



# Granite State Geologist

The Newsletter of the Geological Society of New Hampshire,  
Winter Edition – December 2017 – Issue No. 99

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## In this issue:

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- Legislative update -- new naphthalene standards coming?
- Diamonds don't come from dinosaurs!
- [What is your Board doing?](#)
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- Meteorite identification – For the next time someone asks
- [Upcoming Events](#) and Much More!

## MESSAGE FROM THE PRESIDENT

Well I know you're all busy, so I won't bore you (too much) with my own to-do litany. One thing that makes Christmas preparations fun are all those presents you get for yourself while out shopping for family and friends. I know there are some in my heap of presents to wrap – a couple new shirts and new vacuum cleaner attachments I never wanted to make a special trip to get. They're always just what I wanted. I've also made a point of stopping more to smell the winter berry this season. (They are the closest thing to roses outside now.) It is a season of joy, so a walk in the snow and a cup of eggnog or hot cocoa with some marshmallow fluff can restore the holiday spirit.

NEIGC in Bethel, Maine this fall was a lot of fun. My dog Jack and I tented out three nippy nights and I was glad for a new propane heater I'd bought. I crossed the campground's new suspension bridge over the Androscoggin to a trail around the perimeter of an island. The new mineral museum in Bethel had great examples of local minerals and meteorites, not the least of which were the boulders of local rocks and minerals on the front terrace. I met a number of fun people at the banquet, which had a variety of delicious choices -- Jack enjoyed the roast beef, too. I got to hike around some of my old camping and fishing grounds up by Newry and Riley Township, and there were some great field trips, too! We looked at the Ellis River geomorphology, Screw Auger Falls, and the mafic dikes from the Bumpus pegmatite Mine south of Bethel over to the Songo and Sebago Plutons in Windham. The Bumpus Mine was a real treat because my grandfather knew the family and took his Scout troop there in the middle of the last century, bringing home chunks of aquamarine and rose quartz that he later gave to me and that I still have.



The end of the year is Society's membership renewal time. Send in your dues or renew at the January 11 dinner meeting at

Makris. Joshua Keeley will be presenting on the Snowball Earth hypothesis that the world was covered with ice from pole to pole. The Board has begun planning the summer field trip to look at some Pre-Cambrian rocks, so be sure to support the Society's work with your membership. And maybe your time. Board meetings coming up in March and June will be great opportunities to see how the Society works and consider whether you would make a good candidate at the October meetings biannual elections for officers. We'll be developing a slate in the coming months. See any Board member to find out more.

It's been a great year and we have a lot to be thankful for and lot to look forward to. Merry Christmas and Happy Holidays to one and all, and I'll see you next year.

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A drone captured this image of lava as it flows from the Kilauea volcano in Hawai'i.

<https://www.nationalgeographic.com/photography/proof/2017/12/lava-kilauea-volcano-hawaii-gallery/>

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### **WHAT IS YOUR BOARD DOING? Submitted by Wayne Ives**

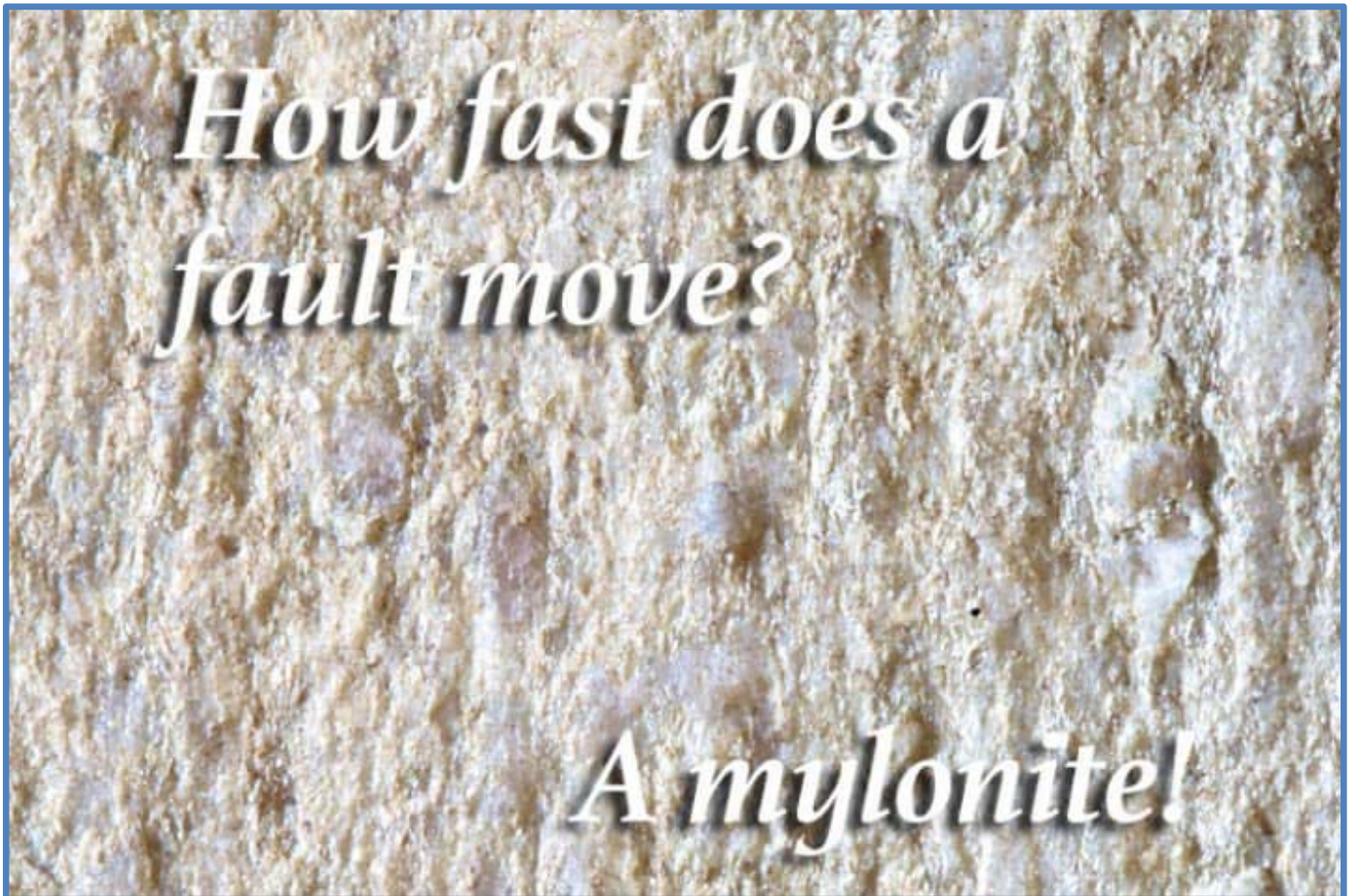
We made some headway on the summer field trip plan – Tom Fargo will be coordinating with MA Geological Society and others he knows to look into the pre-C rocks north of Boston. We looked at the Society's draft calendar of annual to-do list items. We are developing lists of public-access geology sites that will become subjects of the on-line geology sites map. We are going to look into digitizing the Hitchcock volumes. Abby plans to get the back newsletters publications on the web site, and in the future we'll be posting selected, captioned photos of Society field trips along with the field guides. We discussed the policy for managing cancelation of reservations and decided that people need to find their own replacements if they cannot attend at the last minute.

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**GSNH TEE SHIRTS LOOK GOOD ON YOU!**

Ask Tom Fargo about buying one at the next dinner meeting!

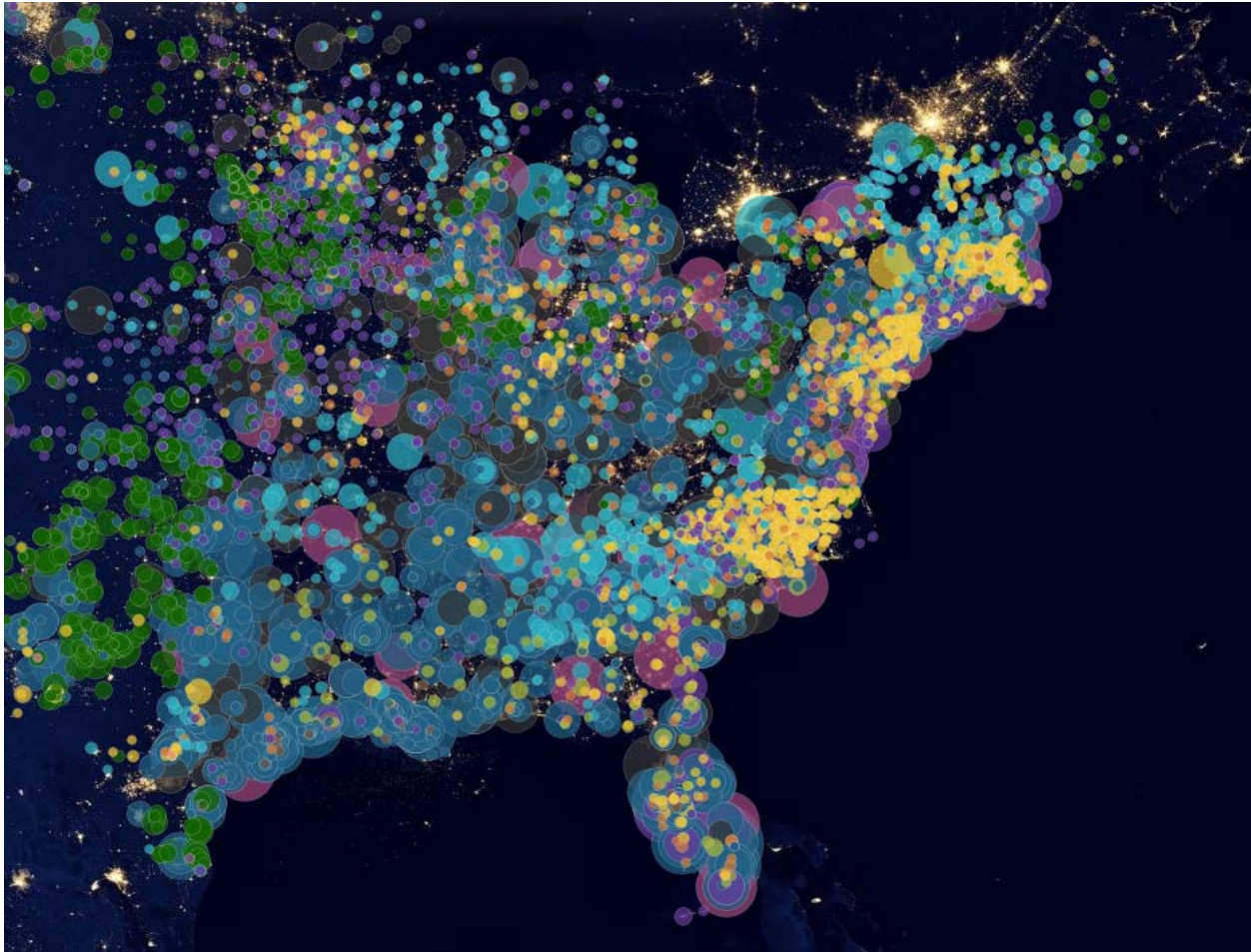
Still only \$18.



