Granite State Geologist

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MESSAGE FROM THE PRESIDENT

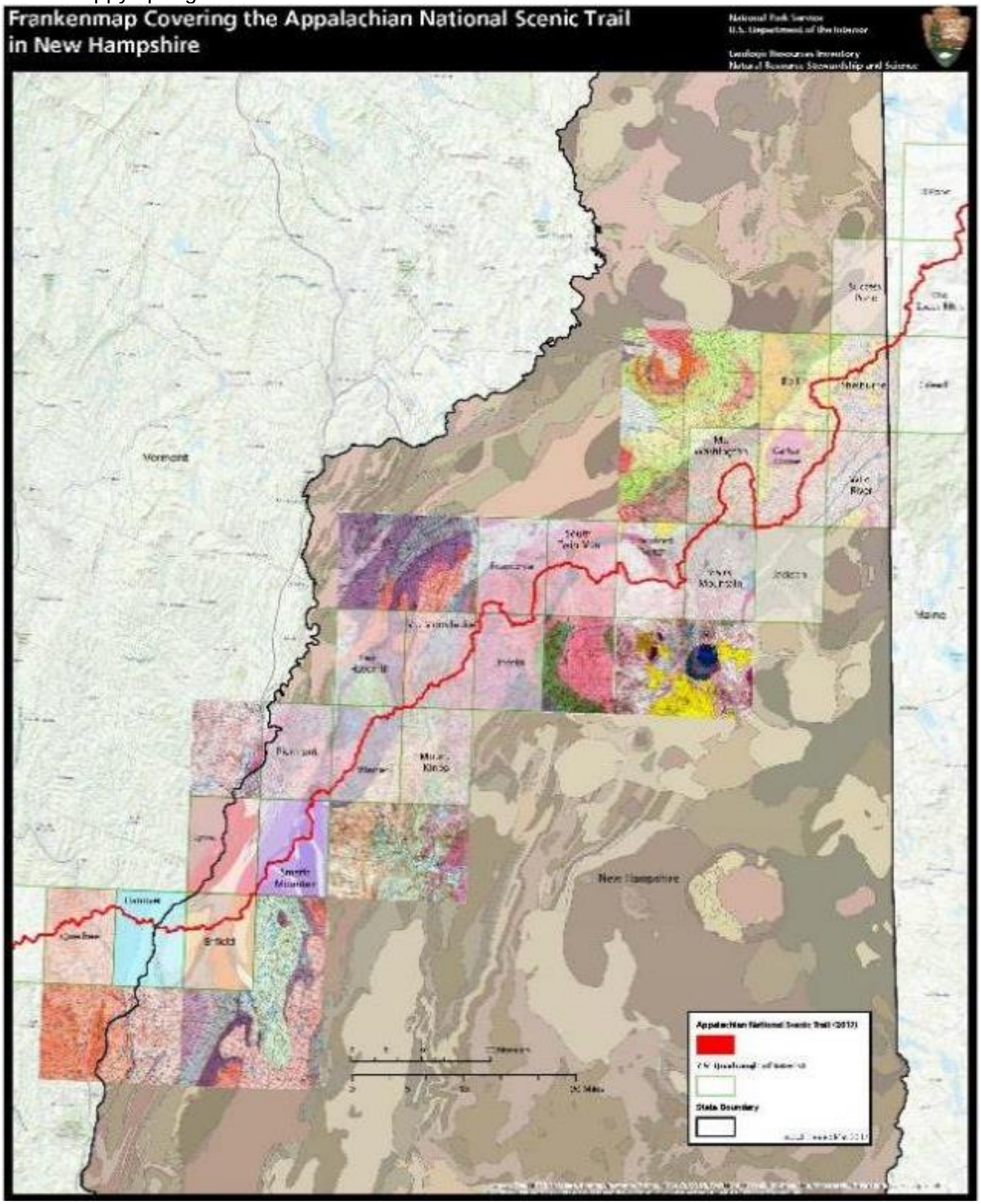
Hello Friends,

Occasionally, the GSNH Board receives notices from other organizations regarding presentations of potential interest to the Society. In November 2021, we received an email from the American Geological Institute (AGI) regarding a webinar on geoscience research in US National Parks. Unfortunately, this announcement came with very short advance notice, so communication to the GSNH membership was not possible. However, you may view the multi-part webinar on the AGI website.

I was aware that the National Park Service (NPS) has completed geologic resource inventories for many of its parks and monuments. I have reviewed published reports for several of the parks, such as Acadia National Park, and I have found the geologic maps and inventory reports, that are available for download, to be very interesting and useful in planning trips to national parks. This got me thinking about what information is available on-line regarding the geology of New Hampshire's US Park Service-managed Saint-Gaudens National Historical Site. Although the NPS geologic resources website for Saint-Gaudens NHS was labeled as under development, I was surprised to find information specific to the geology of the Saint-Gaudens site, and the website included links to digital copies of bedrock geologic maps for the area.

What surprised me even more was my discovery that the NPS has recently started to manage the lands that comprise the Appalachian Trail (AT), referred to in this context as the Appalachian National Scenic Trail. Along with this designation, consultants retained by the NPS have begun assembling a geologic resources inventory for the AT, including the 160.9 mile segment that passes through New Hampshire. One completed task was to develop what the NPS calls a “Frankenmap” that pieces together existing bedrock geologic maps that cover the AT. Copied below is the [NH Frankenmap](). I look forward to further mapping efforts to refine the presentation of the bedrock geology of NH that is underfoot for the multitude of hikers that trek the NH segment of the AT.

I hope you can get outside and enjoy the beauty and natural wonders that New Hampshire has to offer. Happy spring! Tom



GSNH T-Shirts Available!

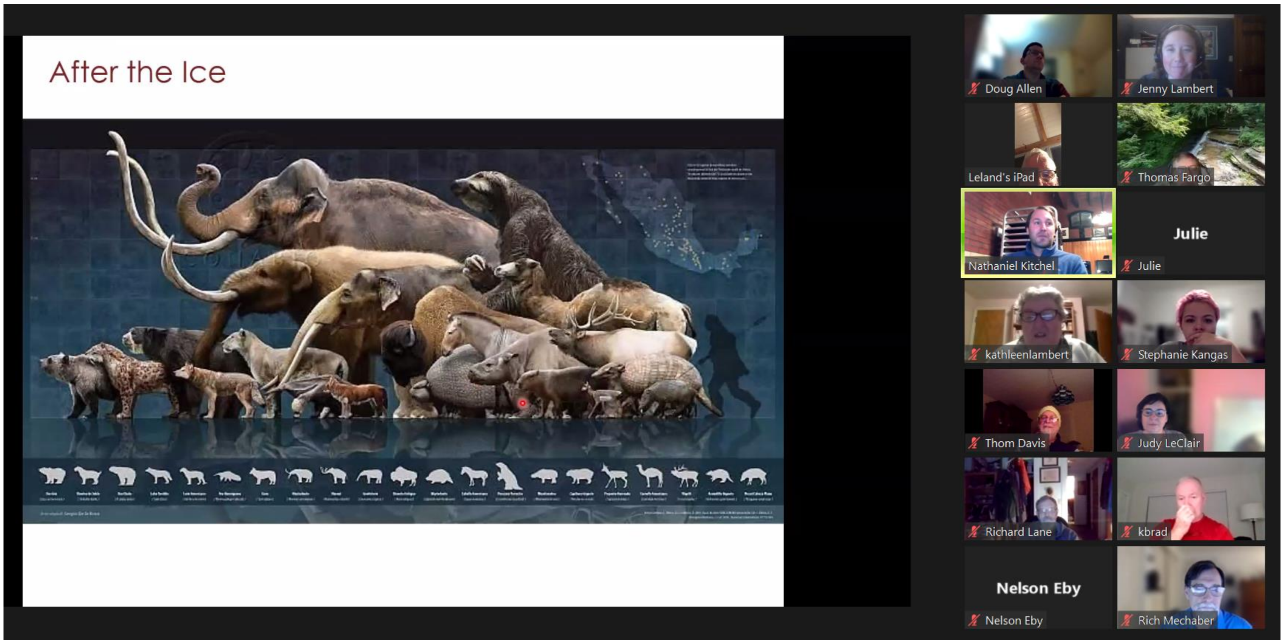
We have a few GSNH T-shirts still available – no XL, and we have just 4 L and a few more M and S sizes left. Send in your order before they're gone! T-shirts will be shipped to you. See order form on second to last page (right before the renewal form).

Front (left photo) and back (right photo) of GSNH t-shirt.

January 2022 Meeting Recap

Our winter meeting was held via Zoom on January 20. We had another good turnout on this one! Items discussed included Shane Csiki's new role at the New Hampshire Geological Survey (NHGS) and retirement from his position as GSNH secretary, a legislative update, and updates from organizations looking to hire geologists.

Nathaniel R. Kitchel of Dartmouth College gave a presentation the recent (2020) carbon dating of the Mt. Holly (Vermont) mammoth, which is the youngest set of probosidean (mammoth/mastodon) remains yet dated in our area. This relatively recent age has implications for the temporal overlap between humans and probosideans both here in New England and in North America in general.



