Spatial Analysis of Hydrothermal Deposits and Siliceous Spicular Sinter at Tikitere Geothermal Field, Taupō Volcanic Zone, New Zealand

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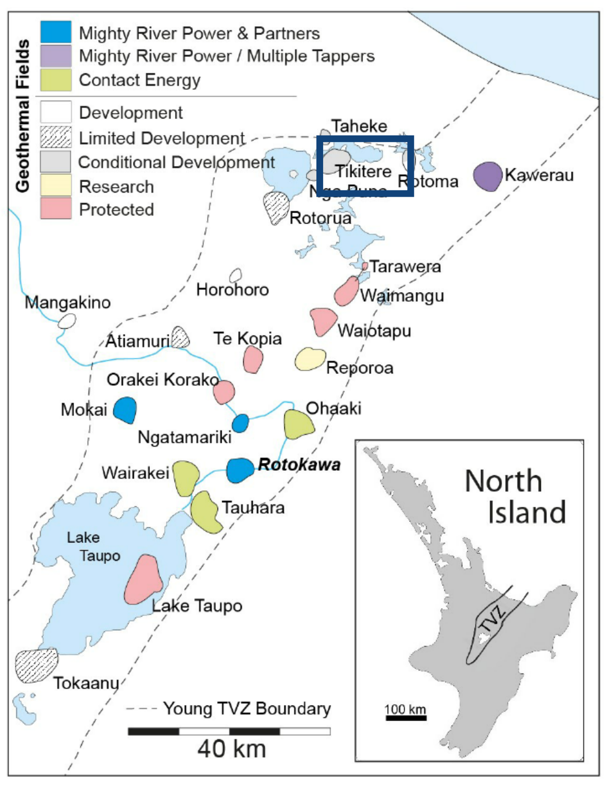


Figure 1: Taupo Volcanic Zone, Tikitere site outlined

1. ABSTRACT

Mapping of varied hydrothermal facies forming in bicarbonate-sulfate waters at Hell's Gate/Tikitere, Taupo Volcanic Zone, Rotorua, New Zealand, enabled a spatial reconstruction of their distribution. In particular, the relation of these facies to distinctive microbe mediated spicular to digitate siliceous hot spring deposits (sinter). The morphology (macro/micro) and geochemistry (XRD) of these deposits can be compared to opaline silica deposits found at Columbia Hills, Gusev Crater, Mars (1, 2, 3). These broadly similar features suggest a rather ubiquitous occurrence of these morphologically distinctive textures. In-depth field mapping of variations in morphology and densities of spicular to digitate deposits defines spatial context. These deposits form from episodic evaporation and wicking in shallow discharge channels; higher densities are seen forming in areas of terracing as shown by NOVA LIDAR scans.

