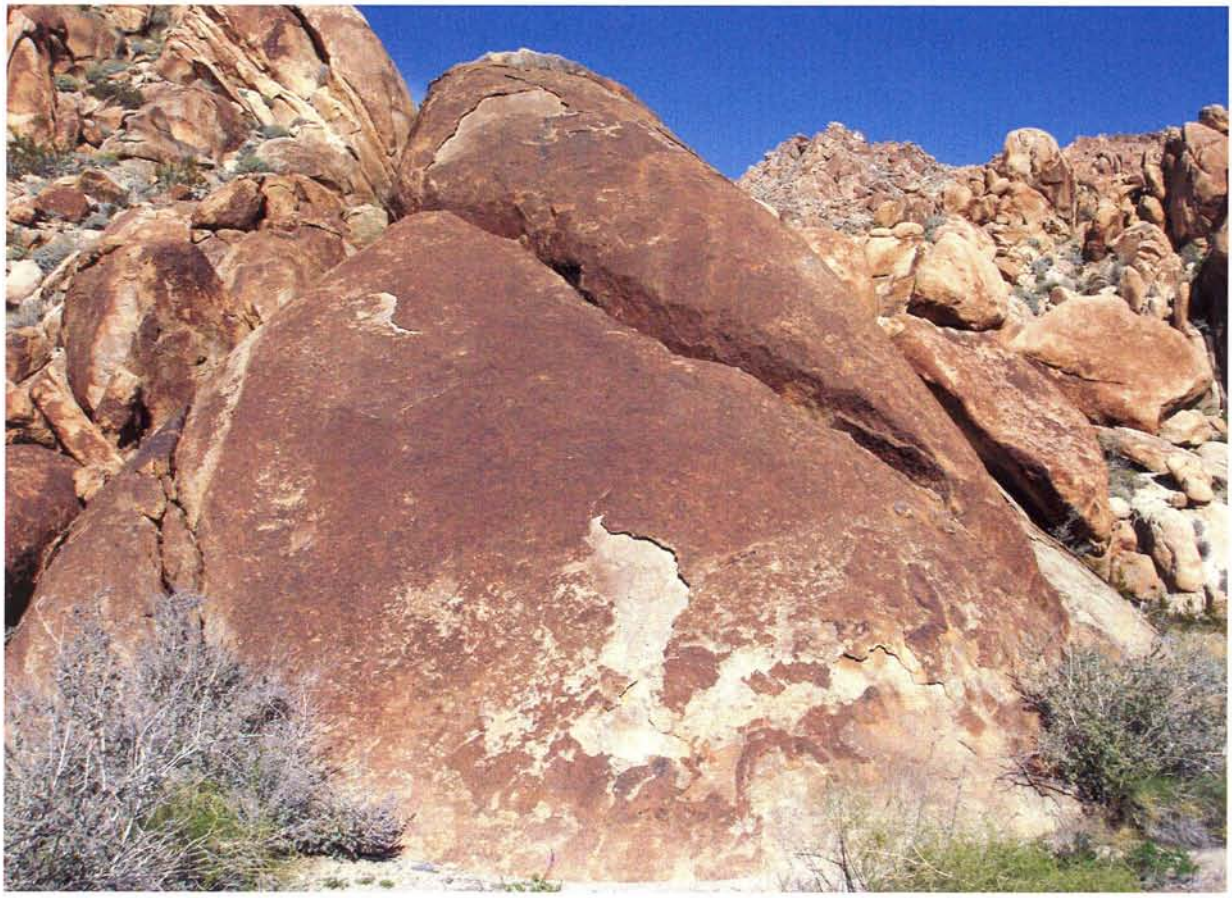
GEOLOGY

Desert Varnish Revisited

Text and Photos by Wayne P. Armstrong



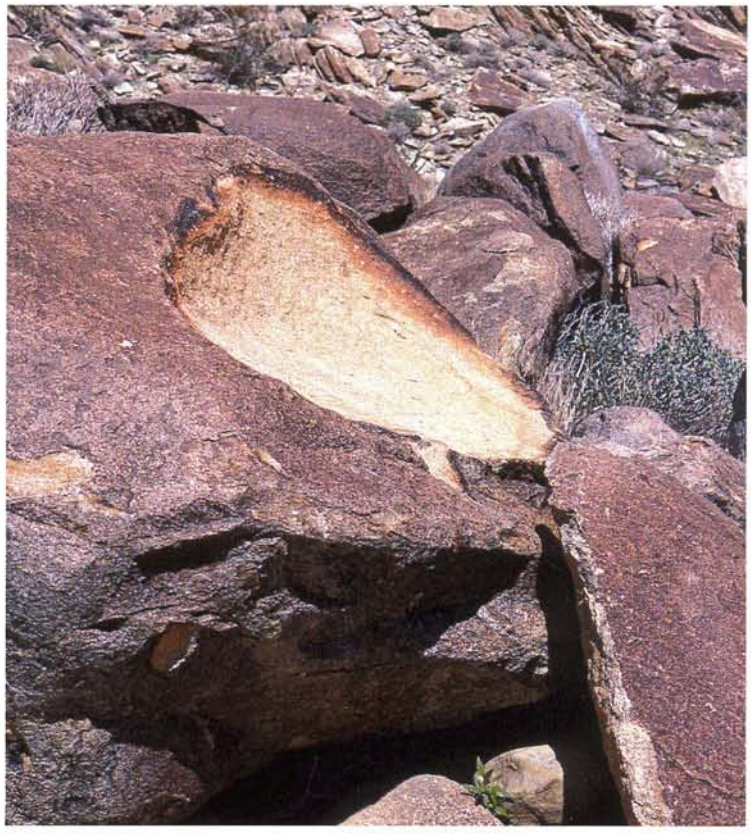
left: Massive boulder coated with red iron oxide desert varnish.