Screenshot from Nathaniel R. Kitchel's presentation on June 20.

Have You Renewed your Membership?

If you have already renewed your 2022 GSNH membership, thank you! If not, please consider renewing. With your membership, you get a discount on dinner meetings (which will happen at some point!) and field trips, information of upcoming events of interest to the geological community, voting privileges at Society business meetings, and automatic subscription to this newsletter! Membership dues also help to support outreach for the greater community.

See the last page of this newsletter for a membership renewal application.

Some New Hampshire rocks of unique interest to science need to be moved – 19 tons of them, to be exact

From David Brooks, Concord Monitor, December 27, 2021.
https://www.concordmonitor.com/rock-geology-new-hampshire-nh-44182605

There are a couple of drawbacks to New Hampshire geology. One is that we don't have fossils – they were all melted by our igneous rocks or scraped away by retreating glaciers – and another is that we don't have true geothermal energy.

Electricity produced by heat bubbling up from Earth's molten innards would be very neat. Alas, it's not for us.

How do we know that we don't have real geothermal energy, which is not to be confused with ground-sourced heat pumps that are sometimes called geothermal? Because of the deepest hole ever drilled in New Hampshire.

That drilling went down 3,000 feet near Conway in 1975, back when the OPEC oil embargo left us interested in finding energy alternatives. (Too bad we didn't stick with that idea.)

The drilling brought up a long, skinny core of rocks that was analyzed by the state geologist, then part of the Energy Research and Development Agency. The analysis found that a type of bedrock called Conway red granite showed potential to produce enough heat, but it only extended down about 150 feet.

"If the entire length had been of that rock type, the potential to support locally-based geothermal energy would have been higher," said Shane Csiki, director of the New Hampshire Geological Survey, a successor to that earlier energy agency.

So that was that. You'll sometimes see Conway marked on geothermal-exploration maps as a possible site, but don't get your hopes up.

Why do I care about this? Because that rock core is now part of a very unusual state document.

The Geological Survey recently put out a request for quotes, seeking somebody to pick up all 38,000 pounds of those rocks from somebody's yard in Weare and truck them to a climate-controlled facility in New Jersey run by Columbia University.

This raises a couple of questions. First, why are these rock cores sitting in a Weare backyard?
As Csiki explained it, the cores were kept for potential geological and scientific interest, although nothing much was done with them. They were stored in a basement of the Walker Building on the state campus, but in 2001 that building was renovated and the cores had to be moved.

"A private landowner in Weare offered to store them. He's a big friend of geology in New Hampshire," Csiki said. The landowner prefers to remain anonymous, perhaps fearing a flood of people requesting free rock storage.

Csiki said the rock cores are still in good shape but the years spent outdoors under rotting tarps have taken a toll on the wooden crates holding them. The state has long been interested in getting them to climate-controlled storage to prevent any chemical or physical deterioration.

Some of the rock cores from a 1975 drilling near Conway have been stored in a Weare back yard for more than a decade. Their packaging has deteriorated. NH DES—Courtesy

Second, why is Columbia University interested in 19 tons of our rocks?

Deep-drilled rock cores are of interest to scientists because they can tell us interesting things about geology. Columbia is a hotbed of such interest, and runs a National Science Foundation-funded site called the Lamont-Doherty Core Repository that stores lots of them.

They learned of these cores and contacted Rick Chormann, the former state geologist.

Once at the lab scientists could analyze the rocks with X-ray fluorescence – "they don't have to cut into them, can leave them in the core boxes, yet I.D. mineral percentages in the cores" – and learn valuable things. Because no other core like it has been drilled in the state, Csiki said, it holds out promise of providing new information about the formation of the White Mountain region.

"This core is a fantastic opportunity for that type of analysis, to learn about the deep history of New Hampshire," he said.

All that's required is to get the 19 tons of the rocks there; hence the request for quotes. The cost should be covered by a grant from the U.S. Geological Survey, to pay for proper storage boxes and shipping.

"We haven't had any offers yet," Csiki said. "Maybe this article will help."

New Hampshire Geological Survey Update

By Shane Csiki, State Geologist and Director, March 2022

Despite being placed into the depths of outdoor cold which has gripped the state much of the winter, The New Hampshire Geological Survey (NHGS) has been already looking forward to the warmer weather of spring and summer . . . by planning our summer field season! We have a very busy field season coming up this year. NHGS staff members Josh Keeley, Mike Howley and Rebecca LeCain will be spending time in the field with our geologic mappers (under STATEMAP). This staff presence will provide some needed field assistance and presence that several of our mappers requested. Additionally, it provides the opportunity for NHGS staff to spend quality time with our seasoned and experienced mappers, in the spirit of mentorship. Several of our long-time mappers are near "retirement," and we are actively seeking to build the capacity for the next generation of mappers, including our own highly qualified staff geologists. As part of this effort, Josh Keeley will be coauthoring two geologic maps this summer with Thom Davis (Mount Moosilauke surficial quad) and Woody Thompson (Shelburne surficial quad). All in NHGS are looking forward to getting outside and spending time doing geology!

We will also be busy this summer continuing to assess culverts in the state, as part of long-standing efforts to identify culverts at greatest risk for failure in a flood, as well as addressing fish passage and hydraulic vulnerability issues. New Hampshire Department of Environmental Service's (NHDES') Aquatic Resources Mitigation program and New Hampshire Homeland Security & Emergency Management's (NH HSEM's) Hazard Mitigation Program use this information to target limited funding of culvert replacements to priority sites that will best address these issues. NHDES will be funding a large initiative, based at University of New Hampshire (UNH), to complete remaining assessments in southeast New Hampshire this summer. With the volume of data coming in, we will be hosting two summer interns who will be dedicated to quality control review. As always, we will also be hosting two interns performing field assessments in southwest New Hampshire, which was impacted by flooding last year. We will be doing all of this in 2022 without the able and reliable coordination provided by Kyle Hacker, who recently made a career move, and is now with Verdantas, in Manchester. Kyle's role with the culvert and flood hazards work was instrumental to the multi-agency program's recent accomplishments. NHGS wishes Kyle sincere success in his new endeavors. NHDES' goal is to complete statewide stream crossing assessment work by 2026.

On the groundwater level monitoring front, Mike Howley has been continuing to make some refinements to our monthly groundwater level data reporting. In addition to monthly posting via NHDES' web page, Mike is now also offering the opportunity to have the report delivered right to your e-mail inbox each month, upon completion. If you would like to receive a copy of the monthly groundwater monitoring report, let Mike (Michael.W.Howley@des.nh.gov) know, and he will add you to the distribution list.

NHGS will again be hosting its annual Mapper's Workshop on **Friday, April 1** from **8:30 AM** to **1 PM**. 4.5 CEUs of credit for Professional Geologists can be earned. This year's agenda includes: presentations from USGS on a New England Top of Rock project and on preliminary geochronology results from the Maine-New Hampshire border, a presentation from the Maine Mineral and Gem Museum, and updates from NHGS' geologic mappers which includes some Ground Penetrating Radar findings from New Hampshire and Antarctica. Once again, the meeting will be all virtual. Registration is required, though attendance is free of charge. To register, contact Rebecca LeCain (Rebecca.M.LeCain@des.nh.gov) and she will provide you the Teams link to the workshop.

GSNH Financial Summary

From Abby Fopiano, Treasurer

As your GSNH Board reviews the financials for 2021, we wanted to pass along a synopsis of recent GSNH financial activity. Within 2020 and 2021, under the COVID pandemic, there was less activity than other years due to the absence of in-person meetings and field trips. GSNH has a healthy bank account that has grown only slightly in the past couple years. The primary influx of monies is from membership dues and the occasional T-shirt sales. T-shirts are still available – and don't forget your Membership dues! Operating expenses are related to website and domain name hosting and PO Box fees. Typically, dinner meeting and field trip dues cover the expense of that event. A mission of GSNH is to advance the science of geology and its related fields through education, research and service. If you have a project that you believe fits this mission – bring it to your GSNH Board. One example project in process is the NH Geology Sites Mapper, which intends to be hosted on our website and offer users a virtual tour (and information on visiting in-person) of fascinating geologic locations within the state.

GSNH has aided other geologic entities in the state through the utilization of our financial infrastructure to make events and fundraising possible. For example, GSNH hosted the Madison Boulder funds for many years and will be helping the Friends of the Pleistocene trip this Spring (see page 33 for announcement). GSNH funds are not spent on these types of collaborations; instead, we act as the means to accept and hold project specific monies until they are transferred or spent on that specific project or event.

REMINDER: GSNH offers grants of up to $500 to teachers (K-12) to help with the purchase earth science related equipment or supplies. We accept applications anytime. The application can be found here: http://www.gsnh.org/classroom-grant.html. Previously funded projects include the purchase of groundwater models and mineral collections. If you know a teacher or school system that may benefit – please pass along the application.

If you have any questions about GSNH financials please contact the GSNH Treasurer, Abby Fopiano at abby@edgewaternh.com.

