EARTHQUAKE
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

February 2025
Volume 14, Issue 2

ESM OUTREACH UPDATE

Mardy Zimmermann, Outreach Coordinator

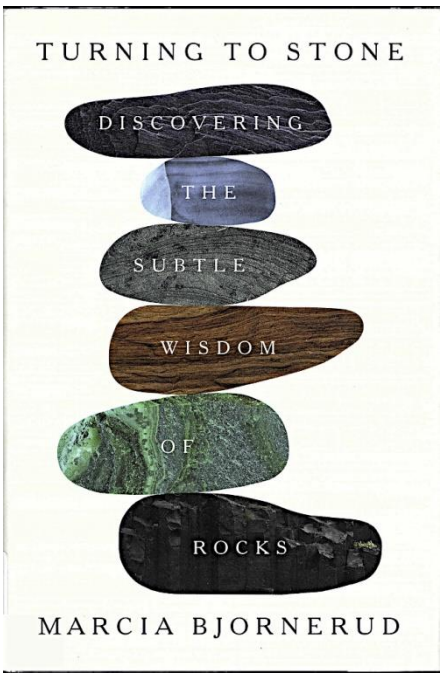
There are no ESM outreach activities to report this month.

◊ ◊ ◊

A Brief History of Granite

By Harvey Jong

One of the books that I read this month includes *Turning to Stone: Discovering the Subtle Wisdom of Rocks* by structural geologist and Fulbright Scholar Marcia Bjornerud[1].



The book is part memoir, part travelogue, and part call to become a mindful inhabitant of our amazing, self-reinventing planet.

The author describes several of her far-flung geological adventures through the perspective of the underlying rocks. She shares her insights and discoveries in revealing their eventful histories. Each chapter is devoted to a specific rock, and this article presents some illustrated highlights from the chapter on granite.

Granite: Popular Building Material & Puzzling Rock

The durability, beauty, and versatility of granite have made the igneous rock a favored building material. It has been used for millennia from monuments in ancient Egypt to present-day capitol domes and kitchen countertops.

[1] Marcia Bjornerud (2024), Turning to stone: discovering the subtle wisdom of rocks. Flatiron Books, New York: 308 p.

Wisconsin State Capitol Building
Ryan Wick photo, - CC_BY_SA-2.0, via Wikimedia Commons
The exterior dome of the Wisconsin State Capitol building in Madison, Wisconsin is constructed of Bethel white granite from Vermont. The 49.4 m (162 ft) tall dome is distinctive in being the only granite capitol dome in the United States and in having the largest volume.

The occurrence and abundance of granite is also enigmatic, and its origin has been the focus of one of the longest-running debates in geology. The term granite is derived from the Latin word *granum* for "grain" which refers to the rock's coarse-grained texture. It is the best known igneous rock and is composed primarily of quartz, potassium feldspar, plagioclase, but may also contain muscovite, "biotite"[2], and amphibole minerals.

"Biotite" Granite
B. Domangue photo, - CC_BY_SA-4.0 International, via Wikimedia Commons
St. Cloud, Minnesota

Abraham Gottlob Werner and Neptunism

The controversy surrounding the nature of granite started around the late 18th century, when Abraham Gottlob Werner (1749-1817), a German geologist, proposed a theory that the rocks and minerals in the Earth's crust, including granite, were deposited from seawater. The theory, which was known as Neptunism, maintained that the Earth was once covered by a vast universal ocean and that the rocks on its surface formed by either physical sedimentation or chemical precipitation as the ocean receded. Igneous rocks, such as basalt and granite, were interpreted as marine deposits which required a completely different ocean composition than that of modern seas. Lava from volcanoes presented a challenge for the theory, but was explained as a special case in which rocks could be melted as a result of burning coal seams.

Abraham Gottlob Werner (1749-1817)
Portrait by Christian Leberecht Vogel (1759-1816), - PD, via Wikimedia Commons

[2] Note that biotite appears in quotes since the International Mineralogical Association no longer recognizes it as a valid species name.

James Hutton and Plutonism

James Hutton (1726-1797)
uwGnf-Sew_8MjQ photo of portrait by Henry Raeburn (1756-1823), - PD, via Wikimedia Commons

James Hutton (1726-1797) was a Scottish geologist, agriculturist, and physician who formulated a rival theory. Hutton inferred that the Earth has been undergoing slow but continuous change and that rocks formed from processes driven by magmatic activity. This theory was called Plutonism, and for many years he searched for supporting evidence.

