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

Earth Science Museum, 3215 W. Bethany Home Rd., Phoenix, AZ 85017
www.earthsciencemuseum.org, scote@earthsciencemuseum.org, 602-973-4291

April 2024
Volume 13, Issue 4

ESM OUTREACH UPDATE

Mardy Zimmermann, Outreach Coordinator

April Outreach

There are no ESM outreach activities to report this month.

Earliest Earthquakes

By Harvey Jong

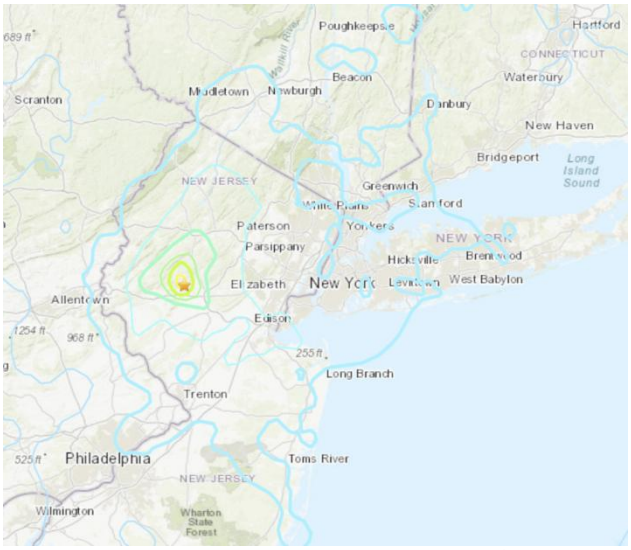
Earthquakes have been in the news lately with tremors occurring in Taiwan and New Jersey. These quakes along with a recent paper on new evidence of ancient earthquakes provided the inspiration for this article. We will explore some of the Earth's earliest earthquakes and how they provide clues on the mysterious beginnings of plate tectonics. But, first, let's take a quick look at the recent temblors.

Epicenter of Taiwan's April 3, 2024 Earthquake
Screen shot of USGS interactive map, - PD, via USGS.gov

On April 3, 2024, a magnitude 7.4 earthquake occurred 18 km (11 mi) from Hualien City on the eastern coast of Taiwan. The epicenter is shown by the star. The quake involved reverse faulting near the boundary of the Eurasia and Philippine Sea tectonic plates.

It was the strongest quake in 25 years, and at least 17 people have died while over 1,100 were injured. The shaking intensity is indicated by the Modified Mercalli Intensity (MMI) contours emanating from the epicenter. The orange-colored contour corresponds to an MMI intensity of 8. Building damage occurs above MMI 6.

Earthquake Damage in Hualien City, Taiwan
Hualien County Government photo, - copyrighted image used with permission, via Wikimedia Commons
This residential and commercial mix use building partially collapsed and was tilting at a precarious angle of over 25 degrees.



Epicenter of New Jersey's April 5, 2024 Earthquake
Screen shot of USGS interactive map, - PD, via USGS.gov

New Jersey experienced a magnitude 4.8 earthquake on April 5, 2024 which was the strongest tremor since 1783. The epicenter at Whitehouse Station in Tewksbury Township is indicated by the star. Unlike the Taiwan quake, this tremor did not occur near a plate boundary. Instead, the intraplate seismic event was a result of oblique reverse and strike-slip faulting within bedrock that formed when the Pangea supercontinent rifted apart about 200 million years ago.

The quake was felt in New York City, Philadelphia, and Washington, D.C. along with other parts of the northeast. The shaking intensity is indicated by the MMI contours. The MMI 6 contour appears in green. No major damage was reported.

Ancient Earthquakes

According to a new study by two New Zealand geologists, the oldest earthquakes may be found in eastern South Africa (Lamb and de Ronde, 2024). The researchers were working on a new, detailed geological map of the Barberton Greenstone Belt which covered fragments of the ancient deep seafloor. They noted something unusual about these seafloor fragments.

Location of the Barberton Greenstone Belt
Map prepared by the U.S. State Department, - PD, via Wikimedia Commons

The Barberton Greenstone Belt is located in eastern South Africa as indicated by the red highlighted area.

