CHARACTERIZING SANDSTONE POROSITY ALONG CURIOSITY'S TRAVERSE USING MAHLI IMAGERY. K. L. Siebach[1] and J. P. Grotzinger[2], [1]California Institute of Technology, Pasadena, CA (ksiebach@caltech.edu).

Introduction: Sandstone porosity develops and is altered through a variety of depositional, diagenetic, and weathering processes. Identification and description of primary and secondary voids in sandstone provides a texture-based constraint to help determine the series of events that occurred during deposition, lithification, and diagenesis of the rock [1]. There are two main types of porosity. Porosity originating from initial spaces between grains incorporated into the sandstone is called primary porosity, and this is progressively occluded during cementation and lithification processes. Any process that increases the porosity of the rock after initial cementation creates secondary porosity. These processes include fracturing of the rock, shrinkage of minerals, and dissolution of sedimentary grains, cement, or authigenic minerals incorporated in the rock [2].

The Curiosity rover has observed a variety of sandstones along its traverse towards Mount Sharp, and an understanding of the porosity of those rocks would provide a key textural constraint on their lithification. Furthermore, a classification of the type of porosity in these rocks could help constrain the diagenetic pore fluid history. For example, if the rock has large secondary pores, the fluid that dissolved portions of the rock to create those pores must be chemically distinct from the fluid that cemented the rock.

The Mars Hand Lens Imager (MAHLI) camera onboard Curiosity has acquired images of several sandstones with a pixel scale of 20 to 30 µm/pixel, allowing identification of fine sand grains and apparent void spaces of comparable size [3, 4]. The pits and apparent void spaces in these images were analyzed to get an upper limit on the porosity of the observed sandstones and to determine what secondary porosity textures are present, which will aid in constraining the stages of diagenesis involved in formation of these sandstones.

Methods: MAHLI images of sandstones that were acquired during the day within 5 cm of a flat rock surface were collected. These include sandstones from the Gillespie Lake unit in Yellowknife Bay, from the Cooperstown outcrop at the first major waypoint en route to Mount Sharp, and from near the rover's current position in the Kimberley quad. For each sandstone image, the apparent void spaces, or pits, visible on the rock surface, were mapped along with the most obvious sand grains incorporated into the sandstone. Only the most clearly distinguishable sand grains were outlined because these are often the largest, and outlining only the clearest grains minimizes errors. The pit diameters could then be compared to the diameters of the largest visible grains in the sandstone for comparison.

To obtain a maximum estimate for the porosity of the sandstones, we assume the pits mapped on the exposed surface of the sandstone are representative of voids within the sandstone, and take a ratio of the area of the mapped pits to the mapped area. This is a maximum estimate for the porosity because pits on the surface may represent voids from that have dissolved or fallen out of the rock due to surface weathering processes, which do not affect the interior of the rock.

