EARTHQUAKE
e-Newsletter about what's movin' and shakin' at the Earth Science Museum

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Volume 14, Issue 6

ESM OUTREACH UPDATE
Mardy Zimmermann Outreach Coordinator

With schools on summer hiatus, there were no outreach programs this month.

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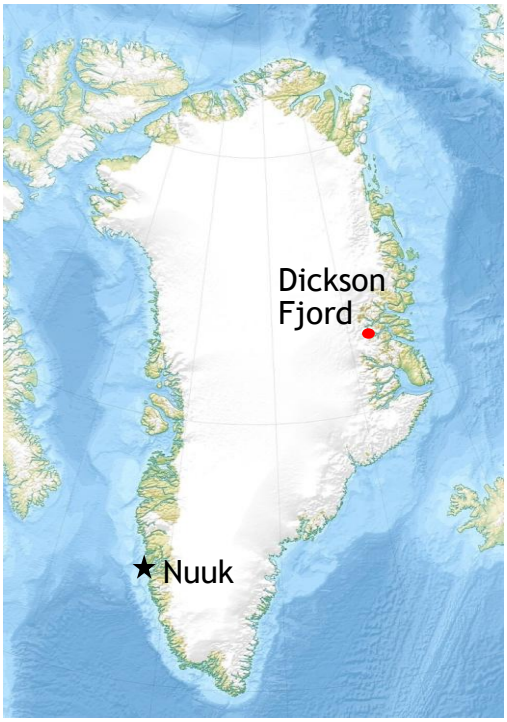
The Greenland Mega Tsunami That Shook the Earth
By Harvey Jong

In September 2023, a massive landslide occurred in Greenland's Dickson Fjord. This event led to a mega tsunami which generated a seismic signal that reverberated across the Earth for nine days. Because of the remote location, no one actually witnessed the event. A recent *Nature Communications* article, however, reported that NASA's Surface Water Ocean Topography (SWOT) satellite did make precise altimetry measurements around the time of the rockslides (Monahan et al., 2025). We'll explore some interesting aspects about this mega tsunami that shook the world.

Dickson Fjord

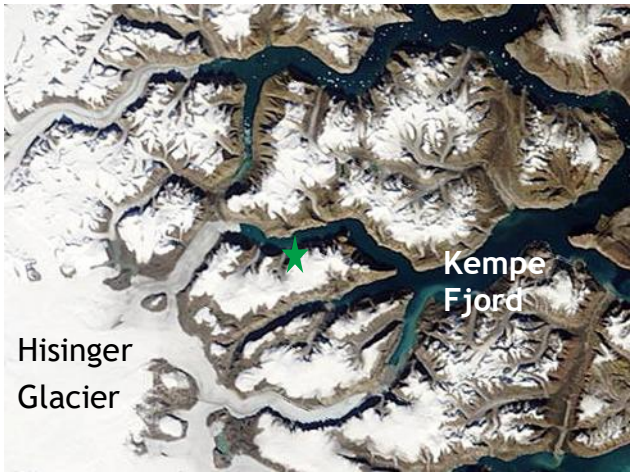


Location of the Dickson Fjord
Uwe Dedering map, - CC_BY_SA-3.0, via Wikimedia Commons

The red dot indicates the location of the Dickson Fjord, while the black star corresponds to Nuuk, the capital and most populous city of Greenland.

The Dickson Fjord is located in northeastern Greenland and was first surveyed in 1899. It is named after Swedish politician Robert Dickson (1843-1924), one of the financial backers of the expedition. The fjord is bounded by the Hisinger Glacier on its western end and empties into Kempe Fjord on the eastern side. The overall length is

around 35 km (22 mi) where 15 km (9.3 mi) runs northwestwards and 20 km (12 mi) extends west-southwest. The maximum width is about 5 km (3.1 mi).



Satellite View of the Dickson Fjord Area
MODIS/NASA image, - PD, via Wikimedia Commons
This true color image was captured by NASA's MODIS spacecraft on August 21, 2003. The Dickson Fjord appears near the center of the photo. The green star indicates the landslide area.

High mountains over 1,000 m (3,281 ft) surround the fjord leading to very steep shores. The bedrock consists of orthogneiss with marble intruded by veins of muscovite-granite.

