EARTHQUAKE

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

National Fossil Day, Wednesday, October 14, 2020

An outcrop of the Permian Kaibab Limestone, north of Pine, Arizona. The fauna here is dominated by spiny productid brachiopods (*Penicularis bassi*). *Photo by Susan Celestian*

FOSSILS OF ARIZONA

Introduction: What are they? How to become a fossil. Common fossils in Arizona.

By Susan Celestian

In this article, I will address fossilization, and will introduce you to some of the most common fossils in Arizona. Maybe you'll consider adding fossil hunting to your geological perambulations.

What is a fossil? Fossils are the prehistoric physical remains (or traces) of organic life. By definition, *prehistoric* means older than 6000 years, although some people define the minimum age of 10,000 years, before a specimen is called a fossil. Personally, I'm not sure an age limit is really necessary, as long as it isn't particularly recent.

It is hard to become a fossil. While billions of organisms have lived and died through geologic time, very few of them have been preserved in the fossil record.

- Predators and scavengers destroy remains.
- Soft parts are seldom preserved -- as opposed to hard parts (such as shells, teeth, and bones). Decay sets in very rapidly.
- Rapid burial enhances the chances of fossilization, by removing an organism from the ravages of decay, scavenging, currents, and so forth.
- Aquatic environments are more conducive to fossilization than are terrestrial ones.

What good are fossils? Fossils play significant roles in the unraveling of our geologic past.

► Using fossils, we can develop a history of lifeforms & increase our understanding of biological evolution.

► Fossils assist geologists in establishing a chronological order to geological events and strata.

- Fossils can be used to establish a relative age date[1] for a rock unit. This is best employed by using <u>index fossils</u> (fossils with short and distinct spans of existence, and wide geographic distribution) and unique <u>assemblages</u> of fossils (rather than individual fossils).
- *The <u>Principle of Biotic Succession</u> states that individual and groups of specific fossils succeed each other in a particular vertical order, and those individuals or assemblages can be used to help put rocks in chronological order.*

  See Figure 1.

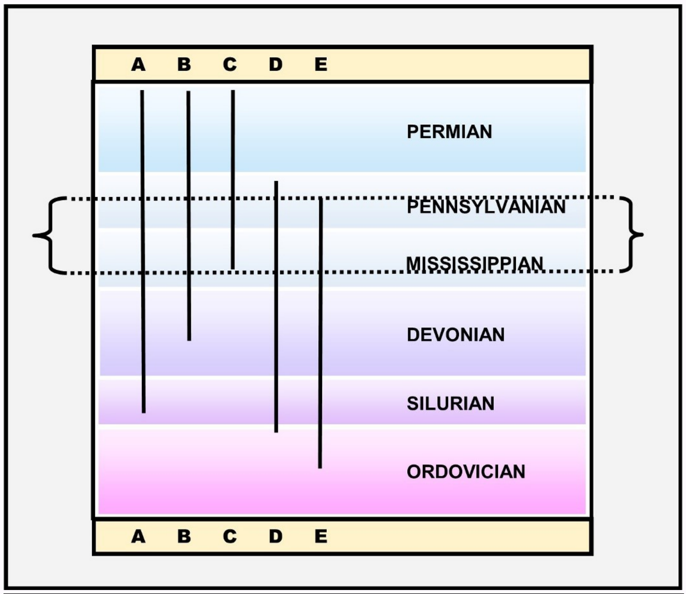

FIGURE 1 RELATIVE DATING USING FAUNAL ASSEMBLAGES By plotting the range of individual fossil species (A-E), the rock in which they are found can be relatively dated, by determining the span of time in which they all existed. In the plot above, the ranges of the five species overlap during the Early Mississippian-Middle Pennsylvanian. Without any more specific information, the strata containing these fossils can be dated as Early-Mississippian through Mid-Pennsylvanian. *Graphic by Susan Celestian*

► Correlation (establishment of equivalency) of now-disparate rock units can be established by identifying their included fossils. Again, this is best employed by using <u>index fossils</u> and unique <u>assemblages</u> of fossils. (The <u>Principle of Biotic Succession</u> *can be used to identify rocks of the same age, now separated by wide horizontal distances.) See Figure 2, on page 3.*

[1] Relative Dates are those that define the age based on chronological order and general position within the geologic time scale. It does not define the age in terms of absolute years.

