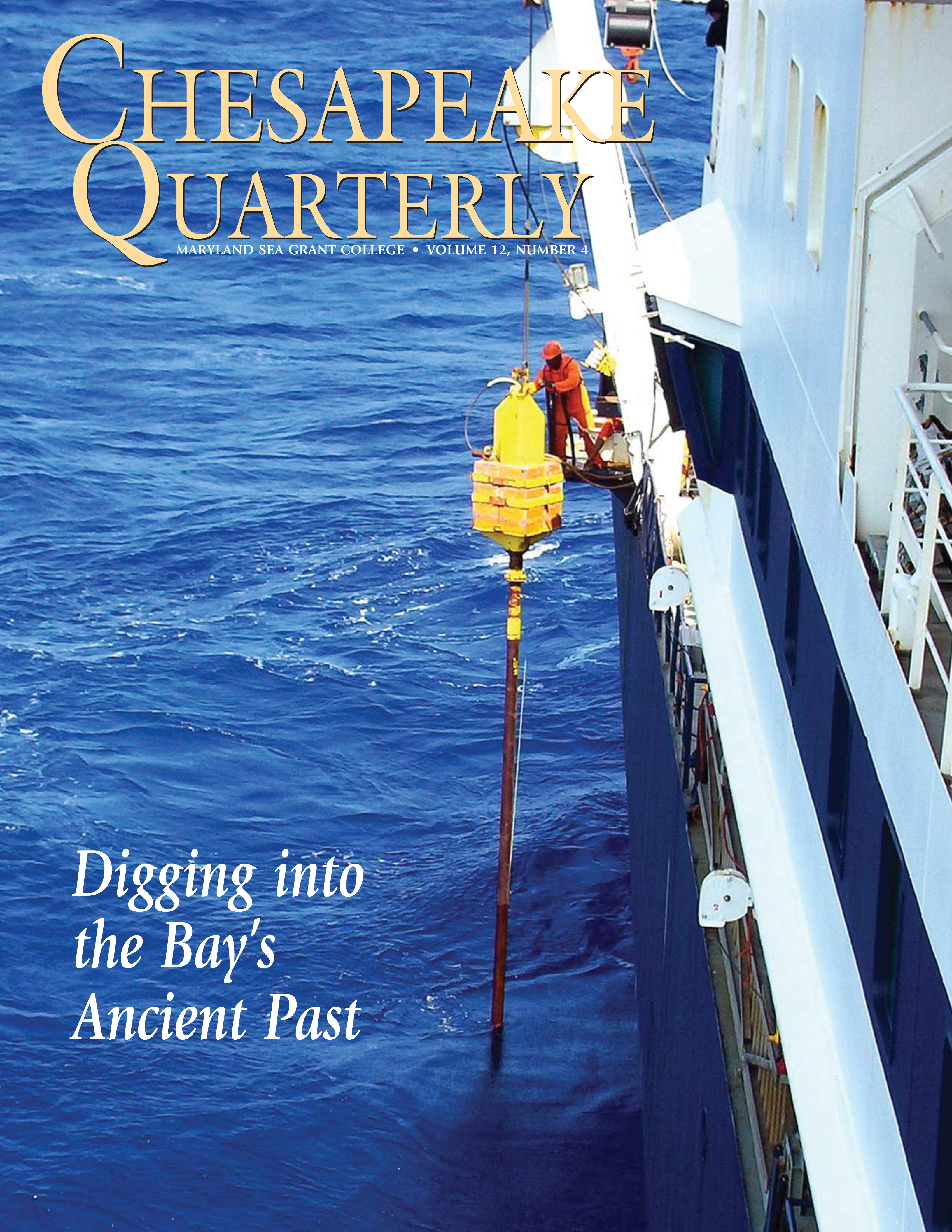

Chesapeake Quarterly

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Digging into the Bay's Ancient Past

contents

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Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed.

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Cover photo: *On board the* RV Marion Dufresne, *a French research vessel, a deck worker gets ready to drop the giant Calypso corer, a sampling device that can drive deep into the bottom of the Chesapeake Bay.*
PHOTOGRAPH, JENNEY HALL

THE DAY BEFORE YESTERDAY

When abrupt climate change came to the Chesapeake Bay

Michael W. Fincham

In October 2003, a little-known think tank in the Department of Defense quietly released a report warning that climate change could happen suddenly — so suddenly it could pose a major threat to our country's national security.

The title of the Pentagon report was a mouthful: *An Abrupt Climate Change Scenario and its Implications for United States National Security*. Those implications included rising seas, flooded coastal cities, at least one drowned country, droughts, food shortages, failed states and fortress states. The report was never designed as a scientific prediction. It was a speculative effort by defense strategists to dramatize all the security threats the country would face if the climate suddenly shifted.

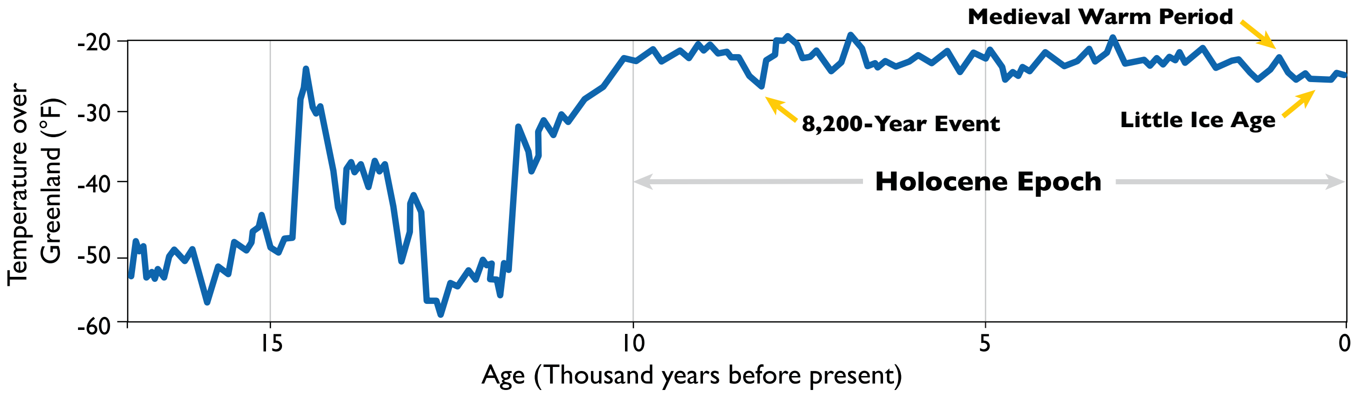
Why was the Pentagon suddenly worried about abrupt climate change? Because new evidence from Greenland showed it had happened before.

On June 2, 2003, a French vessel designed for deep-ocean research entered the Chesapeake Bay, an estuary noted for its shallow waters. On board were a dozen American scientists, most of them geologists or geophysicists who were hoping to punch coring tubes down into the bottom of the Bay and bring up sediments buried there before the estuary formed.

The American scientists had questions about past climate changes and the sediments might hold answers — or at least clues. "We were trying to learn more about the long-term history of the Chesapeake Bay," says Debra Willard of the U.S. Geological Service. Sediments, if you know how to read them, have a story to tell: they catch and hold the remnants of whatever washed into the Bay once upon a time or blew into the Bay or lived and died in these waters. One question the scientists were asking: how has climate change shaped the evolution of this estuary?

To answer their questions, the American scientists had chartered the *RV Marion Dufresne* for 48 hours of round-the-clock coring work. The ship was big, 395 feet long, and it offered five-course French cuisine complete with waiters, wine, cheese plates, and pastries. It also carried the gear and staff that could take very deep core samples. Managed by the Institute Polaire Paul Emile Victor (IPEV), the ship had two key missions: to carry supplies to French research stations near Antarctica and to mount expeditions around the world to uncover evidence of climate change.

"It was the only ship that had the capability to get long continuous cores,"



Thomas Cronin, a research geologist, *(above) collaborated with colleagues at the U.S. Geological Survey, who analyzed sediment cores from the Chesapeake Bay and found evidence of abrupt climate change during the early evolution of the estuary. Ice core indicators (above) show that the Holocene, our current interglacial epoch, began some 11,000 years ago and brought a time of stable temperatures, interrupted by a cool-down 8,200 years ago and later by the Medieval Warm Period and the Little Ice Age.* PHOTOGRAPH, MICHAEL W. FINCHAM; GRAPH, ADAPTED FROM RICHARD B. ALLEY, THE TWO-MILE TIME MACHINE

says Willard. A research geologist with expertise in buried pollen, she coordinated the expedition for the cadre of American scientists, most of them from the U.S. Geological Survey (USGS) and the Naval Research Laboratory. The *RV Marion Dufresne* came equipped with science laboratories, high-end computer workstations, and huge cranes, but its secret weapon was the Calypso corer, one of the longest, heaviest coring samplers in the world.

