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Book Review

Geothermal Biology and Geochemistry in Yellowstone National Park. *(eds WP Inskeep and TR McDermott) 2005. Montana State University Publications, Bozeman, MT, 352 pp. + index.*

Yellowstone National Park is justly famous for its scenic beauty and the large numbers of "charismatic megafauna" roaming the Park's territory. The landscape is majestic and open, due in part to the succession of plant and animal life in a periodically replenished terrain. The geologic influences on the land surface are obvious to visitors, from the Park's volcanic flows to the near-surface heat in the geyser fields and other geothermal areas. Heated water brings chemical energy and life to the surface of the Park and our planet. It also attracts scientists seeking to study the organisms capable of capitalizing on this chemical energy and also able to thrive in extreme, sometimes boiling, sometimes acidic, conditions. Yellowstone National Park has rewarded investigators since the 1960s with discoveries of new organisms able to withstand extreme conditions. These studies in turn have expanded our understanding of the origin and limits of life.

The legacy of chemical and biological research in geothermal regimes, while short in duration, is long in impact. The pioneering work of Thomas D. Brock, who discovered and characterized the first microorganism known to tolerate elevated temperatures (*Thermus aquaticus*), led to the widely used method of DNA amplification called polymerase chain reaction (PCR). The large amount of genomic material that can be prepared by PCR from small biological samples resulted in a revolution in molecular sciences that is ongoing today.

Reports of discoveries of thermophilic and otherwise 'extreme' organisms from geothermal areas, including Yellowstone, are largely confined to the specialty literature of geochemical and microbiological journals. One exception is Brock's pamphlet 'Life at High Temperatures' published in 1994 by the Yellowstone Association for Natural Science, History & Education, Inc. A scholarly collection of current research findings in geochemistry and geobiology of thermal waters was overdue. This need was recognized by the Montana State University Thermal Biology Institute and Department of Land Resources & Environmental Sciences. They convened 'The Thermal Biology Institute Workshop' in Yellowstone National Park in October 2003 with assistance from the National Park Service and NASA Exobiology. A proceedings volume containing 22 papers resulted from the meeting and was published in 2005.

The foreword by Director of the Yellowstone Center for Resources, John Varley, expresses a personal thrill of discovery and enthusiasm for the research that is evident in nearly all of the papers that follow. The subjects covered during the workshop are either new (*e.g.* metabolism of extremophiles) or being applied in new ways (*e.g.* high temperature aqueous geochemistry) and one can imagine the excitement generated at the meeting by the confluence of active researchers in a park setting. The first five papers are organized under the umbrella of geochemistry and discuss how subsurface geology, proximity to magma, faults and fractures, as well as climate effect the chemistry of the geothermal system and the ground and surface waters, including Yellowstone Lake. I read these papers before traveling to Yellowstone National Park last summer and my grasp of the dynamics and range of the hydrothermal processes was greatly enhanced.

The next five papers discuss aspects of chemotrophic metabolism in geothermal waters and thermal soil surrounding steam vents. In these inhospitable environments, communities of bacterial and archaeal primary producers can make a living without sunlight, shuttling electrons from reduced chemicals, such as H_2 or H_2S, to more oxidized molecules, in the process obtaining energy for metabolism and growth. There is a great diversity of organisms capable of chemoautotrophic metabolism in these environments and most apparently obtain their energy from H_2. Much of the H_2 is magmatic, but some may be derived from the bacterial oxidation of CO which, along with CO_2 and CH_4, is a primary carbon source. However, nitrogen fixation, which was recently found to proceed at temperatures above 90°C in deep sea vents, was not observed. This leaves open the question of what is the source of nitrogen for autotrophs in Yellowstone thermal waters.

The next section consists of four papers discussing the occurrence, metabolism and diversity of photosynthetic organisms, mostly cyanobacteria, in thermal waters. Colorful microbial mats and colored steam were first recognized as biological features of Yellowstone by Walter H. Weed in 1889. The prokaryotes that produce these colors cannot inhabit the warmest waters that some of the autotrophs are able to live in, but large populations exist just downstream of many vents and pools. Anoxic phototrophic (purple) bacteria are also found within these communities as well as in other extreme sulfidic environments, such as the bottom of stratified Antarctic lakes.

A final group of six papers is devoted to smaller and/or pathogenic microorganisms that inhabit the thermal waters of Yellowstone. A parasitic nanoarchaea, representing a novel kingdom, was originally found in submarine hot springs around Iceland. Gene sequences representing this kingdom have been identified in DNA collected from Yellowstone thermal springs. Hypothermophilic archaea, for example *Sulfolobus* sp., have proven to be useful analogs of more complex eukaryotic DNA replication systems and may suggest a stronger linkage between archaeal and eukaryotic domains. In Yellowstone thermal and acidic water, viruses inhabit and interact with archaeal (*Sulfolobus* sp.) hosts and share many of their genetic characteristics. Free-living amoebae as well as the human pathogen *Legionella pneumophila* were identified by gene sequencing and/or culturing of microbial mats found in Yellowstone's Nymph Creek.

The last two papers in the collection explore independent topics and warrant individual mention. The first, by Bonheyo *et al.*, reports a method for testing whether microorganisms may be transported by atmospheric deposition from one hot spring to another. Apparently, this is how many new hot springs are inoculated. The final paper is a heart-felt reminder by John Spear to minimize the impact of our presence as researchers and visitors to areas with sensitive habitat. This brings me back to the original feeling I had reading the foreword: an understanding that the researchers themselves are often impacted by the place that they study, with a strong sense of wonder and reverence for their subject.

This is a handsome volume containing many fascinating observations and stimulating discussions. The breadth of topics covered is remarkable for such a specialized workshop and, importantly, a great deal of thought went into the presentation of these topics. This is a well-conceived book, from the organization of papers, to the number of photographs and color plates, to the useful index – rather unusual to find in an edited volume. It is also a well-produced book, one that is easy to read and sturdy, with a good binding and cover. My only negative criticism is that the book is very expensive in hard copy and may not get the distribution it deserves; however, electronic copy is freely available online. I commend the Montana State University and the Thermal Biology Institute for their successful undertaking and hope that they continue to publish similar high-quality products in the future.

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