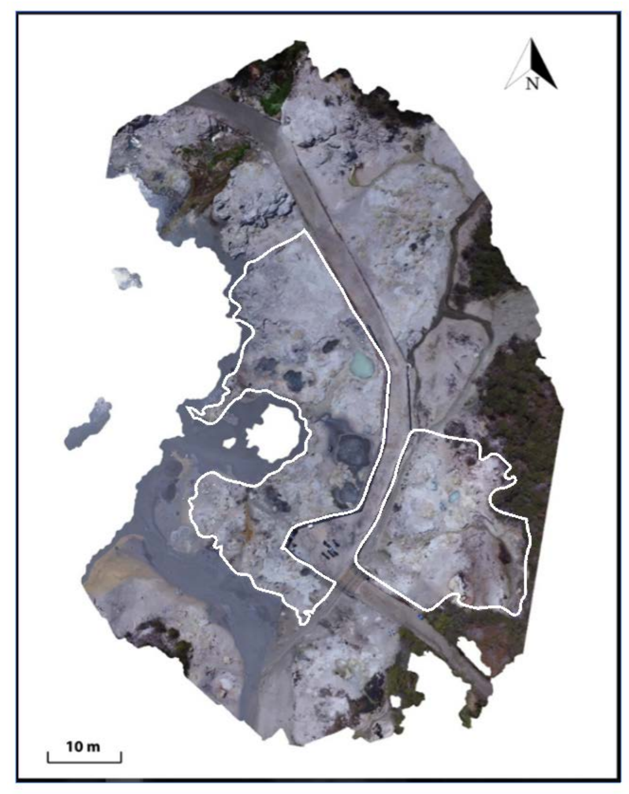


Figure 2: Overview drone image of site with Facies Map trace overlayed

2. FACIES MAP & RESULTS

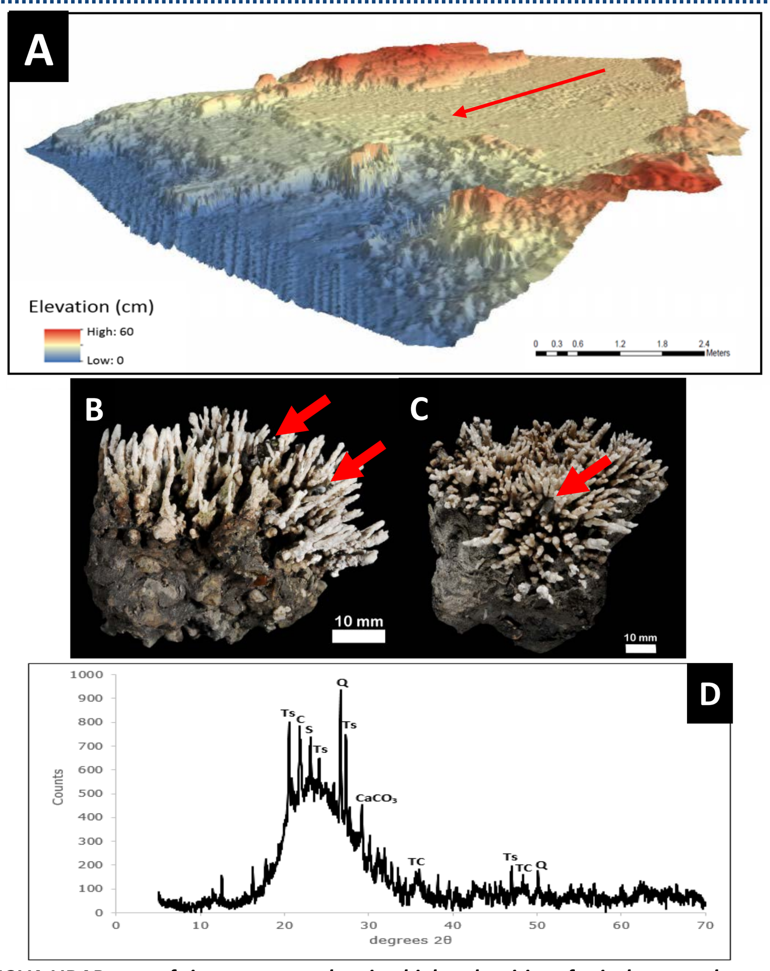


Figure 3: a) NOVA LIDAR scan of sinter terraces showing higher densities of spicules at each terrace step, red arrow shows water flow direction; b) Side view of hand specimen showing spicular sinter forming at the base of terrace steps, red arrows indicate fly adults and lavae; c) Top view of hand specimen showing spicular sinter forming at the base of terrace steps; d) XRD data showing opal-A curve (silica), and detrital Quartz, Sulphur and Calcite

