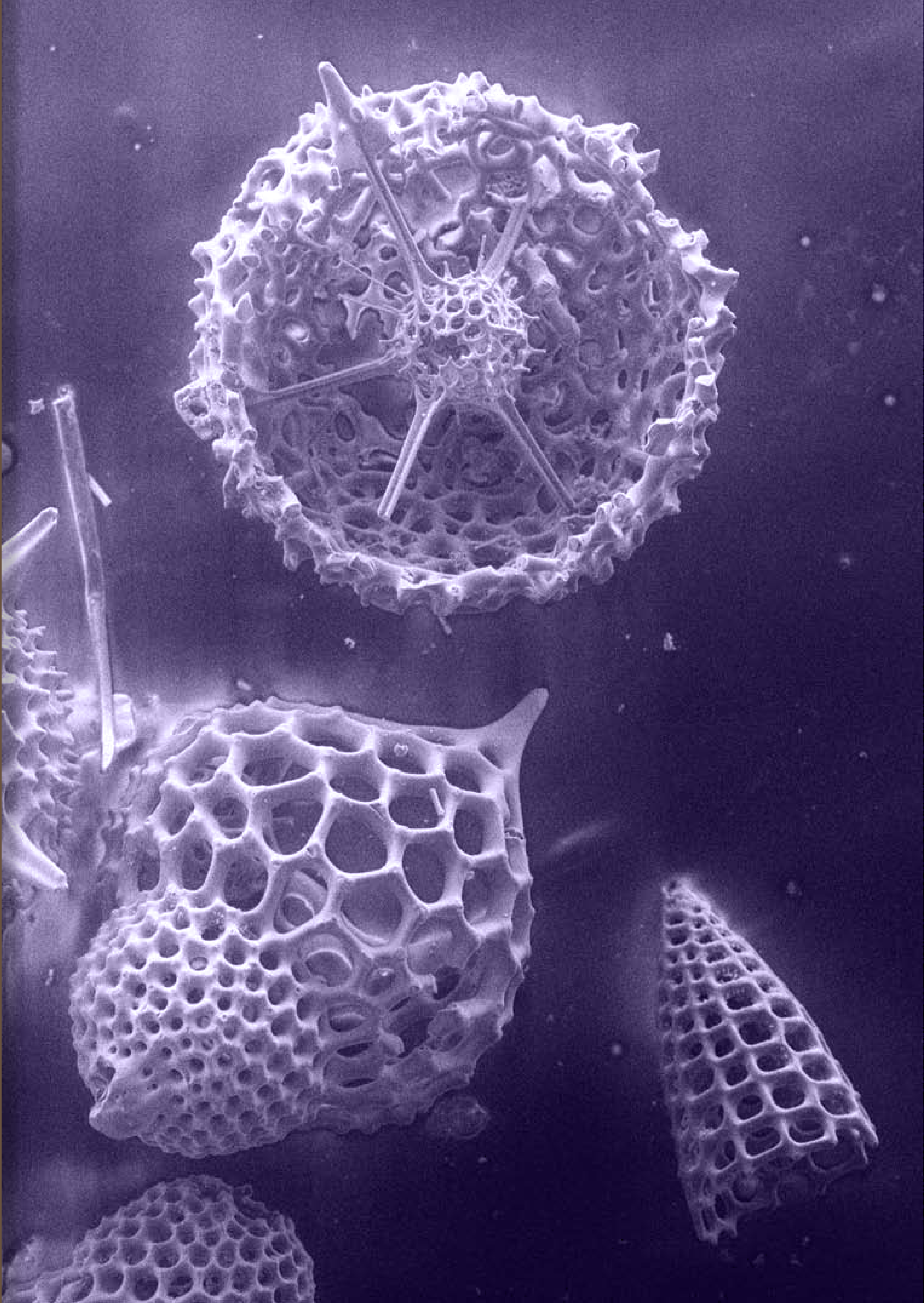

Reading ROCKS

UF geologists travel back in time to understand what made Antarctica cold and what that tells us about climate change today

By Jean Feingold

34 million years ago, Antarctica was covered by a beech forest. 33 million years ago it was covered in ice.

Ellen Martin has spent her career trying to understand what climatic changes occurred all those eons ago and what they can tell us about the future.

"We must look to the past to understand how the climate system works," says Martin, a professor in UF's Department of Geological Sciences. "My research focuses on understanding the complexities of the climate system by looking at the record left behind in the rocks."

Rocks buried thousands of feet beneath the southern oceans.

By studying the chemical composition of microscopic rocks and fossils found in cores drilled from the ocean floor, Martin is getting a clearer picture of the processes that lead to the dramatic climate change in Antarctica.

"Antarctica has a very interesting history," Martin says. "We think of it as a huge, ice-covered continent, but that happened about 33.7 million years ago in roughly 300,000 years, which is very fast in geological time. Before that, it was a green forest."

Martin's research relies on sediment cored from deep beneath the ocean floor by scientists on the research vessel JOIDES Resolution.

The vessel, operated by an international consortium called the Integrated Ocean Drilling Program, travels the world's oceans on two-month expeditions to gather samples from below the sea floor. In addition to the approximately 25 scientists and graduate students on each expedition, hundreds of researchers like Martin utilize the cores.

Over the past decade, Martin has pioneered several innovative techniques for using cores to measure the prehistoric climate.

In a paper in the journal *Science* in 2006, Martin and a graduate student described how they used a rare element found in tiny fish teeth to date the opening of the Drake Passage between the Atlantic and Pacific at the southern tip of South America. The passage created a circular current around the pole and scientists wondered if it contributed to Antarctica's sudden cooling.