How Old Is the Moon? Way Younger Than We Thought

By Jennifer Leman, March 1, 2022. From Popular Mechanics:
https://www.popularmechanics.com/space/moon-mars/a33314141/moon-actual-age/

The moon, it turns out, is much younger than scientists previously thought.

Back in 2020, researchers from the German Aerospace Center and the University of Münster released new estimates for the age of the moon. According to their modeling, it's 85 million years younger than previous estimates have suggested.

Scientists have long estimated that the moon formed some 4.51 billion years ago when a Mars-sized object (which we've since dubbed Theia) smashed into Earth. At the time, the guts of our newly formed planet were beginning to take shape.

The collision tore away a chunk of Earth's mantle and flung it into orbit, where it morphed into a massive ring of dust and rock that began to clump together. "From this, the moon was formed in a short time, probably in just a few thousand years," planetary scientist and study co-author Doris Breuer, of the German Aerospace Center, said in a statement.

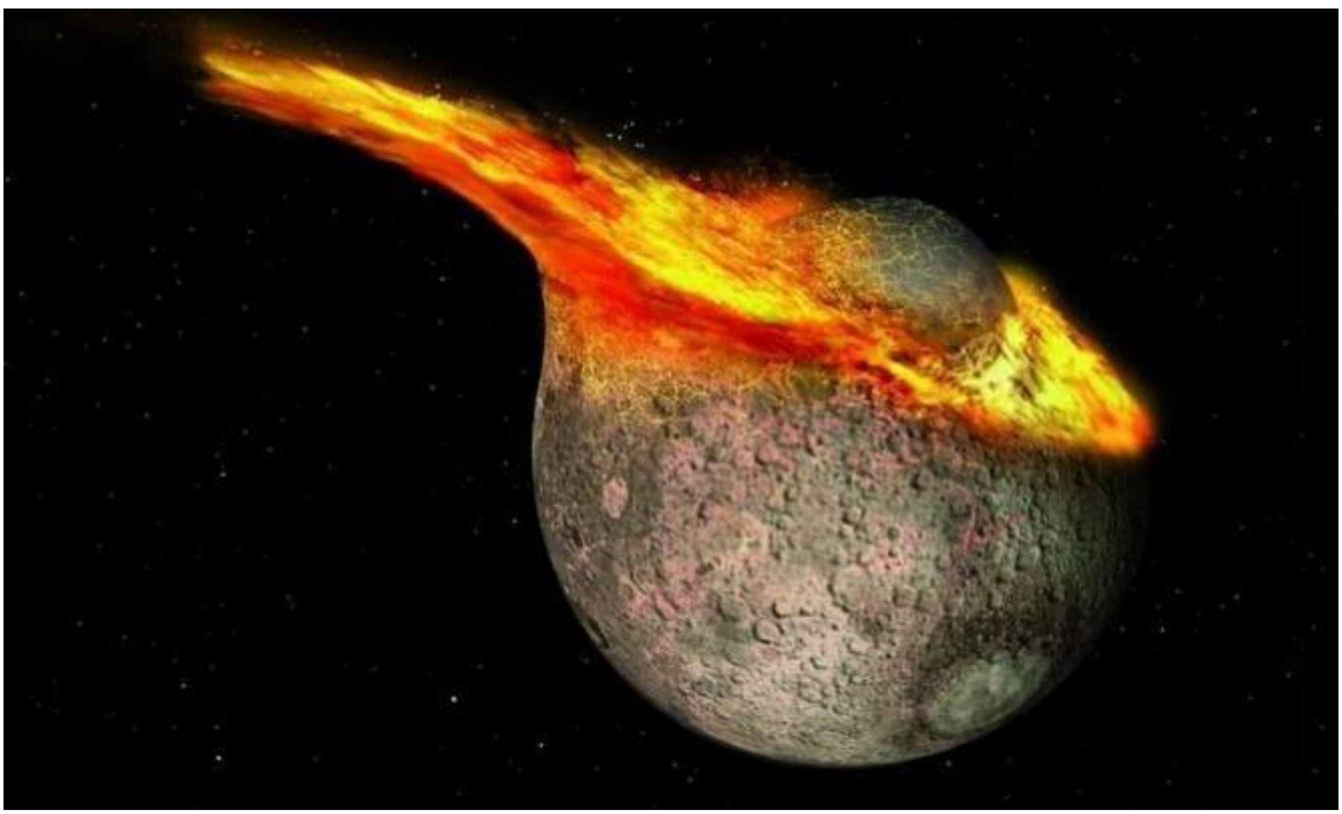
In their paper, published in *Science Advances*, Breuer and her colleagues reveal that this infamous impact occurred around 4.425 billion years ago, give or take about 25 million years. In the aftermath of the impact, the moon looked a lot like Mustafar—a molten marble with a piping hot magma ocean more than 600 miles deep.

The scientists used computer simulations to show exactly how long it would have taken the moon's magma ocean to solidify, as this would help pinpoint the precise age of the moon. Their models indicated it took a whopping 150 to 200 million years for that magma to fully crystalize. Previous models have suggested it only took 35 million years for the moon's hard, rocky exterior to form.

The impact also kickstarted the formation of Earth's core. Heavier elements like nickel and iron sank toward the planet's center, while a layer of silicate rock formed the mantle layer around it.

"This is the first time that the age of the moon can be directly linked to an event that occurred at the very end of the Earth's formation, namely the formation of the core," planetary scientist Thorsten Kleine, of the University of Münster in Germany, said in the statement.

Over the years, we've able to glean bits and pieces of information from the moon rocks brought back during the Apollo missions and Russia's Luna missions. It's been more than 50 years since we first set foot on the lunar surface, and we still have a lot to learn.



From Ron Miller.

Let’s get the terminology straight

By Lee Wilder

There is a difference between WEATHER and CLIMATE. Weather is the current state of the atmosphere: “It is raining”; “Boy is it cold out today”, and “it is supposed to be sunny all this week.”

Climate is the long-term average of a places weather, i.e. its temperature and precipitation. The climate in New Hampshire is different from the climate in California because over the long term both places have different temperatures and amounts of precipitation at different times of the year.

If you want to see the world's different climates and how they are determined and named, type “Koppen Climate Classification” into Google. Wladimir Koppen came up with the original climate naming system as he worked in Botany. Like the climate for New Hampshire, it is based on the long-term averages of the Earth’s temperature and precipitation.

The Earth is very old - most geologist agree that it is somewhere around 4.6 billion years old. Scientists have only been keeping good temperature and precipitation records for the last several hundred years. Some scattered weather records go back 3000 years or more - not much time out of 4,600,000,000 years.

But luckily, we don’t need written records to get an idea of what the climate was like in the past. Biologists can look at the varying growth of tree rings. Since plants and animals live under certain temperature and precipitation conditions, Paleontologists can determine if the climate was wet or dry, hot or cold from the fossil plants and animals that lived there.

The fossil shells of sea organisms in the layers of sand and mud on the floor of the world’s oceans reveal more good ocean temperature records from far in the past. These “fossil records” reveal an Earth with a long history of changing climate. Again type “World Temperature Records” into Google to see the many graph images scientists have plotted from this fossil data. They find that over the Earth’s past, the Earth’s climate has been hotter and colder than it has been in your lifetime.

The most recent cold period started about 2.3 million years ago, as a warmer Earth began to cool. Why did it cool? It seems to have something to do with variations in the Earth’s orbit in relation to the Sun. In fact, the Earth’s average annual temperature got cold enough to allow some high latitude snow (think Labrador) to make it through the summer. Geologist call this most recent cold event the Pleistocene Epoch …” the Ice Age”.

As this snow accumulated, through thousands of years, it froze into a huge sheet of ice.

Hundreds of feet of accumulated snow exert a lot of pressure on the bottom snow layers and they melt and refreeze into ice. Under all this pressure of the overlying weight, the ice becomes "plastic like." This ice begins to *flow* outward from the centers of accumulation. Here in the Northeastern United States, the ice eventually flowed as far south as Cape Cod and Long Island, NY, by some 20,000 years ago. It stopped flowing any further because the Earth's Climate was warming up. (Humans were not here in any number then, burning oil and coal, driving cars and airplanes, or raising huge herds of cattle.)

As the climate continued to warm up, the glacial ice melted back across the Northeast. Only a few degrees temperature change was necessary for this melting to take place. As the climate continues to warm, the rest of the Earth's glacial ice continues to melt.

Besides the swings in Earth's climate temperature caused by the variations in the Earth's orbit in relation to the Sun, increases in the amounts of carbon dioxide, methane and other gases (AKA Greenhouse gases) in the atmosphere, help prevent heat from escaping from the Earth's atmosphere. So instead of warming in another gradual natural cycle, the increase in the Greenhouse gases have caused Earth's average annual temperature to warm more quickly.
So, it is not a "human ***caused*** climate change," it is part of the continued natural climate change cycles, but happening more quickly due to "***human activities***."

