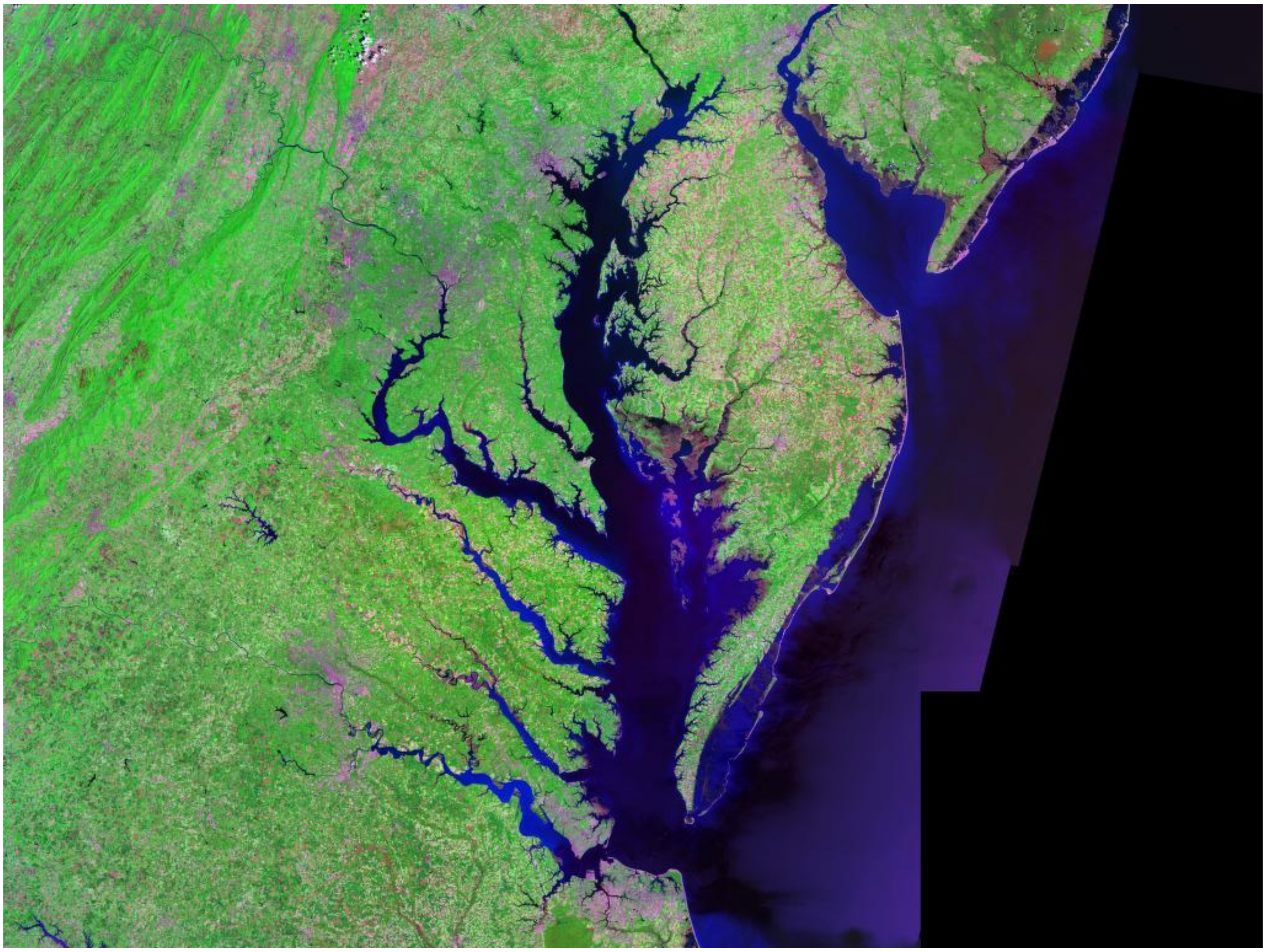
East Coast Field Trip
Chesapeake Bay -- 2012 June 9-10



From http://en.wikipedia.org/wiki/File:Chesapeakelandsat.jpeg

Contents

1 Itinerary

Saturday, June 9
8am – 8:40am: Depart from Safeway (7595 Greenbelt Road, Greenbelt, MD 20770) and drive to **Jug Bay Wetlands Sanctuary** (Lothian, MD). Note!! There is a $5/person entrance fee to Jug Bay.

8:40am - 9:30am: Talk about **hydrology of Chesapeake Bay and wetlands**.

9:30am - 10:30am: Depart from Jug Bay Wetlands Sanctuary and drive to **Calvert Cliffs State Park** (Calvert Cliffs State Park, Lusby, MD). Note!! There is a $5/vehicle entrance fee.

10:30am - 11:30am: Short, easy hike from parking lot to cliffs and talk about **fossils, the Chesapeake Bay impact, and the Miocene extinction**.

11:30am - 12:30pm: Hike back to parking lot and have lunch.

12:30pm - 2:10pm: Depart from Calvert Cliffs State Park and drive to **Chesapeake Exploration Center** (425 Piney Narrows Road, Chester, MD) Note!! The Bay Bridge is a $4 toll road.

2:10pm - 2:30pm: Explore the Exploration Center.

2:30pm - 4:00pm: Depart from Chesapeake Exploration Center to **Dogfish Head Brewery** (6 Cannery Village Blvd, Milton DE).

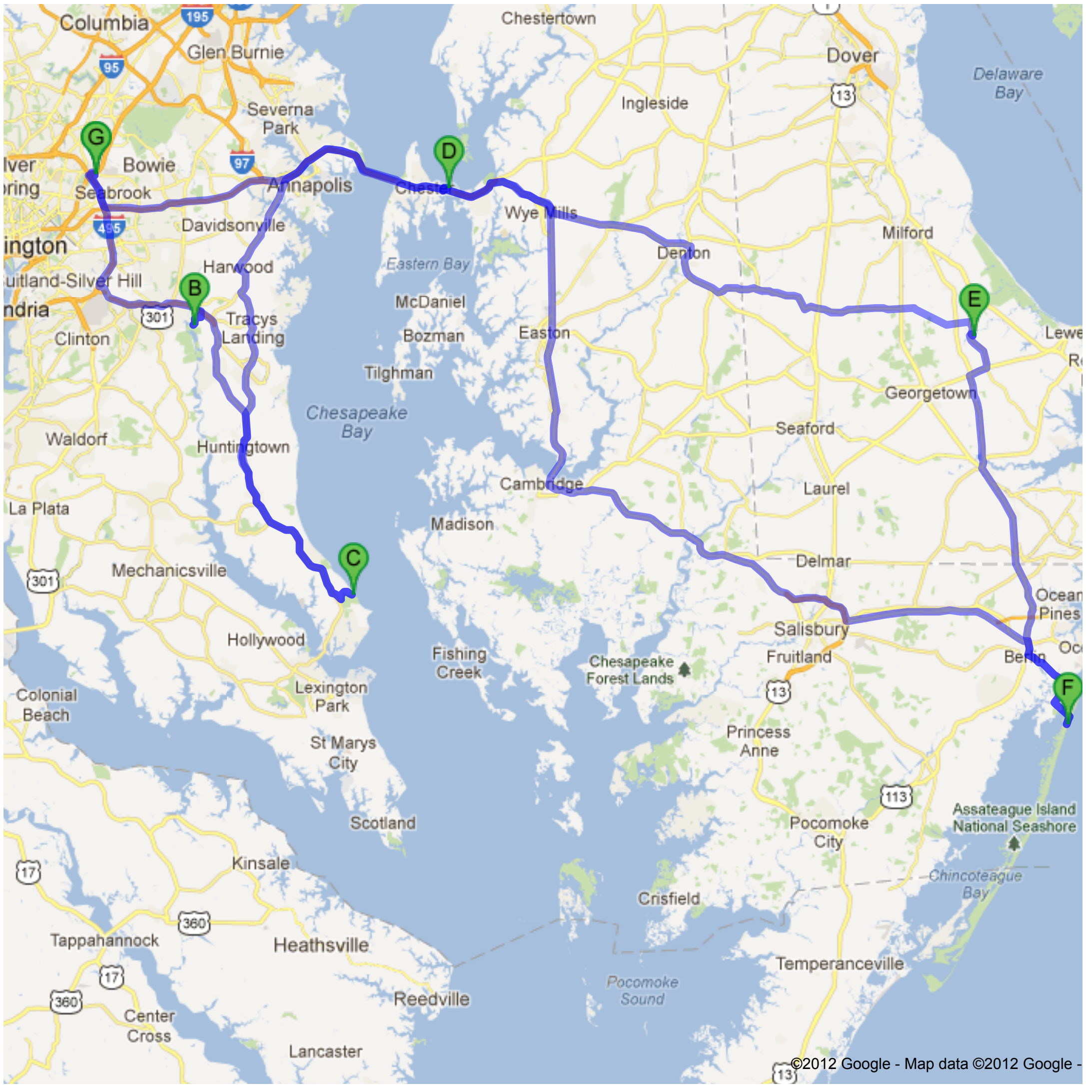
4:15pm - 5:00pm: Take brewery tour and buy beer. The tour is free!

5:00pm - 6:00pm: Depart Brewery and drive to **Assateague State Park** (NOT National Park) camp site (Berlin, MD) and talk about **longshore current and the Assateague horses**. Note!! The campsites cost Brian $132.20 to rent for the weekend.

Sunday, June 10
10:00am - Wake up, breakfast, and depart Assateague.

At this point, some of us are going to look for Ames Ridge, which is part of the rim of the Chesapeake Bay impact crater and is supposed to be about 1.5 hours south of the Assateague campsite on Hwy 13. If youd like to join us, youre welcome. If not, please return your radios to Brian before parting company.

Directions to 7595 Greenbelt Rd, Greenbelt, MD 20770
378 mi – about **8 hours 42 mins**

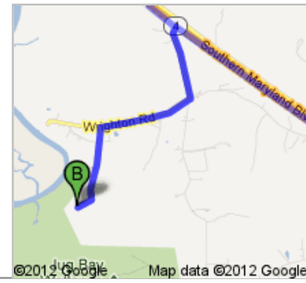


A 7595 Greenbelt Rd, Greenbelt, MD 20770

1. Head **south**	go 0.1 mi total 0.1 mi
2. Turn right toward **Greenbelt Rd**	go 0.1 mi total 0.2 mi
3. Turn left onto **Greenbelt Rd**	go 0.2 mi total 0.4 mi
4. Sharp right onto **Southway** (signs for **Baltimore-Washington Parkway/Washington**)	go 0.1 mi total 0.5 mi
5. Slight right onto the **Balt/Wash Pkwy** ramp to **Washington**	go 0.1 mi total 0.7 mi
6. Merge onto **MD-295**	go 0.4 mi total 1.1 mi
7. Take the **I-95 S/I-495 S** exit toward **Richmond VA/Andrews a F B**	go 0.2 mi total 1.3 mi
8. Merge onto **I-495/I-95 S** About 14 mins	go 11.4 mi total 12.8 mi
9. Take exit **11A** for **MD-4 S/Penn. Ave E** toward **Upper Marlboro**	go 0.3 mi total 13.1 mi
10. Merge onto **MD-4 S/Pennsylvania Ave** About 1 min	go 0.9 mi total 14.0 mi
11. Slight left to stay on **MD-4 S/Pennsylvania Ave** Continue to follow MD-4 S About 13 mins	go 9.7 mi total 23.7 mi
12. Exit onto **Plummer Ln** About 2 mins	go 0.7 mi total 24.3 mi
13. Turn right onto **Wrighton Rd** About 1 min	go 0.6 mi total 25.0 mi
14. Turn left onto **Blue Shirt Rd** About 2 mins	go 0.6 mi total 25.6 mi