With all that gear, the Americans planned to capture the deepest sediment samples ever taken in the history of Chesapeake Bay science, evidence that could hold clues about earlier climate change in the Chesapeake.

Ten years ago the specter of abrupt climate change seemed to invade the American mind-set rather abruptly. Perhaps it was a reflection of post-9/11 fears about how fast the future could turn grim, but a lot of serious people were suddenly talking about it.

The Pentagon report on abrupt climate change was commissioned by Andrew Marshall, long-time director of a think tank called the Office of Net Assessment. Press reports usually called Marshall the "Yoda" of the Pentagon, and *Foreign Policy* magazine in 2012 called him one of the world's top global thinkers. Now 92 years old, Marshall is still on the job, and a big part of his job is still the same: thinking about the unthinkable and reporting his thoughts directly to his boss, the secretary of defense. In 2003 one of his thoughts was that the country should now take seriously the possibility of abrupt climate change.

He had this thought because he knew that many scientists were beginning to take the idea more seriously. Only the

***The deck crew of the* Marion Dufresne** *raises the Calypso corer that captured the longest continuous sediment samples ever taken in the Chesapeake Bay. A researcher (right) withdraws a sample to analyze the chemistry of pore water trapped in long-buried sediments. Debra Willard (opposite page), the research geologist who coordinated the research cruise, has analyzed sediment cores like this to chart changes in forest populations and the arrival of major drought eras during our current interglacial epoch.* PHOTOGRAPHS: ABOVE AND RIGHT, FRENCH POLAR INSTITUTE IPEV; OPPOSITE PAGE, MICHAEL W. FINCHAM

year before, the National Research Council had released a 2002 study warning that climate change could occur quickly, within decades, especially if something happened to slow down or shut down the Atlantic Meridional Overturning Circulation, the ocean conveyor belt that, among other missions, carries heat from the tropics up into the North Atlantic. After Marshall read the scientific study, he commissioned his own study and hired Peter Schwartz and Doug Randall, two self-described futurists, to work out a geopolitical scenario.

Hollywood producers were also skimming those science reports, skipping any inconvenient details about the speed of climate change. In 2004 they created their own vivid version of abrupt climate change by releasing a 125-million-dollar movie, *The Day After Tomorrow*. For geologists, abrupt change usually took several decades, for filmmakers it only took several days. Unleashing the power of digital special effects, they showed New York City succumbing to a new ice age in the space of three weeks, a climate change so abrupt and so devastating it sent the U.S. government decamping to Mexico.

What was the scientific evidence for "abrupt climate change" in the past? The Pentagon modeled its nightmare scenario on a specific episode that struck the planet some 8,200 years ago. The earth was well into our current interglacial era, an age of warming oceans and melting ice sheets, when a major cool-down suddenly arrived. It's called the 8.2 kiloyear event — or the 8.2 ka event in scientific shorthand. It dropped temperature averages in Greenland 38 degrees Fahrenheit in less than 20 years and it altered ocean currents, atmospheric circulation, and weather patterns around most of the planet. In geological time scales, that's abrupt.

The first evidence for the 8.2 kiloyear cooling was found in ice cores in Greenland, but on board the *Marion Dufresne* Tom Cronin and Debra Willard suspected there might also be evidence buried in sediments below the Chesapeake Bay.

As the French ship dropped anchor for its first coring site, Cronin found a spot along the high walkways that hang above the stern deck so he could watch the work crew below prepare the sampling gear. Tall and fit with graying hair and strong opinions, Cronin is a research geologist who joined the USGS in 1978 and has been publishing prolifically ever since on climate change, sea level rise, estuary formation, and ocean circulation. Gathered to watch with him along the walkways were most of the American scientists. Each "core drop" from this kind of ship represented a rare opportunity for gathering deeper sediments and deeper insights into the evolution of the estuary.

The heavy lifting on this ship was handled not by the American or the French scientists, but by a crew of 20 Malagasians recruited from the island of Madagascar, a former French colony. Working the deck in hard hats, they hooked together several pipes into one extended tube, craned it up to the coring platform, and dangled it over the side like a long ice pick. There they could top load the ice pick with weight, up to 10 tons of weight if needed. On deep-ocean drops, all that weight has driven long tubes 230 feet beneath the ocean floor.

Their hopes for a deep drop took a hit

at the first site. The coring pipe drove into the bottom and smacked against a barrier of hard sand. When the Malagasian crew winched it back up and laid it on deck, the American geologists found a badly bent core pipe, holding only a short stub of sand. That hurt. Willard and Cronin hoped an ice pick in that spot would jab all the way down into sediments buried during the last ice age.

Deep cores, however, are hard to come by in the Chesapeake Bay. To drive very far into bottom sediments, a coring tube needs a lot of deep water. And that's the problem: a shallow-water estuary requires shorter coring tubes and shorter drops. On this trip, three more core pipes would come up holding short stubs with 2.7 feet, 2.9 feet, and 8.1 feet of sediment.

"Coring the Bay is very much like fishing," said Peter Vogt, a marine geophysicist with the Naval Research Laboratory who helped pick out coring spots. When the *Marion Dufresne* kept fishing, casting 10 coring pipes in all into Chesapeake waters, the crew eventually landed some big catches: a 42-foot core along the eastern side of the lower Bay, then a 52-footer nearby, a 55-footer off the Patuxent River, two 60-footers off the mouth of the Potomac, and along Kent Island, they raised an 80-foot sediment core, the longest sediment core ever landed in the Chesapeake Bay.

For Cronin, the third core drop was the charm. In the blue twilight of an overcast evening the ship dropped anchor along the eastern side of the lower Bay, and at 10:05 p.m. the core pipe splashed down into dark waters. This would not prove the longest core drop at 52.5 feet, but it hauled up strong evidence that the 8.2 kiloyear cooling once came to the Chesapeake.

With this core Cronin and colleagues would insert a new chapter into the oft-told story about the origins of the Chesapeake Bay. According to the accepted account, the Bay was coming to life as the last glacier era was dying out. When the great ice sheets began melting some 15,000 years ago, sea levels began rising, creeping across the continental shelf, steadily drowning the lower river valley of the ancient Susquehanna River. Roughly 10,000 years ago, the ocean reached the area we now call Norfolk, and pushing north the seawater began turning the lower river into a brackish-water estuary. By 3,000 years ago the estuary reached 190 miles north to Havre de Grace, Maryland.

The new chapter in this story is the 8.2 ka cooling. It came early in this process, and evidence of its abrupt arrival can be seen in the ups and downs of marsh growth in the evolving estuary. As brackish waters began pushing north, marshes were accreting steadily along the borders of the new estuary, keeping pace with rising sea levels. Around 9,000 years ago, however, sea level rise accelerated, and many marshes, unable to keep up, began drowning. It would take the abrupt onset of the 8.2 ka cooling to slow the rate of sea level rise and revive marsh growth. Marsh accretion could once again keep pace with the rising water.

That's the story Cronin and Willard and their colleagues were able to extract from the sediments in core MD03-2656. They carbon-dated key sections of the core and probed its mud for microfossils of plants and animals. They were looking for large groupings and large gaps in population numbers, evidence that would tell them when certain plants and animals flourished and when they faded. Willard focused on pollen, Cronin on animals. Knowing the salinities and temperature ranges for their microfossils, they could use these groupings as indicators for changes in rainfall, salinities, temperatures, and sea level rise.

When saltwater protozoa suddenly flourished, for example, and certain sedge grasses suddenly faded, they could say sea level was rising fast and marshes were disappearing. When the signs reversed, when protozoa numbers dropped and sedge grasses reappeared, "we interpret that as a slowdown in the rate of sea level rise, allowing marshes to grow," says Cronin. And the cause for the slowdown: the big cooling, the 8.2 kiloyear event.

What could bring on such an abrupt climate change? It's easy to see how the sudden onset of the 8.2 ka cooling could lead to the Pentagon's nightmare scenario. It could also, perhaps, inspire yet another Hollywood film, let's call it *The Day Before Yesterday*. It would open with an aerial shot gliding over a huge lake that once covered much of America's Great Plains and parts of Canada (see lake map, p. 7). Some 9,000 years ago, Lake Agassiz was sitting in a depression left behind by the retreat of the Laurentide ice sheet that once stood two miles high, mashing down parts of the United States and all of Canada.