Scientists have long puzzled over this rapid cooling because it occurred in a very warm era when levels of carbon dioxide were three to four times current levels.

Theorists had suggested the plummeting temperatures could be related to the opening of the Drake Passage, but before Martin's research it was unclear whether the opening and development of the circumpolar current occurred before or after the cooling.

Scanning Electron Microscope image of mineral skeletons of radiolarians, tiny zooplankton that live in the surface waters of the ocean. When these organisms die, their skeletons contribute to the underlying ocean sediment. Image courtesy of Ann Heatherington, UF Department of Geological Sciences.

Martin's approach was to analyze isotopes of the metal neodymium, which is absorbed by fish teeth the size of grains of sand lying on the ocean floor.

Because neodymium has a chemical signature that varies depending on whether it came from the Atlantic or Pacific, Martin was able to show that water was moving between the two oceans at least 40 million years ago.

"Before that current developed," Martin says, "water traveled from the equatorial region to Antarctica and back, carrying heat from the subtropics to Antarctica."

While the opening of the Drake Passage could have precipitated the plunge in temperatures because it isolated Antarctica from that warm water, the timing wasn't quite right.

"Our research suggested the ice could not be strictly a consequence of cold water circulating around Antarctica," Martin says.

So she started thinking about other ways of looking at the climate, especially the CO_2 levels, around the time of the cold shift.

"The alternative explanation is that global concentrations of greenhouse gases in the atmosphere, such as CO_2, became low enough to let Antarctica freeze, which is the focus of my current research," Martin says. "Once it started to get cold enough, the ice reflected sunlight away, so it got colder and more ice formed."

Martin applied to the National Science Foundation's Marine Geology and Geophysics Program for funding to continue her studies and was awarded a three-year, $295,000 grant through the American Recovery and Reinvestment Act of 2009. In all, Department of Geological Sciences faculty have been awarded $1.87 million in federal stimulus money to date.

The new research uses lead isotopes found in ocean sediment to understand the kind of rock weathering occurring on Antarctica during the big climate transition.

"When rocks are weathered on a continent, it can happen two different ways," explains Martin. "There's physical weathering from wind or rain or glaciers, which breaks big rocks into little rocks. And then there's chemical weathering when water and CO_2 from the atmosphere combine to form carbonic acid, which dissolves rock."

Climate vs. Weather

Geologist Ellen Martin may have been one of the few people walking across a frigid University of Florida campus this winter who wasn't wondering whether all the talk about "global warming" was just hot air.

But for someone who's looking at global climate 34 million years ago, a change in the local weather is no big deal.

"Weather is a daily atmospheric state, whether it's raining, windy, what the temperature is," she says. "Climate is defined as a 30-year average of weather. It is 'expected' weather."

Martin points out that the mean annual global temperature, averaging readings for every part of the whole world, has increased by 0.7 degrees Centigrade over the past century.

"Florida's cold winter was balanced by, for example, how hot it was in Vancouver during the Olympics," Martin says. "So you can't just look at one place or one short time period and talk about global climate. Global warming is a climate phenomenon. Local cold temperatures are a weather phenomenon. The two should not be confused."

Only chemical weathering removes CO_2 from the atmosphere, so significant chemical weathering at the time of the great cooling could indicate CO_2 levels were changing.

The challenge was that there was no reliable way to differentiate chemical and physical weathering in the geologic record.

"One goal of this research is to develop a new technique to determine the chemical and physical weathering history on Antarctica during this big climate transition," she says. "In geology, we are constantly looking for something we can read in the rock record that can tell us about a fundamental process like this. We don't currently have a good proxy for determining the weathering regime, to determine whether it's chemical or physical."

So Martin and doctoral student Chandranath Basak are developing one.

They are processing 370 small core samples, each just 3 inches long, collected by the JOIDES Resolution in the 1990s from five different sites in the extreme southern Atlantic and Indian oceans.

> "THE BEST WAY TO UNDERSTAND THE COMPLEXITIES OF THE CLIMATE SYSTEM IS BY LOOKING AT THE RECORD LEFT BEHIND IN THE ROCKS."
> — ELLEN MARTIN

Ray Carson

Each sample is analyzed in two ways. First, microscopic fossils provide information about the composition of the ancient seawater. Then, silicate rock fragments are analyzed to learn about the chemical composition of ancient Antarctic rocks.

"We then compare lead isotopes from the seawater and rock records," explains Martin. "When they are the same, it indicates Antarctica was experiencing chemical weathering. When they are different, it implies Antarctica was subject to more physical weathering."

Preliminary analysis of sediments from one site found that the lead isotopes from the seawater and rocks were similar when CO_2 was high and Antarctica was green, indicating there was much more chemical weathering which helped reduce CO_2, leading to the buildup of ice. Analysis of samples after ice had formed showed distinct isotopes for the two fractions, suggesting much more physical weathering. In between, the signals were mixed.

"The point is to expand this to other places and times where we don't know what to expect," she notes. "It will help develop a tool for future studies that can be used to learn more about changes in atmospheric CO_2 concentrations."

Martin says climate is an extremely complex system that is hard to decipher based on human time-span observations.

"The CO_2 we put into the atmosphere today will be there for 100 years. It will take a million years for all of the CO_2 humans have generated already to go away," Martin says. "We must look to the past to understand how the climate system works. The best way to understand the complexities of the climate system is by looking at the record left behind in the rocks."

Ellen E. Martin
Professor, Department of Geological Sciences
(352) 392-2141
eemartin@ufl.edu

Related website:
http://www.clas.ufl.edu/users/eemartin/researchpage.html