Hydrothermal systems as abodes for life on ancient Mars

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Volcanic and/or impact-generated hydrothermal systems may have been the location for the origin of life on Earth, and also Mars. These settings were widespread during the early histories of terrestrial planets, owing to high crustal heat flow and influx of meteoritic material. Like Earth, Mars exhibited volcanism from earliest times nearly up until the present. Given the single-plate nature of Mars' lithosphere, a number of individual volcanoes show nested calderae that formed from eruptions spanning most of Mars' history. Local outgassing from these vents persisted off-and-on for billions of years. Similarly, the 78 largest impact basins (≥ 150 km-diameter) formed from the earliest preserved times until about 3.5 Ga and the larger ones likely hosted hydrothermal systems for up to 10 million years. Given that widespread surface waters were limited in time and transient, volcanic and impact systems represent the most habitable niches for life on Mars through time and should be primary targets for astrobiological exploration.

A variety of relict hydrothermal deposits have been detected on Mars with varying suites of alteration mineral assemblages. Fieldwork has been undertaken to study Earth's volcanic systems as Mars analogs, combined with corollary laboratory experiments and geochemical modeling. These results are used as input for inverse models to back out the environmental conditions of each relict Martian hydrothermal site based on the mineralogies present. This allows discrimination of which of the Mars locales were more or less habitable based on inferences about their longevity, fluid/gas composition, pH, temperature, and redox state.

Microbiology studies of the Mars analog systems are also underway. Deeply-rooted Archaea and Bacteria, present in most locales, employ a variety of metabolisms. The community diversity is strongly dependent on the fluid characteristics including the amount, chemistry, pH, and temperature. At some of the most extreme environments, such as Poas crater lake in Costa Rica, a monoculture of a single organism has been identified in pH 0.2 and 40°C sulfurous lake waters. Understanding hydrothermal systems on Earth provides a baseline for interpreting similar volcanic and impact-induced settings on Mars, which would have been a refuge for life on a globally inhospitable planet.