That depression was now brimming with meltwater from the retreating ice field, eventually holding a small ocean of fresh water, some of which leaked south along the Mississippi River basin. Rimming the lakes on the north and east, however, were the ramparts of the retreating Laurentide. They stood like a great white dam, holding back all that fresh water.

In a still-warming world, that dam had to burst. And sometime well before 8,200 years ago, it did, probably several times and in several places. That dam break kicks off Act II in our movie: icy water rushes through the breaches, huge amounts of water, something like 50 Amazon Rivers, according to Cronin. It's probably headed out through Hudson Bay, the St. Lawrence River, and the Mackenzie Straits.

Scientists call this a "catastrophic release." When this huge flood of fresh water hit the saltwater oceans of the North Atlantic, it caused a catastrophe: it collapsed the Atlantic Meridional Overturning Circulation (AMOC), the great conveyor belt that carries warm and cold water around the globe. The conveyor usually pumps warm, salty waters out of the tropics into northern regions where the water cools off, increases in density, and sinks, pushing cold water southwards in deep, cold underwater currents. This "overturning" system not only circulates heat around the globe: it also drives atmospheric circulation that largely controls weather patterns.

What happens to this conveyor when a tsunami of meltwater arrives? "You are flowing a lot of warm water up north," says Cronin, "and all of a sudden you throw this fresh water on top, and you lower the salinity and the density." Water that is less salty gains buoyancy and loses density. It doesn't sink as easily. In effect, it turns off one of the heat pumps for the planet.

The result: less Gulf Stream heat reached the high latitudes, atmospheric circulation was altered, sea level rise slowed down, and effects were felt around much of the globe. For the movie, it's the perfect Act III plot reversal: the warming of the planet unleashes the cooling of the planet.

And there were more plot twists on the way. The glacier lakes finally drained out, the Atlantic Meridional Overturning Circulation (AMOC) recovered and stabilized, heat flowed again to the Northern Hemisphere, the big 8.2 ka cooling began to wane, and sea levels began to rise again. In the Chesapeake, marshes began drowning for a second time.

There was a happy ending, of sorts, and not just for marsh lovers. Sea level rise began to slow down and stabilize around 7,000 years ago, enabling marsh growth to flourish again in the Chesapeake and setting the stage for a major transition in human history. According to scientists like John Day of Louisiana State University, the rise of urban, state-governed societies began in coastal villages and cities that located alongside estuaries and the lower flood plains of major rivers. Think the Tigris-Euphrates in Iraq, the Nile in Egypt, the Yellow River in China. The rich biological productivity of newly stable coastal areas, says Day, helped unleash the social productivity behind the emergence of early civilization.

What would be the fate of our current version of civilization if a climate change as abrupt as the 8.2 kiloyear cooling arrived sometime soon? The question was hard to answer 10 years ago when Andrew Marshall commissioned his Pentagon scenario. In 2002 the National Research Council (NRC) said there was virtually no research on the economic and ecological impacts of abrupt climate change. A year later a report published by the Royal Society of London came to the same conclusion.

The authors of the Pentagon report were, in effect, "first in the field" to consider the social and political impacts of sudden climate change. But they were offering informed speculation rather than scientific research. Their goal was to create a geopolitical scenario chock-full of what-if speculations — all designed to spur new thinking about threats to American society and security.

What if, for example, the ocean conveyor belt were to collapse in the near future as it did in the not-too-distant past? The climate effects would include temperature drops in North America, Europe, and Asia, coupled with some temperature rises in Australia, South America, and South Africa. Europe could become like Siberia. Coastal cities like The Hague could be flooded out, and countries like Bangladesh could become uninhabitable. China could have less predictable monsoon cycles, colder winters, hotter summers, and food shortages leading to famine. The United States could face shorter, less productive growing seasons and suffer larger floods, especially in mountain regions, and more intense forest fires. Southern countries could suffer less. Australia, for example, could remain a major food exporter.

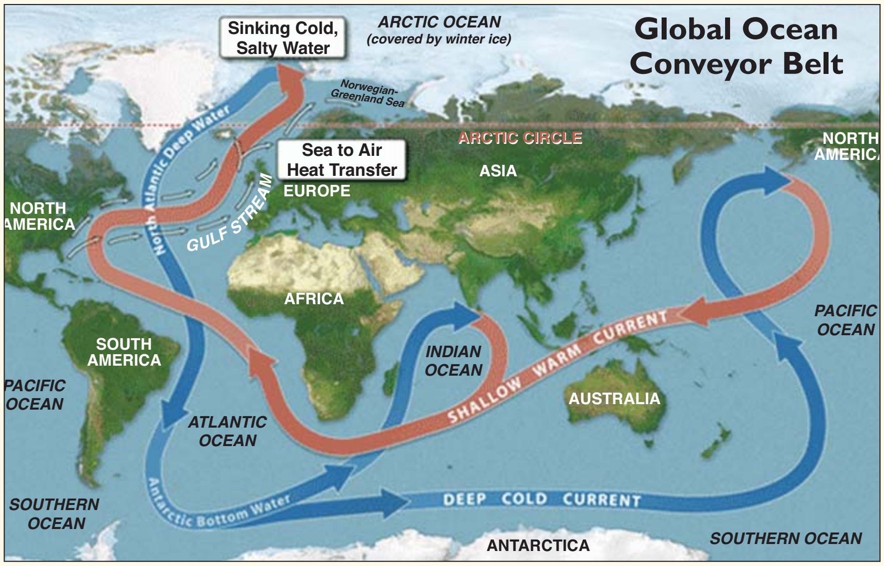
The geopolitical upheavals would include food and water shortages, mass emigrations, wars for resources, and realignments among "have" and "have-not" nations. Would Australia and the United States become "fortress nations?" Would the U.S. and Canada eventually morph into one nation to better control their borders?

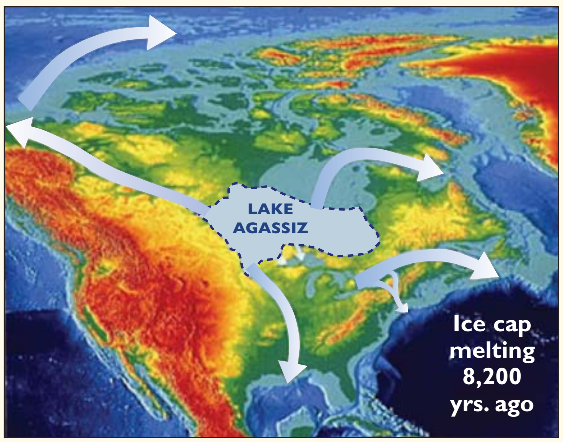
The main point of all these speculations was a "shock and awe" attack on the "gradual change view," the belief that climate change would come slowly. That nations could adapt. That they would have time to increase food production. That they would find technological solutions for water shortages.

In the last 10 years, the "abrupt change view" has been drawing more attention from the American scientific community. The 2002 report by the National Research Council was followed by a 2008 report by the U.S. Climate Change Science Program, and most recently the NRC weighed in again with a study released in December 2013. The new study goes by the title, *Abrupt Impacts of Climate Change: Anticipating Surprises*, and it calls for the U.S. government to create an early warning system that would carefully monitor key earth systems for subtle signs of "tipping points" that could unleash sudden climate changes.

This latest NRC report claims to be the first to examine the research on human, social, and economic impacts. The study was developed in collaboration with

What Caused Abrupt Climate Change?





***The great ocean conveyor belt** is driven by density differences created by temperature and salinity. Warm, salty waters flow out of the tropics along the surface, pumping heat into the atmosphere in northern latitudes. As the surface waters cool, density increases, and these waters sink into bottom currents that move south towards Antarctica. That conveyor belt seems to have slowed several times in the past, as North Atlantic waters were suddenly flooded with fresh, low-salt, low-density meltwater that was too buoyant to sink. The water came from great inland glacial lakes like Lake Agassiz that probably released meltwater through Hudson Bay, the Saint Lawrence River, the Mississippi River, and the MacKenzie Straits.* MAP ILLUSTRATIONS: GLOBAL OCEAN CONVEYOR BELT, SMITHSONIAN INSTITUTION; LAKE AGASSIZ, COURTESY OF MICHAEL LEWIS AND JOHN SHAW, GEOLOGICAL SURVEY OF CANADA ATLANTIC, DARTMOUTH NS, CANADA

the U.S. intelligence community and it concurs with many of the non-scientific speculations in the earlier Pentagon report. Food scarcity and famines, epidemics and pandemics, mass migrations, political instability and wars could all ensue in the aftermath of a sudden climate shift. The national security challenges would be daunting, and the NRC recommended the "excellent discussion" of those challenges found in the Defense Department report ordered up a decade earlier by a "Yoda of the Pentagon" who wanted to spark new thinking.

