



# YELLOWSTONE DISCOVERY

Quarterly publication for members of the Yellowstone Association

# Microbes thrive in extreme conditions

**Thermophiles** provide unique opportunities for scientific research

By Craig Elliott

For the Yellowstone Association With so many magnificent geologic

features, photogenic large mammals, and other crowd-pleasers to see and study in Yellowstone, it's easy to overlook some of the less-obvious wonders. But the next time you're on a board-

walk in a thermal basin, take a look down

at the rusty-colored bacterial mats and streamers living in the hot-water runoff channels. These are teeming communities of microorganisms, and every day thousands of park visitors walk past them, unaware of the vast potential these unique life forms - called "thermophiles" - may hold. These aren't just ordinary creatures; thermophiles are microscopic organisms that live at high temperatures. They all

require hot water, and some may thrive in acidic conditions while others live in alkaline springs. Others utilize sulfur and arsenic. And they are living and thriving in environments - Yellowstone's hot springs - that are lethal to humans. Some of these thermophiles are direct descendants of the earliest life forms on Earth. According to DNA analysis, the organism most closely related to the

Yellowstone's Hayden Valley. During the first 3 billion years of Earth's history, scientists believe microorganisms transformed the atmosphere, which had no oxygen, into one that could support complex forms of life. Microorganisms called "cyanobacteria"

origin of life - Earth's most primitive spe-

cies - lives in a hot spring in



Thermophiles are common in Yellowstone's thermal areas, including Castle

Geyser were the first to use photosynthesis to but remember that samples can only be

process carbon dioxide into oxygen and other byproducts. This oxygen production led to the creation of Earth's atmosphere. Other organisms tapped the energy stored in chemicals, such as iron and hydrogen sulfide, in a process known as "chemosynthesis." Cyanobacteria continue to be

present in some of the unique bacteria mats and streamers common to Yellowstone's thermal areas. Studies have shown that cyanobacteria and other microbes make up most of the species on Earth, but less than 1 percent of them have been studied in-depth. Yellowstone's thermophiles can be

broken down into three distinct groups: those that live in acidic environments, those that live in alkaline environments, and those that live in neutral, carbonate-rich areas. Thermophile communities can be seen throughout Yellowstone,

When the water temperature is be-

tween 163 and 198 degrees Fahrenheit,

collected with a scientific permit. These microorganisms are protected by law, just like Yellowstone's large mammals, and removal of them is prohibited. **Acidic Habitat** 

# The Norris Geyser Basin and the

Mud Volcano area are good spots to (Continued on page 2)

## What's Inside Institute winter course

- catalog enclosed
- Mudslides close East
- Entrance road Debris removed from pool
- Encounters lead to bear deaths Invasive aquatic species

### (Continued from page 1)

view Yellowstone's acidic thermophile habitat. In fact, thermophiles that live in these environments are considered "extremophiles" because they thrive in boiling water that is also highly acidic. are also referred to as They "thermoacidophiles." Some of the hot springs in these two

areas have a pH near 0, and the water

will burn holes in shoes and clothing.

Organisms that live in this environment are some of the toughest creatures on Earth. Viruses have also been found in some near-boiling acidic hot springs. The pH in acidic habitat can range up to 5, and these areas are usually underlain by rhyolite rock When you're looking for thermophile communities in acidic runoff areas, yel-

low streamers and mats will show the hottest areas. These areas are between 140 and 181 degrees Fahrenheit. When the temperature is between 131 and 140 degrees in these habitats, thermophiles form reddish-brown mats. The color comes in part from iron oxide, which the thermophiles metabolize from iron. When the temperature in acidic springs is below 131 degrees, algae spe-

cies form mats in runoff channels. At lower temperatures, green and purple algae are present. **Alkaline Habitat** Most of the hot springs in the

Firehole Valley and West Thumb Geyser Basin are alkaline, so these are good spots to see alkaline habitat for thermophile communities.

thermophiles that live in alkaline habitat will form long streamers in quickly-flowing runoff channels. These streamers may be pink, yellow, orange, white, gray, or black, depending upon the minerals in the water and the species involved. Below 167 degrees, thermophiles will form mats in these alkaline areas. Thermophile mats are vast communities of microorganisms; a 3-inch-

square piece of thermophile mat has more microorganisms than the number of people on Earth. These mats also have many of the same characteristics of a forest community. For example, species in the "canopy," or top layers, need or are able to withstand abundant light. "Understory" species can survive with little light and may metabolize chemicals such as iron and hydrogen. Interaction of the species in these mats can also create a laminated top, giv-

ing the mat a covering that appears solid. Neutral, Carbonate-Rich Habitat Mammoth Hot Springs is underlain