Total: **25.6 mi** – about **37 mins**

B Jug Bay Wetlands Sanctuary, Lothian, MD total 0.0 mi



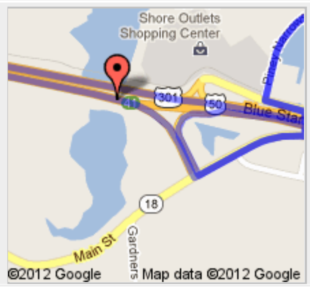
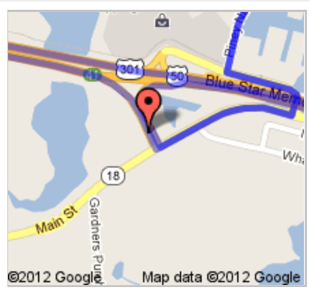
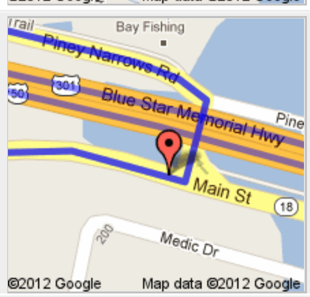
15. Head **northeast** on **Blue Shirt Rd** About 2 mins	go 0.6 mi	total 0.6 mi
16. Turn right onto **Wrighton Rd** About 2 mins	go 0.6 mi	total 1.3 mi
17. Turn left onto **Plummer Ln** About 1 min	go 0.5 mi	total 1.7 mi
18. Slight right to merge onto **MD-4 S** About 23 mins	go 17.1 mi	total 18.8 mi
19. Continue straight onto **MD-2 S/MD-4 S/Solomons Island Rd** About 24 mins	go 15.9 mi	total 34.8 mi
20. Turn left onto **MD-765 S/Hg Trueman Rd** About 4 mins	go 1.0 mi	total 35.8 mi
21. Turn left toward **Camp Conoy Rd**	go 59 ft	total 35.8 mi
22. Turn left onto **Camp Conoy Rd** About 3 mins	go 1.3 mi	total 37.1 mi
23. Slight right About 1 min	go 0.6 mi	total 37.6 mi

Total: **37.6 mi** – about **1 hour 1 min**

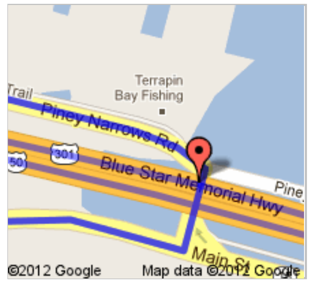
Calvert Cliffs State Park
1, Solomons Island, Maryland - (301) 743-7613

total 0.0 mi

24. Head **west** toward **Camp Conoy Rd** About 1 min	go 0.6 mi	total 0.6 mi
25. Slight left onto **Camp Conoy Rd** About 3 mins	go 1.3 mi	total 1.8 mi
26. Turn right toward **MD-765 N/Hg Trueman Rd**	go 59 ft	total 1.8 mi

27. Turn right onto **MD-765 N/Hg Trueman Rd** About 3 mins		go 1.0 mi total 2.8 mi
28. Turn right onto **MD-2 N/MD-4 N/Solomons Island Rd** Continue to follow MD-4 N/Solomons Island Rd About 33 mins		go 21.4 mi total 24.2 mi
29. Slight right onto **MD-2 N/Solomons Island Rd N** About 8 mins		go 5.7 mi total 30.0 mi
30. At the traffic circle, continue straight onto **MD-2 N/Solomons Island Rd** Continue to follow MD-2 N About 10 mins		go 6.9 mi total 36.8 mi
31. At the traffic circle, take the **1st** exit onto **MD-2 N/Solomons Island Rd** About 17 mins		go 12.6 mi total 49.4 mi
32. Take the **US-50 W/US-301 E** ramp to **Bay Bridge**		go 0.2 mi total 49.6 mi
33. Merge onto **US-301 N/US-50 E** Partial toll road About 21 mins		go 17.0 mi total 66.7 mi
34. Take exit **41** for **MD-18/Main St** toward **Kent Narrows W**		go 0.2 mi total 66.8 mi
35. Turn left onto **MD-18 E/Main St** About 1 min		go 0.2 mi total 67.1 mi
36. Take the 1st left toward **Piney Narrows Rd**		go 187 ft total 67.1 mi

37. Turn left onto **Piney Narrows Rd**



go 0.1 mi
total 67.2 mi

38. Turn right to stay on **Piney Narrows Rd**

go 0.2 mi
total 67.5 mi

39. Slight right to stay on **Piney Narrows Rd**
Destination will be on the left

go 0.1 mi
total 67.6 mi

Total: **67.6 mi** – about **1 hour 39 mins**

D 425 Piney Narrows Rd, Chester, MD 21619 — total 0.0 mi

40. Head **west** on **Piney Narrows Rd** toward **Swan Cove Ln** About 1 min	go 0.4 mi total 0.4 mi
41. Turn left to stay on **Piney Narrows Rd**	go 0.1 mi total 0.5 mi
42. Turn right toward **Main St**	go 187 ft total 0.5 mi
43. Turn right onto **Main St** About 1 min	go 0.2 mi total 0.8 mi
44. Turn right to merge onto **US-301 N/US-50 E** About 7 mins	go 5.3 mi total 6.1 mi
45. Slight right onto **US-50 E/Ocean Gateway** About 9 mins	go 6.9 mi total 13.0 mi

	About 35 mins	
16	47. Turn left onto **MD-16 E/Greenwood Rd** Entering Delaware About 4 mins	go 2.5 mi total 35.9 mi
16	48. Continue onto **DE-16 E/Hickman Rd** About 8 mins	go 7.0 mi total 43.0 mi
16	49. Turn left onto **DE-16 E/DE-36 E/Hickman Rd** Continue to follow DE-16 E About 26 mins	go 16.5 mi total 59.5 mi
	50. Turn right onto **Union St** About 2 mins	go 0.8 mi total 60.2 mi
	51. Turn right onto **Federal St** About 1 min	go 0.4 mi total 60.7 mi
	52. Turn left onto **Church St** About 1 min	go 0.1 mi total 60.8 mi
	53. Turn left onto **Chestnut St/County Rd 249**	go 151 ft total 60.8 mi
	54. Take the 1st right onto **Village Center Blvd** About 1 min	go 0.3 mi total 61.1 mi

Total: **61.1 mi** – about **1 hour 36 mins**

E	6 Cannery Village Blvd, Milton DE	total 0.0 mi

	55. Head **northwest** on **Village Center Blvd** toward **Acre Ln**	go 0.3 mi total 0.3 mi
	56. Turn left onto **Chestnut St/County Rd 249**	go 151 ft total 0.3 mi
	57. Take the 1st right onto **Church St**	go 0.1 mi total 0.4 mi
23	58. Turn left onto **DE-23 S/DE-5 S/Federal St** Continue to follow DE-23 S/DE-5 S About 6 mins	go 3.9 mi total 4.3 mi
404	59. Turn right onto **DE-404 W/U.S. 9 W/Lewes Georgetown Hwy/Seashore Hwy** About 3 mins	go 1.8 mi total 6.2 mi
30	60. Turn left onto **DE-30 S/Rd 248/Gravel Hill Rd** Continue to follow DE-30 S About 14 mins	go 9.2 mi total 15.4 mi
113	61. Turn left onto **US-113 S/E Dupont Blvd** Continue to follow US-113 S Entering Maryland About 25 mins	go 19.5 mi total 34.9 mi
376	62. Turn left onto **MD-376 E/Assateague Rd/Bay St** About 6 mins	go 4.1 mi total 38.9 mi

611	63. Turn right onto **MD-611 S/Stephen Decatur Hwy** Continue to follow MD-611 S About 7 mins	go 4.3 mi total 43.3 mi
	64. Turn right onto **Stephen Decatur Memorial Rd** Destination will be on the right About 2 mins	go 0.8 mi total 44.1 mi

Total: **44.1 mi** – about **1 hour 5 mins**

F **Assateague State Park** total 0.0 mi
10, Ocean City, Maryland - (410) 641-2120

	65. Head **north** on **Stephen Decatur Memorial Rd** toward **MD-611 S/Verrazano Bridge** About 2 mins	go 0.8 mi total 0.8 mi
611	66. Turn left onto **MD-611 N/Verrazano Bridge** Continue to follow MD-611 N About 7 mins	go 4.3 mi total 5.2 mi
376	67. Turn left onto **MD-376 W/Assateague Rd/Bay St** About 6 mins	go 4.1 mi total 9.2 mi
113	68. Turn right onto **US-113 N/Worcester Hwy** About 2 mins	go 1.3 mi total 10.6 mi
50	69. Take the ramp onto **US-50 W/Ocean Gateway** About 21 mins	go 18.5 mi total 29.1 mi
50	70. Merge onto **US-13 N/US-50 W** via the ramp to **Bay Bridge/Dover** Continue to follow US-50 W About 1 hour 59 mins	go 108 mi total 137 mi
495	71. Take exit **7B** to merge onto **I-495 N/I-95 N** About 5 mins	go 3.8 mi total 141 mi
	72. Take exit **22A** for **Baltimore/Washington Parkway** toward **Baltimore N**	go 0.2 mi total 141 mi
193	73. Keep right at the fork, follow signs for **MD-193 E/Nasa Goddard** and merge onto **MD-193 E/Greenbelt Rd**	go 0.3 mi total 142 mi
	74. Slight right	go 0.1 mi total 142 mi
	75. Turn left Destination will be on the right	go 0.1 mi total 142 mi

Total: **142 mi** – about **2 hours 44 mins**

G 7595 Greenbelt Rd, Greenbelt, MD 20770

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Directions weren't right? Please find your route on maps.google.com and click "Report a problem" at the bottom left.

Please print and bring this ticket with you.

8735395711129852 1001

Event	Saturday, June 9th Brewery Tour
Date+Time	
Type	4:15 PM Brewery Tour
Location	6 Village Center Blvd Milton, 19968
Order Info	Ordered by brian jackson on May 16, 2012 6:44 AM

Eventbrite

Name
brian jackson

Payment Status
Paid with Check

Thanks for making a reservation to tour the Dogfish Head Craft Brewery. Just a few reminders:

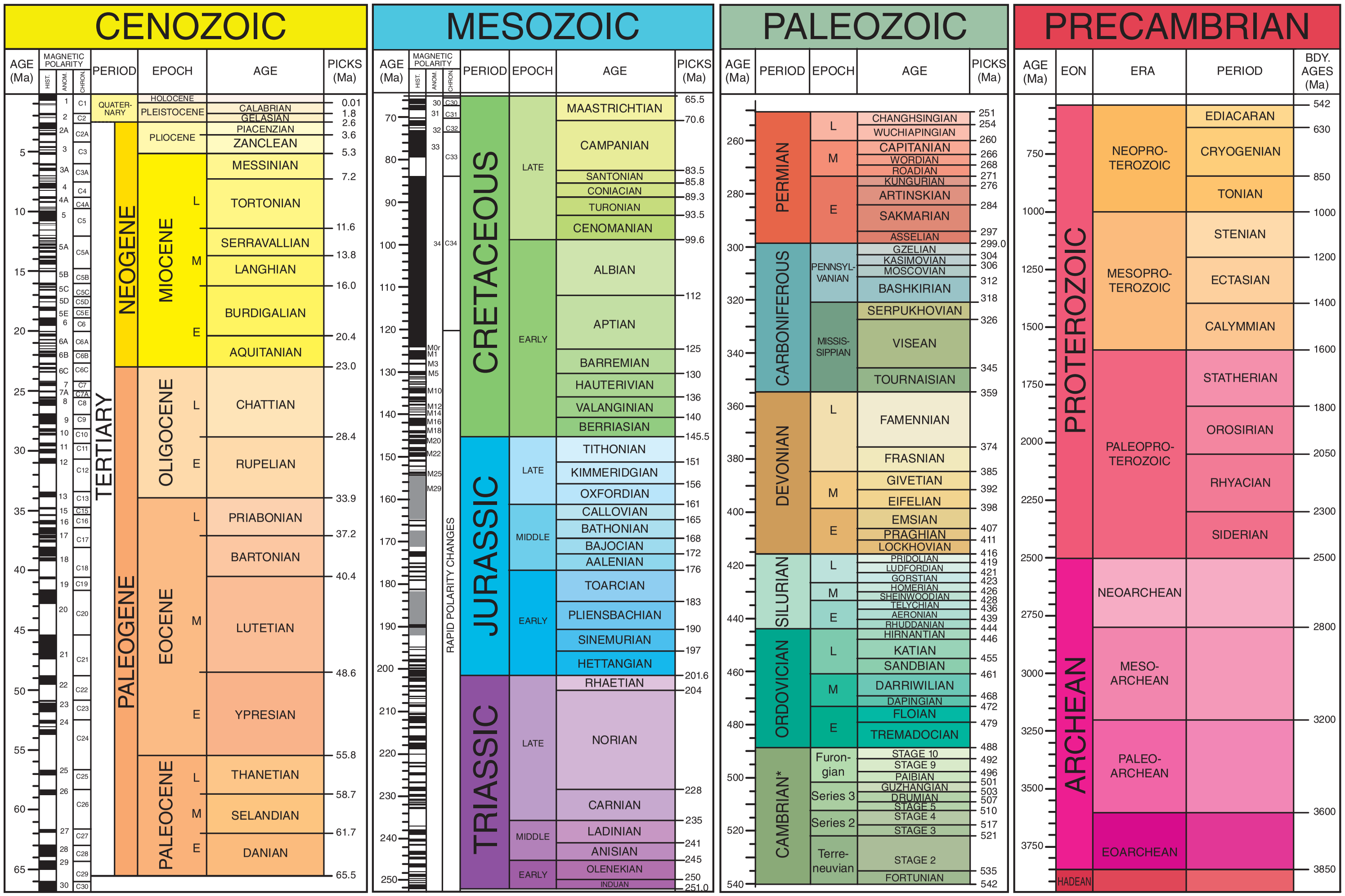
1. Close-Toed shoes are a MUST on the tours -- this means NO flip flops, sandals, etc., also NO high heels.
2. Late Policy: if you are late for your tour, we will assume that you do not plan to join us and will give your spaces away.
3. Well behaved children are welcome on the tour but we ask that you please keep in mind that this is a production brewery. It is encouraged that you carry your child in a bjorn/backback if possible and that you please supervise your child(ren) accordingly during your tour/tasting. Childern 6 and up will need a ticket.
4. The tour can accommodate wheelchairs, but keep in mind that this is a working production facility, therefore we cannot guarantee that you will have access throughout the whole tour route.
5. Due to various safety concerns, there are occasional instances that parts of the "tour route" could be off limits. We are typically able to walk to the brewhouse, cellars, and bottling line and will do our best to tour you everywhere we can based on the occurances the day you arrive.

