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The Mystery of Blood Falls, Antarctica: Lessons from a Planetary Exploration Analogue

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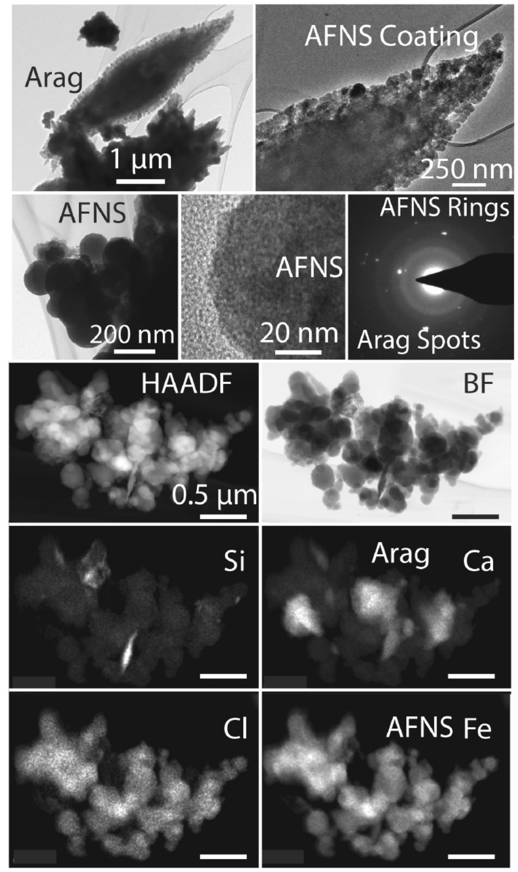
Blood Falls is a unique feature at the northern terminus of the Taylor Glacier in the McMurdo Dry Valleys, Antarctica that forms when subglacial brine episodically emerges to the surface. Upon atmospheric exposure, the outflow forms a red-orange cone presumed from iron (hydr)oxides (IH). The sub-ice aquifer source appears to be concentrated ancient seawater containing a diverse microbial community that may have evolved in isolation for many thousands of years—a unique opportunity to study co-evolution of biology and geochemistry under 100s of meters of ice [1]. Blood Falls represents an analog to Mars and cryovolcanic plumes on Enceladus. Despite its uniqueness, modern analysis of the Falls' mineralogy is lacking. We here apply analytical techniques that have been employed on rovers and orbiters while adding other "Earth-based" methods to test the completeness and accuracy of those satellite-based.

Blood Falls sediments were fully characterized using XRD, FTIR, Raman, VNIR, Mössbauer, ICP-OES, SEM/EPMA, and TEM. XRD identifies varying proportions of aragonite and subordinate calcite, quartz, feldspar and clay minerals. IH may be present, but only in trace levels. Features in FTIR spectra are consistent with aragonite, calcite, and feldspar and rule out the presence of all IH except for trace hematite or ferrihydrite. Raman spectra identified carbonate species, but not IH. Fe^{3+} features in VNIR spectra are most consistent with goethite; other bands result from carbonates. Mössbauer spectroscopy rules out all IHs except for those possibly present as nanophases. ICP-OES analyses are dominated by Ca and Fe. SEM/EMPA show carbonate agglomerates with Fe and Al-rich nanoparticles. TEM analysis isolates phases identified by SEM/EMPA adding crystallographic, compositional and textural data on nanoparticles. TEM confirms the presence of calcite, aragonite, feldspar and quartz, along with abundant amorphous Fe-rich nanospheres. Iron is not a significant component of either calcite or aragonite. Thus, the color of Blood Falls appears to come from amorphous Fe-rich nanospheres, not iron (hydr)oxides or red carbonates. This study illustrates the importance of direct observation of correlated structure and composition of the nanoparticle fraction when surficial low temperature processes and amorphous phases are involved.

[1] Mikucki & Priscu, (2007) *AEM* 73, 4029-4039.



TEM images of (A) Aragonite clusters, (B) AFNS on aragonite, (C) Cluster of AFNS, (D) High resolution image of AFNS, (E) Electron diffraction patterns of AFNS yield rings while aragonite yields spots, (F) High-angle annular dark-field, bright-field, and X-ray maps of AFNS cluster.