



A large varnish-coated boulder that has split apart revealing the lighter granitic core.



Photo: Reena Deutsch

Native Americans utilized desert varnish for their petroglyphs, etching the reddish iron oxide to reveal the granitic surface beneath.



Black manganese oxide desert varnish from the Alabamba Hills near Lone Pine.

GEOLOGY

Desert Varnish Update

by Wayne P. Armstrong

One of the most remarkable biogeochemical phenomena in arid desert regions of the world is called desert varnish. As you descend the steep curves along Montezuma Grade into Borrego Springs or walk up Borrego Palm Canyon, you are immediately surrounded by enormous reddish boulders coated with desert varnish. Although it may be only a hundredth of a millimeter in thickness, desert varnish often colors entire desert mountain ranges black or reddish brown. Desert varnish is a thin coating (patina) of manganese, iron and clays on the surface of sun-baked boulders. Its origin has intrigued naturalists since the time of Charles Darwin.

According to the classic paper by Ronald I. Dorn and Theodore M. Oberlander (Science Volume 213, 1981), desert varnish is formed by colonies of microscopic bacteria living on the rock surface for thousands of years. The bacteria absorb trace amounts of manganese and iron from the atmosphere and precipitate it as a black layer of manganese oxide or reddish iron oxide on the rock surfaces.

This thin layer also includes cemented clay particles that help to shield the bacteria against desiccation, extreme heat and intense solar radiation.

A number of hypotheses have been proposed to explain the origin of desert varnish. Although some crustose rock lichens form thin surface layers on rocks and boulders, they generally cannot survive the arid, sun-baked conditions favorable to desert varnish. Several research papers about the microbial origin of desert varnish have appeared during the past 25 years, including R.S. Perry of the Department of Earth and Space Sciences, University of Washington who received a Ph.D. on the subject in 2004. The microbial origin of desert varnish is difficult to reproduce in the laboratory, particularly the length of time required for a varnish coating to develop. In addition, it is difficult to reproduce the remarkable hardness of desert varnish, which is almost as hard as quartz (nearly 7 on the Mohs scale of mineral hardness). Dr. Perry has authored several scholarly articles on desert

varnish, including his 2003 paper entitled "Biological and Organic Constituents of Desert Varnish: Review and New Hypotheses," which is available on-line. I have summarized some of the major points of his 2003 article as follows:

1. Desert varnish is a hard coating (patina) on the rock surface. Contrary to some references, it is not a weathering product of the rock.
2. The source of the coating minerals, mostly iron and manganese, is derived from deposits of dust from the atmosphere. Dust lands on the rock surfaces and the mineral component becomes concentrated and "glued together" into a hard, microscopic layer.
3. Varnish is associated with colonies of bacteria and microcolonial fungi. DNA and amino acids are also associated with some varnish coatings.
4. Varnish bacteria are involved in the formation of reddish iron oxides and black manganese oxides through



Massive boulder coated with red iron oxide desert varnish.

metabolic oxidation processes.

5. Silicic acid may serve as a cementing agent in some desert varnishes.

Several genera of bacteria are known to produce desert varnish, including *Metallogenium* and *Pedomicrobium*. Because these bacteria live in extreme environments, they are sometimes placed in a category called extremophiles. They consist of minute spherical, rod-shaped or pear-shaped cells only 0.4 to 2 micrometers long, with peculiar cellular extensions. In fact, the individual cells are smaller than human red blood cells, which are about 7.5 micrometers in diameter. Because of the radiating filaments from individual cells and colonies, they are called appendaged bacteria. All living systems require the vital energy molecule ATP (adenosine triphosphate) in order to function. In our cells, ATP is constantly produced within minute bodies called mitochondria. As electrons flow along the membranes of our mitochondria, molecules of ATP are generated. The electrons come from the breakdown (oxidation) of glucose from our diet. Although varnish bacteria do not have mitochondria, they do have a similar inner membrane structure through which electrons flow to generate ATP. In some chemosynthetic bacteria, the electrons come from the oxidation of elements in their environment. This is presumably the

adaptive advantage for varnish bacteria as they produce microscopic layers of black manganese oxide and red iron oxide on desert boulders.

Varnish bacteria thrive on smooth rock surfaces in arid climates. According to Ronald Dorn, perhaps 10,000 years are required for a complete varnish coating to form in the deserts of the southwestern United States. In fact, dating of varnished surfaces is of enormous importance to the study of desert landforms and to the study of early humans in America, since many artifacts lying on the ground become coated with desert varnish. Boulders of the Anza-Borrego Desert region are covered with a reddish-brown iron oxide, while boulders in parts of the Alabama Hills near Lone Pine in the Owens Valley are blackened by a manganese oxide varnish.

If you scratch through the varnish layer, the lighter-colored granitic rock is exposed. I have seen one rock along the trail to Travertine Palms Wash dated at 1945. For thousands of years Native Americans have used desert varnish for their rock carvings (called petroglyphs). Throughout the Alabama Hills are acres of elaborate petroglyphs carved into black desert varnish and Bishop tuff, including spirals, circles, wavy lines, footprints, men, deer

and desert bighorn sheep. It is fascinating to speculate on the origin and meaning of all these carvings.

Desert varnish is widespread on Earth, and its existence on Mars has been proposed based on data from various space missions to the red planet. If it is present on Mars, is the process of formation similar to that on Earth? Are extremophile microbes responsible for the clay and oxide rich coatings? Current research on Earth indicates that the varnish process may involve microbial action plus inorganic processes in which the minerals and clays are cemented together and literally baked onto the rock surfaces. So the next time you walk along one of the many beautiful canyons in Anza-Borrego Desert State Park, stop and contemplate about the origin and magnitude of the magnificent varnish-coated boulders around you.

References

1. Dorn, R.I. and T.M. Oberlander. 1981. "Microbial Origin of Desert Varnish." *Science* 213:1245-1247.
2. Dorn, R.I. and T.M. Oberlander. 1982. "Rock Varnish." *Progress in Physical Geography* 6: 317-367.
3. Perry, R.S. and V.M. Kolb. 2003. "Biological and Organic Constituents of Desert Varnish: Review and New Hypotheses." Available on-line at: http://www.psi.edu/~rperry/perry/SPIE_DV.pdf.

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