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Catalinas' rock: Life's foundation

We owe our soil, our water - even our weather- to it

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It all starts with the rock.

If you've ever sifted an arroyo bottom for "sand rubies" - tiny bits of pale-red garnet - you have uncovered the link between those towering granite cliffs above the Tucson Basin and all that lies below.

Our mountains, rising thousands of feet from the valley floor, are the source of life here in the desert. They create our soil and our weather. Their rubble created our aquifers, and their creeks continue to fill them.

They yield a child's treasure.

The sand rubies that wash into Tucson's north-side arroyos from the Santa Catalina Mountains were once encased in the wilderness granite that helps form our mountain skyline.

Those granite peaks and the other rocks atop the Catalinas and Rincons were once about seven miles beneath the surface and many miles to the west of where the mountains now stand, said geologist George Davis.

A "profound stretching" of the Earth's crust between 26 million and 18 million years ago lifted the rocks and scrambled the geology of the region.

Then, in a series of earthquakes beginning about 15 million years ago, basins fell and mountains rose in a wide swath of the West, from southern Washington to northern Mexico, forming the basin and range province.

A final dramatic push about 5 million years ago along faults bordering the Rincon and Catalina mountains "put exclamation points on the uplifts, increasing further the topographic relief between the heights of mountains and the depths of basins," said Davis.

"Because the mountain blocks are separated, but not completely isolated from one another, they are land forms that for plants and animals offer maximum evolutionary potential."

The slow process produced the diverse and magnificent landscape we see today.

A changing panorama

Varieties of rock weather differently and produce different vegetation.

Botanist Forrest Shreve recognized this on his early trips into the Catalinas, on foot and on horseback, beginning in 1908.

Like naturalists before him, he marveled at "the constantly changing panorama" as desert vegetation gave way to a succession of life zones, capped by a mixed conifer forest.

Shreve, though, was too sophisticated in his science to attribute everything to altitude.

"Inadequate soil moisture prevents downward movement; freezing, upward movement," he wrote in 1912.

Moisture-loving plants exist at lower elevations in shaded, riparian canyons; sun-loving plants thrive at higher altitudes on ridges and south-facing slopes.

Shreve also noticed how different types of rock begat different ecosystems.

On the northeast face of the Catalinas, where limestone predominated, the landscape resembled the more open Chihuahuan Desert, with dominant agaves and stands of mountain mahogany. On the south and west, gneiss and granite produced the classic Sonoran Desert regime, featuring saguaros, palo verde and ocotillo.

seeking secrets

Scientists still don't know exactly how all that happens, and they have recently rigged the slopes of the Catalinas with a variety of instruments to uncover the mountains' secrets.

The Critical Zone Observatory, one of six funded by the National Science Foundation in a variety of watersheds, explores the space between the water table and the tops of the trees, seeking to understand in detail the process of creation.

It begins with rock, but it can't proceed without water, which is why Nate Abramson is busy when it rains or snows.

Abramson helps install and maintain the instruments of the UA's Critical Zone Observatory in the Santa Catalinas. He collects water samples at various points along three hillslopes, from sites just below Mount Lemmon to just above Oracle.

He hikes into the forest to download 120 data loggers that measure temperature, humidity, soil moisture and stream flow. Also, he collects water samples from 30 subsurface pits and 10 locations along streams.

Water creates soil and enriches it. The "parent" rock helps determine what is produced.

In a high canyon of the Catalinas mostly spared by recent fires, two measuring sites about a half-mile apart are dominated by different parent rocks.

The first parent, schist, has crumbly layers and flakes of silvery mica. It weathers more quickly, and the soil here is up to 6 feet deep. In the shaded, wet glens, that deep soil supports deciduous trees - oaks and maples among them. In fall, their yellow and red leaves give the place the feel of an Eastern forest.

Farther up the narrow canyon, granite dominates. It yields to soil more grudgingly. Here, pines dominate, some growing directly from rock. Their roots have found crevices and created fractures that trap soil, further breaking down the rock as they grow.