## MAPPED: HOW THE US GENERATES ELECTRICITY

The US electricity system is often described as the world's largest machine. It is also incredibly diverse, reflecting the policy preferences, needs and available natural resources of each state.

Carbon Brief has plotted the nation's power stations in an interactive map to show how and where the US generates electricity. Supplying electricity to a nation's homes, business and industry is an almost uniquely challenging enterprise. For now, electrical energy is either expensive or inconvenient to store, meaning supply and demand must be balanced in real time. It is also easier to generate power close to home than to transport it over long distances.



The way electricity is generated fundamentally depends on the fuels and technologies available. The march of progress means this mix is changing – but natural resources and geographies are fixed. Moreover, US states have broad powers to influence the electricity systems within their borders.

Putting the US electricity system on a map offers visual confirmation of how important these factors are. Why is solar so prevalent in North Carolina, for example? Or coal in West Virginia?

A few key messages can be gleaned from the map and associated data interactives:

- The US electricity system has been changing rapidly over the past decade.
- This reflects not only federal policy, but also technologies, geographies, markets and state mandates.
- The average US coal plant is 40 years old and runs half the time. Some 15% are at least 50 years old, against an average retirement age of 52.
- Planned new power plants are almost exclusively gas, wind or solar.

You can use Carbon Brief's interactive map, above, to view all the power plants in the US and their relative electricity generating capacities, which are proportional to the size of the bubbles. The dynamic chart in the sidebar summarizes the makeup of the capacity mix.

There's a lot more at <https://www.carbonbrief.org/mapped-how-the-us-generates-electricity>.

## PROPOSED RULEMAKING CHANGING THE WATER QUALITY STANDARDS FOR NAPHTHALENE AND OTHER CONTAMINANTS AT PETROLEUM REMEDIATION SITES

The Geological Society of NH received the following notice of proposed rulemaking that will impact most petroleum remediation sites by raising the water quality standard for naphthalene. Naphthalene is a common recalcitrant contaminant associated with petroleum releases. The proposed rulemaking raises the AGQS from 20 ug/L to 100 ug/L, which may allow earlier closure of some sites.

This rulemaking may also impact hazardous waste site clean-up and wastewater treatment facilities (WWTFs) that discharge to groundwater by lowering the standard for 1,4-dioxane:

NHDES is proposing to amend the Ambient Groundwater Quality Standards (AGQS) in Env-Or 603.03(c), Table 600-1, as noted below. The Initial Proposal and Rulemaking Notice (including the Fiscal Impact Statement) for the rules are available at <https://www.des.nh.gov/organization/commissioner/legal/rulemaking/index.htm#poil>.

The proposed amendments would (1) increase the AGQS for boron, 2-chlorophenol, ethylene glycol, and naphthalene; (2) decrease the AGQS for 2,4-dichlorophenol, 1,4-dioxane, metribuzin (sencor 75DF), and phenol; (3) add an AGQS for non-radioactive strontium; and (4) correct the name of the compound with the acronym PFOS.

The public hearing is scheduled for Thursday, January 25, 2018 at 1:00 PM in Room 208C of the NHDES Offices at 29 Hazen Drive, Concord, NH. (For your information, this is the same date, time, and place as the hearing for amendments to Env-Wq 402 to address the decrease in the AGQS for 1,4-dioxane). The deadline for submission of written comments is 4:00 p.m. on Friday, February 2, 2018. Comments or questions should be directed to the undersigned at the phone or fax number or e-mail address noted below.

Sam Quattrini, P.G.  
Hazardous Waste Remediation Bureau  
NH Department of Environmental Services  
29 Hazen Drive, Concord, NH 03302-0095  
Phone: (603) 271-2890 – Fax: (603) 271-2181

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## FOLLOW UP ON THE GIANT MAGMA BLOB!

In our March 2017 edition, a 01/26/17 article by Ryan Lessard titled **BABY VOLCANO IN NH?** at <http://www.hippopress.com/read-article/baby-volcano-in-nh>, stated that New research suggests state sits atop upwelling of magma. The article discussed the conclusions of Bill Menke, a geologist with the University of Columbia's Lamont-Doherty Earth Observatory, who had collected seismic data and other evidence in NH, Virginia and Louisiana for magma upwellings that he believes are the result of the flow of the upper mantle beneath our continent forcing up the magma.

This December the magma upwelling story was on NHPR who cited the story *Seismic evidence for a recently formed mantle upwelling beneath New England* by Vadim Levin and others that came out in the November 2017 issue of GEOLOGY (Geology (217) 46 (1):87-90). (<https://pubs.geoscienceworld.org/gsa/geology/article-abstract/522870/seismic-evidence-for-a-recently-formed-mantle?redirectedFrom=fulltext>).

The abstract says: Lateral changes in seismic velocity 100–300 km beneath the Appalachian orogen (eastern North America) do not follow the pattern of its major terranes, suggesting that more recent, and possibly ongoing, geodynamic processes are taking place in the sub-lithospheric mantle. One prominent, sharply delineated, seismically slow feature underlying parts of New England (USA) likely reflects a volume of significantly elevated temperatures in the asthenosphere. Using numerous new observations of splitting in seismic shear waves from distant earthquakes, we show that this upper mantle volume also lacks the systematic directional dependence (anisotropy) of seismic wave speed that is ubiquitous beneath most of northeastern North America. This regional anisotropic fabric, which likely forms as the asthenosphere is sheared by North American plate motion, appears to be locally erased beneath central New England, with changes in its strength occurring over distances on the order of 50 km. Highly localized variation in the strength of seismic anisotropy in a region of strongly elevated

asthenospheric temperature suggests the presence of a narrow thermal upwelling in the upper mantle beneath New England. The lack of obvious surface expressions (volcanism or uplift) and the small lateral scale of the hypothesized upwelling suggest a geologically recent phenomenon.

The NHPR story ended with lead author Vadim Levin, geophysicist and professor at Rutgers University. He concluded the interview by saying, "...we found something unexpected, which was extremely pleasant, especially given that three out of the five authors are undergraduate students. It was their work, and we helped them frame it. So professors got to be first authors because we wrote it, but the students did the work.

Science Daily also described the work November 30, 2017 at <https://www.sciencedaily.com/releases/2017/11/171130094142.htm>. Drawing from Rutgers Today (<https://news.rutgers.edu/research-news/mass-warm-rock-rising-beneath-new-england-rutgers-study-suggests/20171121#.WkO0kuSWzRZ>) they quoted Professor Levin as saying, "'The Atlantic margin of North America did not experience intense geologic activity for nearly 200 million years," Levin said. "It is now a so-called 'passive margin' -- a region where slow loss of heat within the Earth and erosion by wind and water on the surface are the primary change agents. So we did not expect to find abrupt changes in physical properties beneath this region, and the likely explanation points to a much more dynamic regime underneath this old, geologically quiet area."

Myself, I've sometimes wondered whether the expansion of the Atlantic Ocean would eventually result in a subduction zone along the continental margin once the oceanic crust became too extended and weak to maintain the westward push. Anybody taking bets on another island arc forming?



## **BITS FROM TWO NEIGC FIELD TRIPS** by Tina Cotton

Another NEIGC has come and gone. However, the guidebook for field trips is online at <http://scarab.bates.edu/neigc2017/> thanks to the efforts of Dyk Eusden and Beverly Johnson from Bates College. Dwight Bradley, who was the speaker at the April GSNH dinner meeting, was a co-leader for a pegmatite trip and graciously hosted a parking spot for the 92 participants on Dyk's east-west transect trip across northern NH. Dwight's farm is adjacent to the Billings Lodge where Marland and Katherine Billings stayed while mapping the Presidentials.



**For a trip intended to accommodate a couple of dozen people, how would you like 92 swarming at your house on the Lost Nation pluton? Photo by Henry N. Berry**

Bethel, Maine has a new gem and mineral museum and gift shop that will have an official opening in 2018. A state-of-the-art lab for analyzing samples is in the basement. The museum specializes in gems from local pegmatites, as well as a small meteorite collection including some moon rocks, and an outdoor display of rocks found in various Maine localities. Some gems were from the Havey and Mount Mica pegmatites that are privately owned and presently being excavated on a small scale.