Unidentified Seismic Object (USO)

Our story begins in September 2023 when an unusual signal was detected by seismic stations around the world. This seismic signal had a very-long period of 92 seconds (10.88 millihertz) and continued over nine days (Svennevig et al., 2024). Unlike the seismic waves from an earthquake, the signal was a simple sine wave, and its source was initially called an Unidentified Seismic Object (USO).

Landslide and Mega Tsunami

An international, interdisciplinary team of scientists was quickly assembled to review and analyze regional and global data related to the event. They determined that on September 16, 2023 at 12:35 UTC (11:35 local East Greenland time) a huge landslide involving 25.5 x 10^6 m^3 (33.4 x 10^6 yd^3) of rock and ice occurred on a mountain peak 1,200 m (3,937 ft) above Dickson Fjord. (Svennevig et al., 2024).

Screen Capture of a Video on the Greenland Tsunami Showing the Area Before the Landslide
Steve Hicks video, via
https://www.youtube.com/watch?v=60T9TKuuujs
This image was taken by a couple of weeks before the landslide. Note that the yellow dashed line indicates the mountain involved with the future rockslide.

Screen Capture of a Video on the Greenland Tsunami Showing the Area After the Landslide
Steve Hicks video, via
https://www.youtube.com/watch?v=60T9TKuuujs

This image, taken by the Danish Army's Sirius Dog Sled Patrol, shows how the mountain and glacier changed after the landslide.

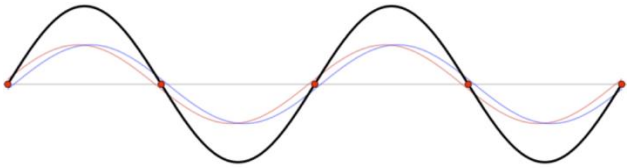
The avalanche of rock and ice into the 540 m (1,772 ft) deep Dickson Fjord triggered a tsunami where the initial backsplash or runup was estimated to reach a height of approximately 200 m (656 ft), and subsequent waves were up to 110 m (328 ft) high. Evidence of these waves appeared on the newly calved glacier front, and the heights are indicated by the red dashed lines in the above image.

The tsunami extended 72 km (44.7 mi) inland to an uninhabited research station at Ella Island. Parts of the station were submerged by the 4 m (13.1 ft) high runup which destroyed some equipment.

Screen Capture of a Video on the Greenland Tsunami Showing the Extent of Runup and Destruction on Ella Island
Steve Hicks video, via https://www.youtube.com/watch?v=60T9TKuuujs
These images, taken by the Danish Navy, show the tsunami runup (indicated by the white arrows) along with some infrastructure damage.

Standing Waves or Seiches

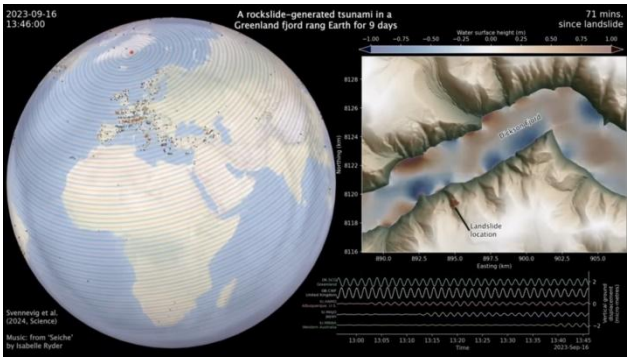
The pattern and slow decay of the mysterious seismic signal suggested that the initial tsunami wave may have been trapped in the highly confined area of the fjord. This wave was reflected back and forth between opposite shores creating standing waves (also called seiches).



Screen Capture of a Standing Wave Animation
Lucas Vieira animation, - PD, via Wikimedia Commons
This image depicts the constructive interference of standing waves. The red wave moves in one direction, the blue wave in the opposite direction, and the black wave represents the resulting combination.

Simulations of the sloshing wave action produced a signal with a frequency of 11.45 mHz (87 s period) which is very close to the 10.88 mHz (92 s period) of the observed seismic wave (Svennevig et al., 2024).

The following visualization presents a side-by-side comparison of the propagation of the seismic signal across the globe and the simulated movement of water in the Dickson Fjord.