What were the lessons of the long cores that came out of the bottom of the Bay?

In 2003 the *Marion Dufresne* ended its Chesapeake cruise at a dock in Baltimore where the French staff threw a wine-and-cheese party for the American scientists. The next day the Malagasian crew lifted dozens of core samples out of the ship's hold and loaded them on trucks destined for the Reston laboratories of the U.S. Geological Survey.

Out of those cores is coming a revised account of the evolution of the estuary, one that includes better dating of key events, more details, and a new chapter on the arrival of the 8.2 kiloyear cooling in the Chesapeake. With their pollen studies, Willard and her colleagues outlined the shifts in forest communities that came with earlier shifts in temperatures and sea levels. They also identified five major droughts, each lasting several centuries, that struck the region over the last 8,200 years.

Findings like these also undercut the gradual change view that seemed to underlie earlier stories about the Bay's evolution. "The rate of sea level rise in the Chesapeake was not constant as the Bay was flooding," says Cronin. "It was kind of staccato" with several "oscillations and hiccups." Some of those oscillations arrived gradually. The 8.2 kiloyear cooling, the big hiccup, arrived abruptly.

The evidence of past climate change in the Chesapeake and in other parts of the planet is sketching a dicey picture of our current interglacial epoch. The Holocene has endured episodes of climate variability kicked off not by human inputs, but by natural forces, by interlocking shifts in ocean dynamics and atmospheric circulations and solar inputs. According to Cronin, "the interglacial that we live in, that we perturb with CO_2, wasn't nearly as stable as some people used to think."

And the odds are the future may not be so stable either. The good news is that the latest NRC report downgraded the chances that the ocean conveyor belt would collapse anytime soon. The worrisome news is that it also elevated the odds that other abrupt changes could be in the works. The Laurentide ice sheet is gone, but the glaciers in Greenland and the ice sheets in Antarctica are still here and they are huge and they are melting.

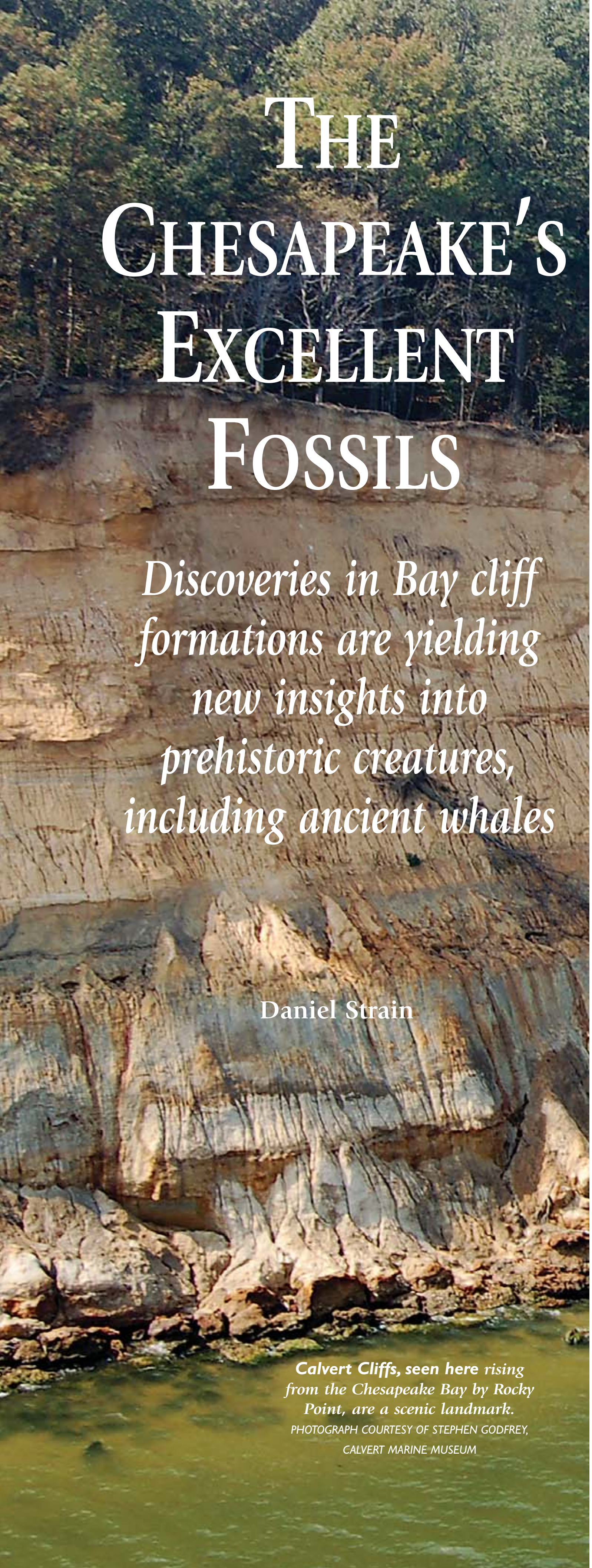
How fast they are melting is a tricky question that scientists are struggling to answer. It seems the meltwater they hold could unleash a climate hiccup not seen since that long-ago 8.2 kiloyear event suddenly cooled off a warming world.

— *fincham@mdsg.umd.edu*

The Chesapeake's Excellent Fossils

Discoveries in Bay cliff formations are yielding new insights into prehistoric creatures, including ancient whales

Daniel Strain



***Calvert Cliffs, seen here** rising from the Chesapeake Bay by Rocky Point, are a scenic landmark.*
PHOTOGRAPH COURTESY OF STEPHEN GODFREY, CALVERT MARINE MUSEUM

Nearly 14 million years ago off the Atlantic Coast, an ancestor of today's whales died. It might have been attacked by a predator or simply succumbed to old age and disease. Either way, the whale sank 100 feet or more to the sea floor below. There, it provided a feast for scavenging sharks and microbes.

Over time, mud and sand trickled down to the sea floor, burying the whale from head to fluke. It wouldn't be seen again until July 2013, when an amateur fossil hunter spotted what looked like a jawbone poking out of a cliff face on the shores of the Potomac River.

Stratford Cliffs straddle the Potomac along a short stretch of Virginia's Northern Neck. At their peak, they rise to more than 100 feet high. Jon Bachman had been searching for sharks' teeth and other fossils on the beaches below those cliffs when he stumbled across the fossilized bone. The large mandible was just visible in the tan cliff face.

Fortunately, not far away lived a paleontologist with a long-time interest in the cliffs, and he knew what to do next. Stephen Godfrey, the curator of paleontology at the Calvert Marine Museum in Solomons, Maryland, began the excavation of the jawbone — which turned out to be much more. Over several weeks, the team, which included a host of volunteers, unearthed from the cliff face an entire whale skull, measuring six feet from front to back. Along with it came many other bones: vertebrae, pieces of ribs, a humerus from right below the whale's shoulder, and part of a flipper bone. For paleontologists, to find so many fossilized pieces of a single whale in one place constituted a bonanza.

The leviathan's remains may seem like an unusual thing to discover around the Chesapeake Bay, but the region has long been known for producing plentiful fossils of marine life, including whales. Most have come from the Calvert Cliffs, located in Maryland about 25 miles northeast of the Stratford features.

Part of the same geologic formation as the Stratford features, Calvert Cliffs run 30 miles down the Bay's western shore, beginning near the town of Chesapeake Beach and ending by Drum Point on the Patuxent River. The cliffs — which turn golden during sunrise — and their surrounding beaches in Calvert County are known for fossilized sharks' teeth and other prehistoric remains. Look closely, and you'll find an explosion of life recorded in stone: whale fossils, yes, but also ancient sand dollars, pecten scallops, and twisting shells from sea snails. These animals all lived during a geologic epoch called the Miocene, which lasted from about 23 to five million years ago. It was an important period in the evolution of whales.

Many people might consider those leavings mere souvenirs, but for paleontologists, the cliffs along the Chesapeake rank among the most important research sites in the Mid-Atlantic region. Fossils found here have certainly contributed much of what we know today about the planet's Miocene seas. For generations, scientists have walked the cliffs, building a better and better picture of what those ancient oceans would have looked like: what creatures plumbed the oceans millions of years ago, and how did they live? The evidence there has even helped scientists understand why some modern whales lack a sense of smell.

When it comes to the history of life on earth, the Chesapeake's cliffs are "particularly good at telling part of that story," Godfrey says, "allowing us to get a really good picture of the diversity of organisms and what they looked like."

