EXPERIMENTAL CONSTRAINTS ON MARTIAN AQUEOUS ENVIRONMENTS AND BIOSIGNATURE PRESERVATION: SIMULATING FLUID FLOW PROFILES AND MICROBIAL DEVELOPMENT IN THE SHALLOW SUBSURFACE.

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Introduction: In-situ investigations of sedimentary rocks by the MER rover *Opportunity* during the traverse from Eagle to Victoria craters exposed distinct void spaces within abraded outcrops in the Burns Formation, Meridiani Planum, Mars. The voids have been interpreted to form via post-depositional mineral dissolution during groundwater-mineral interaction, resulting in secondary pore space. Intricacies between porosity and permeability and their effects on groundwater flow can potentially provide sedimentological reservoirs for microbial matter, or preservation of such biosignature evidence, within a stratigraphic column, providing a novel environment to search for biosignatures.

Methods: In addition to computer modeling of long-term mineral dissolution, our fluid flow experiments will investigate the preservation potential of biosignatures that could remain within secondary porosity after periodic groundwater recharge events described by [1] and modeled after the “wetting upward” eolian system defined by [2]. Investigations will include (A) creating a simulated mm-scale Karatepe section of the Burns Formation in the laboratory. (B) introduce fluids into the mock stratigraphic section (Fig. 1) containing specific organic matter to examine how organics, after fluid recharge events, remain preserved within specific porous spaces [3]. (C) examine the physical structure of secondary pore space to determine how groundwater events modify pore space and potentially destroy organics.

Laboratory simulations of permeability. Fundamental understanding of secondary porosity as a medium for fluid interaction and mineral dissolution will be provided by the established work already completed by [4]. Using relative timelines for specific stages of diagenesis [1] and depositional characteristics [5], our laboratory setup will emulate these parameters in order to model how fluid would have interacted with minerals and flowed (highly unobstructed in some cases after multiple recharge events) in the shallow subsurface crater rim of Endurance crater. Although the Burns Formation texturally is a sandstone, it is composed of >40 volume percent of sulfate minerals, including highly soluble Mg-sulfates, and ≥60 volume percent total chemical constituents (Mg-, Fe-, Ca-sulfates, silica, hematite, ±chlorides) [1,5]. Accordingly, formation of secondary porosity most closely mimics that seen in terrestrial carbonate rocks [1,6]. For this work, we have relied on an approach slightly modified from [7] who recognized a variety of secondary porosity types using factors such as shape, fabric selectivity, depth, size, and geometry. We will utilize previous investigations in pore volume and geometry measurements as well as pore depth analysis as our baseline for secondary porosity estimations [4]. This includes pore connectivity and porosity enhancement associated with stagnant paleowater table as seen in the Whatanga contact [1,2], among other microtextural features.

Although numerous RATed surfaces were created for chemical and Mossbauer analyses, a number of these textures [8] are obscured by the cuttings produced by the abrasion process and a small percentage (3 out of 25 total from Eagle, Endurance, Fram, and Victoria craters) contain widespread recrystallization which significantly changes the geochemistry, suggesting the loss of MgO via $MgSO_4$ removal [9]. The three rocks (Diamond Jenness, Mackenzie, and Tuktoyuktuk) were not used in this investigation since recrystallization obscures sedimentary microtextures including pore space and bedding features.

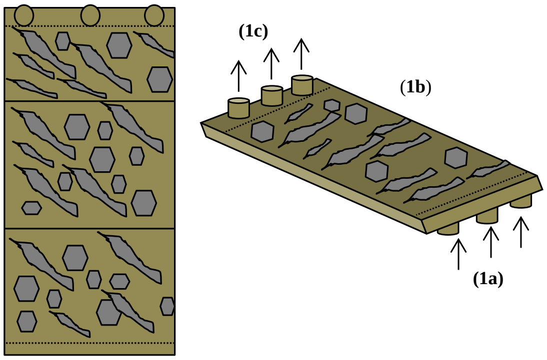

Fig. 1. Top-down and angled view schematics of the mm-scale version of the Karatepe section of the Burns Formation. *Variables for input fluids (1a) will be controlled and mineral dissolution (1b) monitored. Output fluids (1c) will provide insight to geochemical changes.*