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

In 2008, I wrote an article about desert varnish for *The Sand Paper*. This a thin coating (patina) of manganese, iron, and clays on the surface of sun-baked boulders. 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. Black desert varnish is also common in the Alabama Hills west of Lone Pine.

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).

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



Chartreuse lichen (Acarospora) *& orange lichen* (Caloplaca). *The black rock surface is not caused by lichen or desert varnish. It is rock-inhabiting fungus (RIF) in the fungal division Ascomycota.*

surface for thousands of years. The bacteria absorb trace amounts of manganese and iron from atmospheric dust 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. These chemosynthetic oxidations produce ATP (adenosine triphosphate), an energy molecule vital to all living cells.

Several genera of bacteria are associated with 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. Because of the radiating filaments from individual cells and colonies, they are called appendaged bacteria.

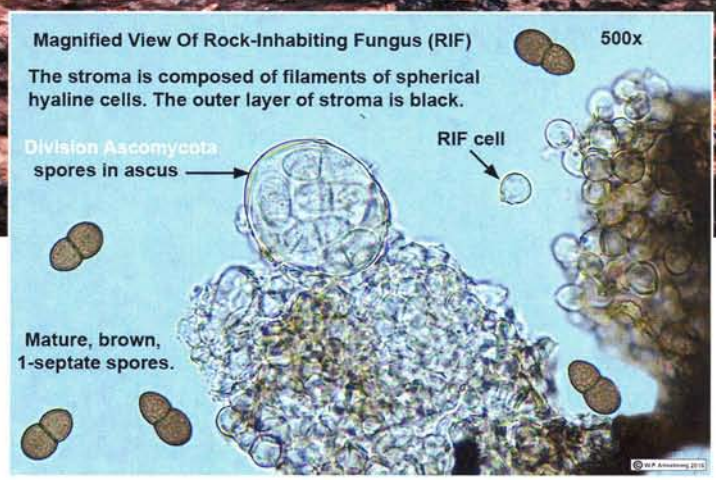
Not everyone agrees that desert varnish has a biological origin. According to Randall Perry of Imperial College London, desert varnish is composed mostly of silica, which can fall from the sky or leach from the rock itself. Willard Moore, an isotope geochemist at University of North Carolina, states that the large amounts of iron and manganese indicate that microorganisms may be involved in the varnish process. Microorganisms associated with coatings on rocks are discussed in a scholarly article by Anna Gorbushina (*Environmental Biology* Vol. 9, 2007).

I have never observed varnish bacteria first hand. I need the culture and staining techniques of a trained microbiologist.

During the past ten years, I have examined many sun-baked boulders in California and Arizona while searching for ants, my latest passion. I took scrapings from boulders that I thought were coated with black desert varnish and examined them under a compound microscope. To my astonishment there were cells and spores of a fungus. I did not see the typical algal cells associated with rock lichens. I contacted Kerry Knudsen, lichenologist at UC Riverside and showed him my images. He said they were of rock-inhabiting fungi (RIFs) of the fungal division Ascomycota. In fact, Kerry is currently researching these amazing organisms and has already published several papers on them.

This volcanic rock is coated with a black layer of RIF. It can be etched with difficulty.

Black layer of rock-inhabiting fungus (RIF) on volcanic rock in the Supersitions of Arizona.



Microscope slide showing brown, one-septate spores of rock-inhabiting fungus (RIF). The stroma (mycelium) consists of a mass of fungal filaments composed of spherical cells. The outer layer of the stroma is black with heavily melanized cells to protect them from intense UV radiation. The spores are produced in a sac-like structure (ascus) typical of the fugal division Ascomycota.

RIFs live on and within exposed rock surfaces. They can live on rough volcanic surfaces, including andesite, rhyolite, and welded tuff. They survive in some of the most extreme terrestrial habitats on earth, including South Africa's ancient Namib Desert and Antarctica. Some authors have postulated that they may have given rise to lichens, and others have suggested that they might be able to survive on Mars. This is a major topic of research by mycologists, lichenologists, and astrobiologists.

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. If you scratch through the varnish layer, the lighter-colored granitic rock is exposed. For thousands of years, Native Americans have used desert varnish for their rock carvings (called petroglyphs). 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. The magnitude of desert varnish is obvious when you travel through Anza-Borrego Desert State Park and observe all the reddish boulders. Just remember that not all black coatings on rocks are desert varnish. Some of these may be rock-inhabiting fungi, an equally common desert extremophile.

References

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