Sierra Nevada bedrock shapes vegetation and topography

Traversing into California's Sierra Nevada from the west, you'll first encounter the grasses and oak woodlands of the mountains' arid foothills, followed by lush conifer stands at the wetter, cooler mid-elevations, and finally, increasingly bare slopes ascending to chilly heights. The progression demonstrates the well-established effects that precipitation, altitude and other broad climatic factors have on vegetation globally. But according to a new study, another major factor underlies growth and helps to shape the landscape in parts of the Sierras, and perhaps elsewhere: bedrock.

"Within that optimal climatic zone at the mid-elevations, bedrock has just as strong of a role in dictating the distribution of forests as climate," says Jesse Hahm, a graduate student in geology at the University of Wyoming and lead author of the study, which correlates tree canopy cover to the bedrock geochemistry beneath the trees. Tree canopy cover is a common proxy for overall forest productivity.

From satellite and ground observations, Hahm and his colleagues noticed that dense tree stands were sometimes juxtaposed with barren rock outcrops, despite sharing weather patterns and terrains that were nearly identical otherwise.

"When you have a patch of ground that can support Giant Sequoias, these iconic megaflora, and then there's a chunk of hillslope nearby that has nothing growing on it, it makes you scratch your head," says Josh Roering, a geologist at the University of Oregon who studies landscape evolution but was not involved in the study.

To investigate the role of bedrock, Hahm and his team analyzed 235 samples from 21 different sites near the National Science Foundation-supported Southern Sierra Critical Zone Observatory. The scientists then compared the samples' bulk geochemistry to the tree cover and type of underlying bedrock where each was collected.

They confirmed that tree cover in their study area, which varied from about 6 to 81 percent, changed markedly across mapped boundaries between different Mesozoic-aged plutons — distinct bodies of rock that solidified from magmas deep underground before being uplifted with the mountains. Although the plutons all have compositions broadly resembling granite, their geochemistry varies substantially, and those with higher concentrations of aluminum, calcium, iron, magnesium and phosphorus had more trees growing above them. In fact, up to 60 percent of the variation in tree cover could be ascribed to differences in bedrock geochemistry, the researchers reported in Proceedings of the National Academy of Sciences.

There is a long history of studies looking at plant-rock interactions, Hahm notes, with "probably the most famous" being those describing species that only grow over specific rock types like serpentinite. "But to our knowledge, most ecologists and people looking at landscape processes have not considered granitic bedrock to be a strong controlling factor on the overlying vegetation." Given that granites in the Sierras and elsewhere around the world are generally similar, he says, the "phenomenon could be widespread."

The bedrock effect "has been hiding in plain sight," Roering says. This study is "a beautiful illustration of coming back to first-order geological observations" and exploring their influence. What's exciting, he says, is that it also "produces a set of observations that we can go out and look for in other places, and then try to encapsulate into our models" of landscape evolution.

Unlike nearby areas in the Sierra Nevada that share the same climate, Bald Mountain's exposed granite is dotted with only sparse vegetation and trees.
Credit: Claire Lukens

"One of the most interesting observations is that the differences in tree canopy cover also correspond to differences in landscape erosion rates," Hahm says, a process he and his colleagues also measured. The bedrock is influencing the presence or absence of vegetation, he says, which in turn influences the creation and retention of soil. "Where soil is present, erosion is faster … and where soil and trees are absent and bedrock is exposed at the surface, the erosion rates are slower," Hahm says, suggesting a link between bedrock composition and the topographic evolution of the landscape.

There are still "some wrinkles" that are going to need more work, Roering says. In particular, he says, the exact mechanisms by which bedrock influences vegetation remain unclear. A rock's chemistry not only determines what elements it releases to the environment, but also affects its mineralogy and mechanical properties, including how it fractures and crumbles into layers of rocky regolith and eventually soil, and to what extent those layers then retain water.

The connections must "be occurring somewhere within the regolith," Hahm says, either through the liberation of plant-essential nutrients like phosphorus, or the generation of porosity and permeability and water control." If bedrock phosphorus levels, which vary by an order of magnitude across the study area, indeed have a big impact, it would represent an intrinsic "bottom-up control," he says, in contrast to the conventional top-down idea that the nutrient limits plant growth after it has been leached from the soil through chemical weathering.

