PRESERVATION POTENTIAL OF ORGANIC MATTER IN SECONDARY POROSITY OF THE BURNS FORMATION, MERIDIANI PLANUM, MARS

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Introduction: The Burns Formation is a series of well sorted sulfate-rich sandstones examined by the *Opportunity* rover. Investigations of these rocks revealed an extensive diagenetic history [1,2] due to the influence of an infiltrating paleo-groundwater table. Due to mineral dissolution of relatively soluble sulfate salts, some primary mineral constituents (likely Mg- and/or Fe(II)-sulfates) were removed [1] leaving behind the secondary pores observed. Previous investigations into volumes and orientation of pores, overall secondary porosity, and permeability [3,4] documented the characteristics of individual pores and an overall decrease in secondary porosity southward from Eagle Crater to Victoria Crater.

The purpose of this paper is to show how the permeability of various regions of the Burns Formation, the connectivity of pore throats within rocks, and the porous networks they are contained in could preserve organic matter if it was ever present but that preservation potential would be strongly controlled by the type of porosity present.

Methods: Our investigations used best-focused Microscopic Imager (MI) mosaics of outcrops abraded by the Rock Abrasion Tool (RAT) onboard the *Opportunity* rover. Several types of analyses were completed with the original MI mosaics, thresholded images, and digital elevation models (DEMs) of selected rocks.

Overall (total) secondary porosity & individual pore geometry: The aforementioned threshold process allowed us to highlight secondary porosity and distinguish it from non-porous regions. The measured areas (assumed to equate to volume) obtained by this method account for all pore space regardless of the specific classification of the individual pore types [3].

Using the original MI mosaics, the length and width of single pores were measured in addition to their orientation relative to the bedding plane. This type of analysis has a structural bias due to pores possibly orienting at an angle parallel to the abraded surface. This appears to be minimal in crater walls where these microtextures are extremely well preserved in cross section. However, the bias may be important in accounting for the lack in pore space observed in regions on the Meridiani Plains in close proximity to Eagle and Endurance craters. Moreover, the absence of pore space observed in other abraded rocks south of the landing site could be due to the stratigraphic position of Erebus and Victoria crater. These craters may have been stratgraphically too high to be readily accessible to the periodic rise and fall of the paleo-groundwater table.

Digital Elevation Models: Advanced image manipulation allowed us to view the sedimentary microtextures available from the original two-dimensional MI mosaics as three-dimensional DEMs. This has given us insight into permeability due to the ability to compare the different types of secondary pores to one another with respect to depth [4]. Furthermore, due to the well constrained stratigraphic position of the rocks within the Karatepe stratigraphic section, we can better evaluate the permeability of the rocks.

Geologic Context: McLennan et al. [1] demonstrated a relative timeline in which various types of secondary porosity immediately followed growth of hematite spherules, all in turn following a recharge event(s) of the paleo-groundwater table. The modification of pore space as well as localized recrystallization (e.g., surrounding concretions) occurred toward the end of the groundwater diagenesis process. Although pore space commonly decreases during diagenesis this has not taken place in the Burns Formation due to the unusual mineralogy allowing for selective mineral dissolution.

The Whatanga contact separates the Upper and Middle units of the Burns Formation and is the only location where significant amounts of secondary pore enlargement is found. This contact is interpreted as a diagenetic front and can be traced in Endurance crater southwest [4] from the Karatepe section to the abraded rock Wharenhui which also possesses similar modified porosity features.

Permeability & pore space: The relationship between secondary porosity and permeability is complex in detail but such a relationship is best accomplished where there are physical connections between individual pores (pore throats). Relatively high volumes of secondary porosity does not necessarily demand high permeability but does suggest the presence of some connectivity between pores.

The secondary porosity observed at Meridiani Planum thus far can generally be related to subsurface permeability. Sheet-like vugs-to-channel pores are fabric selective [5,6] since their orientations are clearly parallel to the bedding plane. Crystal molds are typically found non-parallel to bedding and therefore appear to be non-fabric selective [3]. In the Karatepe stratigraphic section, the fabric selectivity likely contributes to permeability significantly more than pores that are non-fabric selective. Accordingly, the secondary porosity observed at Meridiani Planum that is fabric selective will tend be *effective porosity* (i.e., pore space that contributes to the overall permeability) whereas the crystal molds likely better reflect *ineffective porosity*, thus likely having some access to groundwater, but contributing much less to the permeability within this vertical stratigraphic section.