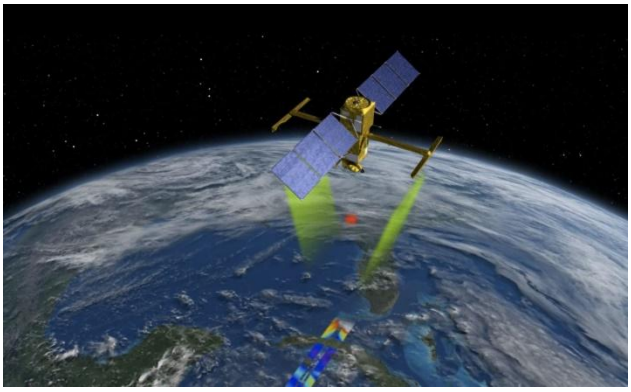
Screen Capture of a Visualization of the Seismic and Tsunami Waves from the Dickson Fjord Landslide

Stephen Hicks, Kristian Svennevig, Thomas Lecocq, and Alexis Marbeouf animation, via https://youtu.be/5et66s74OGs

The left panel shows the seismic wave spreading out from Greenland around the planet where each circle indicates data from a seismic monitoring station. The right panel presents a simulation of the water in the fjord sloshing backwards and forwards over nine days.

SWOT Satellite Measurements

To confirm this hypothesis, a group of University of Oxford researchers used radar altimetry data from the Surface Water and Ocean Topography (SWOT) satellite (Monahan et al., 2025). This satellite was jointly developed by NASA and the Centre National D'Etude Spatilaes (CNES) with contributions from the Canadian Space Agency (CSA) and United Kingdom Space Agency. The SWOT mission objectives include making the first global survey of the Earth's surface water, observing fine details of the ocean surface topography, and measuring how surface water bodies change over time. The spacecraft was launched on December 15, 2022.

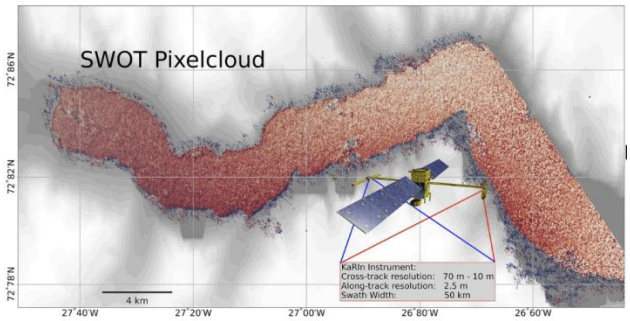


Screen Capture of a Visualization of NASA's and CNES' Surface Water and Ocean Topography (SWOT) Satellite

Screen capture of Scientific Visualization Studio/NASA animation, - PD, via svs.gsfc.nasa.gov

This image shows the SWOT Ka-band Radar Interferometer (KaRin) measuring surface water levels with two antennas that send out radar pulses and triangulate the return signals that bounce back. The instrument provides two-dimensional measurements with a resolution of up to 2.5 m (8.2 ft) extending 50 km (31.3 mi) on either side of the spacecraft.

The SWOT satellite made several observations of the Dickson Fjord after the mega tsunami landslide. These passes occurred 0.5 days, 1.5 days and 4.8 days after the mysterious seismic signal was detected. A single pass produces a "pixelcloud" containing more than 300,000 measurements.



SWOT Pixelcloud of the Dickson Fjord
Fig. 1 B from (Monahan et al., 2025)

The Oxford scientists applied extensive processing to the SWOT data to eliminate unrelated effects, such as tides and winds.

Elevation maps of the fjord at various time points were, then, constructed. The maps clearly showed varying slopes across the fjord with height differences up to 2 m (6.6 ft) (Monahan et al., 2025). More importantly, these slopes occurred in opposite directions indicating that water was

moving backwards and forwards across the fjord.

Significance of the Event

The landslide and subsequent mega tsunami provide a dramatic example of climate change. Glacial thinning in the Dickson Fjord triggered a complex cascade of events that led to an unusual global phenomenon. It highlights the interactions between the Earth's cryosphere, hydrosphere, and lithosphere.

In addition, the event demonstrated the importance of multidisciplinary research efforts in analyzing the nature of unexpected worldwide incidents. Such studies are made possible by advanced comprehensive monitoring of our planet.