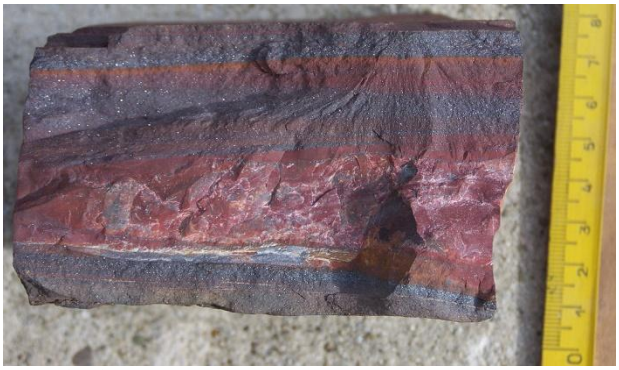
Background on the Barberton Greenstone Belt

The Barberton Greenstone Belt (BGB) is over 100 km (62.137 mi) long and 60 km (37.282 mi) wide. It is one of the oldest geological formations on the Earth, dating back over 3.5 billion years. This feature is well known for its complex geologic history, diverse rock sequences, and more than 300 gold occurrences. The area has been the focus of much activity starting in the 1880's by prospectors who were attracted by the region's gold deposits and more recently by geoscientists seeking insights into different aspects of Earth's early evolution.

Satellite View of the Mountains near Barberton, South Africa
Jeess Allan image created using NASA Landsat 7 data, - PD, via earthobservatory.nasa.gov
Acquired May 30, 2001

The area's characteristic greenstone is named for the green hue of metamorphic minerals, such as chlorite and actinolite, found within mafic to ultramafic rocks. The greenstone is comprised of strongly-folded, volcanic and sedimentary remnants deposited between 3.5 and 3.2 Ga and is surrounded by a variety of granitoid rocks that intruded over a 500 million year period. The rock sequences are well preserved and have provided some of the earliest evidence of a diverse microbial ecosystem.

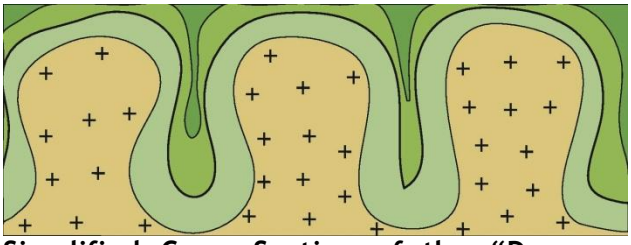
Verdite (Fuchsite Metamorphite)
James St. John photo, - CC_BY_SA-2.0, via Wikimedia Commons
From an Archean (4,031-2,500 Ga) age locality in South Africa, possibly the Barberton Greenstone Belt - 6.5 cm across



Banded Iron Formation Sample
Woudloper photo, sample courtesy of K. Lehmann and Prof. J.D. Kramers, - CC_BY_SA-1.0, via Wikimedia Commons
Moodies Group, Barberton Greenstone Belt, South Africa
Scale is in cm
The sample is from the Moodies Group which is the uppermost stratigraphic unit of the BGB. This unit has been dated ca. 3.22 Ga (billion years old), and includes a banded iron formation containing carbonaceous particles that may be the preserved organic matter of microbes.

Formation of the BGB

Although the structures of the BGB have been well-studied, how these structures formed remains uncertain. Numerous theories have been proposed, but none of the models fully explain the region's complex deformed strata.



Simplified Cross Section of the "Dome-and-Keel" Structure of the BGB
Morabiac diagram, - CC_BY_SA-3.0, via Wikimedia Commons
This cross section depicts domes of tonalite-trondhjemite-granodiorite in orange, while mafic and ultramafic layers wrapping around the domes appear in green.

Some current formation models include the following:

Accretion ("Subduction-Like Model")

The accretion model assumes that the tectonic environment at the time when the BGB formed is similar to present day plate tectonics. It maintains that the development of the BGB was dominated by horizontal movement of the Earth's crust. Through multiple subduction-like events, crustal layers converged and stacked onto an immobile craton (old and stable part of a continent).