One way or another the Earth's climate is warming, the world's glacial ice is going to melt and sea level is going to rise. (Note that many of the world's major cities are coastal cities – New York, London, San Francisco, etc.) And yes, we ought to see if we can slow the rate of warming down by cutting back on our Greenhouse gas emissions. That would give us enough time to prepare for a warmer Earth's climate, it's higher sea levels and it changing weather patterns. That would also give you the opportunity to move to higher ground or buy coastal property at a vastly reduced rate.

What's Your Board Been Doing?

The GSNH Board of Directors met on Thursday, March 10 via Zoom. The first major order of business was to appoint a secretary to replace Shane Csiki, who resigned in October to prevent a potential conflict of interest with his new position at the New Hampshire Geological Survey (NHGS). Rebecca

LeCain has volunteered to serve as secretary and was appointed as interim secretary to fill out the remainder of Shane's term.

Other matters discussed during the meeting included the following:

- financial summary: see page 9 of this newsletter
- membership report: so far, we have received 55 renewals for 2022
- election committee: several Board members are term-limited (secretary, and 2 members-at-large); if interested in serving on the board, please reach out to Julie Spencer (julie.spencer@comcast.net)
- GSNH summer field trip: we will not join with the Friends of the Pleistocene (field trip details on page 33), but will consider our own field trip instead this summer.

The next board meeting is planned for June 16, in-person and outside. Please reach out to a Board member if you'd like to attend.

Earth is spinning faster now than it was 50 years ago

From Kate Golembiewski, Discover. December 20, 2021.
https://www.discovermagazine.com/the-sciences/earth-is-spinning-faster-now-than-it-was-50-years-ago

Credit: Janez Volmajer/Shutterstock

Ever feel like there's just not enough time in the day? Turns out, you might be onto something. Earth is rotating faster than it has in the last half-century, resulting in our days being ever-so-slightly shorter than we're used to. And while it's an infinitesimally small difference, it's become a big headache for physicists, computer programmers and even stockbrokers.

Why Earth Rotates

Our solar system formed about 4.5 billion years ago, when a dense cloud of interstellar dust and gas collapsed in on itself and began to spin. There are vestiges of this original movement in our planet's current rotation, thanks to angular momentum — essentially, "the tendency of the body that's rotating, to carry on rotating until something actively tries to stop it," explains Peter Whibberley, a senior research scientist at the UK's National Physical Laboratory.

Thanks to that angular momentum, our planet has been spinning for billions of years and we experience night and day. But it hasn't always spun at the same rate.

Hundreds of millions of years ago, Earth made about 420 rotations in the time it took to orbit the Sun; we can see evidence of how each year was jam-packed with extra days by examining the growth lines on fossil corals. Although days have gradually grown longer over time (in part because of how the moon pulls at Earth's oceans, which slows us down a bit), during humanity's watch, we've been holding steady at about 24 hours for a full rotation — which translates to about 365 rotations per trip 'round the Sun.

As scientists have improved at observing Earth's rotation and keeping track of time, however, they've realized that we experience little fluctuations in how long it takes to make a full rotation.

A New Way to Track Time

In the 1950s, scientists developed atomic clocks that kept time based on how electrons in cesium atoms fall from a high-energy, excited state back to their normal ones. Since atomic clocks' periods are generated by this unchanging atomic behavior, they don't get thrown off by external changes like temperature shifts the way that traditional clocks can.

Over the years, though, scientists spotted a problem: The unimpeachably steady atomic clocks were shifting slightly from the time that the rest of the world kept.

“As time goes on, there is a gradual divergence between the time of atomic clocks and the time measured by astronomy, that is, by the position of Earth or the moon and stars,” says Judah Levine, a physicist in the time and frequency division of the National Institute of Standards and Technology. Basically, a year as recorded by atomic clocks was a bit faster than that same year calculated from Earth’s movement. “In order to keep that divergence from getting too big, in 1972, the decision was made to periodically add leap seconds to atomic clocks,” Levine says.

Leap seconds work a little like the leap days that we tack on to the end of February every four years to make up for the fact that it really takes around 365.25 days for Earth to orbit the Sun. But unlike leap years, which come steadily every four years, leap seconds are unpredictable.

The International Earth Rotation and Reference Systems Service keeps tabs on how quickly the planet spins by sending laser beams to satellites to measure their movement, along with other techniques. When the time plotted by Earth’s movement approaches one second out of sync with the time measured by atomic clocks, scientists around the world coordinate to stop atomic clocks for exactly one second, at 11:59:59 pm on June 30 or December 31, to allow astronomical clocks to catch up. Voila — a leap second.

Unexpected Change

Since the first leap second was added in 1972, scientists have added leap seconds every few years. They’re added irregularly because Earth’s rotation is erratic, with intermittent periods of speeding up and slowing down that interrupt the planet’s millions-of-years-long gradual slowdown.

“The rotation rate of Earth is a complicated business. It has to do with exchange of angular momentum between Earth and the atmosphere and the effects of the ocean and the effect of the moon,” Levine says. “You're not able to predict what's going to happen very far in the future.”

But in the past decade or so, Earth’s rotational slowdown has … well, slowed down. There hasn’t been a leap second added since 2016, and our planet is currently spinning faster than it has in half a century. Scientists aren’t sure why.

“This lack of the need for leap seconds was not predicted,” Levine says. “The assumption was, in fact, that Earth would continue to slow down and leap seconds would continue to be needed. And so this effect, this result, is very surprising.”

The Trouble With Leap Seconds

Depending on how much Earth's rotations speed up and how long that trend continues, scientists might have to take action. "There is this concern at the moment that if Earth's rotation rate increases further that we might need to have what's called a negative leap second," Whibberley says. "In other words, instead of inserting an extra second to allow Earth to catch up, we have to take out a second from the atomic timescale to bring it back into state with Earth."

But a negative leap second would present scientists with a whole new set of challenges. "There's never been a negative leap second before and the concern is that software that would have to handle that has never been tested operationally before," Whibberley adds.

Whether a regular leap second or a negative leap second is called for, in fact, these tiny changes can be a massive headache for industries ranging from telecommunications to navigation systems. That's because leap seconds meddle with time in a way that computers aren't prepared to handle.

"The primary backbone of the internet is that time is continuous," Levine says. When there's not a steady, continuous feed of information, things fall apart. Repeating a second or skipping over it trips up the whole system and can cause gaps in what's supposed to be a steady stream of data. Leap seconds also present a challenge for the financial industry, where each transaction must have its own unique time stamp — a potential problem when that 23:59:59 second repeats itself.

Some companies have sought out their own solutions to leap seconds, like the Google smear. Instead of stopping the clock to let Earth catch up with atomic time, Google makes each second a tiny bit longer on a leap second day. "That's a way of doing it," Levine says, "but that doesn't agree with the international standard for how time is defined."

Time As a Tool

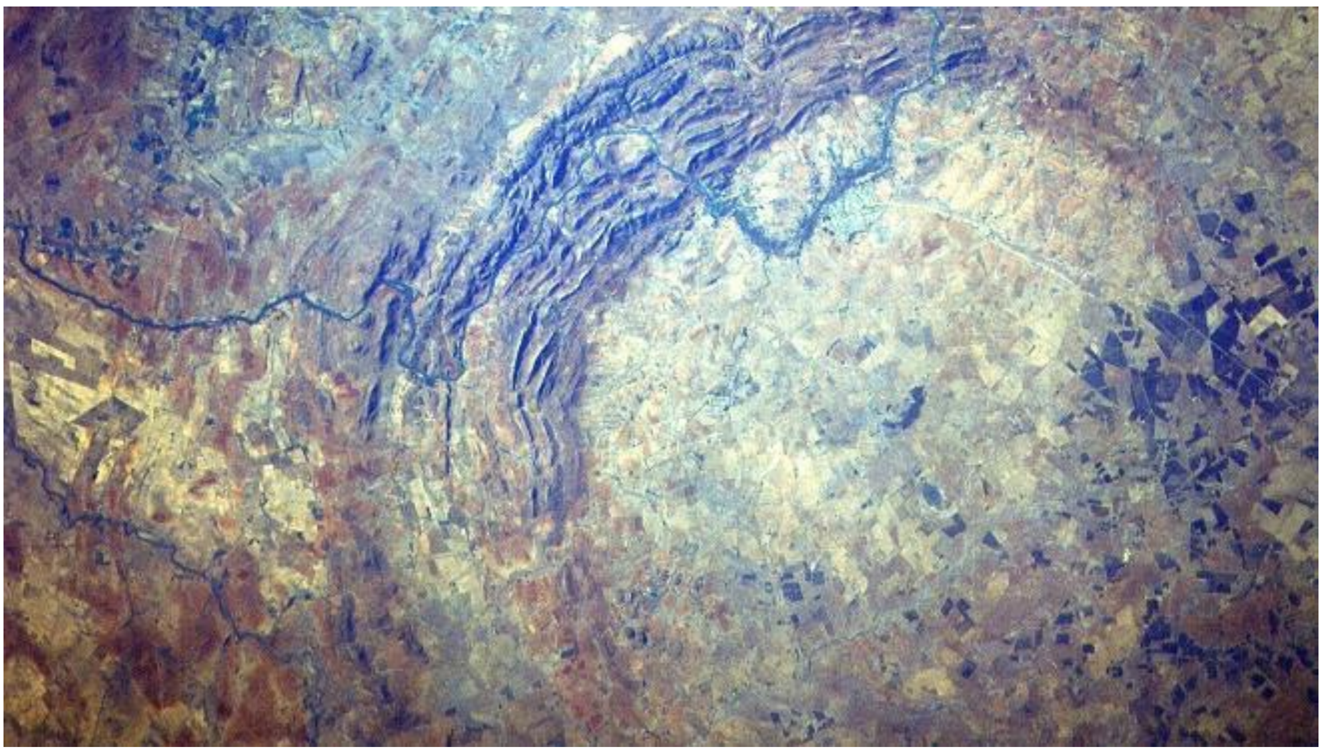
In the grand scheme of things, though, we're talking about very tiny amounts of time — just one second every couple of years. You've lived through plenty of leap seconds and probably weren't even aware of them. And if we view time as a tool to measure things we see in the world around us, like the transition from one day to the next, then there's an argument to be made for following the time set by the movement of Earth rather than the electrons in an atomic clock — no matter how precise they might be.