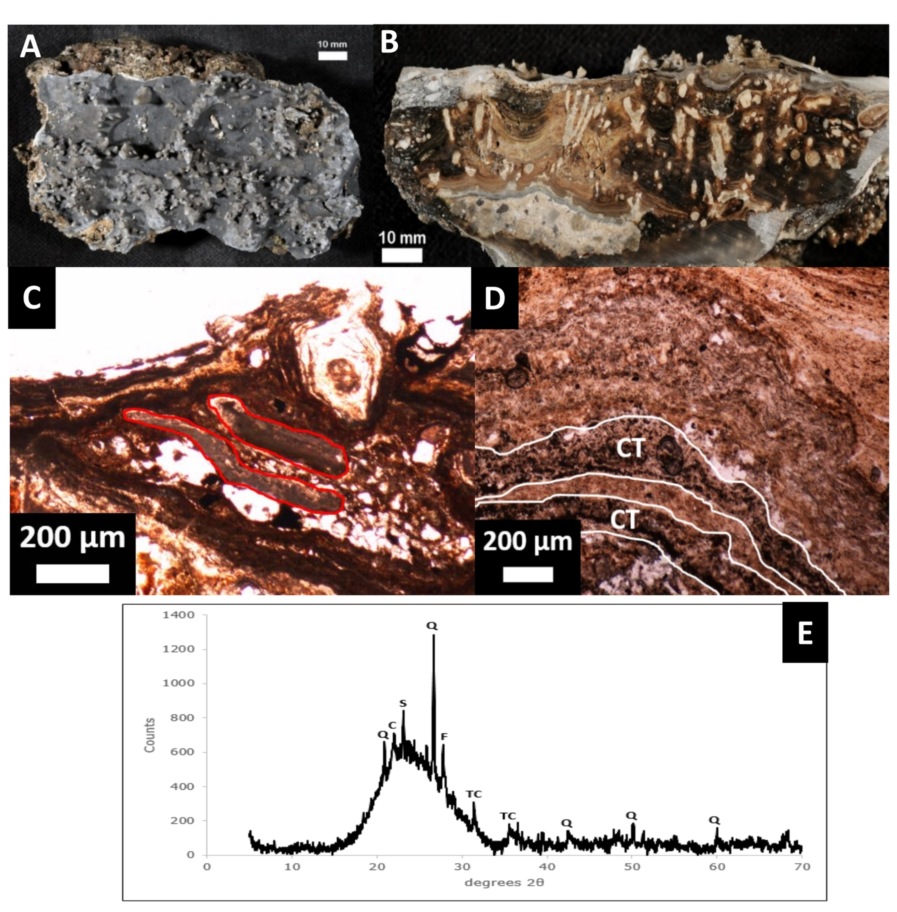
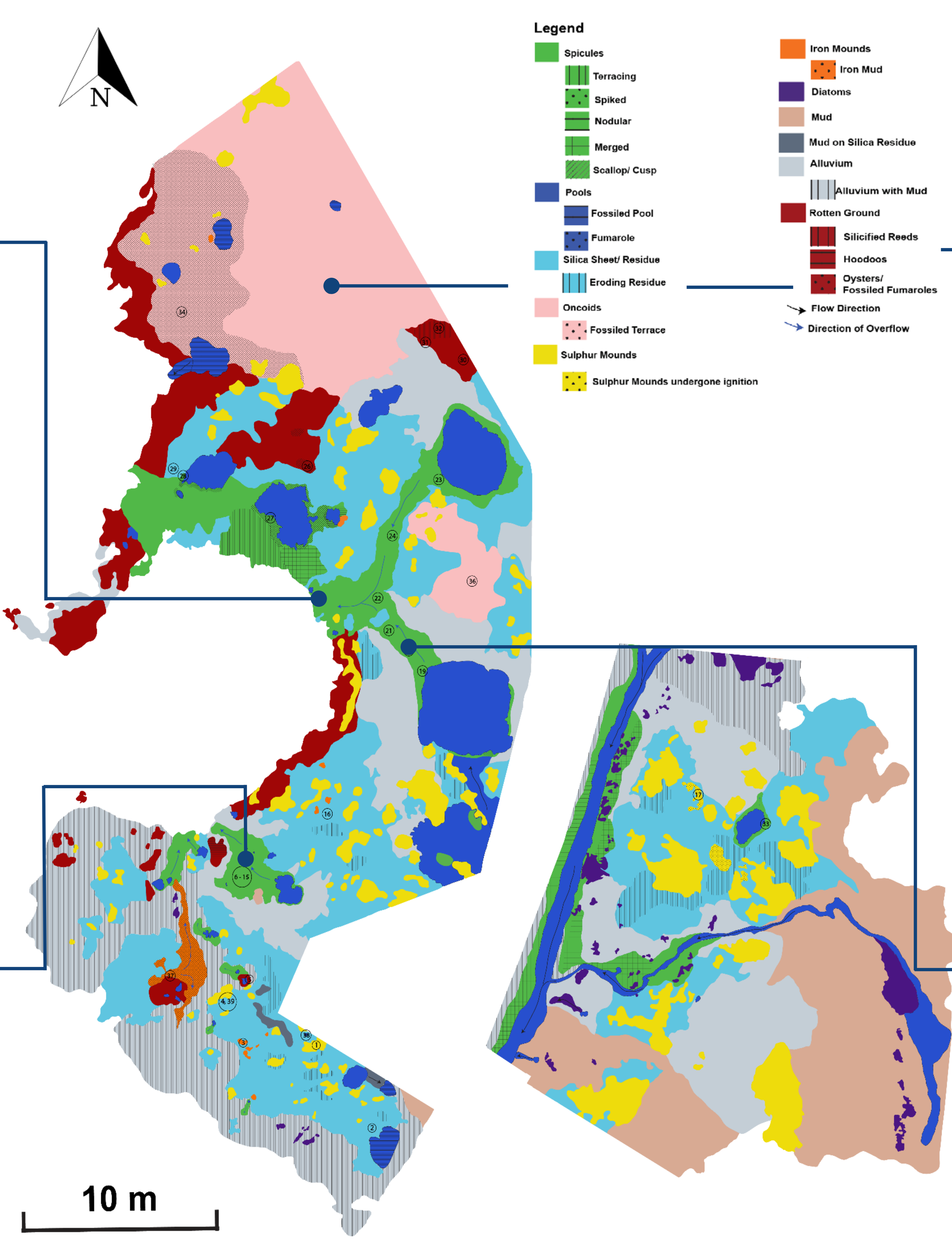