Preservation Potential of Organic Matter: The ability for organic matter to be preserved within a pore network would require that the fluid activity remain low enough not remove organics but high enough to dissolve soluble evaporite minerals. The greater the permeability within an outcrop the less feasible it is for organics to be preserved.

Accordingly, the most important factor is the presence and amount of liquid water but additional constraints include the nature of fluid motion (e.g., calm/stagnant to flowing, also influencing the effective water/rock ratio), groundwater table accessibility (via permeability), composition of the water (e.g., redox state) and fabric selectivity (discussed earlier). Variations in the amount and nature of secondary porosity within the Karatepe section may have resulted in differential access to the pores. Void space in rocks surrounding the Whatanga contact have the greatest secondary porosity volumes recorded [4]. While this allows for ease of fluid movement, it also has the greatest potential to destroy any organics that may have been present and alter the surrounding rock.

Of the various pore types observed [3], crystal moldic porosity has the most non-fabric selective nature in addition to having no observable pore throats connecting them to other void space. Accordingly, such ineffective porosity has the greatest potential to retain any organic matter carried via fluid recharge, should any be present.

Crystal moldic secondary porosity observed in Eagle and Endurance craters is quite different than the porosity found in the Erebus region. At Erebus, the porosity is characterized by having an overall lesser volume and being more dominated by small crystal molds, possibly including molds after a cubic mineral such as halite (Fig 1b). This setting could have relatively high potential for preservation of any sedimentary organic matter if it were ever present.

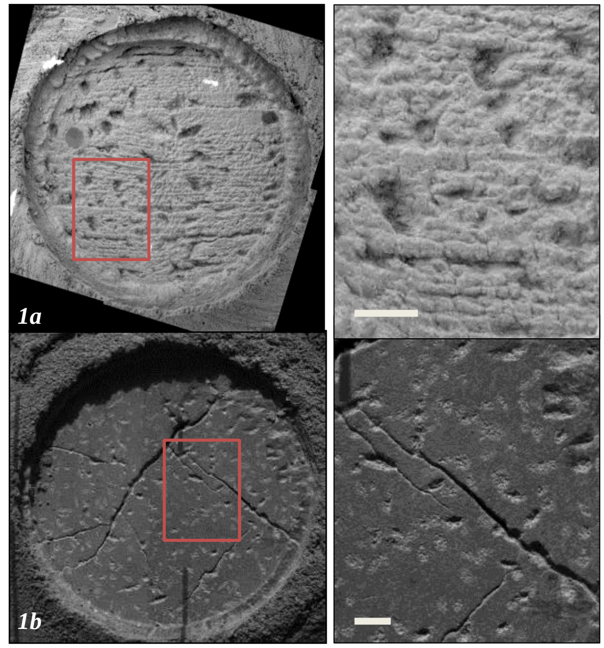

Figure 1. Top: typical crystal molds and elongate-to-sheet-like vugs / channel pores found in Endurance (4mm scale bar). Bottom: decrease in overall secondary porosity while an increase in abundance of crystal moldic porosity found in Erebus (3mm scale bar).

Summons et al. [7] assessed preservation windows along with their textural features that could be observed within Martian sedimentary environments. One process they note includes porosity as an identifiable feature as a consequence of mineral dissolution (among other related features). However, in this same chemical process they note that recrystallization and dissolution fall outside the preservation window as such processes destroy evidence of organics.

In addition, the distance between rocks that contain porosity and rocks that show recrystallization in the subsurface can be fairly small. In the Karatepe section there are three abraded rocks (Diamond Jenness, Mackenzie, Inuvik) that possess areas of recrystallization directly below rocks showing well preserved porosity found in Fig. 1a. This illustrates how subsurface microtextures can change significantly in a local vicinity.

References: [1] McLennan, S. M., et al. (2005) EPSL, 240, 95-121. [2] Grotzinger, J. P., et al. (2005) EPSL, 240, 11-72. [3] Perl, S. M., et al. (2007) LPSC XXXVIII. [4] Perl, S.M., et al. (2008) Seventh International Conference on Mars #3298. [5] Choquette and Pray (1970) AAPG 54 207-250. [6] Lønøy, A. (2006) AAPG 90 1381-1405. [7] Summons, R.E., et al. (2011) Astrobiology, 11: 157-181.