Levine says he thinks that leap seconds might not be worth the trouble they cause: "My private opinion is that the cure is worse than the disease." If we stopped adjusting our clocks to account for leap seconds, it could take a century to get even a minute off from the “true” time recorded by atomic clocks.

Still, he concedes that while it’s true that time is just a construct, a decidedly human attempt to make sense of our experiences in a big, weird universe, “it's also true that you have the idea that at 12 o'clock noon, the Sun is overhead. And so you, although you don't think about it often, do have a link to astronomical time.” Leap seconds are just a tiny, nearly invisible way of keeping that link alive.

A Giant Impact Triggered Earthquakes for Thousands of Years

By Katherine Kornei, Eos, 103. Published February 2, 2022.
https://eos.org/articles/a-giant-impact-triggered-earthquakes-for-thousands-of-years



Geological evidence suggests that earthquakes reverberated for tens of thousands of years after an asteroid struck South Africa. Credit: NASA/STS51I-33-56AA

Every few hundred million years, give or take, our planet is pummeled by a kilometer-scale chunk of rock. These rare, but cataclysmic, impacts are known to have altered ecosystems and caused widespread extinctions. Now, researchers have shown that such events can also trigger earthquakes that persist for thousands of years. This discovery, made at the Vredefort impact structure near Johannesburg, South Africa, sheds light on how the planet’s crust reequilibrates after a massive impact, the team suggests.

A Look Beneath

The Vredefort impact structure is the world's largest extraterrestrial scar. But because of its pronounced age—2.02 billion years, to be precise—the original crater is no longer visible. That's because the cumulative effects of erosion from water, wind, and ice over geologic time have stripped away roughly 10 kilometers' worth of material, said Matthew S. Huber, a geologist at the University of the Western Cape in Cape Town, South Africa, and lead author of the study. "What we're looking at now is what the structure looks like very deep below the impact."

And that's a unique vantage point, said Huber. "We don't have any other large impact craters where we get to see what it looks like when you slice into it."

Taking advantage of that perspective, Huber and his colleagues studied several of the impact melt dikes within the Vredefort impact structure. These vertically oriented slabs of rock crosscut through the region's granites. They likely consist of impact melt, an amalgam of once molten material that pooled at the planet's surface shortly after the cataclysm, previous studies have suggested. And because these dikes are still visible today despite extensive erosion, impact melt must have traveled far below the surface, the researchers surmised. "Why do we have these dikes deep in the subsurface? That's the overarching research question," said Huber.

Rebounding Crust

The opening of fractures in Earth's crust—associated with earthquakes—could have plausibly allowed these dikes to extend to great depths, previous research has noted. Seismic activity makes sense because of the titanic forces at play in the wake of the impact, said Huber. The impact scraped away kilometers of sediments nearly instantaneously, and the planet's crust would have rebounded in response. "This is the same as if you have a glacier that's retreating—the land is rising up again after the glacier has moved away," he said. "It's the same type of isostatic rebound."

But the duration of such ground shaking has never been constrained. And that's an important quantity to understand, Huber and his collaborators note, because it gets at a fundamental question: Is an impact event a one-and-done affair, or do aftereffects continue to roil a region for some time?

"Crustal settling over geologic time has always been suspected around large impact basins, but the duration of that settling has been elusive," said David Kring, a planetary geologist at the Lunar and Planetary Institute in Houston not involved in the research. "The current paper attempts to resolve that issue."

A Striking Boundary

Huber and his colleagues studied five dikes. Three appeared to be homogeneous across their exposed faces. But the remaining two stood out, even at first glance: Their interiors were dark brown, and their peripheries tended to be lighter in color and flecked with beige. “The boundaries between the phases are quite sharp—you can put your finger on the precise contact between them,” Huber told Eos.

Back in the laboratory, the researchers found that the two visually striking dikes were, indeed, chemically inhomogeneous: Their interiors contained a higher fraction of iron and magnesium, and their peripheries tended to be dominated by silicon and potassium. This finding suggests that two chemically distinct pulses of impact melt poured downward to form these dikes, Huber and his colleagues surmised. And that’s possible only if the melt sheet chemically differentiated between the two pulses, the researchers concluded, which in turn implies that some interval of time separated episodes of ground shaking.

The Reign of Earthquakes

The first downpouring of impact melt must have occurred before the melt sheet differentiated, and the second had to have taken place after differentiation but before the melt sheet solidified, the researchers reasoned. On the basis of previous estimates of the timing of those events made by other researchers, Huber and his colleagues concluded that earthquakes shook the region for at least tens of thousands of years.

This finding reveals the enduring nature of massive impact events, said Huber. “It is not simply a moment in time. Even tens of thousands of years after an impact, you would not want to be building a house on the periphery of a crater.”

Controversial impact crater under Greenland’s ice is surprisingly ancient

By Paul Voosen, Science. Published March 9, 2022.
https://www.science.org/content/article/impact-crater-under-greenland-s-ice-surprisingly-ancient

In 2018, an international team of scientists announced a startling discovery: Buried beneath the thick ice of the Hiawatha Glacier in northwest Greenland is an impact crater 31 kilometers wide—not as big as the crater from the dinosaur-killing impact 66 million years ago, but perhaps still big enough to mess with the climate. Scientists were especially excited by hints in the crater and the surrounding ice that the Hiawatha strike was recent—perhaps within the past 100,000 years, when humans might have been around to witness it.

Rocks at the foot of Hiawatha Glacier contained shocked zircon crystals that revealed the impact's age. Pierre Beck.

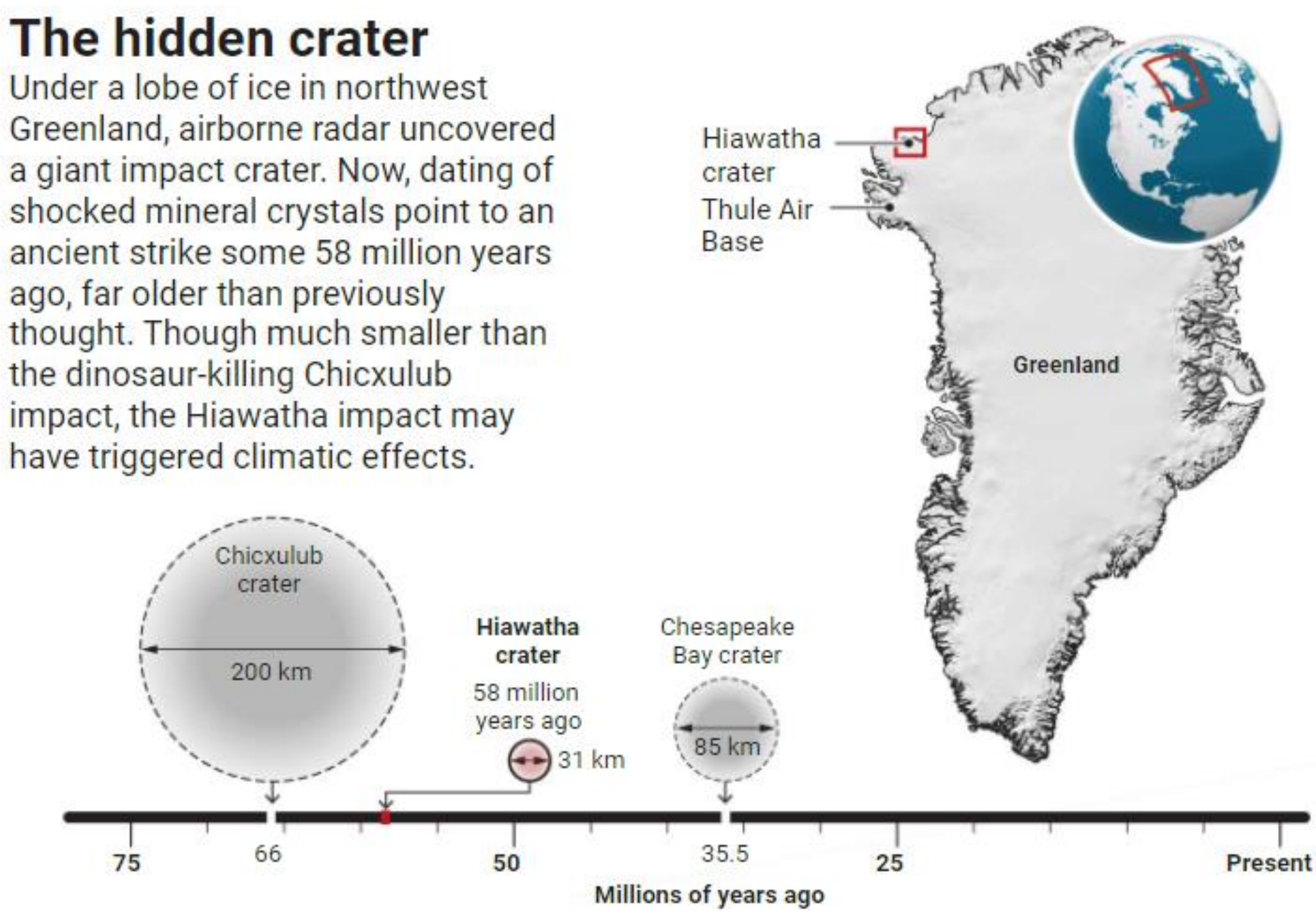
But now, using dates gleaned from tiny mineral crystals in rocks shocked by the impact, the same team says the strike is much, much older. The researchers say it occurred 58 million years ago, a warm time when vast forests covered Greenland—and humanity was not yet even a glimmer in evolution's eye. Kurt Kjær, a geologist at the Natural History Museum of Denmark and a co-author of the new study, says the new date is at odds with the team's initial impression, gleaned from ice-penetrating radar. "But this is the way science works and should work," he says.