Introduction of microbes and detection of biosignatures. One of the challenges to Meridiani Planum having the proper environmental variables for hosting and preserving any ancient form of microbial life are the proper pH and the desiccation of organisms involved [11]. Desiccation infers that such drying out of organisms, while difficult to detect on a microbial scale with current rover in-situ payloads, could require a permeable sedimentary system that has access to brines for organics to occupy while buried far enough away from the Martian surface to avoid destructive interference from solar/UV radiation [12]. Shallow-to-mid subsurface depth (Fig. 2) might provide adequate protection for potential chemotrophic ancient organics but would also need to have access to the groundwater table via permeable sedimentary rocks for optimal access to nutrients, should they have existed during the late Noachian-early Hesperian time period. Which species of terrestrial extremophiles have the resistance to Martian groundwater flow conditions? How does the survivability of chemotrophic organisms change if physically close to soluble minerals and dissolution occurs? These are some of the outstanding questions that motivate this investigation.

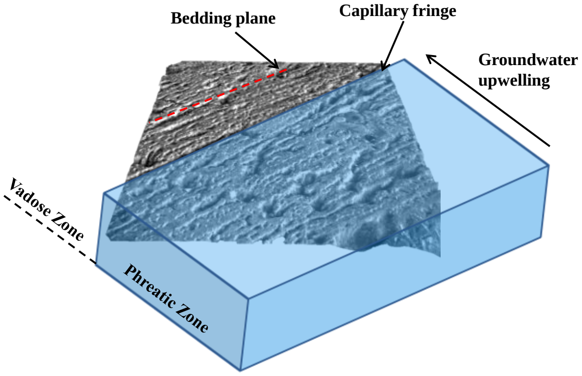

Fig. 2. Representation of the paleo-groundwater table during a recharge event. *The London DEM is shown above containing channel pores that grade into sheet-life vug secondary porosity. These pores are parallel to the bedding plane and have unhindered access to the groundwater table due to orientation and narrow depth. Crystal moldic pores are non-fabric selective and have greater depths.*

Modeling of fluid-flow pertaining to habitability and preservation within the subsurface. Should microbes have existed within the Martian subsurface, they would have been present at a depth and location stable for microbial growth (see [13] for constraints on stromatolite growth in YNP). Stated differently, we would find evidence within Mars' subsurface of microbial material where it previously existed and biosignatures based on the extent of that period of habitation. Fluid at near-neutral pH would allow for ideal transport of such material with the direction, duration, and rate of fluid movement in the subsurface acting independent of the microbes carried along with it [3]. Terrestrially, the restrictions on the survivability of microbial life give us insight to the possible extent of planetary microbial life [14]. Mentioned earlier, fluids at near-neutral pH levels would allow for ideal transport. This is not to say that acidic conditions or fluids that are far from neutral pH levels couldn't assist in microbial survivability and transport. What we know on Earth is a wide range of microbes can indeed thrive in non-ideal environments [15] and rigorous conditions. Organics that fall into this category, noted as extremophiles in several articles, can live in saline environments between 550 and 1100mOsm (observed as halophiles) and settings from pH levels <1.0 (acidophiles) to amounts ~11.0 (alkalophiles). Therefore with proper preservation, evidence of such microbes (if at all initially present) in the subsurface of Mars could be transported via fluid-flow if dimensional parameters allowed [3]. Timing and duration of fluid movement, specifically in Meridiani Planum has been extensively recorded [1,2,5,6] and concurrently the obstacles for early life to have been formed due to low availability of liquid water activity interpreted to have occurred in the region [16] leaves all but a few terrestrial examples of microbes we could endeavor to observe. While the saline settings may not been favorable for the majority of microbial material to thrive [11,16] the physical characteristics of the Karatepe section and geochemical conditions [1,17,18] showing periods of a fluctuating groundwater system could be enough to harbor evidence of subsurface microbial material within secondary pore space. Should these conditions exist however, the likelihood of preservation of biosignatures and/or microbial matter is significantly higher when temperatures remain low and permeability is close to zero [19].

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