Above: Axel Heiberg Island, part of Nunavut Territory, Canada, is uninhabited except for a small seasonal research station.

- > **COORDINATES:** 79° 26 ′ 0″ N, 90° 46′ 0″ W
- > **AREA:** 16,671 SQUARE MILES
- > **HIGHEST POINT:** OUTLOOK PEAK (7,300 FEET)
- > **LANDMARKS:** FOSSIL FOREST, THOMPSON GLACIER, WHITE GLACIER, McGILL ARCTIC RESEARCH STATION, PERENNIAL SPRINGS

JASON SMITH

Above: The runway for the Twin Otter planes that land at the McGill Arctic Research Station. Wolf Peak is in the background and Colour Lake is in the foreground.

Below left: Zena Cardman's watch at five minutes to midnight.

Below right: The Twin Otter that carried Cardman and the rest of the crew to and from their field camp on the island.

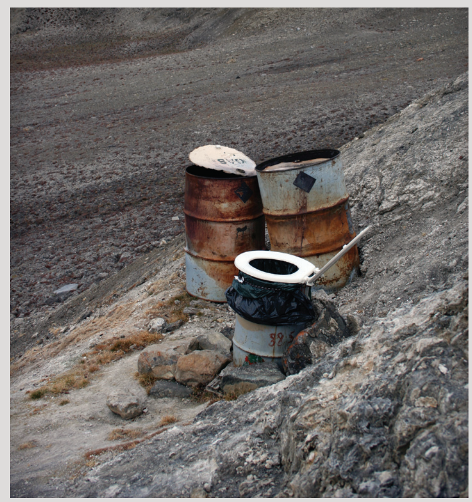
Facing page, top: Axel Heiberg's toilet. Once full, it's emptied into one of the other two barrels, where the solid waste is burned. "You're actually not allowed to pee in the can," Cardman says, "because urine is really nasty when it burns."

Facing page, bottom: Thompson and White Glaciers reflected in Cardman's shades.

Zena's Arctic Adventure

an undergrad looks for life in unlikely places

story and photos
by Zena Cardman



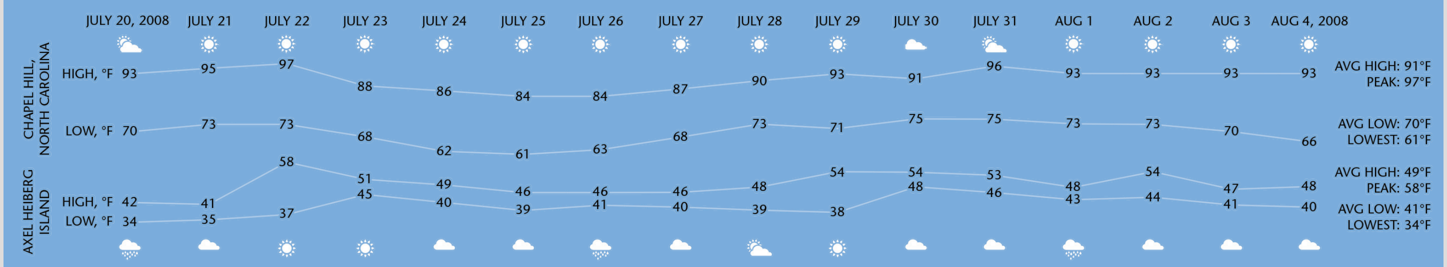
The toilet on Axel Heiberg Island is an old, rusting fuel barrel with a plastic seat stuck on top. You think your toilet seat at home is chilly sometimes? Try sitting on the can in the Arctic.

I'd arrived at this foreboding toilet on Axel Heiberg just a few moments earlier, after flying in from Resolute Bay. Resolute is the northernmost place in this hemisphere to which you can take a commercial flight, and it's the take-off point for many Arctic expeditions.

The bay is home to a small Inuit community (population 229) and an airport. When I say "airport," though, don't think tarmac and terminals. The runways are gravel. The buildings are very small, and so are the planes. After a sleepless night, we crowded into the belly of our tiny Twin Otter with all of our cargo and took off for Axel Heiberg Island.