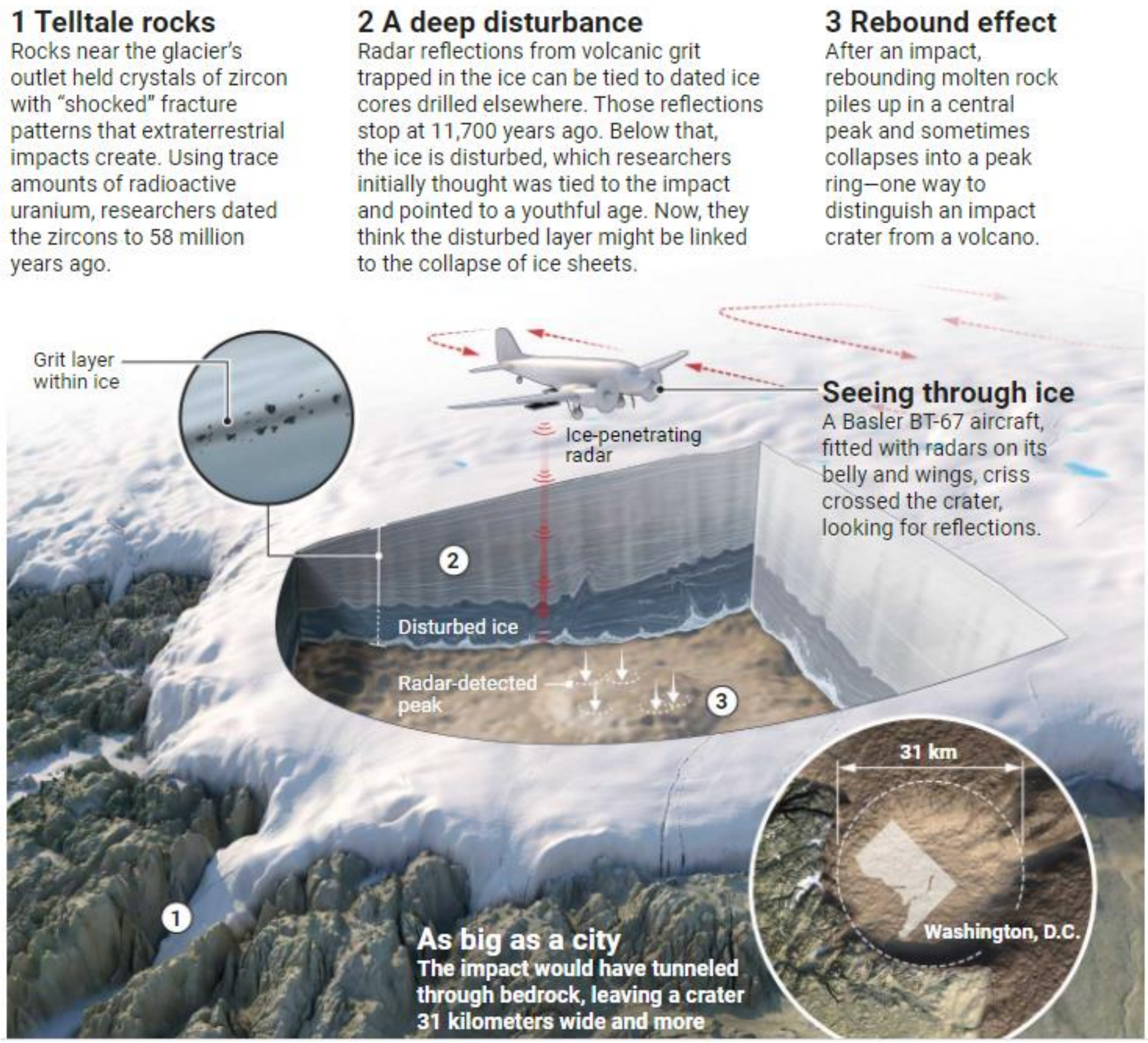
The date is a blow to a group of scientists that for more than a decade has advanced a controversial hypothesis that the Younger Dryas, a drastic, 1000-year cooling about 12,800 years ago, was triggered when a comet struck Earth. They had seized on the first Hiawatha paper as a smoking gun: The crater seemed about the right age, and it was in the right place—near a region of the North Atlantic Ocean that heavily influences Northern Hemisphere climate. Now, says Brandon Johnson, a co-author and impact modeler at Purdue University, West Lafayette, "It's probably safe to put the Younger Dryas impact hypothesis back to rest for a while."

James Kennett, a marine geologist at the University of California, Santa Barbara, and a leading Younger Dryas impact advocate, says the older date for the crater is a surprise, but Kjær's team "makes a very compelling case … I don't think it's related to the Younger Dryas now." That leaves his group where it was before the discovery of Hiawatha: arguing the Younger Dryas trigger was an airburst rather than a body slamming into the ground. Kennett says the team will continue to advance its case with evidence from more than 40 sites worldwide that contain glassy spherules or platinum-rich sediments, which the group believes are indicative of an impact. "It's all alive and well and very active."

Kjær's team originally thought dating the impact would be impossible without drilling through 1 kilometer or so of ice to sample rocks in the center of the crater. The radar data, however, yielded clues to what seemed to be a young age: reflections indicating ice layers older than 11,700 years are deformed, hinting at an impact around that time.

But in 2019, the team got a chance to date the impact directly. Returning to the rivers that spill out from the foot of the glacier and deposit sediment from beneath the ice, they found fist-size rocks that had experienced melting, ostensibly from the heat of the impact. Slices of those rocks went to the lab of Gavin Kenny, a geochronologist at the Swedish Museum of Natural History, who sifted out crystals of the mineral zircon smaller than grains of sand.





Some of zircon crystals were "shocked"—inscribed with linear fracture patterns that are the hallmark of an impact. Trace amounts of radioactive uranium are present in the zircon, and its decay into lead provides an accurate way to date the samples. The impact kicked out the lead impurities in the shocked zircons, effectively resetting the uranium clock. In a study published today in Science Advances, the researchers report that in 28 of these shocked zircon crystals, the decay clock points to an age of 58 million years ago, with an uncertainty of about 1 million years. Nearly 50 grains of sand collected from the same watershed, analyzed using the decay of radioactive potassium to argon, yielded about the same age.

Given the agreement between the two dating systems, "It seems fairly rigorous to me," says Sandra Kamo, a geochronologist at the University of Toronto.

Now, the team is wondering whether the distorted ice it initially took as signs of a recent impact resulted instead from the sudden collapse of ice that bridged the ice sheets covering Greenland and Canada's Arctic archipelago during the last ice age. "Eventually they disconnected—presumably with some dynamic consequences," says Joseph MacGregor, a co-author and glaciologist at NASA's Goddard Space Flight Center.

Similarly, the sharp, well-preserved crater rim seen on radar might be a sign not of youth, but of slow erosion beneath Greenland's ice, Johnson adds. In that case the large, incised valleys detected beneath the ice elsewhere in Greenland could be much older than previously assumed, MacGregor says.