**BITS FROM TWO NEIGC FIELD TRIPS** (continued)



**Lunch stop along Cold Brook where the Moose River fault is exposed showing Ammonoosuc Volcanics and mylonite. Photo by Tina Cotton**

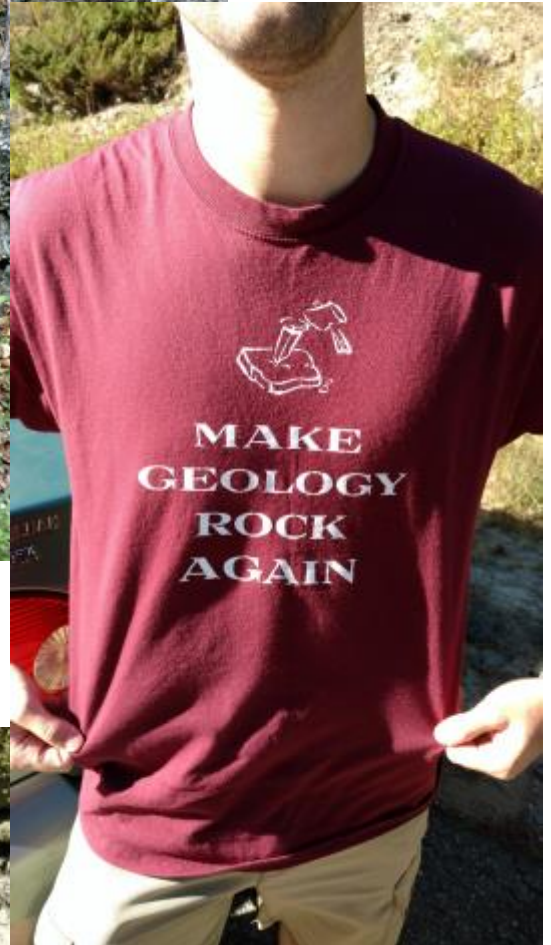


**This photo of tourmaline at the Mount Mica site shows the gradation of colors. Note the quarter for scale. Photo by Tina Cotton**



**MORE NEIGC PHOTOS** (continued)

From top, clockwise: 1) UMaine- Farmington Prof. Dave Gibson illustrates the direction of strike of a mafic dike at the Bumpus Mine, Albany, Maine during the last day of the NEIGC. 2) UM-F Geology Club fundraiser tee-shirt. 3) Examining a mafic dike in a roadside cut. Photos by Wayne Ives.



## LEGISLATIVE COMMITTEE REPORT – December 2017 by Thomas Fargo

Preparations for the 2018 session of NH General Court (State Legislature) are underway. Members of the NH House are required to submit Legislative Service Requests (LSRs or proposed bills) prior to January 4, 2018. The NH Senate rules allow bills to be introduced through February 2018.

The Legislative Committee has identified nineteen bills of interest based on keyword searches. The texts for approximately half of these LSRs are currently available. For the remainder, only proposed bill titles are available on the General Court website. Here's a synopsis of issues addressed in the proposed legislation, so far:

- Eight bills are related to water contamination by perfluorochemicals (PFCs), also known as the emerging contaminants PFOA and PFOS. Several of these LSRs are related to establishing maximum permissible concentrations of PCFs in drinking and surface water; along with monitoring and reporting requirements.
- Two proposed bills would establish water quality standards at lower concentrations for Methyl tert Butyl Ether (MtBE) and arsenic in drinking water.
- It is interesting to note that two of the proposed bills that seek to establish more stringent drinking water quality standards are currently identified as having a fiscal note. This establishes the basis for the Legislature to evaluate the increased cost of such regulations. Previous attempts to make drinking water standards more stringent have failed due to need for water providers to use more advanced treatment technology, and the increased cost to implement same.
- Three LRSs are related to professional registration and regulation in NH. These proposed bills currently appear to seek to strengthen the current system of professional geologist and engineer regulation in NH; rather than eliminate it as in past legislative sessions.
- Two LSRs attempt to repeal or amend recent laws. One would re-establish the pollution prevention program within NHDES. The other LSR would amend RSA 41:11-d to not allow municipalities to restrict the use of water drawn from private wells.

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## UNH RESEARCHERS: MORE WARMING LEADS TO MORE RELEASE OF CARBON

Nov 22, 2017 - After 26 years, the world's longest-running experiment to discover how warming temperatures affect forest soils has revealed a surprising, cyclical response: Soil warming stimulates periods of abundant carbon release from the soil to the atmosphere alternating with periods of no detectable loss in soil carbon stores. Overall, the results indicate that in a warming world, a self-reinforcing and perhaps uncontrollable carbon feedback will occur between the carbon flux of forest soils, caused by the natural respiration of soil microbes and plant roots, and the climate system, adding to the build-up of atmospheric carbon dioxide caused by burning fossil fuels and accelerating global warming. The study appears in the Oct. 6 issue of *Science*.

Over the course of the experiment, the researchers observed fluctuations in the rate of soil carbon emission from the heated plots, indicating cycles in the capacity of soil microbes to degrade organic matter and release carbon. Phase I (1991 to 2000) was a period of substantial soil carbon loss that was rapid at first, then slowed to near zero. In Phase II (2001-2007), there was no difference in carbon emissions between the warmed and the control plots. In Phase III (2008-2013), carbon release from heated plots again exceeded that from control plots. This coincided with a continued shift in the soil microbial community. Microbes that can degrade more recalcitrant soil organic matter, such as lignin, became more dominant, as shown by genomic and extracellular enzyme analyses. In Phase IV (2014 to current), carbon emissions from the heated plots have again dropped, suggesting that another reorganization of the soil microbial community could be underway. If the cyclical pattern continues, Phase IV will eventually transition to another phase of higher carbon loss from the heated plots. Read more at: <http://www.fosters.com/news/20171122/unh-researchers-more-warming-leads-to-more-release-of-carbon>

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## AN ICEBERG THE SIZE OF DELAWARE JUST BROKE IN ANTARCTICA

By Isaac Himmelman

Jul 12, 2017 <http://www.vocativ.com/science/index.html>

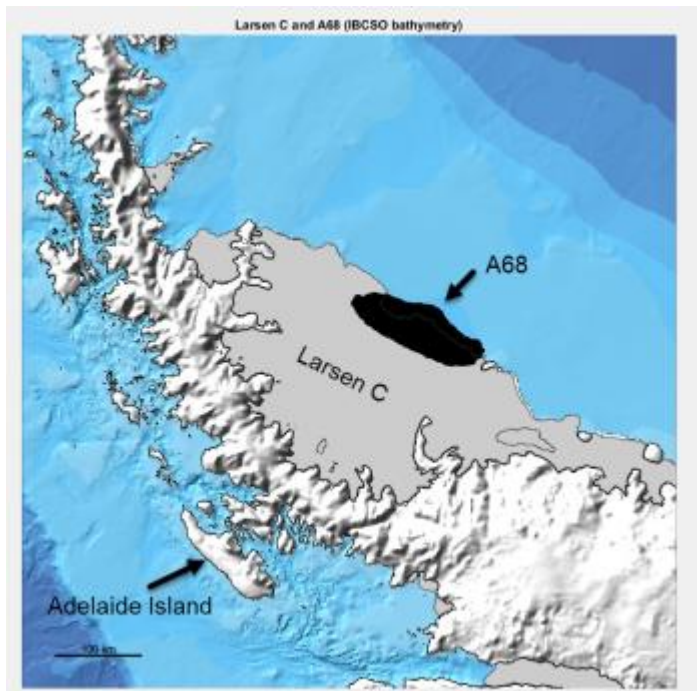


Photo from <https://mallemaroking.org/iceberg-a68-is-big/>

One of the largest icebergs ever recorded broke off from an ice shelf in Antarctica, British scientists announced Wednesday. Known as A68, the iceberg weighs 1 trillion tons and is twice of the volume of Lake Erie. Even though scientists first spotted the 120-mile crack in 2011, an ever-lengthening crack in the ice shelf garnered worldwide attention in the last few months. According to Project MIDAS, which has been monitoring the shelf, A68 broke off from the Larsen C ice shelf between Monday and Wednesday. While the new iceberg won't change sea levels if it melts, it could pose an immediate threat to boats sailing on the South Atlantic.

[And the following posted by Catrin Newman Friday 6 January 2017 at <http://www.swansea.ac.uk/media-centre/latest-research/giantantarcticicebergsettobreakawayswswanseaearchers.php>.] Professor Luckman added that this is a geographical and not a climate event. Although it is believed that climate warming has brought forward the likely

separation of the iceberg. According to estimates, if all the ice that the Larsen C shelf currently holds back entered the sea, global waters would rise by 10cm. "The eventual consequences might be the ice shelf collapsing in years to decades," said Professor Luckman. "Even the sea level contribution of this area is not on anybody's radar; it's just a big geographical event that will change the landscape there." However, the researchers say they have no direct evidence to support this.



[Editor: I **KNOW** –right!?! Apparently, it's also tough finding identifiable pictures of tuff. But they weren't going to say, "Studying volcanoes can be pahoehoe." That's not funny. But, clearly a non-geologist chose this picture to go with this caption.]

**FIREBALL LIGHTS UP NIGHT SKY OVER NEW ENGLAND** By JASON SCHREIBER Union Leader Correspondent December 26, 2017 8:13PM <http://www.unionleader.com/Fireball-lights-up-night-sky-over-New-England>



The webcam at Mount Agamenticus in southern Maine captured an image of a fireball as it streaked across the sky just before 6 p.m. Tuesday. ([www.agamenticus.org](http://www.agamenticus.org))

People in New Hampshire and other parts of New England and the Northeast were treated to an unexpected light show early Tuesday night when a bright fireball that appeared to be a meteor shot across the night sky. Many reported seeing the fireball just before 6 p.m. Greg Kretschmar, host of WHEB's "Greg & the Morning Buzz" radio show, was one of those lucky enough to catch the sight as he was driving north on Route 16 in Newington. Kretschmar said it streaked along the side of him from south to north and he saw what appeared to be "sparks" in the tail with a hint of green. He said the fireball lasted about four or five seconds.