References

Monahan T., T. Tang, S. Roberts, and T.A.A. Adcock (2025) Observations of the seiche that shook the world. *Nature Communications* 16(4777).

Svennevig, K., S. Hicks, T. Lecocq, A. Mangeney, C. Hbert, N. Korsgaard, A. Lucas, M. Keiding, A. Marboeuf, S. Schippkus, S. Rysgaard, W. Boone, S. Gibbons, K. Cook, S. Glimsdal, F. Lovholt, M. Spagnolo, J. Assink, W. Harcourt, J. Malet, M. Myrup, L. Rivera, E. Ruiz-Castillo, S. Wetter, and B. Wirtz (2024) Interdisciplinary insights into an exceptional giant tsunamigenic rockslide on September 16th 2023 in Northeast Greenland, EGU General Assembly 2024, Vienna, Austria, April 14-19, 2024.

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Changes in Greenland's Ice Sheet

Click on the above image to view ice sheet animation

Planetary Visions animation

This animation illustrates the thinning of Greenland's ice sheet since October 2018. It combines measurements from the ESA's CryoSat and NASA's ICESat-2 missions in which blue represents CryoSat data and red indicates ICEStat-2 data. The locations of two examples of extreme thinning, Sermeq Kujalleg (also known as Jakboshavn) and Zachariae Isstrøm, are highlighted at the end of the visualization.

Screen capture from the above video. The drainage of supraglacial lakes, particularly through moulins (vertical shafts in the ice, red arrow), can lubricate the base of the ice sheet, potentially increasing ice flow speed.

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Arizona Rocks 145

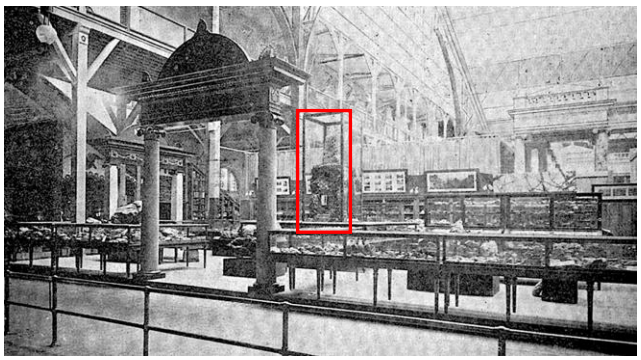
Text by Ray Grant
Photographs from American Museum of Natural History website

What is the “Singing Stone”?

The Copper Queen Consolidated Mining Company set up a large exhibit of Arizona minerals at the 1893 World’s Columbian Exposition (similar to today’s World’s Fair) in Chicago. The purpose was to show the rich mineral deposits of Arizona Territory In support of Arizona’s drive for statehood. Included with the collection was a seven-thousand-pound block of Azurite and Malachite from the Czar Mine in Bisbee.

After the Exposition it was donated to the American Museum of Natural History in New York, where it is on exhibit today. It is called the singing stone because when it was first put on display at the American Museum there was no air conditioning so temperature and humidity would go up. The water content of the minerals would change and this would cause a slight change to their shape and as a result the rock would squeak/sing like “EEEEEEEEE”.

Miners in Bisbee with the singing stone.



Arizona mineral exhibit at the 1893 Exposition, singing stone in glass case outlined in red.

Map of current Mineral Exhibit room at the American Museum of Natural History showing location of singing stone (B5).

Singing stone on display today at the American Museum of Natral History

Pinal Museum and Society News

351 N. Arizona Blvd., Coolidge, AZ

Pinal Geology and Mineral Society next meeting

September 17, 2025

Meetings are the third Wednesday at 7pm, doors open at 6:00

www.pinalgeologymuseum.org

Ray Grant ray@pinalgeologymuseum.org

Pinal Geology and Mineral Museum
May – September hours are Fridays from 10-3, admission is free.
Groups can arrange special visits please call 520-723-3009.

No club meetings in summer and museum open Fridays & Saturdays from 10 - 4 until September.

There are some new exhibits at the museum. Two of them are showing lapidary work, one of polished slabs and one of cabochons. The specimens in these exhibits are from a generous donation from the Sun City Rockhound Mineral Museum to the Pinal Museum.