Figure 4: a) Top view of hand specimen showing nodular-spicular sinter forming in episodic outflow channels b) Side view of hand specimen showing nodular-spicular sinter with broken and incorporated pieces of spicules, pumice clasts, with mud drapes; c) Thin section image of dark brown borrow features (outlined in red); d) Thin section image of clotted texture indicating near-ambient temperatures for formation; e) XRD data showing opal-A curve (silica), and detrital Quartz, Sulphur and Feldspar.



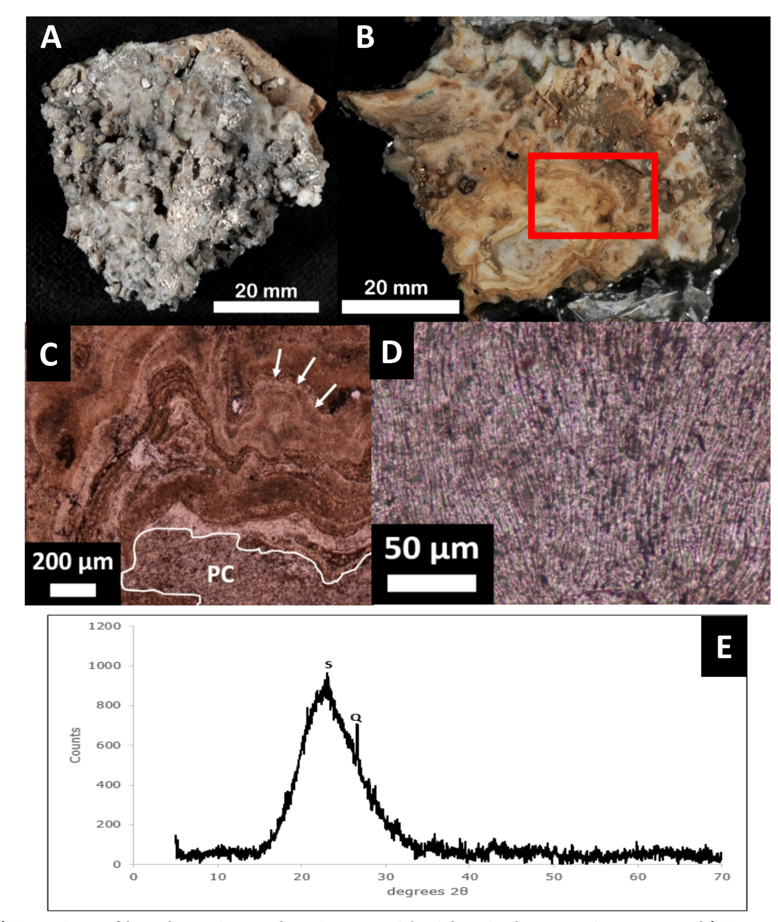


Figure 5: a) Top view of hand specimen showing oncoid with spicules growing on top; b) Cross-section view of oncoid, showing pumice clast centre, wavy laminae, and pseudo-microstromatolites, red box indicates the location of image c; c) Thin section image indicating central pumice clast (PC) overlain by wavy laminae, white arrows indicate silicified radial filamentous microbes; d) zoomed in image of filamentous microbes, showing microbial influences in formation e) XRD data showing opal-A curve (silica), and detrital Quartz and Sulfur.