Jen Wagaman of Milford said she was letting her dogs go outside when she saw the fireball. "I was facing north and it started right above my head and burned very bright white all the way in front of me to the wood line/horizon. Thought it was a firework or flare at first. It was very bright," she wrote on Twitter. Wagaman said it was about 10 times brighter and bigger than any meteor she's seen. "I've only ever seen them when staring up at the sky, and usually just short-lived streaks of light. With this I wasn't even looking up, I was looking straight ahead and this was so big it made me look up," she said.

An image of the fireball was captured by a webcam at the Mount Agamenticus Conservation Region in southern Maine. The fireball was also seen in Maine, Massachusetts and as far away as Montreal, Canada. The National Weather Service in Gray, Maine, tweeted that anyone who saw the fireball should report it to the American Meteor Society through its website, [www.amsmeteors.org](http://www.amsmeteors.org). The site has an interactive form where sightings can be reported. The reports are important because they alert the AMS of "potentially scientifically significant events."

## SOLAR SYSTEM'S FIRST INTERSTELLAR VISITOR DAZZLES SCIENTISTS

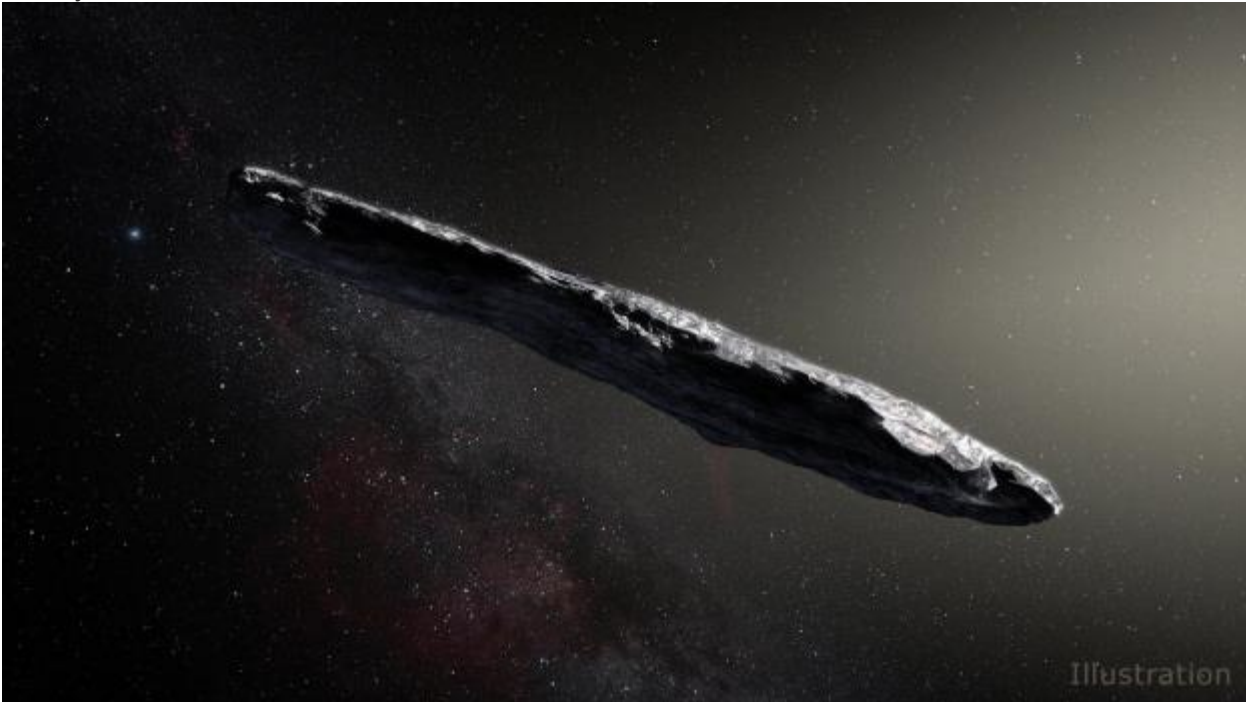
NASA JPL (@NASAJPL) tweeted on Nov 20, 2017

<https://www.jpl.nasa.gov/news/news.php?feature=7006>

Astronomers recently scrambled to observe an intriguing asteroid that zipped through the solar system on a steep trajectory from interstellar space-the first confirmed object from another star.

Now, new data reveal the interstellar interloper to be a rocky, cigar-shaped object with a somewhat reddish hue. The asteroid, named 'Oumuamua by its discoverers, is up to one-quarter mile (400 meters) long and highly-elongated-perhaps 10 times as long as it is wide. That aspect ratio is greater than that of any asteroid or comet observed in our solar system to date. While its elongated shape is quite surprising, and unlike asteroids seen in our solar system, it may provide new clues into how other solar systems formed.

The observations and analyses were funded in part by NASA and appear in the Nov. 20 issue of the journal Nature. They suggest this unusual object had been wandering through the Milky Way, unattached to any star system, for hundreds of millions of years before its chance encounter with our star system.



**Artist's concept of interstellar asteroid 1I/2017 U1 ('Oumuamua) as it passed through the solar system after its discovery in October 2017. Image credit: European Southern Observatory / M. Kornmesser**

"For decades we've theorized that such interstellar objects are out there, and now - for the first time - we have direct evidence they exist," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate in Washington. "This history-making discovery is opening a new window to study formation of solar systems beyond our own."

Immediately after its discovery, telescopes around the world, including ESO's Very Large Telescope in Chile, were called into action to measure the object's orbit, brightness and color. Urgency for viewing from ground-based telescopes was vital to get the best data.

Combining the images from the FORS instrument on the ESO telescope using four different filters with those of other large telescopes, a team of astronomers led by Karen Meech of the Institute for Astronomy in Hawaii found that 'Oumuamua varies in brightness by a factor of 10 as it spins on its axis every 7.3 hours. No known asteroid or comet from our solar system varies so widely in brightness, with such a large ratio between length and width. The most elongated objects we have seen to date are no more than three times longer than they are wide.

"This unusually big variation in brightness means that the object is highly elongated: about ten times as long as it is wide, with a complex, convoluted shape," said Meech. "We also found that it had a

reddish color, similar to objects in the outer solar system, and confirmed that it is completely inert, without the faintest hint of dust around it."

These properties suggest that 'Oumuamua is dense, composed of rock and possibly metals, has no water or ice, and that its surface was reddened due to the effects of irradiation from cosmic rays over hundreds of millions of years.

A few large ground-based telescopes continue to track the asteroid, though it's rapidly fading as it recedes from our planet. Two of NASA's space telescopes (Hubble and Spitzer) are tracking the object the week of Nov. 20. As of Nov. 20, 'Oumuamua is travelling about 85,700 miles per hour (38.3 kilometers per second) relative to the Sun. Its location is approximately 124 million miles (200 million kilometers) from Earth -- the distance between Mars and Jupiter - though its outbound path is about 20 degrees above the plane of planets that orbit the Sun. The object passed Mars's orbit around Nov. 1 and will pass Jupiter's orbit in May of 2018. It will travel beyond Saturn's orbit in January 2019; as it leaves our solar system, 'Oumuamua will head for the constellation Pegasus.

Observations from large ground-based telescopes will continue until the object becomes too faint to be detected, sometime after mid-December. NASA's Center for Near-Earth Object Studies (CNEOS) continues to take all available tracking measurements to refine the trajectory of 11/2017 U1 as it exits our solar system.

This remarkable object was discovered Oct. 19 by the University of Hawaii's Pan-STARRS1 telescope, funded by NASA's Near-Earth Object Observations (NEOO) Program, which finds and tracks asteroids and comets in Earth's neighborhood. NASA Planetary Defense Officer Lindley Johnson said, "We are fortunate that our sky survey telescope was looking in the right place at the right time to capture this historic moment. This serendipitous discovery is bonus science enabled by NASA's efforts to find, track and characterize near-Earth objects that could potentially pose a threat to our planet."

Preliminary orbital calculations suggest that the object came from the approximate direction of the bright star Vega, in the northern constellation of Lyra. However, it took so long for the interstellar object to make the journey - even at the speed of about 59,000 miles per hour (26.4 kilometers per second) -- that Vega was not near that position when the asteroid was there about 300,000 years ago.

While originally classified as a comet, observations from ESO and elsewhere revealed no signs of cometary activity after it slingshotted past the Sun on Sept. 9 at a blistering speed of 196,000 miles per hour (87.3 kilometers per second).

The object has since been reclassified as interstellar asteroid 11/2017 U1 by the International Astronomical Union (IAU), which is responsible for granting official names to bodies in the solar system and beyond. In addition to the technical name, the Pan-STARRS team dubbed it 'Oumuamua (pronounced oh MOO-uh MOO-uh), which is Hawaiian for "a messenger from afar arriving first."

Astronomers estimate that an interstellar asteroid similar to 'Oumuamua passes through the inner solar system about once per year, but they are faint and hard to spot and have been missed until now. It is only recently that survey telescopes, such as Pan-STARRS, are powerful enough to have a chance to discover them.

"What a fascinating discovery this is!" said Paul Chodas, manager of the Center for Near-Earth Object Studies at NASA's Jet Propulsion Laboratory, Pasadena, California. "It's a strange visitor from a faraway star system, shaped like nothing we've ever seen in our own solar system neighborhood."