Critical interactions

Jon Chorover, a professor in the UA Department of Soil, Water and Environmental Science, wants to uncover the biogeochemical processes that yield those different results.

"We want to know how water and rocks and plants and sunlight interact in the zone on Earth's surface that makes life possible," said Chorover, one of the principal investigators for the Critical Zone Observatory. "What we don't know is what path that water takes. We don't know how rock becomes soil."

That "weathering" process is far more complex than the notion of wind and rain wearing down rocks. That's erosion, simple movement.

Weathering is the geochemical magic that happens, mostly under the soil, when eroded metals bond with water, hook up with organic matter and microbes and change into the ingredients for soil.

The UA program is one of six where such weathering is being studied by a diverse group of scientists - the geologists, of course, and the hydrologists, along with chemists, biologists, microbiologists, botanists, soil scientists and ecologists.

The National Science Foundation, which granted the UA $4.35 million for a five-year program to study sites in the Catalinas and in the Valles Caldera in New Mexico, says on its website that it wants to foster understanding of those processes and also predict the critical-zone response to future land-use and climate changes.

Comprehending rock

Understanding the rock requires input from different disciplines, said Julia Perdrial, an assistant research scientist on the project.

"Most interesting questions you can only answer when you at least know what other people are talking about," she said. "It's not enough to know what the rocks are doing, but where the water goes and why it goes there and what it's doing when it gets there."

The current hypothesis is that carbon, water and energy control the structure and function of the critical zone, which contains everything essential for life.

So it takes various specialties to understand it all - plus lots of instruments in the field and lots of chemical analysis in the lab. The samples Abramson returns are analyzed by multiple researchers using an array of high-tech instruments to measure pH and alkalinity, organic and inorganic carbon and a laundry list of elements and isotopes.

The group has performed more than 50,000 separate analyses in each of the past two years.

It's not all lab work. Perdrial goes on annual field trips to install and maintain equipment here and in New Mexico. This summer she helped "baby-sit a stream" for a researcher who needed data on water flow.

Michael Pohlmann's research required that he sample stream water while it is surging and receding during a storm.

He enlisted help from Perdrial and others, and he camped out for two weeks near one of the observatory's collecting sites during summer break as thunderstorms crashed around him without falling on his watershed.

Then, on the Sunday before classes resumed, the big storm hit. He was in Tucson, but drove a university truck up the mountain with one of the project's interns, planning to sample the surge at two-hour intervals and nap in the truck cab in between.

While collecting his first sample, he dropped his keys in the stream and didn't find them until the water receded hours later.

Fortunately, the Mount Lemmon Fire Department was able to open his locked doors so the researchers could stay dry between sampling visits.

He took his last sample at 5 a.m. and headed down for his first day of classes. He was tired - but he had the final data he needed for his master's thesis.

A natural laboratory

Proximity to the university is just one attribute that makes the Catalinas a perfect place for scientific study, said Chorover.

"It's just a remarkable, wonderful, natural lab for doing studies of the critical zone," he said.

"It provides us a wonderful gradient in environment and climate. As we go from the base of the Catalinas, we go from Sonoran Desert into grassland savanna, up through ponderosa pine and eventually into mixed conifer at the top - all within a relatively small geographic area and all on the same type of rock."

Pohlmann, who entertains himself in the field and in the lab by listening to novels, likes the fact that the group is uncovering a narrative that explains life on Earth.

"It's a beautiful story," he said.

Did you know?

The Tucson Mountains once topped the area where the Santa Catalina Mountains now stand.

They slid westward as the Catalinas rose from deep within the Earth, said geologist George Davis.

Davis theorizes that the rocks exposed on Tanque Verde Ridge in the Rincon Mountains "started out a little west of Saguaro National Park West, and ended up in a spot that includes today Saguaro National Park East."

"Life is strange," said Davis.

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