"For me, the biggest question is this feedback between physical and chemical alteration of rock," Roering says. Understanding this interplay is "really the sweet spot of where we need to go."

Timothy Oleson

Extinct reptiles show their true colors

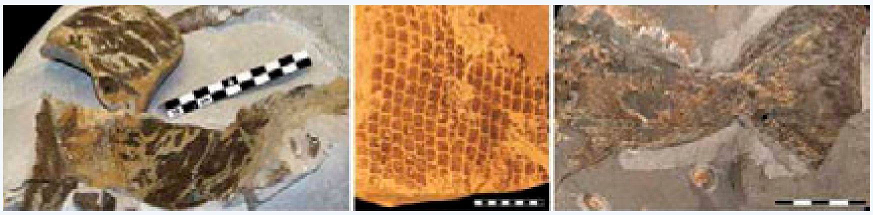
Melanin is the most common pigment in the animal kingdom, responsible for skin color, hair color and eye color in almost all animals. Now the discovery of pigments in well-preserved fossils of three ancient marine organisms is helping to pinpoint how melanin became so ubiquitous.

Dark traces on fossilized skin from three marine reptiles — a 55-million-year-old leatherback turtle, an 86-million-year-old mosasaur, and a 196-million- to 190-million-year-old ichthyosaur — were found to contain melanin, according to a study published in Nature. The three species are only distantly related to one another, suggesting that convergent evolution, where organisms independently evolve similar features, may have played a role. Melanin is a key component in thermoregulation and may have been an important adaptation for marine organisms living in cold waters, Johan Lindgren of Lund University in Sweden and colleagues reported.

Fossils have previously been found displaying evidence of skin rich in microscopic rod-shaped bodies that resemble pigment-producing organelles called melanosomes, but the microstructures' close resemblance to microbes often sparks debates over whether the remnants are truly organelles or are instead bacteria. Lindgren and colleagues used molecular techniques and a scanning electron microscope to confirm the presence of melanin in all three fossils.

The results expand current knowledge of pigmentation in fossilized organisms beyond that of feathered dinosaurs, allowing for the reconstruction of color over much greater ranges of extinct animals.

Mary Caperton Morton



Skin from a 55-million-year-old leatherback turtle (left; scale bar, 10 centimeters), scales from an 86-million-year-old mosasaur (center; scale bar, 10 millimeters), and the tail fin of a 196-million- to 190-million-year-old ichthyosaur (right; scale bar, 5 centimeters).

Credit: left to right: Bo Pagh Schultz, Johan Lindgren and Johan A. Gren

New handheld mineral analyzer

Prospecting for minerals on Mars is rife with challenges, but a new handheld, no-prep analyzer that requires no sample preparation may be just the tool for profiling Martian minerals, as well as those on Earth. Inspired by the analytic challenges posed by future Mars missions, the analyzer combines traditional X-ray fluorescence (XRF) with X-ray diffraction (XRD) into a portable instrument that weighs about 1.5 kilograms.

"The key advantage of this technique is that it's insensitive to the shape of the sample," says inventor Graeme Hansford, an instrument scientist at the University of Leicester in England. Conventional handheld analyzers use only XRF and usually require samples to be ground into a fine powder for analysis, limiting their applications in the field. The new instrument, still in development, will be capable of analyzing the mineral content of small samples within one to two minutes, Hansford says.

The lack of sample preparation comes with trade-offs in the form of low resolution, he says. "This is not a general-purpose field tool," he says. "It's meant for more targeted applications, specifically in mining, where you already know what you're looking for and what you're likely to find."

For example, the analyzer can be used to evaluate the iron oxide content of a sample, along with its oxidation state — important information in mining activities. Manganese ores and limestones could also be tested with the analyzer. "This technology won't be as useful if you're looking for gold or other precious metals where you're looking for one specific metal in very low quantities."

Currently, the analyzer is still in the lab at the University of Leicester's Space Research Center. Hansford expects to have a field-ready prototype ready this fall and a commercially available instrument in two years.

Alexander Seyfarth, senior product manager at Bruker Elemental, which is collaborating with Hansford to develop a commercial version, said in a statement that "Bruker is excited to be involved in this project as it will bring new measurement capabilities to our handheld equipment. In many cases this system will provide information on the crystallography of the sample in addition to the elemental analysis."

Mary Caperton Morton