For more on NASA's Planetary Defense Coordination Office:

<https://www.nasa.gov/planetarydefense>

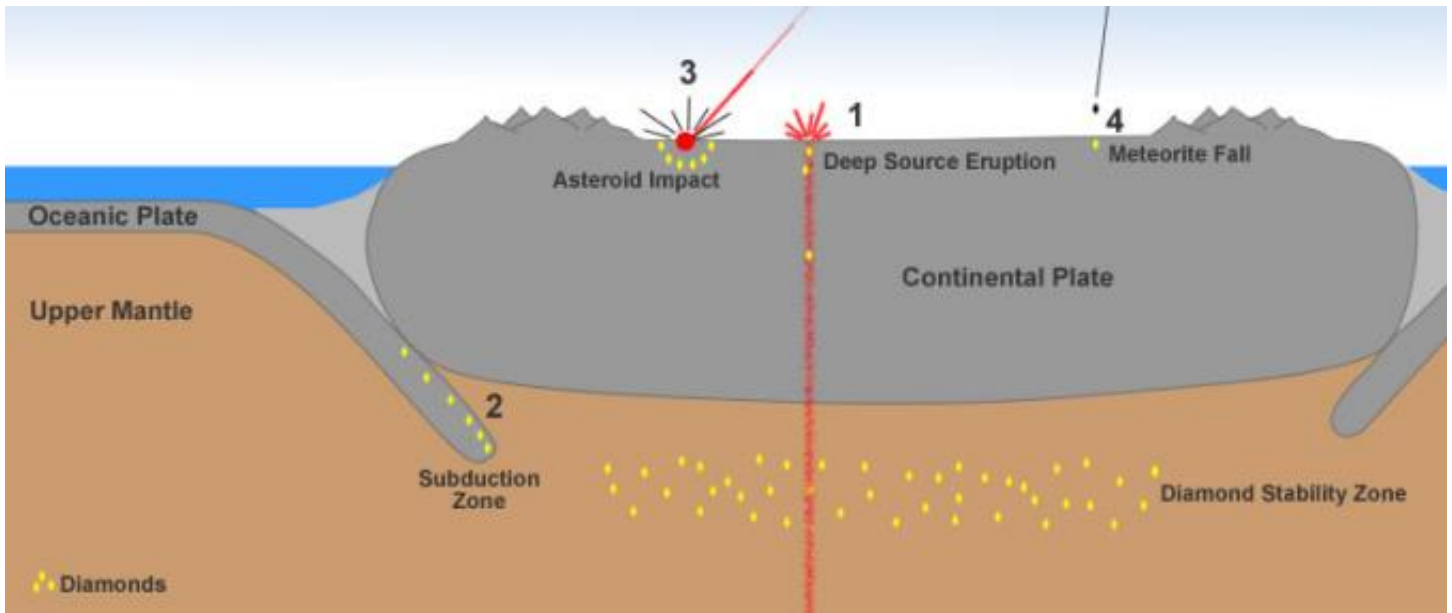
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**Don't forget to pay your dues this month. Membership renewal is January 1<sup>st</sup>. Make checks payable to "Geological Society of New Hampshire."**

## HOW DO DIAMONDS FORM?

**CONTRARY TO WHAT MANY PEOPLE BELIEVE, MOST DIAMONDS DO NOT FORM FROM COAL**

Author: Hobart King, Ph.D. Story and references at <http://geology.com/articles/diamonds-from-coal/>



**Diamond formation: Diamonds found at or near Earth's surface have formed through four different processes. The plate tectonics cartoon above presents these four methods of diamond formation. Additional information about each of them can be found in the paragraphs and small cartoons below.**

**Methods of Diamond Formation** - Many people believe that diamonds are formed from the metamorphism of coal. That idea continues to be the "how diamonds form" story in many science classrooms.

Coal has rarely played a role in the formation of diamonds. In fact, most diamonds that have been dated are much older than Earth's first land plants - the source material of coal! That alone should be enough evidence to shut down the idea that Earth's diamond deposits were formed from coal.

Another problem with the idea is that coal seams are sedimentary rocks that usually occur as horizontal or nearly horizontal rock units. However, the source rocks of diamonds are vertical pipes filled with igneous rocks.

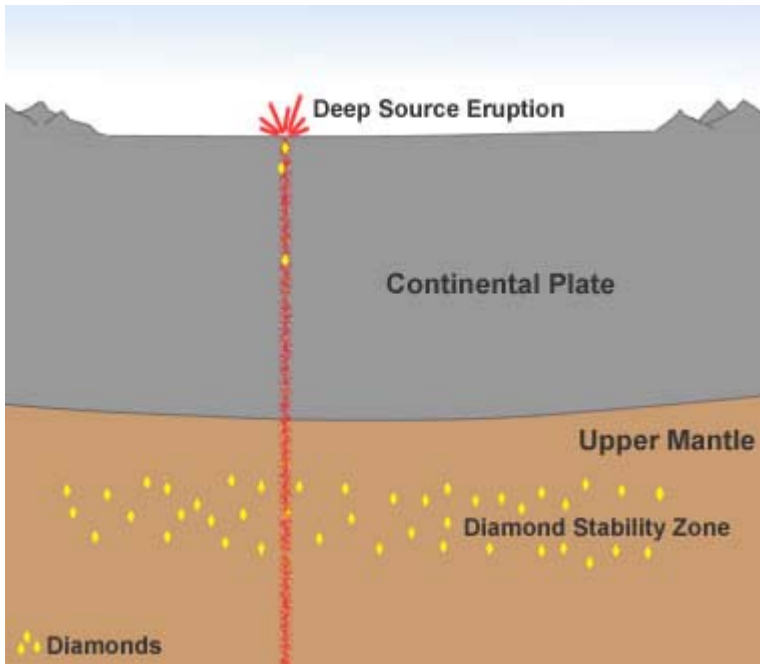
Four processes are thought to be responsible for virtually all of the natural diamonds that have been found at or near Earth's surface. One of these processes accounts for nearly 100% of all diamonds that have ever been mined. The remaining three are insignificant sources of commercial diamonds.

These processes rarely involve coal.

### 1) Diamond Formation in Earth's Mantle

Geologists believe that the diamonds in all of Earth's commercial diamond deposits were formed in the mantle and delivered to the surface by deep-source volcanic eruptions. These eruptions produce the kimberlite and lamproite pipes that are sought after by diamond prospectors. Diamonds weathered and eroded from these eruptive deposits are now contained in the sedimentary (placer) deposits of streams and coastlines.

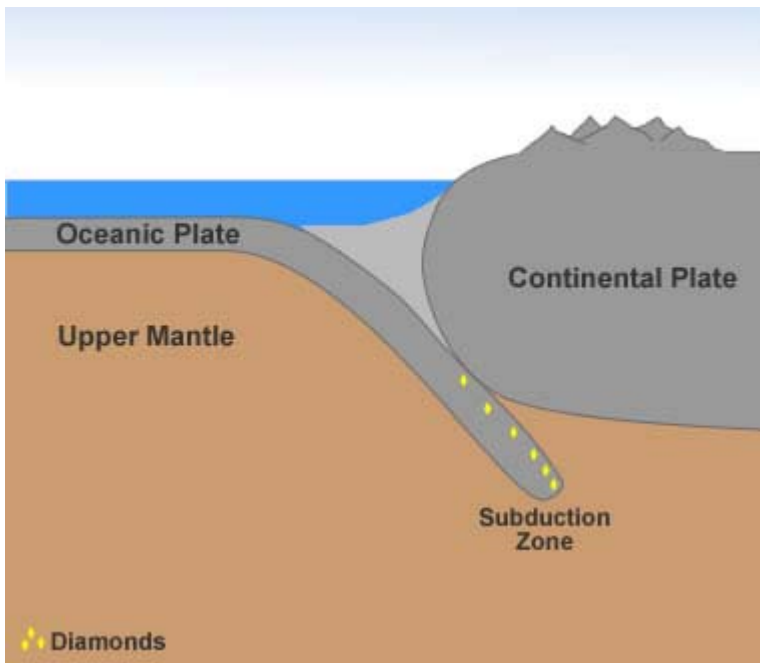
The formation of natural diamonds requires very high temperatures and pressures. These conditions occur in limited zones of Earth's mantle about 90 miles (150 kilometers) below the surface where temperatures are at least 2000 degrees Fahrenheit (1050 degrees Celsius). This critical temperature-pressure environment for diamond formation and stability is not present globally. Instead it is thought to be present primarily in the mantle beneath the stable interiors of continental plates.



**Diamonds from Deep-Source Eruptions:** Most commercial diamond deposits are thought to have formed when a deep-source volcanic eruption delivered diamonds to the surface. In these eruptions, magma travels rapidly from deep within the mantle, often passing through a diamond stability zone on its route to the surface. Pieces of rock from the diamond stability zone may be torn free and carried rapidly upwards to the surface. These pieces of rock are known as "xenoliths" and may contain diamonds.

Diamonds formed and stored in these "diamond stability zones" are delivered to Earth's surface during deep-source volcanic eruptions. These eruptions tear out pieces of the mantle and carry them rapidly to the surface. See Location 1 in the first diagram. This type of volcanic eruption is extremely rare and has not occurred since scientists have been able to recognize them.

Is coal involved? Coal is a sedimentary rock, formed from plant debris deposited at Earth's surface. It is rarely buried to depths greater than two miles (3.2 kilometers). It is very unlikely that coal has been moved from the crust down to a depth well below the base of a continental plate. The carbon source for these mantle diamonds is most likely carbon trapped in Earth's interior at the time of the planet's formation.



**Diamonds From Ocean Sediments?** Subduction zones occur at convergent plate boundaries where one plate is forced down into the mantle. As this plate descends, it is exposed to increasing temperature and pressure. Diamonds have been found in rocks that are thought to have been subducted and then returned to the surface. These types of rocks are very rare, and no known commercial diamond deposits have been developed within them. The diamonds found in these types of deposits have been very small and not suitable for commercial use.