Amazing Objects

On a sunny October morning, the beach where Bachman discovered the latest of the Bay's famous fossils this past summer is quiet. Only Godfrey and a volunteer, a long-time fossil hobbyist named Marco Gulotta, are working here today. The two have returned to this sandy spot in Virginia to dig for parts of the whale that had been left behind when the skull was originally removed.

The nearby Potomac River is as smooth as gelatin. Godfrey, wearing waterproof waders and a flannel shirt, is crouching down in front of a waist-high hole in the sand-colored cliff face. He and Gulotta had recently carved out this small cave, using a gardening hoe and screwdrivers to chip away at the soft, clayey sediment.

"Now at the back of the hole, you can see the brown bone back there. That's a vertebra," Godfrey says. "That's our goal for the day."

The backbone, which is about the width of a basketball, looks solid now, but Godfrey will need to be careful getting it out. After having been buried under sediment for millions of years, fossils like this one often fall apart into many pieces when picked up, Godfrey explains. To avoid that, he will scrape gingerly around the fossil, exposing all of its sides. Then, he'll cover it in bandages coated with plaster — the same bandages that doctors use to mold plaster casts for broken bones. That should keep the vertebra together.

For Godfrey, the work of extracting this bone — and the patience it will require — are worth it. "For me, at the heart of this is an amazing object," Godfrey says. "I want to know what it is, and I want to extract as much information as I can."

In that sense, he's far from alone: Calvert and Stratford cliffs have long been a valuable resource for scientists hoping to extract information about the planet's prehistoric seas. The first fossil from here to pop up in the scientific literature was the shell of a sea snail, illustrated in a 1770 natural history tome, according to the Maryland Geological Survey. And as the catalog of fossils collected from the cliffs grew over the centuries that followed, scientists gained a more complete understanding of life during the Miocene epoch.

The span of time may lack the cultural cachet of other periods like the Jurassic when dinosaurs roamed the earth. But the more scientists learn about the Miocene, the more they are able to grasp its importance in the evolution of many marine organisms.

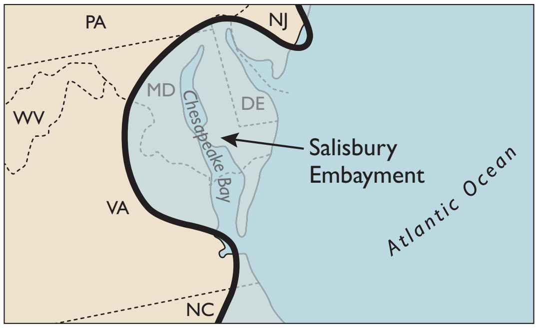
Those organisms would have swum or rested in salt water that was much warmer than are today's oceans, scientists say. Because of high sea levels, a stretch of the Atlantic Ocean, called the Salisbury Embayment, extended far inland over the East Coast, all the way to where Washington, D.C., currently stands. Crocodiles, dolphins, and sharks the size of school buses flourished in this muggy environment.

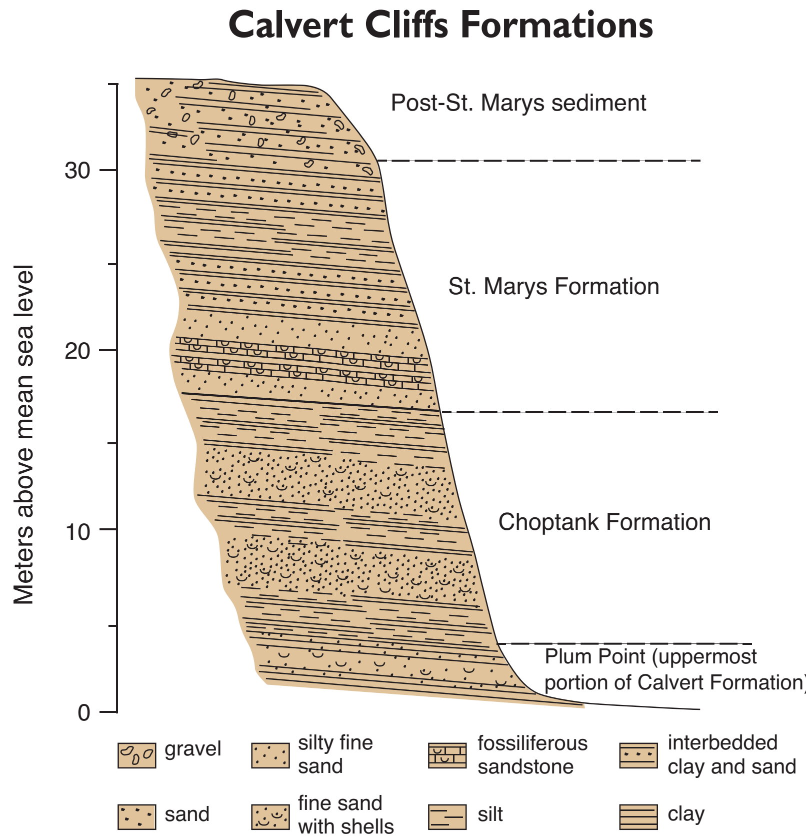
New species of whales emerged during this period, marking the transition of the species from animals that had one "fin" on land and the other in the water to true ocean mammals. Biologists use the

Geological Time Scale

Era	Period	Epoch	Duration
Cenozoic Age of Mammals	Quaternary	Holocene	11,700 yrs ± 99
		Pleistocene	2.588 million yrs
	Tertiary	Pliocene	5.332 million yrs ±0.005
		Miocene	23.03 million yrs ±0.05
		Oligocene	33.9 million yrs ±0.1
		Eocene	55.8 million yrs ±0.2
		Paleocene	65.5 million yrs ±0.3
Mesozoic Age of Reptiles	Cretaceous		145.5 million yrs ±4.0
	Jurassic		199.6 million yrs ±0.6
	Triassic		251.0 million yrs ± 0.4
Paleozoic			542.0 million yrs ±1.0
Proterozoic			

"Okay, that was a good day," *says scientist Stephen Godfrey (top), holding a fossilized whale backbone that's been wrapped in plaster. He spent much of his morning carefully digging around this fossil (middle), which was found at the base of Stratford Cliffs in Virginia. This fossil, like others found along Stratford or Calvert Cliffs, dates back to the Miocene epoch (see time scale above). This geologic epoch was important in the evolution of whales.* PHOTOGRAPHS, DANIEL STRAIN; TIME SCALE ADAPTED FROM A USGS GRAPHIC





A fertile habitat for dolphins, sharks, *and manatee-like mammals called dugongs, the Salisbury Embayment (above left), part of the Atlantic Ocean, covered whole portions of modern-day Maryland during much of the Miocene. The sediments that lay at the bottom of the ancient embayment now make up the geologic formations visible in Calvert Cliffs (above right), shown here in a generic cross-section of the outcrops. The cliffs are split into bands, or strata, made up of different types of sediment. Within each formation is evidence of fluctuations in climate. You tend to see more sands during cooler periods and more clay and silt during warmer ones.* ILLUSTRATIONS ABOVE, REDRAWN BY SANDY RODGERS FROM FIGURES IN CLARK ET AL. 2004; MAP ON OPPOSITE PAGE, ISTOCKPHOTO.COM/UNIVERSITY OF TEXAS MAP LIBRARY

term "radiation event" to describe the rapid appearance of several new species from one or more ancestors.

"You're right on the cusp of where you went from *Archaeocetes*, those are some of the very early whales," says Ralph Eshelman, a paleontologist and the founding director of the Calvert Marine Museum. "And you begin to have this vast radiation where you're getting into the kinds of whales that you have today."

Much of that life is captured in Calvert Cliffs. To date, paleontologists, working for more than a century along the cliffs, have catalogued and named more than 600 fossil species of all types, including mollusks, sharks, birds, and of course, whales.

The journey of those remains from ocean to museum display case was a long one: like the Stratford whale, these organisms died and sank to the bottom of the Salisbury Embayment during the Miocene. As temperatures cooled toward the end of that epoch, sea levels around the globe fell, and the ancient embayment shrank away.

Over time, however, waters rushing over the area where the Chesapeake is now cut their way into that old sea floor, forming what became Calvert Cliffs. Today, this erosion continues to eat away at the precipices, causing the cliffs to recede at a steady clip. While that erosion presents perils to people who live nearby (see Saving Calvert Cliffs, p. 14), it also continuously unearths new specimens for fossil hunters to find and catalog.

