**SPORADIC GROUNDWATER UPWELLING IN DEEP MARTIAN CRATERS: EVIDENCE FOR LACUSTRINE CLAYS AND CARBONATES.** J. R. Michalski[1,2], A. D. Rogers[3], S. P. Wright[4], P. Niles[5], and J. Cuadros[1], [1]Natural History Museum, London, UK [2]Planetary Science Institute, Tucson, AZ, USA. [3]SUNY Stony Brook, Stony Brook, NY, USA. [4]University of New Mexico, Albuquerque, NM, USA. [5]NASA Johnson Space Center, Houston, TX, USA.

**Introduction:** While the surface of Mars may have had an active hydrosphere early in its history [1], it is likely that this water retreated to the subsurface early on due to loss of the magnetic field and early atmosphere [2]. This likely resulted in the formation of two distinct aqueous regimes for Mars from the Late Noachian onward: one dominated by redistribution of surface ice and occasional melting of snow/ice [3], and one dominated by groundwater activity [4]. The excavation of alteration minerals from deep in the crust by impact craters points to an active, ancient, deep hydrothermal system [5]. Putative sapping features [6] may occur where the groundwater breached the surface. Upwelling groundwater may also have played a critical role in the formation of massive, layered, cemented sediments in Sinus Meridiani [7,8], in the Valles Marineris [9], and possibly in Gale Crater [10], where the Curiosity Rover will land later this year. Understanding the past distribution, geochemistry, and significance of groundwater on Mars is critical to untangling the origins of deep alteration minerals, Hesperian sulfate deposits, and crater fill deposits at Gale Crater or in other locations.

**Hypothesis:** If a global, connected groundwater system existed in the Early Hesperian, then evidence for upwelling should be found in the deepest topographic basins present at that time – deep impact craters in particular. If groundwater was instead present only in isolated, disconnected lenses, then evidence for upwelling would occur only in isolated instances.

**Methods:** We investigated the morphology and mineralogy of deep impact craters in the northern hemisphere of Mars using imaging data from HIRISE, CTX, THEMIS, MOC, and HRSC (Figure 1). A mathematical model providing theoretical upwelling zones, given a shallow (400 m) starting condition [4] was digitized and used a s a guide (Figure 1). Deep impact craters were identified using MOLA data. Where deep craters (typically D = 50-100 km and depth = 2-3 km) were identified, images were used to search for the presence of sapping channels or evidence for other intra-crater fluvial activity or for lacustrine deposits. In particular, we searched for locations where evidence for aqueous activity was present in the crater but absent in the terrain outside the crater (*i.e.* the crater was not fed by exterior channels). The mineralogy of deep impact craters was investigated using TES, THEMIS, and CRISM data.

**Results:** We identified ~40 craters of interest in the northern hemisphere, the majority of which occur in western Arabia Terra – a potential upwelling zone of interest [4]. Most of these craters do not contain obvious evidence for intra-crater aqueous activity, but ~10% contain interior channels and possible lacustrine features. Most of the craters of interest are blanketed by dust, which limits the possibilities for investigating the mineralogy of intracrater deposits.

One clear exception is McLaughlin Crater (338.6 E, 21.9 N), which contains interior channels emanating from the crater wall, terminating at an elevation ~200 m above the present day crater floor. This configuration suggests the former presence of a base level, which might indicate the that an ancient lake of this depth existed in McLaughlin. The mineralogy of the crater floor deposits is intriguing. Previous results showed the presence of serpentine within the crater [11]. But, our investigation shows that multiple alteration minerals are present within various geologic contexts.

Layered deposits on the crater floor contain spectral evidence for Mg-rich clay minerals – possibly smectites and smectite/talc interlayered clays – as well as Mg-carbonates. Overlying these layered floor deposits are carbonate- and phyllosilicate-bearing landslide or ejecta deposits. These materials likely correspond directly or indirectly to ejecta from a smaller crater (D = 25 km) that occurred on the southern rim of McLaughlin. Ejecta from that crater is not well preserved or altered around its perimeter, except where that ejecta was deposited into McLaughlin. Where the ejecta occurs below the 200-m-base level, the ejecta is clearly altered and also exhibits flow textures. It is possible that the ejecta from this smaller crater was deposited into a lake in McLaughlin Crater, and/or that the impact of that small crater triggered landslides from the crater wall. In either case, the deposits in this crater would represent sediments that were formed by groundwater upwelling, and rapidly buried. They are therefore of major astrobiological significance and could have extremely high preservation potential for organic materials.