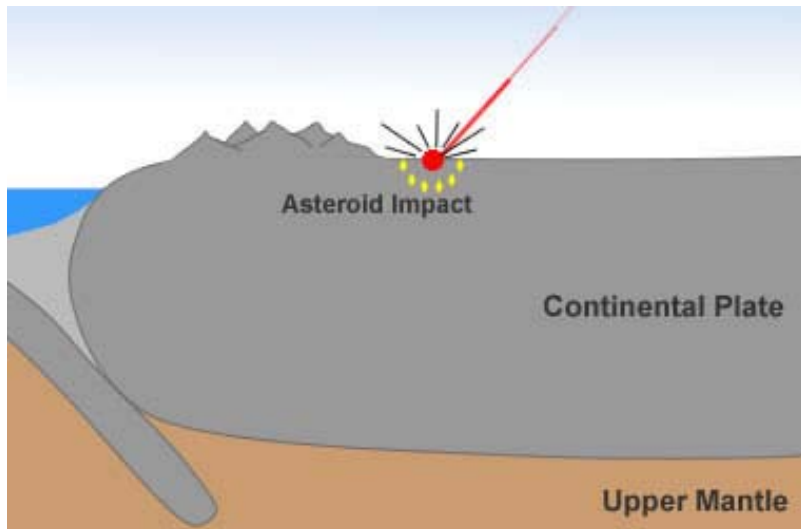
## 2) Diamond Formation in Subduction Zones

Tiny diamonds have been found in rocks that are thought to have been subducted deep into the mantle by plate tectonic processes - then returned to the surface. (See Location 2 in the first diagram.) Diamond formation in a subducting plate might occur as little as 50 miles (80 kilometers) below the



surface and at temperatures as low as 390 degrees Fahrenheit (200 degrees Centigrade). In another study, diamonds from Brazil were found to contain tiny mineral inclusions consistent with the mineralogy of oceanic crust. Others have inclusions that suggest that subducted seawater was involved in their formation.

Is coal involved? Coal is a possible carbon source for this diamond-forming process. However, oceanic plates are more likely candidates for subduction than continental plates because of their higher density. The most likely carbon sources from the subduction of an oceanic plate are carbonate rocks such as limestone, marble, and dolomite, and possibly particles of plant debris in offshore sediments.



**Asteroid Impact Diamonds:** Diamonds have been found in and around the craters of many asteroid impact sites. An excellent example is Popigai Crater in northern Siberia, Russia. Earth has been repeatedly hit by asteroids throughout its history. These asteroids hit with such force that pressures and temperatures high enough to form diamonds are produced. If the target rock contains carbon, the conditions needed to form diamonds might occur within the impact area. These types of diamonds are rare and do not play an important role in commercial diamond mining.

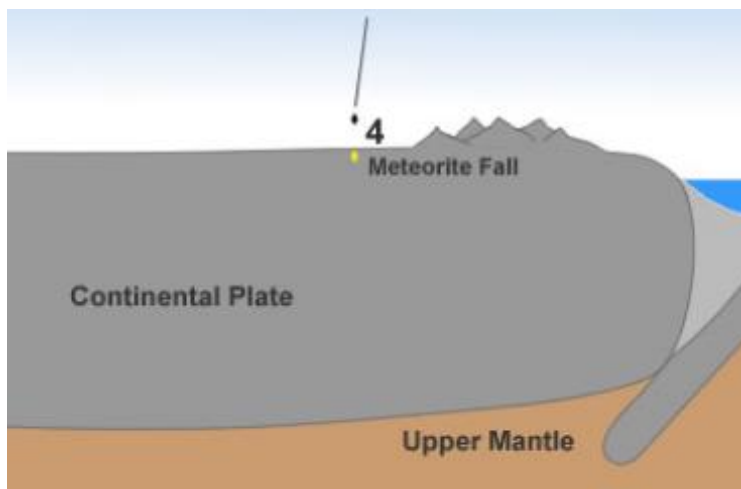
### 3) Diamond Formation at Impact Sites

Throughout its history, Earth has been repeatedly hit by large asteroids. When these asteroids strike the earth, extreme temperatures and pressures are produced. For example: when a six mile (10 kilometer) wide asteroid strikes the earth, it can be traveling at up to 9 to 12 miles per second (15 to 20 kilometers per second). Upon impact this hypervelocity object would produce an energy burst equivalent to millions of nuclear weapons and temperatures hotter than the sun's surface.

The high temperature and pressure conditions of such an impact are more than adequate to form diamonds. This theory of diamond formation has been supported by the discovery of tiny diamonds around several asteroid impact sites. See Location 3 in the first diagram.

Tiny, sub-millimeter diamonds have been found at Meteor Crater in Arizona. Polycrystalline industrial diamonds up to 13 millimeters in size have been mined at the Popigai Crater in northern Siberia, Russia.

Is coal involved? Coal could be present in the target area of these impacts and could serve as the carbon source of the diamonds. Limestones, marbles, dolomites, and other carbon-bearing rocks are also potential carbon sources.



**Extraterrestrial Diamonds:** Diamonds have been discovered in some meteorites. These diamonds are thought to have formed in space in response to asteroid impacts or other severe events.

#### 4) Formation in Space

NASA researchers have detected large numbers of nanodiamonds in some meteorites. (Nanodiamonds are diamonds that are a few nanometers - billionths of a meter in diameter.) About three percent of the carbon in these meteorites is contained in the form of nanodiamonds. These diamonds are too small for use as gems or industrial abrasives; however, they are a source of diamond material. See Location 4 in the first diagram.

Smithsonian researchers also found large numbers of tiny diamonds when they were cutting a sample from the Allen Hills meteorite. These diamonds in meteorites are thought to have formed in space through high-speed collisions similar to how diamonds form on Earth at impact sites.

Is coal involved? Coal is not involved in the creation of these diamonds. The carbon source is from a body other than Earth.

#### The Most Convincing Evidence

The most convincing evidence that coal did not play a role in the formation of most diamonds is a comparison between the age of Earth's diamonds and the age of the earliest land plants.

Almost every diamond that has been dated formed during the Precambrian Eon - the span of time between Earth's formation (about 4,600 million years ago) and the start of the Cambrian Period (about 542 million years ago). In contrast, the earliest land plants did not appear on Earth until about 450 million years ago - nearly 100 million years after the formation of virtually all of Earth's natural diamonds.

Since coal is formed from terrestrial plant debris, and the oldest land plants are younger than almost every diamond that has ever been dated, it is easy to conclude that coal did not play a significant role in the formation of Earth's diamonds.

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#### DATES TO REMEMBER

**January 11, 2018** – GSNH Dinner Meeting at 5:30 at Makris

**March 18–20, 2018** – GSA Northeastern Section 53rd Annual Meeting • Burlington, Vermont Sheraton Hotel and Conference Center

[https://www.geosociety.org/GSA/Events/Section\\_Meetings/GSA/Sections/ne/2018mtg/home.aspx](https://www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/ne/2018mtg/home.aspx)

**June ??-??, 2018** - Northeastern Friends of the Pleistocene 2018 meeting. Look for updates at <http://www2.newpaltz.edu/fop/>.

**August 6-13, 2018 - GRAND CANYON GEOLOGY RAFT TRIP** – See article in previous issue. Fred Beck (Geological Society of Maine) and Alison Jones (GSM and Geological Society of Arizona) lead an eight-day trip on two motorized 34-foot inflatable rafts through 188 miles of the Grand Canyon. For more detailed information, contact Fred Beck at [fmbeck@fmbeck.net](mailto:fmbeck@fmbeck.net), or Alison Jones at [ajones@clearcreekassociates.com](mailto:ajones@clearcreekassociates.com).

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Bill's at the airport picking up his friend Tom, a geologist. They meet up and Bill can't help but notice that Tom seems sad.

Bill: What's the matter Tom?

Tom: The airport lost my luggage. I had my whole mineral collection in there and now it's gone.

Bill: Really sorry to hear that, want to grab some food? That always cheers you up.

Tom: No thanks, I haven't got much apatite.

## **KING TIDE HIGHER THAN EXPECTED IN HAMPTON**

By KIMBERLEY HAAS Union Leader Correspondent December 04, 2017

<http://www.unionleader.com/article/20171205/NEWS22/171209692/1013/NEWS11>

HAMPTON — Side roads were covered in ocean water and waves splashed over barricades in Hampton Monday as the King Tide rolled in just after 11 a.m. Chris Legro, a meteorologist at the National Weather Service in Gray, Maine, said the tide was even higher than predicted. Tide charts had it forecasted at 10.7 feet. Legro said it was measured at 11.2 feet. That means Tuesday's high tide at about noon could be larger than the predicted 10.8 feet, Legro said. That is expected to be the highest tide of the year.

Roger Stephenson, senior outreach consultant for the Union of Concerned Scientists, said nuisance flooding caused by King Tides provides a glimpse into the future as sea levels rise. The Union of Concerned Scientists has analyzed flooding models for 2060 to 2100, and by the middle of this century, large chronically flooded zones will emerge in cities and towns that seldom or never flood today.



**This house on Island Path in Hampton was still surrounded by water Monday afternoon as the King Tide receded. (KIMBERLEY HAAS/Union Leader Correspondent)**

Chronic flooding will profoundly affect large portions of Boston, Fort Lauderdale, New Haven, Newark, Oakland and four of New York City's five boroughs under moderate to worst-case scenarios, according to research by the scientists. Stephenson said top credit rating agencies are now telling coastal towns and cities that they must come up with a preparation plan for rising sea levels or they risk losing access to credit. Bloomberg reported last week that Moody's Investors Service Inc. incorporates climate change into its credit ratings for state and local bonds. The King Tides end in Hampton on Wednesday [December 6], when tides are predicted to be 10.6 feet at 12:53 p.m.

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"I am not a geologist, so I really don't know a lode of geology puns."

