In the Land of Black and White, Microbial Deposition of Ferromanganese on the Walls of Snowy River, Ft Stanton Cave, NM

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Ft Stanton Cave: 50+ km of surveyed passage (14th longest in US)
Snowy River: 19.1 km long and still going!
Cave is hosted in Permian San Andres Limestone
- Soils above the cave developed in mainly limestone and Tertiary gravels (stay tuned for the next talk!)
- Likely source of water in Snowy River is 6 km to SW
Natural History of Snow River Passage

- Large passage forms
- Silt & clay deposited on walls/floor
- Sand & pebbles deposited
- Mn-oxide on walls
- Snowy River calcite
Ferromanganese

Thin coating on mud

Directly on bedrock

Evidence of multiple episodes of growth
Ferromanganese Coatings

May be patchy and discontinuous

Or cover nearly every surface

Victor Polyak Photos
Evidence of regrowth after the Mn-coated mud peeled away in several episodes.
Ferromanganese Coatings

Microbial filaments

Mn-oxides (light gray)
FMD Coatings in the SEM

Root-like structures

Wispy Mn-oxide sheets

Micro-spherules
EPMA Analysis of FMD

- Polished section prepared without carbon-based epoxy
  - Section of Mn-oxide crust on mud collected from cave
  - Sample vacuum impregnated with Na-silicate solution
  - Evaporated copper used for conductive coating instead of carbon for electron probe analysis

<table>
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<th>CO₂</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>K₂O</th>
<th>CaO</th>
<th>MnO₂</th>
<th>Fe₂O₃</th>
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<tbody>
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<td>Mn-oxide</td>
<td>5.00</td>
<td>7.91</td>
<td>2.06</td>
<td>5.13</td>
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<td>0.59</td>
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<td>Mn-oxide</td>
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<td>8.52</td>
<td>1.52</td>
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<td>0.50</td>
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<td>1.10</td>
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<td>1.96</td>
<td>0.90</td>
<td>2.57</td>
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EPMA Mapping of FMD

- X-ray maps on polished section
  - Higher carbon associated with FMD
  - Maps show 2 layers of FMD crust
  - Crust inundated with mud then regrowth

BSE

\(
\begin{align*}
\text{BSE} \quad \{ \text{Surface layer} \} \\
\{ \text{Buried layer} \}
\end{align*}
\)
Metagenomic Dataset from FMD

Number of hits for each domain

By percent of each domain

Top six bacterial phyla

Top archaeal phyla
Mn Oxidation in Oligotrophic Cave Systems

**Chemolithoautotrophy Model**
- oxidation driven by chemolithoautotrophic bacteria on cave walls (modified from [56]).

**Heterotrophy Model**
- oxidation driven by organic matter derived from (1) litter, (2) nutrient-rich waters, or (3) chemolithoautotrophic bacteria within the community.

Mn oxidation driven by chemolithoautotrophic bacterial breakdown of bedrock (hypogene caves)

Mn oxidation driven by nutrient input from exogenous carbon in water, clay, etc. (epigene caves)
Conclusions

• Careful preparation of samples allows EPMA analysis of carbon
• FMD is associated with higher carbon, likely the result of microbial activity
• Microbial community in FMD is dominated by heterotrophic bacteria, chemolithoautotrophs rare
• Nutrients/metals supplied by water & detrital material
• FMD deposition has continued over time and is still active in the cave
Acknowledgements

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