

Shedding Light on the USU Luminescence Lab

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By Ethan Brightbill

We think of truth and light almost as synonyms: something that comes to light is revealed, while something that never sees daylight is hidden or lost forever, and someone who is in the dark doesn't know what's happening. But in the Utah State University Luminescence Lab, the opposite is often true. Darkness becomes a means of preserving information across hundreds of millennia, while light — much of it, at least — threatens to erase ancient knowledge forever.

The lab is one of fewer than a dozen facilities in the United States that performs luminescence dating, a technique that measures the last time when quartz or feldspar was exposed to sunlight. All soils emit very low levels of ionizing radiation, and these two minerals capture the electrons released from that radiation in their crystalline structure over time. If a scientist can determine how much radiation the quartz or feldspar has absorbed, then they can determine how long the object has been hidden from the sun.

Geosciences Professor Tammy Rittenour, the director and co-founder of the Luminescence Lab, described the process as the same as charging a battery.

"The electrons are stored in the crystalline structure, and as long as the quartz or feldspar isn't exposed to light or heat, they remain there and accumulate over time," she said. "In the lab, we can then stimulate them to luminescence, which is just those electrons being kicked out of defects from the crystal and releasing light in the process. The number of trapped electrons is proportional to how long the material has been buried and in turn the amount of light released as a luminescence signal."

In other words, that signal, which scientists draw out by exposing the mineral to blue-green or infrared light, provides a consistent record of how long sediment has been hidden from the sun. Compared to carbon dating, which only works on objects as far back 50,000 years, luminescence dating can "look" further back in time, with some methods reaching hundreds of thousands of years into the past. And because feldspar and quartz are the two most common minerals in the Earth's crust, the technique can be used on sediment anywhere. (Volcanic beaches in places like Hawaii are one of the few exceptions.)

That makes luminescence dating invaluable for anyone interested in the history of the sediment, from a geologist trying to understand the evolution of the Altai Mountains in Mongolia to a historian who wants to determine the construction history of buildings at Colonial Williamsburg. However, performing the dating isn't easy. The same sunlight that imbues a luminescence signal into a mineral can also reset or "bleach" the electron record that quartz and feldspar keep, and so scientists need to take extreme measures to keep even the slightest trace of white light away from samples they're trying to date.

Into the Dark

At the Luminescence Lab, the first line of defense a visitor encounters is an opaque, black revolving door. The room on one side is a standard office space filled with papers and rock samples, but one turn of the door later, and a visitor steps out into what seems like an almost sepia-toned photograph of a laboratory. The amber overhead lights manage to fully illuminate the space, yet their lack of intensity and distortion of color leave a lingering sense of shadow.

Working in such an environment comes with challenges, explained Rittenour. For instance, while the computers run in a special red-light mode, they still display a small square of white whenever their monitors boot, which is enough light to cause bleaching. The power buttons on the equipment also emit problematic light even after being taped over, so the computers can only be booted up once samples have been safely stowed away.

Even the samples themselves can cause problems. While scientists send metal tubes of soil to the lab, what Rittenour and her colleagues use for dating are just individual grains of feldspar or quartz that must be carefully extracted and placed on extremely tiny trays for exposure and imaging. A speck of white sand stands out on a black desk under normal lighting, but in the lab, it can be almost impossible to see.

"We're dating very fine to fine grains," Rittenour said. "They're very small, so the number one way of knowing if there's sand on a surface is simply touching it and rubbing your hand."

The payoff for all that care and precision, however, is vital context needed for understanding other scientific discoveries. For example, scientists already knew that much of Utah was once covered by a massive body of water, Lake Bonneville, and that it flooded at one point in time and catastrophically drained into the Snake River and ultimately the Pacific. By using luminescence dating to establish that the lake overflowed 20,000 years ago, researchers can then single out the events that might have contributed to the flood, such as the shifting of the Bear River's course.

"You can get an age but if you don't have the record, it means nothing," said Rittenour. "You can have the record, but if you don't know how old it was, you can't relate it to the rest of the world and what was happening at that time."