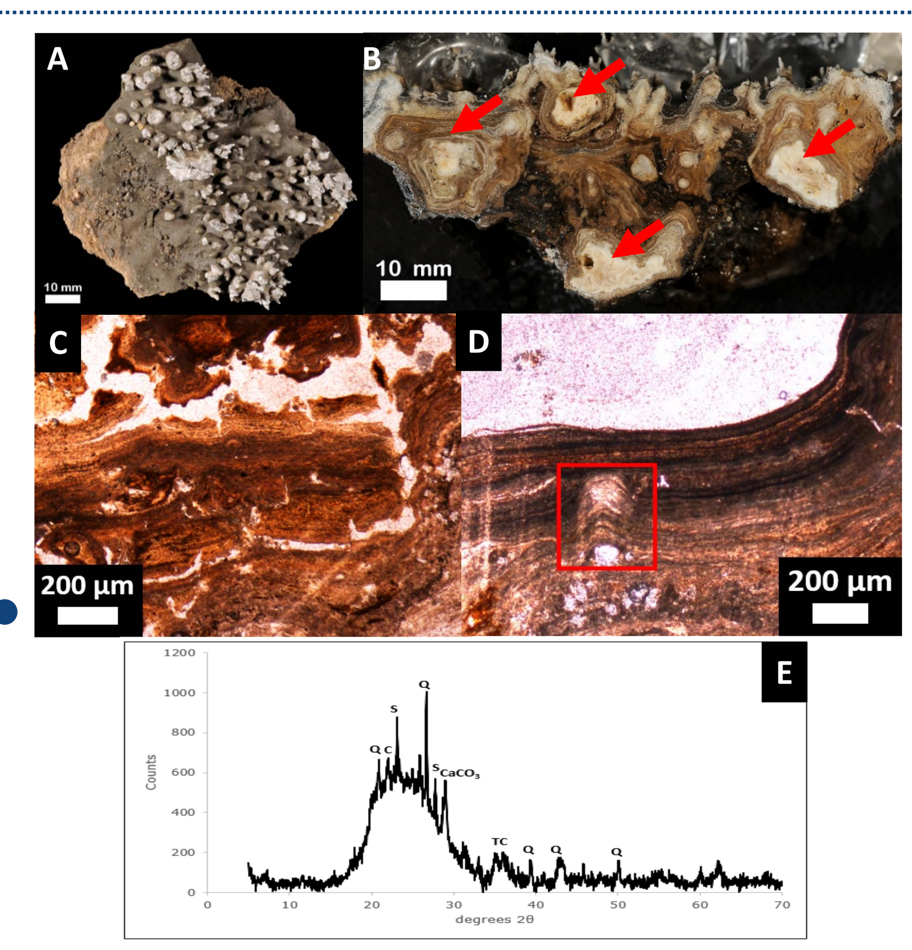
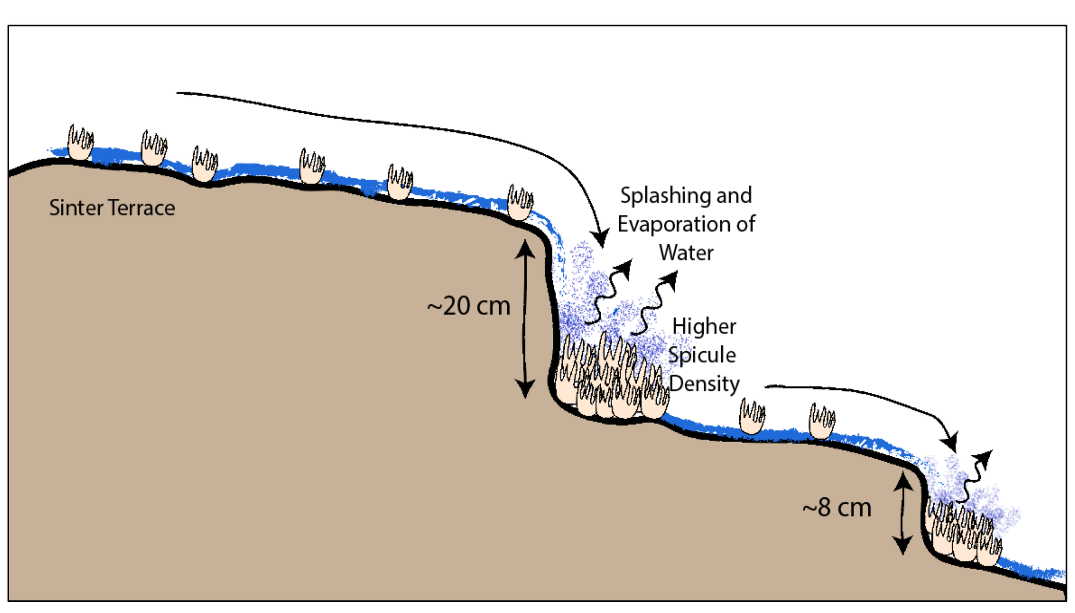
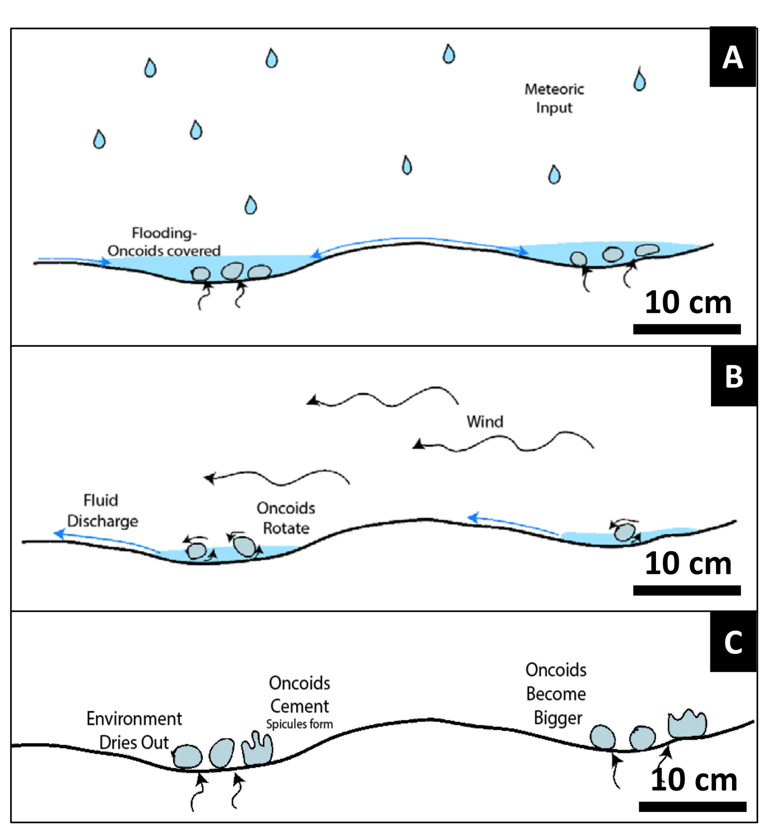


