InClass

A spotlight on faculty and their work

Frozen in Time

Expeditions to Antarctica shed light on the geologic history of Earth.

By Julie Neumann

Every four or five years, Molly Miller sheds her lab coat to don multiple layers of fleece and fabric in order to collect rock samples in the ultimate geologic laboratory: Antarctica. In this frozen landscape she looks for, and finds, evidence that an abundant animal community flourished there more than 200 million years ago. The evidence she studies is the burrows and tracks that these ancient animals left behind in the rock.

Miller, a professor of geology at Vanderbilt for the past 26 years, uses these "trace fossils" to reconstruct the environment, ecosystem and climate that existed in these ancient times. She is convinced that this forbidding land contains important clues about long-term climate change and the origin and evolution of mammals.

After several weeks in the field, geologists consolidate their food supply, which is stored in wooden boxes and buried in the snow.

Miller

One of Miller's specialties is determining the origin of sedimentary rocks using diverse types of data, including the activity of animals that lived in the sediment before it was compacted and cemented into rock. Even though the animals themselves are not preserved, their movements and dwellings are. These behavioral patterns, referred to as trace fossils or bioturbation, allow geologists like Miller to determine the environment in which the rocks were deposited.

Her fascination with the earth and its history began when she was a young child. While on a camping trip at age 9, she discovered a fossil that she identified in *Golden Book of Fossils* as being 350 million years old. Although her interest had been piqued, in the years that followed it gradually faded for lack of encouragement. When she took a geology course during her freshman year of college, however, she quickly rediscovered her old enthusiasm for seeing herself in the perspective of geologic time and past life.

Miller's desire to gain a complete worldview was fueled by the activist atmosphere of college in the 1960s. She spent one summer working in a refugee camp in southwestern Ethiopia, and after graduation she revisited Ethiopia as a Peace Corps trainee. Upon her return she completed her master's degree at George Washington University, where she met and married her husband, Calvin Miller, and taught earth science in high school. Before starting in the doctoral program at UCLA in 1973, the Millers worked as ranger naturalists at Bryce Canyon National Park.

When the couple was ready to enter academia, they faced a new problem. "It was very difficult, especially at that time, to have two jobs—two academic jobs—and have any kind of normal family life," says Miller. "So we decided very early that the way to do this is essentially to share one job and have both parents involved in bringing up the children." Their emphasis on family brought them to Vanderbilt in 1977, where they were the first couple hired under the University's "full status, partial role" program. They each had an academic appointment but with only half the teaching responsibilities.

"The advantage to the small geology department was getting two people with very different specialties," comments Miller. "Then, when we were ready, Vanderbilt allowed us to become full time."

Her husband's research focuses on the Southwestern United States, where he is studying how volcanic activity—particularly the evolution of deep magma chambers—has shaped the landscape of Arizona and surrounding areas of California and Nevada over the last 2.5 billion years. He and his students also are investigating the protracted geological processes that created the southern

continued on page 84

PHOTOS COURTESY OF MOLLY MILLER

Geologist Molly Miller studies rocks in the Transantarctic Mountains, where plant and animal life flourished 200 million years ago.

In Class *continued from page 28*

Appalachian Mountains.

In 1985 a group of Ohio State University scientists and collaborators from around the country traveled to Antarctica in hopes of better understanding its geologic history. By determining how various rock layers were deposited, their goal was to distinguish geographical features such as rivers, swamps and mountains. Of particular interest was a widespread rock unit consisting of shale with interspersed beds of coarser-grained sandstone. Geologists who had previously studied the rock were unable to determine whether this unit was deposited under marine or freshwater conditions—whether a large lake or the ocean had covered the area. In order to answer this question, the scientists invited Miller to come along on their next expedition.

Miller quickly determined the strata had been deposited in fresh water. She observed that the trace fossils it contained closely resembled marks made by modern insects, the dominant bottom-dwelling animals in modern lakes and streams. Miller documented the existence of huge lakes that would have tempered the climate and created a suitable environment for plants and advanced animals such as reptiles.

She found the expedition so exhilarating and the geologic problems so intriguing that she returned in 1995. The question she brought to Antarctica on her second trip was how animals developed differently in fresh and salt-water environments. Five hundred million years ago, animals had spread throughout the bottom of the world's oceans. But far less is known about the initial colonization of lakes and rivers. Freshwater deposits are rare in the geological record because they are deposited above sea level where they are subject to erosion. The four-kilometer-thick sequence of rock in the Transantarctic Mountains that Miller identified have turned out to be the best-preserved freshwater deposits in the world.

This unique record has enabled her to study the manner in which life first spread from the marine into freshwater environments millions of years ago. She has done so by analyzing and dating the extent that these ancient lake and river beds show evidence of disruption by animals.

Perhaps Miller's most intriguing and surprising find has been the discovery of very large burrows, 2 to 20 centimeters in diameter, in 245-million-year-old sandstone deposited in an ancient floodplain beside a river. These burrows fall into two distinct size groups. She has determined that the really big burrows, some of which are more than 2.5 meters long, were almost certainly produced by mammal-like reptiles. Skeletal fragments of these creatures have been found nearby. Similar burrows of the same age in South Africa contain skeletons of curled-up, mammal-like reptiles. The identity of the animals that made the smaller burrows is less clear; crayfish or juvenile mammal-like reptiles are good candidates.

She hopes the burrows will lead her to the early mammals as well. "We know that mammal-like reptiles knew how to live in burrows," she says.

Miller has made the trek to the icy continent five times. Now one of the oldest women doing fieldwork in Antarctica, she spent most of November and December on what could be her last visit to the polar continent, continuing her research with the aid of Vanderbilt graduate student Nichole Knepprath.

"Nearly 10 years ago, during a field expedition, my collaborator, John Isbell from the University of Wisconsin, discovered petrified stumps that paleobotanists interpreted as the remains of a fossil forest," says Miller. "This year it was the Vanderbilt team members who were the fortunate discoverers. We found a much larger, but less well preserved fossil forest at Lamping Ridge, located about 20 miles due south of the Beardmore Camp." The tree stumps—more than 80 in all—occur in three horizons of 260-million-year-old rock, giving an unparalleled glimpse into the structure of an ancient high latitude (Antarctic) forest of that time.

"I'm getting a little old for [these expeditions], so I probably won't be able to do too many more," she admits. "We do an awful lot of hiking, which is physically challenging. I would keep going forever except that I don't want to slow down my co-workers."

The fact that Miller views Antarctica as a both a scientific and character-building experience is not surprising. "Experiences that put yourself in the perspective of a larger place are the most meaningful types of experiences," she says. "Working in refugee camps was very similar to learning about geology. In the camps you are putting yourself in the context of world population and the whole world today. In geology you are putting yourself in the perspective of the entire history of Earth and life.

"When you are in Antarctica, you see yourself as part of the entire system. You are a little more vulnerable and thus more a part of it."

Working in refugee camps was very similar to learning about geology.

In the camps you are putting yourself in the context of world population and the whole world today.

In geology you are putting yourself in the perspective of the entire history of Earth and life.

More about Miller's work, including dispatches from her latest expedition, can be seen on Exploration, *Vanderbilt's online research journal, at http://exploration.vanderbilt.edu/news/features/miller/news_miller.htm#.*