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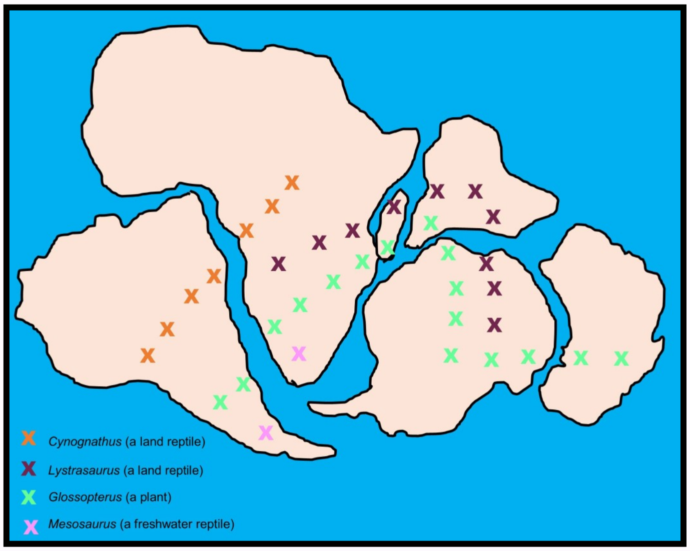

FIGURE 2 CORRELATION USING FOSSILS The major continents of our globe, are now widely dispersed, with large oceans in between. The diagram above illustrates how correlation, of rocks containing four fossils of land-based plants and animals, has allowed geologists to reconstruct the position of the continents during the Late Triassic-Early Permian convergence. In your mind, rotate and move the continents, into the positions they occupy on today's globe, and you can "see" that the various fossil occurrences will not line up -- UNLESS you move them to the positions in the diagram.
Illustration by Susan Celestian

► Paleo-environmental Reconstruction can be accomplished using fossils, usually in conjunction with sediment characteristics and sedimentary structures. Some of the ways fossils are used for paleo-environmental reconstruction are:

- Using the environmental requirements of living species, we may make assumptions about similar and related fossil species (or assemblages of species). *"The present is the key to the past"* applies to rocks AND fossils.
- Oxygen isotope ratios (in water, ice, shells, rocks) are dependent on temperature. The ratios of lighter O^{16} and heavier O^{18}, in fossil shells, can be used to determine water and/or air temperatures. (Higher amounts of O^{18} in shells equals colder temperature.)[2]

[2]https://pages.uoregon.edu/rdorsey/geo334/O-isotopes.html

- The width of tree rings can indicate warm/wet (thick ring) or cool/dry (thin ring) conditions
- The shape of coral colonies may be indicative of the wave energy, with more robust forms common within the wave zone, and more delicate forms below wave base.
- Are fossils arranged randomly, or is there alignment? This can give clues to current directions, storm intensity, wave energy, and so forth.
- In modern assemblages of marine foraminifera,[3] the percentage of planktonic foraminifera ranges from 0% in nearshore environments, to over 90% in deep, offshore environments. This can be related to fossil populations.[4]
- The coiling direction of some planktonic foraminifera species can indicate water temperature. For example: *Neogloboquadrina pachyderma* coils to the right in warm water, and to the left in cold.[5] *See Figure 3.*

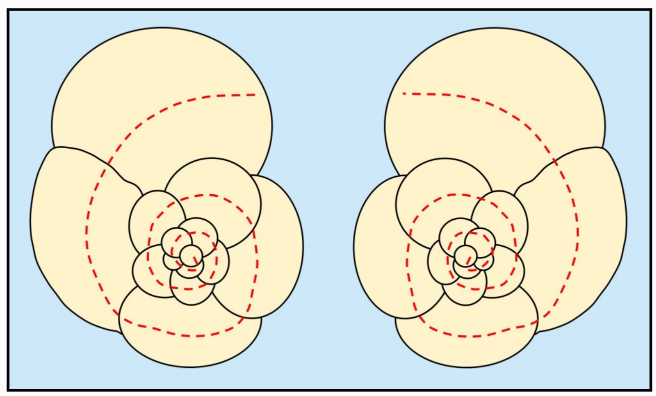

FIGURE 3 TEMPERATURE DEPENDENT COILING DIRECTION IN Neogloboquadrina pachyderma The coiling direction of *Neogloboquadrina pachyderma,* a planktonic foraminifera is temperature dependent. The image on the left coils to the right, indicating warm water; while the image on the right coils to the left, indicating cold water. *Illustration by Susan Celestian*