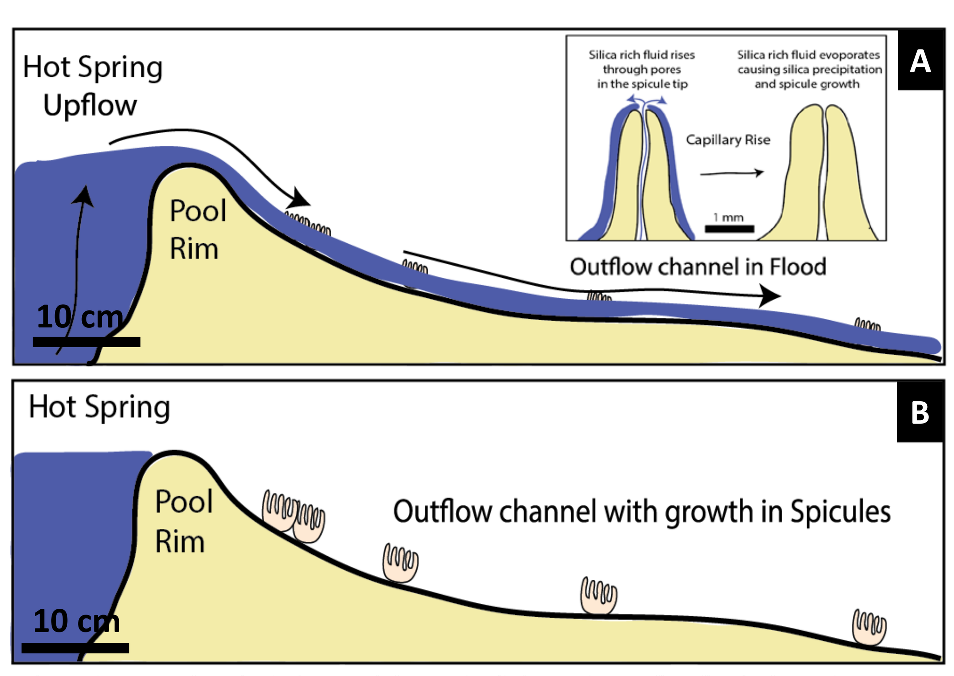
Figure 6: a) Top view of hand specimen showing nodular spicules; b) Cross-section view of nodular spicules, arrows indicate oncoids which provide irregular substrate for silica precipitation; c) Thin section image showing a deposited raft sinterclast; d) Thin section of domal stromatolite (outlined in red square) that has been covered by parallel, horizontal mud drapes; e) XRD data showing opal-A curve (silica), and detrital Quartz, Calcite and Sulfur.