See you on the day of your tour!
-Dogfish Head Tour Crew

For more information, please contact the organizer via email at kristin@dogfish.com

87353957111298521001

2009 GEOLOGIC TIME SCALE



*International ages have not been fully established. These are current names as reported by the International Commission on Stratigraphy.

Walker, J.D., and Geissman, J.W., compilers, 2009, Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C. ©2009 The Geological Society of America.

Sources for nomenclature and ages are primarily from Gradstein, F., Ogg, J., Smith, A., et al., 2004, A Geologic Time Scale 2004: Cambridge University Press, 589 p. Modifications to the Triassic after: Furin, S., Preto, N., Rigo, M., Roghi, G., Gianolla, P., Crowley, J.L., and Bowring, S.A., 2006, High-precision U-Pb zircon age from the Triassic of Italy: Implications for the Triassic time scale and the Carnian origin of calcareous nannoplankton and dinosaurs: Geology, v. 34, p. 1009–1012, doi: 10.1130/G22967A.1; and Kent, D.V., and Olsen, P.E., 2008, Early Jurassic magnetostratigraphy and paleolatitudes from the Hartford continental rift basin (eastern North America): Testing for polarity bias and abrupt polar wander in association with the central Atlantic magmatic province: Journal of Geophysical Research, v. 113, B06105, doi: 10.1029/2007JB005407.

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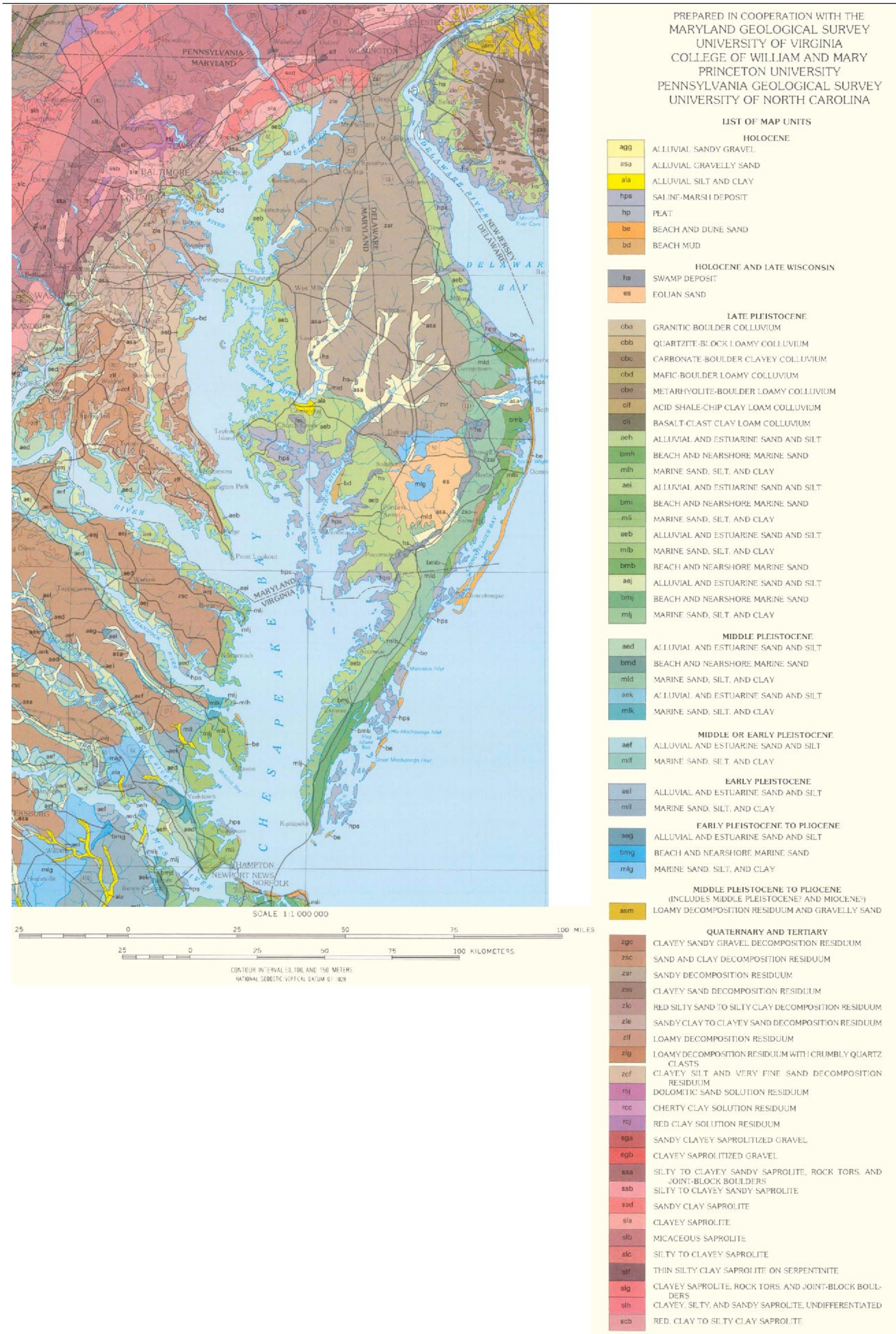
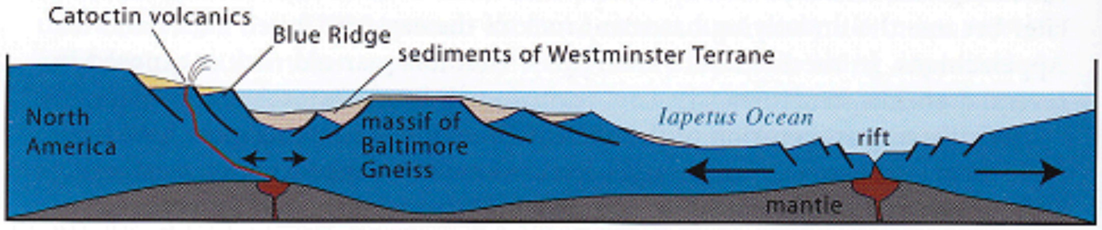
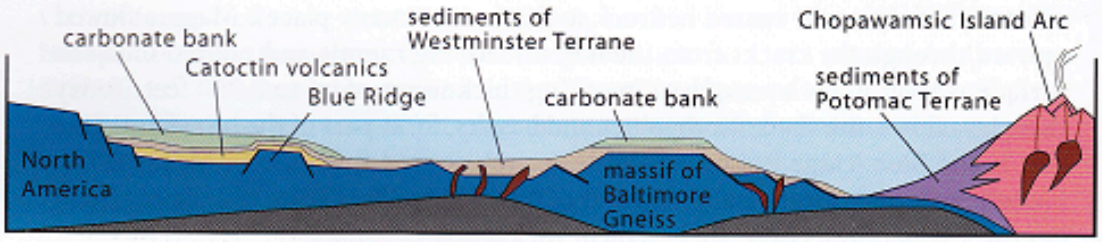

PREPARED IN COOPERATION WITH THE
MARYLAND GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
COLLEGE OF WILLIAM AND MARY
PRINCETON UNIVERSITY
PENNSYLVANIA GEOLOGICAL SURVEY
UNIVERSITY OF NORTH CAROLINA
LIST OF MAP UNITS
HOLOCENE
agg ALLUVIAL SANDY GRAVEL
asa ALLUVIAL GRAVELLY SAND
ala ALLUVIAL SILT AND CLAY
hps SALINE-MARSH DEPOSIT
hp PEAT
be BEACH AND DUNE SAND
bd BEACH MUD
HOLOCENE AND LATE WISCONSIN
hs SWAMP DEPOSIT
es EOLIAN SAND
LATE PLEISTOCENE
cba GRANITIC-BOULDER COLLUVIUM
cbb QUARTZITE-BLOCK LOAMY COLLUVIUM
cbc CARBONATE-BOULDER CLAYEY COLLUVIUM
cbd MAFIC-BOULDER LOAMY COLLUVIUM
cbe METARHYOLITE-BOULDER LOAMY COLLUVIUM
clf ACID SHALE-CHIP CLAY LOAM COLLUVIUM
cli BASALT-CLAST CLAY LOAM COLLUVIUM
aeh ALLUVIAL AND ESTUARINE SAND AND SILT
bmh BEACH AND NEARSHORE MARINE SAND
mlh MARINE SAND, SILT, AND CLAY
aei ALLUVIAL AND ESTUARINE SAND AND SILT
bmi BEACH AND NEARSHORE MARINE SAND
mli MARINE SAND, SILT, AND CLAY
aeb ALLUVIAL AND ESTUARINE SAND AND SILT
mlb MARINE SAND, SILT, AND CLAY
bmb BEACH AND NEARSHORE MARINE SAND
aej ALLUVIAL AND ESTUARINE SAND AND SILT
bmj BEACH AND NEARSHORE MARINE SAND
mlj MARINE SAND, SILT, AND CLAY
MIDDLE PLEISTOCENE
aed ALLUVIAL AND ESTUARINE SAND AND SILT
bmd BEACH AND NEARSHORE MARINE SAND
mld MARINE SAND, SILT, AND CLAY
aek ALLUVIAL AND ESTUARINE SAND AND SILT
mlk MARINE SAND, SILT, AND CLAY
MIDDLE OR EARLY PLEISTOCENE
aef ALLUVIAL AND ESTUARINE SAND AND SILT
mlf MARINE SAND, SILT, AND CLAY
EARLY PLEISTOCENE
ael ALLUVIAL AND ESTUARINE SAND AND SILT
mll MARINE SAND, SILT, AND CLAY
EARLY PLEISTOCENE TO PLIOCENE
aeg ALLUVIAL AND ESTUARINE SAND AND SILT
bmg BEACH AND NEARSHORE MARINE SAND
mlg MARINE SAND, SILT, AND CLAY
MIDDLE PLEISTOCENE TO PLIOCENE
(INCLUDES MIDDLE PLEISTOCENE? AND MIOCENE?)
asm LOAMY DECOMPOSITION RESIDUUM AND GRAVELLY SAND
QUATERNARY AND TERTIARY
zgc CLAYEY SANDY GRAVEL DECOMPOSITION RESIDUUM
zsc SAND AND CLAY DECOMPOSITION RESIDUUM
zsr SANDY DECOMPOSITION RESIDUUM
zss CLAYEY SAND DECOMPOSITION RESIDUUM
zlc RED SILTY SAND TO SILTY CLAY DECOMPOSITION RESIDUUM
zle SANDY CLAY TO CLAYEY SAND DECOMPOSITION RESIDUUM
zlf LOAMY DECOMPOSITION RESIDUUM
zlg LOAMY DECOMPOSITION RESIDUUM WITH CRUMBLY QUARTZ CLASTS
zcf CLAYEY SILT AND VERY FINE SAND DECOMPOSITION RESIDUUM
rsj DOLOMITIC SAND SOLUTION RESIDUUM
rcc CHERTY CLAY SOLUTION RESIDUUM
rcj RED CLAY SOLUTION RESIDUUM
sga SANDY CLAYEY SAPROLITIZED GRAVEL
sgb CLAYEY SAPROLITIZED GRAVEL
ssa SILTY TO CLAYEY SANDY SAPROLITE, ROCK TORS, AND JOINT-BLOCK BOULDERS
ssb SILTY TO CLAYEY SANDY SAPROLITE
ssd SANDY CLAY SAPROLITE
sla CLAYEY SAPROLITE
slb MICACEOUS SAPROLITE
slc SILTY TO CLAYEY SAPROLITE
slf THIN SILTY CLAY SAPROLITE ON SERPENTINITE
slg CLAYEY SAPROLITE, ROCK TORS, AND JOINT-BLOCK BOULDERS
slh CLAYEY, SILTY, AND SANDY SAPROLITE, UNDIFFERENTIATED
scb RED, CLAY TO SILTY CLAY SAPROLITE
CHESAPEAKE BAY
SCALE 1:1 000 000
25 0 25 50 75 100 MILES
25 0 25 50 75 100 KILOMETERS
CONTOUR INTERVAL 50, 100, AND 150 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

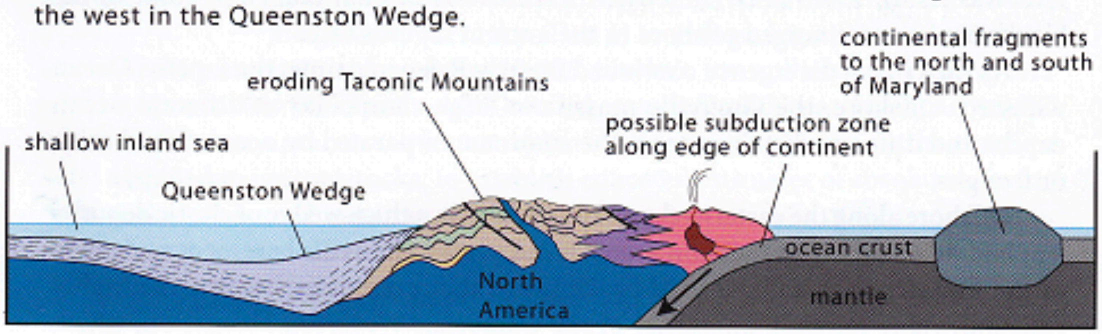
1. LATE PROTEROZOIC TIME (about 650 to 580 million years ago)
As the continent rifted apart in more than one place, blocks of gneiss dropped down along faults. Sediments were deposited on submerged blocks and lava poured out on land.



