SECONDARY POROSITY CLASSIFICATION AND ANALYSIS OF THE BURNS FORMATION, MERIDIANI PLANUM, MARS.

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Introduction: Formation of secondary porosity is a common diagenetic process in sedimentary rocks and occurs during mineral dissolution, rock fracture, mineral transformations involving significant reduction in molar volumes and so forth [1]. In sandstones, the amount of primary intergranular porosity is commonly greater than 15% of the lithified rock volume and secondary porosity, that forms during and after lithification, can be significantly more than this. The shapes and timing of pores can provide important constraints on their genesis and on the history of diagenetic fluid flow through a rock.

The Burns formation, preserved on Meridiani Planum, Mars, is a sequence of well sorted sandstones [2]. Chemical and textural evidence indicates that these rocks contain approximately 50% of chemical constituents in the form of sulfate salts (and possibly amorphous silica [3]), much of which appears to fill a significant proportion of the primary intergranular porosity of the rocks [2]. McLennan et al. [4] noted a variety of systematically shaped void spaces within parts of the Burns formation and interpreted them to represent at least two distinct varieties of secondary porosity formed by dissolution of relatively soluble salts during groundwater recharge.

In this paper, we summarize the types of secondary porosity that have been identified in the Burns formation, attempt to quantify the porosity volumes and comment on their possible genesis.

Analysis: We have used MI mosaics of the various RAT grindings in the Burns formation to evaluate the nature of the secondary porosity. In some cases, the RATing process leaves behind large amounts of cuttings that obscure sedimentary microtextures but in others, microtextures are exquisitely preserved. Figure 1 shows the stratigraphic relationships of the Burns formation, proposed by Grotzinger et al. [2]. Superimposed on the diagram are the MI targets considered in this study.

We employ a simple threshold imaging technique where the features that may be considered as porosity are enhanced as green (Fig. 2). Once threshold images are created they are carefully compared to the standard photographs and features that meet the porosity threshold value but clearly are not porosity (e.g., concretions, margins of RAT holes) are digitally removed. We then calculate the area percent of total porosity and assume that this represents the volume percent. (In future work, we will attempt to estimate the volumes of the different types of porosity using a combination of threshold imaging and manual classification.) It should also be noted that our estimates of porosity volumes should be considered as a lower limit due to the possible filling in of tailings due to the grinding of the RAT hole.

Pore Volumes: We have calculated the secondary porosity of three RAT grindings based on the techniques described above.

London	29.9%
Drammensfjorden	24.6%
Cobble Hill	33.4%

McLennan et al. [4] suggested a possible link between the formation of secondary porosity and growth of concretions. One possible model for concretion growth is by breakdown of sulfate minerals jarosite and/or ferrous sulfate (e.g., melanterite) to form hematite or its precursor goethite. Such reactions are likely to generate significant secondary porosity because the molar volumes of these sulfate minerals are 5-7 times that of ferric oxide minerals. Accordingly, three volume percent of concretions consisting of >50% hematite could lead to up to 20-30% of secondary porosity. The measured porosity volumes are consistent with such a model.

Secondary Porosity Classification: Three fundamental types of secondary porosity have been identified (Fig. 3): fabric selective (crystal mold porosity), non-fabric selective (sheet-like to elongated vugs, channels) and modified pores.

Crystal Mold Porosity: One of the first diagenetic features recognized in the Burns formation was the presence of mm-sized "vugs" as noted by Squyres, et al. [5] Using the porosity classification of Choquette and Pray [1], these are better termed crystal moldic porosity. The average size of these pores have a width of 1±.5mm and a length of 5±3mm. and their shape suggests the former presence of a monoclinic mineral (there may be some smaller cubic forms closer to Erebus crater). The amount of vugs that have been found vary based on location and can be abundant or rare. These pores have been interpreted to represent dissolution of a highly soluble mineral such as Mg-sulfates, ferrous sulfates or chlorides.

Elongated to Sheet-like Vug and Channel Porosity: These porosity types are likely related and occur in patterns that parallel and/or cut across bedding. Choquette and Pray [1] define channel porosity as non-fabric selective secondary porosity where length to width ratios of pores are greater than ten. Many of the pores observed in the Burns formation are elongate but have length to width ratios less than ten. Although many of these vugs cut across primary bedding fabrics, in many places they also appear to preferentially align along bedding thus giving them a mixed fabric selective – non-fabric selective character. Accordingly, these have been termed elongate to sheet-like vugs. They are interpreted to represent dissolution of relatively soluble mineral phase(s) such as sulfates [5].