The view from Axel's sole toilet is a striking panorama of tundra, where two colossal glaciers are slowly making their way into the valley between iron-colored mountains. Situated in the Canadian High Arctic barely ten degrees of latitude from the North Pole, Axel Heiberg is truly otherworldly.

summer here and summer there



CARDMAN VISITED AXEL HEIBERG BETWEEN JULY 20 AND AUGUST 4, 2008. GRAPHIC: JASON SMITH. SOURCES: CANADA'S NATIONAL CLIMATE DATA & INFORMATION ARCHIVE AND WEATHERUNDERGROUND.COM.

It was exactly this resemblance to another planet that lured me to Axel in the first place. Our team was led by Chris McKay, a planetary scientist with NASA and co-investigator for the Phoenix Lander. We set up base camp at the McGill Arctic Research Station (its acronym, appropriately enough, is MARS). With MARS as our home base, we set out to collect samples for astrobiological research.

Above: Chris McKay, a NASA planetary scientist and the leader of this Arctic expedition, looking for carbonates on the side of a cliff that overlooks Thompson Glacier.

Left: Some of Axel's springs gush out of the ground and flow downhill like streams. Here, the white coloring is gypsum. The gray is a film of sulfur-reducing bacteria.

I usually get funny looks when I say the word *astrobiology*. After all, how can we expect to study the origins and distribution of life throughout the universe when we don't even know whether life exists outside of this planet? Astrobiologists start by asking basic questions about the conditions surrounding life. What are the telltale signs that an environment once supported life? What would life need in order to begin and then survive in the harsh environments on planets such as Mars?

Finding these answers begins right here on our home planet. Astrobiologists study the unlikely life surviving in Earth's most extreme environments—places so cold, so dry, or so bizarre that scientists once considered them uninhabitable. These environments are great analogues for extraterrestrial terrains.

Temperatures on Axel Heiberg get as low as –40°F, several degrees colder than Mars's warm weather. On a warm day, Martian temperatures can reach a balmy –30°F. Mars was probably warmer at some point in its history, when the tilt of the planet was shifted so that the polar regions got more sunlight.

This overlap of temperatures makes Axel Heiberg a good place to learn about potential sources of water in Mars's subzero environment. Water is an important piece in the puzzle of extraterrestrial life, since most life on Earth needs water in some form in order to survive.

To astrobiologists, Axel Heiberg's perennial springs are some of the most interesting features on the islands. The springs come right out of the ground, about half an hour's hike from the McGill Arctic Research Station. Some look like little streams flowing down the side of the hill, others look like seeps oozing up from below, and still others look like bubbling ponds. Don't let the Jacuzzi effect fool you, though—the springs are actually quite cold. Fascinatingly, they stay liquid year-round, despite an average annual air temperature of 5°F. We found that each spring is unique—water temperatures and flow rates vary between individual springs.

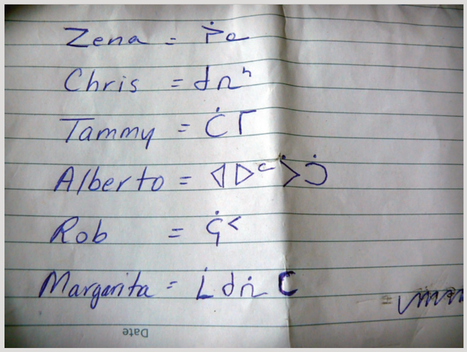
Many springs in cold climates on Earth derive heat from volcanic activity underground. But on Axel Heiberg, a lack of observed magmatic activity makes it necessary to develop a new model. Our accumulating research indicates that the springs probably originate nearly half a mile underground.

Scientists who have been studying these springs since the 1980s suggest that the geothermal gradient alone is enough to raise the temperature of the water. Hydrostatic pressure from a nearby lake then forces the springs to flow upward through the permafrost, making their way to the surface through tube-like structures of gypsum, a salt composed of calcium sulfate. By the time the springs reach the air, they have picked up so much salt that they have three times the salinity of saltwater. The salt acts like an antifreeze, allowing the springs to stay liquid even when the weather is well below the normal freezing temperature of water.

