Facies Mapping and Analysis of Diverse Hydrothermal Sediments and Siliceous Spicular Sinter at Tikitere Geothermal Field, Taupō Volcanic Zone, New Zealand

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Introduction: Mapping of varied active hydrothermal facies by drone, Nova 3D laser scanning, and metric grid at Hell's Gate/Tikitere, Rotorua, Taupo Volcanic Zone, New Zealand, enabled a spatial reconstruction of their distribution, including that of distinctive spicular siliceous hot spring deposits (sinter) developing in spring outflow channels. Geochemical analysis of microbial digitate sinters was undertaken as they have similar morphology and mineralogy compared to opaline silica deposits found at Columbia Hills, Gusev Crater, Mars [1,2]. At Columbia Hills, the silica – formed >3 billion years ago – has been interpreted as hydrothermal in origin, with deposition from alkali-chloride hot spring silica sinter being the most likely origin [3]. The martian features have been compared to siliceous microstromatolites forming in the shallow outflow channels of alkali chloride thermal springs in the dry, high-altitude geothermal field at El Tatio, Chile [4]. Several hot springs around Rotorua, New Zealand, have broadly similar siliceous features, and form in the same position on the discharge aprons of alkali chloride (e.g. those of this study and elsewhere), acid-sulphate-chloride, and acid springs of the region, suggesting a rather ubiquitous occurrence of these morphologically distinctive textures.

Analysis of hot springs temperature, pH and water chemistry provides insight into environmental variations and controls on the formation of the Tikitere deposits, for which >10 hydrothermal facies have been identified. In-depth field mapping of variations in morphology and densities of spicular to digitate sinter (pH 5.9-7.3, 31-79 °C) deposits defines spatial context. The formation mechanism of the Tikitere spicular sinter was inferred to occur due to evaporative wicking, resulting in silica saturation and precipitation. Sinter formation is also attributed to microbial influences, with extracellular polymeric substance (EPS) secreted by microbes providing nucleation sites for silica precipitation. Higher densities of spicular sinter are seen forming in areas of increased slope leading to higher velocity discharge and terracing, with spraying, splashing and silica precipitation occurred upon descent to lower elevations. Nova 3D Laser Scanning of areas of higher density enables an understanding of the formation of these deposits in relation to elevation change, allowing a 3D model of these areas to be extrapolated and correlated to the 2D facies map.

Wetting and drying cycles of outflow channels were also observed in the field and were inferred to episodically occur based on seasonal field observations, and mineralogical (XRD) and microtextural evidence. Convergence of various outflow channels also promoted mixing of hydrothermal fluids. Recent research suggests periodic wetting and drying events, coupled with mixing of mildly acidic terrestrial hot spring fluids, may have provided the foundation for early life [5,6]. Therefore, this study provides an analogue for the early life-fluid mixing hypothesis.

The deposits analysed in this study act as analogues for sinter formation in bicarbonate-sulphate derived fluids in the geologic record. This fluid chemistry has not previously been studied in relation to sinter growth. These features are broadly correlative to the opal-A digitate sinters observed at Columbia Hills [2]. The Tikitere system is predominantly acid-sulphate rich, however bicarbonate waters are found on the peripheries. Thus, possible bicarbonate rich waters may be present on the distal margins of the geothermal system at Columbia Hills. This is evident in the carbonate-rich Comanche outcrops, also located in Columbia Hills, inferred to form in alkaline-neutral volcanic activity [7].

References:

[1] Squyres, S. W., Arvidson, R. E., Ruff, S., Gellert, R., Morris, R. V., Ming, D. W., ... & McLennan, S. M. (2008). Detection of silica-rich deposits on Mars. *Science*, *320*(5879), 1063-1067.

[2] Ruff, S. W., J. D. Farmer, W. M. Calvin, K. E. Herkenhoff, J. R. Johnson, R. V. Morris, M. S. Rice, R. E. Arvidson, J. F. Bell III, P. R. Christensen, S. W. Squyres (2011), Characteristics, distribution, origin and significance of opaline silica observed by Spirit rover in Gusev Crater, Mars, J. Geophys. Res., 116, E00F23.

[3] Ruff, S. W., Campbell, K. A., Van Kranendonk, M. J., Rice, M. S., Farmer, J. D (*In Press*.) The Case for Ancient Hot Springs in Gusev Crater, Mars. *Astrobiology*.

[4] Ruff, S. W., and J. D. Farmer. (2016), Silica deposits on Mars with features resembling hot spring biosignatures at El Tatio in Chile, Nature Commun., 7, 13554.

[5] Van Kranendonk, M. J., Deamer, D. W., and Djokic, T. (2017). Life springs. *Scientific American*, *317*(2), 28-35.

[6] Damer, B., and Deamer, D (*In Press*). The Hot Spring Hypothesis for an Origin of Life. *Astrobiology.*

[7] Morris, R. V., Ruff, S. W., Gellert, R., Ming, D. W., Arvidson, R. E., Clark, B. C., ... Fleischer, I. (2010). Identification of carbonate-rich outcrops on Mars by the Spirit rover. *Science*, 1189667.