He found the "smoking gun/intrusion" at a rock outcrop in the upper end of Glen Tilt, Perthshire, Scotland.

Outcrop with Granite Intruding a Mica Schist
Bbousman photo, - CC_BY_SA-4.0 International, via Wikimedia Commons
This rock exposure at Dail-an-eas Bridge upstream of Forest Lodge in Glen Tilt, Scotland represented the definitive evidence that James Hutton was searching for to support his theory on the formation of the Earth.

"Room Problem" and Granitization

By 1900, Hutton's concept of granite as a solidified magma was accepted by most geologists. The magmatic theory, however, did not adequately explain massive granite bodies, such as the Sierra Nevada Batholith.

View from Glacier Point, Yosemite National Park

James St. John photo, - CC_BY_SA-2.0, via Wikimedia Commons

The granites of Yosemite Valley and Half Dome are part of an extensive intrusive complex called the Sierra Nevada Batholith.

If these features involved magma intruding into other rocks, how was the space for the magma created and what happened to the rocks that were intruded? This conundrum became known as the "room problem".

Some geologists suggested that granites were not magmatic intrusions but formed by the chemical transformation of sedimentary rocks through a cryptic process called "granitization".

Doris Reynolds (1899—1985)

Unknown photographer, via pinterest.com/pin/529032287453165665

Doris Reynolds (1899—1985, also known by her married name Doris Holmes) was a British geologist who developed a theory that fluids moving upwards in the crust penetrated and altered the existing host rock into granite. This "transformist" hypothesis was hotly debated in the geoscience community until the 1960s and was called the "Granite Controversy". Granitization was later abandoned due to the inability to identify the source of "emanations" that supposedly transformed sediments into granite.

Norman Bowen and Fractional Crystallization

Since Hutton's time, a wide range of igneous rock types had been identified which posed another dilemma for the magmatic theory. The different rock types suggested a "plum pudding" model of the mantle with distinct magma reservoirs of different compositions. Such a model, however, is inconsistent with the propagation of seismic waves from earthquakes that indicate a relatively uniform mantle consisting of the rock type, peridotite.

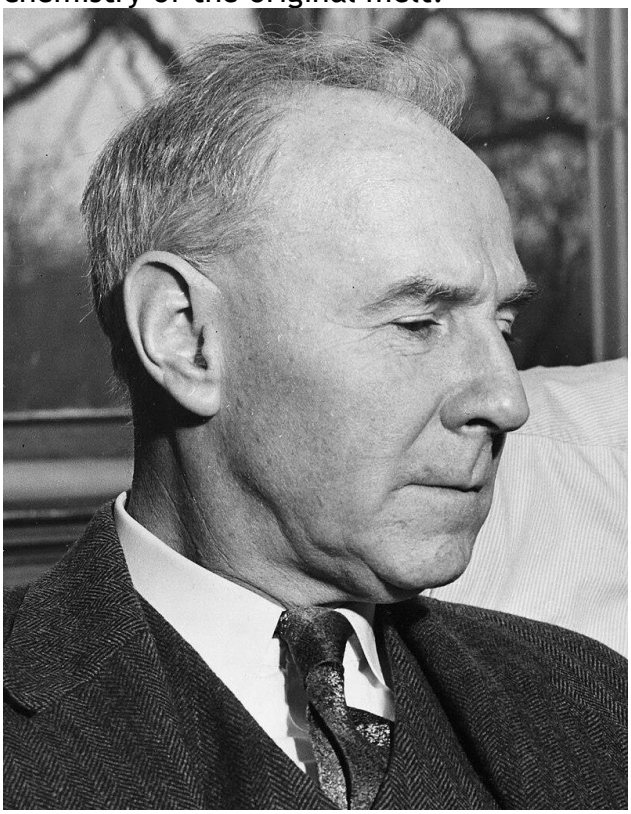
Peridotite with Peridot Xenoliths

Harvey Jong specimen and photo
Peridot Mesa, San Carlos Apache Indian Reservation, Gila County, Arizona
Dimensions: 11 x 9 x 6.5 cm

Peridotite is made mainly of iron- and magnesium-rich silicate minerals, so this raised the issue of how did all the other rock types, including granite, with little or no iron or magnesium form.