Sources of liquid water may be the obvious places to look for life, but organisms can flourish even where water is perpetually frozen. I spent much of my time in the Arctic digging holes in the permafrost, collecting soil samples in a search for life.

Axel Heiberg may be harsh for most large life forms, save the occasional caribou or well-insulated Arctic hare. Look on a smaller scale, though, and you'll find bacteria thriving in permafrost nearly a meter underground. Permafrost occurs on Mars, too, opening the doors for more analog studies.

On Earth, permafrost is characteristic of polar regions. It thaws during the summer, creating an "active layer" of soil. Dig through the layer of soft soil and you will eventually hit the solid, perfectly flat table of ice-cemented ground that exists in the Arctic and Antarctic. Analysis of our soil



Above: Two Inuit schoolteachers wrote out the names of the research team in Innuktitut.

Below: Arctic cotton, a member of the sedge family. Wolf Peak is in the background.

Above: *Lepus arcticus,* an Arctic hare. In winter the hare's coat is white. In summer months, the coat eventually turns brown for better camouflage around mud and rock. The Arctic hare's ears are shorter than those of other hare species.

TAMMY MORGAN

samples in laboratories back in the United States revealed the presence of metal-reducing and sulfur-reducing bacteria much like those found at the other end of the earth in Antarctic permafrost.

Frozen soil isn't the only place on Axel Heiberg to find bacteria. Axel's springs are another logical place to look for life—and indeed, the springs are surrounded by slimy layers of sulfur-reducing bacteria. Microorganisms even form colonies called endoliths inside giant chunks of rock or gypsum salt.

It seems as though life can find a niche no matter how unbelievable the environment. To me, a community of bacteria living where nothing else can is one of the most compelling scientific beauties I can imagine on Earth. I'd pick a barren, frozen desert over a teeming jungle any day, and Mars is the most enticing desert I know. e

Zena Cardman is an undergraduate biology student at UNC. She received funding from the UNC Burch Fellows Program and the North Carolina Space Grant to conduct research in British Columbia and the Canadian Arctic during the summer of 2008. In the Arctic, she also filmed high-definition footage for the PBS television series NOVA.

You can see more pictures, videos, and read Cardman's travel updates at www.zenacardman.com. For more information about the Burch Fellows program, visit www.burchfellows.unc.edu.

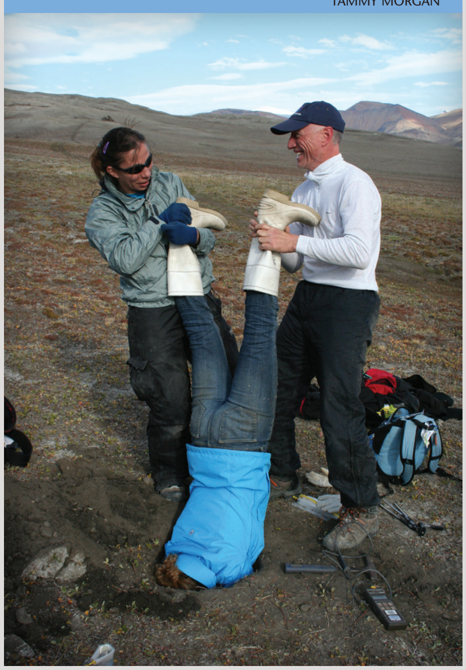
Above left: Cardman on Axel Heiberg.

Above right: Cardman says the station's potted-meat collection has been accumulating for more than twenty years, and is kept mostly as a joke: "I don't think anyone has ever had to resort to eating a can of vintage Klik."

Right: The view from the foot of White Glacier.

Below: Margarita Marinova, Cardman, and Rob Palassou. "We were studying microorganisms that live about a meter underground," Cardman says. "I spent a lot of time with my head and arm down in holes, scooping out permafrost samples with a spoon. One day, I'm minding my own business when all of a sudden my feet are in the air and my head and shoulders have been shoved so far into the hole that I get stuck. I had to get dug out. Awesome."

