Geochemical Cycling and Organomineralization in a Thermal Microbial Community in Big Spring, Thermopolis, Wyoming

VERONICA MALONE
WITH SUZANNE M. SMAGLIK
AND STEVEN J. McALLISTER
DEPARTMENT OF MATH & SCIENCE
CENTRAL WYOMING COLLEGE
RIVERTON, WYOMING

UNIVERSITY OF WYOMING
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Location of Research
The INBRE–funded Thermopolis project began in 2006 with Central Wyoming College faculty and students.

Since this time, students have sampled the hot springs environment to ascertain the biological, geological and chemical aspects.

Recent research on the geochemistry of hot springs and its impact on the development and activity of microbial mats focused this project on analyzing the geochemical equilibrium present.
Overview of Microbial Mats

- Microbial mats are ecosystems often present in hot springs and formed by thermophiles consisting of phototrophic bacteria (Hanada, 2003).

- Because of the unique composition of the source water of geothermal springs in comparison to surface conditions, there exists “thermal and chemical energy gradients that drive a variety of abiotic and microbially mediated reactions” (Macur, 2004).

- The result is often degassing or precipitation.
View of Big Spring

- Big Spring at source
- Abundant visual evidence of microbial mats
- Close up of microbial mats at source

Photos courtesy of Suki Smaglik
Overview of Microbial Mats Continued

- **Depositional environment:**
  - Element cycling
  - Biological activity
  - Mineral concentration

- **Organomineralization:**
  - Direct relationship between the geochemistry of the source water and the surface (Dupraz, 2009)

- Previous studies address the importance of the presence of carbonate ions, available calcium, temperature, pH and the effect of the alkalinity engine.
Christophe Dupraz details the process of carbonate precipitation in depositional hot spring environments.

“Carbonate precipitation is a function of carbonate alkalinity and the availability of free calcium” (Dupraz, 2009).

Various processes intrinsically and extrinsically drive the engine.
The Importance of the Alkalinity Engine

• Intrinsic: Photosynthesis and Respiration

• Metabolism of the microbial community influences both the pH of the environment and the photosynthetic process.

• Creation of an environment that favors precipitation.
The Importance of the Alkalinity Engine

- Extrinsic: Evaporation, degassing, alkaline water input.

- Carbonate precipitation can result primarily from evaporation of water and \( \text{CO}_2 \) degassing.

- For the Big Spring, the abiotic dimension of precipitation occurs almost entirely by carbon dioxide degassing.

- The formation of calcium carbonate in degassing can be expressed:

\[
\text{Ca}^{2+} (\text{aq}) + 2\text{HCO}_3^- (\text{aq}) \leftrightarrow \text{CaCO}_3 (\text{s}) + \text{CO}_2 (\text{g}) + \text{H}_2\text{O (l)}
\]
The Importance of the Alkalinity Engine

- The release of carbon dioxide results in a supersaturation of calcium carbonate.

- “Although the alkalinity engine, responsible for carbonate precipitation, results from an abiotic source, precipitation is initiated on organic substrates” (Dupraz, 2009).

- The alkalinity engine plays a vital role in the development and growth of the microbial community.
Degassing at Big Spring

- Bubbles coming from microbial mats
- Testing to be done on gas emissions

Photo by Suki Smaglik
The Geochemistry of the Big Spring

To obtain a clearer understanding of what occurs in the microbial mat environment that causes the precipitation in the Big Spring of Thermopolis, analysis of the samples included:

- Temperature
- pH
- Total Dissolved Solids
- Hardness
- Alkalinity
Data Collection Methods

- There were 14 test sites.
- Data taken at 10 m intervals beginning at source.
- Between test site 6 and 7, there is a 20 m distance.
- Testing done on site and in the CWC INBRE Research Facility.
Data and Results for Collection Temperature

Variation in Temperature in Distance from Source by Date

Temperature in Celsius

TS 001  TS 002  TS 003  TS 004  TS 005  TS 006  TS 007  TS 008  TS 009  TS 010  TS 011  TS 012  TS 013  TS 014

July 29 2009
August 14 2009
January 24 2010
February 28 2010
March 28 2010
April 18 2010
May 21 2010
Data and Results for pH

- Measurements of pH recorded by Vernier probe
- Testing done on site
- Important distinction in trend shows seasonal variability from May to July
- Decreases in acidity as test sites move further from source
Data and Results for Total Dissolved Solids

- Testing done in lab
- Method involved evaporating water and weighing remaining solids
- Data demonstrates the high content of elements and compounds in water.
Data and Results for Hardness

- Testing done in lab by EDTA titration.
- Data illustrates the richness of mineral content in water.
- Very hard water levels are > 181 mg/L
Data and Results for Alkalinity

- Testing done in lab
- High Range Alkalinity Test
- Data illustrates availability of calcium carbonate that decreases as precipitation increases
Visibility of Precipitates

- Preliminary precipitation as site 3
- Photo courtesy of Suki Smaglik

- Filamentous precipitation as site 9
- Photo courtesy of Suki Smaglik
Creation of Precipitate

Aragonite? “cauliflower”

Calcite rhombohedrons

- SEM photos courtesy of Tracey Wilcox.
Discussion

- Layering of the microbial mats due to mineralization contribute to a series of interactions by the microbial community with available minerals.

- Each test site illustrates the richness of mineral content and the activity of the biological community.

- Results demonstrate the existence of microenvironments that are influenced microscopically by mineral concentration and macroscopically influence precipitation.
The environment of the Big Spring in Thermopolis, Wyoming, is a very dynamic interplay among the elements available in the source water and the air-water interface as well as the biological activity of the microbial community.
Further Research

- Because of the isolation of each of these environments, one could speculate on the diversity present in various geographic locations.

- Further research is necessary to determine the unique and delicate balance created in these extreme environments with specific focus on understanding the variety of reactions in the layers of the microbial mat.

- In particular, it would be important to understand the source water, pathways through geological formation, and the gases released.


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