Pore Modification: Although less common (2-3 occurrences) we have observed the presence of significantly enlarged pores. These oversized vugs are about two to three times the size of regular vugs and are found to modify each of the three types of secondary porosity.

This process of pore modification occurs dominantly at cm- to dm-scale stratigraphic zones in the upper part of the Burns formation, notably above and below the Whatanga contact separating the middle and upper units [2]. To date, samples (C) and (E1), shown in Fig. 1, have these enlarged pores. These zones have been interpreted to represent diagentic fronts associated with the presence of a paleowater table [2,4].

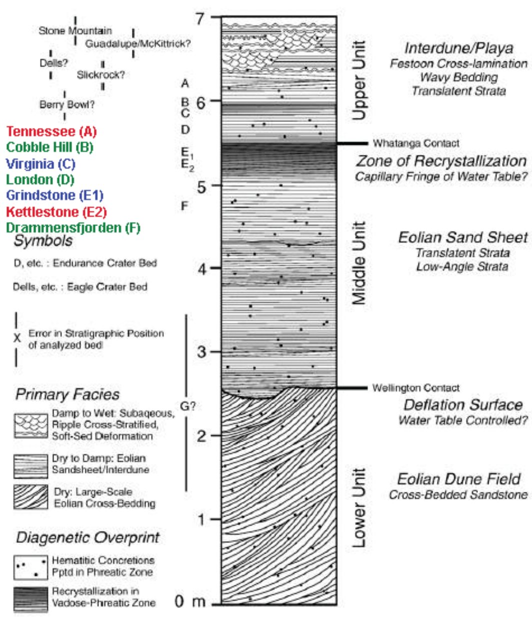

Figure 1. Stratigraphic column of the Burns formation adapted from Grotzinger et al [2] showing the locations and names of the MI mosaics in Endurance crater that were used in our analysis (green), obscured and cannot be examined (red), and mosaics that will be used in the future (blue).

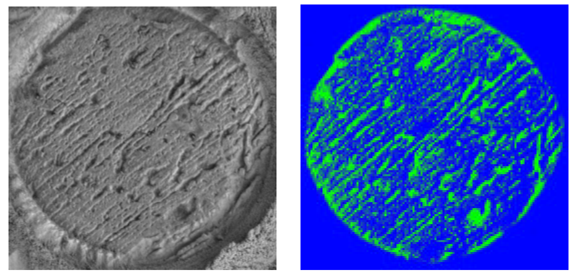

Figure 2. Original MI mosaic of Cobble Hill (left) and its thresholded image (right) that highlights porosity. Note the apparent enrichment of porosity along the outer margin of the RAT hole (concretions show the same effect). This is an artifact of the processing and such enrichments are digitally removed before estimating the amount of secondary porosity.

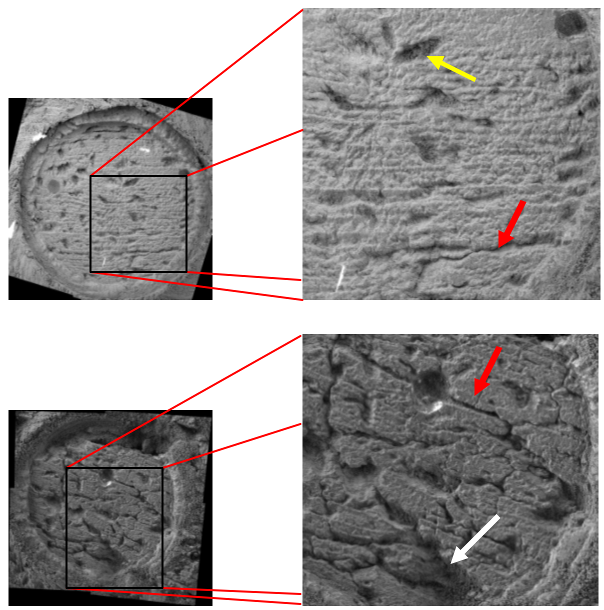

Figure 3. MI mosaics of the RATed surfaces London and Grindstone. Close up images showing examples of crystal mold porosity (yellow arrow), sheet-like to elongate porosity (red arrow) and an example of pore modification (white arrow) where the volume of sheet-like vugs has been increased substantially

References: [1] Choquette, P. W. and Pray, L. C. (1970) Am. Assoc. Pet. Geol. Bull. 54 207-250. [2] Grotzinger, J. P., et al., (2005) EPSL, 240, 11–72. [3] Glotch, T. D., et al. (2006) LPSC *XXXVII* (this volume). [4] McLennan, S. M., et al., (2005) EPSL, 240, 95-121. [5] Squyres, S. W., et al., (2004) Science, 306, 1709– 1714.