AZ Mining, Mineral & Natural Resources Education Museum Update June 2025

https://ammnre.arizona.edu/

Catie Carter Sandoval
cscarter@email.arizona.edu
703.577.6449

Help support the museum at:
http://tinyurl.com/SupportMM-NREMuseum

This summer we are planning some new exhibits and collaborations, starting with a brand-new display coming soon to the Sun City Mineral Museum. We recently deinstalled our previous exhibit of southwestern rocks and minerals, which was in place since fall 2023. That display featured over 30 specimens including collector's pieces, mining ores, industrial minerals, and lapidary art. Our new display coming in July will showcase exceptional Arizona minerals from historic mining localities in celebration of the 35th Anniversary of the museum's opening. We will share more about that in next month's update. Thank you to everyone for your continued support and we hope you're having a great summer.

The display recently deinstalled at the Sun City Mineral Museum

Sun City Mineral Museum Director Carol Bankert George next to the 'Arizona Minerals' display, which features specimens listed in the former Arizona Mining & Mineral Museum's teaching kit.

Azurite & malachite specimen recently deinstalled

Sun City Rockhound Mineral Museum
Sundial Recreation Center
14801 N. 103rd Ave.
Sun City, AZ 85351

The museum offers private party tours for schools, clubs and individuals. We'd love to show off our museum to your club or private group. If you are interested, please contact the museum at scrockmuseum@gmail.com.

Please take a minute to check out our new website at scrockmuseum.com.

Museum Summer renovations

By Carol Bankert-George Museum Director

The museum will be closed for painting and the installation of new cabinets June 23rd through July 11th. If all goes on schedule, the museum will reopen on July 12th, just in time to celebrate International Rock Day (July 13th). The purpose of this day is to foster appreciation for rocks and their role in the Earth's history and human development. In honor of this day the museum will be giving 'junior rock hunters' who stop by and do a scavenger hunt a gift of rock specimens and a geology themed sticker. Come join in the fun!

Over the next few months, the museum will be updating and rotating specimen displays. Catie Sandavol of the Arizona Mining, Mineral and Natural Resources Education Museum, will be installing a new display mid-July. This new display will feature Arizona minerals with an emphasis on the state's rich mining history.

Please enjoy a couple of photos of displays from our museum.

