The Nature Of Geysers In Yellowstone National Park

Known for lighting the way to the creation of the U. S. National Park Service, Yellowstone National Park is home to a large array of wildlife, a supervolcano, and many microorganisms. The park, spread across Montana, Nevada, and Idaho, was established by Congress and signed into law by President Grant in 1872, granting free access to all who wished to see it. The Yellowstone region sits on top of a supervolcano- a volcano where magma bubbles close to the Earth’s surface, spreading heat and creating hydrothermal systems. The hydrothermal systems vary in characteristics, but all are caused by the pressure of the underground seismic activity. Just as unique as their haven, the microorganisms that inhabit these hydrothermal systems are some of the earliest life forms on Earth. Many microorganisms, called thermophiles, have been found living in geysers. Thomas Brock (1995) observed pink gelatinous shapes located near the geysers, flourishing at a staggering 180 F degrees, in 1965. A closer examination indicated that the shapes were similar to filaments, elongated and wavy. These shapes contained proteins-- but no chlorophyll-- and Brock confirmed that they were bacteria, thriving at high temperatures (Brock 1969); they were named hyperthermophiles. The thermophiles at Yellowstone utilize inorganic sources of energy, giving way to ample opportunities to seek answers about their ancestry.

While the hydrothermal systems include hot springs, mudpots, travertine terraces, and fumaroles, it is often the geysers that attract wide-eyed travelers to the greens of Yellowstone. The geysers are rare on the planet, and rightfully so, because their unique structure prohibits water from freely flowing. As one looks upon Old Faithful, a geyser known for its regular intervals, the steam rises in anticipation of the water. As the smoke-like steam gathers, it lifts the water above the ground, creating a natural fountain that can reach heights of 6-8 feet. The steam pushes the water out of the holes, creating violent outbursts. The water rises higher and higher with each spout, threatening to spill over the world as you crane your neck backwards to see it reach its limits. Old Faithful overtakes your hearing, leaving you with the loud sound of water fighting itself to reach newer heights.

These geysers are not homes to large-form life, since the temperatures often reach 250 F, along with thin surfaces that can break and lead into scorching hot water. Thermophilic Archaea, have proven to exist prior to the cyanobacteria in the geysers-- they do not rely on photosynthesis. However, the bacteria near the surface of the geysers contain chlorophyll and rely on photosynthesis for energy attainment, thus appearing a teal-green color in pictures. The enzymes of these thermophiles are active at high temperatures, which was shocking to many scientists due to the usual denaturing of enzymes at extreme temperatures. One specific bacterium found in Yellowstone by Brock is Thermus aquaticus, which has gained popularity in the medical and biology industry. A brilliant yellow, immobile bacterium, which, unlike other thermophiles, grows slowly at 131 F degrees, and thus it is found in hotter Yellowstone geysers, where lower temperatures are 150 F degrees. The protein-synthesizing system of Thermus aquaticus also proved to be active at high temperatures, challenging what many believed to be the upper temperature limit of organic life. Thermus aquaticus attain energy through chemosynthesis, or through indirect photosynthesis from cyanobacteria. These sources include the algal-bacterial mat, other heterotrophs, chemoautotrophs, and the surrounding soil. The algal-bacterial mat is at the surface of hot springs and is home to decomposing organic matter.

It is believed to be one of the biggest sources of organic energy for T. aquaticus. The T. aquaticus' structure is different from that of most bacteria, because it possesses a three layered membrane. The inner plasma membrane has a sequence of rod-like structures, called "rotund bodies" (Tindall, Kenneth R. , and Thomas A. Kunkel. 1988). The rest of the structure is similar to that of other bacteria, and T. aquaticus also reproduces asexually through mitosis. While Brock gathered a number of cultures from Thermus aquaticus, he was able to show that it was present in a number of artificial hot-water environments. This allowed other researchers to gather T. aquaticus and learn more about its characteristics, and eventually discover that it possesses the Taq polymerase, an enzyme for polymerase chain reaction that is used to replicate pieces of DNA (Brock 1997). Taq polymerase is able to survive the high temperatures necessary during PCR, being able to fulfill the job of DNA polymerase. Its prime temperature is 75- 80 Celsius, when it can polymerize near 150 nucleotides per second per enzyme molecule. At 90 Celsius, the Taq polymerase does not complete polymerization, but it does not denature or unsettle. Taq is also highly accurate, making only 1x10^-4 to 2x^10^-5 errors per base pair; this combined accuracy and lack of heat sensitivity make Taq extremely popular in medicine and genetics, as it allows for superior DNA synthesis and enzyme production (Sharp & Williams 1995).

Geysers rely on various factors to truly differentiate from a hot spring, or any other hydrothermal system. In the presence of water and a source of intense heat, a hot spring will form. Geysers differentiate from hot springs through the presence of a natural plumbing system. The design of this system must withstand immense pressure while its shape dictates the intensity of the water flow. The supervolcano underneath Yellowstone drastically heats all water that flows out to different regions, similar to blood running through veins. In the geysers, this water often flows up in steam, meeting the cooler water near the surface and eventually beginning to reach the boiling level. Once the geyser is full, which can vary depending on the size, it erupts. When the water cools at the surface, geyserite forms around the rims of the geyser. The calcium carbonate that is carried to the rims crystallizes into travertine, creating white rock. The luminous shades of green, red, blue, orange, and yellow that often appear are formed due to the algae and microorganisms that live near the rims. They blend together as if they know they belong to each other, each color slowly fading and transitioning into another. The fiery reds appear on the outer rings of the geyser, slowing moving into a vivid yellow, and eventually fading into a cool, deep blue.

The intense heat of the geysers are ideal for T. aquaticus, but in order to fully understand the unique relationship that exists between the two, we must evaluate other factors. T. aquaticus' optimum pH level is 7. 5 to 8, thus the waters must be relatively neutral in H+ concentrations. Additionally, the salinity in the water highly affects the bacterium due to its strong sensitivity; it cannot grow in an environment with NaCl levels above 1%. Some strains of T. aquaticus have been found to be halotolerant, but none are halophilic. Sharp, Richard & Williams, Ralph 1995) There is also minimal dissolved oxygen in the water of the geysers-- it can be said that T. aquaticus use nitrate as their main electron acceptor. T. aquaticus is an unusual organism with distinct characteristics, and it rightfully resides in an equally remarkable home.

The discovery of these thermophiles were not significant solely for Yellowstone or scientists, but for all people because it provided a further temperature at which organic life could live. Brock's discovery revolutionized the significance of geysers; they have since been full of research teams observing and testing for other microbes. It allowed for us to understand that there is not yet a known measurement on the upper limit of life. Furthermore, the life forms that are found in geysers are as rare as geysers themselves, as they not only exist in environments unsuitable for most organisms, but thrive. Geysers do not provide ample energy for thermophile-- they rely on the sun or other nearby bacteria-- but they provide the particular habitat necessary. The Taq polymerase found in Thermus aquaticus has given the fields of microbiology and DNA a powerful tool, and this bacterium is only the beginning of what lives to be known in geysers.