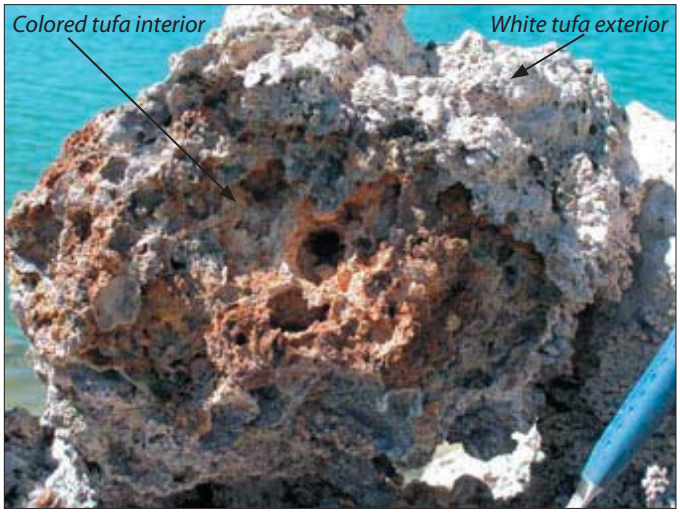
Geomicrobiology of Mono Lake tufa

by Mike Thomas and Jack Farmer, Arizona State University

Editor's note: Mike Thomas and Jack Farmer are studying Mono Lake's mysterious tufa towers, uncovering new answers and new questions too. We thought Mono Lake enthusiasts, especially those into science, would enjoy learning more of the details behind the formation of this much-loved geologic wonder straight from the researchers themselves.

Take a look at a piece of dry tufa along the Mono Lake shoreline, and chances are you're looking at a microbial habitat, or at least the remnant of one. Above the shoreline, tufa surfaces can be a home for both living and dormant microorganisms. Within tufa interiors, microbes may also live as endoliths (literally, "within rock"), occupying microscopic cracks in the tufa, or dissolving the carbonate minerals with organic acids. Below the lake surface, both newly formed tufa deposits, as well as tufa surfaces recently re-submerged by the rising lake level, are home for flourishing microbial communities, called biofilms. Indeed, submerged tufa surfaces look green, reflecting the presence of films of chlorophyll-pigmented photosynthetic communities.

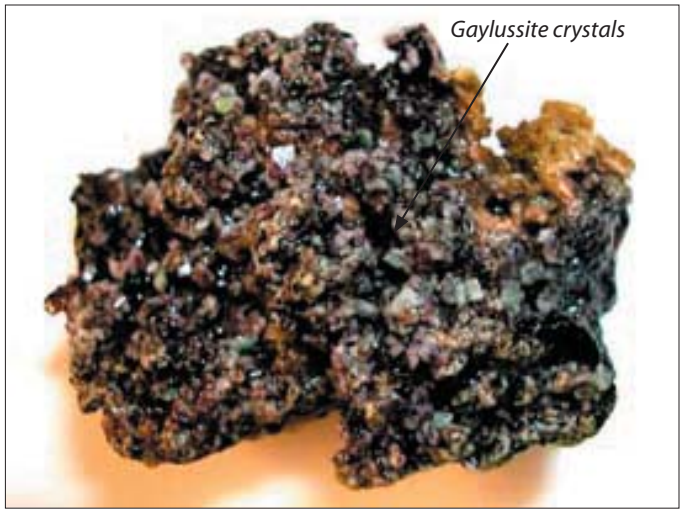
Our studies are revealing that these microbial ecosystems contribute substantially to the formation of the tufa by enhancing the precipitation of carbonate minerals from lake waters. They also alter primary tufa fabrics and mineral compositions once the deposits have been laid down.



PHOTOS COURTESY OF MIKE THOMAS

The interior of a tufa tower, showing a central conduit and the darker insides of orange, red, gray, and black colorings, which suggest accessory minerals such as iron oxides or sulfides.

The formation of Mono Lake's tufa towers has long been a subject of controversy. The most widely held view is that the tufa towers form inorganically, at sites where calcium-rich spring waters mix with bicarbonate-rich lake waters. Our research has been looking at tufa towers using more integrative methods of geomicrobiology to investigate the ways in which microbial communities may influence tufa deposition and how microbial processes alter the tufa after they have formed.



Tufa sample obtained from the base of a submerged tower, showing gaylussite crystals. Microbial biofilms inside the crystals show pigments ranging from green to purple. Sample size: ~3 cm.

Microbial populations change in response to seasonal and longer-term changes in the climatic and geochemical conditions of the lake. At a microscale, transient environments near tufa surfaces and within tufa interiors provide opportunistic environments where microbial populations take advantage of local biogeochemical conditions in order to meet their energy requirements. Where conditions are stable, microbial ecosystems may begin to actively control microenvironmetal conditions through their combined metabolic processes and the active biological cycling of elements. Our research has been showing that microorganisms may play a key role in tufa deposition by acting as nucleation sites for precipitating minerals, and by altering microscale pH conditions and elemental concentrations favorable for carbonate precipitation.

