SEDIMENTOLOGICAL CONSTRAINTS ON AN INFILTRATING PALEOWATER TABLE IN THE BURNS FORMATION, MERIDIANI PLANUM, MARS

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Introduction: Rocks studied at Meridiani Planum by Opportunity have revealed evidence of diagenetic processes as a result of an infiltrating groundwater table through the Burns formation, a series of well sorted sulfate-rich sandstones [2]. McLennan et al. [1] showed an assortment of void spaces and interpreted them to signify at least two unique types of secondary porosity produced by dissolution of relatively soluble salts during at least four recharge events of this water table.

The purpose of this paper is to use the amount and distribution of secondary porosity to better constrain the hydrological setting of the Burns formation at Meridiani Planum.
Secondary Pore Classification: We have identified three types of secondary porosity: (1) sheet-like to elongated vug / channel porosity, (2) crystal moldic porosity, and (3) a modified (pore enlarged) version of both. The concept of fabric selectivity is important when classifying the origin and timing of pores. A pore is fabric selective when there is a clear relationship to the primary fabric elements (crystals, bedding). If no such correlation can be found the pore is non-fabric selective [4]. Crystal molds are typically fabric selective whereas sheet-like to elongated vug / channel porosity has a mixed non-fabric selective – fabric selective nature. The fabric selectivity of modified pores cannot be determined due to the unknown overall extent and shape of the pores but is highly unlikely to be fabric selective at least on a cm- to dm-scale.

Elongated to Sheet-like Vug / Channel Porosity (Fig. 3): These types of secondary porosity mostly occur in patterns that both parallel and cut across bedding planes. Choquette and Pray [4] classified channel porosity as a non-fabric selective secondary porosity that have length to width ratios greater than ten. Many of the pores studied in the Burns formation are elongated but have length to width ratios less than ten. Although many of the vugs cut across the primary bedding fabrics they also preferentially align along bedding thus giving them both a non-fabric selective – fabric selective character (see previous section). These pore types are interpreted to represent dissolution of relatively soluble mineral phase(s) such as Mg- and Fe-sulfates [1]. Since they are mostly found together we deduce that they are related and have a common origin. Although sampling is limited, this type of secondary porosity may be more abundant in the RATed surfaces at Endurance crater than in other regions studied, for example, at Erebus crater.

Crystal Moldic Porosity (Fig. 4): Noted by Squyres, et al. [5] as “vugs”, this mm-sized texture was one of the first diagenetic features observed in the Burns formation. Using the classification scheme of Choquette and Pray [4] these pores are more accurately categorized as crystal moldic porosity. The average dimensions of these pores have a width of 1mm (s.d.=0.5mm) and a length of 5mm (s.d.=3mm). Their tabular shape suggests the previous existence of a monoclinic mineral. The abundances of these crystal molds have been found to vary greatly from place to place. Crystal moldic porosity has been interpreted to represent dissolution of a highly soluble mineral such as ferrous sulfates, Mg-sulfates, or chlorides [1,5]. In the vicinity of Erebus crater there is evidence for “filled” crystal molds with cubic crystal habits, suggesting the former presence of halite [6].
Pore (Modification) Enlargement (Fig. 5): Although less frequent we have observed the presence of extensively enlarged pores. These oversized vugs are considerably larger than the size of regular elongate to channel vugs and are found to modify each of the other types of secondary porosity. The amount of modification (if any) varies from rock to rock. The process of pore enlargement occurs mostly within cm- to dm-scales in stratigraphic zones in the upper part of the Burns formation, particularly in the area of the Whatanga contact, separating the upper and middle units [2]. Within the Karatepe stratigraphic section in Endurance crater, the Grindstone and Virginia RAT holes exhibit these enlarged pores. The RAT hole Wharenhui, southeast of Burns Cliff, also contain pores that share this enlargement and is also very close to the boundary represented by the Whatanga contact. Zones that contain pore modification have been interpreted to represent diagenetic fronts associated with the presence of a stagnant paleowater table [1,2].

Hydrologic Relationships: Although the estimated volumes of secondary porosity in the Burns Formation may appear large (up to 42%), in fact such values are not unusual in terrestrial sedimentary rocks [4]. The associations between secondary porosity and permeability, hydraulic conductivity, and energy balance within the groundwater system all play an important role in constraining the environment of fluid flow. The amount of total secondary porosity in Endurance crater ranges from 30-42% which includes all types and modifications (Fig. 6). The single rock RATed in the Erebus region (Strawberry) has the lowest amount. This could be due to a RAT surface that may not be orthogonal to the bedding plane, as is the case for the other RAT surfaces. The ratio of crystal molds to elongated pores is also reasonably uniform among the analyzed RAT targets (Fig. 7).

Fig. 4: Cropped images from Virginia, Grindstone, and London RAT holes showing crystal moldic porosity. This type of secondary porosity is mostly found perpendicular or non-parallel to the bedding plane.

Fig. 5: Cropped images from Virginia and Grindstone RAT holes showing enlargement of pores above and below the Whatanga contact. This contact is interpreted to be a diagenetic zone associated with a stagnant paleowater table.

Fig. 6: Total secondary porosity estimated from thresholded images. All types of pores, enlarged or otherwise are included. Percentages in Endurance crater are fairly uniform between 30-42%.
Future Work: In order to better constrain the hydrological regime of diagenesis in the Burns formation, future work will concentrate on these areas:

- Obtain three dimensional shapes of crystal molds and compare differences, apparent depth, size and geometry (Figs. 8,9).

- Continue to evaluate the distribution of secondary porosity in the rocks at Endurance crater, Erebus crater, and in Victoria crater when we locate an appropriate stratigraphic section.

- Use predefined DEMs to help visually assist us in identifying the three types of secondary porosity (Figs. 9a,b).

- We will also attempt to recreate a laboratory model of secondary porosity found in the Burns formation using a variety of materials, such as gypsum sands mixed with halite.