Convective Overturn ("Lava Lamp-Like Model")

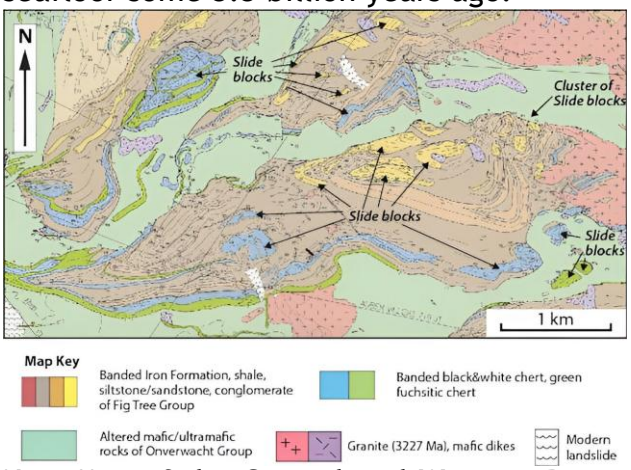
Convective overturn, which is also known as vertical tectonics, suggests that gravity-driven instabilities were responsible for the dome-and-keel structure. Similar to the "blobs" in a lava lamp, dense portions of an overlying greenstone layer sank down into a partially melted granitic middle crust. The granitic melts were forced sideways and upwards to form the dome structure.

Asteroid Impact ("Deep Impact Model")

In 2014, another theory was proposed that the creation of the BGB involved a huge asteroid impact event that occurred about 3.26 billion years ago. Based on the discovery of sand-sized spherule deposits with high concentrations of iridium and chromium isotope anomalies, geoscientists constructed a model of the extreme seismic waves produced by the impact and the resulting deformed structures (Sleep and Lowe, 2014). The asteroid was estimated to be around 37-58 km (23-36 mi) wide which is roughly five times the size of the impactor that caused the Chicxulub crater near the Yucatán Peninsula and the eventual dinosaur extinction.

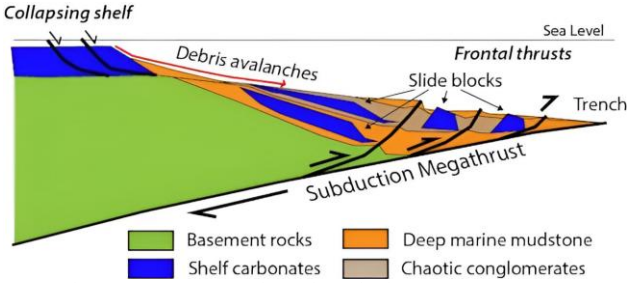
Unusual "Déjà Vu" Jumble of Rocks

Returning back to the article about the earliest earthquakes, the New Zealand geologists working on a new geological map of the BGB noticed something familiar about what would have been the ancient deep seafloor some 3.3 billion years ago.



New Map of the Central and Western Parts of the Barberton Greenstone Belt
Cornel de Ronde map, - CC_BY_SA-4.0, via phys.org
This map shows a jumble of volcanic and sedimentary rocks piled on top of huge "slide blocks".

The map was very similar to another geological map of the seafloor off the coast of New Zealand about 20 million years ago. The coastal region is situated along New Zealand's largest fault, the megathrust in the Hikurangi subduction zone. Frequent large earthquakes triggered submarine landslides of bedrock which resulted in random piles of slide blocks.



Profile of New Zealand Subduction Zone
Simon Lamb diagram, - CC_BY_SA-4.0, via phys.org
This diagram shows how frequent large earthquakes may have caused huge blocks of the continental shelf to collapse, slide down to the seafloor, and pile up on top of each

other. Debris avalanches from subsequent quakes later flowed down either surrounding or covering these blocks.

The striking similarity of the two maps suggests that ancient earthquakes involving subduction may have occurred around 3.3 billion years ago.

References:

Lamb, S. and E.J. de Ronde (2024) Large-scale submarine landslides in the Barberton Greenstone Belt, southern Africa—Evidence for subduction and great earthquakes in the Paleoarchean. *Geology.* Published online February 27, 2024 doi: 10.1130/G51997.1.

Sleep, N.H. and D.R. Lowe (2014) Physics of crustal fracturing and chert dike formation triggered by asteroid impact, ~3.26 Ga, Barberton greenstone belt, South Africa. *Geochemistry, Geophysics, Geosystems.* 15(4): 1054-1070.

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Side Note on Verdite

Verdite is the trade name for grayish green to bright green metamorphic rocks that are used as a semi-precious gemstone. The distinctive green color is due to the presence of fuchsite, a chromium-rich variety of muscovite mica. The name is derived from the Latin word virdis for “green”. (Note that verdite may be incorrectly labeled as “buddstone” which is actually a green variety of chalcedony.)