TAMMY MORGAN



the mystery mounds

By most measures, Pavilion Lake is completely normal. A picturesque body of fresh water in British Columbia, carved out by a glacier some eleven thousand years ago, it has an ordinary pH, temperature, and mineral content. Yet the lake hosts a collection of bizarre structures that may someday help us detect past or current life on other planets. In the mid-1990s, scientists discovered microbialites at the bottom of the lake, luring researchers from NASA, the Canadian Space Agency, and a number of universities.

Microbialites are intricate carbonate formations that can be created by diverse microbial organisms. They look like coral, but without the tropical color schemes. In fact, microbialites are modern analogues for Precambrian reefs, which were some of the earliest indicators of life on Earth. Such structures were once common on the surface of Earth, but these days they are typically found only in extremely salty water. So what were microbialites doing in Pavilion Lake?

I came face to face with them while SCUBA diving alongside other scientists with the Pavilion Lake Research Project. In shallow waters, microbialites are small and resemble cauliflower. Up close, you can see individual sand-like grains. Some crumble like dirt between your fingers. As you dive deeper, the microbialites become larger and harder, and resemble giant artichokes.

Since 2004, scientists have been diving extensively in the lake. Yet SCUBA diving has its limitations. And so this year, for the first time, the Pavilion Lake Research Project brought in a pair of Nuytco DeepWorker submersibles to explore the lake.

Simply deploying the subs was a bold undertaking. Usually DeepWorkers are launched from enormous ships with the help of cranes. But with nothing but highway access to the lake, ships and cranes were not an option. Instead, we built a miniature barge, like a floating swing set. We lowered the subs by hand on chains, and divers guided them out from under the barge.

Twice each day pilots flew the submersibles over predetermined contours of the lake, taking high-definition video of the lake bottom. Using the ninety hours of video recorded, our goal is to create a high-resolution map of microbialite morphologies throughout the lake. Combined with ongoing biochemical experiments in the lake, our new knowledge of microbialite distribution will eventually help us see the big picture. We hope to piece together how these microbialites are formed, and why their structures are so varied.

—Zena Cardman

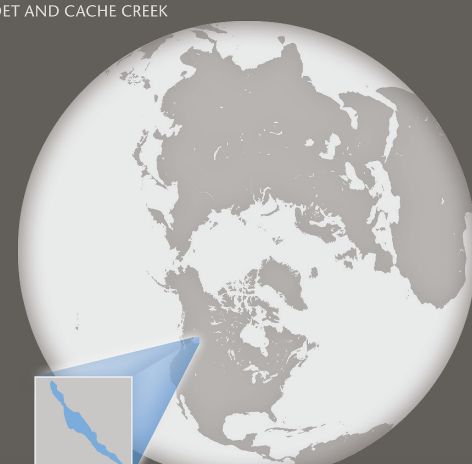
Above: Darlene Lim, a researcher at NASA Ames and principal investigator for the Pavilion Lake Research Project, saws through a microbialite sample. "We're interested in the center of microbialites, as well as the most recently formed outer layer, and a handsaw happens to be a convenient way to slice them open," Zena Cardman says. "This was one of the 'artichoke' microbialites from deep down in the lake, so it was particularly dense."

Below left: Astrobiologist Dale Andersen, diving next to one of the deep microbialite mounds in Pavilion Lake.

Below right: Pavilion Lake in Marble Canyon, British Columbia, Canada is one of the few places on Earth where microbialites can be found.

- > **COORDINATES:** 50° 52′ 0.37 N, 121° 44′ 30.88″ W
- > **MAXIMUM LENGTH:** 3.6 MILES
- > **MAXIMUM WIDTH:** 0.5 MILES
- > **SURFACE ELEVATION:** 2,690 FEET
- > **LANDMARKS:** CLIFFS OF MARBLE CANYON, CHIMNEY ROCK, THE TOWNS OF LILLOOET AND CACHE CREEK

DONNIE REID



JASON SMITH