Ti-Group Elements in Siliceous Sinters as Martian Analogs

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Introduction

Hydrothermal settings are a potential habitat for living organisms on Mars. Silica deposits observed at Home Plate, Gusev Crater, Mars, have been argued (Ruff and Farmer, 2016) to be formed in a hydrothermal setting based on their morphological similarity to terrestrial silica sinters from El Tatio, Chile (Fig. 1). The presence of TiO₂ in the silica deposits has been used both for and against a hot spring origin. If the silica at Home Plate (Fig. 5) is a volcanic sinter, then it is a potential astrobiological target for Mars Sample Return. Hydrothermal settings are a potential habitat for living organisms on Mars. Silica deposits observed at Home Plate, Gusev Crater, Mars, have been argued (Ruff and Farmer, 2016) to be formed in a hydrothermal setting based on their morphological similarity to terrestrial silica sinters from El Tatio, Chile (Fig. 1). The presence of TiO₂ in the silica deposits has been used both for and against a hot spring origin. If the silica at Home Plate (Fig. 5) is a volcanic sinter, then it is a potential astrobiological target for Mars Sample Return.

Hypotheses

One: Opaline silica is a residue left behind after acid-sulfate leaching of metal cations from basaltic rocks (Squires et al., 2006).

Support: Ti is assumed to be immobile under such conditions. High TiO₂ abundances observed in Home Plate silica is consistent with this assumption.

Two: Opaline silica is a precipitate (sinter) from neutral-to-alkaline hot spring fluids.

Support: Their digitate morphology; Ti-bearing (anatase) silica sinters are known to occur on Earth.

Objectives

To ascertain whether the abundances of Ti-group elements (Ti, Nb, Ta, Zr, Hf) in sinters from terrestrial hot spring and geyser fields could be used to distinguish between an origin as an acid-sulfate residue or as a deposit from a hydrothermal setting.

Methodology

Samples

Silica sinters were obtained from El Tatio and Puchuldiza, Chile. The El Tatio sinters display the digitate morphology (Fig. 2) used as evidence of a biological origin by silicea-secreting microorganisms.

Analytical

Total digestion of samples using HNO₃, HF and HCl. Analyzed using an inductively coupled plasma mass spectrometer (ICP-MS), Thermo Element 2, at NHMFL.

Results

Fig. 3: SiO₂ vs. TiO₂ concentrations for sinters from El Tatio and Puchuldiza (this study) compared with silica deposits from Home Plate (Mars) (Gellert et al., 2006), and sinters from Iceland and New Zealand (Preston et al., 2008).

Fig. 4: Mantle-normalized abundances of Ti-group elements in sinters (this study). Basalts which have mantle-like abundances are high.

Discussion

The concentration of Ti-group elements found in siliceous sinters from this study are shown to have lower Ti/Zr ratios relative to mantle abundances, implying aqueous fractionation of the Ti-group elements. Mantle-like Ti/Zr ratios would be expected if the silica was a residue of acid-sulfate leaching of basaltic rocks. It should be noted that the TiO₂ abundances found in sinters in this study are lower than that reported from Martian silica (Fig. 3) (Ruff and Farmer, 2016), and from some terrestrial sinters (Preston et al., 2008). The Martian digitate structures are representative of flowing water that support microbes, therefore their unique resemblance to those found on Earth in similar hydrothermal settings make silica sinter deposits ideal targets in the search for ancient life on Mars.

Conclusion

Mass spectrometry on samples from Earth show that fractionation of mantle-like abundances does occur in hydrothermal hot spring settings. The presence of Ti-group elements in these sinters show that they indeed precipitate from the hot spring fluids. This study found that the relative inter-element fractionations of Ti/Zr/Nb could be exploited as a tool to distinguish hydrothermal sinters from residues of acid-sulfate leaching. Despite the powerful analytical capabilities of the Martian rovers, trace element data collected in this study is still possible only with ground-based laboratory techniques. This study has laid the groundwork for analyzing silica returned by future Mars missions, which would be a high priority due to the astrobiological potential of sinters.

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Fig. 1: Nodular and digitate silica structures found at Home Plate, Mars by the Spirit Rover compared with similar features at the El Tatio hot springs, Chile. These structures have been taken to be evidence of biosignatures on Mars (Ruff & Farmer, 2015).

Fig. 2: Sections of sawn samples from this study with laminations across the samples and digitate structures on top.

Fig. 5: Home Plate, Gusev Crater, Mars. Red marks the rover Spirit’s tracks and yellow encloses the opaline silica surface.

Fig. 6: Spectral effect of halite on silica on Mars and three hot spring locations on Earth (Ruff & Farmer 2016).