Mineralogy and Organic Preservation Acid Sulfate Fumaroles and Thermal Features: Analogs for Mars Early Aqueous History

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Sulfates recently detected on Mars are posited to have formed from fluids derived from basaltic weathering and igneous volatile input, ultimately precipitating from acidic brines subjected to desiccation and freeze-thaw cycles. Key issues concerning Martian sulfate deposits are their relationship to aqueous clay deposits, and whether or not specific sulfate deposits represent former habitable environments (see Soderblom and Bell, 2008; Tosca et al., 2009). Modern terrestrial volcanic fumaroles and hot springs precipitate sulfates and clays under similar conditions and can help demonstrate that certain acid sulfate mineral assemblages reflect habitable environments. We studied the mineralogy and organic chemistry of volcanic fumaroles and thermal features at Valles Caldera (VC), New Mexico, in order to link mineral assemblages similar to those found on Mars to specific pH and salinity conditions found in analogue environments. We also studied the organic geochemistry of fumarole efflorescent deposits and mud pots in order to determine the fate and preservation potential of organic matter in these environments.

Reconnaissance study of VC led to recognition of dry leach zones, active fumaroles with encrustations, boiling mud pots, and sulfur springs. Each of these environments was assayed for temperature, pH, minerals, and organic matter. Mineral deposits were studied with SEM-EDS and the In Situ Terra XRD / XRF instrument. The dry leach zones consist of altered outcrop or alluvium located near a sulfidic gas seep and may host minerals such as jarosite developing as thin rinds on altered igneous host rock, or clays and gypsum crystals precipitating in soils. The active fumaroles have visible gas emanations and mm- to cm- thick encrustations of silica, sulfur, gypsum, jarosite, alunogen and other minerals. Green biofilms were observed in the interior regions of some deposits. Mud pots have extremely low pH (<2) but may vary in terms of temperature. Mud pots include sulfidic gas seeps and host clay / silica slurries that are also known to support archaean communities. Sulfur springs are aqueous deposits that usually have higher pH (<2) and lower temperatures due to dilution of with meteoric water sources. Seeps can cause oxidation of surfaces and support biofilms composed of sulfur – metabolizing microbial communities.

We assayed organic matter from acidic mud pots, gypsiferrous soils, and primary mineral precipitates surrounding fumaroles to understand how pH and sulfate content may discriminate against or enhance preservation of specific classes of organic compounds in acid sulfate environments (see Benner et al., 2000). Key challenges to understanding the fate of organic matter in fumarole and thermal spring environments are the wide range of possible source material (fossil organics as well as modern plant debris and extremophile microbial communities), and divergent indicators of age, source, and thermal maturity of organic matter, imposed by high heat flux. High sulfur content, long chain alkanes (max > nC29), unresolved complex mixtures (UCM) of solvent extractable hydrocarbons, polyaromatic hydrocarbons (PAHs), and insoluble macromolecular organic complexes (asphaltene, kerogen moieties) are common features of hydrothermal organic matter distributions. Different organic sources are reflected in long chain n-alkanes and waxes (from plants), abundant functionalized C₁₇ – C₂₀ alkanes, squalane,
and isoprenoid alkanes (microbial communities), and epimerized distributions of fossil hopanoids, steroids, and aromatic compounds (fossil organics; see Matsumodo and Watanuki, 1990; Botz et al., 2002). Jahnke et al. (pers. comm.) are also conducting ongoing research on organic matter distributions at hydrothermal springs, including several acidic sites at Yellowstone National Park, WY.