The cliffs, then, provide scientists with the means to look back through time, helping them understand how fossilized organisms from the Miocene fit into the broader history of life on earth. The key to doing that lies in the cliffs' geology.

If you look closely at the faces of the Calvert Cliffs, you can see distinct bands, or strata, bearing sediments in different colors running across the surface — Peter Vogt, a retired geologist who lives in Calvert County, likens the cliffs to a "layer cake." Those layers, in turn, also function like a sort of timeline.

It works like this: through decades of study, researchers have roughly estimated the age of the various strata in the Chesapeake's cliffs. They've done that mostly by searching through the cliff layers to find "index fossils." In general, these fossils, which are often types of mollusks or single-celled organisms, are known to have flourished at only one point in the history of life on earth. That makes them a shortcut for dating geologic strata: if you find the right index fossil at a certain point in your cliffs, for instance, then you can roughly estimate the age of the whale skull sitting nearby.

Scientists have split the geology of Calvert Cliffs into three main groups of layers, or formations: the Calvert, Choptank, and St. Marys formations. The oldest of the three, the Calvert Formation, sits at the base of the cliffs. That's about where Jon Bachman found his whale. These layers reach back to about 18 million years ago and represent the Miocene at its warmest. Temperatures then were around six degrees Fahrenheit warmer than they are today.

By the time you reach the St. Marys Formation, the youngest of the bunch, the Miocene oceans had begun to cool. Those layers, found at the top of the cliffs, stop around eight million years ago, coinciding with the disappearance of many warm-weather-loving organisms from Maryland — why, perhaps, you don't see crocodiles around the Bay anymore.

Worldwide, there are few locales that carry such a long-running record of marine organisms in the Miocene, scientists say. In addition to the Calvert Cliffs region, paleontologists have also dug up rich veins of marine fossils in sea cliffs around Antwerp, Belgium and a set of desert outcrops in Peru. But Maryland scientists argue that their paleontological sites are the best: fossils found here have tended to be older than those from Peru and in better condition than fossils from Belgium. The cliff chain "really deserves being considered one of the most important geological localities on the East Coast of the United States," Eshelman says.

David Bohaska, a collections manager for vertebrate paleontology at the Smithsonian Institution's National Museum of Natural History, agrees. He first encountered the fossils of Calvert Cliffs on a seventh-grade field trip. "As a kid, reading about dinosaurs and such, you always think of the Gobi Desert or expeditions out west," says Bohaska, who grew up in the Towson area. "I'm a proud Marylander. It's kind of neat that my home state is, in fact, famous for some of its fossils."

The First Museum

Stephen Godfrey, who joined the Calvert Marine Museum in 1998, has probably done more than anyone in recent years to find new information about those famous fossils. And just as his fossils undertook a long journey before reaching the museum, so did he.

Today the modest scientist works out of an office near the museum's main exhibit hall by the water in Solomons. The room is a testament to his love of natural history. On the walls and shelves are paintings of melting glaciers and a model of a *Brachiosaurus* skull — all pieces made by the scientist, who moonlights as an amateur artist and sculptor. On his way in, he affectionately pats the head of a model of a baby duck-billed dinosaur

1 Cove Point
2 Calvert Cliffs State Park
3 Plum Point
4 Chesapeake Beach
5 Stratford Cliffs

that's knee-high and painted green. "This was my first," he says.

That love of piecing together animals started early. As a child, Godfrey became taken with the idea of founding his own museum.

"My bedroom was transformed into a museum: seashells, insects, anything. Fungi, whatever I could collect," Godfrey says. "I would label all these things. My room, I kid you not — I had things hanging from the ceiling."

He particularly liked skeletons, finding the raw materials he needed to build his own from road-kill specimens: raccoons, dogs, and other assorted animals. Using glue and wire, plus a textbook of animal anatomy loaned to him by his uncle, Godfrey would meticulously rebuild the animals' injured skeletons — bringing the creatures back to life. Sort of.

But the budding scientist's upbringing initially steered him away from a career in paleontology. Godfrey, whose parents were devout Christians, was raised as a young-earth creationist. For much of his youth, he believed that the world was only a few thousand years old and rejected the science of evolution. When he became a graduate student in paleontology, it wasn't to dig up dinosaurs but to evaluate for himself whether the evidence presented for evolution in textbooks had merit.

But Godfrey got lucky: as a student, he was invited on a paleontological expedition to a quarry in Kansas. There, members of the expedition uncovered numerous slabs of rock that still bore the footprints of prehistoric lizards that lived during the time of the dinosaurs. "We came upon these little imprints, and, for me, it was just earth-shattering," he says.

The scientist, who now talks passionately about the deep history of life, still keeps one of those rock slabs in a file cabinet in his office. He takes it out and traces the imprints, no bigger than what a pigeon would leave behind, with his fingers. "You can see the little toes," he says. "Front foot, back foot."

Oceans of Whales

These days, the former creationist isn't dabbling in dino footprints. But his work around Calvert Cliffs has given him the chance to help build on what scientists know about the history of life on earth — albeit a small bit of it.

He's thrown himself especially into the study of whales. And for good reason: near the middle of the Miocene, there were more species of whales alive than at any other time, including the present. The creatures' success likely comes down to warm ocean temperatures, says Olivier Lambert, a paleontologist specializing in whales at the Royal Belgian Institute of Natural Sciences in Brussels. The balmy conditions seen during the Miocene would have supported huge schools of fish and other whale food.

And at the time, new species of whales were emerging, while older ones were drifting toward extinction. Long-snouted dolphins, small whales with unusually long snouts, for instance, can be found in Calvert Cliffs' older layers. But as you move forward in time, they slowly dwindle, then disappear entirely for reasons that are still unclear.

On the flip side, most of the modern families of whales that we see today arose during the Miocene. The epoch saw the first relatives of modern dolphins, porpoises, beaked whales, and narwhals. The Rorquals, a family that today includes blue whales, and right whales also came into existence around this time.

In all, scientists have catalogued and named 28 species of fossil whales found at Calvert Cliffs, marking different periods in the evolution of these creatures. Today, only around 80 species of whales swim the seas worldwide.

Now, one of the challenges facing Godfrey and his colleagues is to identify a single fossilized whale — the one found by Jon Bachman in Virginia.

For now that specimen — owned by the foundation behind Stratford Hall, the historic estate where the whale was found — is being kept at the Calvert Marine Museum. Having run out of space in his lab, Godfrey installed the skull in one of the museum's exhibit halls. It's next to a wall-sized display illustrating the entire history of life on earth.

The skull is lying upside down, with the roof of its large maw visible to guests passing by. In life, this whale might have stretched out to around 25 feet long. That puts it at about the same size as a modern-day minke whale. At this point in the Miocene, Godfrey says, whales had yet to hit the mammoth sizes of species alive today like blue whales. Shrimpish or not, the skeleton is remarkable, in large part because of its completeness. Usually, when whales die, their bones are scattered across the sea floor, making them difficult to dig up in one piece. The find isn't the most complete of Godfrey's career. But it's close.

Volunteers at the museum have already begun the painstaking process of "prepping" what's left of it. Using paint brushes and dental scalers, they will slowly dust and scrape the mud and clay away from the animal's skull, leaving only the coffee-colored fossil behind.

As the skull emerges from the muck, Godfrey's work will begin. "As we prep the skull, the initial task will be [to ask] what kind of whale will it be," he says. "It's probably a known form, but we don't know that for sure. There's a slim chance that this is a new kind of extinct whale."

Even without a name, Godfrey can still glean valuable information about how this animal might fit into the evolution of whales. Based on where it was found in the cliffs, for instance, Godfrey's team estimates that this specimen is about 14 million years old. It was also a "baleen" whale, a group of animals that exist today and include blue, humpback, and gray whales.

These creatures are known for taking a diverse approach to eating, Godfrey says. Some, like blue and minke whales, feed by way of their gaping mouths. As they swim, they open up, capturing schools of krill and other small organisms. Gray whales, on the other hand, go for creatures living in the mud. Using their tough heads, they rake the ocean bottom, slurping up a host of burrowing organisms.

Based on the anatomy of its skull, however, the Virginia whale doesn't seem to fit cleanly into either category, Godfrey says. He suspects that this animal may represent a mid-way point in the evolution of whale dining. The members of this species were "a little bit like gray whales, but they were heading toward what blue whales were doing," he says.

For a paleontologist with a deep love of evolution, knowing how ancient animals lived is a big part of the fun.

"If you can describe a fossil, name it, that's fun. But if you can tell more of the story, that's kind of the bonus," Godfrey says. "Who doesn't like a good story?"