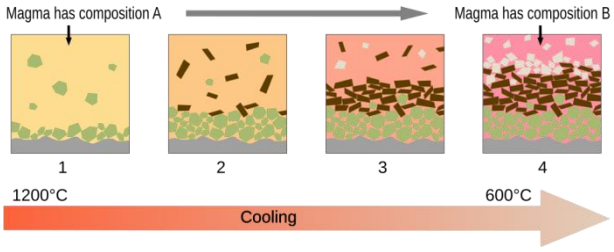
The solution to this problem emerged in the 1920s when experimental geochemist Norman Bowen (1887-1956) prepared lab samples representing the mantle and observed that different minerals crystallize at different temperatures. As solidified crystals settled out by the influence of gravity, the remaining melt evolved towards

compositions far different from the chemistry of the original melt.



Norman Bowen (1887-1956)
Smithsonian Institution photo, - no known copyright restrictions, via Wikimedia Commons

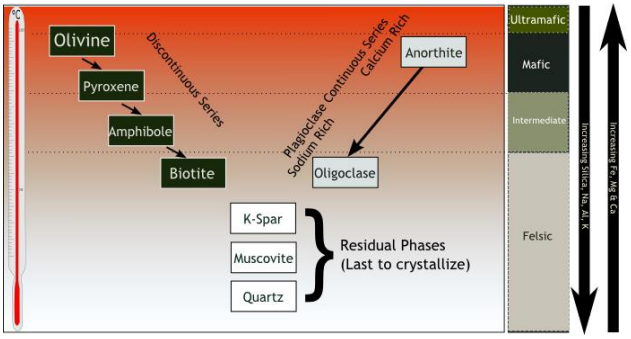
This fractional crystallization process is similar to the process of crude oil distillation where different types of hydrocarbons, such as diesel oil, kerosene, and gasoline, are refined based on their different boiling points.



Fractional Crystallization
Woudloper diagram, - CC_BY_SA-3.0, via Wikimedia Commons
The principles behind fractional crystallization are shown in this diagram. While cooling, magma composition evolves as different minerals crystallize from the melt:

1. Olivine crystallizes
2. Olivine & pyroxene crystallizes
3. Pyroxene & plagioclase crystallizes
4. Plagioclase crystallizes

The sequence in which minerals crystallize from a magma with decreasing temperature is called the "Bowen's reaction series."

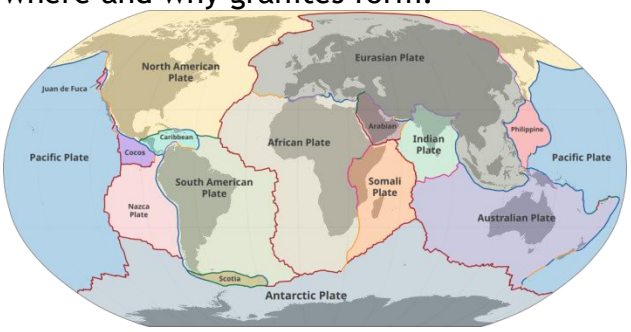


Bowen's Reaction Series
Colvine diagram, - CC0-1.0 UPD, via Wikimedia Commons

Geologists who supported granitization were aware of Bowen's work, but they dismissed the relevance of his lab results in explaining the complex geology in the "real" world. They severely criticized and ridiculed Bowen, and sadly Bowen died by suicide in 1956.

Plate Tectonics, Meteorite Bombardment, and Early Granite Formation

Around the mid-to-late 1960s, the theory of plate tectonics was accepted by geoscientists. It provided a framework for where and why granites form.



Map of the Earth's Principal Tectonic Plates

M. Bitton map, - CC_BY_SA-3.0, via Wikimedia Commons

This map depicts the different plate boundary types where the colored lines indicate the following:

- Spreading center
- Extension zone
- Subduction zone
- Collision zone
- Dextral transform
- Sinistral transform

Three major tectonic settings where granite and its volcanic equivalent, rhyolite, has and continues to be generated include:

1. Continental arcs above subduction zones, such as the Cascades
2. Continental rift zones, such as the East African rift
3. Continental hot spots, such as Yellowstone

These production sites, however, present a "chicken-and-egg" problem. It seems that granites have developed in areas where continental crust, which is dominated by granitic rocks, already existed. In addition, about 70 percent of the current continental crust was formed prior to three billion years ago which is before the time that most geologists believe that the subduction-dominated, granite-producing plate tectonic processes started on the Earth.