The composition of verdite may vary from mainly fuchsite to fuchsite mixed with minor amounts of albite, chlorite, corundum, quartz, rutile, and talc. As a result, its hardness may vary between 3 and 4. Verdite is usually opaque and has a vitreous, silky, or pearly luster.

The original occurrence of verdite was reported at the North Kaap River, Kaap Station, South Africa. As mentioned earlier, verdite has been found in the Barberton Greenstone Belt. It may be associated with gold deposits, such as the Sheba-Fairview Complex which hosts several gold mines. Other localities include Eswatini (formerly known as Swaziland, the small kingdom bordered by Mozambique to the northeast and by South Africa to the north, west, south, and southeast) and Zimbabwe which is recognized as an important source.

Verdite’s relative softness and foliated texture limits its gemstone applications that include cabochons, tumbled stones, and carvings. The native Shona people in Zimbabwe, South Africa, and Mozambique consider verdite to be a sacred stone and have created intricate sculptures and talismans.

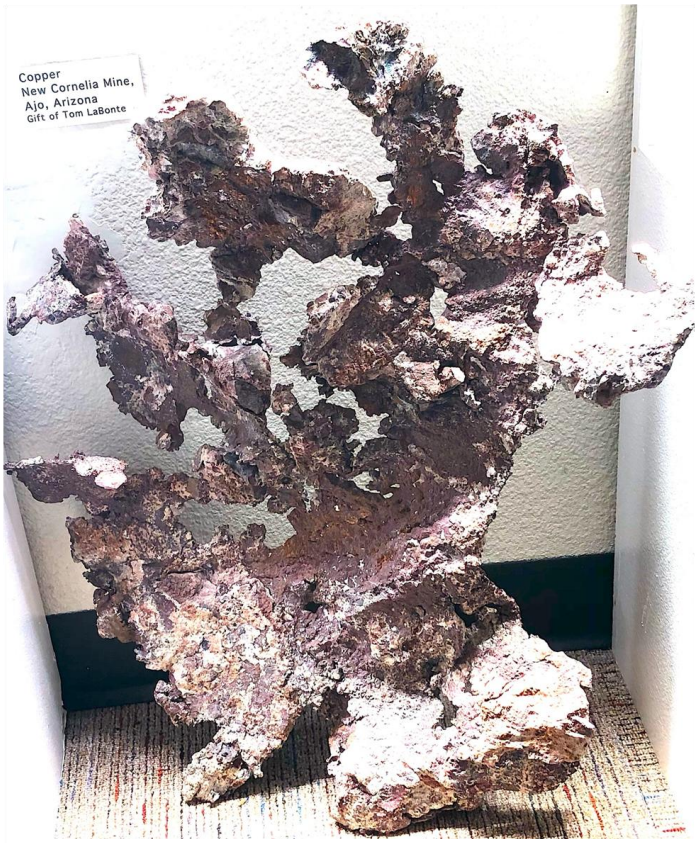
Verdite - Corundum (var. Ruby) and Fuchsite
Rob Lavinsky, iRocks.com photo, - CC_BY_SA-3.0, via Wikimedia Commons
Eswatini
6.9 x 4.5 x 2.2 cm

Arizona Rocks 131

Text by Ray Grant
Museum photographs

I have not said much about the Pinal Geology and Mineral Museum in this column, Shirley has done a great job reporting about our activities and meetings.

Following last month's rocks about native copper, I would like to invite you to visit the museum and see the native coppers shown here. Some you can touch or carefully pick up.



This large copper is from the New Cornelia Mine in Ajo. You are free to touch this one to feel the rough nature of the surface. It has a common alteration product of copper oxide. Specimen is a gift of Tom Labonte.

This copper is from the New Cornelia Mine in Ajo and shows how the oxide coating can be cleaned off the specimen. Gift of Sharleen Harvey

This copper from Ray Mine shows unusual twin crystals. Ray Mine has produced lots of copper and some of best copper specimens in the world. Loan from Ken Rippere

Copper is malleable and this copper stopped the crushers at Ray Mine and it took some hours to get it free and start crushing again. Gift of Mike Henry who helped to work it free

AZ Mining, Mineral & Natural Resources Education Museum Update April 2024

https://ammnre.arizona.edu/

Catie Carter Sandoval
cscarter@email.arizona.edu
703.577.6449

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

Earlier this month, we led an "egg carton minerals" activity for students at a local charter school. The activity invited students and their family members to pick six rock and mineral specimens (with labels) to take home in a six-count egg carton. The specimens included a combination of industrial minerals and collector favorites: coal, talc, chalcopyrite, calcite, red jasper, and rose quartz. Each group of specimens was accompanied by a sign listing the chemical formula, as well as information about mineral properties and common uses. The students loved selecting their own pieces and sharing their own knowledge about earth science. I asked several students to name their favorite rock or mineral of the evening and the overwhelming response was… coal! We brought over 200 specimens of each mineral and by the end of the evening, almost every piece was gone. We look forward to continuing our educational outreach this summer.