A Nose for Whales

Right now, there's a whole story laid out around his office. This one has to do with a less well-known piece of the evolution of whales — how some lost their ability to smell.

To tell that story, Godfrey points to a series of animal skulls around his office.

Some of the skulls are from fossil animals, but others came from modern ones. There's a cow skull, one from a moose, and another from a modern bottlenose dolphin.

Godfrey picks up one of the items. This skull, taken from a deer, has been sliced right behind where the creature's nostrils would have been. The cut lets you look back into the animal's nasal passages. "You can see the turbinates," Godfrey says, poking his ballpoint pen into the deer's nose, "very thin, scroll-like bones."

And, indeed, jammed behind the nose, there's a collection of twirling bones. End-on, they look a bit like old parchments stacked on a shelf. These fragile-looking structures were critical to the deer's sense of smell, Godfrey says. After inhaling, odors would have pooled around these bones, allowing the animal to pick up the smells.

You might not think that whales, which spend most of their lives underwater, can smell at all. But some living whales, Godfrey notes, have similar structures inside their own nasal passages. That indicates that they can also smell the salty sea air. In particular, it's the baleen whales, like the species collected from Virginia, that seem to be able to take a good sniff.

But another group, called toothed whales, can't smell. They don't need to. Unlike baleen whales, these mammals, which include dolphins, sperm whales, and narwhals, hunt fish and squid using the equivalent of sonar — they listen to how noises bounce around in the environment. That trait, shared by bats, is called echolocation.

To explore when toothed whales lost their ability to smell, Godfrey came up with a new technique for using a CT scanner to measure various structures in the skulls of fossil whales. To start off, he examined the skull of a roughly 16-million-year-old toothed whale — called a *Squalodon* — that had been found high up in Calvert Cliffs. The creature, it turns out, still had the remnants of turbinates buried in its nasal passages, Godfrey says. And that suggests that it, too, could take in aromas.

By the time bottlenose dolphins emerged around the globe in relatively modern times, however, those structures had disappeared entirely. "In the Miocene, we actually see the loss of the sense of smell in toothed whales," he says.

Baleen whales, on the other hand, never lost their ability to smell, Godfrey says. In fact, according to his research, the structures involved in their sense of smell remained largely unchanged over tens of millions of years of evolution. The fact that these whales hung onto their smell structures for so long suggests that they needed that anatomy to survive, Godfrey says. And they're likely still putting their sense of smell to good use today.

A collector's dream, *the Chesapeake's eroding cliffs have unearthed a variety of ancient species, as these examples show. What looks like a trough of dirt (opposite page, top) is actually a "field jacket" containing a fossilized whale skull found earlier this year in Stratford Cliffs. Curators are slowly cleaning the skull. Other species include a crocodile (opposite page, bottom left) and a now-extinct long-snouted dolphin (above). No creature has captured the imagination of non-scientists quite so much as the megalodon, a hulking shark that could grow up to about 60 feet long. Lucky fossil hunters can still find the shark's teeth (opposite page, bottom right). On the small end of the scale is the sea snail belonging to the genus* Ecphora *(opposite page, bottom middle).* PHOTOGRAPHS COURTESY OF STEPHEN GODFREY, CALVERT MARINE MUSEUM

Scientists working with modern whales have reasoned that these animals may be using their noses to follow schools of krill and other organisms. These stinky crustaceans are known to give off a slight odor — it is part of the smell that most people associate with the ocean, says Godfrey. "Just like a wild animal, a raccoon, opossum, a dog, can follow a scent… baleen whales seem to be doing the same thing," he says.

The paleontologist and his colleagues published their findings on whale smell in two papers in 2013 in the journals *The Anatomical Record* and *Comptes Rendus Palevol*.

Olivier Lambert, the Belgian paleontologist, notes that scientists had long known about the diverging senses of smell in baleen and toothed whales, "but what Stephen did is he tried to quantify this," he says. "And this is a nice advance in the field."

Growing a Backbone

Back on the beach in Virginia, Godfrey is almost done extracting the whale vertebra. Stowed in its plaster "field jacket," the find should be safe to move now. Giving a grunt, the paleontologist rolls it out of its hole, all in one piece.

Godfrey's day of digging may be over, but he knows that paleontology around the Chesapeake's cliffs will continue for decades. Long after Godfrey is retired, researchers will continue to improve the picture of how animals like whales evolved during this one period in prehistory, fossil by fossil. "If we keep finding new stuff, keep finding new fossils," he says, "then we have a much better chance of… moving paleontology forward and describing in greater detail the diversity of animals that were here before us."

On his way out, the paleontologist hoists the heavy fossil into his knapsack, then heads down the beach, carrying it on his own back — one more small piece of a much, much bigger story.

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Saving Calvert Cliffs

Efforts to control erosion may threaten unique geology

Daniel Strain

Thousands of years ago, natural processes began to form Calvert Cliffs, which loom over the Chesapeake Bay as a natural and scientific marvel.

Erosion was the chief engineer that built these cliffs. Over millennia, wind and waves steadily weathered away the Bay's western shore, exposing the towering structures, among the tallest cliffs along the Mid-Atlantic. Those processes continue today, presenting rewards and risks, depending on your point of view.

Scientists are drawn to these rock faces, which extend along some 30 miles of shoreline in Calvert County, Maryland, because that same erosion has helped to expose a panoply of fossils. They include the remains of ancient whales and other sea creatures. Such discoveries have helped researchers better understand the evolution of marine organisms worldwide (see The Chesapeake's Excellent Fossils, p. 8).

But for those who have chosen to buy homes along the cliffs' top, erosion has been a mixed blessing. Yes, it created the 100-foot walls where residents can look out over the Bay and the ships passing by. But erosion has also caused the edge of these cliffs to recede toward nearby houses, by up to three feet a year in some places. Many homes are now at risk of tumbling down to the beaches below.

Some residents who live near the steep cliffs have worked for decades to slow the steady collapse that threatens their homes. These efforts, however, can have unintended consequences. In this case, humans risk permanently altering the appearance of the cliffs, a local landmark, and may make them useless as a scientific resource. As homeowners living elsewhere beside the Bay have discovered, controlling erosion can be a challenge that has no easy solutions.

On the beach below his home *in Scientists' Cliffs, retired geologist Peter Vogt points to his "blackboard." He removed the moss and ivy from this bare patch of cliff face the day before to prepare for a school group that he's leading to explore the local geology. Erosion-control efforts could slow the retreat of the cliffs but also block access to these unique formations.* PHOTOGRAPH, DANIEL STRAIN

The Classroom

Peter Vogt, a geologist, places a high value on Calvert Cliffs as a teaching tool. He lives in Scientists' Cliffs, a rustic community about midway along the chain of outcrops. He thinks of the beach below his home as a classroom. Vogt often guides field trips from local schools to the beach so that students can get a firsthand look at the region's special geology and fossil specimens.

On a windy day, the scientist takes a walk down the sandy strip to show off the local geology. He reaches a bare patch of cliff face, which he calls his blackboard. Like a math teacher standing in front of a chalkboard filled with equations, Vogt points to interesting events in the planet's history that have been recorded in this gray surface. "It's like our local equivalent of the Grand Canyon," says Vogt, who retired years ago from the U.S. Naval Research Laboratory near Chesapeake Beach.

And like that national landmark, these cliffs owe their existence to erosion. Millions of years ago, the sediment contained in the outcrops made up an ancient sea floor. Then, as ages passed, sea levels rose and fell over and over again around the area where the Chesapeake now sits — driven by a series of ice ages and warmer periods that occurred across the globe. As waters curved around what is now known as Maryland's western shore, they slowly carved away at the ancient sediments there. Eventually, the steep cliffs that you see today were formed.

Or as Vogt puts it, spectacular geology and erosion often go hand in hand. "Most of our national monuments are due to erosion," he says.

Erosion can occur along the cliffs for a number of reasons, he explains. Water lapping at the base of the cliffs undermines the outcrops, causing them to collapse. And as ice freezes and thaws on the cliff face, it also weakens the features. This melting causes soft, moisture-rich chunks of sediment to slip off the cliff face and slide down to the beach.

Over long time periods, the cliffs by Vogt's house recede by less than a foot of land per year on average, according to rough estimates reported by the Maryland Department of Natural Resources Coastal Atlas program. Elsewhere, the cliffs can recede much faster. At spots north of Cove Point toward the south end of the county, for instance, Calvert Cliffs are pushed back annually by nearly three feet on average.

That high rate of erosion — much faster than what you would see by rocky cliffs — hinges on the sediment trapped in the cliffs: many portions of the cliff chain are made up of loosely bound sands, silts, and clays. For waves in the Bay, that's like cutting through butter.