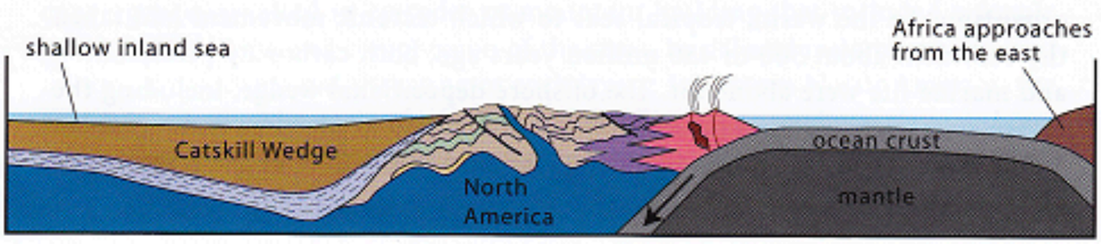
2. MIDDLE CAMBRIAN TO ORDOVICIAN TIME (about 500 to 450 million years ago)
An island arc forms offshore. Sediments are deposited undersea and carbonate banks form in shallow waters.



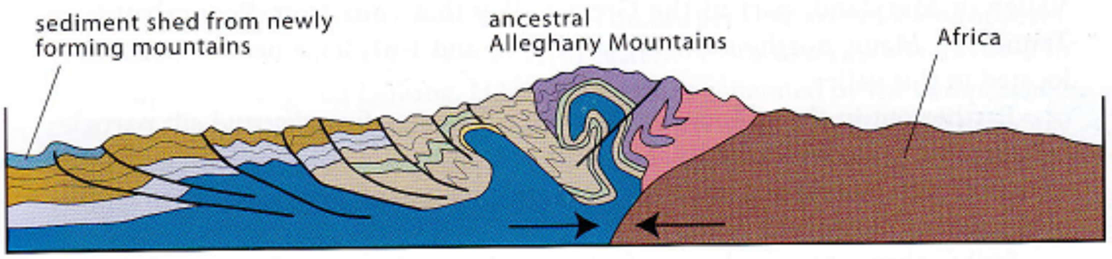
3. MIDDLE ORDOVICIAN AND SILURIAN TIME (about 480 to 420 million years ago)
The Chopawamsic Island Arc collides with North America in the Taconic mountain building event. The huge mountains erode with sediments accumulating to the west in the Queenston Wedge.



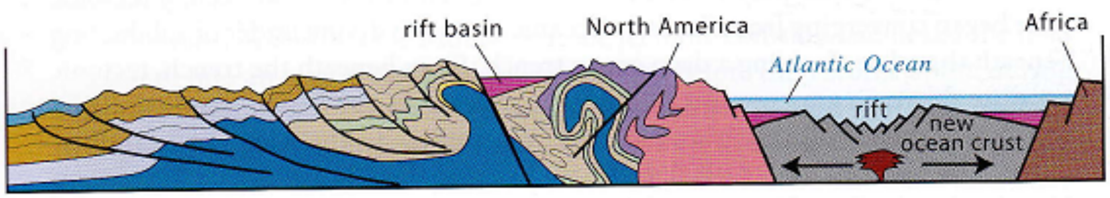
4. DEVONIAN TO MISSISSIPPIAN TIME (about 410 to 350 millian years ago)
Microcontinents collide with North America north and south of Maryland and Delaware in the Acadian mountain building event. Sediments eroded from the mountains collect in a basin to the west, creating the Catskill Wedge.



5. PENNSYLVANIAN AND PERMIAN TIME (about 320 to 250 million years ago)
Africa collides with North America in the Alleghanian mountain building event, forming the supercontinent Pangea.

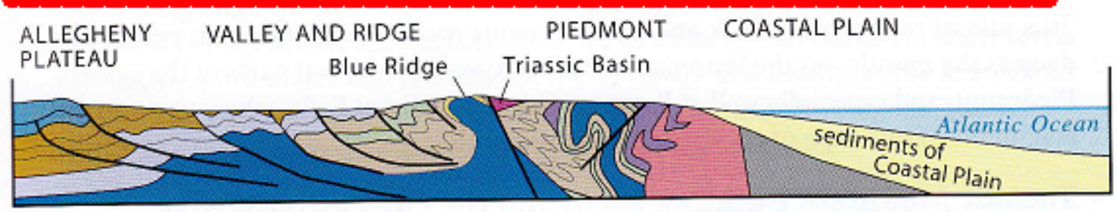


6. LATE TRIASSIC TIME (about 200 million years ago)
Pangea rifts apart, and the Atlantic Ocean fills the growing gap between North America and Africa.

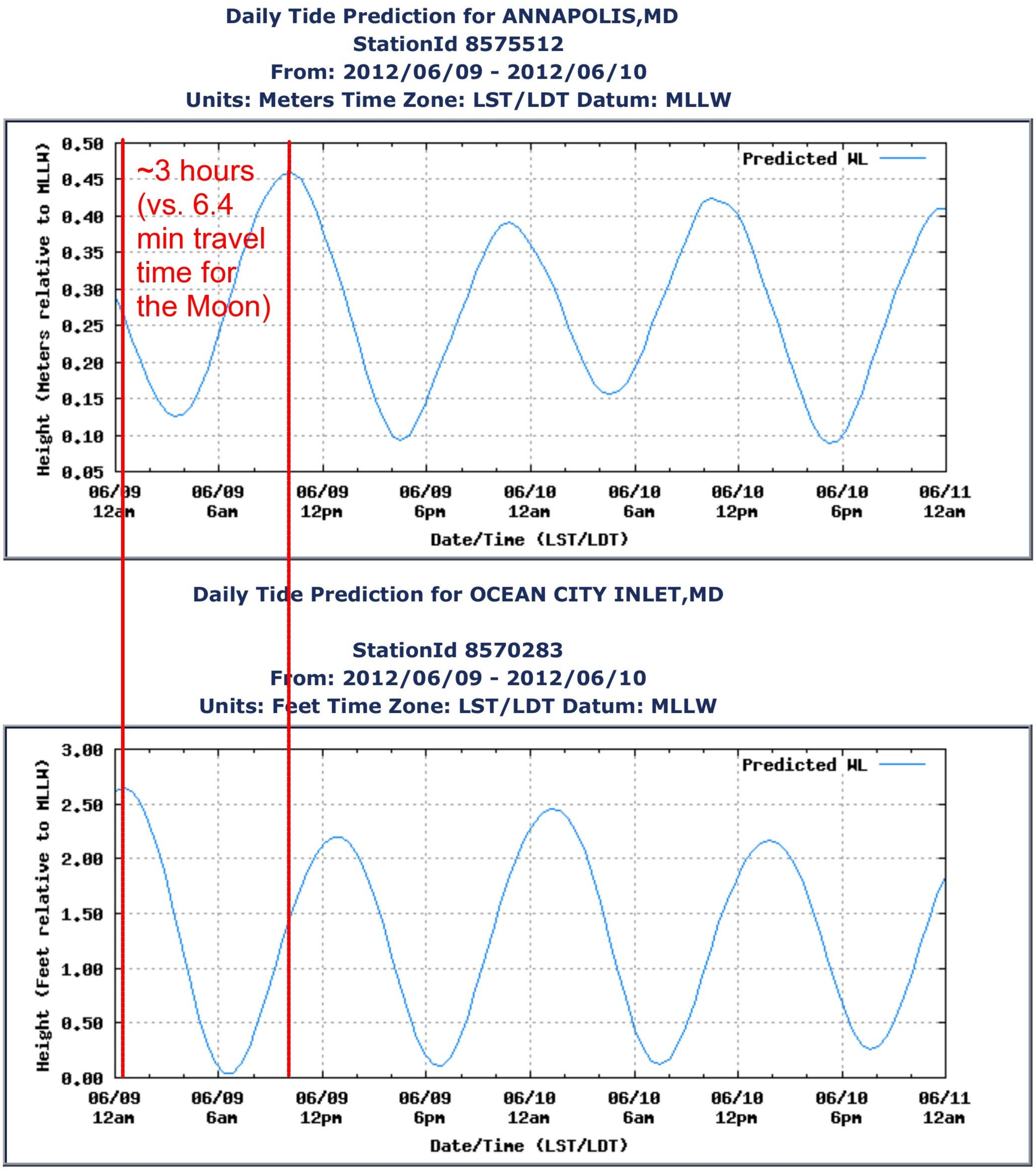


7. CRETACEOUS TO MODERN TIME (about 145 million years ago to present)
The mountains erode and huge amounts of sediment accumulate on the continental shelf, forming the modern coastal plain.

35 Ma - Chesapeake Bay impact



These seven sections show the major events in the geologic history of Maryland, Delaware, and D.C. The drawings are intended to present an overview of the big picture but do not in any way represent the exact positions or shapes of the rocks in times past. —Modified from Gates, Muller, and Valentino, 1991; Kunk and others, 2004


Daily Tide Prediction for ANNAPOLIS,MD
StationId 8575512
From: 2012/06/09 - 2012/06/10
Units: Meters Time Zone: LST/LDT Datum: MLLW
~3 hours
(vs. 6.4
min travel
time for
the Moon)
Predicted WL
Height (Meters relative to MLLW)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
06/09 12am
06/09 6am
06/09 12pm
06/09 6pm
06/10 12am
06/10 6am
06/10 12pm
06/10 6pm
06/11 12am
Date/Time (LST/LDT)
Daily Tide Prediction for OCEAN CITY INLET,MD
StationId 8570283
From: 2012/06/09 - 2012/06/10
Units: Feet Time Zone: LST/LDT Datum: MLLW
Predicted WL
Height (Feet relative to MLLW)
3.00
2.50
2.00
1.50
1.00
0.50
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Hydrology of the Chesapeake Bay Watershed

Brian Jackson

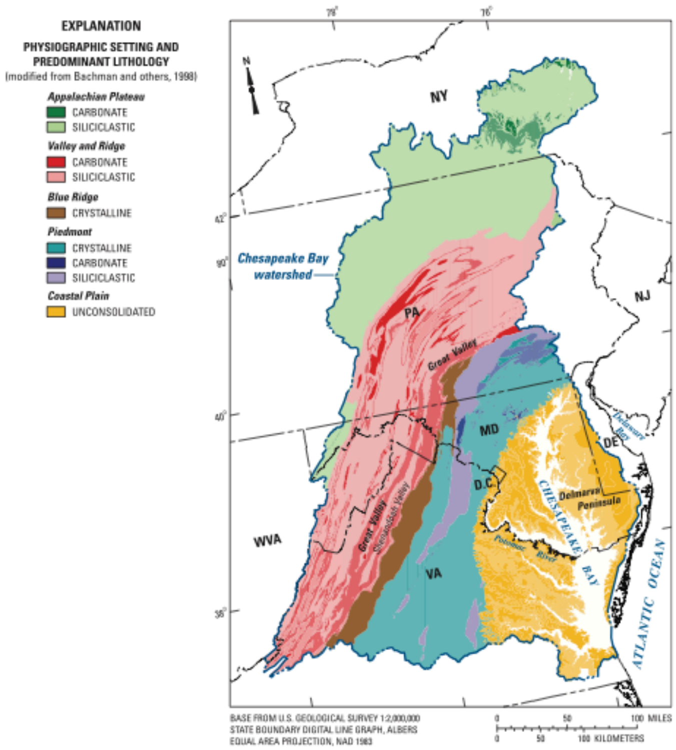


Figure 1: From Ator+ (2011) - http://pubs.usgs.gov/sir/2011/5167/

-Chesapeake Bay (CB) is largest of 130 estuaries in US and drains 166,000 km^2 in six states and the District of Columbia

-CB is drowned channel of ancestral Susquehanna River - Before ocean levels rose at end of last ice age, 18ka, CB was not a bay

-Deep river valley cut by Susquehanna (now submerged) makes for excellent shipping channel

-Streams/rivers carry hundreds of thousands of tons of sediment/nutrients across hundreds of km (and many local and state jurisdictions) - Major sources of nutrients (N and P) include wastewater treatment plants, fertilizer and manure applications, and (for nitrogen) atmospheric deposition. Mineral dissolution also produces N/P

-Transported materials pass through riparian forest/wetlands, where nutrients absorbed into biomass of grasses and trees and stored for ~10 years - Figure 2. About 60% of watershed is forested.