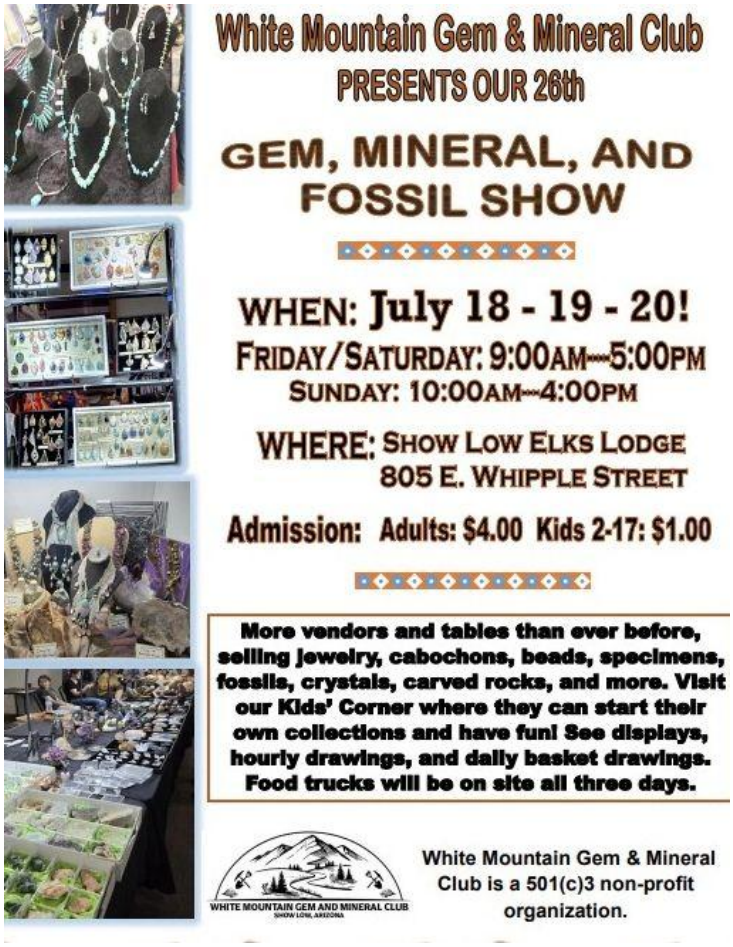
C. Sandoval photo

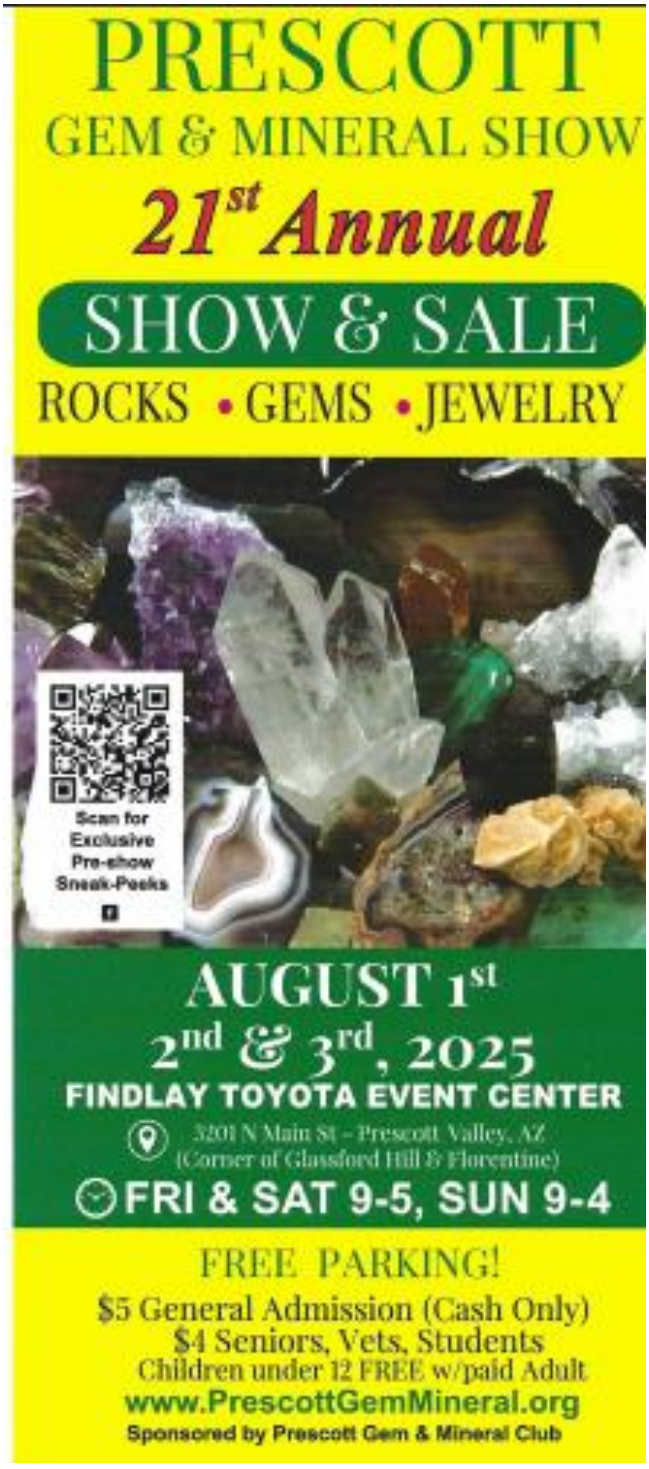
Winter Hours
October – April
10 am to 1 pm
Closed Thurs., & Sunday
Summer Hours
May-September 10am-1pm
Saturdays only

Arizona Field Trip Locations

Mineral/rock specimens from all 50 states

Arizona Rock and Gem Shows





Apache Junction Rock & Gem Club
Meetings are on the 2nd Thursday
Next Meeting: July 10, 2025, 6:30 pm
www.ajrockclub.com
@ Club Lapidary Shop
2151 W. Superstition Blvd., Apache Jct.