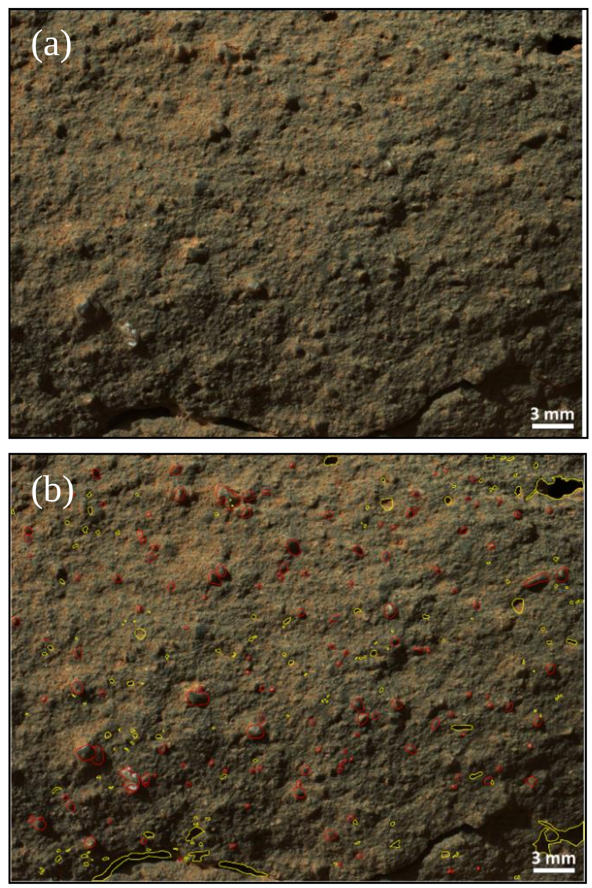

Figure 1. (a) MAHLI image of Gillespie Lake target within the Gillespie Lake outcrop acquired on sol 132 from a 5 cm standoff. (b) Same image, with red outlining the clearest grains and yellow outlining void spaces. Note the particularly large void space in the upper right-hand corner.

Conventional pore texture classification techniques require high-resolution comparison of the pore shapes to the grain shapes [2]. In order to do a modified pore texture classification using the MAHLI surface images, the pit diameters were compared to the diameters of the largest, clearest grains. As a first order classification, the pits were categorized as either “oversized” (greater than the average measured grain diameter) or “grain-scale” (smaller than or equal to the average measured grain diameter).

Results: At the time of the writing of this abstract, apparent pits had been mapped in three MAHLI frames from two rock units- the Gillespie Lake and Ungava targets in the Gillespie Lake member and the Rensselaer target in the Cooperstown member. Apparent pit mapping has indicated that the average area of pits compared to surface area, or the apparent porosity of the sandstones, is quite low, with less than 5% porosity measured in each of the three MAHLI images mapped (Table 1). This is particularly significant because this apparent porosity is an upper limit on sandstone porosity because of included apparent pores due to surface weathering.

After the apparent pits were mapped, the pit area were compared to the outlined grain areas to determine what percentage of the outlined pits were “oversized” relative to the average outlined grain. In the Gillespie Lake and Rensselaer targets, oversized pits made up about 10% of the overall pits mapped. In the Ungava target, about 40% of the overall pits were oversized relative to the visible grains (Table 1).

Sol	Target	Apparent Porosity	Percent “oversized” pits
132	Gillespie Lake	1.9%	9%
154	Ungava	2.2%	39%
442	Rensselaer	2.5%	10%

Table 1. Apparent porosity and percent of oversized pits mapped for each target

Discussion: The presence of a variety of pore textures in sandstones observed by Curiosity indicates a variety of diagenetic and weathering events. Grain-scale pits could represent leached grains (either primary or replacement), or grains that have fallen out due to surface weathering processes. Oversized pits are less likely to represent primary porosity. One option is that such large pits, as observed in the Ungava target, represent an original grain and/or mineral type that was larger than the average grain and more prone to weathering out of the rock in current conditions, e.g. intraclasts. A second option is that the primary mineral that formed the large grains was altered during diagenesis, either completely dissolving or forming a much softer mineral which has since weathered out of the rock through wind erosion. A final option is that the void spaces were formed by dissolution of a secondary precipitate, or a replacement mineral. This would require two diagenetic fluid stages: an initial fluid that caused recrystallization of a secondary mineral, and a later fluid which was caustic to the newly-formed precipitate.

Summary: Pits, or apparent void spaces, on the surfaces of sandstones were identified and mapped using MAHLI imagery. These were compared to the size and shape of visible sand grains and classified using a basic scheme to determine the percent and origin of the porosity. The presence of potential secondary porosity would imply that multiple diagenetic fluids altered the rock during and after lithification; first depositing secondary minerals and later dissolving them.

References: [1] Schmidt, V. and McDonald D. A. (1979) *SEPM Special Publication 26*, p. 175-207. [2] Schmidt, V. and McDonald D. A. (1979) *SEPM Special Publication 26*, p. 209-225. [3] Edgett, K.S., et al. (2012) *Space Science Reviews*, 170(1-4), p. 259-317. [4] NASA-JPL (2013) *Mars Science Laboratory Project Software Interface Specification (SIS), Mast Camera (Mastcam), Mars Hand Lens Imager (MAHLI), and Mars Descent Imager (MARDI) Experiment Data Record (EDR) and Reduced Data Record (RDR) PDS Data Products*.