In other news, new Executive Director Marta continues her own education of all things rocks, minerals and historic mining equipment. She recently met with a small group of millmen (including Andre and Bill L.) led by Monday Crew leader Bill Yedowitz. Bill gave Marta a full primer on the outdoor mining equipment including the history, how each item was used, and how they can be utilized today as part of the mining equipment demonstrations. This was a great opportunity for Marta to learn more about the equipment and see our volunteers in action.

This spring and summer we will continue to move forward with museum planning and will keep you posted about any important updates. Thank you so much for supporting the AZ Mining, Mineral and Natural Resources Education Museum.

"Egg Carton Minerals" display with instructions and completed egg carton. Specimens included coal, talc, chalcopyrite, calcite, jasper, and rose quartz.

Students picking their specimens at the egg carton mineral activity.

Bill Y. and Marta watch the Swallow Mine 5-stamp mill in action, while Bill L. operates the mill above.

Pinal Museum and Society News

351 N. Arizona Blvd., Coolidge, AZ

Pinal Geology and Mineral Society next meeting

May 15, 2024

Meetings are the third Wednesday at 7pm, doors open at 6:30

Everyone is welcome!

www.pinalgeologymuseum.org

Ray Grant ray@pinalgeologymuseum.org

Through May, museum hours are 10 to 4 Wednesday through Saturday, admission is free.

The Pinal Geology and Mineral Society's May 15th meeting program will be:

Geologic features and other good places to visit in Arizona during the hot summer

Sun City Rockhound Mineral Museum
Sundial Recreation Center
14801 N. 103RD Ave.
Sun City, AZ 85351
scrockmuseum@gmail.com
623-428-6442

C. Sandoval photo

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

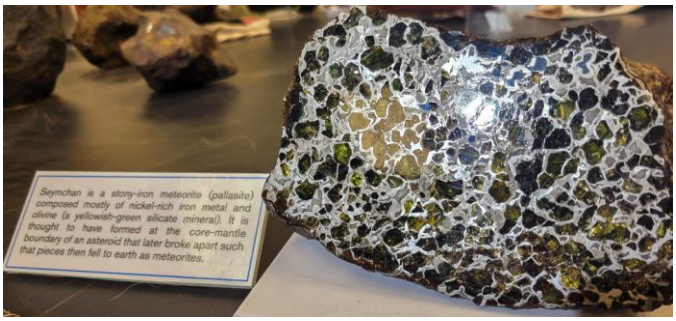
The Sun City Rockhounds explore Mars, the Moon and Meteorites at ASU
By Colin Morley, Sun City Rockhound Club

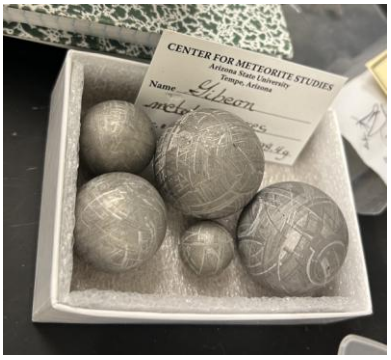
In our 60th anniversary year the club looked as far into the past as it is possible to do by handling rocks. Surrounded by rocks that came from space our rockhound club was taken into the highly secure "Vault" at the Center for Meteorite Studies at ASU. Our thanks to Meg Hufford from ASU for her invaluable help on securing this visit for the club.

Founded in 1961, the center is one of Arizona State University's first-established research institutes, and it is home to one of the world's largest university-based meteorite collections. This is not the first time that our Rockhound club has been invited for a visit, and hopefully not the last. The person using codes to unlock the doors to the first outer chamber and letting us in was the Collection Curator, Laurence A. J. Garvie. He is a Research Professor, School of Earth & Space Exploration. He achieved his PhD. at the University of Bristol (1992) – Dr. Garvie deciphers early Solar System processes through the use of innovative, high-spatial-resolution electron microscopic and spectroscopic studies of meteorites. Laurence then prepared us to move into the inner sanctum. Bags were left in the outer chamber and we moved through into a highly controlled, low humidity environment, past a barrier designed to ensure that the 'outside' stayed outside. Laurence is very enthusiastic about his job and had the ability to pitch the information in a way that we could understand it. He sorted out some samples of meteorite that we could handle and explained a little about each.