# by limestone deposits from ancient seas.

When underground hot water circulates to the surface, it brings along calcium carbonate from the limestone, and sulfur from hot, fluid, underlying rock. This means the Mammoth Hot Springs are rich in sulfur and carbonate. But at high temperatures, sulfur (in the form of hydrogen sulfide) is toxic to

cyanobacteria. So these bacteria are found farther downstream at Mammoth, where the sulfur has been removed by The Mission of the Yellowstone Association The Yellowstone Association, in partnership with the National Park Service,

color in Mammoth's active terraces. Cream-colored streamers of bacteria form when source pools at Mammoth

other organisms. These downstream

cyanobacteria contribute to the orange

Hot Springs are above 151 degrees. Sulfur and calcium carbonate materials deposited on the thermophiles provide the cream color. Below 151 degrees, the thermophiles at Mammoth will form green and purple mats. Deposits of calcium carbonate also

build up the terrace structures, and at the same time trap microbial communities within the newly forming rock ma-"Stromatolites" are sediments that have been laminated by microbial activ-

ity, and when found in ancient rocks can provide evidence of early microbial ecosystems. Stromatolites also form when Yellowstone's hydrothermal features trap thermophiles within travertine and sinter deposits. Mammoth Hot Springs is a good location for studying ongoing stromatolite activity because of its abundant communities of thermophiles and its quick rate of deposition. These "biosignatures" of thermo-

fossil record and can help scientists recognize similar features in other locations, such as Australia's 350-million-year-old sinter deposits. Ongoing studies and practical applications

philic communities are preserved in the

### Yellowstone's thermophiles provide valuable clues to early life on Earth, but they are also helping scientists look for

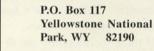
YELLOWSTONE **ASSOCIATION** 

## fosters the public's understanding, appreciation and enjoyment of Yellowstone National Park and its surrounding ecosystem by funding and providing

educational products and services. **Table of Contents** 

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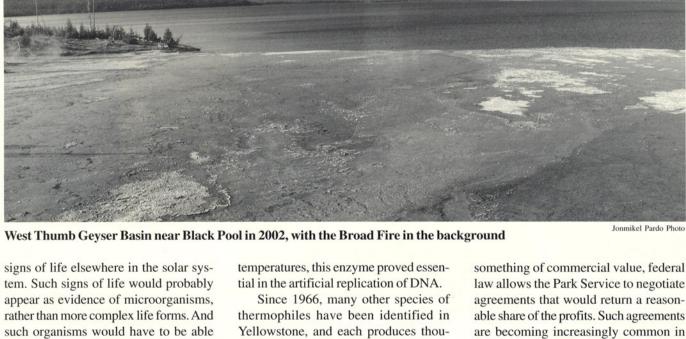


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such organisms would have to be able Yellowstone, and each produces thousands of uncommon, heat-stable proother countries, and in 1997 Yellowstone to survive in extreme conditions, much teins. These heat-stable proteins are

like Yellowstone's thermophiles. If stromatolites are ever found in the rocks studied on Mars or other planets, they would provide solid evidence that life once existed elsewhere in the solar system. NASA is currently studying Yellowstone thermophiles as part of its search for signs of life on Mars. Because signature that can be seen with satellite imagery, scientists are looking for the same signature in Mars' ancient volca-

cyanobacteria display a biogeochemical noes and suspected hot springs. And the study of thermophiles doesn't stop there. Another growing topic, sure to confront Yellowstone's resource managers for the foreseeable future, is that of "bioprospecting." This

activity is defined as searching for useful compounds in nature, and Yellowstone's thermophiles are believed to be a virtually untapped treasure trove. A discovery in Yellowstone was essential to one of the most exciting developments of the twentieth century. In 1966, Dr. Thomas Brock discovered a way to grow one of the thermophiles,

Thermus aquaticus, living in Mushroom Pool in the Lower Geyser Basin. An en-

zyme known as "Taq polymerase" was

later discovered in Thermus aquaticus,

and because it can withstand extreme

becoming increasingly important to ad-

vancements in science, medicine, and industry. Thermophile research has already led to practical applications in producing ethanol, treating agricultural food waste, recovering oil, bleaching paper pulp, improving detergents, and a host of other discoveries. And researchers believe that more than 99 percent of Yellowstone's thermophiles are still unidentified. Yet another topic related to thermophiles concerns the ethical, economic, and legal implications of thermophile re-

search. National Park Service regulations prohibit the commercial use or sale of analysis.

park specimens themselves, as well as any "harvesting" of microbes beyond the tiny samples needed for scientific However, the information and insight gained from these studies can be patented and commercialized, and the benefits and profits can be enormous. For example, the DNA fingerprinting pro-

But Yellowstone received no compen-

When park-based research yields

sation for that discovery.

cess, made possible by the Taq polymerase enzyme, has earned hundreds of millions of dollars for its patent holder.

became the first U.S. national park to enter into such an agreement with a private corporation. However, the issue was taken to court by groups opposed to bioprospecting, and the agreement is on hold pending environmental impact analysis. As scientists begin to unlock the secrets of thermophiles, Yellowstone will remain an invaluable resource; it is a preserve for one of the greatest concentrations of thermophilic diversity and unique genetic resources on Earth. So the next time you're walking through a thermal area, don't just look at the hot springs and geysers themselves; con-

sider the incredible creatures living there, and the vast potential they represent. Much of the information in this article was taken from "Yellowstone Resources and Issues 2004," an annual Park Service publication available through the Association. The chapter from which this article was adapted was written by the NASA Astrobiology Outreach Education Team. Additional in-

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