[3]Foraminifera (or forams) are single-celled animals that secrete a usually calcium carbonate shell. Planktonic forms spend their lives floating.
[4]https://ucmp.berkeley.edu/fosrec/Culver.html
[5]https://ucmp.berkeley.edu/fosrec/Olson2.html

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- Paleo-geography can be deduced from the fossil record. By using fossils (animals, plants/pollen, trace) to ascertain the environment of deposition, scientists can use fossils to determine ancient geography, more fully than that based on rocks alone. In that way, pictures of Earth changing through time can be visualized. Where were the shallow or deep oceans? Where were shorelines? Where were there swamps? Where were lakes? What areas were forested?.......

- Trace Fossils (borings, burrows, tracks, trails, coprolites (fossil poop), footprints, eggshells, tooth marks, gastroliths, skin impressions…..) indicate:
  - feeding behavior
  - lifestyle
  - stride length
  - physical features not usually preserved (like skin texture)
  - food sources
  - who or what else lived in an area. For example, pollen in coprolites (fossil poop) can reveal what plants were nearby.
  - wave energy (ex: heavy waves are indicated by prevalence of burrows)

- Microfossils are very important to the oil industry, and have been for 100 years. (As the name implies, they tend to be very small, some not visible without a microscope.)

  Drilling and coring are the processes of sampling rocks in the subsurface, often at great depth. A drill chews up rock and the muddy bits directed to the surface for study; or a special drill bit produces a length of cylindrical core (*See Figure 4*), that can be studied.

  Microfossils are brought to the surface whole, within the rock bits or cores; while larger fossils would be cut up and damaged.

FIGURE 4 DRILL CORES
These rods of rock are drill cores. Cores like this (or broken bits of rock) are used by geologists to explore the subsurface. Obviously, it would be difficult to retrieve whole, undamaged fossils of most fauna, when drilling sedimentary rocks. However, each core could be chock full of undamaged microfossils.

When you view the fossils that are collectable in the Pennsylvanian Naco Formation (pages 5-7) you will see fusulinids -- an extinct type of foram microfossil.

Photos by Susan Celestian

- Many species of forams, and assemblages of forams, are used to fairly narrowly define the age of rock strata. So are very helpful in the search for known oil-bearing strata.

- The color of pollen, and conodonts (tiny jaw parts of an extinct tiny worm-like creature), darken with heat after burial.[6] This color change reflects the heat to which the rocks have been subjected. The various shades of brown/gray can be assigned to specific temperatures or ranges of temperature. Oil forms between $65^{\circ}C$ and $150^{\circ}C$ -- so below that oil does not form. And above that, organic remains convert to natural gas and graphite.[7] Oil companies can plot the color changes in the target fossils to help focus their exploration efforts.

[6] Conodont Color Alteration -- an Index to Organic Metamorphism, Anita G Epstein, Jack Burton Epstein, & Leonard Dorreen Harris, 1977, Professional Paper 995.
[7] http://large.stanford.edu/courses/2013/ph240/malyshev2/#:~:text=The%20organic%20material%20in%

Fossils continued on page 5….

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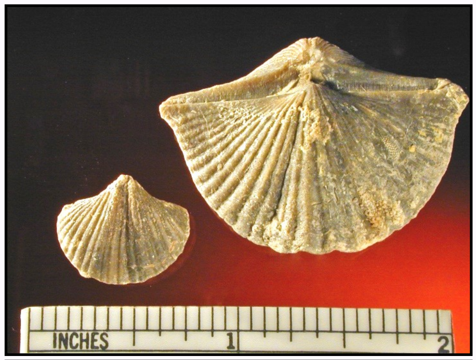
SO, what fossils can you expect to find in Arizona? There are many areas where you and your family can wander and find invertebrate fossils. Shallow seas covered much of the state during the Paleozoic and into the Mesozoic, so fossil shells are locally abundant. Fossil wood -- especially from the Triassic Chinle Formation -- is conditionally collectable[8].