Daisy Mountain Rock & Mineral Club
Meetings are on the 1st Tuesday
(unless a Holiday then 2nd Tuesday)
Next Meeting: September 2, 2025, 6:30 p.m.
www.dmrmc.com
@ Anthem Civic Building
3701 W. Anthem Way, Anthem, AZ

Maricopa Lapidary Society, Inc
Meetings are on the 3rd Tuesday
Next Meeting: August 19, 2025, 7:00 pm
www.maricopalapidarysociety.com
@ North Mountain Visitor Center
12950 N. 7th St., Phoenix, AZ

Mineralogical Society of Arizona
Meetings are on the 3rd Thursday
(Except June & December)
Next Meeting: September 18, 2025 @ 6:30
@ Franciscan Renewal Center, (Piper Hall),
5802 E. Lincoln Drive, Scottsdale, AZ
www.msaaz.org

Pinal Geology & Mineral Society
Meetings are on the 3rd Wednesday
Next Meeting: September 17, 2025, 7:00 pm
www.pinalgeologymuseum.org
351 N. Arizona Blvd., Coolidge

West Valley Rock & Mineral Club
Meetings are on the 2nd Tuesday
Next Meeting: July 8, 2025, 6:30 pm
www.westvalleyrockandmineralclub.com
Buckeye Community Veterans Service Center
402 E. Narramore Avenue, Buckeye, AZ

Gila County Gem & Mineral Society
Meetings are on the 1st Thursday
(unless a Holiday then the next Thursday)
Next Meeting July 3, 2025, 6:30 pm
www.gilagem.org
Club Building
413 Live Oak St, Miami, AZ

Wickenburg Gem & Mineral Society
Meetings are on the 2nd Friday
(February & December on the 1st Friday)
Next Meeting: September 12, 2025, 7:00 pm
www.wickenburggms.org
@ Coffinger Park Banquet Room
175 E. Swilling St., Wickenburg, AZ

ESM's Meeting Notice

ESM's next meeting will be at North Mountain Visitor Center, 12950 N. 7th St., Phoenix, on Tuesday, TBA 2025, at 6:30 p.m.

BECOME A MEMBER!
Join the Earth Science Museum's

IS IT TIME TO RENEW YOUR MEMBERSHIP?
Please renew today! ☺☺☺

_ _ _ _ _ _ _ _ cut here _ _ _ _ _ _ _ _ _

ESM Earth Science Investigation Team Membership Form

_____ New Member _____ Renewal

Membership levels:

_____ ESI Family $20

_____ ESI Individual $10

Membership benefits:

- Monthly e-newsletter *Earthquake*
- Official team membership card
- Knowledge that your contribution is making a difference in earth science education.

MANY THANKS TO OUR MAJOR DONORS!

AZ Leaverite Rock & Gem Society

Flagg Mineral Foundation
www.flaggmineralfoundation.org

Friends of the AZ Mining & Mineral Museum

Maricopa Lapidary Society
http://maricopalapidarysociety.com/

Mineralogical Society of AZ
www.msaaz.org

Payson Rimstones Rock Club
https://www.rimstonesrockclub.org/

Sossaman Middle School

White Mountain Gem & Mineral Club
www.whitemountain-azrockclub.org

Sun City Rockhound Club & Mineral Museum
https://suncityaz.org/recreation/clubs/rockhound-club-mineral-museums/

Wickenburg Gem & Mineral Society
http://www.wickenburggms.org
www.facebook.com/pages/Wickenburg-Gem-and-Mineral-Society/111216602326438

West Valley Rock and Mineral Club
http://www.westvalleyrockandmineralclub.com/

Staples Foundation
www.staplesfoundation.org

Anita Aiston	Will & Carol McDonald
Peter & Judy Ambelang	Debbie Michalowski
Stan & Susan Celestian	Janet Stoeppelmann
Russ Hart	Dennis & Georgia Zeutenhorst

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Editor E-Mail:
scote@earthsciencemuseum.org

We're on the Web!

Visit us at:

www.earthsciencemuseum.org

Mission
Our Mission is to excite and inspire all generations about earth sciences through educational outreach.

Vision
We envision a community where students and the general public have curiosity about, passion for, and understanding of the underlying principles of earth sciences.

For more information about the ESM, how to become a member or how to arrange for a school visit or Community function, go to: www.earthsciencemuseum.org.

NOTICE:
ESM's next meeting will be at North Mountain Visitor Center, 12950 N 7th St, Phoenix, on Tuesday, TBA 2025, at 6:30 p.m.

THANK YOU FOR YOUR CONTINUING INTEREST & SUPPORT!!!

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