We were introduced to each of the meteorite groups. The samples ranged from extremely dark and heavy nickel-iron meteorites to very light (in color and in weight) silicate examples.

Dr. Laurence Garvie explaining the different types of meteorites

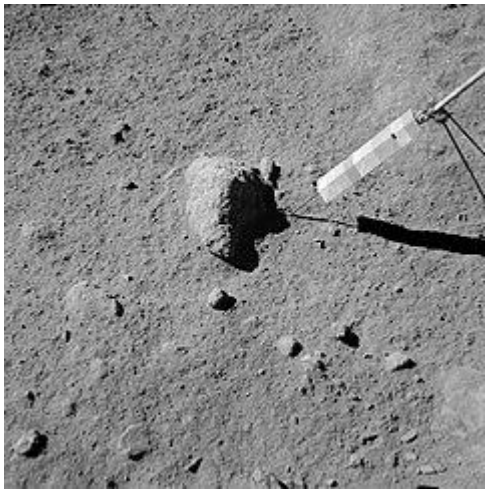




Pallasite a stony-iron meteorite (above)
Gibeon iron meteorite (left)
All photos by Carol George except where noted.

We were also hosted by Dr Steve Ruff, a Research Professor (FSC), of the Mars Space Flight Facility at ASU. Steve is a planetary geologist with a focus on the mineralogy of Mars determined via infrared spectroscopy, part of an effort to understand the geologic history of Mars and potential for past habitability. Through field work in Mars analog settings and laboratory work using field samples, his work is to better interpret observations from Mars. Steve Ruff may be better known to established club members from his annual talks on the progress of the Mars missions and latest discoveries. Steve has been a meeting guest speaker to Sun City Rockhound club for 20 years. Steve may be known to others as "Mars Guy" from his YouTube videos. They are worth watching.
Steve took us into a laboratory that he uses and explained the process for obtaining a signature from rocks and using earth processes and rocks to add geologic understanding to the Martian findings.

We rounded off the day by seeing the control room where real-time data arrives from the moon for later analysis. We couldn't leave that building without seeing a large-ish chunk of Moon rock that was collected at the Apollo 15 landing site. This alien rock was brought back and has been extensively examined and tested and is more formally known as sample 15555. It is basalt and basalt is probably the most common rock in Arizona. It may only be a relatively common type but – this erupted and crystallized almost 3.3 billion years ago. However, this rock is predominantly composed of silicate minerals such as olivine, pyroxene, plagioclase, along with some opaque minerals such as ilmenite, an iron-titanium oxide. All of the basalts collected at the Apollo 15 site were found to be the same age, and it is likely that they are related geologically. The bulk composition of 15555 is thought to represent that of a primitive volcanic melt and has been used for experimental studies related to the geologic origin of lunar basalts. Planetary scientists use information gleaned from such analyses to gain key insights into how terrestrial planets like the Moon and Earth form and evolve. Our thanks to Col. David Scott for collecting it on his field trip to the moon.
Our thanks to all at ASU who made this trip possible.



Lunar Sample 15555, "Great Scott": on the lunar surface prior to collection. The object at right is a gnomon, used for scale.
Photo by NASA, Apollo 15