A good place to start is at the Indian Gardens Paleo Site, about 12 miles east of Payson, on Hwy 260. A sign marks the turn into the parking lot. At this site, you will be collecting in the Naco Formation -- a Middle Pennsylvanian (about 300 million years ago) silty limestone, deposited in a deltaic or near-deltaic environment.

Following are photos of some of the most common Naco fossils -- definitely not an all-inclusive list! (*Photos by Stan Celestian*)

BRACHIOPODS

Composita subtilita This is the most common fossil here -- an ovate brachiopod. You will find many different sizes (young to mature)



Anthracospirifer occiduus

Derbyia crassa

Linoproductus praettanionus

Antiquatonia portlockiana

Echinaria semipunctata

Juresania nebrascensis

[8]Petrified wood may be legally collected on private property, or on BLM land -- where you may collect 25 pounds per day, plus 1 piece, for a total of 250 pounds/year, for personal (non-commercial) use. The NFS has slightly different (and variable) rules.

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Naco Formation continued...

BIVALVES & GASTROPODS

Various small bivalves

Wilkingia terminale

Myalina (Myalina) nacoensis, a mussel.

Phestia sp.

Bellerophon (Bellerophon) crassus

Gastropod

INARTICULATE BRACHIOPOD

Inarticulate Brachiopod Looks like a bluish-white, peaked cap.

BRYOZOANS

Branching Bryozoa Twiggy fossils with pinprick-sized holes.

Fenestrate (Lacy) Bryozoa

Massive or encrusting Bryozoa

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Naco Formation continued...

CRINOIDS

Aglaocrinus sp. This is a crinoid calyx -- arms and "head". In life, it was attached to a 'stem', such as seen in the green photo to the right. It is rare to find a calyx, but disarticulated plates, from the various crinoid species present, are common.

Aglaocrinus sp.

Crinoid Stem Fragments

Metacromyocrinus sp.

Eirmocrinus jeani

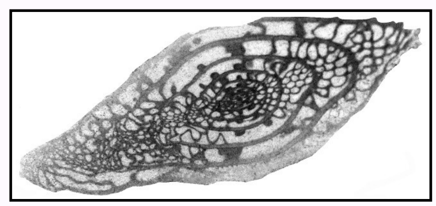
REPLACED BY QUARTZ (JASPER)

Replaced by Jasper In other sites around the Payson area, you may find fossils that have been replaced by quartz (red jasper). These can be etched out of the rock with DILUTED muriatic acid (pool acid).

OTHER & RARE

Horn Coral

Conularid



Fusulinids The fusulinids (a foraminifera) in the top photo are from a different locality, but you may find some in the rock, like the bottom photo, at the Paleo Site. The center photo is an image of the interior structure, made from an acetate peel of one of the fusulinids.

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Another formation that you might encounter is the Devonian-age Martin Formation (350-400 million years old). The attractive characteristic of this formation is that the fossils have been replaced by quartz, and therefore they are released from the rock by weathering -- or by diluted muriatic acid (pool acid) in a bucket in your driveway.

Some of the more common Martin fossils follow (*photos by Stan Celestian*):