The Acasta Gneisses found in northwestern Canada, represent the oldest known surviving Earth rocks. They formed 4.2 billion years ago and have a granitic composition.

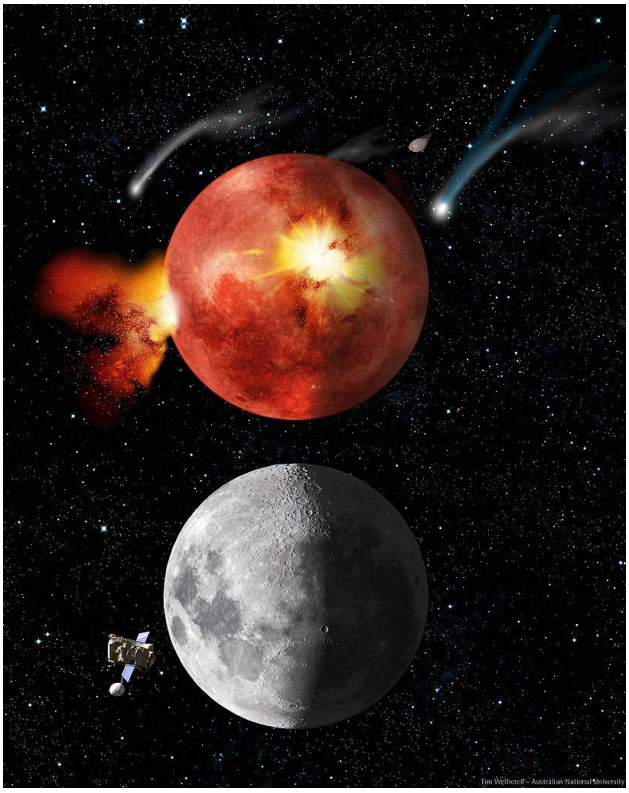
Acasta Gneiss

Pedroalexandrade photo, Natural History Museum in Vienna specimen, - CC_BY_SA-3.0, via Wikimedia Commons

The Acasta Gneiss is a highly deformed and metamorphosed tonalite, trondhjemite, and granodiorite (TTG) rock.

These oldest remnants along with younger granitic rocks found in shield areas of all modern continents seem to exhibit evidence of interaction with water. This may provide a hint as to how the Earth might have laid down the granite foundations of the continents before subduction began.

One possible scenario that has been proposed involves an extraterrestrial connection. Around 4.2 to 3.8 billion years ago, the inner Solar System may have experienced an unusually large number of asteroid and comet collisions. This period is called the Late Heavy Bombardment, and evidence of these impacts is seen on the Moon where the primordial crust may have been punched through by meteorites resulting in the dark, basalt-filled basins known as maria (term derived from the Latin word for "sea").



Artist Conception of the Moon During and After the Late Heavy Bombardment
Timwether illustration, - CC_BY_SA-3.0, via Wikimedia

Similar giant impacts may have occurred on the Earth fracturing its crust (Johnson et al., 2022). The cracks may have allowed surface water to infiltrate deep inside the Earth which aided the process of fractional melting. The formative basaltic mantle may have been heated by convection and interacted with the water to yield magmas with compositions that were more granite-like. Through successive iterations over time, a bottom-up "refining" of these magmas yielded the large volume of granite that make up the continental crust.

