GEOMETRIES AND FACIES DISTRIBUTIONS IN YELLOWSTONE'S SILICEOUS HOTSPRINGS: IMPLICATIONS FOR MARTIAN EXPLORATION.

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Introduction: Despite the fact that relict hotspring deposits have been cited as potential candidates for Martian planetary exploration [1], relatively little is known about the important facies relationships associated with these features. Thus, research into the sedimentological aspects of Yellowstone's hotsprings has recently gained impetus. Several siliceous hotsprings throughout Yellowstone National Park, Wyoming, (Fig. 1) were studied in order to ascertain details about the characteristics of these accumulations.

The geometry of the siliceous deposits is highly dependent on a number of factors, the most important of which are topographic relief and geochemistry of the waters. Yellowstone's siliceous deposits group into four broad categories: spires/pinnacles, domal mounds, terraced mounds, and pools. Importantly, each of these morphologies is similar to those described in travertine accumulations [2], and thus, comparisons can easily be made. Synthesizing the characteristics of these four types of siliceous hotsprings facilitates construction of a general facies model consisting of vent, pool, discharge channels, and debris aprons (Fig. 2).

Geometries/Morphologies: *Spires/pinnacles* are high relief features at spring loci; they commonly occur in subaqueous settings. Recently, a team of USGS researchers has discovered a number of siliceous spires at the bottom of Yellowstone Lake [3]. They are very large features, resembling "black smoker" chimneys from oceanic settings. Little is known about their origin, however, they presumably form in areas where hot water is vented. Spires are very large sub-conical features, resembling Liberty Cap in the Mammoth Terrace area of Yellowstone. These distinctive geometries should be readily apparent hotspring/vent indicators on Mars, especially since lake deposits may have already been identified on the Martian surface [4]. It remains to be determined, however, whether microbes associated with the vents are well-preserved in these precipitates.

Domal mounds are very broad, gently sloping features entirely composed of siliceous sinter with a shield or lens morphology. Generally, these form in areas where small amounts of water are discharging. The spring vent and pool tend to be very small in area, consisting of a small pool with rimming stromatolites. Immediately adjacent to the vent and pool are anastomosing discharge channels colonized by a wide variety of microbes. As precipitates accumulate, the spring discharge channel migrates by meandering or avulsion in order to discharge into an area of lower elevation. Abandoned outflow channels are indicated by desiccated, silicified microbial mats. Immediately surrounding these mounded features are debris aprons. These aprons consist of platy siliceous intraclasts derived from the weathering of the siliceous precipitates.

Terraced mounds are similar to terraced deposits described from travertine precipitating systems, however, siliceous terraces are not nearly as common. They have a characteristic stair-step morphology consisting of small pools (terracettes) and a series of rimstone dams. The dams are few in number, commonly resulting from large trees falling into the deposit thereby creating "synthetic" dams which are subsequently silicified. In areas where these terraced mounds exist, flow and precipitation rates seem to be relatively high (~1cm/yr)[5]. Pools associated with terraced deposits tend to be substantial, on the order of 5-7m across.

Ponds are often found occupying nearly self-contained depressions, and usually have very low precipitation rates. Very little water is discharged from these sites. Precipitation of silica is minimal, and consists of smooth, sculpted pool precipitates and a rim of stromatolites. Due to the low relief of these siliceous ponds, a great deal of detrital material is probably incorporated into these deposits. Disharge channels are absent or very poorly developed.

General Facies: Major features common to each subaerial siliceous deposit include vent, pool, discharge channel, and debris apron.

Vent: Little is known about siliceous vents because they are the highest temperature facies. Some exposed vent pipes are irregular in cross-section and up to 50cm wide. They are lined by aggregates of chalcedony which lack flow direction indicators.

Pool: These are bowl-shaped depressions ranging from 50cm in domal mounds to many meters in ponds. Pools exhibit sculpted opal which bears distinctive macroscopic flow structures. These flow structures can be linear or more like siliceous scales or "rills". A close look at the interior of the pools often reveals irregularities or shelves which represent former pool margins. Stromatolites are common along the margins of the pools. Mineral precipitation seems to be greatest near the pool margins.

Discharge Channels: Anastomosing channels are ephemeral, and migrate by meandering and avulsion. A gradation in microbes occurs across these channels as well as downflow in response to differences in the temperature regimes. Discharge channels are characterized by siliceous shrubby precipitates or extensive microbial mats. Microbial mats appear to be best developed in low discharge flow regimes.