Secrets Beneath the Ice

A more dramatic example can be found in the Greenland Ice Sheet. In the 1960s, the United States established a base called Camp Century in the far north of the Arctic island. While part of the installation's mission was to conduct scientific research, it also had a secret secondary objective (codenamed Project Iceworm) to house nuclear missile silos where they could strike at targets across the Soviet Union. The latter mission proved untenable, and the base was abandoned in 1967, but the research side of the project did turn up results, including a 1.3-kilometer ice core that contained sediment from a time when that part of Greenland—perhaps even the entire island—was not under a glacier.

Scientists at the time were able to learn much from the core, but they couldn't determine when Greenland went through the warming period the sediment hinted at. Fortunately, the sample was well-preserved enough for the USU Luminescence Lab team to extract a domino-sized sample of unbleached sediment decades after it was originally extracted from under the ice sheet. While a parallel team of scientists had already used other methods to determine that the base of the sediment record was less than 3 million years old, Rittenour and her colleagues narrowed that range down to a mere 400,000 years.

"That sounds super old to most people, but it's actually quite young to a geologist, and much younger than when the Greenland Ice Sheet first formed," said Rittenour. "Over the last million years, the planet has swung between

colder and warmer glacial and interglacial periods as a result of variations in the Earth's orbit around the sun, and we've known there was an exceptionally warm interglacial more recently that might have led to melting in Greenland. Now we know that 400,000 years ago, it was warm enough to at least melt this one section of the ice."

Gold, Bison, and Water

Most of Rittenour's work ties into climate science, but she and the Luminescence Lab technicians work on projects in other fields as well. The lab is in the process of dating the first described Columbian mammoth (found in the state of Georgia) by using the surrounding sediment, and it's currently working with a company to determine the stability of the landscape around a gold mine in the Dominican Republic. Scientists at the lab also do work that looks at more recent events: one of the technicians is examining the site of Cache Valley's recent Green Canyon Fire to see if the burning of different materials leads to different luminescence signals in the underlying soil after a forest fire.

Archaeology is another common point of collaboration, with such projects being frequent enough that the Luminescence Lab website has individual pages dedicated to describing how to collect samples from pottery, human-placed rocks, and walls and buildings respectively. In a recent case, one of Rittenour's students examined sand from a bison jump in Wyoming near Yellowstone National Park. By lining the approach to a cliff with small stone cairns that limited visibility, Indigenous people in the area created an efficient and low-risk system for herding the buffalo off the edge to harvest them for food. Luminescence dating revealed the site to be 400 to 500 years old.

Rittenour recalled another time when the Pueblo of Laguna, New Mexico, reached out during a legal battle to get their water rights back. First water use had priority over later use, she explained, so if the Pueblo could document that their ancestors were using the water before Europeans arrived, they would have a claim to the water.

"We ended up involved in the court case," Rittenour said. "We had to be deposed by lawyers and document how we collected samples and what ages they were. And yes, it turns out that native people were using the water hundreds of years ago prior to European contact."

Sediment as Augur

Even when the connection to the present isn't immediately obvious, the lab's efforts to understand the past frequently shed light on the world today. The dating of the sample from Greenland is a poignant example: if the ice sheet partially or fully melted 400,000 years ago after a warming period that built up more slowly than what the Earth is currently experiencing as a result of fossil fuel use, then the ice sheet is likely to melt again — and Rittenour noted that scientists have been consistently noting just that for decades now.

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"If you melt substantial parts of the Greenland Ice Sheet, sea levels will rise, and it impacts communities across the globe," she said. "If the ice sheet is gone, you also lose this big, white reflector of solar radiation, and that means the Earth is absorbing more energy, which speeds up warming even faster. We have satellite images that show this has been occurring for decades, and not just in Greenland, because the same thing is happening to the West Antarctic Ice Sheet."

In a sense, what Rittenour and her team decipher from trace radiation is not just the Earth's history, but also a glimpse of its future.

"It's surprising that the ice sheet melted in what we consider to be a fairly recent period," Rittenour said. "But it also provides guidance on what could happen if we don't start turning the system around."

The Memory of Darkness, Light, and Ice

A new documentary chronicles how scientists in the 1960s discovered evidence of a time when there was life where the Greenland Ice Sheet is now, and how researchers today # including Professor Tammy Rittenour and assistants in the USU Luminescence Lab # used new technologies to understand those findings and what they mean for our planet's future.

The film examines how bits of a 1.3-kilometer-long core sample drilled by the U.S. Army decades ago are unlocking stories of Earth's history thanks to modern tools and methods.

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