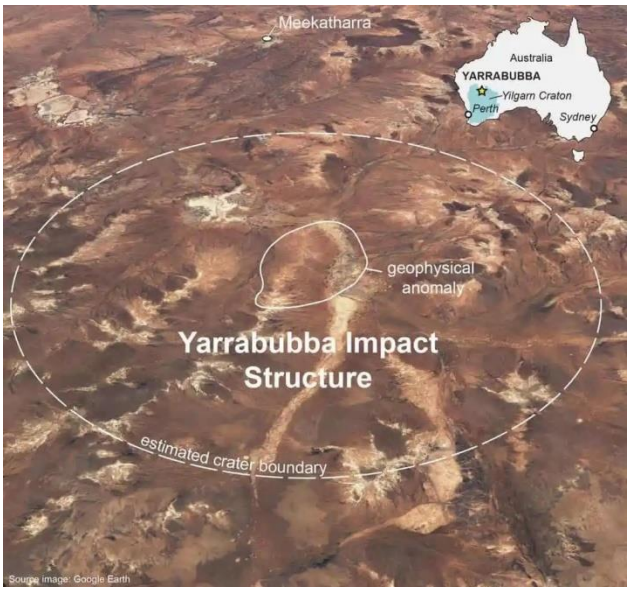
References

Johnson, T.E., C.L. Kirkland, Y. Lu, R. Hugh Smithies, M. Brown, and M.I.H. Hartnady. (2022) Giant impacts and the origin and evolution of continents. *Nature* 608: 330-355.

◊ ◊ ◊

Earth's Oldest Meteorite Impact Structure

Due to erosion and tectonic activity, no meteor craters from the Late Heavy Bombardment have survived on Earth. The oldest known impact structure is an eroded crater remnant located in Western Australia near Yarrabubba Station. Based on uranium-lead radiographic dating of shock-recrystallized monazite, the age of the 70 km (43.5 mi) diameter Yarrabubba impact structure has been established at 2,229 ± 5 million years ago (Erickson et al., 2020).



Yarrabubba Impact Structure
Erickson et al., 2020 image

Since no crater remains, the impact structure was detected by an aeromagnetic anomaly.

While the structure's age places it after the Late Heavy Bombardment, the impact roughly coincides with the age of the youngest Paleoproterozoic glacial deposits. That period in Earth's geological history has been dubbed "Snowball Earth" which is a completely different story.

References

Erickson, T.M., C.L. Kirkland, N.E. Timms, A.J. Cavosie, and T.M. Davison (2020) Precise radiometric age establishes Yarrabubba, Western Australia, as Earth's oldest recognized meteorite impact structure. *Nature Communications* 11, 300, 8 p.

◊ ◊ ◊

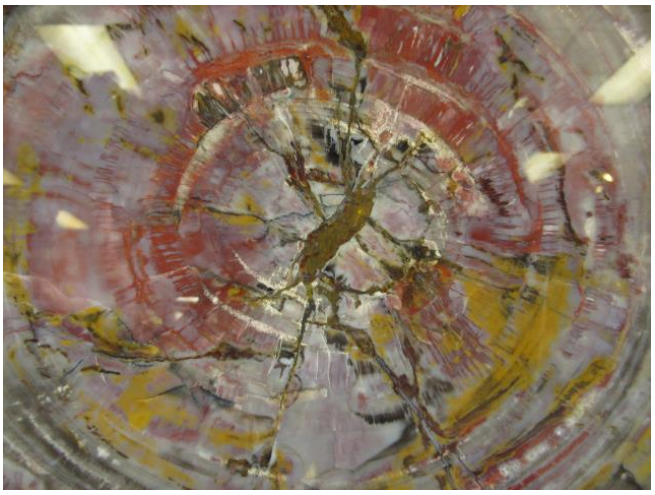
Arizona Rocks 141

Text and photos by Ray Grant

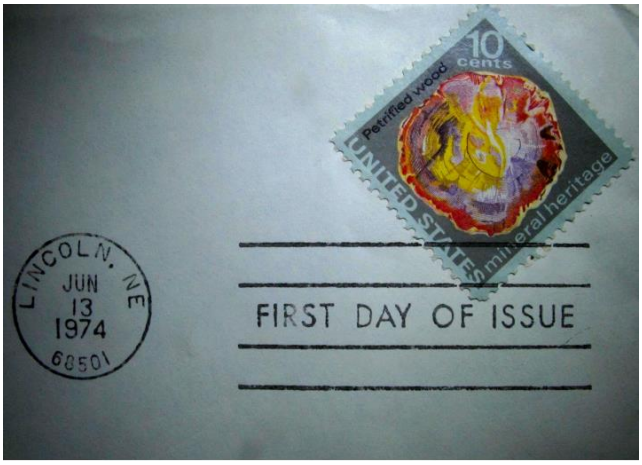
Several Arizona minerals appear on United States postage stamps. Petrified wood is the mineral quartz and the Arizona state fossil. It was on a stamp issued on June 13, 1974. It was named the state fossil in 1988. It is part of a set of four stamps with amethyst, rhodochrosite, and tourmaline (elbaite) on quartz.

