SPRING MOUNDS AND CHANNELS AT DALHOUSIE, CENTRAL AUSTRALIA Mary C. Bourke[1,2], John Clark[3], Michael Manga[4], Peter Nelson[4], Kevin Williams[5], Julie Fonseca [6]. Brad Fobar [1]. [1]Planetary Science Institute, Tucson, Arizona, mbourke@psi.edu, [2]OUCE, University of Oxford, UK, [3]Australia/Mars Society Australia P.O. Box 327, Clifton Hill, VIC 3068, Australia, [4]Department of Earth and Planetary Science, University of California, Berkeley, California, USA.

Introduction: Small dome, mound and pitted cone features observed on Mars may represent volatile release from the subsurface by processes such as mud volcanism or mound spring formation [1-4]. Spring deposits have a wide range of morphologies yet, there are few published accounts on their characteristics and formation. This inevitably limits our ability to accurately detect these features on Mars from either satellite or lander perspectives. Clarke and Stoker [1] brought attention to the analog potential of the Dalhousie Mound Complex (DMC) in Australia. Here we report the results of two field expeditions to DMC to document the range of spring deposit morphologies, sediments, their formation and preservation.

Study Area: The DMC is a major groundwater landform system fed by a discrete geothermally heated groundwater source. The study area is located at the margin of the Great Artesian Basin [5] in the northern part of semi-arid South Australia. The complex consists of a cluster of more than 60 active springs and numerous fossil spring deposits. The water is carried in the Late Jurassic Algebuckina Sandstone beneath the aquaclude of the Bulldog Shale. Subsurface strata dip up in the mid-Cenozoic Dalhousie anticline and water is brought near the surface in focused flow, along a series of faults that breach the anticline's crest.

Active spring mound and channel morphology: We identified a range of morphologies associated with spring deposits.

Figure 1 Aerial view of spring pool. Note narrow sinuous vegetated channel draining from pool.

Depressions. Mound springs at DMC likely begin as small negative relief features. One began forming 5 years before our field visit and had attained a width of 6 m and a depth of 30 cm. The dessicated clays at the surface overlie saturated muds at shallow depth. The presence of circumferential tension cracks indicate that sagging, rather than deflation is the primary formation mechanism.

Pools. Pools are circular to elongate in shape. Larger pools may form by coalescing. They vary in width from 30-160 m and reached a maximum depth of 10 m. They are found both at local surface elevation and on top of mounds.

Mounds. Mounds are generally symmetrical, but may display 'bulging' on the flank where seepage zones occur. They are low features attaining heights of 6 m and widths of 180 m.

Spring channels. The channels, close to source are heavily vegetated and this likely dominates their pattern and morphology. They are narrow, sinuous, leveed systems (Fig.1). Recently abandoned channels show evidence of piping indicative of active throughflow at depth. Downstream, the channels merge with other spring outflows to form wide, shallow, anastomosing system separated by carbonate-rich islands.

Islands are located within the channels and are low (~1 m), circular to elliptical, vegetation free surfaces ~ 55 m wide. They are halite encrusted and appear highly susceptible to aeolian erosion once dessicated. However at depth, there are thick carbonate deposits which have higher preservation potential.

Spring Sediments: The mounds are constructed of clays, carbonates, gypsum, and iron oxides. While highly variable on an individual scale, all the tufa samples consist of five main textural components in varying ratios; siliceous detritus, carbonate mud, carbonate grains (peloids, lumps, and fossils), coarse calcite cements, and voids. Two microfacies are represented in the data analyzed so far: 1) The vegetated mound microfacies is composed of a very vuggy limestone formed by the decay of plant matter. Some peloids, lumps, and microbial filaments and mollusc fragments may be present. 2) The pool microfacies is dominated by either carbonate mud or fine-grained cement. Minor voids may be present, but typically pools are too deep to have much vegetation. Microbial features and mollusc fragments are common. Pool facies may undergo extensive fracturing, recementation, and recrystallisation during diagenesis.

The presence of a mix of vadose and phreatic textures in the cements indicates they form at and beneath the water table. This is consistent with the model of upward mound growth where the saturated zone transgressing through mound sediments that formerly were above the water table. During the waning of the mound water flow can be expected to stagnate and fall. As a result the solute load of the mound may increase due to evaporative concentration, resulting in a final phase of gypsum precipitation. Some vadose carbonate cements may also occur during this phase.