BRACHIOPODS

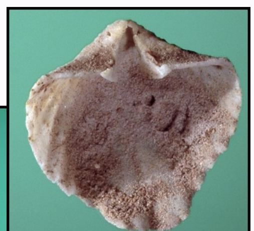
Ambocoelia sp. About 1/4” or less

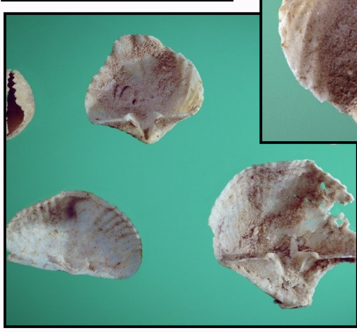
Atrypa sp. About 1” or less diameter

Pseudoatrypa sp. About 1 1/4” diameter

Cupularostrum saxitalis. About 3/8” or less

Cyrtospirifer whitneyi

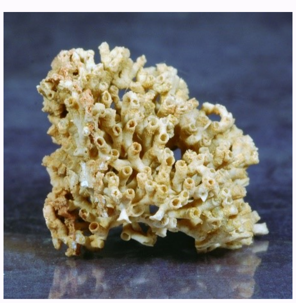




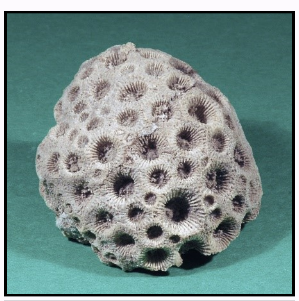
Tenticospirifer cyrtiniformis

Indospirifer orestes

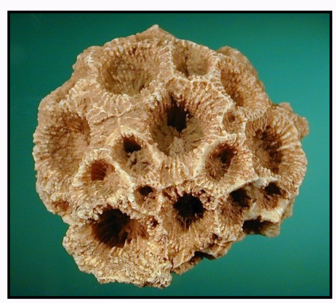
CORALS



Aulopora sp. Each hole is about 1/16”



Hexagonaria sp. 1 1/2” across



Hexagonaria sp. 1 1/2” across

Horn Coral 1-1 1/4” diameter

Pachyphyllum woodmani Each hole about 1/4”

Pachyphyllum nevadensis Each hole about 1/4”

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Martin Formation continued...

Thamnopora sp This is a very common coral in the Martin Formation. It is a branching coral, with holes the size of pencil points.

Disphyllum sp These images show you the upper and lower surfaces of the colony. Each hole is about 1/4” across, and this colony is 6 1/2 “ across.

Stromatoporoid Found as several species, stromatoporoids are largely preserved as thin, irregular layers. When preservation allows, you will be able to see the ‘pillar and laminae’ structure, especially on a polished surface (see inset).

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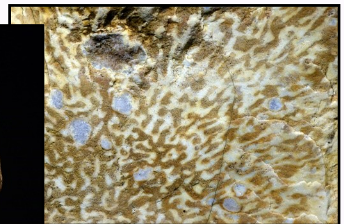
A third fossiliferous marine formation is the Kaibab Limestone, the rock that caps the Mogollon Rim -- so you are likely to encounter it while hiking, cutting a Christmas tree, or fishing. The Kaibab is Early-Middle Permian (about 250 million years) in age.

In some units, the fossils are replaced by quartz. In others, the fossils are preserved as internal molds, so tend to lack much detail. Photos of some common and more uncommon fossils follow (*Photos by Stan Celestian*):



Actinocoelia meandrina Very common in areas, this is a sponge. Generally found as siliceous concretions, sometimes the exterior is very spongy-looking (as in the blue photo on the right).

Penicularis bassi This is another very common Kaibab fossil. It is a brachiopod -- a productid (fossils -- usually spiny -- with one very convex shell, and another flatter shell). That morphology allowed the organism to "float" in soft sediment, without sinking. (Note the spine nubs.)

Meekela sp. , *A* brachiopod about 1 1/4" across

Bivalve internal mold.

Echinoid (sea urchin) plates and spines

Bivalve Both of these images (with red background) are internal molds of bivalves.

Gastropod Like the bivalves, there are numerous gastropods in the Kaibab. This is one, preserved as an internal mold.

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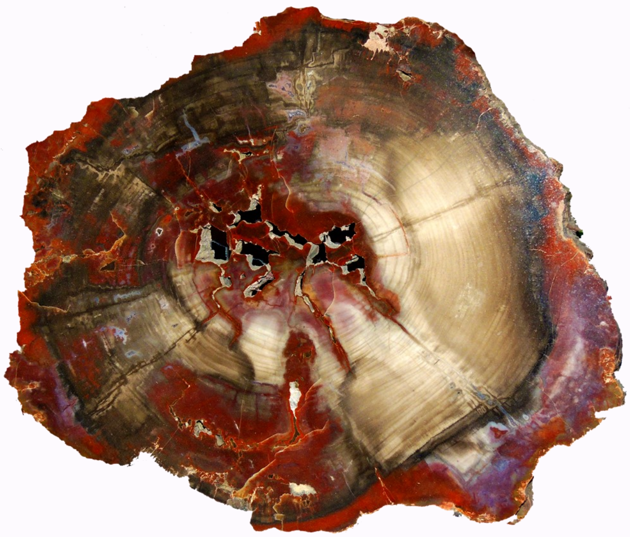
Scattered Mesozoic rocks of Arizona contain fossils -- largely molluscs (bivalves, cephalopods) and plants. Cenozoic rocks contain marine fossils, (molluscs, forams, barnacles echinoids), plants, and vertebrates (fish, mammoths, horses, camels, and so on) -- the latter which is off limits on public land, as far as collecting goes. Vertebrate fossils are protected by the Antiquities Act; nevertheless amateur enthusiasts have been responsible for locating important discoveries (for more, go to page 11).