3. DISCUSSION- FORMATION PROCESSES

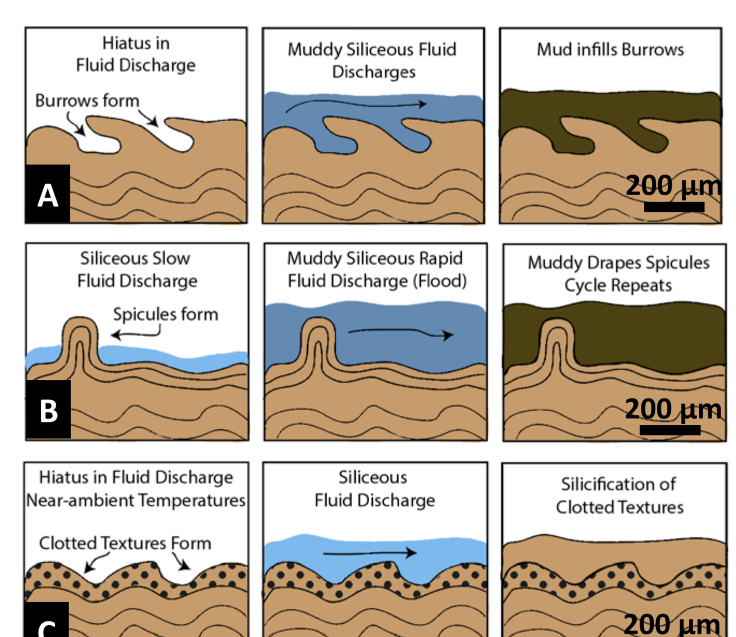




Above Figure 7: Schematic diagram showing the inferred formation of spicules on terraces (from Figure 3). Spicule density becomes higher at the bottom of terrace steps due to the upwards spraying and evaporation of silica rich geothermal fluids. The rapid cooling of fluids causes the silica to precipitate, entombing microbes within the stromatolitic spicules. Right Figure 8: Schematic diagram of inferred oncoid formation diagram (from Figure 5) a) meteoric inputs create shallow pools of water on the inactive terrace, promoting evaporation and silica precipitation; b) water discharge and aeolian process promote oncoid rotation; c) the environment dries out, precipitated silica causes the oncoids to become bigger, some cement and spicules form due to the lack of rotation. Microbes textures are preserved such as filamentous strands seen in Figure 5d.



Above Figure 9: Inferred spicule growth from episodic hot spring outflow floods (formation process for spicules seen in Figure 4 and 5); a) outflow channel is in flood due to a rise in hot spring surface height (caused by changes in the underground plumbing of the geothermal system, and/or meteoric inputs) resulting in the submergence of spicules with possible spicule subaerial formation occurring from capillary rise mechanisms; b) channel is no longer in flood, silica rich fluid evaporates resulting in silica precipitation and the preservation of microbial textures.



Above Figure 10: Inferred formational process for various micro textures identified; a) formation and preservation of burrows due to hiatuses in muddy fluid discharge, with burrow infilling occurring in floods; b) burial of spicules due to the sudden flooding of muddy siliceous fluids causing preservation from mud drapes; c) formation of clotted textures due to covering by siliceous fluids which are hotter than the near-ambient temperatures required to form clotted textures.

4. RELEVANCE TO MARS

Understanding microbial-sinter interactions in geothermal systems is important for early evolutionary models of terrestrial life on earth and possibly on other planets and/or moons. This study is the first to analyse sinter formation in bicarbonate-sulfate fluids, providing new analogues. These features are broadly correlative to the opal-A digitate sinters observed at Columbia Hills, Mars (2, 3). The bicarbonate waters are found on the peripheries of the Tikitere Geothermal Field. Similarly, bicarbonate rich waters may have been 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 (4).

5. REFERENCES

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