The 1.5-kilometer-wide asteroid that produced Hiawatha would have been regionally devastating, but there is no sign that the dust cloud and fires that might have followed the impact disrupted the global climate 58 million years ago. The strike would have come 3 million years before the Paleocene-Eocene Thermal Maximum (PETM), [a 100,000-year temperature spike] that some have used as an analogy for human-induced climate change.

But Sidney Hemming, a geochemist at Columbia University, says the age data are complex enough that the uncertainty might be as much as 5 million years, opening the possibility that the impact and the PETM are connected. "I'd be hard pressed to be that confident that it's not that," she says. She points out that glass spherules tied to the PETM, presumably forged and thrown up in an impact, have been [found off the coast of New Jersey]. For now, the Hiawatha team is combing through geological records for signs of disturbances 58 million years ago, Kjær says. "We're commencing that journey now."

Other impact mysteries in Greenland remain to be solved. Soon after the original Hiawatha paper came out, MacGregor identified a possible second impact crater nearby, larger and more eroded than Hiawatha. (It remains unconfirmed.) And the region is also famed as the home of fragments from a massive iron meteorite that weigh in total some 58 tons. "It is a hot spot for impact up there," Kjær says.

The study is also a good reminder that, despite all the interest in catastrophic asteroid impacts, none has yet been clearly shown to have caused a global environmental change—other than the dino killer 66 million years ago at Chicxulub, on Mexico's Yucatán Peninsula. "I love impacts more than your average scientist," Johnson says. "But when you have some piece of data that is difficult to describe or understand, impacts are usually not the answer."

Woolly mammoth tooth found by a Maine fisherman raises over $10,000 to help Ukrainian families

By Logan Sherwood, WOKQ. Published March 15, 2022.
https://wokq.com/woolly-mammoth-tooth-found-by-a-maine-fisherman-raises-over-10000-to-help-ukrainian-families/

Geologists at the University of New Hampshire identified a 12,000-year-old Woolly Mammoth tooth that was caught off the shore of Plum Island in Newburyport, Massachusetts.

The tooth was found this past December by Captain Tim Rider while he was dredging for scallops, according to NECN.

New England Fishmongers via Facebook

According to the New England Fishmongers, a Facebook group that catches and sells fish caught off the New Hampshire and Maine seacoast, the tooth has been at Captain Rider's restaurant in Kittery, Maine.

Knowing people would be interested in purchasing this piece of pre-human history, Captain Rider decided to do something incredible: donate 100% of the proceeds to humanitarian efforts in Ukraine, according to NECN.

The 11-inch, 7-pound Woolly Mammoth molar was posted on eBay for auction. In about five days, the ancient artifact was sold to the highest bidder - over $10,000.

WOW.

With the recent sale, the tooth will leave Rider's restaurant and briefly be replaced with $10,300. According to a Facebook post from New England Fishmongers, that money will go directly to the World Central Kitchen, whose current mission is serving hot meals in Ukrainian cities and feeding those refugees fleeing the country.

"I can't imagine what it is like for folks over there, so we found a charity that works with food, and our chefs know the chefs who started that," said Rider in the NECN article. "Obviously, I can't solve the world's problems as a fisherman, but I can contribute to help the people that are suffering."

Calcite Crystals and Earth's Microbial History

From Earth Science Picture of the Day, January 5, 2022.
Photographer and Summary Author: Henrik Drake
https://epod.usra.edu/blog/2022/01/calcite-crystals-and-earths-microbial-history.html

This photo (next page) shows calcite crystals taken from a deep fracture in Swedish granite that were used to study Earth's mineralogy and microorganism history. These kinds of mineral related biosignatures were used as part of a new study to look for ancient habitable conditions at deep depths. The recent article published in the PNAS Journal in November 2021 was the first study of Earth's mineral and microbiology history from a thermochronological perspective. The study describes Earth's Precambrian cratons and how habitability has persisted for not much longer than the past 1 billion years.

Related Links:

- Calcite Crystals and Microbial Activity Within the Earth's Crust
- Henrik's Linnaeus University Website

Sweden Coordinates: 56.8545, 14.8300

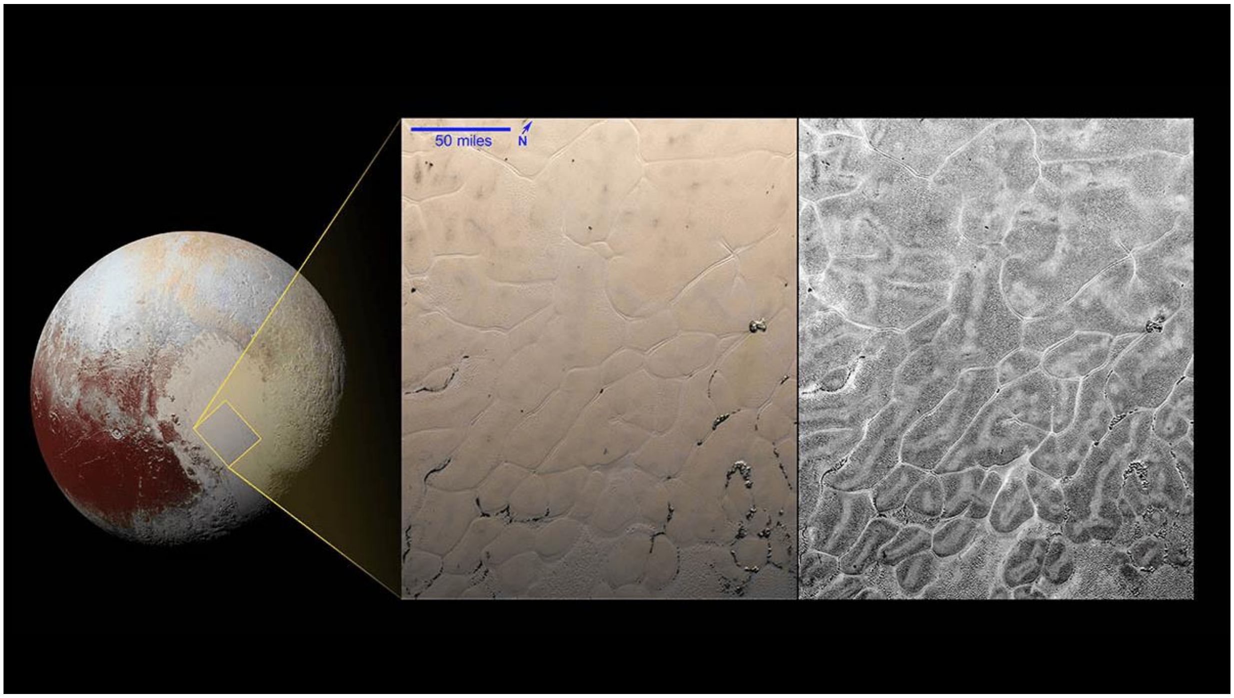
Clues to Pluto's History Lie in Its Faults

By JoAnna Wendel, Eos. Published January 31, 2022.
https://eos.org/research-spotlights/clues-to-plutos-history-lie-in-its-faults

The world first glimpsed Pluto up close when NASA's New Horizons spacecraft whizzed by it in July 2015. One of the most exciting discoveries scientists made based on New Horizons data was that Pluto, despite orbiting at more than 5 billion kilometers from the Sun, may contain a liquid water ocean under its water ice surface.

This liquid water ocean has huge implications for how Pluto formed and retained enough heat to melt all that ice. In the years since the New Horizons flyby, two general formation hypotheses have emerged. The first starts with a "cold" Pluto, which involves Pluto forming over millions of years by the slow accretion of cold objects. This version of Pluto eventually would have coalesced enough material that radiative heating from the inside would melt the subsurface ocean. The other hypothesis involves a "warm" or "hot" Pluto, in which Pluto formed over a shorter time period in violent collisions that heated its interior, formed the ocean, and eventually cooled the planet into the majority ice ball we know today.

One clue that can help scientists understand Pluto's formation is the thickness of its outer icy crust as well as the geological features that make up its surface. In a new study, McGovern et al. focused on Sputnik Planitia, a vast basin that makes up the western portion of Pluto's bright "heart." Sputnik Planitia formed after an impact and eventually filled in with nitrogen ice. Heat driven by convection formed cell-shaped structures in the nitrogen ice, which has captivated scientists. This basin measures 1,500 × 900 kilometers and features a ridge that rises 1 kilometer above the surrounding landscape. Fractures and cracks radiate from the basin like spokes on a bicycle wheel, the authors write.



Scientists studied Pluto's "heart" to better understand how thick its lithosphere is and thus how it formed. Credit: NASA/JHUAPL/SwRI

These fractures and cracks are key to understanding how the nitrogen ice load affects Pluto's surface, which would depend on how thick that surface is. The nitrogen ice pushes down on Pluto's outer layer, or lithosphere. Depending on the thickness of the lithosphere when the nitrogen ice first flowed into the basin, different patterns of cracks would form.

The researchers ran computer models testing various starting conditions for Sputnik Planitia to find the lithosphere thickness that best fits today's geological features. They found that the lithosphere is probably 45–70 kilometers thick and that the initial depth of the impact crater that forms Sputnik Planitia was probably shallow, no more than 3 kilometers deep.