The most famous of the plant fossils are petrified wood, which occurs in many Arizona locations, notably the 225 million year old Triassic Chinle Formation (of Petrified Forest fame), the Pliocene (5.4 to 2.4 million years) Colorado River Gravels of southwestern Arizona, and Mesozoic deposits in eastern Arizona. Keep in mind that you may collect on private land (with permission), but if on BLM land, you are limited to 25 pounds a day, plus one piece, for up to 250 pounds a year, for personal non-commercial use. (Similar rules apply in the National Forest, but they are less clear.) If in a National Park, look only! You may collect (for a fee) colorful petrified wood at DoBell Ranch, near Holbrook, Arizona. The last time I was there (2019), it was $40 for a 5-gallon bucket.



Some of the world's most colorful petrified wood comes from Arizona. Buried quickly in water-saturated, siliceous volcanic ash-rich sediment, decay was delayed, and quartz filled in pores and replaced the wood. Impurities, such as iron oxides and manganese oxides, account for the colors. In the photo on the left, you can see tree rings. Often the cellular structure is preserved, making identification to genus and species possible.

Fossil Wood of Southern Arizona These two specimens are from somewhere in southwestern Arizona. They are Pliocene in age. Preservation is by quartz replacement, but more delicately than that 'up north'. The fossils are porous, the wood grain is preserved, and even borings are obvious. Between the tan color, and the visual woodiness, at first sight they are hard to distinguish from real wood.

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You never know what you might find, as you wander the rocks of Arizona. At least twice, new dinosaur species have been discovered by amateurs.

In November 1994, Richard Thompson, a U of A geology graduate student (and peer of my son), was inspired by the movie *Jurassic Park*, and ventured into the desert, intent on discovering a dinosaur. AND he found one! In the Cretaceous (105-93 million years old) Turney Ranch Geological Formation in the Whetstone Mountains of Cochise County, Thompson discovered a partial skeleton weathering out of the sandstone. Ron Ratkevich, of the Arizona-Sonora Desert Museum led the excavation and study, that revealed a new species of brachiosaur (a group of dinosaurs thought to have died out 125 million years ago). The creature was named *Sonorasaurus thompsoni* -- how cool would it be to be a geology student and have a dinosaur named after you!? And then on April 10, 2018 it became the official State Dinosaur of Arizona. For more information and an image, go to http://www.dinochecker.com/dinosaurs/SONORASAURUS and https://commons.wikimedia.org/wiki/File:Sonorasaurus_thompsoni.jpg.

In 2000, Tucson resident and amateur paleontologist, Stan Krzyzanowski, volunteered at a dig jointly sponsored by the New Mexico Museum of Natural History (NMMNH) and Arizona-Sonora Desert Museum. He found a partial skull in the Late Cretaceous Fort Crittendon Formation (73 million years old), in Adobe Canyon, southeast of Tucson. After 20 years, a team of researchers, from the NMMNH, decided to focus on a study of those bones (and others discovered in the 1990s). They determined that it was a new species of horned dinosaur, and dubbed it *Crittendenceratops krzyzanowskii*, thereby honoring its discoverer. You can see an image of this Arizona native at https://www.foxnews.com/science/new-horned-dinosaur-species-discovered-arizona-wows-paleontologists.

So wherever you wander, keep your eyes on the ground. Paleontological surprises await!

These are vertebrate foot prints, common in the Permian (275 million years) Coconino Sandstone of Arizona. We encountered this slab, while poking around, along the Rim Road on the Mogollon Rim. *Photos by Stan Celestian*

More footprints in the Coconino Sandstone -- this time in slabs we purchased at a rock yard, for patio stones.

Photos by Stan Celestian