Debris Aprons: Because many of Yellowstone's siliceous deposits have topographic relief, weathering processes create debris aprons which form fans around the mounded deposit. Most of the debris consists of platy siliceous sinter clasts derived from upstream facies. Based on observations of numerous cores drilled in the thermal basins of Yellowstone, much of the subsurface material above the igneous basement consists of a veneer of these deposits.

Discussion and Conclusions: Yellowstone's siliceous hotsprings exhibit a wide variety of distinctive morphologies. Many of these morphologies are analogous to those in the many travertine precipitating systems of the park. It is these distinctive morphologies that make these deposits easy to discern from adjacent deposits. Synthesis of these deposits yields a relatively simple facies model which facilitates our recognition of these features in the terrestrial and probably extraterrestrial rock record. In terms of Martian exploration strategies, identification of these siliceous hotspring facies undoubtedly will aid in better defining promising targets for exobiological investigation.

References: [1] *An Exobiology Strategy for Mars Exploration* (1995) NASA SP-530, [2] Chafetz, H.S. and Folk, R.L. (1984), *JSP*, 54, 289-316, [3], Shanks, W.C., III, et al., (1997), *EOS-Trans.*, 78, 46, 808-809, [4] Malin, M.C. and Edgett, K.S., (2000), *Science*, 290, 5498, 1927-1937, [5] White, D.E., et al., (1988), *The Geology and Remarkable Thermal Activity of Norris Geyser Basin, Yellowstone National Park, Wyoming*, USGS Prof. Paper 1456.

Acknowledgements: This research is supported by a NASA-JSC Astrobiology Grant (to HC), SEPM Foundation Robert J. Weimer Grant for Student Research (to SG), GSA Student Grant (#6239-98 to SG), and the Explorers Club-Rocky Mountain Chapter Grant for Student Research (to SG). The National Park Service graciously provided permission to sample.

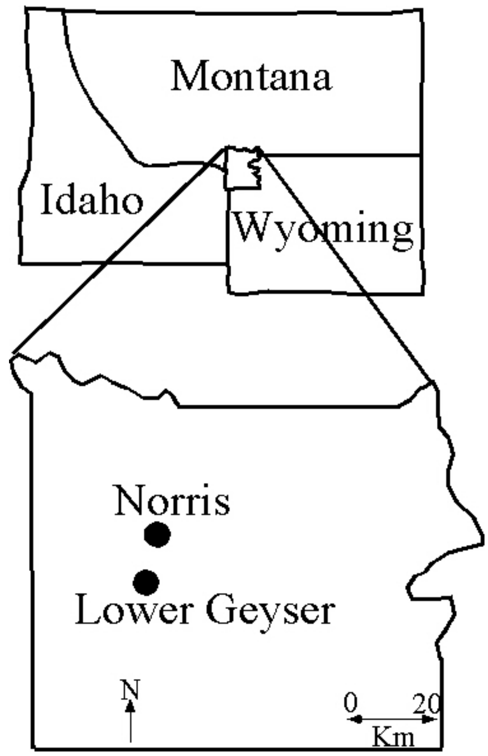

Figure 1: Location map of Yellowstone National Park. Siliceous hotsprings were observed throughout the park, however, major areas of interest were the Norris and Lower Geyser Basins.

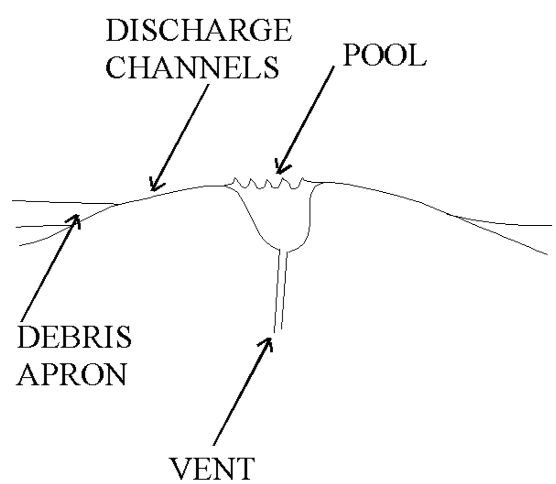

Figure 2: Generalized schematic cross-section through a subaerial siliceous hotspring deposit showing major facies.