**Conclusions:** In general, the survey of ancient, deep craters has not shown evidence for widespread groundwater upwelling, which leads us to conclude that an ancient Martian groundwater system was probably formed of disconnected pockets at various locations and depths, rather than a major global groundwater system. Groundwater upwelling may have been a rare event and where it occurred, the fluids may have been alkaline, Mg-rich brines conducive to the formation of clays rather than sulfates. However, further work is needed to establish the viability of groundwater upwelling as a major geologic process on Mars.

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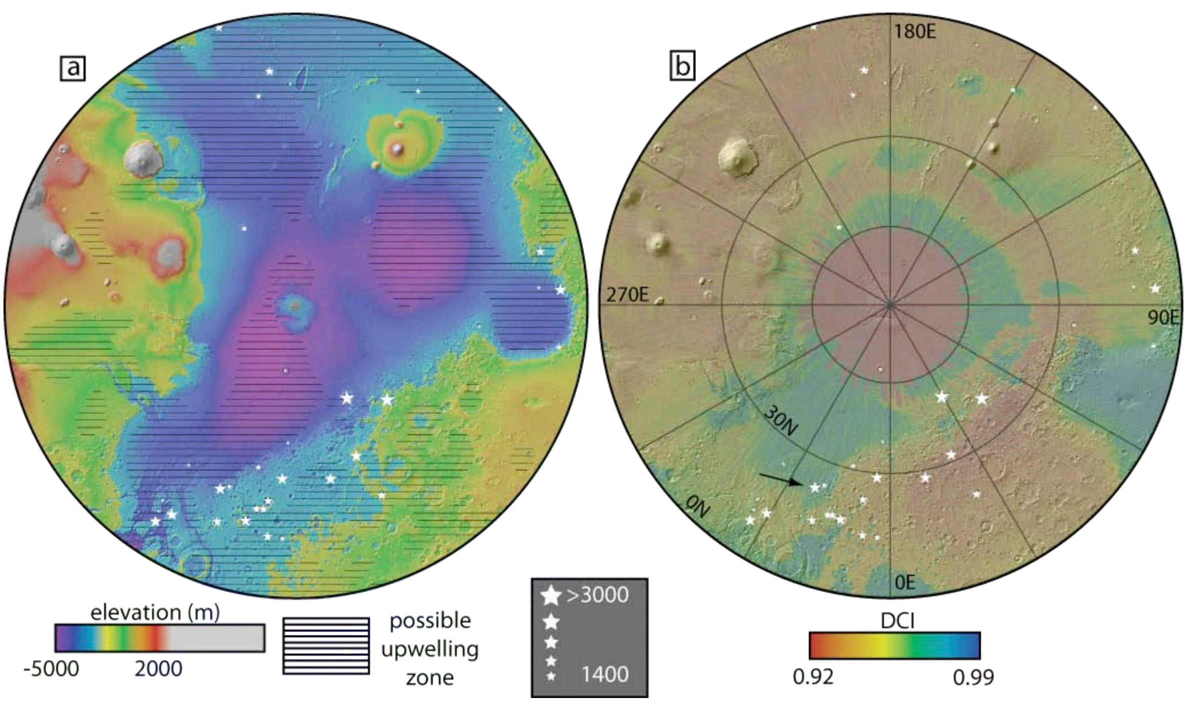


**Figure 1:** MOLA elevation of the northern hemisphere of Mars (a) showing he locations of deep craters (white stars), where symbol size is scaled by crater depth from 1400 to >300 m. Theoretical upwelling zones from [4] are also shown (assuming initial 400 m depth to water table). TES dust cover index data (DCI) [12] are shown at right (b). DCI values <0.96 are indicative of dusty surfaces where crustal compositons are masked to further spectroscopic composition. The black arrow in "b" points to a low-dust region where up-welling is expected to have occurred, the location of McLaughlin Crater.