-Human development of watershed since colonial times has increased N/P fluxes by about 10x.

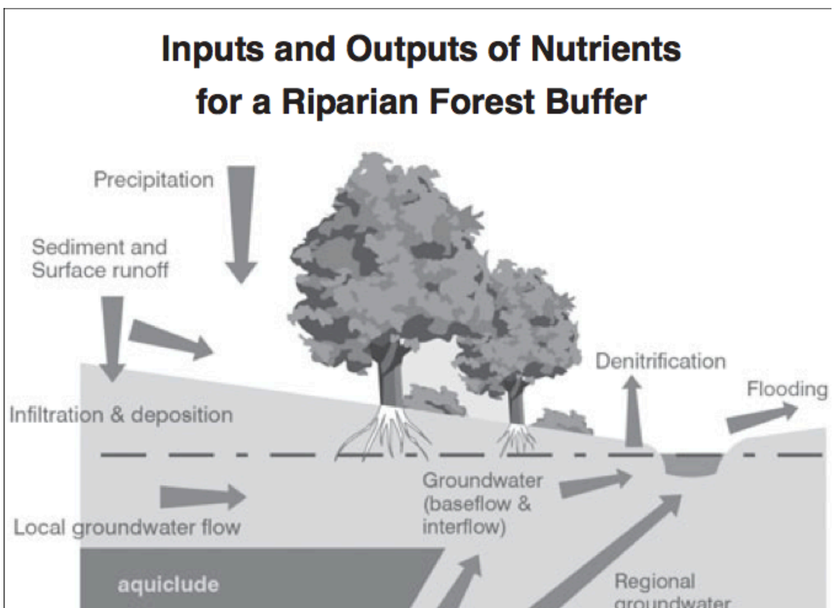


Figure 2: Riparian forest buffers filter, transform, and store nutrients, while stabilizing floodplains. – [link]

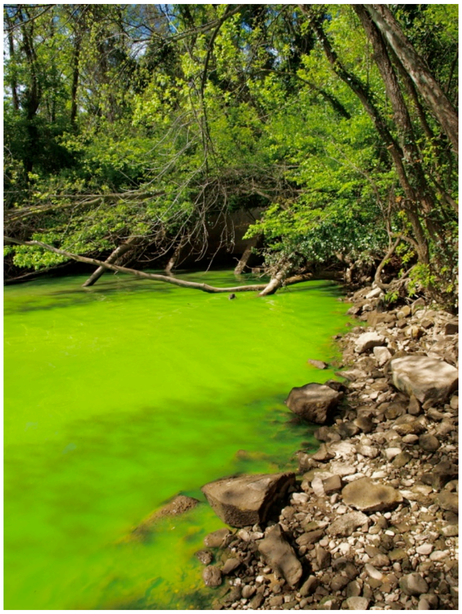


Figure 3: Eutrophication of the Potomac River is evident from the bright green water, caused by a dense bloom of cyanobacteria.

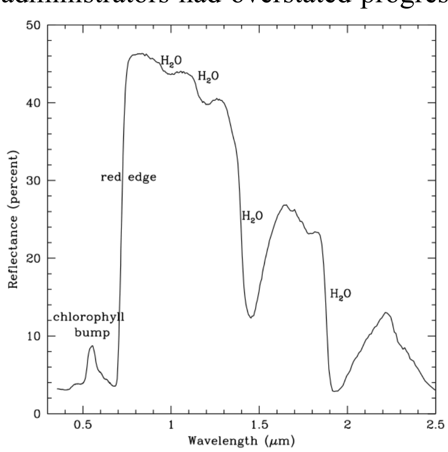
-Nutrient transport results in eutrophication - the ecosystem response to the addition of artificial or natural substances. Negative environmental effects include hypoxia, the depletion of oxygen in the water, which induces reductions in specific fish and other animal populations.

-In the 1970s, the Chesapeake Bay was discovered to contain one of the planet's first identified marine dead zones, where hypoxic waters were so depleted of oxygen they were unable to support life, resulting in massive fish kills. Crabs are sometimes observed to amass on shore to escape pockets of oxygen-poor water, a behavior known as a "crab jubilee". Hypoxia results in part from large algal blooms, which are nourished by the runoff of residential, farm and industrial waste throughout the watershed.

-Increased transport of sediments increase stream and bay turbidity (cloudiness), and oysters in CB can quickly filter sediment. However, overharvesting has reduced the area of oyster reefs in CB by 82% over the last 50 years.

- In 1983, the governors of Maryland, Virginia and Pennsylvania; the mayor of the District of Columbia; and the administrator of the United States Environmental Protection Agency (EPA) signed The Chesapeake Bay Agreement of 1983, forming the Chesapeake Bay Program (CBP).

-Since then, CBP has created several initiatives to reduce bay pollution, but no initiative has been entirely achieved. One hurdle is cost: An estimate in 2006 from a "blue ribbon panel" said cleanup costs would be $15 billion (Wikipedia). Another is the watershed's size: several states that don't adjoin CB contribute pollution (DE, NY, WV, and PA). Some limited success, though: The bay improved slightly in terms of the overall health of its ecosystem, earning a rating of 31 out of 100 in 2010, up from 28 in 2008, but a report in 2008 in the *Washington Post* suggested that government administrators had overstated progress on cleanup efforts as a way to "preserve the flow of federal and state money to the project."



The Planetary Connection –

Figure 4: Chlorophyll reflection as a biosignature - Reflection spectrum of a deciduous leaf (data from Clark et al. 1993). The small bump near 500 nm is a result of chlorophyll absorption (at 450 nm and 680 nm) and gives plants their green color. The much larger sharp rise (between 700 and 800 nm) is known as the red edge and is due to the contrast between the strong absorption of chlorophyll and the otherwise reflective leaf. – Seager+ (2005).

Miocene Fossils at Calvert Cliffs -- Shawn Nock

The Miocene fossils in the Calvert Cliffs are present in three distinct formations:

- Calvert Formation (17-21 mya) (Pink in attached map)

  "Interbedded dark green to dark bluish-gray, fine-grained argillaceous sand and sandy clay; thickness 0 to 150 feet." (4)

- Choptank Formation (14-17 mya) (Gray in attached map)

  "Interbedded brown to yellow very fine-grained to fine-grained sand and gray to dark bluish-green argillaceous silt; locally indurated to calcareous sandstone; prominent shell beds; thickness 0 to 50 feet." (4)

- St. Mary's Formation (8-12 mya) (Blue in attached map)
  "Greenish-blue to yellowish-gray sandy clays and fine-grained argillaceous sand; thickness 0 to80 feet." (4)

At the southern end of the cliffs (where the state park is) it is the St. Mary's formation that is visible (and in some places a little of the Choptank formation may be visible). The Choptank and Calvert formations are clearly visible in North Calvert Cliffs.

** St. Mary's deposit: Fossil Types **

Mostly Mollusks and Shark Teeth / Skate Dental Plates. However fossils of several hundred species of microscopic fossils have been identified. Several large marine mammal fossils have been recovered (whales and porpoises).

The primary mollusk fossils in the St. Mary's Formation are from the genera: Placopecten and Chesapecten. The most abundant we'll see is Chesapecten santamaria (2, Plate 7, figure 7). "It is characterized by 12 to 14 rather broad radial ribs that are usually slightly wider than the interspaces between them. The surface of the ribs and the interspaces are marked by many relatively fine scaly riblets." (2 "Family Pectinidae")

** Interesting Miocene Facts: **

* The bay, most of Maryland and coastal Virginia was a shallow tropical sea.

* The silty and sandy content of the Miocene deposits in Maryland was derived from the erosion of older Coastal Plain deposits and crystalline rocks of the Piedmont region." (1)

** Interesting Maryland Fossil Trivia: **

* "The first fossil described from North America was found in deposits of the St. Marys Formation. This fossil, Ecphora quadricostata was illustrated in a work on Mollusca published in England in 1685." (1)

* "In general, the fossil shells may be distinguished from present day forms by the fact that their shells are usually thicker and are chalky white or gray. Modern shells are more colorful and often are glossy." (1)

Lithology:

Descriptions from a Bluff, 0.6 mi (1.0 km) downbay from Little Cove Point, Calvert County, Md. Quite close to Calvert Cliffs State Park (3)

	ft	m
** Pliocene Era **		
Sand, grayish-orange (10YR 7/4), interbedded with thin clay layers, flaser-bedded, ripple-marked	30	9.1
Sand, reddish-orange (10YR 5/6) medium- to coarse-grained, burrowed, crossbedded, with pebbles and cobbles at base	5.0	1.5
** Miocene Era - St. Marys Formation **		
Sand, yellow-orange (10YR 5/6), poorly sorted, burrowed	13.0	4.0
Sand, olive-gray (5Y 4/1), fine-grained, silty, interbedded with silty clay	15.0	4.6
Sand, olive-gray (5Y 4/1), silty, fine-grained; molluscan molds only	11.0	3.4
Sand, olive-gray (5Y 4/1), silty, fine-grained, glauconitic; abundant mollusks	5.0	1.5
Sand, olive-gray (5Y 4/1), silty, fine-grained; few mollusks	6.0	1.8
Sand, olive-gray (5Y 4/1), fine-grained, very shelly; mollusks dominated by Turritella, many worn	1.0	0.3
Sand, grayish-olive-gray (5G 4/1), silty, fine-grained, burrowed; small, fragile mollusks	3.0	0.9