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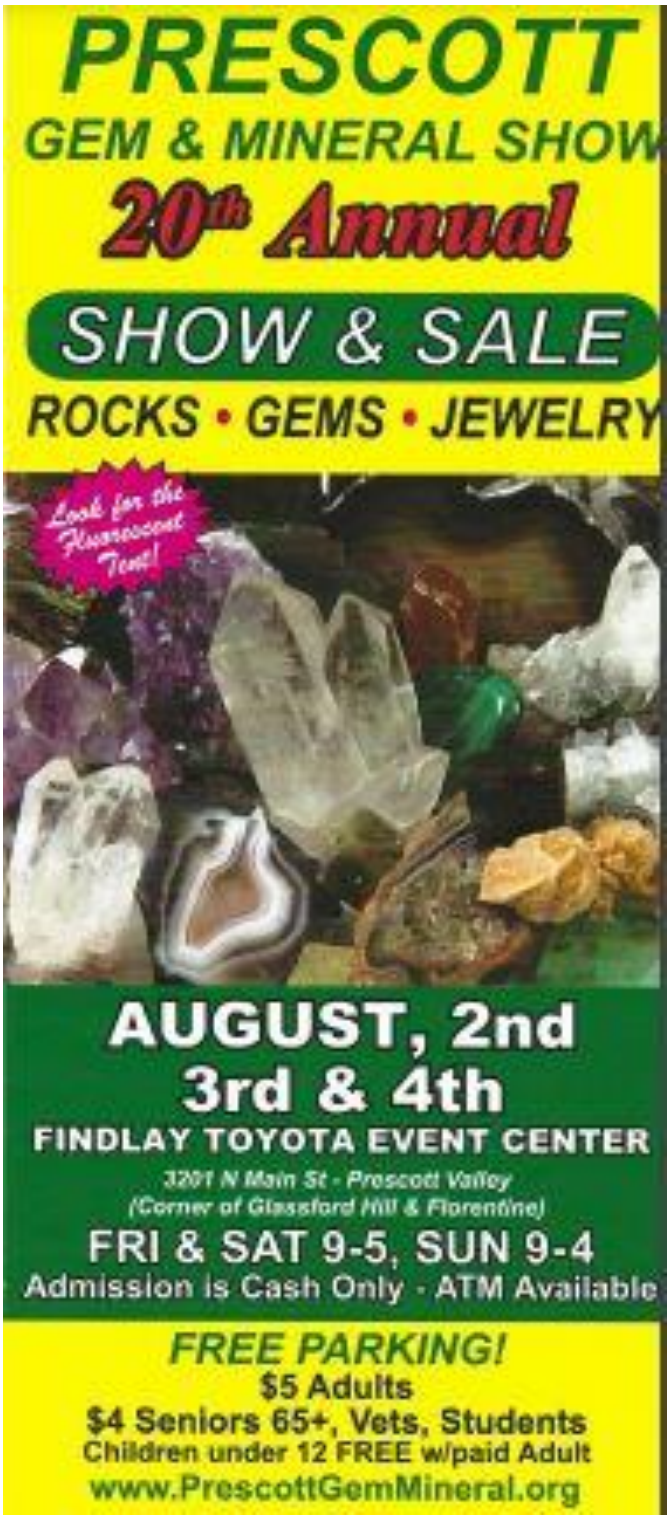
Arizona Rock and Gem Shows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www.PrescottGemMineral.org


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mingusgem.club
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Cabochons • Findings • Rock Slabs
Geode Splitting • Daily Raffles
Jr. Rockhound Room Activities
and much more!

Apache Junction Rock & Gem Club
Meetings are on the 2nd Thursday
Next Meeting: May 9, 2024, 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: May 7, 2024, 6:30 p.m.
Please go to their website for more info
www.dmrmc.com
@ Anthem Civic Building
3701 W. Anthem Way, Anthem, AZ

Maricopa Lapidary Society, Inc
Note: New meeting day
Meetings are on the 3rd Tuesday
Next Meeting: May 21, 2024, 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 December & June)
May 16, 2024, 7:30 pm
Franciscan Renewal Center, (Piper Hall)
5802 E. Lincoln Drive, Scottsdale
www.msaaz.org

Pinal Geology & Mineral Society
Meetings are on the 3rd Wednesday
Next Meeting: May 15, 2024, 7:00 pm
In person meeting
www.pinalgeologymuseum.org
351 N. Arizona Blvd., Coolidge

West Valley Rock & Mineral Club
Meetings are on the 2nd Tuesday
Next Meeting: May 14, 2024, 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: May 2, 2024, 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: May 10, 2024, 7:00 pm
www.wickenburggms.org
@ Coffinger Park Banquet Room
175 E. Swilling St., Wickenburg

ESM's Meeting Notice

ESM's next meeting will be at North Mountain Visitor Center, 12950 N. 7th St., Phoenix, on Tuesday, TBA 2024, at 6:30 p.m.

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Join the Earth Science Museum's

esi: Earth Science Investigation team

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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

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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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.

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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 2024, at 6:30 p.m.

THANK YOU FOR YOUR CONTINUING INTEREST & SUPPORT!!!

Earth Science Museum
3215 W. Bethany Home Rd.
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