SAMPLE RETURN FROM ANCIENT HYDROTHERMAL SPRINGS. Carlton C. Allen[1] and Dorothy Z. Oehler[1]. [1]NASA-Johnson Space Center, Houston, TX 77058. carlton.c.allen@nasa.gov, dorothy.z.oehler@nasa.gov

Introduction: Hydrothermal spring deposits on Mars would make excellent candidates for sample return. Molecular phylogeny suggests that that life on Earth may have arisen in hydrothermal settings [1-3], and on Mars, such settings not only would have supplied energy-rich waters in which martian life may have evolved [4-7] but also would have provided warm, liquid water to martian life forms as the climate became colder and drier [8]. Since silica, sulfates, and clays associated with hydrothermal settings are known to preserve geochemical and morphological remains of ancient terrestrial life [9-11], such settings on Mars might similarly preserve evidence of martian life. Finally, because formation of hydrothermal springs includes surface and subsurface processes, martian spring deposits would offer the potential to assess astrobiological potential and hydrological history in a variety of settings, including surface mineralized terraces, associated stream deposits, and subsurface environments where organic remains may have been well protected from oxidation.

Previous attempts to identify martian spring deposits from orbit have been general or limited by resolution of available data [12-14]. However, new satellite imagery from HiRISE has a resolution of 28 cm/pixel, and based on these new data, we have interpreted several features in Vernal Crater, Arabia Terra as ancient hydrothermal springs [15, 16].

Spring-like Features: Vernal Crater is a 55-km-diameter, Noachian impact structure, centered at 6°N 355.5°E, in SW Arabia Terra. The features interpreted as spring deposits are light-toned, elliptical structures, ~200m wide by 450 to 550m long, with low relief and apical depressions (Figs. 1-3). They have bright, terraced and asymmetric flanks, double concentric tonal anomalies having circumferential curved faults, and are associated with flat-topped outcrops, river-like channels, and two regional fracture sets. The fracture sets are composed of multiple linear faults that pre-date the mounds. Two prominent spring-like features have been identified and each displays all of the characteristics listed above [15, 16].

Discussion: The spring-like features are interpreted as low mounds, based on enhanced brightness on their western (sun-facing) sides. Neither feature exhibits a detectable shadow in HiRISE imagery, indicating that local slopes do not exceed the sun angle of 34° above the horizon. Each mound has a circular depression, at a location interpreted as the apex.

The martian structures have a striking similarity to terrestrial spring mounds, such as those at Dalhousie, Australia (Fig. 4) [17-19]. Analog features include size,

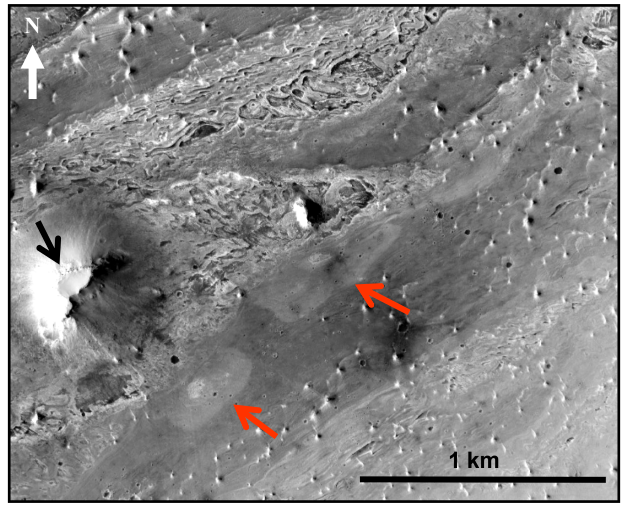

Fig. 1. Spring-like mounds in Vernal Crater, Arabia Terra. Red arrows indicate the elliptical tonal anomalies of the East and West Mounds. Mesa-like outcrop (black arrow). HiRISE image PSP_002812_1855.

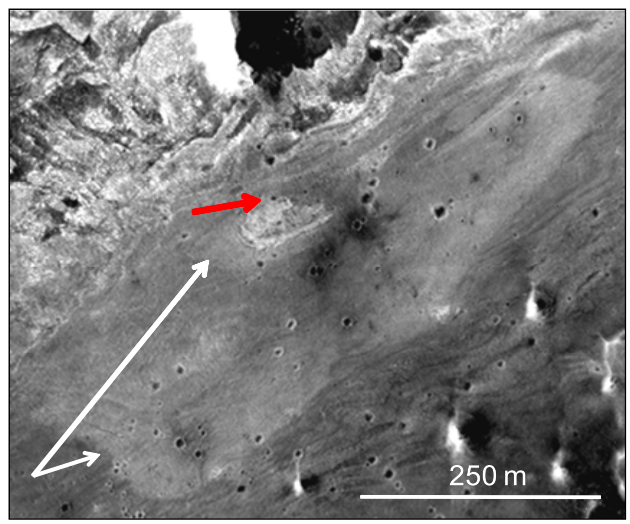

Fig. 2. East mound: inner and outer tonal anomalies (white arrows) and terraced side with apical depression (red arrow). HiRISE image PSP_002812_1855.

shape, tonal anomalies, apical depressions, lateral terraces, asymmetry, and association with river-like channels, mesas, and regional faulting.