Two other Arizona minerals are on stamps. They are azurite from Bisbee and wulfenite from the Red Cloud Mine. These stamps were issued on September 17, 1992 as part of a set of four with copper and variscite.. Wulfenite was made the Arizona state mineral in 2017. They announced the first day of issue in advance so I printed the special envelopes and sent them to the Post Office to get the first day of issue stamp.

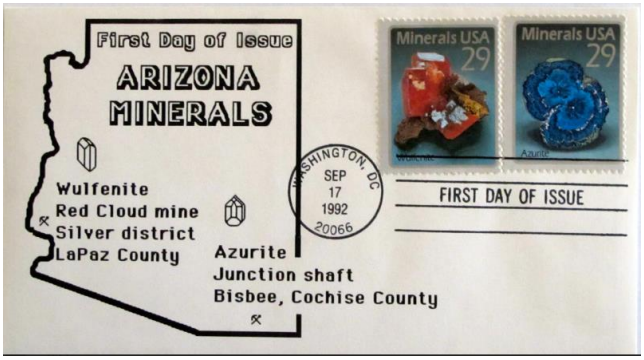
So for the eight United States mineral stamps, three are from Arizona.



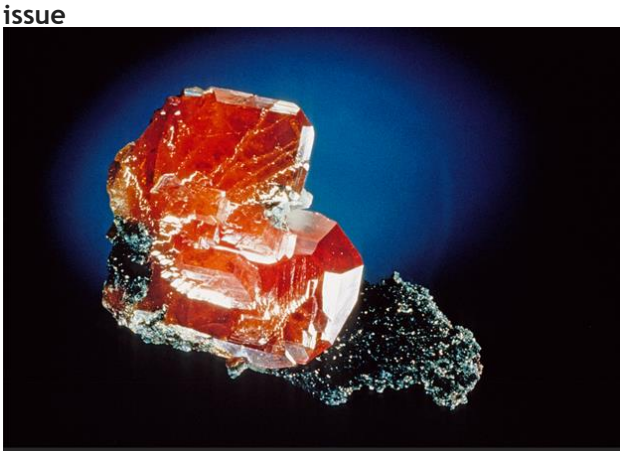
Petrified wood from Petrified Forest



Arizona petrified wood stamp first day of issue



Arizona wulfenite and azurite stamps first day of issue



Red Cloud wulfenite specimen

Azurite specimen used for stamp at Smithsonian exhibit in Tucson

Pinal Museum and Society News

351 N. Arizona Blvd., Coolidge, AZ

Pinal Geology and Mineral Society next meeting

March 19, 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
September – May hours are Wednesday – Saturday from 10-4, admission is free.
Groups can arrange special visits please call 520-723-3009.

Our March 19 meeting program will be Stephen Reynolds and Julia Johnson about their new book "The Roadside Geology of Arizona".

On February 19, 42 students visited the museum, and February 20, 39 students visited. They were first grade students from the West School in Coolidge. Each student was given a question sheet with photographs of a number of exhibits in the museum and when they found the exhibit in the photograph, they marked it on the paper. When they left, they were all given a treasure bag containing some fossil and mineral samples.

AZ Mining, Mineral & Natural Resources Education Museum Update February 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 February we participated as a special exhibitor at the 70th Annual Tucson Gem and Mineral Show at the Tucson Convention Center, which ran from February 13 to 16, 2025. As we mentioned in last month's update, this year's theme was "Shade of Green: Experience the Magic!" and we chose to do an educational display that showcased some of the different minerals and ores needed to transition from fossil-fuel based energy to clean energy over the coming decades. Our exhibit featured a small selection of specimens from the museum collection, organized by native element: copper, silver, lithium, aluminum, cobalt, chromium, nickel, silicon, graphite, manganese, molybdenum and zinc. Each grouping included basic information about the element and how it is used for building clean energy infrastructure, with a representative specimen or specimens from either Arizona or North American-based localities. The only exception was a manganese nodule from the Pacific Ocean floor. It was fun to see visitors reading our labels and taking photos. We look forward to our next gem show exhibit at the Denver Gem and Mineral Show in September!

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

In addition to participating in STEAM events, 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.