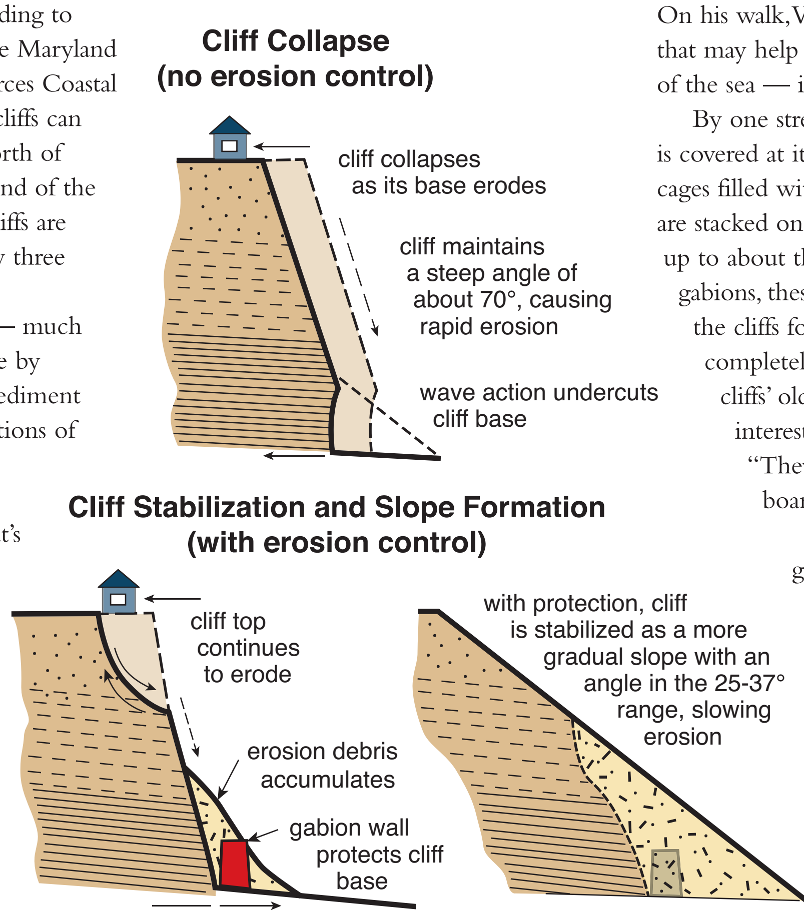
Vogt's home sits about 250 yards from the cliffs' edge, so he doesn't have to worry much about that erosion. But many of his neighbors aren't so lucky.

Gary Loew is another homeowner in Scientists' Cliffs who is very familiar with this erosion. Recently retired from an administrative position at the U.S. Army Corps of Engineers, Loew grew up in Scientists' Cliffs in the 1950s and 60s. The community was founded in 1935 and today encompasses nearly 250 homes owned by a mix of retirees, professionals, and seasonal residents.

When Loew was a child, only a narrow strip of front yard separated his parents' house from the cliff face — and a steep drop. Today, there's nothing left of that waterfront cabin.

That is because in 2011, the Calvert County government applied for a grant through the Federal Emergency Management Agency to buy 10 privately owned homes along the cliffs. The houses, located at the edge of the outcrops, were in imminent danger of being lost to erosion. And two of them, including the old Loew house, were part of Scientists' Cliffs. All but one of the 10 homes have since been demolished.

"It was very sad," Loew says. "I mean,



Erosion can get you in two ways *on Calvert Cliffs, scientists have shown. Naturally eroding cliffs maintain a steep slope as they recede. Cliffs protected by erosion-stabilization efforts — like gabions — ideally, recede more slowly, becoming gentle slopes. Either way, houses that are too close to the edge may come tumbling down.* ILLUSTRATIONS, ADAPTED BY SANDY RODGERS FROM FIGURES IN CLARK ET AL. 2004

it was not only my childhood home. My father built it."

In order to prevent such losses, the Calvert County government adopted regulations in the 1980s to limit development near to the cliffs' edge. But plenty of homes were built before and remain standing today. As of 2011, more than 230 houses sat within 100 feet of the cliffs' edge, according to data kept by the Calvert County government. Roughly one-third of those were within 20 feet.

"If you can see the sea, then the sea can see you," says Kenneth Rasmussen, a geologist at the Northern Virginia Community College who lives a short walk away from Brownie's Beach at the north end of the cliff chain. "And it's going to get you eventually."

Slowing the Inevitable

On his walk, Vogt points out a remedy that may help homeowners to get ahead of the sea — if only for a little while.

By one stretch of beach, the cliff face is covered at its base with a line of mesh cages filled with heavy rocks. The cages are stacked on top of each other, adding up to about three feet high. Called gabions, these contraptions stretch down the cliffs for more than 100 feet. They completely block from view the cliffs' oldest and arguably most interesting layers, Vogt says.

"They're destroying my blackboard," he says.

This small stretch of gabions is just the beginning. Over the next several years, residents of Scientists' Cliffs plan to put in around 1,600 feet of gabions up and down the beaches here. In all, the project will cost the community around $40 to $45 per linear foot of gabions installed, estimates Norman Prince, a local homeowner who chairs the Beach and Cliffs Committee for the residents of Scientists' Cliffs.

But for him and many of his neighbors, the gabions will be worth it: these structures — which perform a similar role to rip-rap, or large boulders that have been stacked on top of each other — should protect the cliffs from waves. And, engineers say, that should help to slow erosion.

Such ventures aren't unheard of locally: most of the length of Calvert

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Cliffs falls inside privately-owned land. A large cliffside development to the south of Scientists' Cliffs, called Chesapeake Ranch Estates, for instance, also recently obtained permits to similarly protect its cliffs.

Vogt, however, contends that efforts like these merely trade one problem for another. Erosion may be a hazard for homeowners, but it's also the key to Calvert Cliffs, he says. When the cliffs are allowed to erode naturally, as they have done for millennia, they recede. And as they recede, they retain the steep, vertical drop that the features are known for. It's a bit like cutting a piece out of a cake.

But when humans slow that erosion from happening, the cliffs don't stay cake-like: the base of the cliffs remains stable, but the top continues to crumble away. Before long, what was once a steep cliff becomes a gently curving hill that is soon covered in moss, ivy, and, eventually, trees.

The consequences of that transformation for scientists like Vogt would be dire: as the cliffs form into hills, the features' geologic strata — his teaching surfaces — would become buried under layers of dirt, making them all but invisible. Without erosion, the supply of fossils that paleontologists also love so much would be effectively cut off, too.

A 2004 report by a research team led by the U.S. Geological Survey concluded that Calvert Cliffs could be transformed this way in 35 to 40 years or even less following the installation of structures like gabions.

A long line of gabions *(metal cages containing large rocks) was installed in fall 2013 to protect this cliff base in Scientists' Cliffs. Erosion along the length of the cliffs threatens to overtake several homes, dumping them into the surf.* PHOTOGRAPHS: LEFT, DANIEL STRAIN; RIGHT, DAVID BROWNLEE

That seems to leave the Bay's cliff dwellers with a difficult choice: lose the cliffs or lose your homes. Vogt isn't the only scientist who has argued for saving the cliffs.

"If Calvert Cliffs are unique, which I truly believe they are, why do we want to destroy that uniqueness?" asks Ralph Eshelman, a paleontologist who served as the founding director for the Calvert Marine Museum in Solomons. "Why do we want the shores of the Chesapeake Bay to look like the shores along the rest of the East Coast?"

Living with Erosion

In the end, erosion will eventually swallow some homes on Calvert Cliffs no matter what steps are taken to control it, scientists say. Whether the cliffs collapse from below or erode from the top and form slopes, houses close to the edge will still be undermined. Homeowners, in other words, can't escape the Bay forever.

It's a reality that the residents of Scientists' Cliffs are aware of, says Norman Prince. "We're not doing this with the idea that we are going to preserve in perpetuity the houses that are presently on the cliff face," he says. "We are doing this to slow the process down."

Despite the risk, Gary Loew, who saw his old family home lost to erosion, wanted to spend his retirement there. He and his wife purchased a house about a year ago around 50 feet from the cliff edge. Loew says they did so because they love the community. They've formed tight bonds with their neighbors, and erosion or no, the view is a beauty.

He also thinks that he will have enough time to get the most out of his home before the eroding cliff face draws too close. "It's a calculated risk," he says. "I'm retired. I'm older. I figure we've got 10 or 15 years in this house before we have to downsize, so I think I'm good."

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