Mound Spring Evolution: Based on field and laboratory studies we propose a 6-stage conceptual model that illustrates the evolution of DMC mound springs (Fig. 2). 1) Pressurized groundwater flows through fissures to the surface. The undersaturated spring water dissolves the bedrock gypsum. 2) This coupled with local weathering and deflation results in a depression which fills with water. 3) The saturated springwater precipitates calcite along the pool margin and the mound grows. 4) The hydraulic gradient is reduced with mound growth and the pool shrinks. 5) The pool continues to reduce in volume with mound growth and seepage may occur along the mound flank. 6) Mound pool is closed at the surface and seepage occurs along flank.

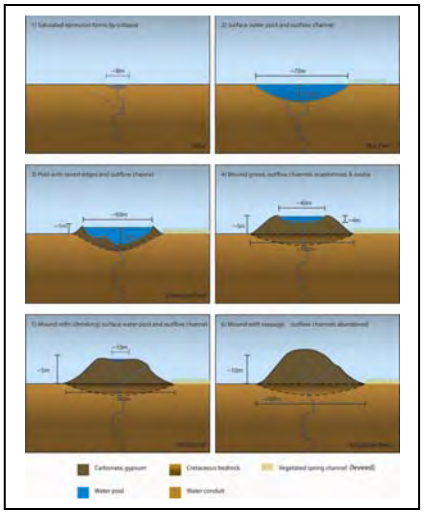

Figure 2 Conceptual model of mound springs formation at Dalhousie Mound Springs Complex.

Relict spring deposit morphology and degradation: There are several mesas and mounds in the field area, some date to the Early Neogene. The flat-topped mesas can be extensive (4.7 km long and 15 m high). Others form low (< 2 m), flat-topped ridges or mounds. Spring deposits cap the circular and elongate bedrock mesas. The carbonate strata are generally < 2 m thick and petrographic analysis indicate shallow pool and channel facies. Source mound morphologies for these deposits were not preserved. In fact, no fossil mounds composed entirely of spring deposits were found at DMC. This would suggest that weathering and erosion significantly impact the preservation potential of mound spring form on planetary surfaces.

The mesas are currently degraded by local runoff, aeolian erosion, mass movement and weathering. In some locations, erosion by runoff and weathering has removed the protective carbonate cap, leaving a conical-shaped mound with a large depression (Fig. 3). These are similar to the pitted cones and domes observed on Mars [3]. Other mound springs are degraded to asymmetrical hills that have the appearance of streamlined islands. The variability of relict spring deposits found at Dalhousie has not been previously reported in the literature and will enable a more rigorous assessment of Martian landfroms.

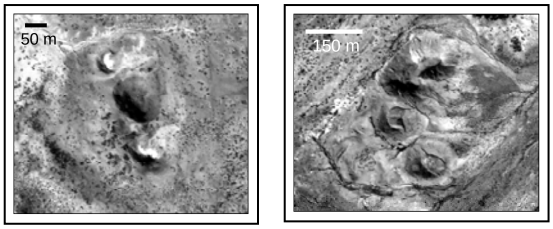

Figure 3 We use high resolution multispectral IKONOS satellite data (1 m/px pan; and 4 m/px IR, R, G, B) as it is similar in scale to the Mars Orbiter Camera (MOC) data on the surface of Mars (8 - 1.5m/px) and allows the identification of spring and channel signatures from a remote sensing platform. Above are degraded spring deposits that have pitted cone and mesa form.

Conclusion: The morphometric data presented here on both active and fossil springs will improve our ability to identify potential spring deposits on Mars from satellite platforms.We show that the preserved form can be as domes, pitted cones, or mesas. This suggests that the range of morphologies assigned to potential spring deposits on Mars can now be extended beyond cone-shapes. The data suggest that mound spring sediments can persist in the landscape for extensive periods (e.g. at DMC for ~ 20 million years). The findings from this work are being used to build and improve models of mound spring formation and spring discharge on Earth and on Mars [6].

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References:[1]J. D. A. Clarke and C. Stoker, (2003) *LPSC XXXIV abstract 1504*[2]L. S. Crumpler, (2003) *Sixth International conference on Mars*, pp. abs.3228 [3]W. H. Farrand, *et al.*, (2005) *Journal of Geophysical Research (Planets)*, **110** [4]J. Skinner, J. A. and K. L. Tanaka, (2007) *Icarus*, **186**, pp. 41-59. [5]M. A. Habermehl, (2001) *Geological Society of Australia Special Publication*, **21**, pp. 127-144.[6]P. A. Nelson, *et al.*, (2007) *LPSC, this Volume*