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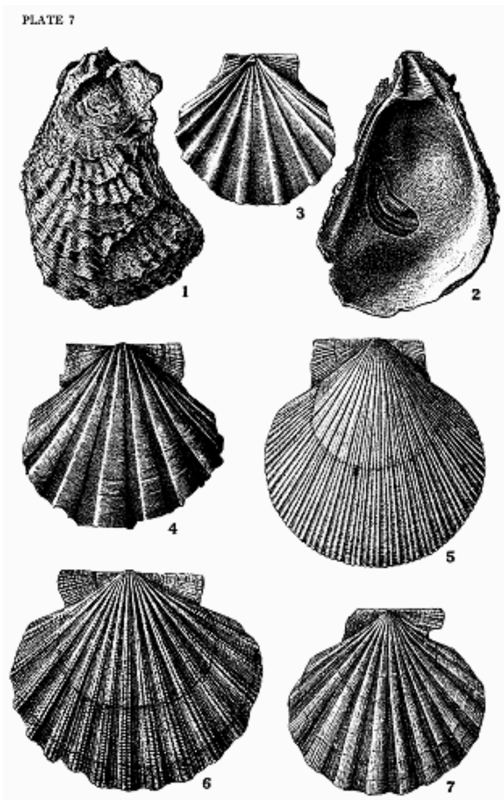
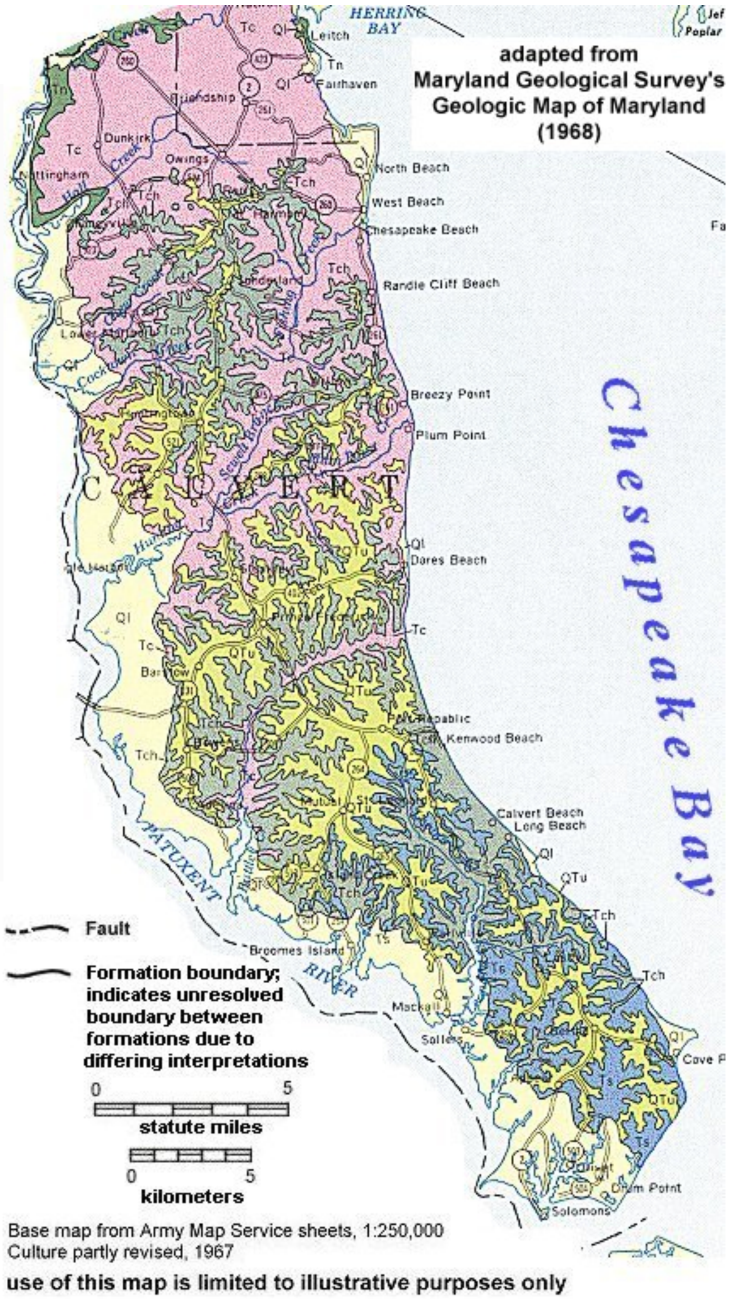
3: Ward, L., Powars, D.; "Tertiary Lithology and Paleontology, Chesapeake Bay Region"; 2004

http://pubs.usgs.gov/circ/2004/1264/html/trip9/index.html

4. Adapted from "Geologic Map of Maryland", 1968
http://www.mgs.md.gov/esic/geo/cal.html





"Meteroid Mayhem in Ole Virginny": The Chesapeake Bay Impact Crater

by Catherine Neish

Chesapeake Bay Field Trip (Spring 2012)

The Chesapeake Bay Impact Crater

The Chesapeake Bay Impact Crater is a buried impact basin on the east coast of Virginia, and the largest known impact crater in the US. It consists of a ~85 km annular trough, a deeper ~38 km inner trough (~1 km deeper), and a central uplift (Figures 1 and 2). It formed during the late Eocene, **35 Myr ago**, when a warmer climate and resultant higher sea level made eastern Virginia a shallow marine location (< 300 m of water) on the outer continental shelf. The inner and outer annuli are both filled by the "Exmore" breccia unit, and since the impact, 150-400 m of sediments have accumulated above the crater. As a result, the surface morphology is almost entirely flat.

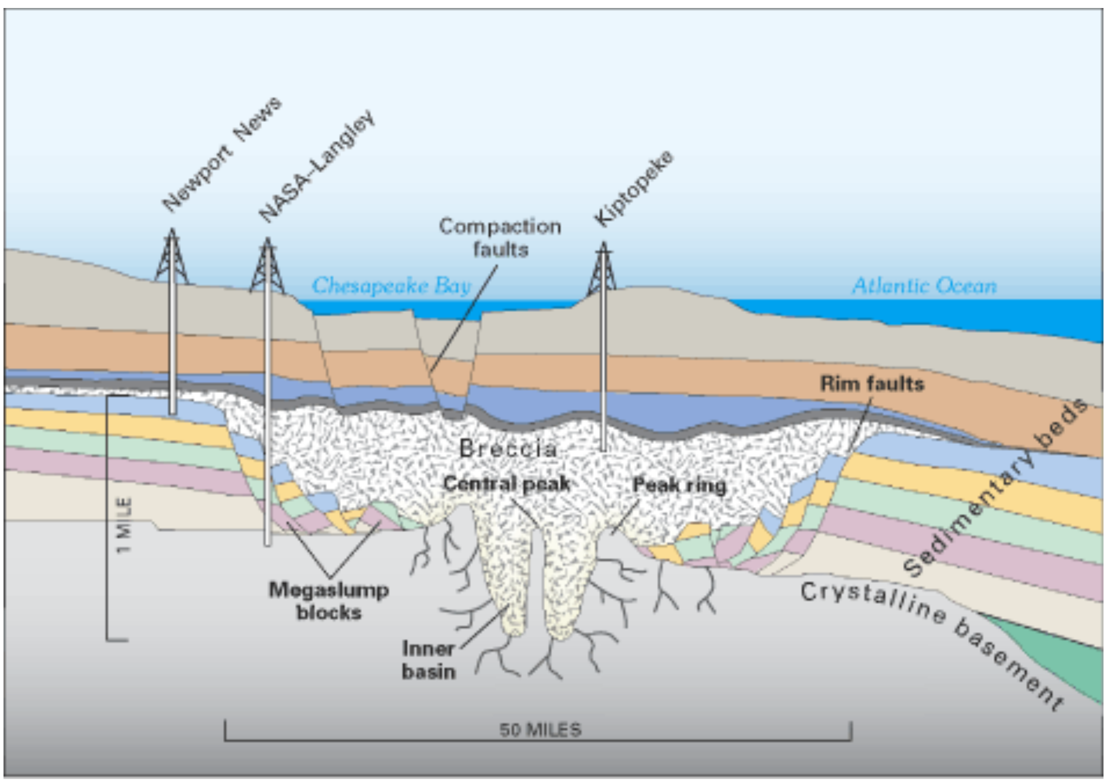


Figure 1: Cross-section of the Chesapeake Bay impact crater, as inferred from bore holes, seismic surveys, and gravity data.

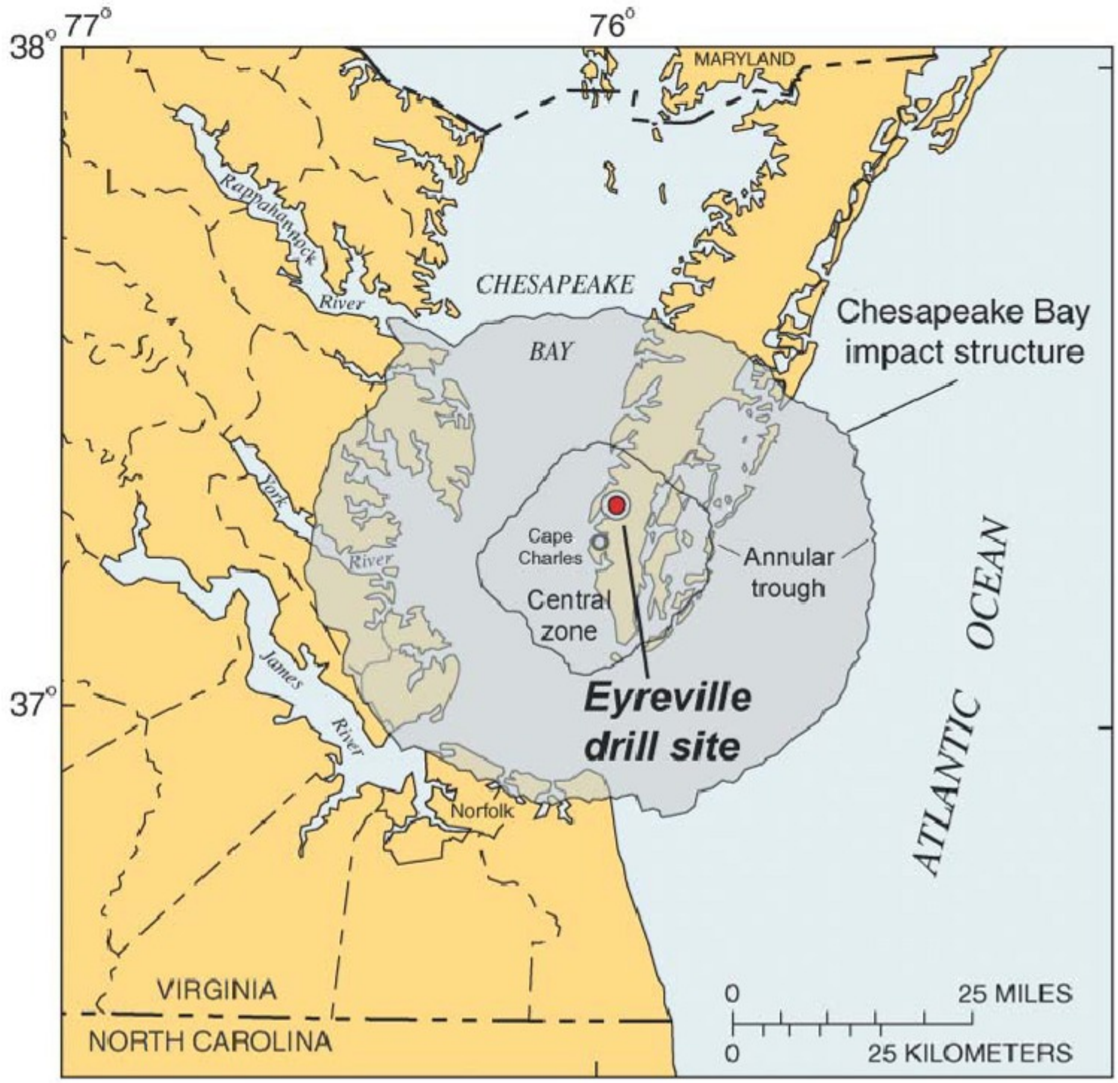


Figure 2: The location and extent of the Chesapeake Bay impact crater. The center of the crater lies beneath Cape Charles, VA.

The first hints of the crater's presence were discovered by John Cederstrom, who identified an odd breccia layer of varying composition and age when surveying Virginia's Coastal Plain for new aquifers during World War II. Evidence for a late Eocene impact on the east coast of the United States was later discovered in 1983, when the Deep Sea Drilling Project found tektites and shocked quartz off the coast of Atlantic City, NJ. This impact was not linked to the Chesapeake Bay breccia unit until the early 1990s, when C. Wylie Poag obtained seismic profiles over the bay. The discovery was published in the August 1994 issue of Geology: "Meteroid Mayhem in Ole Virginny: New Evidence of an Impact Crater Beneath Chesapeake Bay and Possible Source of the North American Tektite Strewn Field" by Poag, Powars, Poppe, and Mixon. This discovery was confirmed with the identification of shocked grains within the basement layer, and additional seismic profiles.

Marine impact basins

The structure of the Chesapeake impact basin is similar to other marine craters on Earth (i.e., Lockne, Sweden), but is quite different from similarly sized subaerial craters on Earth (i.e. Popigai, Siberia) and peak-ring craters on other planets. In particular, marine impacts have the morphology of an 'inverted sombrero', and tend to lack any significant surface topography, including the absence of a raised rim. Collins and Wünnemann (2005) attribute the unusual shape of Chesapeake Bay to the rheological variability of the target material, namely, the presence of a weak sedimentary layer over the crystalline basement. The weak nature of the sedimentary sequence prolonged the impact-induced deformation, and water aided in the fluidization of the sediments, expanding the structure to a diameter much larger than the transient cavity (Figure 3). They estimate that the bolide that formed the Chesapeake Bay impact crater was smaller than previously estimated (3.2 km in diameter), and would have formed a ~40 km crater if it had impacted on land. Experiments support the idea that larger craters are formed in saturated targets. A water depth of ~12 times the projectile diameter is required before craters are no longer observed in the targets (Baldwin et al. 2007).