So I said to the geologist, "Wow, taking core samples. That sounds pretty interesting," and he says, "Actually, it's really boring."

**TRUMP TO OPEN DOOR FOR OIL DRILLING OFF THE EAST COAST** By JENNIFER A. DLOUHY Bloomberg December 11, 2017

The Trump administration is preparing to unveil as soon as this week an expansive offshore oil plan that would open the door to selling new drilling rights in Atlantic waters, according to people familiar with the plan. President Donald Trump ordered his Interior Department to write the new blueprint with the aim of auctioning oil and gas drilling rights off the East Coast — territory that his predecessor, former President Barack Obama, had ruled out. The Interior Department's coming draft proposal, an initial milestone in replacing the Obama-era sale plan, dovetails with the oil industry's push for new places to drill, said the people, who asked not to be identified before a formal announcement. Trump's proposal would span the years 2019 to 2024, replacing the Obama plan, which runs through 2022.



**Off Shore Oil Rigs in the Santa Barbara Channel near the Federal Ecological Preserve enroute to the Channel Islands National Marine Sanctuary in March 2015. The Trump administration is preparing to open the door to drilling rights in the Atlantic ocean. (Al Seib / Los Angeles Times)**

Industry leaders have lobbied the Trump administration to sell drilling rights in the U.S. Atlantic as a way to complement existing oil production in the Gulf of Mexico. It is not clear how much oil and gas exists off the East Coast, because existing data stems largely from decades-old geological surveys and more than four-dozen wells drilled in the 1970s and 1980s. Oil companies also want the Trump administration to sell drilling rights in Arctic waters north of Alaska and in the eastern Gulf of Mexico — where federal law bars new oil leasing through 2022.

Lawmakers from Florida have fought efforts to expand offshore drilling they say would imperil the state's tourism-tied economy and are seeking to extend that ban.

While most U.S. waters are technically open for oil and gas development, the activity can only take place on leases sold under the government's five-year plan. The legal process for assembling that drilling blueprint starts broad, with the number of potential sales and the available acreage often whittled down as regulators move from an initial draft to a proposal and ultimately, the final program. Industry trade groups have urged the government to take an inclusive approach and leave all options open for now, because once offshore areas are yanked out, they can't be easily restored.

"It's important that the federal government make available new prospective areas to search for oil and gas to ensure we keep up with future demand," said Dan Eberhart, chief executive officer of drilling services company Canary LLC. "It doesn't mean we should necessarily drill everywhere, but it is

important to know what resources we have so we can make informed decisions about the best places to drill.”

Environmentalists argue it would be shortsighted for the Trump administration to keep considering new oil drilling off the East and West coasts, given deep opposition from local residents worried about potential oil spills jeopardizing fishing and tourism. “The Trump administration is trying to grab the pristine ocean waters Americans own and hand them to polluters for exploitation and ruin,” said Alexandra Adams, a senior advocate with the Natural Resources Defense Council. “We will fight this with our coastal communities who’ve made their opposition clear: They won’t subject their economies and their whole way of life to the dangers of a devastating oil spill.”

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## THE NH GEOLOGICAL SURVEY GROUND WATER LEVEL NETWORK SUMMARY

Submitted by Lee Wilder of the NHGS

The NHGS is now posting its monthly groundwater levels from its network of NH Observation Wells online at: <http://www.des.nh.gov/organization/commissioner/pip/publications/geologic/groundwater-levels.htm>. The data for all of the wells in the NH Groundwater Level Network are shared with and posted on the USGS website at: <http://groundwaterwatch.usgs.gov/statemap.asp?sc=33&sa=NH>. A map of both the New Hampshire and Vermont Groundwater Level Network is at <https://groundwaterwatch.usgs.gov/netmapT2L1.asp?ncd=NHV>.



Fall water level round. Photo by Lee Wilder, NHGS

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## HAVE YOU FOUND A SPACE ROCK?

**AN INTRODUCTORY GUIDE TO METEORITE IDENTIFICATION** From a series of articles by Emmy Award-winning television host, producer, science writer, adventurer, and world-renowned meteorite specialist Geoffrey Notkin, *Aerolite Meteorites* <http://www.aerolite.org/>

**How Rare Are Meteorites?** One of my happy tasks as a meteorite hunter is running a web site that specializes in my favorite subject. We receive hundreds of thousands of visitors each year, and I try to maintain a fair balance on the site between education, photographs and reports about our expeditions, and commercial sales of meteorites. One of the most frequently visited sections of the site is a detailed guide to meteorite identification. As a result of that guide we receive, almost daily, inquiries by letter and email from hopeful individuals who think they may have found a rock from outer space.

Meteorites are among the rarest materials that exist on our planet—far less common than gold, diamonds, or even emeralds. So, the chances of discovering a new example are slim—even for those of us who make their living hunting for, and studying, meteorites. I do spend a significant amount of time each year assisting people who think they may have found the real thing, but the odds are against it. Out of the many hundreds of suspected space rocks sent to us for testing, far less than one percent turn out to be genuine visitors from outer space.

**What Are Meteor-Wrongs?** A specimen that is thought to be a meteorite, but turns out instead to be a common earth rock is affectionately and humorously dubbed a *meteor-wrong*. The surface of our planet is rich in terrestrial iron oxides such as magnetite and hematite (many of which will stick to a magnet), dark black rocks such as basalt, and many different types of man-made metallic by-products such as runoff (slag) from old smelters, and castoff iron implements that have corroded over time. All of these materials are frequently mistaken for meteorites. Identification of a genuine meteorite takes a practiced eye, but there are a number of simple tests that can help hopeful rock hounds determine if they have stumbled across a rare space rock, or just a common earthbound stone.

**Visual Identification of Meteor-Wrongs** - Meteorites tend to look different from the ordinary terrestrial rocks around them. They do not contain the common earth mineral quartz, and in general do not contain *vesicles*. When gas escapes from cooling molten material, it creates small pinprick holes or cavities in a rock's surface. The volcanic rock pumice, often used in skin care for the removal of callouses, contains vesicles which is one of the reasons it is very light in weight. If a suspected meteorite looks like a sponge, with lots of tiny holes, it is probably volcanic rock or slag of earthly origin.



**Meteorwrong: Slag**—sometimes called **cinder or runoff**—is a **by-product of metal smelting and usually consists of a conglomerate of metal oxides**. Slag is one of the substances most commonly mistaken for meteorites, as it appears burned and melted on the surface and often sticks to a magnet due to its high iron content. It is used in road and railroad building, as ballast, and even in the manufacture of fertilizer. In other words, it is all over the place. Take special note of the vesicles—small holes and cavities created by escaping gases. Vesicles are not found in meteorites, so an experienced eye will immediately identify this as a meteor-wrong. The scale cube pictured is 1 cm. Photo by Geoffrey Notkin

### Meteorite Identification:

**The Magnet Test** - Meteorites are divided into three basic groups: irons, stones, and stony-irons. Practically all meteorites contain a significant amount of extraterrestrial iron and nickel, so the first step in identifying a possible meteorite is the magnet test. Iron and stony-iron meteorites are rich in iron, and will stick to a powerful magnet so strongly that it can be difficult to separate them! Stone meteorites

also, for the most part, have a high iron content and a good magnet will happily adhere to them. Many earth rocks will also attract a magnet, so this is not a definitive test, but it's a good step in the right direction. Lunar and Martian meteorites, and most *achondrites* (stone meteorites without chondrules) contain little or no iron and even a powerful magnet will generally have no effect on them. However, these meteorite types are so extremely rare that, as a general rule, we discount specimens that will not adhere to a magnet.

**Weight and Density** - Iron is heavy and most meteorites feel much heavier in the hand than an ordinary earth rock should. A softball-sized iron meteorite will likely weigh five or six pounds, making it seem unnaturally dense. Imagine holding a steel ball bearing as big as a grapefruit and you'll get the idea.

**Visual Identification of a Fusion Crust** - When a *meteoroid* (a potential meteorite) streaks through our atmosphere, tremendous heat is generated by atmospheric pressure. The surface of the rock melts and the air around it incandesces. As a result of this brief but intense heating, the surface burns and forms a thin, dark rind called *fusion crust*. Meteorites literally began to burn up in our atmosphere, so they tend to appear darker than the terrestrial rocks around them. Desert varnish forms on the surface of some earth rocks, particularly in arid areas, and can easily be mistaken for fusion crust by an untrained eye. True fusion crust does not occur on earth rocks. It is delicate and will weather away over time, but a freshly fallen meteorite will exhibit a rich black crust, much like a charcoal briquette.

**Visual Identification of Regmaglypts** - *Regmaglypts*, popularly known as thumbprints, are oval depressions-often about the size of a peanut-found on the surface of many meteorites. These indentations look much like the marks a sculptor might make with his fingers on a wet lump of clay, hence their name. Regmaglypts are created as the meteorite's outer layer melts during flight and they are another feature unique to meteorites.



**Stone meteorite with fusion crust:** This 307.1-gram stone meteorite fell as part of a shower on October 16, 2006 in Mauretania. It is an ordinary chondrite (H5) and an excellent example of a complete fusion crusted stone. This specimen was picked up immediately after the fall. Note the very fresh, rich black fusion crust which is reminiscent of a charcoal briquette. Fusion crust is thin and fragile and will weather away over time, so a recently fallen stone will exhibit a dark black crust with no weathering or rust stains. Photo by Geoffrey Notkin

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Did you hear about the heroic geologist? After he saved the day, erode away into the sunset!

