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Compositional controls on physical properties of digitate sinter in hot springs: Implications for remote sampling on Mars

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Since the first discovery of silica-rich deposits on the Martian surface, these deposits have represented an important potential target in the search for evidence of ancient extraterrestrial life. Development of Martian sample return mission proposals involves targeting this siliceous material that resembles digitate siliceous hot spring deposits (sinter) found in hot spring pools and outflow channels on Earth. However, an understanding of the physical parameters (namely strength) are required for the successful design of a sampling system. This investigation integrates micro-porosity, composition, and hardness measurements to quantify the strength of digitate sinter collected from both acid-sulfate and alkali-chloride hot spring systems across the Taupo Volcanic Zone in New Zealand, and to determine how depositional environment affects the composition and strength of these siliceous features.

Given the irregular shape and small size of the Earth-analog digitate sinter, micro-computed tomography (microCT) and nano-indentation have been employed to determine porosity and silica hardness, respectively. Scanning electron microscopy (SEM), back scatter electron (BSE) imaging and energy dispersive spectrometry (EDS) provide *in situ* chemical variation across the digitate structures, providing a direct comparison between hardness and composition. X-ray diffraction (XRD) also provides important constraints on the crystalline structure (or lack thereof) of the digitate materials. MicroCT results indicate very low total porosity, even on the 1-2 micrometer pixel scale, with values from 4.6-10%. In comparison, sinter substrate from a sample from an alkali chloride spring has a porosity of 17%. Microporosity is not evenly distributed and is largely controlled by the microstromatolitic growth structures of the digitates. Modern samples are all dominated by amorphous silica, analogous to samples on Mars, with little compositional variability (predominantly silica) despite clear change in sample density and obvious banding evident from image analysis. Hardness measurements on digitate sinter from Mars Pool (colloquial name based on textural similarity to Martian silica deposits) along the Lake Rotokawa shoreline, suggest significant variations corresponding to microstromatolitic banding within the digitate feature, with hardness from 246 to 3279 MPa. Combining the composition, hardness, and porosity data allows us to estimate strength for these digitate sinters, providing critical constraints for future potential remote sampling missions.