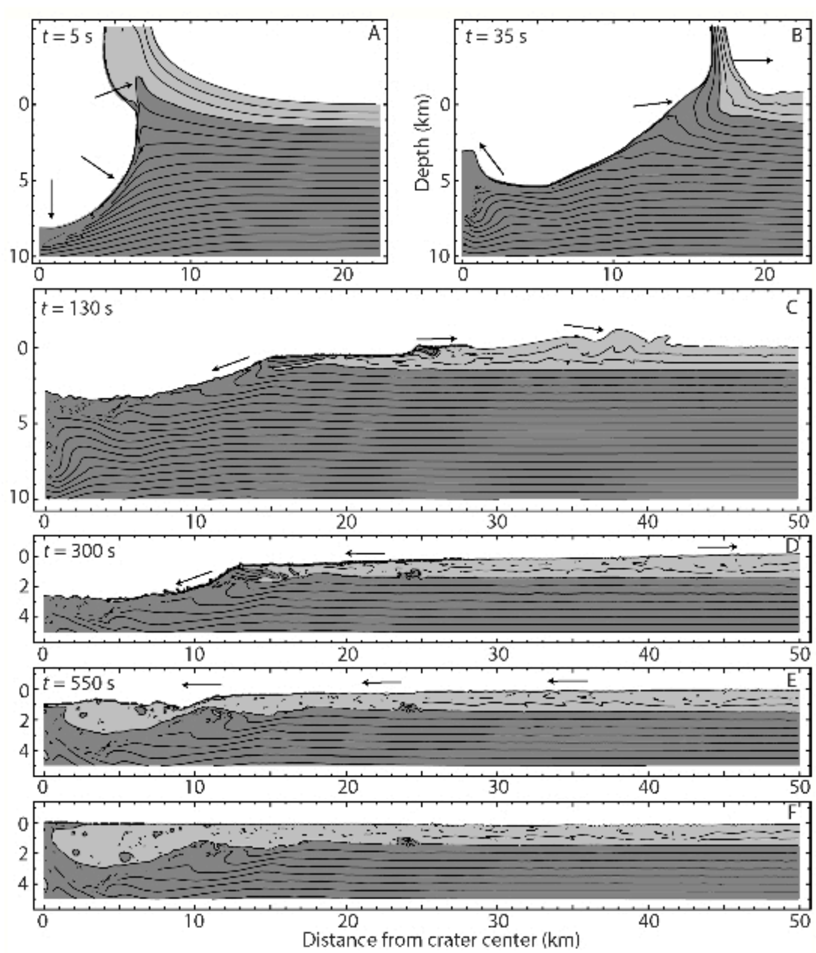


Figure 3: Simulation of Chesapeake Bay impact by Collins and Wünnemann (2005). Dark gray indicates the crystalline basement and light gray indicates the sedimentary unit.

Planetary connection: Mars and Titan

Horton et al. (2006) proposed that marine impacts might have occurred on Mars where near-surface sediments are thick and contain volatiles. They identified several flat-floored, rimless impact structures associated with layered terrain that may represent wet-target impact craters (Figure 4). Wet-target impact basins may be difficult to recognize on other planets, however, since sedimentation has completely covered the topographic expressions of all known marine-target craters on Earth. However, buried craters can later be exposed at the surface by erosion (i.e. Lockne crater, Lindström et al. 1996). It is possible that this lack of topography may help to explain the relative dearth of impact craters observed near the poles of Titan (first noted by Wood et al. 2010). If Titan's polar regions are saturated by liquid hydrocarbons, craters formed in those regions may lack any recognizable topographic expression (C. Neish, personal communication).

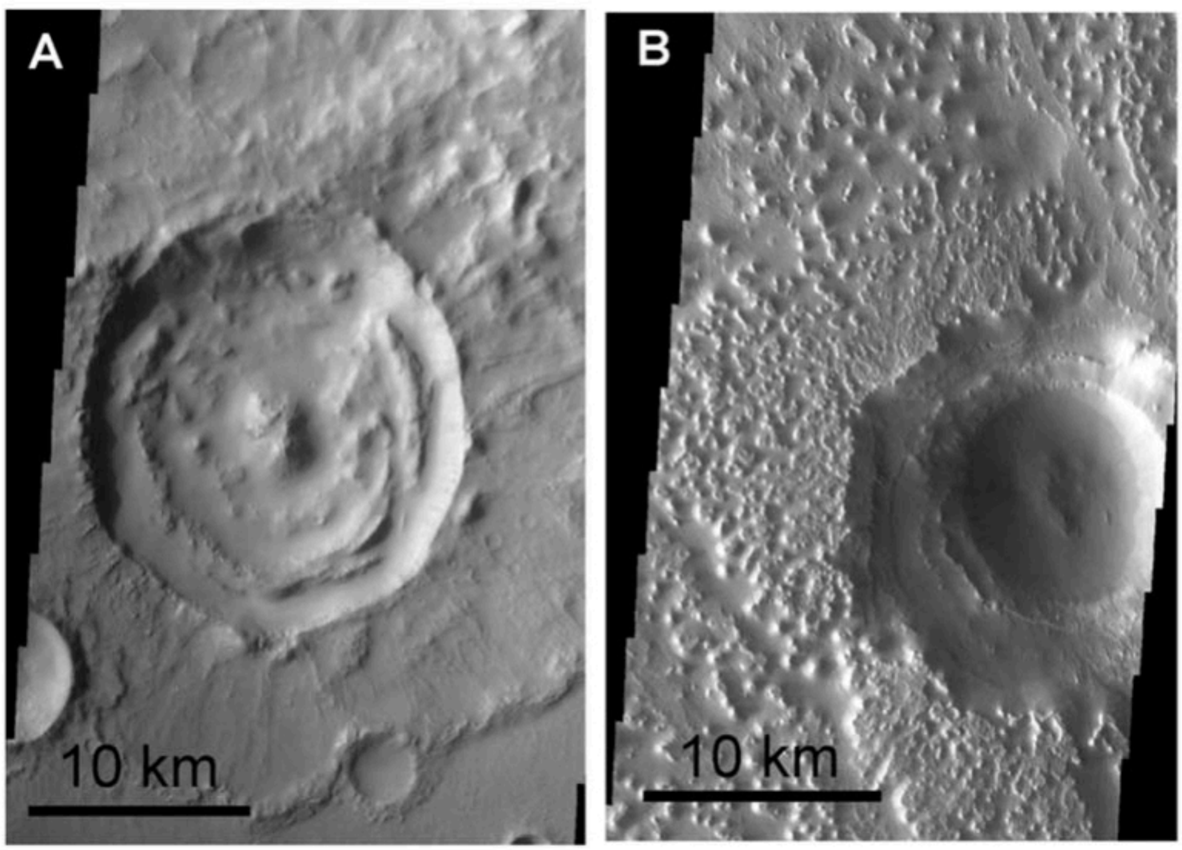
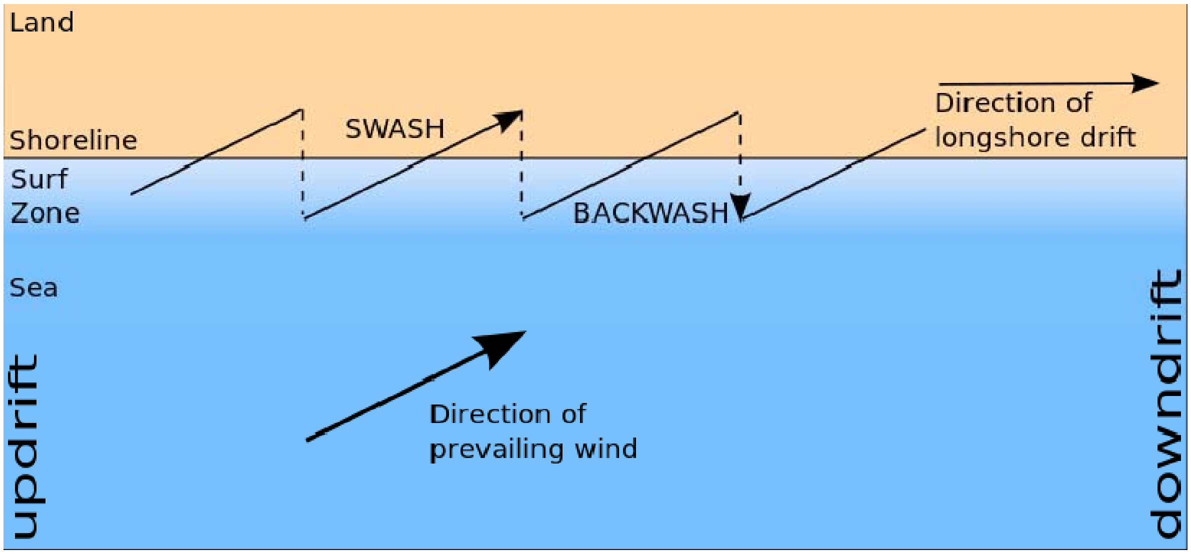


Figure 4: Two Martian craters identified by Horton et al. (2006) with inverted sombrero morphology.

Longshore current

• When waves strike the beach at an angle, a current is set up along the shore (longshore current) in which the net movement of water, and of the sand that it carries, is parallel to the coast.

•



• During summer, prevailing waves from the southeast
  • *longshore current (and sand) moves northward*
• During winter storms, waves from the northeast
  • *longshore current (and sand) moves southward*

• On an annual basis, the net movement is ~150,000 m^3 of sand to the south

• When a wave encounters a steeper beach slope longshore currents stronger (see Grier and Cohen, 1994)

• Jetties interrupt not only the flow of sand, but of the longshore current
  • *Downcurrent side of the jetties, the longshore currents will be erosive until all the sediment that has been removed from the current is replaced*

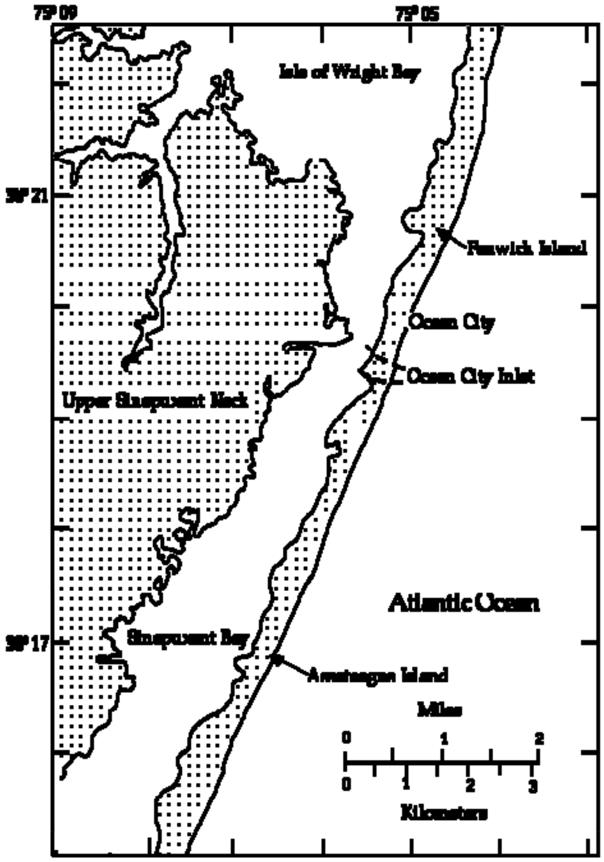
Longshore current in OC

- Storm of 1933 opened inlet to Isle of Wight Bay
  - Army Corps of Engineers built jetties to keep the inlet open
  - Jetties helped to build an extensive beach for the city which was good for vacationers and storm protection.
  - HOWEVER, sand stopped by the Ocean City jetties was not available to replenish sand lost to the longshore current along Assateague,
    - *Island has seen severe erosion and migrated landward (next page)*

- Offset of the two barrier islands—Fenwick and Assateague—is approximately 1 km
  - *The effects attributable to the jetties have extended about 15 km southward from the inlet.*

- Restoration project began in 2002 ($63M)
  - National Park Service, the Army Corps of Engineers, and the Minerals Management Service.
  - 25-year project involves mechanically dredging sand onto the Assateague Island beaches
  - initial, short-term phase:1.8 million cubic yards of sand dredged from Great Gull Bank, a linear shoal on the shelf

Longshore current



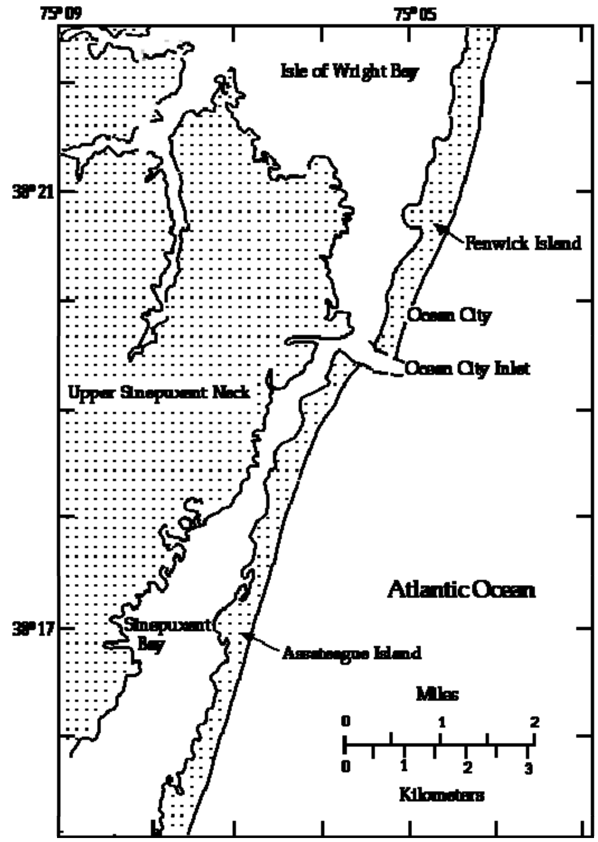
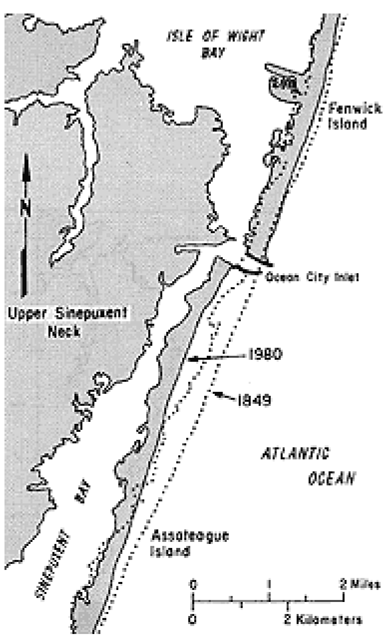


Figure 1. Approximate coastline along Maryland's barrier islands prior to 1933. The hurricane of 1933 cut the Ocean City Inlet (marked by dashed lines across the barrier island) and broke the barrier island into two distinct islands, Fenwick and Assateague.	Figure 2. Approximate coastline along Maryland's barrier islands in the 1980s.