McGovern and colleagues note that their finding is consistent with the "hot" theory of Pluto formation that posits Pluto formed via violent impacts and started out with more liquid, much of which froze over the following millennia. They also note that the stress on the outer shell created by the nitrogen ice is probably facilitating some cryovolcanism at several sites surrounding Sputnik Planitia. (*Journal of Geophysical Research: Planets*, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JE006964, 2021).

Citation: Wendel, J. (2022), Clues to Pluto's history lie in its faults, Eos, 103, https://doi.org/10.1029/2022EO220059. Published on 31 January 2022.

NHGS Annual Geologic Mapping Workshop 2022

The 2022 New Hampshire Geological Survey (NHGS) Mapping Workshop will be on Friday, April 1, 2022 from 8:30 AM to 1:00 PM via Microsoft Teams. Registration is required; please email Rebecca LeCain, Rebecca.M.LeCain@des.nh.gov, to register. NHGS will issue 4.5 CEUs for Professional Geologists who join for the entire length of the workshop. The agenda is below:

8:30 - 8:50: *Welcome and New Hampshire Geological Survey Update*
Shane Csiki, State Geologist and Director

8:50 - 9:05: *An update on USGS FEDMAP activities in the Northeast and summary of the bedrock geology of the 7.5-minute Woodstock quadrangle*
Greg Walsh, U.S. Geological Survey

9:05 – 9:20: *Mapping New England's Top of Rock*
Mary DiGiacomo-Cohen, U.S. Geological Survey

9:20 - 9:50: *Direct dating of critical minerals: U-Pb geochronology studies of cassiterite from western Maine pegmatites and beyond*
Christopher Holm-Denoma, U.S. Geological Survey

9:50 - 10:20: *Introducing the Maine Mineral and Gem Museum*
Myles Felch, Maine Mineral and Gem Museum

10:20 - 10:30: *NHGS Publications project update*
Rebecca LeCain, Outreach Coordinator, New Hampshire Geological Survey

10:30 - 10:50: Break

10:50 – 11:10: *Improving surficial geologic mapping using ground-penetrating radar: Some examples from the Winchendon Quadrangle in NH and the McMurdo Dry Valleys in Antarctica*
Mike Prentice, Geoscy, LLC

11:10 - 11:30: *Using LiDAR to map the regional pattern of ice flow across New Hampshire*
Robert Newton, Smith College

11:30 - 11:50: *Update on Indian Stream Area bedrock geologic mapping*
David Converse, Wallace Bothner, Christian Jahrling

11:50 - 12:10: *Highlights of the bedrock geology in the Berlin, NH 7.5' Quadrangle, NH*
J. Dykstra Eusden, Bates College

12:10 - 12:30: *Surficial Geology of the Berlin Quadrangle, Northern New Hampshire*
Woody Thompson

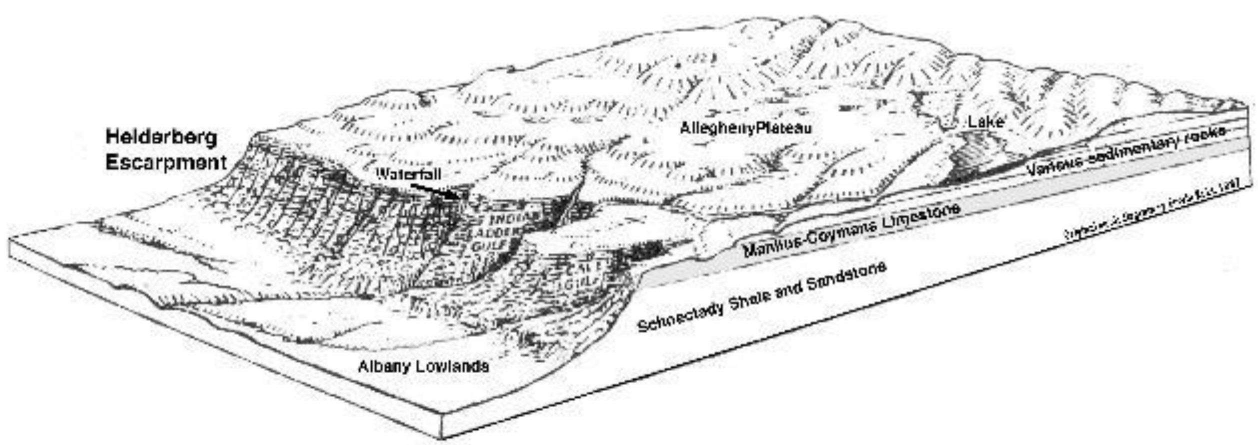
12:30 - 12:50: *Progress report on the Moosilauke Septum*
Peter Thompson (NHGS Contract Mapper) and Justin Strauss (Dartmouth College)

12:50 - 1:00: *Closing Remarks*
Shane Csiki, State Geologist and Director

New York's Helderberg Escarpment Waterfalls

From Earth Science Picture of the Day, February 22, 2022.
Photographer and Summary Author: Thomas McGuire
https://epod.usra.edu/blog/2022/02/new-yorks-helderberg-escarpment-waterfalls.html

The Helderberg Escarpment of New York State is located where sedimentary rock layers dip about 1° to the south, but the land surface dips to the north. This has created a broad, shallow cuesta that ends at a steep north-facing slope more than 200 meters (700 ft) high. See diagram.



Small north-flowing streams fall off the Manlius-Coymans Limestone edge of the Allegheny Plateau at John Boyd Thatcher State Park, 15 miles (24 km) southwest of Albany, New York. Rock formations are often named for the rock type (here, it's limestone), and the geographic location where the rock unit is characteristically exposed. A walking path leads beneath both waterfalls. In the winter, icicles formed from the spray of the falls drape over the abrupt cliff. Photo taken on June 24, 2021.

Photo details: SONY DSC-HX80 camera; 4.1mm; f3.5; 1/320 second exposure.

Helderberg Escarpment Waterfalls, New York Coordinates: 42.578015, -74.001971

Related Links

- Spelunking in Onesquethaw Cave
- Niagara Escarpment
- Author’s Science Books

Student Links

- Geology of New York: A Simplified Account (Isachsen et al)

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APRIL MEETING ANNOUNCEMENT

TOPIC: The Deglaciation of New England and Its Relation to Climate: The Fusion of Varves, Radiocarbon Ages, Paleomagnetism, and Critters in Lakes.

SPEAKER: Jack Ridge, Tufts University

DATE/TIME: 7PM, April 22, 2022

Please send Sharon Lewandowski an email to request a Zoom invite for the January meeting: sharon.lewandowski@des.nh.gov.

DATES TO REMEMBER

Please check online or the contact info below to confirm the status of these events. The list is current as of publication date but may change.

March 31, 2022 – **Maine Sustainability & Water Conference**, Augusta Civics Center https://umaine.edu/mitchellcenter/2022-maine-sustainability-water-conference/

April 1, 2022 – **NHGS Annual Geologic Mapping Workshop** – via Microsoft Teams; 8:30 AM to 1:00 PM. Please email Rebecca LeCain, Rebecca.M.LeCain@des.nh.gov, to register. See page 29 for an agenda.

April 21, 2022 – **GSNH dinner meeting** – See section above.

April 23-24, 2022 – **Southeastern New Hampshire Mineral Club 17th Annual 2022 Rock, Gem and Mineral Show**, Dover Elks Lodge #184, 282 Durham Road, Dover, NH. https://www.senhmc.org/show

April 30-May 1, 2022 – **New England Gem & Mineral Show 2022**. Coolidge Hall at the Topsfield Fairground. https://10times.com/gem-mineral-topsfield

June 3-5, 2022 – **Friends of the Pleistocene Summer Field Trip**.

June 16, 2022 – **GSNH Board of Directors Meeting** in Hopkinton. Contact a GSNH board member for details.

June 25-26, 2022 – **Gilsum Rock Swap 2022**. Gilsum Elementary School and Community Center, 640 Route 10, Gilsum, NH. https://gilsum.org/rockswap/

October 13, 2022 – **GSNH dinner meeting** – Nathaniel Kitchel will give a presentation on the Younger Dryas; this will be the first post-pandemic in person dinner meeting. Watch for details in the next newsletter.

Looking for some continuing ed credits? Some webinar series are below:

- clu-in.org compiles webinars of interest to EPA and the environmental community here: https://clu-in.org/training/#upcoming
- The geoscience online learning initiative (GOLI) has several webinars and short courses: https://www.americangeosciences.org/workforce/goli

MEMBERSHIP & RENEWAL APPLICATION

Geological Society of New Hampshire

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__ Events Committee

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__ Other:

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______ Student Member (Annual Dues $10.00)…Please complete **Education** section above.

Make checks payable to **"Geological Society of New Hampshire."** Note that GSNH dues are not deductible as a charitable contribution, but may be deductible as a business expense. Please return this completed application form with any necessary corrections and a check for the appropriate dues to the GSNH at the address above. The Society's membership year runs from January 1 to December 31.

Signature: ______________________________ Date: ____________________