The areal density of 5-25 m-diameter craters on each martian mound is approximately 150 per km^2, suggesting that the two features are roughly contemporaneous, with maximum surface ages of approximately 100 my [20]. This implies that the terraced mounds must be indurated and cemented to have survived millions of years of wind erosion.

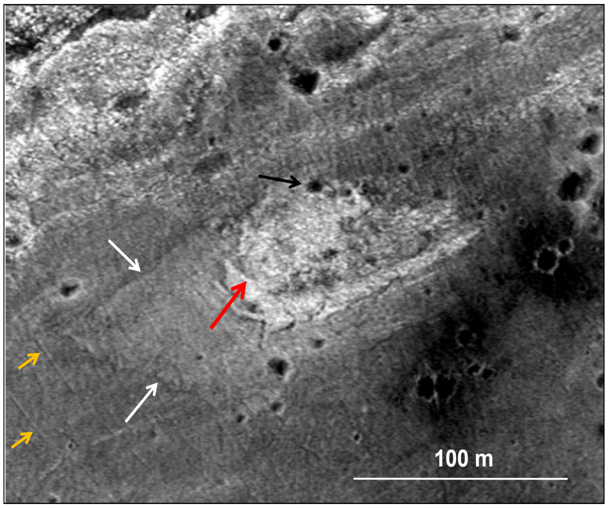

Fig. 3. East mound: inner tonal anomaly (white arrows), bright terrace (red arrow), apical depression (black arrow), linear faults (orange arrows). HiRISE image PSP_002812_1855.

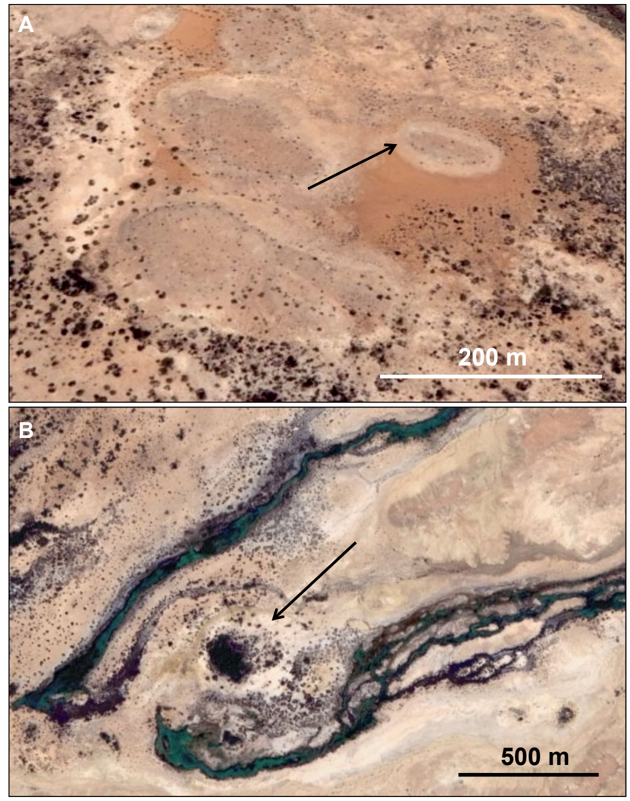

Fig. 4. Spring mounds from the Dalhousie Complex, Australia. A. Elliptical tonal anomalies (arrow). B. Active mound with apical depression (arrow) and associated stream channels. Images from Google Earth.

The elliptical shapes of the tonal anomalies and the fact that both mounds display concentric halos suggest that anomaly formation has involved either surface evaporation of pooled liquids (as occurs at Dalhousie) or a subsurface reaction front between fluids and host sediments. Either case implies the past presence of liquid water. This conclusion is supported by the evidence for cementation and by the associated channels that resemble surface rivulets and sapping gullies at Dalhousie [15, 16]. Since liquid water probably has not been stable on the surface of Mars since the late Noachian/Early Hesperian, it is likely that subsurface flow brought comparatively warm waters to colder, shallower settings and that the springs were hydrothermal with respect to local geology.

The composition of the Vernal features is uncertain. Unique mineralogy of the mounds was not detected by CRISM. Spectra from Vernal Crater are dominated by the bright dust that is ubiquitous in Arabia Terra. Nevertheless, the light tone of the mounds is clearly in contract to surrounding sediments and this suggests that the mounds are composed of a distinctive mineralogy. The persistence of the topography and terracing of the Vernal mounds, despite ubiquitous wind erosion, suggests that these features are indurated, analogous to the cementation observed in terrestrial spring deposits.

Astrobiological Priority for Sample Return: Identification of ancient thermal springs on Mars is of major importance to astrobiology, as these could be sites where martian life evolved, sought refuge as the climate became colder and drier, and where evidence of that life may be preserved. Carefully selected rock and mineral samples, returned to Earth for detailed laboratory analysis, may provide the first compelling, organic evidence of martian microorganisms.

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