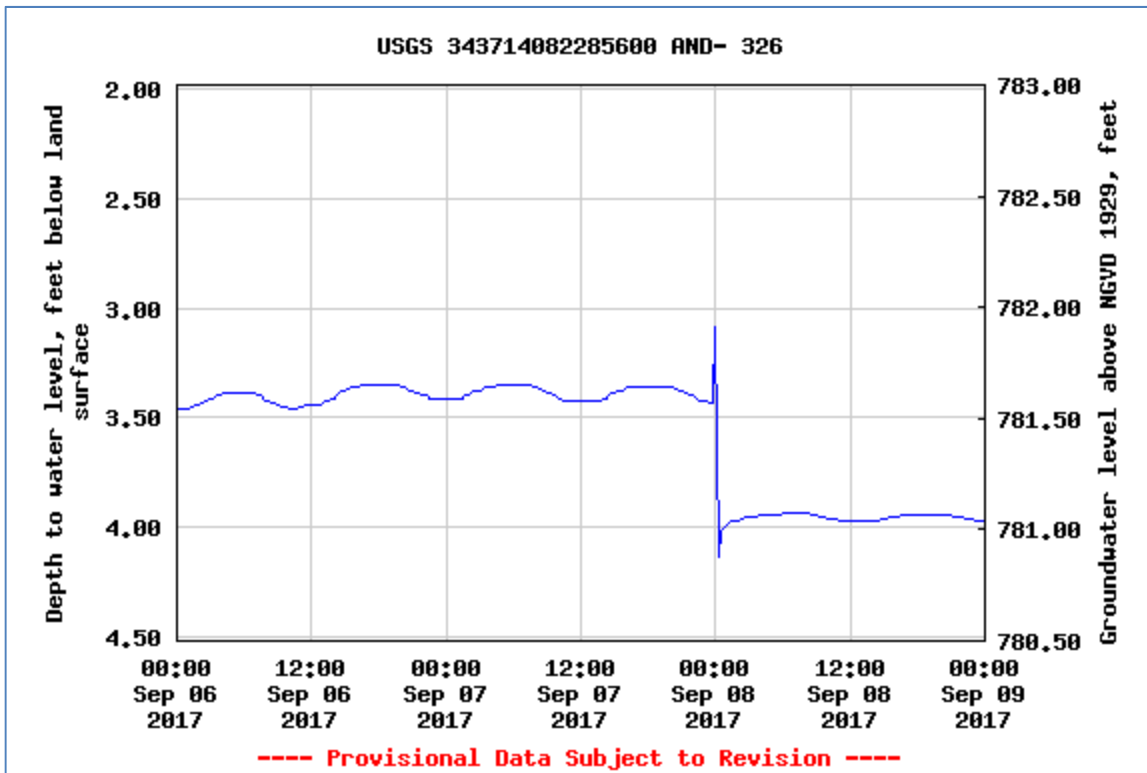
Seismologists never have a steady job.

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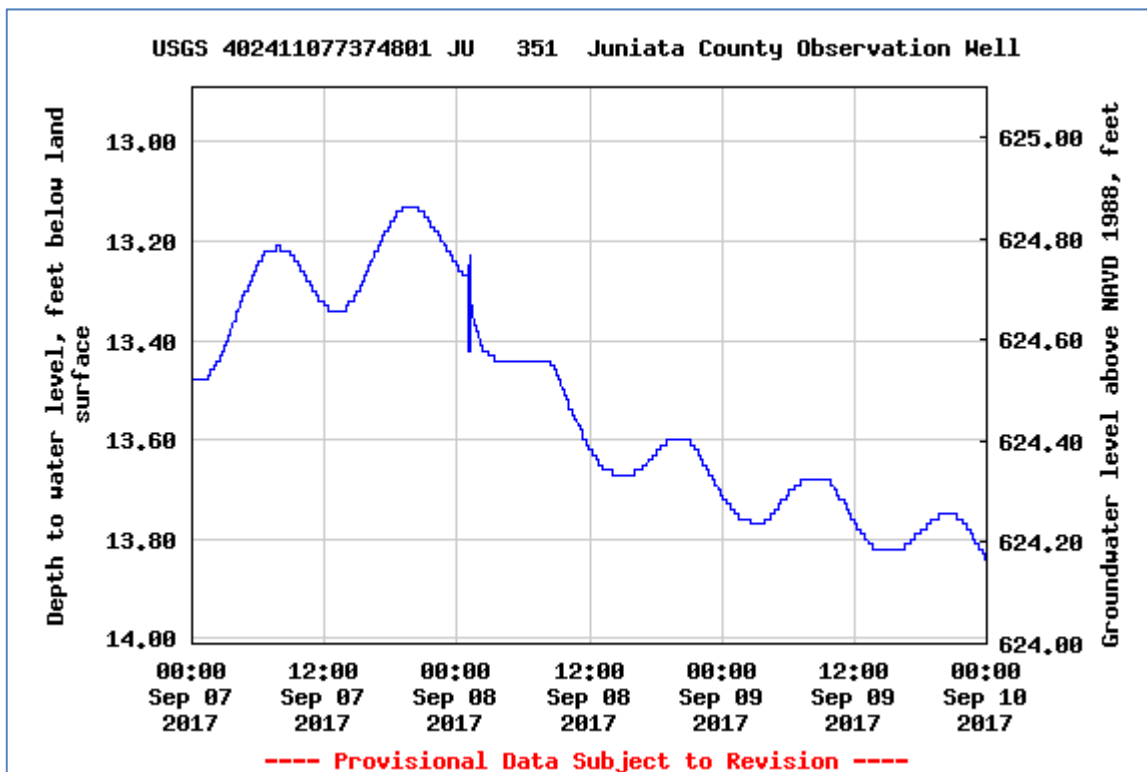
**USGS NOTES WATER LEVEL IMPACTS FROM EARTHQUAKE** – Sources: Emails from

Thomas Mack and Rodney Sheets

A magnitude 8.1 earthquake in Mexico September 7, 2017 affected water levels across the country -- here is a sampling from Virginia, through Iowa and into California. A brief statement is available at <https://owi.usgs.gov/blog/earthquake/>.



South Carolina  
[https://waterdata.usgs.gov/sc/nwis/uv?cb\\_72019=on&format=gif\\_default&site\\_no=343714082285600&period=&begin\\_date=2017-09-06&end\\_date=2017-09-08](https://waterdata.usgs.gov/sc/nwis/uv?cb_72019=on&format=gif_default&site_no=343714082285600&period=&begin_date=2017-09-06&end_date=2017-09-08)



Pennsylvania  
[https://waterdata.usgs.gov/nwis/uv?cb\\_72019=on&format=gif\\_default&site\\_no=402411077374801&period=&begin\\_date=2017-09-07&end\\_date=2017-09-08](https://waterdata.usgs.gov/nwis/uv?cb_72019=on&format=gif_default&site_no=402411077374801&period=&begin_date=2017-09-07&end_date=2017-09-08)





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# Geological Society of New Hampshire

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## GSNH 2018 Winter Dinner Meeting

### "Snowball Earth: From the 42nd Parallel Perspective, Idaho and Massachusetts"

#### **Speaker: Joshua Keeley, Hydrogeologist, NH Geological Survey**

Josh got his bachelor's degree in Geosciences from University of Rhode Island where he focused on glacial geology and geomorphology. He earned his master's degree in Geology from Idaho State University where he studied Neoproterozoic glacial strata and Basin and Range tectonics. He recently joined the NHGS as a hydrogeologist after six years consulting in various fields from Alaska to Panama including gold exploration, geothermal exploration, and environmental assessment.

**THURSDAY, January 11, 2018**

**Makris Lobster House Restaurant  
354 Sheep Davis Rd, Concord, NH 03301**

5:30 pm Social Hour; 6:30 pm Buffet Dinner; 7:15 pm Speaker

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**RSVP by 4 pm Friday, January 5, 2018 to get the reservation price**  
SPACE AT THIS VENUE IS LIMITED TO 80...RESERVE EARLY!

Advance Reservations: \_\_\_\_\_ Member (Dues Paid) \$25.00  
\_\_\_\_\_ Non-member \$28.00

\_\_\_\_\_ **Please indicate the number of vegetarian meals – leave blank for none.**

- Member at the Door \$27.00
- Non-Member at the Door \$30.00
- Students \$10.00 with valid student ID card (Reservation Requested)

GSNH will also accept dinner reservations by e-mail, which will then allow you to pay at the door. **Please note that e-mail reservations constitute an agreement with the Society for which you will be responsible to pay, whether you are able to attend or not, unless you cancel your reservation by noon the Tuesday before the Dinner.**

Reply via e-mail to: [sharon.lewandowski@aecom.com](mailto:sharon.lewandowski@aecom.com).

Mail to: **Sharon Lewandowski**

**GSNH Dinner Meeting, PO Box 401, Concord, NH 03302.**

**Checks payable to: GSNH.**

Name(s) \_\_\_\_\_

Address: \_\_\_\_\_

Your phone or e-mail: \_\_\_\_\_

**The lecture part of the program counts as 1.5 hours of CEU contact hour credit.**



MEMBERSHIP & RENEWAL APPLICATION

Geological Society of New Hampshire

PO Box 401, Concord, NH 03302

Name: \_\_\_\_\_

(Please print clearly)

E-mail: \_\_\_\_\_

Renewing Members: Only update this section if you have changes to your contact information (including email) or educational history.

New applicants: please complete this section.

Preferred address/email to receive GSNH Communication: \_\_\_ Home or \_\_\_ Business

Home Address:

Business Address:

Home address lines

Business address lines (Employer):

Home Telephone: \_\_\_\_\_

Office Telephone: \_\_\_\_\_

New Hampshire PG # (if applicable) \_\_\_\_\_

Education: Degrees received or in progress:

Table with 4 columns: Year, Degree, Major, College or University

I volunteer to help with one of the following committees or tasks:

- Membership Committee, Regulations Committee, Communications Committee, Legislative Committee, Education Committee, Giving a talk at a meeting, Events Committee, Other: (Newsletter or Website, circle preference)

Membership Category:

- Regular Member (Annual Dues \$20.00)
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: \_\_\_\_\_