Sun City Rockhound Club and Mineral Museum
Education Outreach STEAM Event
By Cynthia Malkowski Publicity Chairperson

This season, our Rockhound Education Committee is participating in several STEAM events in order to share our knowledge of rocks and minerals with this wonderful educational program. Our most recent events were held at Desert Harbor Elementary in Peoria and at Scottsdale's Black Mountain Elementary, with an upcoming event at Peoria's Cheyenne Elementary.

Our Education Committee consists of eight active and devoted club members. Many of whom are former educators, who represent the club at these school events.

Per Desert Harbor elementary, January 31 "was our 3rd annual STEAM Night! We had so many amazing community partners come out and showcase what they are all about! Students got to experience how Science, Technology, Engineering, Art, and Mathematics apply to real jobs and activities!"

Sun City Mineral Museum Open House and Annual Rock Sale Event Details

C. Sandoval photo

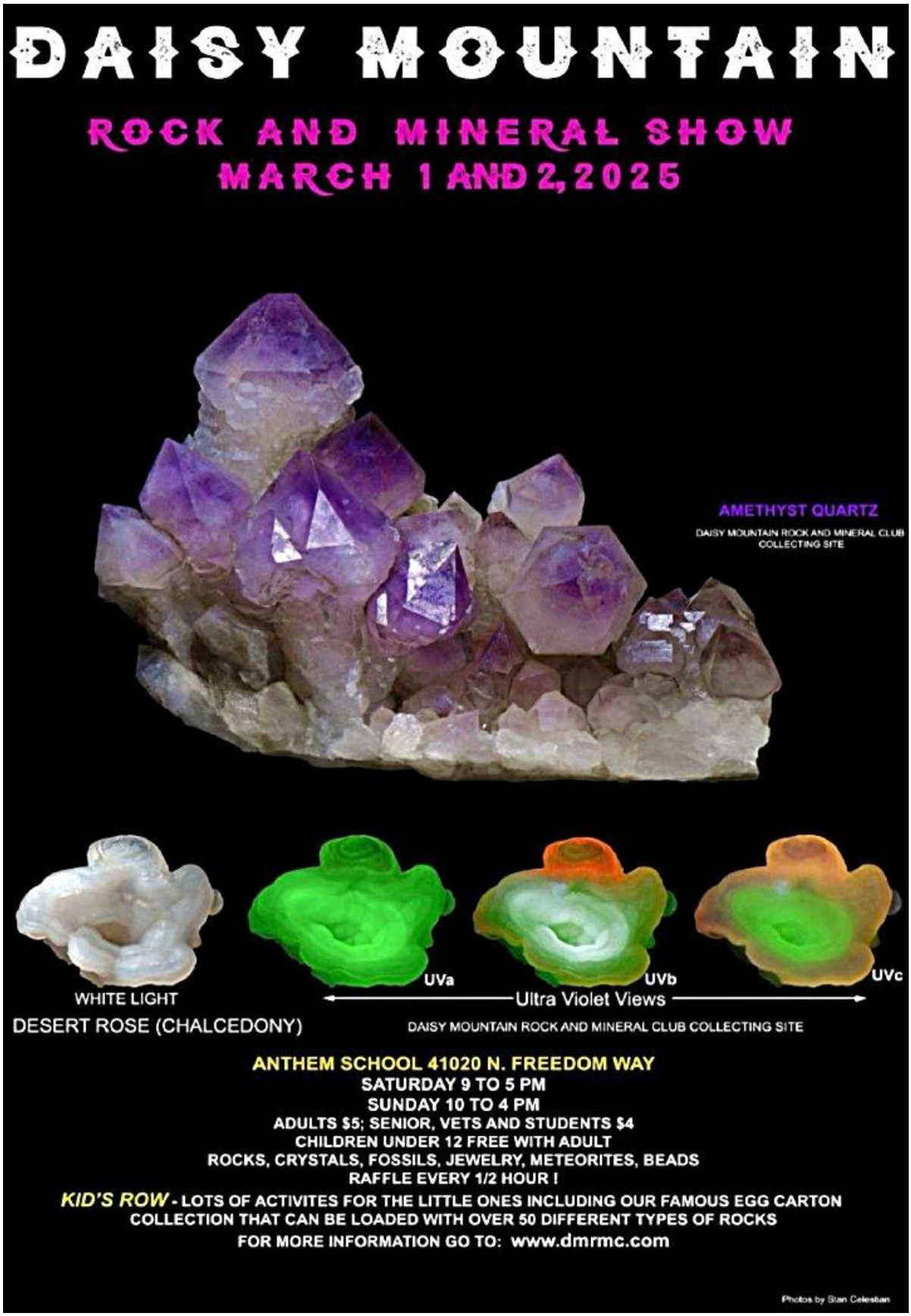
Winter Hours
October – April
10 am to 1 pm
Closed Thurs., & Sunday
Summer Hours
May-September 10am-1pm
Saturdays only