Geomicrobiologists have long suspected common physiological processes, such as photosynthesis and sulfate reduction, may induce carbonate precipitation in microbial biofilms. Our work suggests that these processes may also be common on tufa surfaces in Mono Lake. As microbes induce the precipitation of carbonate minerals, they may also become entombed and preserved as fossilized biosignatures.

We have observed that some tufa minerals may precipitate preferentially on and within certain types of microbial biofilms. For example, the mineral gaylussite (hydrated sodium carbonate), a widespread mineral in Mono Lake, typically precipitates in close association with cyanobacterial biofilms, entombing numerous microbes within the crystals that form. Gaylussite is metastable and quickly transforms to more stable forms of calcium carbonate (calcite and aragonite). Depending on local microenvironmental

Continued on page 25

Mono Lake welcomes new Ranger Jim Pence

by Clare Cragan

As the summer of 2005 neared its end, Mono Lake Tufa State Reserve Ranger Deana Freeman moved to a position with the National Park Service in Northern California. After months of anticipation the California State Parks Department announced they had selected Jim Pence, a 25-year State Park Service veteran, as the new ranger! In a time of budget cuts in nearly every state and federal agency, the Mono Lake Committee was relieved to see the position filled and excited to meet the newest addition to the Mono Basin.

Pence most recently worked at Marshall Gold Discovery State Historic Park in Coloma, California, but he has worked in locations all over the state. He started as a lifeguard at Huntington Beach during college and has held ranger positions at Turlock Lake, Folsom Lake, and the North Fork of the American River.

Challenging water issues are not unfamiliar to Pence. His past positions have found him involved with historic irrigation reservoirs for the Central Valley, recreational boating areas, and Wild and Scenic Rivers threatened by dams. Pence is a great match for Mono Lake's rich water history.

Pence has many ideas for the State Reserve, and the ambition to make projects happen. In just a few short months he's managed to restore a sensitive area damaged by OHV use—just in time to see the once-degraded area bloom with wildflowers. He also hopes to secure grant funding for much-needed work at the Old Marina site on the west shore of the lake.

CLARE CRAGAN

Mono Lake Tufa State Reserve Ranger Jim Pence at Old Marina.

In his time off you may see Ranger Pence and his wife, Sara, paddling around the tufa in their kayaks—at a safe distance from nesting osprey, of course! The Committee is very happy to welcome them to the Mono Basin, and hope they'll enjoy this majestic place for many years to come.❖

Tufa from page 18

conditions, associated microbes may or may not be incorporated into the tufa and preserved as fossilized cells. More commonly, microorganisms leave behind other "calling cards" in the form of geochemical (isotopic or molecular) biosignatures in the carbonate minerals, signatures that are specific to certain types of microbes and their processes. Such biogeochemical markers are often more widespread and better preserved than cellular remains and are therefore of broader interest when interpreting the microbial fossil record.

If you have ever looked closely at the tufa along the Mono Lake shoreline, you have probably noticed that they vary a lot in both texture and color. Tufa textures range from dense and laminated to spongy and clotted. Surfaces of exposed tufa towers are commonly white to tan-colored, but where broken open to expose their interior, hues can range from gray to black, to orange to reddish brown. Lab analysis of the mineralogy of these interior surfaces reveal that the calcium carbonate includes accessory minerals, such as iron oxides and sulfides that account for the color differences. Understanding the role that microbes play in mediating the precipitation of these accessory minerals is an area of active research.

For those who know it, Mono Lake is certainly a special place on planet earth. Studying microbe-mineral interactions in extreme places like Mono Lake is helping us to expand our understanding of the range of microbial habitats on earth, with a focus on the extreme environments that may have been widespread during the early history of the planet. But the varied interactions between microbes and minerals also hold great interest for planetary scientists and astrobiologists who are interested in exploring for life on other planets in our solar system. We are only beginning to appreciate the potential connections that places like Mono Lake may hold for other planetary environments, within and beyond our solar system. For example, Mono Lake is widely regarded as an important analog for Mars, which appears to have held many similar terminal lake basins earlier in the planet's history.

The next time you visit Mono's famed tufa towers, pause to ponder the origin of these unique structures that lend so much to the lake's mysterious charm. Whether you are looking at the dry and crumbling remnants of the tufa formed during bygone glacial days, or staring at the picturesque towers only recently exposed by a declining lake level, Mono Lake tufa tells a unique story that is fundamentally rooted in the interactions of microscale physical, chemical, and biological processes.❖

*Mike Thomas, Ph.D. candidate, and Professor Jack Farmer are located at Arizona State University in the School of Earth and Space Exploration (*http://sese.asu.edu*) and can be contacted at* mdthomas@asu.edu*, or* jfarmer@asu.edu*.* *Their research is supported by a grant from the NASA Astrobiology Program.*