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http://soundwaves.usgs.gov/2002/11/research.html
http://www.newworldencyclopedia.org/entry/Assateague_Island
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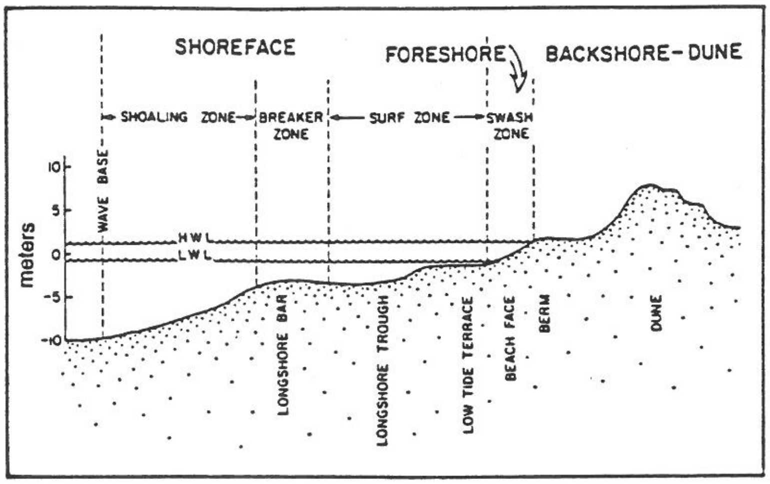
SEPT. 1994

Longshore Currents and Grain Transfer:
Creating a River of Sand

Produced and Directed by Barbara Cohen and Jennifer Grier

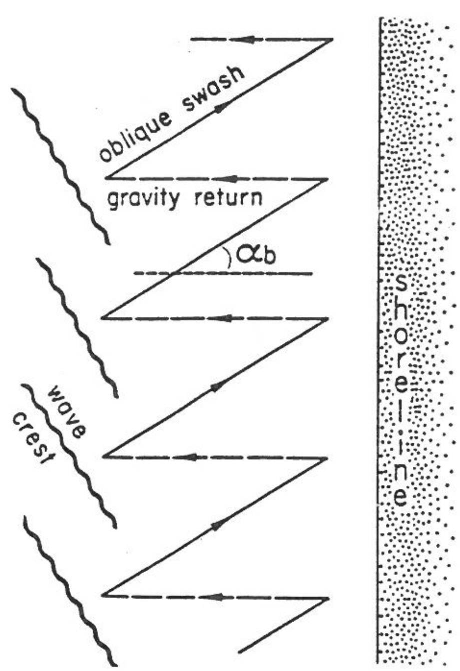
Some potentially useless information:

fig. 1



<u>Shoaling Zone:</u> initial shallowing of the shore, where wavelength and wave velocity decrease, and wave height increases.
<u>Breaker Zone:</u> where waves steepen to the point where orbital velocity exceeds wave velocity and the wave breaks.
<u>Surf Zone:</u> breaking waves generate turbulence that throws sediment into suspension and creates a bore wave that transports this sediment landward in this zone. The width of this zone is governed by the beach slope: the steeper the beach face, the narrower the surf zone.
<u>Swash Zone:</u> a rapid, very shallow swash moves up the beach, followed almost immediately by a backwash flow down the beach. Sand here moves in a zigzag motion:

fig. 2

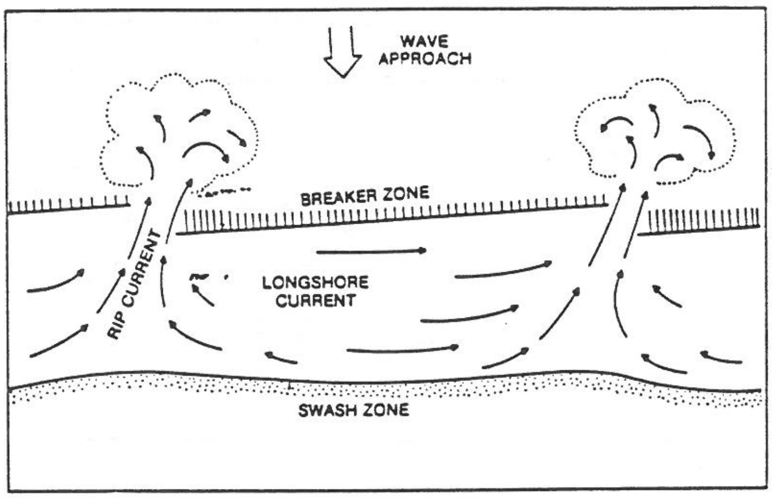


The zigzag motion of the sediment along a steep beach face under the wave swash. The incoming wave swash drives the sand up the beach at an oblique angle and the return gravity flow washes it back to its original level.

Cohen & Grier Longshore Currents: *Creating a River of Sand*

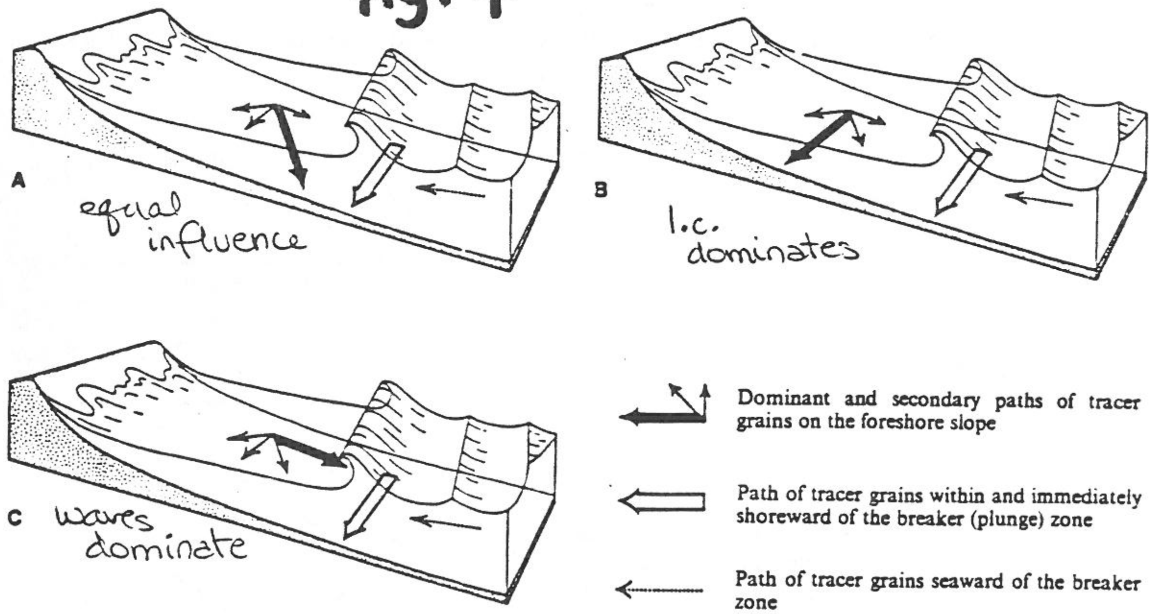
As breakers and winds pile water up against the beach, they not only create bidirectional translation waves that move back and forth in the swash zone, but they also create two types of unidirectional currents. ***Longshore currents*** are generated when waves that approach the shore at an angle break, and a portion of the translation wave is deflected laterally parallel to the shore. These currents move parallel to shore following longshore troughs (the ridge-and-runnel system) in the lower surf zone. As incoming waves pile up water and block its return seaward, the longshore currents carry water to a break between sand bar, where it flows outward in a ***rip current*** (see also Chabot and Hoppa, this book).

fig. 3



Both wave action and longshore currents move sand along beaches. The direction of net sand transport in the longshore current is, obviously, parallel to the beach in the direction of current flow. This takes place in the surf zone runnels. In the swash zone, however, motion is more complex, and depends on the relative intensities of wave motion vs. longshore currents.

fig. 4



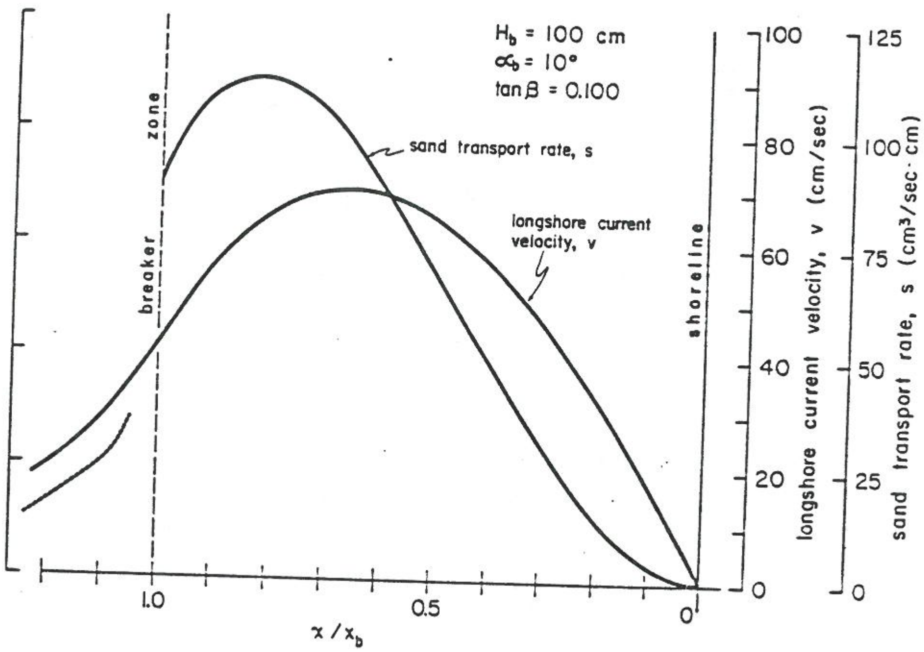
Transport of sand on beaches by longshore currents under different surf conditions. A. Sediment movement under surf conditions where the longshore current and the wave motion exert an equal influence. B. Sediment grain motion under conditions of a high-velocity longshore current (velocity >60 cm/sec). C. Sediment grain motion where the longshore current velocity is <30 cm/sec. and the onshore-offshore motion of waves controls the sediment grain transport.

Cohen & Grier **Longshore Currents:** ***Creating a River of Sand***

The wave effect includes, but is not limited to, the velocity of the waves. Longshore current velocity is related to the incoming wave height and the approach angle. There is no accepted all-inclusive theory, though, that allows prediction of current velocity. Empirical relations try to fit observed data using variables such as distance from shore to breaking point, water depth, cross-sectional area of the breaking wave, friction factors, energy considerations, and various fudge factors.

The wave effects and longshore currents work together in transporting sand down a beach to create coastline structures like spits. The sand transport rate can be related to the longshore current rate in this fascinating diagram:

fig. 5



The distribution of the longshore sand transport across the width of the nearshore obtained by having the local transport proportional to the product of the bottom stress exerted by the waves and the local value of the longshore current velocity.

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