- Museum open house March 7-8
  - Time: 9AM -2PM
- Location: Sun City Mineral Museum
- Sun Dial Recreation Center 14801 N. 103rd Ave, Sun City AZ.85351
- Rock Sale March 8th,
  - Time: 8AM-1PM
- Location: Sun Dial Recreation Center breezeway

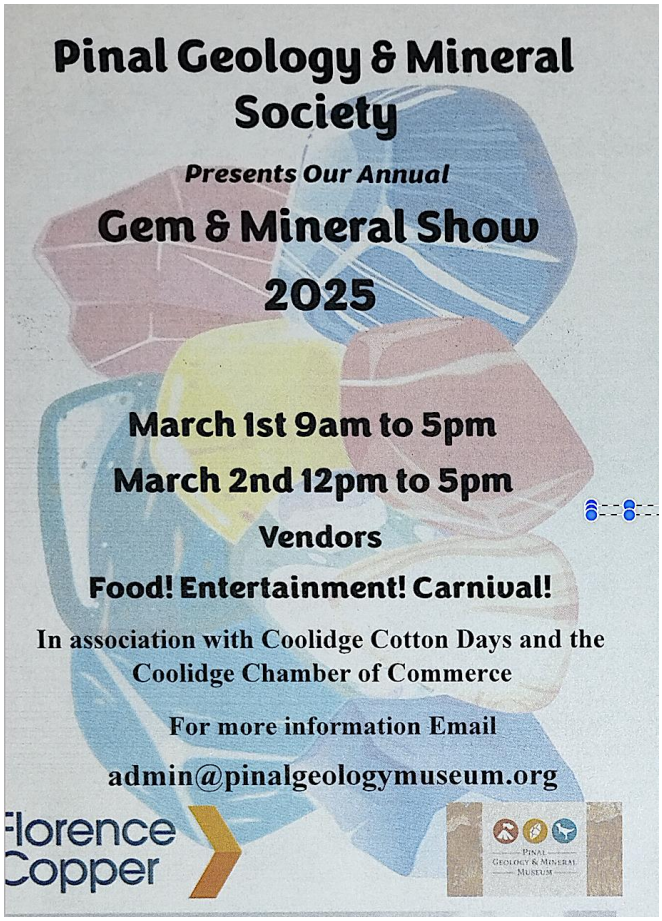
Purchase specimens at rock bottom prices! Slabs, landscaping rocks, minerals from private collections! Egg carton specimens for one dollar! Something for every level of collector!

Members of our dedicated Education Committee

Arizona Rock and Gem Shows



Arizona Rock and Gem Shows



MOHAVE CO. GEMSTONERS
KINGMAN, ARIZONA

Annual show

Mohave County Gemstoners

May 3, 4, 2025

Sat. 9-5, Sun. 9-4

Free admission and parking

Mohave County Fairgrounds
2600 Fairgrounds Blvd.
Kingman, AZ

Arizona Rock and Gem Shows

Apache Junction Rock & Gem Club
Meetings are on the 2nd Thursday
Next Meeting: March 13, 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: March 4, 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: March 18, 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 December & June)
March 20, 2025
@ 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: March 19, 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: March 11, 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 March 6, 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: March 14, 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

esi: Earth Science Investigation team

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

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

Name: _____

Address: _____

City, State, Zip: _____

Email: _____

Phone Number: _____

Mail form & payment to: Earth Science Museum
3215 W. Bethany Home Rd., Phoenix, AZ 85017

For Office Use Only

Card given/mailed: _____

Database updated: ☐ Distribution Lists updated: ☐

Card ID # _____ Expires: _____

Earth Science Museum
3215 W. Bethany Home Rd.
Phoenix, AZ 85017

Phone:
602-973-4291

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!!!

Earth Science Museum
3215 W. Bethany Home Rd.
Phoenix, AZ 85017